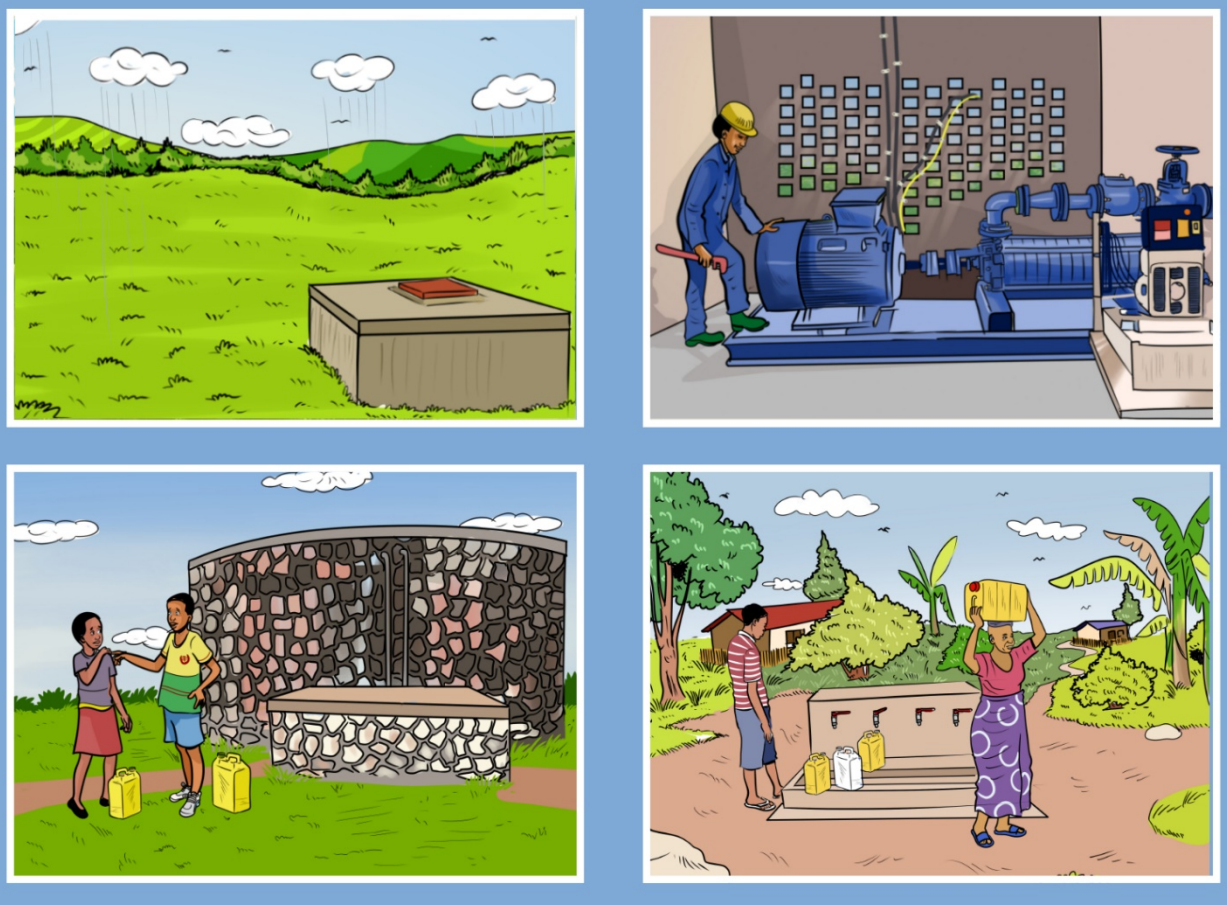
REPUBLIC OF RWANDA

MINISTRY OF INFRASTRUCTURE

Training Module
on
Procedure of Operation and Maintenance
for
Pipe Water Supply Systems



Edition 1.0

May 2019

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Preface

Access to safe drinking water is crucial, not only for people's health and wellbeing, but also for poverty reduction and economic development;

Improving the access, quality, availability and sustainability of water supply services in RWANDA is the top priority in the Sector;

Rwanda has committed to reach SDGs targets by 2030 through the different programs such as the NST1 and 7 Years Government Program with the aim of achieving universal access to basic water and sanitation services by 2024. In order to achieve this target, an appropriate institutional system has to be in place.

The development of the National guidelines for Sustainable Rural Water Supply Services and all its supporting documents (Manuals, Training Modules, etc.) is part of the mechanism to develop the Operation and Maintenance in the Rural Water Supply, and make an important guidelines to Districts, Private Operators, User communities and all the stakeholders in the Rural Water Supply Services sub-sector.

I want to extend my appreciation to the stakeholders, especially JICA/RWANDA through the RWASOM Project, for the effort to have these important documents in place.

We look forward to positive impact of the developed documents through the O&M framework in the rural water services, sustainability of existing water infrastructures and overall, an improved and sustainable clean water supply service toward the communities in RWANDA.

Patricie UWASE

PERMANENT SECRETARY

Acknowledgement

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A series of workshops were held in the project, and a lot of stakeholders in Rwanda, development partners, and NGOs technically contributed in the formulation of the module. The Ministry of Infrastructure and Water and Sanitation Cooperation Ltd (WASAC) therefore, extends special thanks to these stakeholders for allowing their staff to participate in the production of this module.

The Ministry is also indebted to JICA for assisting in the development of the module, and many who have not been mentioned here but contributed in different ways.

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List of Acronyms

AC	Asbestos Cement
CI	Cast Iron pipes
DI	Ductile Iron
FRP	Fiber Reinforced Pipes
GS	Galvanized Steel
PE	Poly Ethylene
PVC	Polyvinyl Chloride
NPSHA	Net Positive Suction Head Available
NPSHR	Net Positive Suction Head Required
RPM	Rotations Per Minute
RTD	Resistance Temperature Detector
VFD	Variable Frequency Drive

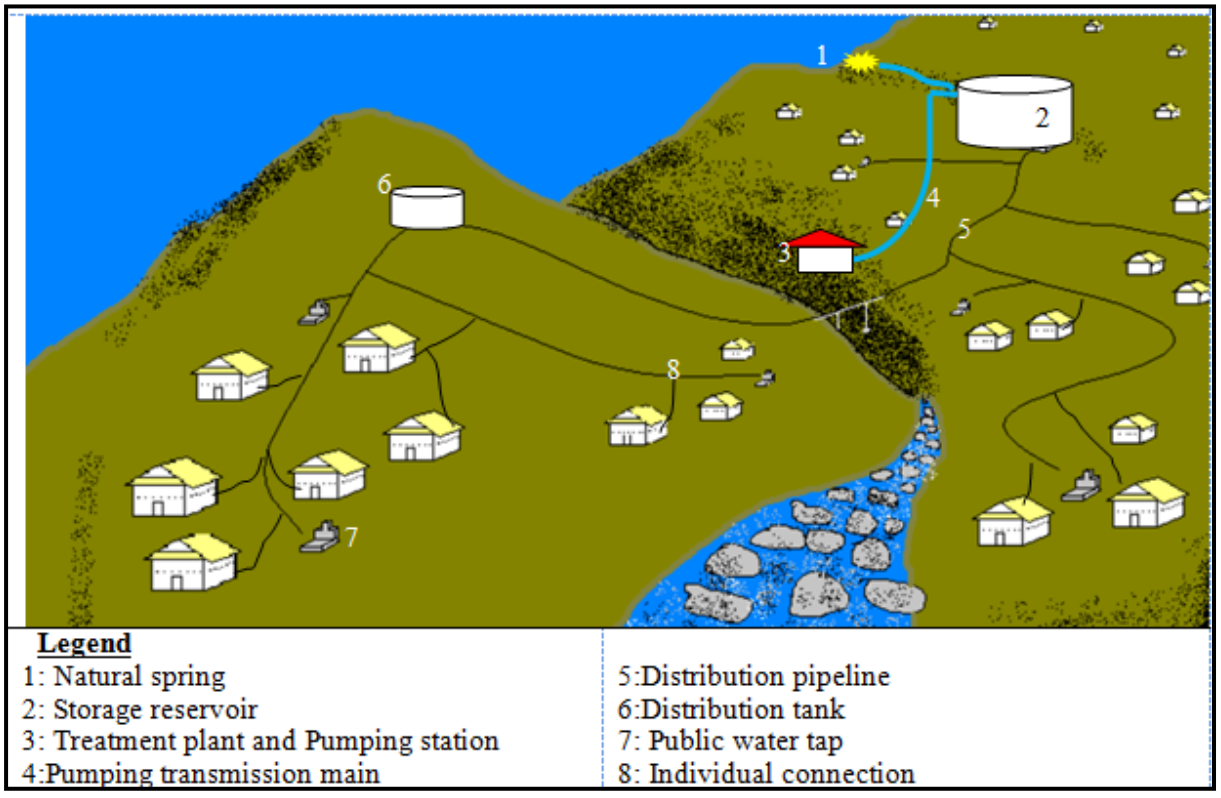
1 General

1.1 Component of a typical water supply scheme

A piped water supply scheme comprises of the following main units:

- Source / Intake arrangements
- Raw water storage
- Transmission line
- Treatment unit (Chemicals addition, flocculation, filtration and disinfection)
- Pumping station
- Balancing reservoir
- Distribution system
- Chambers (washout chambers, collection chambers, air release chambers, valve chambers, etc.)

The following picture outlines a typical water supply scheme.



(Picture adapted from Rich Rotto 1997)

Figure 1: Sketch of a typical piped water supply system

2 Concept of Operation and Maintenance

2.1 Operation

Operation is defined as the everyday activities of running and handling of a water supply facility (Davis, Brikké, & Boesveld, 1995). Operation of a water asset has the purpose of continuously conveying up to the consumers, the water of safe quality, in the satisfaction of desired quantity and service pressure.

2.2 Maintenance

Maintenance is a collection of those activities required to sustain the water supply in a proper working condition (Davis et al., 1995). The author has distinguished 3 categories of maintenance which are:

i. Preventive maintenance: regular inspection and servicing of a water system without any observed problem, in order to preserve assets and minimize further breakdowns.

ii. Corrective or curative maintenance: minor repair and replacement of damaged and worn out parts for maintaining the water infrastructure under safe working condition.

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

In our case we will combine corrective and crisis maintenance in the category of curative maintenance.

2.3 Planning and organizing the operation

In order to continuously maintain the sustainability of the water infrastructure and deliver safe and enough water to the consumers, the operator should adequately plan for the required actions, the procedures and strategies for implementation. Planning is the responsibility of the managers. They thus make provisions for:

- Timing and frequency of actions along a work day, week, month, term and a year.
- Types of Operation and Preventive maintenance required such as the General System Inspection, Pumping equipment operation, Chlorination ...
- Procedures and strategies
- Budget, tools and materials
- Decide and assign responsible actors for each action.

2.4 Work day

Working hours a day for operation and maintenance will be at least 9 hours. The example of the daily schedule is displayed in the following table.

Table 1: Example of daily working time table

Time	Activity
06:30 - 07:00	Arrival and check before starting operation
07:00	Start operation and services
07:00 – 12:00	Operation, preventive maintenance and curative maintenance
12:00 - 13:00	Lunch rest
13:00 - 17:00	Operation, preventive maintenance and curative maintenance
17:00	Stop operation and services
17:00 – 17:30	Checking after stopping operation

(FEPEAR, 2014)

2.5 Activity of daily operation

- Add chemicals to the water
- Start and stop operation of a pump
- Discharge water into the network
- Manipulate valves
- Adjustments for balancing the flow discharge across the distribution network
- Managing the hydraulic functionality of the whole water network
- Fill the buckets at the public tap
- Reading water meter
- Recording result of operation and maintenance

2.6 Activity of preventive maintenance

- Inspection for the system
- Change oil and filters for engine
- Put grease in rotating parts of a motor
- Flush a distribution system without complaints
- Cleaning inside of the operator room
- Re-paint the fittings connecting the mains to a reservoir
- Inspect the condition of meters

3 Water Intake

3.1 Water source

3.1.1 Types of sources

The main sources of water are rain from which precipitations accumulate over and under the earth surface, thus giving rise to:

1. Surface water sources rivers, streams, lakes, ponds, dams
2. Sub surface sources: natural springs
3. Ground water sources: wells including open wells, dug wells and boreholes

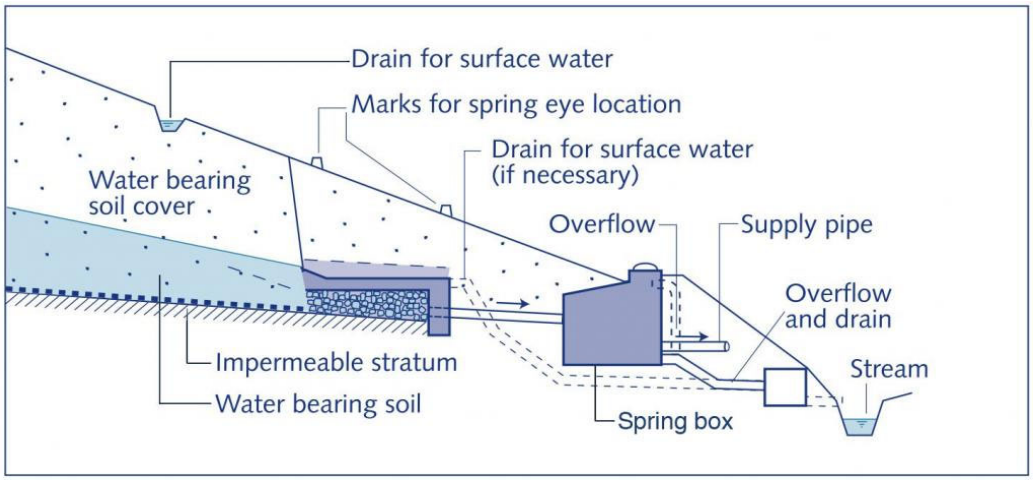
There are 3 features of a source such as quality of water, the quantity and reliability which are the most interesting during the appreciation of an appropriate water sources.

