HYDROGEOLOGY AND DRILLING SUPERVISION TRAINING

Day 2

Course Objectives Day 2

- **Borehole Site Selection**
- **Geophysical Exploration**
- **Drilling Methods**
- **Drilling Construction and Design**

Main Purpose in Understanding Geology in Rural Water Supply Projects

- **Permeability and porosity**
- **Geophysical Method**
- **Drilling Technique**
- **Water Quality**
- **Logistics**

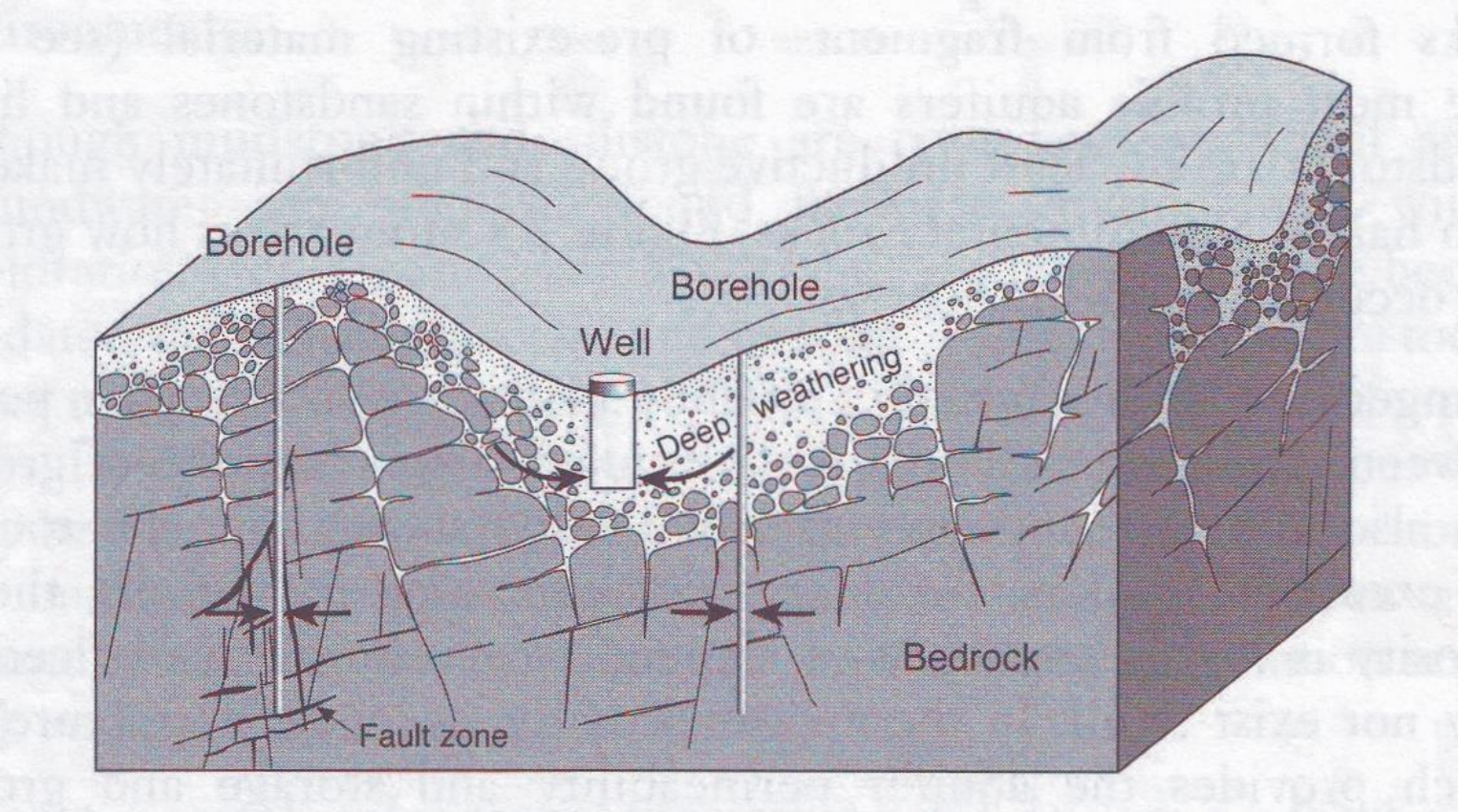
Main Geological Division

- **Igneous**
  - **Intrusive**
  - **Extrusive**
- **Weathering**
- **Sedimentary Environments**
- **Metamorphic**

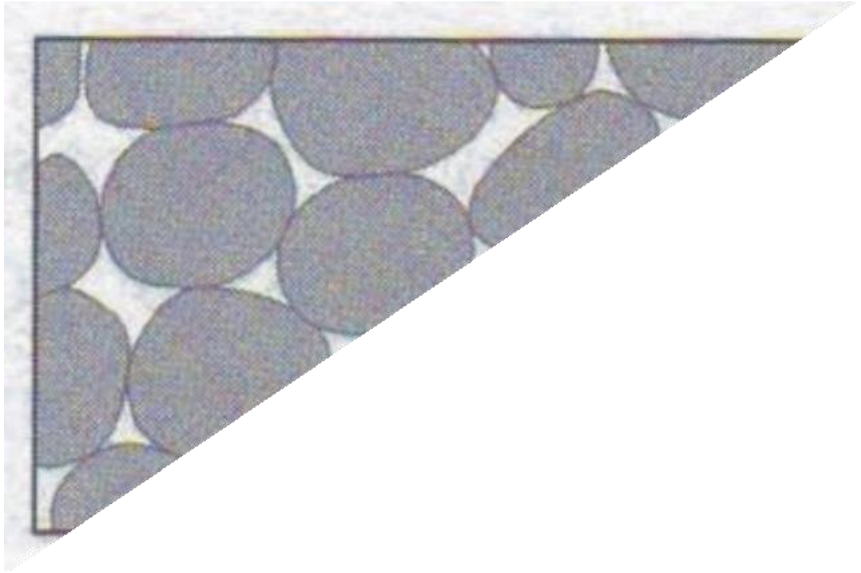
Why Use Groundwater

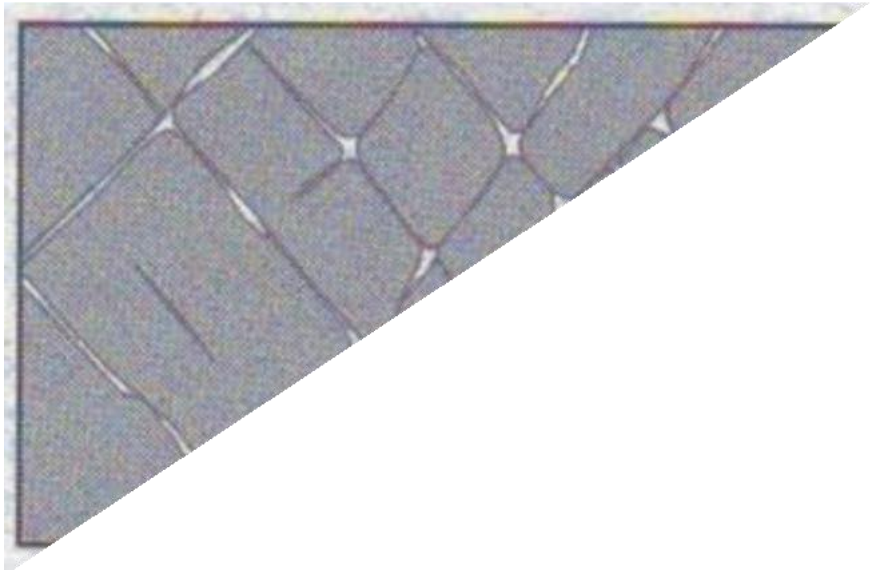
- Areas where there is no surface water nearby
- Quality is good
- Responds slowly to changes in weather patterns
- Drought
- Safer than collecting from Rivers

Weathering of Bedrock



Intergranular and Fractured Aquifers





Identification of Rocks

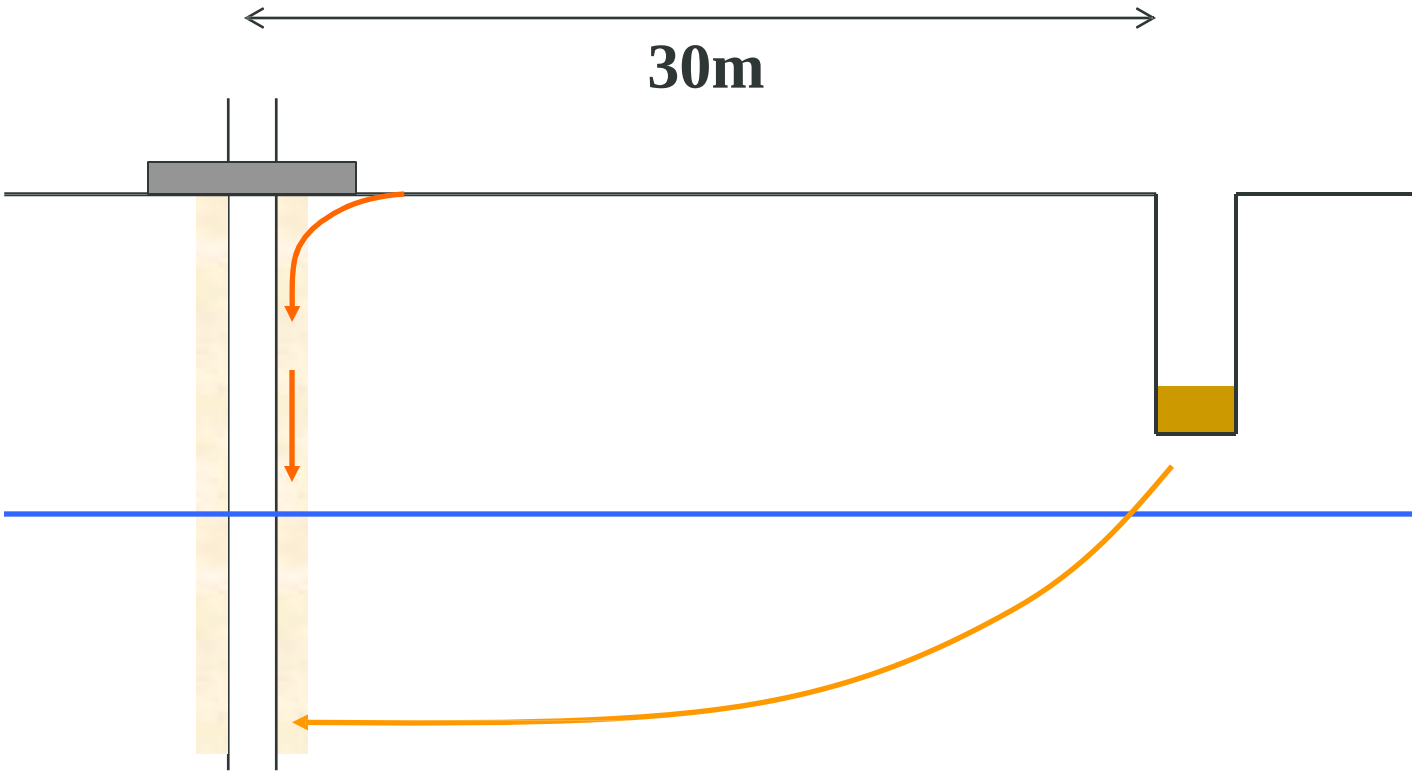
- Consolidation
- Porosity
- Grain Size
- Roundness
- Sorting
- Weathering
- Colour

Quality

Health and acceptability are based on:

- Chemical
- Microbiological
- Turbidity

Reducing the Risk



Field Measurements

Parameters

•pH, EC, Fe and N – carried out after drilling and at the end of pumping test

- After sterilisation using chlorine

- Testing of water for Microbiological contamination

Why Is Mathematics Important

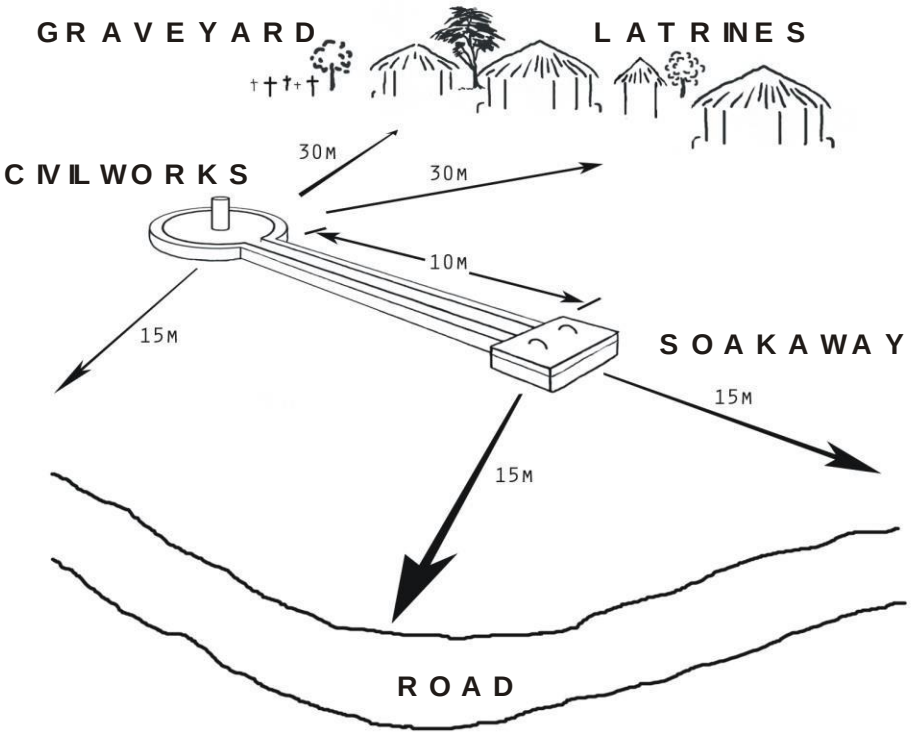
- Flow Rates
- Water Levels
- Borehole Design
- Development
- Pumping Tests
- Distance/Length
- Volume of gravel pack

Borehole Location

- Set time for Siting
- Establish boundaries
- Avoid problem areas IF POSSIBLE

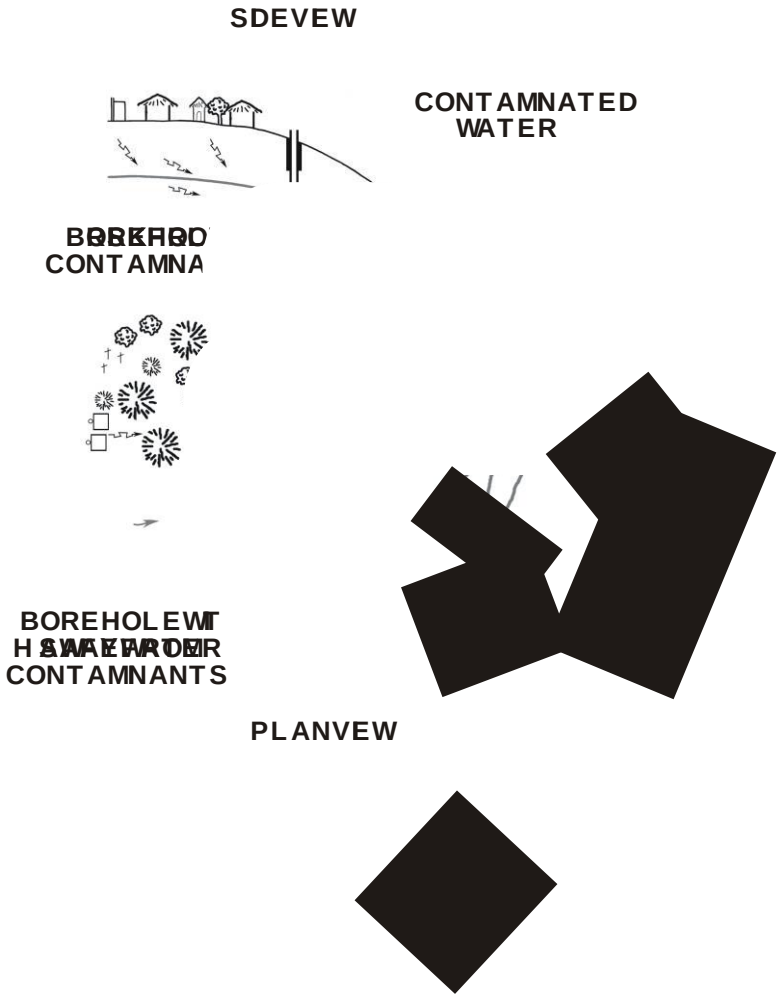
Borehole Location Considerations

- Pit Latrines
- Roads - Existing and Planned
- Anthills
- Depressions
- Areas likely to flood

