



Ministry of Water, Irrigation and Electricity

# **OPERATION & MAINTENANCE MANUAL**

## **RURAL WATER PIPED SCHEMES**

**(Parts A, B, C)**

### **Water Sources and Electromechanical Equipment**

Document 04

Addis Ababa 2018



## FOREWORD and ACKNOWLEDGEMENTS



Her Excellency, Mrs Frenesh Mekuria, State Minister of the Ministry of Water, Irrigation and Electricity

Ethiopia has made great achievements during the last 10 years in providing improved water supply service for its rural population. As a result, Ethiopia achieved the Millennium Development Goal (MDG) target in water supply. The target was achieved mainly through the implementation of small community water supplies. Today the number of these small community water supplies is well over 200,000 and serving a population of 50 million rural people. In order to keep these water supplies operational, the National Rural Water Supply (RWS) Operation and Maintenance Management (O&MM) Manual and Strategic Framework was prepared.

The National RWS O&MM Strategic Framework for Ethiopia is an outcome of collective efforts carried out through a consultative process across the nine regional states by the Federal and Regional Governments and Development Partners (DPs).

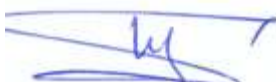
I wish to acknowledge the invaluable inputs of Ministry of Water, Irrigation and Electricity staff Regional Water Bureaus, Zone and Woreda Water Offices, Community-Led Accelerated WASH Project (COWASH), Water Action, Action Aid, JICA, World Bank, African Development Bank, DFID, UNICEF, Ethiopian Catholic Church Social & Development Coordination Office of Harar, Millennium WASH Alliance, Ethiopian WASH Alliance, all visited rural piped system Water Boards and Water Administration Offices (WAOs), numerous WASHCO members, user communities and several key individuals who gave freely their time, provided data and information and arranged scheme visits. Special thanks go to Demewoz Consultancy Company in the development of this document.

I would like to underscore the technical and financial support and extensive assistance we received from the Government of Finland financed COWASH project in this strategic framework and manual preparation.

I therefore request that all decision-makers, water technical staff at federal, region, zone, woreda, kebele and community levels secure budget for maintenance management and make sure that continuous improved water supply is provided to all Ethiopians. I believe that this manual will make it possible.

Providing rural water services is irreducibly complicated; there is no single solution for sustainability. Sustainable services rely on an interlocking network of different actors and institutions – all of which need to function at least well enough. Sustainable rural water supply means that whole system from regulation through provision of adequately resourced support services is ensured with accountability.

Addis Ababa in March 2018

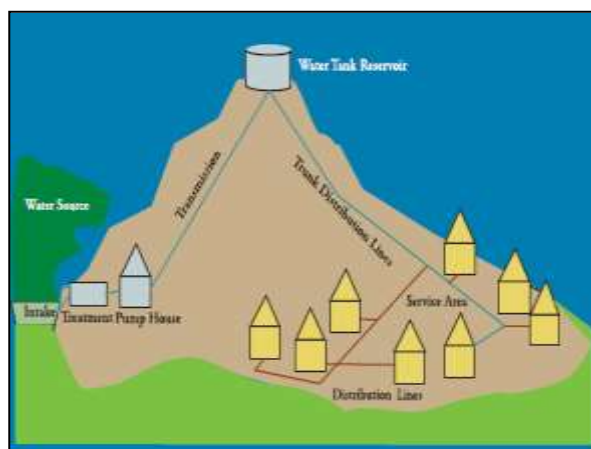
A handwritten signature in blue ink, appearing to be 'Frenesh Mekuria'.

**Frenesh Mekuria**  
State Minister

Frenesh Mekuria  
State Minister  
Ministry of Water, Irrigation and Electricity  
Ethiopia

# **MINISTRY OF WATER, IRRIGATION AND ELECTRICITY**

## **GENERIC OPERATION AND MAINTENANCE MANAGEMENT MANUAL FOR RURAL WATER PIPED SCHEMES**



### **RURAL WATER PIPED SCHEMES**

**(Parts A, B, C)**

**Water Sources and Electromechanical Equipment**

**PART – A: INTRODUCTION**

**Document 4**

## RPS O&M Manual, Water Sources and Electromechanical Equipment

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## PART – A: INTRODUCTION

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## Acronyms

CBMS	Community Based Maintenance System
CBO	Community Based Organization
CMP	Community Managed Project
CSO	Civil Society Organization
DFID	Department for International Development (UK)
DAG	Development Assistance Group
FGD	Focus Group Discussion
GIS	Geographical Information System
GTP	Growth and Transformation Plan
IDA	International Development Agency (WB)
JICA	Japan International Cooperation Agency
ICB	International Competitive Bidding
KDC	Kebele Development Committee
LSP	Local Service Provider
MDG	Millennium Development Goal
M&E	Monitoring & Evaluation
MIS	Management Information System
MoE	Ministry of Education
MFI	Micro Finance Institution
MoWIE	Ministry of Water, Irrigation & Electricity
NCB	National Competitive Bidding
MVS	Multi Village System
NGO	Non-governmental Organization
NWI	National WASH Inventory
O&M	Operation & Maintenance

OWNP	One WASH National Program
PBT	Pressure Break Tank
RPS	Rural Piped System
RWCO	Regional WaSH Coordination Office
SNV	Netherlands Development Organization
SP	Spare Part
TVETC	Technical Vocational & Educational Training College
UAP	Universal Access Plan
UNICEF	United Nations Children's Fund
WASH	Water Supply Sanitation and Hygiene
WAO	Water Administration Office
WASHCO	Water Supply Sanitation and Hygiene Committee
WDC	Woreda Development Committee
WB	World Bank
WIF	WASH Implementation Framework
WSG	Woreda Support Group
WUG	Water User Group
WWO	Woreda Water Office
WWT	Woreda WASH Team



## DEFINITIONS OF TERMS:

<b>Accessibility</b>	Is having a functional and reliable water supply facility without any barriers within a radius of 1500 metres for Rural Water Supply
<b>Access Coverage</b>	Is the percentage of people with access to safe, adequate and reliable water supply within 1500m at 15 l/c/d for rural community
<b>Adequate Water</b>	Is the quantity of water required to meet the minimum demand per capita per day. The standard being 15l/capita/day by 2015 for Rural people
<b>Borehole Depth</b>	The term “shallow” in Ethiopia is used to refer to a borehole up to about 60m in depth; “medium” depth refers to 60-150m; “deep” boreholes are drilled up to about 450m
<b>Community</b>	Refers to a group of people living in a designated area who share residential and developmental challenges and benefits. It may also refer to all people sharing such challenges and benefit regardless of geographical and social boundaries
<b>Community Based Management</b>	Is the process of empowering community members to assume the lead role in decision making about the levels of services they require, whilst organizing themselves to plan, implement, operate and maintain their water supply and sanitation facilities.
<b>Community Management</b>	Is a form of community participation in which the community takes the final decision on all aspects of planning, implementation, management, monitoring, evaluation, O&M of the water supply facility
<b>Evaluation</b>	Is the periodic and systematic review and analysis of a practice to determine the relevance, effectiveness, efficiency and impact of programmes/projects compared to the set objectives
<b>Functionality</b>	The term functionality refers to the number or percentage of working/operational rural water supply schemes out of the total number of rural water supply schemes constructed at any given period.
<b>Kebele/Tabia</b>	Is the lowest administration unit in the Ethiopian government's administrative hierarchy
<b>Maintenance</b>	Refers to activities required to sustain the water supply facilities in a proper working condition. It includes preventive maintenance, corrective maintenance and crisis maintenance.
<b>Monitoring</b>	Is the regular and continuous checking of whether plans, activities and situations are being implemented as planned, and includes the provision of feedback to facilitate the taking of corrective measures by relevant stakeholders.
<b>Operation</b>	Operation refers to the routine activities necessary to make the system function
<b>Point Water Supply</b>	In rural water supply context, these are hand dug wells, shallow wells, on-spot springs types of schemes
<b>Preventive Maintenance</b>	Refers to an activity that includes checking the status of hand pump components at regular fixed intervals
<b>Rehabilitation</b>	Is the correction of major defects and the replacement of equipment to enable the facility to function as originally intended.
<b>Reliable Water Supply</b>	Is the supply of water on a continuous basis meeting the minimum demand per capita per day



<b>Repair</b>	It is the restoration of a defective component to return the facility to acceptable working condition. The cost of the repair should be borne by the community.
<b>Rural Area</b>	“Areas of population outside urban and peri-urban using point or surface water sources for which the community is responsible for the O&M”. in addition, low population densities characterize rural areas, with small houses isolated from each other.
<b>Rural Piped System</b>	It is a water supply system feeding various villages and small towns by gravity, pumping and a combination system through public taps and yard connections
<b>Safe water</b>	Is water that is free from harmful quantities of physical, chemical and pathogenic matter and that meets the minimum Ethiopian standards (usually WHO Guidelines)
<b>Seed Money</b>	Is the initial sum of money disbursed to an organization in order to create/start a revolving fund for undertaking a designated programme
<b>Scheme (Water)</b>	The entire facility (concrete works, pipes, pumps) established to extract water from a water source, and distribute it to (close to) people’s homes
<b>Sustainable Supply Chain</b>	Is a system of procuring and supplying spare parts that guarantees a continuous supply of spare parts
<b>Source (Water)</b>	The natural water source only, i.e. spring, groundwater, river, etc
<b>Supply chains</b>	Is the term used for the process that relates all activities involved with the flow and transformation of goods from the raw materials stage through to the end-user, as well as the associated information flows
<b>WASHCO</b>	It is a committee of representatives from a number of Water, sanitation and hygiene Point Committee of the same village. Sometimes WASHCO committee may refer to 2 or more village representatives benefitting from a water and sanitation point.
<b>Woreda</b>	It is the lowest administration unit (next to Kebele), in the Ethiopian government’s administrative hierarchy.

# **1 INTRODUCTION**

## **1.1 General**

Rural water supply service delivery is shifting more and more towards piped water supply schemes as a result of improving standards of living and increase aspirations of the rural population. Where local water sources are scarce or not fit for drinking due to poor water quality, the most common option left is to bring in water from an outside source. If this source is far away or very deep, then economies of scale dictate that more than one village be served by the same system.

Thus, this RPS which crosses villages, Woredas, Zones and even regions required well organized and systematic operation and maintenance management to ensure the sustainability of the service.

The objective of an efficient operation and maintenance management of a water supply system is to provide safe drinking water as per designed quality and quantity, with adequate pressure at convenient location and time at competitive cost on a sustainable basis.

It has been observed that lack of attention to the important aspect of Operation & Maintenance (O&M) of water supply schemes in several small towns and villages often leads to their dysfunction or deterioration of the useful life of the systems necessitating premature replacement of many components, incurring huge losses. As such even after creating such assets by investing Millions of Birr, they failed to provide the proper services effectively to the community for which they have been constructed and became dysfunctional or remained underutilized most of the time.

Some of the key issues contributing to the poor Operation & Maintenance (O&M) have been identified during the assessment as follows:

- Lack of finance, equipment, material, and inadequate data on Operation & Maintenance;
- Inappropriate system design; and inadequate Workmanship;
- Inadequate operating staff;
- Illegal tapping of water;
- Inadequate training of personnel;
- Lesser attraction of maintenance jobs in carrier planning;
- Lack of performance evaluation and regular monitoring;
- Inadequate emphasis on preventive maintenance;
- Lack of O & M manual;
- Lack of real time field information etc.

Therefore, there is a need for clear-cut sector policies and legal framework and a clear demarcation of responsibilities and mandates for O & M of water supply schemes.

Governments, external support agencies and communities are recognizing the importance of integrating O&M components in all development phases of water supply projects, including the planning, implementation, management, and monitoring phases. The Federal Ministry of Water, irrigation and Electricity plays a vital role in creating an

“enabling environment” within which an O&M policy framework can be developed, one of the key elements of sustainability.

Government can foster such an environment in a number of ways, including through legal provisions, regulations, education initiatives and training programmes, and by communicating information. If supportive O&M policy is not forthcoming from the federal government, then support for O&M at the local level will be hindered. An important role of local government is to promote an awareness of national policies and to support community water-user committees. Both the project staff and the recipient communities should be made aware of the O&M implications, as the communities themselves have responsibilities in the management and O&M of their water-supply and sanitation systems. However, many Woreda Water Offices have insufficient resources and are unable to provide effective support.

The roles and responsibilities of the actors involved in O&M need to be well defined, especially where governments are shifting from their traditional role as a services provider to that of a facilitator of service provision.

According to the One WASH National Program (OWNP), high priority has been given to capacity building in O&M for both rural and urban water supply and sanitation. This should initially focus on addressing the significant number of rural piped water schemes which appear to have been constructed without sufficient community and woreda involvement and ownership and which now have serious operational and O&M problems. It is stated in the document that appropriate and sustainable solutions should be identified so that communities have access to affordable spare parts and maintenance services within a reasonable distance, preferably by the private sector.

The OWNP plan proposed allocated budget for maintenance support is about 22 Million USD while for rehabilitation and expansion is about 96 Million USD. This shows that attention is given for O&M on the existing schemes. It is also proposed to construct 1,828 rural piped systems in 2015 in addition to the existing schemes. So, the developing of these manuals is timely.

Thus, the various topics of the O&M management manuals uses as guiding tools to resolve the above-mentioned constraints.

## **1.2 The Manuals**

This **RURAL PIPED SYSTEM AND PASTORAL AREAS WATER SUPPLY OPERATION AND MAINTENANCE MANUAL** is the second manual next to the O&M management manual developed for point water sources, prepared for the use of prospective and actual owners /communities, water boards / WASHCOs, operators, Woreda and Zone Water Offices, Regional Water Bureaus and Federal Ministry of Water, irrigation and Electricity.

Its purpose is to introduce the institutional models available and the legal requirements that apply to RPSs; the operational and maintenance principles and issues relating to water supply; and the management principles and good practices that must be adopted in order to attain viability and sustainability in the RPS business. Hopefully, the Manuals will facilitate the work of the professional managers and staff engaged in running the water administration by putting in their hands a ready resource reference for their everyday use. For those who are new or less exposed to the demands of the RPS business – including those who sit as board members of community based organizations as well as those in Woreda and NGOs who have joined the efforts to ensure safe water for the communities they serve – hopefully it will be an aid in understanding the institutional, operational,

financial, and management issues involved, and thus enable them to participate more effectively in advancing the objectives of the water sector.

Overall, the local and international partners (especially the Government of Finland and COWASH) who cooperated in making these Manuals possible hope that they will help the participants in the rural water supply sector to understand better the nature of the water supply business, its responsibilities to the stakeholders, and the role of the government agencies and regulatory bodies that seek to help them operate sustainably while protecting the consumers.

### 1.3 On the Use of the Manual

This RPS OPERATION AND MAINTENANCE MANUAL and the companion volumes and parts in the series can at best serve as a general reference and guide. As they refer to the information, recommendations, and guidelines contained in them, readers are urged to consider them always in relation to their own specific requirements, adapting and applying them within the context of their actual situation.

Even as they refer to this Manual for information, its users are advised to consult with qualified professionals – whether in the private sector, in the Zone or Woreda Water Offices, or in the regulatory and developmental agencies concerned with the water sector – who have had actual experience in the construction, management, operation, maintenance, and servicing of water supply systems and RPS – including those other professionals who can help them in the financial, legal and other aspects of their RPS business.

### 1.4 Manual Organization

The entire manual of the Rural Piped System and Pastoral area Water Supply Technologies has three volumes and 21 parts. Moreover the consultancy assignment has made assessment in all regions and prepared Assessment Report.

The three volumes in this series of the OPERATION AND MAINTENANCE MANUALS are as follows:

#### **VOLUME – I TECHNICAL OPERATION AND MAINTENANCE REQUIREMENTS FOR RURAL PIPED SYSTEM**

This Volume – I of the manual contain 9 different technical parts that considered as the requirements of operation and maintenance for rural piped system. In fact this technical O&M requirements can also use by the urban Water Utilities. Rural Piped System Executive Water Boards / WASHCOs, Water Administration Offices / The Operators use these manuals.

PART - A	INTRODUCTION
PART - B	WATER SOURCES FOR WATER SUPPLY
PART - C	ELECTRO-MECHANICAL EQUIPMENT
PART - D	TRANSMISSION AND DISTRIBUTION SYSTEM
PART - E	SPARE PARTS SUPPLY AND MANAGEMENT
PART - F	EQUIPMENT AND TOOLS MANAGEMENT MANUAL
PART - G	LEAKAGE DETECTION AND CONTROL
PART - H	FIXED ASSET INVENTORY

**VOLUME – II: MANAGEMENT REQUIREMENTS FOR O&M OF RURAL PIPED SYSTEM**

This second volume of the manuals focuses mainly on scheme management, human resources requirements, Monitoring & Evaluation, Management Information System and Reports. It has 4 parts as mentioned below.

PART- A	FINANCIAL MANAGEMENT
PART – B	COMMUNITY BASED SCHEME MANAGEMENT
PART – C	MONITORING & EVALUATION, MIS AND REPORT REQUIREMENTS
PART – D	HUMAN POWER AND CAPACITY BUILDING REQUIREMENTS

This volume presents the considerations and requirements of community based management of rural piped system, mainly by Executive Water Board for large RPS schemes and WASHCOs for small RPS. Large RPS managed by recruited operators called Water Administration Office, whose human powers as well as capacity building needed are well described in the manual. Monitoring and evaluating of this office by EWB and in turn by regional Water Bureau's, Zone and Woreda Water Office requirement is elaborated. On top of that the report requirements by different actors are also described in the manual.

**VOLUME – III: O&M REQUIREMENTS FOR PASTORAL AREAS WATER SUPPLY TECHNOLOGIES**

PART – A	INTRODUCTION TO PASTORAL WATER SUPPLY TECHNOLOGIES
PART – B	SAND/SUBSURFACE DAM
PART – C	HAFIR DAM AND BERKAD
PART – D	ROOFTOP AND ROCK CATCHMENT RAIN WATER HARVESTING
PART – E	SOLAR POWERED PUMPING SYSTEM
PART – F	WINDPOWERED PUMPING SYSTEM
PART – G	FINANCIAL MANAGEMENT
PART – H	COMMUNITY BASED MANAGEMENT

This Volume –III of the manual has eight parts which focused on the pastoral areas water supply technologies. The scheme community based and financial management system is similar with the management provided for rural piped system. Those pastoral area water supply technologies are also possible to apply for the highland water supply systems like rainwater harvesting.

Apart from these 3 volumes of the manuals, the following guidelines and documents are also prepared:

- ☞ Guideline for Preparation of Business Plan for RPS,
- ☞ Developing Operation and Maintenance Strategic Framework
- ☞ Developing Training Materials for WASHCO's

## **1.5 Objectives of Operation and Maintenance**

The Manual on Operation and Maintenance is intended to serve as a guide to strengthening the technical, operational and managerial capabilities required of the concerned personal to operate and maintain water supply services as per acceptable norms of quantity, quality, sustainability, reliability and cost.

The manual also helps to:-

- Identifying human, equipment and material resources required to ensure operation and maintenance of the systems.
- Creating know-how of scheme and financial management by water boards and WASHCOs
- Prepare detailed schedule for operation and maintenance activities.
- To give clear procedure and tact of operation and maintenance.

The core objective in ensuring the sustainability of the schemes through proper O&M management of the schemes, so the water supply service can be sustainable if:

- It functions and is being used;
- It is able to deliver an appropriate level of benefits (quality, quantity, convenience, comfort, continuity, affordability, efficiency, reliability, equity, health);
- It continuous over a prolonged period of time (which goes beyond the life-cycle of the equipment);
- Its management is institutionalized (community management, gender perspective, partnership with local authorities, involvement of formal/informal private sector);
- Its operation, maintenance and administrative and replacement costs are covered by itself;
- It can be operated and maintained by the Water Administration Office with limited external support like technical assistance, training and monitoring.
- It does not affect the environment negatively.

Hence, in order to make a system sustainable, at least it requires the consideration and the achievement of the above issues, which is a long process.

## **1.6 Necessity of the Manuals**

The Manual on Operation and Maintenance is a long felt need of the Rural piped system and pastoral areas water supply technologies.

The Necessity of developing these O&M manuals is due:

- There is neither national guideline nor generic O&M Management of the Points Water System or RPS, to answer water resources development policy says,
- There is no O&MM supportive functional organizational structure of MoWIE, to oversee and interpret whenever necessary at least in overall policy or regulatory terms,
- There is no uniform implementation/ institutional arrangement on how the rural water supply systems are managed,

- The WASHCOs (\*1) or the caretakers are not able to make major maintenance & they mainly rely on Woreda Water Office and regional Water Bureaus support for O&MM,
- Woreda Water Offices and Water Boards / WASHCOs do not have the required equipment, technical guidelines, budget and trained human resource to give the required service to the community,
- The level of technical support required by WASHCO from Woredas, Zonal offices and local private operators has not been identified,
- The support from Woreda /Zonal office is not planned and is rather based on breakage reports, and repairs are usually not carried out in time,
- There is no planned and timely preventive maintenance carried out by WASHCOs/Woredas/zonal offices and on the other hand no enabling environment is created for WASHCO to get support from private local service providers,
- O&MM cost recovery principle of rural water supply is somewhat misinterpreted. Although the government has assigned staff for O&MM at Regional, Zonal and Woreda level (2-3 people) the budget allocated for O&M and monitoring the status of schemes is insufficient at all levels,

At present, there is no comprehensive manual on this subject to benefit the field personnel and to help the O& M authorities to prepare their own specific manuals suitable to their organizations/ schemes.

As per the Water Resources Management Policy and Regional proclamations, all the rural water supply schemes are to be operated and maintained by local bodies (Woredas and Communities), therefore, this operation and maintenance manual has been prepared to facilitate/institutionalize the operation and maintenance system of rural water supply schemes.

## **1.7 Definition of Operation and Maintenance**

### **1.7.1 Operation**

Operation refers to the routine activities necessary to make the system function. The proper operation of a scheme results in its optimum use and contributes to a reduction in breakdowns and maintenance needs.

This involves the correct handling of facilities by the user communities for long use of components of the facilities.

### **1.7.2 Maintenance**

Maintenance refers to periodic inspection, replacement or repairs the damaged parts, cleaning of filters etc. Maintenance can be divided into two types: 1) Preventive maintenance (Planned maintenance), 2) Corrective maintenance (breakdown maintenance) and 3) crisis maintenance (unplanned maintenance).

**Preventive maintenance** refers to systematic pre-scheduled activities or programmes of inspections and maintenance activities aimed at the early detection of defects and implementation of actions to avoid breakdowns or deterioration. Preventive maintenance is 'pre active' since activities are conducted before a defect occurs. Often the cost of

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\* WASHCO can be also a "Board" in case of multi-village schemes or large rural piped schemes.



preventive maintenance activities is low compared with corrective maintenance or rehabilitation.

**Corrective maintenance** refers to activities conducted or repairs carried out as a result of breakdowns or noticeable infrastructure deterioration. Corrective maintenance is inherently 'reactive' in that it is carried out after some defect is discerned, often because the system is not operating as intended.

**Crisis maintenance:** unplanned responses to emergency breakdowns and user complaints to restore a failed supply.

**Rehabilitation:** entails the correction of major defects and the replacement of equipment to enable the facility to function as originally intended. Rehabilitation becomes necessary when it is no longer technically feasible or economically viable to maintain a facility in good working order. Maintenance will become uneconomic if the long term cost of rehabilitation and subsequent operation is more favorable than continued repair and maintenance.

### 1.7.3 Consequences of Poor O&M

It was learnt during the assessment part of this project, O & M is not given enough attention and instances of poor operation and maintenance practices have in many occasions largely contributed to:

- decreased quality of the produced drinking water,
- many interruptions of supply and reduction in reliability,
- reduction in lifetime of the various facilities which could lead already in the near future to high rehabilitation cost,
- reduction of sustainability,
- water wastage by many leaks,
- lack of consumer's confidence and resistance for water use,
- Reduction of willingness to pay water bills and consequently less income for the water supply service office.

### 1.7.4 Causes of poor O&M

Causes of insufficient O&M, which may be attributed to different management levels within the organization, as undertaking's top level management and executive staff, are:

- ☞ Lack of sufficient funds for operation and especially maintenance activities:
  - O&M cost is partly subsidized and has to be substantially covered by revenue collection, which is mostly disappointing, because the billing/collection- ratio is 100% and low water rates that are politically stipulated. Lack of service is generally leading to reduced consumer payments.
- ☞ lack of knowledge how to organize proper maintenance:
  - Inappropriate staffing of the Water Administration Office due to a combination of staff limitations (financial reasons), and inflexible employment agreements (political reasons), Transfer officers from other posting is not so easy too.
- ☞ lack of know-how and skilled personnel
  - Inexpert use of facilities has to prevent,

- Frequently not sufficient training facilities for off - and on- the job training are present.
- ☞ Lack of information exchange between engineers and operators, e.g. regarding the background of given instructions,
- ☞ lack of basic means and "tools" for performing proper operation and especially preventive maintenance (e.g. O & M manuals, standard procedures, logistical support),
- ☞ lack of available, stored spare parts and long delivery times, lack of tools and equipment,
- ☞ **Sub-standard quality** of various materials and equipment ( e.g. taps, valves, meters, fittings, Gaskets), causing frequently expensive and time consuming repairs and/or replacements. One of the reasons that cheap, inferior parts are used lays in the tendering procedure in which mostly the cheapest contractor is awarded. The use of inferior materials has also a negative effect on the motivation of staff involved.
- ☞ Adequate procedures for commissioning of schemes are mostly lacking. Due to initial defectives O&M suffers already from the beginning.
- ☞ Sometimes the organization of the water supply undertaking is not well tailored to O&M activities, maybe due to lower priority of O&M within the undertaking. The concept of being "consumer friendly" is often poorly developed and the number of contacts between supplier and client are restricted.
- ☞ Responsible officers and operators are not motivated, or are not aware of the importance of O&M, may have other personal interests, or are so occupied with the day to day administrative duties that less time for O&M activities remains.

The O&M responsibilities and duties are generally not considered to be attractive or give job satisfaction, due to poor salaries and lack of incentives, encouraging and interest of superiors, logistical support or career possibilities.

## 1.8 Requirements for Sustainable O&M

In these Manuals, CBM shall be widely endorsed as the essential component of a sustainable O&M approach, with the following being in place:

- **Skills:** Capacity building of communities to ensure that they are effective in their participation at the various stages of the RWS programmes. Considerable investment should be made in terms of time and funding to effectively carry out capacity building initiatives.
- **Awareness:** User communities' appreciation of the advantages of reliable and adequate safe water supply. This will see the manifestation of economic and social benefits and improvement in their health status. This is achieved through public campaigns.
- **Availability of spare parts:** The necessary materials and equipment should easily be available for communities to keep the systems operational using the skills imparted during the capacity building process. Sustainable supply chains should be established at the Woreda level for providing necessary spare parts and materials at a reasonable market price.

- **Adequate fundraising by communities:** Community financing towards O&M activities at the community level should be developed and enhanced. This should include accurate cost determination of O&M for different available technologies.
- **Making funds available for O&M:** Identification and facilitation of income generating activities will have to be undertaken by the Government and support agencies. The establishment of loan schemes could be a bridge towards community financial independence in effectively managing their RWS systems.
- **Legal provisions:** Appropriate legal provisions such as statutory instruments, by-laws, regulations and other similar initiatives should be introduced. This will prompt communities to be committed and to establish clear ownership of the facilities. Local Woredas may have to formulate by-laws to enforce these Manuals.
- **Monitoring and evaluation:** There should be effective monitoring of the entire set up of the O&M systems to ensure sustainable O&M is achieved.
- **Mechanism of quality control:** Mechanisms should be developed that will ensure good workmanship of the water supply installations. Poor workmanship is a recipe for failure of efficient and effective O&M systems.

## 1.9 Rural Piped System

### 1.9.1 Definition

It is defined as it is a water supply system which serves more than one rural village and small towns in combination from a single source or combination of sources; with gravity or pumping or combination system; with a distribution system that is managed by elected community representatives and operated by recruited scheme operators (local service providers).

### 1.9.2 Special Features of RPS in Ethiopia

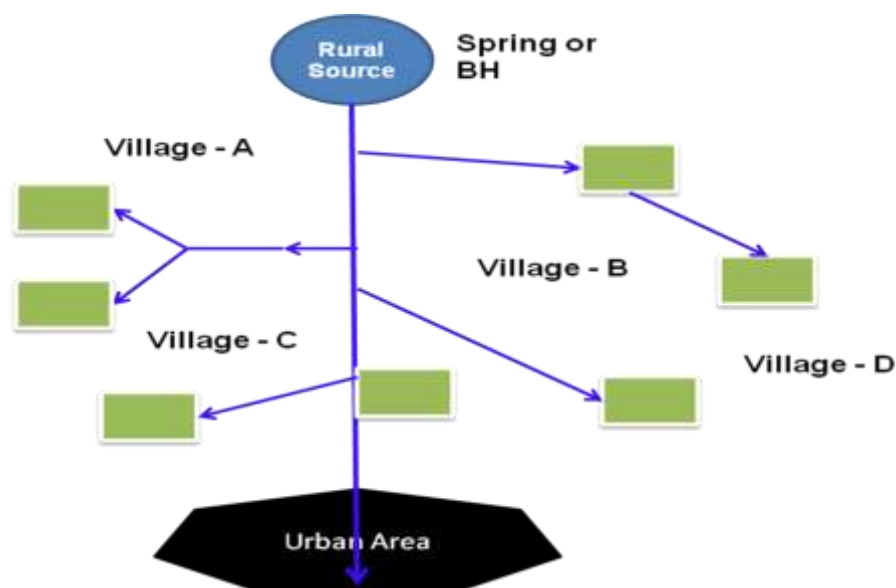
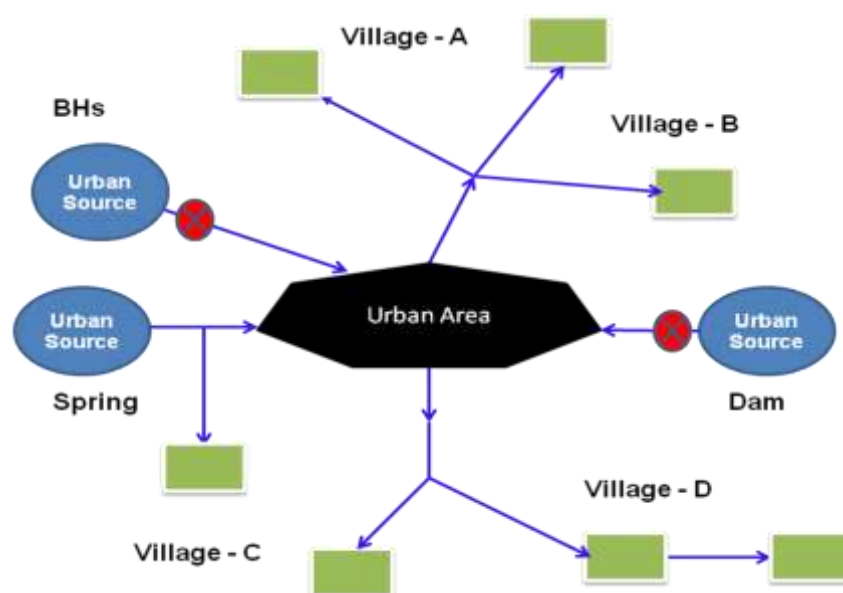
RPS schemes in Ethiopian context are distinguished through the following characteristics:

- One source supplies several rural villages and possibly one or more small towns,
- The source is located far away from the users and their villages,
- The systems have large installations such as head works, pumping stations, long transmission lines, service reservoir, distribution system, water points and connections,
- Users are organized to form an association and select representatives to ensure effective oversight of the scheme,

The management of the scheme requires professional operator.

### 1.9.3 Configuration of Rural Piped System

Two different types of RPS configuration predominately exist. These are presented in Figure 1.1 and 1.2. Figure 1.1 is showing the water sources are mainly from the rural area, like that of Robe-Melliya and Hetosa, which feeds the various villages and end to the urban areas. The other one is the sources belongs to urban area like dams and deep boreholes, which mainly feed to the urban community and extended to the various nearby villages as presented in Figure 1.2.

**Figure 1-1: Water sources from rural area RPS distribution****Figure 1-2: Water sources from urban area RPS distribution**

The two systems are totally having different service delivery models. The former one is fully managed by community elected management bodies, while the later, delivery the service by urban water utility. This report focuses on the community managed rural piped system.

## 1.10 Classification of Maintenance

### 1.10.1 Scheduled (Preventive Maintenance)

It may be defined as the care and servicing by individuals involved with maintenance to keep equipment/facilities in satisfactory operational state by providing for systematic inspection, detection, and correction of incipient failures either prior to their occurrence or prior to their development into major failure.

a) Objectives of POM are to:

- enhance capital equipment productive life,
- reduce critical equipment breakdowns,
- allow better planning and scheduling of needed maintenance work,
- minimize production losses due to equipment failures, and
- promote health and safety of maintenance personnel

The most important principle to keep continuous management support is: *“If it is not going to save money, then don’t do it!”*

b) Elements of Preventive Operation and Maintenance (POM):

The following are the list of elements of preventive operation and maintenance.

**Table 1-1: Elements of Preventive O&M**

No	Elements	Description
1	Inspection	Periodically inspecting materials/items to determine their serviceability by comparing their physical, electrical, mechanical, etc., characteristics (as applicable) to expected standards
2	Servicing	Cleaning, lubricating, charging, preservation, etc., of items/materials periodically to prevent the occurrence of incipient failures
3	Calibration	Periodically determining the value of characteristics of an item by comparison to a standard; it consists of the comparison of two instruments, one of which is certified standard with known accuracy, to detect and adjust any discrepancy in the accuracy of the material/parameter being compared to the established standard value
4	Testing	Periodically testing or checking out to determine serviceability and detect electrical/mechanical-related degradation
5	Alignment	Making changes to an item’s specified variable elements for the purpose of achieving optimum performance
6	Adjustment	Periodically adjusting specified variable elements of material for the purpose of achieving the optimum system performance
7	Replacement	Periodic replacement of limited-life items or the items experiencing time cycle or wear degradation, to maintain the specified system tolerance

c) Items necessary for effective POM program:

- accurate historical records of equipment,
- manufacturer’s recommendations,
- skilled personnel,
- past data from similar equipment,
- service manuals,
- unique identification of all equipment,
- appropriate test instruments and tools,

- management support and user cooperation,
- failure information by problem/cause/action,
- consumables and replaceable components/parts, and
- Clearly written instructions with a checklist to be signed off.

### **1.10.2 Un-scheduled (Breakdown) Maintenance**

Un-scheduled maintenance helps in preventing breakdown of equipment but totally avoiding is impractical. Some failures could not be identified easily but needs fault tracing and correction in other words trouble shooting. Repairing the failed part cannot be a full solution to the problem as long as reasons of failure are not known. Knowing the exact problem will assist in preventing repetitive failures. As in all repairs and maintenance activities, correct procedures must be followed in repairing break downs. These procedures must be followed in repairing break downs. These procedures include testing by instruments, trouble shooting or any other means but the manufacturer maintenance manual is the best reference to follow correct repair procedures.

## **1.11 O&M at National Level**

The Ministry of Water, irrigation and Electricity (MoWIE) is the lead institution that shall ensure that O&M of RWSS facilities is sustainable. The roles and responsibilities of the Ministry shall be to:

- Provide policy direction and co-ordinate RWSS sector programmes and support agencies, as well as all sector stakeholders.
- Manage and disseminate RWSS information including the use of advocacy.
- Invest in sectoral planning, development and construction of RWSS infrastructure.
- Establish standards, guidelines and inspectorates to monitor the effectiveness of the RWSS O&M system.
- Promote private sector participation in O&M of RWSS facilities in liaison with line ministry involved in RWSS.
- Monitor the supply chain links for spare parts in liaison with line ministries involved in imports and export of goods to ensure *timely deliveries*.
- Undertake formation and reviews of policies and their enforcement.
- Facilitate training and capacity building within the RWSS sector at the national, regional, woreda, kebele and community levels.

The MoWIE will employ an O&M unit staff to oversee the implementation of O&M activities under Water Supply and Sanitation Directorate.