3.1.2 Intake arrangements

An Intake is a device or structure placed on a water source to permit withdrawal of the water from that source and to discharge into a water system (GoI, 2013). There are various catchment arrangements depending on the types of the sources. The following pictures show a typical intake arrangement of a natural spring:

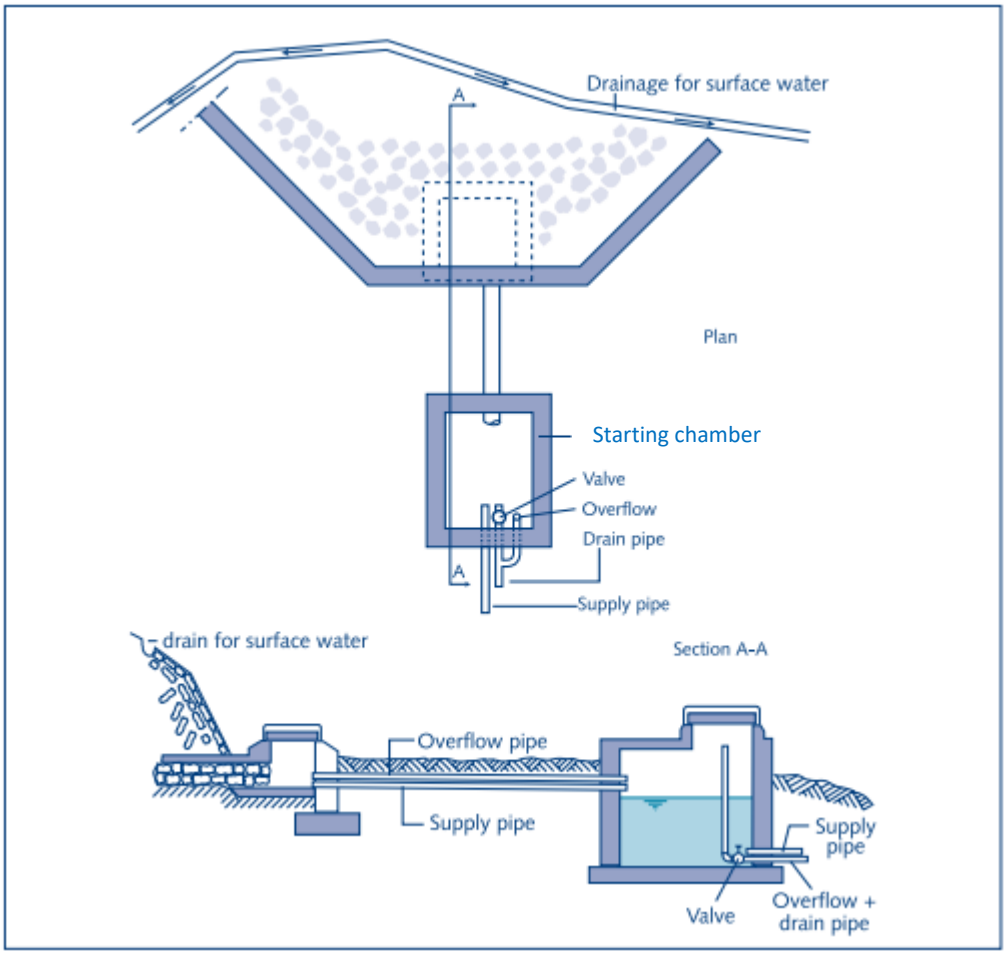
3.2 Natural springs

A natural spring is an opening where water from an aquifer emerges to the soil surface and spread continuously in the nature. Mostly the quality of springs' water is safe and people are used to develop a catchment arrangement to the openings of the springs and transfer that water to the places of use through pipes water systems. The figure below depicts sample technique of springs' water catchment:



(Smet & Wijk, 2002)

Figure 2: Lay-out of a spring water collection area



(Smet & Wijk, 2002)

Figure 3: Low cost option for collection area

During harnessing of a natural spring, the spring eyes are dug from the ground, cleared and collected first into gravels filter medium then directed into a spring box. The purpose of the spring box is to collect water from different springs, allow settlement of suspended particles and to discharge the water into the transmission main.

3.2.1 Main issues of the sources

- Seasonal or gradual fluctuations in water production
- Turbidity during rainy seasons due to erosion bringing about transportation of deposits, debris
- Pollution
- Leakages
- Clogging
- Damaging / collapse of the catchment arrangement due to external destruction actions or aging
- Conflicting uses between various consumers such as animals, people, irrigation, fishing, boats...)
- Growing of trees in the catchment

3.2.2 Preventive O&M of a natural spring

- Catchment protection: Protection of the catchment has two main objectives: (i) to improve the recharge of the aquifer, and (ii) to prevent contamination of the groundwater. This requires activities such as:
- Planting lawn grasses to mitigate erosion
- Controlling for growing and uprooting potential trees in catchment zone
- Cleansing of the surface water drain or protection ditch
- Fencing of the catchment zone (about 50 m radius)
- Tracking the quality of water
- Controlling the yield of the source
- Respect standard of protection of source

Table 2: Schedule of operation and preventive maintenance activities in the catchment zone

Components	Actions	Frequency
Lawn grasses	Trim, replace and adds plants	Once a month
Growing trees in the catchment zone	Cut and uproot any trees growing over the catchment trenches.	As required
Springs marks	Maintain the location and repaint in red and white the springs marks (concrete sticks)	Once a year
Fence	Renew or reinforce the fences posts, lattices Trim uneven growing trees	Check once in three months and perform as required
Drainages / Protection ditch	• Clean off mud, sediments and deposits • Cut grasses and trees growing in the trenches.	• After heavy rains • Once in three months
Surrounding catchment area.	Fight Erosion through: • Maintain land cover and runoff barrier • Develop water retaining and infiltration trenches	Check one a year and perform as required
Check the quality of water	• Taking the water temperature with a thermometer	Every day
	• Testing the turbidity of water	More often during rainy season
Yield of the source	• Measuring the source discharge	In the beginning, in the middle and at the end of every season.

3.2.3 Estimating the spring yield

The measurement of the flow rate of a spring is conducted by two persons. And it is expressed in liters per second.

For a non develop spring, the material required include a plough, shovel, a piece of pipe, a graduated bucket or a container, pile of clay, few stones, a block note and pen and a chronometer.

Procedures

- Clear the site and channel the water through a unique water way.
- Construct an earthen dam to retain the water, using the clay and stones if necessary.
- Insert an outlet in the dam with the pipe piece.
- After construction let water flow for a time and stabilize (This may take more or less 15 minutes for a small source). The stability is achieved once the level of the water in the dam is no more changing.
- One person takes to the outlet a graduated bucket or a container of well-known capacity. The other person records with a chronometer the time it takes to fill the container. Repeat the experience 4 times and do the average of the time required to fill the container.
- To calculate the flow rate, take the capacity of the container in liters and divide the average time it has taken to fill it.

3.2.4 Curative maintenance of the natural springs

Common problems of natural sources are the following: Leakage, Turbidity after rain, Sudden change of temperature, Drop of production during dry season, pollution.

a) Leakage:

Leakage of a source can occur due to cracks in the catchment after a natural disaster such as land slide, an earth quake or uneven land settlement. Also collapse of catchment can occur due to aging, invasion of roots, rodents, construction defaults or inappropriate operation. Most of the time, remedying a leaking source requires opening the catchment trenches and redo the lining of the catchment trenches with the new clay. The following table proposes solutions for various failures of natural springs' catchments.

b) Turbidity

In general, the quality of spring water is good. That can be justified by a persistent colorless (no color) and constant temperature properties. If spring water changes color after rain or if its temperature changes along the day, it is a sign of poor or thin soil layers over the aquifer. Thus the purification of the recharge water from the rain while this water is infiltrating through the soil layers is not reliable.

Table 3: Issues and remedies of the natural springs

Failure	Possible cause	Remedy
Leakage:	Natural disaster like: land slide, earth quake or uneven land settlement	Redo the catchment
	Collapse of internal arrangement of catchment materials (clay, gravel, pipes, back filling)	Redo the catchment

Failure	Possible cause	Remedy
	Diverting of sources	Redo the catchment
	Trees or rodents intrusion	Inspect the damage by follow the pathway of intrusion. If the damage is still larger, seal it with clay. If the catchment is deeply affected, redo it.
Turbidity & change of temperature along the day	Thin soil layers during infiltration	Treat water before use Forbid use of the catchment zone for farmers activities
	Cracks in the catchment allowing external water intrusion	Redo the catchment
	Quality of bedrock	Let suspended materials in water settle down or treat it before distribution
	Collapse of catchment	Redo the catchment
	Clogging or Insufficient slope of intake pipe	Readjust the intake pipe
Dropdown of production	Leakage	Redo the catchment
	Trees invasion	Cut and uproot the trees in catchment zone and surrounding area
	Drought	Reinforce the source with other closer sources.
Pollution	Toilets and dump pit in surrounding areas	Close or relocate the existing pits. Ban digging of new toilet pits.
	Activities (grazing, washing ...) in catchment zone	Fencing
	Damaged catchment	Repair the catchment.

3.3 Surface water sources

Surface water sources include rivers, streams, lakes and ponds. The most common method of intake for the surface water sources are the dams.

3.3.1 Frequent issues of the dams

Seepage

Seepage is the flowing of water through the embankment of the dam. The main causes of seepage in the dams are the roots of trees, construction defaults and rodents invasion. Once the seepage has started, it grows progressively, thus opening wide and creates a water path tunnel. This phenomenon is known as piping. In the end that tunnel may bring out the collapse of the dam.

Overtopping

Overtopping is the flowing of water over, or around the dam. That happening causes the erosion the soil particles from embankment of an earthen dam. Overtopping occurs when the spillway has been under designed or if there are entrapped debris hindering an adequate evacuation of overflow water.

Structural failures

Common structural failures of the dams are slides, overturning, cracks and settlements. Those failures result from bad construction materials or poor design and implementation techniques.

3.3.2 Preventive Operation and maintenance of the dams

Table 4: Activities and schedule for preventive maintenance of dams

Component	Maintenance activity	Frequency
Embankment	• Vegetation control	Twice per year minimum
	• Rodents control	Check once per year, then perform as required
	• Minor earthwork, erosion repair	Check once per year, then perform as required
	• Erosion protection	As required
Principal spillway	• Vegetation control	Every six month
	• Minor earthwork, erosion repair	Check every six month, perform as required
	• Erosion protection	Check every six month , perform as required
	• Concrete repair	As required
Emergency spillway	• Vegetation control	Every six month
	• Minor earthwork, erosion repair	Check every six month
	• Erosion protection	Check every six month
	• Concrete repair	As required

Intake / Outlet structures	Trash rack cleaning *	After every major storm
	Mechanical operation	Once per year
	Internal conduit inspection	Once per year
	Concrete features inspection	Once per year
Masonry walls	Vegetation control	Every six month
	Missing stones	As required
Miscellaneous Safety and access Features	Vehicle / Pedestrian access road (s) maintenance	Once per year
	Fence, locks, signs inspection	Once per year

Table adapted from: (Rocque, 2001)

*A trash rack is a wooden or metal structure, frequently supported by masonry, that prevents water-borne debris (such as logs, boats, animals, masses of cut waterweed, etc.) from entering the intake (https://en.wikipedia.org/wiki/Trash_rack

Image of a trash rack (AWMA Water control solutions

https://www.awmawatercontrol.com.au/products/trash-screen-trash-rack/)

3.3.3 Curative maintenance of the dams

Table 5: Types of failure and recommended actions

Types of Failures	Possible cause	Procedure for solution
Seepage/Piping	Seepage water exiting at abutment contact	• Study leakage area to determine quantity of flow and extent of saturation • Inspect frequently for Slides • Water level in the impoundment may be lowered to increase embankment safety
	Seepage water exiting as a boil in the foundation	• Examine boil for transportation of foundation materials, evidenced by discoloration. If soil particles are moving downstream, create a sand bag or earth dike around the boil

Types of Failures	Possible cause	Procedure for solution
	Rodents activity	• Control rodents to prevent more damage. Determine exact location of digging and extent of tunneling. Remove rodents and backfill existing holes
Overtopping/Erosion	Blocked/inadequately sized spillway	• Remove all trees and shrubs on and within 1meter of the embankment. Properly backfill void with compacted material. • Control vegetative growth in spillway channel. • Install log boom or trash rack in front of spillway entrance to intercept floating debris
	If riprap is broken down or missing	• Re-establish normal slope. Place bedding and competent riprap
	If erosion was observed	• Protect eroded area, compacted soil and re-establishing turf
Structural failure such as cracking, settlement and slides	Large cracks, slide, slump or slip	• Measure extent and displacement of slide. If continued movement is seen, begin lowering water level until movement stops
	Wall displacement / open joints	• Reconstruct displaced structure. Water-stops should be used at joints where feasible.
	Large cracks	• Cracks without large displacement may be repaired by patching, in which case surrounding areas should be cleaned or cut out before patching
	Leakage through joints or cracks	• Check area behind wall for paddling of surface water. Check and clean drain outfalls, flush lines, and weep holes
	Valve leakage	• Raise and lower gate slowly until debris is loosened and floats past valve. When reservoir is lowered, repair or replace trash rack

Table adapted from: (Rocque, 2001)

3.3.4 Structure of boreholes

The structure of boreholes must be determined considering, besides the foreseen deepness, the pumping flow, the groundwater level, the water quality, etc.

Boreholes pump groundwater from the confined aquifer, that is why, unlike wells (artesian wells), the pumping flow is depending on perforation, diameter and deepness of it, as well as by the aquifers, the pump capacity, etc.

Generally steel pipes are used for the casing of boreholes, which thickness will be determined by the ground condition. However, when there is corrosive possibility for the water quality influence, the quantity of water or galvanic corrosion, there are cases in which thicker pipes are utilized, PVC pipes, stainless steel pipes, fibre reinforced pipes (FRP), etc., according to necessity.

The joints of casing pipes and screen pipes must be connected perfect, for example, welded, threaded or flanged joints.

For pumping groundwater from boreholes, submersible pumps are mainly utilized, which specifications are determined by the pump diameter, flow rate, total head, electric tension, frequency, pump performance, axis power, etc.