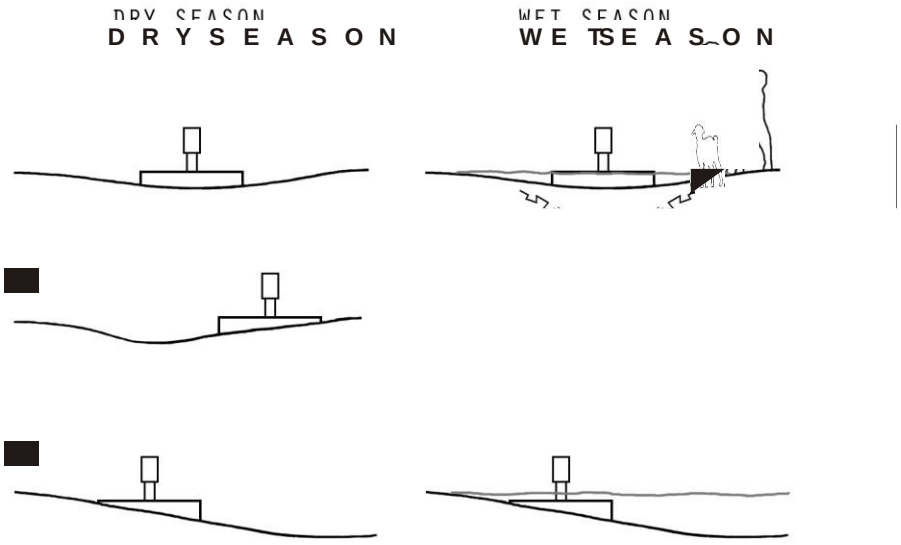

GRAVEYARD
LATRINES
CIVIL WORKS
30M
30M
10M
15M
SOAKAWAY
15M
15M
ROAD

Distances

Contaminants



Flooding



Site Selection

- Construction NOT the only consideration
- Sense of ownership
- Site selection must involve community
- 200m apart
- Areas likely to flood

Siting Problems

- Not in the right place for community

- Too far away

•Explaining Groundwater potential – better to have a wet borehole in a slightly inconvenient place

- Community Agreement Form

Community Agreement Form

Republic of Zambia

WATER SUPPLY PROGRAMME SUPPORT - COMPONENT 1
RURAL WATER SUPPLY AND SANITATION

COMMUNITY AGREEMENT FORM

Ministry of Local Government and Housing
DISS

We the community of ……..…… Located

in……..……Ward

in……..……District

Hereby declare that we are in agreement with the borehole siting crew concerning the location of our borehole.

……..	……	……..
Community Representative	Date	Siting Crew Leader
……..		……..

LOCATION MAP

NOTE - Two copies should be signed with one remaining with the community and one copy remaining with the siting crew
Please PRINT names below signatures

Geophysical Surveying

- **Geophysics and GW**
- **Why do we use Geophysics**
- **Main ground Geophysical methods**

The Survey

- Schedule visit
- Boundaries of village
- Preferred locations
- Assistance with survey

Resistivity

- Resistivity Theory
- Resistivity Sounding
- Resistivity Traversing

Resistivity

Resistivity Theory

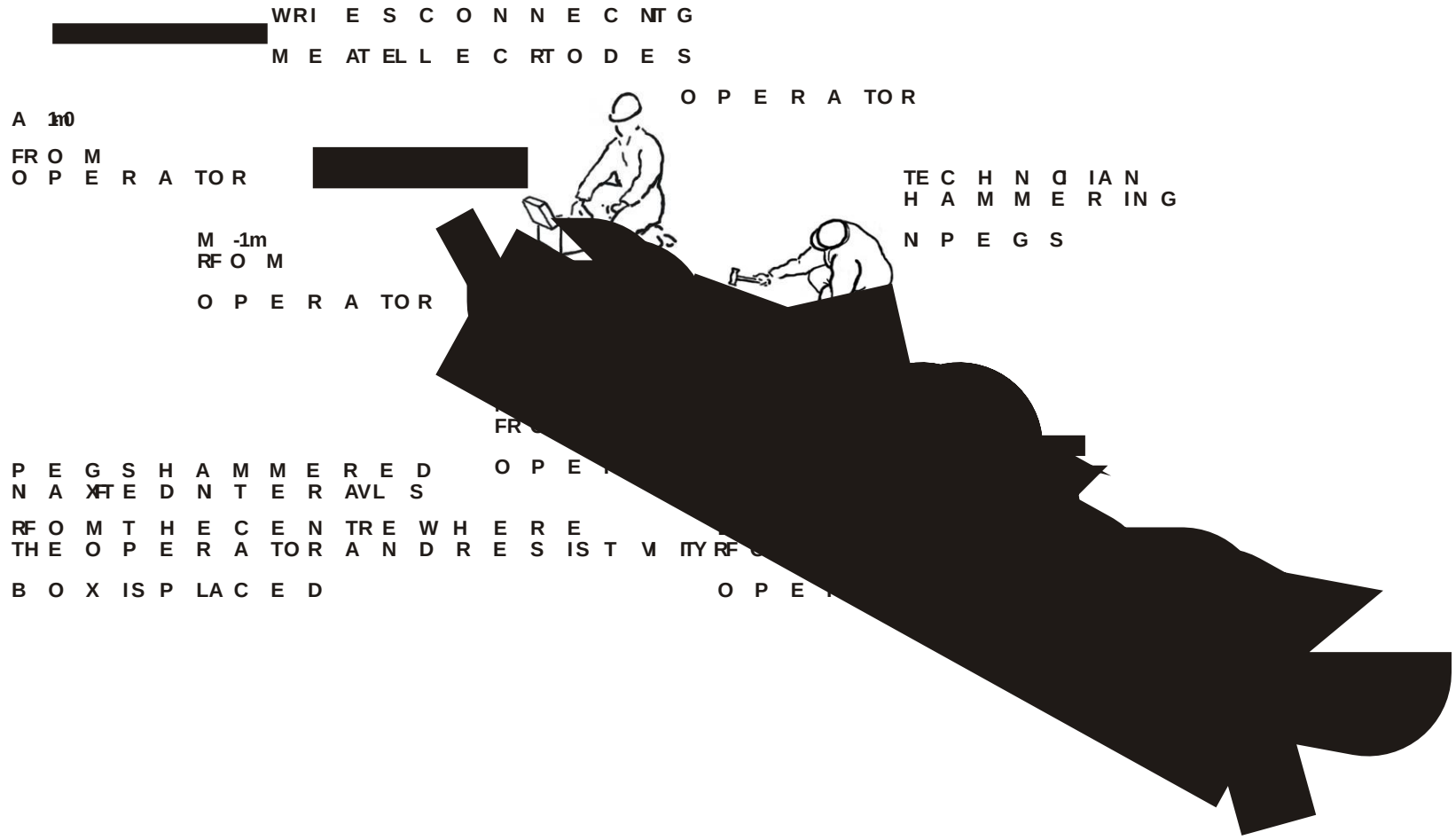
- Different rocks have different electrical properties