## **1.12 Who and How will use this Manual?**

This manual is intended primarily for the Water Boards / WASHCOs, Water Administration Offices / Operators in charge of the operation and maintenance of the Rural Piped System of water supply schemes. In addition it is also a useful tool for Ministry of Water, irrigation and Electricity, Regional Water Bureaus, Zone and Woreda Water Offices, supporting

organizations and relevant stakeholders to support, monitor and evaluate the plan and implementation of the O&M functions to achieve its objective stipulated above.

### **1.13 Dissemination of the Manual**

These manuals are developed by the initiative of the Ministry of Water, irrigation and Electricity (MoWIE) with the financial and technical support of the Finland Government and COWASH. Thus, the manuals will be disseminating to all stakeholders involved in Rural Piped System stakeholders.

The MoWIE will disseminate to the Regional Water Bureaus: The RWBs in turn will distribute to the Zone and Woreda Water Offices. The Zone or Woreda Water Offices will distribute to the respective rural piped system Water Administration Office and WASHCOs.

Secondly, the MoWIE will disseminate these manuals to the relevant development partners (World Bank, African Development Bank, DFID, UNICEF) and various NGOs like Water Aid, Action Aid, Water Action, Plan International, SNV, International Rescue Committee, REST, ORDA, ODA and other unmentioned relevant stakeholders.

### **1.14 Revision of the Manual**

These manuals tried to cover all the necessary topics Operation and Maintenance Management of scheme components that demanding in rural piped system, however, due to the various technological upgrading, they can me revised and updated. Hence, periodical updating the technical manual is mandatory so as to fit the technical issue overlooked and to suite to the particular nature of the system for the RPS. Hence, the Water Board / WASHCOs in consultation with MoWIE and Regional Water Bureau, shall update its manual so as to suit the operation and maintenance activities and achieve the following three basic measuring gauges:

- Less costly
- Prompt
- Better service or quality

Updating can be made to these manuals due to the following reasons.

- Update the tasks and responsibilities listed in this manual so as to include new installations or exact recommendation of manufacturers.
- Update the maintenance management system as per the realistic path.
- Update the procedures for procurement and store keeping meeting the service scope.
- Update the system components in the manual to suit the prevailing water supply system components.

Updating of the Operation and Maintenance manual by RPS Water Administration Office shall strictly comply with the arrangements of the available components stipulated in the drawing (sketches) with all the information about the scheme components described. In other words preparation of RPS specific Operation and Maintenance follows preparation of sketches most preferably GIS based drawings with all the required geographical, physical and capacity related etc. information included.



## **1.15 O&M AT NATIONAL LEVEL**

The Ministry of Water, irrigation and Electricity is the lead institution that shall ensure that O&M of RWSS facilities is sustainable. The roles and responsibilities of the Ministry shall be to:

- Provide policy direction and co-ordinate RWSS sector programmes and support agencies, as well as all sector stakeholders.
- Manage and disseminate RWSS information including the use of advocacy.
- Invest in sectoral planning, development and construction of RWSS infrastructure.
- Establish standards, guidelines and inspectorates to monitor the effectiveness of the RWSS O&M system.
- Promote private sector participation in O&M of RWSS facilities in liaison with line Ministry involved in RWSS.
- Monitor the supply chain links for spare parts in liaison with line ministries involved in imports and export of goods to ensure timely deliveries.
- Undertake formation and reviews of policies and their enforcement.
- Facilitate training and capacity building within the RWSS sector at the national, Regional, Woreda, Kebele and community levels.

The MoWIE will establish an O&M section to oversee the implementation of O&M activities.

## References

References for each of the manuals are specified in each topics of the manuals.

## **RURAL WATER PIPED SCHEMES**

**(Parts A, B, C)**

### **Water Sources and Electromechanical Equipment**

## **PART – B: WATER SOURCES FOR WATER SUPPLY**

**Document 4**

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## **2. WATER SOURCES FOR WATER SUPPLY**

### **1.16 General**

This Chapter covers the basic concepts and procedures for proper operation and maintenance of water sources and the equipment used at these sources to prepare the water for distribution.

It covers the operation, maintenance and rehabilitation required for wells, infiltration gallery, river intakes, impounding reservoir of the sources for water supply.

A properly designed and constructed well can give many years of trouble-free service.

Good O&M seeks to avert well failures, which are usually indicated by reduced (if not, complete loss of) pump discharge or deterioration in the quality of the water.

Good O&M actually begins even before a well is put into operation. Before actually operating a well, it must be determined /obtained the following information which will guide its well operating and O&M procedures:

- Safe pumping level
- Pump curves
- Well design
- Location of discharge line shut-off valve and pressure gauge.

### **1.17 Objective of O&M for Water Sources**

The objectives of operation and maintenance of sources of water supply schemes are:

#### **Box 1: O&M Objectives at Water Sources**

- 1) The water sources should be able to supply water which is safe to drink after treatment,
- 2) To ensure the water sources be perennial and have sustainable yield,
- 3) To keep the water quality satisfied the demand and not be allowed to deteriorate,
- 4) To minimize or no disruption in water supply systems due to depletion of water sources,
- 5) To have least possible expenditure on the repair and maintenance of the water sources,
- 6) To have proper record of the water sources, so that their time to time performance could be known,
- 7) A methodical long-range program of source inspection and monitoring should be introduced to identify problems so that a regular program of preventive maintenance can guarantee reliability and continuity,
- 8) GIS supported maps should be prepared for all type of water sources.



## **1.18 Water Sources**

Mainly the sources of water supply are divided into three major classifications, such as: groundwater, surface water and rain water.

### **1.18.1 Groundwater**

The ground water supplies include dug, bored, driven and drilled wells, springs and infiltration galleries.

Ground waters are usually free of turbidity, colour and odours, and bacteria, but it may be hard or corrosive and in some cases may contain iron, manganese and hydrogen sulphide. Treatment, if necessary at all, will usually consist of chlorination as a proactive measure.

The aquifer comprises the supply reservoir its ability to yield water in the amount desired can be determined from test well. The number, size, depth and spacing of wells will depend on the maximum day demand.

### **1.18.2 Surface Water**

Surface water supplies may be further divided into river, lake, pond, canal and reservoir supplies. Dams are constructed to create artificial storage. Canals or open channels can be constructed to convey surface water to the project sites. The water is also conveyed through pipes by gravity or pumping.

In general, the surface sources are characterized by soft water, turbidity, suspended solids, some colour and microbial contamination.

To be acceptable for drinking purpose water should be free of all of these items, except hardness, which however, should be reduced when too high.

The type of treatment employed depends on the kind and extent of impurities to be removed. The size of the treatment depends on the capacity requirements to meet the maximum day demand.

### **1.18.3 Rainwater**

Rain falls upon the surface of the earth may be considered as the original source of all the water supplied. Water, as source of drinking water, occurs as surface water and ground water. Three aspects should be considered in appraising water resources e.g., the quantity, the quality, and the reliability of available water. The operation and maintenance requirement for the rainwater harvesting is addressed in Volume-III of the manual as pastoral areas water supply technologies, and can be referred when needed.

## **1.19 Sources of Water Supply Facilities**

The sources of water supply facilities included:

- Dam and impounding reservoirs,
- Lake and River intakes,
- Wells and Boreholes,
- Springs

The operation and maintenance procedures, the preventive maintenance program and schedule is given in the following sections.

## 1.20 Operation and Maintenance Requirements

### 1.20.1 Wells and Boreholes

Boreholes are usually drilled wells, which are required in the harder earth formations or where the aquifer is deep. These wells are fitted with electrically or mechanically driven pumps (submersible or line shaft turbine pumps).

Drilled wells have tight metallic or plastic casing and require little structural maintenance.

Wells drilled in aquifers of sand or small gravel require that a well screen with fine opening be used in the water source section to prevent the entry of sand or others solid particles. As a further aid, to keep out fine particles, a gravel package artificial wall is provided around the well casing and screen.

Boreholes may change their yield as a result of clogging of the wells or screens or over pumping of the aquifer. Wells should discharge within the specific pumping rates, which were established during the pumping test of the well.

#### 1.20.1.1 Component of Borehole

Table 2.1.presents different identified components of borehole and discussed its purposes

**Table 2-1: Components of Borehole**

No.	Item	Purpose
1	Borehole	Protected hole which penetrates to the aquifer and which is filled by water from the aquifer.
2	Wellhead	Prevents surface water from seeping down the edge of the casing and entering the aquifer or borehole
3	Borehole casing	Casing prevents the hole from collapsing
4	Screens	Perforated parts of the casing to allow water from the aquifer to enter the borehole
5	Seal	Prevents seepage water from moving from higher aquifers or near surface to lower aquifers
6	Submersible electrical pump	Raise water from aquifer to tank. The pump is located in the hole and is protected by the borehole casing
7	Rising Main	Water is raised from the pump to the tank through the rising main
8	Dipper tube	Dipper tube allows the water level in the borehole to be measured
9	Meter	Measures volume of water extracted by the borehole from the aquifer

No.	Item	Purpose
10	Pump House	Structure which usually contains the control panel. If the pump in use is an electrical submersible, then the pump house is also likely to contain the generator or the circuit board for the mains electricity power.
11	Generator (Genset)	Provides electricity to run the pump. Generator may also be a standby for when mains power is not available. Generator is driven by a motor/engine which may be diesel powered
12	Control panel	The control panel is a set of electrical circuits whose purpose is to control the power to the pump
13	Fuel Store	A well ventilated and secure store for fuel
14	Tank	Borehole water is typically raised to ground or elevated tank from which water is distributed to the consumer points

### 1.20.1.2 Causes of Failure of Wells

Well may be failed due to inadequate design, faulty construction and operation, lack of timely maintenance. The main causes for source failure are categorized as under:

- i) Incorrect design: for instance use of incorrect size of screen and gravel pack, wrong pin pointing of well site resulting in interference,
- ii) Poor construction e.g. the borehole may not be vertical; the joints may be leaky, wrong placement of well screen, non-uniform slots of screen, improper construction of cement slurry seal to prevent inflow from Saline aquifer,
- iii) Corrosion of screens due to chemical action of water resulting in rupture of screens,
- iv) Faulty operation e.g. over pumping, may causes the rupture of strainer casing pipes due to piping action of water, poor maintenance,
- v) Adverse aquifer conditions resulting in lowering of the water table and deterioration of water quality,
- vi) Mechanical failure e.g. falling of foreign objects including the pumping assembly and its components,
- vii) Incrustations due to chemical action of water,
- viii) Inadequate development of wells,
- ix) Placement of pump sets just opposite the strainer casing pipes, causing entry of silt by rupturing slots of pipes.

### 1.20.1.3 Well Operation

After production wells are in operation, a regular program of observation should be carried out:

- Water levels should be measured periodically in all wells, whether pumping or idle,

- Water samples should be collected for chemical analysis,
- Detailed record of well performance should be maintained,
- A running tabulation of pumping should be recorded.

Problems arising from excessive pumping, contamination, salt-water intrusion, decline of water levels and unusual changes in temperature can be solved only when adequate data are available concerning the performance of the well.

#### 1.20.1.4 Water level and Drawdown

Water level and draw down measurements are necessary for accurate determination of the capacity of a well and for operation within safe limits of capacity. Comparison of these measurements over a period of time reveals changes in well characteristics and shows when maintenance is necessary.

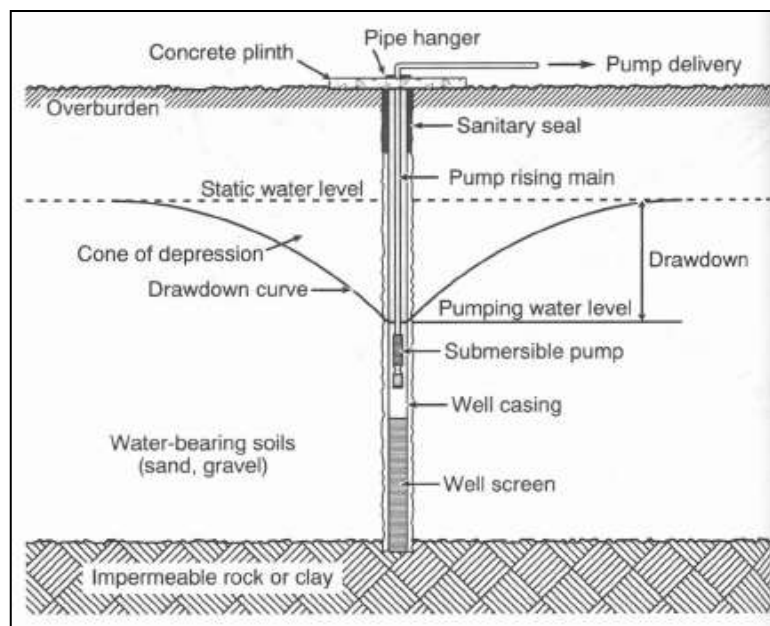
Pumping water level and Drawdown can be measured with the help of an electrical depth gauge or an Air line gauge.

In case of measurement by an electrical depth gauge, an electrode is suspended in the borehole by a metallic cloth tape. The conductor terminal clip is fixed with the metallic casing of the borehole. The electric circuit is completed when the electrode touches the water surface which is indicated by the galvanometer. The corresponding depth is read on the tape.

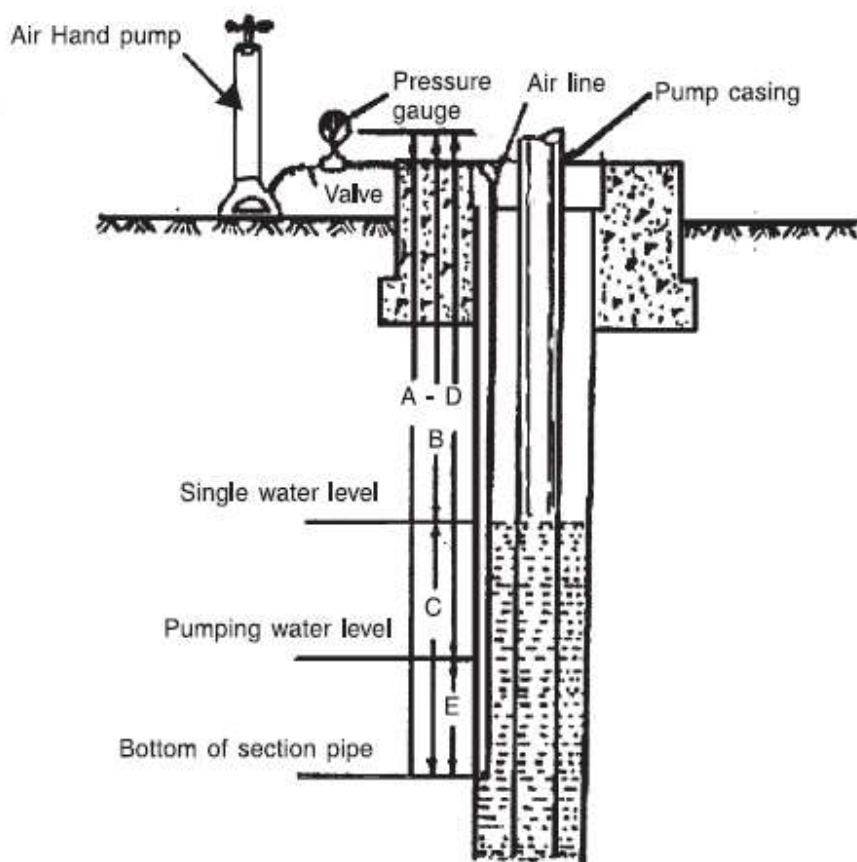
Air line gauge method is most commonly used for measurement of Static Water Level (SWL), Pumping Water Level and draw down. Air pipe can be lowered in borehole through a slot or a hole provided in the flange in case of flanged assembly and in the annular space in case of socket assembly. In this method air is pumped into the line until the maximum possible pressure is reached.

Normally, the air line is full of water up to the level of water in the well (static or pumping water level). When air is forced into the line, it creates pressure which forces water out of the lower end until it is completely expelled and the line is full of air. If more air is pumped in, air, instead of water, is expelled and it is not possible to increase the pressure further.

The head of water, C or E (as shown in the Figure 2.1), above the end of the line maintains this pressure, and the gauge shows the pressure or head above the end of the line. If the gauge is graduated in meters of water, it registers directly the amount of submergence of the end of the line. This reading subtracted from the length A of the line, gives the water level B or D (static or pumping water level).



**Figure 2-1: Airline Installed in Borehole for measuring water level**



### 1.20.1.5 Borehole Sounding

For identification of lithological details electrical logging can be used for uncased bores while Gamma logging can be used for both, cased and uncased bores. Borehole camera can be used for identification of the condition of borehole, casing and strainer pipes.

### 1.20.1.6 Well Yield

The most accurate and most often used method of determining well yield is by actual pumping test. A newly developed or an existing well whose yield is to be determined is pumped continuously for a given length of time and the yield characteristics are determined.

#### a) Maximum Yield

This is the maximum well yield in liters per minute that can be pumped from the well over a six-hour period; during which, pumping rate is maintained so that the pumping level remains stationary, but any increase in pumping rate would cause the well to run dry.

#### b) Desired Yield

This is the rate at which the well is expected to produce. The desired yield is considered to be attained if the pumping level remains unchanged during six hours of pumping at that rate.

### **c) Safe Yield**

This is the rate of pumping that produces a drawdown of 50 percent of the drawdown obtained when the well was built and pumped at a maximum yield. Operating a well within its safe yield will prolong its productive life.

Example: A 110 meters well has a static water level of 20 meters. The pumping level for a maximum yield is 90 meters. Hence the drawdown for the maximum yield becomes  $90 - 20 = 70$  meters. Fifty percent of this is 35 meters. Thus, the safe yield the number of liters per minute pumped from well that will produce a drawdown of 35 meters.

#### **1.20.1.7 Specific Capacity**

This is the number of litres per minute pumped per meter of drawdown. The specific capacity is not the same for each meter of drawdown, but is approximately, so when the drawdown is not too great. Knowing the specific capacity of the well enables the operator to estimate the drawdown that will be produced at different pump settings.

According to available data the specific capacity of wells should be measured at regular intervals either monthly or bi-monthly and it should be compared with the original specific capacity. As soon as 10 to 15% decrease in specific capacity is observed steps should be taken to determine the cause and accordingly corrective measures should be taken. Rehabilitation procedures should be initiated before the specific capacity has declined by 25%. A check list given below can be used to evaluate the performance of a well:

If a well delivers 6000 litres per minute at 15 meters of drawdown, the specific capacity =  $6000/15 = 40$  litres per minute per meter.

1. Static water level in the production well,
2. Pumping rate after a specific period of continuous pumping,
3. Specific capacity after a specified period of continuous pumping,
4. Sand content in a water sample after a specified period of continuous pumping,
5. Total depth of the well,
6. Efficiency of the well,
7. Normal pumping rate and hours per day of operation,
8. General trend in water levels in wells in the area,
9. Draw down created in the production well because of pumping of nearby wells.

A significant change in any of the first seven conditions listed above indicates that a well or pumping rate is in need of attention.

#### **1.20.1.8 Well Maintenance**

- a) Wells should be pumped carefully and within specific pumping rates

Excessive pumping rates may cause sand and silt to pack in and around the well screen, thus clogging the screen, or fill the voids in the gravel-packed wells, consequences in reduction of yield.

When a well pump is started or stopped, a certain amount of agitation occurs in the aquifer which causes clogging or cave-ins that will reduce the yield. Need for changing methods of pump operation can be determined from inspection on Well performance and quantity of water produced.

- b) Measure water level and drawdown related to the pumped discharges. These have to be carried out correctly. Records must be kept so that operational and maintenance decision can be made. The various levels are measured by using a steel tape, electrode or an air and pressure gauge.
- c) Clean Well screen when operating data on yield or drawdown show that Well cleaning is necessary. All recommended method should comply with the screen manufacturer's instructions. Screen cleaning should always to be carried out by experienced professional personnel. The cleaning methods employed are: 1) backwash or surging, 2) Dry ice or with hydrochloric acid.
- d) When yields have been reduced over a period of time, it may be possible to recover all or part of the original yield by surging. This consists of forcing water from the well, back through the well screen or gravel-pack into the aquifer. The screen and area around the well are this washed and many of the fine particles responsible for clogging are removed. Trained operating personnel can accomplish this by starting and stopping the pump at short intervals.

This procedure should be repeated until the discharge is clear.

- e) Backwash with larger volumes of water may give better results. This has to be carried out by professional personnel. A combination of backwashing with water and back blowing with compressed air by pulling out the installed pump may give good results. This has to be carried out by professional experienced with this technique.
- f) Cleaning with dry ice is simple and safe. However, it may not give desired results. To use this method, drop dry ice into the well casing and seal off the top of the well. The gas expansion creates a violent surging which produces back pressure, back washing the screen.

#### **1.20.1.9 O&M Schedule for Deep Borehole**

The following boxes illustrate the O&M activities required at various periods.

##### **Box 2: Daily O&M Activities for Boreholes**

###### **❖ Daily O&M activities:**

- ✓ Clean the pump house.
- ✓ Check available Voltage in every phase.
- ✓ Check reading on ammeter is normal – stop pump if electric motor is drawing too much current and report problems, open isolation valve.
- ✓ Check power factor.
- ✓ Confirm water is being delivered
- ✓ Check for leaks in the rising main.
- ✓ Continue to check voltmeter and ammeter readings during the day.
- ✓ Maintain pumping log book and history sheets of tools, plants & equipment's.
- ✓ Observe the abnormal sound of pumping machinery by listening the
- ✓ Changes in noise level.



❖ **Weekly activities at the tank:**

- ✓ Testing water quality using a Field Test Kit (for small schemes only)

❖ **Annual activities may include but not limited to:**

- ✓ Remove the pump and rising main from the well and inspect.
- ✓ Check pipe threads and re-cut corroded or damaged threads.
- ✓ Replace badly corroded pipes.
- ✓ Inspect electric cables and check insulation between cables.
- ✓ Check as per Recommendations of manufacturer's operational manual.

#### **1.20.1.10 O&M Resources for Motorized Borehole**

Pump operator is required for pump operation and billing and collection. Skilled labor is required for pump and motor servicing and maintenance. Materials and equipment include pipes for the rising main, tools for maintenance and repair, oil for the motor, spare parts for the motor and electrical control panel. Finances would typically be from the household paying water charges, Woreda Water Office, Zone Water Office and regional Water Bureau, depending on the situations.

#### **1.20.1.11 Rehabilitation of Boreholes**

The correction of the situations mentioned under section 2.5.1.2 at (i) to (iii) above is a very difficult and costly affair. Therefore, a decision whether to rehabilitate an old well or construct a new should be based on the cost benefit analysis. Following remedial measures can be taken for correcting situation mentioned under section 2.5.1.2 at (iv) to (viii).

##### **Faulty Operation**

Boreholes should run in such a way that the pumping water level should always remain above the level of well screen. Over pumping will expose the well screen, which may result in incrustation and corrosion. Over pumping results in excessive drawdown, which may causes differential hydrostatic pressures, leading to rupture of well screen. Negligence in timely repair and maintenance may result in poor performance of the tube well.

Therefore, before any permanent damage is done to borehole, it should be ensured that the borehole is operated at its designed capacity and timely repair and maintenance are done.

## **Adverse Aquifer Conditions**

In adverse aquifer conditions where water table has depleted but the quality has not deteriorated, wells can generally be pumped with considerable reduced discharge.

## **Mechanical Failure**

The falling of pumping set assembly and its components into the borehole can be minimized by providing steel wire holdings throughout around the assembly length including pumping set or by providing and clamping a steel strip around the pumping assembly.

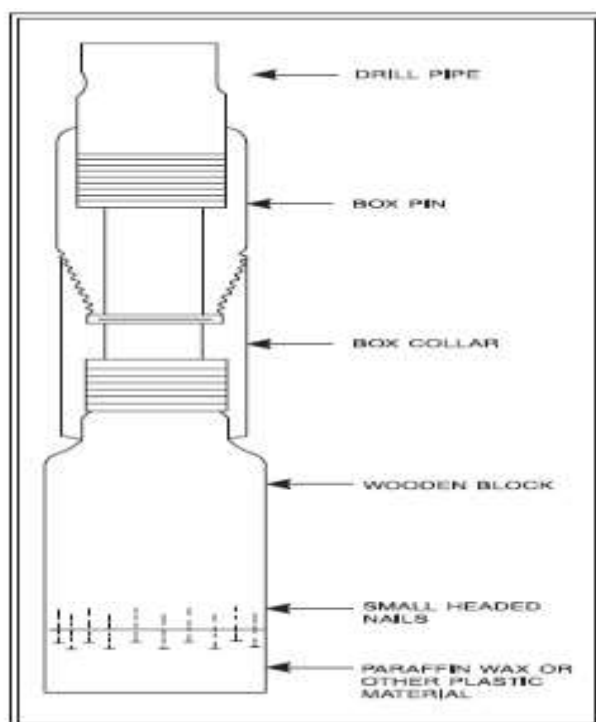
However, in spite of proper care sometimes foreign objects and pumping set assembly components may fall in the well. In corrosive water the column pipe joints and pump parts may get progressively weakened due to corrosion, get disconnected and fall into the well.

These foreign & falling objects may damage the well screen resulting into failure of the well. However where well screen is not damaged, then by proper fishing the fallen objects can be taken out of the well making it functional again. Following are the steps taken for fishing out the fallen objects in the bore holes:

### **(a) Impression Block**

An impression block is used to obtain an impression of the top of the object before attempting any fishing operation. Impression blocks are of many forms and design. Figure 2.2 illustrates an impression block made from a block of soft wood turned on a lathe. The diameter of the block is 2 cm less than that of drilled hole. The upper portion is shaped in the form of a pin and driven to fit tightly into the box collar of a drill pipe. To ensure further safety, the wooden block is tied with wire or pinned securely to the collar. Alternatively, the block could be fixed to a bailer. A number of nails are driven to the lower end of the block with about 1 cm of it projecting out. A sheet metal cylinder of about 5 to 7 cm is temporarily nailed around the block to hold molten wax, which is poured into it. Warm paraffin wax, soap or other plastic material poured into the cylinder is left to cool and solidify. The metal cylinder is then removed.

The nail heads hold the plastic material to the block. To locate the position of a lost object, the impression block is carefully lowered into the hole until the object is reached. After a proper stamp is ensured, the tool is raised to the ground surface, where the impression made in the plastic material is examined for identifying the position of the lost object and designing or selecting the right fishing tool.

**Figure 2-2: Impression Block****(b) Fishing Tools to Recover Fallen Objects**

The term 'fish', as used in tube well technology, describes a well drilling tool, pump component or other foreign body accidentally fallen or struck in boreholes. The type of fishing tools required for a specific job will depend on the object to be lifted and the position in which it is lying in the well. It may often be necessary to design a fishing tool to suit a particular job. However, series of fishing tools suitable for different jobs are available in the market, which could be adapted or modified to suit a particular requirement.

**1.20.1.12 Incrustation****Diagnosing Incrustation Problems**

Chemical incrustation is indicated by a gradual reduction in yield of the well. However, it can also happen with a gradual lowering of the water table due to over-pumping or inadequate ground water recharge. This fact can be verified by studying the behaviour of the groundwater level over the service period of the borehole. Incrustation in the form of slime produced by iron bacteria decreases well yield due to clogging of the well screen and casing.

Incrustation also clogs the fractures & fissures of rocky zone of well which is prevalent in boreholes. This trouble can be identified from the performance curves of the well. In this case the reduction in well yield is somewhat more rapid. Water quality analyses are used to identify the type of incrustation.

**Types of Incrustations**

The various types of incrustation in order of the frequency of occurrence are:

- Precipitation of carbonates, sulphates and silicates of calcium and magnesium,

- Precipitation of hydroxides, oxides and other compounds of iron and manganese,
- Slime produced by iron bacteria and other slime producing organisms,
- Deposition of soil materials (Mechanical Incrustation).

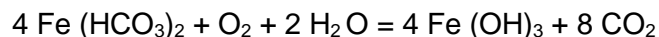
#### **(a) Calcium and Magnesium**

Calcium carbonate is one of the most extensively found minerals. Its solubility depends upon the quantity of free carbon dioxide in the water which in turn depends upon the pH, the temperature and the pressure. On pumping, a low-pressure zone is created around the well and some of the dissolved carbon dioxide is released from solution. Some calcium bicarbonate is then reconverted into calcium carbonate which is deposited as cement like material on the screen and in the sand and gravel around it. This incrustation builds up a shell around the screen which may be several centimetres thick. Partial incrustation may extend back as much as a metre into the water-bearing formation. In addition to the sand grains around the well which are cemented together, other substances like aluminium silicates, iron compounds and organic material may also be entrapped in the carbonate scales. Many a time the calcium carbonate may only be a small fraction of the deposit but is usually the basic binder. This type of deposit accounts for about 90 per cent of the cases of incrustation.

#### **(b) Iron and Manganese Salts**

Bicarbonates of iron and manganese are more soluble in water than their hydroxides. In incrusting regions the groundwater is generally charged to its full capacity with these salts.

It is believed that an increase of its velocity in the vicinity of the well is enough to upset the balance and precipitate out the insoluble iron and manganese hydroxides. These are jelly like and fluffy. Oxidation can then occur due to the dissolved oxygen in the water and these are transformed into hydrated oxides. Hydrated ferrous oxide is a black sludge while ferric oxide is reddish brown like common rust. Ferrous bicarbonates are moderately soluble in water, the solubility increasing if the water is acidic. Ferric salts are, however, insoluble in alkaline or weakly acidic water. Thus, a reduction of acidity can also cause precipitation of the iron salts. Ferrous bicarbonates also get oxidised when they come in contact with oxygen to form insoluble ferric hydroxide.



Oxidation is more marked in water table boreholes, which are run intermittently, because air can get into the zone of daily depletion of water table and oxidise the salts there. In such cases sand particles of the aquifer can get progressively coated with iron oxide, thus reducing the void spaces and encroaching upon the storage capacity of the formation.

Clogging by manganese occurs much less frequently. Soluble manganese bicarbonates react with oxygen to form insoluble manganese hydroxide which precipitates as a sooty or dark brown deposit.

In general, waters containing more than 400 ppm bicarbonates, 100 ppm sulphates, or 400 ppm silicates can be considered incrusting. Water containing 2 ppm iron or 1 ppm manganese can be considered incrusting. Water can also pick up iron from the well casing itself.

**(c) Bacteria**

Iron bacteria such as crenothrix grow attached to the screen or voids of the aquifer, and feed on carbon compounds like bicarbonates and carbon dioxide in addition to the iron in solution.

Release of carbon dioxide, deficiency of oxygen, and darkness favour their growth. During their life cycle they change the dissolved iron into the insoluble ferric state. This is deposited in the void of the aquifer surrounding the screen or in a jelly like sheath which surrounds the bacteria. This slime can clog the screen slots and the pores of the aquifer. They may grow in water pipes as well and clog the same. Similar bacteria can also cause oxidation manganese compounds to insoluble form.

Sometimes sulphate reducing bacteria are also found in ground water which reduces the sulphates in the water to hydrogen sulphide. Hydrogen sulphide so formed attacks the iron pipes to form insoluble iron sulphide, which deposits as a scale.

**(d) Silt and Clay Deposits (Mechanical Incrustation)**

Silt and clay material can sometimes move on to the screen and clog the same. This may also clog the fractures & fissures of rocky zone of a well which is prevalent in bore wells. Such clogging may be because of improper development or inadequate design and construction.

**1.20.1.13 Rehabilitation of Incrusted Boreholes**

It is very necessary that the type of incrustation is determined before deciding upon the treatment to be given. This can be done by analysing the water pumped by a well and examining samples of aquifer from around the well screen. Samples of incrustation taken from other wells in the same formation give very good information.

The most important factor in treatment by chemicals is an effective contact between the chemical and the deposit on the well screen as well as in the aquifer adjacent to it. The chemical solution tends to penetrate only those parts of the aquifer where it gets the least resistance, i.e. which are comparatively free from clogging. Hence it is very necessary to agitate the solution vigorously and to surge it so as to force it into areas which offer resistance. A treatment may have to be repeated a couple of times and the second or subsequent treatment will open up the more heavily clogged up areas.

Incrusted wells can be cleaned by acids, chlorine, dispersing agents, etc. Hydrochloric and sulphuric acid are effective in removing carbonates and partially effective in removing iron and manganese oxides. Glassy phosphates are able to disperse iron and manganese oxides, silts and clays. Chlorine is effective in removing bacterial growth and slime.

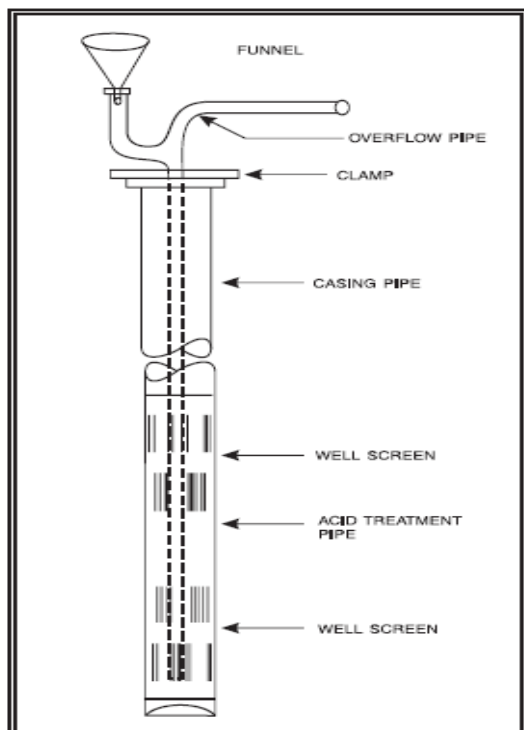
Different methods of rehabilitating incrustated wells are given below:

**Hydrochloric Acid treatment****(a) Inhibitor**

Carbonate-type incrustation (mineral scale) is removed by hydrochloric acid treatment. Concentrated hydrochloric acid of commercial grade (28% strength) is usually used in well treatment. It should contain a suitable inhibitor which helps in the quick dissolution of calcium and magnesium carbonates. It also slows down the acid attack on mild-steel well casings. Hence, the possibility of any damage to the pipe during treatment is minimised. If

inhibited acid cannot be obtained, a home-made inhibitor can be used. A solution of about 0.7 kg of gelatine in warm water, added to 100 litres of acid is usually adequate.

**Figure 2-3: Set up of Acid Treatment**



**(b) Treatment procedure**

1. The arrangement of equipment required for hydrochloric acid treatment is shown in Fig. 2.3. It consists of a 2 to 2.5 cm diameter plastic pipe which is long enough to reach the bottom of the well. The pipe, supported by suitable clamps, is lowered into the well. The upper end of the pipe is provided with a funnel inlet and overflow arrangement with a T-joint. The overflow takes care of any sudden blow out.
2. A solution of hydrochloric acid is prepared as indicated above. The acid solution required for one treatment should be 1.5 to 2 times the volume of water in the screened portion of the well. Sufficient acid is poured into the well to fill the bottom 1.5m depth of the screen. The acid-feeding pipe is then raised to about 1.5m and more acid poured. Even though acid is heavier than water and will displace it, the two will mix readily when stirred and the acid becomes easily diluted.
3. The effectiveness of acid treatment depends upon the contact between the chemical and the deposits on the well screen as well as in the adjacent aquifer. Chemical penetration will follow the path of least resistance. Hence, it is difficult to treat a clogged aquifer. It is, therefore, essential to agitate the acid solution vigorously and to surge it with a view to forcing the solution into the aquifer formations offering resistance. As soon as the acid solution is poured, it should be agitated in the well for one to two hours, with the help of a surge plunger. The solution should then be bailed out. Bailing is continued until almost clear water is obtained.
4. In the second stage of treatment, the process is repeated using the same quantity of acid. Surging is continued for a longer period before bailing out the water. Generally,

two treatments should be sufficient to achieve the desired results. During acid treatment, neighboring wells within a 60m radius should not be operated.

### **(c) Adaptability**

Hydrochloric acid treatment is best suited when incrustation is due to calcium and magnesium carbonates. The treatment may not be successful in removing iron and manganese crusts. It attacks the steel well casing to some extent. However, damage can be minimized by using suitable inhibitors. Hydrochloric acid treatment is not suitable for agricultural strainers which consist of brass wire-mesh wrapped over a perforated galvanized iron pipe. In such a screen, treatment will result in rapid electrolytic corrosion of the screen.