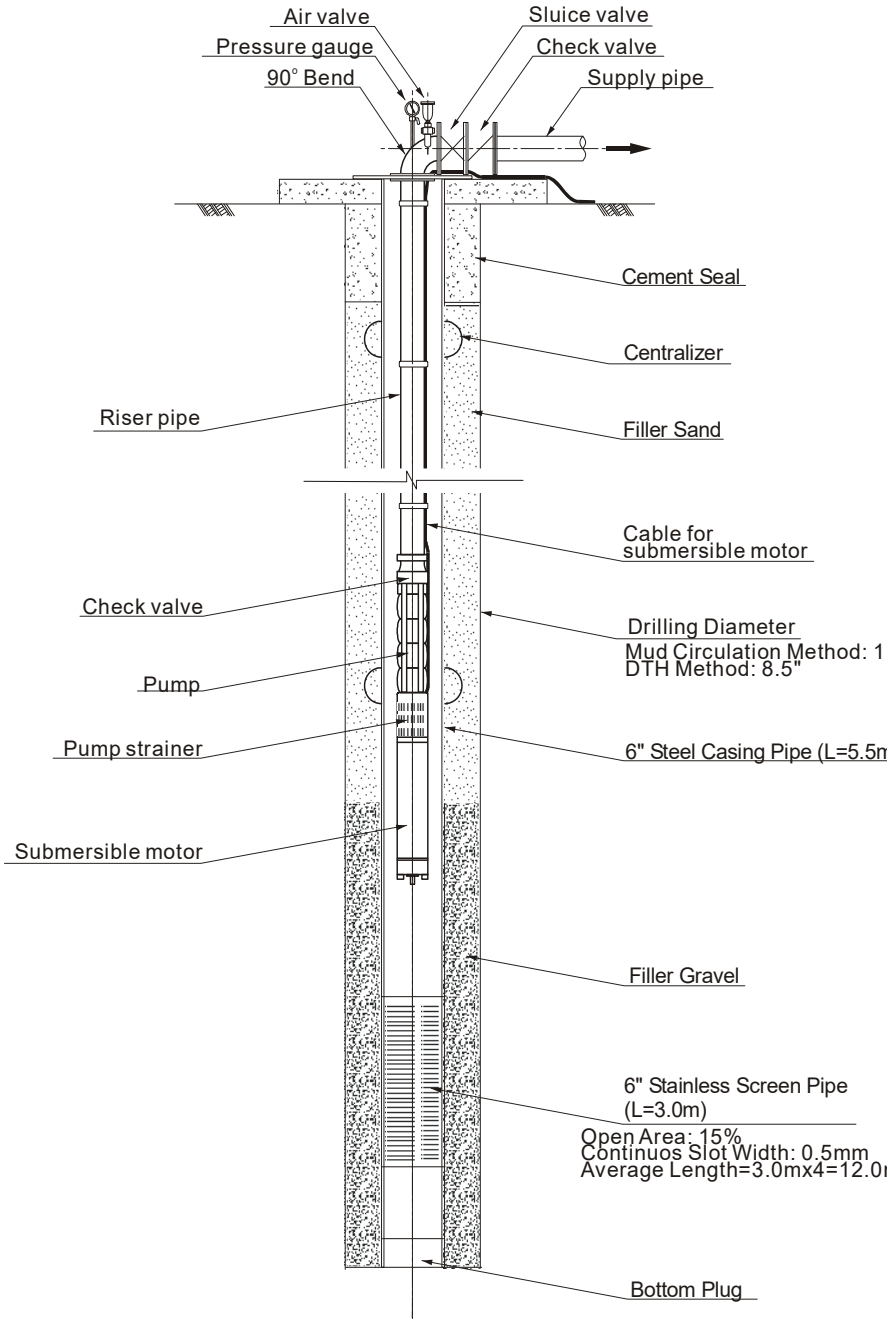


Figure 4: Example of the structure of borehole with submersible motor pump

3.3.5 Preventive maintenance of boreholes

The borehole has its maximum pumping capacity, in normal cases, at the moment to end its construction. The borehole capacity declines through aging, according to the passage of time, whether it is used or not.

The capacity decrease of the borehole during the pumping is mainly due to obstructions, though the water is not pumped, the convection inside the borehole conducts to oxidation right through the deepest part, being able to cause obstructions because of chemical reactions.

It is difficult to keep maintaining the initial pumping capacity. In the case of capacity declining, it is possible recovering it through rehabilitation works, etc.

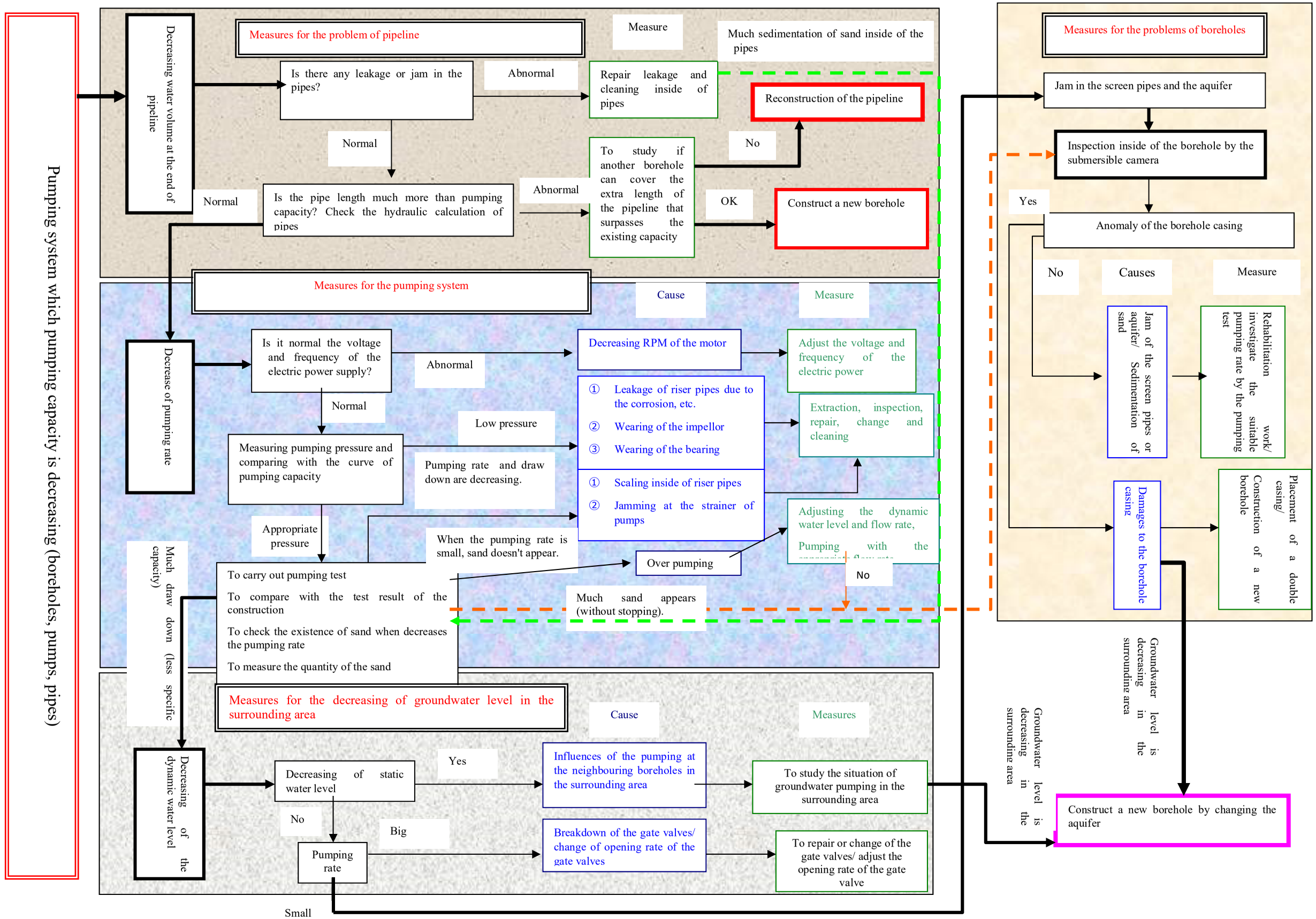
There are 3 related factors with the functioning of the borehole:

i) water quantity

ii) water level

iii) water quality

When the borehole functioning becomes worse, phenomena like water pumping volume decrease, water level lowering and water quality change might be occurred. Among these factors, the water quantity decrease and water level lowering appear at the same time. It means that for some reason the water level declines, and the water quantity. On the other hand, the water level decrease may affect the water quality. As one of the most representative cases, it is mentioned iron, salt, manganese, fluoride and other minerals should be found in boreholes depending on the geological condition. That is why it must be constantly measured the 3 aforesaid factors to diagnose the borehole.



Source: Nissaku Co., Ltd.

Figure 5: Diagnostic diagram of deep borehole

3.3.6 Curative maintenance of boreholes

Cause of reduction in well performance

There are many variables that contribute to reduction in well performance. That is to say,

- Pump damage or wear,
- Well screen and casing corrosion or incrustation,
- Incrustation of the aquifer,
- Structural failure of the well

These problems are often traced to factors such as poor well design or construction or improper selection of pump materials. Besides, hydrogeological conditions may contribute to reduced well performance. For examples,

- Reduced aquifer recharge,
- Over pumping of aquifer,
- Interference from nearby wells

Change in groundwater quality is also a significant factor in well performance decline.

Clayey material on the hand pump plunger caused by siltation

Incrustation on the well screen

Figure 6: Siltation and incrustation in the borehole

3.3.7 Method of curative maintenance of borehole

There are typical methods of curative maintenance for the borehole as follows;

- Air lifting method
- Mechanical bailing with a bailer
- Mechanical surging with a surge block
- High-velocity water jetting

It is recommended to refer to Table 6 when selecting the curative maintenance methods. Each method is outlined below.

Table 6: Applicability of Curative Maintenance Method by Type of Borehole

Type of Borehole		Applicability of Curative Maintenance Method			
Type	Material of casing and screen pipe	Air lifting	Mechanical bailing with a bailer	Mechanical surging with a surge block	High-velocity water jetting
Borehole with handpump	uPVC, dia. 4"	applicable	less applicable	inapplicable	inapplicable
Borehole with motorized pump	Steel or stainless steel dia. 6" - 14"	less applicable	applicable	applicable	applicable

4 Operation of the Pumping Cabin

4.1 Water pumps

4.1.1 Security and tidiness in the pumping cabin

A pumping station is a delicate place which deserves special tidiness and protection. Important actions, arrangements and procedures for operation and maintenance inside the pumping station are depicted in the Table 7.

Table 7: Security and tidiness in the pumping premises

Item to control		Reasons	Methods/ Actions/ Arrangements	Responsible persons	Frequency
01	Limit accessibility to workers and notified people	• Protect the station (fragile material, valuable equipment, fuel reserve, tools); • Protect people (risk of fire, burn, cut).	• Fencing the pumping premises • Closing and controlling the entrance gates • Hiring permanent guards	• Manager • Guardian • Care taker	Always
02	Clean the pumping station	• Avoid contamination of the quality of water • Make attractive and motivating working environment • Good impression to water consumers	• Washing and sweeping surfaces outside and inside • Trim and weeding garden's plants • Maintenance of lanes	• Cleaner	Twice a week
03	Ensure safe storage/ use of substances	• Avoid deterioration of reagents • Avoid effect on human being • Avoid accident including fire, corrosion ...	• Put bags of reagents on timber cases • Maintain suffocating substances tightly closed • Avoid humidity and excessive brightness in the storage medium	• Manager • Team leader • Workers	Always
04	Guarantying Hygiene	• Maintain safe and healthy working conditions	• Provide toilets, washing facilities and drinking water	• Manager • Team leader	Always

Item to control		Reasons	Methods/ Actions/ Arrangements	Responsible persons	Frequency
05	Implement emergency procedures – evacuation in case of fire or other significant incidents.	• Maintain safe and healthy working conditions	• Provide wide open doors and windows and a ring for alarming	• Manager • Team leader	Always
06	Heavy noise from pumps	• Preserve hearing	• Avoid long time stays in the pumping house • Bear Headphones	• Workers	Always
07	To prevent accidents and cases of work-related illness	• provide adequate control of health and safety risks arising from work activities	• Distribute personal protective equipment such as Masks, gloves, helmets, working clothes… • Provide enough training to the staffs • Avail the first aid box containing ointments, adhesive bandages, Soaps, Gloves, Goggles, Alcohol pad, Scissors , Paracetamol , Plastic tweezers	• Manager • Team leader	Always
08	Precaution against small fire	• Extinguish	• Provide extinguisher bottles • Pile of sands and shovel	• Manager • Team leader • Workers	Always

Source: Guidelines of operation and maintenance for PO and the Districts (Suswas, 2016) and (HSE, 2014)

4.1.2 Operation of the pumps

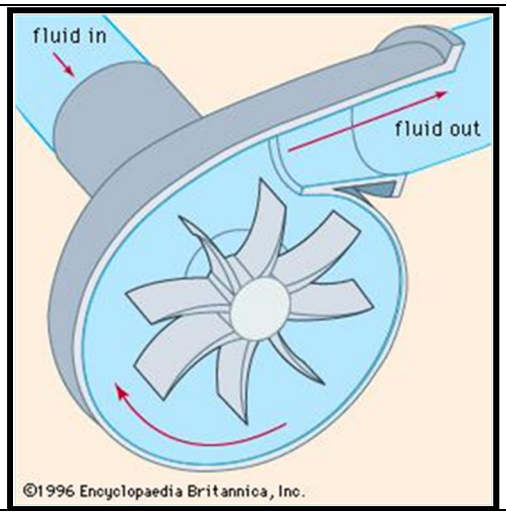
There are many types of pumps which can be grouped into 3 categories:

- Velocity / turbine pumps like centrifugal pumps;
- Positive displacement pumps like piston pumps.
- Direct lift pumps

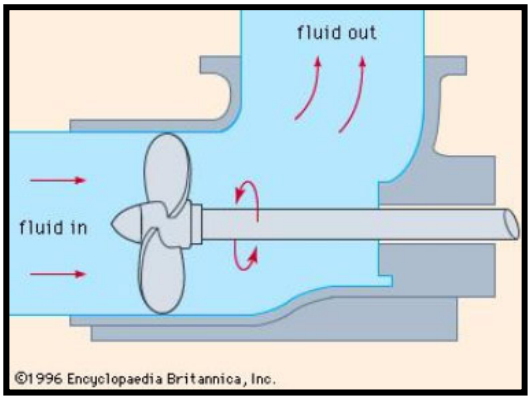
The principle of function of a positive displacement pump is base in trapping a fixed amount of water and forcing that trapped volume into the discharge pipe.

Concerning the Direct lift pump, the liquid is enclosed in a container which is raised to a desired height. This is the case of the Bucket wheels, bucket chains and Archimedes screws.

Velocity pumps are the common type used for *potable water* pumping applications: For this type of pumps, kinetic energy is transmitted to the fluid by increasing the flow velocity. This increase in energy is converted into potential energy (pressure). Example of velocity pumps include the centrifugal horizontal pump.



Volute centrifugal pump (Encyclopedia Britannica, Inc. 2017) retried at https://www.britannica.com/technology/pump/images-videos



Axial flow centrifugal pump (Encyclopedia Britannica, Inc. 2017) retried at https://www.britannica.com/technology/pump/images-videos

Figure 7: Radial vs. axial centrifugal pumps

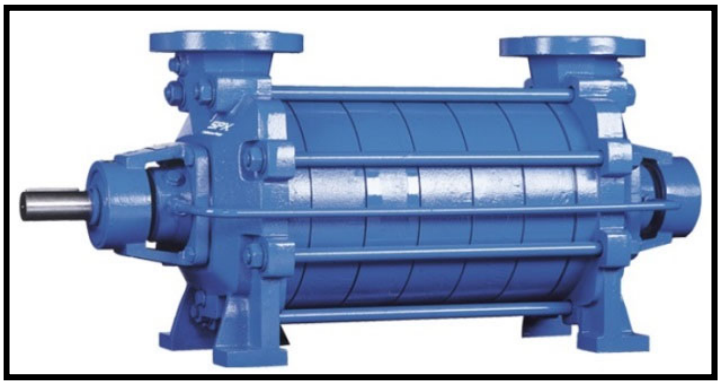


Figure 8: Multistage centrifugal pump

(Johnson Pump, 2017)

4.1.3 Starting and stopping water pumps

Every time, before starting pumps, the pumps operator should ensure that all installations are in healthy conditions to allow proper functionality of the pumps. For that reason, the following inspections need to be conducted.

a. Check the condition of the source of energy

Condition of the source of the energy shall be checked by the method shown in the Table below.