•Electrical properties also are effected by weathering and fractures

•Having an idea of the Geology before the survey is useful

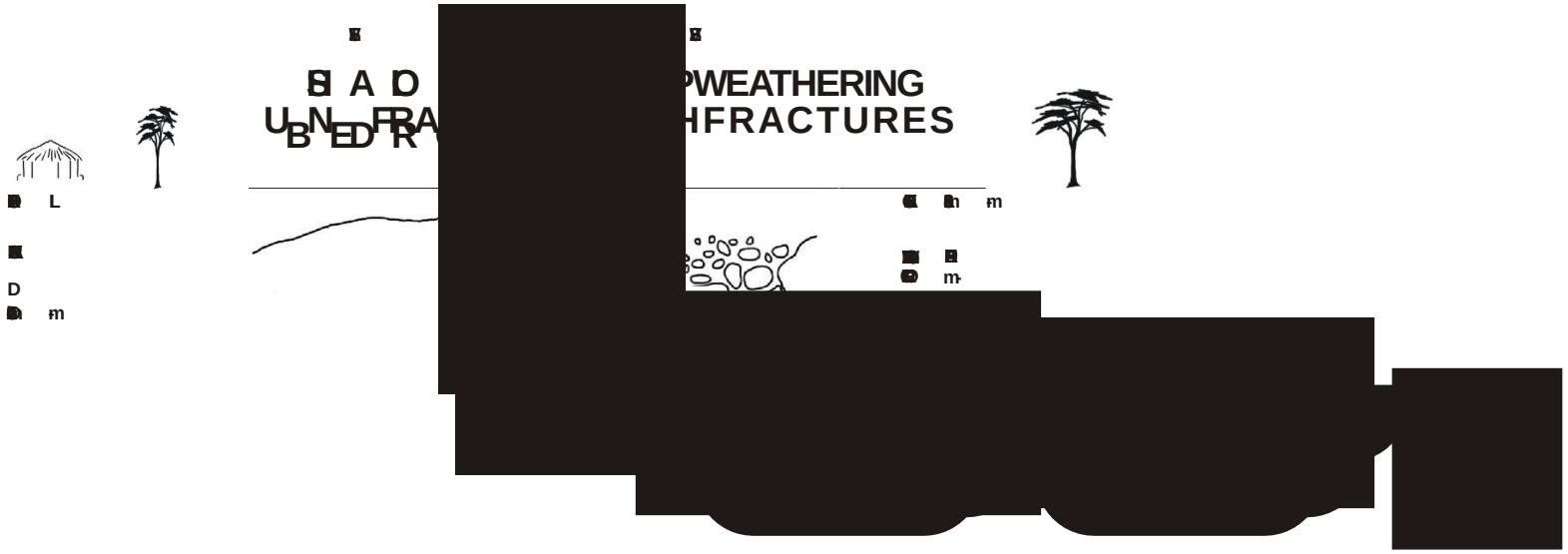
Resistivity Sounding

Resistivity Setup



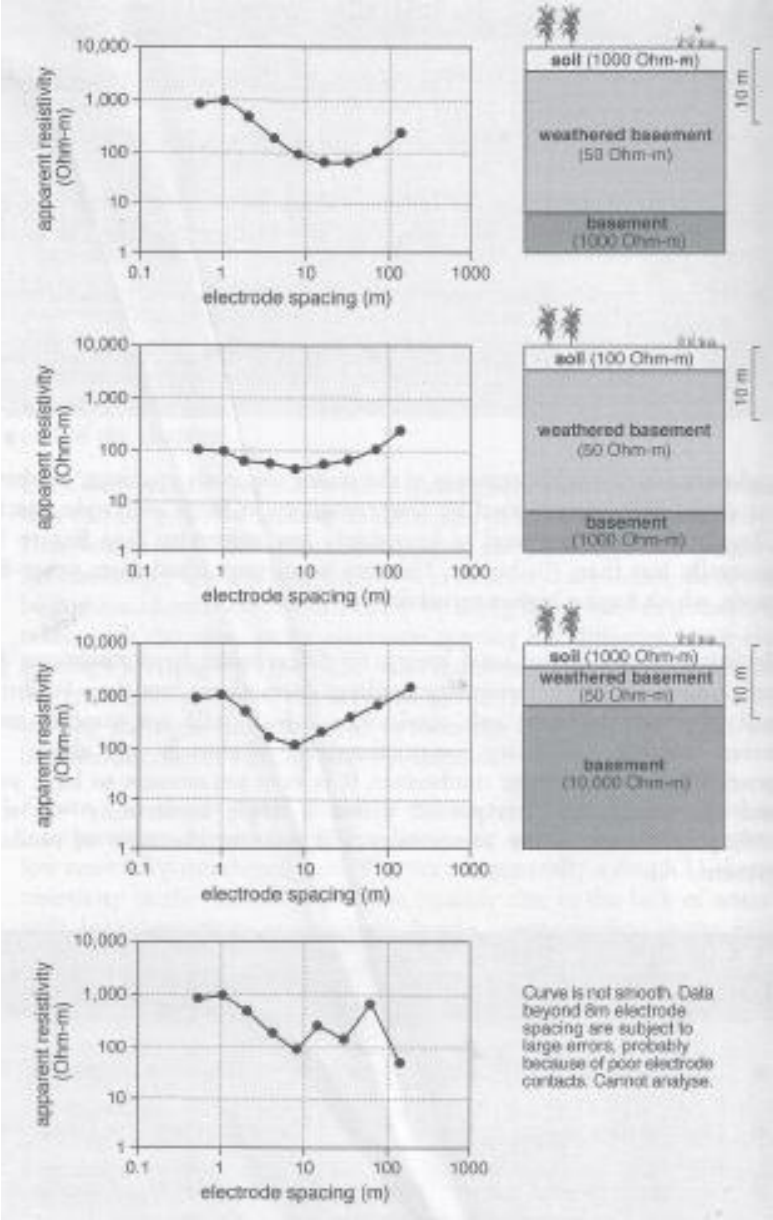
Resistivity Array

Resistivity Sounding



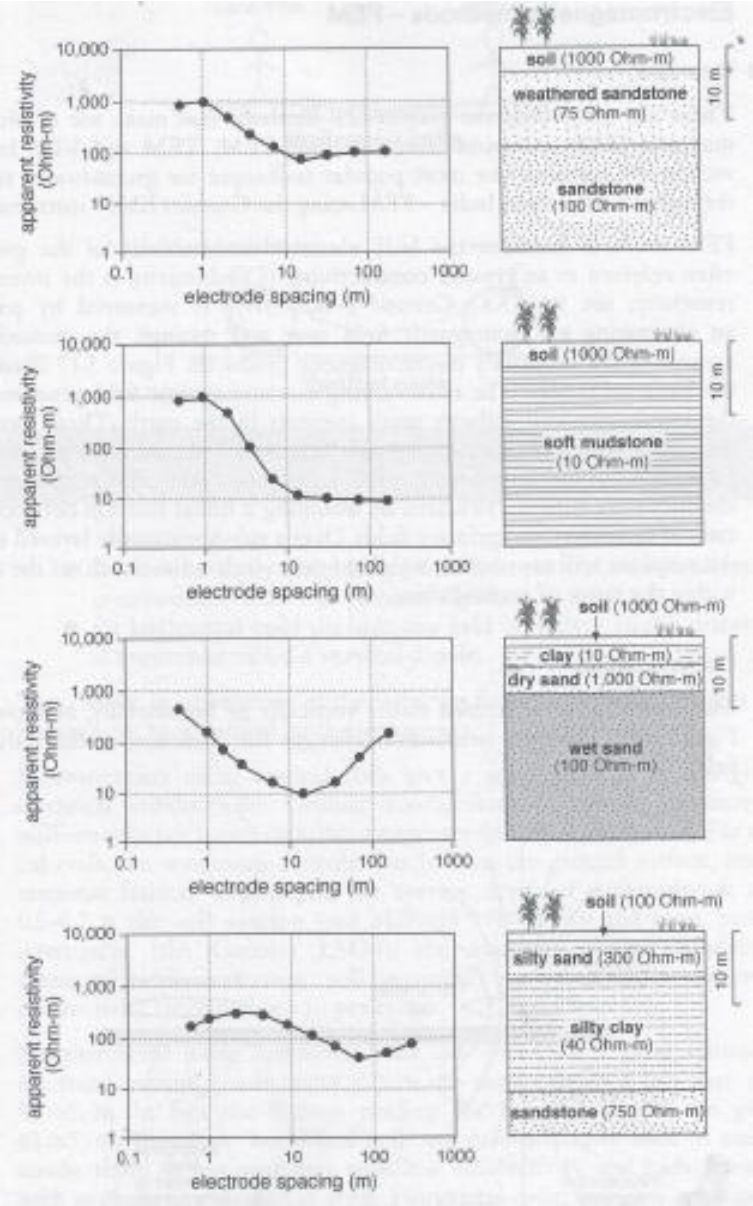
Resistivity Sounding Graphs

Basement Rocks



Resistivity Sounding Graphs

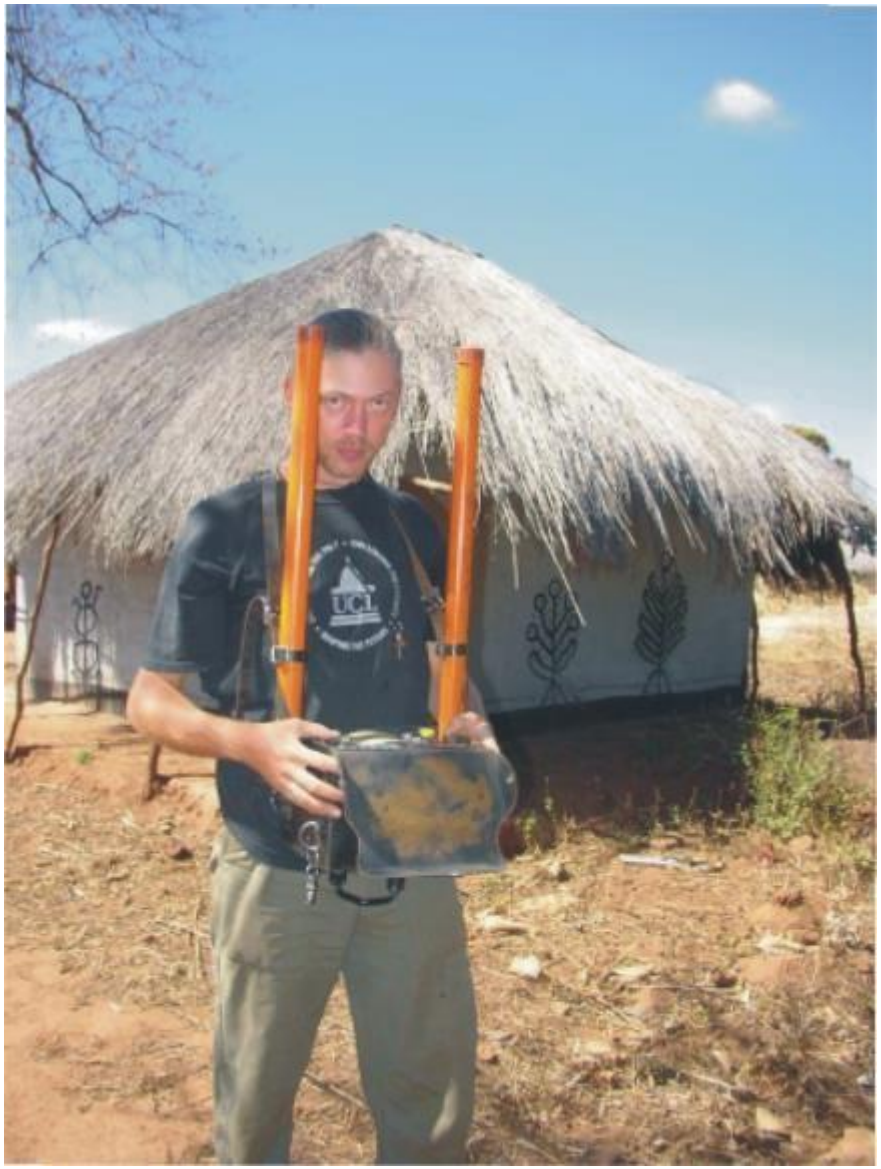
Sedimentary Rocks



Resistivity Traversing

Electromagnetics (EM)

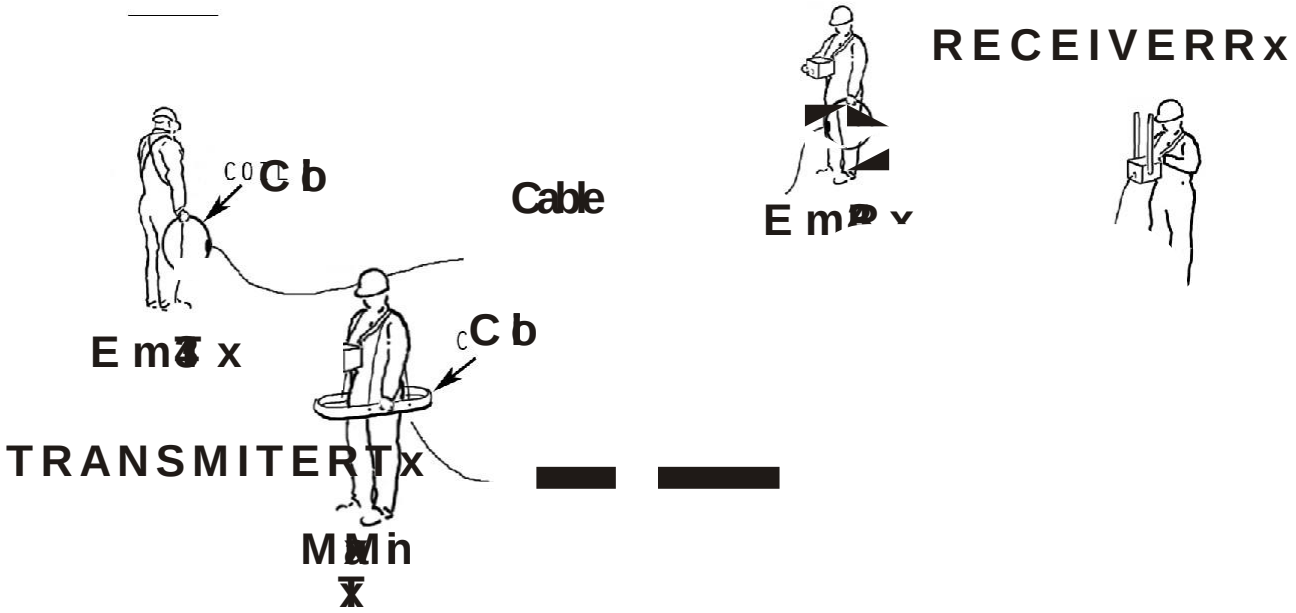
- **EM Theory**
- **Ground EM Methods**
- **Airborne EM**



