Annex 3.32
Training Material for Leakage Detection in Spring 2017

In the Name of Allah the Most Beneficent, the Most Merciful

Current Scenario of Leak Detection at WASA's

By
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Water Specialist

February 2017

What are your Training Expectations?

Outline of Presentation

- Basic knowledge of Leak Detection
- Water Network Maintenance and Leakage Detection
- Types and Sounds of Leakage
- Factors causing Leakage
- Existing situation of Five WASA's for Leakage Control

Basic Knowledge of Leakage Detection

Day 1

- Current Scenario of Leak Detection
- Countermeasures for Leakage Control
- Leakage Survey Equipment
- Repairing of Burst Pipeline

Water Network Maintenance & Leakage Detection (OJT)

Day 2

- On Site Leakage Detection
  - Acoustic Leak Detector
  - Acoustic Bar
  - Non Metal Pipe Locater
- Visit of Leakage Repairing Site (Green Town, WASA Sub Division)

Installation & Operation of Leakage Detection Equipment (OJT)

Day 3

- Equipment Installation & Operation

  - Metal Pipe Locator
  - Ultrasonic Flow Meter
  - Pressure Recorder

Site Visit and Leak Detection Action Plan

Day 4

- Visit of Plasco Pipe Industry, Gujrat

Day 5

- Preparation of Leak Detection Action Plan by Training Participants

Learning Outcomes

- Build Basic Knowledge of Leak Detection through use of the Leakage Detection Equipment
- Understand Installation and Operation of Equipment(Pressure Recorder, Ultrasonic Flowmeter etc.)
- Develop Leak Detection Action Plan

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Current Scenario of Leakage Detection

- Introduction to Leakage
- Types and Sounds of Leaks
- Factors Causing Pipe Leakages
- Situational Analysis of Leakage Detection in Five WASAs

Course: Leakage Detection and Repair-W 7231

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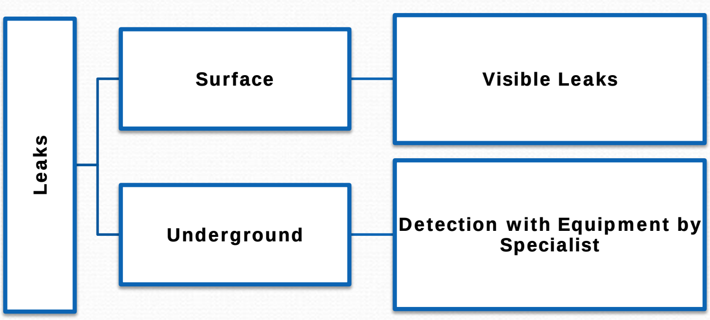
Water Balance

System Input Volume	**Authorised Consumption**	Billed Authorised Consumption	Billed Metered Consumption	Revenue Water
			Billed Unmetered Consumption	
		Unbilled Authorised Consumption	Unbilled Metered Consumption	Non- Revenue Water (NRW)
			Unbilled Unmetered Consumption (e.g. flat rates not billed)	
	Water Losses	Commercial (Apparent Losses)	Unauthorised Consumption (e.g. illegal connections)	
			Metering Inaccuracies	
		Physical (Real Losses)	Leakage on Transmission and/or Distribution Mains	
			Leakage and Overflows at Utility's Storage Tanks	
			Leakage on Service Connections up to point of Customer use	

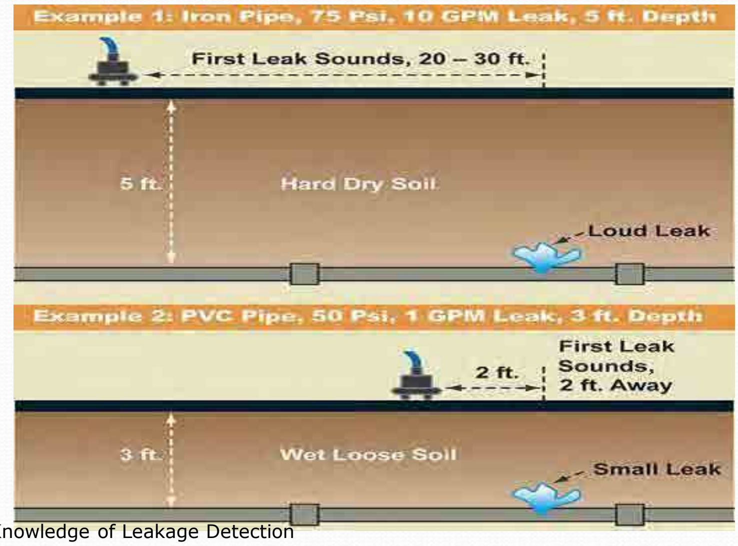
Types & Sounds of Leakage



Leak sound depends on:
- Pipe Diameter
- Material
- Kind of Joints
- Leakage Flow
- Depth
- Soil Density

False Leak sound:
- Water flow sound
- Sewage flow into manhole
- Breeze sound
- Driving Vehicles Sound
- Urban noise

Types & Sounds of Leakage



Factors Causing Leakage

Internal Factors

- Pipe quality & material deterioration
- Design mistake and installation (poor connections & joints
- High pressure, water hammering, water basicity (corrosion)

External Factors

- Heavy traffic and load, earth movement
- Seasonal variation in temperature
- Earthquake and construction work by the other utilities

Existing Situation of Five WASA's for Leakage Control

Items	Lahore	Faisalabad	Gujranwala	Multan	Rawalpindi
No. of leakage survey teams	52	2	0	9	15
No. of person in one team	3	8	0	4	2-3
No. of days of leakage survey (person*days/year)	62	8*150=1200	0	4*1=4	Every day
No. of hours of leakage survey (person*hours/month)	9.6	8*250=2000	0	24	Office hour
Length of leakage survey (km/year)	9.1	750	0	0	300
No. of surface leakage detection (number/year)	2700	68	0	576	640
No. of underground leakage detection (number/year)	300	427	0	2880	Nil
How to detect underground leakage	Manual detect	Helium gas	Manual detect	Manual detect	N/A

(Source: JICA Quarterly Report, January 2016)

Existing Situation of Five WASA's for Leakage Control

Items	Lahore	Faisalabad	Gujranwala	Multan	Rawalpindi
No. of repairing leakage	3000	672	1137	3456	Nil
No. of leakage per kilometer of distribution pipeline	0.389	0.456	3.056	3.294	0.556
No. of leakage report from citizens	2950	1737	1137	3110	225
Done the Minimum Flow Measurement	N/A	Yes	N/A	N/A	N/A
Equipment : Acoustic Rod	0	0	0	0	0
Equipment : Correlative leak detector	0	0	0	0	0
Equipment : Leak noise correlator	1	5	0	0	0

(Source: JICA Quarterly Report, January 2016)

Existing Situation of Five WASA's for Leakage Control

Items	Lahore	Faisalabad	Gujranwala	Multan	Rawalpindi
Equipment : Metal pipe locator	1	0	0	0	0
Equipment : Non-metal pipe locator	0	0	0	0	0
Equipment : Other leakage detector	0	Helium gas	0	0	0
Metering ratio (%)	1	18	0	0	0
NRW (%)	41	32.9	35	22	31
Mapping System / DMA	U.D. (GIS/ DMA)	Yes (Mapping)	Yes (DMA)	N/A	U.D. (GIS)

(Source: JICA Quarterly Report, January 2016)

Leak Detection Equipment at WASA Lahore


Old Type Leak Correlator


Acoustic Leak Detector


Metal Pipe Locator


Electromagnetic Flow Meter

Leak Detection Equipment at WASA Faisalabad

Helium Gas Leak Detector

Acoustic Leak Detector

Leak Detector

Metal Detector

Installed Pipe Network by Material & Length

Pipe Material	Faisalabad	Gujranwala	Lahore	Multan	Rawalpindi
Cast Iron Pipe (CI), km	4		449	38	4
Asbestos Cement Pipe (ACP), km	1200	209	3567	1176	225
Polyvinyl Chloride (PVC), km	8	241	254	62	116
High Density Polyethylene (HDPE), km	7	-	802	10	186
Concrete (Hume) Pipe, km	-	16	-		14
Ductile Iron Pipe (DIP), km	-	-	326		4
Steel Pipe, km	-	-	-		35
Galvanized Iron (GI) pipe, km	-	29	-	162	29
Total	**1219**	**495**	**5398**	**1149**	**613**

(Source: JICA Quarterly Report, January 2016)

Contact Information

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In the Name of Allah the Most Beneficent, the Most Merciful

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Counter Measures for Leakage Control

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February 2017

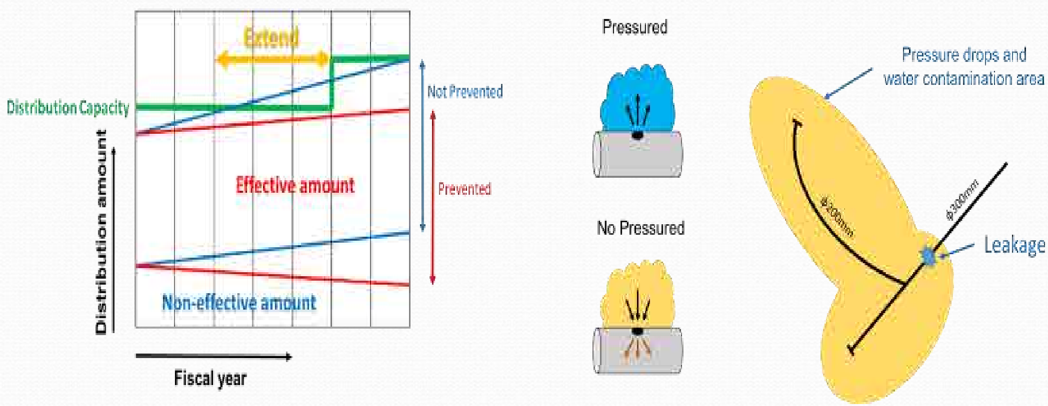
Outline of Presentation

- Leakage Survey Method
- Water Quality Based Leakage Detection
- Leakage Prevention Work

Objectives of Leakage Control

- To maximize utilization of the limited water resources
- To maintain water pressure in the network
- To prevent water contamination
- To prevent potential accidents leading to leakage

Importance of Leakage Prevention Work



Leakage Survey Methods

- **Leakage Survey**
  - **Acoustic Survey**
    - **Door to Door**
    - **Road Survey**
    - **Valves/Hydrants**
  - **Measuring Survey**
    - **Direct**
    - **Indirect**
  - **Other Survey**
    - **Water Pressure**
    - **Road Patrol**
    - **Correlative**
    - **Boring**
    - **Water Quality**

Acoustic Survey

Detection from Valves

Detection from Water Meter

Acoustic Survey with Leak Detector

Measuring Survey

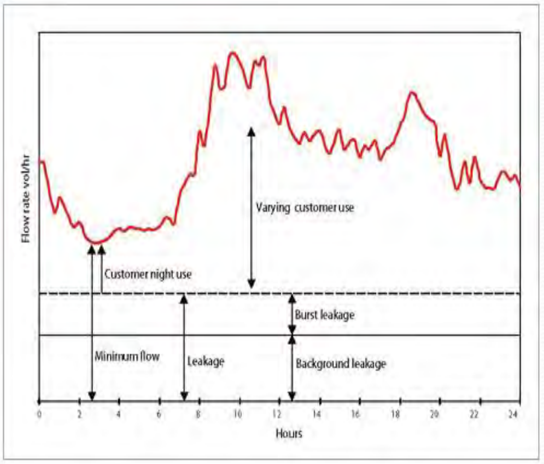
- A service area (block) is isolated by closing the valves.
- Water can be supplied temporarily by pipe or with a hose connected with fire hydrant.
- Water lost due to leakage in the area is determined by using electromagnetic or ultrasonic flowmeter.
- Minimum flow is recorded at midnight with continuous supply of water.
- This process is repeated several times to find accurate leakage flow value.

Measuring Survey

1. Minimum Night Flow or Bottom-Up Approach

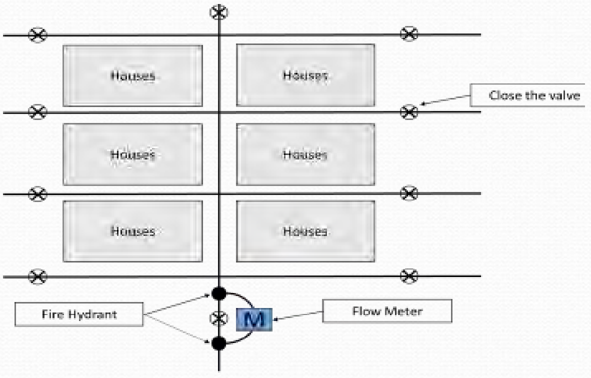
[Net Night Flow] = [Minimum Night Flow] - [Minimum Night Consumption]

- Customer demand is minimum at night, water operators have to account for the minimum night consumption (MNC), i.e. the night-time customer demand, such as toilet flushing, washing machines, etc.



Measuring Survey

- In a system with 100% metering, MNC is calculated by measuring the hourly night flow for all non-domestic demand and a portion (e.g. 10%) of domestic meters within the DMA.
- Measured directly from the data logging devices or the flow graph.



Measuring Survey

2. Integrated or Top Down Approach

Leakage = Distribution Input – Consumption

- Leakage is the remaining amount of the annual water balance.
- A consistent approach is used to estimate leakage using this method.

Distribution Volume Analysis (Example of WASA Faisalabad)

System Input Volume 93.5 MGD	Authorized Consumptio n 62.7 MGD	Billed Authorized Consumption 61.7 MGD	Billed Metered Consumption (including water exported)	0%	Revenue Water 64.6%
			Billed Non-metered Consumption	64.6% (100%)	
		Unbilled Authorized Consumption 0.94 MGD	Unbilled Metered Consumption	0%	Non-Revenue Water (NRW) 35.4%
			Unbilled Non-metered Consumption	1.5% (1%)	
	Water Losses 30.8 MGD	Apparent Losses 14.76 MGD	Unauthorized Consumption	13% (329%)	
			Metering Inaccuracies	1% (100%)	
		Real Losses 16.1 MGD	Leakage on Transmission and/or Distribution Mains	5 % (0.25%)	
			Leakage and Overflows at Utilities Storage Tanks	(0.2%)	
			Leakage on Service Connections up to Customers' Meters	14.7% (N/A)	
				Total	93.5 MGD/100 %

Index of International Water Association (IWA)

ILI = CAPL/MAAPL

- ILI = Infrastructure Leakage Index
- CAPL (liters/day): Current Annual Volume of Physical Losses
- MAAPL (liters/day): Minimum Achievable Annual Physical Losses

- MAAPL (liters/day) = $(18\times L_m+0.8\times N_c+25\times L_p)\times P$
  - MAAPL (liters/day): Minimum Achievable Annual Physical Losses
  - L_m : mains length (km)
  - N_c : number of service connections
  - L_p : total length of private pipe, property boundary to customer meter (km)
  - P : average pressure (m)

Infrastructure Leakage Index

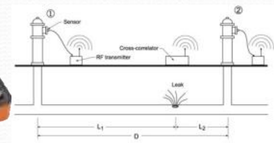
The ratio of the CAPL to MAAPL, or the ILI, is a measure of how well the utility implements the three infrastructure management functions:



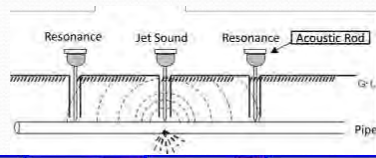
- Repairs
- Pipelines and Asset Management
- Active leakage control

- ILI is particularly useful in networks where NRW is relatively low, below 20%.
- ILI can help to identify which areas could be reduced further.


Other Survey



- Water Pressure Recording Survey
- Road Surface Survey
- Correlative survey
  Leak sound correlator installed at two points – at divide valve and fire hydrant - between a stop valve and a meter.
  The leaks are detected by moving the device point to point above the pipeline.
- Boring survey
  Leak point detection is easy by the use of bore survey in combination with acoustic rod
- Residual chlorine based survey

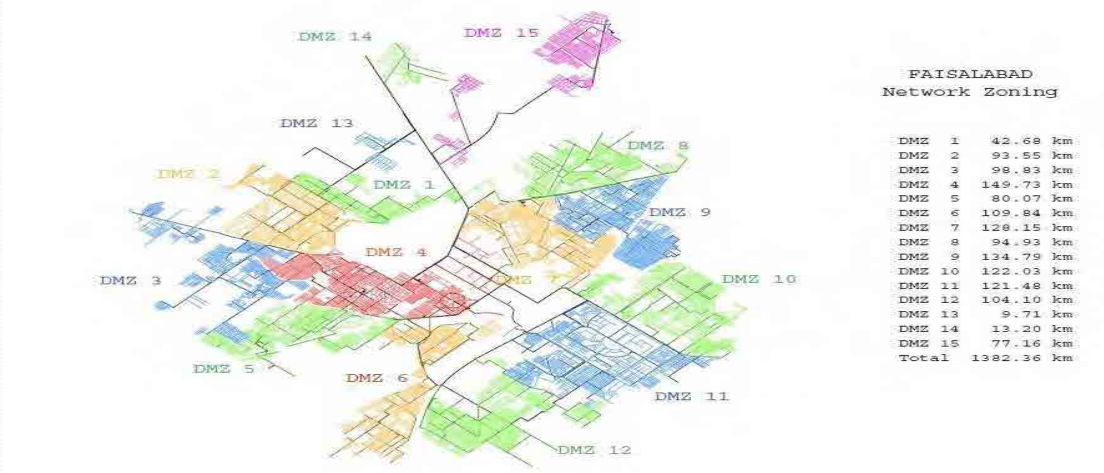


-Inject sample water & switched on "ZERO" | -Inject A&B, drop by drop | -Inject sample water 2mL by syringe | -"READ" switched on

District Metered Area (DMA)

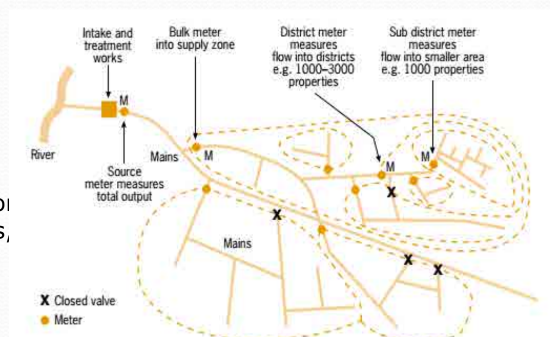
- Water network area is divided into zones to minimize physical losses.
- Zones can be further sub divided into a series of small sub-systems to make easy for losses calculation, often referred to as District Metered Areas (DMAs).
- Each DMA should be hydraulically isolated to calculate volume of water lost within that area.
- The purpose of this division is
  - To reduce NRW,
  - Minimize the water quality problems, and
  - To sustain water pressure in the lines to supply uniform quantity of water.

District Metered Area Zones



DMA Establishment

- Size of DMA (number of connections – generally between 1,000 and 3,000).
- Number of valves that must be closed to isolate the DMA – should be kept to a minimum – natural boundaries should be used wherever possible to reduce cost.
- Topographic features that can serve as boundaries for the DMA, such as rivers, drainage channels, railroads, highways, etc.
- Number of flow meters to measure inflows and outflows, minimum meter required
- Flat area selection, more easy to control pressure and fluctuation.
- Ensure all pipes within and out of the DMA are either closed or metered.



(Source: WHO Manual, 2001)

Water Quality Based Leakage Detection

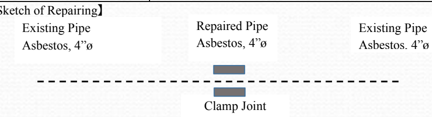
- Residual Chlorine
- PH judgment
- Conductivity based judgment

Water Source	pH value	Conductibility (μs/cm)
Drinking water	Approx. 6.7～7.5	Approx. 100～300
Rain water	Under 6.0	Approx. 40～90
Groundwater	Approx. 6.4～7.5	Approx. 300～1000
Sewage	Over 7.0 (High)	Over 500 (High)

Site Record Sheet

Date and Time	10:50 am; 11 February, 2016
Address	Civic Centre Near Cine Star Cinema
Person in charge	Mr. Shamas Ayoub Gujjar – SDO Green Town
Organization of repairing team	Pipe fitter x 1, Helper x 2
Diameter(mm)	4"
Material and Kind of Joint	Asbestos, wooden cork inserted into the hole and metal clamp along-with water proof sponge was used
Age (installation year)	45
Shape of leak point	Hole of 0.5" diameter
Pressure (kg/m^2)	Low
Depth(m)	4.5'
Soil around the pipe	Rough soil and garbage
Traffic density	Medium
Supply Hour	14
Cause of the leak	
Quantity of leak (m^3/min)	
Time of Repairing (Hour)	3

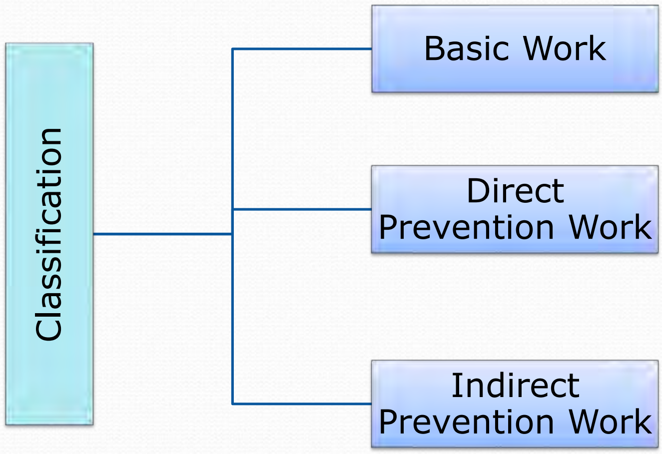
【Sketch of Repairing】



【Picture of Repairing】

Location on the Map】
Coordinates: 31.450828 N, 74.310791 E

Leakage Prevention Work



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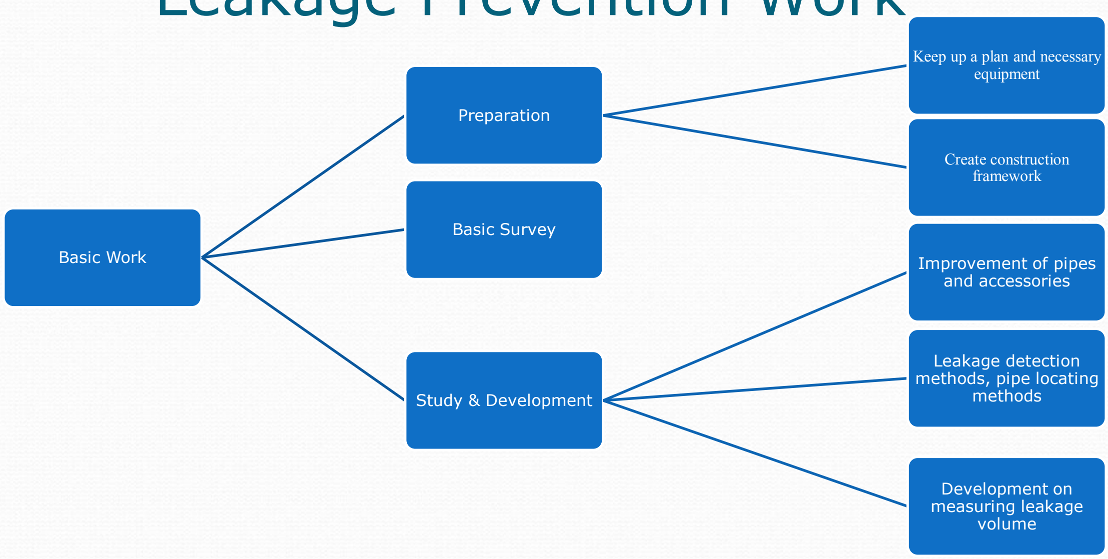
Leakage Prevention Work



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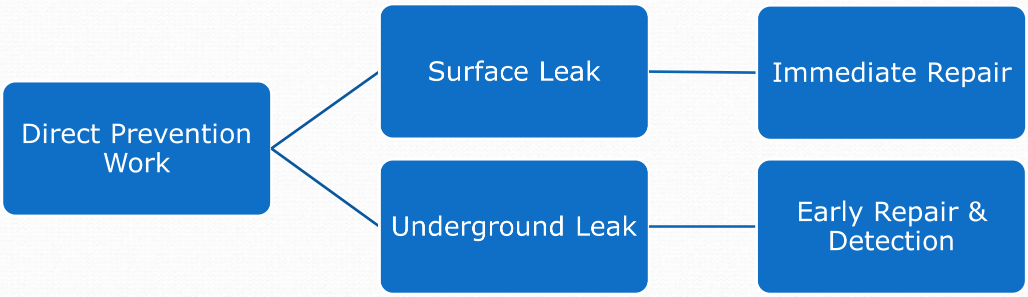
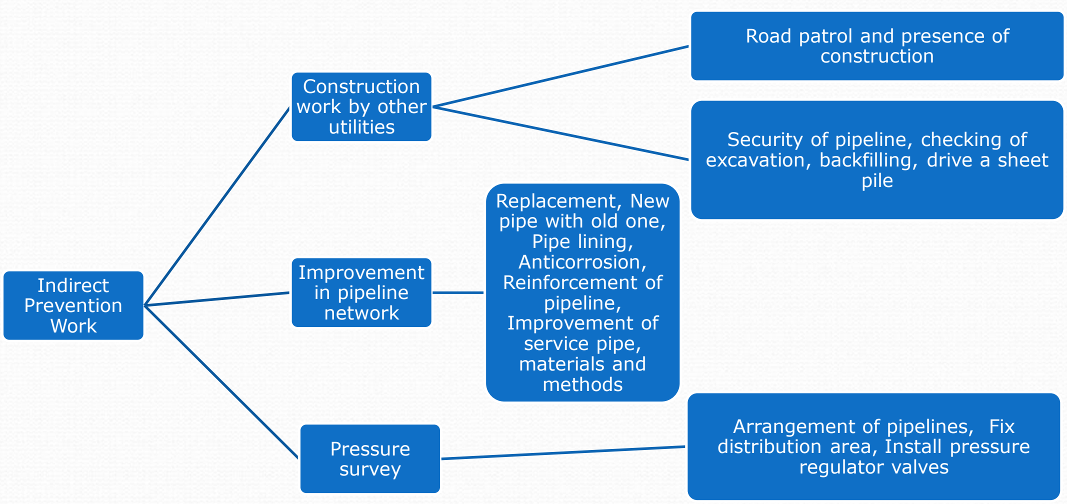
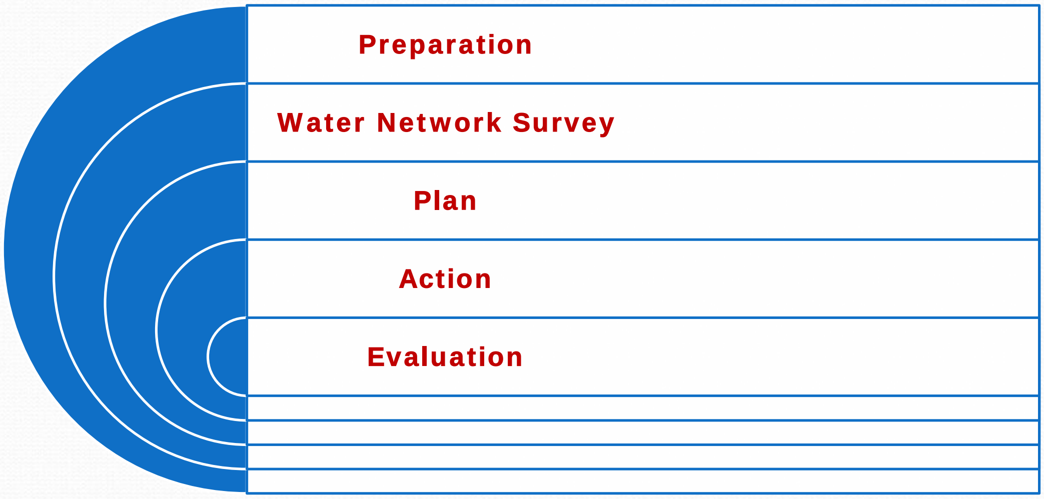
Leakage Prevention Work



Leakage Prevention Work



Leakage Prevention Procedure



Procedure For Leakage Prevention

- Preparation
  - Establishment of leakage detection cell and team
  - Procurement of equipment
  - Preparation of maps for water distribution
- Water Network Survey
  - Distribution analysis and analysis of water volume error
  - Analysis and distribution of Ground Water, cause of Leakage Volume

Leakage Prevention Procedure

- Plan
  - Set the Target Value
  - Set the Planning year
  - Decide the Survey Method
- Action
  - Leakage Survey
  - Analysis of Cause of Leakage
  - Measuring of Prevention Volume
  - Preventive Work
  - Countermeasure of Leakage
- Evaluation
  - Analysis of Results
  - Compare the Plan and Action

Contact Information

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In the Name of Allah the Most Beneficent, the Most Merciful

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Leakage Survey Equipment

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February 2017

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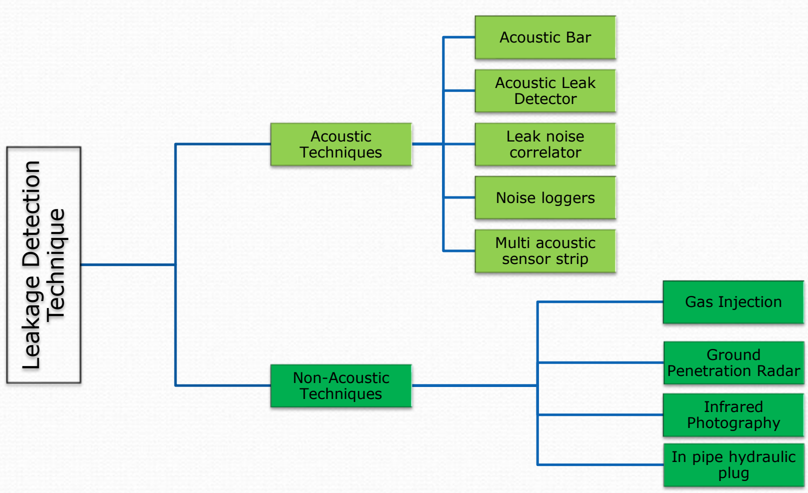
Outline of Presentation

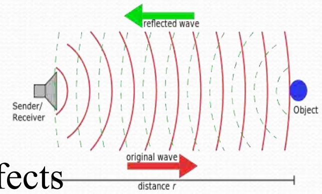
- Leakage Detection Techniques
- Working Principle of Leakage Detection
- Types of Leak Detector

Leakage Detection Techniques



Working Principle of Leakage Detection

- Based on multiple scientific information
- Vibrations and noise caused by the leak & Electromagnetism contributing in amplifying sound effects



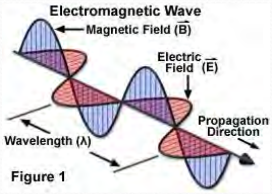
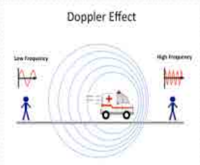
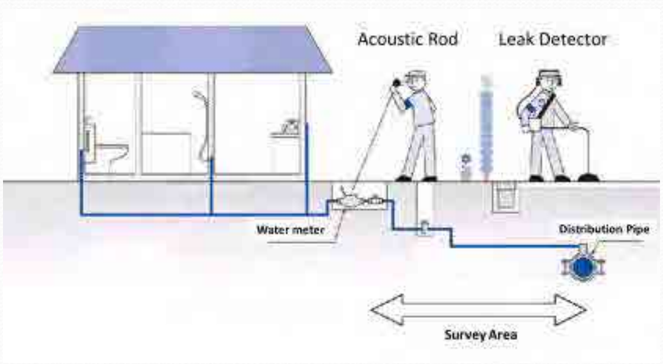


Figure 1



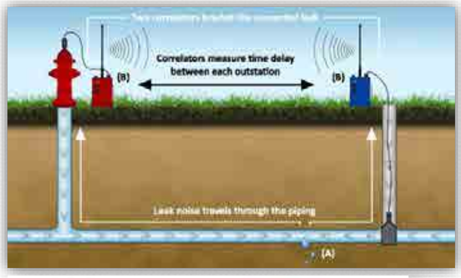
Acoustic Rod & Electronic Leak Detector

- Sound is amplified and transmitted to headphones
- As the sound is high exactly above the leak, indication leads to pinpoint exactly.



Leak Correlator

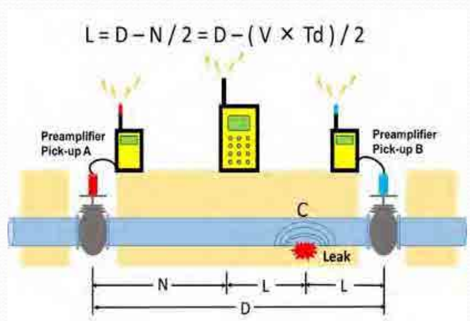
- Water Leakage in pipelines produce noise.
- Noise travels by two routs:
    - Travels through the ground to the surface
    - Travels through wall of the pipe & water
- Correlator detects noise sound transmitted in the wall of the pipe and the water.
- Pipe fittings such as flow meters, valves and hydrants are used as access points.
- Leak position is pinpointed by selecting two approximate location around the leak.



Leak Correlator

Leak sound is transmitted through the pipe to either side of leakage. At randomly selected points on both sides of the leak, it shows "noise travel time difference or time delay" due to difference in distance from the leak, represented by "Td".

- When this time delay (Td) is multiplied by the sound velocity (V) through the pipeline, the distance (N) between points A and C is calculated.
- Subtracted "N" from the distance (D) between A and B, and divided by 2 to determine the distance (L) to the leak point.

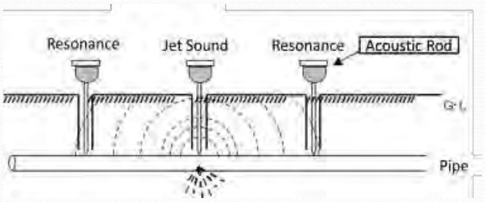


Acoustic Rod/Bar

Specification				
Type	Cap dia.* Thickness (mm)	Total Length (mm)	Dia. of Iron Bar (mm)	Material
LSP-1	ø 67x29	1,013	7	Stainless Steel

Use:

- Place the tip of acoustic rod at the point where doubt of leakage is evident
- Catch the stick below the listening cap and place ear on the cap of acoustic rod
- Hear the sound of leaked water, if no leakage at that place repeat the same procedure aside this place
- Very useful to listen leaks sound at hydrants and valves



Factors affecting performance:

- Pressure
- Depth

Leak Detector

Operation:

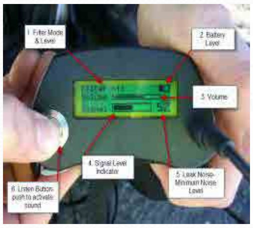
- Use head phones remembering Left and Right direction.
- Turn volume up to half using the dial on the headphone cable.
- Ensure good contact of microphone and surface area.
- Press and hold silver button to listen sound.
- With every press and release of the silver button, the noise level will be recorded in the memory.
- To see memory data for the last eight soundings, press and hold the pink "M" button on the amplifier.
- To turn filter on, press and hold the green + & - filter buttons simultaneously. The filter bandwidth is +/- 100Hz.

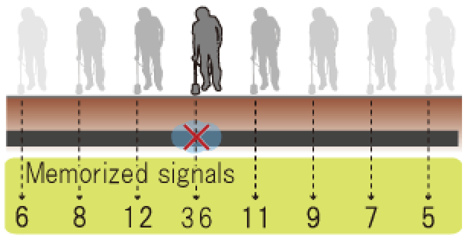
Components:

- Amplifier with waist belt
- Hand probe microphone
- Ground microphone plate
- Probe rods
- Stereo headphones
- Connecting cable

Leak Detector
Important Points & Precautions

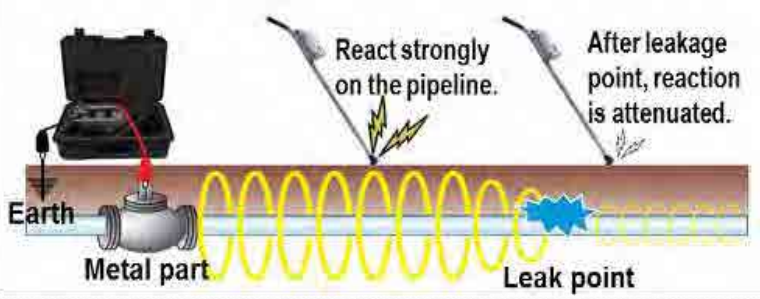
- Use filter in case of high background noises
- Leakage sound depends upon,
  - Water pressure
  - Crack or hole size
- Operator should stay stable during its use
- Required practice to pinpoint or identify leaks.
- Don't use in rainy days.
- Sensors are water resistant, but control unit and head phones are not resistive. Keep them away from water .





Non-Metal Pipe & Leak Locator

- Works on electrical insulation properties of the non-metal pipes.
- Does not require "leak noise‟.
- Pass a high frequency electromagnetic waves through the "water" in the pipe.
- Plastic pipe' electrical insulation properties creates a boundary with the earth, making the tracing of pipe routes easy using the same essential idea as a buried cable detector.



Non-Metal Pipe Locator

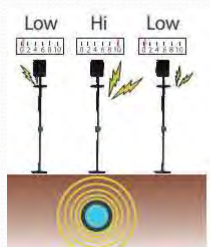
Components:

- Transmitter with current meter and voltmeter
- Receiver
- Cord with alligator clips
- For earth 25 m extension cable with drum Earth rod
- Charger for transmitter
- Charger for receiver
- Locking plier

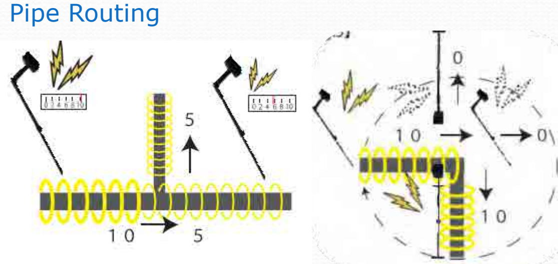
Installation

Non-Metal Pipe Locator Operation:

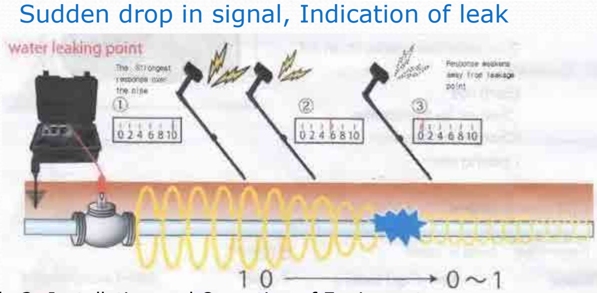
Move Receiver like a Pendulum



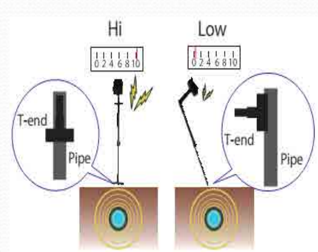
Pipe Routing



Sudden drop in signal, Indication of leak



Identification of buried appurtenances



Metal Pipe Locator

Operation:

Direct Method

- Battery test for transmitter and receiver
- Use cords inside the box, attach one alligator clip to the coupler clamp and the second with rod for grounding. Attach the plugs in transmitter.
- Put coupler clamp on valve or house meter that is above the pipe line.
- Use receiver and walk on the surface with receiver similar as like pendulum motion.
- High value on the meter of receiver and high pitch of the sound identifies the location of buried pipe line.

Indirect Method

No clamping & no grounding

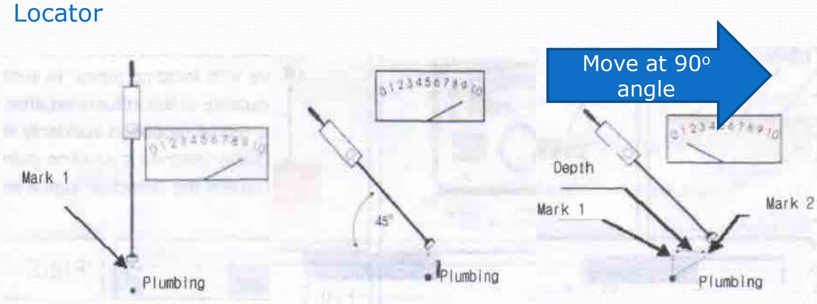
Components

- Transmitter
- Receiver
- Carrying Case with Inductive Antenna
- Chord Set
- Inductive Coupler
- Optional Headset

Metal Pipe Locator

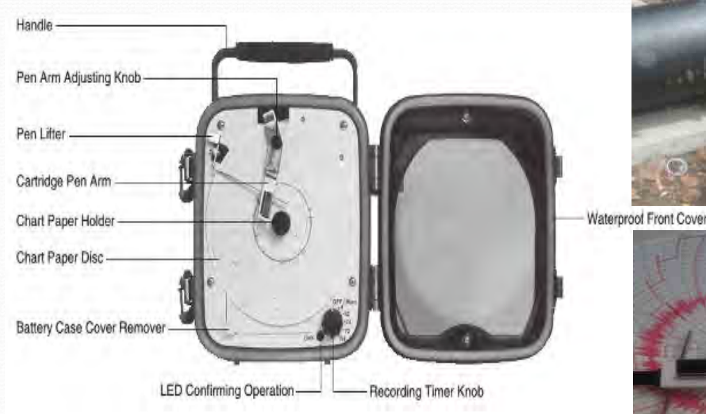
Determining Pipe Depth

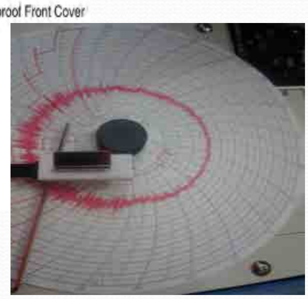
Using Both Non-Metal Pipe Locator and Metal Pipe Locator

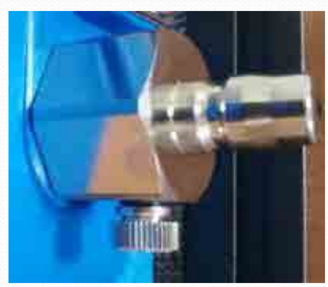


Depth= approx. 4 ft. etc.

Pressure Recorder

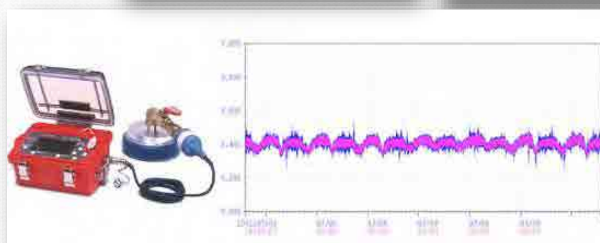






Pressure Recorder

- Develop the pressure charts to check fluctuation of water flow in distribution system.
- Can be used for pressure testing of new pipelines.
- Installation can be made in the chamber, at pumping station, at fire hydrants and at the valves in water networking system.



Ultrasonic Flowmeter

Components

- Device Setting:

Configuration Menu (SIMPLE) → Pipe & Fluid Setting (Outside diameter & thickness) → Probe Distance

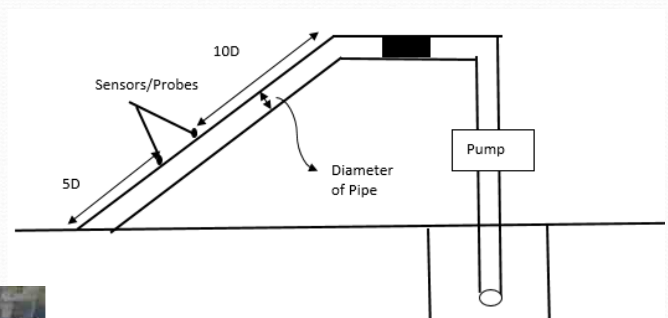
- Installation:

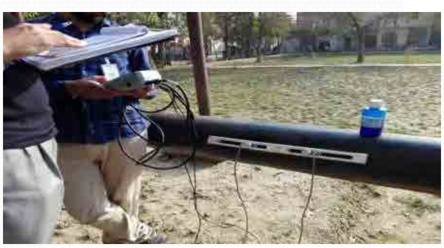
Ultrasonic Flowmeter

Installation Procedure

Data Required

- Pipe Diameter
- Pipe Material
- Probes ID Number
- Pipe Thickness



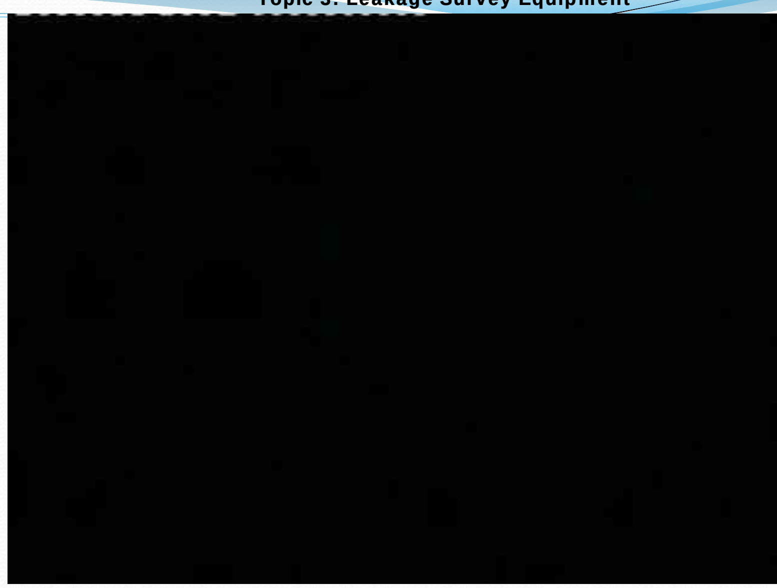


Gas-Permeation Inspection Method

- Identify the leaks by injecting gas having less specific gravity
- *Helium gas* due to its high cost is replaced with the *gas mixture* (5% hydrogen, 95% Nitrogen).
- Mixture is non-soluble in water, compliance with ISO 10156 standard and its safety is globally recognized.
- In areas where "acoustic type leak detection" is difficult due to surrounding noise (traffic area, congested area and factory area), gas injection method is used.