Table 8: Method of checking the condition of the source of energy

Item to inspect		Method
01	Power is available in all 3 phases	• Check voltage of each line with respect to ground using volt meter • voltage of each line with respect to ground is more or less same +/- 20 volt • If the source of energy is a generator, check the condition of the generator • Check the fuel and lubricant in the generator • Check the condition of the battery of the generator
02	All connections are properly thimble	• Closer observation
03	Trip circuit for relays is in healthy state	• In healthy situation all the contacts except protective relay contact are in close position.

b. Check the conditions of the pumps

Condition of the pump shall be checked by the method shown in the following table.

Table 9: Method of checking the conditions of the pumps

Item to inspect		Method
1	Check functioning of lubrication system of different pump elements	• Observation and manipulation
2	Check stuffing box to ensure that it is packed properly.	• Observation and manipulation
3	Check and ensure that the pump is free to rotate	• Observation and manipulation
4	Check if the pump is turning in the right direction	• Observation and manipulation

c. Check the availability of water

Availability of the water shall be checked by the method shown in the Table 10.

Table 10: Method of checking the availability of water

Item to inspect		Method
1	be ensured that the water level in the sump/intake is above low water level and inflow from the source is adequate	• Read the water level gauge • Open the trapdoor of the intake structure and observe
2	Check if the level of suspended material and the turbidity of water are acceptable in order to avoid abrasive sands or to pump useless water.	• Take a sample in transparent beaker and observe • Take sample to the laboratory if necessary

d. Records to be taken before starting pump operation

The following items shall be recorded before starting operation.

- Timings when the pumps are started, operated and stopped during 24 hours
- Index of electric meters including the current drawn by each pump-motor set and total current drawn at the installation
- Voltage in all three phases and the frequency of the current
- Readings of vacuum and pressure gauges
- Bearing temperature for pump and motor
- Index of water levels in reservoirs

- Readings on the pressure gauges
- Water level in intake/ sump
- Flow meter reading
- Any specific problem or event in the pumping installation or pumping system

e. Starting process

Procedure of starting operation of the pump shall be the followings.

i. Open the suction valve
ii. Open any recirculation or cooling lines
iii. Fully close or partially open the discharge valve, depending on system conditions
iv. Start the pump
v. Slowly open the discharge valve until the pump reaches the desired flow
vi. Check the pressure gauge to ensure that the pump quickly reaches the correct discharge pressure
vii. If the pump fails to reach the correct pressure, perform these steps
    - Stop the pump
    - Prime the pump again
    - Restart the pump
viii. Monitor the pump while it is operating
    - Check the pump for bearing temperature, vibration and noise
    - If the pumps exceed normal levels, then shut down the pump immediately and correct the problem
ix. Repeat steps vii and vi until the pump runs properly

If the source of energy is an engine generator, the following action shall be taken.

- Let it run without load for 3 minutes to heat
- Check volts and amperes dials (if any) and all indicator lights.
- Engage the pump.
- Monitor all lights and indicators.
- Attention should be paid to the sounds of machines.
- Check that there are no leaks of fuel or water.

f. Stopping a pump in normal conditions

Under normal circumstances, stop pumping takes place more or less by taking reverse actions at startup.

Normal stopping occurs when:

- The discharge tank is full;
- The water level of suction tank is at the limit;

- Time is up for stopping machines

g. Stopping procedures

i. Monitor all lights and indicators. Attention should be paid to the sounds of machines. Check that there are no leaks of fuel or water and no overheating.

ii. Close the delivery valve gradually (sudden or fast closing should not be resorted to, because it may give rise to water hammer pressures)

iii. Stop the pump. If there is an engine generator the pump should be stopped first and then the engine generator.

iv. Open the air vent in case of vertical turbine and submersible pump

v. Stop lubricating oil or clear water supply in case of oil lubricated or clear water lubricated pump.

vi. Record water meter reading, pressure gauges reading and stop time.

vii. Check fuel, whether they are sufficient for the next day.

viii. Check the cleanliness, clean the station and appliances

h. Pump stopping in emergency situation

The emergency conditions are all suspect or critical operating situations such as red light, heating, dials showing abnormal data, power failure or tripping. Those conditions require direct stopping. In case of power failure, precautions are necessary to prevent auto-restarting on resumption of power.

The emergency procedure should be defined case by case depending on the configuration of the station.

- It will be written and displayed in the station.
- All personnel on the station will be trained on it twice a year.

The following principles should be applied to define the procedure:

- An Operator's employee shall be permanently at the station while working.
- They need to know all the specific points that can trigger an emergency stop.
    - Abnormal noise;
    - Heating of device;
    - Red lights;
    - Loss of oil, fuel or water;

- Gauge that is not at it is routine pressure;
- Voltage or amperage that is not normal (heat up and burn the control box);
- Safety Issues: heavy rains, thunderstorm with lightning, suspicious people.

Table 11: Rules to be respected during operation of a pump

	Activity	Frequency	Method
01	Prime the pump before starting	If the pump has been out of use for a relatively long period of time	Water needs to be flushed back into it and forced through in order for it to create enough pressure to begin pumping again. • Turn off electrical power to the pump. • Locate a plumbing fixture that provides access to the pump system • Prepare a hose that can be connected to an independent water source • Flush the hose to remove any build-up. • Open any relief valves on the pump system • Insert the hose in the plumbing fixture • Turn on the water to the hose • Wait for water to enter the tank. • Turn off the water to the hose. • Restore power to the pump and turn on the pump system • Wait for the pump to finish its cycle • Repeat all steps until the pump is primed and functioning normally
02	Prevent dry running	Every time	• Fill the intake tank • Open the valves between intake and the pumps
03	• Avoid overheating of casing and pumps • Maintain the normal efficiency of the pumps	Every time	• Respect the head-discharge characteristics of the pump. Don't pumps near or beyond the shutoff head.
04	Maintain the voltage within the range of 10% of the pump design voltage	Every time	
05	Reduce starting load on motor	Every time	• Start a pump of low or medium specific speed against closed delivery valve

Activity		Frequency	Method
			Start a pump of high specific speed against closed delivery valve Normally the pumps used in water supply schemes are of low and medium specific speeds
06	Control sudden change in flow velocity which can cause the water hammer pressures	Every time	Operate gradually the delivery valve
07	For parallel operating pumps, the pumps should be started and stopped with a time lag between two pumps. In order to restrict change of flow velocity to minimum and to restrict the dip in voltage in incoming feeder.	Every time	Read the evolution of pressure on the pressure gauge to determine and maintain adequate time lag.
08	For the pumps operating in series, start and stop them sequentially, with minimum time lag.	Every time	• Next pump 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.
09	Avoid idle pumps in the pumping station	Every time	• 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 • Unequal running should be ensured so that all pumps do not wear equally and become due for overhaul simultaneously
10	If any undue vibration or noise is noticed, the pump should be stopped immediately and cause for vibration or noise be checked and rectified	Every time	• Stop pump immediately after notification of vibration or noise •
11	Bypass valves of all reflux valve, sluice valve and butterfly valve shall be	Every time	Close valves.

Activity		Frequency	Method
	kept in closed position during normal operation of the pumps		
12	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.	Every time	Avoid frequent starting and stopping.

Source: Operation and maintenance manual for rural water supplies

During pumping operation "except for fully automated stations, all others must have a guardian at all times during pumping.

This may be the station's day or night guard, who has received specific instructions about what to monitor and how he can stop pumping (emergency procedure).

The Operator must be aware of the value of the pumping facilities, and his responsibility for their life span.

4.1.4 Preventive maintenance of the pumps

Method of preventive maintenance of the pumps is mentioned in the Table 12.

Table 12: Method of preventive maintenance of the pumps

Actions		Frequency	Method
01	Check for any abnormal bearing noise	Daily	• Repeated hearing standing at different locations
02	Check belt tension. In case this is excessive it should immediately be reduced	Monthly	• Push it with the thumb and estimate the flexion.
03	Examine oil in oil lubricated bearing for contamination by dust, grit, etc.	Monthly	• This can be judged from the colour of the oil
04	Clean oil lubricated bearings and replenish fresh oil	Quarterly	• Anti-friction bearing should have its housing so packed with grease that the void space in the bearing housing should be

Actions		Frequency	Method
			between one third to half.
05	Check tightness of cable gland, lug and connecting bolts	Quarterly	• Push it with the thumb and estimate the flexion.
06	Check and tighten foundation bolts and holding down bolts between motor and frame	Quarterly	• Push it with the thumb and estimate the flexion.
07	Check vibration level	Quarterly	• with instrument if available; otherwise by observation
08	Check air gaps.	Annually	• Put a hand closer an opening • Attentive hearing
09	Check resistance of earth connections	Annually	• Observation

4.1.5 Curative maintenance of the pumps

Prevalent failures and breakdowns of the pumps occur in pumps' efficiency, packing adjustment and misaligned head shafts.

a. Low pump efficiency

If the pump performance tests reveal that the pump is operating at significantly lowered efficiencies, the pump should be pulled out, inspected and repaired or reconditioned. This work is best referred for servicing to the manufacturer or a pump repair specialist.

b. Packing adjustment

The water flowing through the stuffing box should be maintained at a level just enough to prevent overheating. The gland nuts should be loosened or tightened one-quarter turn only to allow the packing to equalize against the pressure.

c. Checking and Adjusting Misaligned Head Shaft

Pump vibrations could indicate a misalignment of the head shaft. This can be checked by the following procedure:

- Remove the motor dust cover, motor head nut and key, and take out the motor drive flange.
- Check if the head shaft is concentric with the motor hollow shaft bore.
- If needed, adjust by using shims.

Other technical problems can be controlled guided by the Operational manual from manufacturer as in following table:

Table 13: Curative maintenance of jet centrifugal pumps

Trouble	Likely cause of trouble	Remedy
Pump Motor fails to start	Blown fuse or open circuit breaker.	Replace fuse or reset circuit breaker.
	Motor or starting switch out of order.	Inspect / repair. Refer to equipment supplier or experienced mechanic or electrician
	Break in wiring.	Repair circuit wires
	Stuffing box may be binding or tightly packed	Check packing by manually rotating shaft.
		Loosen packing nut just enough to allow a slow seepage of water and free the shaft.
	Scale or sand in the impeller	Open pump and remove scale by acid treatment and/or sand.
Pump runs but delivers no water	Pump lost first priming	Repeat priming. Follow manufacture's priming instruction.
	Pump repeatedly loses priming due to leaky drop pipe or suction pipe.	Pull out drop pipe and seal the leaks.
	No water at source due to over pumping	Reduce pumping rate or deepen the well.
	Collapse of well casing or screens	Replace with new one. If diameter of old casing is large, insert new casing inside the damaged casing. Consult driller.
	Clogging of well screens	Surging or acid treatment. Consult driller.
Pump runs but delivers only a small amount of water	Well not yielding enough water.	Do pumping test or deepen the well
	Air leaks in the suction pipe.	Pull the drop pipe from the well & seal leak
	Incrustation or partial clogging of well screen.	Surging or acid treatment. Consult driller.
	Impeller is worn out or lugged with scare or trash.	Open the pump and clean / replace impellers
	Foot valves may be obstructed	Clean foot valve
Noisy pump	Bearing or other working parts of pumps are loose or need to be replaced	Tighten or replace defective parts

Trouble	Likely cause of trouble	Remedy
	Pump motor is loosely mounted	Tighten mounting
	Low water level in well	Reduce pumping rate and regulate water level (lower and upper limit)
	Presence of air in suction line	Repair air leaks.

For submersible pumps common problems and remedy can be tackled as indicated in the Table 14.

Table 14: Curative maintenance of submersible centrifugal pumps

Trouble	Likely causes	Remedies
Pump motor fails to start	Motor overload	Overloaded contacts close automatically. Check cause of overload
	Low voltage	Check voltage
	Blown fuse, broken or loose connections	Check fuses, relays, electric condensers and all electrical connections
	Motor control box not in proper position	Ensure box is in right position
	Damaged cable installation	Locate and repair the damaged cable.
	Cable, splice or motor windings may be grounded or wet.	Check the ground by using an ohmmeter. If grounded, pull out the unit and inspect cable and splice. Cut the unit loose from the cable and check each part separately using an ohmmeter.
	Pump stuck by corrosion or abrasive	Pull out pump, examine and remove foreign matter.
Pump runs but delivers little or no water	Pump not submerged	Lower the unit into the well or replace by a smaller capacity pump
	Discharge pipe may be leaking	Examine discharge line by pulling out one joint at a time.
	Check valve may be clogged or corroded	Pull out pump and clean or replace check valve
	Pump badly worn-out by sand or abrasive	Replace pump. Clean well thoroughly of abrasive before putting the new unit in.
	Strainers or impellers clogged with sand or scale	Pull out pump unit and remove the scale / sand.

Trouble	Likely causes	Remedies
	Scaled or corroded discharge pipe	Replace pipe
Pressure valve fails to shut	Discharge pipe	Adjust or replace discharge pipe
	Switch may be defective or out of adjustment	Adjust or replace pressure switch
	Discharge pipe may be leaking	Raise unit one pipe joint at a time until leaks is found. Repair leaks.

Other common problems of pumps are treated in the Table 15.