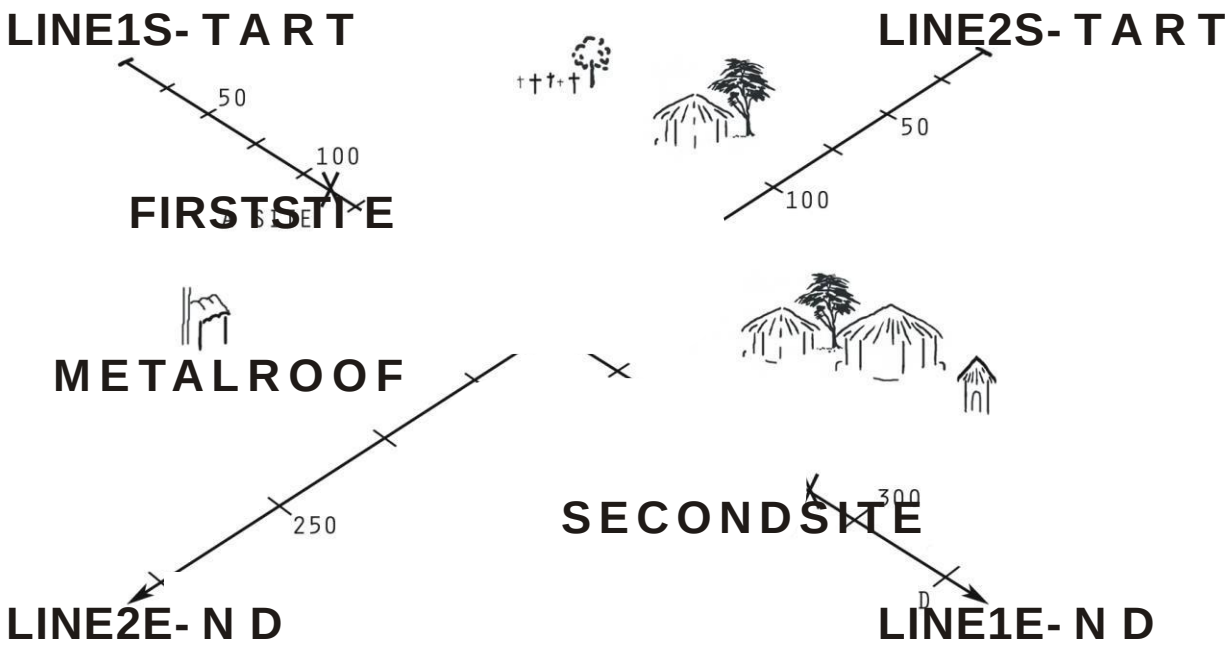
EM Reciever MaxMin

EM Transmitter MaxMin

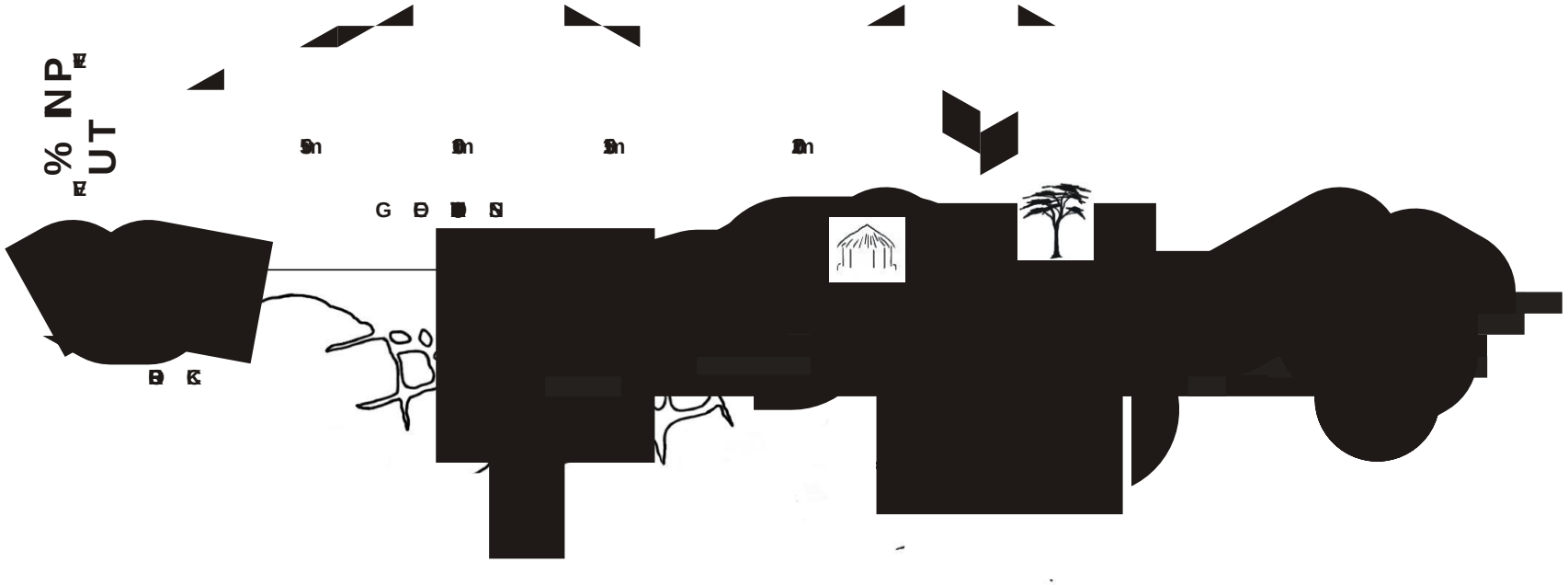
EM Reciever MaxMin



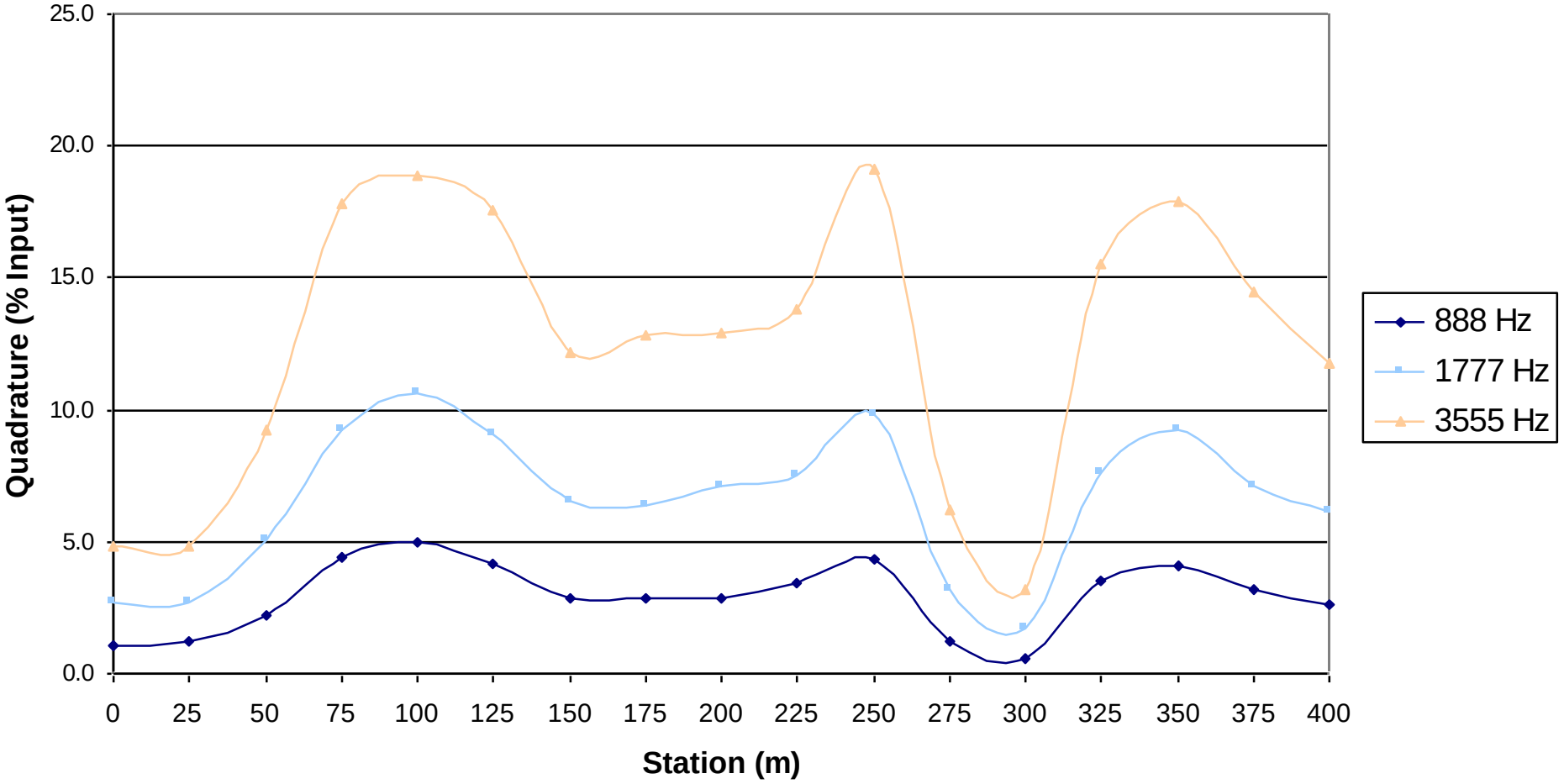
EM Lines/Traverses



MaxMin Data



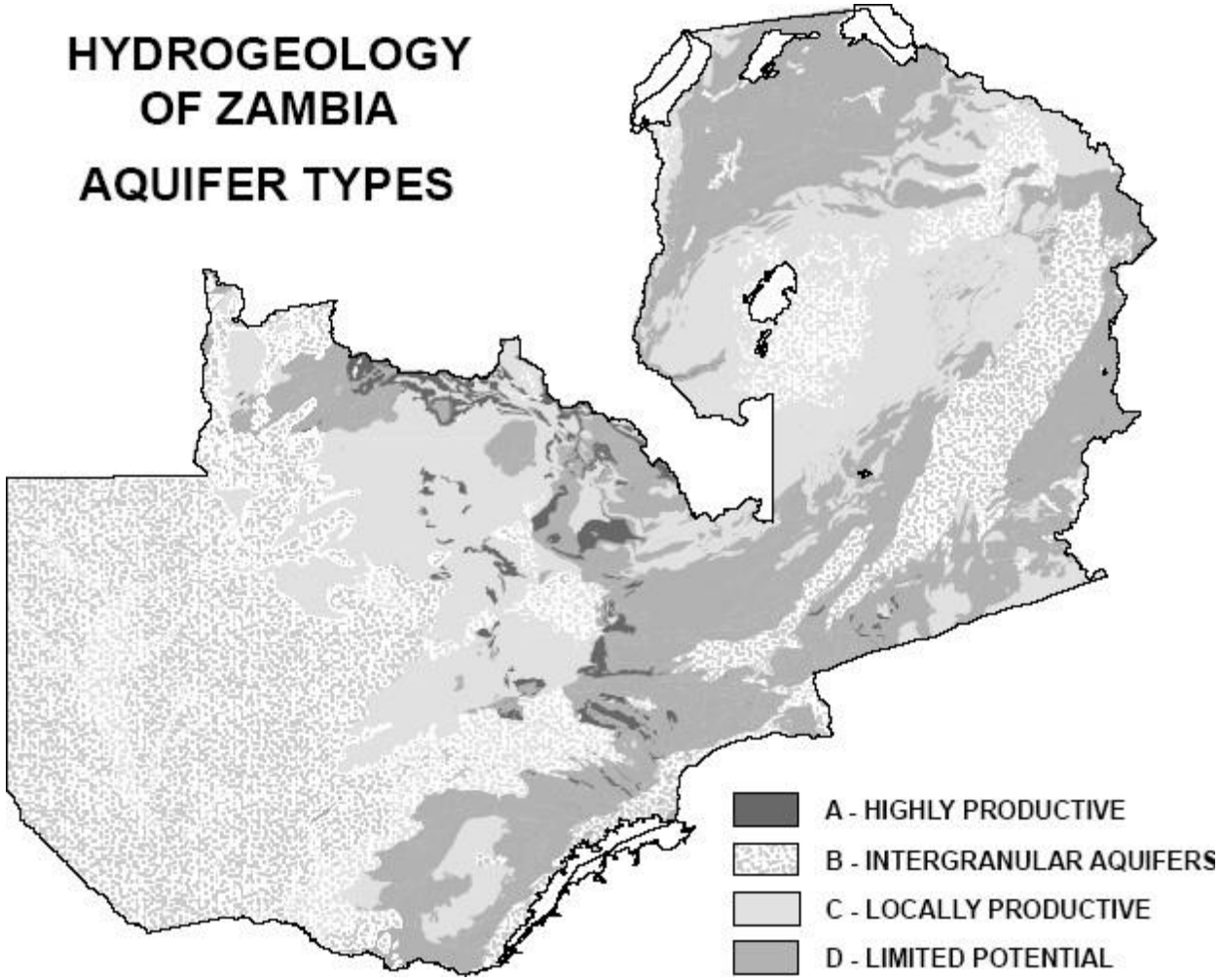
MaxMin EM Traverse



Marking the site

- **Priority (A) and Backup (B)**
- **GPS Sites with Codes**
- **Must be at least 150m apart**
- **Community agreement Form**

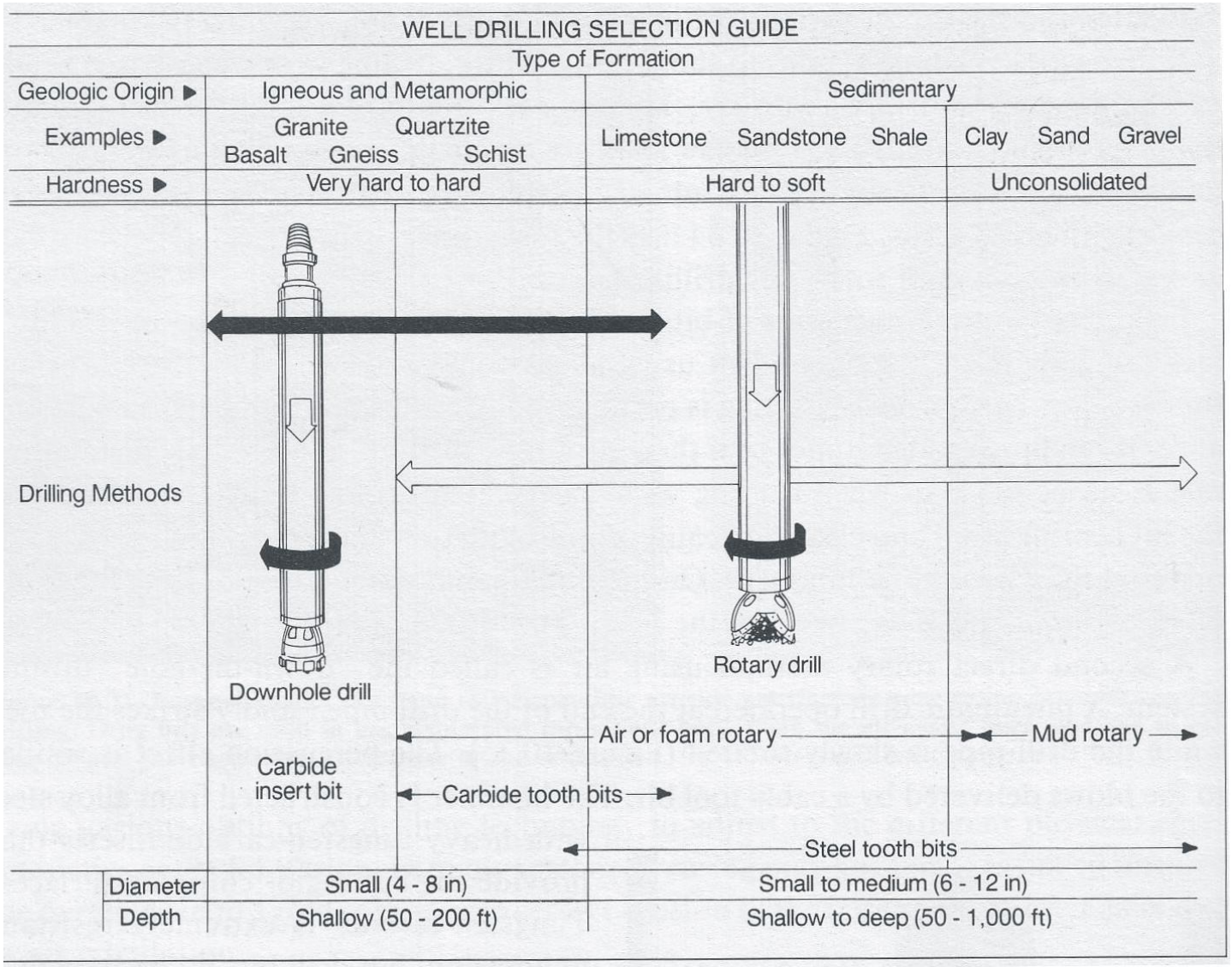
Geophysics and Aquifers

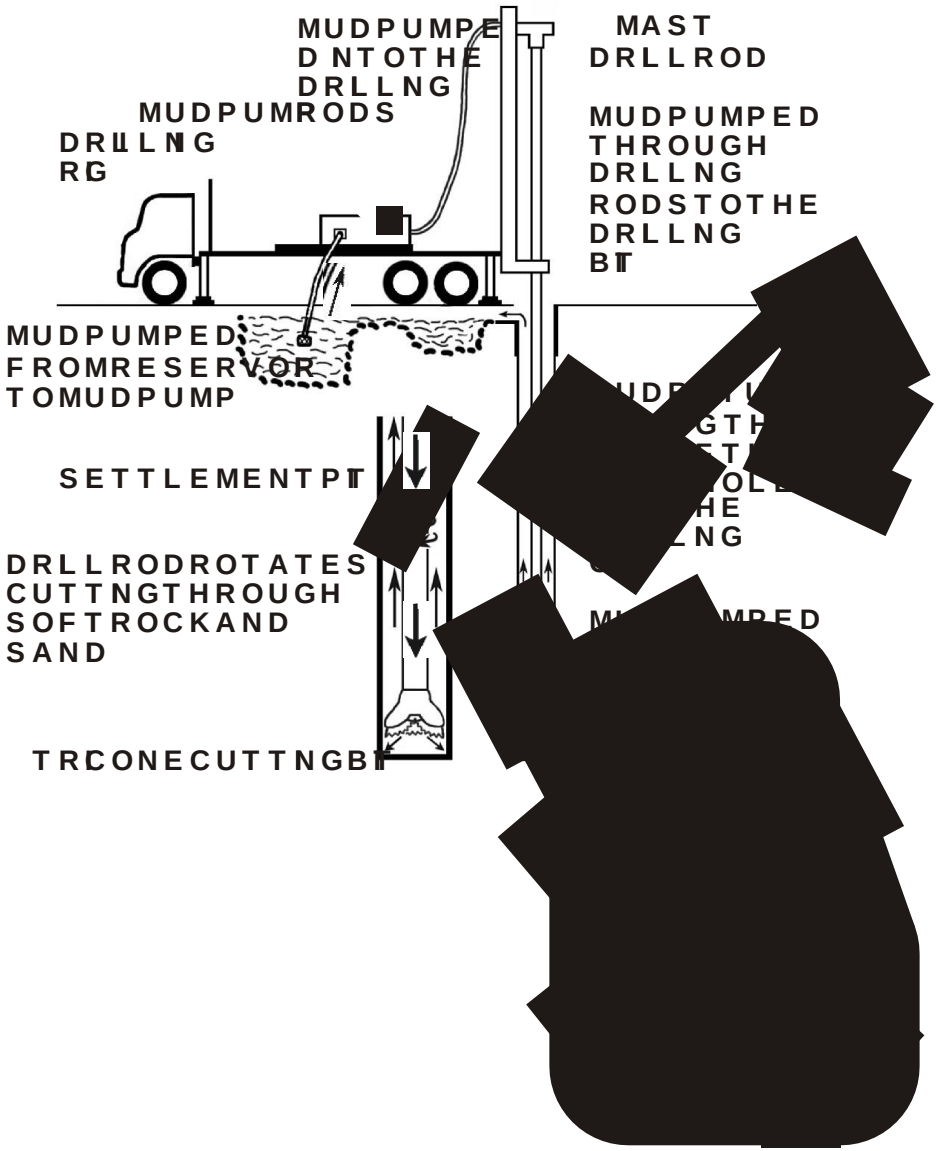


Survey Results and the Community

- Explanation of why Geophysics is being done
- Existing water sources
- Any visible rocks - outcrop/well construction
- Reason for possible distance to site
- Problems

Drilling


WELL DRILLING SELECTION GUIDE
Type of Formation
Geologic Origin ▶
Igneous and Metamorphic
Sedimentary
Examples ▶
Granite Quartzite
Basalt Gneiss Schist
Limestone Sandstone Shale
Clay Sand Gravel
Hardness ▶
Very hard to hard
Hard to soft
Unconsolidated
Drilling Methods
Downhole drill
Rotary drill
Air or foam rotary
Mud rotary
Carbide insert bit
Carbide tooth bits
Steel tooth bits
Diameter
Small (4 - 8 in)
Small to medium (6 - 12 in)
Depth
Shallow (50 - 200 ft)
Shallow to deep (50 - 1,000 ft)



Mud Rotary Drilling Rig

Mud Rotary Drilling Rig

Mud Drilling Bits


Tricone

Mud Rotary Drilling

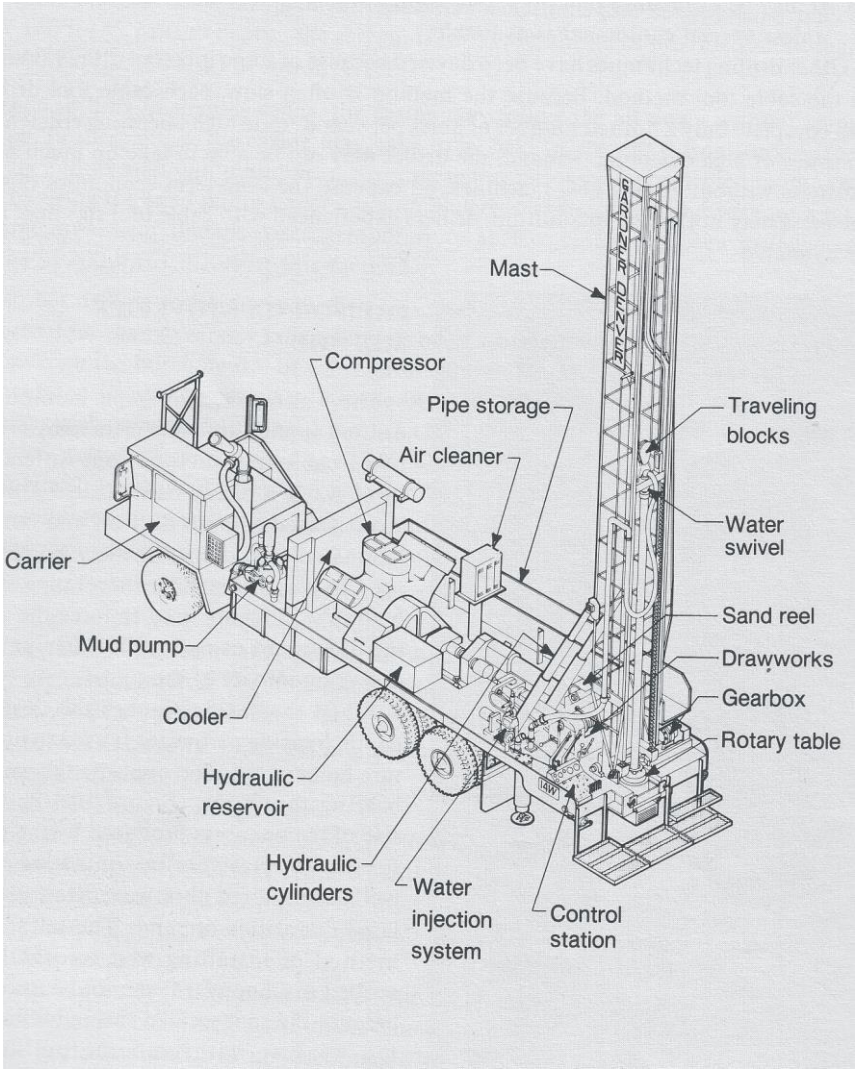
- Rotary Drilling Method
- Unstable formations
- Can penetrate some hard rocks
- Need experienced drillers