Leakage Detection Video

Localizing, Locating & Pinpointing



Contact Information

Zia Mustafa
Water Specialist

In the Name of Allah the Most Beneficent, the Most Merciful

1

Repairing of Leakage & Burst Pipe line (OJT)

By
Zia Mustafa
Water Specialist

February 2017

2

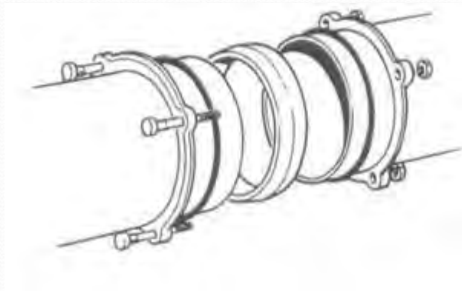
Outline of Presentation

- Repairing Materials
- Repairing Procedure at the Site (AC Pipe)
- On Site Leakage Repairing
- Repairing Tools and Machinery
- Pipe Jointing
- Comparison of Materials and Methods of AC Pipe

Assignment

AC Pipe Repairing Material

- Gibault Joint Material



AC Pipe Repairing Material

- Clamps & Water Proof Rubber

AC Pipe Repairing Material

- Rubber Tube & Wooden Piece/Cork

- Tire Tube Rubber

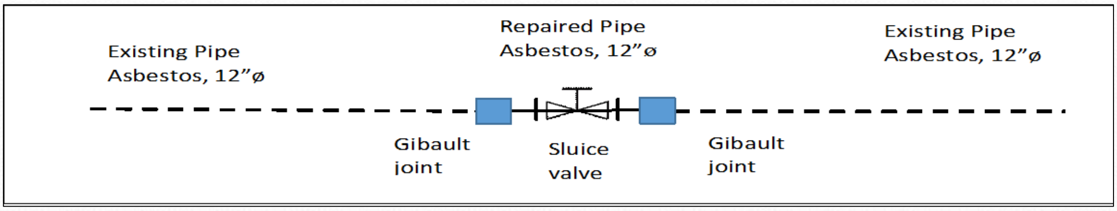
AC Pipe Repairing Material

- Socket & Socket Ring

- Flange

Repairing Procedure at Site

Gibault Joint

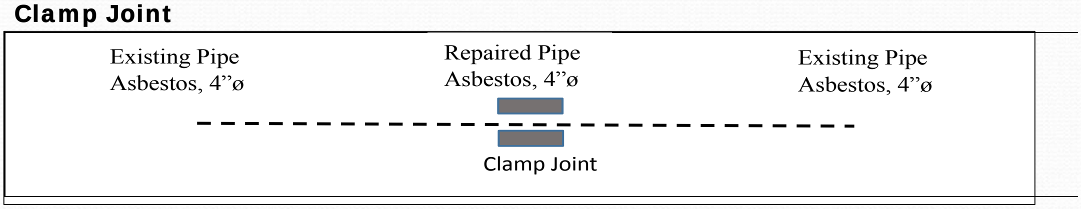


Module 2: Water Network Maintenance & Leakage Detection

9

Repairing Procedure at Site

Clamp Joint



Module 2: Water Network Maintenance & Leakage Detection

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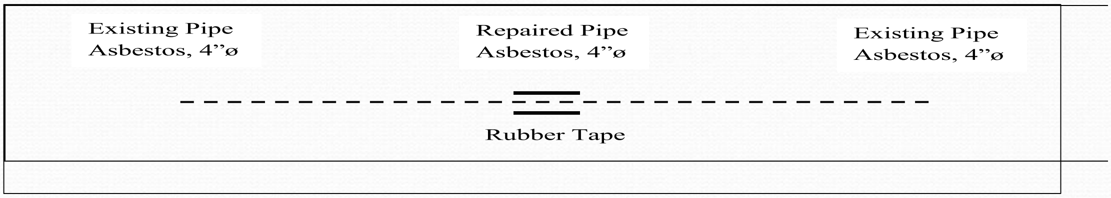
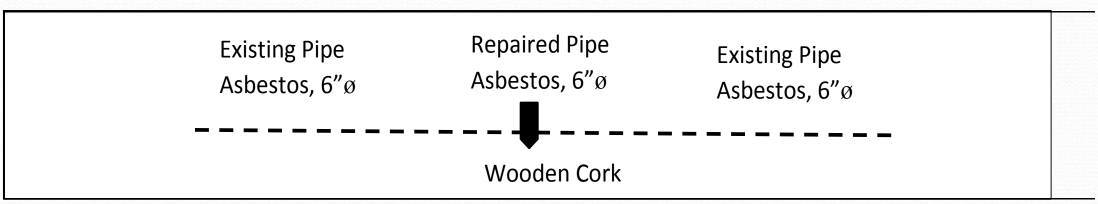
Repairing Procedure at Site

Rubber Tube



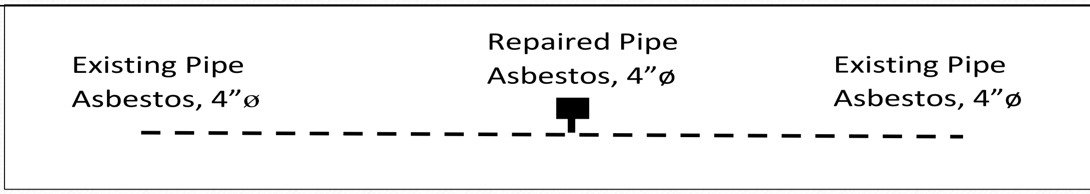
Repairing Procedure at Site

Wooden Piece or Cork

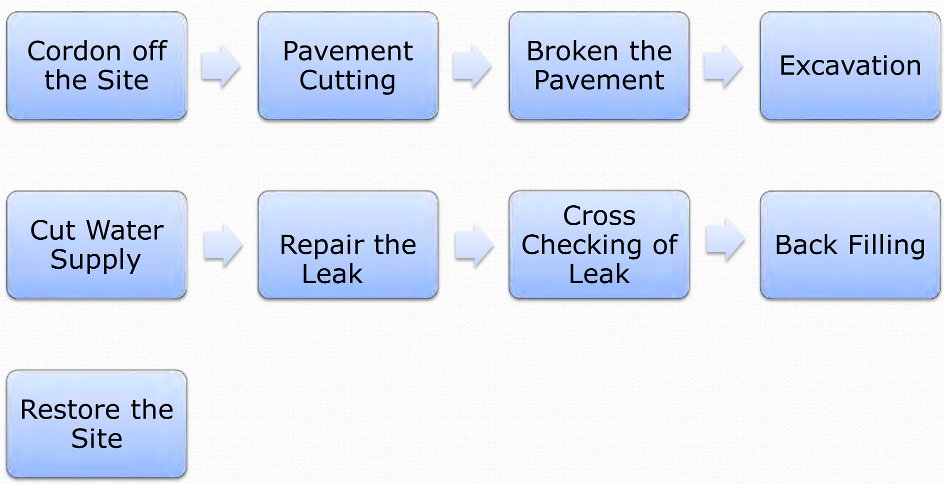


Repairing Procedure at Site

End Plug



On Site Leakage Repairing



Cordon off Site

- Cones
- Reflection Tape
- Diversion Board


Personal Protective Equipment

- Mask
- Gloves
- Shoes
- Hamlet
- Goggles (eye wear)
- Multi Gas Monitor





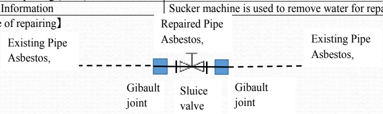
Repairing Tools & Machinery

- **Hand Tools**
  - Adjustable Wrench
  - Screw Driver
  - Hammer & Maul
  - Hand Saw
  - Bucket
- **Cutting Tools**
  - Snap Cutter
  - Pipe Cutter
- **Excavation Tools**
  - Shovel
  - Grape Hoe
  - Pick Axe
- **Excavation Machinery**
  - Pavement Breaker
  - Sucker Machine
  - Excavation
  - Portable Soil Compactor

Site Data Recording

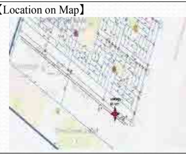
Date and time	10:20 am, 11 February, 2016
Address	Hamdard Chowk, Ali Road
Person in charge	Mr. Shamas Ayoub Gujjar – SDO Green Town
Organization of repairing team	Pipe Fitter x 2, Helper x 2, Worker x 2 (Sucker Machine)
Diameter(mm)	12”
Material and Kind of joint	Asbestos, a sluice valve is installed after removing the cracked portion
Age (installation year)	45 years
Shape of leak point	5” long crack
Pressure (kg/m2)	High
Depth(m)	4.5’
Soil around the pipe	Rough mud, but after repairing a cemented valve chamber will be formed to operate valve in the future
Traffic density	High
Supply Hour	18
Cause of the leak	Old pipe and high Pressure (main transmission line connected with four tube wells
Quantity of leak (m3/min)	
Time of Repairing (Hour)	4-5
Other Information	Sucker machine is used to remove water for repairing

Figure of repairing】



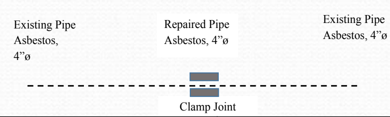
【Picture of repairing】

【Location on Map】



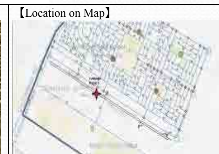
Date and time	10:50am 11 February, 2016
Address	Civic Centre near Cine Star Cinema
Person in charge	Mr. Shamas Ayoub Gujjar – SDO Green Town
Organization of repairing team	Pipe fitter x 1, Helper x 2
Diameter(mm)	4”
Material and Kind of joint	Asbestos, wooden cork inserted into the hole and metal clamp along-with water proof sponge was used
Age (installation year)	45
Shape of leak point	Hole of 0.5” diameter
Pressure (kg/m2)	Low
Depth(m)	4.5’
Soil around the pipe	Rough soil and garbage
Traffic density	Medium
Supply Hour	14
Cause of the leak	
Quantity of leak (m3/min)	
Time of Repairing (Hour)	3

【Figure of repairing】



【Picture of repairing】

【Location on Map】

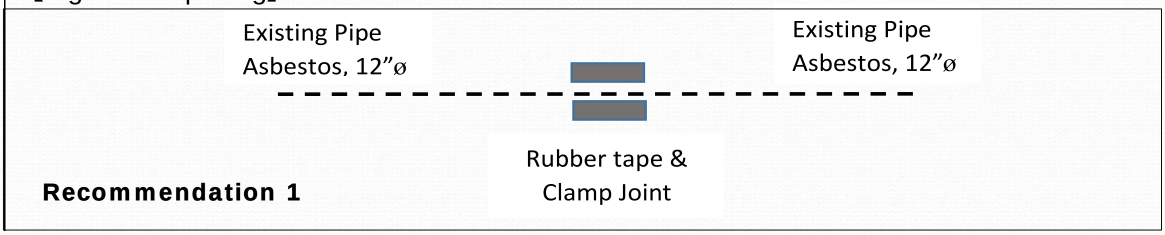


Pipe Jointing

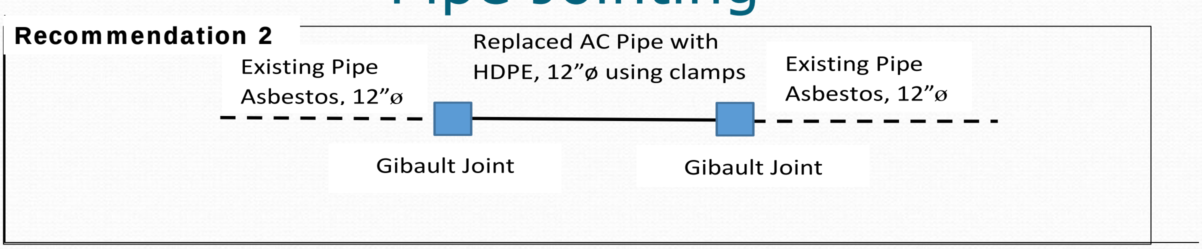
Following are the few recommendations sketches are also shown.

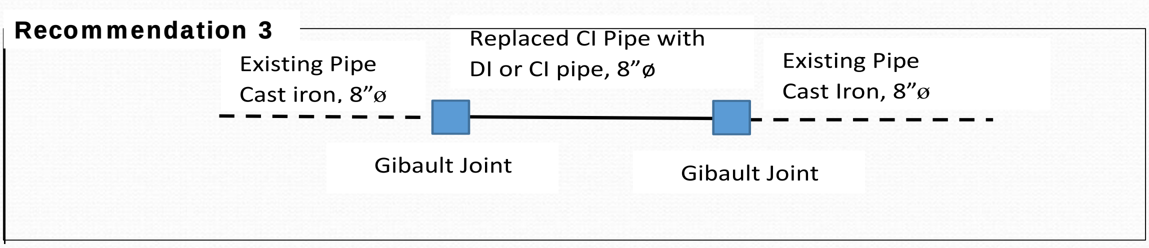
- Recommendation 1: For 12" dia. AC pipe repairing, use clamp joint & rubber tape
- Recommendation 2: For 12" AC pipe with HDPE pipe, use HDPE pipe with Gibault joint
- Recommendation 3: For 8" Cast Iron pipe use Gibault joint to join CI or DI pipe of 8"

【Figure of repairing】



Pipe Jointing





Polyethylene Pipe

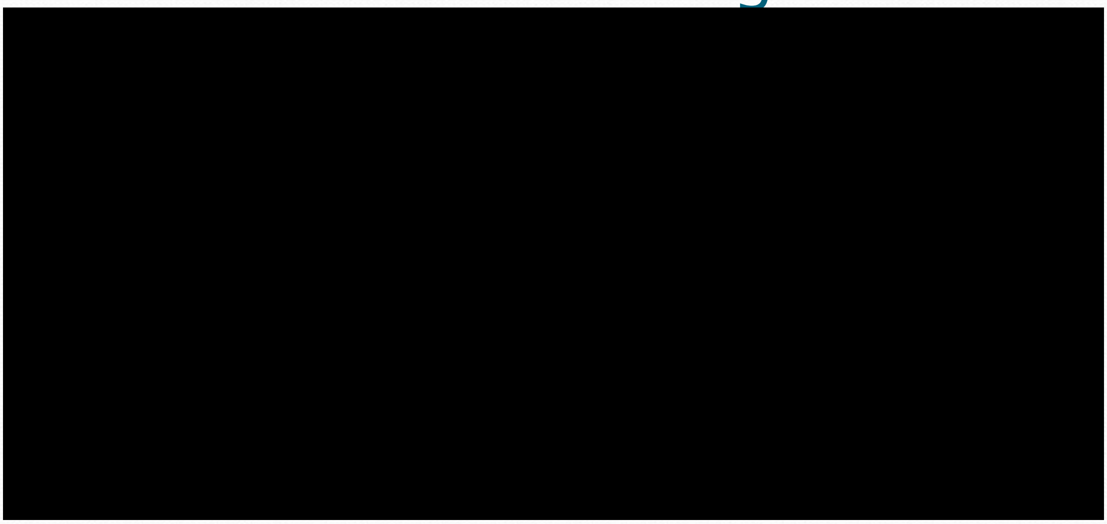
- Polyethylene (PE) is fast replacing conventional material in piping for water supply and distribution. HDPE pipe size range from 20mm to 500mm.

- ❑ Clamp Pipe and fitting
- ❑ Align in axial direction
- ❑ Joint end cleaning
- ❑ Facing
- ❑ Fusion pressure adjustment
- ❑ Time & Voltage Adjustment
- ❑ Insert heat plates or Wire Connection
- ❑ Pipe Fusion

Thermal Electrofusion Jointing

Butt Fusion Video

Butt Fusion Jointing Videos



Comparison of Materials and Methods of AC Pipe

Method	Cost	Life	Availability	Skill Level Required	Time to Repair	Pressure of Line	Remedy	Shape of Leakage Point	Remarks
Rubber Tube	Low 25 PKR/piece	Short ~ 1 year	Easy	No	Short ~ 40 minutes	Low ~ 4 bar	Temporary	Hole /Crack	Only Recommended in the case of emergency but not a permanent remedy. Clamps should be used to increase the joint life.
Cork	Low 100 PKR/piece for 3" dia. Pipe 1000 PKR/piece for 12" dia pipe	Short ~ 1 year along with tube	Easy	No	Medium ~ 1.5 hr	Low ~ 4 bar	Temporary	Hole	Recommended only in case of emergency along with rubber tube. The piece of cork should be accurate, do not put extra size cork in hole of the pipe that results in the biological contamination of water. Not a permanent method, use it with clamps.

Comparison of Materials and Methods of AC Pipe

Method	Cost	Life	Availability	Skill Level Required	Time to Repair	Pressure of Line	Remedy	Shape of Leakage Point	Remarks
Clamp	Medium 125-150 PKR/kg for 4" dia. pipe e.g. Clamp for 4"dia pipe 2 kg iron plate is used.	Medium ~ 8-10 years	Easy	Basic	Medium ~ 1-1.5 hr	High ~ 7-8 bar	Permanent	Hole/ crack	Used where cracks or hole sizes are not so large. (e.g. Ø 4"~ 10.16 cm Ø 6"~ 15.24 cm).Use clamps with at least length of 2 inch more than the crack or hole diameter to cover it safely. It has long life as compare to rubber tube and cork. Can be used at shallow depth with low pressure but in case of high pressure we recommend to use Gibault joint. Clamp joint considered as a permanent remedy with maximum durability.

Comparison of Materials and Methods of AC Pipe

Method	Cost	Life	Availability	Skill Level Required	Time to Repair	Pressure of Line	Remedy	Shape of Leakage Point	Remarks
Gibault Joint	High 1200 PKR/piece for 6" dia. pipe	Long ~ 15 years	Medium	Skilled	Medium ~ 2 hr	High ~ 9 bar	Permanent	Burst /Replace of line	It is an expensive but permanent method for repair. Used where we have to repair the burst line or replace a pipe with another pipe of 5-7 feet of length. The rubber ring of Gibault joint becomes hard with the passage of time (duration 4-5 years), cracks are formed on it that lead to the leakage of water. Check the rubber ring before using Gibault joint. Replace the rubber ring after 4-5 years of usage, to prevent leakage.

Comparison of Materials and Methods of AC Pipe

Method	Cost	Life	Availability	Skill Level Required	Time to Repair	Pressure of Line	Remedy	Shape of Leakage Point	Remarks
Socket Joint	High 450 PKR/ piece for 4" pipe. 550 PKR/ piece for 6" pipe.	Long ~ 20 years	Medium	Skilled	Medium ~ 2 hr	High ~ 9 bar	Permanent	Burst/ replace of line	It is a little bit expensive compared with clamp joint but a permanent method for repair. . Used only in AC pipe only where we have to repair the burst line or replace pipe with another pipe of 5-7 feet of length. This method is not mostly used in routine repairs, used where new pipe line is being laid. It is a time taking process, and very inconvenient in presence of water.

Assignment

Group Presentation

- Current Practices for leakage prevention and pipe from each Water Utility.

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Contact Information

Zia Mustafa
Water Specialist

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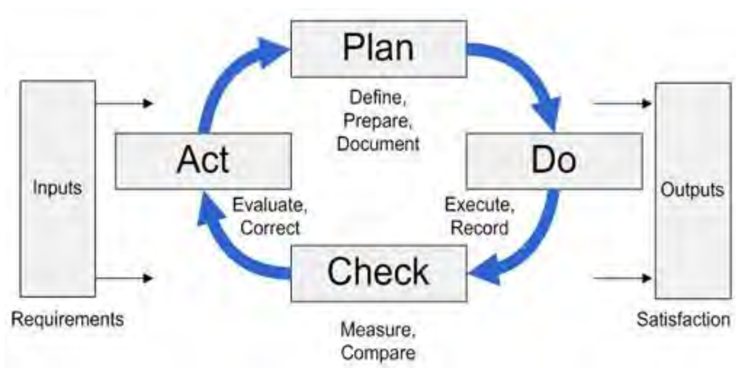
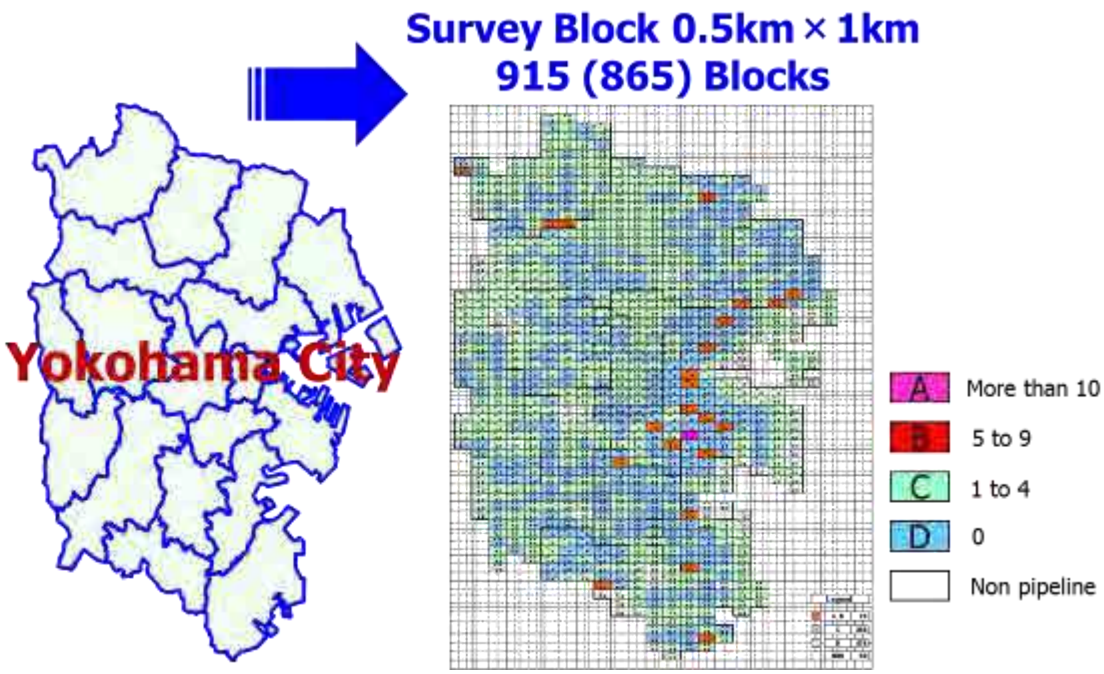
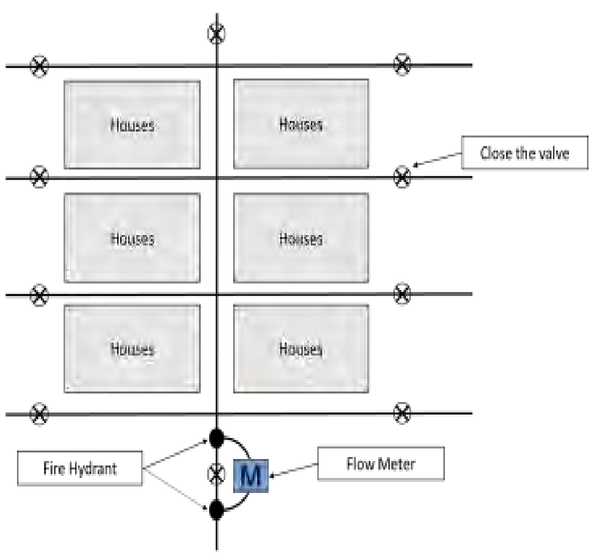
STEP BY STEP PROCEDURE FOR LEAKAGE PREVENTION PLAN

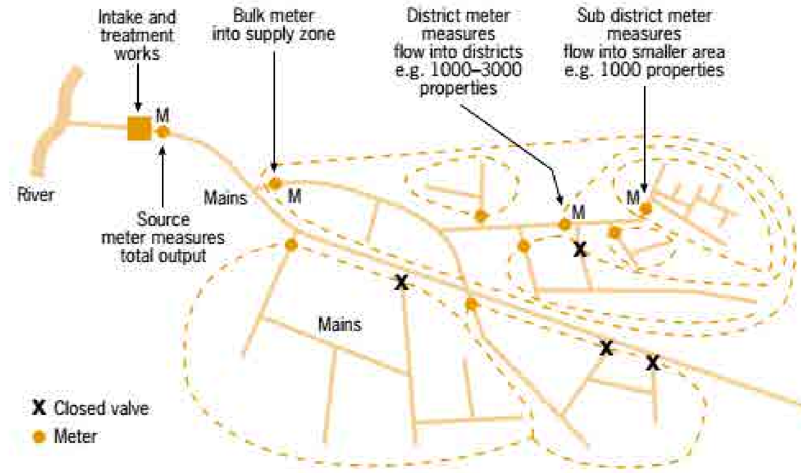
Sr. No.	Guideline	
1.	Preparation	1. Establishment of Leakage Detection Cell and Team 2. Preparation of Water Distribution Network Maps and Drawings 3. Procurement of Equipment
2.	Basic Survey	1. Analysis of Water Supplied and Pressure 2. Divide the City into Blocks 3. Study of Pipe Age, Material and Quality 4. Preventive Works
3.	Plan	1. Set the Target Value 2. Set the Planning year 3. Decide the Survey Methods
4.	Action/ Implementation	1. Leakage Survey 2. Analysis of Causes of Leakage 3. Leakage Volume Calculation 4. Quick Repairs (Surface Leakage) 5. Systematic Detection and Repair (Underground Leakage) 6. Countermeasures for Leakage
5.	Evaluation	1. Analysis of Results 2. Compare Plan with Action

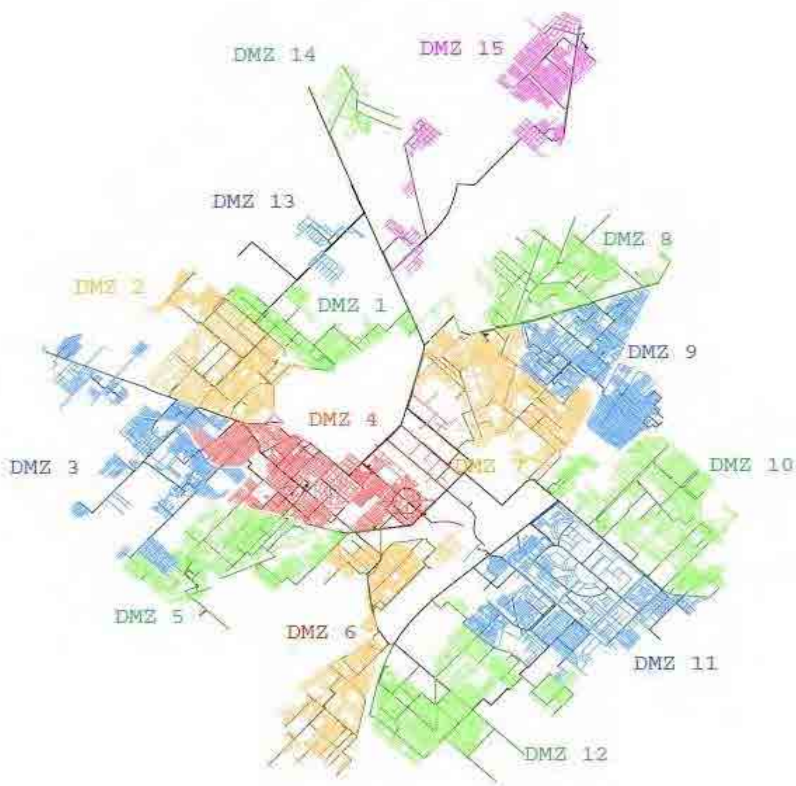



Survey Block 0.5km × 1km
915 (865) Blocks
Yokohama City
A More than 10
B 5 to 9
C 1 to 4
D 0
Non pipeline


Houses
Houses
Close the valve
Houses
Houses
Houses
Houses
Fire Hydrant
M
Flow Meter

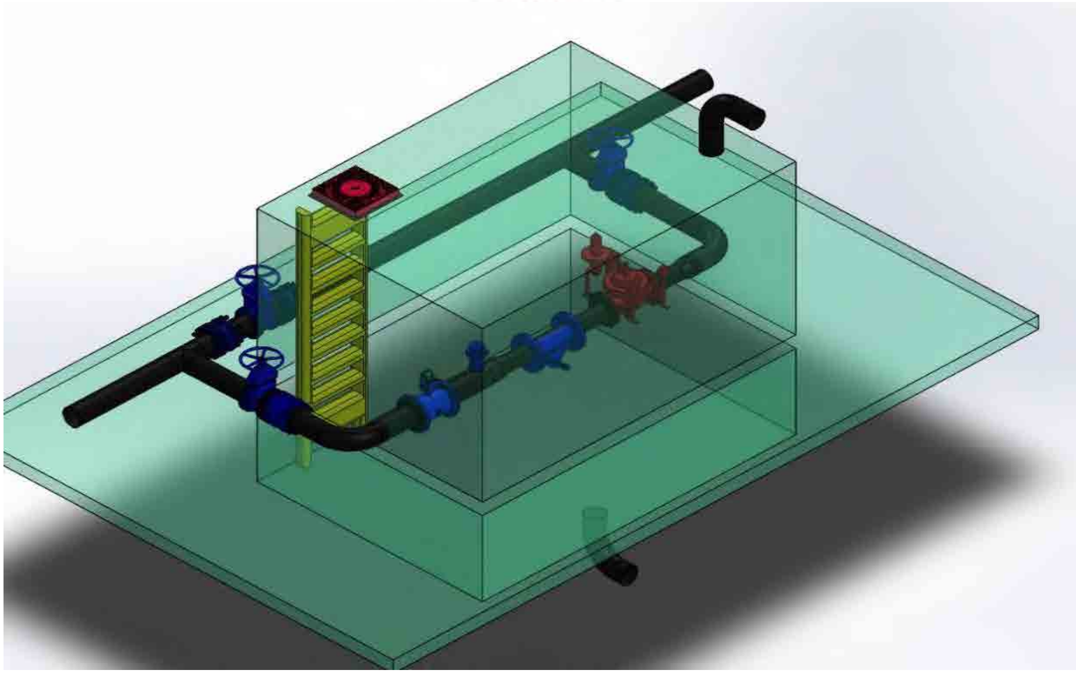

Flow rate vol/hr
Varying customer use
Customer night use
Burst leakage
Minimum flow
Leakage
Background leakage
0
2
4
6
8
10
12
14
16
18
20
22
24
Hours

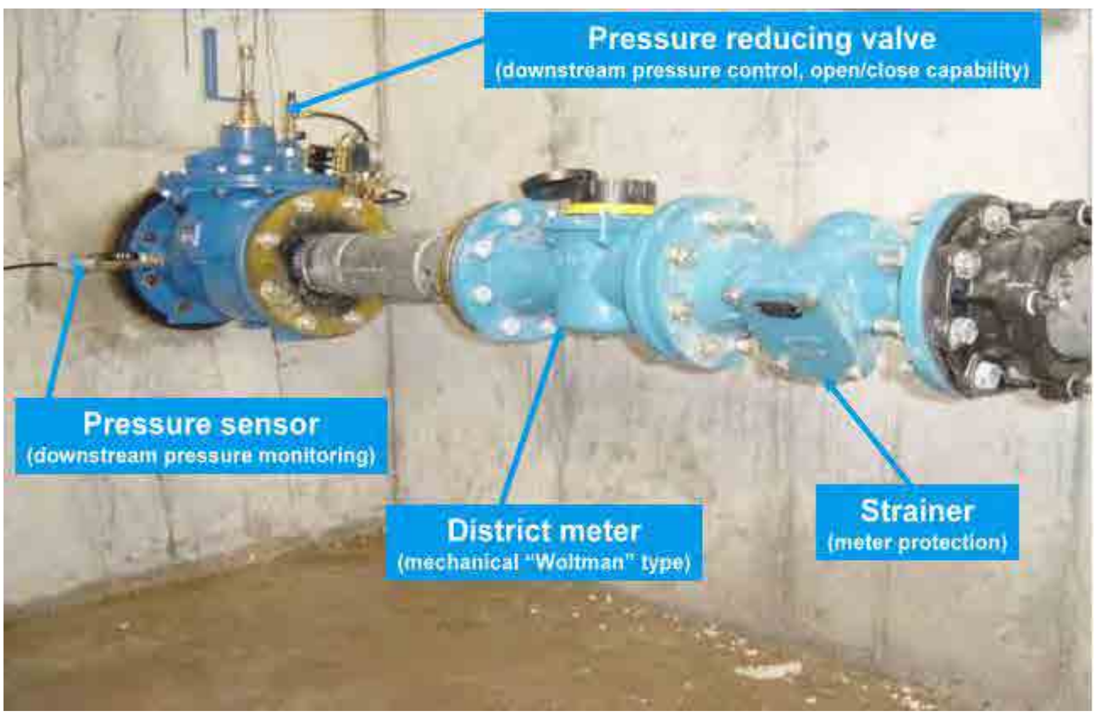




FAISALABAD
Network Zoning

DMZ 1	42.68 km
DMZ 2	93.55 km
DMZ 3	98.83 km
DMZ 4	149.73 km
DMZ 5	80.07 km
DMZ 6	109.84 km
DMZ 7	128.15 km
DMZ 8	94.93 km
DMZ 9	134.79 km
DMZ 10	122.03 km
DMZ 11	121.48 km
DMZ 12	104.10 km
DMZ 13	9.71 km
DMZ 14	13.20 km
DMZ 15	77.16 km
Total	1382.36 km




Pressure reducing valve
(downstream pressure control, open/close capability)
Pressure sensor
(downstream pressure monitoring)
District meter
(mechanical "Woltman" type)
Strainer
(meter protection)

COURSE OUTLINE

Leakage Detection and Repair

W 7231

2016

1. Course Information

<table>
<tr><td colspan="2">Course Title: Leakage Detection and Repair</td><td>Course Code: W 7231</td></tr>
<tr><td colspan="2">Course Prerequisite: Understanding of Water Distribution Network</td><td>Course Duration: 4 days</td></tr>
<tr><td colspan="2">Participants: BS-11 to BS-17 and equivalent
• SDOs
• Sub Engineers
• Supervisors</td><td>No. of Modules: 3</td></tr>
<tr><td colspan="2">Language of Instructions: English and Urdu</td><td>Course Timings: 9 am to 4 pm</td></tr>
<tr><td>Start Date:
03 Oct, 2016</td><td>End Date:
06 Oct, 2016</td><td>Credit Hours: 3</td></tr>
</table>

2. Faculty Information

Faculty Names	
Course Leader : Mr. Chiaki Suzuki	
Module Leader : Mr. Sami Ullah	

3. Brief Course Description

The overall objective of leakage control is to diagnose how water loss is caused and to formulate and implement an action plan to eliminate leak upto technically and economically acceptable limits. Specific objectives of any leak detection would include: reduction in water losses to a minimum; cater for additional demand; improve customer satisfaction and enhance revenue.

This course will focus on leakage detection and prevention techniques in water supply network. Although, the preventive measures taken for leakage control by utility service providers are well practiced, yet, controlling and repairing underground pipe leakages are a great challenge. This course has been designed to introduce basic know-how of the leak detection, leak repair and proactive leakage prevention in underground water supply pipes to the course participants. In addition, this course will enable course participants to develop leak detection plan, and, install and operate leak detection equipment using various methods for leak prevention.

The course comprises the following modules:

Module 1: Basic Knowledge of Leakage Detection
Module 2: Water Network Maintenance and Leakage Detection, On Job Training (OJT)
Module 3: Installation and Operation of the Leakage Detection Equipment (OJT)

4. Course Goals

This course will enable participants to enhance their knowledge and skills in identification and fixing of leaks in underground water supply pipes through the use of equipment and preventive maintenance.

5. Course Objectives

Sr. No.	Objectives
1.	Develop basic knowledge of leakage detection in underground water distribution system.
2.	Understand different types of leaks and techniques of leak material and type of pipe repairing material.
3.	Learn to use different types of leakage detection equipment with respect to pipe material.
4.	Develop knowledge about working principles of using pressure and flow based devices.

6. Learning Outcomes

6.1. Knowledge Outcomes

Description
Knowledge of effective leakage detection, repairing and prevention techniques in the field.
Understand the working principles and use of equipment to identify leakages in underground pipes.

6.2. Skill Set Outcomes

Description
Development of leakage detection plan.
Recording and analysis of leak data during field work.
Preventive maintenance of water supply pipes with reference to leakage.
Hands-on knowledge of using different leakage detection equipment.

6.3. Professional Attitude Outcomes

Description
Realize the need of saving valuable water through collection of leakage data in an organized manner.
Understand the importance of Standard Operating Procedures (SOPs) for repair of pipelines in a professional manner.
Strengthen team work skills.

7. Course Structure

7.1. Modules

Module 1	Basic Knowledge of Leakage Detection
Module 2	Water Network Maintenance and Leakage Detection (OJT)
Module 3	Installation and Operation of the Equipment (OJT)

7.2. Field Visits

Sr. No.	Week No.	Place of Visit	Activities Planned
NA			

7.3. Site Visits

Sr. No.	Week No.	Place of Visit	Activities Planned
1.	1	Water Distribution	- Learning to develop leakage detection plans - Learning to follow SOPs for leakage detection

		Network (location to be decided later on)	equipment. - Locating the leak points on the basis of flow rates and pressure fluctuation in the pipelines - Learning repair techniques in case of leakages and / or bursting of pipelines

7.4. On-The-Job Training Activities

Sr. No.	Week No.	Place of Visit	Activities Planned
1.	1	Water Distribution Network	- Learning onsite use of leak detection equipment - Location and Identification of buried/underground pipe leakages - Learning to proactively prevent pipe leakages

7.5. Assignments

Sr. No.	Assignment
1.	The course participants will prepare an action plan for leakage detection, pipe repairing and prevention of future leaks.
2.	The course participants will prepare site visit reports incorporating all important aspects associated with the use of leak detection equipment.

8. Instructional Plan

Sr. No.	Topics	Sub-Topics	Instructional Method	Duration	Training Delivery Mode
Day 1					
1.	Current Scenario of Leakage Detection	• Introduction to Leakage • Types and Sounds of Leaks • Factors Causing Pipe Leakages • Situation analysis of Leakage Detection in Five WASAs	Course Plan and Introduction Brainstorming Presentation Group Activity	10 Minutes 10 Minutes 20 Minutes 20 Minutes	Theory Visual Aids
2.	Countermeasures for Leakage	• Leakage Survey Methods • District Metered Area (DMA) • Distribution Volume Analysis • Calculation of Leakage Volume • Water Quality Based Leakage Detection • Record of Leak Points • Classification for the leakage prevention work • Procedure of Leakage Prevention	Brainstorming Presentation Group Discussion Individual Activity	20 Minutes 1 Hour 30 Minutes 30 Minutes	Theory Visual Aids

3.	Leakage Survey Equipment	• Equipment and Devices - Types, Functions and Usage	Presentation Demonstration	20 Minutes 50 Minutes	Theory Visual Aids
4.	Repairing of Leakage and Burst Pipeline	• Repairing Materials • Repairing Procedure at the Site • Record of the Leakage Sites • Recommendations for Pipelines Repairing • Comparison of Various Leakage Fixing Methods	Brainstorming Presentation Group Discussion	25 Minutes 1 Hour 30 Minutes	Theory Visual Aids
Day 2					
1.	On Site Leakage Detection	Leakage Detection Equipment • Acoustic Rod • Leak Detector	Visit Briefing Site Visit Visit Report	30 Minutes 5 hours 30 Minutes	Practical
Day 3					
1.	Installation and Operation of Leakage Detection Equipment (OJT)	Standard Operating Procedures; • Non- Metal Pipe Locator • Metal Pipe Locator • Metal Detector • Ultrasonic Flow Meter • Pressure Recorder	Visit Briefing Site Visit Visit Report	30 Minutes 5 hours 30 Minutes	Practical

		• Road Measure		
Day 4				
1.	Action Plan for Leakage Prevention	• Preparation of Action Plan for Leakage Prevention by each water utility.	Briefing Group Discussion Group Presentation	1 Hour 3 Hour and Minutes 1 Hour and Minutes

Practical Hours	21
Theory Hours	7
Total Hours	28

9. Required Tools and Equipment

Sr. No.	Name of Tool and/or Equipment	Quantity
1.	Leak Detector	2
2.	Acoustic Rod	2
3.	Non-Metal Pipe Locator	2
4.	Road Measure	2
5.	Metal Detector	2
6.	Metal Pipe Locator	2
7.	Pressure Recorder	2

10. Grade Evaluation Criteria

Sr. No.	Type	Percentage (%)
1.	Class Participation	20 %
2.	Assignments	20 %
3.	Project	10%
5.	Final Examination	50 %

11. Essential Readings

Sr. No.	Author (s) Last Name, Year of Publication	Book or Report Title	Publisher Name and Place of Publication
1.	Farley, M. (2001)	Leakage Management and Control	World Health Organization, Geneva
2.	Hamilton, S., Charalambous, B. (2013)	Leak Detection Technology and Repair	IWA, United Kingdom (UK)
3.	Wave Training Programe (2010)	Non-Revenue Water (NRW) Course for Water Service Providers (WSPs)	Federal Ministry for Economic Cooperation and Development, Kenya

12. Reference Materials

Sr. No.	Author (s) Last Name, First Initial and Year of Publication	Book or Report Title	Publisher Name and Place of Publication
1.	Hughes, D.M., Oxenford, J., Titus, R. (2014)	Pipe Location and Leakage Management for Small Water Systems	Water Research Foundation, Denver
2.	UN-Habitat (2012)	Leakage Control Manual, Utility Management Series for Small Towns, Volume 5	UN-Habitat, Kenya
3.	Butler, D. (2001)	Leak Detection and Management	Halma Water Management, United Kingdom (UK)

13. Course Leader and Module Leader Profile

Course Leader Profile
Mr. Chiaki Suzuki, Director for International Coordination Business Department Yokohama Waterworks Bureau.

Module Leader Profile
Mr. Sami Ullah is working as Senior Instructor for Leakage Detection and Repair course at Aljazari Academy. He holds a Masters' Degree in Water Resources Engineering from University of Engineering and Technology, Lahore. He has five years of practical experience in the field of environment and water resources sectors. As a faculty member, he has conducted various site visits and field trainings. He has actively accompanied the JICA counterpart in training of the trainers (TOTs). He is optimistic and confident to adopt active training approaches.

MODULE OUTLINE

Course Code: W 7231

Basic Knowledge of Leakage Detection
Module No. 1

2016

1. Module Information

Module: 1of 3		Module Duration (Hrs.): 7
Participants: BS-11 to BS-17 and equivalent • SDOs • Sub Engineers • Supervisors		Module Prerequisites: Not Required.
Languages of Instruction: English and Urdu		Module Timings: 9 am to 4 pm
Start Date: 03 Oct, 2016	End Date: 06 Oct, 2016	Venue: Al-Jazari Academy

2. Faculty Information

Faculty Names	
Module Leader: Sami Ullah	
Instructor (s): Sami Ullah	

3. Module Overview

Participants will learn: (a) how to detect leaks and pinpoint leak locations in supply network, and (b) use of leak detection equipment. Major topics covered under this module will include basic knowledge of leak detection techniques, function and usage of leak detection equipment and counter measures for leakage. This module has key importance as it will develop the capacity and capability of the participants to effectively survey the surface as well as underground pipeline leakages and repair them. This will help water utilities to conserve water and control losses thereby reducing the production and distribution cost of water distribution system.

4. Learning Outcomes

4.1. Knowledge Outcomes

Description
Acquire basic knowledge of leak detection in metal and non-metallic pipes
Understand the leakage survey methodologies
Learn about maintaining record of leak points and benefits of record keeping
Understand the principles of leak detection equipment required for finding leakages in metallic and non-metallic pipes
Learn to apply various leakage prevention techniques

4.2. Skill Set Outcomes

Description
Understand leaks in relation to pipe material, pressure, flow and ambient noise around supply lines
Develop leak detection plans
Use of appropriate leak detection equipment
Detect, Record and Report leakage points in water supply network

4.3. Professional Attitude Outcomes

Description
Realize the gravity of relationship between leakage loss and cost of water supply
Understand the role of leakage prevention techniques in improving service delivery of WASAs

5. Instructional Plan

Sr. No.	Topics	Sub-Topics	Instructional Method	Duration	Training Delivery Mode
		Day 1			
1.	Current Scenario of Leakage Detection	• Introduction to Leakage • Types and Sounds of Leaks • Factors Causing Pipe Leakages • Situation analysis of Leak Detection in Five WASAs	Course Plan and Introduction Brainstorming Presentation Group Activity	10 Minutes 10 Minutes 20 Minutes 20 Minutes	Theory Visual Aids
2.	Countermeasures for Leakage	• Leakage Survey Methods • District Metered Area • Distribution Volume Analysis • Calculation of Leakage Volume • Water Quality Based Leakage Detection • Record of Leak Points • Classification of Leakage Prevention Work • Procedure of Leakage Prevention	Brainstorming Presentation Group Discussion Individual Activity	20 Minutes 1 Hour 30 Minutes 30 Minutes	Theory Visual Aids
3.	Leakage Survey Equipment	• Equipment and Devices - Types, Functions and Usage	Presentation Demonstration	20 Minutes 50 Minutes	Theory Visual Aids

6. Assignment (s)

Assignment: Preparation of leakage detection plan for respective WASA Sub Division.

7. Learning Resources

- Lecture Notes
- Presentation and Videos
- Equipment Manuals
- Manual

8. List of Reading Materials

Sr. No.	Author (s) Last Name, First Initial and Year of Publication	Book or Report Title	Publisher Name and Place of Publication
1.	Hughes, D.M., Oxenford, J., Titus, R. (2014)	Pipe Location and Leakage Management for Small Water Systems	Water Research Foundation Denver
2.	UN-Habitat (2012)	Leakage Control Manual, Utility Management Series for Small Towns, Volume 5	UN-Habitat, Kenya
3.	PMDFC (2015)	Operation and Maintenance Manual of Punjab Municipal Development Fund Company (PMDFC)	PMDFC, Lahore
4.	Farley, M. (2001)	Leakage Management and Control	World Health Organization, Geneva
5.	Hamilton, S., Charalambus, B., (2013)	Leak Detection Technology and Implementation	IWA, London

Leakage Detection and Repair

W 7231

Basic Knowledge of Leakage Detection
Module 1

Current Scenario of Leakage Detection
Lecture 1

Participant Lecture Notes

2016

1. Lecture Information

Lecture Topic:	Lecture Duration: 1 hour
• Introduction to Leakage • Types and Sounds of Leaks • Factors Causing Pipe Leakages • Situation of Leakage Detection in Five WASAs	

2. Introduction to Leakage

2.1. Leakage

Leakage occurs in all distribution networks. The amount of water lost through leakages vary widely from country to country and between the regions of a country. It is important to distinguish between total water loss (sometimes referred to as 'unaccounted-for water' (UFW)) and leakage i.e., physical or real water loss.

- Total water loss describes the difference between the amount of water produced and the amount which is consumed.

$$\text{Total Water Loss} = \text{Total Water Produced} - \text{Total Water Consumed}$$

$$\text{Total Water Loss}\ (\%) = \frac{\text{Total Water Loss}}{\text{Total Water Produced}} * 100$$

- **Leakage** is one of the several factors leading to loss of water, and comprises the *physical losses* from pipes, joints and fittings, and from overflowing service reservoirs. These losses can range from minor to major or severe, and may remain undetected for months or even years.

- *Non-physical losses* are the other components of the total water loss, e.g. meter under-registration, illegal connections, theft and illegal or unknown use.

- The *larger physical losses* of water are usually occur from burst pipes, or from the sudden rupture of a joint, whereas *smaller physical losses* are from leaking or "weeping" joints, fittings, service pipes, and connections as shown in **Figure 1**.

- The *volume lost by physical losses* will depend largely on the pressure in the system, and on the "awareness" time, i.e., how quickly the leak/burst is noticed and dealt with. This in turn depends on whether the soil type allows water to be visible at the surface. It also depends on the leak detection and repair strategy of the water supply utility.

Figure 1: Water Loss from hole (left) and crack (right) of an Asbestos Cement Pipe

2.2. Water Balance

Table 1. Water Balance Presenting Leakage Components

<table>
<tr><td rowspan="6">System Input Volume</td><td rowspan="4">Authorised Consumption</td><td rowspan="2">Billed Authorised Consumption</td><td>Billed Metered Consumption</td><td rowspan="2">Revenue Water</td></tr>
<tr><td>Billed Unmetered Consumption</td></tr>
<tr><td rowspan="2">Unbilled Authorised Consumption</td><td>Unbilled Metered Consumption</td><td rowspan="4">Non-Revenue Water (NRW)</td></tr>
<tr><td>Unbilled Unmetered Consumption (e.g. flat rates not billed)</td></tr>
<tr><td rowspan="2">Water Losses</td><td rowspan="2">Commercial (Apparent Losses)</td><td>Unauthorised Consumption (e.g. illegal connections)</td></tr>
<tr><td>Metering Inaccuracies</td></tr>
</table>

		Physical (Real Losses)	Leakage on Transmission and/or Distribution Mains	
			Leakage and Overflows at Utility's Storage Tanks	
			Leakage on Service Connections up to point of Customer use	

All terms used in the above (**Table 1.)** are listed in chronological order in the glossary, as one would read the water balance from left to right. Some of the terms are self-explanatory yet are still listed for consistency.

Difference between Waste Water and Leakage

- Household losses caused by poor plumbing, tanks overflowing are water wastages, and can be controlled/reduced by household metering.
- Wastage of water also occur from standpipe destruction, taps left "open" valve less pipe in the area of intermittent supply.
- Leakages are water loss from the poor joints, cracks, holes or accidental bursts due to pointed load over weak section of the pipe.

3. Types and Sounds of Leaks

Leaks are categorized into two major types as shown in **Figure 2**.

a) Surface leaks
b) Underground leaks

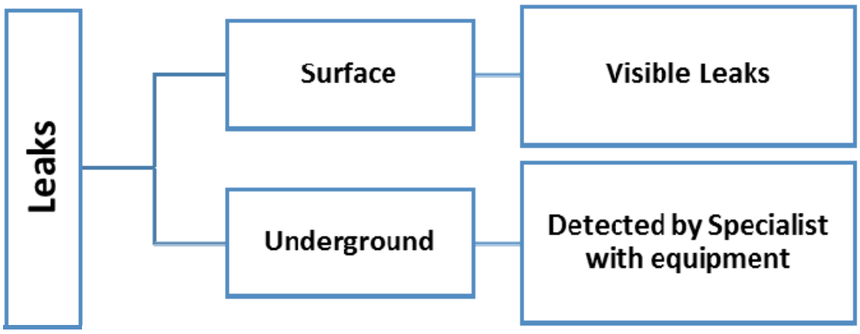


Figure 2: Leakage Types

If the rate of underground leakage is high, wetness is visible from the surface, making it easy to identify and pinpoint the leak. In some cases, however, leaking water from underground pipes percolates down and makes undetectable channels. The detection of such points is very important to avoid water losses and water contamination especially in case of intermittent water supply system.

Leakage sound is different depending on the pipe material, shape of the leak hole, water pressure and changes by a transmission route and distance described in **Table 2**. The detection distance i.e., how far around the leak vibration can be detected depends upon the pressure in the pipe, pipe material and the depth of the pipe. Leak sound in case of PVC pipe need extra care as it appears within a few feet around the leak even if the depth underground is shallow as shown in **Figure 3.** Higher pressure and high flow rate makes leak detection easy.

Table 2. Transmission of the Leakage Sound

Condition	Transmission Length		Remarks
	Long	Short	
Diameter	Small	Large	Hard to vibrate a large diameter.
Material	CIP, DIP, SP	PVC, ACP	Vibration occur in metal pipe more than non-metal pipe.
Kind of Joints	Socket Joint	Rubber Joint	Rubber attenuates leaking sound.
Leakage Amount	High	Low	Low leak amount has small leakage sound.
Pressure	High	Low	Low pressure has small leakage sound
Depth	Shallow	Deep	Leakage sound attenuate with deep depth
Density of Soil	Thick	Rough	Leakage sound attenuate with rough density of the soil

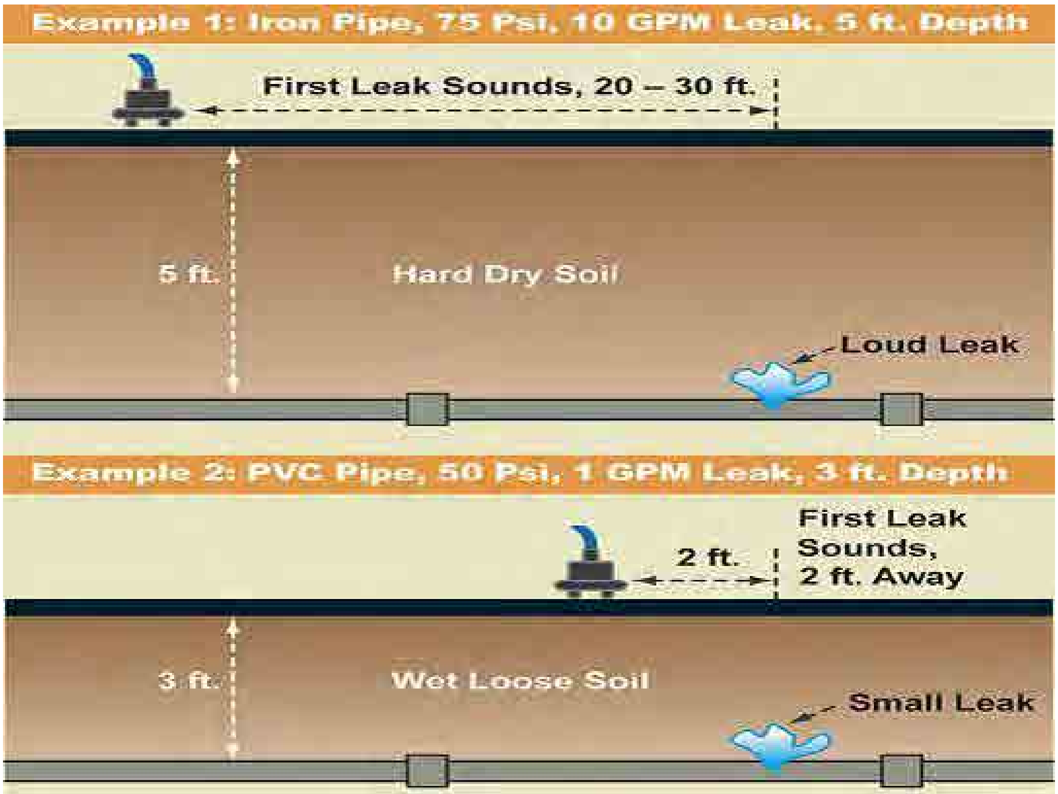


Figure 3: Distance of Leak Depends upon Pressure, Depth of Pipe and Material of Pipe

False Leak Sounds: Since leakage sound is affected by several factors including environmental noise, density of soil, equipment used and above all experience of the operator, occasionally, it becomes difficult to distinguish between true and false sound as given in **Table 3**.

Table 3. False Leak Sound

Types of False Sound	Characteristic and Others
Water Flow Sound	Sound from service pipe when water is passing smoothly
Sewerage Flow into Manhole	Cause of low pitch echo sound when the sewerage flow in the manhole. It is similar to the leak sound
Breeze Sound	Wind velocity about 4 to 6 m per minute, realize skin keenly is most similar leak sound. If the velocity more it quench the leak sound
Driving Vehicle Sound	Friction sound by tire and road. It is more similar to leak sound even the distance is more than 60 m
Urban Noise	Vibration sound of the buildings cause of wind and noise inside the buildings

Transformer sound	Vibration sound of transformer cause of magnetism
Electric motor sound	Shaft and fan sound of motor of the air conditioner, house centrifugal pump and vending machine

4. Factors Causing Pipe Leakages

- Water supply facility consists of reservoir, intake, transmission, filtration, distribution and water supply equipment.
- Leakage occurs from the network due *Internal and External factors.*
- All measures for leakage prevention should focus on supply network.
- **Table 4** delineates the factors leading to leakage within supply network.