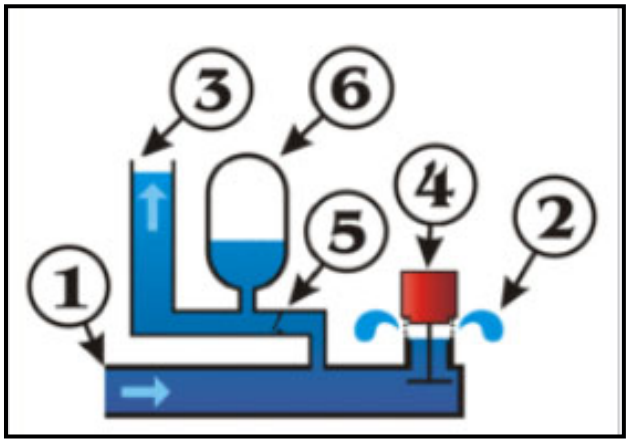
Table 15: Most common problems of pumps

Problems	Reasons	Remedy
Corrosion	Different fluid properties can corrode the pump	• Remove and replace the damaged parts • Avoid aggressive water in the pump
Cavitation causing the damage of the impeller or the pump housing	Cavitation is the result of inadequate suction pressure due to: • Suction water level of the supply was lower than normally expected. • Upstream suction butterfly valve contributed to suction losses and turbulence • Pumps operating head is considerably lower than the rated head. As a result the pumps is operating at considerably higher capacity	• Throttle the pumps so as to operate at a lower capacity wherein the Net Positive Suction Head Available (NPSHA) exceeds the Net Positive Suction Head Required (NPSHR) • Trim the impeller to reduce capacity • Add a Variable Frequency Drive (VFD) to reduce speed and capacity • Replace impellers with ones constructed of more cavitation resistant materials. • Replace pumps with new pumps better matched to the system head and NPSHA conditions
Wear of the Impeller	Can be worsened by suspended solids	Remove the pump and remove suspended solids.
Leakage	A wrong rotating shaft	Check and repair

Figure 9: Example of cavitation

4.1.6 Hydraulic ram

The hydraulic ram needs no external source of power. The ram utilizes the energy contained in a flow of water running through it, to lift a small volume of this water to a higher level. The phenomenon involved is that of a pressure surge, which develops when a moving mass of water is suddenly stopped. A steady and reliable supply of water is required with a fall sufficient to operate the hydraulic ram. Favourable conditions are mostly found in mountainous areas



Basic components of a hydraulic ram:

1. Inlet – drive pipe
2. Free flow at waste valve
3. Outlet – delivery pipe
4. Waste valve
5. Delivery check valve
6. Pressure vessel

Advantages

- No power sources are needed, and therefore no running costs.
- Suitable for low income area
- Simple design technology
- Protection of electro mechanical equipment

a. Starting an hydraulic ram pump

After installation of a new ram or when an existing ram has stopped, the following proceeding are performed in order to run it:

- Manually push down the waste valve already in closed position and put it open. If the flow is sufficient, it will then cycle at least once.
- If it does not continue to run by itself, repeat pushing down the waste valves several times until it runs.
- If the ram stops with the waste valve in the down (open) position, it must be lifted manually and kept up for as long as necessary for the supply pipe to fill with water and for any air bubbles to travel up the pipe to the source. Then it can be started manually by pushing it down a few times as described above. Having a valve on the delivery pipe at the ram makes starting easier.
- Close the valve until the ram starts cycling, then gradually open it to fill the delivery pipe. If opened too quickly it will stop the cycling. Once the delivery pipe is full the valve can be left open.

b. Maintenance of hydraulic ram pump

- Curative maintenance includes: "activities as replacement of the valve rubbers when they wear out, adjusting the tuning, and tightening bolts if they get loose. Occasionally the hydraulic ram may need dismantling for cleaning.
- Failure to deliver sufficient water may be due to improper adjustment of the waste valve, having too little air in the pressure vessel, or simply attempting to raise the water higher than the level of which the ram is capable.
- If the ram is broken due to climatic or mechanical problems, the damaged component can be removed and replaced by a new one or repaired through adjustment, welding, etc.
- If the recycling has stopped check the adjustment of the waste valve or the amount of water flow, then restart it manually.
- Check the sediments and debris in water which may clog the valves and prevent the cycling of the system. It is reasonable also to provide screen or strainer at water catchment.
- Check also the materials used during installation such as uniformity of pipes, the bending, etc.

4.2 Power drivers

4.2.1 Diesel engine

Diesel engines have the important advantage that they can operate independently at remote sites. The principal requirement is a supply of fuel and lubricants and these, once obtained, can be easily transported to almost any location. Diesel engines, because of their ability to run independently of electrical power supplies, are especially suitable for driving isolated pumping units such as raw water intake pumps.

a. Preventive maintenance of diesel engine

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.

Before start operation:

Operate the diesel engine at about 1,000 rpm for at least 5 minutes or until warm. This would allow the lubricant and coolant to circulate around the engine.

Every 8 hours operation:

Check coolant level, sump oil level, oil reservoirs, for oil, water or fuel leaks and clean oil bath cleaner.

Every 200 hours of operation:

- Drain and renew engine lubricating oil.
- Renew lubricating oil canisters.
- Check tension of drive belt.
- Clean fuel water trap.
- Lubricate dynamo rear brush.
- Clean air filter element.

Every 400 hours of operation:

- Renew fuel and air filter elements.
- Check hoses and clips.
- Clean lift pumps sediment chamber.

Every 2,400 hours of operation:

- Check and adjust valve clearances.

- Service injector units.

4.2.2 Electrical motor

Electric motors generally need less maintenance and are more reliable than diesel engines. They are therefore preferable as a source of power for pumping, if a reliable supply of electric power is available. The electric motor should be capable of carrying the workload that will be imposed, taking into consideration the various adverse operating conditions under which the pump has to work. If the power requirement of a pump exceeds the safe operating load of the electric motor, the motor may be damaged or burnt out. Attention must also be paid to the characteristics of the motor and the supply voltage.

There is sometimes a tendency to use general-purpose motors offered by the manufacturers without giving due consideration to the characteristics of the particular pump used. This results in frequent failure or burning out of the motor. The squirrel-cage motor is mostly selected for driving a centrifugal pump as it is the simplest electric motor manufactured.

4.2.3 General operation and maintenance for electrical motor

The most important items for good maintenance of an electric motor, aside from checking for bearing wear, are regular use, and keeping it warm (from operation), clean, and dry. Moisture is an enemy of insulation along with oil and dust.

Every motor should be operated for 5-6 hours at least every week. The longest useful life of a motor is obtained from a unit which is never shut down and cooled off, especially in a humid climate. Listed below are some maintenance tips.

Every Day:

- Check temperature of motor housing with hand.
- Check lubrication reservoir level.
- Check air vents for blockage.
- Check external wiring for frayed insulation or loose connections.
- Check voltage and current at each leg of the three phases.

Every Month:

- Check motor housing temperature.
- Check shaft alignment.
- Check input horsepower under load.

Every Year:

- Vacuum all dust out of windings and motor case.
- Drain lubricant, flush out oil reservoir with kerosene, and replace with factory-approved lubricant.

Every Three Years:

- Examine winding insulation for damage.
- Clean oil connectors and contact points with fine emery cloth.
- Inspect shaft and bearings for scour, wear or damage.
- Check input horsepower under load.

Table 16: General operation and maintenance of the motor

Description		Frequency	Method
01	Clean external surface of motor	Daily	• Blowing air • Wiping dust with a soft and dry tissue • Sweeping the dust with the brush
02	Examine earth connections and motor leads	Daily	Observation
03	Check temperature of motor and check whether overheated.	Daily	Temperature observation should be taken with Resistance Temperature Detector (RTD) or thermometer
04	Check the function of the oil ring lubricating bearing	Daily	Observation
05	Check for any abnormal Bearing noise	Daily	Hear the noise
06	Check belt tension	Monthly	Press the belt downward using the thumb and measure deflection with a ruler
07	Check insulation resistance	Monthly	Observation
08	Check condition of stator, stamping, insulation, terminal box, fan etc.	Annually	
09	Regular operation and maintenance records	Daily	• Record characteristics of the pump such as rating, model,

Description		Frequency	Method
			class of duty, class of insulation, efficiency curve • Record identity and address of the manufacturer • Record the date of installation and commissioning • Make records of monthly, quarterly, half yearly and annual maintenance and inspections about insulation level, air gap etc.
10	Checking the condition and maintaining the transformers, breakers, contactors and protection relays	Daily and Monthly	• Circuit diagram of breaker/relay circuit should be pasted on door of switch gear and additional copy should be kept on record. • Proceed to the regular maintenance and servicing of the components.
11	Check temperature of motor and check whether overheated	Daily	• Temperature observation should be taken with RTD (Resistance Temperature Detector) or thermometer
12	Wipe brush holders and check contact faces of brushes of slip-ring motors	Quarterly	If contact face is not smooth or is irregular, file it for proper and full contact over slip rings
13	Check insulation resistance of the motor	Quarterly	Observation
14	Clean winding of motor, bake and varnish if necessary	Half a Year	Clean, bake and varnish
15	In case of slip ring motors, check slip-rings for grooving or unusual wear, and polish with smooth polish paper if necessary	Half a Year	Check and polish
16	Clean and flush bearings with kerosene and examine for flaws developed, if any, e.g. wear and scratches	Annually	Clean and flush.

Description		Frequency	Method
	Immediately after cleaning, the bearings should be coated with oil or grease to prevent ingress of dirt or moisture		
17	Blow out dust from windings of motors	Annually	• Blow with clean dry air • Make sure that the pressure is not so high as to damage the insulation
18	• Clean and varnish dirty and oily windings • Re-varnish motors subjected to severe operating and environmental conditions	Annually	Cleaning
19	Clean external surface of the motor.	Monthly	• Use air blower machine to remove dry dirty • In case of oil and sticky dirty, use appropriate detergent and soft cloth
20	Examine earth connections and motor leads	Daily	• Closer observation

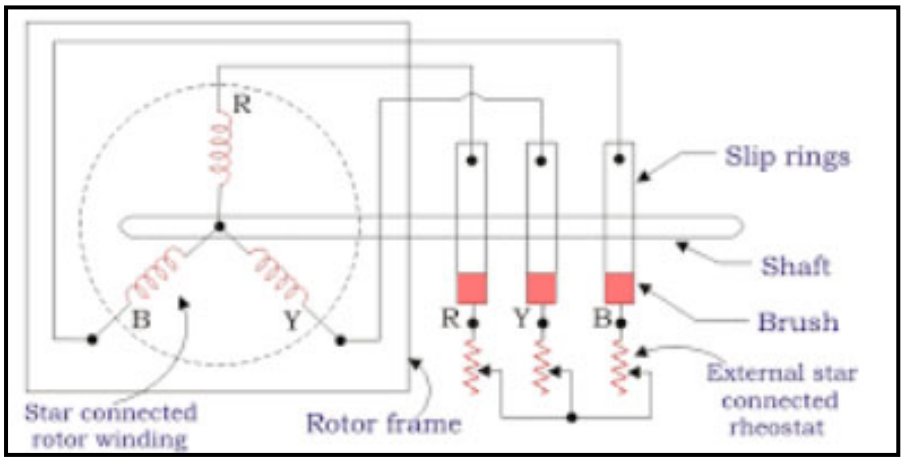


Figure 10: Image of a star connected rotor winding as part of electrical motor

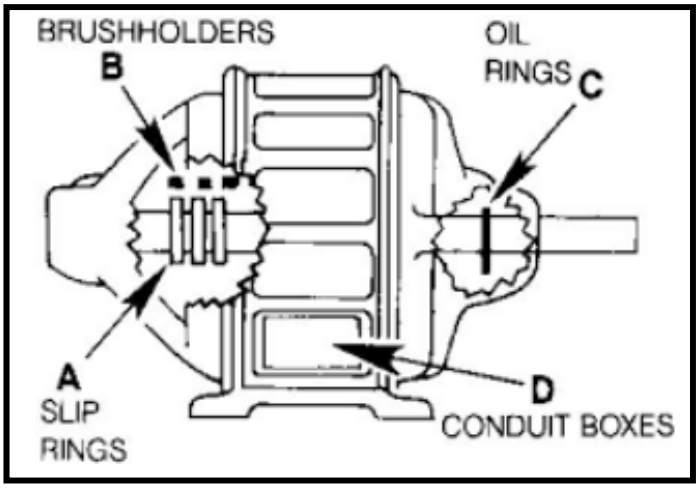


Figure 11: Slip rings and brush holders of electrical motor

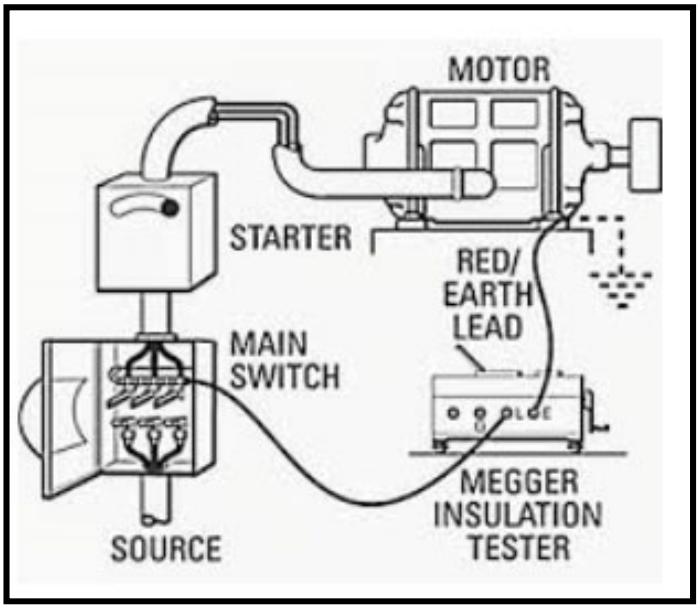


Figure 12: Motor insulation system

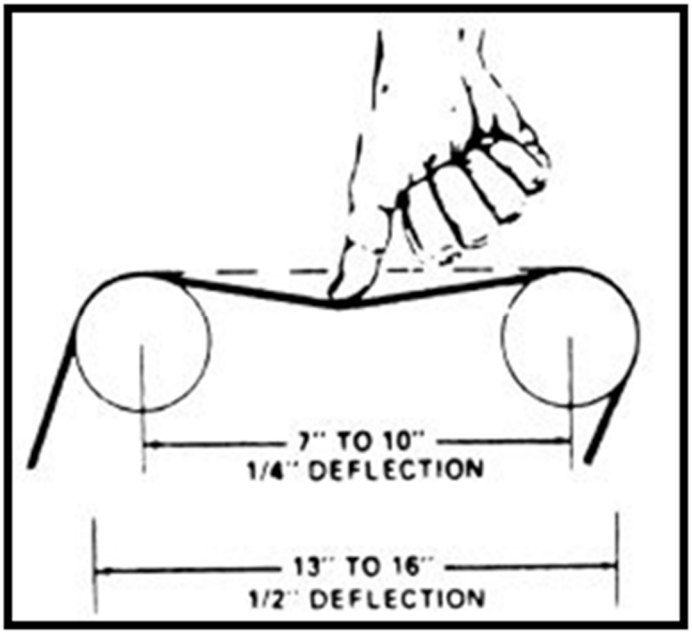


Figure 13: Checking of the belt tension with a thumb

5 Disinfection / Chlorination

Disinfection is the destruction (killing) or at least complete inactivation of harmful micro-organisms present in the water.

Drinking water is disinfected to kill bacteria, viruses and parasites, which may exist in the water and may cause illness and diseases like campylobacter, cholera, amoebic dysentery, giardia (beaver fever) and cryptosporidium. The disinfection of potable water is almost universally accomplished by the use of gaseous chlorine or chlorine compounds. Chlorine is easy to apply, measure and control. It persists reasonably well and it is relatively inexpensive. Other methods of disinfection are also available viz. ozone, ultra-violet light, chlorine dioxide, silver ionization etc.(GoI, 2013).