Marsh Funnel

Marsh Funnel Reading

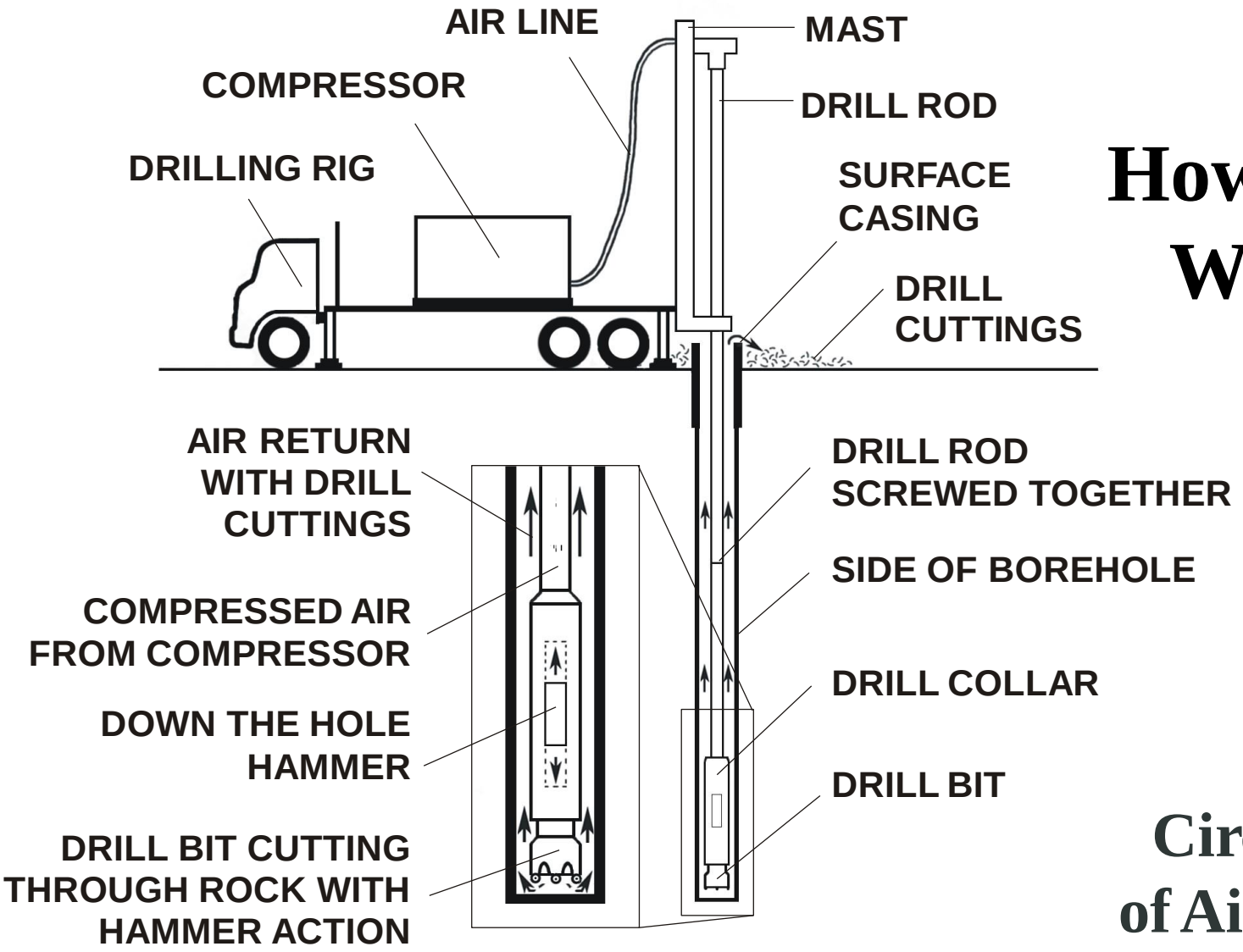
Viscosity of the Drilling Fluid

Material Drilled	Appropriate Marsh Funnel Viscosity (seconds)
Fine sand	35 - 45
Medium sand	45 - 55
Coarse sand	55 - 65
Gravel	65 - 75
Coarse gravel	75 - 85



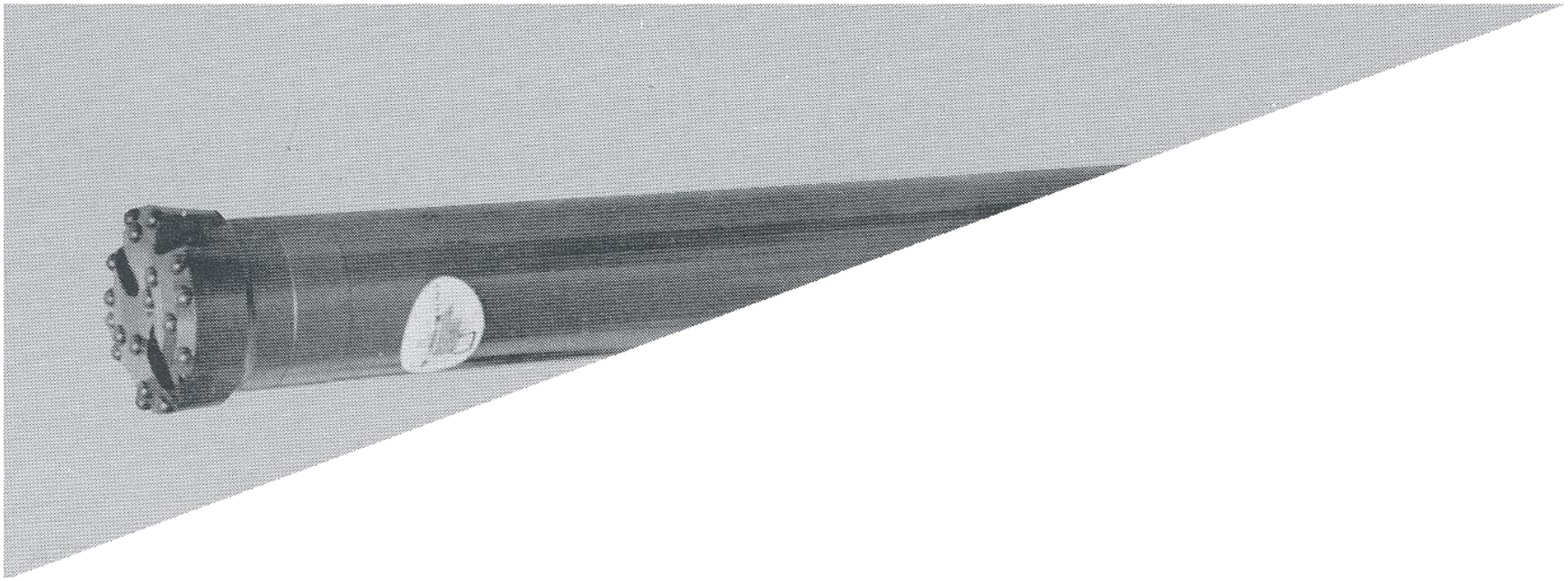
DTH Drilling

How DTH Works

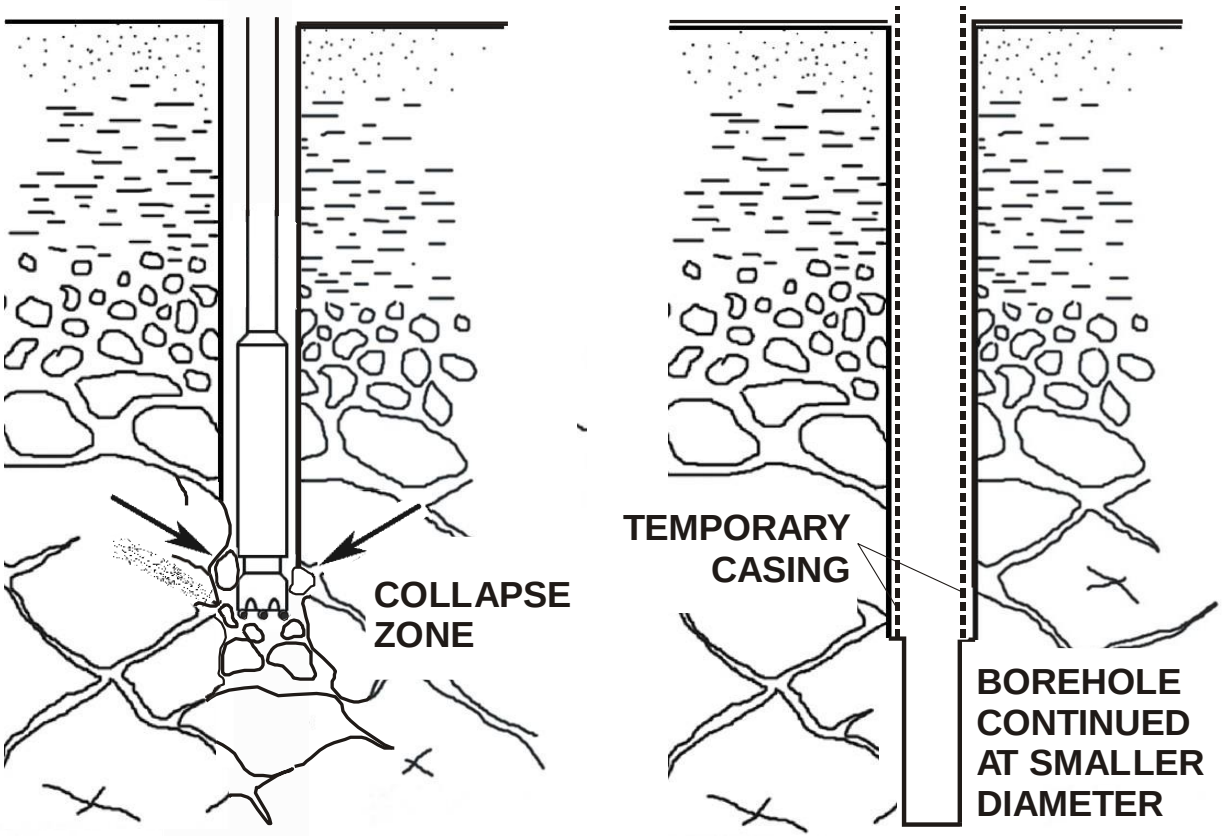


Circulation of Air/Foam

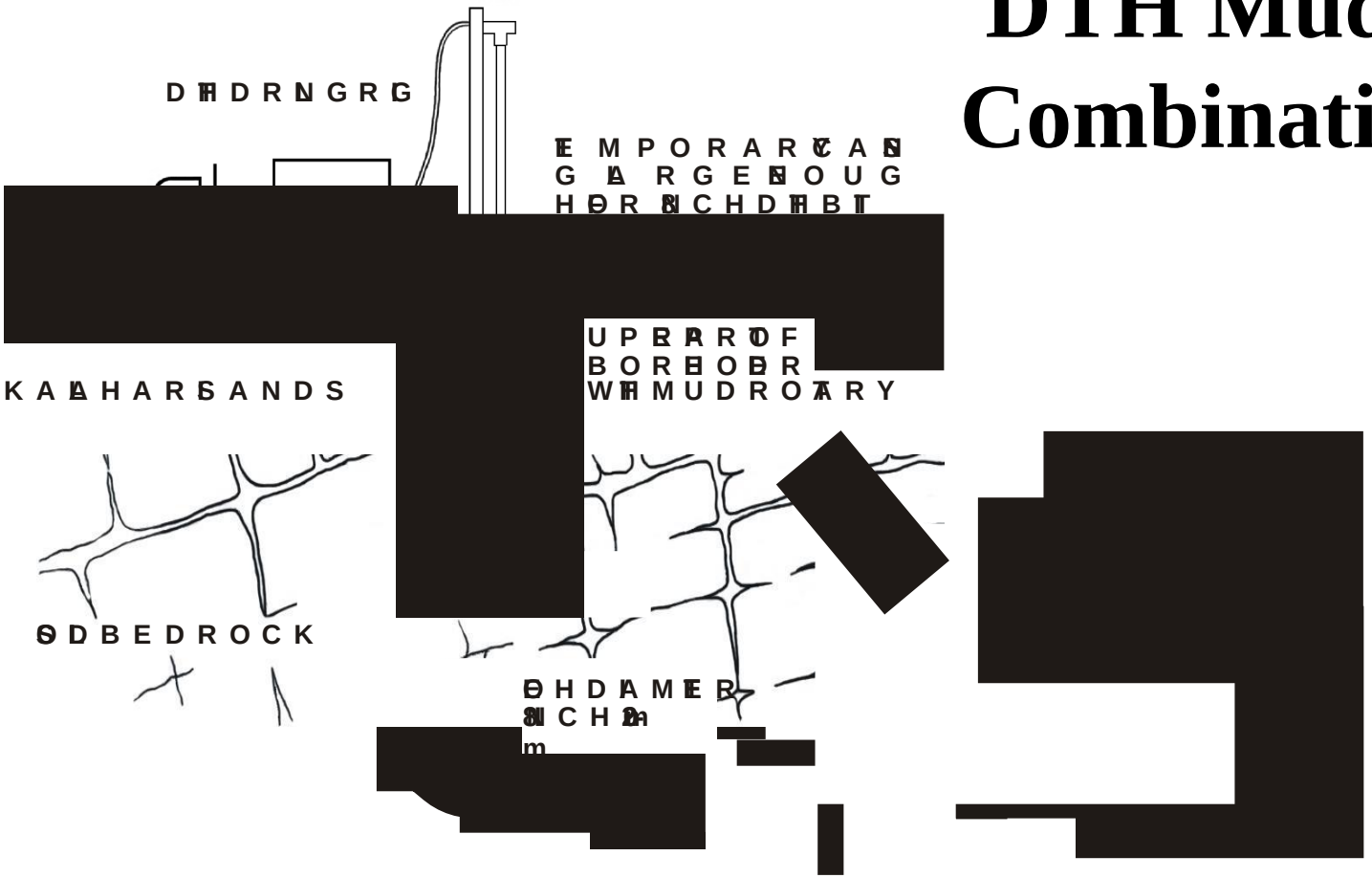
DTH Hammer Bit



Collapsing Holes



DTH Mud - Combination



Access of Drilling Rigs

- Drilling rigs can weigh up to 30 tons
- Deep sand is not the issue - warned in contract
- Bridges and Dambos are the issue
- If this issue dealt with early - mitigate

Combination Drilling

Drilling Diamaters

- Sandy Formation - min 200mm EOH

Unconsolidated followed by hard rocks

- Unconsolidated/Weathered rock 200 - 250mm
- Fresh rock 165 - 176mm

Roles and Responsibilities

- Show the location of the drill site

•Advise the driller about depth and design of borehole based on information collected during drilling

- Should **NOT** attempt to tell the driller how to drill
- Needs a good working knowledge of set up
- Instruct the driller on what data to collect
- Description of Lithology