Table 4. Factors of Leakage

Internal Factors	External Factors
Pipes and Materials - Material and structural defects in the pipes, joints and accessories from the beginning - Deterioration in the strength due to corrosion - Deterioration of material by the passage of time i.e. with respect to the age of pipe - Untidy joints or poor workmanship	**Pipe Surroundings** - Heavy traffic or heavy pointed load at the weak pipe section - Pit due to the leakage cause of accident - Earth movement due to poor compaction - Burst due to the water freezing inside the pipe - Soil contamination by the discharge from the factories - Design not according to the site condition (Gaps b/w design and site) poor design
Design and Construction - Design mistake (over or under-design capacity) - Poor connections and joints - Inappropriate backfilling - Attachment with other Structure (Lack of protection b/w them) - Potential of corrosion in different materials	**Other Constructions and Disaster** - Change of installation condition by other construction work - Topographic changes due to earthquake - Inappropriate traffic loads
Inner Side of the Pipe - High Pressure, Air, Water hammer and acidity / basicity of water (cause of	

corrosion inside the pipe)	
Others: Multiple causes or combination of the internal and external factors	

4.1. Effects of Internal Factors

1. Water loss from water reservoir
2. Water loss from transmission and distribution facilities
3. Water loss from the pipe due to cracking and corrosion of the pipe
4. Water loss from the connections at the consumer end.
5. Water loss from the joints
   a. Deterioration of rubber and loosen of the bolt-nut
6. Leakage from the fittings
   a. Leakage occurs from valves having cotton thread in the packing as shown in **Figure 4**. Cotton threads breaks under excessive tightening by plumbers

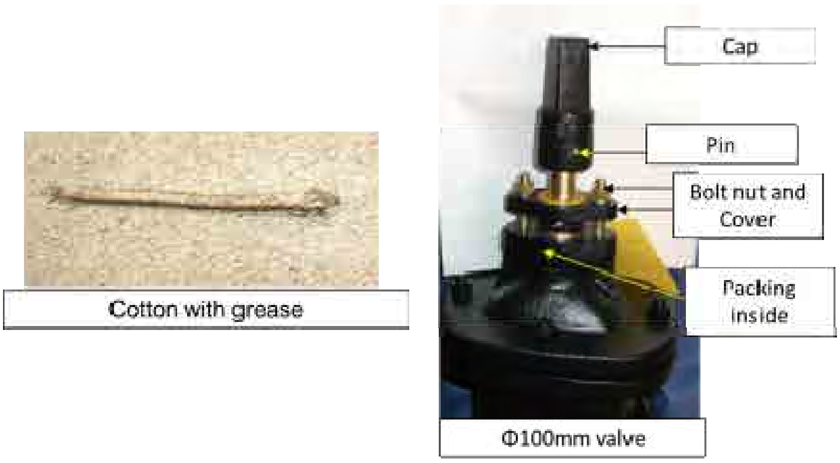


Figure 4: Valve with Inside Packing of Cotton (Source: Yokohama Waterworks Bureau)

   b. Leakage from air valves - Leakage occur from the gap of the float valve and its base where water introduces rust and sand produces adhere and scratches. Cross sectional view of the air valve is shown in **Figure 5.**

Figure 5: Air release valve (**Source:** Shimizu Iron Works Cooperation and Maezawa Industries, Inc.)

c. **Leakage from fire hydrant** – Packing Deterioration may create water leaks. Compression type fire hydrant with the parts labelling is shown in **Figure 6.**

Source: Mueller Co., Decatur, IL January 2010

Figure 6: Fire Hydrant (Source: WASA Lahore)

7. Leakage occurs from the service pipes: Different kinds of service pipes are in use in water utilities as given below. Each type of pipe material has its own strength and weakness. Advantages and disadvantages of most commonly used pipes are given in **Table 5**.
   a. Lead Pipe (LP)
   b. Galvanize Iron Pipe (GP)
   c. Stainless Steel Pipe (SSP)
   d. Copper Pipe (CP)
   e. Polyvinyl Chloride (PVC)
   f. High Impact Vinyl Pipe (HIVP)
   g. Polyethylene pipe (PEP)
   h. Hard Vinyl chloride lining steel pipe (SGP-VB)

i. High Density Polyethylene Pipe (HDPE)
j. Mild Steel Pipe
k. Asbestos Cement (AC) Pipe

Table 5. Pros and Cons of using Different Pipe Martials for Water Supply

Pipe Material	Pros	Cons
Galvanized Iron	-Low initial cost -Toughness -Long life -Easy inspection -Fast assembly	-Contain lead and Corrode easily -Deposits buildup causing blockages
HDPE Pipes	-Flexible -Easily transported because can be rolled -Used in trenchless installations -Lightweight -Resistant to cracking	-Difficult to locate -Fusion jointing require skilled installer and special equipment -Not suitable for large diameters
PVC pipe	-Inert and stable material -Resists corrosion -Cheap -Easy to install -Smooth interior surface -Very low frictional losses	-Very brittle (break or crack easily) - Less flame resistant - At higher temperature their strength reduces
Cast Iron	-Inexpensive -Durable -Ability to withstand high pressure -Easy to install -Leak location straightforward	-Heavy , Brittle, -Corrodes in soft water, water with high chloride or sulphate -tuberculation reduces carrying capacity -Leaves a metallic taste in water due to leaching of iron
Ductile Iron Pipe	-High strength for supporting earth loads, less brittle than CI, lighter than CI	-Heavy weight -May require wrapping or cathodic protection in corrosive soils or water, typically lined to limit corrosion

Asbestos Cement	-Rigid -Light weight in long lengths -High tensile strength -Easily tapped, cut -Low friction to water flow -Corrosion resistant to most soils and water -Flexible joints can be used to allow some deflection	-No longer used in new constructions because under corrosive conditions it can release asbestos fibers harmful to human health -Easy breakage when bent -Difficult to locate

4.2. Effects of External Factors

Following are the most common external factors leading to leakages or bursts in the water distribution system:

1. Road construction
2. Heavy pointed load and vibration from the traffic
3. Land subsidence due to the earthquake
4. Unsuitable environment for the pipe material – Soil quality, wide range temperature, corrosive gas, stray current, acid rain, etc.
   - Shallow depth
   - Small gap from the other pipes and structure
   - Soil movement due to construction work
5. Seasonal variation in water temperature and cause of pipe burst from distribution pipes
6. Pipe corrosion
   - Due to the electric corrosion by the surroundings installation
   - Classified as *electrolytic corrosion* which is generally caused by an artificial electric equipment like the electric-railway and electric protection equipment, and the *natural corrosion* which is caused by the environment. Further breakdown in electrolytic corrosion and natural corrosion are shown in **Figure 7**.

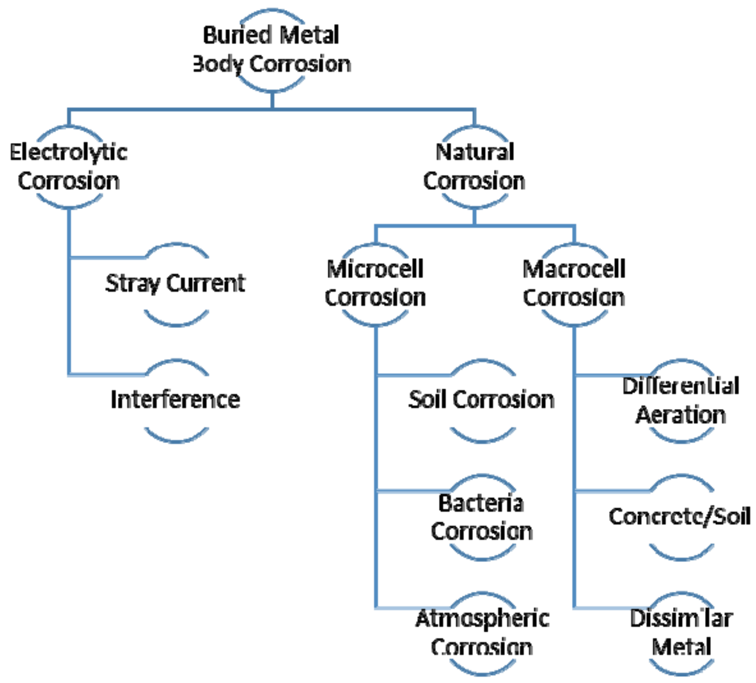


Figure 7: Breakdown of Electrolytic and Natural Corrosion in Underground Metal Pipes

7. External Damage by the Other Utilities
   - Repair and maintenance work by the PTCL, Gas pipelines and roads etc.
   - There should be a mark on the surface to save from such damages.

5. Situation Analysis of Leakage Detection in Five WASAs

Leakage in water distribution system is not only a problem of developing countries; most developed countries are facing these issues as well. Better quality of pipeline, adoption of new technologies, high quality of workmanship and precise fittings give them better control over water losses in the network. In Pakistan, water loss due to leakage is not only caused by the aged pipelines networks, un-awareness about new technologies, poor fitting and poor workmanship but also due to insufficient equipment for physical loss reduction and untrained manpower.

Following are the points representing overall situation about leak detection of each WASA. This information was collected from the water utilities through field visits, meetings and filling the questionnaires. Purpose was to know the current status and the prevailing procedure of surface and ground leakage detection and repair in each agency.

- Each water and sanitation agency has the leak detection team but the number of persons in the team are different, depending upon the frequency and number of complaints, task assigned to the teams, training of the staff and availability of leakage detection equipment.
- The type of equipment available with Lahore WASA for leakage detection is shown in **Figure 8**. In Lahore, leak detection teams only look for the illegal connections rather leaks.
- Rawalpindi and Multan WASAs have the inspection teams but they don't have any kind of leak detection equipment.


Old Leak Correlator


Acoustic Leak Detector


Metal Pipe Locator


Electromagnetic Flow Meter

Figure 8: Leakage Detection Equipment at WASA Lahore

- Excluding Faisalabad WASA, each agency is locating and identifying leakages without using any equipment.
- Only WASA (Faisalabad) uses proper equipment for leak detection. In Faisalabad, WASA workers of leak detection team were using Helium gas equipment but they had to quit due to its high operational cost. Equipment in use by the WASA staff Faisalabad are

shown in **Figure 9.**

- Average number of Leaks repaired by each WASA are different as shown in **Table 6**.
- WASA Gujranwala and Multan has the highest number of leaks per kilometer. Multan has 8.5 times more leaks in their pipe infrastructure as compared to Lahore. However, due to the non-availability of sufficient data, it is very difficult to make true comparison.
-

Helium Gas Leak Detector

Acoustic Leak Detector

Metal Locator

Leak Detector and EM Flow meter

Figure 9: Leakage Detection Equipment at WASA Faisalabad

Table 6: Leakage Detection Review of WASAs Capacity

(Source: JICA Questionnaires and Quarterly Report, January 2016)

Items	Lahore	Faisalabad	Gujranwala	Multan	Rawalpindi
No. of leakage survey teams	52	2	0	9	15
No. of person in one team	3	8	0	4	2-3
No. of days of leakage survey (person*days/year)	62	8*150=1200	0	4*1=4	Every day
No. of hours of leakage survey (person*hours/month)	9.6	8*250=2000	0	24	Office hour
Length of leakage survey (km/year)	9.1	750	0	0	300
No. of surface leakage detection (number/year)	2700	68	0	576	640
No. of underground leakage detection (number/year)	300	427	0	2880	Nil
How to detect underground leakage	Manual detect	Helium gas	Manual detect	Manual detect	N/A
No. of repairing leakage	3000	672	1137	3456	Nil
No. of leakage per kilometer of distribution pipeline	0.389	0.456	3.056	3.294	0.556
No. of leakage report from citizens	2950	1737	1137	3110	225
Done the Minimum Flow Measurement	N/A	Yes	N/A	N/A	N/A
Equipment : Acoustic Rod	0	0	0	0	0
Equipment : Correlative leak detector	0	0	0	0	0
Equipment : Leak noise correlator	1	5	0	0	0
Equipment : Metal pipe locator	1	0	0	0	0
Equipment : Non-metal pipe locator	0	0	0	0	0
Equipment : Other leakage	0	Helium gas	0	0	0

Items	Lahore	Faisalabad	Gujranwala	Multan	Rawalpindi
detector					
Metering ratio (%)	1	18	0	0	0
NRW (%)	41	32.9	35	22	31
Mapping System / DMA	U.D. (GI S/DMA)	Yes (Mappin g)	Yes (DMA)	N/A	U.D. (GIS)

- Water is supplied in urban areas through different type of pipe materials (Cast iron (CI), Asbestos cement (AC), Polyvinylchloride (PVC), High Density Polyethylene (HDPE), Concrete (Hume) Pipe, Ductile Iron Pipe (DIP), Steel Pipe and Galvanized Steel Pipe). Among all the pipes used, Asbestos Cement (AC) has maximum length in all water utilities. Polyethylene pipes rank second in length after AC pipes.
- Total water supplied and water billed in term of revenue by each water utilities of Punjab is shown in **Table 7.**

Table 8: Present Status of Revenue and Non-Revenue Water across Five WASAs
(Source: JICA Questionnaires and Quarterly Report, January 2016)

Name of WASA	Supplied Water (MGD)	Revenue Water (MGD)	Non-Revenue Water (MGD)
WASA Lahore	238	147	91
WASA Faisalabad	112	76	36
WASA Rawalpindi	81	46	35
WASA Multan	45	36	9
WASA Gujranwala	21	13	8

5.1. Comparison of Leakage Rate of Other Countries

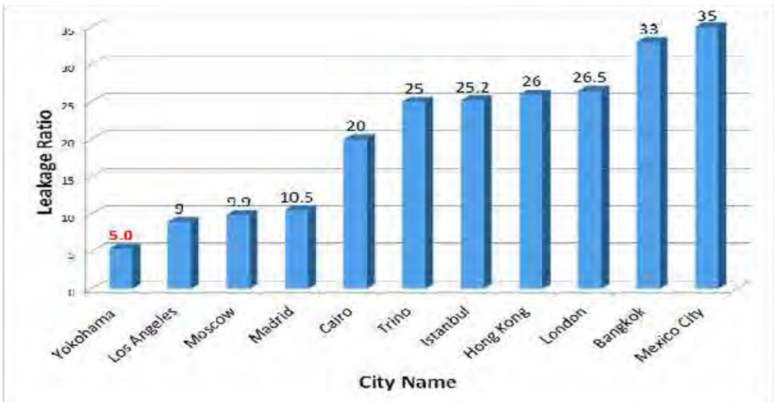


Figure 10: Comparison of Leakage Ratio in Different Cities of the world (2010) (Source: Yokohama Water Works Bureau, Japan.)

$$Leakage\ Ratio = \frac{Annual\ Leakage\ (m3)}{Annual\ Supply\ (m3)} * 100$$

Table 9. Urban Water Losses in Asia

(Source: World Bank Workshop on Non-Revenue Water, 2016)

Region	Non-Revenue Water		Physical Losses	Comm. Losses	NRW	Value
	%	(million m3/day)	(billion m3/year)			billion USD/year
Central and West Asia	40%	5.2	1.4	0.5	1.9	0.6
East Asia	25%	34.8	9.5	3.2	12.7	3.8
Middle East	30%	12.5	3.4	1.1	4.5	1.4
South Asia	35%	12.7	3.5	1.2	4.7	1.4
South East Asia	35%	13.0	3.6	1.3	4.9	1.5
Total Asia		**78.3**	**21.4**	**7.3**	**28.7**	**8.6**

5.2. Activity

Brief presentations on background and current practices of leakage control and management system by the participants from respective WASAs.

1. Prepare tables similar to Table 1 and Table 2 in the above description.
2. Presentation in groups on leakage detection situation, practices and equipment in use at the respective water utility.

6. Reference Material

1. Supply, W., Council, S. C., Farley, M., Water, S., & World Health Organization. (2001). Leakage management and control: a best practice training manual.
2. Wave Training Programme Kenya. (2010). Non-revenue water (NRW) course for water service providers (WSPs) in Kenya: Trainers manual.
3. JICA Quarterly Report. (2016). Project for improving capacity of WASAs in Punjab province in Islamic Republic of Pakistan.

Leakage Detection and Repair

W 7231

Basic Knowledge of Leakage Detection
Module 1

Countermeasures for Leakage
Lecture 2

Participant Lecture Notes

2016

1. Lecture Information

Lecture Topic: Countermeasures for Leakage	Lecture Duration: 2 Hours 20 Minutes
• Leakage Survey Methods • District Metered Area • Distribution Volume Analysis • Calculation of Leakage Volume • Water Quality Based Leakage Detection • Record of Leak Points • Classification of Leakage Prevention Work • Procedure for Leakage Prevention	

2. Countermeasures for Leakage

Need for Leakage Prevention

There is a dire need of leakage countermeasures techniques or leakage prevention work for continuous water supply and its efficient use. Stopping leaks in the distribution system not only stops the economic loss but also helps in avoiding water contamination, flawed water supply system, and destruction of the transmission line pathways. **Figure 1** illustrates how the countermeasure or leakage prevention work introduces positive impacts in the water distribution system.

Therefore, it is very important to install most appropriate type and size of the pipelines at appropriate depth to minimize leakage potential and maximize detection as well as repair of the leaky pipe. Pressure in the pipelines is also an important factor. Leakages reduce pipe pressure and thus invite contaminations into the pipe as shown in **Figure 2.**

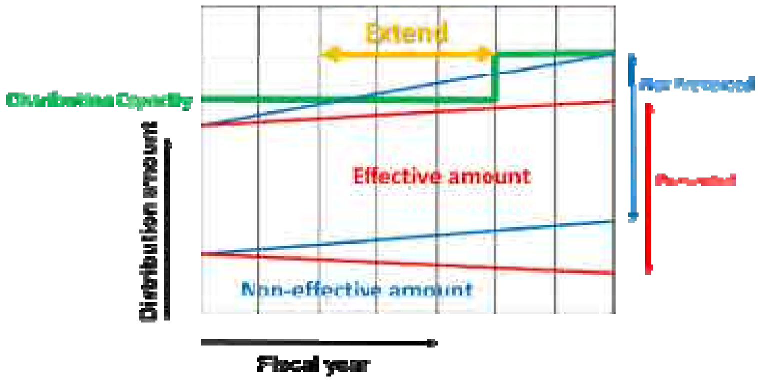


Figure 1: Importance of Leakage Prevention Work

Objectives of Leakage Prevention

- To maximize utilization of the limited water resources
- To improve economy
- To prevent potential accidents leading to leakage
- To maintain water pressure in the network
- To prevent water contamination

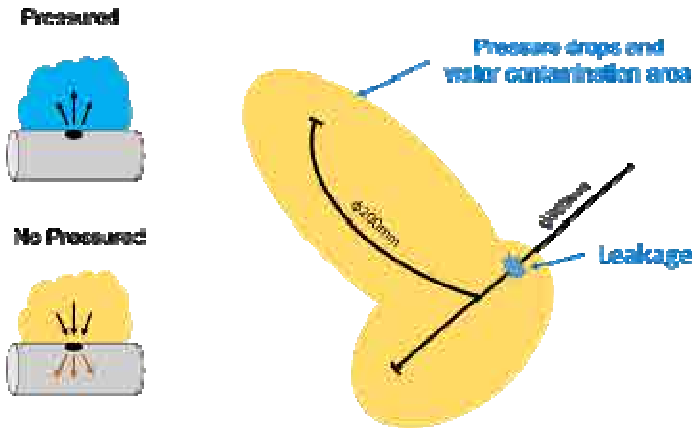


Figure 2: Water Contamination due to Pressure Drop

2.1. Leakage Survey Methods

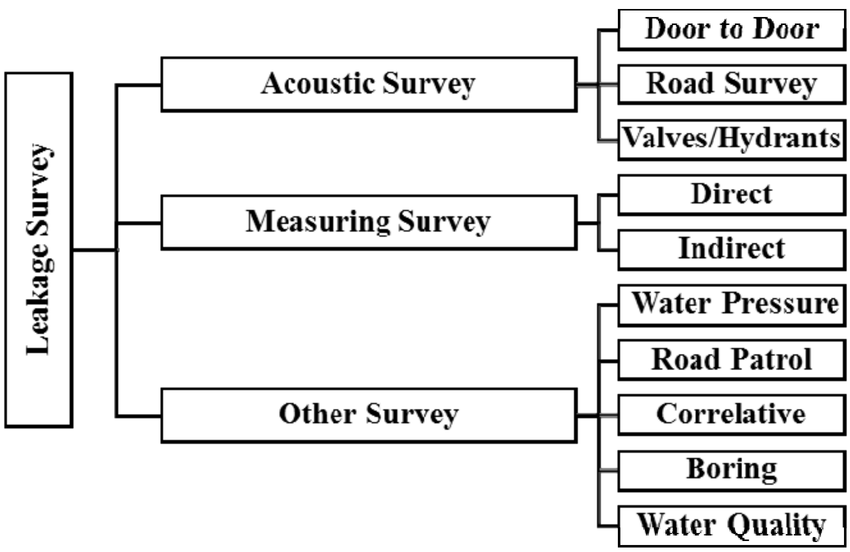


Figure 3: Type of Leakage Survey Methods

2.1.1. Acoustic Survey

Figure 4: Detection from Valves by Acoustic rod

In practical applications, leak pinpointing is performed by most utilities with common equipment based on vibro-acoustic transducers, such as listening devices (namely, geophones and listening rods, whose efficiency largely depends on the operator skills) and noise correlators (which automatically pinpoint leaks by means of signal correlation techniques). In this method, leakage sound is detected at ground surface and at the house connections (water meter and other appurtenances) using leak detectors such as acoustic rod. Underground leak points are located by detecting and correlating different sounds. Keep record of all the sounds specifically the leakage sound characteristics on a register. This method, that is most widely used, requires vast experience, practice, interest, and awareness by the operation

1. **Detection at Valves and Hydrants**

Leaks are detected with acoustic rods at the divide valves and fire hydrants shown in **Figure 4**. This survey is comparatively fast, but the detection of small leaks is difficult in this method. However, with the combination of the equipment like leak detector and leak correlator, leaks can be detected and located.

2. **Detection from Stop Valves and Water Meters**

Detection is carried out on a house call at installed water meters and stop valves using acoustic rods and leak sound correlators as shown in **Figure 5**. In this method, several points are checked in addition to valves and hydrants. Smaller leaks can be detected by using this method.

Figure 5: Detection from Water Meters

3. **Detection at Pipeline**

A water leak detector is moved from point to point on the road above the pipelines. This survey is mostly carried out late night or early morning to minimize impacts of surrounding noise (traffic noise etc.) as shown in **Figure 6**.

.

Figure 6: Acoustic Survey with Leak Detector

2.1.2. Measuring Survey

A service area (block) is isolated by closing the valves. Water can be supplied by temporary pipe or with a hose connected with fire hydrant. The water lost due to leakage in the area can be determined by using electromagnetic or ultrasonic flowmeter etc. In this method, minimum flow is recorded at midnight with continuous supply of water. This process is repeated several times to find accurate flow value.

Various types of flow meters are available e.g., electromagnetic type, car-loaded (mobile type), and portable type depending upon the accuracy intended and easiness of recording. However, turbine types of flow meters shown in **Figure 7** are mostly used by the water utilities.

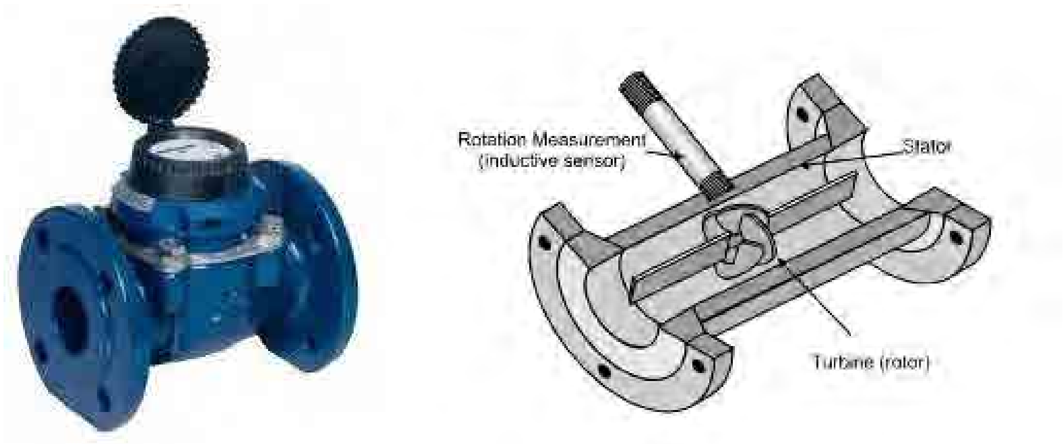


Figure 7: Turbine Type Flow Meter

Block Flow Measuring or District Metered Area Measuring:

- Install the flow meter at the inlet point of the surveyed block shown in **Figure 8.**
- Close all the valves at the exit flow points of the block.

- Check the valves during turnoff; stop any leakage at the valve connections or from the valves packing.
- Record the minimum flow (leakage flow) as shown in **Figure 9**. Leaking pipes can also be detected by providing partitions in the pipelines by installing divide valves within the surveyed block.

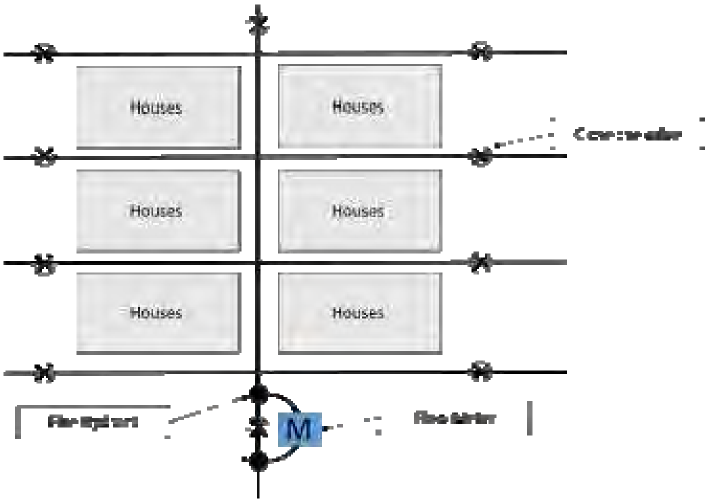


Figure 8: Block Flow Measurement

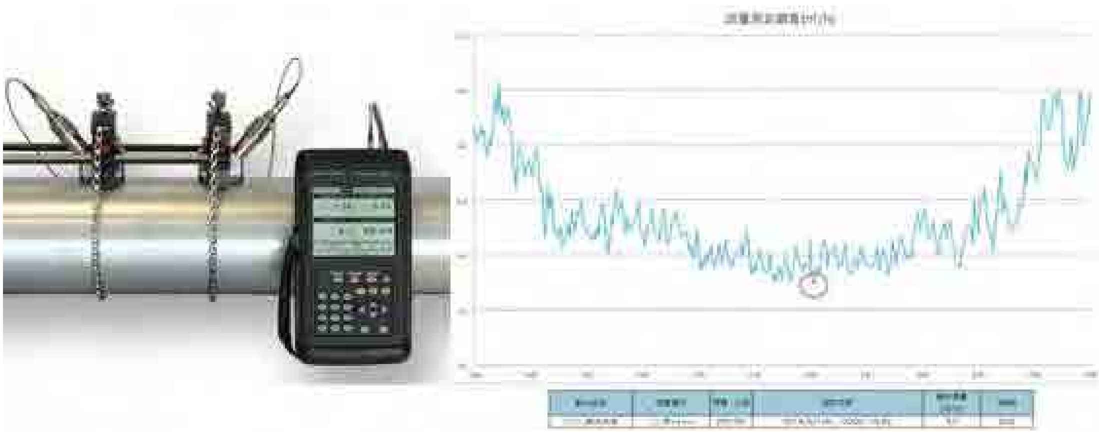


Figure 9: Minimum Flow Record Measured with Flow Meter (Source**:** RS Hydro Ltd.)

2.1.3. Other Surveys

- Water Pressure Recording Survey
- Road Surface Survey

- Correlative survey: This leak detection method uses a leak sound correlator. Pick-up devices are installed at two points - at divide valve and fire hydrant - between a stop valve and a meter. The leaks are detected by moving the device point to point above the pipeline.
- Boring survey: Leak point's detection is easy by the use of bore survey in combination with acoustic rod shown in **Figure 10**.
- Residual chlorine based survey shown in **Figure 11.**

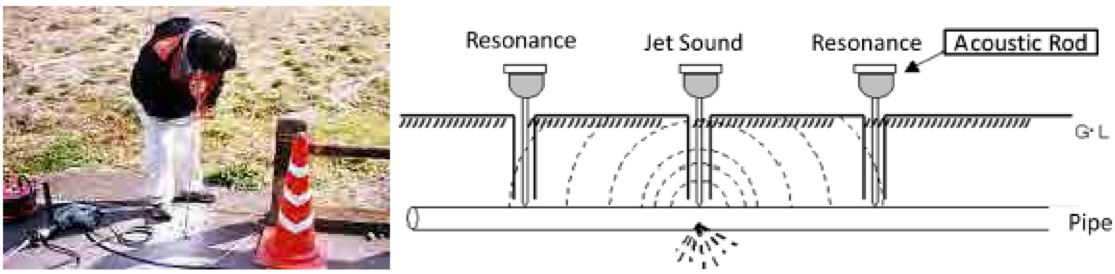


Figure 10: Acoustic Rod with Boring Survey (Source: life-line Co., Ltd.)

Figure 11: Leak Detection by Residual Chlorine Detection

2.2. District Metered Area (DMA)

Non-revenue water management is more cost effective when the supply system areas are divided into zones. The zones are further divided into a series of small sub-systems to make easy for NRW calculation. These small sub-systems often referred to as District Metered Areas (DMAs). Each DMA should be hydraulically isolated to calculate volume of water lost within the area. The purpose of this division is to enhance managerial output in order to reduce NRW, minimize the water quality problems, and to sustain water pressure in the lines to supply uniform quantity of water.

2.2.1. Establishing DMA

Following are a set of criterion for preparing a preliminary DMA design. These must be tested either in the field or by using a network model as shown in **Figure 12.**

- Size of DMA (e.g. number of connections – generally between 1,000 and 3,000).
- Number of valves that must be closed to isolate the DMA – should be kept to a minimum – natural boundaries should be used wherever possible.
- Number of flow meters to measure inflows and outflows (the fewer meters required to lower the establishment costs and more accurate flow measurement).
- Ground level variations and pressure fluctuations within the DMA (flat area more stable pressure and easy to control pressure).
- Topographic features that can serve as boundaries for the DMA, such as rivers, drainage channels, railroads, highways, etc.
- To divide a large system into a series of DMAs, it is essential to close valves to isolate a certain area and install flow meters. This process can affect the system's pressures, both within that particular DMA as well as its surrounding areas.
- The water utility therefore must ensure that the water supply to all customers is not compromised in terms of quality, pressure, and supply hours.
- In establishing a DMA, the water utility should limit the number of inflows, which if kept to one meter would enable the accurate measurement of water metering into the DMA and help to reduce the cost of design, setup and installation.
- Ensure all pipes within and out of the DMA are either closed or metered by performing an isolation test.

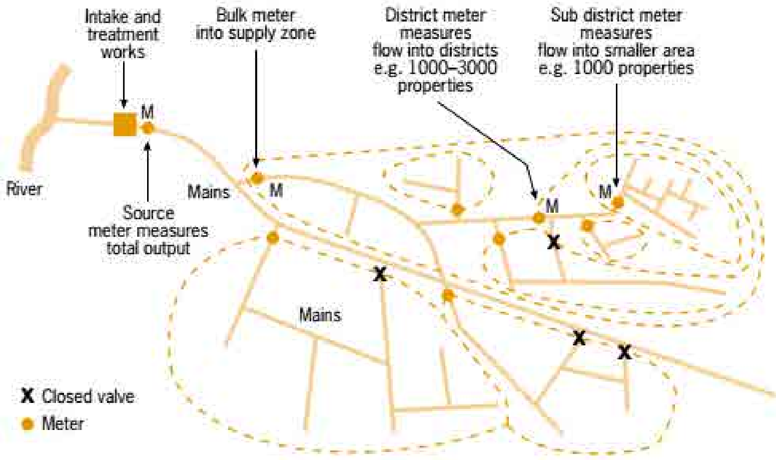


Figure 12: District Metered Areas (Source: WHO Manual, 2001)

2.3. Distribution Volume Analysis

Distribution volume analysis categorizes the consumed and lost water into different classes. It is most important catalogue to grasp the practical utilization of water and leakage situation in water supply system. Following **Table 1** is the distribution volume analysis table for one of the water utility in Punjab from the quarterly JICA report, 2016. Such kind of information was collected from each WASA by filling Training Need Assessments (TNAs) survey forms.

Table 1: Distribution Volume Analysis

<table>
<tr><td rowspan="9">System Input Volime 93.5 MGD</td><td rowspan="4">Authorized Consumption 62.7 MGD</td><td rowspan="2">Revenue Water 66.1%</td><td rowspan="2">Billed Authorized Consumption 61.7 MGD</td><td>Billed Metered Consumption (including water exported)</td><td>0%</td></tr>
<tr><td>Billed Non-metered Consumption</td><td>100%</td></tr>
<tr><td rowspan="7">Non-Revenue Water (NRW) 32.9%</td><td rowspan="2">Unbilled Authorized Consumption 0.94 MGD</td><td>Unbilled Metered Consumption</td><td>0%</td></tr>
<tr><td>Unbilled Non-metered Consumption</td><td>1%</td></tr>
<tr><td rowspan="5">Water Losses 30.8 MGD</td><td rowspan="2">Apparent Losses 14.76 MGD</td><td>Unauthorized Consumption</td><td>32.9%</td></tr>
<tr><td>Metering Inaccuracies</td><td>100%</td></tr>
<tr><td rowspan="3">Real Losses 16.1 MGD</td><td>Leakage on Transmission and/or Distribution Mains</td><td>0.25%</td></tr>
<tr><td>Leakage and Overflows at Utilities Storage Tanks</td><td>0.2%</td></tr>
<tr><td>Leakage on Service Connections up to Customers’ Meters</td><td>N/A</td></tr>
</table>

2.4. Calculation of Leakage Volume

Volume of Leakage = Leak flow rate (Q) x Leak duration (T) x Number of leaks (N)

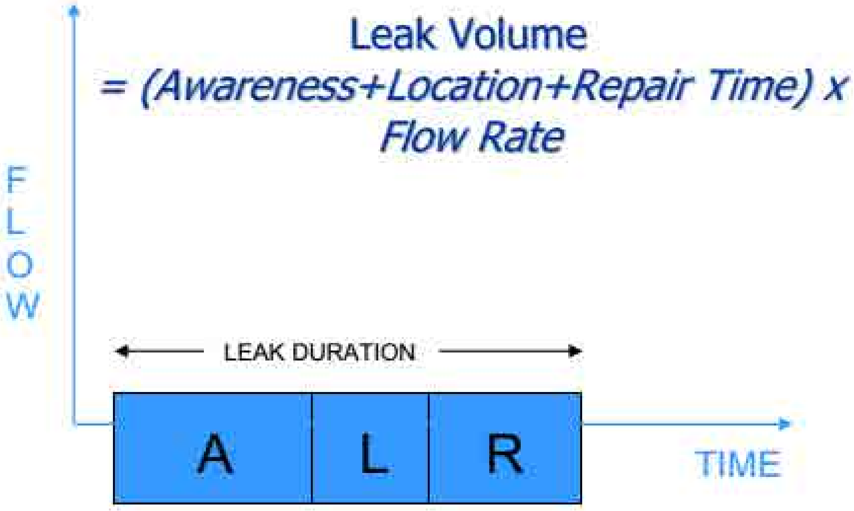


Figure 13: Leakage Duration and Volume

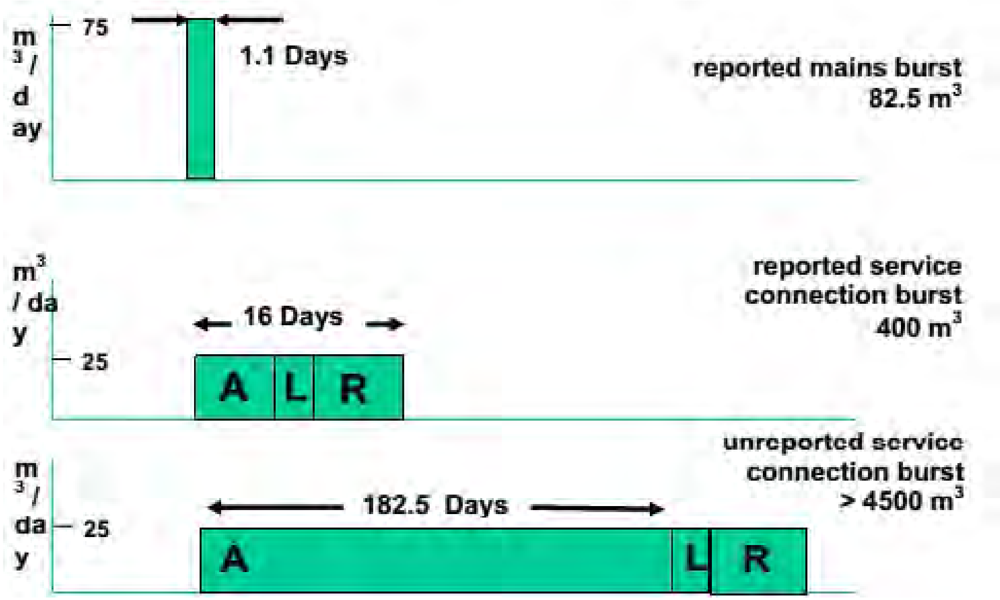


Figure 14: Run Times of Bursts on Service Pipes and Mains (Source: IWA Guidance Notes)

1. Minimum Night Flow or Bottom-Up Approach

The flow rate is determined at midnight or early in the morning when the consumption of water is at minimum.

[Net Night Flow] = [Minimum Night Flow] - [Minimum Night Consumption]

This MNF within a DMA can be measured directly from the data logging devices or the flow graph. Although customer demand is minimum at night, water operators have to account for the minimum night consumption (MNC), i.e. the night-time customer demand, such as toilet flushing, washing machines, etc. In a system with 100% metering, MNC is calculated by measuring the hourly night flow for all non-domestic demand and a portion (e.g. 10%) of domestic meters within the DMA. The utility will then estimate the total MNC in terms of liters per second as shown in **Figure 15**.

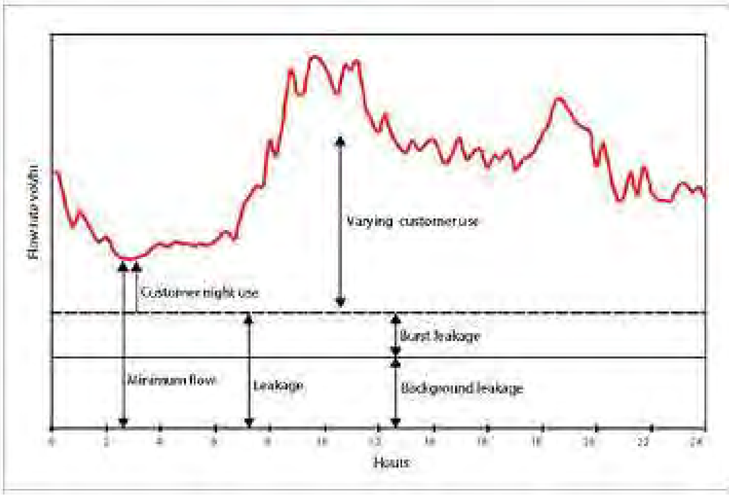


Figure 15: Minimum Night Flow Approach

2. **Integrated Flow or Top-Down Approach**

Leakage is remaining amount of the annual water balance calculation. A consistent approach is used to estimate leakage using this method. Estimate for unmeasured consumption show large variations, but the influence of the consumption estimate on the leakage may be readily measured.

Leakage = Distribution Input - Consumption

3. **Index of International Water Association (IWA)**

The IWA Water Loss Task Force developed a system-specific equation for the lowest technically achievable Annual Real Losses for well-managed infrastructure in good condition.

ILI = CAPL/MAAPL

ILI = Infrastructure Leakage Index
CAPL (liters/day): Current Annual Volume of Physical Losses

MAAPL (liters/day): Minimum Achievable Annual Physical Losses

$$\textbf{MAAPL (liters/day)} = (18\times L_m + 0.8\times N_c + 25\times L_p)\times P$$

L_m = mains length (km)
N_c = number of service connections
L_p = total length of private pipe, property boundary to customer meter (km)
P = average pressure (m)

The ratio of the CAPL to MAAPL, or the ILI, is a measure of how well the utility implements the three infrastructure management functions - repairs, pipelines and asset management, and active leakage control. Although a well-managed system can have an ILI of 1.0 (CAPL = MAAPL), the utility may not necessarily aim for this target, since the ILI is a purely technical performance indicator and does not consider economic consideration.
The ILI is particularly useful in networks where NRW is relatively low, for example below 20%, as the ILI can help to identify which areas could be reduced further.

2.5. Water Quality Based Leakage Detection

Following are the judgment approaches to know the leaks present in the water supply system based on water quality. These approaches are very useful to get alert, provide useful results if continue on regular basis.

- Residual Chlorine Judgment (at the site)
- PH judgment

Table 2. pH Value and Conductivity

Water Source	pH value	Conductibility (μs/cm)
Drinking water	Approx. 6.7～7.5	Approx. 100～300
Rain water	Under 6.0	Approx. 40～90
Groundwater	Approx. 6.4～7.5	Approx. 300～1000
Sewage	Over 7.0 (High)	Over 500 (High)

- Conductivity based judgment
- Water temperature based judgment
- Trihalomethane based judgment:

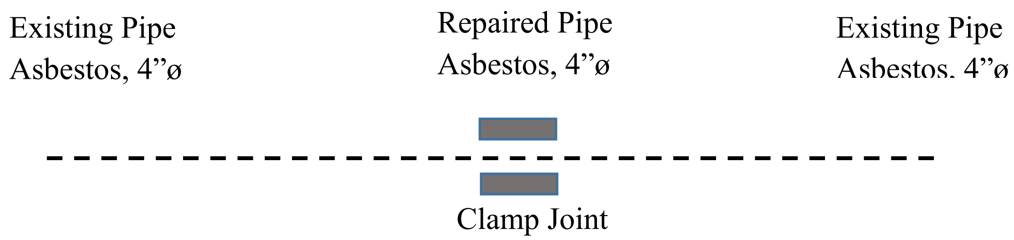
- Trihalomethanes (THMs) are a group of four chemicals that are formed along with other disinfection by products when chlorine is used to control microbial contaminants in **drinking water** react with naturally occurring organic matter in **water**.
- Presence of Trihalomethane in water tells water quality deterioration. However, this distinction needs a technical knowledge and special equipment. Therefore, it requires water laboratory testing.

2.6. Record of Leakage Points

At the advance stage of leakage prevention work, it will be more effective if real situation of the leakage is grasped and recorded (**Table 3**) because of high revenue ratio with the passage of time.

Table 3: Registry of Leakage

Date and Time	10:50 am; 11 February, 2016
Address	Civic Centre Near Cine Star Cinema
Person in charge	Mr. Shamas Ayoub Gujjar – SDO Green Town
Organization of repairing team	Pipe fitter x 1, Helper x 2
Diameter(mm)	4”
Material and Kind of Joint	Asbestos, wooden cork inserted into the hole and metal clamp along-with water proof sponge was used
Age (installation year)	45
Shape of leak point	Hole of 0.5” diameter
Pressure (kg/m^2)	Low
Depth(m)	4.5’
Soil around the pipe	Rough soil and garbage
Traffic density	Medium
Supply Hour	14
Cause of the leak	
Quantity of leak (m^3/min)	
Time of Repairing (Hour)	3

<table>
<tr><td colspan="2">【Sketch of Repairing】
</td></tr>
<tr><td>【Picture of Repairing】
</td><td>Location on the Map】
Coordinates: 31.450828 N, 74.310791 E
</td></tr>
</table>

2.7. Classification of Leakage Prevention Work

Leakage Prevention works are classified into three categories, basic work, direct work and indirect work as given in **Table 4.**

In order to achieve the desired goals, water utilities should have to endorse these to prevent the leakages. Although adopting direct prevention work will reduce the leaks, but to reduce cost and to make water utility services economical indirect prevention work should be preferred.

Table 4: Classification of Leakage Prevention Work

Leakage Prevention Work	Items	Measures
Basic Work	Preparation	• Create construction framework • Keep up a plan and necessary equipment
	Basic Survey	• Grasp information on distribution and leakage volume

	Study and Development	• Improvement of pipes and accessories • Leakage detection methods, pipe locating methods • Development on measuring leakage volume
Direct Prevention Work	Surface Leak	• Immediately repair
	Underground leak	• Early Detection and Repair
Indirect Prevention Work	Other Companies Construction*	• Road patrol and presence of construction • Security of pipeline, checking of excavation, backfilling, drive a sheet pile
	Improvement in Distribution and Service Pipeline Network	• Replacement, New pipe with old one, Pipe lining, Anticorrosion, Reinforcement of pipeline, Improvement of service pipe, materials and methods
	Pressure Survey	• Arrangement of pipelines, Fix distribution area, Install pressure regulator valves

*Pipeline protection from the construction work

Lay a sheet 60 cm above the pipeline written clearly "*There is a water pipeline below this sheet*" as shown in **Figure 13**.

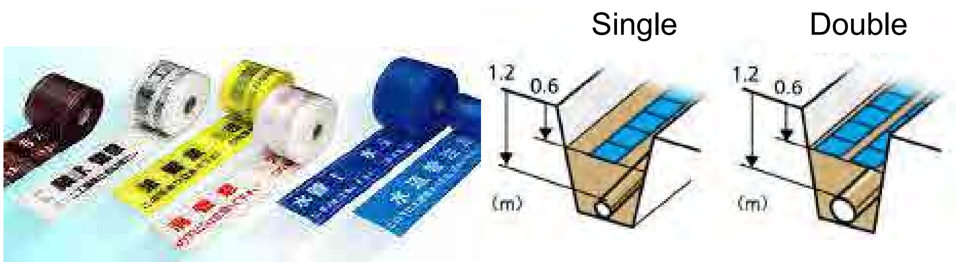


Figure 16: Protection of Water Supply Pipelines (Source: Ishimark Co.)

2.8. Procedure for Leakage Prevention

In order to fix and prevent Leak, the procedure outlined in **Table 5** can effectively be followed:

Table 5: Procedure for Leakage Prevention

Sr. No.	Guideline	Detail	
1.	Preparation	1. Establishment of Leakage Detection Cell and Team 2. Procurement of Equipment 3. Preparation of Distribution Map 4. Others	1. Preparation of Leakage Prevention Plan based on the past data 2. Purchase, lease, rental and regular services 3. Application of Survey Map and Mapping Data
2.	Water Network Survey	1. Distribution Analysis and Analysis of water volume error 2. Analysis and Distribution of Ground Water, Grasp the Cause of Leakage Volume 3. Others	1. Analysis of Underground Leakage by Leakage Management Section 2. Grasp the distribution of leakage, Cause and Leakage Volume 3. Divide the City to Survey Blocks
3.	Plan	1. Set the Target Value 2. Set the Planning year 3. Decide the Survey Method 4. Others	1. Around the Five Percent of Leakage ratio 2. Classify the each Blocks within the total blocks 3. Acoustic, Sound Pressure and Correlative Survey
4.	Action	1. Leakage Survey 2. Analysis of Cause of Leakage 3. Measuring the Prevention Volume 4. Preventive Work 5. Countermeasure of Leakage	1. All the administrative area will be surveyed regularly 2. Investigation at the Repairing 3. Measuring Leakage Volume by eye and simple scale 4. Repairing for Private Sector 5. Countermeasures for AC pipes
5.	Evaluation	1. Analysis of Results 2. Compare the Plan and Action	1. Review of the Classification of Blocks by the Number of Leakage, Survey Method and Equipment 2. Review of Classification of

			Blocks for next year 3. Evaluation of cause of leak, Chose of repairing method and repairing material

2.8.1. Leakage Detection Survey

Leak detection involves various types of survey depending upon the population density, age of the distribution system, type of pipe material. A few basic steps in leak detection surveys are given in **Table 6** and a brief detail is given in the subsequent section.

Table 6: Steps in Leakage Detection Survey

Sr. No.	Items	Details
1	Survey Plan	Plans for survey blocks, survey methods, survey material and organization of efficient survey teams
2	Preparation	Check the differences between the map and site based on the block, houses and distribution map
3	Door to Door Survey	Acoustic survey at the water meter and the bib cock.
4	Road Surface Survey	Leakage detection for underground service and distribution pipe
5	Confirmation Survey	Re-check the leak sound detected by acoustic survey and judge leak present or not to decide the leakage point
6	Summarize of Survey	Summarize and analysis the result

2.8.2. Water Network Survey

1. **Analysis of Volume of Distribution Water**

When making water leak prevention plans, it is important to analyze distribution and leakage volumes based on the most recent data, and to be aware of revenue and leakage ratio i.e.,

2. **Analysis of the Cause of Leakage**

Determine the causes of leakage by analyzing data for the past repair work. It is advisable to establish a grading system by the type of pipe, its diameter, design pressure, design flow and the cause of leakage. A separate system of analysis should be developed for distribution and service pipes.

3. Survey of the Leakage Distribution

Identify the leak prone areas by plotting the leakage points on the pipe distribution map. Leak prone areas should be surveyed on priority basis, and where frequent leakages occur, pipelines must be replaced.

4. Survey of the Age of the Pipeline Age

Old pipes are more prone to leakages. This tendency, however, may accelerate in some soils which may be acidic and therefore prone to rusting. Maps of pipelines giving the diameter, material, depth underground and year of installation, using colorcoding are indispensable. High pressure, old pipelines must be surveyed more frequently.

2.8.3. Developing Leakage Detection Program

1. Target Values and Design Year

To establish target values i.e., the percent reduction target for any year, it is recommended to set high goals considering the status of leaks, water demand and other economic aspects. It is also recommended to establish medium or long-term plans with the annual work schedules.

2. Survey Methods

Choose most effective method of survey considering the pipe size, leak size, pipe material, pressure, flow of actual leakage and other economic factors.

3. Survey Areas

When an area is too large to be surveyed in a single program year, the area may be divided into sub-areas to be surveyed in cycle of the years. Care must be exercised to ensure that the outcome of the survey remains most effective in terms of practicality and economy for the number of years considered. Leakage prone sections should be given priority, and be subject to shorter survey cycles.

4. Work Blocks

In order to control leakage more effectively, divide the area into work blocks. First, measure the potential leakage quantity in each work blocks, then based on the data, locate critical leakage points and repair the leakages pro-actively. Surveys of the leakages are best conducted in areas of suitable block size. It is, however, dependent on the block area, distribution pipe network, scatter of the streets and the number of households served. Figure 17, below shows the distribution of survey blocks on Yokohama City.

A commonly used yardstick is to consider 1 to 3km of distribution pipelines as a block. Yokohama City adopted yardstick is 0.5km ×1km.

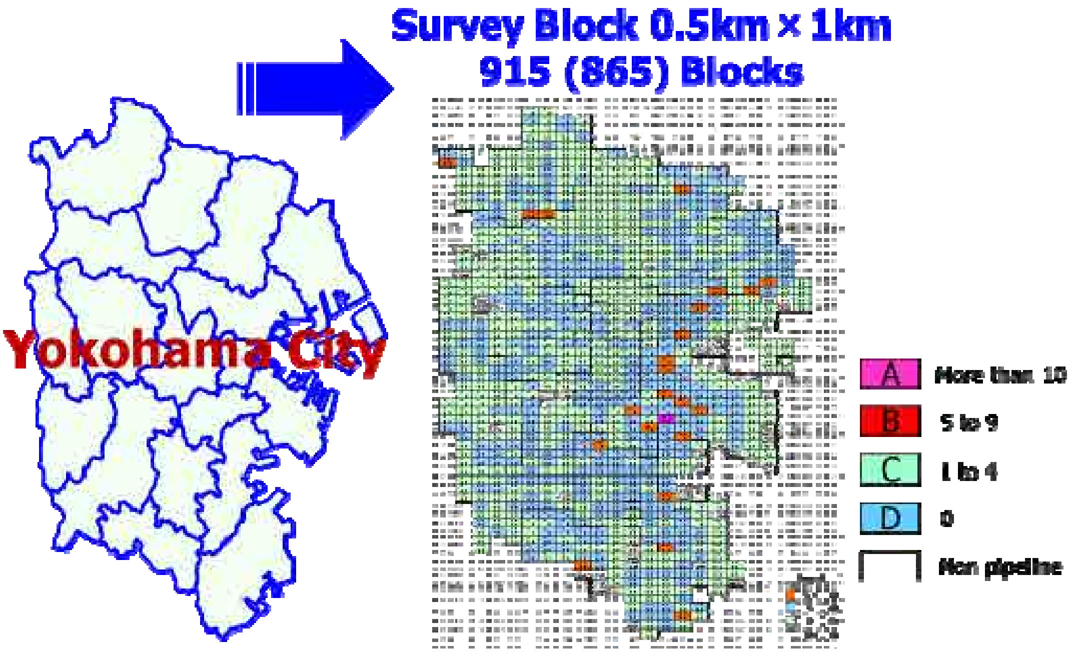


Figure 17: Survey Blocks in the City of Yokohama (Source: Yokohama Waterworks Bureau)

General idea of the cost of leakage prevention is almost equal to economic loss of the leakage.