5.1 Methods

- Disinfection by chlorinated lime or bleaching powder ($Ca(OCl)_2$,$CaCl_2$,$Ca(ClO_3)_2$,H_2O)
- Chlorination by gaseous chlorine
- Electro-chlorinator
- Chlorination by calcium hypochlorite
- Chlorination by sodium hypochlorite (HTH)

Solutions should have concentrations between 5 and 1% of free chlorine, the latter being the most stable solution. Some 10% of the chlorine remains in the settled sludge. The following table shows quantity required to prepare a solution 1% of free chlorine.

Table 17: Dosage for preparation 1% of free chlorine solution

Compound	Available chlorine quantity	Quantity to make a liter of 1 % chlorine solution
Chlorine gas	100 %	0
Calcium hypochlorite	70-74 %	14 grams
Bleaching powders	34-37 %	30 grams
Sodium hypochlorite (HTH)	12-15 %	80 grams

5.1.1 Disinfection by bleaching powder

- Fill clean water in the dosing vat of capacity suitable for 24 hours requirement.
- Add bleaching powder in the dosing vats full of water
- Mix manually or Turn on a motor-reduction gear operated slow speed stirrer

- Let mix for at least 1 hour
- Stop the mixer
- Let sediments settle down. The precipitates of calcium hydroxide settle at the bottom of the vat.
- Open the taps and drain the supernatant in a new dosing vat.
- Inject the solution (supernatant) in raw water for pre-chlorination, in the storage reservoir as for post chlorination or inject chlorine in distribution system as break point chlorination.
- The injection is made by opening a gravity flowing pipe or using special dosing pumps.
- For effectiveness of chlorination, contact period of at least 4 hours shall be maintained

5.1.2 Precautions

- The Operator should use hand gloves, aprons and other protective apparel, while handling and mixing
- The valves, stirrer, tanks, plumbing arrangements require renovation at every 6 months.

5.1.3 Chlorination by gaseous chlorine

Normally, chlorine at a normal pressure is a toxic, yellow green gas, and is liquid at high pressure. Chlorine gas is released from a liquid chlorine cylinder by a pressure reducing and flow control valve operating at a pressure less than atmospheric pressure. The gas is injected in the water supply pipe where highly pressurized water is passed through a venture creating a vacuum that draws the chlorine into the water stream. Adequate mixing and contact time must be provided after injection to ensure complete disinfection of pathogens. It may be necessary to control the PH of water. A basic system consists of chlorine cylinder mounted with vacuum regulator, chlorine gas injectors, and a contact tank or pipe. Prudence or state regulation would require that a second cylinder and gas regulator be provided with a change-over valve to ensure continuity of disinfection. Additional safety and control system may be required.

5.2 Curative maintenance of DOSATRON

Curative maintenance of a DOSATRON is described table below.

Table 18: Curative maintenance of a DOSATRON

SYMPTOM	CAUSE	SOLUTION
Motor piston		
DOSATRON	The Dosatron is not on “ON”	Put the button on “ON”

SYMPTOM	CAUSE	SOLUTION
does not start or stop	Air has not been bled from unit	Bleed air from unit, by bleed button
	Maximum flow exceeded	• Reduce flow, restart unit • Return the Dosatron to your distributor
	Motor piston stalled or damaged	Return unit to your service center for repair
	Leak at the security	• Check or clean valve seal • Return the Dosatron to your distributor
No water at the outlet	Network pressure is not sufficient	Increase the pressure to more than 0.3 bar
Injection		
Water flowing back into concentrate container	Contaminated, worn or missing check valve parts	Clean or replace it
No suction of concentrate	The piston motor has stopped	See motor piston section
	Air leak (inlet) in the suction tube	Check the tightness between nut and suction hose
	Blocked suction tube or clogged strainer	Clean or replace it
	Missing or worn suction check valve seal	Clean or replace it
No suction of concentrate	Missing or warn plunger seal	Clean or replace it
Under injection	Worn injection stem	Replace it
	Suction of air	• Check the tightness of the nuts in the injection area • Check suction tube
	Dirty or worn check valve seal	Clean or replace it
	Maximum flow exceeded (cavitation)	Reduce flow
	Worn plunger seal	Replace it
	Worn injection stem	Replace it

SYMPTOM	CAUSE	SOLUTION
Leak		
Leak between motor part and injection part	Injection sleeve seal is damaged or positioned incorrectly	Replace it
Leak between the adjusting nut and the blocking ring	Injection stem seal damaged, positioned incorrectly or missing	Replace it
Leak between pump body and top cap	Top cap seal is damaged, positioned incorrectly or missing	Unscrew the top cap, clean the seal seating and replace or change the seal. Position correctly the top cap.

6 Transmission Line

6.1 Transmission by gravity through channels

6.1.1 Maintenance of unlined canal transmitting raw water

- All grass should be scraped and weed removed from the silted bed.
- Silt deposited should be removed.
- Bed should be levelled and their gradient regularized.
- Berms should be kept straight by trimming.
- Flow meters should be installed at the head and tail of canals at important points in between. Then the reading should be observed and recorded daily.
- Both edges of the bank especially the inner one should be neatly aligned and should be free from holes, weeds.
- Ensure there is no Seepage through the banks.

6.1.2 Maintenance of lined canals transmitting raw water

- Cavity or pockets or any activity detected behind the lining should be carefully packed with sand or other suitable material
- Care should be taken to ensure that the lining does not get damaged or displaced
- Damaged portion of lining should be removed and replaced with fresh lining of good quality by preparing a thoroughly compacted sub-grade before laying fresh sub-grade
- The cracks in the lining should be filed with standard sealing compound. An effective sealing may be obtained by cutting 'V' groove along the face of the cracks before filing with sealing compound
- Seepage through embankments if any should be observed from time to time and remedial measure should be taken.
- Silt deposition if any noticed should be flushed out when the water is silt free.
- Aquatic weed growth if observed below the supply level should be removed. Land weed growing over the free board should also be controlled.
- Canal banks should be inspected for seepage condition at the outer slope and for some distance beyond the toe especially in high fill reaches.

6.2 Transmission line in pipes

6.2.1 Frequent problems of transmission pipes

- Clogging
- Punctures and leakages
- Air entrapment
- Water Hammers
- Lack of documentation (Plans, history)
- Water quality deterioration

6.2.2 Preventive maintenance of the transmission line through pipes

Develop and conduct a surveillance programme for leaks in pipelines, pipe joints and valves.

i. Develop and conduct a water quality surveillance programme.

ii. Develop and conduct a programme for locating and repairing leaks including rectifying cross connections if any, arrange for flushing, cleaning and disinfecting the main transmission,

iii. Establish procedures for checking and optimizing the safe water quality

iv. Servicing of valves, expansion joints etc.

v. Maintenance of valve chambers

The table below summarizes the schedule of main activities for the preventive maintenance of a transmission pipe line.

Table 19: Schedule of activities for preventive maintenance of a transmission pipe line

Description	Frequency	Methods
Scouring of pipeline	Monthly	• Flushing • Air scouring • Swabbing / pigging/ scrapping
Leakages control	Daily	• Work regularly along the pipeline and check if there is any leakage • Appoints informants to report eventual leakages • Replace aged gaskets • Control the acceptable pressure in pipelines

Description	Frequency	Methods
		• Check the erosion bared pipes and bury them in deep. Where not feasible protect them with a casing
Water quality monitoring	Daily	• Chlorine Residual Testing and injection
Records and reports	Daily	• Updated transmission system maps with alignment plans. Longitudinal sectional plans • Record of daily readings of flow meter at upstream and downstream end of pipeline • Pressure reading of the transmission system • Identification of persistent low pressure location along the pipeline • Record of age of pipes and fittings • Record on when the pipeline leaks were repaired or pipe changed and the cost of materials and labour cost thereof

a. Flushing method

Generating a flow of high velocity inside the pipe in order to washout the loose particles. The pressure to put in pipe depend on the nature of deposits to remove and the conditions of the pipes. The following table gives some recommendations:

Table 20: Recommended velocity and discharge during flushing through various pipes

Pipe diameter (mm)	Velocity (m/s)	Discharge (l/s)
50	1.3	2.70
75	1.6	7.20
100	1.8	15.00
150	2.2	41.00
200	2.6	83.00

(Trifunovic, 2014)

b. Disadvantages

- Large amounts of water used (particularly in large diameters pipes)
- The velocity increase in the pipe being flushed may disturb the flow and pressure pattern upstream of the cleaned section
- In areas with progressive corrosion, flushing offers only a partial improvement
- Not all parts of the distribution system may be equally suitable for the generation of high velocities (e.g. in low pressure areas) (Trifunovic, 2014)

c. Air scouring method

In situations where water quantities available for pipe cleaning are limited, air scouring can be used as an alternative method to flushing. By this method, compressed air is injected into a continuous flow of water. Pushed by the air, the water will form into discrete slugs forced along the pipe at high velocities. (Trifunovic, 2014)

d. Mechanical cleaning

This method includes swabbing, pigging or scrapping in which an abrasive object is inserted into a pipe and driven along by the water pressure, pushing the deposits ahead or a hard tool is used to strum off the sediments from the pipe.

6.2.3 Curative maintenance of the transmission pipe line

- Repairing of broken pipes
- Disinfection of pipeline in case of deterioration of water quality
- In case of air entrapment, operate the air valve located at that point if there is no air valve, washout the section affected and adjust the bed slope of pipes.
- If there are water hummers in the pipeline, it is an indication that the pipeline needs the installation of an anti-ram vessel or the installed anti-ram is not functioning correctly. One of the frequent issues of anti-ram is the inadequate air pressure. If this is the case refill the anti-ram vessel with the air.

7 Storage

7.1 Storages facilities

Different types of tanks are constructed in concrete, stones, bricks, metallic and polyethylene. The purpose of storing water is to meet the flow demand and to accommodate the period of interruption of production. Storage tank are normally located in relatively high points. They are equipped with a single inlet, but mostly outlets pipes are more, depending on the branches to serve.

7.2 Frequent problems of the storages tanks

- Accumulation of dirty on the bottom due to settlement of suspended materials
- Leakage due to cracks in the walls
- Leakages in the fittings
- Security of the access trapdoors

7.3 Operation of the service reservoirs

The activities of operating a water reservoir have the main objective of matching the storage capacity of that reservoir with the water demand in the command area.

The distribution of consumption over 24 hours is as follows:

- Between 11 pm to 4 am: in general, there is no consumption. This is the time to store more water.
- From 7 am to 10 am: the consumption is considerably increasing.
- From 11 am to 2 pm: the consumption decreases a little.
- From 5 pm to 8 pm: peak time. The consumption is at highest level.
- In general, we have 8 hours during the day where the consumption is high comparatively to production. This is the time the water system needs to use the storage water to supplement the water production.

Activities of operation of a water reservoir

- Opening, closing, handling, adjustment, settlement of inlet and outlet valves
- The maximum water levels to be maintained in the Storage Reservoir at each morning should be known to ensure that the system demands are met for the day. Usually water levels are read at the same time each day and the readings recorded.

Inspect regularly the quality of water in the reservoir. Reservoirs are good places to test the quality of water distributed in the network because they are open and then allow sampling and

naked eye observation for potential sediments, rust and chemical precipitates. The smell of water can also tackle from the reservoirs.

7.4 Preventive maintenances of storage reservoirs

- Handling and oiling trap doors
- Cleaning and washing the surfaces of the tanks
- Cleaning aeration chimneys and adjusting / replacing mosquitoes mesh
- Use the access ladder to climb over the tank instead of hooking and treading the fittings.
- Avoid prolonged stay of water in the tank as it putrefies and gives a bad odor
- Prevent access to lizards and rodents in tanks because after a time they swamp and die in the water.

The following table summarizes most performed action for preventive maintenance of the reservoirs

Table 21: Methods and strategies of maintaining the water reservoirs

SUBJECT	ACTION
GENERAL	Check if the name of the valves and piping such as washout, inlet, outlet, by-pass, overflow is be painted clearly and repaint if necessary.
TANK outside	Check the appearance and seals and clean if necessary. Check that there are no threatening erosions around the facility. Fix what does not need a mason, otherwise report and propose action.
MASONRY	Control the appearance and coatings and sealing; clean if necessary.
COVER / SLAB	Check corrosion and grease hinges if necessary. If corrosion propose action.
INLET Pipe, flow limiter, float valve	Check if there are no roots in the pipes, scrape deposits. Check inlet, the operation of float valve (adjust if necessary). Dismantle the coupling and clean up.
VALVES: Inlet, Outlet, By-pass	Check the operation and clean all valves and fittings.
VENTILATION	Verify the free passage of air and the prevention of access of water and detritus from the outside. If corrosion propose action.
OVERFLOW	Check free passage of water and protection against access of water and detritus from outside. Check status of fittings and valves.

SUBJECT	ACTION
DRAIN or WASH OUT	Check status. Maintain against erosion. Check status of fittings and valves
LADDERS	Check the condition and clean. Propose action if corrosion appears.
WATER METER (if present)	Calibrate the water meter at the discharge side of the reservoir by closing some time the flow to the reservoir and measuring the decrease in water level, multiply it with the surface of the reservoir and compare the volume with the registration of the water meter at the beginning and at the end of this operation. Alternative: calibrate the water meter with the help of calibration equipment if available.

7.5 Emergency maintenance of storage tanks

- Repairing the fissures in wall or in the base of the tank
- Scratch and remove the existing internal coating all along fissure
- Prepare a cement mortar of 350 kg/m^3
- Apply carefully the mortar
- Smoothen the surface
- Keep the surface wet after one day

8 Distribution System

8.1 General

8.1.1 Common issues in the distribution systems

8.1.1.1 Intermittent System

A water supply system is intermittent when the supply is not continuous. This causes several problems such as:

- Storage structures which are not always wet are likely to experience cracks.
- Consumers are urged to store water in unsafe containers and that affect the quality of water
- Taps are left open and when the supply resumes unexpectedly, there is wastage of water
- Operators are confused for proper handle of valves in order to ration available water

8.1.1.2 Low Pressure in the network

There are various causes of low pressure in the network including:

- Inappropriate setting of valves
- Insufficient water flow due to production drop or the high peak consumption rate

8.1.1.3 Leakages

Leakages occur in failure of joints or broken pipes. That may be a result of poor quality materials, bad installation, aging, mechanical chocks, high or negative pressure, corrosion and vandalisms.

Leakages cause huge physical water losses, drop of pressure in pipes and water quality deterioration.

8.1.1.4 Unauthorized Connections

The issues with unauthorized connections are that:

- They disturb the normal hydraulic functionality of the network as they connect from inappropriate junction points.
- They don't save water then deprive water from authorized connections.
- They harm the water quality in pipelines
- They damage existing installation, breaking pipes and introduce materials of poor quality.

8.1.1.5 Extension of Service Area

Extension of services area leads to overloading of the previous pipes sections then the loss of pressure.