Before Drilling

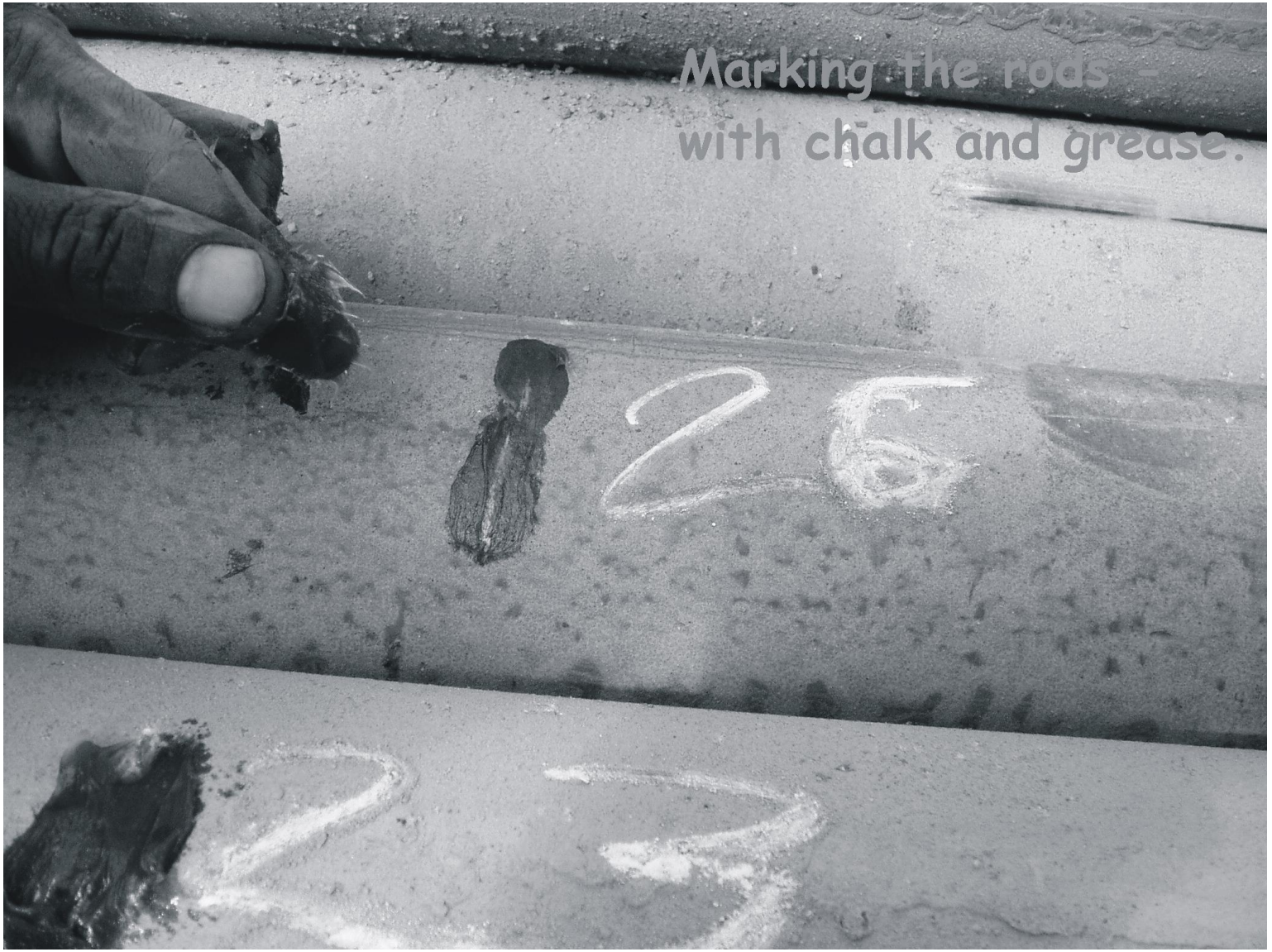
•The contractor must not start till shown the site by clients representative

- Should be clearly marked

•Should be an A (Priority) and a B (Backup) site

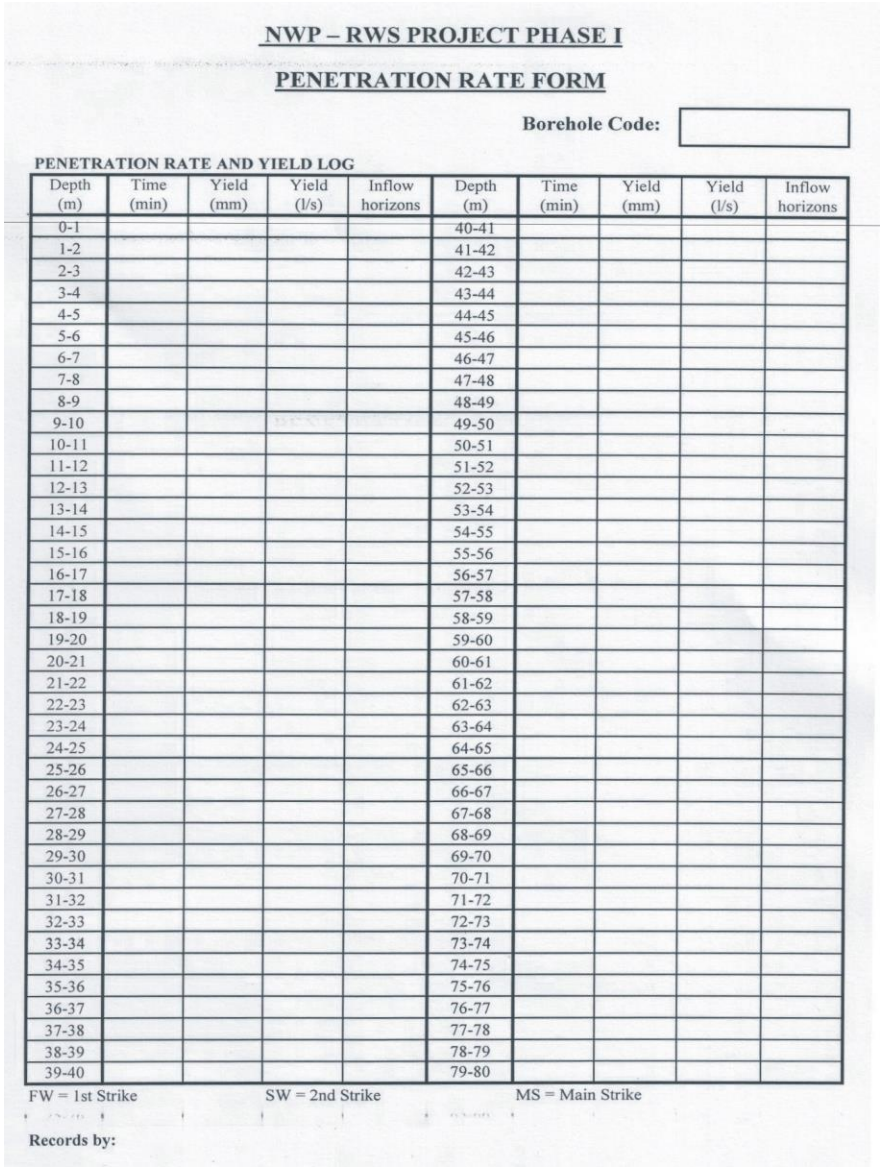
Supervision of Drilling

- GPS location of the drill site
- Mark rods
- Penetration Rates
- V Notch Weir
- Formation sampling and Interpretation
- Marsh Funnel
- DATA - used to design borehole


Marking the roads -
with chalk and grease.

Penetration Rate

- per metre
- Stop Watch
- Relative rates
- Breakdowns



NWP – RWS PROJECT PHASE I

PENETRATION RATE FORM

Borehole Code:

PENETRATION RATE AND YIELD LOG

Depth (m)	Time (min)	Yield (mm)	Yield (l/s)	Inflow horizons	Depth (m)	Time (min)	Yield (mm)	Yield (l/s)	Inflow horizons
0-1					40-41				
1-2					41-42				
2-3					42-43				
3-4					43-44				
4-5					44-45				
5-6					45-46				
6-7					46-47				
7-8					47-48				
8-9					48-49				
9-10					49-50				
10-11					50-51				
11-12					51-52				
12-13					52-53				
13-14					53-54				
14-15					54-55				
15-16					55-56				
16-17					56-57				
17-18					57-58				
18-19					58-59				
19-20					59-60				
20-21					60-61				
21-22					61-62				
22-23					62-63				
23-24					63-64				
24-25					64-65				
25-26					65-66				
26-27					66-67				
27-28					67-68				
28-29					68-69				
29-30					69-70				
30-31					70-71				
31-32					71-72				
32-33					72-73				
33-34					73-74				
34-35					74-75				
35-36					75-76				
36-37					76-77				
37-38					77-78				
38-39					78-79				
39-40					79-80				

FW = 1st Strike SW = 2nd Strike MS = Main Strike

Records by:

Penetration Rate for Mud Rotary

Marsh Funnel

Mud Mixing

Comment

NWP – RWS PROJECT PHASE I

PENETRATION RATE FORM FOR MUD ROTARY DRILLING

Borehole Code:

PENETRATION RATE AND YIELD LOG

Depth (m)	Time (min)	Yield (mm)	Marsh Funnel (seconds)	Mud Mixing Comment	Depth (m)	Time (min)	Yield (mm)	Marsh Funnel (seconds)	Mud Mixing Comment
0-1					40-41				
1-2					41-42				
2-3					42-43				
3-4					43-44				
4-5					44-45				
5-6					45-46				
6-7					46-47				
7-8					47-48				
8-9					48-49				
9-10					49-50				
10-11					50-51				
11-12					51-52				
12-13					52-53				
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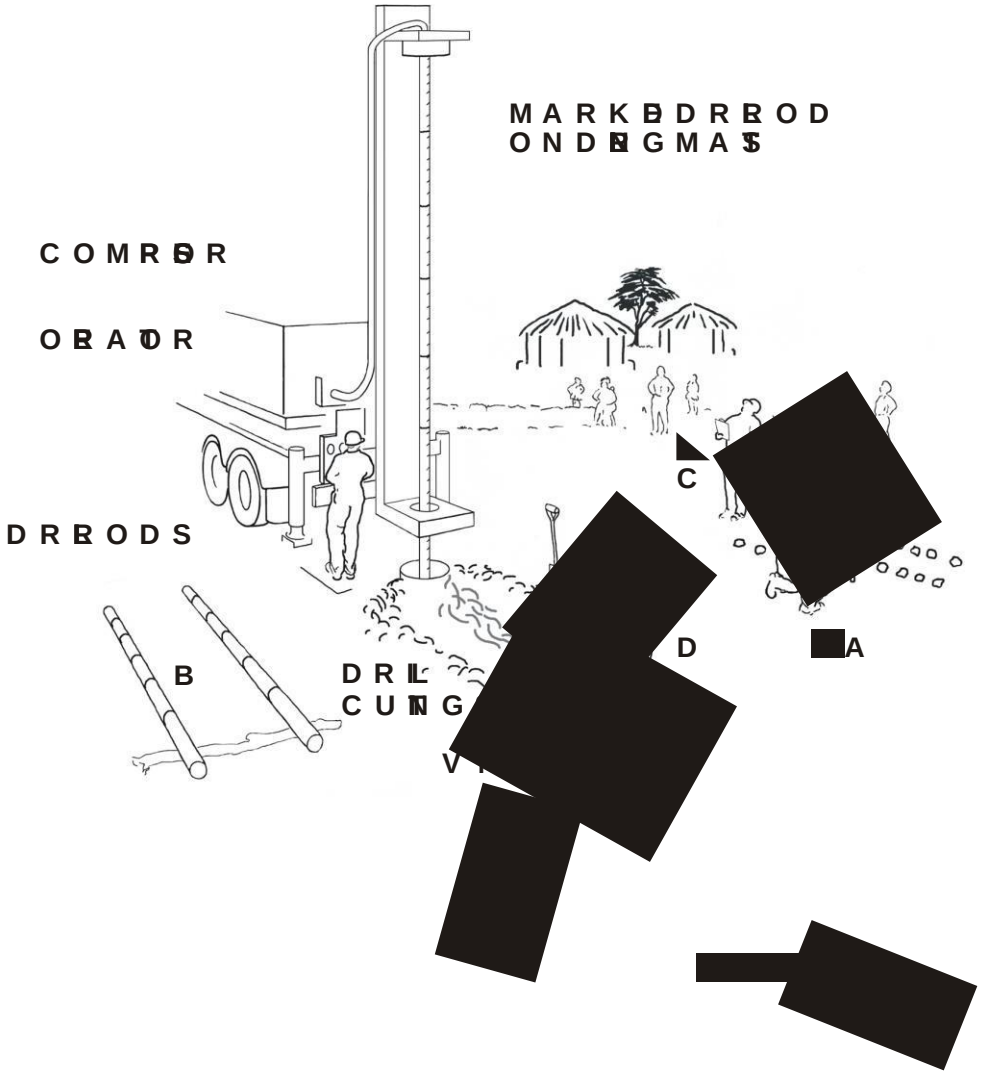
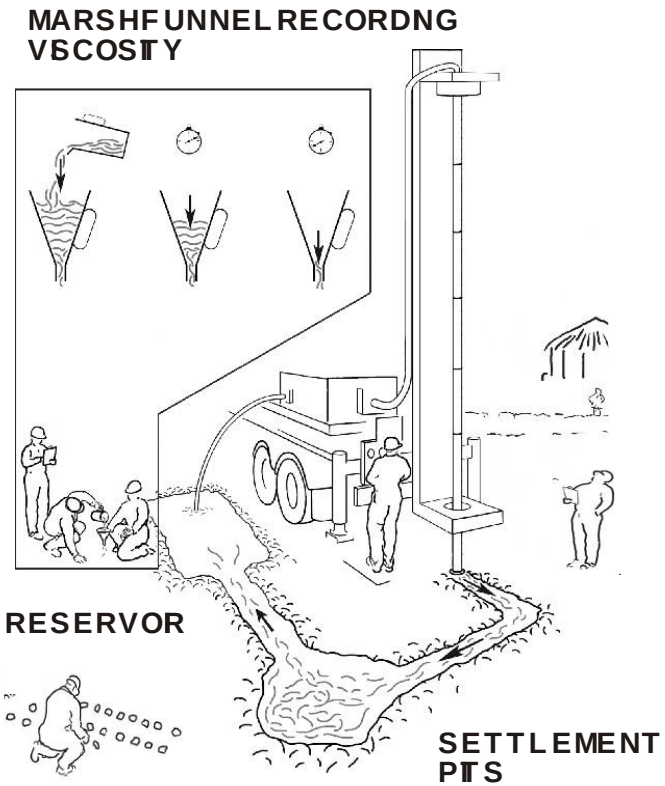
20-21					60-61				
21-22					61-62				
22-23					62-63				
23-24					63-64				
24-25					64-65				
25-26					65-66				
26-27					66-67				
27-28					67-68				
28-29					68-69				
29-30					69-70				
30-31					70-71				
31-32					71-72				
32-33					72-73				
33-34					73-74				
34-35					74-75				
35-36					75-76				
36-37					76-77				
37-38					77-78				
38-39					78-79				
39-40					79-80				