3. Reference Material

1. Supply, W., Council, S. C., Farley, M., Water, S., & World Health Organization. (2001). Leakage management and control: a best practice training manual.
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4. Ariyoshi, H. (2014). Loss, strategy for water leakage control in Japan: IWA workshop on water & energy and water.
5. Waterworks Guidelines, 2005. Strategy for water leakage control in Japan.

Leakage Detection and Repair

W 7231

Basic Knowledge of Leakage Detection
Module 1

Leakage Survey Equipment
Lecture 3

Participant Lecture Notes

2016

1. Lecture Information

Lecture Topic: Leakage Survey Equipment (Types, Functions and Usage)	**Lecture Duration:** 1 Hour 10 Minutes

2. Leakage Survey Equipment

Leakage detection equipment relies on multiple scientific information. Commonly used leak detectors make use of vibrations and noise caused by the leak. Electromagnetism helps in amplifying these effects. In general, leakage detection equipment are either based upon acoustic or non-acoustic techniques as given in **Table 1** below:

Table 1: Leakage Detection Techniques & Methods

Leakage detection methods		Suitability for		
		Service pipes	**Distribution mains**	**Trunk mains**
Acoustic techniques	Basic Listening stick	Yes	Yes	
	Electronic listening stick	Yes	Yes	
	Leak noise correlator		Yes	Yes
	Noise loggers		Yes	
	Multi acoustic sensor strip	Yes	Yes	
	In pipe sounding			Yes
Non- acoustic techniques	Gas injection	Yes	Yes	
	Ground penetrating radar	Yes	Yes	Yes
	Infrared photography			Yes
	In pipe hydraulic plug	Yes		

2.1. Acoustic Rod

The acoustic rod is a metal bar (about 9 mm in diameter and 1 to 1.5m in length) equipped with a vibrating plate which catches leak sounds by direct contact with valves, hydrants and pipes.

The acoustic rod is used only to determine the existence of leaks. Leak location is finalized using leak detector.

2.2. Leak Detector

This instrument detects leak sounds transmitted underground with a pick up device at the ground surface, the detected sound is amplified and transmitted to headphones. As the sound is strongest directly above the leak, the detection of this sound leads to the exact location of the leak. The use of acoustic rod and leak detection equipment is shown in **Figure 1**.

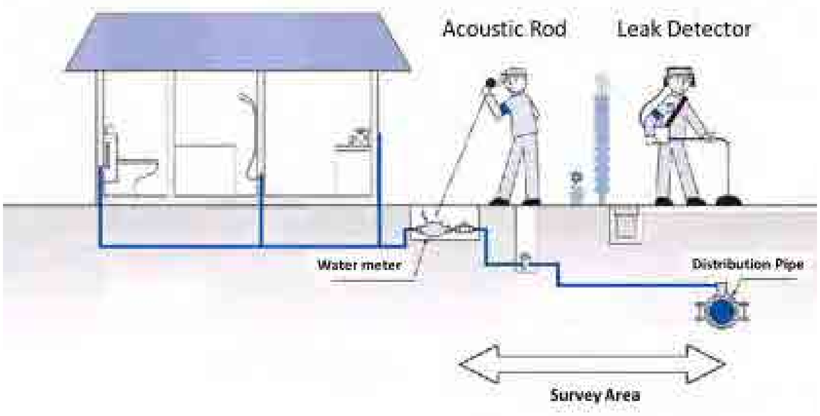

Figure 1: Leak Detection by Acoustic Rod and Leak Detector

2.3. Leak Correlator

This device identifies the location of the leak by intercepting leak sound generated at two valves, on opposite sides of the leak, with a microphone. It measures the difference in transmission time of the leak sound between the two valves on the same pipe and processes the information by computer. This correlator is used effectively where the pipes are laid deep and in busy streets where direct sound detection is difficult. However, the reliability of results is affected by the accuracy or inaccuracy of pre-fed information and the inherent decrease of computation accuracy due to the size and length of pipelines between two valves. The survey does not need a supply cut as it can be made on "live" pipelines. **Figure 2** shows a schematic and calculation of leak distance from one of the two selected valves.

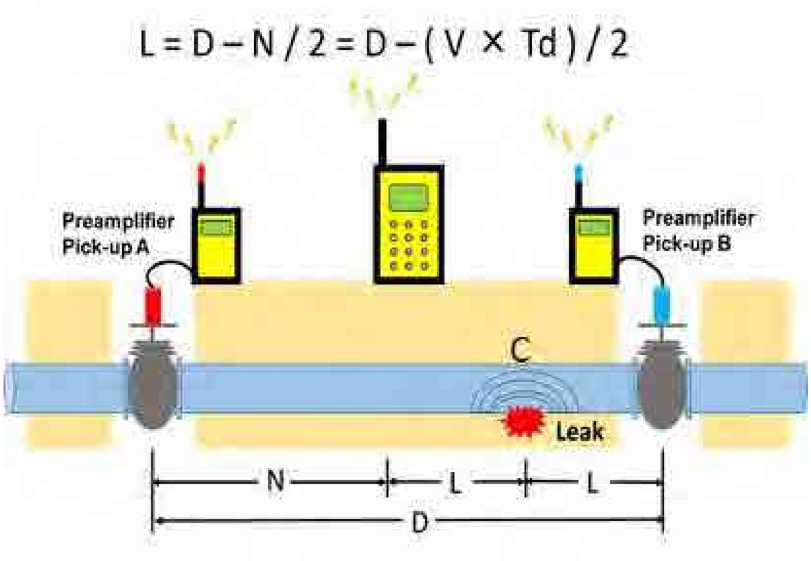

Figure 2: Leak Correlator

➢ **Computation of Leak Location**

Leaks in pipelines produce noise. This noise travels by two routs: it travels through the ground to the surface or it is transmitted in the wall of the pipe and the water. Correlator detects noise transmitted in the wall of the pipe and the water. "Pipe fittings" such as flow meters, valves and hydrants are used as access points. The position of leak can be pinpointed by picking up two points on the pipe around approximate location of the leak

Leak sound is transmitted through the pipe to either side of the leak. At randomly selected points on both sides of the leak, it shows “noise travel time difference or time delay” due to the difference in distance from the leak. This is represented by “Td”.

1. When this time delay (Td) is multiplied by the sound velocity (V) through the pipeline, the distance (N) between points A and C can be determined as shown in Figure 2.
2. Next “N” is subtracted from the distance (D) between A and B, and divided by 2 to determine the distance (L) to the leak point.

2.4. Multi-Point Correlating Radio Loggers

Multi-point correlating radio loggers can localize and locate leak locations over wide areas in a short time. It can be cited as an advanced variant of the Leak Correlator. Components and working of the multi-point correlator can be understand from **Figure 3**.

The advantage of multipoint correlation is that anyone can use it for highly-accurate diagnostics of leak locations by setting multiple correlators inside a chamber, record the “leak noise” at time when water usage in minimum (i.e. late at night or early in the morning) and collects contineous data.

This technology makes use of computer models where multiple loggers are set inside chamber at valves, and data is gathered or instructions issued while driving over the manholes by car. Using computer models and data collected from multiple loggers, leaks can be continually detected over a wide area from a remote location via Internet. In Abu Dhabi, about 10,000 loggers are continuously monitoring now.

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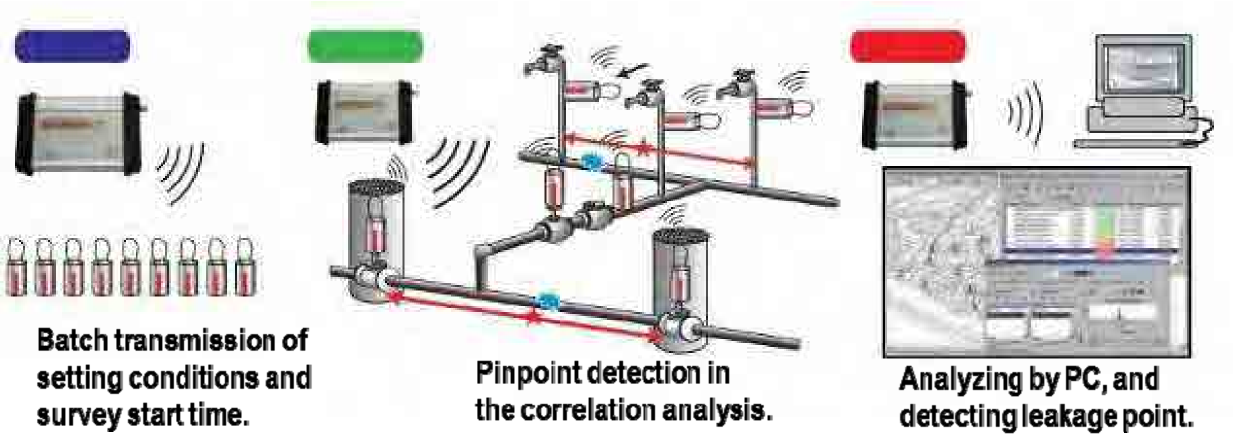


Figure 3: Multi-Point Correlating Loggers (Source: GOODMAN INC)

2.5. Gas-Permeation Inspection Method

In areas where "leak noise" detection is difficult due to loud surrounding noise levels, such as traffic area, congested area and factory area, the gas-permeation inspection method is very useful in such areas.

The gas-permeation inspection method detects and pinpoint the leaks by injecting gas with a low specific gravity into the pipe and by detecting the gas which is discharged from the leak location. ***Helium gas*** was being used as permeation gas. However, due to its high cost, it has been replaced with the ***gas mixture*** (5% hydrogen, 95% Nitrogen). This mixture is non-soluble in water, compliance with ISO-10156 standard and its safety is globally recognized. **Figure 4** illustrate the gas permeation equipment.

Figure 4: Tracer Gas Sampling Equipment (source: Sewerin Technologies**)**

2.6. Electromagnetic Flowmeter

The most common flow-meter (other than differential pressure and positive displacement flow meters) is magnetic flow meter, also known as electromagnetic flow meter or commonly just called a mag meter. In this case, a magnetic field is applied to the flow meter tube, which provides a potential difference proportional to the flow velocity perpendicular to the flux lines. Thus electromagnetic induction is used for leak detection as shown in **Figure 5**.

The magnetic flow meter requires a conducting fluid, for example, water that contains ions, and an electrical insulating pipe surface, for example, a rubber-lined steel tube.

If the direction of the magnetic field were constant, electrochemical and other effects at the electrodes would make it difficult to distinguish between the potential difference due to fluid flow and the one induced by magnetic field. To mitigate this, in modern magnetic flow-meters, the magnetic field is constantly reversed, cancelling out the electrochemical potential difference, which does not change direction with the magnetic field. This however prevents the use of permanent magnets for magnetic flow-meters.

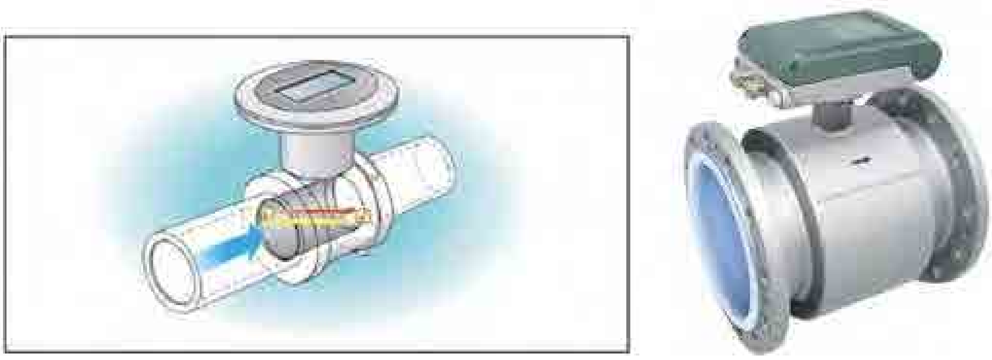


Figure 5: Principle of Electromagnetic Flowmeter (Source: Aichi Tokei Denki co., ltd).

2.7. Mobile Type Electromagnetic Flowmeter

The principle of the electromagnetic flow-meter is to calculate the fluid velocity by measuring the current flow in digital terms. The electromotive pathway a watercourse induces is measured, the current velocity is measured and it is converted into the flow rate in the magnetic field (N and S).

Using this equipment, investigation time should be early in the morning or late night (from 0:00am to around 5o'clock). Connect with hydrant and this hydrant with fire hose between the valves, connect the mobile electromagnetic flow-meter having φ50mm and φ25mm with hose to measure the minimum flow (**Figure 6**). When the flow rate in the pipe is reduced, the staff change the flow-meter to φ 25mm manually. It is used for a minimum flow measurement.

Figure 6: Pictorial View of Mobile Type Electromagnetic Flowmeter (Source: FUJI TECOM INC. and JICA Project in Brazil)

2.8. Ultrasonic Flowmeter

An ultrasonic flow meter is a type of flow meter that measures the velocity of a fluid with ultrasound to calculate the volume of flow. Ultrasonic flow meters are affected by the acoustic properties of the fluid and can be influenced by temperature, density, viscosity and suspended particulates depending upon the type of flow meter. Ultrasonic flowmeters are often inexpensive to use and maintain because these do not require moving parts like mechanical flow meters.

Using ultrasonic transducers, the flow meter measures the average velocity along the path of an emitted beam of ultrasound by averaging the difference of measured transit time between the pulses of ultrasound propagating into and against the direction of the flow or by measuring the frequency shift by the Doppler Effect as described in **Figure 7**. Minimum night flow can be determined by this recording flow with computer assisted programs as shown in **Figure 8.**

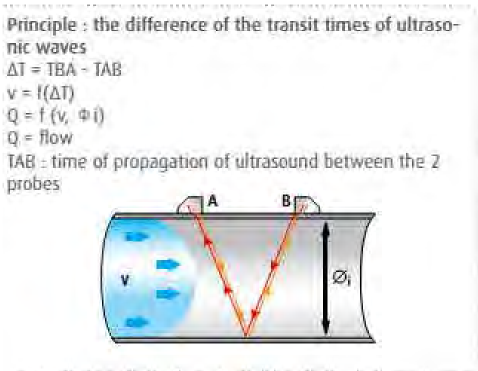


Figure 7: Principal of Ultrasonic Flowmeter

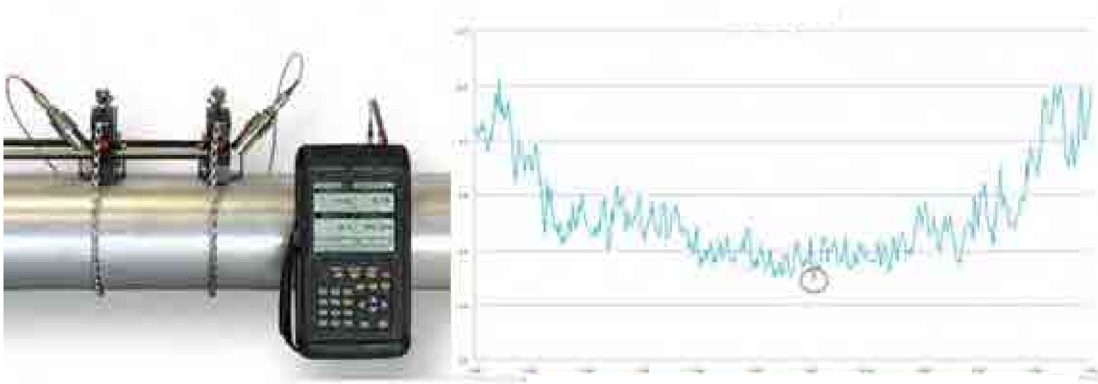


Figure 8: Graphical presentation of UF meter with PC (Source: RS Hydro Ltd.)

2.9. Water Pressure Recorder

Complete water proof and air sealed mechanism is present in this equipment. Recording can be observed through the round window when the cover is closed. Its compact, sturdy construction increases its ease of portability and durability under hard moist conditions. It is useful in checking fluctuations in water pressure as an efficient means of controlling water systems as shown in **Figure 9**. This equipment is very useful for:

- Keeping track of varying water pressure at night.
- Preventing water leaks by controlling water pressure.
- Making a water pressure distribution chart to find irregularities of flow in the system.
- Eliminating districts of poor water service caused by low water pressure.
- Testing water pressure after laying pipe.

It establishes the reliable workmanship in construction of water pipe and produces an evidence with the chart, a record the fault-free work. There are number of points of water leaks. About 90% are at the positions like joint with the distribution valve, control valve and water meter. Therefore, after installing and repairing such fittings, the plumbers are required to confirm that there is no water leak from the manufactured pipe. Such information is required to report with reliable evidence. With a view to complete the above confirmation and report, Fuji Portable water pressure recorder Model FJN-501 is recommended to be used together with test pump. This equipment is shown in Figure 9 (a,b) below.

Figure 9 (a): Working of Pressure Recorder

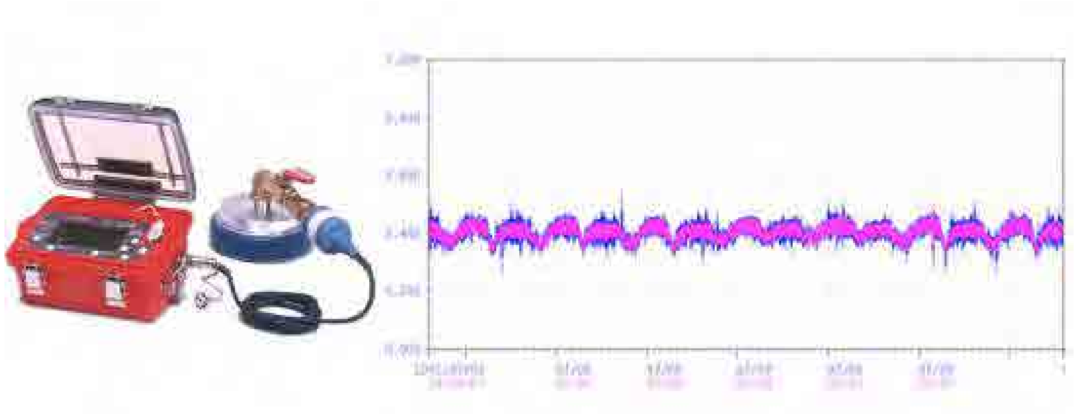


Figure 9 (b): Pressure Recorder Graph (Source: FUJI TECOM INC.)

2.10. Plastic Pipe and Non-Metal Leak Detectors

This detector works on the electrical insulation properties of the plastic pipes. It does not require "leak noise", instead it passes a high frequency through the "water" in the pipe (**Figure 10**), for which the plastic pipe's electrical insulation properties create a boundary with the earth, making the tracing of pipe routes easy using the same essential idea as a buried cable detector . The detection of the leak location works on the principle that the electrical current which leaks to the earth together with the water is detected on the surface as attenuation of the receiver sensitivity, making simple leak detection possible.

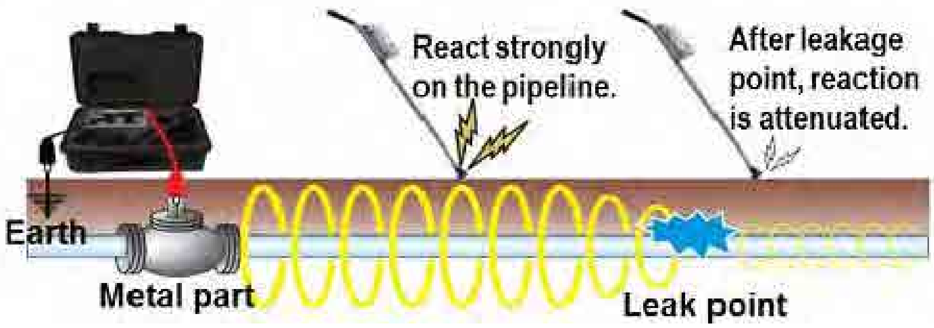


Figure 10: Water leak and non-metal pipe locator (Source: GOODMAN INC).

2.11. Magnetic Pipe Locator

This device is used to identify the location, depth and direction of underground utilities such as iron pipes, power lines and signal cables by generating a magnetic field in the pipeline detected by a receiver as presented in **Figure 11**.

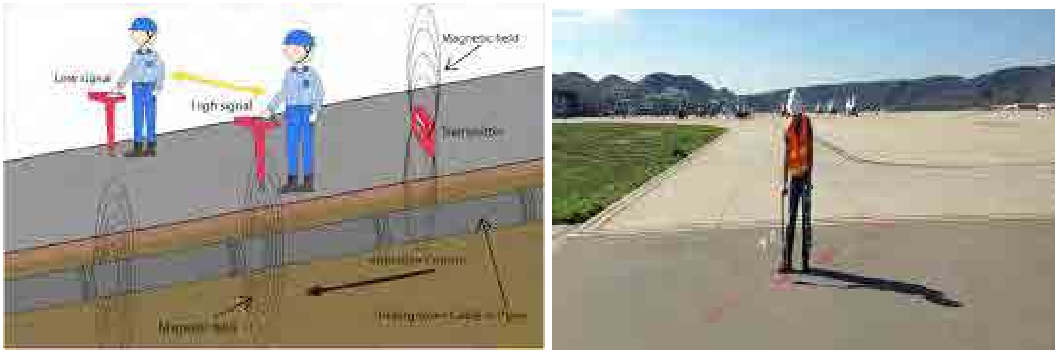


Figure 11: Magnetic Pipe Locator (Source: FUJI TECOM INC.)

2.12. Metal Locator

A **metal locator**, shown in **Figure 12**, uses an oscillating electromagnetic field to detect metal objects that reflect the signal through induced eddy currents. The Locator can also interpret distance and uses tones or beeps, and possibly a visual display, to indicate the presence of metal.

Many metal locators can also indicate the type of metal located as each metal has a different phase response. Locators often allow the operator to set parameters such as sensitivity, sensing width, and track speed etc.

Figure 12: Metal Locator

2.13. Underground Search Radar

Underground Search Radar emits high-frequency electromagnetic pulses into the ground to map subterranean features as shown in **Figure 13**. Soil penetration increases as frequency decreases, but spatial resolution suffers. Changes in the dielectric constant of the soil medium is reflected by the radar, identifying the location of materials. Data collection is carried out by rolling a ground penetrating radar (GPR) system over the area. This is a fast, inexpensive, leak locating technique that also registers non-metallic utilities.

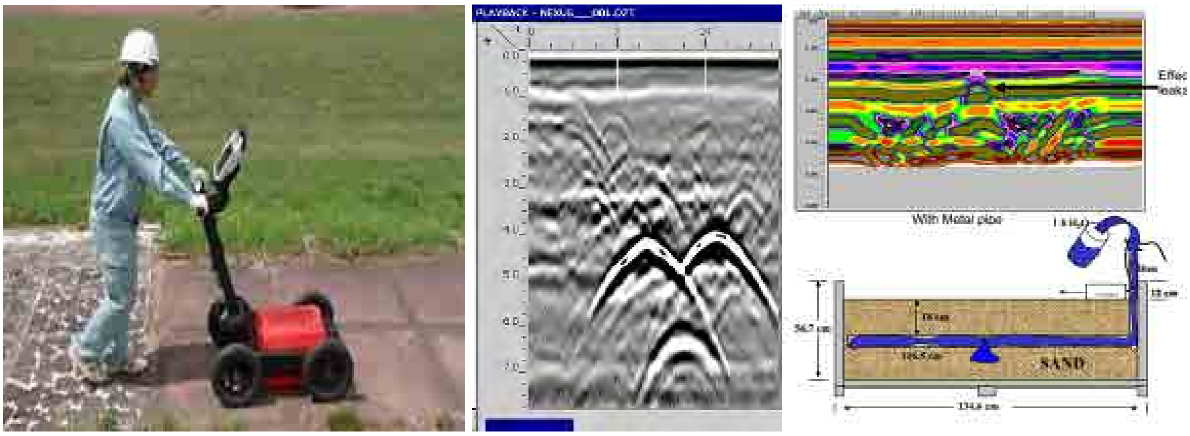


Figure 13: Search Radar (left) and Image (Center & Right) (Source: Hokkaisuiko Consultant Corp. and Ground Penetrating Radar Systems, Inc.)

2.14. L-sign Leakage Monitoring System

L-sign leakage monitoring system is a method to monitor water leakage constantly and its performance is as precise as acoustic leakage detection performed by professional engineers. L-sign monitors leakage automatically. **Figure 14** illustrates the L-sign placement on a fire hydrant.

Figure 14: L-sign Install at a fire hydrant (Source: Suido-tec. Co., Ltd.)

3. Reference Material

1. JICA Quarterly Report, 2016. Project for improving capacity of WASAs in Punjab province in Islamic Republic of Pakistan.
2. http://www.ultraflux.net/en/products/flowmeters-for-liquids-full-pipes/uf-801-p-portable/
3. http://www.fujitecom.com/products/pcl.html
4. www.fujitecom.com/catalogue/FJN-501-e.pdf
5. http://www.sewerin.co.uk/products/water-leak-location/m-130/
6. https://greenlee-cdn.ebizcdn.com/media/52031017REV04.pdf
7. http://www.ehmltd.co.uk/TRU001

MODULE OUTLINE

Course Code: W 7231

Water Network Maintenance and Leakage Detection (OJT)

Module No. 2

2016

1. Module Information

Module: 2 of 3		Module Duration (Hrs.): 7
Participants: BS-11 to BS-17 and equivalent • SDOs • Sub Engineers • Supervisors		Module Prerequisites: Module 1 needs to be completed successfully before starting Module 2
Languages of Instruction: English and Urdu		Module Timings: 9 am to 4 pm
Start Date: 03 Oct, 2016	End Date: 06 Oct, 2016	Venue: Al-Jazari Academy

2. Faculty Information

Faculty Names	
Module Leader Mr. Sami Ullah	
Instructor (s) Mr. Sami Ullah	

3. Module Overview

This module will enable course participants to acquire practical knowledge, skills and trainings in conducting leak surveys, identifying location of leak points (i.e. from pipes, valves, pipe joints and fittings), use of different leakage detection equipment with regards to pipe material, accurately pinpoint underground or surface pipeline leakages and finally apply various techniques for pipe leaks repair.

The major interventions envisaged under this module will cover on job training regarding leakage detection and subsequent application of countermeasures for leakage repairs and pro-active prevention. This module is focused on capacity building of water utilities employees in the field of leak detection and repair. It will increase their technical and operational capability to handle surface and underground leakages which at the moment, is nearly non-existent in WASA, due to lack of technical capacity and non-availability of leakage detection equipment. This module will help developing skills of WASA staff in detecting leak in the supply network, and operating leakage detection equipment. This, in turn, will help reduce water losses in supply lines thereby conserving water and improving the water supply service delivery of WASA to its consumers.

4. Learning Outcomes

4.1. Knowledge Outcomes

Description
Learn how to detect and pinpoint leaks through a water supply network survey with the help of leakage detection equipment.
Develop capability to recognize sounding of flow of water in pipelines with the use of equipment such as acoustic rod, leak detector etc.
Learn to develop and implement Standard Operating Procedures (SOPs) for leak detection equipment
Acquire hands-on experience on using leak detection equipment and pipe repair techniques

4.2. Skill Set Outcomes

Description
Understand leaks in relation to pipe material, pressure, flow and ambient noise around supply lines
Develop leak detection plans
Use of appropriate leak detection equipment
Detecting, Recording and Reporting leakage points in water supply network

4.3. Professional Attitude Outcomes

Description
Realize the gravity of relationship between leakage loss and cost of water supply
Understand the role of leakage prevention techniques in improving service delivery of WASAs

5. Instructional Plan

Sr. No.	Topics	Sub-Topics	Instructional Method	Duration	Training Delivery Mode
(Part of the First Day)					
1.	Repairing of Leakage and Burst Pipeline	• Repairing Materials • Repairing Procedure at the Site • Record of the Leakage Sites • Recommendations for Pipelines Repairing • Comparison of each Method	Brainstorming Presentation Group Discussion	25 Minutes 1 Hour 30 Minutes	Theory Visual Aids
Day 1					
1.	Leak Detection at the Site	Leak Detection Equipment • Acoustic Rod • Leak Detector	Visit Briefing Site Visit Visit Report	30 Minutes 5 hours 30 Minutes	Practical

6. Assignment (s)

1. Prepare the site visit report and write all aspects associated with the use of leakage detection equipment at the site.

7. Learning Resources

Available Leak Detection Equipment (leak detector and acoustic rod); Equipment Quick Manuals

8. List of Reading Materials

Sr. No.	Author (s) Last Name, First Initial and Year of Publication	Book or Report Title	Publisher Name and Place of Publication
1.	Hughes, D.M., Oxenford, J., Titus, R. (2014)	Pipe Location and Leakage Management for Small Water Systems	Water Research Foundation, Denver
2.	UN-Habitat (2012)	Leakage Control Manual, Utility Management Series for Small Towns, Volume 5	UN-Habitat, Kenya
3.	PMDFC (2015)	Operation and Maintenance Manual of Punjab Municipal Development Fund Company (PMDFC)	PMDFC, Lahore
4.	Farley, M. (2001)	Leakage Management and Control	World Health Organization, Geneva
5.	Hamilton, S., Charalambus, B., (2013)	Leak Detection Technology and Implementation	IWA, London

Leakage Detection and Repair

W 7231

Water Network Maintenance and Leakage Detection (OJT)
Module 2

Repairing of Leakage and Burst Pipeline
Lecture 1

Participant Lecture Notes

2016

1. Lecture Information

Lecture Topic: Repairing of Leakages and Bursts in Pipeline	Lecture Duration: 1 Hours 15 Minutes
• Repairing Materials • Repairing Procedure at the Site • Record of the Leakage Sites • Recommendations for Pipelines Repairing • Comparison of various repairing methods	

2. Repairing of Leakages and Bursts in Pipeline

2.1. Repairing Material

Following are the materials frequently used by the staff at all WASAs for the repairing of leaks and bursts in pipelines:

2.1.1 Gibault Joint

Gibault Joint also known as mechanical joints is used in case of water leakages in medium or high pressure lines (fed by two or more tube wells).

A Gibault joint for the pipe of four (4) inches diameter with its all components is shown in the **Figure 1**. These are only used when other methods fail.

The Gibault joint consists of the following parts:

1. Nut & Bolts 2. Rubber Rings 3. Flange 4. Drum

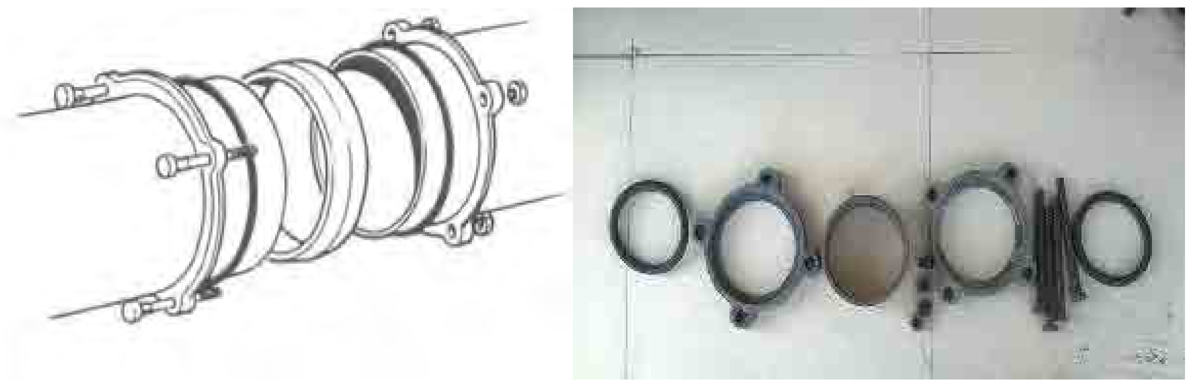


Figure 1: Gibault Joint (Left) & Joint Components (Right)

2.1.2. Clamps

Clamps are mostly used with water proof rubber piece. It is used to repair pipes having medium or high pressure lines. Components of the clamps include:

1. Clamp (Thickness: 1/8 in. - 1.5/8 in. Ø: as per requirement)
2. Nut & Bolts (Length: 4 - 6 in., Ø: 4/8 – 5/8 in.)
3. Rubber Piece
4. Ø 4”Pipe = 6” wide clamp is used
5. Ø 6”Pipe = 6” wide clamp is used

There are different sizes of clamps shown in **Figure 2**, used according to the situation and the requirements.

Figure 2: Different Sizes of Clamps

2.1.3 Rubber Tube

Rubber tubes are easily available in the market at very low price as shown in **Figure 3**. Scissor is used to cut the tube of suitable width and length. To use this repairing material only the following items are required

1. Rubber Tube
2. Scissor

Figure 3: Rubber Tubes

2.1.4 Wooden Piece/ Cork

A special type of wood (Birch or Rose Wood) is used in those types of leakages mostly occurs in the form of hole shape in the Asbestos Concrete water supply line. Wood piece is sharpened and wedged into the hole to stop leakage as shown in **Figure 4**.

Figure 4: Wooden Piece

Figure 5: Dead-end plug or Stopper

2.1.5 Threaded Stopper/ Dead-end Plug

It is used in case of complaint from the domestic connections. Also used to cut the water supply to certain section (**Figure 5**).

2.1.6 Socket and Socket Ring

It is used when we have to change the length of pipe. Minimum 1 feet length of Asbestos Pipe is changed by using these sockets with rings on both ends. Socket Ring is used for joining of socket with pipe. It works as water seal not to allow water leakage.

Figure 15: Socket

Figure 7: Socket Ring

2.1.7 Flange

Flange is used between Gate valve and Gibault Joint shown in **Figure 8**.

Figure 8: Flange

2.2 Repairing Procedure at the Site

2.2.1 Gibault Joint

Step 1: Mark the section of pipe for valve insertion or repairing of pipe.

Step 2: Cut and remove the damaged peace of pipe.

Step 3: Ensure bolting is loose and apply pipe lubricant if required and slide Gibault along pipe.

Step 4: Insert valve, coupled with the flange joint, and slide-Gibault and couple it with flange and tightened all the bolts as shown in **Figure 9 and Figure 10.**

Figure 9: Gibault Joint

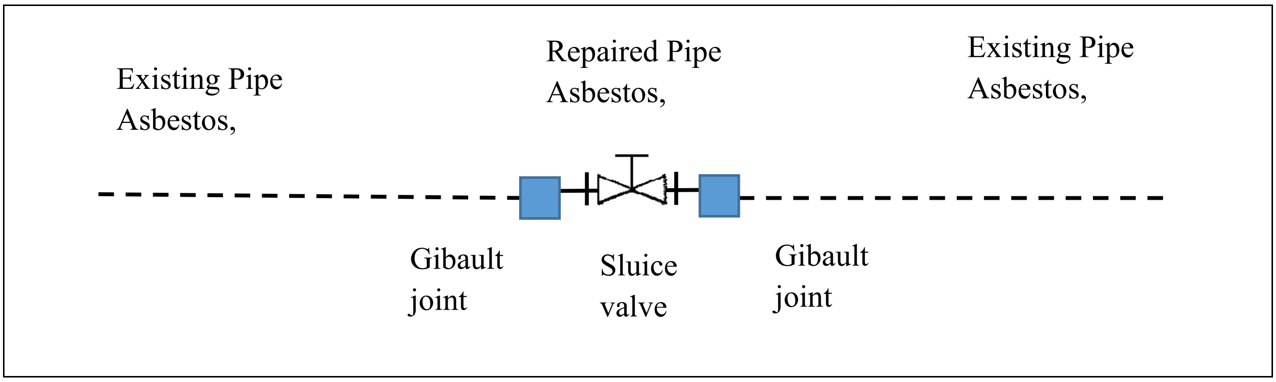


Figure 10: Schematic of Sluice Valve with Gibault Joint

2.2.2 Wedge-Rubber-Clamp Joint

Step 1: Wedge in the wooden cork into the hole by hammering.

Step 2: Cut the additional part of the cork using saw/axe.

Step 3: Cut the rubber strip according to the size of the hole and place it over the wooden piece.

Note: Sometime in case of low pressure water supply line, instead of wooden cork, rubber piece is directly placed on the hole.

Figure 11: Clamp Joint

Step 4: Adjust the clamp on the rubber piece and tightened the bolts very carefully as shown in **Figure 11 and Figure 12**.

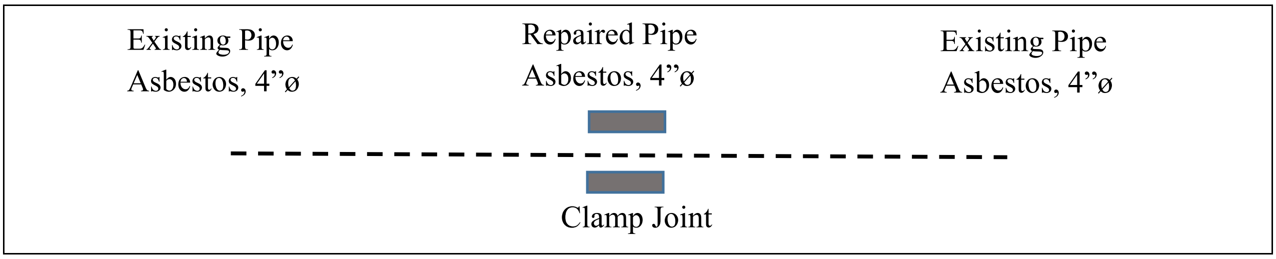


Figure 12: Schematic of Wedge-Clamp Joint

2.2.3 Rubber Tube Joint

In case of crack with a hole, rubber tape is directly and tightly wrapped over it. The following steps are taken for this type of repairing.

Step 1: Insert the wooden cork into the hole through hammering.

Step 2: Cut the additional part of the cork using cutter.

Step 3: Wrap the rubber tube very tightly around the leaked point and tie it at the end. Note: Sometime more than one tube is used if the crack is bigger to bind the cork firm at its position as shown in **Figure 13 & Figure 14.**

Figure 13: Joint with Rubber Tube

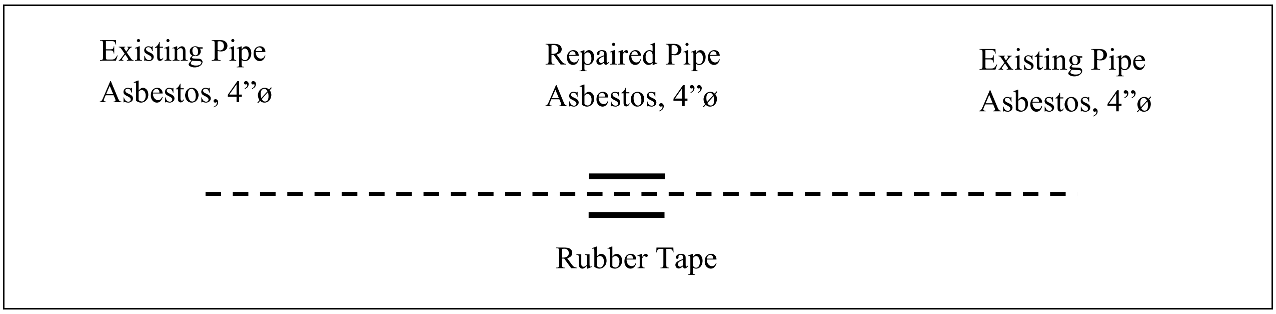


Figure 14: Rubber Tube Joint

2.2.4 Wooden Piece/Cork Joint

Step 1: Make a wooden piece of the required size using knife.

Step 2: Insert it into the hole by hammering.

Step 3: Cut the remaining part of the wooden piece, above the level of pipe using saw or axe.

Figure 15: Cork Joint

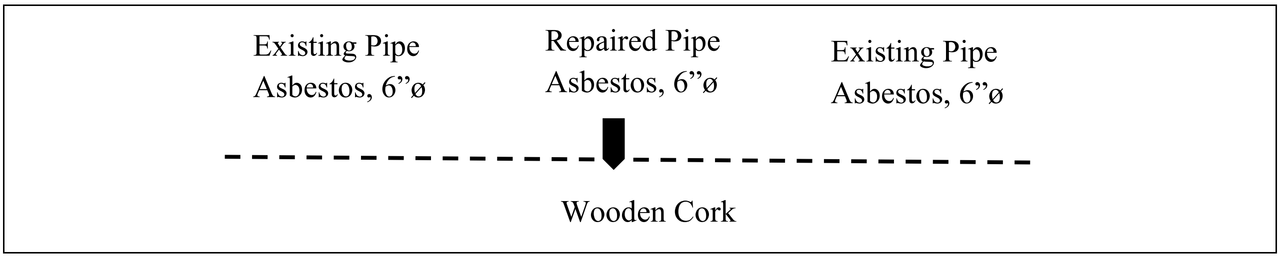


Figure 16: Schematic of a Cork Joint

2.2.5 Stopper or Dead-end Plug

Figure 17: Dead End Plug

In case of leakage from any abandoned or poorly-closed domestic connection point, only a new stopper is properly threaded into the pipe as shown in Figure 14.

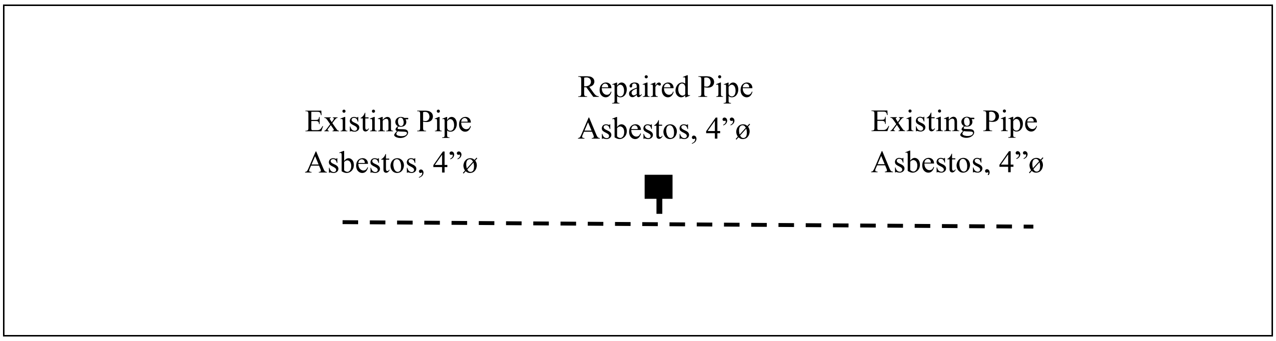


Figure 18: Schematic of Stopper or Dead end plug

2.2.6 Repairing Procedure of HDPE pipe at the Site

High-density polyethylene (HDPE) or polyethylene high-density (PEHD) is a polyethylene thermoplastic made from petroleum. It is sometimes called "alkathene" or "polythene" when used for pipes.

High density polyethylene plastic pipe (HDPE) delivers exceptional value, unwavering reliability and remarkable advantages over conventional types of piping. It's today's right choice for water, drainage, fuel gas, conduit and plumbing & heating.

a) Jointing Method

There are available number of types of jointing HDPE pipes depending on the size and type of application.

- Compression fitting
- Molded butt fusion fitting
- Electrofusion fitting

b) Molded Butt Fusion

- Place the pipes in clamps with ends against the trimming tool and pipe markings aligned
- Align and level components using support rollers
- Tighten the pipe clamps to grip and re-round the pipes
- Use the trimming tool to ensure continuous shavings are cut from each surface
- Check that there is no visible gap between the trimmed faces
- Place the heater plate in the machine and close the clamps so that the surfaces to be joined are touching the plate
- Using the hydraulic system, apply the pressure previously determined
- Maintain the applied pressure until the pipe begins to melt and uniform bead of 2-3mm is formed on each end
- Check that the pipe does no slip in the clamps. The pipe ends must maintain contact with the heater plates
- Once the heat soak time is completed, remove the heater plate, ensuring that the plate does not touch the melted surfaces
- Immediately close the clamps and bring the melted surfaces together at the previously determined pressure
- Hold under pressure for the appropriate cooling time

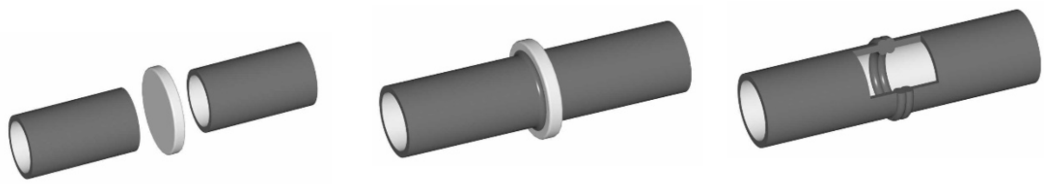


Figure 19: Molded Butt Fusion

Figure 20: Molded Butt Fusion

c) Electrofusion Fitting

- Check that pipe is cut at 90° to the pipe axis
- Mark the fusion zone on the pipe and scrape to remove oxide layer
- Clean the scraped area of the pipe, and fittings (avoid touching the fusion zone)
- Mark the insertion depth (half the length of the fitting) on both pipe ends to be joined, clamping the components in place if required
- Insert the pipe ends into the Electrofusion fitting. For larger diameters, assembly can be assisted by tapping around the face with a plastic hammer
- Start the fusion process, using a preheating phase if applicable
- Wait the appropriate cooling time and quality check the fusion
- Mark the fusion parameters on the pipe

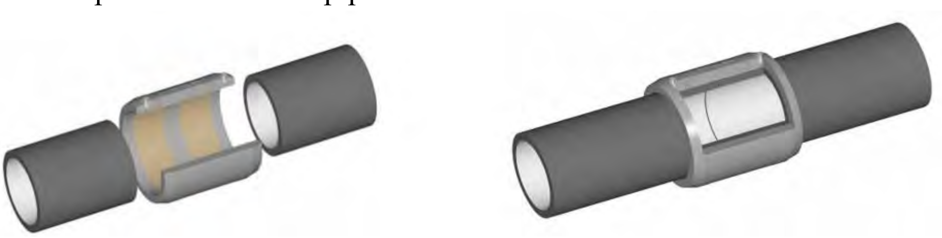


Figure 21: Electrofusion Fitting

Figure 22: Electrofusion Fitting

d) Compression Fitting

- Cut the pipe at 90° to its axis
- Inter over the pipe end in the following order: nut, clinch ring and O-ring on the mouth of the pipe
- Insert the pipe end and the O-ring onto the body of the joint, up to the insertion depth tab
- Push the clinch ring into the body of the joint
- Engage the nut and fully tighten

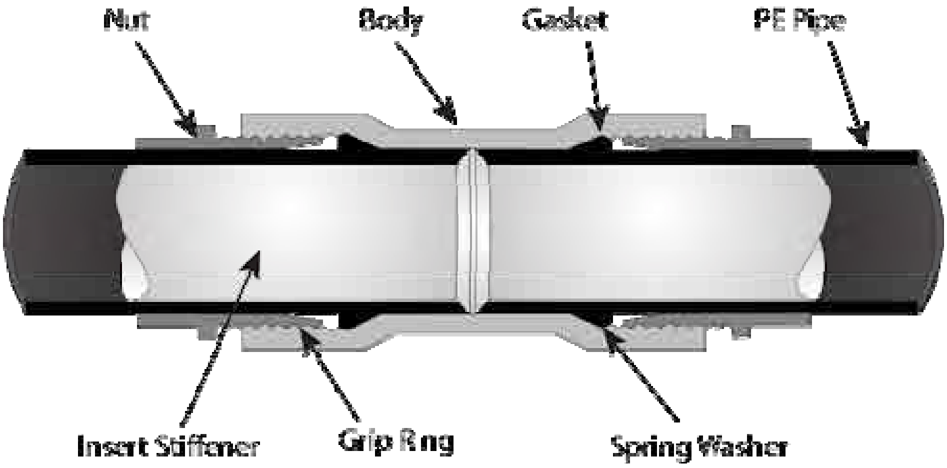


Figure 23: Electrofusion Fitting

Advantages

- Strong, durable, flexible and lightweight
- Highly-resistant to corrosion, abrasion and chemicals
- No Change comes in winter & summer season
- Easy Installation
- Significant overall cost savings
- Super smooth internal surface, reducing the chance of pipe cloggage
- Long-term service life

Disadvantages

- High degree of thermal expansion
- Poor puncture resistance
- Need electrical welding
- Subject to stress cracking
- Flammable
- Poor temperature capability
- Poor weathering resistance

2.3 On-site Leakage Repairing: Procedure, Machinery and Equipment

Following repairing procedure along with required tools and machines are generally used for on-site repairs.

Cordon off the Site	•Cones, Reflection Tape (Yellow), Diversion Boards.
Cut the Pavement	•Pavement Cutter.
Break the Pavement	•Breaker, Pick axe.
Excavate	•Breaker,Excavator, Shovel,Grape hoe
Cut off Water Supply	•Adjustable Wrench, Plier.
Reapair the Leak	•Rubber Tube,Wooden Piece, Clamp, Gibault Joint. •Scissor,Knife,Adjustable Wrench, Hammer/Maul, Snap Cutter, Hand Saw,Water Bucket. •Sucker Machine.
Cross Check the leak	•Open the Gate Valve, Turn on the Tube Well, Check physically Repaired area.
Back Fill the ditch	•Excavator, Shovel, Grape Hoe.
Restore the site	•Use Portable Compactor to level the Ground, Re-build the Road on Repaired Area.

2.3.1 Cordon Off the Site

Sr. No.	Name	Picture	Description
1	Safety Cones		Placed on roads or footpaths to temporarily redirect traffic in a safe manner.
2	Reflective Tape		Used to show area is blocked or under maintenance.
3	Diversion Boards		Placed on the roads or footpaths to temporarily redirect traffic in a safe manner.

2.3.2 Safety Measures

Sr. No.	Name	Picture	Description
1	Safety Helmet		Helmets protects user's head by absorbing mechanical energy and obstruction against penetration.

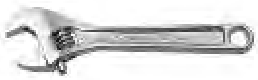
2	Safety gloves		For the protection of the wrist, hand, fingers, and thumbs from abrasion or cuts etc.
3	Safety shoes		To avoid slip, direct contact of polluted water with our skin, and to avoid foot injury
4	Safety goggles		To protect eyes and the area around the eyes
5	Gas mask		To protect the user against inhaling airborne pollutants and toxic gases
6	Gas Detectors		To detect combustible, flammable and toxic gases and oxygen depletion.

2.3.3 Cut off Water Supply

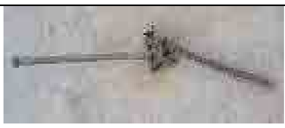
- Turn off the water source
- Close gate valve half at main line of water supply if the water pressure is very high (>5 bar). No need to close the gate valve if the water pressure is < 2 bar.

2.3.4 Repairing Tools for Plumber

2.3.4.1 Hand Tools

Sr. No.	Name	Picture	Description
1.	Adjustable Wrench		For tightening of bolts.
2.	Screw Driver		For tightening of screws.
3.	Hammer and Maul		For hammering of cork into the leaked pipe.
4.	Hand Saw		Cutting the extra cork or HDPE pipes.
5.	Bucket		Pouring out leaked water from the dig hole.