8.1.1.6 Aging

Aged pipes bring out several complications such as:

- Frequent punctures
- Metallic corrosion thus reducing the internal pipes 'section and polluting the water quality
- Difficult to repair and to fix new connections

8.1.1.7 Lack of records

The efficient maintenance of a water network is grounded on the information drawn from design, as built drawings, map, history of breakdown, repairs and maintenance, fittings arrangement, function schedule, transited discharge... however most of the time such kind of data are missing.

8.1.2 Field inspection

Inspection of a pipeline requires walking along it while observing conditions of pipelines protection structures (columns, anchor blocs, casings), potential leakages, vandalisms, unauthorized connections, erosions, land sliding, roots of trees, ponds of waste waters in the ways of pipes, and others elements which may hamper the condition of pipelines.
Normally pipes are laid deep between (1.00 m and 1.20 m).

In case of leakage, not always water flows at the ground surface. Sometimes the leaking water flows in ground and goes to find outlet far away from the leaking point. If you find an abnormal soil humid or coldness, introduce a soft wooden stick in soil and check if get wet. Also loss of pressure or the drop of flow rate are good indications of leakages in line.
If an obstacle or other object harmful to the function of the pipeline is found, plan to remove it as soon as possible.
It is advisable to regularly take the pictures because they give a memory of day to day site conditions, the location of an event, but also pictures may contain information that you couldn't discern before.

8.1.3 Routine operation of the distribution system

- Opening, handling, servicing and closing valves
- Monitoring and adjusting pressure in pipes for proper hydraulic functionality
- Releasing entrapped air
- Measuring, monitoring of transited flow rate and proper rationing

8.1.4 Preventive maintenance of the distribution system

Distribution system is the main way to transit water to the consumers. It thus deserves careful operation and maintenance actions. The frequency and technique used for maintaining distribution systems are described in the following table.

Table 22: Activities, frequency and techniques for maintaining a distribution system

Actions		Frequency	Methods
01	Mapping, design and drawings	When there is a change	• Collect as built documents from the District and make update every time there is a change • If maps and drawing are not available, conduct your own survey using GPS, theodolite and informants • All details to be depicted in the drawings including: i. Depth of pipes ii. Slope of pipes iii. Surface ground iv. Section and material of pipes v. Design flow and pressure vi. All connections vii. Other buried or exposed objects near the pipes viii. Location of flow meter, water taps, valves and pressure gauge.
02	Keeping the records	Every day	• Regularly site inspection • Write each observation, history, observations details regarding: i. Working or stopping hour ii. Flow rate and pressure iii. Break down iv. Repairs details v. New extension connected
03	Tracking the working or	Every hour	• Go and observe if there is water passing through

Actions		Frequency	Methods
	stopping hour of the network		the water meter. Indeed, if figures in the water meter are not changing water is not passing. • Watch if water is reaching the tank installed in the line.
04	Tracking the flow rate	Once a week	• Take the reading of the water meter (in litres) go and read again one hour later • Subtract the previous reading from the last ones. • The result that you obtain is the flow discharge in litres per hour • You also can use a bucket and a chronometer at the inlet of the break pressure.
05	Records analysis	Every day	• Information regarding flow rate and pressure should be compared to the requirements or appropriate standards in order to decide for further adjustment.
06	Control of low pressure	Every day	• Don't leave a line valve partially open. Open it completely • Avoid too low water level in the service tank • Avoid failure of the pumps feeding directly the line • Avoid too high velocity in small pipes
07	Control of high pressure	Every day	• Avoid sudden valves closing which generate water hammer • Do never over pressurize pipes with the pumps • Operate and set correctly pressure release valves • Do never bypass a pressure balancing chamber or a pressure break tank
08	Prevention of Leakages	Every day	• Routine inspection of the pipeline for identifying potential dangers likely to damage the pipes • Adjustment of unsafely laid pipes • Protecting, covering and casing exposed PVC pipes • Control and adjustment of proper pressure in pipes • Slow opening and closing of valves • Quick replacement of suspected fittings or pipes
09	Prevention of unauthorized connections	Every day	• Regular survey along the pipelines • Balance the quantity of water injected in the command area and water billed • Easy policy of private connection

Actions		Frequency	Methods
			• Arrange loans for implementing private connections • Sensitization about consequence on public health, sustainability of the infrastructure and fines • Informants
10	Dealing with aged pipes	Every 6 months	• Reducing excess pressure in pipelines • Inspection and control for potential abnormal pipes behaviors • Gradual replacement of most aged pipes
11	Dealing with intermittent system	Every 3 months	• Maintain a unique unchanged supply schedule and communicate it to consumers • Motivate the operators of valves in lines for appropriate setting of valves for maintaining equitable rationing • Check in idle hours if all taps are closed.
12	Servicing pipelines	After repair	• Cleaning and maintaining supports (anchors blocs and columns), casings and valves
13	Prevention of clogging	Every 3 months	• Control the strainers at the beginning of pipelines, • Make sure that water is free from suspended materials, debris and sediments. • Washing out

8.1.5 Curative maintenance of the pipeline

In case of breakage of pipes, leakage in joints, problems in water flow quick actions are necessary to maintain or resume the supply of water to consumers. The table below provides some hints to check and correct such technical problems in water mains.

Table 23: Repairs of various problems occurring in water mains

Failure	Cause	Solutions
Broken pipes	Crack due to excess pressure	Replace the pipe with the one of adequate Nominal pressure.
	External Mechanical chock or corrosion	Cut and remove the damaged section. Then provide spare pipes and repair the section having the problem.
Leaking joints	The rubber is broken, damaged or aged.	Replace the rubber with a new

Failure	Cause	Solutions
		one
	Wrong joint installation	Revise the pipes connection
	Slipping pipes due to excessive slope	Put anchor block to stabilize pipes.
Clogging	Deposits	Flush or washout pipes
	Invasion of trees' roots in pipes	Cut and uproots the trees, mostly the species of Eucalyptus surrounding the pipes. Repair the affected section of pipes.
	Bottle neck in glue joint	Dismantle pipes joint and redo it using small amount of glue
Flow anomalies	Entrapped air	Operate the existing air release valve, Check the need of an additional air release valve and install it.
	Inadequate control valves setting	Set the control valves appropriately.
Water hammer	Inappropriate provision of anti-ram	• Check and recharge the existing anti-ram vessel with air. • Install an anti-ram system if there isn't any.
	Sudden manipulation of flow control valves	Careful manipulation of the flow control valves
Collapse of pipes	Failure of support columns or anchor blocks	Reconstruct
	Casings of the pipes are broken	Provide new casings.
Unauthorized connections	Healthy installations without meter	Provide a water meter and record the connections
	Unhealthy installations	Cut the connection and redo it properly
Unearthing	Erosion and land slide transportation	• Dig again the trench according to the pipe size and regulation • Level the trench and make appropriate slope • Prepare the bed of the pipes with a layer of sand • Lay again pipes and back fill • Protect the area with erosion preventive grasses

8.1.6 Standard pipes repair procedures

- Identify or locate the vanishing point
- Dig out the pipes. The length to unearth should be enough to allow the movement of existing pipes.
- Determine the nature and the size of the pipe: if it is not mentioned on the map of the network one must measure it with a rule. Normally pipes may be made of Poly Vinyl Cloride (PVC), Poly Ethylene (PE), Galvanized Steel (GS), Ductile Iron, and Asbestos Cement (AC). Asbestos and Cast Iron pipes are uncommon.
- Determine pipe connection method and repair parts: Common repair methods use: rubber joints, Glue Seals, merchant couplings or weld repair sleeve for Galvanized Steel, repair clamps, dismantling joints for DI and other bigger pipes.

<table>
<tr><td>  </td><td>  </td></tr>
<tr><td>Steel repair clamp</td><td>Steel repair sleeve</td></tr>
<tr><td>  </td><td> 
</td></tr>
<tr><td colspan="2">Merchant couplings</td></tr>
</table>

- Cut and remove the damaged section of pipe
- Carve both edges from either side of the cut pipes

a. For PVC glue joints

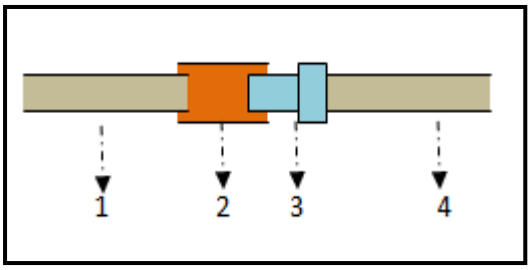
- Clean the edges of pipes as well as the inner sides of the repair socket with appropriate cleaner spirit
- Apply the glue around the edges of the pipes
- Let it exposed to the air for a while (5 minutes)
- Enter the edges of the pipes inside the repair socket
- Let it solidify for about 4 hours
- After solidification inject water inside the line to rest the tightness of the repaired section.

b. For rubber ring pipes

- Clean and lubricate the notches of the repair socket
- Lubricate and insert the rubber ring inside the notches of the fast repair PVC socket
- Push in the edges of the pipes inside the repair socket

c. For steel pipes using merchant coupling

- Thread both ends
- Wrap/ roll around the threaded ends with several layers of Teflon.
- Insert one threaded end of the pipes inside the merchant coupling and fix it
- Insert a union into the second end of merchant union
- Fix the other end of the union to the remaining threaded end of the pipes
- Using union during repairing of a Galvanized steel pipe is a cheap but not sustainable solution.
- The best solution is a dismantling joint or welding a repair sleeve.



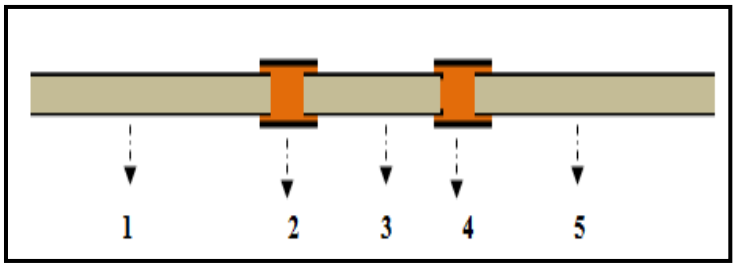
Legend

1&4: Pipe to repair

1 : Merchant Coupling

2 : Union

Figure 14: Schematic illustration of a typical GS pipe repair using merchant coupling



Legend

1& 5: Existing Pipe to repair

2& 4: welded steel repair sleeve

3: Spare pipe piece

Figure 15: Schematic illustration of a typical GS pipe repair using a repair

d. Using dismantling or Johnson joint

Dismantling joints or Johnson joints are used to repair rigid pipes. Dismantling joints are recommended to repair larger size PVC pipes, larger size High Density Polyethylene Pipes, Steel pipes bigger than 2" and all Cast Iron pipes.

e. Process:

- Cut and remove the damaged section from the pipe to repair.
- Trim both ends of the cut pipes
- Cut a spare piece of the pipe to insert in the removed part. The length should be 2 cm shorter than the removed section.
- Rig out the spare pipe piece with the dismantling joints at both ends
- Put the spare pipe piece inside the empty space to repair.
- Slide the dismantling joint in the junction of the existing pipe and the repair part.
- Tighten the dismantling joint through fastening the screws.

Dismantling joint is an easy but expensive solution. Attention should be taken during carving of the broken pipes. Similarly, a small mistake in measuring the spare pipe piece may spoil the achievements to good result.

8.1.7 Optimum records information

- Updated map, drawing, fittings arrangement and operational manuals of the water infrastructure
- Readings of pressure and flow rate at various points
- Age and condition of pipes for various sections
- Planed actions for different sections of the pipeline
- Number of connections their descriptions and locations
- Identified unauthorized connections

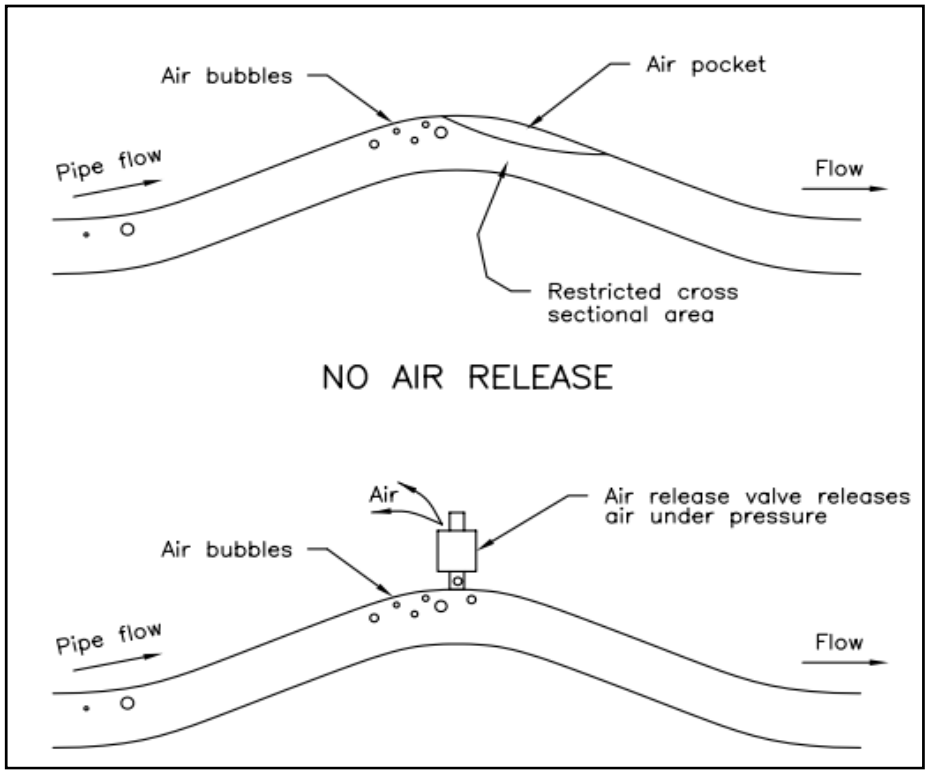
- Condition of water meter in private connections
- Repairs to be conducted in private connections
- Location of water meter and their conditions
- Leak points and causes
- Residual chlorine level in different points of the network
- Bacteriological quality as tested in different points
- Inventory of activities conducted separately for repairing and for inspecting the network as well as their respective costs
- Complaints from customers.

8.2 Air release valves

8.2.1 Necessity of air release valve

Air release valves or air relief valves are the devices installed in the higher point of the pipeline in order to enable the evacuation of the air pockets from flowing water. The exhaust of air from the pipeline is needed to avoid water hammer and to increase water flow efficiency.

The main origins of air in water are pumps, change of water temperature and change of pressure. Also during the drainage of the pipeline air enters into the line through the valve or different openings. The following pictures give scenario of air accumulation and releasing from pipes.



(Missouri Livestock Watering Systems Handbook)

Figure 16: Releasing air from the pipeline

Figure 17: Picture of an air release valve

8.2.2 Aging and breakage problem

Air valves should be inspected at least once a year. Given that some air valves are installed in remote and inaccessible places, they are exposed to the risks of vandalism damages and wear. Also some air release valves are buried so that during heavy rainfall they are flooded causing silting.