### **(d) Safety measures**

Hydrochloric acid is harmful to skin and can result in serious injury to eyes, if handled carelessly. Similarly, formation of gases, when the acid is poured into the well, can cause suffocation which could be fatal. Therefore, necessary care should be taken while treating the well. Good ventilation should be provided in the area around the pump house. All persons handling the acid should use rubber gloves and protective masks. A box of baking soda is kept handy, to neutralize the effect of acid if it falls on the body.

### **Sulphamic Acid Treatment**

1. Hydrochloric acid and sulphamic acid are used when calcium carbonate is the principal incrusting material. Although it is more expensive than hydrochloric acid but it has number of advantages i.e. it is less aggressive, it is relatively safe to handle and it does not attack M.S. well casings like hydrochloric acid. Hence, sulphamic acid is commonly used for treatment in case of wells having mild steel screens or casings with deposits of calcium and magnesium salts. Sulphamic acid ( $\text{NH}_2\text{SO}_3\text{H}$ ), is commercially available in granular and pelletized forms. It is available under different trade names having a corrosion inhibitor and a wetting agent. A color indicator is also introduced in the pellet which would change the color of the solution from violet to orange yellow, once the incrustation is completely dissolved. Sulphamic acid is soluble in water and the weak solution does not give any hazardous fumes nor irritates the skin.
2. Sulphamic acid in granular form is poured into the well through a plastic or iron pipe. The material so poured is agitated to dissolve it in water. Sometimes it is poured into the well in a 20 per cent solution with water. In this case, first the solution is prepared by dissolving one bag of acid (powder or pellets) at a time in a 200 litre capacity drum.

Arrangement is made for pouring the solution to the bottom end of the tube well. This is done by a 25 mm or suitable diameter PVC siphon tube, keeping one end of it in a funnel at the top of another 25 mm pipe already lowered into the bottom of the tube well through the space between the pump and well casing. The end of the siphon is to be kept in the tank containing the sulphamic acid solution. The solution is then poured into the tube well through the pipe. The rate of feeding of the solution is controlled by a valve provided at the end of the delivery pipe so that the solution enters the tube well gradually in order to avoid faster chemical reaction at the initial stage.

The feeding rate is regulated in such a way that the entire solution is added over a period of 2 to 3 hours. The solution is allowed to remain in the tube well for about 24 hours.

3. When the acid is available in pelletized form, the pellets could be dropped directly into the well in small quantities. Additional granular material is added to the well, as the reaction proceeds so as to keep the required strength of the solution. With surging, the reaction can be completed in 16 to 24 hours. After this period of 16-24 hours, about 4 to 6 hours of adding the chemical, the well is developed by compressed air or pump.

This will loosen the incrustated chemical on the tube well screen and the surrounding aquifer. The tube well water is then pumped out. Pumping is continued intermittently for about 10 hours, till clean water is obtained.

4. The quantity of the sulphamic acid required depends on the quantity of water in the well. The usually recommended quantity of sulphamic acid (by weight) to be added in a tube well is about 7 to 10 per cent of the weight of water in the well. Thus, in a 20 cm diameter borehole with a water column of 100m, the volume of water being 3.14 m<sup>3</sup>, the total quantity of sulphamic acid required for a treatment is about 250kg.

It is often desirable to add a corrosion inhibitor and a wetting agent (low detergent soap) to improve the performance of the acid. The quantities of both these additives are about 10 per cent each of the weight of sulphamic acid. The corrosion inhibitor prevents corrosive action of the acid on the metal of the well pipe. The wetting agent improves the dispersing and cleaning action of the acid. Fluronic F-68 or Pluronic L-62 is commonly used as wetting agents. When the two additives are used with the acid, it is necessary to mix them in a bucket containing clean water, so as to form heavy but pourable slurry, and add this slurry to the well through a tube.

5. The solubility of sulphamic acid decreases with decrease in temperature as shown in

**Table 2-2: Solubility of Sulphamic Acid in Water**

Temperature (0c)	5	10	15	25
Dry Acid solubility in 100 liters of water (kg)	17	18	20	23
Acid Concentration of saturated solution (%)	14	15	17	19

6. Safety precautions

Sulphamic acid in granular and pelletized forms, though less aggressive than hydrochloric acid, should be handled with caution. However, when used as a concentrated solution, it should be very carefully handled. Water-proof gloves and goggles should be worn by those handling it. Hydrogen sulphide and carbon dioxide gases are produced in considerable volumes during the reaction. The former is produced when iron sulphate is present. Both these gases are heavier than air. Hence, no person should be allowed to stand in a depression or a pit near the well during treatment.

7. Necessary conditions for acid treatment

The following are the major requirements for acid treatment of water wells:

- a) The metal of the well screen must be such that it is not damaged by the acid.
- b) The well screen must be constructed of a single metal in order to avoid electrolytic corrosion, as in the case of a bi-metallic alloy.



- c) A fair knowledge of the kind of incrusting material is essential to determine the proper procedure in well treatment. Samples of incrustations taken from other wells in the same formation are useful indicators of the causes of incrustation. Water quality analysis is also useful to obtain information on the kind of incrusting material.
- d) Adequate ventilation of well treatment site is necessary.
- e) Wells located in the neighborhood (within 30m) of the well must be shut down during the process of treatment.
- f) In all acid treatments, the acid should be handled with care. Good ventilation should be provided when operating in a confined area, like a pump house. Adequate provision should be made for disposing the waste water which is pumped out during its treatment. The waste water must be kept away from domestic wells, ponds or other water bodies used for human or cattle consumption. The waste, when diluted, will not adversely affect plants. Pumping the waste during acid treatment is a process of brisk surging, followed by slow pumping until the water becomes clear and free of odor and foam.

### **Glassy Phosphate Treatment**

Glassy phosphate or polyphosphates are used for well treatment when iron oxide, manganese oxide, silt and clay are the materials causing incrustation. Sodium hexameta phosphate ( $\text{NaPO}_3$ )<sub>6</sub> is one of the most commonly used polyphosphates. They do not dissolve the incrusting material and fuming or boiling does not take place. Phosphates have cleaning and dispersing properties which, when coupled with vigorous agitation, break the incrusting material. Thus, the incrustation gets dispersed and is easily pumped out. Calcium hypochlorite is also added to it in small quantities. It helps in chlorinating the well and killing the iron bacteria or similar organisms which may be present in well water.

#### **a) Treatment procedure:**

Glassy phosphate solution is prepared in a tank or drum. The amount of glassy phosphate to be added depends on the quantity of water in the well. Generally, 15 to 30kg of glassy phosphate is used for every 1000 litres of water in the well. It should be dissolved in water by suspending it in a tank in a cloth net or gunny bag, and should not be simply dumped.

A mixture of about 1.2 kg of calcium hypochlorite per 1000 liters of water is desirable. It helps kill iron bacteria and other organisms. The solution so prepared is poured into the well. This is followed by vigorous surging, which will help the chemical loosen and disperse the deposits inside the pipe as well as outside. The dispersed material passes out through the screen openings. Surging can be done using a surge plunger, compressed air, or by horizontal jetting.

If the pump installed in the well is not removed, the same can be used for surging. Surging by pumping is not very effective but can be used for convenience. Surging with a pump is done by starting and stopping it as often as possible. Operation is continued for a period of about four hours. The pump is then left idle for about two hours. The process is repeated twice or thrice. When the chemical has been in the well for about 24 hours, surging is again repeated several times. The waste is then pumped out and the well flushed thoroughly. Even while the well is being flushed out, surging is done a few times at intervals, and pumping continued until fairly clean water is obtained. The entire procedure may be repeated two or three times, using a fresh charge of polyphosphates and calcium hypochloride. The chemical is quite safe to use and does not require any special safety precautions.

### **b) Removal of Hydrogen Sulfide (H<sub>2</sub>S) Bio Fouling:**

Sulphate reducing bacteria in ground water reduce the sulphates in the water to hydrogen sulphide, which produces foul smell known as bio fouling. This bio fouling can be removed by the method mentioned above. This can also be removed by super chlorination of water.

### **Chlorine Treatment**

In case of wells incrustated with bacterial growth and slime deposits, chlorine treatment has been found most effective. Though acid may kill the bacteria, it is unable to remove the slime. Chlorine kills the bacteria as well as oxidizes the organic slime, thus loosening it.

Calcium hypochlorite Ca (OCl)<sub>2</sub> is often used for chlorine treatment. It is available in powder form, containing about 70 per cent free chlorine. The quantity required is generally 20 to 25kg for deep wells. Sodium hypochlorite Na OCl can also be used. Sometimes chlorine gas in water solution is also used but special equipment is required for its application.

### **a) Treatment procedure**

The desired amount of the chemical is put in the well directly, or in a water solution, to give the proper concentration of chlorine. When chlorine solution is used, it can be introduced into the well slowly through a plastic pipe of small diameter, over a period of about 12 hours in case of large wells. About 14 to 18 kgs of chlorine will be required for this purpose. Small wells require less chlorine and the period of application can be decreased accordingly.

Chlorine is corrosive in the presence of water. It should, therefore, be handled carefully so that it does not harm the pump, well casing and screen. It is not necessary to remove the pump, but it should be ensured that the plastic pipe carrying concentrated chlorine solution is not discharging the liquid directly on any part of the pump, well casing or screen. As soon as the chlorine solution is introduced, a sufficient quantity of water (50 to 100 times the volume of water standing in the well) is added to the well from an outside source, with a view to forcing the chlorine solution into the water-bearing formation. The well is then surged, using any of the standard techniques of surging. In case the pump has not been removed, the same can be used for surging, though not very effectively. Successful chlorine treatment of a well may require three or four successive operations.

### **Combined Hydrochloric Acid and Chlorine Treatment**

Hydrochloric acid treatment followed by chlorine treatment is highly effective. The acid readily dissolves the carbonates while the chlorine helps to remove the slime deposited by iron bacteria. The two treatments are alternated, the acid treatment being performed first. The cycle may be repeated two or more times.

### **Dry Ice Treatment**

The use of dry ice to open up incrustated screens is still in the experimental stage. Dry ice is carbon dioxide gas which is solidified by application of a large pressure. When it is put into a well, it is quickly converted into gas is not allowed to escape and is forced through the screen.

In this process the material choking the screen is loosened. There may also be some reconversion of salts into soluble bicarbonates due to the action of dry ice. Dry ice can also be used after acid treatment for agitating and creating back pressures for surging. It

may cause severe burns if it comes in contact with the body. Hence heavy gloves or tongs should be used while handling it.

#### **1.20.1.14 Inadequate Development**

##### **General**

Sometimes due to carelessness at the time of construction proper development of the borehole is not done which results in constant inflow of the sand particles causing choking of the filtering media and strainers. Such boreholes need redevelopment. The redevelopment of borehole will have following effects:

- 1) Redevelopment of well involves removal of finer material from around the well screen, thereby enlarging the passages in the water-bearing formation to facilitate entry of water.
- 2) Redevelopment removes clogging of the water-bearing formation.
- 3) It increases the porosity and permeability of the water-bearing formation in the vicinity of the well.
- 4) It stabilizes the formations around the well screen so that the well will yield sand-free water.
- 5) Redevelopment increases the effective radius of the well and, consequently, its yield.

##### **Method of Redevelopment**

Following are the methods of well redevelopment:

- 1) Over-pumping with pump.
- 2) Surging with surge block and bailing.
- 3) Surging and pumping with air compressor.
- 4) Back-washing.
- 5) High-velocity jetting.
- 6) Dynamiting and acid treatment.

For rehabilitation purpose any suitable method of redevelopment can be used as mentioned above. The largely used method is surging and pumping with compressed air. In this method surging with compressed air is a combination of surging and pumping. In the process a large volume of air is released suddenly into the well casing pipe, which produces a strong surge.

Pumping is done with an ordinary air lift pump. To achieve successful redevelopment of the well the submergence ratio (along with two airlines in water divided by its total length) is important. For obtaining the best results the ideal submergence ratio should be about 60%.

The efficiency of development reduces rapidly if the desired submergence ratio is not maintained.

The equipment required for surging and pumping operation consist of an air compressor and a tank of required size, drop pipe and an airline with a suitable arrangements for raising and lowering each independently, flexible high pressure air hose for the supply of

compressed air to the air pipe, pressure gauge, relief valve, a quick opening wall in the outlet of the tank, tee joint and pipe jointing material.

Normally, air compressors of 500 cum. per hour at 7kg/cm<sup>2</sup> to 800 cum. per hour at 17kgs/cm<sup>2</sup> are used for development/redevelopment work of the borehole. Whenever under capacity air compressor is used for the development of the well, in such condition proper development is not possible and such wells become sick after a short period of use. These boreholes can only be rehabilitated by adopting the procedure of development of well which is known as redevelopment of the well.

### **Submergence Requirement of the Airline and Selection of Air Compressor**

#### **Submergence Requirements of the Airline**

For achieving successful development/redevelopment of a well, submergence requirement of the airline is given below in table 2.3.

**Table 2-3: Submergence Requirements of the Airline**

<b>Lift (m)</b>	<b>Maximum Submergence (%)</b>	<b>Optimum Submergence (%)</b>	<b>Minimum Submergence (%)</b>
6	70	66	55
10	70	66	55
15	70	66	50
20	70	64	50
25	70	63	50
30	70	60	45
40	65	60	45
50	65	60	45
60	60	50	40
70	55	50	40

#### **Selection of Air Compressor**

The two most important factors in the selection of an air compressor for well development/redevelopment are the requirement of pressure and capacity. The required air pressure is determined, based on the length of air pipe below the static water level. Before air can be discharged from the lower end of the air pipe, the compressed air must push all the water out of the pipe. To do this, the air pressure must be greater than the water pressure before starting to pump water. The required pressure of compressor will be slightly more than submergence of the airline in the water.

A useful rule of thumb to estimate the compressor capacity is to provide about 0.28 m<sup>3</sup>/l of free air for each litre per minute of water at the anticipated pumping rate.

## **Redevelopment Procedures**

For redevelopment of the tube well following steps are to be followed:

- Lower the drop pipe and air line in the well up to the desired submergence. The bottom of the drop pipe should be kept about 60cm above the bottom of the screen and the air line is kept about 30cm higher than the bottom end of the drop pipe.
- Turn on the air from the compressor and the well pumped by the conventional air lift principle until the discharge water is free from sand.
- Air entry into the well is then cut off by closing the valve between the tank and the compressor and in the meantime, the air line is lowered so that it is about 30cm below the bottom of the drop pipe. The airline is thus at the same position as in the backwashing method.
- The air valve is quickly opened to allow the compressed air from the tank into the well.
- This tends to surge water outwards through the well screen openings.
- The air pipe is raised again and the cycle repeated until the water discharged from the well is relatively free of sand. The above operation of back-washing and pumping completes one operation of surging.
- The entire assembly is then raised to a height of about one meter and the operations repeated until the well section along the entire length of the screen has been developed.
- Finally, the air pipe is lowered again to the bottom of the well and the equipment operated as a pump to flush out any sand that might have accumulated inside the screen.

Normally, with this method of redevelopment all the wells drilled in alluvial formation with inadequate development can be successfully redeveloped. This method has also been tried for sick wells drilled in rocky formations and encouraging results have been noticed. The use of disbursing agents like Polyphosphates have also been found useful in rehabilitating the wells with redevelopment method drilled in alluvial formation with inadequate development.

### **1.20.1.15 Prevention of Incrustation and Corrosion**

At the time of construction of wells and even afterwards some steps can be taken for the prevention of incrustation and corrosion. These steps are given below:

#### **Prevention of Incrustation**

In case of wells where the water is charged with undesirable chemicals, incrustation cannot be prevented entirely, but it can be delayed, and kept in check by keeping the draw-down as small as possible. In this way a considerable release of carbon dioxide does not take place and precipitation of carbonates in well screens is kept in check. In order to reduce the head loss to a minimum, the well should be developed properly so that aquifer losses are reduced to the minimum. A screen having a large open area and fully penetrating the aquifer should be installed. This results in lower entrance velocities as well due to which precipitation of iron salts and carbonates is retarded. The pumping rate should be reduced and the pumping period increased. The required quantity of water may be obtained from several wells rather than pumping a few large wells at excessive flow rates. Lastly, the screen should be cleaned periodically, say once a year, even if the

discharge has not fallen off. This last point is very important because if partial choking takes place, it is very difficult to eradicate the same completely.

### 1.20.1.16 Prevention of Corrosion

#### Application of Corrosion Resistant Paints and Coatings

Corrosion can be controlled to a large extent by applying anti corrosive paints on the steel pipes at the time of construction of the tube well. Non corrosive casing pipe and strainers (such as PVC pipes and strainers) can also be used at the time of construction of tube well to avoid corrosion. Some commonly used paints/coatings to control corrosion are of aluminium, asphalt, red lead and coal tar. Now days, a number of epoxy paints for this purpose are also available in the market.

#### Cathodic protection of mild steel tube wells in corrosive ground water:

The following are two methods for applying cathodic protection against corrosion of mild steel pipes:

- (a) Sacrificial anode
- (b) Impressed current

**(a) Sacrificial anode:** For wells sacrificial anode cathodic protection is used which is detailed below:

In case of the sacrificial anode system of cathodic protection, a metal of higher negative potential than that of the material of the pipe to be protected is used as the anode.

The metal pipe acts as the Cathode and the intervening water as electrolyte (Fig. 2.4), thus establishing the flow of electrons from the anode to this cathode. During electrolysis, the anode gets dissolved slowly and the metal ions in the solution are deposited at the Cathode. Thus, the main pipe (well pipe) is protected from corrosion by sacrificing the metal of the anode. Sacrificial anodes are easy to install and no power costs are involved. They are effective in prolonging the service life of mild steel tube wells in corrosive water. However, the anodes have to be replaced periodically at the end of their useful life.

The anodes may be made of magnesium, zinc, aluminum, tin or their alloys. They are commercially available\* in diameters ranging from 1.5 to 8 cm and lengths of 1 to 3 m.

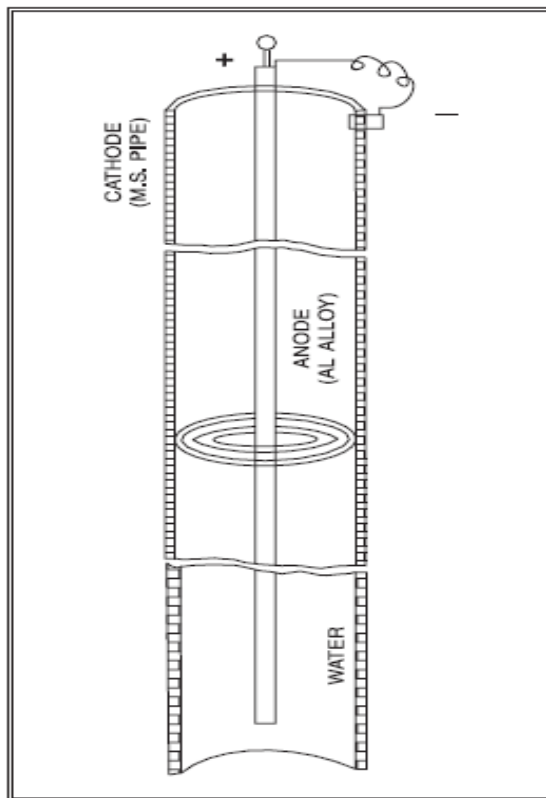
Research findings have established the adaptability of Aluminum-zinc-tin alloy in the cathodic protection of tube wells (a commonly used alloy has Al 90%, Zn 7% and Sn 3%).

Alloys cast in steel core pipes of 1 cm diameter are also available. The anode rods are threaded at their ends for jointing with each other through sockets or couplings.

**(b) Impressed Current:** In the Impressed current method electric current is passed from current source through anodes buried in the soil some distance from a mild steel pipeline.

This method is extensively used in protecting mild steel pipelines in water supply projects but its applicability in wells has not yet been established.

**Figure 2-4: Cathodic Protecting Arrangement for Boreholes**



#### **1.20.1.17 Artificial Recharge of Groundwater**

Artificial recharge of ground water can be achieved by the following:

i) *Stream flow harvesting comprising of*

- Anicuts
- Gully plugging
- Loose stone check dams (LSCD)
- Dams

ii) *Surface flow harvesting*

- Tank
- Ponds

iii) *Direct recharge*

- Recharge of wells
- Through injected wells
- Through roof top rain water harvesting structures.

#### **1.20.1.18 Conservation of Groundwater**

Following are the steps for conservation of ground water:

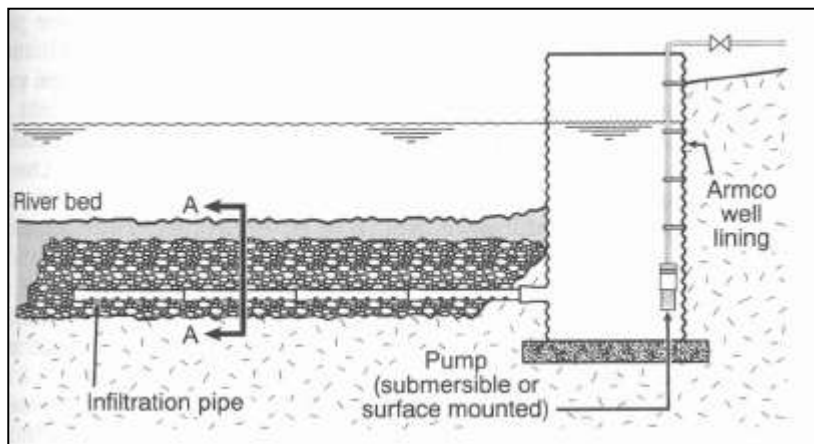
1. Improvement of home plumbing systems.
2. Reuse of recycled water.
3. By creating public awareness by Information, Education and Communication (IEC) activities.
4. By introducing sustainable water tariff.
5. By rain water harvesting.

### 1.20.2 Infiltration Well and their Maintenance

Infiltration well is located in river beds where sufficient sand depth is available. These wells are sunk up to the depth where hard strata are met with. The porous concrete portion will facilitate infiltration of water into the well. The diameter generally varies from 3 to 5m. The regular inspection of infiltration well needs to be conducted.

If illegal sand mining is done around or near the well, there is the possibility of the structure getting tilted to one side. To obviate this problem, it is essential to protect the infiltration well from sand mining. Sometimes the wells may get tilted

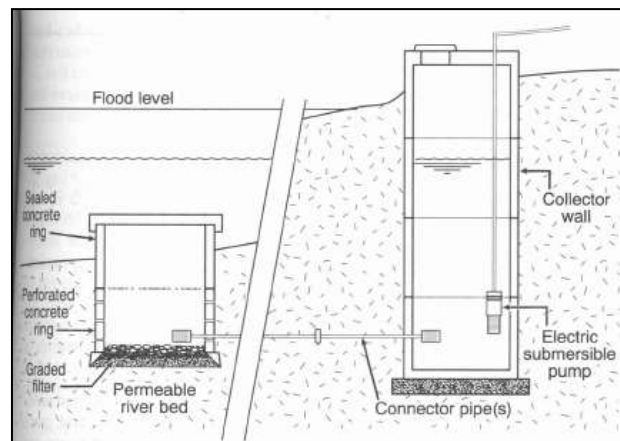
due to sand erosion during flood times and to overcome this problem packing of sand bags around the wells should be done.



It should be ensured that flood water does not enter into the well through the manhole cover during flood times and hence the manhole cover must be made water tight. Water quality test and specific yield of the well should be conducted during pre-rainfall and post rainfall period to assess the quality of water and the yields.

### 1.20.3 Infiltration Gallery

An infiltration gallery is a horizontal drain made from open jointed or perforated/slotted pipes, or a block drain, which is laid below the water table and collects ground water. The pipe should be driven into the well with proper slope to ensure continuous flow and the well points (horizontal drain) should be well under water table in dry season. Infiltration galleries need soils which are permeable to allow sufficient sub-surface water to be collected. The gallery should be surrounded with a gravel pack to improve flow towards it and to filter any large particles that might block the perforation. Horizontal boring at different depth and





direction, in open wells is one of the types of infiltration galleries. Water collected is taken to a collection well or sump, and then either withdrawn directly or pumped to a storage tank.

Infiltration gallery is often used in conjunction with other water supply scheme as a means of increasing the quantity of water intake in areas of poor water yield in this instance one or more galleries are built which drain into the central point, such as a hand dug well or spring box.

These are called collector wells, it is important to protect it from contamination by locating it uphill and the minimum safe distance from any source of contamination.

#### **1.20.3.1 Sanitary Inspection of Infiltration Gallery**

Sanitary inspection of Infiltration Gallery is required to be conducted in once a year by Woreda Water Offices, particular attention should be paid to the catchment area of the gallery, especially with shallow galleries. The water collected in Infiltration galleries has often not had as much filtration as well or spring water thus may be more vulnerable to contamination. Water quality testing should be done twice a year, once in the wet season and once in the dry season. The water at various points in the gallery, at the collector well or sump and the distribution system should also be tested.

#### **1.20.3.2 Maintenance of Infiltration Gallery**

The following O&M aspect shall be followed:-

Never exceed the design pumping rate- not more than 60% of the yield. Higher pumping rate could cause fine sediment to enter the filter and reduce the opening size of slots and the sand may enter screen and block the part of intake opening causing more sand pumping.

1. Do not let the gallery unused for longer time since it may tend to lower the hydraulic conductivity of filter pack.
2. The maintenance of galleries involves back washing and chemical treatment. The back washing time required can be 5-10 minutes. For back washing, compressed air can also be used.

## 1.20.4 Spring Collection Chamber

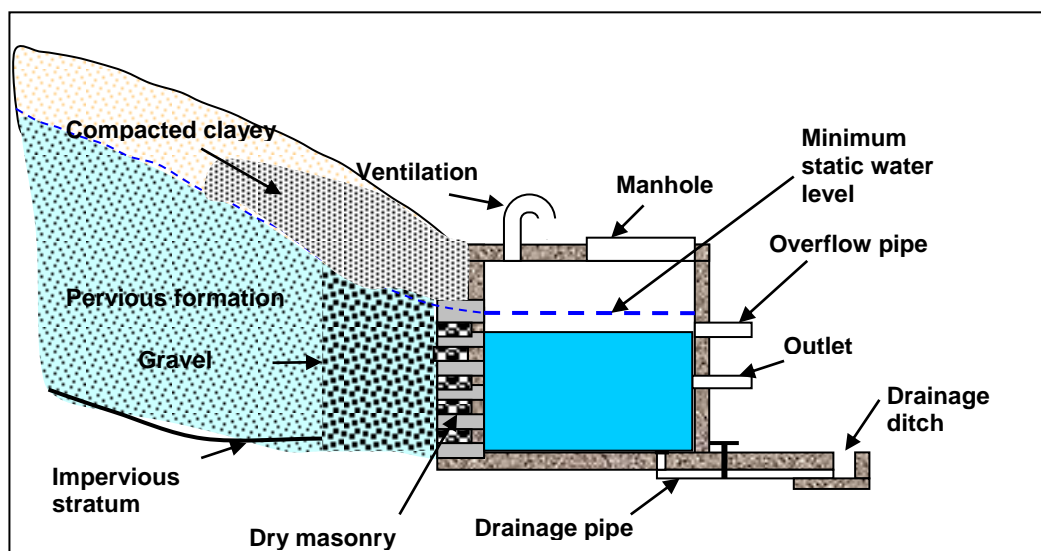
### 1.20.4.1 General

Spring structures are easy to operate and maintain. One of the main advantages of springs as water sources is that they are inexpensive to develop. The structures needed to protect them require little attention after installation. No structure, however, is completely maintenance free. Even the most simply designed spring structure needs periodic maintenance to ensure that it provides good-quality water in sufficient quantities. This manual note describes the periodic maintenance needed for spring boxes and seep collection systems so that they operate effectively for many years.

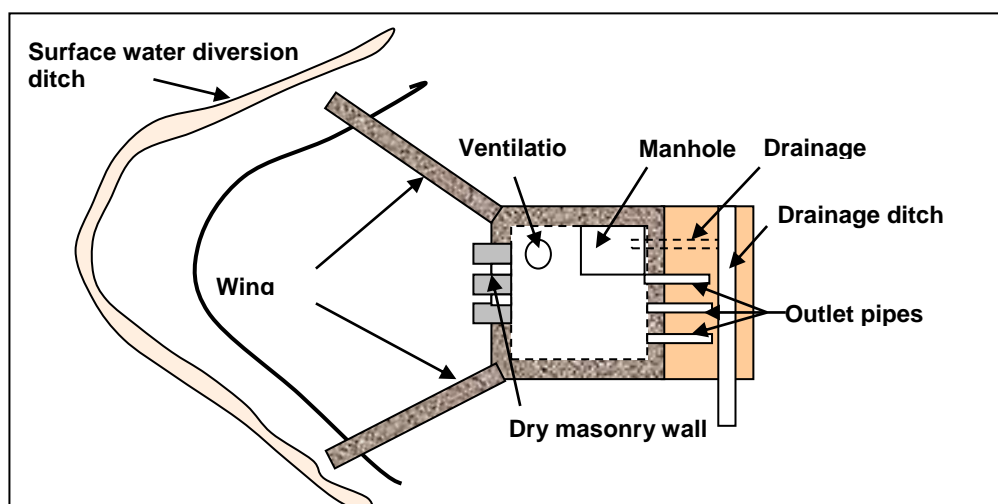
### 1.20.4.2 Components of Spring Chamber

Figure 2.5 and 2.6 are illustrated the various components of spring box for understanding when carrying out operation and maintenance activities.

**Figure 2-5: Schematic Section of Spring Development with Spring Box**



**Figure 2-6: Schematic Plan of Spring Development with Spring Box**



**1.20.4.3 Operation and Maintenance Requirements**

Springs are the ideal sources of groundwater which is usually pure at the source and can be piped to a storage and distribution points. It is essential that spring sources be protected against pollution at the source by a concrete, brick or masonry collecting chamber, water will be conveyed from the collecting chamber through a pipe in which may be fitted a controlling valve. There will also probably be an arrangement for disposing of surplus flows.

To use a spring as a source of water supply:

- The spring should be protected from surface water pollution by constructing a deep diverting ditch,
- The spring and collecting basin should have a water tight top, preferably concrete,
- Access and inspection manholes, when provided, should be tightly fitted and kept locked,
- Drainage ditches intended to keep surface water away from the spring should always be clear,
- When there is a distinctive wet and dry season the ditches should be cleared of any rubbish or vegetation before the first rains are due. Any overflow channel should also be cleared eliminate to the possibility of water backing-up.
- The collecting chamber should be inspected at least once a month to check whether cleaning is necessary. Depending upon the origin of the spring and the collecting chamber constriction it will be necessary to empty and clean out the chamber at regular intervals. The walls should then be scrubbed down with a solution of bleaching powder giving chlorine strength of at least 50 ppm,
- A vegetation should be kept clear of the spring,
- Stock should be kept at a distance by means of a fence or wall. The fence and the wall shall be kept in good repair,
- Periodic bacteriological examination should be conducted and the water disinfected,
- Water should be withdrawn only through a pipe by natural flow or by pumping; dipping or bailing should be prevented.

**1. Inspect the Spring Box, Reservoir, Tap Stand and Site**

Every month you should do a general inspection of the whole system. This includes:

**Box 3: Lists of Spring Box, Reservoir and Public Water point Inspection****A. The Spring Box**

- Check the general condition. Are there cracks in the concrete or signs of leaks?
- Is there wet ground around the spring box? This may indicate a leak.
- Is water flowing out of the overflow pipe? If so this may indicate a blocked outlet pipe.
- Is there stagnant water around the spring box? If so proper drainage must be provided,
- Is the spring box having algae? If so clean and disinfect the spring box
- Is the spring box properly protected from external pollutants? If so properly protect the spring box.

**B. The Reservoir**

- Check the general condition. Are there cracks in the concrete or signs of leaks?
- Is there wet or boggy ground around the reservoir? This may indicate a leak.
- First thing in the morning before people have started collecting water, and with all the taps off, is there water flowing out of the overflow? Check how full the reservoir is. How does it compare with when the spring was first constructed? If there is less water, there may be a blockage or leak in the spring box or connecting pipe.
- How is the drainage from the overflow pipe?
- Open the manhole cover and look inside. Does it look clean and in good condition? Is there anything in there such as leaves, sticks or other vegetation?

**D. The Site**

- Check the condition of the fence. Walk all around the fence and make sure that it is in good condition and there are no holes or places where animals can get in.
- Check the surface water diversion ditch. Is it clear? Is there any water sitting in it?
- What is the general condition of the site? Does it need to be cleaned of excess vegetation or other materials?
- Walk along the pipelines connecting the spring box to the reservoir and the reservoir to the tap stand (and any other pipelines if they exist – for example to clothes washing area or an animal watering trough). Are there any wet patches? These may indicate leaking pipes or pipe joints. Check any gate valves to make sure they are in good condition and are not leaking.

**Table 2-4: Summary of O&M Requirement for Spring Protection**

Activity	How Often	Who by	Materials & Spare Parts	Tools & Equipment
Clean Spring surroundings	Weekly	Community		Broom, bucket, hoe, machete
Repair fence and clean surface drains	Monthly	Caretakers & Community (as necessary)	Wood, rope, wire	Machete, axe, knife, hoe, spade, pickaxe
Repair pipes and taps	As needed	Water Supply Service Office/Caretaker	Spare pipes, valves, joints, taps, washers, cement, sand, gravel	Bucket, trowel, spanner (wrench), flat spanners
Check water quantity	Monthly	Water Supply Service Office		Bucket, watch
Check water turbidity	After each heavy rain or flood	Water Supply Service Office/Caretaker		

Activity	How Often	Who by	Materials & Spare Parts	Tools & Equipment
Check water quality	Annually or after repair	Zone &/or Woreda	Laboratory supplies	Laboratory
Wash and disinfect spring	Annually or after repair	Water Supply Service Office/Caretaker	Chlorine	Bucket, wrench, brush
Repair faucets	When the need arises	Water Supply Service Office/Caretaker	Spare faucet and thread.	Wrench
Repair cracks	When the need arises	Water Supply Service Office/Caretaker	Cement, sand gravel	Bucket, trowel, hoe, spade, wheel barrow

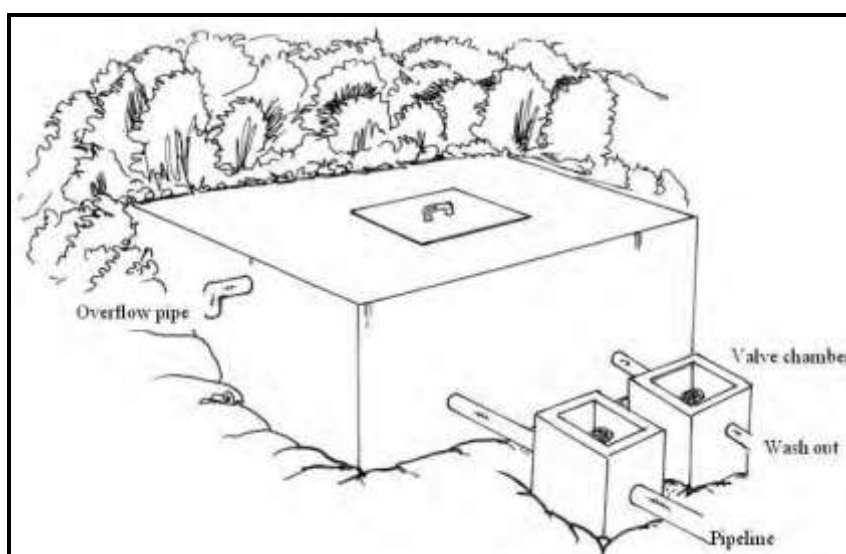
## 2. Troubleshooting for Spring Intake

The causes and the solution for unexpected problem at spring intakes is presented in Table 2.5.

**Table 2-5: Troubleshooting for Spring Intake**

No.	Problem	Probable Cause	Possible Solution
1	Leaking gate valve	Worn out valve	Replace stuffing box packing in gate valve or replace entire valve
2	No/ little water flowing into intake chamber	Inlet pipe blocked	Inspect source and unblock pipe
3	Overflow from intake chamber	Gate valve blocked Blockage in pipeline (e.g. airlock) Damaged strainer Clogged strainer	Remove and clear valve (replace if necessary) Check/open nearest air Valve Replace strainer Clean strainer
4	Dirty water	Silt in chamber	Clean out chamber

**Figure 2-7: Typical Spring Intake**



## 1.20.5 River and Lake Intakes

### 1.20.5.1 General

An intake structure is required to withdraw water from a river, infiltration gallery, lake or reservoir. In the latter, it is often built as an integral part of the dam. Typical intakes are tower intakes, submerged intakes and shore intakes. Their primary functions are to supply the highest quality water from the source and to protect piping and pumps from damage or clogging as a result of wave action, flooding or floating and submerged debris.