2.3.4.2 Machinery Used for Leak Repairing in Water Pipes

Sr. No.	Name	Picture	Description
1	Snap Cutter		Used to cut asbestos pipe

2	Pipe Cutter		Used for cutting the metal and plastic pipe

2.3.4.3 Excavation Tools

Sr. No.	**Name**	**Picture**	**Description**
1	Shovel		For digging
2	Grape Hoe		For digging
3	Pick Axe		Used for landscaping, breaking up hard surfaces.

2.3.4.4 Excavation Machinery

Sr. No.	Name	Picture	Description
1	Pavement Breaker		Use to break up rock, pavement, and concrete.
2	Sucker Machine		For sucking the bulk water in excavated area.
3	Excavator		For excavating the land to see the leaked portion and to repair it.
4	Portable Soil Compactor		For levelling the dig surface after back filling.

2.4 The Global Positioning System

The Global Positioning System (GPS) is a U.S.-owned utility that provides users with positioning, navigation, and timing (PNT) services. This system consists of three segments: the space segment, the control segment, and the user segment.

GPS technology is now in everything from cell phones and wristwatches to bulldozers, shipping containers, and ATM's.

Global positioning system applications generally fall into 5 major categories:

- Location – Determining a position
- Navigation – getting from one location to another
- Tracking – monitoring object or personal movement
- Mapping – create map or world
- Timing – bringing precise timing to the world

2.4.1 GPS Functions:

Giving a location:

Its ability to accurately triangulate your position based on the data transmissions from multiple satellites. It will give your location in coordinates, either latitude and longitude or Universal Transverse Mercators (UTMs).

Point to point navigation:

This GPS navigation feature allows you to add waypoints to your trips. By using a map, the coordinates of a trailhead or road or the point where you're standing, you can create a point-to-point route to the place where you're headed.

Route navigation:

By combining multiple waypoints on a trail, you can move point-to-point with intermediate bearing and distance guides. Once you reach the first predetermined waypoint, the GPS receiver can automatically point you to the next one or you can manually do this.

Keep a Track:

Tracks are some of the most useful functions of **navigation systems**. You can map where you've already been. This virtual map is called a track, and you can program the **GPS system** to automatically drop track-points as you travel, either over intervals of time or distance. This can be done on land or in a nautical setting and allows you to retrace your steps.

While marking the location of Manhole

Figure 24: Marking Location of Manhole by Using GPS

2.4.2 Uses of GPS device

The survey team are formulated on the basis of that each team consists of two members. GPSs are issued with batteries to all the teams.

Figure 25: GPS Device

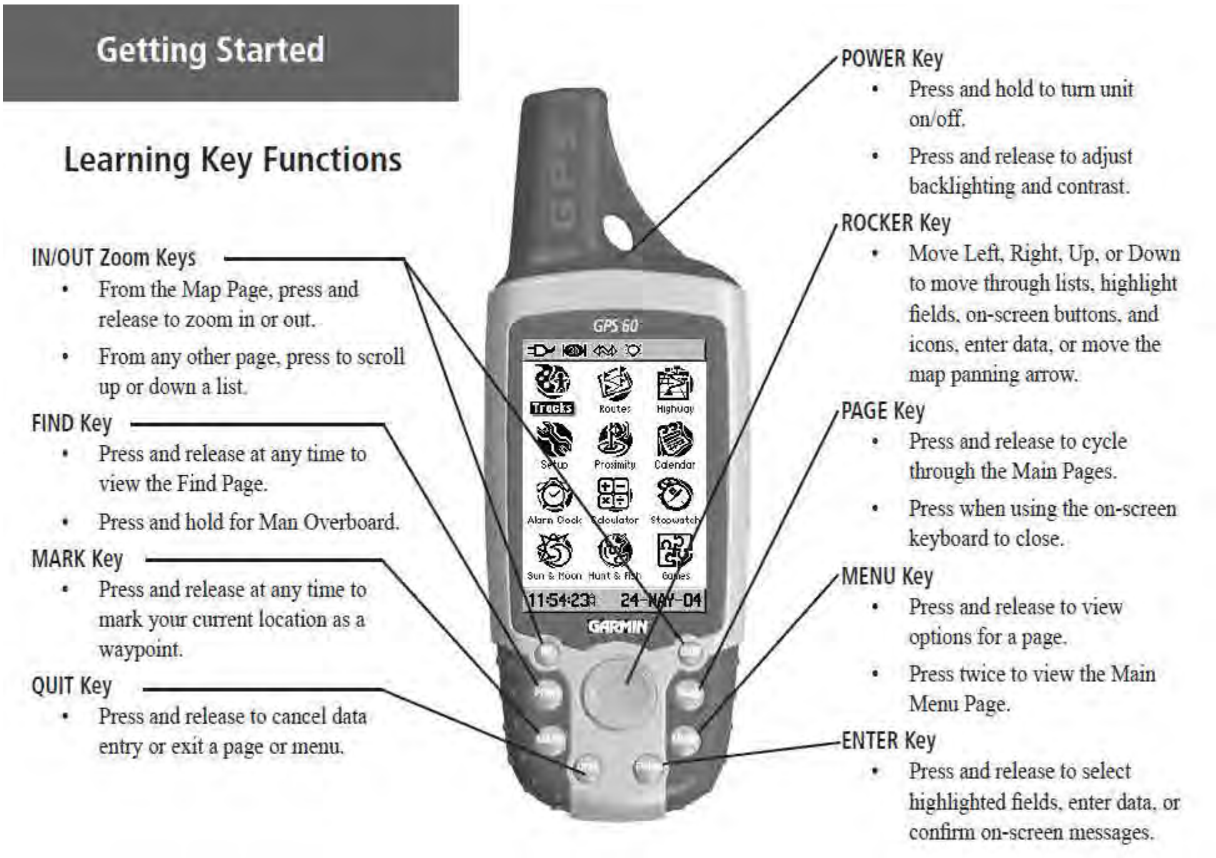


Figure 26: Key Function of GPS

Use following steps during the field survey;

- Installed the batteries in the GPSs and turn the GPS by pressing the turn on button.

Figure 27: Cells Installation

Figure 28: Power Button

- After pressing the menu button, the main window of GPS is given as;

Figure 29: Menu button **Figure 30: Main window**

- Set the GPS units as WGS84 by using setup on main windows
- In order to mark the location, check the satellite signals strength for accuracy and mark point when the maximum 4 signals strength is required.

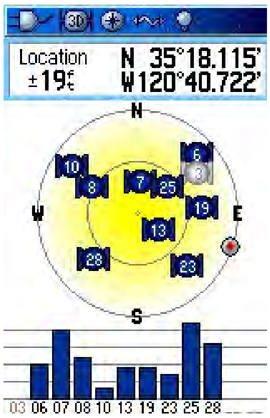


Figure 31: Shows signal strength

- Mark current location by press and hold mark and select mark way points.

Figure 32: Mark button

- Save the location by writing the GPS point name and click ok.

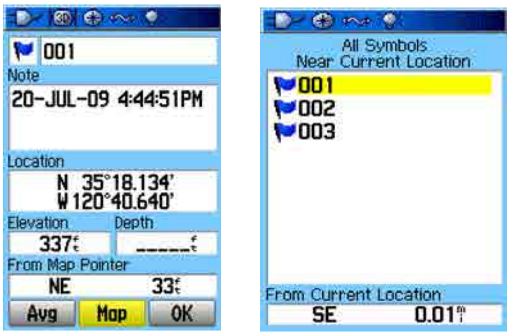


Figure 33: How to save GPS location

- The GPS saved location/waypoint can be deleted or edited.
- In order to view saved points, go to list where the way points saved and go to map windows.
- GPS has the facility to keep track record on GPS during the field survey.
- After the field visit the GPS data downloaded on work station then mark the location on Google Earth.

2.4.3 GPS Applications

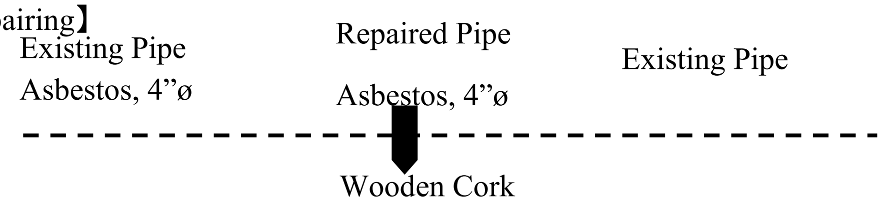
- Major communications networks, banking systems, financial markets, and power grids depend heavily on GPS for precise time synchronization.
- Some wireless services cannot operate without it.
- GPS saves lives by preventing transportation accidents, aiding search and rescue efforts, and speeding the delivery of emergency services and disaster relief.
- GPS also advances scientific aims such as weather forecasting, earthquake monitoring, and environmental protection.
- The scientific community uses GPS for its precision timing capability and position information.
- GPS enables automatic vehicle location and in-vehicle navigation systems that are widely used throughout the world today.
- GPS technology supports efforts to understand and forecast changes in the environment.
- The surveying and mapping community was one of the first to take advantage of GPS because it dramatically increased productivity and resulted in more accurate and reliable data. Today, GPS is a vital part of surveying and mapping activities around the world.

2.5 Record of the Leakage Sites

Report 1.

Date and Time	10:30am, 30 December, 2015
Address	Shah Jilani Road
Person In Charge	Mr. Shamas Ayoub Gujjar – SDO Green Town
Organization of Repairing Team	Pipe Fitter, Assistant Pipe fitter and helper
Diameter(mm)	101.6 (4”)
Material and Kind of joint	Asbestos pipes, wooden cork inserted into the hole
Age (Installation Year)	
Shape of leak point	Round hole of diameter 1” i.e. 25.4mm
Pressure (kg/m2)	Pressure was low because the tube well was not working
Depth(m)	1.22 (4’)
Soil around the pipe	Mud (soft)
Traffic density	High
Supply Hour	16
Cause of the leak	Leakage occurred due to negligence of telephone department during installation of new telephone line. During excavation by the team of telephone department, the pipe damaged.
Quantity of leak (m3/min)	
Time of Repairing (Hour)	3 hours

【Figure of repairing】



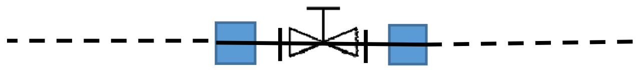
【Picture of repairing】

【Location on Map】

Report 2.

Date and time	10:20 am, 11 February, 2016
Address	Hamdard Chowk, Ali Road
Person in charge	Mr. Shamas Ayoub Gujjar – SDO Green Town
Organization of repairing team	Pipe Fitter x 2, Helper x 2, Worker x 2 (Sucker Machine)
Diameter(mm)	12”
Material and Kind of joint	Asbestos, a sluice valve is installed after removing the cracked portion
Age (installation year)	45 years
Shape of leak point	5” long crack
Pressure (kg/m2)	High
Depth(m)	4.5’
Soil around the pipe	Rough mud, but after repairing a cemented valve chamber will be formed to operate valve in the future
Traffic density	High
Supply Hour	18
Cause of the leak	Old pipe and high Pressure (main transmission line connected with four tube wells
Quantity of leak (m3/min)	
Time of Repairing (Hour)	4-5
Other Information	Sucker machine is used to remove water for repairing

Figure of repairing】



【Picture of repairing】

【Location on Map】

Report 3

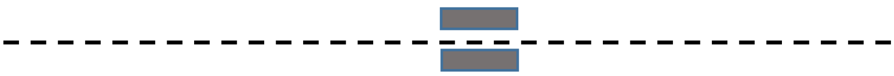
Date and time	10:50am 11 February, 2016
Address	Civic Centre near Cine Star Cinema
Person in charge	Mr. Shamas Ayoub Gujjar – SDO Green Town
Organization of repairing team	Pipe fitter x 1, Helper x 2
Diameter(mm)	4”
Material and Kind of joint	Asbestos, wooden cork inserted into the hole and metal clamp along-with water proof sponge was used
Age (installation year)	45
Shape of leak point	Hole of 0.5” diameter
Pressure (kg/m2)	Low
Depth(m)	4.5’
Soil around the pipe	Rough soil and garbage
Traffic density	Medium
Supply Hour	14
Cause of the leak	
Quantity of leak (m3/min)	
Time of Repairing (Hour)	3

【Figure of repairing】

Existing Pipe
Asbestos,
4”ø

Repaired Pipe
Asbestos, 4”ø

Existing Pipe
Asbestos, 4”ø



Clamp Joint

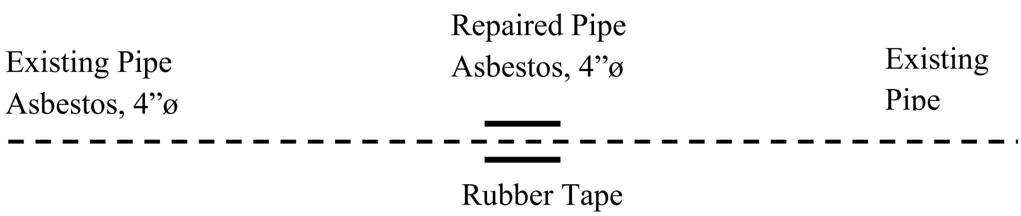
【Picture of repairing】

【Location on Map】

Report 4.

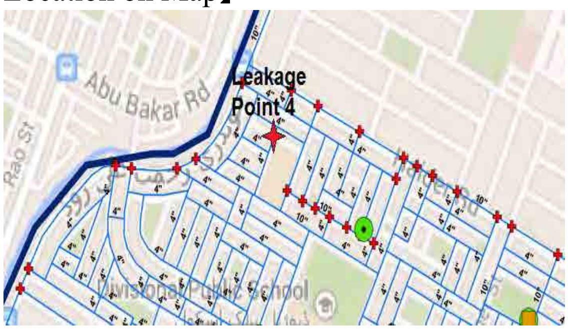
Date and time	10:40am, 12 February, 2016
Address	City District Government School, Block – 2, Township
Person in charge	Mr. Shamas Ayoub Gujjar – SDO Green Town
Organization of repairing team	Pipe Fitter x 1, Helper x 2
Diameter(mm)	4”
Material and Kind of joint	Asbestos, Rubber tube (6m, Cycle/ Motor Cycle) wrapped on pipe
Age (installation year)	45
Shape of leak point	Crack on the pipe
Pressure (kg/m2)	Medium (One Tube well is directly feedind)
Depth(m)	3’
Soil around the pipe	Soft mud
Traffic density	Medium
Supply Hour	14
Cause of the leak	
Quantity of leak (m3/min)	Low
Time of Repairing (Hour)	3

【Figure of repairing】



【Picture of repairing】

Location on Map】



Report 5.

Date and time	11:10am, 12 February, 2016
Address	Gate No. 2, Model Bazar, Sector C1 Township
Person in charge	Mr. Shamas Ayoub Gujjar – SDO Green Town
Organization of repairing team	Pipe Fitter x 1, Helper x 3
Diameter(mm)	6”
Material and Kind of joint	Asbestos, wooden cork inserted in the hole and tube was wrapped on pipe
Age (installation year)	45
Shape of leak point	Hole
Pressure (kg/m2)	High
Depth(m)	3.5’
Soil around the pipe	Soft Mud
Traffic density	Medium
Supply Hour	16
Cause of the leak	
Quantity of leak (m3/min)	Medium
Time of Repairing (Hour)	3

Figure of repairing】

Existing Pipe
Asbestos, 6”ø

Repaired Pipe
Asbestos, 6”ø

Existing Pipe
Asbestos, 6”ø

Rubber Tape

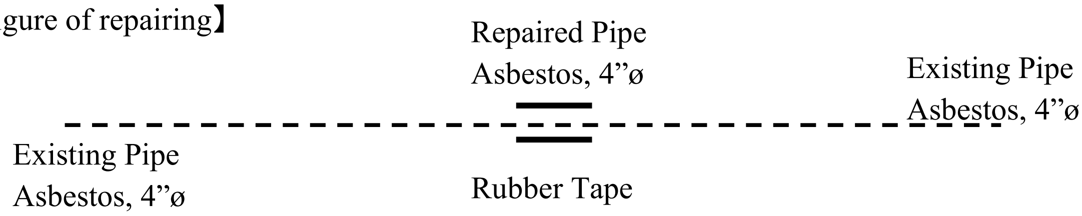
【Picture of repairing】

【Location on Map】

Report 6.

Date and time	11:50am, 12 February, 2016
Address	Gate No. 3, Model Bazar, Sector C1 Township
Person in charge	Mr. Shamas Ayoub Gujjar – SDO Green Town
Organization of repairing team	Pipe Fitter x 1, Helper x 2
Diameter(mm)	4”
Material and Kind of joint	Asbestos, Double tapes were wrapped on the pipe around the crack
Age (installation year)	45
Shape of leak point	Crack on the down side
Pressure (kg/m2)	Low
Depth(m)	2.5’
Soil around the pipe	Soft Mud
Traffic density	Low but loaded trucks passes occasionally
Supply Hour	14
Cause of the leak	
Quantity of leak (m3/min)	Low
Time of Repairing (Hour)	3
Other Information	1 Tube well is feeding directly Two rubber tubes (used in cycle/ motor cycle) for tapping are used because leakage is not controlled by single tape

【Figure of repairing】



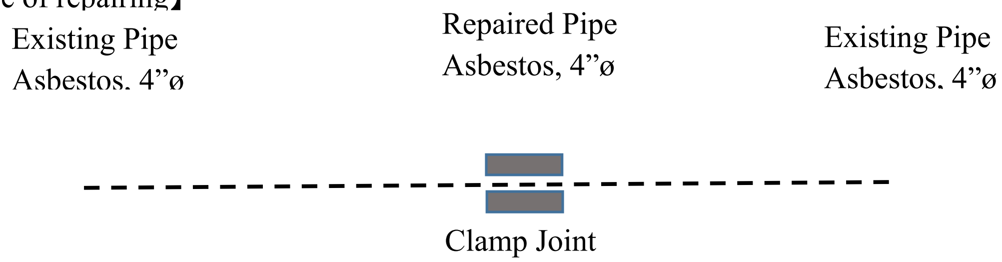
【Picture of repairing】

Location on Map】

Report 7.

Date and time	12:25pm, 12 February, 2016
Address	Sector D1, Block 3, Green Town
Person in charge	Mr. Shamas Ayoub Gujjar – SDO Green Town
Organization of repairing team	Pipe Fitter x 1, Helper x 2
Diameter(mm)	4”
Material and Kind of joint	Asbestos, wooden cork inserted into the hole and metal clamp along-with water proof sponge was used
Age (installation year)	7
Shape of leak point	Hole
Pressure (kg/m2)	
Depth(m)	1.5’
Soil around the pipe	Rough soil full of stones of irregular size and shape
Traffic density	Low, very narrow street
Supply Hour	14
Cause of the leak	
Quantity of leak (m3/min)	Medium
Time of Repairing (Hour)	3

【Figure of repairing】



【Picture of repairing】

【Location on Map】

Report 8.

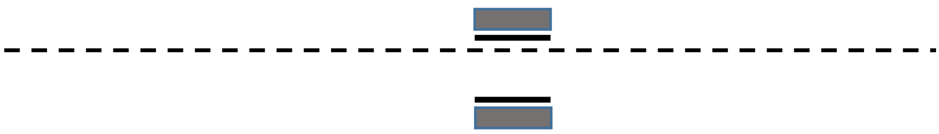
Date and time	11:10am, 15 February, 2016
Address	Bagrian Road near Over Head Tank No. 4
Person in charge	Mr. Shamas Ayoub Gujjar – SDO Green Town
Organization of repairing team	Pipe Fitter x 1, Helper x 2
Diameter(mm)	8”
Material and Kind of joint	Asbestos, wooden cork inserted into the hole. Then tape was wrapped around the pipe and then metal clamp along-with water proof sponge was used
Age (installation year)	45
Shape of leak point	Hole
Pressure (kg/m2)	High
Depth(m)	3.5’
Soil around the pipe	Soft Mud
Traffic density	High
Supply Hour	18
Cause of the leak	
Quantity of leak (m3/min)	High
Time of Repairing (Hour)	

【Figure of repairing】

Existing Pipe
Asbestos,

Repaired Pipe
Asbestos, 8”ø

Existing Pipe
Asbestos, 8”ø



Rubber Tape & Clamp Joint

【Picture of repairing】

【Location on Map】

Report 9.

Date and time	11:50am, 15 February, 2016
Address	near Model Bazar Township
Person in charge	Mr. Shamas Ayoub Gujjar – SDO Green Town
Organization of repairing team	Pipe Fitter x 1, Helper x 2
Diameter(mm)	4”
Material and Kind of joint	Asbestos, dead end plug inserted into an old and abandoned distribution water connection
Age (installation year)	10-15
Shape of leak point	
Pressure (kg/m2)	Low
Depth(m)	3’
Soil around the pipe	Soft mud
Traffic density	Low
Supply Hour	14
Cause of the leak	Old abandoned domestic connection is leaked
Quantity of leak (m3/min)	Low
Time of Repairing (Hour)	3

【Figure of repairing】

Existing Pipe
Asbestos, 4”ø

Repaired Pipe
Asbestos, 4”ø

Existing Pipe
Asbestos, 4”ø

Dead-end Plug

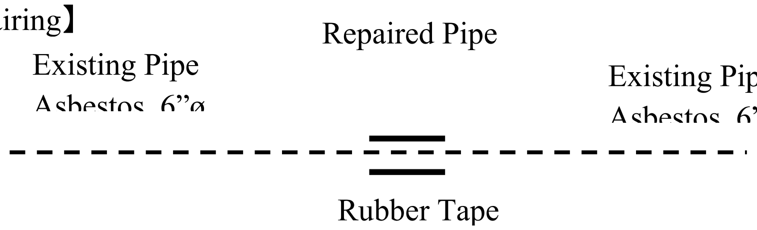
【Picture of repairing】

Location on Map】

Report 10.

Date and time	11:30am, 25 October, 2015
Address	Shalimar colony street number 14
Person in charge	Mr. Khalid Gujjar – SDO Shalimar Colony Multan.
Organization of repairing team	Senior pipe fitter, Pipe Fitter and helper
Diameter (inches)	6”
Material and Kind of joint	Asbestos pipes, wooden cork inserted into the hole
Age (installation year)	10
Shape of leak point	Round hole of diameter 1” i.e. 25.4mm
Pressure (kg/m2)	Low Pressure because the tube-well was not working and gate valve was closed.
Depth(m)	1 (3.22’)
Soil around the pipe	Mud (soft)
Traffic density	Low
Supply Hour	6
Cause of the leak	
Quantity of leak (m3/min)	
Time of Repairing (Hour)	2.5 hours

【Figure of repairing】



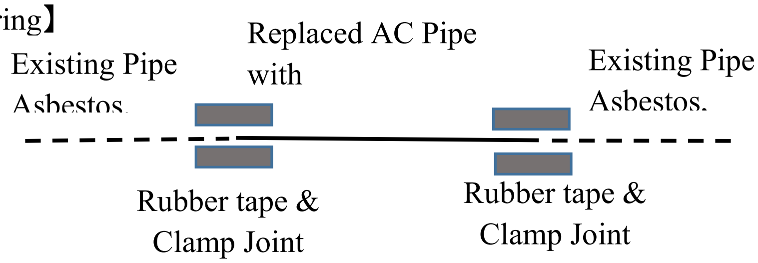
【Picture of repairing】

【Location on Map】

Report 11.

Date and time	4:00 pm, 25 February, 2016
Address	Chungi no 14
Person in charge	Mr. Hafeez Lagari – SDO water supply complaints.
Organization of repairing team	Senior pipe fitter, 2 Pipe Fitter and 4 helper
Diameter (inches)	12”
Material and Kind of joint	Asbestos pipe replaced with HDPE pipe with rubber tube and clamps.
Age (installation year)	
Shape of leak point	Pipe break
Pressure (kg/m2)	Pressure was low because the tube well was not working and valve is closed.
Depth(m)	2.13 (7’)
Soil around the pipe	Mud (a bit hard)
Traffic density	Very High
Supply Hour	6
Cause of the leak	Due to the negligence of Metro Bus excavation team, they don’t know the location of buried pipe line and broke it through excavation.
Quantity of leak (m3/min)	
Time of Repairing (Hour)	6 hours
Other Information	Sucker machine is used to remove water for repairing.

【Figure of repairing】



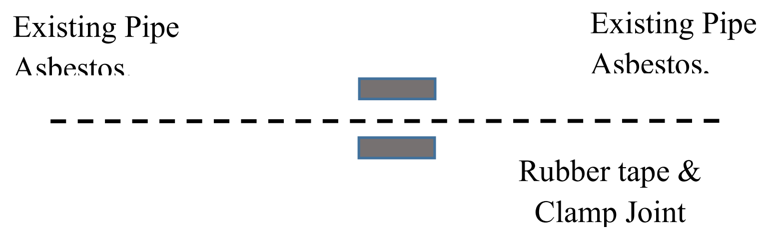
【Picture of repairing】

【Location on Map】

2.6 Recommendations for Pipelines Repairing

Case 1:

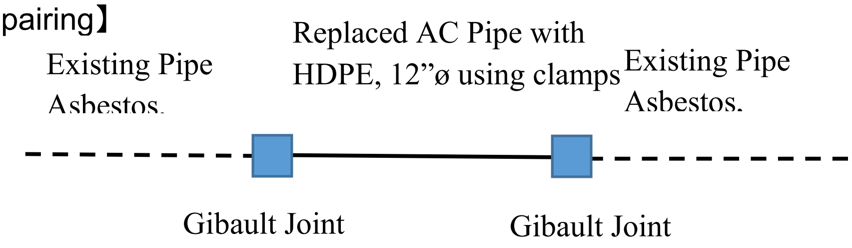
【Figure of repairing】



Instead of just using rubber tube for leaking repair, use clamps with them for long lasting repair.

Case 2:

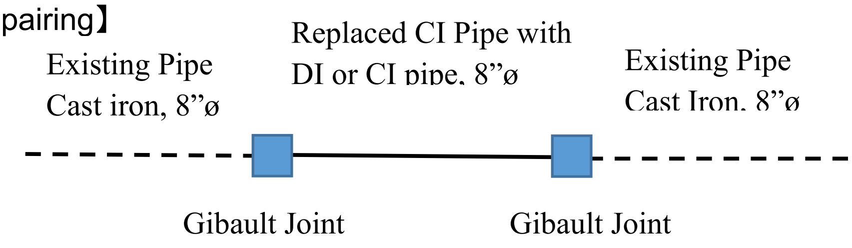
【Figure of repairing】



Use Gibault joint, when you need to connect HDPE pipe with AC pipe. Instead of using Rubber tube or clamps as they are not a long lasting solution.

Case 3:

【Figure of repairing】



Use Gibault joint or sump joint, when you need to connect CI pipe or DI pipe with CI pipe.

2.7 Comparison of Repairing Materials and Methods

Method	Cost	Life	Availability	Skill Level Required	Time to Repair	Pressure of Line	Remedy	Shape of Leakage Point	Remarks
Rubber Tube	Low 25 PKR/piece	Short ~ 1 year	Easy	No	Short ~ 40 minutes	Low ~ 4 bar	Temporary	Hole /crack	Only Recommended in the case of emergency but not a permanent remedy. Clamps should be used to increase the joint life.
Cork	Low 100 PKR/piece for 3” dia pipe 1000 PKR/piece for 12” dia pipe	Short ~ 1 year along with tube	Easy	No	Medium ~ 1.5 hr	Low ~ 4 bar	Temporary	Hole	Recommended only in case of emergency along with rubber tube. The piece of cork should be accurate, do not put extra size cork in hole of the pipe that results in the biological contamination of water. Not a permanent method, use it with clamps.

Method	Cost	Life	Availability	Skill Level Required	Time to Repair	Pressure of Line	Remedy	Shape of Leakage Point	Remarks
Clamp	Medium 125-150 PKR/kg for 4” dia pipe e.g. Clamp for 4”dia pipe 2 kg iron plate is used.	Medium ~ 8-10 years	Easy	Basic	Medium ~ 1-1.5 hr	High ~ 7-8 bar	Permanent	Hole/ crack	Used where cracks or hole sizes are not so large. (e.g. Ø 4”~ 10.16 cm Ø 6”~ 15.24 cm).Use clamps with at least length of 2 inch more than the crack or hole diameter to cover it safely. It has long life as compare to rubber tube and cork. Can be used at shallow depth with low pressure but in case of high pressure we recommend to use Gibault joint. Clamp joint considered as a permanent remedy with maximum durability.

Method	Cost	Life	Availability	Skill Level Required	Time to Repair	Pressure of Line	Remedy	Shape of Leakage Point	Remarks
Gibault Joint	High 1200 PKR/piece for 6” dia. pipe	Long ~ 15 years	Medium	Skilled	Medium ~ 2 hr	High ~ 9 bar	Permanent	Burst /replace of line	It is an expensive but permanent method for repair. Used where we have to repair the burst line or replace a pipe with another pipe of 5-7 feet of length. The rubber ring of Gibault joint becomes hard with the passage of time (duration 4-5 years), cracks are formed on it that lead to the leakage of water. Check the rubber ring before using Gibault joint. Replace the rubber ring after 4-5 years of usage, to prevent leakage.

Method	**Cost**	**Life**	**Availability**	**Skill Level Required**	**Time to Repair**	**Pressure of Line**	**Remedy**	**Shape of Leakage Point**	**Remarks**
Socket Joint	High 450 PKR/ piece for 4" pipe. 550 PKR/ piece for 6" pipe.	Long ~ 20 years	Medium	Skilled	Medium ~ 2 hr	High ~ 9 bar	Permanent	Burst/ replace of line	It is a little bit expensive compared with clamp joint but a permanent method for repair. . Used only in AC pipe only where we have to repair the burst line or replace pipe with another pipe of 5-7 feet of length. This method is not mostly used in routine repairs, used where new pipe line is being laid. It is a time taking process, and very inconvenient in presence of water.

3. Reference Material

1. JICA Progress Report, June 2016. Project for Improving Capacity of WASAs in Punjab Province, Leak Detection text book written by Chiaki Suzuki, Yokohama Waterworks Japan.
2. Leak Location and Repair Guidance Notes March 2007 version 1 IWA water loss task force by Richard Pilcher et.al.
3. http://marleypipesystems.co.za/marley-pipe-news/457-joining-hdpe-pipe-traditional-modern-methods
4. : Garmin GPS 60 user Manual

Leakage Detection and Repair

W 7231

Water Network Maintenance and Leakage Detection (OJT)
Module 2

On-Site Leakage Detection
Lecture 2

Participant Lecture Notes

2016

1. Lecture Information

Lecture Topic: On-Site Leakage Detection Leak Detection Equipment a. Manual for Acoustic Rod b. Manual for Leak Detector	**Lecture Duration:** 1 Day

2. On-Site Leakage Detection

2.2. Leak Detection Equipment

a) Acoustic Rod

Acoustic rod is also known as listening stick because of its use to detect underground leakages through noise amplification shown in **Figure 1**. This is an acoustic listening instrument for point-check, house connections, and valve survey. It is designed with an effective amplification structure in resonant chamber, which detects louder leak noise on metallic as well as plastic pipelines.

Figure 1: Acoustic Rod (Listening Stick)

Specification:

Type	Cap dia. Thickness (mm)	Total Length (mm)	Dia. of iron bar (mm)	Material	Weight
LSP-1	ø 67x29	1,013	7	Stainless Steel	360 g

- Listening range is very high through P.V pipe or non-metal pipe.

Operation:

- Place the tip of acoustic rod at the point where doubt of leakage as in **Figure 2**.

- Catch the stick below the listening cap and place ear on the cap of acoustic rod.
- Hear the sound of leaked water, if no leakage at that place repeat the same procedure aside this place.

Figure 2: Use of Acoustic Rod

- Very useful to listen leaks sound at hydrants and valves.

Boring Survey:

- Bore a hole above the pipe line very carefully, so the acoustic rod can touch the pipe to listen leakage sound.

Factors Affecting Performance:

- Pressure: Higher the pressure; easier to listen leakage sound
- Depth: Less pipe depth; easier to listen the leakage sound.

Maintenance:

- Clean the tip of acoustic rod after use.
- Cover it properly.
- Store at dry place because the cap is not water resistant try to make it safe from water.
- Do not put any kind of weight on the stick that possibly will results in the bending of rod and lowers the sensitivity of leakage detection.

b) Electronic Leak Detector

It is a digital acoustic leak locator with superior crystal clear sound, easy to use and operate. Following are the main components of the Leak Detector also shown in **Figure 3**.

Components:

- Amplifier with waist belt
- Hand probe microphone
- Ground microphone plate
- Probe rods
- Stereo headphones
- Connecting cable

Figure 3: Acoustic Leak Detector

Specification:

- The control unit has high strength polyvinyl chloride (PVC) material that is resistant to high UV radiations.
- Power supply comprises of 4 x standard LR6" or "AA" Alkaline batteries.
- The equipment has frequency range of 1 – 5000Hz.
- The control unit has amplification capacity of ≥60 dB.
- The sensitivity in the hand probe ≥ 15v/g.
- The control unit has a display showing battery status, noise level, volume setting and signal strength.
- The center frequency of a band-pass filters shown as a numeric value. The operator can tune the exact filter setting required in increments of 40Hz.
- The filter activation only takes one simple press.

Installation:

1) Connect the head phone to the amplifier via. 3.5 mm stereo socket on the right side of the display.
2) Attach the microphone cable by screwing the four way connector into the socket on the microphone handle.

Figure 4: Headphone Attached with Amplifier (Left) and Hand Probe Microphone (Right)

3) Connect the opposite end of the cable to the amplifier. (Ensure that the two red dots are aligned; the unit will automatically turn itself on) as shown in **Figure 4**.
4) Screw the rods directly with microphone or with the ground plate to create a listening stick used to detect and locate leaks in valves, taps, hydrants, pipes and meters as shown in **Figure 5**.

Figure 5: Ground Microphone (Left) and With Rods (Right)

5) Cable should be gently coiled to prevent unnecessary damage. Attach the amplifier around the waste using webbing clips provided and quick release clips as shown in **Figure 6**.
6) Place headphones over ears according to the labeling on the headphone left at the left and right at right side.
7) Ensure no loose or dangling cables!

Figure 6: Amplifier with Waist Belt and Cable

Operation:

The system can be activated either by pushing the silver button on the handle or the button on the control unit. Microphone can be used to pin point leak under hard surfaces such as concrete and asphalt with or without the ground plate attached. Move the microphone step by step along the track of the pipe within 30 mm or 1 feet to find the loudest point by using maximum leak values as demonstrated in **Figure 7**.

Screw the magnet to the ground plate or directly to the microphone. The magnet is perfect for direct listening on the fittings where the leak is quite and difficult to distinguish. Use of rods may create problems in microphone holding and making it stable.

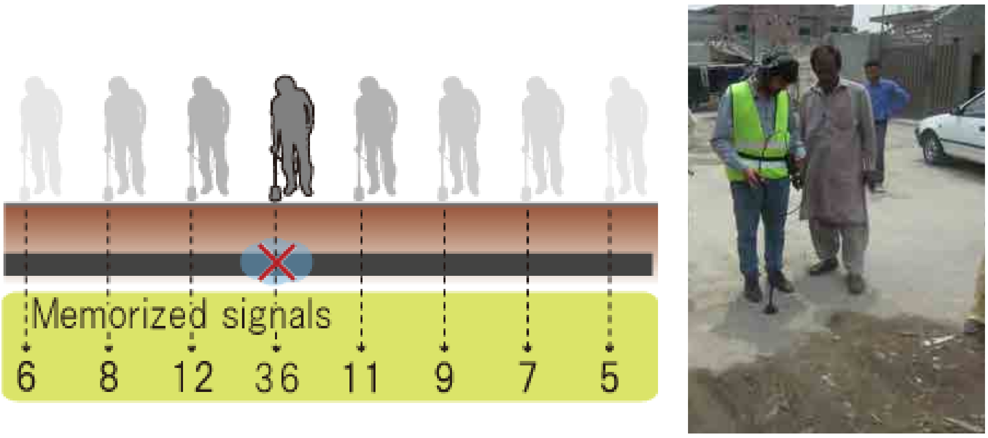


Figure16: Leak Detector Operation

1) Use head phones remember Left and Right direction.
2) Turn volume up to half using the dial on the headphone cable.
3) Ensure good contact is made between microphone and surface area.
4) Press and hold the silver button to listen sound. Releasing the button will terminate sound.
5) With every press and release of the silver button the noise level will be recorded in the memory.

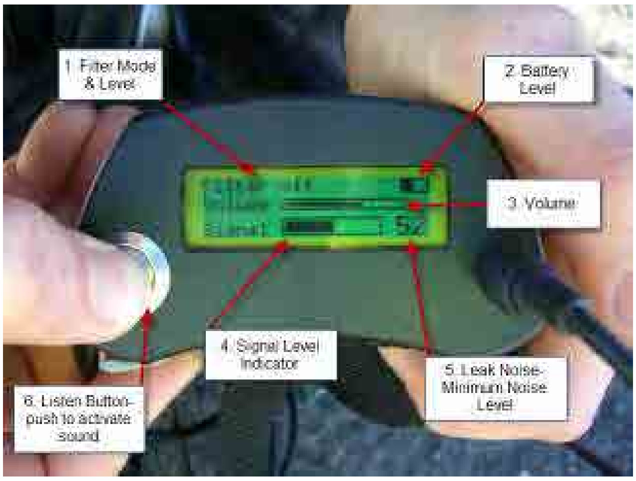


Figure 17: Labelled Diagram for Amplifier

6) The display shows 1. Filter Mode & level; 2. Battery level; 3. Volume; 4. Signal level indicator; 5. Leak noise-minimum noise level, 6. Listen button to activate sound when filter is on a numerical value will be displayed as shown in **Figure 8**.
7) To see memory data for the last eight soundings, press and hold the pink "M" button on the amplifier. The last eight reading can be seen right to left while latest is on the right.
8) To turn the filter on press and hold the green + & - filter buttons simultaneously. The filter bandwidth is +/- 100Hz.

Note: *Filter Activation* – Filter is used when the background noise is more. In order to observe the specific sound at microphone place filter is activated. By changing frequency in the range one can detect the point.

Figure 9: Memory Data (Left) and Labeled Buttons on Amplifier (right)

9) Change the filter frequency by pressing the green + or – button. This eliminate the surrounding noise while focusing on a particular leak frequency.
10) The numeric value of minimum noise, readings start at high and drop to the lowest value.
11) Listen leak sound for minimum of 10 seconds, allow enough time for background noise to fade away.
12) The leak may be a constant noise or the quietest noise.
13) Try to listen to and record the highest sound for exact location of the leak point.
14) Minimum noise level (value between 00 and 99); on the lower right-hand corner, is indicated during a listening session. As long as the "listen" button is kept pressed, the control unit automatically samples and records the lowest noise level, indicating the true leak noise without ambient interference. When the "listen" button is released, this value will automatically be saved in the memory. The last 8 leak values can be recalled on your display shown in Figure 9.
15) To activate the back light display, press the both blue buttons at the same time.

Note: When the backlight is switched on, the battery consumption will triple and thus reduce the battery life!!

While listening switch is on, the backlight will automatically be switched off to save battery consumption.

Important points: Identification of the leaks by the Acoustic Leak Detector depends on the following important points.

- Condition of the Leakage (hole size or crack).
- Pressure of water (Low pressure-shallow pipe; high pressure-deep buried pipe)
- Soil or earth condition around the pipe.
- An experienced person of 10 years will take less than 10 sec for leakage detection while for beginners it will take 2 to 3 mins or more. For error free reading, operator should stay stable without any movement.
- Just un-plug the wire from control unit it will not memorize the sound or value.
- Avoid to use in rainy days and don't operate when the wind speed is more than the 6 m/s.
- Sensors are water resistant, but control unit and head phones are not resistive. Store it at safe, shaded and dry place. Do not allow any load over the bag carrying equipment.

Troubleshooting:

Fault	**Cause**	**Solution**
No Sound	A damaged cable or headphones Headphone volume is too low	Replace connection cable or headphones Increase volume from headphone control
No Display	Dead batteries	Replace batteries
No Display	Cable fault	Replace connection cable
Noise Level 25, no sound	Cable fault	Replace connection cable
Disruption in Display	Circuit Board	Return to manufacture "Gutermann"
Sound in 1 earphone	Headphone problem	Replace Headphone
Cannot plug in hand probe or Geophone	Damaged connection socket	Return to manufacturer "Gutermann"

3. Reference Material

1. http://www.fujitecom.com/products/wld.html
2. http://en.gutermann-water.com/products/acoustic-microphones/aquascope-3-combined kit/
3. JICA Progress Report, June 2016. Project for Improving Capacity of WASAs in Punjab Province.

MODULE OUTLINE

Course Code: W 7231

Installation and Operation of Leakage Detection Equipment (OJT)

Module No. 3

2016

1. Module Information

Module: 3 of 3		Module Duration (Hrs.): 14
Participants: BS-11 to BS-17 and equivalent • SDOs • Sub Engineers • Supervisors		Module Prerequisites: Module 1 and Module 2 needs to be completed successfully before starting Module 3
Languages of Instruction: English and Urdu		Module Timings: 9 am to 4 pm
Start Date: 03 Oct, 2016	End Date: 06 Oct, 2016	Venue: Al-Jazari Academy

2. Faculty Information

Faculty Names	
Module Leader Mr. Sami Ullah	
Instructor (s) Mr. Sami Ullah	

3. Module Overview

This module will enable course participants to acquire hands-on training and practical knowledge in detection of leakages in underground and surface pipeline leakages using various equipment and techniques. This module will cover on-job training on leak detection and preparation of action plan for leakage prevention. Module will enhance the capability of the participants in installation and operation of the leak detection equipment, flow meter and pressure record devices in metal and non-metal pipes generally used for water supply network.

4. Learning Outcomes

4.1. Knowledge Outcomes

Description
Understand the principle and working of leakage detection and flow measurement equipment, their installation and usage in the field.

Know how to develop and implement Standard Operating Procedures (SOPs) for leak detection.
Compare performance of various equipment in identification of leakages.
Learn how to plan and implement leak repair protocol.

4.2. Skill Set Outcomes

Description
Recording and Reporting leakage points in water distribution network
Measuring distance between the leaks
Use of appropriate leak detection equipment
Understand leaks in relation to ambient noise of water in pipelines
Prepare planned activities for leakage detection

4.3. Professional Attitude Outcomes

Description
Realize the need for assurance of full supply without any loss to consumers
Realize the role of leakage prevention techniques in improving service delivery of water utilities

5. Instructional Plan

Sr. No.	Topics	Sub-Topics	Instructional Method	Duration	Training Delivery Mode
			Day 1		
1.	Installation and Operation of Leakage Detection Equipment at the Site	Standard Operating Procedures: • Non-Metal Pipe Locator • Pressure Recorder • Ultrasonic Flow Meter • Metal Detector • Metal Pipe Locator • Road Measure	Visit Briefing Site Visit Visit Report	30 Minutes 5 hours 30 Minutes	Practical
			Day 2		
2.	Action Plan for Leakage Prevention	• Preparation of Action Plan for Leakage Prevention by each water utility.	Briefing Group Discussion Group Presentation	1 Hour 3 Hour and 30 Minutes 1 Hour and 30 Minutes	Practical

6. Assignment (s)

2. Prepare the site visit report and write all important aspects associated with the use of leakage detection equipment at the site.
3. Prepare an action plan for water network maintenance and leakage prevention.

7. Learning Resources

Available Leak Detection Equipment (Metal Locator, Non-Metal Pipe Locators, Road Measures, Ultrasonic Flowmeter, Pressure Recorder, Metal Pipe Locator); Equipment Quick Manuals

8. List of Reading Materials

Sr. No.	Author (s) Last Name, First Initial and Year of Publication	Book or Report Title	Publisher Name and Place of Publication
1.	Hughes, D.M., Oxenford, J., Titus, R. (2014)	Pipe Location and Leakage Management for Small Water Systems	Water Research Foundation, Denver
2.	UN-Habitat (2012)	Leakage Control Manual, Utility Management Series for Small Towns, Volume 5	UN-Habitat, Kenya
3.	PMDFC (2015)	Operation and Maintenance Manual of Punjab Municipal Development Fund Company (PMDFC)	PMDFC, Lahore
4.	Farley, M. (2001)	Leakage Management and Control	World Health Organization, Geneva
5.	Hamilton, S., Charalambus, B., (2013)	Leak Detection Technology and Implementation	IWA, London

Leakage Detection and Repair

W 7231

On-Site Installation and Operation of Leakage Detection Equipment (OJT) Module 3

Lecture 1

Participant Lecture Notes

2016

1. Lecture Information

Lecture Topic: Quick Reference Manuals	Lecture Duration: 1 Day
1. Non-Metal Pipe Locator 2. Pressure Recorder 3. Ultrasonic Flow Meter 4. Metal Detector 5. Metal Pipe Locator 6. Road Measure	

2. Installation and Operation of the Equipment

2.1. Non-Metal Pipe Locator

Introduction

Pipe locator D-305 is an electronic instrument which locates underground non-metal pipes and identifies the leaks in the pipes such as HDPE, AC, and PVC etc. as shown in **Figure 1**.

Figure 1: Non-Metal Pipe Water Leak Locator D-305

Specifications

Features	Transmitter	Receiver
Power	12 V shield battery	NiMH rechargeable
Operating Time	Approx. 6 hours	Approx. 20 hours

Transmission Output	30 W	Replace connection cable
Operating Temperature	-15~50 °C	-20~60 °C
Weight	11 Kg	

Components

- Transmitter with built-in dust proof and water proof casing having current meter and voltmeter shown in **Figure 2.**
- Receiver
- Cord with alligator clips
- 25 m extension cable with drum for earth
- Earth rod
- Charger for transmitter
- Charger for receiver
- Locking plier

Figure 2: Transmitter with Parts Labelling

Functions

- This instrument transmits electromagnetic waves to trace the underground pipe routes.
- Identifies the leakage point in non-metallic pipes [AC, PVC, polyethylene, etc.] up to 500 m length and 4m depth with high precision.
- Measures the depth of buried pipes.

Operation

1. **How to connect transmitter?**

- Make sure that the transmitter power is OFF. Plug the red test lead into the positive terminal (red jack) of the transmitter and connect the alligator clip to the metal part of the pipe to be tested.
- Plug the black test lead into the negative terminal (black jack) of transmitter and using the extension cord drum cable connect the other side to the isolated metal object such as a signpost, located over 10m away from the pipe being detected in order to establish good earthing connection.

Figure 3: Place for Earthing

- If place for earthing is not available, use earth rod for grounding in 45° angle with reference to valve on which alligator clip is attached as presented in **Figure 3**.
- Turn the transmitter ON and set "output adjustment dial" according to the distance from the transmitter.
- Turn and adjust the "impedance matching dial" to get strongest output.
- Receiver movement can be done in any direction (backward or forward) to the valve attached with alligator because the electromagnetic waves moves along the pipe in every direction.

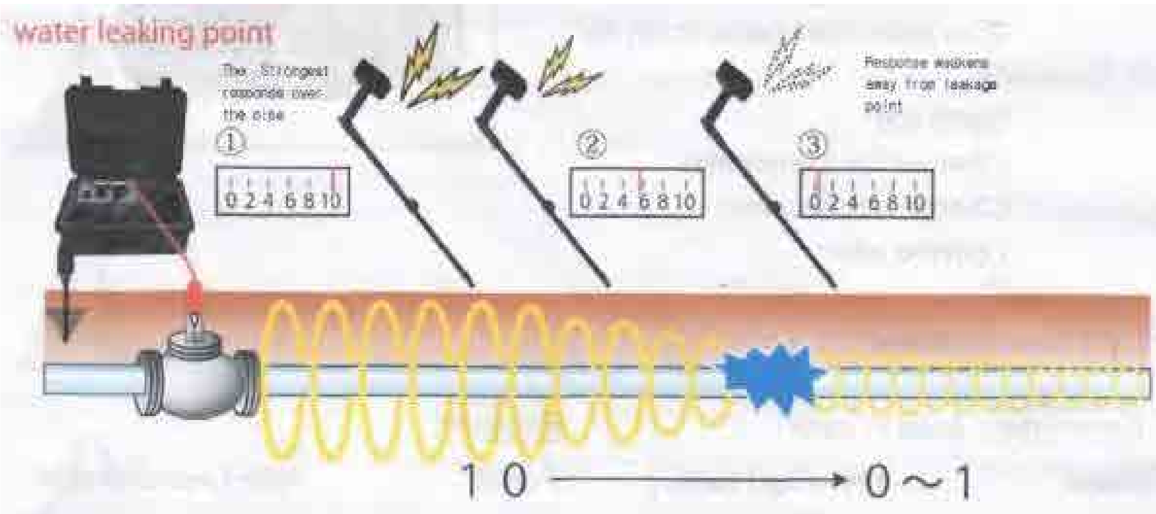


Figure 4: Sensitivity Response at Receiver

At any distance, adjust the transmitter output in such a way that meter on receiver show sensitivity level of around 8 to 10 as demonstrated in **Figure 4**.

2. **How to Detect Pipe Line?**

- Connect the transmitter and set output adjustment dial between1 and 2.
- Adjust the receiver's sensitivity volume knob in such a way that meter indicates values between 8 to 10 while continuously detecting signal from the transmitter. The maximum sensitivity is showed when receiver's T-shaped antenna is perpendicular to the pipe shown in **Figure 5**.

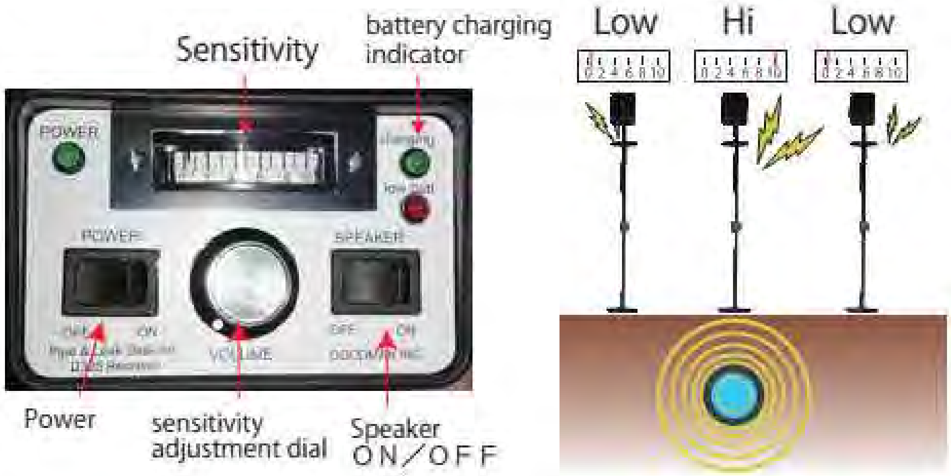


Figure 5: Antenna Sensitivity Adjustment with Movement

- Maximum signal and tone will be heard only when the receiver antenna is directly perpendicular to the pipe as depicted in **Figure 6**.
- Move in straight direction while moving the receiver keeping it 10 cm above the ground.