FW = 1st Strike SW = 2nd Strike MS = Main Strike

A calibrated V-notch plate for measuring yield during the drilling process


MARKED DRILL ROD ON DRILL MAST
COMPRESSOR
OPERATOR
DRILL RODS
B
DRILL CUTTING
C
D
A


MARSH FUNNEL RECORDING VISCOSITY
RESERVOIR
SETTLEMENT PITS

A calibrated V-notch plate for measuring yield during the drilling process

Drill Samples Mud Drilling

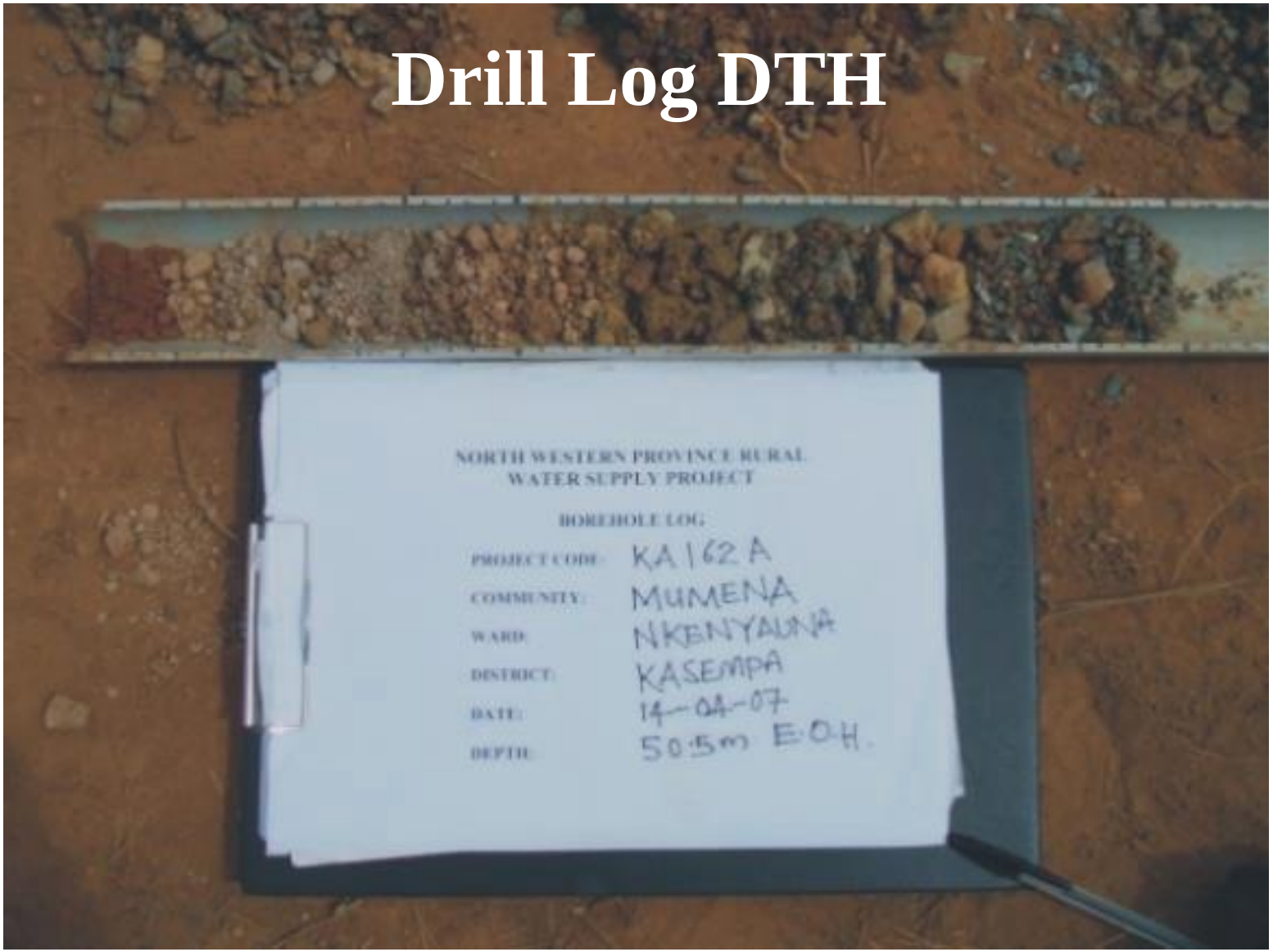
Water Quality

Parameters to be measured on site if water clears

- pH
- EC/TDS
- Iron - If water clears
- Nitrate

Drill Samples DTH

Drill Log DTH

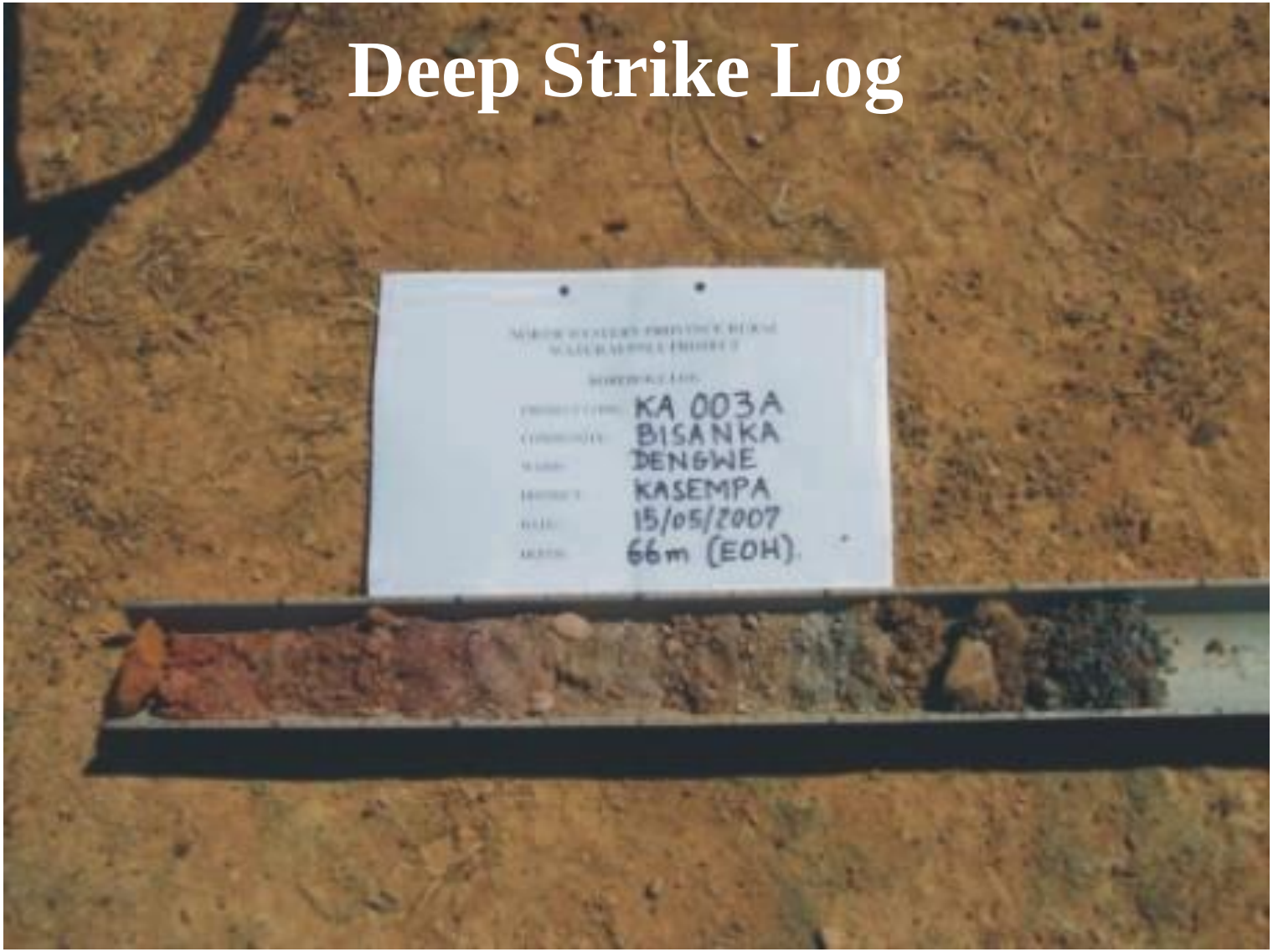


Drill Log


NORTHWESTERN PROVINCE
RURAL WATER SUPPLY PROJECT
BOREHOLE LOG
BOREHOLE CODE: KO 047A
COMMUNITY: SAMUNUNGA
WARD: LULI
DISTRICT: KABOMPO
DATE: 28-08-07
DRILLED DEPTH (EOH): 52 mbgL
DEPTH INSTALLED: 51
ESTIMATED COLLAPSE: 1m

Deep Strike

Deep Strike Log



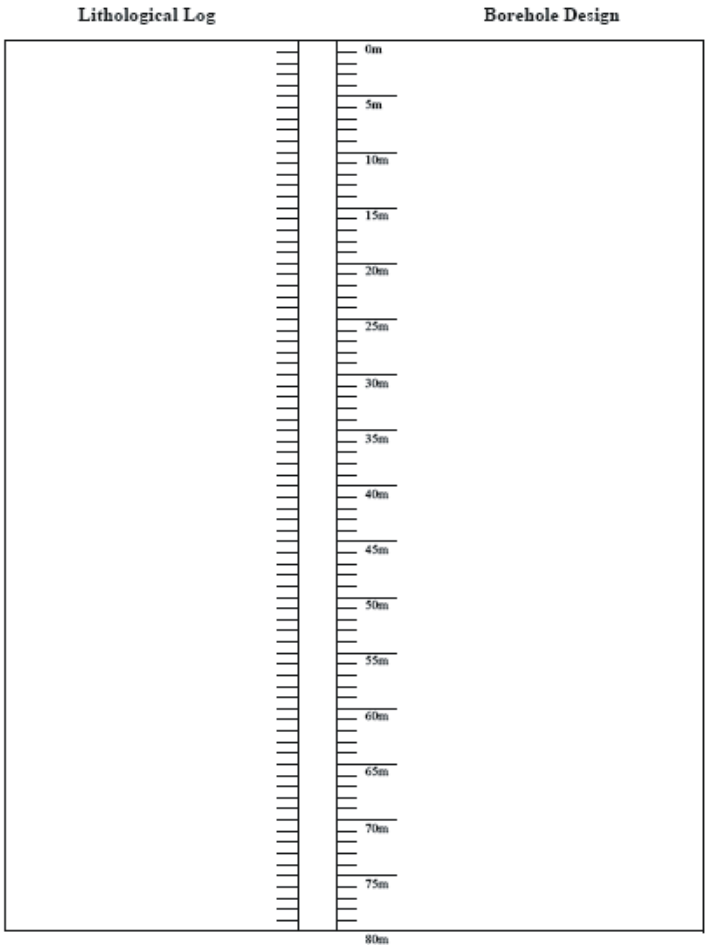
Drill Samples Low Yield

Borehole Graphic

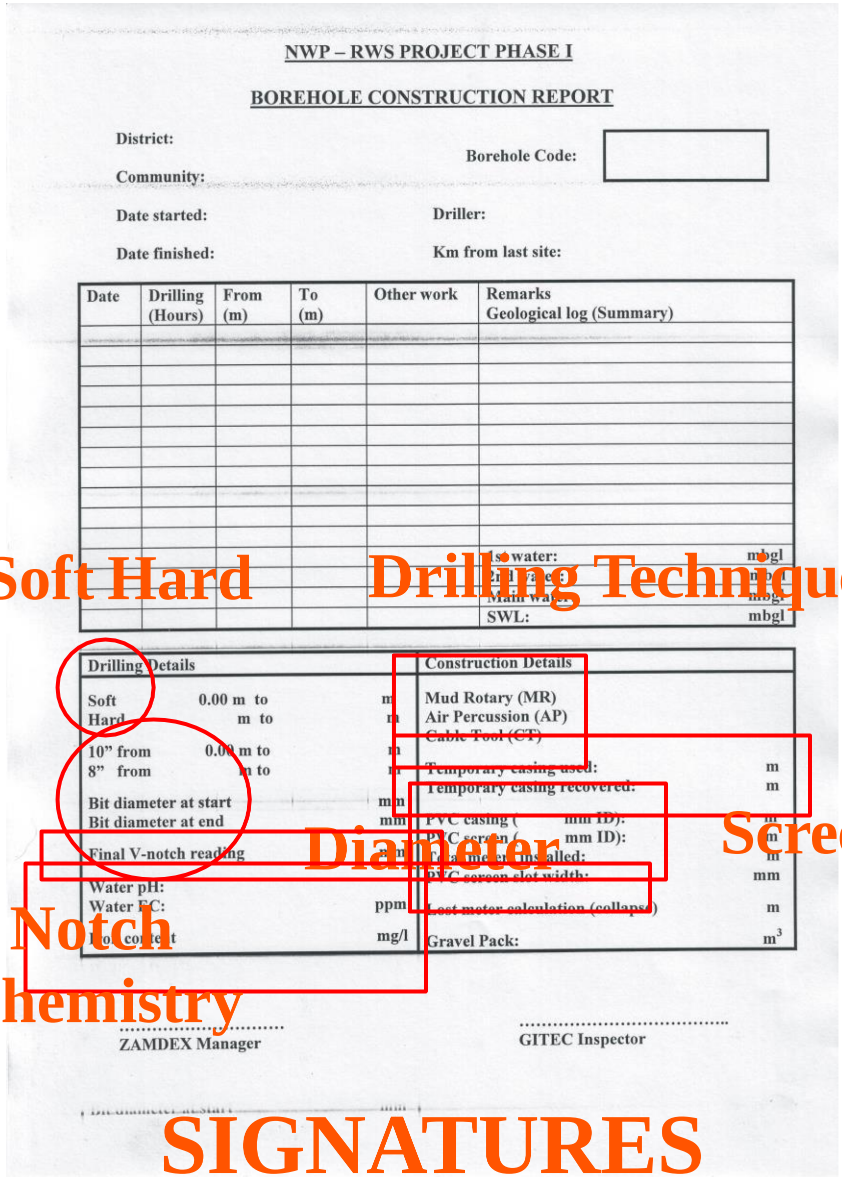
NORTH WESTERN PROVINCE - RURAL WATER SUPPLY PROJECT
BOREHOLE GRAPHIC

DISTRICT | DATE

COMMUNITY | BH CODE



Elements of Borehole Construction Report



NWP – RWS PROJECT PHASE I

BOREHOLE CONSTRUCTION REPORT

District:

Community:

Borehole Code:

Date started:

Driller:

Date finished:

Km from last site:

Date	Drilling (Hours)	From (m)	To (m)	Other work	Remarks Geological log (Summary)
					1st water: mbgl
					2nd water: mbgl
					Main water: mbgl
					SWL: mbgl

Drilling Details		Construction Details	
Soft 0.00 m to	m	Mud Rotary (MR)	
Hard m to	m	Air Percussion (AP)	
		Cable Tool (CT)	
10" from 0.00 m to	m	Temporary casing used:	m
8" from m to	m	Temporary casing recovered:	m
Bit diameter at start	mm	PVC casing (mm ID):	m
Bit diameter at end	mm	PVC screen (mm ID):	m
Final V-notch reading		Total meter installed:	m
		PVC screen slot width:	mm
Water pH:		Lost meter calculation (collapse)	m
Water EC:	ppm		
Iron content	mg/l	Gravel Pack:	m^3

....
ZAMDEX Manager

....
GITEC Inspector

Borehole Design Elements

Physical Elements

- Screen
- Casing - Sump
- Gravel Pack
- End Cap

Borehole Design Factors

- Borehole Efficiency
- Inflow of fine material minimised
- Quality Materials
- Sealed off from contamination
- Allow for 1m Collapse

Borehole Design Balance

- Borehole Efficiency - Flow rate of 0.2l/s
- Inflow of fine material - pack/screen
- Quality Materials - Appropriete

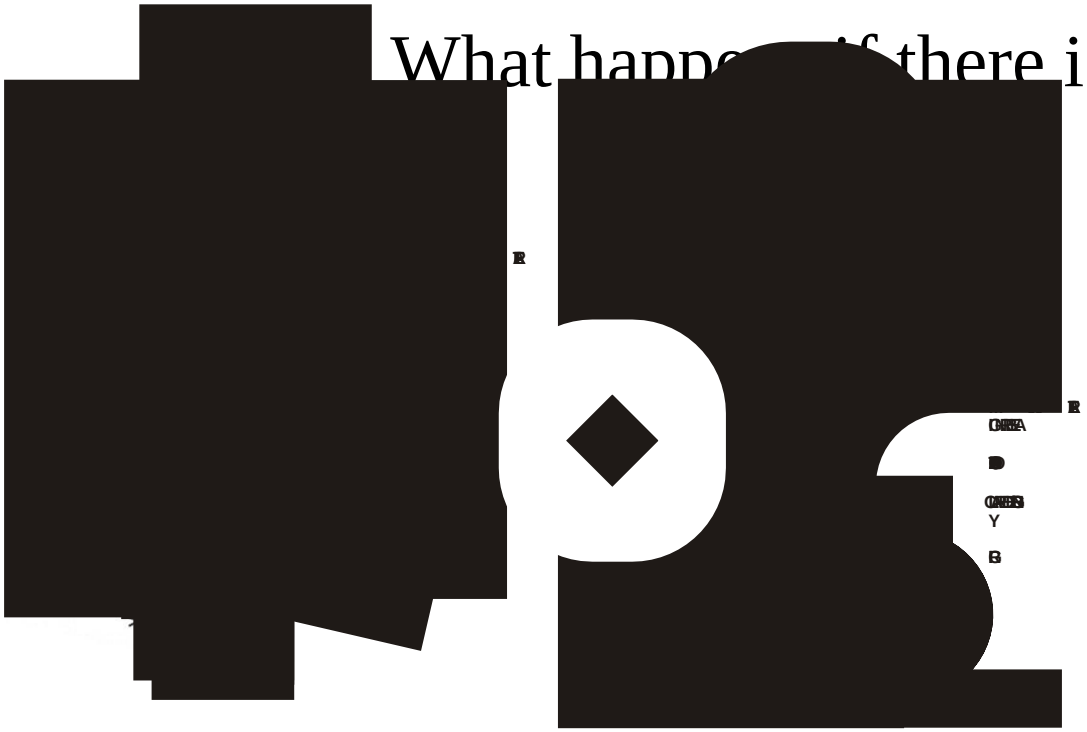
= COST BALANCE =

Borehole Design - Installation

- Gravel Pack and Casing/Screen MUST be on site when drilling is completed
- Borehole can start to collapse immediately
- Check quality of gravel pack and screen
- Take casing screen off lorry and put in order