Intake towers are common for lakes and reservoirs with fluctuating water levels, or variations of water quality with depth. Ports at several depths permit selection of the most desirable water quality any season of the year.

A submerged intake consists of a rock filled crib or concrete block supporting and protecting the end of the withdrawal pipe. Because of low cost, under water units are widely used for small river and lake intakes. Although they have the advantage of being protected from damage by submergence, if repair is needed they are not readily accessible.

Shore intakes are also suitable for both lake and river intakes. Shore intakes located adjacent to a river must be sited with consideration for water current that might threaten the safety of the structure and potential flooding. Also, water quality consideration and distances from the pumping station and treatment plant are important.

### 1.20.5.2 Intake Components

The table 2.6 described the components of the river intake.

**Table 2-6: Components of Intake**

No.	Component	Function
1	Catchment Area	Surface area where water flows towards the source
2	Source	Where water is taken from, e.g. river or stream
3	Intake	The structure to abstract the water from the source
4	Intake chamber	Collects water from the source
5	Valve chamber	Protects the control valve
6	Weir (river intake)	Wall that regulates the level of the river
7	Infiltration gallery	Perforated pipe and filter material that enables water to enter pipe and be channeled to the sump
8	Sump	Collection chamber from which water is drawn
9	Screen/ strainer	Sieves objects entering the pipeline
10	Washout	Pipe and valve that is opened to allow cleaning of the chamber
11	Perimeter Fence	Boundary to stop livestock & children from entering source area
12	Compensation pipe	Pipe at the bottom of the intake weir to allow for downstream flow regardless of level of water above weir

**1.20.5.3 Intake Specific O & M tasks**

The following maintenance works should be carried-out:

- Intake opening and screens should be kept free of vegetation and other materials, which could restrict the flow.
- Check walls or supports for any damage, undercutting, bypassing and repair;
- Silt should be cleaned out to avoid sediments being drawn off with water
- Any gate or sluice should be examined every month to ensure that they are in working order.
- After flood flows the banks and bed of the river adjacent to the intakes should be examined for signs of erosion. Any scouring or erosion should be repaired immediately.
- Check intake pipes regularly; inspect and clean screens.
- Measure water level and turbidity daily,
- Open washout on weir wall and remove accumulated silt;
- Open washouts to clear out silt from chambers;
- Clear screen of any material and replace if damaged;
- Disinfect spring box if someone has entered;
- Read master meter.

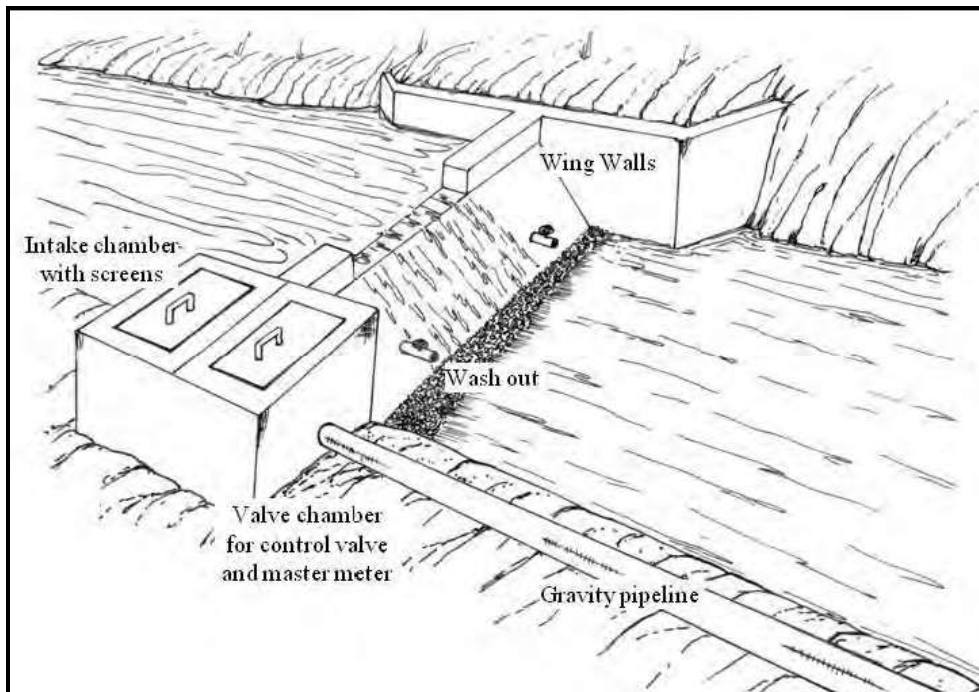
**1.20.5.4 Troubleshooting for River Intake**

Table 2.7 present the problems, potential causes and solutions for the river intake with weir wall or sump.

**Table 2-7: Troubleshooting for River Intake with Weir or Sump**

No.	Problem	Probable Cause	Possible Solution
1	No/ little water flowing into intake chamber or sump	Screens on inlet chamber clogged	Clean screens
2	Erosion around side of weir wall	Insufficient height of wing and cut off walls to prevent flow around the weir	Construct or raise wing and cut off walls to prevent flow around weir
3	Undercutting of weir wall on downstream toe or undercutting of sump	Excessively turbulent flow over weir wall and insufficient width of downstream apron	Provide protected apron (Concrete, grouted rip rap, etc) at toe of weir wall or around base of sump.
4	Dirty water	Excessive sediments upstream of weir wall Silt in intake chamber or sump	Clean out sediments from area immediately upstream of weir Clean out chamber Protect catchment from severe erosion.

**Figure 2-8: Typical River Intake with Weir Wall and Sump**



#### **1.20.5.5 Problems in Operation**

Some of the problems that may arise during the operation of Intakes are given below. Necessary steps should be taken to set right the same.

- (i) Fluctuations in water level,
- (ii) Water withdrawal at various depths,
- (iii) Hydraulic surges, ice, floods, floating debris, boats and barges,
- (iv) Withdrawal of water of the best available quality to avoid pollution, and to provide structural stability,
- (v) Operation of racks and screens to prevent entry of objects that might damage pumps and treatment facilities,
- (vi) Minimizing damage to aquatic life,
- (vii) Preservation of space for
  - a) Equipment cleaning,
  - b) Removal and repair of machinery,
  - c) Storing, movement and feeding of chemicals.

#### **1.20.5.6 Operation and Maintenance**

- (i) Operating criteria, equipment manufacturer's operating instructions and standard operating procedures should be bound into a manual and used for reference by operators. If written references are not available for a particular facility, they should be prepared with the assistance of knowledgeable operators, engineers and manufacturers.



- (ii) Screens should be regularly inspected, maintained and cleaned.
- (iii) Mechanical or hydraulic jet cleaning devices should be used to clean the screens.
- (iv) Intake structures and related facilities should be inspected, operated and tested periodically at regular intervals.
- (v) Proper service and lubrication of intake facilities is important.
- (vi) Operation of Gates and Valves.

Some of the causes of faulty operation are as under:

- Settlement or shifting of supporting structures which could cause binding of gates and valves,
- Worn, corroded, loose or broken parts,
- Lack of use,
- Lack of lubrication,
- Vibration,
- Improper operating procedures,
- Design errors or deficiencies,
- Failure of power source or circuit failure, and
- Vandalism.

#### **1.20.5.7 Record Keeping**

The records to be maintained shall include the following aspects:

- (i) A history of operations and maintenance performed on Intake facilities.
- (ii) When and under what conditions, failure or malfunctions occur.

#### **1.20.5.8 Safety**

When working around Intake Structures proper safety procedure involving use of electrical and mechanical equipment and water safety should be observed. Proper safety procedures should be documented and included in the manual containing the operating procedure.

#### **1.20.6 Impounding Reservoirs**

A dam impounding water is another type of source where operational staff can also undertake the activities, which is strictly maintenance type of work. The dam may be constructed of earth, rock fill, masonry or concrete.

Storage or impounding reservoirs intended to supply water for domestic purposes need to be carefully protected from pollution both during and after construction.

All matter likely to affect the quality of the water should be cleared from the reservoir site, particularly vegetation that on decay might cause unpleasant tastes and odours in the water.

All habitation should be removed from the catchments area and the land should remain uncultivated, both to prevent the washing of soil in to the reservoir and to avoid the risk of pollution from manures.

The catchments area should be kept free from cattle and should be guarded also against trespassers who might cause any pollution.

**Table 2-8: Components of Impounding Reservoir**

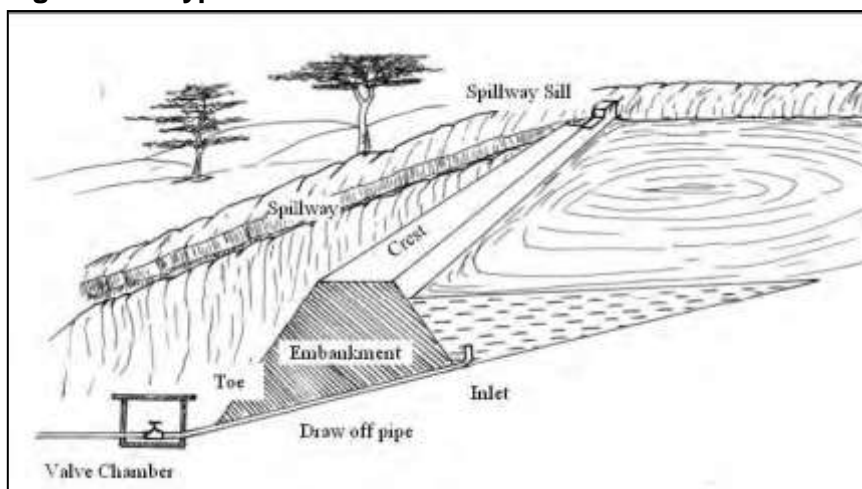
No.	Items	Purposes
1	Catchment Area	Area above the source where rain falls and the runoff comes from
2	Source	Where water is taken from, e.g. river or stream
3	Inlet channel	A channel that conveys water from the source and puts it into the dam
4	Pan Embankment	Wall of excavated material
5	Dam Embankment	Wall that is built and compacted to hold the water
6	Storage area	The volume that is filled with water
7	Spillway sill	Wall in the spillway to control top water level
8	Spillway channel	Channel to safely discharge excess water to water course or away from the dam/pan
9	Outlet/draw-off	Pipe-work to take water out of the dam
10	Perimeter fence	Constructed to prevent livestock, wild animals and children from entering the dam/pan area and contaminating the water

#### 1.20.6.1 Catchment Area Maintenance

Where does the silt come from? Which part of the catchment contributes the most silt and why? Are soil erosion features (e.g. gullies), exposed roots of bushes and trees, etc) visible?

Inspect the catchment area for signs of harmful activities (charcoal burning, over-grazing etc). The catchment area could be improved through proper watershed management such as terracing, check dam, gabion, a forestation, etc activities over the catchment area. Such issues well discussed in Water Supply Safety Plan of the point source manual.

**Figure 2-9: Typical Embankment Dam**



The following tasks are relevant to the operations and maintenance of the system components. These may include:

**Box 4: O&M tasks for Catchment area**

- Patrol perimeter fence and repair,
- Clear bush from and repair inlet channel (an eroded inlet channel can become the main watercourse),
- Inspect and desilt silt trap(s) and inlet channels
- Desilt pan before top water level reaches embankment (Note: inlet channel needs to be blocked during desilting)
- Clear bush from spillway
- Check spillway sill for damage and repair as necessary
- Check spillway channel for signs of erosion and take steps to prevent erosion by improving grass cover, stone pitching, spreading flow in the channel by building horizontal sill(s)
- Check dam embankment for cracks and erosion and repair
- Check dam embankment for tree or bush growth and remove, improve grass cover on embankment
- Check downstream side and toe of dam wall for leaks.
- Open and close all outlet valves once a month
- Monitor leakage from dam

#### 1.20.6.2 Trouble shooting for Impounding Reservoir

The following are potential unexpected problems and what might be the cause and solutions for impounding reservoir.

**Table 2-9: Trouble Shooting for Impounding Reservoir**

No.	Problem	Probable cause	Possible solution
1	Leakage along toe of dam wall	Poor design and construction	Monitor leakage
2	Water does not last long after end of rains	Reservoir area has accumulated a significant amount of silt, Erosion of catchment area, Excessive seepage due to pervious soil in reservoir area	Remove silt from reservoir area Reduce erosion in catchment area. Apply and mix in clay, preferably bentonite clay to impoundment area
3	No water from outlet	Outlet pipe blocked	Clear blockage at mouth of draw off pipe. ; Protect pipe by placing ballast surround to mouth of draw off pipe; Note a blocked pipe through a dam can be very difficult to unblock. Do NOT remove the pipe

No.	Problem	Probable cause	Possible solution
4	Polluted water	Livestock in dam/pan Contamination from catchment area	Fence pan/dam Control access; discourage open defecation in the catchment
5	Excessive weed growth	High nutrient concentration in water	Address source of nutrients, possibly by controlling access to dam/pan or catchment area by livestock

Technical Assistance – technical assistance should be sought if the dam or pan shows signs of excessive leakage/seepage, erosion of inlet channel (pans) and erosion of spillways and where dam embankment integrity is in doubt.

### 1.20.6.3 Types of Dams

Dams may be classified into two main categories

#### (i) Rigid Dams

These include dams of concrete, masonry, steel or timber.

#### (ii) Non Rigid Dams

These include a) Rock fill dams b) Earthen dams c) Composite sections having a combination of rock fill and any type of earth fill construction.

### 1.20.6.4 Inspection of Dams

For proper Operation and Maintenance of a dam and adopting remedial measures, regular inspection of the dam, appurtenant structures, reservoir area, and downstream channel in the vicinity of the dam should be conducted in a systematic manner.

Adequacy and quality of maintenance and operating procedures and operation of control facilities should be properly examined and all possible remedial measures should be taken to set right the deficiencies so detected.

Particular attention should be given to detecting evidences of leakage, erosion, seepage, excessive wetness or slushiness in the area downstream of dam, presence of sand boils, change in water table conditions downstream, slope instability, undue settlement, displacement, tilting, cracking, deterioration and improper functioning of the drains and relief wells, evidence of excessive pore pressure conditions, encroachment on the free board allowance.

Following guidelines outline some of the factors to be duly considered to ensure implementation of the operation and maintenance procedures.

#### (a) Embankment Structures

##### 1. Settlement

The embankments and downstream toe areas should be examined for any evidence of localized or overall settlement, depressions or sinkholes.

## 2. Slope Stability

Embankment slopes should be examined for irregularities in alignment and variances from smooth uniform slopes, unusual changes from original crest alignment and elevation, evidence of movement at or beyond the toe, and surface cracks which indicate movement.

## 3. Seepage

The downstream face of abutments, embankment slopes and toes, embankment structure contacts, and the downstream valley areas should be examined for evidence of existing or past seepage. The presence of animal burrows and tree growth on slopes which may cause detrimental seepage should be examined.

## 4. Drainage Systems

The slope protection should be examined to determine whether the systems could freely pass discharge and that the discharge water is not carrying embankment material.

## 5. Slope Protection

The adequacy of slope protection against wave, currents and surface runoff that may occur at the site should be evaluated. The condition of vegetation cover should be evaluated.

### **(b) Spillway Structures**

Examination should be made of the structures and important features of all service and auxiliary spillways, which serve as principal or emergency spillways.

1. Control gates and operating machinery.
2. Unlined saddle spillways.
3. Approach and Outlet channels.
4. Stilling basin (Energy dissipaters).

### **(c) Outlet Works**

The outlet works examination should include all structures and features designed to release reservoir water below the spillway crest through or around the Dam.

#### 1. Intake Structure:

Entrances to intake structure should be examined for conditions such as silt or debris accumulation, which may reduce the discharge capabilities of the outlet works.

2. Operation and emergency control gates.
3. Conduits, sluices, water passages etc.
4. Stilling Basin (Energy dissipaters).
5. Approach and outlet channels.
6. Drawdown facilities.

Facilities provided for drawdown of the reservoir to avert impending failure of the dam or to facilitate repair in the event of stability or foundation problems should be examined.

**(d) Concrete Structure in General**

The examination of concrete structures shall include the following:

1. Concrete surfaces.
2. Structural cracking.
3. Movement - horizontal and vertical alignment.
4. Junctions.
5. Drains-Foundation, Joint, Face.
6. Water Passages.
7. Seepage or leakages.
8. Monolith joints-construction joints.
9. Foundations.
10. Abutments.

**(e) Reservoir**

The following features of the reservoir should be examined to determine to what extent the water impounded by the dam would constitute a danger to the safety of the dam or a hazard to human life or property.

1. Shore Line

The landforms around the reservoir should be examined for indications of major landslide areas which may reduce reservoir capacity or create waves that might overtop the dam.

2. Sedimentation

The reservoir and drainage area should be examined for excessive sedimentation or recent developments in the drainage basin, which could cause a sudden increase in sediment load thereby reducing the reservoir capacity.

3. Backwater flooding

The reservoir area should be examined for features subject to potential backwater flooding resulting in loss of human life and property.

4. Watershed Runoff Potential

The drainage basin should be examined for extensive alterations to the surface of the drainage basin such as changed agricultural practices, timber clearing, railroad or highway construction or real estate developments that might extensively affect the runoff characteristics. Upstream projects that might have impact on the safety of the dam should be identified.

**(f) Downstream Channel**

The channel immediately downstream of the dam should be examined for conditions, which might impose any constraints on the operation of the dam.

**(g) Special Observations**

1. Every attempt should be made to anticipate and have engineer-observers present on site at items of large spillway and outlet discharge.
2. Warning, safety and performance instrumentations:
  - Piezometers, flow recorders, accelerometers, seismoscopes, joint meters, and gauge points, strain meters, stress meters, inclinometers, direct and inverted plumb lines, surface reference monument, stage recorders, extensometers.

**1.21 Scheduled Maintenance Schedule****1.21.1 Preventive Maintenance and Schedule**

The maintenance program is made up of a collection of individual maintenance actions. Each major unit in a water supply facility has a specific maintenance program designed for that particular unit. This program will range from routine daily inspections and tasks, to others done weekly, monthly, quarterly, semi-annually and annually. The columns at the right of each page of the PM checklist, show the frequency of the maintenance items, i.e. D = Daily, W = Weekly, M = Monthly, Q = Quarterly, SA = Semi-annually, and A = Annually.

**1.21.2 Preventive Maintenance Checklist**

The following PM checklists are based on the information obtained from the existing manufacturer's operation and maintenance manuals. It provides instructions for inspecting, cleaning, lubricating and adjusting equipment used in different water supply systems.

**Table 2-10: Preventive Maintenance Checklist for Water Sources Facilities**

No.	PM Checklists	D	W	M	Q	S	A
<b>1</b>	<b>Boreholes</b>						
1.1	Record time and rate of pumping						●
1.2	Measure water levels and draw down and keep record			●			
1.3	Take water samples for chemical analysis				●		
1.4	Make sure that concrete apron around the well is water tight. Make the necessary minor repairs.				●		
1.5	Clean well, screen and gravel packing, when required (by qualified personnel only)						●
1.6	Keep a running tabulation of pumping	●					
1.7	Test yield of borehole						●
<b>2</b>	<b>Springs</b>						
2.1	Inspect sanitation conditions		●				
2.2	Check concrete structure for cracks		●				

No.	PM Checklists	D	W	M	Q	S	A
2.3	Check the manhole cover is well secured and tight		●				
2.4	Check concrete structure and steel parts repair if required					●	
2.5	Clean sediment and disinfect spring box					●	
2.6	Check that spring is suitably protected from surface water pollution				●		
2.7	Take water samples for analysis						●
<b>3</b>	<b>Lake and River Intakes</b>						
3.1	Check the Water Quantity and Quality Regularly	●					
3.2	Check the depth of the Lake and estimate the amount of silt flowing in			●			
3.3	Examine intake opening and screen, clean vegetation and remove silt, leaves and debris			●			
<b>4</b>	<b>Dams and Impounding Reservoirs</b>						
4.1	Inspect spill way clean as necessary		●				
4.2	Inspect concrete and masonry dam for leakage and make repairs			●			
4.3	Inspect slopes and repair and erosion				●		
4.4	Inspect water shed and clean as necessary				●		
4.5	Inspect for algae and aquatic weeds and take measures as necessary					●	
4.6	Inspect sediment flowing into the water storage and take necessary measures				●		
4.7	Take water samples and send for analysis				●		
4.8	Inspect fences, and repair					●	

## 1.22 Water Sources Protection

### 1.22.1 General

Water source protection aims to ensure the reliability of the sources, but may also contribute to improvement. Improvement means increasing the quality of the water, increasing the yield, or diminishing the fluctuations in both. This may render the source adequate for different uses and reduce the cost of the water supply system. The following steps have to be followed in undertaking effective water source protection works:

- Identify the potential water source problems;



- Understand factors causing and/or aggravating water source problems; and
- Take appropriate measures to minimize the occurrence of water source problems and remedy the already happened water source problems.

The detailed water supply safety plan presented that demonstrated how the water sources are protected from the remote catchment areas to where the water source is located. Please refer that manual at Point Water Sources Operation and Maintenance Manual volume.

The following sections will treat these points in their order of listing and a typical water source protection project is outlined.

### 1.22.2 Water source problems

A water source problem occurs when a source is inadequate or unreliable. An adequate source ensures supply of drinking water in sufficient quantity and quality. A reliable source (by definition) meets present and future demand according to the design criteria, in terms of both quality and quantity. Water quality is sufficient when it meets agreed standards when reaching the consumer. Water quantity of a source is sufficient when the safe yield of the source meets the daily demand throughout the design period of the water supply system. Table 2-11 gives classification of possible water source problems.

**Table 2-11: Defining Water Source Problems**

Perceived source problem	Possible diagnosis	
	Source inadequate	Source unreliable
Source yield as anticipated, but not sufficient to satisfy all users due to unforeseen circumstances	x	
Source yield not sufficient to meet present demand	x	
Water demand increases more than anticipated, and exceeds source yield	x	
Yield meets present demand, but not the design demand as anticipated		x
Water quality below agreed standard	x	
Water quality deteriorates		x
Water quality not acceptable to users	x	

### 1.22.3 Environmental factors affecting drinking water sources

The main environmental factors affecting the water quality of larger sources are pollution by industrial waste products, pesticide and fertilizer contamination, and domestic sewage pollution, while the yield of water sources appears to be affected predominantly by extraction beyond sustainable yields and by unsustainable land use changes taking place on a wider scale.

#### 1.22.3.1 Contamination by pesticides and fertilizers

There are two types of pollution from pesticides and fertilizers: point pollution and non-point pollution. Point pollution refers to the concentrated input of chemicals into the water sources from a distinct place such as a storage area, from the direct discharge of pollutants into the water, or from spraying on the water sources itself. Non-point pollution

occurs due to gradual influx of low-concentrations of chemicals into the water source, for instance from irrigated farmland. Through time, the washing of chemicals into surface water and leaching of chemicals into groundwater result in gradually increasing concentrations of contaminants to toxic levels.

### **1.22.3.2 Over-extraction of Groundwater**

The causes are several folds:

- Lack of yield potential and recharge data from which sustainable extraction levels can be determined and used in planning;
- Uncontrolled and unsustainable use coupled with lack of regulations;
- Ineffective and inadequate enforcement of legislation to maintain sustainable extraction;
- Comparative operational advantage of groundwater over surface water;
- Lack of adequate alternative surface water resources partly due to pollution of these sources; and
- Absence of an effective large-scale artificial recharge program.

Where saltwater reserve is located adjacent to a groundwater source, unsustainable extraction of groundwater can lead to quality problems in the form of saltwater intrusion.

Another major problem associated with groundwater depletion is when large urban areas pump water from highly porous aquifers below, subsidence occurs as soil pores collapse.

### **1.22.3.3 Land use changes in large source catchment area**

Deforestation and erosion is increasing at a rapid rate. As forests are cleared, water rushes unimpeded down slopes, carrying with it valuable soil and causing flooding in the lower areas. Wells increasingly dry up during the dry season because less water was retained in the soil to percolate into water tables.

Urbanization creates a largely impermeable surface and provides fast drainage channels down which storm water can flow, changing natural flood pattern. Consequently, less water infiltrates into the ground thereby affecting the yield of aquifers.

## **1.22.4 Measures for minimizing water source problems**

Measures that need to be taken to minimize the occurrence of drinking water source problems and to resolve them, at least partially, when they occurred can be considered in two steps: risk assessment and technical solutions. The first step, as the name says it, is concerned with the identification of possible causes of the drinking water source problems and taking preventive measures that will minimize the chances for the occurrence of water source problems. The technical solutions, while contributing to the effort of minimizing the occurrence of water source problems, attempt to remedy the already happened water source problems.

### **1.22.4.1 Risk assessment**

It is recognized that water quality can be ensured more effectively when avoiding the risk for contamination by human waste, agricultural chemicals, livestock faeces, and industrial discharge. Assessing the risk of drinking water source problems requires knowledge of

the possible causes of such problems under local conditions at the source and in the catchment area.

Risk assessment is preferably carried out in the planning stage of a water supply system development in which the objectives are to select sites with the lowest risk factor and to plan for preventive actions. The main focus areas of risk assessment are briefly discussed hereunder:

#### **a) Source and site selection**

Sustainable use of sources requires site and source selection allowing subsequent protection of the source and its catchment area. Generally, the following procedure should be followed in selecting surface water sources:

- Take water as near to the watershed as possible;
- Choose sources with catchments as sparsely inhabited as possible;
- Choose supplies that consistently yield low-turbidity water;
- Frequently inspect catchment areas for pollution sources; and
- Avoid activities that may pollute upstream locations.

For the selection of groundwater sources, procedures should be more systematic, both in terms of locating high-yielding sites and in terms of avoiding sites with high potential for contamination by seepage from surface. Monitoring groundwater conditions is also of crucial value in determining the contamination risk.

#### **b) Catchment Protection**

This is basically a systematic appraisal of catchment areas of the sources and identification of pollution sources. This knowledge forms the basis for the delimitation of protection zones in which human activities must be regulated. Protection zones are conceptually important for the design, prioritization, and distribution of water resources protection measures. The zones can be delimited with respect to the level and nature of risk, resulting in more coherent and incisive protection strategies. Protection zones are commonly delimited as follows:

- the inner zone, defined as the area in which there is a direct risk of contamination;
- the outer zone, defined as the area in which the water may be at risk from indirect contamination; and
- The catchment area, the whole area from which water flows to the intake.

The effectiveness of protection zones relies on the local people's commitment to protection measures established.

#### **c) Sanitary Surveying**

Sanitary survey is a form of risk assessment, which examines the technical quality of a water supply point, the manner of use by consumers, the surrounding environmental hygiene conditions and the potential causes of contamination. Their purpose is to minimize the level of risk on on-site contamination by identifying remedial measures that can quickly and easily be taken. Coupled with bacteriological analysis, sanitary surveys provide a methodology on which successive improvements can be made to water supply conditions.

For a meaningful assessment of the sanitary status of water sources and the level of risks for waterborne disease transmission, the faecal contamination grading given in Table 2.11 (rather than a simple classification of 0=safe, >0=unsafe) should be used:

**Table 2-12: Faecal Contamination Grading**

Grade of Risk	E-coli-Faecal coliforms/100 ml	Risk Factor
A	0 (WHO Guideline)	No risk
B	1 - 10	Low risk
C	11 - 100	Intermediate to high risk
D	101 - 1000	Gross pollution; high risk
E	> 1000	Gross pollution, very high risk

#### **d) Technical Solutions**

Possible solutions to source problems include improved sanitation, physical protection, soil and water conservation, wastewater treatment and recycling, artificial recharge, and avoiding groundwater mining. A single technical approach is often not enough to remedy or protect water sources, as gross pollution of water supply sources usually has more than one cause. Therefore, effective drinking water source protection may need to adopt a multiple intervention strategy. In this sub-section, the technical solutions mentioned above are briefly described.

##### **(i) Improvement in sanitation**

Use of latrines and other sanitary systems reduce faecal pollution risk by excluding contamination of the topsoil or ground surface so that excreta is not washed into surface water. The design of the latrine must ensure that there is no link between the excreta and the groundwater, which involves consideration of silting, soil type and depth, and the location of groundwater level and its seasonal fluctuation.

##### **(ii) Physical protection of wells**

This involves the construction of a proper wellhead to avoid the seeping of polluted surface water down the side of well casing and into the groundwater. The well site should also be fenced and guarded properly in order to avoid clothes washing, bathing, and open defecation in the vicinity of the well and to protect the wellhead from being damaged.

##### **(iii) Soil and water conservation**

Soil and water conservation activities can decrease turbidity of surface water sources by preventing sediment transport, increasing groundwater discharge and decreasing surface flow peaks by increasing infiltration. Methods include terracing, contour ploughing, infiltration buffers, and various forms of runoff farming.

##### **Waste water treatment and recycling**

Both industrial effluent and domestic sewage have to be treated to minimize pollution risk. For domestic sewage, different on-site and off-site technical options are available.

Wastewater recycling, if carried out correctly, can be a form of water source protection as well as conservation. Contamination risk of water sources is decreased through proper

recycling and increases the efficient use of the water source. Wastewater is treated by less expensive methods because only partial treatment is needed for recycling use such as for irrigation or for a range of industrial processes where water quality standards are not critical.

#### **(iv) Artificial Groundwater Recharge**

Artificial recharging of aquifers can be used to decrease the groundwater table recession and the effect of saltwater intrusion. A range of techniques are available, their application being governed by cost, geological and topographic conditions, and the size of the aquifer to be recharged. At a small and medium scale, recharge is predominantly from infiltration ditches, ponds and basins, through retention of river underflow using sub-surface dams, and through retention of river floodwater.

#### **(v) Avoiding groundwater mining**

The first step in avoiding groundwater mining is to quantify the limiting hydrologic yield of an aquifer. This is frequently taken as the long-term average recharge of the aquifer.

Having found the potential yield of an aquifer, the maximum abstraction rate must be limited to this value unless measures that enhance the yield of the aquifer such as artificial recharging are implemented. If the current abstraction rate is less than the yield of the aquifer, it means the source has a potential for future expansion or it can be used for some other purpose. On the other hand, if groundwater mining has already taken place, the abstraction rate has to be revised immediately to the potential yield of the aquifer.

The Federal Government of Ethiopia has issued a Water Resources Management Proclamation (Proclamation No 197) in 2000. This proclamation requires major water users to get water use permit from the Ministry of Water Irrigation and Electricity or the Regional Water Bureaus. This Proclamation is yet to be implemented. However, once implemented, the water supply service office of each town has to secure water right permit from the water resources development of the region.

## Annexes

### Annex A: Monthly Check sheet for spring Type-1

Site Name:	Technician/Plumber Name
------------	-------------------------

Date	Facility	Work Condition			Crack Yes/No	Leak/Broken Yes/No	Wet Ground Yes/No	Clean in/outside Yes/No	Drainage Ok Yes/No	Overflow Ok Yes/No	Pipe Ok Yes/No	Valve Ok Yes/No	Remark
		Check	In case of “Non- Functioning										
			When Stop	When Repair									
	Spring Box	Functioning/ Non---functioning											
	Tap	Functioning/ Non---functioning			/		/	/	/	/			
	Spring Box	Functioning/ Non---functioning											
	Tap	Functioning/ Non---functioning			/		/	/	/	/			
	Spring Box	Functioning/ Non---functioning											
	Tap	Functioning/ Non---functioning			/		/	/	/	/			
	Spring Box	Functioning/ Non---functioning											
	Tap	Functioning/ Non---functioning			/		/	/	/	/			

**Annex B: Monthly Check sheet for spring Type-2**

Site Name:	Technician/Plumber Name
------------	-------------------------

Date	Facility	Work Condition			Crack Yes/No	Leak/Broken Yes/No	Wet Ground Yes/No	Clean in/outside Yes/No	Drainage Ok Yes/No	Overflow Ok Yes/No	Pipe Ok Yes/No	Valve Ok Yes/No	Remark
		Check	In case of “Non- Functioning										
			When Stop	When Repair									
	Spring Box	Functioning/Non---											
	Tapstand- No.1	Functioning/Non---											
	Tapstand- No.2	Functioning/Non---											
	Spring Box	Functioning/Non---											
	Tapstand- No.1	Functioning/Non---											
	Tapstand- No.2	Functioning/Non---											
	Spring Box	Functioning/Non---											
	Tapstand- No.1	Functioning/Non---											
	Tapstand- No.2	Functioning/Non---											

**Annex C: Daily Water Production Record**

Month: \_\_\_\_\_

Name of Operator: \_\_\_\_\_

Year: \_\_\_\_\_

Borehole/Spring No. \_\_\_\_\_

Day	Meter reading		Water Production (m <sup>3</sup> /day)	Day	Meter reading		Water Production (m <sup>3</sup> /day)
	Start	End			Start	End	
1				16			
2				17			
3				18			
4				19			
5				20			
6				21			
7				22			
8				23			
9				24			
10				25			
11				26			
12				27			
13				28			
14				29			
15				30			
<b>Total Water Production (m<sup>3</sup>/month)</b>							

Checked by: \_\_\_\_\_

Signature: \_\_\_\_\_

Date: \_\_\_\_\_



**Annex D: Daily Water Distribution Record**

Month: \_\_\_\_\_

Name of Operator: \_\_\_\_\_

Year: \_\_\_\_\_

Reservoir Name: \_\_\_\_\_

This data measured at the outlet of the reservoir

Day	Meter reading		Water Distributed (m <sup>3</sup> /day)	Day	Meter reading		Water Distributed (m <sup>3</sup> /day)
	Start	End			Start	End	
1				16			
2				17			
3				18			
4				19			
5				20			
6				21			
7				22			
8				23			
9				24			
10				25			
11				26			
12				27			
13				28			
14				29			
15				30			
<b>Total Water Distributed (m<sup>3</sup>/month)</b>							

Checked by: \_\_\_\_\_

Signature: \_\_\_\_\_

Date: \_\_\_\_\_

## **RURAL WATER PIPED SCHEMES**

**(Parts A, B, C)**

### **Water Sources and Electromechanical Equipment**

## **PART – C: ELECTRO-MECHANICAL EQUIPMENT**

**Document 4**

## PART – C: ELECTRO-MECHANICAL EQUIPMENT

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## **3. ELECTRO - MECHANICAL EQUIPMENT**

### **3.1 General**

A pump is a device, which raises or transfers liquids at the expense of power input or a unit that transfers the mechanical energy of a motor or an engine into potential and kinetic energy of a liquid.

Generally, a pump is a machine, which adds energy to a fluid or extracts energy from it. If the machine adds energy to the fluid, it is commonly called a pump, but if it extracts energy, it is called turbine.

The work of a pump consists in transforming the mechanical energy of a motor (drive) into fluid energy; that is imparting power to a flow of fluid passing through it. The energy imparted to the fluid in the pump enables the former to overcome the hydraulic resistance and rise to a geodetic elevation.

Pumping equipment and pumping station are very important components in water Supply system. Pumping machinery is subjected to wear, tear, erosion and corrosion due to their nature of functioning and therefore is vulnerable for failures. Generally, more number of failures or interruptions in water supply is attributed to pumping equipment than any other component. Therefore, correct operation and timely maintenance and upkeep of pumping stations and pumping machinery are of vital importance to ensure uninterrupted water supply.

Sudden failures can be avoided by timely inspection, follow up actions on observations of inspection and planned periodical maintenance. Downtime can be reduced by maintaining inventory of fast moving spare parts. Efficiency of pumping machinery reduces due to normal wear and tear. Timely action for restoration of efficiency can keep energy bill within reasonable optimum limit. Proper record keeping is also very important.

Obviously due attention needs to be paid to all such aspects for efficient and reliable functioning of pumping machinery. This chapter discusses procedures for operation and maintenance and addresses pertinent issues involved in O&M of pumping equipment.

This part of the manual deals with the operation and maintenance requirements for pumping equipment, driving equipment, pumping station and ancillary equipment.