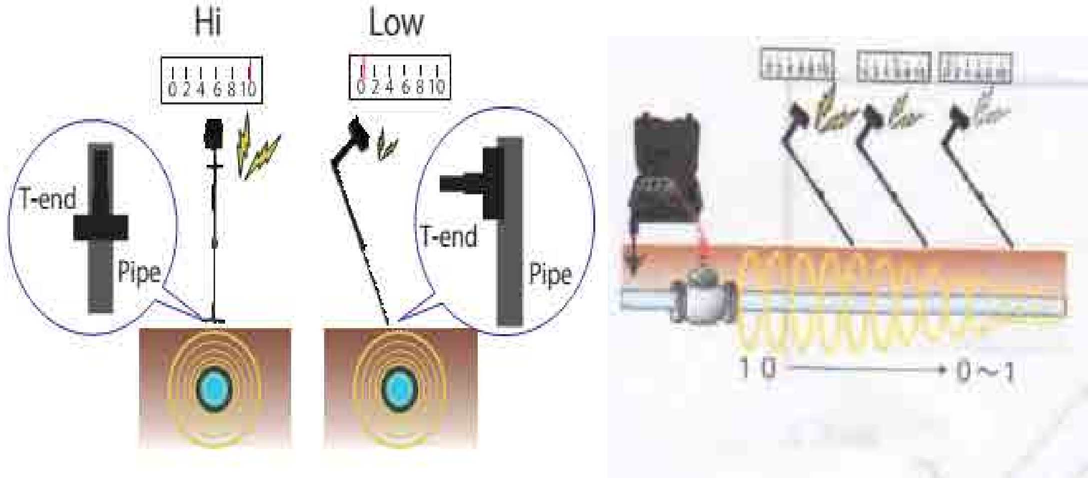


Figure 6: Signal Strength with respect to Antenna Placement and Buried Pipe

- If the signal suddenly fades away while moving above the pipe route, there is the possibility of a junction point or bend so turn the receiver through 360° around the point to confirm the route as shown in **Figure 7**.

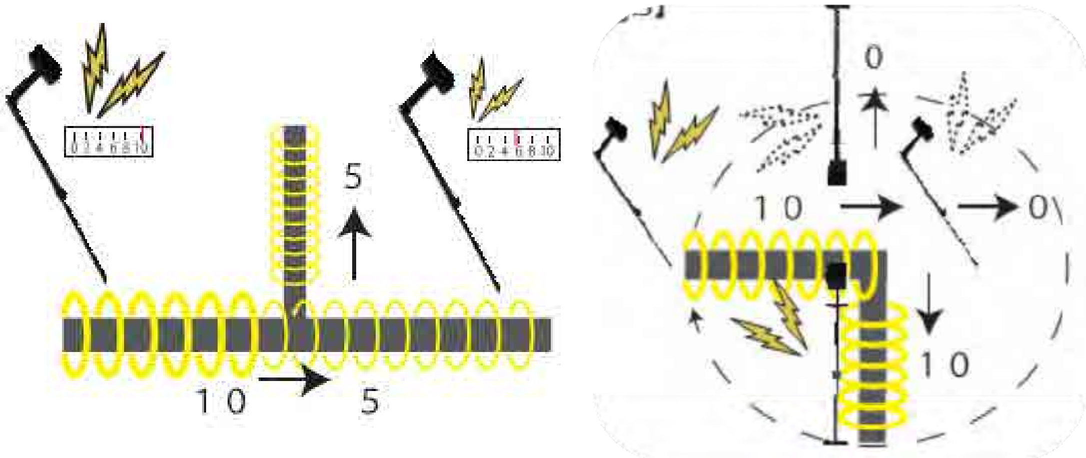


Figure 7: Pipe Route Identification

3. Identification of Leak Location

- Connect the transmitter to the suspected leaking pipe.
- Detect and confirm the pipe route while marking the line on the ground.
- Mark the point where the meter signal strength suddenly drops.

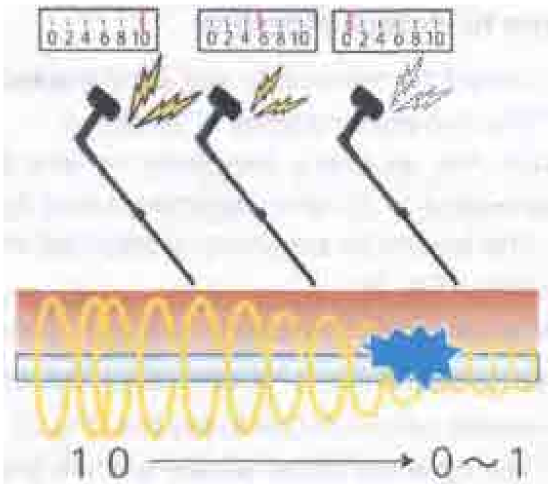


Figure 8: Leak Identification

- Repeat again and again slowly and search the line in the area of the "mark". The point where meter level drops and shows significant results is a leakage point as shown in **Figure 8**.

4. How to Measure the Depth of Underground Pipe?

- Place "Mark 1" directly above the underground pipe as in **Figure 9**.

- Keep the T- shape antenna close to “Mark 1” tilt the receiver at 45° (the signal tone becomes week so adjust the receiver’s sensitivity) shown in **Figure 10**.

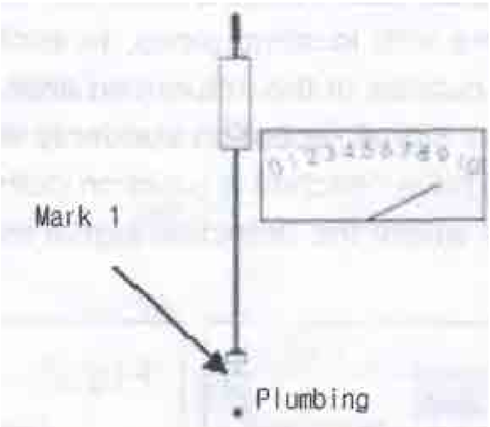


Figure 9: Marking Point

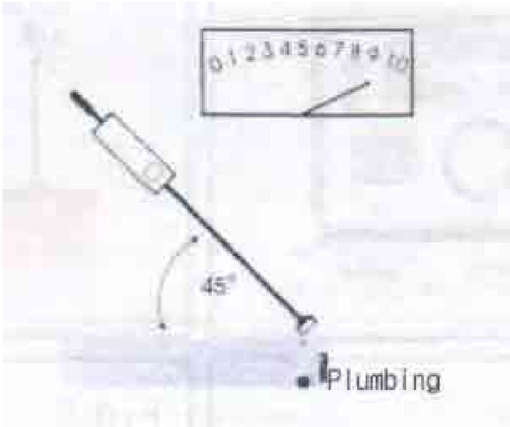


Figure 10: Receiver Inclination

- Slowly move the T-shaped antenna perpendicular to the pipe, Place “Mark 2” where you again start to hear the signal.
- Distance between “Mark 1” and “Mark 2” equals the depth of buried pipe shown in **Figure 11**.

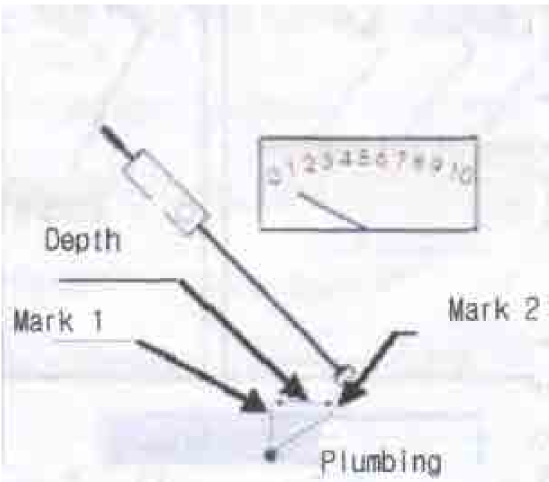


Figure 11: Buried Pipe Depth Determination

Note:

- Before connecting or removing any test lead, make sure that the transmitter’s power is turned OFF.

- Connect the charger to charge receiver and transmitter directly (100-240V).
- Induced electromagnetic waves spread into both live and ground line.
- Save both the transmitter and the receiver from moisture. This equipment works more efficiently when power lines and poles are at least 10 m away.

2.2. Water Pressure Recorder

Introduction

Water pressure recorder FJN-501 is used to measure the pressure of water in supply lines shown in **Figure 12**. This portable pressure recorder draw pressure fluctuation lines on a chart for multiple hours.

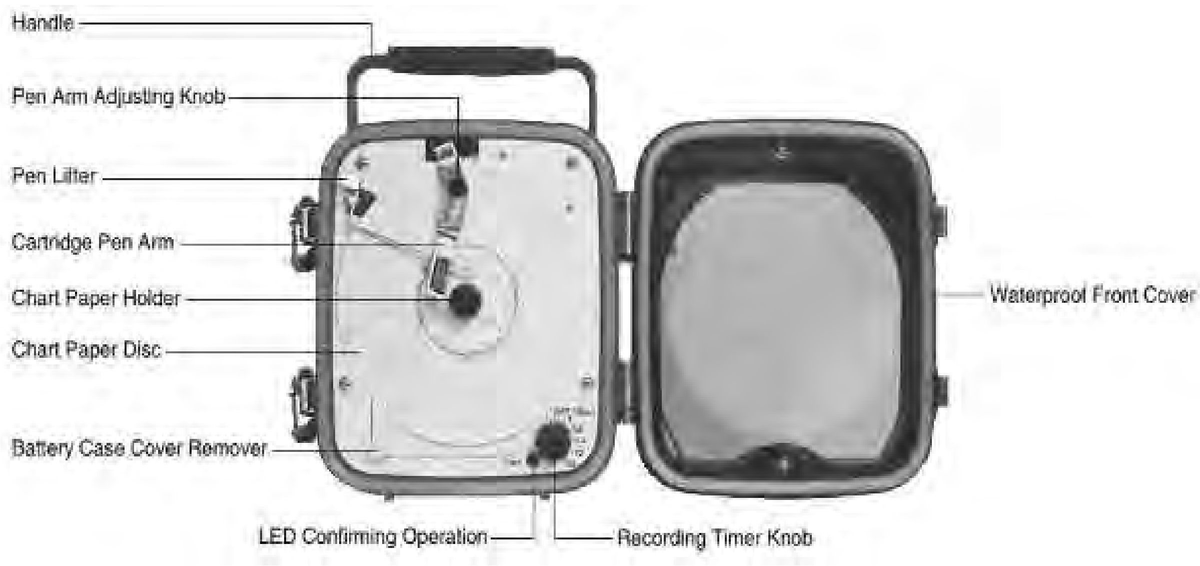


Figure 12: Water Pressure Recorder

Specification

Table 1: Pressure Recorder Specification

Features	FJN-501
Pressure range	0.5, 1, 1.4, 2 MPa.
Recording time	4,12,24,72,168 Hours
Power Check	CPU does not work at Voltage < 2.2 v
Mode Check	LED indicates by blinking

Operating Power	3 Volts (Minimum 2.2 v)
Battery Life	4h – 80days 12h – 220days 24h – 380days 72h – 720days 168h – 970days
Weight	1.35 Kg

Operation

- Unlock the clip and open the front cover.
- Push down the pen lifter to lift up the arm, remove chart paper holder by pulling upward, remove the used paper and replace with the new one as shown in **Figure 13**.
- Before inserting chart paper, check battery status. Turn the knob at 4 hour position and confirm if the LED Light is ON and OFF for 1 minute than status is good, if no light then change the battery.
- Remove the cap of the cartridge pen and fit it on pen holder. Release the Pen lifter and put down the pen arm so that the pen pointer touches the chart paper softly. (After use remove the pen from arm and place cap back to save tip dry).

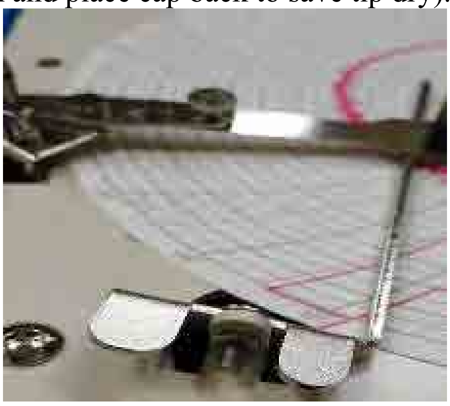


Figure 13: Ink Arm Lifter

- Make sure that the pen pointer is located on the zero line. Adjust it with the help of screw on the arm of pen.

Figure 14: Cartridge Pen Adjustment

- Rotate the chart paper disc to adjust the chart at starting point. The pen point automatically comes to the starting point when the recording is finished.
- Always keep the knob to OFF position before changing chart paper.
- Close the front cover after cleaning the water proof packing.
- Connect the hose with meter (valve side).
- Remove air using air release knob as in **Figure 15**. before and after use of the gauge.
- Wash the valve and the connector. Also remove air from inside the connecting valve and fire hydrant.
- Clean and remove air from the hose pipe of the pressure gauge.

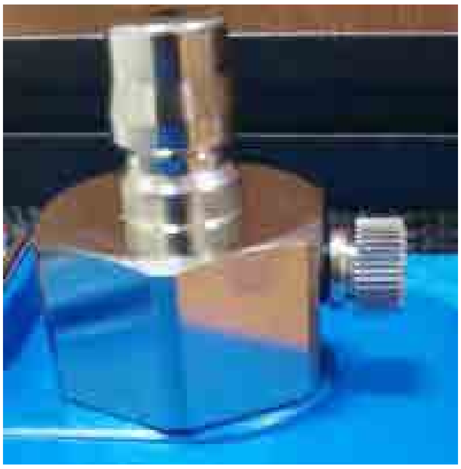


Figure 15: Air Release Knob

Pressure Conversion Table

Pressure recorder chart tells the pressure in mega pascal (MPa) unit. Our common practices is to use units in Bar, PSI and Meter (m). The following Table 2 shows the conversion.

Table 2: Pressure Conversion Table

MPa	Bar	Psi	Meter
1	10	145	102
0.5	5	73	51
0.2	2	29	20.4

2.3. Portable Ultrasonic Flow Meter

Ultrasonic flow meter measures the velocity of the fluid in a pipe using ultrasound and calculates flow rate based upon pipe diameter as shown in **Figure 16**.

Installation

Flow Meter Setting

- Switch ON the device by pressing the power button (on the right side of the meter) for 3 seconds.
- Go to Pipe/Fluid setting, press down and enter pipe diameter in mm, the pipe material (polyethylene, asbestos etc.) and thickness of the pipe wall. In fluid settings choose water temperature as 20°C without disturbing the rest of the settings In general option select unit by + & - buttons.

Figure 16: Ultrasonic Flow Meter

- Press down in chord 1, enter probe number being used as SE1586 or 1515. Choose V type option as suggested by manufacturer keeping rest of the settings unchanged. Method of installing the probes (V, W or N type) depends upon the pipe diameter and availability of the space.
- Cursor down and press F key for 2 to 3 seconds. It will save the settings. Press down to check the status of battery, flow-meter will display the probe sensor spacing for the installation of probes SE1586 as shown in **Figure 17**.

- After entering the desired inputs, attach the cable of the probes the meter will display the flow rate.

Figure 17: SE 1586 Probe Installation

Probe Adjustment

- Mark with chalk where probes to be attached on the pipe.
- Use sand paper to clean and smoothen the pipe surface for good bond of probe sensors with the pipe.

Figure 18: Probes Wires Connection

- Clean the pipe with cloth piece at the chosen probe location.
- Apply gel on each probes and spread gel at the fix points.
- Attach probes at the pipe on specific distance and ensure that the gel interfaces between the probe and the pipe.
- Insert wire plug on the upper right side of the meter which have 5 small holes while on other side two wires attached them with probes wires shown in **Figure 18**.

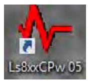
Note:

- After use, press the button at the right side for 3 seconds to turn off the ultra-sonic flow meter.
- Reset all the settings by choosing configuration option
- Before leaving, check the batteries status. Batteries must have sufficient charge.
- It takes 3 to 4 hours to fully charge the batteries which would last for 8-10 hrs.

- Probes having sensors are very sensitive so handle with care.

2.4. Potable Ultrasonic Flow Meter Software Installation Procedure

Summary:

Through this Software we can check "minimum night flow" and flow rate of water for every second. It can give us continuous data of 14 hours of water flowed. By using such data we can design the water requirements of a community by keeping their needs. Helps in leakage detection, pump flow control and energy audit. Their Graphical representation helps to identify the more or less usage of water with respect to time. By 

using average 3 days "minimum night flow data" we can detect leakage.

Installation of Software:

Click on loader file ⇨ Chose English ⇨ Software and Technical Documentation ⇨ Select UF801P ⇨ Software Setup V5 ⇨ Download and Click on Yes ⇨ Select English & Press OK ⇨ Click next ⇨ Program is installed and a Logo is appeared on your desktop.

How to connect with your Laptop or PC:

- With the use of VGA and serial cables connection is made between flow meter device and laptop or PC as explained in **Figures 19**.

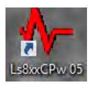
Figure 19: Cables

Figure 20: Cables

- Plug in cable to Ultra-Sonic flow meter (on the lower side) as shown in **Figure 21.**

Figure 21: Plug connection with ultrasonic meter

How to operate Software:

- Click software icon, which appear on the desktop. 
- Click on options on menu toolbar and select **"Option"** then go to "**Auto Search**" from drop down as shown in **Figure 22**.

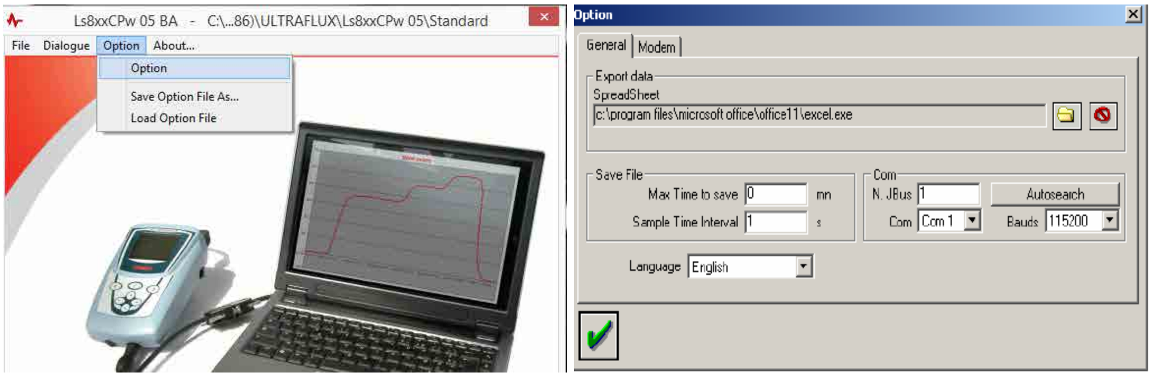


Figure 22: Auto search

- After **"Auto Search"** completion, click on  **"OK"** and click to save the settings as shown in **Figure 23.**

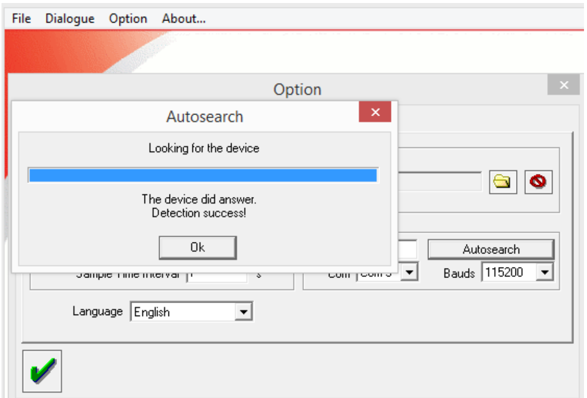


Figure 23: Save the setting

- Click on **"Dialogue"** in menu bar tool bar and select "**measuremet".** The **"Measurement"** is ground in two catogeries. In **"General"** which shows tha actual flow and totalizers.As shown in **Figure 24.**

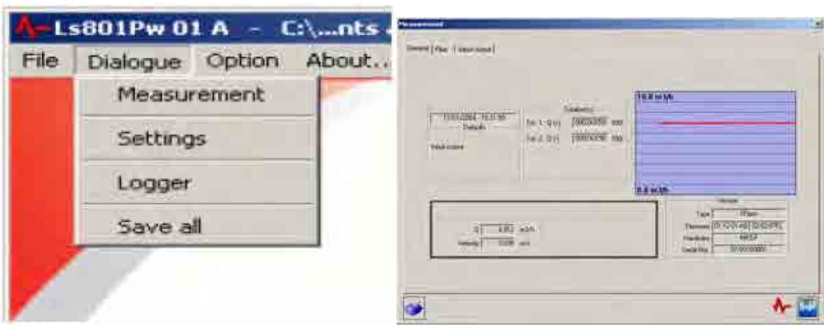


Figure 24: Actual flow

In “Pipe” category shows technical display with control data.

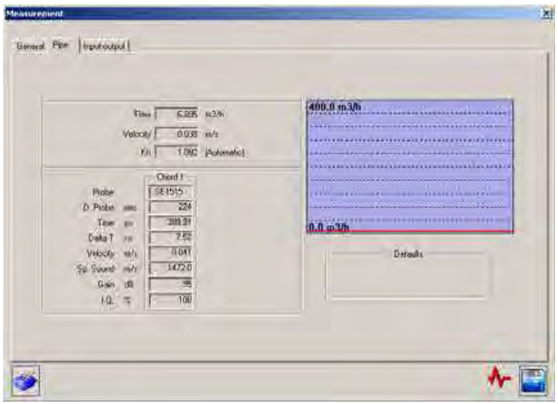


Figure 25: Technical display

- Click on **“Dialogue**” in menu toolbar and select **“settings”.** You can change the general settings to “simple”, “Advance”. In pipe section, you can reduce the graph scale limits as shown in **Figure 26.**

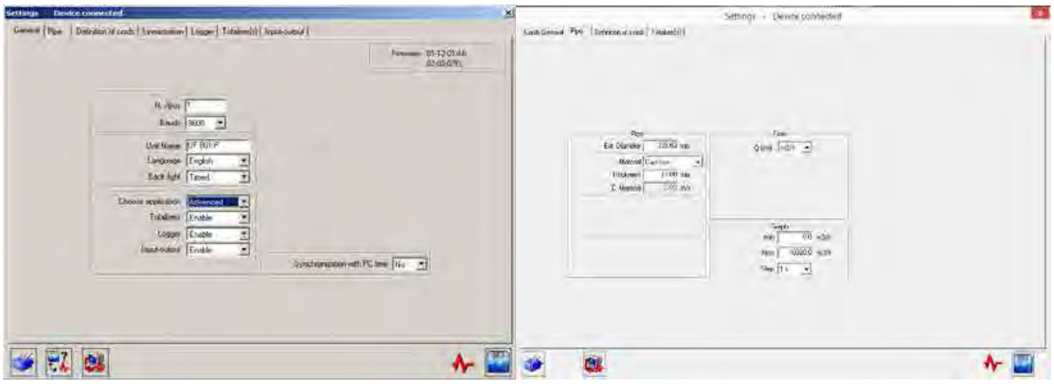


Figure 26:Settings

To save data file use the display  logo at the bottom right corner in the setting screen as shown in **Figure 27**.

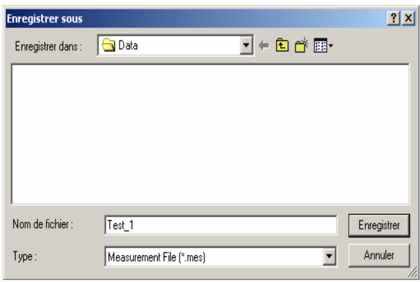


Figure 27: How to save data

This logo is used to start graph recording and save file by clicking this logo. In order to change pipe setting, logo is used for transfer data to the device as shown in **Figure 28.**

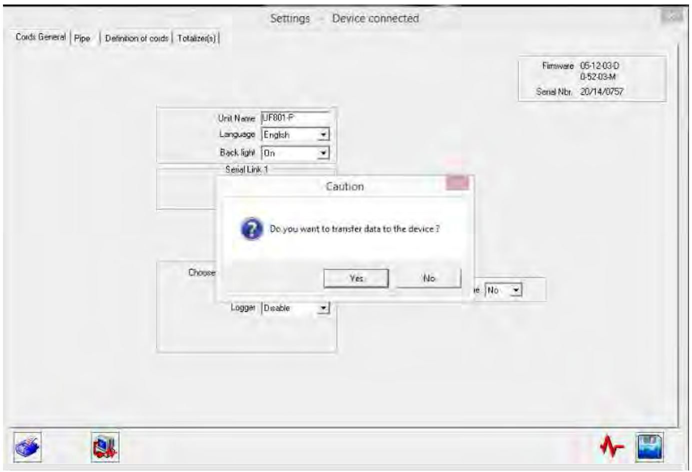


Figure 28: Purpose of logo

How to Convert Data into Excel Sheet:

- Click on **"File"** option in toolbar, and select "**Open**" to pick already saved file.

Figure 29: How to check saved files

- By selecting excel option in red circle shown in Figure, select "**Tick**" option and again save the file as shown in **Figure 30**.

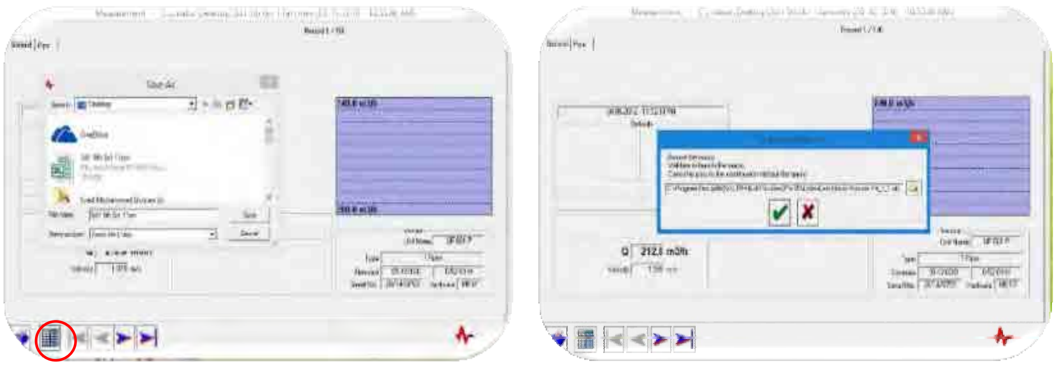


Figure 30: How to save the again

- Open the save Excel sheet to get flow data and its graphical presentation in chart as presented in **Figure 31**.

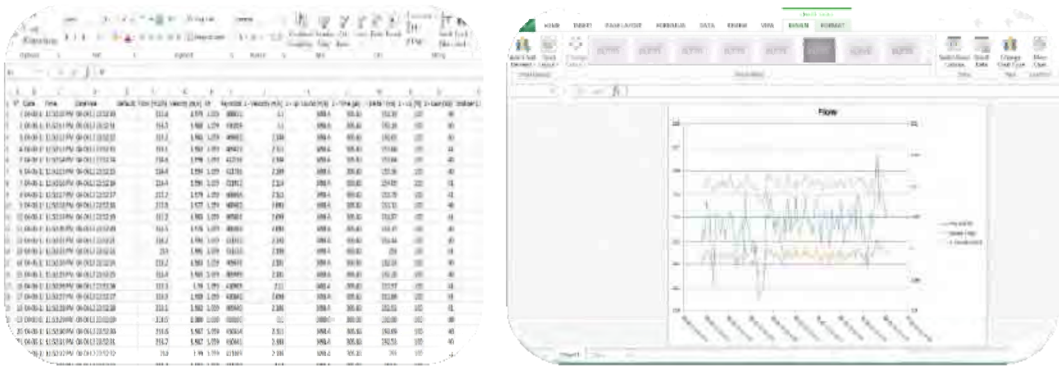


Figure 31: Graphical representation

2.5. Metal Detector

Introduction

Metal detector M130 is an electronic instrument which sense the presence of metal either on the surface or underground. M130 is used to locate metal valves and manhole covers in the water utilities shown in **Figure 32.**

Figure 32: Metal Detector

Specifications

- One piece unit comprising a control unit and search coil which are connected through handle and shaft.
- Single control knob for ease of handling by one hand.
- Does not require re-zeroing
- Measures up to 1.5 - 2 feet deep metal pipes
- Powered by PP3 (6V block) battery
- Ideal for valve boxes, hydrants and buried manhole covers by generating electromagnetic waves shown in **Figure 33**.
- Have option of headphone attachment for a clear sound at a noisy site.

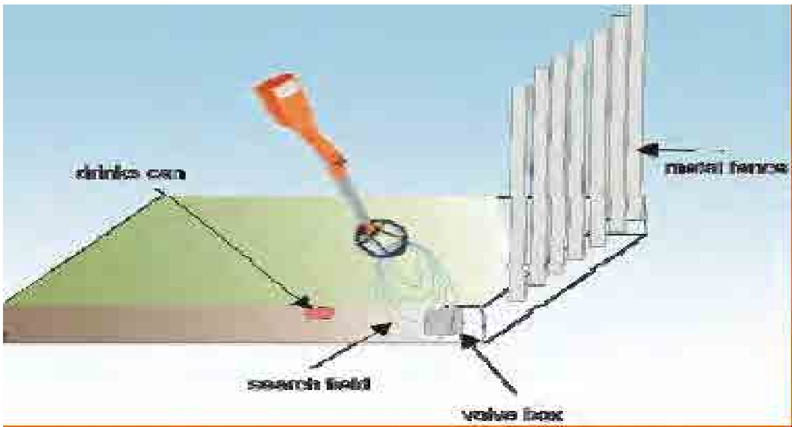


Figure 33: Valve Detection

Operation

- Hold the search coil away from any metal, turn the equipment "ON" by rotating the knob clockwise and adjust the knob until the unit produces low frequency buzz and vibrating sound.
- A continuous sound will be heard and red light will illuminate when any metal comes in the range of detector.
- Hold the search head 4 – 6 inches above the ground during search.
- The outline of manhole covers can be identified by bringing the search coil up the side of the object from different sides.
- Turn the knob anti-clockwise to reduce sensitivity so that the edge of the target is easy to identify.

After Use

- To conserve battery life, remember to switch the unit off when not in use.
- If the unit is not used for an extended period of time, remove the batteries before storing it.
- Always place equipment in its safety bag, keep it away from direct water contact weather and do not put any kind of load on it.

Note

- To check the status of battery, hold the coil away from any metal. If the LED glows red or the unit buzzes continuously, add new batteries (or recharge if NiCD batteries are used)
- The Meter has built-in reject circuit against silver foil of cigarette packs, screws etc. No signal will be received when search coil touches such objects.
- At the hand side there is a battery box. Follow the instructions on the back of the cover to replace batteries.
    - Open the cover, and remove the upper side two dry cell batteries.
    - Push the battery box forward then pull the back side of box in upward direction.
    - Remove the wire connection from battery box. Bring out the box from the case, turn behind and replace the other two dry batteries.

2.6. Metal Pipe Locator

Introductions

This equipment model 501 is used to locate the path and depth of buried cable, service wires, metallic pipe or conduit and locate the end of a cut cable shown in **Figure 21.**

Components

- **Transmitter**

The transmitter is housed in an aluminum case and is powered by eight (8) 1.5V AA batteries. The transmitter has an On/Off control knob which is also used to adjust the output level and a light emitting diode (LED) indicating the battery condition.

Figure 34: Metal Pipe Locator

In addition, the transmitter has an automatic shut-off feature after 1.5 hours of non-use. Effective range is greater than 4000 feet (1220 m) in length and for depths up to 7 feet (2.13m).

- **Receiver**

The receiver is encased in an aluminum housing, mounted with an antenna and is powered by one 9V battery. Like the transmitter, the receiver will automatically shut itself off after 1.5 hours of non-use. The receiver has a speaker for listening to the signal, a meter for monitoring the signal level, a headset jack, an on/off volume control knob and an antenna for detecting the tone over the cable.

- **Carrying Case with Inductive Antenna**

The case is used for storing and transporting the Tracker II system and is constructed of bubbled polyethylene.

- **Chord Set**

An 8 foot pair of leads with plugs and clips is included for connecting the transmitter to the cable or pipe.

- **Inductive Coupler**

The inductive coupler induces a tracing tone on a cable, wire or pipe by clamping around it.

- **Optional Headset**

The headset can be used to monitor the received signal in high noise level areas and is plugged into the receiver jack provided.

Specifications

- **Electrical Transmitter**

Output Voltage: 40 Vp-p (140 mW) maximum
Output Frequency (nominal):
Carrier: 447.5 kHz
Audio Modulation: 1 kHz
Voltage Protection: 250 VAC

- **Battery**

Transmitter: (8) AA 1.5V
Receiver: 9 VDC (NEDA 1604, JIS 006P or IEC 6LR61)

- **Battery Life (nominal)**

Transmitter: 30 hours
Receiver: 10 hours

- **Operating/Storage Conditions**

Operating Temperature: 0 °C to 50 °C (32 °F to 122 °F)
Storage Temperature: -17 °C to 75 °C (0 °F to 167 °F)
Effective range is greater than 4000 feet in length and for depths up to 7 feet.
The receiver & transmitter will automatically shut itself off after 1.5 hours of non-use.

Note

- Do not expose this unit to rain or moisture.
- Inspect the test leads or accessory before use. They must be cleaned and dry, and the insulation must be in good condition.
- Before closing the case, remove the test leads from the circuit and shut off the unit.
- Connecting one lead to a conductor and the other to earth ground via screwdriver should have maximum distance.

Operation

Battery test for Transmitter

Plug the cable chord in the transmitter, rotate its knob to full value and make two short alligator clips. Red led light blinks which indicating that battery is in good condition.

Battery test for Receiver

Rotate the receiver’s knob clockwise. Turn the transmitter on to 3rd position and pass receiver antenna close to the transmitter. Any indication from the receiver indicates acceptable battery condition.

Direct method

- Use cords inside the box, attach one alligator clip to the coupler clamp and the second with rod for grounding. Attach the plugs in transmitter.
- Put coupler clamp on valve or house meter that is above the pipe line.
- Use receiver and walk on the surface by moving receiver similar to pendulum motion.
- High value on the meter of receiver and high pitch of the sound identify the location of buried pipe line.

Indirect method

First method:

- Plug the black leads from the box with transmitter.
- If the location of the valve or pipe beneath the ground is known, put the transmitter case on it to find the location of the pipe.
- There is no need to earth in this case

Second method:

- If you don't know the location of valve or pipe, move both receiver and transmitter case at the same time side by side (in zig zag direction) in order to find its location.
- There is no need for grounding in this case.

Operating Receiver

Turn receiver control knob on and rotate clockwise to the 12:00 position. If optional head set is to be used, plug headset into receiver jack provided. A peak meter indication will be seen and a strong tone will be heard when the receiver/antenna is directly over the cable or pipe.

Locating Path

The transmitter control knob should initially be set as low as possible to minimize the scattered effect in congested areas.

- Connect transmitter properly and set output level to 3rd position. Radius should be approximately 10 to 15 feet from the transmitter location to the receiver. The peak meter indication and the tone from the speaker or the headset will indicate the presence of pipe.
- The receiver control knob should be adjusted and needle on receiver should be on between 1&2 so that any increase or decrease in signal can be detected and accuracy can be maintained.
- Return to the transmitter and increase the output level as needed for the distance and depth required (See **Figure 35**)

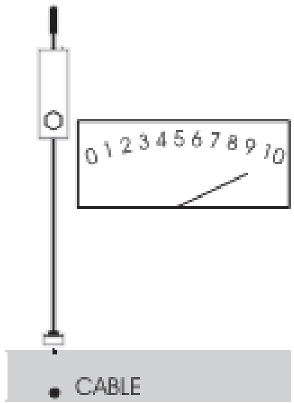


Figure 35: High Electric Voltage

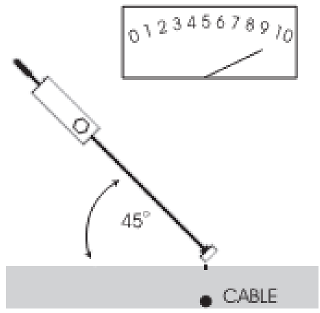


Figure 36. Ground Marking

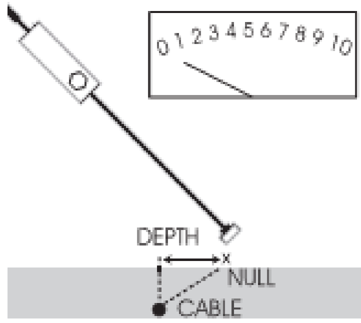


Figure 37. Depth Measurement

Determining Depth

Mark the ground directly over the path as shown in **Figure 36**. Hold the receiver at a 45-degree angle close to the ground. Maintain this angle and slowly move the receiver away from the path opposite the handle. (See **Figure. 37**) The tone will decrease to a minimum and then increase again. Mark the spot where the signal is at its minimum. The depth of the cable will be the distance between the two points marked.

Maintenance

The only service required for maintaining proper operation is the periodic replacement of the batteries in the transmitter and receiver units.

- To replace the 501R battery:
  - Remove (2) screws and separate case.
  - Replace the 9V battery. Observe polarity.
  - Re-assemble case and tighten screws. DO NOT OVERTIGHTEN SCREWS.
- To replace the 501T battery:
  - Remove (2) screws (indicated by arrows) and separate case.
  - Replace (8) AA 1.5V batteries. Observe polarity.
  - Re-assemble case and tighten screws. DO NOT OVERTIGHTEN SCREWS.

Periodically wipe with a damp cloth and mild detergent; do not use abrasives or solvents.

2.7. Walking Measure

This equipment is used to measure the distance from the reference point to end point. Simple to measure distance and marking points shown in **Figure 38.**

Figure 38: Walking Measure

Specification

Length (inches)	Distance Range	Wheel Distance	Meter	Weight
98.5	1-99999 m	1 revolution = 1 m	Analog	2.5 kg

Operation

- Unfold the rod from plastic lock and grip it straight.
- Push the yellow cover to lock the stick.
- Make sure meter reading should be on zero.
- Place the yellow mark attached with wheel as a reference on the ground from where you want to measure the distance.
- Move straight to the end point, to avoid any measuring error.
- Avoid to use in muddy area that results in the error of the measurement.
- Don’t hold the plastic rod which is rotating while equipment is in operation condition, which results in the failure of analog meter.

Maintenance

- Clean the outer surface of the wheel.
- Greasing the rod from its bend on weekly basis or as per required.
- Properly cover up the equipment with its cover.
- Place the equipment on dry place and don’t put weight on it.

3. Reference Material

1. JICA Progress Report, June 2016. Project for Improving Capacity of WASAs in Punjab Province.

2. http://www.ultraflux.net/en/products/flowmeters-for-liquids-full-pipes/uf-801-p-portable/
3. http://www.fujitecom.com/products/pcl.html
4. www.fujitecom.com/catalogue/FJN-501-e.pdf
5. http://www.sewerin.co.uk/products/water-leak-location/m-130/
6. https://greenlee-cdn.ebizcdn.com/media/52031017REV04.pdf
7. http://www.ehmltd.co.uk/TRU001

OJT IMPLEMENTATION PLAN

Lecture Topic: On-Site Installation and Operation of LD Equipment **Date: 04, 05 Oct, 2016**

Academy Trainer(s): Mr. Chiaki Suzuki & Mr. Sami Ullah **OJT Trainer(s): Mr. Sami Ullah**

Days	Place	Target Knowledge & Skills	Equipment/ Machinery/ Material	Step by step Procedure	Time	Evaluation
Tue.	Green Town Water Distribution Network	-Identification of various kinds and characteristics of leak sounds -Identification of false sound - Buried pipes leak detection	- Acoustic Rod - Leak Detector	1. Briefing in the Class with visual aids, Important points to be recalled before leaving for leakage detection 2. Participants will be asked to read through quick manuals for all equipment. 3. Travelling towards the	9:00 am to 9:45 am	Observation On the basis of SOPs followed or not Pipe path identification and depth of the pipe along with Leaks Flow and pressure measurement

				selected leakage site with consultation of WASA sub-divisional office. 4. Confirmation of Personal Protective Equipment (PPE) 5. Demonstration of Leak Detection equipment with Standard Operating Procedures by the faculty person at the site	9:45 am to 10:15 am 10:15 am to 11:30 am	Leak Identification Site Visit Report
	- Overhead reservoir (OHR) Green Town - C Block or D Block Pumping Station for flow measurement by the Ultrasonic flow meter - Pressure recording at	- Non-metal pipe underground path identification - Leaks identification in non-metal pipes -Pressure measurement in the pipeline and its fluctuations -Measurement of flow rate and volume supplied	-Water Leak and Non-Metal Pipe Locator -Pressure Recorder -Ultrasonic Flow Meter -Metal Locator -Metal Pipe	6. Practical demonstration with SOPs for all equipment. Equipment installation, operation and maintenance procedures will be performed at the site. 7. Back to Office 8. Site Visit Reflection	11:30 am to 2:30 pm 2:30 pm to 3:15 pm 3:15 pm to 4:00 pm	

	the fire hydrant located near Umar Chowk in Green Town	- Underground metal detection (i.e. valves, manhole covers, metal pipe) - Underground metal pipe path with its depth measurement	Locator			
Wed	At that day participants will be divided into groups. Following the same procedure as above on the first day of OJT, they will install and operate all equipment by themselves to locate the pipes and pinpointing the leakages. Water flow and pressure recording will be done by using flow meter and pressure recorder to know the flow and pressure fluctuations in the water supply lines.				4 hours 30 minutes	Site Visit Reflection

ALJAZARI ACADEMY

Leakage Detection and Repair

W 7231

Action Plan for Leakage Prevention
Lecture 2

Practical

2016

1. Lecture Information

Lecture Topics:	Lecture Duration: 1 Day
• Action Plan for Leakage Prevention	

2. Action Plan for Leakage Prevention

2.1. Briefing

The participants will prepare leakage prevention action plan for the respective water utilities. Before this exercise, Instructor will explain generic procedure in the form of presentation slides or word document. Participants will be divided into groups of same water utilities. Each group will discuss its action plan in the light of knowledge gained in three days of training. Participants will share the following information and keep all these necessary information for the action plan at the start of training.

1. GIS Maps of the Water Distribution System of the respective Water Utility.
2. Basic information of Water Supply System (Total Water Supplied, Consumed, Pipe Types & Material etc.)

Table 1. Procedure for Leakage Prevention

Sr. No.	Guideline	
1.	Preparation	1. Establishment of Leakage Detection Cell and Team 2. Procurement of Equipment 3. Preparation of Water Distribution Network Maps and Drawings 4. Others
2.	Basic Survey	1. Analysis of Water Supplied and Pressure 2. Divide the City into Blocks 3. Study of Age and Material Strength 4. Preventive Work 5. Others
3.	Plan	1. Set the Target Value 2. Set the Planning year 3. Decide the Survey Methods 4. Others
4.	Action/ Implementation	1. Leakage Survey 2. Analysis of Cause of Leakage 3. Leakage Amount Measurement 4. Quick Repairs (Surface Leakage)

		5. Systematic Detection and Repair (Underground Leakage) 6. Countermeasures for Leakage
5.	Evaluation	1. Analysis of Results 2. Compare the Plan and Action

2.2. Learning Resources

- Laptop at least 7 No.
- A3 Sheets
- Clip Board with stand
- Markers
- Projector
- Internet Facility

3. Preparation of Action Plan by Participants

Trainer will facilitate each group, motivate and contribute actively in their discussion. If any group feels trouble guidance will be given. Participants have to prepare word document along with power point presentation.

4. Group Presentations

Each group will present its plan before the class. Every participant will give his/her suggestion. If there will be any update required thirty minutes will be given to incorporate the update at the end of presentations.

5. Reference Material

1. Leakage Management and Control: A best practices training manual by Malcolm Farely, World Health Organization Geneva, Swizerland, 2001.
2. JICA Quarterly Report, 2016. Project for Improving Capacity of WASAs in Punjab Province.
3. Training Manual: Non-Revenue Water (NRW) Course for Water Service Providers (WSPs) in Kenya, Wave Training Programme Kenya, May 2010.
4. IWA workshop on Water & Energy and Water 2014 Loss, Strategy for Water Leakage Control in Japan by Hiroki Ariyoshi.
5. www.jwwa.or.jp/jigyou/seminar_file/L05.pdf

GLOSSARY

Acoustic: The branch of physics concerned with the properties of sound, Acoustic is relating to sound or the sense of hearing.

Amplifier: An **amplifier**, electronic **amplifier** or (informally) amp is an electronic device that increases the power of a signal. It does this by taking energy from a power supply and controlling the output to match the input signal shape but with a larger amplitude.

Authorized Consumption: The volume of metered and/or unmetered water taken by registered customers, the water supplier and others who are implicitly or explicitly authorized to do so by the water supplier, for residential, commercial and industrial purposes. It also includes water exported across operational boundaries. Authorized consumption may include items such as fire fighting and training, flushing of mains and sewers, street cleaning, watering of municipal gardens, public fountains, building water, etc. These may be billed or unbilled, metered or unmetered.

Billed Authorized Consumption: Those components of Authorized Consumption which are billed and produce revenue (also known as Revenue Water). Equal to Bill Metered Consumption plus Billed Unmetered Consumption.

Billed Metered Consumption: All metered consumption which is also billed. This includes all groups of customers such as domestic, commercial, industrial or institutional and also includes water transferred across operational boundaries (water exported) which is metered and billed.

Billed Unmetered Consumption: All billed consumption which is calculated based on estimates or norms but is not metered. This might be a very small component in fully metered systems (for example billing based on estimates for the period a customer meter is out of order) but can be the key consumption component in systems without universal metering. This component might also include water transferred across operational boundaries (water exported) which is unmetered but billed.

Bursts: Events with flow rates greater than those of background losses and therefore detectable by standard leak detection techniques. Bursts can be visible or hidden.

Commercial (Apparent) Losses: Includes all types of inaccuracies associated with customer metering as well as data handling errors (meter reading, estimates on flat rates and billing), plus unauthorized consumption (theft or illegal use). **Note:** Over-registration of customer meters, leads to under-estimation of Physical (Real) Losses. Under-registration of customer meters, leads to over-estimation of Physical (Real) Losses.

Countermeasures: An action taken against an unwanted action or situation.

Customer Metering Inaccuracies and Data Handling Errors: Commercial (Apparent) Water Losses caused by customer meter inaccuracies and data handling errors in the meter reading and billing system.

District Metered Area (DMA): A discrete area with a permanent boundary defined by flow meters and/or closed valves. District Meter Area, an area that has a defined and permanent boundary, usually containing 500–3000 properties, into which flows are continually monitored

Doppler Effect: An increase (or decrease) in the frequency of sound, light, or other waves as the source and observer move towards (or away from) each other. The effect causes the sudden change in pitch noticeable in a passing siren, as well as the red shift seen by astronomers.

Electrolytic Corrosion: The process in which a metallic surface is continuously corroded by other metal it is in contact with, due to an electrolyte and the flow of an electrical current between the two metals, caused from an external source of electromotive force (EMF).

Electromagnetic Radiation; Classically, electromagnetic radiation consists of electromagnetic waves, which are synchronized oscillations of electric and magnetic fields that propagate at the speed of light through a vacuum.

Electromagnetic Waves: Electromagnetic waves are formed when an electric field couples with a magnetic field. The magnetic and electric fields of an electromagnetic wave are perpendicular to each other and to the direction of the wave.

Electromagnetic waves are **waves** which can travel through the vacuum of outer space. Mechanical **waves**, unlike **electromagnetic waves**, require the presence of a material medium in order to transport their energy from one location to another.

Filter: Filter is an essential option to when there is a background noise and the leak is hard to hear. Filter is used when the sound of leaks cannot be heard. Change the filter frequency by pressing the green + or – filter button. This can eliminate the background noise and help focus on a particular frequency.

Infrastructure Leakage Index (ILI): The ILI is a measure of how well a distribution network is managed (maintained, repaired, rehabilitated) for the control of real losses, at the current operating pressure. It is the ratio of Current Annual volume of Physical Losses (CAPL) to Minimum Achievable Annual Physical Losses (MAAPL).

ILI = CAPL / MAAPL

Being a ratio, the ILI has no units and thus it facilitates comparisons between countries that use different measurement units (metric, U.S., or imperial)

Minimum Achievable Annual Physical Losses (MAAPL) is called “Unavoidable Annual Real Losses (UARL)” by the International Water Association.

Leakage and Overflows at Utility’s Storage Tanks: Water lost from leaking storage tank structures or overflows of such tanks caused by e.g. operational or technical problems

Leakage on Service Connections up to point of Customer Metering: Water lost from leaks and breaks of service connections from (and including) the tapping point until the point of customer use. In metered systems this is the customer meter, in unmetered situations this is the first point of use (tap) within the property. Leakage on service connections might be reported breaks but will predominately be small leaks which do not surface and which run for long periods (often years).

Leakage on Transmission and/or Distribution Mains: Water lost from leaks and breaks on transmission and distribution pipelines. These might either be small leaks which are still unreported (e.g. leaking joints) or large breaks which were reported and repaired but did leak for a certain period before that.

Leakage Prevention Works: Works carried out for the prevention of leakage. These are categorized into basic, direct, and indirect works.

Leakage Ratio: This is a ratio of annual leakage to annual supply.

Macrocell Corrosion: Macrocell corrosion can occur when the actively corroding bar is coupled to another bar which is passive, either because of its different composition or because of different environment.

Microcell Corrosion: A corrosion microcell is a microscopic cell formed on a continuous piece of metal consisting of an anode and cathode immediately next to each other. This creates the electrochemical conditions that make corrosion possible. Corrosion microcells are formed due to impurities, environmental conditions, and other factors.

Minimum Night Consumption: Minimum Night Consumption is part of the Minimum Night Flow and is normally composed of three elements: 1. Household night use 2. Non-household night use; 3. Exceptional night use.

Minimum Night Flow (MNF): The Minimum Night Flow (MNF) normally occurs during the early morning period. The MNF is the most meaningful piece of data as far as physical loss levels are concerned. During this period, consumption is at a minimum and therefore physical losses are at the maximum percentage of the total flow. The estimation of the physical loss component at Minimum Night Flow is carried out by subtracting an assessed amount of Minimum Night Consumption for each of the customers connected in the zone being studied.

Net Night Flow: Net Night Flow is the difference between Minimum Night Flow and Minimum Night Consumption and is equivalent to Night Leakage.

[Net Night Flow] = [Minimum Night Flow] - [Minimum Night Consumption]

Non-Revenue Water: Those components of System Input which are not billed and do not produce revenue. Equal to Unbilled Authorized Consumption plus Physical (Real) and Commercial (Apparent) Water Losses.

Physical (Real) Losses: Physical water losses from the pressurized system and the utility's storage tanks, up to the point of customer use. In metered systems this is the customer meter, in unmetered situations this is the first point of use (tap) within the property. The annual volume lost through all types of leaks, breaks and overflows depends on frequencies, flow rates, and average duration of individual leaks, breaks and overflows. **Note:** Although leakage, after the point of customer use, are excluded from the assessment of physical water losses, this does not necessarily mean that they are not significant or worthy of attention for demand management purpose.

Revenue Water: Those components of Authorized Consumption which are billed and produce revenue (also known as Billed Authorized Consumption). Equal to Billed Metered Consumption plus Billed Unmetered Consumption

System Input Volume: The volume of treated water input to that part of the water supply system to which the water balance calculation relates.

Trihalomethanes (THMs): THMs are a group of four chemicals that are formed along with other disinfection by products when chlorine or other disinfectants used to control microbial contaminants in **drinking water** react with naturally occurring organic and inorganic matter in **water**.

Ultrasound: Ultrasound is acoustic (sound) energy in the form of waves having a frequency above the human hearing range. The highest frequency that the human ear can detect is approximately 20 thousand cycles per second (20,000 Hz). This is where the sonic range ends, and where the ultrasonic range begins.

The **average person** can hear sounds down to about 0 dB, the level of rustling leaves. Some people with very good hearing can hear sounds down to **-15 dB**. If a sound reaches **85 dB** or stronger, it can cause permanent damage to your hearing.