Other problems include: Leakage, clogging and admission of air into the pipe under low atmospheric conditions.

8.2.3 Operation and maintenance of air release valves

According to the Guidelines of operation and maintenance for PO and District, the following actions should be controlled for the optimum operation of an air release valve of a water scheme:

- Check outside masonry and inside of manhole.
- Ensure that water can infiltrate through the bottom into the sump.
- Check the status of the metallic cover / slab and good closure.
- Check if there are no leaks
- Operate the stop valve.
- Unscrew the cap on the head, to bring forth some water.
- Let out the air and dust.

- Close the cap

8.2.4 Curative maintenance of air release valves

Frequent issue of the air release valve is leakages: Leakage on the air release valve may be due to bad position of the ball, when the gasket is damaged or the cause may be abrasion of the ball itself. In both cases, the remedy is to replace the damaged parts.

8.3 Washout

Washouts are the points where water from the network can be forced out. This require the manipulation of the valves provided for that purpose in order to reject water from pipelines towards artificial rejection basins, the natural streams or any other water ways.

8.3.1 Role of washouts in the network

Washouts are necessary as the help cleaning deposits thus contributing to the maintenance of water quality. In addition, washouts allow the elimination of solid intrusions that may hamper free flowing of water inside pipelines. Washout are also required to facilitate the pipes repair and other operations on pipes, as they the water contained in the pipelines is exhausted through the washouts and the work is performed in a more flexible dry medium.

Figure 18: Soak away / tail end of a washout

8.3.2 Operation and preventive maintenance of washouts

According to the Guideline of Operation and maintenance for PO and District, the following actions should be controlled for the optimum operation of a washout of a water scheme:

- Check outside masonry and inside of manhole.
- Ensure that water can infiltrate through the bottom into the sump,
- Check the status of cover / slab and good closure.
- Ensure that the pipe toward soak away pit is in good conditions and well protected
- Control, clean and maintenance the structure at the drainage tail end.
- Test the condition of the pipes support for pressure balancing.
- Handle and manipulate regularly the valves of the washout. This will help to unclog the pipes, preserve safe water quality.

8.3.3 Curative maintenance of washouts

Frequent problems of the washouts include the clogging, give way of fittings or supports in concrete, rusting of valves, leakages, water stagnation, and collapse / cave-in of the chamber.

If the washout is clogged cutting the flow of water in the line, it may due to deposits in lower point. Thus, dismantle the valve and adjacent pipes clean them from dirty and deposits and install them again.

In case of rusting valves, handle it through repeated open and close exercises until you fill it is to perform 3 turns freely. If there is no success, remove and replace it.

Flooding or water stagnation: Most of washouts are constructed in lower point valleys, where water logging conditions are most likely to happen. In such hazards, execute an open trench to drain water from the chamber / box toward the existing water way.

Leakage in the washout may occur due to dislocation in the junction of the fittings or in the damage or failure of the valve. Check if the problem is dislocation in fittings and fix them properly, otherwise replace the valve.

As the washouts are constructed in lower valleys, they may be flooded or buried by runoff sediments thus causing collapse of the masonry box. In such cases, the masonry is to be reconstructed in hardcore not in bricks and coated whit a strong mortar (1:3 cement sand mix ratio).

Due to high pressure in valley, the support anchors of pipes and fitting of washout may give way. It is recommended to regularly check the conditions of the supports in lower points with high pressure and reconstruct the new ones if the firsts are destroyed.

8.4 Pressure relief boxes with float valve

In rural areas, the pressure relief boxes of the water schemes implicate mainly;

(i) the reservoirs commonly known as balancing chambers which break pressure built-up inside pipelines due to drop in site elevation in limited cases.

(ii) the manholes harbouring the pressure control valves can be installed in the lines.

8.4.1 Operation and maintenance of pressure relief boxes

The operation and maintenance of a pressure relief box requires activities such as the general inspection of the condition of the reservoir as well as the free movement of installations every month.

- If there are leaks or broken parts, they should be repaired.
- Check the function of the float valve once per week.
- Clean dirty and deposits from components parts of the float valve in order to prevent blockage.
- Check the junction of the float valve to the inlet pipe at least once per month.
- If there are fissures in the walls, they are to be repaired with a mixture of one measure of cement per three measures of sand.
- The inlet, outlet and washout pipes and other connecting appurtenances should be controlled.
- In case any leak is detected, it should be repaired immediately.
- Ascertain if the float ball completely closes the valve. This can be ensured by handling it in open and close positions.
- Look if the float ball is water tight without any cracks or holes, so that water can't access inside the ball.
- The position of the ball on the rod can be enlarged or shortened by screwing in or unscrewing it from the rod.

8.4.2 Curative maintenance of pressure relief box

The main issue of a pressure release box is the functionality of the float valve mechanism.

- If there is leakage or blockage the reason can be corrosion, dirty or deposit. Thus it is recommended to dismantle the float valve, clean it and mount it again. Then repeatedly open and close the valve manually until a free movement is ensured.
- Puncture of the float valve: Seal it with glue paste. if the result is not good; replace it with the new one

- Distortion of the float beam: Check if the operating pressure fit with the manufacturer prescription. Straight it again with the help of adjustable and pipe wrenches
- Damage or loss of the hinge pin: Provide and install a new one.

8.5 Control valves

8.5.1 Types and role of control valves in the network

a. Control valves

Those are the valves which are installed wherever in the network to in order to regulate the flow and the pressure. They also are installed at the junctions where the branches or individual connections articulate to the mains. The purpose of such valves is to enable the control of supply or isolation of a connected branch / connection at any time required.

In most cases, the manholes harboring the connection control valves are larges in sizes depending on the number of connections hold in and the size of fittings installed. In general their internal dimensions vary from 0.80 m x 0.80m up to 2.00 m x 2.00 m.

b. Isolation valves

Sectioning valves are installed in the mainline to allow cut off of water flow for maintenance and repair, when there is breakage, water quality correction or any other works in the network.

Control valves box 1

Control valves box 2

Figure 19: Pictures of control valves installed in the water network

8.5.2 Operation and maintenance of control valves

- Cleaning for trash, mud, insects, rodents and stagnant water.
- The internal size of a valve control box must be enough (at least 0.8 m x 0.8 m for small dimension fittings up to DN 80) in order to allow the cleaning and operation activities.
- Handling and servicing the valves
- Check leakages
- Adjustment of the flow
- Security for locking the trap door

The following inspection should be regularly conducted on the valves:

- Locate the valve in the field.
- Check if the location is the same as shown on the drawing.
- Check whether the valve can be reached by men.
- Check if the key can be put on the valve to operate it.
- Control if the valve is in the right (open or close) position (the normal position).
- Check if the valve can be turned without excessive force.
- Check if the valve can be turned at least three times 360^{o}.
- Preferably it is checked if the section (the part of the network which is bordered by two or more valves) can be fully closed (take into consideration that the customers have no water for some time).
- Valves operated manually should be opened all the way, then closed one quarter turn to prevent the valve from sticking in the open position
- Valves should be opened and closed slowly at an even rate to reduce the risk of water hammer
- Unless otherwise indicated, valves are opened by turning the hand wheel or key counterclockwise; and closed in the clockwise direction

8.5.3 Curative maintenance of control valves

Frequent problems in the valves boxes are due to the fault of the valves or the structure of the boxes themselves.

Leaving valves idle cause rust and blockage. It is advisable to check control valves at least once a month. In case of broken or blocked valve, replace it. The valve is considered as blocked if it

cannot turn 3 round without forcing. The valve is said broken, if it cannot close, it cannot open or if it is leaking. In all cases broken and blocked valves are to be replaced directly.

In water scarce areas, the control valves boxes are damaged. Trap doors are forced by vandalisms acts as some people want to keep themselves supplied regardless of the flow distribution that the operator has set. In case of such kind of vandalism, it is recommended to cover the boxes with heavy reinforced concrete blocks.

9 Customer Connection

9.1 Customer connection

9.1.1 Need for inspections

Individual connections deserve special follow-up by private operators because most of them are new with regards to water usage and management. They thus need guidance on handling water installations, saving water and safe care of water. Water meters, water faucet and service valves are weak and breakable fittings which once installed in the house hold require proper inspection for potential damage or breakage in other to avoid huge water losses. In addition, some individuals may be dishonest with low willingness to pay for water. They thus are attracted to install bypass pipes before water meter in order to draw free water. The purpose of inspection is to prevent such hazard in order to safely supply water at the satisfaction of the consumers and in the limit of affordable cost.

9.1.2 Major issues

- Illegal connections
- Water theft / robbery through bypassing
- Unmetered connections
- Unclear figures in the water meters due to opaque protection glasses
- Aged or faulty meters
- Poor installation in the junction to the main line
- Poor quality of materials or works during connection
- Unbalanced service pressure and flow rate among households
- Misrule in the process of request and implementation of the new connections

9.1.3 Routine operation and maintenance of customers connection

- Inspection for leakage and functionalities of junctions to the mainline and installation in the households
- Make sure that the meter and the water faucet are protected by a box in wood or metallic materials.
- Call users of each household to maintain tidiness of water faucets and water meters.
- Take users accustomed to inform for any leakage or other service problems.
- Keep update the meters inventory,
- Read records of all meters at least once a month.

- Test and calibrate suspected / inaccurate meters. To test a meter, one can use a gauged bucket and a chronometer. Several meters have a seep hand, 1 complete rotation equals 10 litres.
- Set / adjust connections control valves for governing the delivered quantity and pressure.
- Clean, and handle the Key hole boxes.
- Checking the illegal connections, bypass and water theft: Go in the connected water house. Open one taps and let water flow for a time. Check if the meter is turning. If the water is flowing and the meter is not turning. It may a proof of bypass connection or faulty meter. Explore the prevailing installation and the functionality of the meter.
- Check the installation of the water meters. Some customers, in the attempt cheat the water invoices, after the day of meter readings by the operator; they shift the installation of the meter and put it in reverse position. It is recommended to inspect the meter position unexpectedly.

9.1.4 Curative maintenance of customers connection

a. Low service pressure or quantity

Low pressure and insufficient flow to the individual connections may be due to;

(i) improper adjustment of the control valve,

(ii) the number of connections is overloading the design capacity of pipes or

(iii) accumulation of deposits in the pipes.

The remedy is:

(i) Readjust properly the control valves' according to the required pressure and quantity.

(ii) Flush out deposits from the pipes

(iii) Replace existing pipes with the pipes of the capacity matching the water demand.

If water is found dirty or inadequate quality (odor, contaminants) due to intrusion, pipe punctures, the solution is to washout the water from pipes for a while, let the pipes be cleaned and then resume the service.

b. Leakage:

Once a leakage is identified in at individual connection, the first step is to isolate the connection through closing the control valve at the junction to the main line. Repair the leakage using standard quality materials then open the control valve to supply again the connection. The first water must be flushed out as the quality may not be safe due to intrusions.

Here are steps for the correction of a dripping water faucet:

a) Close the water flow with the ballcock.
b) Unscrew with an adjustable wrench the superior crown of the water faucet.
c) Check the gasket at the end of the stem. If it is worn out or torn, change it, take out the fastening screw and install a new gasket
d) Place and adjust the crown with the item and verify its functioning opening the ballcock

9.2 Water meter

9.2.1 Introduction

Size of domestic water meters range from 3/4" to 2" while bigger size are for the meter installed in the main pipelines, at the pumping station and at the treatment plant to measure bulk water.

Problems of water meters may bring out to complete stopping, improper records, breakage and water quality deterioration.

9.2.2 Major issues of water meter

The main factors of problems are:

- Over aging: Normally the life span of a water meter is 10 years. Beyond that period water meters should be replaced.
- Wrong manipulation or purposefully reverse installation by users in attempt to cheat the water bill
- Darkness of the cover glass
- Clogging of strainers, rusting and solidification of component elements

9.2.3 Operation and maintenance of water meter

- Dismantle the water meter and clean inside to remove entrapped dirty and free the strainer from dirty every 6 months.
- Control the condition of the water meter (leakage, breakage, installation slope, ...) and replace damaged parts such as gaskets, protection glasses, strainer ... every 6 months. During such activities, handling the meter gently avoiding jerks, transport and store the water meter in a soft medium
- Meters should be protected. Aerial meter should be covered with wooden or metallic boxes and closed with a padlock. Ground meters should be harboured inside man holes chambers.

Those chambers are to be protected against flooding, seepage or water logging. Clean the chambers once in three months.

- Clean the meters, the cover glasses and the chambers once in three months
- Replace all meters aged over than 10 years
- Verify the installation of water meter once a month and adjust it if necessary.

9.2.4 Curative adjustment and reparation of water meter

Defected parts observed directly on site such as broken glass, cover, or wiper must be replaced.

If the meter has stopped working, remove it and take it to the appropriate meters repair workshop.

9.3 Padlocks, steps, handgrips, metal lids, etc.

Padlocks help for tightly closing the trap doors of the chambers, and water taps as well as the doors of the kiosks, the rooms in the treatment plants and in pumping stations.

Most of the padlocks vanish quickly as they are exposed to the outside rains and sun. Common problem with padlocks is the difficulty to open or to close.

The maintenance of a padlock deals with inspection of functionality. The inspection should be as frequent as once a month. At the time of inspection, proper lubricants such as motor engine oil or cooking oil should be applied to prevent blockage. During verification tour, vanished padlocks should be removed and replaced.

Steel Hand grips, Steps and lids are inserted in the walls of reservoirs and chambers to allow access. After a certain time, those steps take rust or they loosen from the walls holders. The condition of the ladders / steps should be checked every year:

- Check presence of rust and if it start attacking the metal clean it with the metallic brush, or sand paper and apply an anti rust paint.
- Check the firmness or strength of the steps in the wall. If some are loosening, reinstall them again.

9.4 Fast joint repair

9.4.1 Use of fast joints

Fast joints are used to repair the broken pipes in easy and quick ways. The fast joints are a solution for pipes laid in a location where it is difficult to dig such as in the streets and where a quick intervention is required after a pipe burst in order to resume the water supply.

a. Advantages:

- It is not necessary to discover long pipes section for carrying out the repair, especially when the pipe is larger than 2 inches of diameter and it is not needed so many persons to do the repair or digging the ditch.
- Less time is used to repair the damage in the pipes.

b. Disadvantages:

- Higher cost than the traditional method.
- It is not easy to find them in the local market or little municipalities.

9.4.2 Method and procedures for fast joint repair

- Dig out the broken section of pipe
- Cut and remove the broken section from the existing pipe.
- Trim and clean the ends of pipes to connect
- Prepare O-rings for the installation,
- Introduce the O-rings in the fast joint,
- Place the joint rapidly, first, placing it in an end and then living it up for joining both ends.

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