### **3.2 Components in Pumping Station**

The components in pumping station can be grouped as follows:

#### **a) Pumping Equipment**

- Pumps and other mechanical equipment, i.e. valves, pipe work, vacuum pumps
- Motors, switchgears, cable, transformer and other electrical accessories.

Pumps are required in a water supply system:

- i) When water must be raised from one level to another,
- ii) When the pressure in the main must be increased,

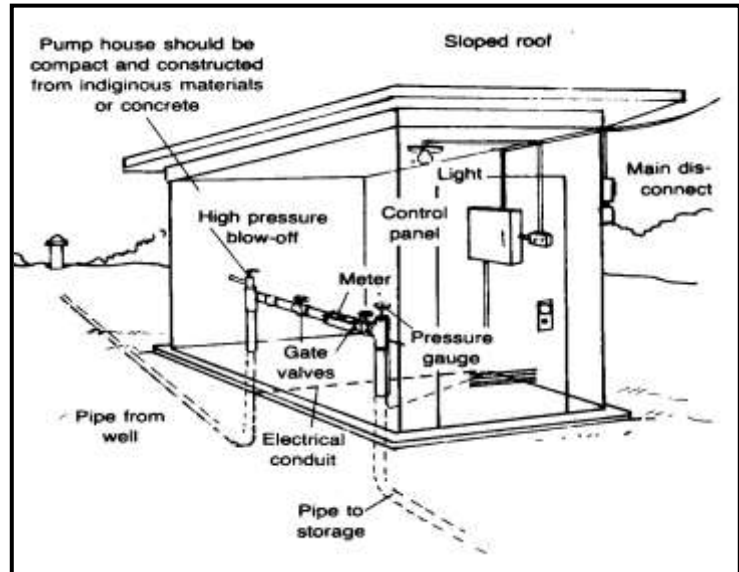
- iii) When the elevation of the source is such that water will not flow by gravity into the tank.

**b) Ancillary Equipment**

- Lifting equipment,
- Water hammer control device,
- Flow meter,
- Diesel generating set,

**c) Pumping station**

- Sump/intake/well/borehole,
- Pump house,
- Screen,
- Gate/Valve



### 3.3 Types of Pumps

Following types of pumps are used in water supply systems:

- i) Centrifugal pumps
- ii) Vertical turbine pumps
  - Oil lubricated
  - Self water (pumped water) lubricated
  - Clear water lubricated
- iii) Submersible pumps
  - Vertical borewell type pump-motor set
  - Monobloc open well type pump-motor set
- iv) Jet pumps
- v) Reciprocating pumps

Surface water pumps mainly consist of:

- (i) Horizontal centrifugal pumps
- (ii) Vertical centrifugal pumps
- (iii) Vertical submersible motor pumps

For deep wells the pumps are normally placed below dynamic water level. Depending on the type of pump, deep well pumps are either driven by a submerged electric motor fixed rigidly beneath the pump (submersible pump) or by a power force at the surface, which is transmitted



through a drive shaft (driven shaft pumps).

The most common ground water pumps are:

- (i) Shaft driven helical rotor pumps
- (ii) Line shaft deep well pumps
- (iii) Submersible motor pumps

### 3.3.1 Submersible Pump

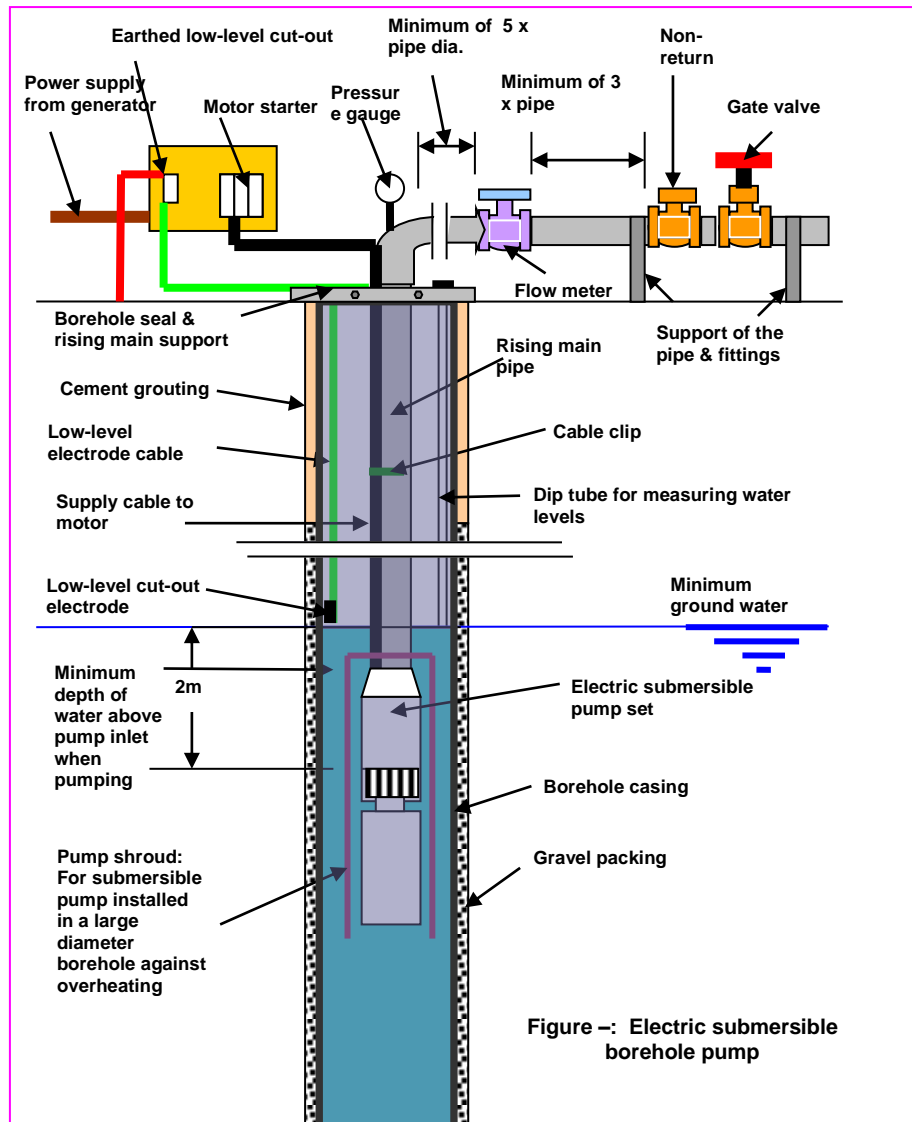
For deep-well applications, centrifugal pumps are housed with the electric engine in a single unit that is designed to be submerged. Usually, a multiple-stage pump is used.

The multiple-stage pump is placed above a motor and under a check valve that leads to the rising main.

Submersible pumps are self-priming, if they do not run dry. To prevent the pump from running dry, the water level in the well must be monitored, and pumping must be stopped if the water level drops to the intake of the pump.

Power is delivered through a heavily

insulated electricity cable connected to a switch panel at the side of the well. The power may come from an AC mains connection, a generator, or a solar power system.



#### a) Potential Problems

1. sand or other particles may enter the pump and cause abrasion damage,
2. the rising main may corrode,



3. the pipeline system can be damaged by the severe pressure surges that result when the pump is started or stopped abruptly,
4. The main limitations of a submersible centrifugal pump are its price, the need to maintain a reliable supply of electricity or fuel, and the high level of technology involved.

### **3.3.2 Horizontal Centrifugal Pumps**

Centrifugal pumps are commonly used for low and high service to lift and transport water. The two essential parts of a centrifugal pump are rotating membrane with vanes and the impeller and surrounding case.

The impeller driven at a high speed throws water into a volute which channels it through the nozzle to the discharge piping. This action depends partly on centrifugal force; hence, the particular name given to the pump. The function of the pump passages is to develop water pressure by efficient conversion of kinetic energy. A closed impeller is generally used in pumping water for higher efficiency, while an open unit is used for waste water containing solids. The casing may be in the form of a volute (spiral) or may be equipped with diffuser vanes. Several other variations in design involve casing and impeller modifications to provide a wide range of pumps with special operating features, including:

- i) Side-inlet centrifugal pump
- ii) Single-suction close-coupled centrifugal pump,
- iii) Double-suction volute centrifugal pump
- iv) Multi-stage centrifugal pump.

### **3.3.3 Vertical Centrifugal Pumps**

All the definitions used above for horizontal centrifugal pumps are relevant to pumps operating vertically. The pump is driven by a vertical shaft, which is usually coupled, to a driving unit above floor level.

Pumps commonly used in such installations are:

- Vertical enclosed- shaft pump
- Vertical opened-shaft pump

The suction pipe is usually connected to a wet well (wet pit) structure, which means that the location of the pump is almost lower than wet well water level and suction pressure is positive.

### **3.3.4 Booster Pump**

Booster pumps are pumps which take water from a supply main and discharge it at a higher pressure to another point in the same pipeline, and are also used to increase pipeline pressure in outlying areas when loss of head is too great along the line. They may operate in conjunction with filling of elevated storage tanks.

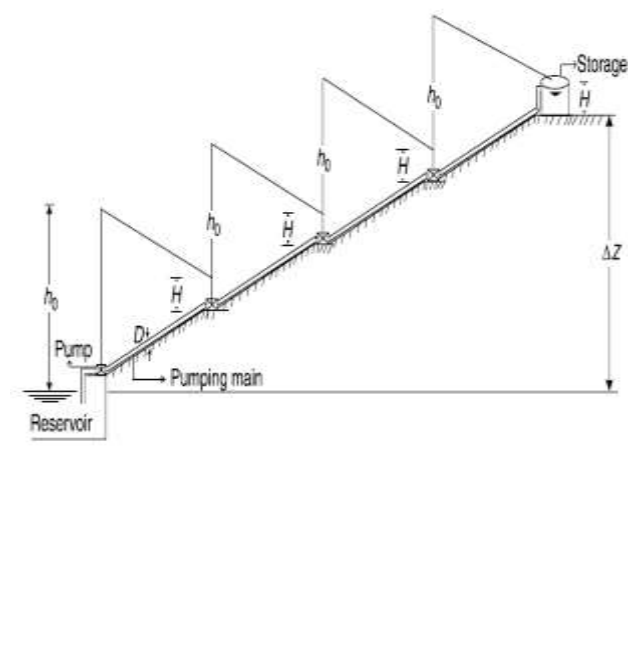
For a very long pipeline or for large elevation difference between the entry and exit points, the pumping head is excessive and pipes withstanding such a high pressure may not be available, or the provision of high-pressure pipes may be uneconomical. In such a case,

instead of providing a single pumping station, it is desirable to provide a number of pumping stations.

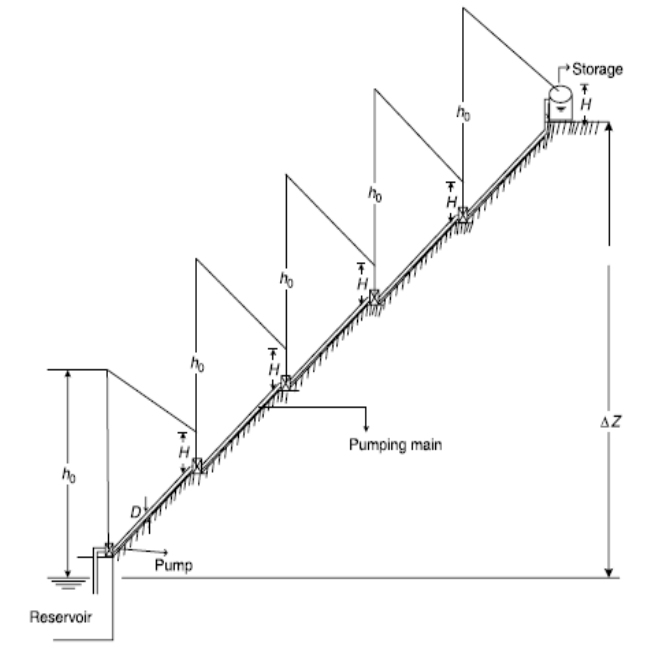
For a long pipeline on a relatively flat topography, a series of boost pump station is provided as shown in Figure 3.1.

Pipeline on topography with large elevation difference, in the case of intake structures are located at a much lower level than the water treatment plant or clear water reservoir to supply raw water from a river or lake. It is not economic to pump the water in a single stretch, as this will involve high-pressure pipes that may not be economic.

**Figure 3-1: A Typical Multi-stage pumping main on flat topography**



**Figure 3-2: A Typical Multi-stage high rising pumping main**



### 3.4 Brands of Pumps and Generators under operation in Ethiopia

The following lists of pumps and generator brands existing in Ethiopia for water supply system. These are:

#### a) Submersible Pumps

- |             |            |              |
|-------------|------------|--------------|
| 1) Lowara   | 4) CMS     | 7) Frankline |
| 2) Grundfos | 5) Stac    | 8) TATA      |
| 3) Caprari  | 6) Pleuger |              |

#### b) Surface Pumps

- |            |                  |
|------------|------------------|
| 1) KSB     | 5) Cimonath      |
| 2) Caprari | 6) CMS           |
| 3) Rovatti | 7) Hydraulic Ram |
| 4) TATA    |                  |

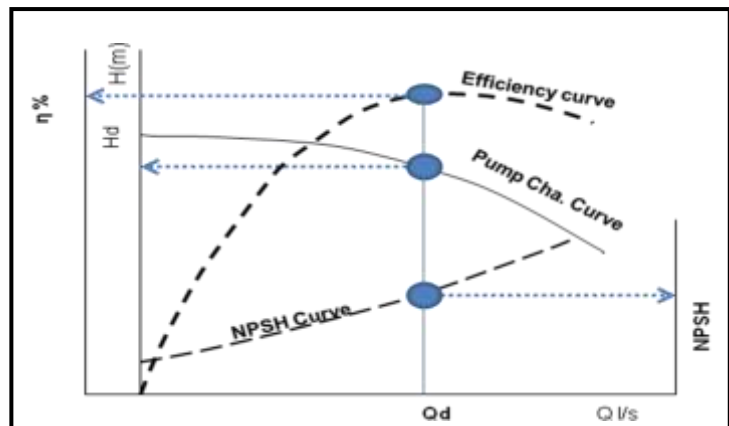
**c) Engine and Alternators (generators)**

Engine	Alternator
Lister	Lister
Deutz	Mecc alte
Sun	Marelli
Lombardini	Linz
Daewoo	
Johndeer	
Perkins	
Fiat	
Sleunz	
Kelesker	

**3.5 Operation and Maintenance Common to all Pumps****3.5.1 Important Points for Pump Operation**

The following Important points shall be observed while operating the pumps:

- a) Dry running of the pumps should be avoided,
- b) Centrifugal pumps have to be primed before starting,
- c) Pumps should be operated only within the recommended range on the head-discharge characteristics of the pump,
  - If pump is operated at point away from duty point, the pump efficiency normally reduces.
  - Operation near the shut off should be avoided, as the operation near the shut off causes substantial recirculation within the pump, resulting in overheating of water in the casing and consequently, in overheating of the pump.
- d) Voltage during operation of pump-motor set should be within + 10% of rated voltage. Similarly current should be below the rated current as per name plate on the motor.
- e) Whether the delivery valve should be opened or closed at the time of starting should be decided by examining shape of the power-discharge characteristic of the pump. Pump of low and medium specific speeds draw lesser power at shut off head and power required increases from shut off to normal operating point. Hence in order to reduce starting load on motor, a pump of low or medium specific speed is started against closed delivery valve.



Normally the pumps used in water supply schemes are of low and medium specific speeds. Hence, such pumps need to be started against closed delivery valve.

The pumps of high specific speed draw more power at shut off. Such pumps should be started with the delivery valve open.

- f) The delivery valve should be operated gradually to avoid sudden change in flow velocity which can cause water hammer pressures.

It is also necessary to control opening of delivery valve during pipeline - filling period so that the head on the pump is within its operating range to avoid operation on low head and consequent overloading. This is particularly important during charging of the pumping main initially or after shutdown. As head increases the valve shall be gradually opened.

- g) When the pumps are to be **operated in parallel**, the pumps should be started and stopped with a time lag between two pumps to restrict change of flow velocity to minimum and to restrict the dip in voltage in incoming feeder. The time lag should be adequate to allow to stabilize the head on the pump, as indicated by a pressure gauge.



- h) When the pumps are to be **operated in series**, they should be started and stopped sequentially, but with minimum time lag. Any pump, next in sequence should be started immediately after the delivery valve of the previous pump is even partly opened.

Due care should be taken to keep the air vent of the pump next in sequence open, before starting that pump.

- i) The stuffing box should let a drip of leakage to ensure that no air is passing into the pump and that the packing is getting adequate water for cooling and lubrication. When the stuffing box is grease sealed, adequate refill of the grease should be maintained.
- j) The running of the duty pumps and the standby should be scheduled so that no pump remains idle for long period and all pumps are in ready-to run condition. Similarly unequal running should be ensured so that all pumps do not wear equally and become due for overhaul simultaneously.
- k) If any undue vibration or noise is noticed, the pump should be stopped immediately and cause for vibration or noise be checked and rectified.
- l) Bypass valves of all reflux valve, sluice valve and butterfly valve shall be kept in closed position during normal operation of the pumps.
- m) Frequent starting and stopping should be avoided as each start causes overloading of motor, starter, contactor and contacts. Though overloading lasts for a few seconds, it reduces life of the equipment.

### **3.5.2 Undesirable operations**

Following undesirable operations should be avoided:

#### **1. Operation at Higher Head**

The pump should never be operated at head higher than maximum recommended. Such operation results in:

- Excessive recirculation in the pump,
- Overheating of the water and the pump,
- The radial reaction on the pump shaft increases causing excessive unbalanced forces on the shaft which may cause failure of the pump shaft.

As a useful guide, appropriate marking on pressure gauge be made. Such operation is also inefficient as efficiency at higher head is normally low.

#### **2. Operation at Lower Head**

If pump is operated at lower head than recommended minimum head:

- Radial reaction on the pump shaft increases causing excessive unbalanced forces on shaft which may cause failure of the pump shaft.

As useful guide, appropriate markings on both pressure gauge and ammeter are made.

Such operation is also inefficient as efficiency at lower head is normally low.

#### **3. Operation on Higher Suction Lift**

If pump is operated on higher suction lift than permissible value:

Pressure at the eye of impeller and suction side falls below the vapor pressure, it results in flashing of water into vapor.

These vapor bubbles during passage collapse resulting in:

- Cavitations in the pump,
- Pitting on suction side of impeller and
- Casing and excessive vibrations,
- In addition to mechanical damage due to pitting, discharge of the pump also reduces drastically.

#### **4. Throttled operation**

At times if motor is continuously overloaded, the delivery valve is throttled to increase head on the pump and reduce power drawn from motor. Such operation results in inefficient running as energy is wasted in throttling. In such cases, it is preferable to reduce diameter of impeller which will reduce power drawn from motor.

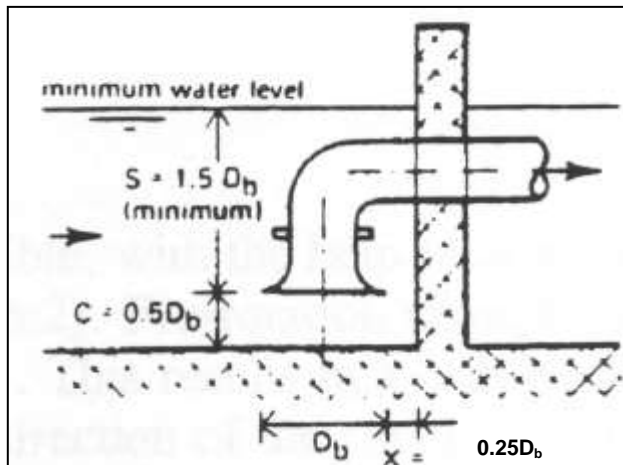
## 5. Operation with Strainer/Foot Valve Clogged

If the strainer or foot valve is clogged, the friction loss in strainer increases to high magnitude which may result in pressure at the eye of the impeller falling below water vapor pressure, causing cavitations and pitting similar to operation on higher suction lift.

The strainers and foot valves should be periodically cleaned particularly during rainy season.

## 6. Operation of the Pump with Low Submergence

Minimum submergence above the bell mouth or foot valve is necessary so as to prevent



air entry into the suction of the pump which gives rise to vortex phenomenon causing excessive vibration, overloading of bearings, reduction in discharge and efficiency. As a useful guide the lowest permissible water level is marked on water level indicator.

Thus, the submergence depth shall be 1.5 X the diameter of the bell mouth. The operator should always check this requirement by looking the water level indicator.

## 7. Operation with Occurrence of Vortices

If vibration continues even after taking all precautions, vortex may be the cause. All parameters necessary for vortex-free operation should be checked.

### 3.5.3 Starting Pumps

#### 3.5.3.1 Check before Starting of Pumps

#### Box 5: Things to be checked when starting the pump operation

**Following points should be checked before starting the pump.**

- ☞ Power is available in all 3 phases,
- ☞ Trip circuit for relays is in healthy state,
- ☞ Check voltage in all 3 phases,
- ☞ The voltage in all phases should be almost same and within + 10% of rated voltage, as per permissible voltage variation,
- ☞ Check functioning of lubrication system specifically for oil lubricated and clear water lubricated VT pumps and oil lubricated bearings,

- ☞ Check stuffing box to ensure that it is packed properly,
- ☞ Check and ensure that the pump is free to rotate,
- ☞ Check over current setting if the pump is not operated for a week or longer period,
- ☞ Before starting it shall be ensured that the water level in the sump/intake is above low water level and inflow from the source or preceding pumping station is adequate.

### 3.5.3.2 Starting and Operation of Pumps

Procedures for starting and operation of different types of pumps are described below:

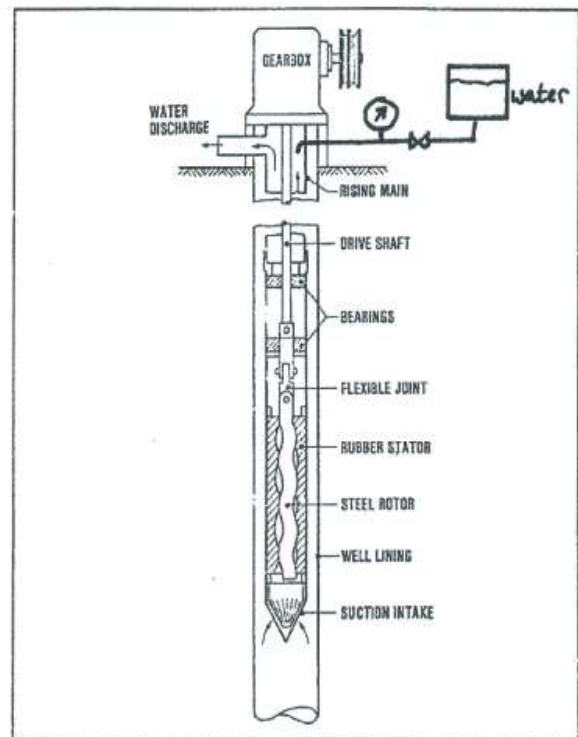
#### a. Centrifugal Pump (low and medium specific speed)

- i) To start a centrifugal pump, the suction pipes and the pump should be fully primed irrespective of the fact whether the pump is with positive (flooded) suction or suction lift.

The centrifugal pump with positive suction can be primed by opening valve on suction side and letting out air from the casing by opening air vent.

Centrifugal pump on suction lift necessitates close attention to prime the pump fully.

To achieve this, the suction pipe and the pump casing must be filled with water and entire air in suction piping and the pump must be removed. If vacuum pump is provided, the pump can be primed by operating vacuum pump till steady stream of water is let out from delivery of vacuum pump. In absence of vacuum pump, priming can be done by pouring water in casing and evacuating air through air vent or by admitting water from pumping main by opening bypass of reflux valve and delivery valve. Check all joints in the suction pipe and fittings.



- ii) Close the delivery valve and then loosen slightly.
- iii) Switch on the motor, check that direction of rotation is correct. If the pump does not rotate, it should be switched off immediately.
- iv) Check vacuum gauge, if the pump operates on suction lift. If the pointer on gauge gradually rises and becomes steady the priming is proper.

- v) Pressure gauge should be observed after starting the pump. If the pump is working correctly, the delivery pressure gauge should rise steadily to shut off head.
- vi) When the motor attains steady speed and pressure gauge becomes steady, the delivery valve should be gradually opened in steps to ensure that the head does not drop below recommended limit. (In the absence of recommendations, the limit shall be about 85% of duty head for centrifugal pump).
- vii) Check that ammeter reading is less than rated motor current.
- viii) Check for undue vibration and noise.
- ix) When in operation for about 10-15 minutes, check the bearing temperature, stuffing box packing, and leakage through mechanical seal and observe vibrations, if any.
- x) Voltage should be checked every half an hour and should be within limit.

**b. Vertical Turbine Pump (of low and medium specific speed)**

- i) Close delivery valve, and then loosen slightly.
- ii) If pump is oil-lubricated, check the oil in the oil tank and open the cock to ensure that oil is flowing at the rate of 2-4 drops per minute.

If the pump is self water-lubricated and length of column assembly is long (15 m or above), external water shall be admitted to wet and lubricate the line shaft bearings before starting the pump.

If the pump is external clear water lubricated, the clear water lubricating pump should be started before starting main pump.

- iii) Open the air vent in discharge/delivery pipe.
- iv) Switch on the motor and check correctness of direction of rotation. If the pump does not rotate, it should be switched off immediately.
- v) Check that oil is flowing into the pump through the sight glass tube. The number of drops/min. should be as per manufacturer's recommendations (normally 2-4 drops/minute).

For clear water lubricated pump, check that lubricating clear water is passing into the column assembly.

- vi) Check pressure gauge reading to ensure that pump has built up the required shut off head.
- vii) When the motor attains steady speed and pressure gauge becomes steady, the delivery valve should be gradually opened in steps to ensure that the head does not drop below recommended limit. (In absence of recommendation, the limit shall about 75% of duty head for VT & submersible pump).
- viii) If steady water stream is let out through air vent, close the air vent.
- ix) Check that ammeter reading is less than rated motor current.



- x) Check for undue vibration and noise.
- xi) When in operation for about 10-15 minutes, check bearing temperature, stuffing box packing and observe vibration if any.
- xii) Voltage should be checked every half an hour and should be within limit.

**c. Submersible Pumps**

Starting of a submersible pump is similar to vertical turbine pump except that steps- ii, v, and xi are not applicable and since motor is not visible, correctness of direction of rotation is judged from pressure gauge reading which should indicate correct shut off head.

**d. Jet Pump**

The procedure for starting jet pumps is similar to centrifugal pump except that priming by vacuum pump is not possible. Priming needs to be done by filling the pump casing and suction line from external source or by pouring water.

**e. Vacuum Pump**

The procedure for starting vacuum pump is similar to centrifugal pump except that priming is not necessary and valves on both suction & delivery side of vacuum pump should be fully open.

**f. Reciprocating Pump**

The steps stipulated for centrifugal pump are equally applicable for reciprocating pump. However exceptions as follows are applicable.

- The pump should be started against partially open delivery valve.
- The pump should never be started or operated against closed delivery valve.

**3.5.4 Stopping the Pump**

**3.5.4.1 Stopping the Pump under Normal Condition**

Steps to be followed for stopping a pump of low and medium specific speed are as follows:

**Box 6: Things to be checked when stopping the pump operation**

- i) Close the delivery valve gradually (sudden or fast closing should not be resorted to, which can give rise to water hammer pressures).
- ii) Switch off the motor.
- iii) Open the air vent in case of V.T. and submersible pump.
- iv) Stop lubricating oil or clear water supply in case of oil lubricated or clear water lubricated VT pump as applicable.

#### 3.5.4.2 Stopping after Power Failure/Tipping

If power supply to the pumping station fails or trips, actions stated below should be immediately taken to ensure that the pumps do not restart automatically on resumption of power supply. Though no-volt release or under volt relay is provided in starter and breaker, possibility of its malfunctioning and failure to open the circuit cannot be ruled out.

In such eventuality, if the pumps start automatically on resumption of power supply, there will be sudden increase in flow velocity in the pumping main causing sudden rise in pressure due to water hammer which may prove disastrous to the pumping main.

Secondly, due to sudden acceleration of flow in the pumping main from no-flow situation, acceleration head will be very high and the pumps shall operate near shut off region during acceleration period which may last for few minutes for long pumping main and cause overheating of the pump. Restarting of all pumps simultaneously shall also cause overloading of electrical system.

Hence, precautions are necessary to prevent auto-restarting on resumption on power. Following procedure should be followed.

- i) Close all delivery valves on delivery piping of pumps if necessary, manually as actuators cannot be operated due to non-availability of power.
- ii) Check and ensure that all breakers and starters are in open condition i.e. **off**-position.
- iii) All switches and breakers shall be operated to open i.e. **off**-position.
- iv) Open air vent in case of V.T. or submersible pump and close lubricating oil or clear water supply in case of oil lubricated or clear water lubricated V.T. pump.
- v) Information about power failure should be given to all concerned, particularly to upstream pumping station to stop pumping so as to prevent overflow.

### 3.6 Preventive Maintenance of Pumping Equipment

Lack of preventive and timely maintenance or poor maintenance can cause undue wear and tear of fast moving parts, and premature failure of the equipment.

The shortcomings in maintenance can also result in increase in hydraulic and power losses and low efficiency. Inefficient running of the pump increases burden of power cost. Importance of preventive maintenance, therefore, need not be overstressed.

Appropriate maintenance schedule and procedure need to be prescribed for all electrical and mechanical equipment based on manufacturers' recommendations, characteristics of the equipment, site and environment conditions i.e. temperature, humidity, dust condition, etc.

The preventive maintenance schedule shall detail the maintenance to be carried out at regular intervals i.e. daily, monthly, quarterly, half yearly, annually etc. or operation hours. The schedule shall also include inspections and tests to be performed at appropriate interval or periodicity.

General guidelines for maintenance schedules for pumps and associated electrical and mechanical equipment are enlisted below. The guidelines should not be considered as

total, full-fledged and comprehensive as characteristics of equipment and site conditions differ from place to place.

### **3.6.1 Maintenance Schedule for Pumps**

#### **3.6.1.1 Daily Observations and Maintenance**

##### **a) Daily Maintenance**

- ☞ Clean the pump, motor and other accessories,
- ☞ Check coupling bushes/rubber spider,
- ☞ Check stuffing box, gland etc.

##### **b) Routine observations of irregularities**

The pump operator should be watchful and should take appropriate action on any irregularity noticed in the operation of the pumps. Particular attention should be paid to following irregularities:

1. Changes in sound of running pump and motor,
2. Abrupt changes in bearing temperature,
3. Oil leakage from bearings,
4. Leakage from stuffing box or mechanical seal,
5. Changes in voltage,
6. Changes in current,
7. Changes in vacuum gauge and pressure gauge readings,
8. Sparks or leakage current in motor, starter, switch-gears, cable etc,
9. Overheating of motor, starter, switch gear, cable etc.

##### **c) Record of operations and observations**

A log book should be maintained to record the hourly observations, which should cover the following items:

1. Timings when the pumps are started, operated and stopped during 24 hours,
2. Voltage in all three phases,
3. Current drawn by each pump-motor set and total current drawn at the installation,
4. Frequency (50Hz),
5. Readings of vacuum and pressure gauges,
6. Motor winding temperature,

7. Bearing temperature for pump and motor,
8. Water level in intake/sump,
9. Flow meter reading,
10. Daily PF over 24 hours duration,
11. Any specific problem or event in the pumping installation or pumping system e.g. burst in pipeline, tripping or fault, power failure.

#### **3.6.1.2 Monthly Maintenance**

1. Check free movement of the gland of the stuffing box; check gland packing and replace if necessary,
2. Clean and apply oil to the gland bolts,
3. Inspect the mechanical seal for wear and replacement if necessary,
4. Check condition of bearing oil and replace or top up if necessary.

#### **3.6.1.3 Quarterly Maintenance**

1. Check alignment of the pump and the drive. The pump and motor shall be decoupled while correcting alignment, and both pump and motor shafts shall be pushed to either side to eliminate effect of end play in bearings,
2. Clean oil lubricated bearings and replenish with fresh oil. If bearings are grease lubricated, the condition of the grease should be checked and replaced/replenished to the correct quantity. An anti-friction bearing should have its housing so packed with grease that the void space in the bearing housing should be between one third and half. A fully packed housing will overheat the bearing and will result in reduction of life of the bearing,
3. Tighten the foundation bolts and holding down bolts of pump and motor mounting on base plate or frame,
4. Check vibration level with instruments if available; otherwise by observation,
5. Clean flow indicator, other instruments and appurtenances in the pump house.

#### **3.6.1.4 Annual Inspection and Maintenance**

A very thorough, critical inspection and maintenance should be performed once in a year. Following items should be specifically attended:

1. Clean and flush bearings with kerosene and examine for flaws developed, if any, e.g. corrosion, wear and scratches. Check end play. Immediately after cleaning, the bearings should be coated with oil or grease to prevent ingress of dirt or moisture.
2. Clean bearing housing and examine for flaws, e.g. wear, grooving etc. Change oil or grease in bearing housing.

3. Examine shaft sleeves for wear or scour and necessary rectification. If shaft sleeves are not used, shaft at gland packing should be examined for wear.
4. Check stuffing box, glands, lantern ring, mechanical seal and rectify if necessary.
5. Check clearances in wearing ring.

Clearances at the wearing rings should be within the limits recommended by the manufacturer. Excessive clearance reduces discharge and efficiency of the pump. If the wear is only on one side, it is indicative of misalignment. The misalignment should be set right, and the causes of misalignment should be investigated.

6. Check impeller hubs and vane tips for any pitting or erosion,
7. Check interior of volute, casing and diffuser for pitting, erosion, and rough surface,
8. All vital instruments i.e. pressure gauge, vacuum gauge, ammeter, voltmeter, wattmeter's, frequency meter, tachometer, flowmeter etc. shall be calibrated,
9. Conduct performance test of the pump for discharge, head and efficiency,
10. Measures for preventing ingress of flood water shall be examined. Ingress of flood water in sump, well, borehole shall be strictly prevented. Seal cap shall be provided above borehole.
11. Check vibration level.

### 3.6.1.5 Overhaul/Service of Pump

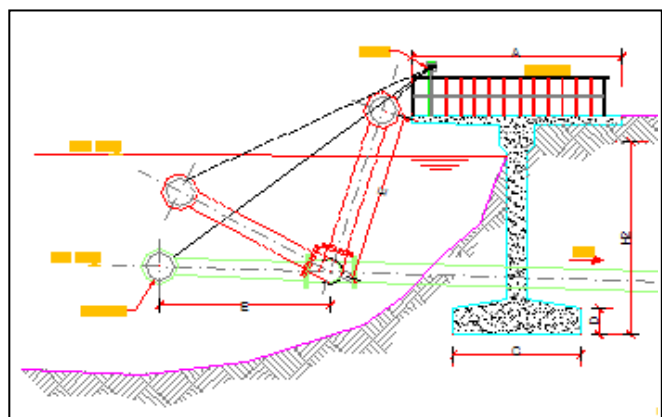
It is difficult to specify the periodicity or interval for overhaul in the form of period of service in months/years or operation hours, as deterioration of pump depends on nature of service, type of installation i.e. wet pit or dry pit, quality of water handled, quality of material of construction, maintenance, experience with particular make & type of pump etc.

However generally, following operational hours may be taken as broad guidelines for overhauling.

- Submersible pump – 5,000 – 6,000 hours
- Vertical turbine pump – 12,000 hours
- Centrifugal pump – 15,000 hours

### 3.6.1.6 Problems in Long Column Pipes in VT Pumps

Very long column pipes in vertical turbine pump at river intake or intake well constructed in impounded reservoir are required to be provided due to large fluctuations in water level from minimum water level during dry period to high water level during wet period. Such long column pipes (if length exceeds about 15 m) usually causes problem of fast wearing of



line- shafts bearings in case of water lubricated pumps. Such longer suspended assembly is also more prone to rotation or swinging of column assembly due to vortices.

Precautionary measure as follows may be taken:

- a. Prevention of premature wear of water lubricated bearings in column pipes Water lubricated bearings usually are of rubber or neoprene and wear fast if dry running, occurs during starting of VT pumps. Therefore to avoid dry running water is admitted from external source (usually a tank near the pump provided for the purpose) into the column pipe for about 3-4 minutes so as to wet the bearing before starting the pump,
- b. Preventing rotation or swinging in column assembly,

### **3.6.1.7 History Sheet**

History sheet of all pumps shall be maintained. The history sheet shall contain all important particulars, records of all maintenance, repairs, inspections and tests etc.