The term "**ultrasonic**" applied to **sound** refers to anything above the frequencies of audible **sound**, and nominally includes anything over 20,000 Hz. Frequencies used for medical diagnostic ultrasound scans extend to 10 MHz and beyond.

Unauthorized Consumption: Any unauthorized use of water. This may include illegal water withdrawal from hydrants (for example for construction purposes), illegal connections, bypasses to consumption meters or meter tampering.

Unbilled Authorized Consumption: Those components of Authorized Consumption which are legitimate but not billed and therefore do not produce revenue. Equal to Unbilled Metered Consumption plus Unbilled Unmetered Consumption.

Unbilled Metered Consumption: Metered Consumption which is for any reason unbilled. This might for example include metered consumption by the utility itself or water provided to institutions free of charge, including water transferred across operational boundaries (water exported) which is metered but unbilled.

Unbilled Unmetered Consumption: Any kind of Authorized Consumption which is neither billed nor metered. This component typically includes items such as firefighting, flushing of mains and sewers, street cleaning, frost protection, etc. In a well-run utility it is a small component which is very often substantially overestimated. Theoretically this might also include water transferred across operational boundaries (water exported) which is unmetered and unbilled – although this is an unlikely case.

Water Losses: The difference between System Input and Authorized Consumption. Water losses can be considered as a total volume for the whole system, or for partial systems such as transmission or distribution schemes, or individual zones. Water Losses consist of Physical (Real) Losses and Commercial (Apparent) Losses.

AlJazari Water & Sanitation Academy
Form A
Course Evaluation

Please provide your honest evaluation of the training course that you have just undertaken. Your evaluation will help to improve the future delivery of trainings by Al-Jazari Academy.

Sr.No.	How satisfied were you with:	Not Satisfied 1	Somewhat Satisfied 2	Satisfied 3	Very Satisfied 4
1	Difficulty level of training themes				
2	Quality of Training Materials (PPT Slides, Handouts, Lecture notes etc)				
3	Relevance of on-site training and field training activities				
4	Overall Presentation quality of Trainer(s)				
5	Trainer's expertise on topics and topics delivery skills?				
6	Time and length of training				
7	Practical activities and exercises at classroom				
8	Difficulty level of assessment and evaluation (assignment, exercises, project, action plan etc)				
9	Logistics arrangements such as (classroom, vehicles, tea and lunch etc)?				
10	Overall quality of the training?				

11) Would you like to recommend this course to your colleagues?

Yes ☐ **No** ☐

If no, then kindly give two major reasons

____

____

12) Kindly write two suggestions for further improvement of **<u>Training Materials</u>** (PPT Slides, Handouts, Lecture notes etc.?)

____

____

____

13) Two comments on overall training length and training timing.

____

____

____

14) Kindly provide two suggestions for further improvement related to site visits and field training activities.

____

____

15 a). Course Learning Outcomes (what extent were course learning outcomes accomplished?)

No	Course Learning Outcomes	Accomplished	Not Accomplished
1	Ability to provide various types of leakages control measures		
2	Ability to operate leakage detection equipment		

3	Demonstrate SOPs for pipelines repair in professional manner		
4	Record and analyze of water network maintenance		
5	Prepare action plan for leakage detection prevention		

15 b) If your responses are more in negative, then please elaborate why do you think the course learning outcomes were not fulfilled?(three major reasons only)

____

____

____

Name: ___________________________ Signature: __________________________

Note: The information contained in this form will be used for evaluation and analysis. We may also use your comments in certain publications/ reports.

AlJazari Water & Sanitation Academy

Form B

Trainer(s)' Evaluation

Trainer Name :--Course Name:-------------------------------------

No	Items	Below average 1	Average 2	Good 3	Very good 4	Excellent 5
1	Qualification & experience					
2	Technical Knowledge of the content					
3	Explanation of content					
4	Demonstration and professional capability of handling equipment					
5	Use of different content delivery techniques (group discussion, activities, and exercises)					
6	Management of on- site trainings					
7	Time management					
8	Presentation Skills					

9	Quality of Learning materials (PPT slides, handouts, lecture notes)					

10) Any other suggestion or comment.

____

____

____

Name: __________________________ Signature: _________________________

Note: The information contained in this form will be used for evaluation and analysis. We may also use your comments in certain publications/ reports.

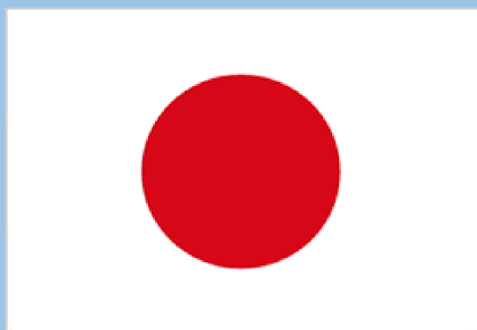
Annex 3.33
Training Material for O&M of Sewer and Storm Water Drainage in Spring 2017

In the name of Allah, the most Gracious and ever Merciful

Introduction

Welcome To Al-Jazari Academy

2/20



Introduction

3/20

Welcome To All Stakeholders

Introduction

4/20

Course Team

Mr. Yusuki Ando
JICA Expert

Mr. Muhammad Irfan
Course Leader

Mr. Rizwan Qazi
JICA Coordinator

Ms. Ammara Asif **Ms. Maryam Rabbani**
Young Professionals

Course Reviewer
Prof. Dr. Sajjad Haider (UET), Lahore

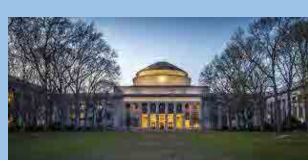
Operation and Maintenance (O&M) of Sewerage and Drainage System including Safety Precautions

Code: S 3221

Modules 03

Duration 09 Days

Class Work
Field Work



Modules

Module 1
- Safety Control and Measures for Sewerage and Drainage Works
- 03 Days

Module 2
- Operation and Maintenance (O&M) of Storm Water Drainage System
- 02 Days

Module 3
- Operation and Maintenance (O&M) of Sewer System
- 04 Days

Introduction

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HOW WE WILL PROCEED . . .

- Module Introduction
- Expected Learning Outcomes
- Lectures
- Tea Break
- Field Work
- Lunch Break
- Presentation by Participants
- Comments by Participants
- Day Work Conclusion

1

2

3

4

5

6

Sign off

Introduction

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WHAT WILL ANIMATE THE TRAINING SESSION. . .

- Mini Lectures
- Video Clips
- Discussions
- On-Site-Training
- Case Histories
- Q&A
- Presentations

Course Evaluation Criteria

- **Total 100**
  - Attendance 25%
  - Participation 35%
    - Class Work 15%
    - Field Work 20%
  - Assignments 40%
    - Action Plan (Module 1)=20%
    - Action Plan (Module 2)=20%

Please Note:
Participants with active participation, maintaining 80% attendance and passing their exam with at least 70% score will be awarded certificates

Reference Material

Book : Operation & Maintenance of Wastewater Collection Systems (Vol. 01)
By: Kenneth D. Kerri & John Brady (California State University, USA)

O&M Manual : Water Born Sanitation Operations and Maintenance Guide
By: S J van Vuuren & M van Dijk (University of Pretoria, South Africa)

Operation Manuals : **(1)** Portable Gas Monitor (GX-8000)
RIKEN KEIKI Co., Ltd. Japan

(2) Valve Box Locator M130
SEWERIN, UK

WHY O&M TRAINING IS ESSENTIAL . . .

Open Drain

Open Drain is Silted Badly

1. Solid waste
2. Bushes & weed growth

Covered Drain

Covered Drain is Choked

1. Root growth
2. Solid waste

Pump Replacement Operation at Disposal Station

1. Metallic boom contacting electricity conductors
2. No traffic management exercised

WHY O&M TRAINING IS ESSENTIAL . . .

<u>Manhole Lid Missing</u>

1. Tree branch is used as replacement (Self help)

<u>Kerb Grating Missing</u>

1. Solid waste entry is evident

<u>Uncovering Manhole</u>

1. Non-standard method applied

Introduction

WHY TRAINING IS MANDATORY . . .

Un-Cleaned Wet Well

1. Poor screening may cause damage to pump internal parts.

No Compliance with SOP

1. Unsafe working (without PPE).

Un-Safe Sludge Handling

1. Non-hygienic conditions
2. PPE no-where

Introduction

WHY TRAINING IS MANDATORY . . .

1. Proper care & maintenance is ignored

Non-Functional Bucket Machine (Winch Machine)

Introduction

WHY TRAINING IS MANDATORY . . .

O&M Training is Essential Every Where

Introduction

ADVANTAGES OF AN EFFICIENT (O&M) SYSTEM

- Full use of the system over its intended <u>design life</u> will be achieved
- It will result in <u>high reliability</u> of equipment and facilities as designed
- It will ensure that facilities and equipment are available as <u>intended</u>
- It will maintain the <u>value</u> of the infrastructure investment
- There will be a collection of accurate <u>information and data</u> on which the operation and maintenance can be planned and budgeted for.
- It will <u>reduce costs</u> since planned maintenance and repairs are much more cost-effective than late-night emergency repairs

In the name of Allah, the most Gracious and ever Merciful

Operation and Maintenance of Sewer & Storm Water Drainage System including Safety Precautions

S 3221

Module 01

Safety Control and Measures for Sewerage and Drainage Works

03 Days

Module 02

O&M of Storm Water Drainage System

02 Days

Module 03

O&M of Sewer System

04 Days

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Module 01 (An Overview)

Safety Control and Measures for Sewerage and Drainage Works

No. of Topics 06 | No. Lectures 09 | Theory 04 OST 03

DAY 01	❑ Risks and hazards associated with sewers & drains	❑ Risks and hazards	Theory
		❑ Control measures	Theory
	❑ Safety practices for sewers & drain O&M	❑ Current safety practices in WASA & Visit to WASA Training Center	OST
DAY 02	❑ Use of safety gears	❑ Concept of PPEs	Theory
	❑ Best safety practices	❑ Working in confined spaces	OST
		❑ Tests for hazardous gases	
DAY 03	❑ First aid	❑ Arrangements for medical treatment	Theory
	❑ Traffic control practice	❑ Identification of a specific manhole	OST
		❑ Traffic control plan	

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Module 01

Safety Control and Measures for Sewerage and Drainage Works

Topic No. 01
Risks and Hazards Associated with Sewers & Drains

Lecture No. 01
Risks and Hazards

Theory

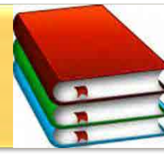
Lecture Breakdown	Duration
Objectives	1 Hour
Important Definitions	
Hazards & Risks related to Sewer & Drainage Works	
Risk Assessment	
Summary	
Q&A	

Module-1 Lecture-1 Risks and Hazards

4/15

Objectives:

- To Give an overview of job related hazards & risks
- Assessment of risks at WASA work sites during O&M

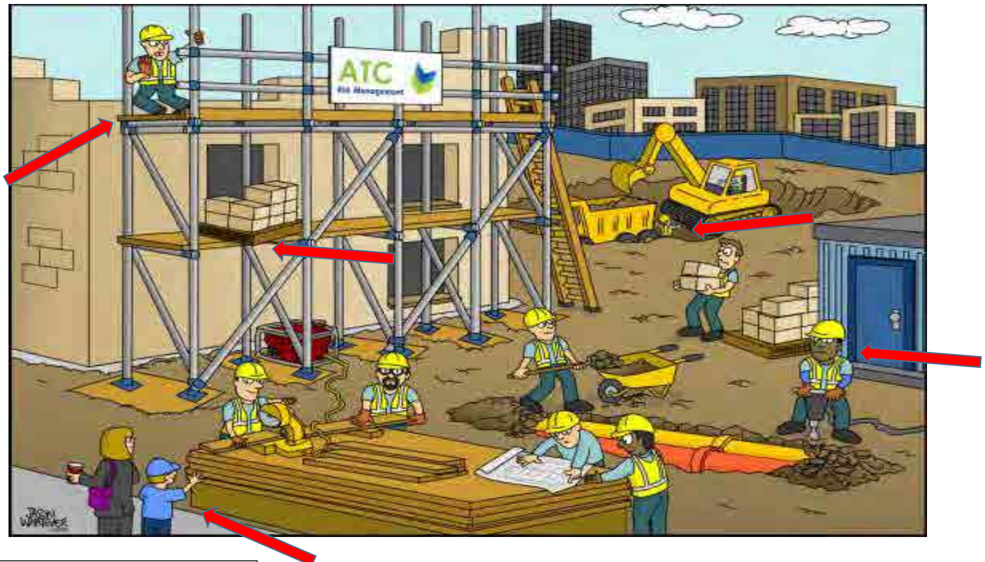


Important Definitions

Hazard	A Hazard is a potential source of harm.
Risk	Risk is the likelihood that a person may be harmed.
Assessment	Identify hazards + Analyze or evaluate risk + Determine methods to control
Prioritization	Evaluating risks and ranking them in their order of severity.

Find out the Hazards in office…

Find out the Hazards at Work Site…



Module-1 **Lecture-1** Risks and Hazards

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Comprehension of Hazard and Risk:

(Video Clip…Duration: 0:2:45)

VIDEO

Module-1 **Lecture-1** Risks and Hazards

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Risk Assessment at WASA Work Sites:

Target	Steps
Determine Risk	1
Decide if the Risk is Tolerable	2
Review the Risk	3
Develop Control Measures	4

Likelihood of Harm	Severity of Harm		
	Slight Harm	Moderate Harm	Extreme Harm
Very unlikely	Very low risk	Very low risk	High risk
Unlikely	Very low risk	Medium risk	Very high risk
Likely	Low risk	High risk	Very high risk
Very likely	Low risk	Very high risk	Very high risk

Actual Hazards Related to Sewers & Drains:

Enlist the hazards for this O&M crew

Manhole De-Silting Operation (Night) near Ferozepur Road, Lahore

Summary:

- **Hazards** are always present **at & around** WASA work sites
- **Risk Assessment** is no doubt utmost **necessary** before commencing O&M works
- O&M Works can be done **safely** if best practices & **Control Measures** are adopted


THANK YOU!

In the name of Allah, the most Gracious and ever Merciful

Safety Control and Measures for Sewerage and Drainage Works

Topic No. 01
Risks and Hazards Associated with Sewers & Drains

Lecture No. 02
Control Measures

Theory

Lecture Breakdown	Duration
Objectives	1 Hour
Important Definitions	
Various Control Measures	
Brainstorming Session	
Summary	
Q&A	

Module-1 Lecture-2 Control Measures

Objectives:

To aware participants about various control measures to be adopted to avoid risks during O&M.

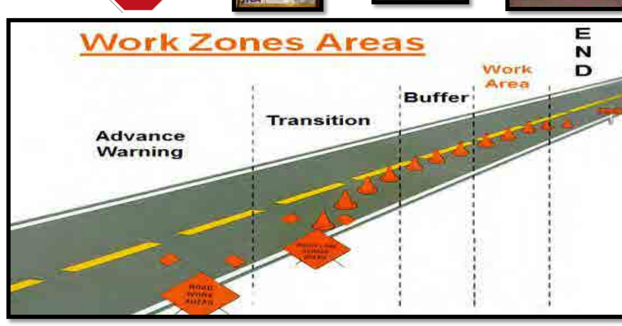
Important Definitions

- **Control Measures** — **Actions that reduce the potential of exposure to hazard**

Elimination	**Remove hazard from the workplace**
Substitution	**Replace hazardous materials or machines with less hazardous ones**
Engineering	**Design modifications to reduce the hazard**
Administration	**Procedure changes, employee training, signs, labels & exercise breaks**
PPE	**Protective clothing, helmets, goggles & equipment etc.**

Control Measures during O&M:

Vehicles



Routing Traffic around Job Site

- ❑ Advance Waring Area
- ❑ Transition Area
- ❑ Buffer Space
- ❑ Work Area
- ❑ Termination Area

Control Measures during O&M:

Confined Space

Atmospheric Hazards:

Explosive	Toxic	Deficiency
Methane - CH_3	Hydrogen Sulfide - H_2S Carbon Monoxide - CO	Oxygen - O_2

Any space where:

- ❑ Existing ventilation is insufficient
- ❑ Oxygen is deficient
- ❑ Access is difficult
- ❑ Getting out is difficult
- ❑ Not designed for permanent dwelling

Control Measures:

- ❑ Use gas detector/monitor
- ❑ Continuous Ventilation
- ❑ Continuous Testing
- ❑ Self Contained Breathing Apparatus (SCBA)

Control Measures during O&M:

Physical Injury

Hazards:

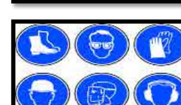
- ❑ Uneven Footing
- ❑ Poor Balance
- ❑ Awkward Position
- ❑ Ladder Drop
- ❑ Weak Manhole Rungs
- ❑ Dropping Tool
- ❑ Sharp Objects

Risks:

- ❑ Strained Muscles
- ❑ Torn Skin
- ❑ Abrasion
- ❑ Swelling
- ❑ Puncture
- ❑ Fracture

Control Measures:

- ❑ Correct Position/Orientation
- ❑ Correct SOP
- ❑ Light Weight Ladder
- ❑ Avoid Tool Drop & Throw/Toss
- ❑ PPE (Helmet + Goggles + Gloves + Safety Shoes)



Control Measures during O&M:

Infections & Diseases

Hazards:

- ❑ Parasite
- ❑ Virus
- ❑ Infection
- ❑ Illness
- ❑ Urine & Feces of Rat

Risks:

- ❑ Fever
- ❑ Headaches
- ❑ Nausea
- ❑ Muscular Pain
- ❑ Tetanus
- ❑ Polio
- ❑ Typhoid

Control Measures:

- ❑ Personal Cleanliness
- ❑ Keep & Wash Cloths Separately
- ❑ No Eating/Drinking at Job Site
- ❑ Disinfect the Manhole
- ❑ Prevent Infectious Discharge Entry
- ❑ PPE (Goggles + Gloves + Wader+ Safety Shoes)

Module-1 Lecture-2 Control Measures

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Control Measures during O&M:

Insects-Bugs-Rodents

Hazards:

- ❑ Black Widow Spider
- ❑ Violin Spider
- ❑ Scorpions
- ❑ Rat
- ❑ Mosquito
- ❑ Cockroaches

Risks:

- ❑ Allergy & Fever
- ❑ Infections
- ❑ Poisoning
- ❑ Rat Bite
- ❑ Rabies
- ❑ Malaria

Control Measures:

- ❑ Spray Insecticide
- ❑ Ventilate Manhole
- ❑ Wash Manhole
- ❑ PPE (Gloves + Wader)
- ❑ Get Medical Attention

Module-1 Lecture-2 Control Measures

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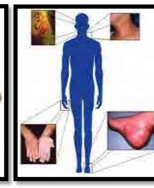
Control Measures during O&M:

Toxicants

Risks:

- ❑ Inhalation
- ❑ Dermal Contact (Absorption)
- ❑ Ingestion
- ❑ Splash



Hazards:

- ❑ Acids
- ❑ Bases
- ❑ Poisons
- ❑ Hazardous Liquids
- ❑ Solid Chemicals

Control Measures:

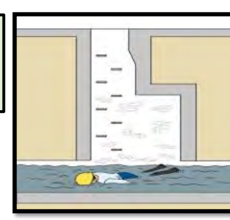
- ❑ Avoid Accidental Spill
- ❑ Avoid Deliberate Action
- ❑ Implement Law
- ❑ PPE (Gloves + Gums)
- ❑ Get Medical Attention

Control Measures during O&M:

DROWNING

Risks:

- ❑ Drowning
- ❑ Injury
- ❑ Death



Hazards:

- ❑ Large Sewage Flow
- ❑ Accidental Slip
- ❑ Fall
- ❑ Uneven Base
- ❑ Weak Eyesight

Control Measures:

- ❑ Watch Your Steps
- ❑ Wear Life Jackets
- ❑ Use Life Line
- ❑ Get Medical Attention

Summary

HAZARDS

Chemicals + Toxic & Explosive Gases + Physical Injury + Insects & Infectious Conditions

CONCLUSION

O&M WORKS AT WASA WORK SITES CAN BE PERFORMED SAFELY WHEN HSE RULES & CORRECT SOPs ARE FOLLOWED

Questions & Answer Session:

Q. 01:
How can you protect yourself from diseases when working at **WASA** work sites?

Q. 02:
How can you protect yourself from **insects** when working in a **manhole**?

Q. 03:
How can you protect yourself from **drowning** when working in a **manhole**?

In the name of Allah, the most Gracious and ever Merciful

Module 01

Safety Control and Measures for Sewerage and Drainage Works

Topic No. 02
Risks and Hazards Associated with Sewers & Drains

Lecture No. 03
Current Safety Practices in WASA

OJT

Lecture Breakdown	Duration
OJT	0.5 Hour
OJT Cycle for WASA Site	
OJT Success at WASA Site	
Current Safety Practices in WASA	
Pictorial…	
Q&A	

OJT…Dates Back

Module-1 Lecture-3 Current Safety Practices in WASA

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On-the-Job (OJT) Training:

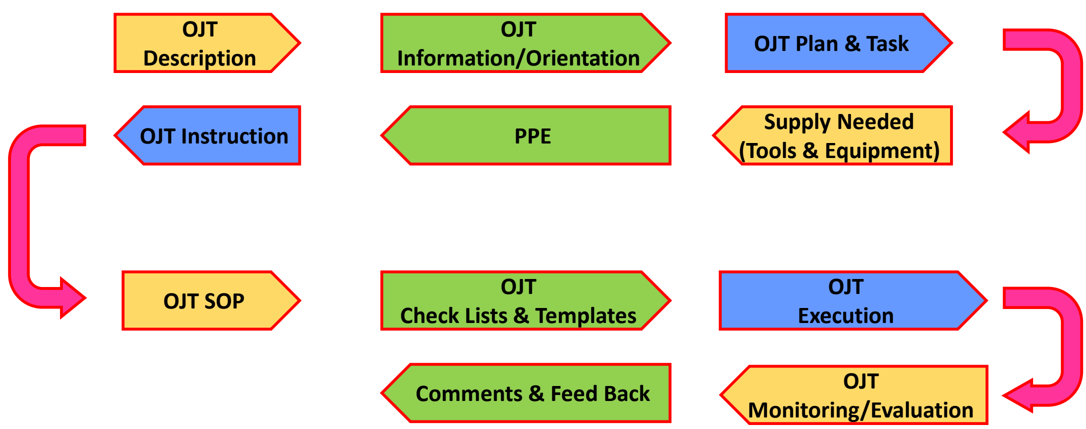
1	Training where the **"Trainer" instructs the new "Trainees"** on the skills needed to perform his/her new job effectively
2	Either the **Trainee performs the job** while the Trainer instructs **Or**
3	The **Trainer performs the job** while the Trainee observes.
4	On-the-Job training should take place mostly in the **field**; however, some **classroom** training is also permissible.

On-the-Job (OJT) Training:

'Training at a site away from the actual work environment' (00:00:42)

VIDEO

OJT Cycle



OJT Success

1) Understand the need of OJT
2) Comprehend the aim & plan
3) Read through the templates (for filling in the observations during OJT)
4) Travel towards WASA work site
5) Get the orientation
6) Wear the requisite PPE
7) Chose safe position for observation
8) Remain as close to the normal working position as possible
9) Follow the directions of Trainer
10) While performing OJT keep in mind the WASA policies and local rules
11) Use the accompanying equipment & tools with care
12) Fill in the templates with accurate data
13) Write a concise report after return

IMPORTANT: TRAINER WILL EVALUATE THE TRAINEES' PERFORMANCE DURING OJT

Example

OJT Description
- ❑ Current Safety Practices in WASA

OJT Plan & Task
- ❑ To visit various WASA work sites where O&M works are in progress
- ❑ To observe that up to which level the HSE standards are being adopted during O&M works

OJT Information
- ❑ De-silting & Cleaning operation at a Manhole affected by Chronical Blockages WASA Lahore (Green Town Sub-Division)

Supply Needed
- ❑ HSE related check lists

PPE




Current Safety Practices in WASA

				Outcomes
Hazard Identification	→	Yes/No	→	Likelihood of Injuries & Casualties
Risk Assessment	→	Yes/No	→	Staff & Machines prone to losses
Control Measures	→	Yes/No	→	Injuries & Casualties
Personnel Protective Equipment (PPE)	→	Yes/No	→	Injuries & Casualties
Record & Evaluation	→	yes/No	→	System never improves

Current Safety Practices in WASA

- Current Safety Practices in WASA

		Outcomes
Traffic De-route during O&M Works →	Yes/No →	Accidents
Confined Space Policy →	Yes/No →	Deaths

Current Practices vs Best Practices (Pictorial)

Questions & Answer Session:

Q. 01:
How you assess the implementation of HSE rules in **WASA** during various O&M jobs?

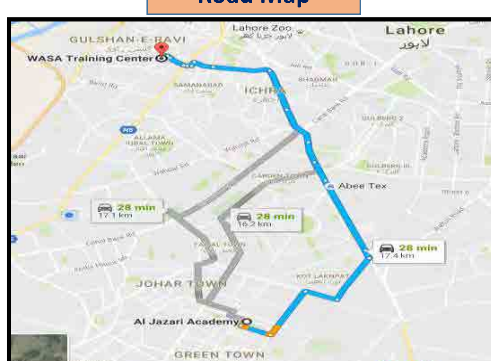
Q. 02:
What are the reasons behind non-implementation of HSE practices at WASA work sites?

Q. 03:
What are your suggestions to improve & implement the HSE policies during O&M jobs?

Field Visit

WASA Training Directorate
Gulshan-e-Ravi
LAHORE

Road Map

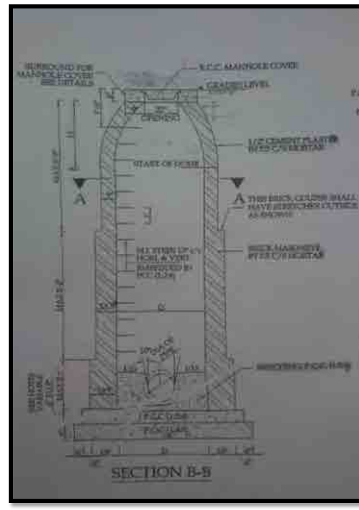


17 Km – 30 Min.

OBJECTIVE:
- To observe training facilities & infrastructure at the directorate
- Preparation of visit report on return

Remember: PPE are necessary

Field Visit to Gulshan-e-Ravi WASA Training Directorate



Manhole Structural Details

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Field Visit to Gulshan-e-Ravi WASA Training Directorate

Trunk Sewers

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In the name of Allah, the most Gracious and ever Merciful

Module 01

Safety Control and Measures for Sewerage and Drainage Works

Topic No. 03
Use of safety gears during operation & maintenance of sewerage & drainage system

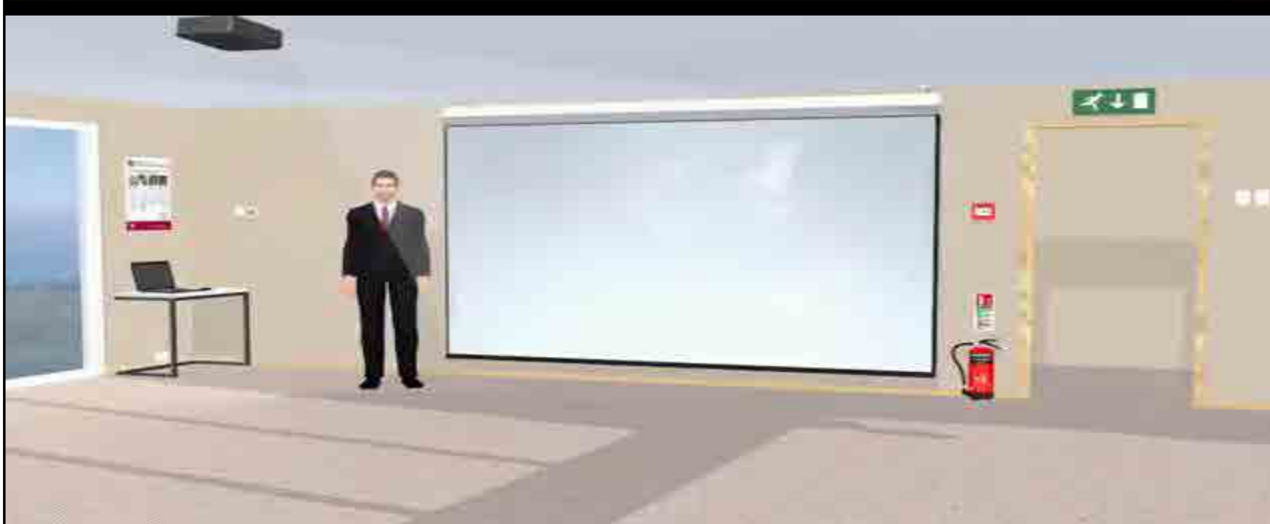
Lecture No. 04
Concept of Personal Protective Equipment (PPE)

Theory

Lecture Breakdown	Duration
Purpose of PPE	1.0 Hour
Selection of PPE	
PPE in Details	
Care & Maintenance	
Q&A	

PPE	**Protective clothing, helmets, goggles, or other garments or equipment designed to protect the wearer's body from injury or infection.**
Purpose of PPE	**When controlling measures e.g. elimination, engineering, work practice and administrative controls do not provide sufficient protection against the HAZARDS & RISKS, personal protective equipment (PPE) must be used as a last resort.**
Selection of PPE	**The selection of appropriate PPE is based upon the hazard assessment and many other factors.**
Care & Maintenance	**Clean and properly maintained PPE is important to ensure the effectiveness and proper functioning of PPE and to prevent transmitting infections.**
	

PPE (00:03:03)



PPE Selection Criteria

Identify the Potential Hazards

Impact + Penetration + Compression + Chemical + Heat/Cold + Harmful Dust + Light + Radiation

Determine the Types of Protective Equipment Available for the Present Hazards

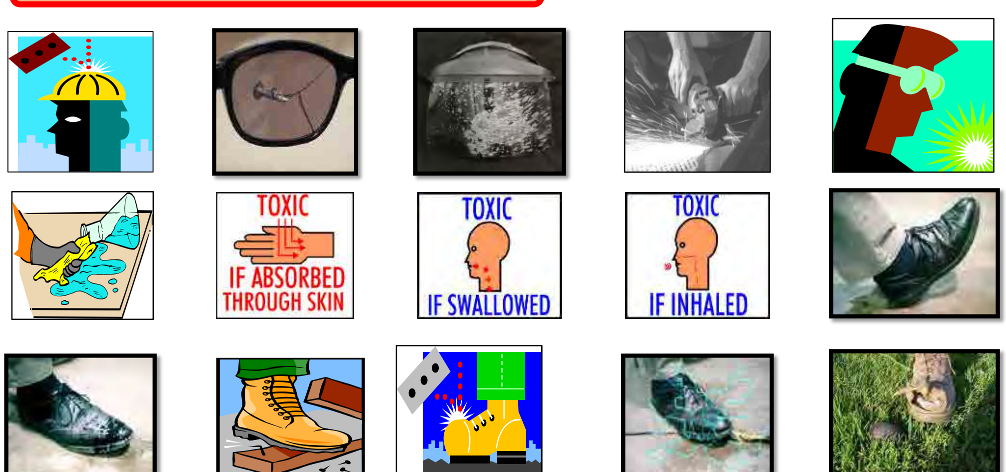
Evaluate the Effectiveness of the PPE

Select Appropriate Protective Equipment

Provide a Variety of Sizes to Properly Fit all Users

Select Equipment that is Compatible with other PPE

VARIOUS HAZARDS AT WORK SITE



PPE Selection Criteria

- Ease of Use
- Comfort
- Fit to Wearer
- Weight
- Mobility
- Unit Cost
- Sizes Available
- Cleaning
- Launder ability
- Visibility
- Training Requirements
- Environmental Conditions
- Duration of Protection
- Conform to Standards

REMEMBER : PPE IS LAST LINE OF DEFENCE AGAINST ACCIDENTS & INJURIES

PPE EXAMPLES

Chemical & Splashing Liquid	
Eyes	Goggles Face Shield
Head + Neck + Face	Hood Face Shield Masks
Feet + Toes	Slip-Resistant Shoes
Hands	Butyl Rubber Neoprene Gloves
Body: Arms + Legs	Chemical/Liquid Resistant Clothing

Heat	
Eyes	Goggles
Head + Neck + Face	Helmet Cap
Feet + Toes	Leather Shoes
Hands	Cotton Gloves
Body: Arms + Legs	Flame Resistant Clothing

PPE EXAMPLES

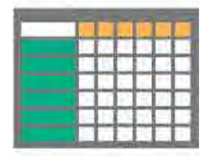
Dust/Flying Debris		Impact/Compression	
Eyes	Goggles	Eyes	Goggles Face Shields
Head + Neck + Face	Face Shield Dust Mask Helmet	Head + Neck + Face	Class G, E, or C Helmet
Feet + Toes	Safety Shoes	Feet + Toes	Hard Toed Shoes
Hands	Appropriate Gloves	Hands	Metal Mesh Gloves
Body: Arms + Legs	Protective Clothing	Body: Arms + Legs	Leather Clothing

PPE EXAMPLES

Electrical Hazards		Puncture/Cuts/Abrasions	
Eyes	Goggles	Eyes	Goggles
Head + Neck + Face	Helmet Class E	Head + Neck + Face	Face Shield
Feet + Toes	Electrical Hazard Footwear	Feet + Toes	Puncture Resistant Sole Shoes
Hands	Rubber Gloves and Insulating Sleeves	Hands	Metal Mesh Gloves
Body: Arms + Legs	Garment from Synthetic Clothing	Body: Arms + Legs	Clothing made of Cotton or Leather

PPE SELECTION ON THE BASIS OF HAZARD ASSESSMENT

Work Site: ___________________
Sub-Division:_________________
Foreman: ____________________
Date: ________________________



SR. NO.	JOB	HAZARDS	PPE REQUIRED

Employees Training in PPE Use

Employers are required to train each employee who must use PPE

- **When PPE is necessary?**
- **How to properly put on, take off, adjust and wear the PPE?**
- **The limitations of the PPE**
- **Proper Care, Maintenance, Useful Life and Safe Disposal of PPE**

PPE Care & Maintenance

Clean and Properly Maintained PPE is Important to Ensure the Effectiveness of PPE

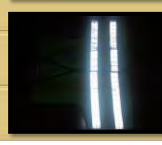
Care & Maintenance Includes….

Cleaning of PPE + Storage of PPE + Examination + Testing

Repair + Replacement of Worn Components + Safe Disposal





PPE Care & Maintenance

Helmet	Clean hard hats regularly Store head protection out of the sun Check the headband Replace a hard hat if it is cracked or dented	
Goggles	Clean safety glasses and goggles regularly Store eye protection preferably in a clean dust-proof case Replace safety glasses if frames are bent	
Respirators	Clean and disinfect Check for holes & cracks Store in a safe location which is protected from dust	
Gloves	Keep gloves clean and dry Have a backup pair in case gloves get wet Replace worn or damaged gloves right away	
Safety Shoes	Wipe wet or soiled shoes with a clean cloth Have worn or damaged shoes repaired, or replace them	


THANK YOU!

In the name of Allah, the most Gracious and ever Merciful

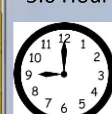
Module 01

Safety Control and Measures for Sewerage and Drainage Works

Topic No. 04
Standard Safety Practices during Sewer and Manhole Operations

Lecture No. 05
Working in Confined Space

OJT

Lecture Breakdown	Duration
Safety Equipment & Procedures	5.0 Hour
Precautions before Manhole Entry	
Procedure during Manhole Entry	
While Operator is in Manhole	
Special Problems relates with Manhole O&M	
After Leaving the Manhole	
Q&A	

Manhole – A Confined Space

FOLLOW SAFE PRACTICES

USE GOOD JUDGMENT AT ALL TIMES

…WHILE WORKING IN MANHOLES…

Safety Equipment & Procedures

Self-Contained Breathing Apparatus (SCBA)		**Ventilation Blower with Hose**	
Tripod		**Manhole Enclosure**	
Portable Atmospheric Alarm Unit (Gas Monitor)		**Safety Harness with Lifeline**	

Safety Equipment & Procedures

Winch

Hard Hats (Safety Helmet) with Removable Torch

Ladders

Protective Clothing

Ropes & Buckets

Cones + Barricades + High-Level Flags

Safety Equipment & Procedures

First Aid Kit

Clean Clothes

Fresh Water

RESCUE NO. 1122

Soap

Accident during Manhole Operation (00:04:52)

Module-1 Lecture-5 Working in Confined Space

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Precautions before Manhole Entry

Health Conditions of Operator: ✓ Be in good health ✓ Be in sound physical condition ✓ Be free from alcohol or drugs	
Required Tools + Materials + Equipment: ✓ Examine the condition of all required tools ✓ Arrange tools & equip. so that work must be accomplished with single entry & exit	
Foreman or Crew Leader should Hold Briefing ✓ To explain about HSE rules ✓ To explain the work sequence ✓ To explain SOP	

Module-1 Lecture-5 Working in Confined Space

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Manhole Entry Form

Date: **Structure Entering:** **Location:** **Person Entering:** **Supervisor:**		
	Not Applicable	**Complete**
1. Unit Pumped Out		
2. Unit Ventilated		
3. Explosive Vapors Less Than 20% Of LEL		
4. Oxygen Content 19.5% Minimum		
5. H_2S Less Than 10 Ppm		
6. PPE and Rescue Devices		
a. Harness on Person Entering		
b. Lifeline Attached to Harness		
c. SCBA on Employee Entering		
7. Emergency Procedure Explained and Understood		
Send Original To Supervisor **Send Copy To Safety Officer**		

Procedure during Manhole Entry

Following procedure shall be adhered to:

- ❑ **A confined space entry form shall be used to review the necessary precautions**
- ❑ **All traffic control measures shall be taken**
- ❑ **All valves or power sources shall be locked out**
- ❑ **An initial test of the atmosphere must be performed**
- ❑ **All persons who enter a confined space shall be instructed about hazards**
- ❑ **All persons entering a confined space shall wear a rescue harness with attached lifeline**
- ❑ **No smoking shall be permitted inside or within ten feet (1O ft.) of a confined space**
- ❑ **At least one person shall remain outside the confined space while it is occupied**
- ❑ **Atmospheric testing shall continue while the confined space is occupied**
- ❑ **All persons in a confined space shall vacate immediately if the warning alarm is activated**
- ❑ **A hard hat shall be worn at all times in a confined space**

Operation of Manhole Entry

Following procedure shall be adhered to:

- **Place the manhole safety enclosure around the manhole**
- **Calibrate the portable atmospheric monitor BEFORE removing the manhole cover**
- **Test the manhole from top to bottom for oxygen deficiency, explosive and toxic (hydrogen sulfide) gases**
- **Never use hands to remove the manhole cover**
- **Open manholes upstream and downstream from the work area**
- **Sweep the area before removing the manhole cover**
- **Before entering the manhole start the ventilation blower**
- **Once the operator going into the hole confirm safety harness and lifeline is attached**
- **Continue to use the atmospheric monitoring system**

While Operator is in Manhole

Following procedure shall be adhered to:

- **The end of the lifeline must be secured outside of the confined space**
- **Whenever an operator is in a manhole continuously test the atmosphere**
- **The operator in the manhole must be observed continuously**
- **If there are any indications of trouble immediately remove the operator**

Special Problems of Manhole Work

Following problems may occur during working in manhole:

- ❑ Sharp odor or prolonged breathing of an odorous atmosphere will cause the sense of smell to be temporarily lost
- ❑ NEVER allow anyone to enter a manhole until the oxygen content tests greater than 19.5 percent oxygen
- ❑ Victims suffering from a lack of oxygen may require artificial respiration if the case is severe

Module-1 Lecture-5 Working in Confined Space

13/17

After Leaving the Manhole

Following steps should be taken after operation inside manhole:

1. Take hot shower.
2. Put on clean clothes.
3. Don’t wear the clothing worn in manhole, at home.
4. Never expose your family to any object which was in contact with your clothing.
5. No clothing should be washed with the family laundry.

Module-1 Lecture-5 Working in Confined Space

14/17


THANK YOU!

In the name of Allah, the most Gracious and ever Merciful

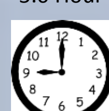
Module 01

Safety Control and Measures for Sewerage and Drainage Works

Topic No. 04
Standard Safety Practices during Sewer and Manhole Operations

Lecture No. 06
Test for Hazardous Gases

OJT

Lecture Breakdown	Duration
Various Gas Monitors	5.0 Hour 
Purpose of Use	
Portable Gas Monitor GX-8000	
Names & Functions for Each Part	
Start the Gas Monitor	
LCD Display, Features & Cautions	
Q&A	

Gas Monitoring at Manhole

Various Gas Monitors

Purpose of Use

Gas monitor enables simultaneous monitoring of the following four types of gases in <u>Manholes</u>:

1- Oxygen O_2

2- Methane CH_4 } COMBUSTIBLE GAS

3- Carbon Monoxide CO

4- Hydrogen Sulfide H_2S } TOXIC GASES

Al-Jazari Apparatus

Portable Gas Monitor
GX-8000

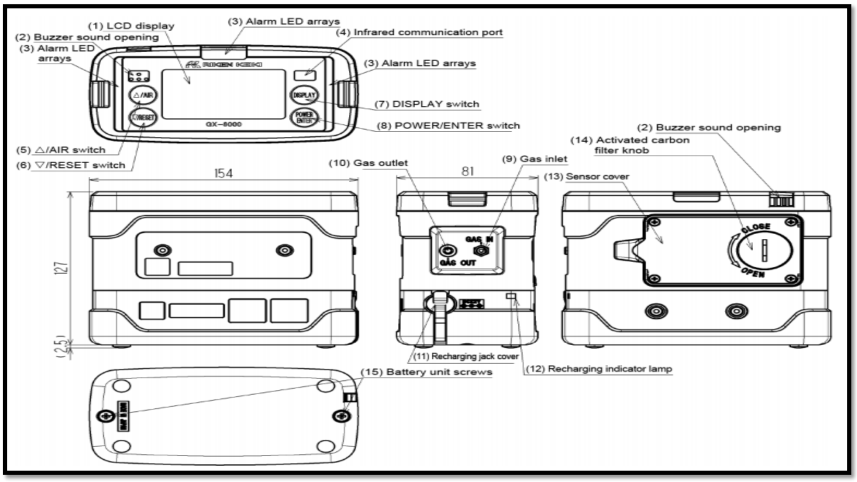
Make:
RIKEN KEIKI Co. Ltd Tokyo Japan

Accessories:

1. **Li-ion battery unit**
2. **AC powered charger**
3. **Shoulder strap**
4. **Gas sampling probe**

Portable Gas Monitor GX-8000 - Accessories

Names & Functions for Each Part (Various Views)



Starting 'Gas Monitor'

1

<<Start-up Procedure>>

Keep the POWER switch pressed for three seconds or more.

↓

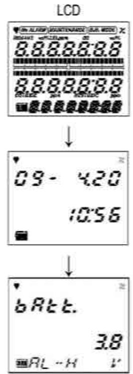
All LCDs light up.

LCD

Alarm lamp lights up.
Buzzer sounds once. (Beep)

Date/Time Display

Battery Voltage Display



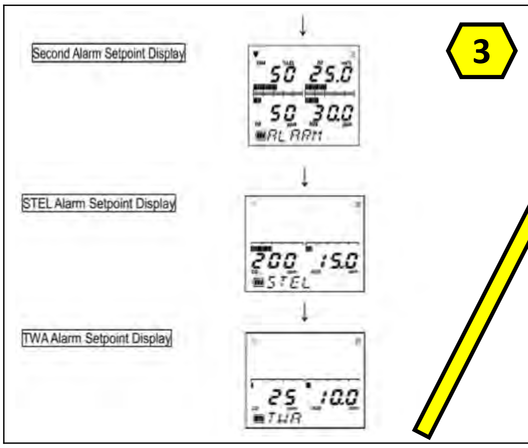
2

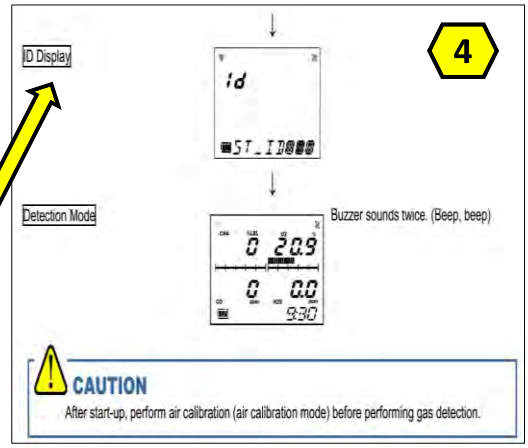
Gas Name Display

Full Scale Display

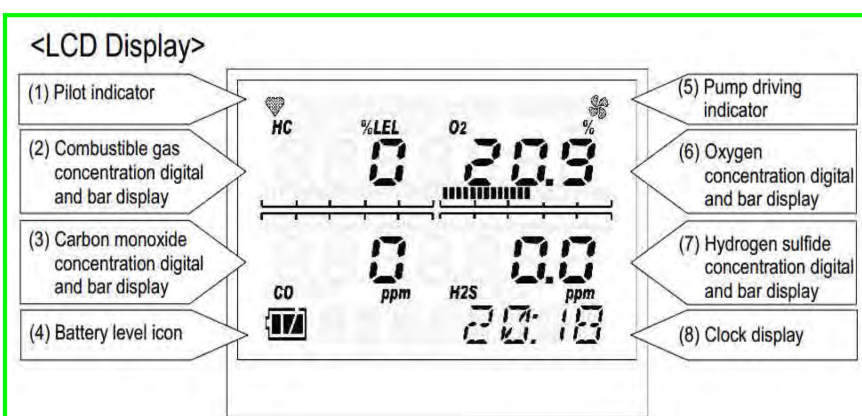
First Alarm Setpoint Display

Starting 'Gas Monitor'





LCD Display

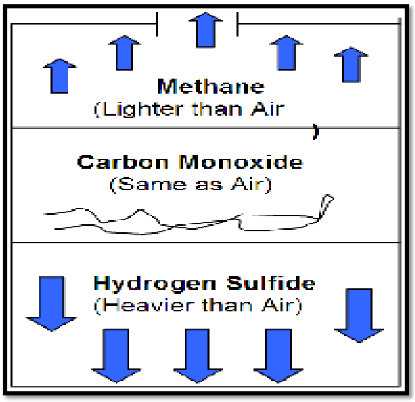


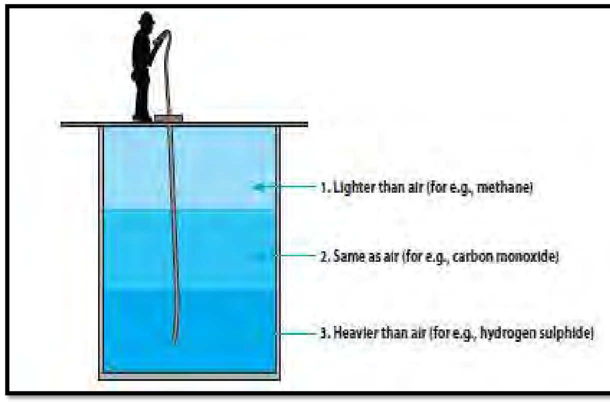
Features of Portable Gas Monitor GX-8000

- ❑ Portable and battery operated
- ❑ Continuously and simultaneously monitor for toxic and flammable gases
- ❑ Audible and visible **ALARMS**
- ❑ Small enough and light enough to be worn by an operator
- ❑ Over 10 hours of continuous operation on one full battery charge
- ❑ Automatic audible and visible low battery alarm
- ❑ Remote sample hose

Basic Functions & Operation (5:23)

Physical Appearance of Gases in Manhole





Cautions regarding Gas Monitor

- ❑ Do not drop or give shock to the gas monitor.
- ❑ Pressing buttons unnecessarily may change the settings.
- ❑ Do not use the gas monitor in a place where the temperature drops below -20ºC or rises over 50ºC.
- ❑ Do not use the gas monitor where it is exposed to oil, chemicals, etc.
- ❑ Verify that the pump driving indicator is rotating before using the gas monitor.
- ❑ Do not forget to perform a regular maintenance.


Thank You!!!

In the name of Allah, the most Gracious and ever Merciful

Module 01

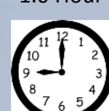
Safety Control and Measures for Sewerage and Drainage Works

Topic No. 05
First Aid in Emergency Situations

Lecture No. 07
Arrangements for Medical Treatment

Theory (Visual Aids)

Lecture Breakdown	Duration
Objectives	1.0 Hour
Purpose of First Aid	
Phases of First Aid	
First Aid Rules	
Various Emergencies around Job Site	
Q&A	



Objectives

The objective of this lecture is to improve capacity of participants to render first aid in emergency situations

FIRST AID :
First aid is the assistance given to any person suffering a sudden illness or injury, with care provided to preserve life, prevent the condition from worsening, and/or promote recovery.

Purposes of First Aid

1. Prevent further injury
2. Preserve life
3. Promote recovery

Phases of First Aid

1. Self-aid
2. Assistance from a companion
3. Emergency treatment
4. Initial surgery

First Aid Rules

1. Do not get excited
2. Do not move injured victim unless it is necessary
3. Keep the victim lying down
4. Keep the victim warm and comfortable
5. Examined the victim gently
6. Avoid allowing the victim to see his own injury
7. Do not try to give any solid or liquid substance by mouth
8. Do not touch open wounds or burns with fingers or other objects
9. Seek medical attention immediately

Various Emergencies around Job Site

Respiratory Emergency

Wound/Cut

Drowning

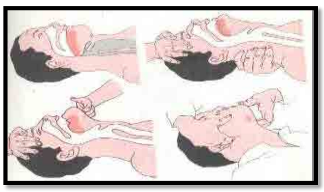
Burns

Poison /Snake Bite

Fire Accidents

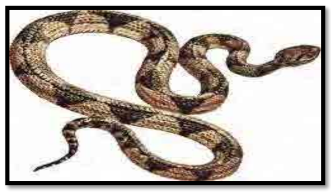
Respiratory Emergency

- ❑ Common Causes
- ❑ Signs & Symptoms
- ❑ First Aid Measures



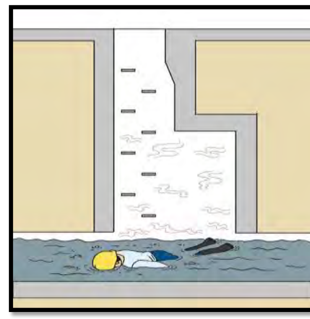
Snake Bite

- ❑ Signs & Symptoms
- ❑ First Aid Measures



Drowning

- ❑ First Aid Measures



Wound

- ❑ Common Causes
- ❑ First Aid Measures

Burns

- ❑ First Aid Measures

Fire Accidents

- ❑ Fire & Causes
- ❑ Fire Suppression
- ❑ Fire Extinguisher


Thank
You!!!