It shall generally include the following:

1. Details of the pump, rating, model, characteristic curves, performance test report etc,
2. Addresses of manufacturer & dealer with phone & fax number and e-mail addresses,
3. Date of installation and commissioning,
4. Brief details and observations of monthly, quarterly and annual maintenance and inspections,
5. Details of breakdown, repairs with fault diagnosis, replacement of major components i.e. impeller, shaft, bearings, wearing rings,
6. Results of annual performance test including discharge and efficiency,
7. Yearly operation hours of the pumps,
8. Brief findings of energy audit.

### **3.6.2 Maintenance Schedule for Motors**

#### **3.6.2.1 Daily Maintenance**

The following activities presented in Box-3 below shall be carried out as a daily maintenance of pumping motor:

#### **Box 7: Daily Maintenance Tasks for Motor**

1. Clean external surface of motor,
2. Examine earth connections and motor leads,
3. Check temperature of motor and check whether overheated. The permissible maximum temperature is above the level which can be comfortably felt by hand. Hence temperature observation should be taken with RTD or thermometer. (Note: In order to avoid opening up motors, a good practice is to observe the stator temperature under normal working conditions. Any increase not accounted for, by seasonal increase in ambient temperature, should be suspected).

4. In case of oil ring lubricated bearing:
  - ☞ Examine bearings to check whether oil rings are working,
  - ☞ Note bearing temperature,
  - ☞ Add oil if necessary.
5. Check for any abnormal bearing noise,

### 3.6.2.2 Monthly Maintenance

#### Box 8: Monthly Maintenance Tasks for Motor

1. Check belt tension. In case where this is excessive it should immediately be reduced,
2. Blow dust from the motor,
3. Examine oil in oil lubricated bearing for contamination by dust, grit, etc. (this can be judged from the colour of the oil),
4. Check functioning and connections of anti-condensation heater (space heater).
5. Check insulation resistance by mongering

### 3.6.2.3 Quarterly Maintenance

#### Box 9: Quarterly Maintenance Tasks for Motor

1. Clean oil lubricated bearings and replenishes fresh oil. If bearings are grease lubricated, the condition of the grease should be checked and replaced/replenished to correct quantity.

An anti-friction bearing should have its housing so packed with grease that the void space in the bearing housing should be between one third and half. A fully packed housing will overheat the bearing and will result in reduction of life of the bearing.
2. Wipe brush holders and check contact faces of brushes of slip-ring motors. If contact face is not smooth or is irregular, file it for proper and full contact over slip rings.
3. Check insulation resistance of the motor.
4. Check tightness of cable gland, lug and connecting bolts.
5. Check and tighten foundation bolts and holding down bolts between motor and frame.
6. Check vibration level with instrument if available; otherwise by observation.

#### **3.6.2.4 Haft Yearly Maintenance**

##### **Box 10: Haft Yearly Maintenance Tasks for Motor**

1. Clean winding of motor, bake and varnish if necessary.
2. In case of slip ring motors, check slip-rings for grooving or unusual wear, and polish

#### **3.6.2.5 Annual Inspection and Maintenance**

##### **Box 11: Annual Inspection and Maintenance Tasks for Motor**

1. Clean and flush bearings with kerosene and examine for flaws developed, if any, e.g. wear and scratches. Check end-play. Immediately after cleaning, the bearings should be coated with oil or grease to prevent ingress of dirt or moisture,
2. Clean bearing housing and examine for flaws, e.g. wear, grooving etc. Change oil or grease in bearing housing.
3. Blow out dust from windings of motors thoroughly with clean dry air. Make sure that the pressure is not so high as to damage the insulation.
4. Clean and varnish dirty and oily windings. Re-varnish motors subjected to severe operating and environmental conditions e.g., operation in dust-laden environment, polluted atmosphere etc.
5. Check condition of stator, stamping, insulation, terminal box, fan etc.
6. Check insulation resistance to earth and between phases of motors windings, control gear and wiring.
7. Check air gaps.
8. Check resistance of earth connections.

#### **3.6.2.6 History Sheet**

Similar to history sheet of pump, history sheet of motor should be maintained. The history sheet should contain all important particulars, records of periodical maintenance, repairs, inspections and tests.

It shall generally include the following:

1. Details of motor, rating, model, class of duty, class of insulation, efficiency curve, type test result and type test certificate etc.



2. Date of installation and commissioning.
3. Addresses of manufacturer & dealer with phone & fax number and e-mail addresses.
4. Brief details of monthly, quarterly, half yearly and annual maintenance and observations of inspections about insulation level, air gap etc.
5. Details of breakdown, repairs with fault diagnosis.
6. Running hours at the time of major repairs.

### 3.6.3 Maintenance Schedule for Valves at Pumping Station

The following five types of valves in pumping installation exist, these are:

1. Foot valve,
2. Sluice valve,
3. Knife gate valve,
4. Non-Return (Reflux) valve, and
5. Butterfly valve.

Maintenance of valves at pumping station is presented in Table 3.1.

**Table 3-1: Maintenance of Valves at Pumping Stations**

Type of Valves	Maintenance Tasks
<b>Foot Valve</b>	<ul style="list-style-type: none"> <li>☞ Clean foot valve once in 1-3 months depending on ingress of floating matters,</li> <li>☞ Clean flap of the foot valve once in 2 months to ensure leak proof operation,</li> <li>☞ Inspect the valve thoroughly once in a year. Check for leakage through foot valve after priming and observing level in volute casing.</li> </ul>
<b>Sluice and Knife Gate Valves</b>	<ul style="list-style-type: none"> <li>☞ Check gland packing of the valve at least once in a month. It should be ensured that pickings' inside the stuffing box are in good trim and impregnated with grease.</li> <li>☞ It may be necessary to change the packing as often as necessary to ensure that the leakage is within limit.</li> <li>☞ Grease should be applied to reduction gears and grease lubricated thrust bearing once in three months.</li> <li>☞ Check tight closure of the valve once in 3 months.</li> <li>☞ A valve normally kept open or closed should be operated once every three months to full travel of gate and any jamming developed due to long disuse shall be freed.</li> <li>☞ Inspect the valve thoroughly for flaws in guide channel, guide lugs, spindle, spindle nut, stuffing box etc. once in a year.</li> </ul>

Type of Valves	Maintenance Tasks
	<ul style="list-style-type: none"> <li>☞ Important <b>DON'T</b> for valve is that it should never be operated with oversize hand wheel or cap or spanner as this practice may result in rounding of square top and hand wheel or cap or spanner may eventually slip.</li> <li>☞ An important <b>DON'T</b> for valve is that it should never be operated under throttled i.e. partially open condition, since such operation may result in undue chatter, wear and failure of valve spindle.</li> </ul>
<b>Non-Return (Reflux) Valve</b>	<ul style="list-style-type: none"> <li>☞ Check proper operation of hinged door and tight closure under no-flow condition once in 3 months.</li> <li>☞ The valve shall be thoroughly inspected annually. Particular attention should be paid to hinges and pins and soundness of hinged door.</li> <li>☞ Condition of dampening arrangement should be thoroughly examined once in year and necessary maintenance and rectification as per manufactures' instructions shall be carried out.</li> <li>☞ In case of dampening arrangement, check for oil leakage and replace oil once in a year.</li> </ul>
<b>Butterfly Valve</b>	<ul style="list-style-type: none"> <li>☞ Check seal ring and tight shut-off once in 3 months.</li> <li>☞ Lubricate gearing arrangement and bearing once in 3 months.</li> <li>☞ Inspect the valve thoroughly including complete operations once in a year.</li> <li>☞ Change oil or grease in gearing arrangement once in a year.</li> </ul>
<b>General</b>	<ul style="list-style-type: none"> <li>☞ Operate bypass valve wherever provided once in 3 months.</li> <li>☞ Flange adapter/dismantling joint provided with valve shall be loosened and retightened once in 6 months to avoid sticking.</li> </ul>

### 3.6.3.1 Annual Inspection and Maintenance

1. Examine all components and wiring thoroughly and rectify as necessary.
2. Change oil or grease in gear box and thrust bearing.
3. Check condition of gears & replace gears if teeth are worn out.

### 3.6.4 Maintenance Schedule for L.T. Starters, Breakers and Panel

Note: Circuit diagram of starter/breaker should be posted on door of switch gear and additional copy should be kept on record. Table 3.2 below is presented the maintenance tasks for Starter, breaker and panel in the pumping station.

**Table 3-2: Maintenance Activities of L.T Starter, Breaker and Panel**

Maintenance Duration	Activities
Daily	<ul style="list-style-type: none"> <li>☞ Clean the external surface.</li> <li>☞ Check for any spark or leakage current.</li> <li>☞ Check for overheating</li> </ul>
Monthly	<ul style="list-style-type: none"> <li>☞ Blow the dust and clean internal components in the panel, breaker and starter.</li> <li>☞ Check and tighten all connections of cable, wires, jumpers and bus-bars. All carbon deposits shall be cleaned.</li> <li>☞ Check relay setting</li> </ul>
Quarterly	<ul style="list-style-type: none"> <li>☞ Check all connections as per circuit diagram.</li> <li>☞ Check fixed and moving contacts and clean with smooth polish paper, if necessary.</li> <li>☞ Check oil level and condition of oil in oil tank. Replace the oil if carbon deposit in suspension is observed or color is black.</li> <li>☞ Check insulation resistance.</li> <li>☞ Check condition of insulators.</li> </ul>
Yearly	<ul style="list-style-type: none"> <li>☞ Check and carry out servicing of all components, thoroughly clean and reassemble.</li> <li>☞ Calibrate voltmeter, ammeter, frequency meter etc.</li> </ul>

### 3.6.5 Maintenance Schedule for Lifting Equipment

Relevant points in the maintenance schedule for lifting equipment, depending on the type of lifting equipment i.e. chain pulley block, monorail (travelling trolley and chain pulley block), manually operated overhead crane and electrically operated travelling crane is presented in Table 3.3 below.

**Table 3-3: Maintenance Activities of Lifting Equipment**

Maintenance Duration	Activities
Quarterly	<ul style="list-style-type: none"> <li>☞ Check oil level in gear box and top up if required.</li> <li>☞ Check for undue noise and vibration.</li> <li>☞ Lubricate bearings and gear trains as applicable.</li> <li>☞ Check insulation resistance of motors</li> </ul>
Haft Yearly	<ul style="list-style-type: none"> <li>☞ Clean limit switches.</li> <li>☞ Clean all electrical contacts</li> </ul>
Yearly	<ul style="list-style-type: none"> <li>☞ Change oil in gear box.</li> <li>☞ Conduct load test of crane for rated load or at least for maximum load required to be handled. All fast-moving components which are likely to wear should be thoroughly inspected once in a year and if necessary shall be replaced.</li> </ul>

### 3.6.6 Maintenance Schedule for Water Hammer Control Devices

Maintenance requirements of water hammer devices depend on type of water hammer control device, nature of its functioning, water quality etc.

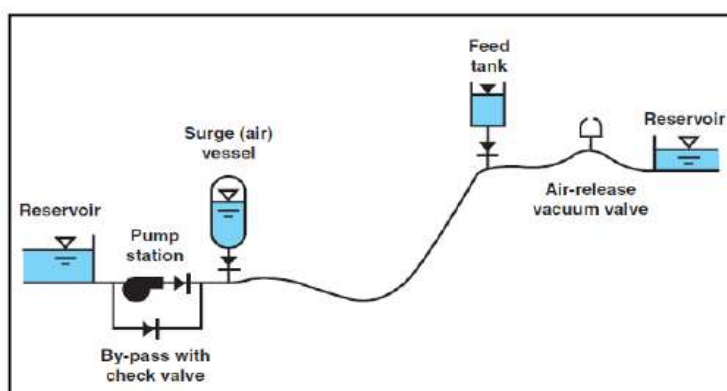
Type of water hammer control devices used in water pumping installations is the following:

- Surge tank
- One-way surge tank
- Air vessel (air chamber)
- Zero velocity valve and air cushion valve.
- Surge anticipation valve (surge suppressor)
- Pressure relief valve.

General guidelines for maintenance of different types of water hammer control devices are presented here:

#### 3.6.6.1 Surge Tank

The following maintenance activities shall be carried out at surge tank in the transmission line.



- **Quarterly:** Water level gauge or sight tube provided shall be inspected, any jam rectified, all cocks and sight tube flushed and cleaned.
- **Yearly:** The tank shall be drained and cleaned once in a year or earlier if frequency of ingress of foreign matter is high.
- **Valve maintenance:** Maintenance of butterfly valve, sluice valve and reflux valve shall be attended as specified for valves on pump delivery in section above,
- **Painting:** Painting of tanks shall be carried out once in 2 years.

#### 3.6.6.2 Air Vessel

Air vessel maintenance in the transmission line is presented in Table 3.4.

**Table 3-4: Maintenance Activities of Lifting Equipment**

Maintenance Duration	Activities
Daily	<ul style="list-style-type: none"> <li>☞ Check air-water interface level in sight glass tube.</li> <li>☞ The air water level should be within range marked by upper and lower levels and shall be preferably at middle.</li> <li>☞ Check pressure in air receiver at interval of every 2 hours.</li> </ul>
Quarterly	<ul style="list-style-type: none"> <li>☞ Sight glass tube and cock shall be flushed.</li> <li>☞ All wiring connections shall be checked and properly reconnected.</li> </ul>

Maintenance Duration	Activities
	☞ Contacts of level control system and pressure switches in air supply system shall be cleaned.
<b>Yearly</b>	☞ The air vessel and air receiver shall be drained, cleaned and dried. ☞ Internal surface shall be examined for any corrosion etc. and any such spot cleaned by rough polish paper and spot-painted. ☞ Probe heads of level control system shall be thoroughly checked and cleaned.

▪ **Accessories:**

☞ Maintenance of panel, valves and air compressor etc. shall be carried out as specified for respective appurtenances.

### 3.6.6.3 Zero velocity valve and air cushion valve

Foreign matters entangled in valve shall be removed by opening all hand holes and internal components of the valves including ports, disk, stem, springs, passages, seat faces etc. should be thoroughly cleaned and checked once in 6 months for raw water and once in a year for clear water application.

### 3.6.6.4 Surge anticipation valve (surge suppressor)

Pilot valves and tubes shall be flushed and cleaned every month

### 3.6.6.5 Pressure relief valve

The spring shall be checked and freed from jam every month.

## 3.6.7 Maintenance Schedule for Air Compressor

### a) Daily :

- Clean external surface.
- Check oil level and top up if necessary.

### b) Monthly :

- Clean oil filter
- Clean air filter

### c) Quarterly :

- Check condition of oil and change if dirty.
- Check grease in bearing housing and replenish/change if necessary.
- Check condition of oil in air filter and change if dirty.

### d) Half yearly:

- Change oil.

- Change oil filter element.
- Thoroughly clean air filter.
- Clean bearing and bearing housing and change grease/oil.

**e) Yearly:**

- Thoroughly check all components, piping valve etc. and rectify if necessary.

### **3.7 Maintenance of Pumping Station**

Maintenance of pumping station such as screens, gate, sump / intake / well and pump house including civil works as described below:

#### **3.7.1 Screens**

1. Screen should be cleaned at a frequency depending on ingress load of floating matters. The frequency in monsoon season shall be more than that in fair season. However, cleaning frequency should be at least once in a week, or, if head loss in screen exceeds 0.20 m.
2. Care should be taken to remove and dump the screening far away from the pump house.
3. Lubricate wheels and axle of wheel burrows.
4. The screen, catch tray and screen handling arrangement shall be thoroughly inspected once in six months and any item broken, eroded, corroded shall be rectified.

#### **3.7.2 Sluice Gate**

**a) Monthly :**

- ☞ The sluice gate normally remains in open position and closed only when inflow is to be stopped. Since floating matters may adhere to the gate and may accumulate in the seat, it should be operated once in a month. In order to ensure that gate remains free for operation,

**b) Yearly :**

- ☞ The gate should be thoroughly inspected once in a year preferably after wet season and components found worn out shall be replaced. Particular attention shall be paid to the seats of the frame and gate.
- ☞ The gate should be closed to check the leakages. For this purpose, the sump/intake shall be partly dewatered so that differential head is created on the gate and leakage test at site can be performed.

#### **3.7.3 Sump/Intake Well**

- ☞ All foreign floating matters in the sump/intake shall be manually removed at least once in a month and shall be disposed off away from pump house,
- ☞ De-silting of intake/sump shall be carried out once in year preferably after wet season. Care should be taken to dump the removed silt away from pump house.

- ☞ It is generally observed that reptiles like snakes, fish, etc. enter intake particularly in wet season. The intake should be disinfected.
- ☞ The sump/intake should be fully dewatered and inspected once in a year.
- ☞ It is advisable to undertake leakage test of sump once in a year. For this purpose, the sump shall be filled to FSL and drop in water level for reasonably long duration (2-3 hours) should be observed. If leakage is beyond limit, rectification work shall be taken.

#### **3.7.4 Pump House**

- ☞ The pump house should be cleaned daily. Good housekeeping and cleanliness are necessary for pleasant environment,
- ☞ Entire pump house, superstructure and sub-structure shall be adequately illuminated and well ventilated. Poor lighting, stale air etc. create unpleasant environment and have an adverse effect on will of the staff to work,
- ☞ Wooden flooring and masonry stone grating wherever damaged should be repaired on priority,
- ☞ It is observed that at many places, roof leaks badly and at times the leakage water drips on the panel/motor which is dangerous and can cause short circuit and electric accidents. All such leakages should be rectified on priority.
- ☞ All facilities in sub-structure i.e. stair case, floors, walkways etc. should be cleaned daily.
- ☞ Painting of civil works should be carried out at least once in two years.

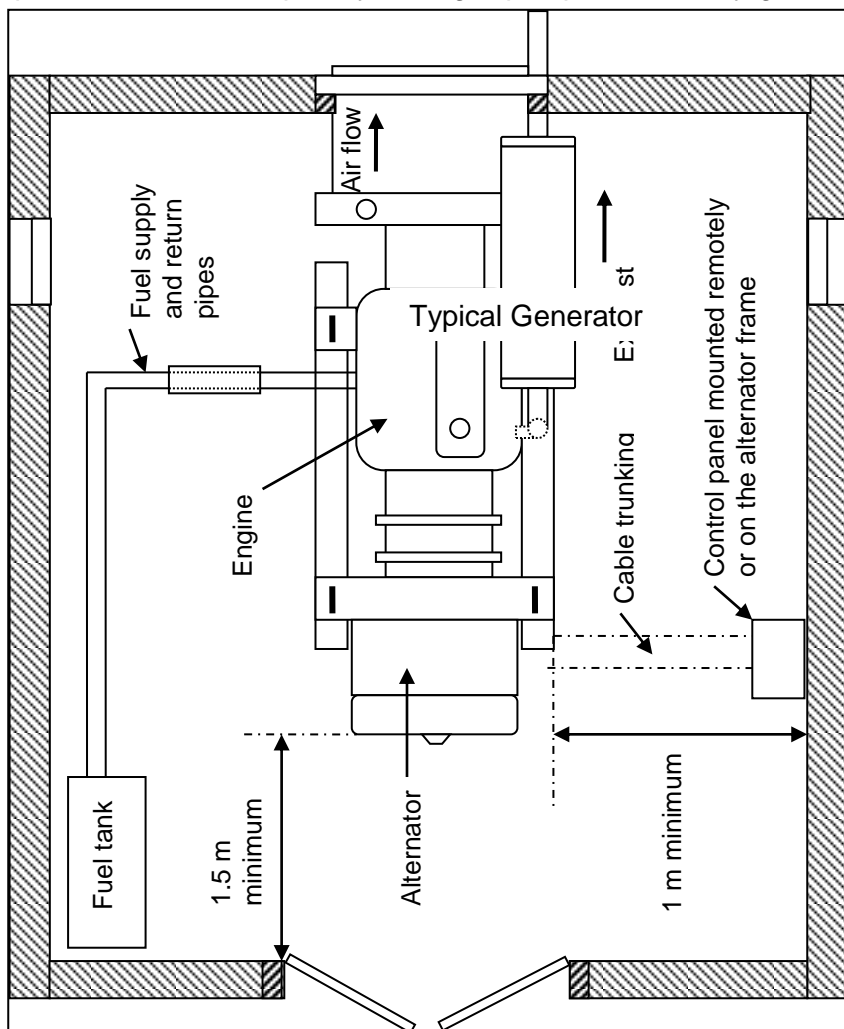
## 3.8 Driving Equipment

### 3.8.1 Diesel/Gasoline Engines/Alternators

Engines are used by water supply services to power pumps for emergency backup and in some remote installations where power is not economically available. Engines commonly used by water schemes include gasoline engines and oil engines (diesels).

A diesel engine is a machine, which produces power by burning oil in a body of air, which has been compressed to a high pressure by a moving piston. It is called an engine because it is a machine that produces power. Because the burning or combustion of the oil takes place within the engine itself, the machine is known as an internal combustion engine.

Diesel generators are frequently used as a stationary power source. The main parts of the engine are the cylinders, pistons, valves and crankshaft. Air is compressed by a piston inside a cylinder and diesel fuel is injected into it by a high pressure pump, which results in an explosion that moves the piston. In turn, the piston turns a crankshaft, which can be put to use, for example, by driving a pump or electricity generator. Valves in the cylinder regulate the inflow of fuel and air, and the outflow of exhaust gases.



**Figure 3-3: Plan of a Typical Generator House**

- diesel engines are well-suited for stationary, high-power output;
- with good maintenance they are dependable energy sources;
- It is important to select a brand that has a good reputation, and for which servicing and spare parts are locally available.



Gasoline engines can be used for direct connection to centrifugal pumps operating at a moderate heads, but need a reducing gear to low pumping heads. They are generally not considered as economical for duty.

### 3.8.1.1 Identification

Generating set rating plate gives information about a generating set and is provided on each generator. Atypical plate is shown here below.

GENERATING SET	
Serial No	<input type="text"/>
Type	<input type="text"/>
Year of manufacture	<input type="text"/>
Rated power	<input type="text"/> KVA
Rated power factor	<input type="text"/>
Maximum ambient temp	<input type="text"/>

### 3.8.1.2 Start Up Procedure

#### a) Before starting, make the following checks:

Table 3-5 presents below is checking and service shall be carried out for generator engine.

**Table 3-5: Pre-Start Check and Service of Generator Engine**

No.	Description	Checking
1	Oil	Check the different types of oil, coolant and fuel levels. The oil level may be checked with the engine running or stopped. The recommended method of checking is while the engine is not running. Badly contaminated or deteriorated oil shall be replaced immediately regardless of the replacement interval, and the oil level has to be maintained between the lower and upper marks of the oil dip stick.
2	Radiator	Check the coolant level on the control board meter. If additional water is needed, remove fill cap and add as necessary. In addition to this, always check randomly radiator core, mountings, hose, steam-relief tube and valve are in good condition, correctly assembled, securely mounted and do not leak.
3	Fuel Tank	Fuel can be added to the tank by removing the fill cap on top of the fuel tank. After completion of refuelling, be sure to tighten the fuel tank cap to protect against vandalism.

No.	Description	Checking
4	Batteries	<p>Check electrolyte level in each battery cell and maintain the level to the bottom of the fill openings with distilled water.</p> <p>Clean the top of the batteries with a clean cloth.</p> <p>Keep the terminals clean and coated with petroleum jelly.</p> <p>Check the indicating meter located on the control board, it is always expected to indicate at least nominal battery rating unless and otherwise the meter is faulty.</p>
5	Instruments and Gauges	<p>Check the following meters at frequent intervals under the full range of engine speeds for correct readings, if unusual readings are observed stop the equipment immediately and report to the supervisor.</p> <ul style="list-style-type: none"> <li>▪ Ammeters</li> <li>▪ Voltmeters</li> <li>▪ Speedo-meter</li> <li>▪ Temperature gauge</li> </ul>
6	Accessories	<p>Check accessories such as fuel pump, carburettor, generator, regulator, starter, fan belt and water pump for loose connections or mountings.</p>

**b) Start engine, make the following checks:**

Box-8 describes the checking of generator engine during the start of the operation.

**Box 12: Checking during starting of Generator Engine**

- ☞ Observe engine warm up.
- ☞ Check that the starter has adequate cranking speed and engages and disengages properly without unusual noise.
- ☞ Do not place engine under load before reaching normal operation condition.
- ☞ Check oil pressure and all other instruments (Tachometer, Voltmeter, Temperature gauge).

**c) During Operation**

During operation, operators must correct simple defects only and if the defects are beyond their capacity the defects are to be reported to the supervisor. Box-9 describes the checking's to be carried out during the engine in operation.

**Box 13: Checking during operation of Generator Engine**

- ☞ Check clutch (if applicable).
- ☞ Check engine controls and watch for poor engine performance such as the lack of usual power, misfiring, unusual noise, stalling, overheating, or excessive exhaust smoke. Check that engine responds satisfactorily to the controls and the controls are correctly adjusted.
- ☞ Check leaks.
- ☞ Check accessories and belts.
- ☞ Check alternator meter for correct operating current and voltage. Adjust if required.

**d) After operation, make the following checks:****Box 14: Checking after operation of Generator Engine**

- ☞ Check any irregularities noticed previously.
- ☞ Check fuel, oil and water.
- ☞ Check instruments.
- ☞ Check battery.
- ☞ Check accessories and belts.
- ☞ Check fuel filters.
- ☞ Check for leaks.

**3.8.1.3 Switching Off Procedure**

1. Turn engine off,
2. Record end time on Log Chart,
3. Check for any oil leaks.

**3.8.1.4 Schedule of Preventative Maintenance for Diesel Engines**

In almost all cases, diesel engine prime movers are designed as standby units, these must be given proper care to prolong their life and for their efficient operation. In the absence of the equipment operating manual, listed below are suggested preventive maintenance practices.

**Table 3-6: Schedule of PM for Diesel Engines**

O&M Duration	Activities
Daily Operation/ every 8 hours (To be carried out by Operator)	<ul style="list-style-type: none"> <li>☞ Check fuel and engine oil levels, top up if necessary</li> <li>☞ Check water level in radiator &amp; top up if necessary and secure the cap</li> <li>☞ Check tension of alternator drive belt, check battery condition/water level</li> </ul>

O&M Duration	Activities
	<ul style="list-style-type: none"> <li>☞ Check the lubricating oil pressure at the gauge</li> <li>☞ Check for loose nuts and bolts, check and correct any leaks or engine damage</li> <li>☞ In very dusty conditions clean air cleaner element, drain and clean dust bowl</li> <li>☞ Check exhaust pipe</li> <li>☞ Check foundation bolts</li> </ul>
Every 100 hours or 3 months (To be carried out by skilled mechanics)	<ul style="list-style-type: none"> <li>☞ As for daily services.</li> <li>☞ Renew engine lubricating oil</li> <li>☞ Renew engine oil filter</li> <li>☞ Drain water from fuel filter and pre-filter</li> <li>☞ Check the condition of the battery fitted</li> <li>☞ When moderately dusty, empty bowl and clean or replace the air cleaner element</li> <li>☞ Clean the compressor air filter</li> <li>☞ Check and adjust idle speed</li> </ul>
Every 200 – 250 hours or 6 months (To be carried out by skilled mechanics)	<ul style="list-style-type: none"> <li>☞ As for previous servicing</li> <li>☞ Change the engine oil and oil filter element</li> <li>☞ Clean fuel strainer, fuel tank breather. Renew fuel filter canister</li> <li>☞ Clean battery terminals</li> </ul>
Every 400 hours or 12 months (To be carried out by skilled mechanics)	<ul style="list-style-type: none"> <li>☞ As for previous servicing</li> <li>☞ Replace air cleaner element</li> <li>☞ Renew fuel filter element</li> <li>☞ Check concentration of coolant</li> <li>☞ Check the battery charging system. Check alternator drive belt for wear, Check</li> <li>☞ wiring harness &amp; connections and tighten if required</li> <li>☞ Check injectors for performance</li> </ul>
After 600 hrs or 18 months (To be carried by skilled mechanics)	<ul style="list-style-type: none"> <li>☞ As for 200 hour servicing and maintenance</li> <li>☞ Renew coolant</li> <li>☞ Renew alternator drive belt</li> <li>☞ Tighten cylinder head</li> <li>☞ Check and adjust valve clearances</li> <li>☞ Check electrical system</li> <li>☞ Check all nuts and bolts for tightness</li> <li>☞ Check engine mountings</li> </ul>

### 3.1.1 D.C Battery

The following maintenance schedule shall be applicable for D.C. Batteries:

- i. **Daily:** Check voltage and specific gravity of the batteries and battery supply for the tripping circuit.
- ii. **Monthly:** Check the battery charging & fuses and clean contact faces.

Apply petroleum jelly or grease to battery terminals.

- iii. **Quarterly:** Check to ensure that battery is not overcharged/under charged.
- iv. **Yearly:** Check rectifier, diode, rheostat motor thoroughly.

## 3.2 Control Panel

The primary function of any control board is to regulate equipment within the limits of its performance at some distance away from it.

To accomplish this, controls fall into two basic categories:

- First, operating controls, which as the name implies, regulating the equipment manually or automatically to start or stop activity, and
- Second, safety controls that are designed to prevent damage to equipment in the event of malfunction.



On small water systems, switches are primary operating controls that can be used to directly start and stop electrical current flowing. In larger systems, additional operating controls are needed such as motor magnetic starters and contractors. Electrical safety controls, or auxiliary protection devices, are applied to do one of the following jobs: -

- First, they may provide a manual and automatic means of an electrical disconnection in the event of excessive current flow to the equipment.
- Second, they may protect the equipment from overheating caused by overloading, lack of water, voltage variations and other causes.

Control panel provides means of starting and stopping of equipment, monitoring its operation, and automatically shutting down the set in the event of a critical condition arising such as low oil pressure or high engine temp.

Normally all control panels are equipped with some type of safety devices and instruments. The following description explains the function of each item on the panels.

Safety devices fall into two classes: - Alarms to give warning of trouble and shut down device to stop the operation before damage results.

Alarm systems are usually electrical because the warning can be given best by electrical siren, bells, or lights. Shutdown systems may be operated electrically or by direct mechanical action. Safety devices should receive regular inspection, testing, and maintenance to insure reliable action.

Whether an alarm is sufficient or not, whether the equipment should be stopped automatically or not, depends on how closely the apparatus is attended. If an attendant is always nearby, an alarm is generally enough that can act promptly, either to correct the fault or stop the equipment manually if he could not correct the condition before damage would result.

Control panels are available for both indoor and outdoor installations. Indoor panel types are wall mounted with or without separate sections for control and power. Separate section has the advantage of higher personnel security. Outdoor panels are equipped with an outer security door. Lockable with separate key, that covers all control devices. They are equipped with a rain canopy. These types of panels are as standard provided with a main disconnect switch for incoming supply and with separate fuse or circuit breaker for each pump.

### **3.3 Facilities for Maintenance and Repairs**

The following facilities should be provided for maintenance, inspection and repairs in the pumping installation:

- ☞ Adequate stock of consumables and lubricants,
- ☞ Adequate stock of spare parts,
- ☞ Tools and testing instruments,
- ☞ Lifting equipment,
- ☞ Ventilated and illuminated adequate space for repairs.

#### **3.3.1 Consumables and Lubricants**

Adequate stock of gland packing, belts, gaskets, lubricating oil, greases, transformer oil, insulation tape, sealing compound, emery paste etc. shall be maintained. The consumables and lubricants shall be of proper quality and grade. Quantity shall be decided depending on consumption and period required to procure and replenish the stock.

#### **3.3.2 Spare parts**

Adequate stock of spare parts should be maintained to avoid downtime due to non-availability of spares. Generally spares required for one-two years maintenance as per list below shall be kept in stock. The list should not be considered as full-fledged and comprehensive and should be updated and revised in light of manufacturers' recommendations and previous history of repairs undertaken.

**Table 3-7: Lists of Spare parts need to be stock for O&M of Pumps and Generators**

No.	Spare part Items	No.	Spare part Items
1	Set of wearing rings	12	Lantern ring
2	Shaft sleeves	13	Coupling for line shaft
3	Bearings	14	Slip ring unit
4	Gland packing's and gaskets	15	Carbon brushes
5	Coupling bushes and bolts	16	Fixed and moving contacts
6	Line shaft bearings and spiders	17	Lugs
7	Line shaft	18	Gland for cable termination
8	Pump shaft	19	Fluorescent tubes and lamps
9	Shaft enclosing tube	20	Fuses
10	Tube tensioning plate	21	Impeller
11	Gland nut	22	Rotating assembly of pump (for large pumping installation)

### 3.3.3 Tools and Testing Instruments

The pumping installation should be equipped with all necessary tools, testing instruments and special tools required for repairs and testing. Their quantity and special tools depend on size and importance of installation.

Generally the following tools and testing instruments shall be provided:

**Table 3-8: Lists of Tools and testing Instruments required for O&M**

No.	Lists of Tools	No.	Spare part Items
1	Double ended spanner set and ring spanner set	11	Bearing puller
2	Box spanner set	12	Torque wrench
3	Hammers (of various sizes and functions)	13	Clamps for column pipes, tube and line shaft
4	Screw driver set	14	Specials tools such as grinder, blower, drilling machine
5	Chisel	15	Tap and die set
6	Nose pliers, cutting pliers	16	Bench vice
7	Files of various sizes and smooth/rough surfaces	17	Special tools for breakers
8	Adjustable spanner	18	Fluorescent tubes and lamps
9	Pipe wrenches	19	Crimpling tool
10	Heating stove for heating sleeves	20	Rotating assembly of pump (for large pumping installation)
1	Insulation tester		Earth resistance tester

No.	Lists of Tools	No.	Spare part Items
2	Tongue tester		Wattmeter, CT and PT
3	AVO meter		Dial gauge
4	Test lamp		Tachometer

### 3.3.4 Lifting and Material Handling Aids

The following lifting and material handling aids shall be kept in the pump house:

- Chains
- Wire rope
- Manila rope
- Chain pulley block and tripod.
- Other lifting equipment
- Hand cart
- Ladder

## 3.4 Renewable Energy System

The most applicable renewable energy sources for water supply are solar and wind energies. The operation and maintenance requirements for these energy sources are described in sections below.

Under appropriate conditions wind and solar based pumping offer several advantages such as low running costs and minimal environmental impact. While the upfront investment on solar or wind energy based water supply schemes is higher than for conventional systems, the financial costs on a life cycle basis are often more favourable since the much lower running costs due to the almost free supply of energy offsets the incremental initial investment cost.

Maintenance costs of solar systems are also low, since the photovoltaic cells have been proven to be very reliable in practice. As such the operation and maintenance costs can easily be covered by a community.

### 3.4.1 Solar Powered Pumping System

#### 3.4.1.1 General

There is very little technically that can go wrong with a solar system if it has been installed correctly. The submersible pump in combination with the control unit has a number of safety features that protect it in the event of problems occurring.

Whilst it is very “hi-tech”, the high level of reliability, minimal maintenance, need for spare parts and low operating costs make it appealing for rural locations. The main threat to the reliability of solar systems is human interference, from vandalism and efforts at repair.

As a rule of thumb, solar pumping systems should generally be considered for applications of less than 8 to 10 kW peak.



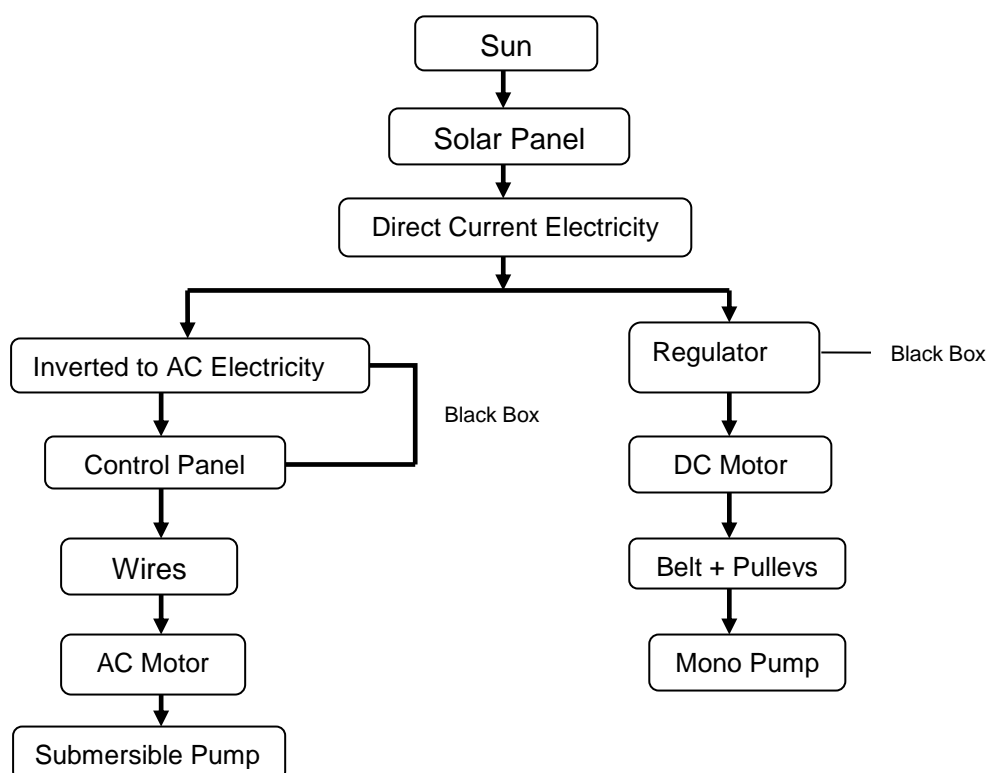
**3.4.1.2 Components of Solar Energy System**

Table 3-9 below is shown the various components of solar energy that requires fulfilling the operation and maintenance aspects. Solar panel/photovoltaic array converts solar energy to D.C electricity.

**Table 3-9: Components of Solar Energy System**

No.	description	purpose	description	purpose
1	Inverter: D.C to A.C	Used for power conditioning for high power applications. Converts D.C to A.C	Regulator	Regulates voltage
2	Wires	For electric power transmission	Belt and Pulleys	Used for turning the shaft in the rising main
3	AC Motor	Convert electrical output of the solar panels in to mechanical	DC Motor	Convert electrical output of the solar panels in to mechanical energy
4	Submersible Pump	Pump with an attached motor. Both pump and motor below the water level at the bottom of the borehole	Mono Pump	A rotary pump mainly with discharge head, rising main and the pump element

System component described in Table 3-9 can be described in the form of chart as presented in Figure 3.4 below.

**Figure 3-4: Components of Solar Energy System**

**3.4.1.3 Operation and Maintenance Procedures of Solar Energy System****a) Submersible pump**

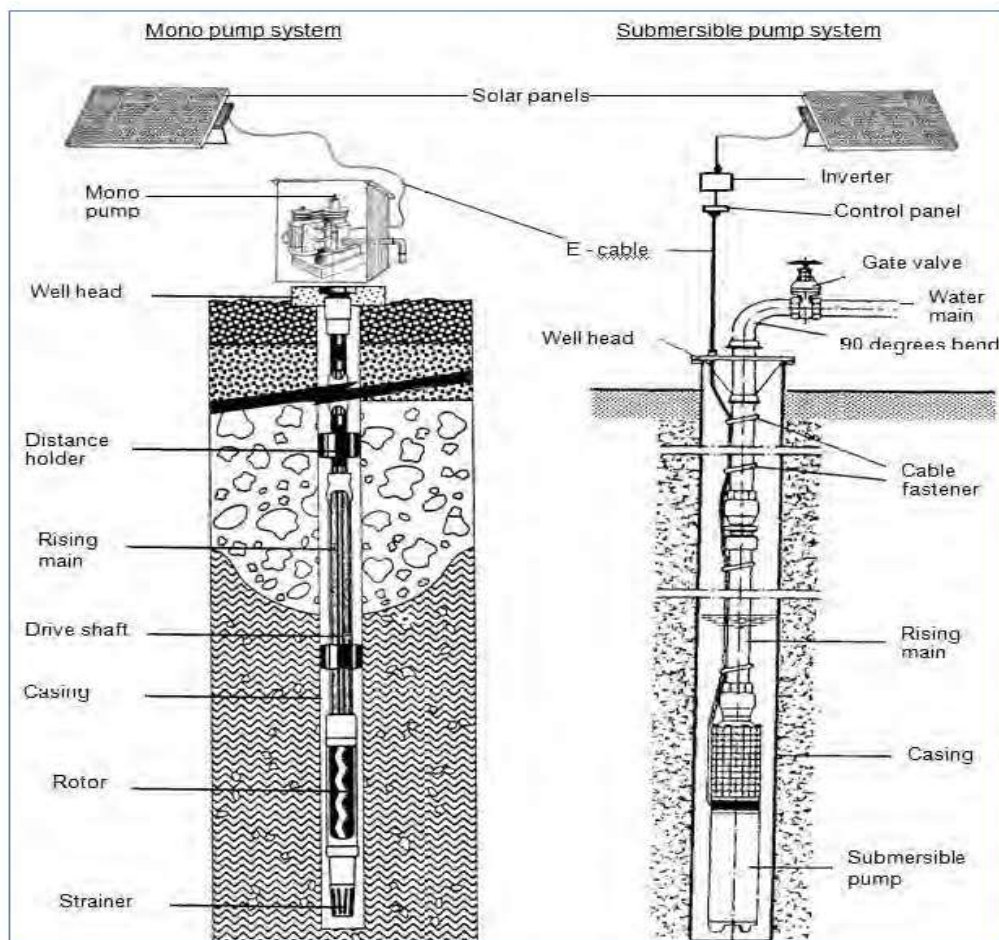
The submersible pump is manufactured to a very high specification and will operate on a daily basis without problem for at least 5 years, probably many more. The motor is contained within the pump and is cooled by the water passing over it. It has built in protection features, which together with the control panel ensure that it is protected from risk of overheating, drop in water level, or voltage irregularity.

**b) Control unit (s)**

Depending on the system in place there may be a simple on/off control unit or a more complicated looking control panel with digital display. In the event that there is a backup power source, there may be two switches or control units. These are to protect the pump, should not be tampered with in any way and should only be installed and maintained by a qualified electrician. The most common reason for solar pumps getting damaged is because an unqualified person tried to fix it. Incorrect wiring can bypass the inbuilt protection features of the system and cause brand new equipment to be permanently and irreparably damaged.

Maintenance tasks include dusting control panel on a weekly basis.

**Figure 3-5: Solar Energy System with the Groundwater**



### **c) Solar panels (photovoltaic modules)**

These have no moving parts and there is very little that technically can go wrong with them. Consequently many of them have a 20 year manufacturer's guarantee. The main risk to the panels is from theft, vandalism or children throwing stones which cause damage. Theft in particular is a major problem in most areas, so WUAs need to ensure thorough security measures are in place to minimize these threat and panels are well secured.

Maintenance tasks include:

- Clean solar panels weekly if they are covered with dust (in very dusty areas clean twice a week using a wet cloth)
- Protect the fragile solar panels (panels and solar pump within a fenced enclosure of 40 m radius for protection and therefore the fence requires to be kept in good condition and the gate should be safely secured).
- When carrying out any servicing of this equipment ensure the right qualified personnel do the work.

### **d) Motors**

Some DC motors need replacement brushes; this is usually a simple operation (far simpler than, e.g. servicing a small engine powered pump).

Brushes will probably need to be replaced after two years of operation.

### **e) Inverter (AC) automatic/Regulator (DC)**

- Install away from sunshine, it is usually affected by heat more than 20 – 25°C. If the temperature rises more than this, the system switches off and vice versa. This switching on and off is not good.
- Should be kept away from water.
- It is an enclosed system and should not be tampered with.

### **f) Wires**

- should be placed in conduits and buried underground and in case of replacement use the right wires (ultra-violet rays resistant)

### **g) Pulleys and Belts**

- Check tension and replace damaged or worn out ones.

### **h) Exposed terminals (on panels or inverter)**

- Should be checked regularly for corrosion or damage.

#### **3.4.1.4 Non-Routine Maintenance / Troubleshooting**

Table 3-10 below is described the troubleshooting for solar energy system.

**Table 3-10: Troubleshooting for Solar Energy System**

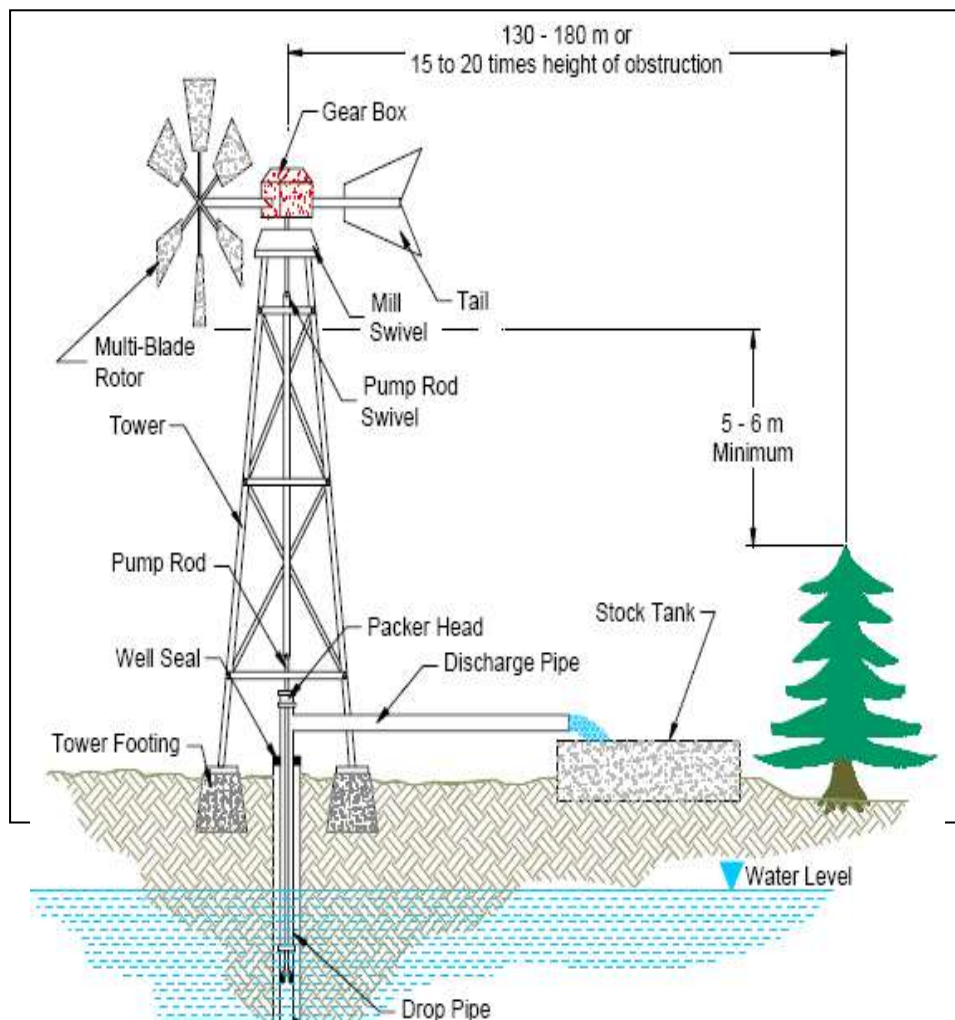
No.	Problem	Causes	Solution
1	Low or no power/ slow motor (less water pumped)	Poor electrical connection due to dirt; wet or corroded terminals; insufficient sun	Clean, dry or replace the terminals
		Dusty Solar Panel	Wipe out dust
2	System switching ON and OFF	Inventor/ regulator poorly installed	Install away from sunshine/water
3	Motor Stops	Worn out brushes	Replace brushes
4	Water leaking from discharge head (mono pump)	Leaking pump gland seal	Tighten pump gland nuts slightly (do not over tighten)

### 3.4.2 Wind powered Pumping System

#### 3.4.2.1 General

The wind technologies consist of either a conventional mechanical wind pumping systems using a small wind turbine installed directly over the well and powering a positive displacement pump, or wind- electric pumping options using a wind turbine to generate AC power to run a submersible centrifugal pump.

Wind pumping systems are generally a viable option in areas with average wind speeds above 3 to 4m/s, with mechanical systems preferred at lower wind speeds.

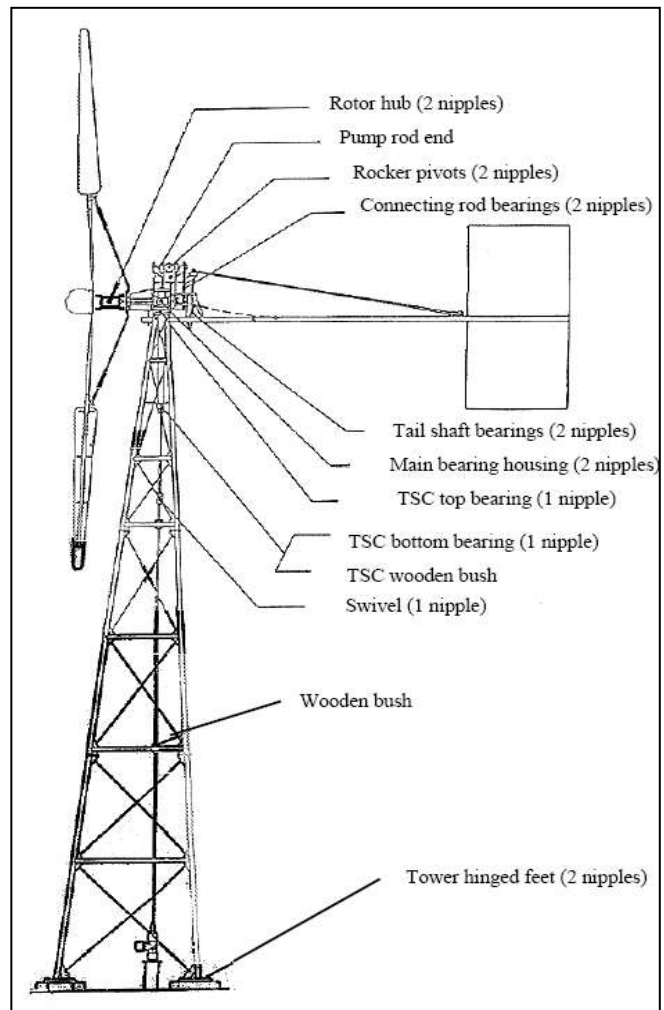
**Figure 3-6: Typical Wind Energy System**

Windmills can provide the energy to move a pump. The most common models have a rotor fixed to a horizontal axis that is mounted on a steel tower. The tower of the windmill is usually 9–15 m high. Wind drives the rotor and this movement is transmitted to drive a pump (usually a piston type), either directly or via a gear box. A vane keeps the rotor facing the wind during normal wind speeds, but there is also a mechanism to position the rotor parallel to the wind to avoid damage to it from excessive wind speeds. Some windmills are fixed facing the wind, others are manually oriented, and some have a braking system.

### 3.4.2.2 Identification of Components

The main components of the wind pump are:

- Rotor
- Tower
- Transmission assembly
- Pump rods
- Riser and stuffing box
- Outlet
- Base plate
- Borehole casing



**Figure 3-7: Locations of windmill lubrication**

### 3.4.2.3 Operation and Maintenance of Windmill

Operation is often automatic. Some windmills require manual release of the furling mechanism after excessive wind. When no pumping is needed, the windmill may be temporarily furled out of the wind by hand. Windmill and pump should be checked regularly and any abnormality corrected.

Every month, the windmill and pump must be checked visually. The bolts on the pumping rods tend to come loose, and loose nuts and bolts should be tightened and moving parts greased, as necessary. Paintwork should be maintained annually, and the lubrication oil changed in the gear box (if one is used). Poor maintenance will lead to the bearings wearing out rapidly and the wind will then damage the rotor and other pump parts. Maintenance for a windmill-driven piston pump is comparable to that for a heavily-used handpump.

The following activities carried out as a routine maintenance of wind pump:

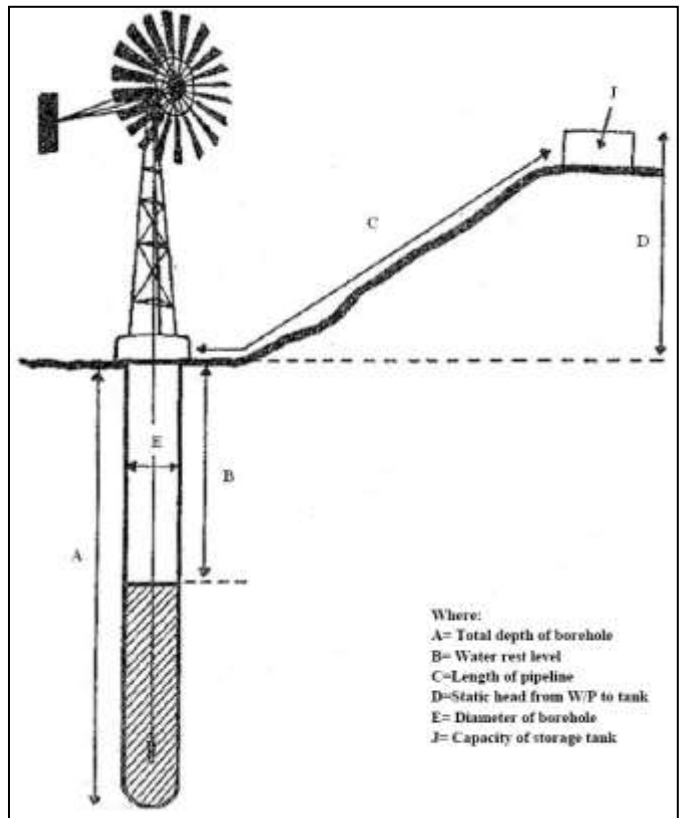
- Patrol perimeter fence and repair,
- Check tower frame for damage, loose bolts, or weakness,

- Check condition of pumping rods and securing bolts,
- Grease all grease nipples,
- Check rotor blades are not bent or damaged,
- Measure volume of water delivered by each stroke to check, condition of pump washers
- Replace pump washers,
- Check pipe line from wind pump to tank,
- Test all valves,
- Repaint tower,
- Take water sample for analysis.

### 1. How to tie and secure the rotor

How to Furl and Secure the Wind Pump Rotor:

- a) Choose an undamaged piece of rope at least 2 cm thick, and long enough to pass a double strand round both anchor points on the rotor
- b) Secure the middle of the piece of rope securely underneath one of the tower cross beams just opposite the rotor ring
- c) Take one end and loop it round where the blade spar crosses the rotor ring, and choose one where the blade is together with a rotor support spar. This will reduce the chance of damage to the rotor or blade spar if the wind changes direction very strongly during maintenance.
- d) Having secured the rotor in this one place, get the assistant to turn the rotor until the rope is tight, and then take the other end of the rope and lash it in the opposite direction to another blade and support bar.
- e) Make sure the knots are tight
- f) Never leave the wind pump tied up after leaving. A strong wind could result in the rotor being bent.
- g) Never try to furl the wind pump while up the tower; this can be dangerous
- h) Never leave the rope hanging from the furling chain, after the
- i) maintenance has been carried out, as it could get entangled,
- j) damaging the rotor, or enable unauthorized people to tamper with the machine
- k) Make sure at least two people (the operator and assistant) can demonstrate how to do this satisfactorily



### 2. Greasing

This is the main routine maintenance activity that should be carried out on wind pumps. Greasing prevents wear on the moving parts and helps to ensure that the wind pump runs

for a long time without requiring major repairs. See Figure 3.6 above for the locations of lubrication.

- a) Greasing must be done using a GREASE GUN.
- b) Greasing should be done EVERY 6 MONTHS.
- c) Each greasing session will use approximately 1 x ½ kg tin of grease.
- d) Apply 2-3 strokes of the grease gun on each grease point.
- e) The points that should be greased are shown on Diagram shown in Figure 3.6; they are marked on the machine in “red”.
- f) Make sure at least two people (the operator and assistant) can locate the grease points and demonstrate how to do the greasing satisfactorily.

### **3. Safety Procedures**

Like many powerful mechanical devices, wind pumps can be dangerous, if they are not approached with the correct attitude and experience. Adherence to the following simple rules will help prevent accident.

#### **Box 15: Safety Procedures for Wind Pump**

1. Always work on the wind pump with at least two people, never work on a wind pump alone,
2. Keep your fingers well clear of any moving parts,
3. When climbing the wind pump keep your feet clear of the moving pump rods, and check you are not coming up directly under the rotor,
4. If possible do not stand or work underneath the wind pump, when someone is working on it, unless you are wearing a hard hat/helmet,
5. It is good practice to wear hard hat/helmet at all times, even if you are just climbing the wind pump to check its operation. It is quite easy to get distracted and this could result in the crank striking your head, as it rotates,
6. The towers have steps built into one of the tripod legs, please use them,
7. The tower is designed with sufficient clearance between it and the tower legs, to allow you a safe clearance, should the rotor change direction, while you are up on the wind pump,
8. Even if you are experienced with working up on the wind pump, it is also still a good idea to use a simple quick release harness, to attach yourself to the tower. This also allows you to use both hands when necessary,
9. Never allow children to play on or near the wind pump,
10. Experienced people actually sit on top of the transmission while checking or servicing it. No matter how experienced you get, never do this without securing the rotor first,
11. While servicing your machine it is easy to leave grease on the tower. Please make sure it is wiped off before you leave, as it could cause someone to slip.



### 3.4.2.4 Troubleshooting for Windmill

**Table 3-11: Troubleshooting for windmill**

No.	Problem	Causes	Solution
1	Wind pump does not self furl	Furling mechanism not working	Repair furling system
2	Windmill working but no water being raised	Borehole has run dry Pump washers leaking Leaky riser	Remove pump and Inspect/repair. Use dipper to check water level in borehole

## 3.5 Safety Practice

### 3.5.1 General

Personnel engaged in operation and maintenance work of water supply system are confronted with the usual work hazards of physical injury. These hazards can be eliminated or reduced by the use of appropriate safety equipment and tools. Also by giving training and orientation to maintenance crew is one way of minimizing the danger.

#### **Safety Rules: General**

1. Keep fire extinguisher or bucket of sand close at hand to deal with fires,
2. No smoking in pump house or fuel store,
3. Wear protective clothing that fit well. No loose clothes that can get caught in the moving parts of the engine,
4. Never put cleaning rags or other loose items in your pockets when you are in the pump house. It can get caught in the moving parts,
5. Wear good protective shoes.
6. Keep the floor of pump house and store clean and dry, so that you will not slip

### 3.5.2 Safety Measures

#### **1. General Practices**

All personnel engaged in the operation and maintenance of water supply system will become familiar with safety instructions. Personnel should not be assigned to work without adequate instruction in the appropriate safety procedures.

#### **2. Personnel Protection**

*Face and Eye Protection:* Suitable spectacle or goggles should be worn during any operation in which fragments of work material are liable to strike the operator's eyes.



*Hand Protection:* Friction, minor scratches, rough, sharp and hot materials are the everyday work hazards against which require gloves to be worn.

*Safety Belts:* Safety belts should be worn when working on scaffolds or at dangerous height.

### **3. Proper Use of Tools**

A high percentage of accidents in operating and maintenance water supply system is caused by improper use of tools. This source of injury can be reduced by observing the following precautions:

- Always select the appropriate tool for the job;
- Check tools at frequent intervals, and repair or replace them if defective;
- Do not use tools on moving machinery; stop the machine before making adjustments;
- Maintain steady footing to avoid slipping, stumbling, or falling;
- Protect hands with gloves when working in confined places. Do not wear rings;
- In carrying sharp or pointed tools, be sure they are covered or pointed away from the body in case of a fall;
- Wear eye protection when using impact tools on hard, brittle material;
- After using tools, clean them and place them in their proper place where they will not be damaged or create a work hazard;
- Learn and apply proper methods of handling and using tools;
- Where fire or explosion hazards exist, tools made of non sparking material will be used.

### **4. Pumping Station Maintenance**

*House Keeping:* Housekeeping standards at working place should be consistent with good safety practice.

This involves a compliance with the following:

- Floors, windows, walls and equipment should be kept clean;
- Tools should be properly stored when not in use;
- Minor repairs of structures and appurtenances (belonging, accessory) should be made as soon as the need for such repair is known.

### **5. Safety Instructions**

All personnel should be kept aware of the need for safety practice by reminding them of specific safety instructions. Such instructions, posted by the installations engineer or other authority, will include information on how to contact the nearest medical officer and other emergency activities; procedures for the latest approved methods of first-aid instructions for the common types of physical injury. Posted first-aid instructions will be backed up by periodic first-aid courses for appropriate personnel, including demonstrations and drills.

## **6. Electrical Hazards**

Danger is always present where pumps, motors and generators is operating and where high voltages are used. Constant attention and alertness is the best way to avoid injury.

**Oiling:** Take the following precautions in oiling equipment:

- Stop machinery before oiling cleaning or adjusting it;
- Lock the control board so that no one can start a machine being worked on;
- Before starting, be certain that personnel are clear of danger and that working parts are free to move without damage;
- Apply enough oil or grease to give good lubrication without overflows and wipe up immediately all spilled oil or grease

## **7. Repairs**

- Lock the control board where there is a switch before beginning work so that the equipment cannot be started by another person.
- Place substantial blocking under any equipment suspended or supported by jacks or a chain hoist before commencing work;
- Assure proper ventilation in the work area;
- Keep a suitable fire extinguisher neat at hand and ready for use;
- Do not consider a job completed until after it has been checked to make sure that lock washers, cotter pins and safety devices are in place.

## **8. Control Boards**

The following requirements will be met in guarding against physical injury and fire hazards in control board installations:

- Provide adequate illumination;
- Place insulating mats on the floor of control board;
- Open control boards will be made accessible only to qualified personnel and be properly guarded or screened;
- Ground all electrical equipment, including control board frames.

## **9. Diesel Engines**

Follow the manufacturer's instruction manuals for operating and servicing an engine.

Before starting an engine:-

- Make sure that all moving and rotating parts are in place;

- Remove all tools and meters that are near the engine;
- Make sure that floor in vicinity of engine is clean and in orderly condition, as well as free of all spillage of oil, grease, fuel and water;
- Check to see that all personnel are clear of danger.

#### **Repair:**

- Never wear gloves, jewellery, neckties, long sleeves or loose or torn clothing near engine with moving parts;
- Keep hair clear of moving parts, wear a cap;
- Keep shoes in good condition, avoid rubber heels; use a non slip material;
- Do not oil, adjust, or repair an engine while it is running or its exhaust manifold is hot;
- Do not smoke while working on an engine;
- Keep the floor around engines clean, dry and free of slippery materials and spillage immediately;
- Upon completion of repairs, give the area a check to insure that all tools, portable lamps, ropes and other objects have been removed and that the cleanup has been thorough.

#### **General Apparatus Precautions:**

- Weak, damaged, or imperfect apparatus will never be used. As soon as the equipment is known to be defective, remove it from service and either repair or dispose of it.

### **10. Fire Protection**

A neat well-ordered workshop reflects good safety policy. All unnecessary materials and other wreckage or scattered fragments should be disposed of promptly. Keep suitable safety containers available for discarded, soiled wiping clothes.

- Locate fire extinguishers in hallways of work rooms. Use lights, signs, and arrows to indicate the location of extinguishers;
- Inspect and recharge extinguishers in accordance with instructions;
- Post telephone numbers of the fire department for quick emergency reference;
- Provide several means of exit so that personnel will not be trapped in case of fire.

### **11. First Aid**

- All personnel should be given first-aid instruction in order to minimize the ultimate effects of injuries which occur in the course of work;

Each facility of the installation water supply system shall be provided with a complete first-aid kit when approved by competent medical authority.

## 3.6 Troubleshooting

Trouble shooting is a systematic way of tracing and correcting faults in machinery or equipment. The successful trouble shooter must have these abilities:

- Be able to recognize symptoms of trouble when he sees, hears, smells, or feels them or when the log readings differ marked from normal.
- Be able to determine quickly what adjustments or repairs are added.
- Be able to follow a systematic and logical method of inspection in order to locate the cause of trouble quickly.

Successful trouble shooting can be accomplished in a minimum of time if a trouble shooter:

- Recognize the apparent operational trouble.
- Diagnose the trouble from the wiring diagram and trouble shooting.
- Verify the diagnosed trouble by checking with appropriate test instruments.

When trouble shooting:

- Check the easiest problem first
- Use the trouble shooting guide to locate the problem.
- Know the trouble first before disassembly the component.
- Determine what caused it.
- See if a problem in one component has affected another component.
- Work safely.

The following charts (checklist) takes in most common symptoms, itemizes possible causes and suggests response. Because of the wide variation types, sizes, designs, and materials of construction, the charts are restricted to those types of most commonly encountered. The manufacturer's instruction books must be carefully studied before any attempt is made to maintain particular equipment.

This section of the manual presents trouble-shooting charts for pumps, motors and diesel engines commonly used in water supply schemes. The charts are prepared separately in order to enable water supply technicians, mechanics and operators to have a quick reference when they encounter mechanical or electrical problems. The charts are compiled from equipment manufacturer's manuals, and consist of trouble shooting charts for the following facilities:

- Centrifugal Pumps
- Electrical Submersible Pumps
- Electrical Motors
- Diesel Engines / AC Generators.

### 3.6.1 Troubleshooting for Delivery Pipes, Header and NRV

Table 3-12 presents the troubleshooting faults, causes and remedies to be taken for delivery pipes, header and non-return valve.

**Table 3-12: Troubleshooting for delivery pipes, header and NRV**

Fault	Cause	Remedies
Undue thrust on pump foundation and bend in delivery pipe causing shearing or uprooting of foundation bolts of pumps and thrust on common header	Dismantling joint is not properly designed, to counter thrust at the elbow in the pump	Provide dismantling joint of proper design. The design should ensure that it has long tie-bolts connecting rigid flanges and thus taking up the pull caused by thrust at pump
Cracks in welded jointed of individual delivery and common header	The cracks are caused due to thrust at dead end of common header	Provide thrust blocks at dead (free) end of common header
Reflux valve (NRV) closes with slam and high noise in the event of shut-down or power failure or tripping	The reflux valve is not designed for non-slam in closure	<ul style="list-style-type: none"> <li>Replace with reflux valve designed for non-slam closure</li> <li>Taken up issue of old valve to valve manufacturer</li> </ul>

### 3.6.2 Centrifugal Pump Troubleshooting Charts

The following remarks under troubleshooting of the surface pumps are identified. The remark gives more attention on faults, causes and remedies for those troubles during the operation of the pumps.

**Table 3-13: Troubleshooting of Surface Pump**

Fault	Cause	Remedies
No water delivered	Lack of Prime	<ul style="list-style-type: none"> <li>Fill pump and suction pipe completely with water</li> </ul>
	Speed too low	<ul style="list-style-type: none"> <li>Check whether motor is directly across the line and receiving full voltage</li> <li>Frequency may be too low. May have open phase. Correct this (50 Hz)</li> </ul>
	Discharge head too high	<ul style="list-style-type: none"> <li>Check pipe friction losses Larger pipe may be needed. Are valves wide open?</li> </ul>
	Impeller plugged	<ul style="list-style-type: none"> <li>Remove top of pump and clean impeller</li> </ul>
	Suction lift too	<ul style="list-style-type: none"> <li>Check suction pipe for friction losses. If static lift is too high, water to be pumped must be raised or pump lowered</li> </ul>
	Wrong rotation	<ul style="list-style-type: none"> <li>Compare turning of motor with directional arrow on pump</li> </ul>
	No water or too low water level in bore hole	<ul style="list-style-type: none"> <li>Increase the installation depth of the pump, throttle the pump or replace it by a smaller model to obtain a smaller capacity</li> </ul>
	Closed sluice valve	<ul style="list-style-type: none"> <li>Adjust the sluice valve</li> </ul>

Fault	Cause	Remedies
	The check valve has blocked in the closed position	<ul style="list-style-type: none"> <li>Disconnect the pump from the pipe and check Send the pump to an authorized after sales service center if necessary</li> </ul>
	Air leaks in suction	<ul style="list-style-type: none"> <li>Test for leaks with flame or match (water pumps only)</li> </ul>
	Line or strainer blocked	<ul style="list-style-type: none"> <li>Clean strainer, Remove obstructions</li> </ul>
The electric pump fails to start	The selector switch is set to OFF position	Turn to the ON position
	The motor is not powered	<ul style="list-style-type: none"> <li>Check whether the fuses have burned out or</li> <li>whether the circuit protecting relay has activated</li> <li>check whether the equipment is receiving power</li> </ul>
	The automatic monitoring devices (level gauge, etc) are not enabling the equipment	Wait until the correct operative conditions have been restored or check the efficiency of the monitoring devices
	The motor starter overload tripped out	Reset the motor starter overload, if it trips out again check the voltage again
	The motor starter or contactor is defective	Replace
	The control circuit has been interrupted or is defective	Check electric installation
	Dry running protection has cut off the electricity supply due to low water level	Check the water level, if it is okay, check the water level electrode
	The pump drop cable is defective	Repair or replace the pump cable
The fuses burnout	Fuse of inadequate size	Replace with fuses suited to the power draw of the motor
	Insufficient electrical insulation	check the insulation resistance, repair or replace
	Damaged power supply cable or connection	Replace the cable if necessary, or remake the connection
The overload relay activates after a few seconds service	Full voltage is not reaching all the motor phases	<ul style="list-style-type: none"> <li>Check the condition of the electrical equipment</li> <li>Check the terminal strip is well tightened</li> <li>Check the power supply voltage</li> </ul>
	The power draw unbalance between the phases	<ul style="list-style-type: none"> <li>Check the unbalance according to instruction manual</li> <li>send the motor to an authorized after sales service center</li> </ul>

Fault	Cause	Remedies
	Abnormal power draw	▪ Check that the star or delta connections are correct. If it is excessive reduce it by means of the sluice valve on the delivery pipe
	Wrong relay setting	▪ check that the setting amperage is correct
	The rotor is jammed	Disconnect the power supply and attempt to release the rotor by hand ▪ send the unit to an authorized after sales service center if necessary
	The power supply voltage fails to correspond to that of the motor	check the power supply or replace the motor
	Pump back pressure is lower than specified in purchase order	Adjust to the duty point
	Motor is running on two phases only	Replace the defective fuse Check the electric connection
	Transport lock has not been removed from the shaft groove	Remove
The overload relay activates after a few Minutes service	Wrong relay setting	▪ check that the setting amperage is correct
	Main voltage too low	▪ Check for losses on the power main. ▪ Contact the electricity board
	Power draw unbalance between the phases	▪ Check the unbalance according to instruction manual ▪ if necessary overhaul the electric motor
	Abnormal power draw	▪ Check that the star or delta connections are correct. If it is excessive reduce it by means of the sluice valve on the delivery pipe
	The electric pump fails to turn freely since parts of it are rubbing	Send the unit to an authorized service center
	The motor turns in the wrong direction	Invert two of the three phases
	The electric pump fails to turn freely owing to a high concentration of sand	Reduce the flow rate by means of sluice valve
	The group has sanded up	Clear the well or the unit
	Electric panel temperature high	Check that the relay has been sent to the compensated ambient temperature Protect the electric control panel from the sun and heat

Fault	Cause	Remedies
The electric pump delivers at decidedly poor flow rate (refer with reduced capacity below)	Air intake from suction mouth	Increase the suction mouth head
	The motor turns in the wrong direction	Inverse two of the three phases
	The check valve is blocked in a particularly closed position	Disconnect the pump from the pipe and check
	Worn electric pump	Replace worn components by new ones Send the pump to an authorized after sales service center
	Partially closed sluice valve	Open the sluice valve
	Pump operating in cavitations condition	Compare the suction pressure with NPSH values in the specific technical documentation
	Suction head is too high/ NPSH available (positive suction head) is too low	Check/alter liquid level <ul style="list-style-type: none"> <li>▪ fully open the shut off valve in the suction line</li> <li>▪ change suction line, if the friction losses in the</li> <li>▪ suction line are too high</li> <li>▪ check any strainers installed/suction opening</li> </ul>
The electric pump is too noisy and vibrates	Plant installed incorrectly	Increase the suction mouth head
	Water containing a high amount of gas	Increase the suction mouth head
	Worn shaft and the guide bearing	Send the pump to an authorized after sales service center
	Pump imperfectly fixed to its base	Check according to the specification
	Worn shaft support	Send the unit to an authorized after sales service center
	Pump operating in cavitations condition	Compare the suction pressure with the NPSH values in the specific technical documentation
	Excessive stress transmitted from the pipes to the pump casing	Connect the pump to the pipes by means of compensating couplings
	Pump is wrapped	Check pipe line connections and secure fixing of pump, if required, reduce the distance between the pipe clamps. <ul style="list-style-type: none"> <li>▪ fix the pipe line using anti-vibration material</li> </ul>
	Rotor is out of balance	<ul style="list-style-type: none"> <li>▪ Clean the impeller</li> <li>▪ rebalance the impeller</li> </ul>



Fault	Cause	Remedies
The pump runs at a reduced capacity	The suction head is larger than anticipated	Throttle the pump or replace it by a smaller model to obtain a smaller capacity
	The valves in the discharge pipe are partly closed or blocked	Check and clean or replace the valve
	The discharge pipe is partly choked by impurities	Clean or replace the discharge pipe
	The non return valve is partly blocked	Pull out the pump and check or replace it
	The pump and the suction/delivery pipe are choked by impurities	Check and clean or replace the pump
	The pump is defective	Repair/Replace the pump
	Leakage in pipe work	Check and repair the pipe work
	The delivery pipe is defective	Replace
Frequent start and stop	The differential of the pressure switch between the start and the stop pressures is too small	Increase the differential. However the stop pressure must not exceed the operating pressure of the pressure tank, and the start pressure should be high enough to ensure sufficient water supply
	The water level electrode or level switches in the reservoirs have not been installed correctly	Adjust the intervals of electrodes/level switch to ensure suitable time between the cuttings –in and cutting-out of the pump. See installation and operating instructions for the automatic devices used. If the intervals between stop/start cannot be changed via the automatics, the pump capacity may be reduced by throttling the discharge valve
	The non return valve is leaking or stack half open	Pull out the pump and clean/replace the non return valve
	The volume of air in the pressure/diaphragm tank is too small	Adjust the volume of air in the pressure/diaphragm tank in accordance with its installation and operating instructions
	The pressure/diaphragm tank is too small	Increase the capacity of pressure/diaphragm tank by replacing or supplementing with another tank
	The diaphragm of the diaphragm tank is defective	Check the diaphragm tank
Excessive leakage at the shaft seal	Defective gasket	Fit new gasket between volute casing and discharge cover

Fault	Cause	Remedies
Excessive bearing temperature	Pump is warped	Check pipe line connection and secure fixing of pump; if required, reduce the distance between the pipe clamps. Fix the pipe lines using anti-vibration material
	Increase axial trust	Clean balancing holes in the impeller Fit new wear rings
	Insufficient or excessive quantity of lube or unsuitable lube	Top up, reduce or change lubricant
Motor protection switch trips the pump	Pump back pressure is lower than in the purchase order	Adjust to duty point
	Incorrect setting of motor protection switch	Check setting Fit new motor protection switch
	Transport lock has not been removed from the groove	Remove

### 3.6.3 Electrical Submersible Pumps Troubleshooting Charts

Table 3.14 shows the faults, causes and the corresponding remedies for submersible pumps.