In the name of Allah, the most Gracious and ever Merciful

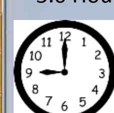
Module 01

Safety Control and Measures for Sewerage and Drainage Works

Topic No. 06
Traffic Control Practice during Sewer and Manhole Cleaning Operations

Lecture No. 08
Identification of a Specific Manhole

OJT

Lecture Breakdown	Duration
Objectives	5.0 Hour
Reasons for Identifying a Specific Manhole	
Early Metal Locator	
Manhole Cover Locator	
Parts with Labels	
Working Principle	

Objectives

The objectives of this lecture are:

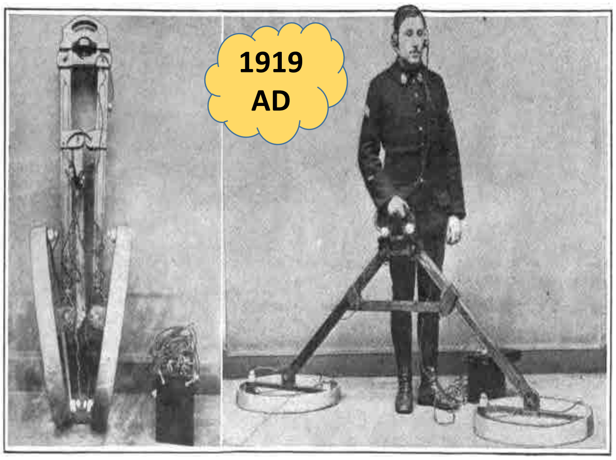
- To understand the need of locating a buried manhole
- To comprehend the working principle of metal locator device
- To identify the **buried manhole** with the help of metal locator

Reasons for Identifying a Specific Manhole

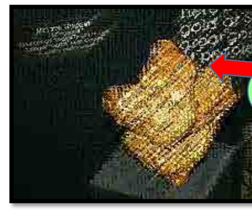
The reasons are:

- To conduct an inspection survey against the sewer system related complaint
- To initiate operation and maintenance work at the rightly identified manhole for redressing the complaint received

Early Metal Locator



1919 AD



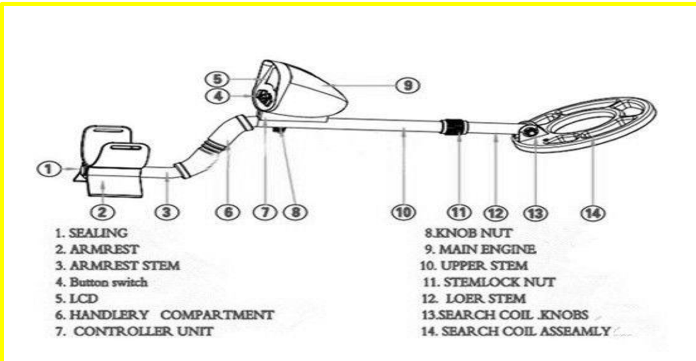
4.9 Kg Gold Found in California

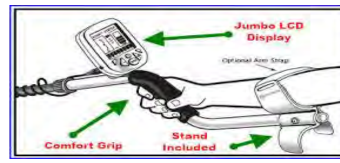
Manhole Cover Locator

Al-Jazari Apparatus

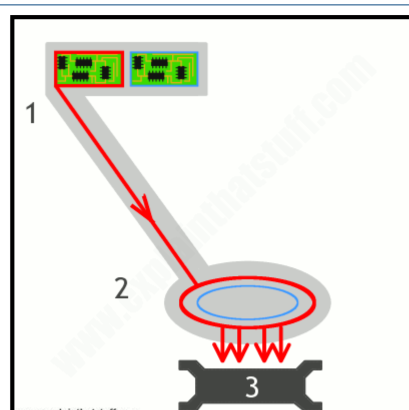
(Donated by: JICA)

Manhole Cover Locator (Parts with Labels)





Working Principle of Manhole Cover Locator (Al-Jazari Apparatus)



Working Principle of Manhole Cover Detector

1. A battery in the top of the metal detector activates the **transmitter circuit** (red) that passes electricity to the **transmitter coil**
2. When electricity flows through the transmitter coil, it creates a **magnetic field** all around it.
3. If you sweep the detector above a **metal object** electric current flow inside the metal object.
4. This flowing electric current creates a loudspeaker buzz and alerting you you've found something.

Locating a Lost / Buried Manhole Cover (00:01:06)

In the name of Allah, the most Gracious and ever Merciful

Module 01

Safety Control and Measures for Sewerage and Drainage Works

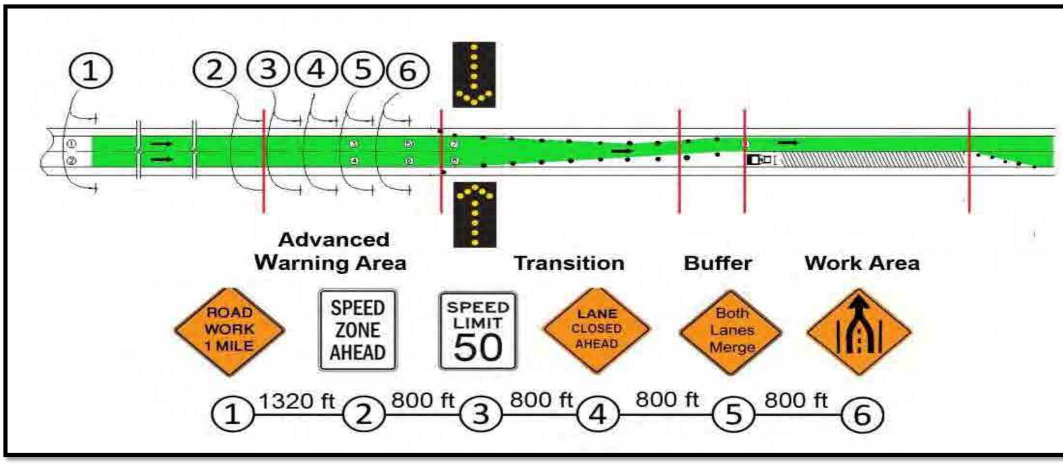
Topic No. 06
Traffic Control Practice during Sewer and Manhole Cleaning Operations

Lecture No. 09
Traffic Control Plan

OJT

Lecture Breakdown	Duration
Objectives	5.0 Hour
General Conditions	
Traffic Control Criteria	
Areas of Traffic Control	
Traffic Control Devices	
Q&A	

Traffic Routing Layout



Objectives of Routing Traffic Around Job Site

<u>To Create a Safe zone for WASA Staff + Machinary + Tools & Equipment :</u>

Who are busy at or near the roads in operation and maintenance works e.g.

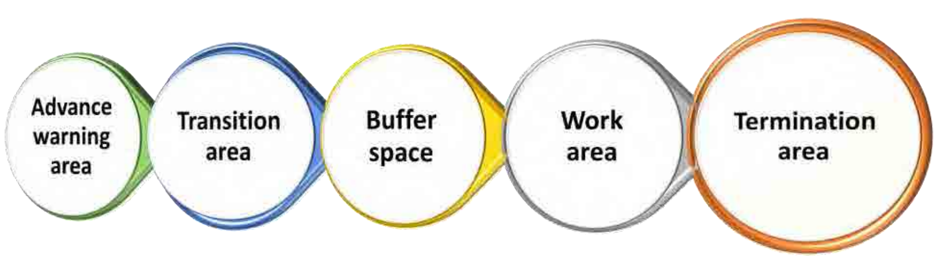
- ✓ Manhole de-silting,
- ✓ Drain dredging,
- ✓ Replacement of sewer pipe

Routing Traffic Criteria

Answers to several questions will determine traffic control criteria around the WASA work site:

- Is traffic moving at a low speed (0-60 Km/Hr.) or a high speed (60-90 Km/Hr.)?
- Is the road two-lane, one-way or two-way?
- Is it undivided four-lane?
- Is it multi-lane one-way?
- Are pedestrian walkways affected?
- Is it in a residential area?
- Will a lane closure be required?
- Will more than one lane be closed?
- Will traffic control be required during peak traffic periods or at night?

Areas of Traffic Control



1 - Advance Warning Area

- The purpose of this area is to **alert drivers** to activity ahead.
- Allow them enough time to alter their driving patterns prior to reaching the work area.

2 – Transition Area

- **Traffic is channeled** from the normal traffic lane to the path required to move it around the work area

3 – Buffer Space

- This zone provides an **additional margin** of safety for both traffic and working operators

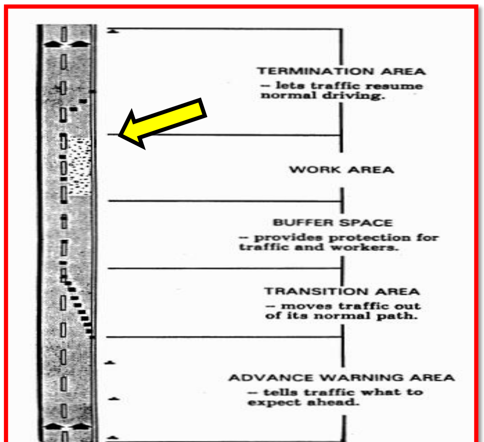
4 – Work Area

- Work area is that portion of the road which contains the **work activity** and equipment, is closed to the traffic

5 – Termination Area

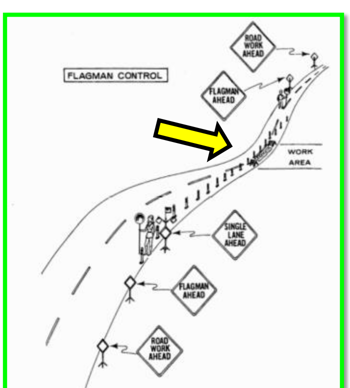
- This area provides a short distance for traffic to **get clear of the work area** and to return to the normal traffic lanes

Pictorial Views of Traffic Routing

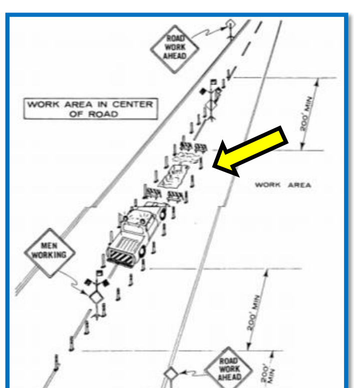


General Layout

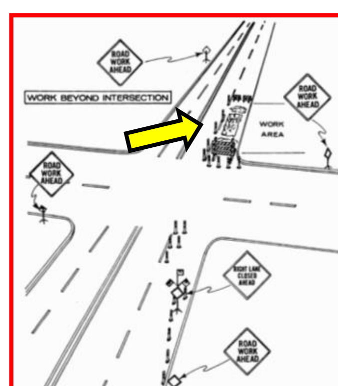
Pictorial Views of Traffic Routing



Flagman Control

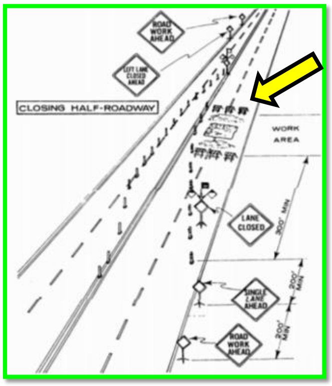


Work Area in Center of Road

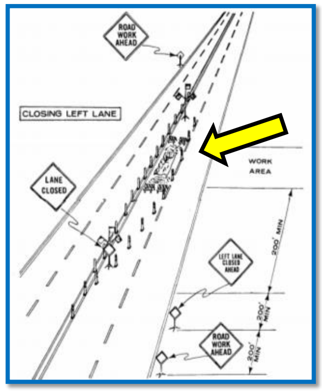


Work Beyond Intersection

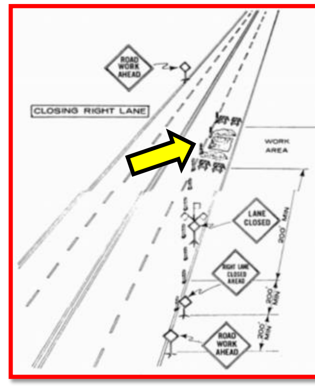
Pictorial Views of Traffic Routing



Closing Half-Roadway



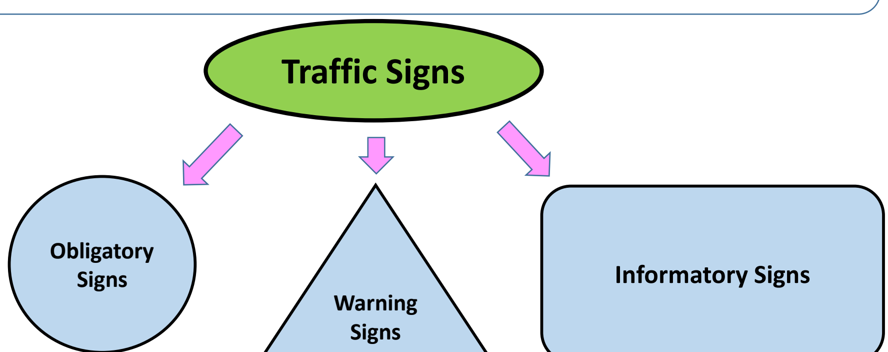
Closing Left Lane



Closing Right Lane

Traffic Control Devices

Traffic control devices are <u>**markers**, **signs** and **signal devices**</u> used to inform, guide and control traffic, including pedestrians, motor vehicle drivers and bicyclists



Traffic Control Devices

Questions & Answer Session:

Q. 01:
Who should be **contacted** before setting up a work site at a Road?

Q. 02:
How can **traffic be warned** of your presence at a road?

Q. 03:
How can motorists be **safely routed** around a job site?

O&M of Drainage System

O&M of Drainage System

- Components
- O&M Objectives

Strategy for Improvement

- Sensitizing Senior Decision Makers
- Assessing the Existing Facilities
- Identification of Factors affecting Quality of Maintenance
- Snags in Management
- Immediate Action Plan
- Long term Action Plan

Course

Operation and Maintenance (O&M) of Sewer & Storm Water Drainage System including Safety Precautions

Module 2

O&M of Storm Water Drainage System

Lecture 1

Need for O & M of Storm Water Drainage System

Lecture Contents

1. Storm Water Drainage System and its Components
2. Current Issues
3. Sediment Deposition
4. Need for O&M
5. Maintenance of Drains

Storm Water Drainage System

- Receives runoff from inlets and conveys the runoff to some point where it is then discharged into a channel, water body, or piped system

- It may be a
  - closed-conduit
  - Open channel

- "Storm sewer" replaced with the term "storm drain" to differentiate between sanitary sewers and storm drains

Culvert

- A drainage pipe used to convey a stream through a road or embankment
- It may carry a stream for a long distance underground to a surface discharge location
- Short in length and open at both ends and often must withstand substantial traffic loads

Module-2 Lecture-1

Ditch

- Ditches are constructed to convey water from storm runoff to an adequate outlet.
- A good ditch is shaped and lined and does not cause flooding, erosion, or sedimentation.

Gutter

- That portion of the roadway section adjacent to the curb which is utilized to convey storm water runoff.

Module-2 Lecture-1

Drop Inlet

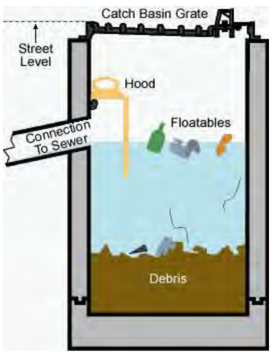
A location where storm water runoff from an open area enters the storm drain system.

Drop inlets are usually part of the public drainage system, but can sometimes be considered private.

Catch Basin

A structure in the form of a chamber which is provided along with the sewer line to admit clear rain Water free from silt, grit, debris, etc, into the combined sewer

Allows rainwater runoff to be safely collected to prevent road and property flooding



Critical Issues

Encroachment of drains

Silting of drains due to constant blockages

Stability of drainage cross-sections dislocated and damaged old lining of the drains

Critical Issues

- Unpleasant odor of dirty water flowing in the drains
- Absence of comprehensive data on storm-water drainage network
- Inadequate attention to cleaning of natural drains and clearance of excess floral growth on the drains
- Free access to dispose wastewater from nearby habitation

Sediment Deposition & Related Issues

Due to the sediment deposition the problems occurred in the **open channel** includes:

- ❑ Encourages prolific weed growth
- ❑ Cause flooding of various degrees of magnitude
- ❑ Ponding of water creates breeding grounds for some disease causing agents
- ❑ Silted roadside drains produce ponding on roads

Sediment Deposition & Related Issues

In the case of **buried or completely covered** storm channels, problems occurred are:

- ❑ Silting + Weed Growth + Bushes
- ❑ Release & accumulation of gases (that can be highly corrosive to the channel material)

Need for Maintenance

Lack of regular maintenance cause the accumulation of the sediment and garbage in the drain

Extensive, regular sediment removal is a difficult and expensive process

Routine inspection and preventive maintenance are the best ways to prevent blockages and deterioration of drains

O&M of Drainage System

Departments should devise maintenance procedures including:

- Frequency of inspection
- Programme for dredging
- Necessary repair works
- Documentation for maintenance records

In the name of Allah, the most Gracious and ever Merciful

Course

Operation and Maintenance of Sewer & Storm Water Drainage System including Safety Practices

Module 2

Operation and Maintenance of Storm Water Drainage System

Lecture 2

Measurement of Sludge Quantity in Drains

Lecture Details

Class Work
Field Work

Documents
Equipment & Tools
PPE

- Presentation + Discussion on Current Practices
- Estimation of Deposited Sludge
  (at Maulana Shaukat Ali Drain, Akbar Chowk, Township)
- Drain map of area + Templates

- Ranging Rod + Aluminum Staff + Distance Meter+ Road Signs + Traffic Cones etc.
- Helmet + Goggles + Hand Gloves + Safety Shoes + Gum Boots







Lecture Contents

- Need of Measurement of Sludge Quantity in Drains
- Equipment
- Procedure
- Sludge Volume Calculations
- Observations

Need for Measurement of Sludge Quantity in Drains

- To prevent excessive sediment built-up
- No standard method of measuring the sediment build-up
- A regular monitoring programme and measurement tools will ensure that the depth of accumulated sludge is accurately measured
- Inconsistent and inaccurate readings of sediment accumulation could result in too frequent maintenance

Equipment

1- Staff with Disc

- Consists of a rod with a flat disc (welded to its base)
- The depth of sludge is measured off the graduations on the rod
- This will then be used to find the actual sediment depth

Advantages

- Portable and cheap
- Need minor maintenance
- Can be used in any type of drain

2- Ranging Rod

- Ranging Rod (6 feet Height)
- Colour Coded
- Each Segment is 01 Foot Long
- Metal Conical Tip for Penetration in Sludge

3-Distance Meter (Surveyor's Wheel) & Use

Step 01

Before Measurement (Reading 0-0)

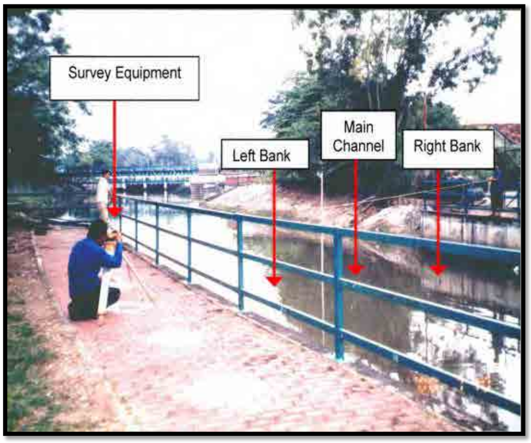
Lo = 119 m

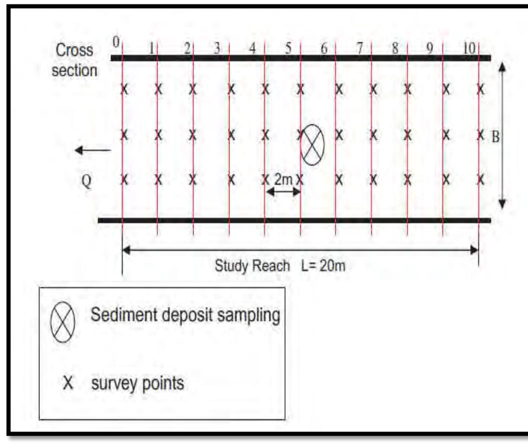
Step 02

Li = 115 m

Step 03

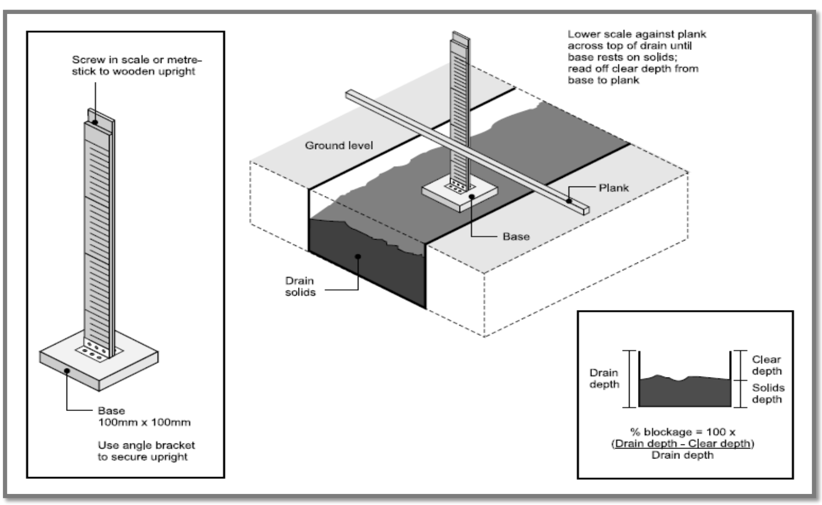
Layout





Module-2 Lecture-2 (Measurement of Sludge Quantity in Drains)

More Sketches



Module-2 Lecture-2 (Measurement of Sludge Quantity in Drains)

Sludge Measuring Procedure

1. First **select the venue** where you have to do dredging or sediment thickness measurement
2. Select some **culvert or bridge**
3. Properly apply **traffic control plan**
4. Ensure that each worker has worn the proper **safety gadgets**
5. Find out the **dimensions** of the drain i.e. Length Width and Depth
6. **Mark** the stations on the drain

Sludge Measuring Procedure

7. Two persons at both banks of the drain are required
8. **Find the depth** by using staff having graduations on it
9. Find out the **capacity of dump truck** for transporting sludge
10. **Calculate the number of trips** by dumper from dredging to disposal site
11. Also calculate the **time required by the dumper per trip** and total time for overall operation
12. If the **cleaning along the road** is required because of spillage of waste then clean that

Road Map for Field Work

Road Map for Sludge Measurement Site

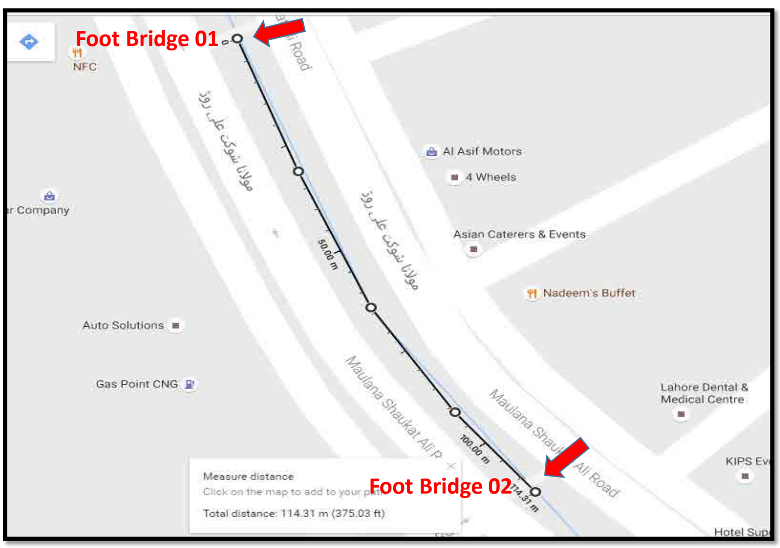
Maulana Shaukat Ali Road (Near Shauk Chowk)

Distance: 4.0 Km
Travel Time: 10 Min.

Module-2 Lecture-2 (Measurement of Sludge Quantity in Drains)

13/19

Layout Map of Drain Segment



Top View of Field Work Area (Sludge Measurement Site)

Maulana Shaukat Ali Road (Near Shauk Chowk)

Module-2 Lecture-2 (Measurement of Sludge Quantity in Drains)

14/19

Foot Bridges

Foot Bridge 01

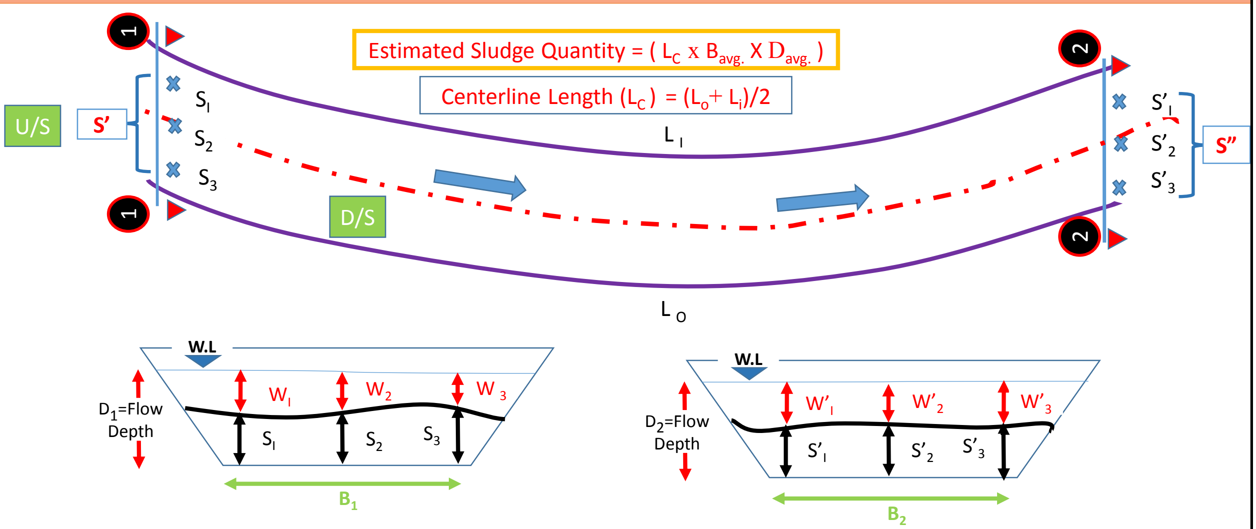
Foot Bridge 02

Maulana Shaukat Ali Drain (Secondary Type)

Sketches (Layout and X-Section)

Estimated Sludge Quantity = (L_C x $B_{avg.}$ X $D_{avg.}$)

Centerline Length (L_C) = (L_o+ L_i)/2



X-section 1-1

X-section 2-2

Sludge Volume Calculation

Depth at Foot 1		Avg. Depth at Foot 1 S_{avg}	Depth at Foot 2		Avg. Depth at Foot 2 S'_{avg}	Overall Avg. Depth D_{avg}	Width at Foot 1 B_1	Width at Foot 2 B_2	Avg. Width B_{avg}	Length Inner L_i	Length Outer L_o	L_c	Sludge Volume V
S_1			S'_1										
S_2			S'_2										
S_3			S'_3										

Estimated Sludge Quantity (Vol.)
$= (L_C \times B_{avg.} \times D_{avg.})$
CUM or CFT

Estimated Sludge Quantity (Vol)
= (X X)
CUM or CFT

$L_C = (L_O + L_I) / 2$ (if drain stretch is curved)
$S' = (S_1 + S_2 + S_3 + \ldots) / n$
$S'' = (S'_1 + S'_2 + S'_3 + \ldots) / n$
$D_{avg.} = (S' + S'' + S''' + \ldots) / n$
$B_{avg.} = (B_1 + B_2 + B_3 + \ldots) / n$

Observations

Sr. No.	Observations	Remarks
1.	Type of de-silted material	
2.	Flow conditions before the dredging	
3.	Flow conditions after the dredging	

Course

Operation and Maintenance of Sewer & Storm Water Drainage System Including Safety Practices

Module 2

Operation and Maintenance of Storm Water Drainage System

Lecture-3

Tools and Equipment for Drain Cleaning Operations

Contents

- ❑ Hydraulic Excavator
  - Excavation Buckets
  - Variations of Excavators
- ❑ Silt Pusher Boat
- ❑ Cutter Suction Dredger
- ❑ Dredge Pump

Hydraulic Excavator

- Excavators (Hydraulic Excavators) are heavy construction equipment consisting of a boom, dipper (or stick), bucket and cab on a rotating platform known as the "house"
- All movement and functions of a hydraulic excavator are accomplished through the use of **hydraulic fluid**, with hydraulic cylinders and hydraulic motors

Excavation Buckets

Digging Bucket

- Excavates materials using a pulling movement
- It is often implemented to remove thin layers of silt

Dredging Bucket

- Slightly different from standard buckets
- Characterized by holes that retain silt while allowing water to escape

Visor Bucket

- Traditional excavation bucket
- Excavate thin and very dense layers with low water content

Excavation Buckets

Clamshell

- Operates using a gripping movement
- Excavate thick layers of silt and for transferring materials
- Layer thickness must be at least 0.5 m in order to achieve reasonable productivity

Environmental Grab Bucket

- An alternative type of grab bucket
- Enables an almost horizontal closing movement
- The maximum opening is circa 80% larger than a traditional grab bucket
- Relatively thin layers can also be excavated efficiently

Excavation Buckets

Backhoe

- It has emerged as a suitable workhorse for soils:
  - glacial tills
  - fragmented or softish, crumbly rock
  - variety of non-rock types of soils that have stones
- May be used for dredging relatively small quantities of material that are at varying depths
- Often used for bulk dredging of a variety of sediments

Variations for Excavators

A wide range of variations have been developed for hydraulic excavators over the years due to:

- Height restrictions
- Propulsion issues
- Insufficient access to the water bottom

The following variations can be encountered:

- Excavator boat
- Amphibious Excavators
- Tractor with Side-Arm

Excavator Boat

Amphibious Excavator

Tractor with Side-Arm

Silt Push Boat

- A silt push boat is like a floating bulldozer, which has been developed especially for cleaning ponds, lakes and small waterways
- The machine is primarily used in situations where it is difficult to work from the water's bank

Range of Applications

- Primarily suitable for soft water bottoms (silt, clay, turf, mud, etc.)
- Effective on relatively long, straight waterways
- It can also be used for thicker layers.
- Only effective in relatively shallow waters.
- Depending on the dimensions of the machine, it is possible to work in **Depths of up to 2 m**
- Machine becomes unsuitable when depths exceed 3 m

Cutter Suction Dredger

❑ A cutter suction dredger is a dredging machine that is used in continuous excavation processes and is positioned using spud poles or winch cables

Range of Applications

- Generally only suitable for silt, clay and sand.
- Depending on the dredger design, be used up to **6 m deep**
- The soil type and project conditions must be known for each project
- For **harder bottoms** (i.e. sand), a cutter with larger cutting sections must be selected in order to penetrate the layer of sand

Dredge Pump

❑ Used to suck dredging materials from the water bottom
❑ The pump's suction opening is guided through the center of ditches to maximize contact with dredged materials
❑ Dredge pumps can be mounted to a tractor or crane, or can also be placed on a boat

Range of Applications

- Only suitable for soft water bottoms (silt, turf, etc.)
- Suited to waterways with non-polluted silt
- **Cutter** can also be attached for dredging more solid water bottoms
- Dredge pumps are **susceptible to stones** and **branches**, which could block the opening
- Less suited to dredging activities in urban settings

Dredge Pump

Observations

Module-2 Lecture-3

Module-2 Field Visit-01
(Observation of De-Silting Machinery)

Date:
Day:
Field Visit Site:
Temp.

Name:
Designation:
WASA/TMA:

Sr. No.	Machinery					Attachment(s)		Remarks
	Name/Type	Nos.	Manufacturer /Year	Capacity (Tons)	Fuel Consumption (Liters/day)	Name/Type	Capacity (Tons)	
1.								
2.								
3.								
4.								
5.								
6.								
7.								

Module-2 Lecture-3

Course

Operation and Maintenance of Sewer & Storm Water Drainage System Including Safety Practices

Module 2

Operation and Maintenance of Storm Water Drainage System

Lecture 4

Dredging and Desilting Operations

Contents

Small Scale Dredging

Small-scale dredging projects generally involve drainage channels and modified rivers in areas with artificial (pumped) drainage and smaller urban and suburban waterways, which are not used for shipping activities

Critical Processes in Small-Scale Dredging

- Accessibility along and in channels and lakes
- Logistics and transport of material in populated areas (traffic)
- Limited space for disposal of sediment and waste
- Sensitive project environment:
  - hinder to surroundings
  - highly visible
  - public opinion and interest
- (Old) embankments, low bridges, etc.
- Household waste & objects

Module-2 Lecture-4

5/12

Dredging Process

Excavation

Process involves the:
Dislodgement;
Removal of sediments (soils) and/or rocks

Dredger – is used to excavate the material either:

- Mechanically
- Hydraulically
- By combined action

Transportation

Transportation of dredged material is achieved by:

- In self-contained hoppers of the dredgers;
- In barges;

Rarely used transport methods are:

- Truck
- Conveyor belt

Utilization or Disposal

- In **construction projects**, dredging is driven by the demand for dredged material.
- In **navigation and remediation dredging**, the project is driven by the objective of removing the material from its original place

Module-2 Lecture-4

6/12

Contd…Case Study

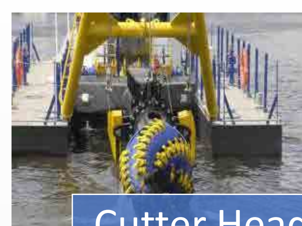
Dredging location	Equipment	Transport	Placement in CDF
Small-scale Urban	**Hydraulic Dredging**	-Hydraulic pipe	Pipeline with diffuser/pontoon
Drainage channel Canal Lake	Cutter dredger Suction dredger Pumps Auger Dredger	- Split barges - Combination	Dumping or pipeline Combination

Parameters	Numbers
Dredging production rates	**100 - 200 m^3/ hour**
Water depth	**1 – 5 m**

Dredging Techniques

Hydraulic Dredging

- Used for maintenance dredging projects
- Removal of loosely compacted materials by cutter heads, dustpans, hoppers, hydraulic pipeline, plain suction, and side casters



Cutter Head

Mechanical Dredging

- Used either for maintenance or new-work projects
- Removal of loose or hard compacted materials by clamshell, dipper, or ladder dredges

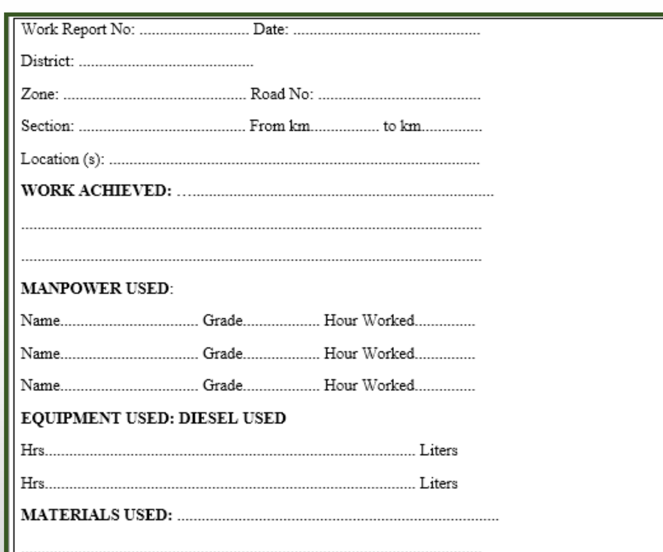
Clamshell

Selection Criteria for Dredging Techniques

While selection of dredging technique, the following factors must be taken into consideration:

- Composition of dredged materials
- Type and level of pollution
- Size of project
- Acceptable opacification and spillage
- Required accuracy
- Side-effects
- Ecological considerations

Workplace Worksheet



Work Report No: .... Date: ....

District: ....

Zone: .... Road No: ....

Section: .... From km................. to km..............

Location (s): ....

WORK ACHIEVED: ....

....

....

MANPOWER USED:

Name................................ Grade.................. Hour Worked..............

Name................................ Grade.................. Hour Worked..............

Name................................ Grade.................. Hour Worked..............

EQUIPMENT USED: DIESEL USED

Hrs... Liters

Hrs... Liters

MATERIALS USED: ....

....

Course

Operation and Maintenance of Sewer & Storm Water Drainage System Including Safety Practices

Module 2

Operation and Maintenance of Storm Water Drainage System

Lecture 5

Maintenance of Storm Water Drainage System

Contents

O & M Plan

Requirement of O & M Plan

- Define the Area to be Covered
- Identify Problem Areas
- Set an Inspection Schedule
- Assign Responsibility for Inspection
- Define What Categories of Work will be Performed Under this Program
- Identify Parties Responsible for Debris Removal
- Keep Records
- Budget

O & M Plan for Open Drains

Storm water system feature	Are any of these conditions present?	Problem	Recommendation
General	Dumped yard wastes or no degradable materials (glass, plastic, Styrofoam, etc.) are present in pond	Accumulation of trash and debris	Remove trash and debris and dispose of properly.
	Undesirable vegetation is invading the pond	Nuisance, poisonous, or noxious weeds	Seek advice from the Dept. of Agriculture before applying pesticides. Certain pesticides should not be used near waterbodies.

O & M Plan for Open Drains

Storm water system feature	Are any of these conditions present?	Problem	Recommendation
General	Grass is taller than 10"m	Overgrown vegetation	Mow grass regularly. Grass should be mowed to a height of 4-9" for best storm water control. Avoid over-applying fertilizers. Excessive fertilizer application may compound water quality problems.
	Offensive color, odor, or sludge is present	Unknown or uncharacteristic substances	Remove substance and eliminate its source. If you don't know if the substance is hazardous, either take a sample or contact a qualified hazardous waste consultant for more information.
	Excessive mosquito population is present	Mosquitos	Install predacious bird and bat nesting boxes to control insects

Module-2 Lecture-5

7/22

O & M Plan for Open Drains

Storm water system feature	Are any of these conditions present?	Problem	Recommendation
General	Water flows through holes in dam or berm; holes are present around pond	Rodents	Destroy rodents and repair dam or berm.
	Large trees interfere with maintenance activities	Overgrown trees	Remove trees that interfere with access or maintenance activities. Preserve trees that are not a problem
	Accumulated sediment exceeds 10% of the designed pond depth	Excessive sediment	Clean out sediment to original shape and depth of the pond. Re-seed pond, if necessary, to control erosion.

Module-2 Lecture-5

8/22

O & M Plan for Storm Sewers

Storm water system feature	Are any of these conditions present?	Problem	Recommendation
General	Accumulated sediment or trash exceeds 20% of the diameter of the pipe	Excess accumulation of sediment or trash	Clean out sediment and trash from pipe. You can use a high pressure hose, vacuum suction, or other appropriate cleaning method.
	Vegetation is impeding water flow	Overgrown vegetation	
	Pipe is rusted; protected coating is damaged	Corroded pipe	Replace or repair pipe to original design specifications.
	Dent in pipe has reduced the pipe diameter by 20%; water flow is impeded; pipe is broken	Defective pipe	
	Water is leaking from pipe	Cracked pipe	

Maintenance Activities for Road Drainage

Drains

Defect	Cause	Outcome	Remedies
Obstruction and Silting	Vegetation growth, loose silt and rock; Invert Slope is too flat	Blockage	Cleaning & Clearing; Deepen ditch (de-silting), and/or provide new turnouts
Drain Lining is Damaged	Poor Construction; Sudden change in flow direction; Soil Settlement	Erosion; Damage to lining	Erosion control (Turfing and Wattling); Repair lining; Realign drain

Drains

Defect	Cause	Outcome	Remedies
Invert and sides of drain are eroded	Invert slope is too steep	Soil Erosion; Carriageway washed away	Erosion control; Re-grade/realign drains; Repair scour protection; Line drain slopes
Drain Cross-Section Destroyed	Vehicular or animal traffic; Cave-in	Partial Silting; Erosion	Reshape/regrade Ditch; Line the drain

Culverts

Defect
Silting or Debris Blocking

Cause
1. Invert slope too flat;
2. Culvert constructed too low;
3. Vegetation and floating debris lodging

Outcome
1. Intended waterway opening will be reduced;
2. Ponding on upstream side;
3. Road embankment overflow

Remedies
1. Clearing and cleaning;
2. Provision of a debris rack

Module-2 Lecture-5

13/22

Culverts

Defect
Cracks

Cause
Settlement of soil below culvert

Outcome
Minor Damage:

Light cracking in headwall, wing walls and main structure

Major Damage:

Large relative movement of culvert pipes

Remedies
1. Repair cracks
2. Reconstruct at correct level and fall

Module-2 Lecture-5

14/22

Culverts

Defect
Erosion of Culvert bed at Outfall

Cause
1. Too fast water flow due to steep culvert invert;
2. Culvert invert has been constructed too flat with an **excessive drop** at the outfall

Outcome
1. Streambed is washed;
2. Collapse of culvert downstream head and wing walls and road embankment

Remedies
1. Erosion repair
2. Construct outfall basin

BMPs for Storm Water Drainage System

Catch Basins/Inlet Structures

Municipal staff should regularly inspect facilities to ensure the following:

- Immediate repair of any deterioration
- Cleaning before the sump is 40% full
- Clean structures in high pollutant load areas just before the wet season
- Keep accurate logs of the number of catch basins cleaned
- Record the amount of waste collected
- Store wastes in appropriate containers or temporary storage sites

Open Channel

- Consider modification of storm channel characteristics to:
  - Improve channel hydraulics,
  - Increase pollutant removals, and
  - Enhance channel/creek aesthetic and habitat value.
- Conduct channel modification/improvement in accordance with existing laws.

Illegal Dumping

- Regularly inspect and clean up hot spots
- Establish a system for tracking incidents. The system should be designed to identify the following:
  - Illegal dumping hot spots
  - Types and quantities (in some cases) of wastes
  - Patterns in time of occurrence
  - Mode of dumping
  - Responsible parties
- Post "No Dumping" signs in problem areas with a phone number for reporting

Module-2 Lecture-5

19/22

BMPs for Dredging

Module-2 Lecture-5

20/22

BMPs for Dredging

- Installation of temporary silt fence
- Fence shall remain in place for the duration of the maintenance dredging activity
- Stop the activity if watercourse flows are encountered
- Accumulated silt shall be removed to the greatest extent possible
- Dredging shall be conducted with hand tools and/ or a tracked equipment

BMPs for Dredging

- Dredging shall be held to the absolute minimum necessary to achieve the target channel width, depth and gradient
- The channel banks shall be sloped such that the resulting channel banks are stable
- Maintenance dredging shall not straighten or shorten the existing channel alignment
- Woody material embedded in the channel bank shall be left undisturbed and intact

Course

Operation and Maintenance of Sewer & Storm Water Drainage System Including Safety Practices

Module 2

Operation and Maintenance of Storm Water Drainage System

Lecture 06 & 07

Sludge Handling & its Disposal

Planning for Sludge Disposal → Lecture-6

Sludge Disposal Techniques → Lecture-7

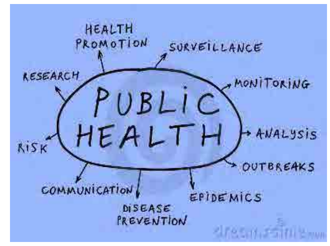
Lecture-6: Planning for Sludge Disposal

Contents

- Importance of Site Selection
- Early Considerations
- Requirements for Site Selection
- Screening Process for Site Selection
- Site Selection Criteria
- Factors to be considered for Criteria

Importance of Site Selection

- Minimizes the future impact on public health
- Reduces the cost of:
  - Design and Construction
  - Operation
  - Maintenance



Module-2 Lecture- 6

5/24

Early Considerations

Size

- depends on the waste stream over the predicted site life and provision for sufficient buffer zones

Strategic Location

- determined by the waste generation areas to be served and transport routes

Module-2 Lecture- 6

6/24

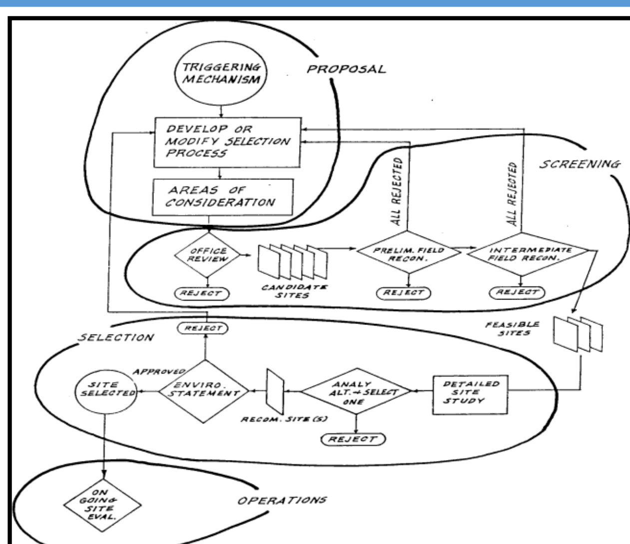
Requirements for Site Selection

- Spatial and urban planning requirements
- Spatial and regional requirements
- Required land area
- Transportation distances
- Local site conditions
- Topography
- Climate conditions
- Hydrogeological conditions
- Geological conditions
- Geo-mechanical conditions
- Environmental protection

Module-2 Lecture- 6

7/24

Site Selection Process



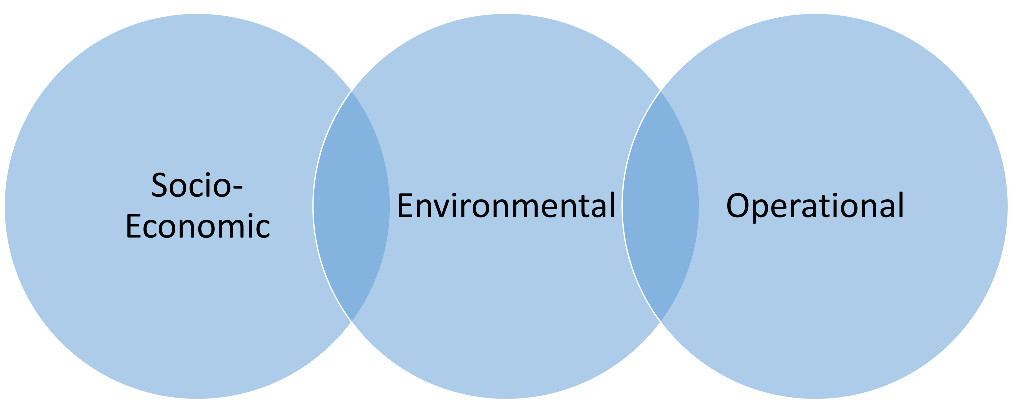
Module-2 Lecture- 6

8/24

Site Selection Criteria

- Physical Site
- Access
- Topography
- Proximity
- Hydrology
- Geology
- Soils
- Drainage
- Surface Water
- Temperature
- Ground Water

Factors to be Considered for Criteria

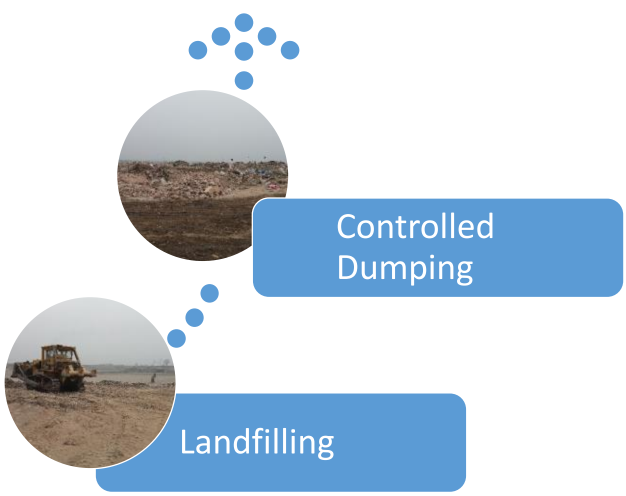


Lecture-7: Sludge Disposal Techniques

Contents

- Introduction
- Controlled Dumping
  - Important Considerations for Controlled Dumping
- Landfilling
  - How it Works
  - Sludge Disposal at a MSW Landfill
  - Sludge/Solid Waste Mixture
  - Sludge/Soil Mixture

Disposal Techniques for Sludge



Controlled Dumping

- Essential burial of waste in earth on a daily basis, in an isolated and demarcated site
- An established system for rotational and organized deposit of waste
- To prepare the site to retain its waste more effectively

Module-2 Lecture- 7

13/24

Important Considerations

- Minimize its chances of contact with **humans and animals**
- Waste should be covered with a soil layer **10-15cm** deep
- If coverage with soil is not possible, **lime** may be deposited over the waste
- **Access** to these dedicated disposal areas should be **restricted**
- It would require **supervision by staff**
- Prevent scavenging

Module-2 Lecture- 7

14/24

Sanitary Landfilling

- Landfill is the site where waste is isolated from environment until it is safe

(Until completely degraded biologically, chemically and physically)

Module-2 Lecture- 7

15/24

How it Works

- In landfill operation, Sludge is spread and compacted in thin layers within a small area
- To allow for proper compaction, the **cell depth** should not exceed about **2 meters**
- The cell is then covered with a **layer of soil** which is spread uniformly and then compacted
- To provide an adequate **seal the cover** should normally be at least 20 cm thick

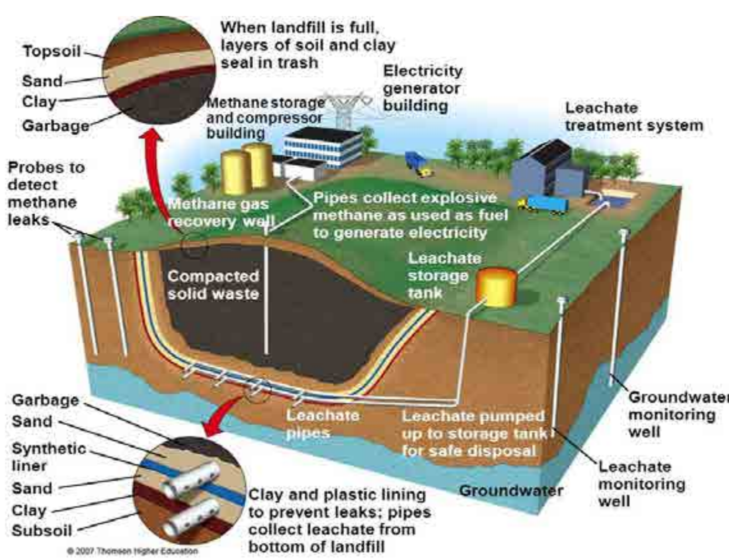
Module-2 Lecture- 7

16/24

How it Works

- When a number of cells reach the final desired elevation, a **final cover of about one meter** of earth is placed and it is again compacted
- Landfill must be provided with **Liners** to prevent the migration of waste out of landfill to adjacent surface soil or ground water or surface water during anytime

How it Works



Sludge Disposal at a MSW Landfill

Sludge Disposal

- Sludge/solid waste mixture
- Sludge/soil mixture

Sludge/Solid Waste Mixture

- Sludge is deposited atop solid waste and mixed as thoroughly as possible with the solid waste
- The mixture is then spread, compacted, and covered in the usual manner used at MSW landfills
- The minimum sludge solids content is approximately 20 percent
- The sludge is usually spread by conventional landfill operating equipment

Sludge/Solid Waste Mixture

- To provide adequate workability of the sludge/solid waste mixture, the bulking ratio for a 20 percent solids sludge should be **4 mg of solid waste to 1 wet mg of sludge**
- **Sludge application rates** for sludge/solid waste mixtures compare favorably with rates for other types of sludge disposal methods
- **Disposal rates** generally range from 500 to 4,200 yd^3 of sludge per acre (900 to 7,900 m3 of sludge per ha)

Sludge/Soil Mixture

- Sludge is mixed with soil and applied as intermediate or final cover over completed areas of the MSW landfill
- This is not strictly a sludge landfilling method from an engineering standpoint, because the sludge is not buried

But it is a viable and proven option for disposal of sludge at MSW landfills