**Table 3-14: Troubleshooting chart for submersible pumps**

Fault	Cause	Remedies
<b>The electric pump fails to start</b>	The selector switch is set to OFF position	Turn to the ON position
	The motor is not powered	<ul style="list-style-type: none"> <li>Check whether the fuses have burned out or</li> <li>whether the circuit protecting relay has activated</li> <li>check whether the equipment is receiving power</li> </ul>
	The automatic monitoring devices (level gauge, etc) are not enabling the equipment	Wait until the correct operative conditions have been restored or check the efficiency of the monitoring devices
	The motor starter overload tripped out	Reset the motor starter overload, if it trips out again check the voltage again
	The motor starter or contactor is defective	Replace

Fault	Cause	Remedies
	The control circuit has been interrupted or is defective	Check electric installation
	Dry running protection has cut off the electricity supply due to low water level	Check the water level, if it is okay, check the water level electrode
	The pump drop cable is defective	Repair or replace the pump cable
<b>The fuses burnout on start up</b>	Fuse of inadequate size	Replace with fuses suited to the power draw of the motor
	Insufficient electrical insulation	check the insulation resistance, repair or replace
	Damaged power supply cable or connection	Replace the cable if necessary, or remake the connection
<b>The overload relay activates after a few seconds service</b>	Full voltage is not reaching all the motor phases	<ul style="list-style-type: none"> <li>Check the condition of the electrical equipment</li> <li>Check the terminal strip is well tightened</li> <li>check the power supply voltage</li> </ul>
	Power draw unbalance between the phases	<ul style="list-style-type: none"> <li>Check the unbalance according to instruction manual</li> <li>send the motor to an authorized after sales service center</li> </ul>
	Abnormal power draw	<ul style="list-style-type: none"> <li>check that the star or delta connections are correct</li> </ul>
	Wrong relay setting	<ul style="list-style-type: none"> <li>check that the setting amperage is correct</li> </ul>
	The rotor jammed	Send the unit to an authorized service center
	The power supply voltage fails to correspond to that of the motor	Change the motor or change the power supply
<b>The overload relay activates after a few minutes service</b>	Wrong relay setting	<ul style="list-style-type: none"> <li>check that the setting amperage is correct</li> </ul>
	Main voltage too low	Contact the electricity board

Fault	Cause	Remedies
	Power draw unbalance between the phases	Check the unbalance according to instruction manual <ul style="list-style-type: none"> <li>▪ send the motor to an authorized after sales service center</li> </ul>
	The electric pump fails to turn freely since parts of it are rubbing	Send the unit to an authorized service center
	The electric pump fails to turn freely owing to a high concentration of sand	Reduce the flow rate by means of sluice valve
	The group has sanded up	Clear the well or the unit
	Electric panel temperature high	Check that the relay has been sent to the compensated ambient temperature Protect the electric control panel from the sun and Heat
<b>The electric pump at delivers decidedly poor flow rate</b>	Air intake from suction mouth or pump operating in cavitation conditions	Increase the suction mouth head
	The motor turns in the wrong direction	Inverse two of the three phases
	The check valve is blocked in a particularly closed position	<ul style="list-style-type: none"> <li>▪ Disconnect the pump from the pipe and check</li> <li>▪ Send the pump to an authorized after sales service center if necessary</li> </ul>
	Worn electric pump	<ul style="list-style-type: none"> <li>▪ Send the pump to an authorized after sales service center</li> </ul>
<b>Although it operates the electric pump delivers absolutely no water</b>	Pump un primed owing to insufficient head	Increase the suction mouth head
	The check valve has blocked in the closed position	<ul style="list-style-type: none"> <li>▪ Disconnect the pump from the pipe and check</li> <li>▪ Send the pump to an authorized after sales service center if necessary</li> </ul>
	Closed sluice valve	Adjust the sluice valve
	Excessively worn electric pump	Send the pump to an authorized after sales service center
	No water or too low water level in bore hole	Increase the installation depth of the pump, throttle the pump or replace it by a smaller model to obtain a smaller capacity
	Pumping system total head is higher than pump head capacity	Select and change the pump set suitable for the system head

Fault	Cause	Remedies
<b>The electric pump is too noisy and vibrates</b>	Plant installed incorrectly	Increase the suction mouth head
	Water containing a high amount of gas	Increase the suction mouth head
	Worn shaft and the guide bearing	Send the pump to an authorized after sales service center
<b>The pump runs at a reduced capacity</b>	The drawdown is larger than anticipated	Increase the installation depth of the pump, throttle the pump or replace it by a smaller model to obtain a smaller capacity
	The valves in the discharge pipe are partly closed or blocked	Check and clean or replace the valve
	The discharge pipe is partly choked by impurities	Clean or replace the discharge pipe
	The non return valve is partly blocked	Pull out the pump and check or replace it
	The pump and the riser pipe are choked by impurities	Pull out the pump. Check and clean or replace the pump
	The pump is defective	Repair/Replace the pump
	Leakage in pipe work	Check and repair the pipe work
	The rising pipe is defective	Replace
<b>Frequent start and stop</b>	The differential of the pressure switch between the start and the stop pressures is too small	Increase the differential. However the stop pressure must not exceed the operating pressure of the pressure tank and the start pressure should be high enough to ensure sufficient water supply.
	The water level electrode or level switches in the reservoirs have not been installed correctly	Adjust the intervals of electrodes/level switch to ensure suitable time between the cutting –in and cutting-out of the pump. See installation and operating instructions for the automatic devices used. If the intervals between stop/start cannot be changed via the automatics, the pump capacity may be reduced by throttling the discharge valve
	The non return valve is leaking or stack half open	Pull out the pump and clean/replace the non return Valve

Fault	Cause	Remedies
	The volume of air in the pressure/diaphragm tank is too small	Adjust the volume of air in the pressure/diaphragm tank in accordance with its installation and operating instructions
	The pressure/diaphragm tank is too small	Increase the capacity of pressure/diaphragm tank by replacing or supplementing with another tank
	The diaphragm of the diaphragm tank is defective	Check the diaphragm tank

### 3.6.4 Electric Motors Troubleshooting Charts

**Table 3-15: Troubleshooting chart for Electric Motor**

Fault	Cause	Remedies
Motor fails to operate No voltage	Loose or broken wiring inside	Perform continuity test of Motor circuit
	Electric power switch not	Turn on the power switch
	Open field or armature winding	Repair open winding or replace motor
	Brushes worn out excessively	Replace brushes
	Brushes springs broken or too	Replace brush springs
	Brush sticking in brush holder	Replace or clean and adjust brushes
Motor fails to operate. Draws high current when switch is turned on	Short circuit in motor circuit	Locate the short circuit and make repair
	Short circuit inside the motor	Remove and repair the motor
	Open field winding in shunt	Remove and repair the motor
	Motor over loaded	Reduce the load or install motor capable of carrying greater load
	Mechanical stoppage (seized bearings or binding parts in mechanism)	Locate and repair defective part
	Motor driven parts need lubrication	Lubricate parts as necessary

Fault	Cause	Remedies
	Applied voltage low	Compare voltage supply with motor voltage as indicated on the nameplate
	defective wiring or poor connection	Perform voltage continuity test of motor wiring
	Short circuit in armature winding	Remove and repair motor
	Brushes sticky in holder or worn out, or brush springs weak	Lubricate parts as necessary part
Motor runs too fast	Excessive supply voltage	Check and adjust level of motor supply voltage
	Short circuit in field windings	Remove and repair the motor
Motor overheat	Bearings of motor drive	Remove and repair the motor
	Excessive applied voltage	Check voltage and adjust to the proper level
	Short circuit in the field windings	Remove and repair the motor
	Excessive brush arcing	Replace and adjust brushes
Motor Vibrating and noisy	Loose or broken motor mounting	Repair or replace motor mountings
	Worn bearings or shaft	Remove and overhaul the motor
	Driven mechanism damaged or broken	Replace brushes
	Brushes worn excessively	Replace brushes
	Brushes sticking holders	Replace or clean brushes
	Brushes incorrectly located	Position brushes properly
	Commutator dirty or excessively worn or pitted	Clean or repair motor as necessary
	Open circuit in one or more armature coils	Remove and repair the motor
	Internal connections Wrong	Check the internal connections against a circuit diagram and make corrections
	Two leads to a 3- phase motor reversed	Reverse connections of two incoming power heads

Fault	Cause	Remedies
Leakage of oil or grease on winding	Thrust bearing oil seal damaged	Clean the spilled oil on winding. Replace oil seal.
	Excessive oil, grease in bearing	Reduce quantity to correct extent. Grease should be filled up to maximum half space in bearing housing.

### 3.6.5 Diesel/Gasoline Engines Troubleshooting Charts

Table 3-16 shows the troubleshooting of the Diesel Generator Engines is identified action to be taken during the operation.

**Table 3-16: Troubleshooting chart for Diesel Generator Engine**

Fault	Cause	Remedies	
Engine fails or is difficult to start	Not declutched (where possible)	operation	disengage
	Below starting limit temperature		Glow the engine
	Engine shut off lever not in stop position (shut off magnet defective )		Adjust the lever
	Air cleaner clogged/ turbo charger defective	Combustion	Replace
	Worn cylinder liner and piston ring		Replace
	Battery defective or discharged	electrical	Recharge/replace
	Electric cable connections to starter electrical system loose or oxidized		Clean and tighten
	Starter defective or pinion does not engage		Repair or replace
	Incorrect valve clearance	engine	Adjust
	Leaking injection line		tighten/replace
	Flame glow system/ heating pipe defective		replace
	Injection valve defective		Repair/replace
	Air in fuel system		Bleed
	Fuel filter/fuel pre-cleaner clogged		clean/replace
	Incorrect SAE class or grade of engine lube oil		change



Fault	Cause	Remedies	
	Compression pressure too low		<ul style="list-style-type: none"> <li>▪ -Adjust valve clearance</li> <li>▪ Replace piston, piston ring, liner, head gasket, nozzle, air cleaner</li> <li>▪ tighten cylinder head torque or</li> <li>▪ engine overhaul *</li> </ul>
	No fuel in the tank or incorrect grade of fuel		Clean and fill the tank with recommended fuel
	Fuel pump delivery valve scoured		Repair/replace
	Injector loose on sit		tighten
Engine starts but runs unevenly/ stalls	Incorrect valve clearance	engine	Adjust
	Leaking injection line		Tighten/replace
	Flame glow system/heating pipe defective		Repair/replace
	Injection valve defective		Repair/replace
	Air in fuel system		Bleed
	Fuel filter/fuel pre-cleaner clogged		clean/replace
	Compression pressure too low		See above *
Engine overheats Temperature Monitor gives warning	Oil level too low	operation	Top up
	Oil level too high		Lower level
	Air cleaner clogged/turbo charger defective	combustion	Repair/Replace
	Air cleaner service switch/indicator defective		Repair/Replace
	Exhaust counter pressure too high		De-carbonize
	Charge-air line leaking, only with charged engines	Cooling system	Tighten/replace
	charge air cooler clogged		Clean/replace
	Oil cooler air and/or oil side clogged		Clean/replace
	Cooling fan, thermostat defective, v-belts ripped or loose		Repair/replace

Fault	Cause	Remedies	
	Cooling air temperature rise/heating short circuit Cooling air fins bent, cracked, dirt or missing		Repair/replace cooling system components Repair/replace
	Incorrect valve clearance	engine	Adjust
	Vent line clogged		clean
	Injection valve defective		Adjust/replace
	Oil filter defective		Replace
	Over load		Correct to the rated load
	Injection timing faulty		Adjust timing
Engine gives poor performance	Engine shut off lever not in stop position (shut off magnet defective)	operation	Adjust the lever
	Oil level too high		Lower level
	Air cleaner clogged/turbocharger defective	combustion	Replace
	Air cleaner service switch/indicator defective		Replace
	LDA defective (leak in connecting line) only with charged engines		Replace
	Exhaust counter pressure too high		De- carbonize
	Charge – air line leaking, only with charged engines		Repair/replace
	Charge air cooler clogged		Clean/replace
	Incorrect valve clearance	Engine	Adjust
	Leaking injection line		Tighten/replace
	Injection (pump/valve) defective		Repair/replace
	Air in fuel system		bleed
	Fuel filter/fuel pre-cleaner clogged		clean/replace
	Compression pressure too low		See above *
Engine not firing on all cylinders	Incorrect valve clearance	Engine	Adjust
	Leaking injection line		Tighten/replace
	Injection valve/nozzle defective		Repair/replace

Fault	Cause	Remedies	
	Air in fuel system		bleed
	Fuel filter/fuel pre-cleaner clogged		clean/replace
	Compression pressure too low		See above *
Engine has little or no oil pressure	Oil level too low	operation	Top up
	Excessive inclination of engine		adjust
	Oil cooler air and/or oil side clogged	Cooling system	Clean/replace
	Oil pressure switch/oil pressure gauge defective	electrical	Repair/replace
	Incorrect SAE class or grade of engine lube oil	engine	Change standard oil
Engine Oil consumption excessive	Oil level too high	operation	Lower level
	Excessive inclination of engine		adjust
	Engine predominantly operated at low load		Apply operating load
	Air cleaner clogged/turbocharger defective	combustion	Replace
	Oil filter defective	engine	Replace
	Incorrect SAE class or grade of engine lube oil		Change standard oil
Engine Smokes blue Engine Smokes-white	Oil level too high	operation	Lower level
	Excessive inclination of engine		adjust
	Engine predominantly operated at lower load		Apply operating load
	Air cleaner clogged/turbocharger defective	combustion	Replace
	Oil in combustion chamber	engine	Clean/flash
	Below starting limit temperature	operation	Glow engine
	Incorrect valve clearance	engine	Adjust
	Flame glow system/heating pipe defective		replace
	Injection valve/nozzle defective		Repair/replace

Fault	Cause	Remedies	
	Compression pressure too low		See above *
Engine smokes - black	Air cleaner clogged	combustion	replace
	Air cleaner service switch/indicator defective		replace
	Exhaust counter pressure too high		De- carbonize
	Charge-air line leaking, only with charged engines		Repair/replace
	Charge air cooler clogged	Cooling system engine	clean
	Incorrect valve clearance		Adjust
	Injection valve/nozzle defective		Repair/replace
	Compression pressure too low		See above *
	Overload		Apply rated load
	Inlet air temperature too high		Ventilate the room

### 3.6.6 AC Generator/Alternators Troubleshooting Charts

Table 3-17 shows the troubleshooting of the Diesel Generator Engines is identified action to be taken during the operation.

**Table 3-17: Troubleshooting chart for Alternator Generator Engine**

Fault	Cause	Remedies
The alternator does not excite	Insufficient residual voltage	Excite the rotor using the battery
	Connection break	Reset the connection
	Broken rotating diode bridge	replace
	Insufficient speed	Adjust speed regulator of the engine
	Windings failure	Check winding resistance and replace damaged parts
	Broken voltage regulator	replace
	The excitation circuit shorted or interrupted	Check continuity and repair
Low or no voltage	Low speed	Reset engine to normal speed

Fault	Cause	Remedies
	Winding failure	Check winding resistance and replace damaged parts
	Broken rotating diode bridge	Replace
	Broken voltage regulator	Replace
	Wrong voltage regulator setting	Adjust VG trimmer of voltage regulator
	Fuse blown	Replace
Correct no load voltage but too low with load	Low speed with load	Adjust the rotating speed of the engine
	Broken voltage regulator	Replace
	Defective rotor winding	Check winding resistance and replace damaged parts
	Load is too high	Reduce the load
	Wrong overload protection setting	Adjust OL trimmer of the voltage regulator
Correct no load voltage but too low with high load	Appliance with capacitors on the load	Reduce capacitive load
	Broken voltage regulator	Replace
	Wrong connection of phases	Reset the connection of phases
Unstable voltage	Rotating mass is too small	Increase the flywheel of the primary engine
	Uneven speed	Check and repair speed regulator of the engine
	Wrong stability of control setting	Adjust ST trimmer of voltage regulator
	Faulty regulator	Replace
Noisy functioning	Wrong coupling	Correct coupling
	Short circuit in a winding or on load	Check windings and the load
	Faulty bearing	Replace
Voltage too high	Potentiometer voltage unset	Rotate the potentiometer until the voltage reaches the rated value
	Faulty regulator	Replace AVR

Fault	Cause	Remedies
The alternator will not energize (no load voltage 20-30% of rated voltage)	Fuse blown	replace
	Connection's cut on the exciter stator	Check the continuity and repair
	Incorrect connections of exciter stator	Reverse the two wires from the exciter stator

### 3.6.7 Starter, Breakers and Control Circuit

Table 3-18 shows the troubleshooting for starter, breakers and control circuit.

**Table 3-18: Troubleshooting for Batteries**

Trouble	Causes	Remedies
Starter/breaker not switching on	<ul style="list-style-type: none"> <li>Non availability of power supply to the starter/breaker</li> <li>Over current relay operated</li> <li>Relay reset not operating</li> <li>Castle lock is not locked properly</li> </ul>	<ul style="list-style-type: none"> <li>Check the supply</li> <li>Reset the relay</li> <li>Clean and reset relay</li> <li>Remove lock and lock it properly</li> </ul>
Starter/breaker not holding on ON-Position	<ul style="list-style-type: none"> <li>Relay contacts are not contacting properly</li> <li>Latch or cam worn out</li> </ul>	<ul style="list-style-type: none"> <li>Check and clean the contacts</li> <li>Readjust latch and cam.</li> </ul>
Starter/breaker tripping within short duration due to operation of over current relay	<ul style="list-style-type: none"> <li>Over current relay setting incorrect</li> <li>Moderate short circuit on outgoing side.</li> <li>No or less oil in dashpot</li> <li>Dashpot oil not of proper grade</li> <li>Sustained overload</li> <li>Loose connection</li> </ul>	<ul style="list-style-type: none"> <li>Check and reset to 140-150% of normal load current.</li> <li>Check and remove cause for short circuit.</li> <li>Fill oil up to level mark.</li> <li>Check and use oil of correct grade</li> <li>Check over current setting.</li> <li>Check for short circuit or earth fault</li> <li>Examine cause of overload and rectify</li> <li>Clean and tighten.</li> </ul>
Starter/breaker not tripping after over current or short circuit fault occurs	<ul style="list-style-type: none"> <li>Lack of lubrication to mechanism</li> <li>Mechanism out of adjustment</li> <li>Failure of latching device</li> <li>Mechanical binding</li> <li>Relay previously damaged by short circuit</li> <li>Heater assembled incorrectly</li> </ul>	<ul style="list-style-type: none"> <li>Lubricate hinge pins and mechanisms</li> <li>Adjust all mechanical devices i.e., toggle stops, buffers, springs as per manufacturer's instructions</li> <li>Examine surface, clean and adjust latch. If worn or corroded, replace it</li> </ul>

Trouble	Causes	Remedies
	<ul style="list-style-type: none"> <li>▪ Relay not operating due to:               <ul style="list-style-type: none"> <li>○ Blown fuse</li> <li>○ Loose or broken wire</li> <li>○ Relay contacts damaged or dirty</li> <li>○ Damaged trip coil</li> <li>○ C.T. damaged</li> </ul> </li> </ul>	<ul style="list-style-type: none"> <li>▪ Replace over current relay (and heater, if provided)</li> <li>▪ Replace over current relay and heater</li> <li>▪ Review installation instructions and correctly install the heater assembly               <ul style="list-style-type: none"> <li>○ Replace fuse.</li> <li>○ Repair faulty wiring; ensure that all screws are tight.</li> <li>○ Replace damaged contacts.</li> <li>○ Replace coil</li> <li>○ Check and repair/replace.</li> </ul> </li> </ul>
Overheating	<ul style="list-style-type: none"> <li>▪ Poor condition of contacts</li> <li>▪ Contacts out of proper alignment</li> <li>▪ Contacts burnt or pitted</li> <li>▪ Loose power connection</li> <li>▪ Sustained over current or short circuit/earth fault</li> <li>▪ Poor ventilation at location of starter/breaker</li> </ul>	<ul style="list-style-type: none"> <li>▪ Clean and polish contacts.</li> <li>▪ Align the contacts</li> <li>▪ Clean the contacts with smooth polish paper or if badly burnt/pitted, replace contacts. (Contacts shall be cleaned with smooth polish paper to preserve faces. File should not be used)</li> <li>▪ Tighten the connection</li> <li>▪ Check cause and rectify</li> <li>▪ Improve ventilation</li> </ul>
Overheating of auto transformer unit	<ul style="list-style-type: none"> <li>▪ Winding design improper</li> <li>▪ Transformer oil condition poor</li> </ul>	<ul style="list-style-type: none"> <li>▪ Rewind</li> <li>▪ Replace transformer oil in auto-transformer unit</li> </ul>
Contacts chatter	<ul style="list-style-type: none"> <li>▪ Low voltage</li> <li>▪ Poor contact in control circuit</li> </ul>	<ul style="list-style-type: none"> <li>▪ Check voltage condition. Check momentary voltage dip during starting. Low voltage prevents magnet sealing.</li> <li>▪ Check coil voltage rating.</li> <li>▪ Check push button station, (stop button contacts), auxiliary switch contacts and overload relay contacts and test with test lamp</li> <li>▪ Check for loose connections in control circuits.</li> </ul>

Trouble	Causes	Remedies
	<ul style="list-style-type: none"> <li>Defective or incorrect coil</li> </ul>	<ul style="list-style-type: none"> <li>Replace coil. Rating should be compatible for system nominal voltage.</li> </ul>
Contacts welding	<ul style="list-style-type: none"> <li>Abnormal inrush of current</li> </ul>	<ul style="list-style-type: none"> <li>Check for grounds &amp; shorts in system as well as other components such as circuit breaker.</li> </ul>
	<ul style="list-style-type: none"> <li>Low voltage preventing magnet from sealing</li> </ul>	<ul style="list-style-type: none"> <li>Check and correct voltage</li> </ul>
	<ul style="list-style-type: none"> <li>Short circuit</li> </ul>	<ul style="list-style-type: none"> <li>Remove short circuit fault and ensure that fuse or circuit breaker rating is correct</li> </ul>
Short push button and/or over heating of contacts	<ul style="list-style-type: none"> <li>Filing or dressing</li> </ul>	<ul style="list-style-type: none"> <li>Do not file silver tips. Rough spots or discoloration will not harm tips or impair their efficiency</li> </ul>
	<ul style="list-style-type: none"> <li>Interrupting excessively high current</li> </ul>	<ul style="list-style-type: none"> <li>Check for short circuit, earth fault or excessive motor current</li> </ul>
	<ul style="list-style-type: none"> <li>Discolored contacts caused by insufficient contact pressure, loose connections etc.</li> </ul>	<ul style="list-style-type: none"> <li>Replace contact springs, check contact for deformation or damage. Clean and tighten connections</li> </ul>
	<ul style="list-style-type: none"> <li>Dirt or foreign matter on contact surface.</li> </ul>	<ul style="list-style-type: none"> <li>Clean with carbon tetrachloride</li> </ul>
	<ul style="list-style-type: none"> <li>Short circuit</li> </ul>	<ul style="list-style-type: none"> <li>Remove fault &amp; check fuse or breaker rating whether correct.</li> </ul>
Coil open circuit	<ul style="list-style-type: none"> <li>Mechanical damage</li> </ul>	<ul style="list-style-type: none"> <li>Examine and replace carefully. Do not handle coil by the leads</li> </ul>
	<ul style="list-style-type: none"> <li>Burnt out coil due to over voltage or defect</li> </ul>	<ul style="list-style-type: none"> <li>Replace coil.</li> </ul>
Magnets & other mechanical parts worn out/broken	<ul style="list-style-type: none"> <li>Too much cycling.</li> <li>Dust and dirt or mechanical abuse</li> </ul>	<ul style="list-style-type: none"> <li>Replace part and correct the cause of damage.</li> </ul>
Noisy magnet (humming)	<ul style="list-style-type: none"> <li>Defective coil</li> </ul>	<ul style="list-style-type: none"> <li>Replace coil</li> </ul>
	<ul style="list-style-type: none"> <li>Magnet faces not mating correctly</li> </ul>	<ul style="list-style-type: none"> <li>Replace magnet assembly. Hum may be reduced by removing magnet armature and rotating through 180°.</li> </ul>
	<ul style="list-style-type: none"> <li>Dirt oil or foreign matter on magnet faces</li> </ul>	<ul style="list-style-type: none"> <li>Clean magnet faces with carbon tetrachloride</li> </ul>
	<ul style="list-style-type: none"> <li>Low voltage</li> </ul>	<ul style="list-style-type: none"> <li>Check system voltage and voltage dips during starting</li> </ul>
Failure to pick-up and/or seal	<ul style="list-style-type: none"> <li>Low voltage</li> </ul>	<ul style="list-style-type: none"> <li>Check system voltage and voltage dips during starting</li> </ul>
	<ul style="list-style-type: none"> <li>Coil open or shorted.</li> </ul>	<ul style="list-style-type: none"> <li>Replace coil.</li> </ul>



Trouble	Causes	Remedies
	<ul style="list-style-type: none"> <li>Wrong coil</li> </ul>	<ul style="list-style-type: none"> <li>Check coil voltage rating which must include system nominal voltage and frequency</li> </ul>
	<ul style="list-style-type: none"> <li>Mechanical obstruction</li> </ul>	<ul style="list-style-type: none"> <li>With power off, check for free movement of contact and armature assembly. Remove foreign objects or replace contactor</li> </ul>
	<ul style="list-style-type: none"> <li>Poor contact in control circuit</li> </ul>	<ul style="list-style-type: none"> <li>Check and correct.</li> </ul>
Failure to drop out	<ul style="list-style-type: none"> <li>Gummy substances on pole faces or in mechanism</li> </ul>	<ul style="list-style-type: none"> <li>Clean with carbon tetrachloride</li> </ul>
	<ul style="list-style-type: none"> <li>Voltage not removed from control circuit</li> </ul>	<ul style="list-style-type: none"> <li>Check control circuit</li> </ul>
	<ul style="list-style-type: none"> <li>Worn or rusted parts causing binding e.g. coil guides, linkages</li> </ul>	<ul style="list-style-type: none"> <li>Replace contactor</li> </ul>
	<ul style="list-style-type: none"> <li>Residual magnetism due to lack of air gap in magnetic path</li> </ul>	<ul style="list-style-type: none"> <li>Replace contactor</li> </ul>
	<ul style="list-style-type: none"> <li>Improper mounting of starter</li> </ul>	<ul style="list-style-type: none"> <li>Review installation instructions and mount properly</li> </ul>
Failure to reset	<ul style="list-style-type: none"> <li>Broken mechanism worn parts, corrosion dirt etc.</li> </ul>	<ul style="list-style-type: none"> <li>Replace over-current relay and heater</li> </ul>
Open or welded control circuit contacts in over current relay	<ul style="list-style-type: none"> <li>Short circuit in control circuit with too large protecting fuses.</li> </ul>	<ul style="list-style-type: none"> <li>Rectify short circuit in general. Fuses over 10A rating should not be used.</li> </ul>
	<ul style="list-style-type: none"> <li>Misapplication, handling too heavy currents.</li> </ul>	<ul style="list-style-type: none"> <li>Check rating and rectify.</li> </ul>
Insufficient oil in breaker/ starter ( if oil cooled)	<ul style="list-style-type: none"> <li>Leakage of oil</li> </ul>	<ul style="list-style-type: none"> <li>Locate point of leakage and rectify</li> </ul>
Oil dirty	<ul style="list-style-type: none"> <li>Carbonization of moisture from atmosphere</li> </ul>	<ul style="list-style-type: none"> <li>Clean inside of tank and all internal parts. Fill fresh oil</li> </ul>
Moisture present in oil	<ul style="list-style-type: none"> <li>Carbonization of moisture from atmosphere</li> </ul>	<ul style="list-style-type: none"> <li>Clean inside of tank and all internal parts. Fill fresh oil.</li> </ul>

### 3.6.8 Batteries

Battery troubles revealed in service may be due to inadequate maintenance, incorrect operation and incorrect charging. Many battery troubles can be traced to charging source; undercharging or excessive overcharging eventually leads to battery trouble.

**Table 3-19: Troubleshooting for Batteries**

<b>Trouble</b>	<b>Causes</b>	<b>Remedies</b>
Readings of specific gravity and voltage very erratic even after equalizing charge for at least 48 hrs	Battery life is over	<ul style="list-style-type: none"> <li>☛ Check the following <ul style="list-style-type: none"> <li>▪ Age of battery.</li> <li>▪ Capacity</li> <li>▪ Appearance of plates.</li> <li>▪ Depth of sediments below plates</li> </ul> </li> </ul>
Several cells showing low charge voltage at the end of extended charge	Internal short circuit	Open cells and examine for damage or displaced separators, lead particles between plates or buckled plates
Battery overheats	Poor contacts or badly welded joints	Clean and tighten all bolted connections, reweld doubtful welded joints.
Battery damp and dirty, wood trays deteriorated or metal work corroded	Poor maintenance, over topping, or lid sealing compound cracked.	Keep battery dry and clean. Do not overtop when adding water. Clear away all traces of acid and old sealing compound from cell lids
Hydrometer test (at 80°F) show less than 1.200 specific gravity		Battery should be recharged. Give high rate discharge test for capacity. If cell test OK recharge and adjust gravity of all cells uniformly. Check operation and setting of voltage regulator, make a thorough check of the electrical system for short circuits, loose connections, corroded terminals etc.

### 3.6.9 Air Compressor

Table 3-20 shows troubleshooting for Air compressor of its fault, causes and remedies.

**Table 3-20: Troubleshooting for Air Compressor**

<b>Trouble</b>	<b>Causes</b>	<b>Remedies</b>
Compressor does not start	<ul style="list-style-type: none"> <li>▪ Dirty contacts</li> <li>▪ Loose electrical connections or faulty wiring</li> </ul>	<ul style="list-style-type: none"> <li>▪ Clean the contacts on all switches and controls.</li> <li>▪ Tighten connections. Check wiring and rewire if necessary</li> </ul>
Compressor noisy	<ul style="list-style-type: none"> <li>▪ Loose or misaligned coupling</li> <li>▪ Insufficient clearance between piston and valve plate</li> <li>▪ Motor or compressor bearing worn out</li> <li>▪ Loose or misaligned belts.</li> <li>▪ Loose foundation bolts or holds down bolts</li> <li>▪ Improper support or isolation of piping</li> </ul>	<ul style="list-style-type: none"> <li>▪ Check alignment &amp; tightness.</li> <li>▪ Replace worn parts.</li> <li>▪ Replace bearing.</li> <li>▪ Check alignment &amp; tension.</li> <li>▪ Belt slack should be at the top</li> <li>▪ Tighten bolts.</li> <li>▪ Provide sufficient right angle bends in piping to absorb vibration &amp; support firmly with suitable hangers</li> </ul>
Pipe rattle	<ul style="list-style-type: none"> <li>▪ Inadequately supported piping or loose pipe connections</li> <li>▪ No muffler in discharge line or muffler improperly located</li> </ul>	<ul style="list-style-type: none"> <li>▪ Support pipes or check pipe connections</li> <li>▪ Install or move muffler closer to compressor.</li> </ul>
Compressor will not load	<ul style="list-style-type: none"> <li>▪ Low oil pressure</li> <li>▪ Capacity control valve stuck open</li> <li>▪ Unloaded element stuck</li> </ul>	<ul style="list-style-type: none"> <li>▪ See item below</li> <li>▪ Repair or replace.</li> </ul>
Oil pressure lower than normal or no oil pressure	<ul style="list-style-type: none"> <li>▪ Low oil charge</li> <li>▪ Faulty oil gauge</li> <li>▪ Defective oil pressure regulator</li> <li>▪ Clogged oil suction strainer</li> <li>▪ Broken or worn oil pump.</li> <li>▪ Worn compressor bearings</li> </ul>	<ul style="list-style-type: none"> <li>▪ Add oil</li> <li>▪ Check and replace</li> <li>▪ Repair or replace.</li> <li>▪ Clean</li> <li>▪ Replace pump assembly.</li> <li>▪ Replace</li> </ul>

## Annexes

### Annex E: References

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## Annex F: Pump Operation record for electricity

[illegible]

## Annex G: Pump Operation record for generator

[illegible]

## Annex H: Generator Maintenance Record for Generator

[illegible]

**Annex I: Diesel Powered Generator: Engine Log**

Date	At Start		During Operations		At End			
	Fuel Added (Liters)	Start Time	Voltage (Volts)	Current (Amps)	Time	Total Time (Hrs)	Kw-hrs (meter reading)	



## Annex J: Engine Service Form

Engine Make: \_\_\_\_\_ Date of Service: \_\_\_\_\_ Hours at Current Service: \_\_\_\_\_

Model: \_\_\_\_\_ Name of Mechanic: \_\_\_\_\_ Hours at Next Service: \_\_\_\_\_

CATEGORY	ITEM	CHECKED (Tick if checked)	WORK DONE	COMMENTS
<b>LUBRICATION</b>	Engine Oil			
	Oil Filter			
	Greasing			
<b>FUEL SYSTEM</b>	Fuel Filter			
	Injector/Fuel Pump (leakages)			
	Tank (leakages)			
	Fuel Lines (cracks, leaks)			
<b>ENGINE</b>	Belts			
	Air Filter			
	Plugs/Injectors			
<b>ELECTRICALS</b>	Battery			

Comments: \_\_\_\_\_

\_\_\_\_\_

Signature: \_\_\_\_\_

Signed (name) \_\_\_\_\_

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