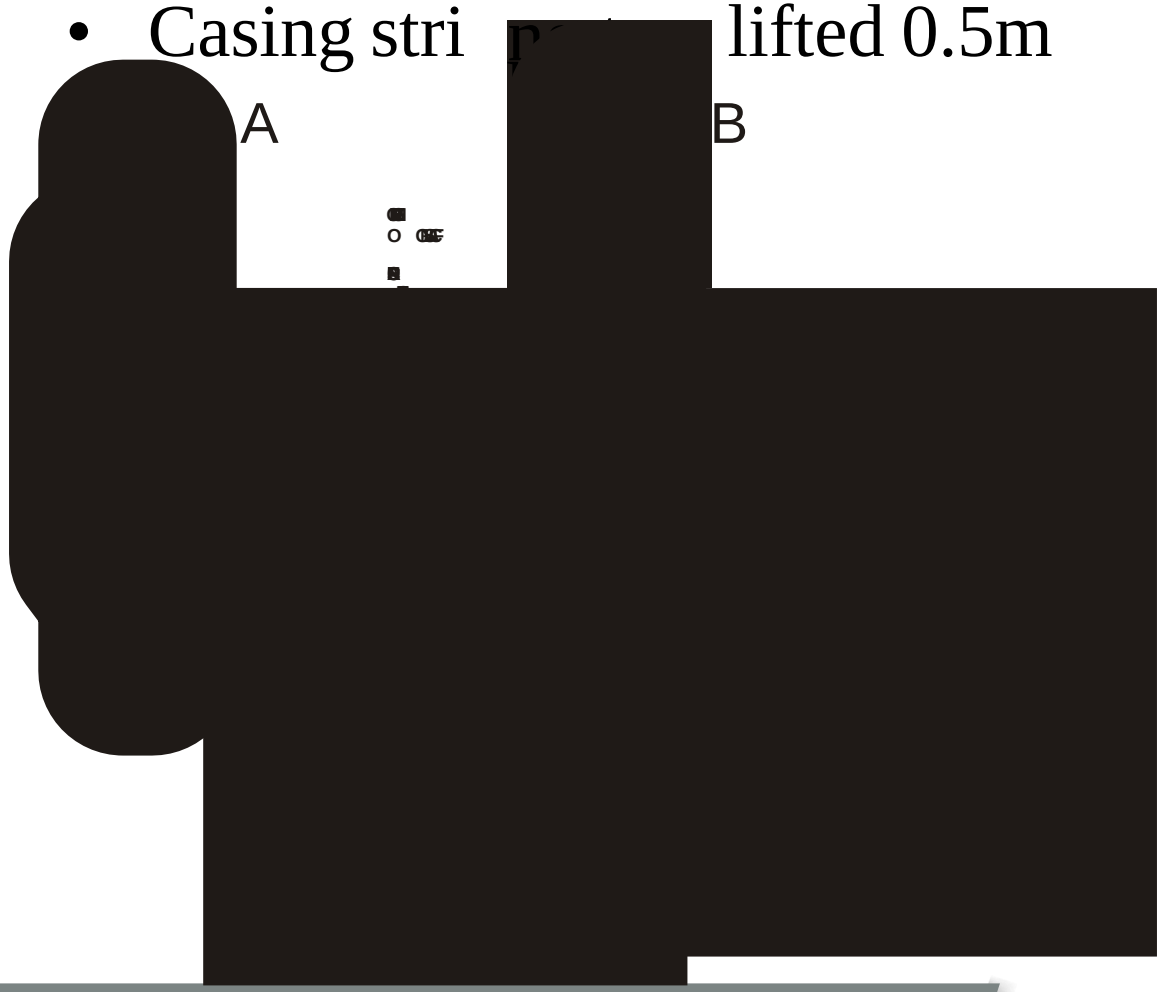
Borehole Installation and Collapse

What happens if there is a collapse?



Casing Must Hang

- Casing stri[illegible] lifted 0.5m



Gravel Pack - Function

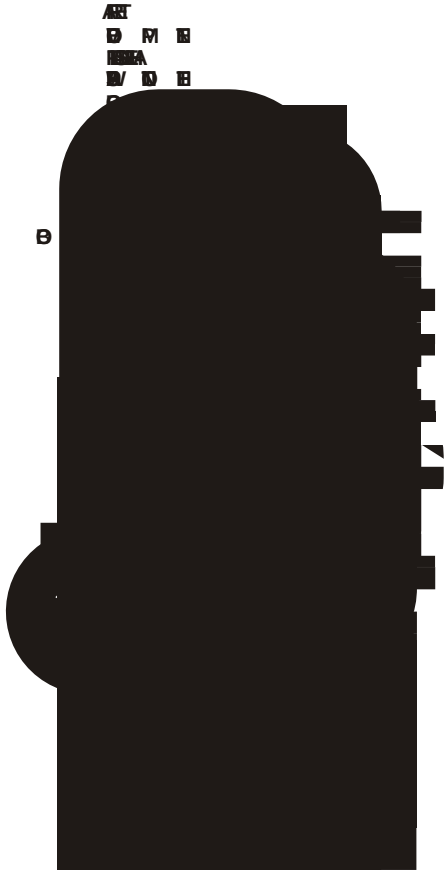
- Filter

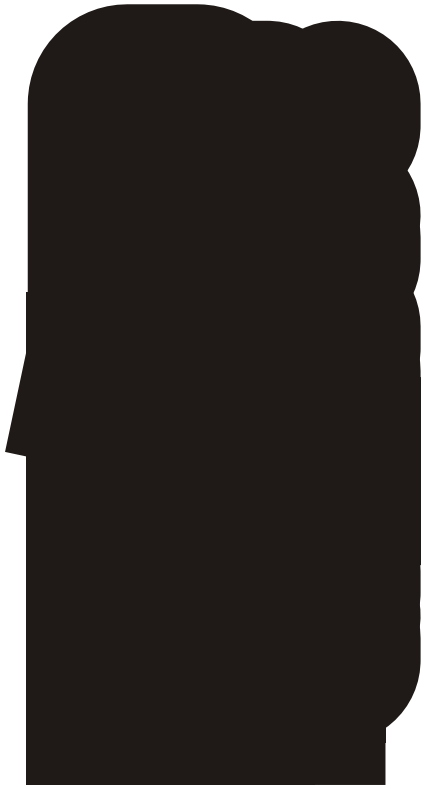
- Formation stabiliser

Gravel Pack

- Material
- Shape
- Size
- Sorting
- Gravel Pack Supply

Gravel Pack - Function



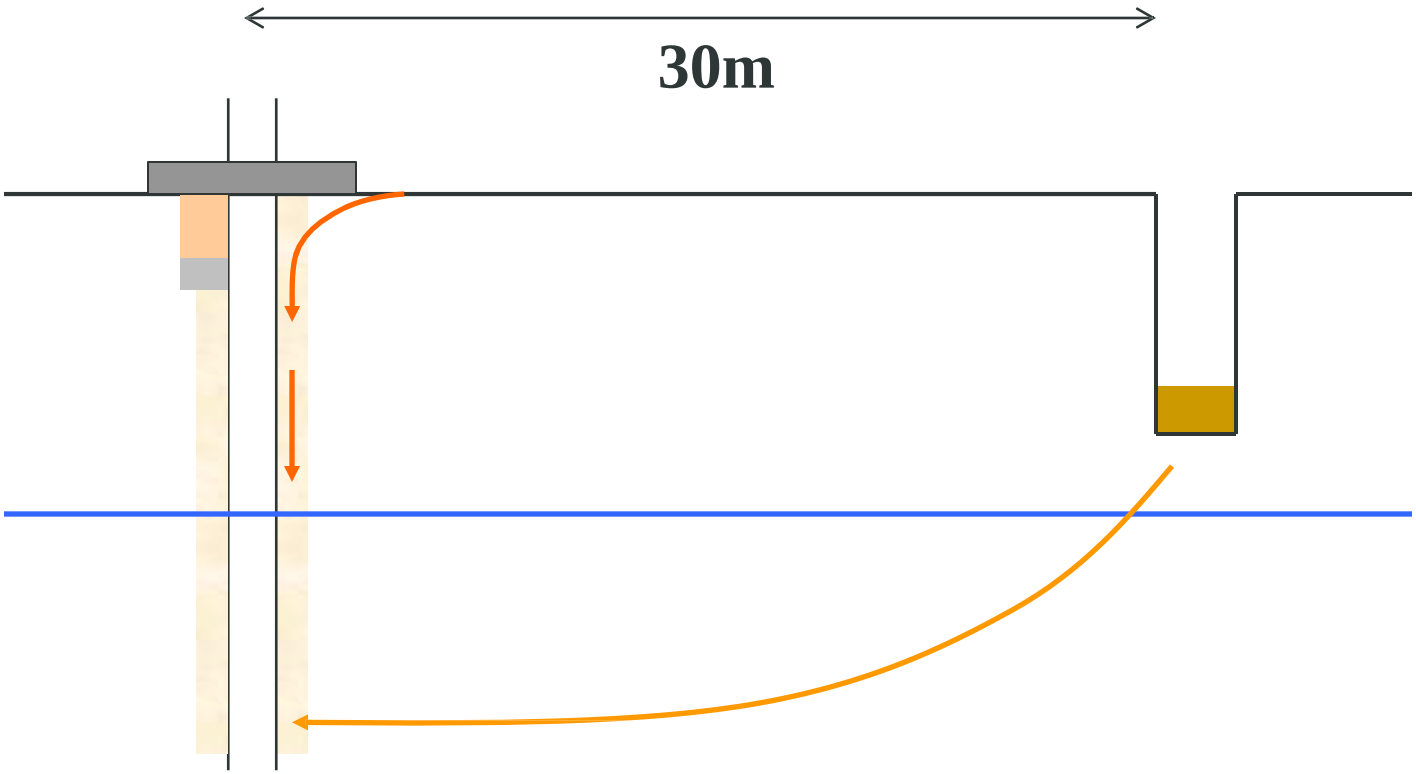


- Formation Stabiliser
- Filter

Gravel Pack in Unstable Formations

Formation Stabiliser

Sanitary Seal



Securing the Borehole

- Why its done

- Implications if its not done

Borehole Design Overview

Borehole Design in Unconsolidated Formations

- All sedimentary and unconsolidated formations 200mm EOH
- Screen and Gravel Pack size must be correct
- Screen and Gravel Pack should be checked before mobilisation

Borehole BoQ

Details Drilling Activities

- Mobilisation
- Borehole Drilling
- Borehole Lining and Installation

Technical Specifications

- Diameter of Borehole
  - EOH
  - Telescoping

ANNULAR SPACE

- Sedimentary section min - 200mm
- Hard Rocks EOH - 165 to 176mm

Verticality and Alignment

- Casing must allow installation without obstruction
  - Can seriously effect pump
  - 3m Dummy
- If not vertical contractor either fix or drill new BH

Protection/Temporary Casing

- Installed in unstable formations
- Steel tube of sufficient diameter
- Removable
- Should install gravel pack before pulling out temporary casing

Borehole Tricks

- Invoicing twice
- Mobilisation for combination holes
- Depth of borehole
- Drilled formation
- Dry holes
- Poor quality civil works

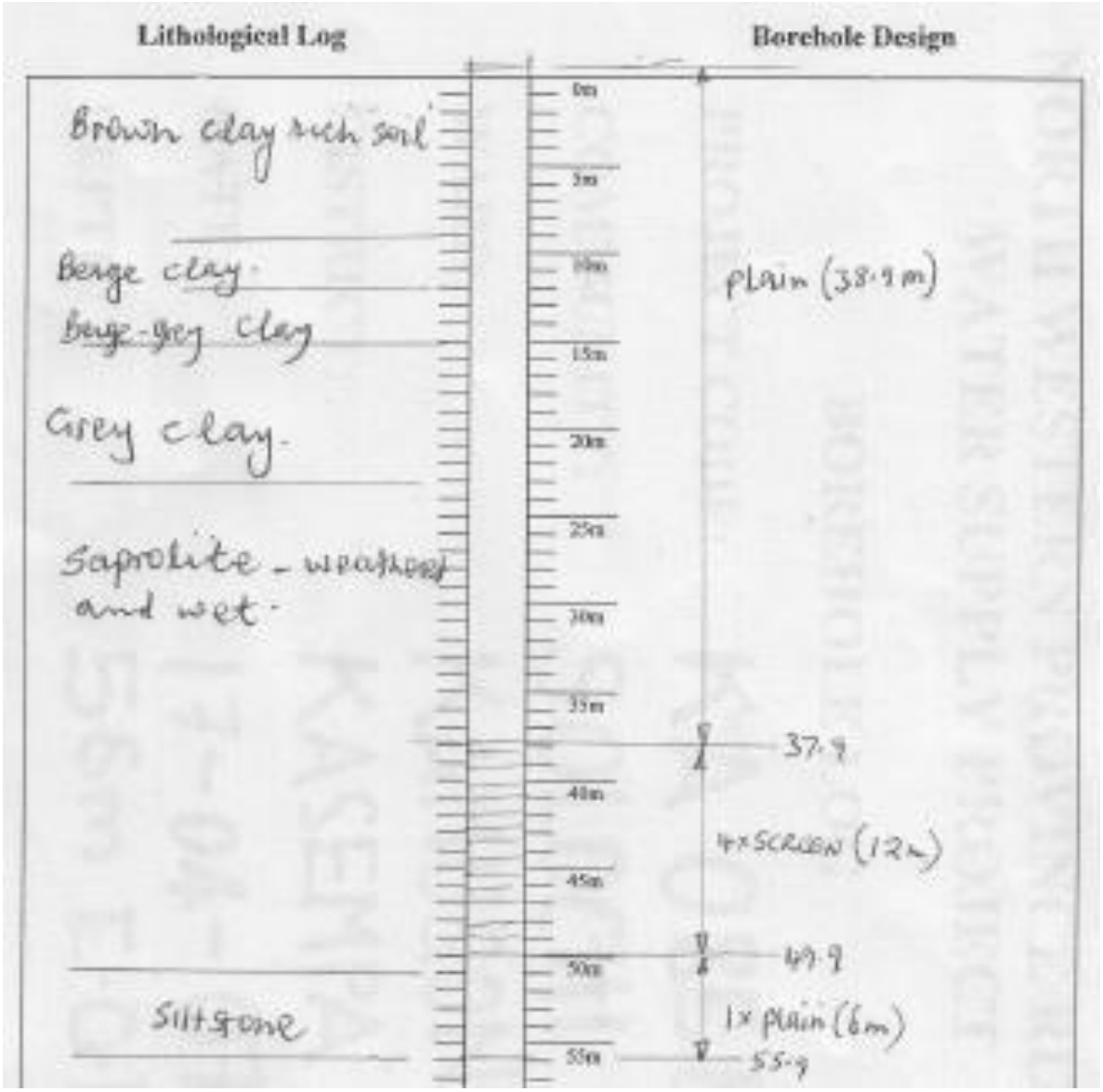
Borehole Supervision and Community Participation

- Essential to involve community
- Supervision of drilling contractors
- Supervision of test pumping
- Supervision of civil works construction

Borehole Design

- This is done on site before the end of drilling
- Make sure of casing/screen dimensions
- Remember the end cap
- Draw it out and double check

Borehole Data for Design



Borehole Data for Design

BOREHOLE CONSTRUCTION REPORT

District: KASEMPA

Borehole Code: KA 085 B.

Community: SOLOCHI

Date started: 17/04/2007

Driller: YADIAH

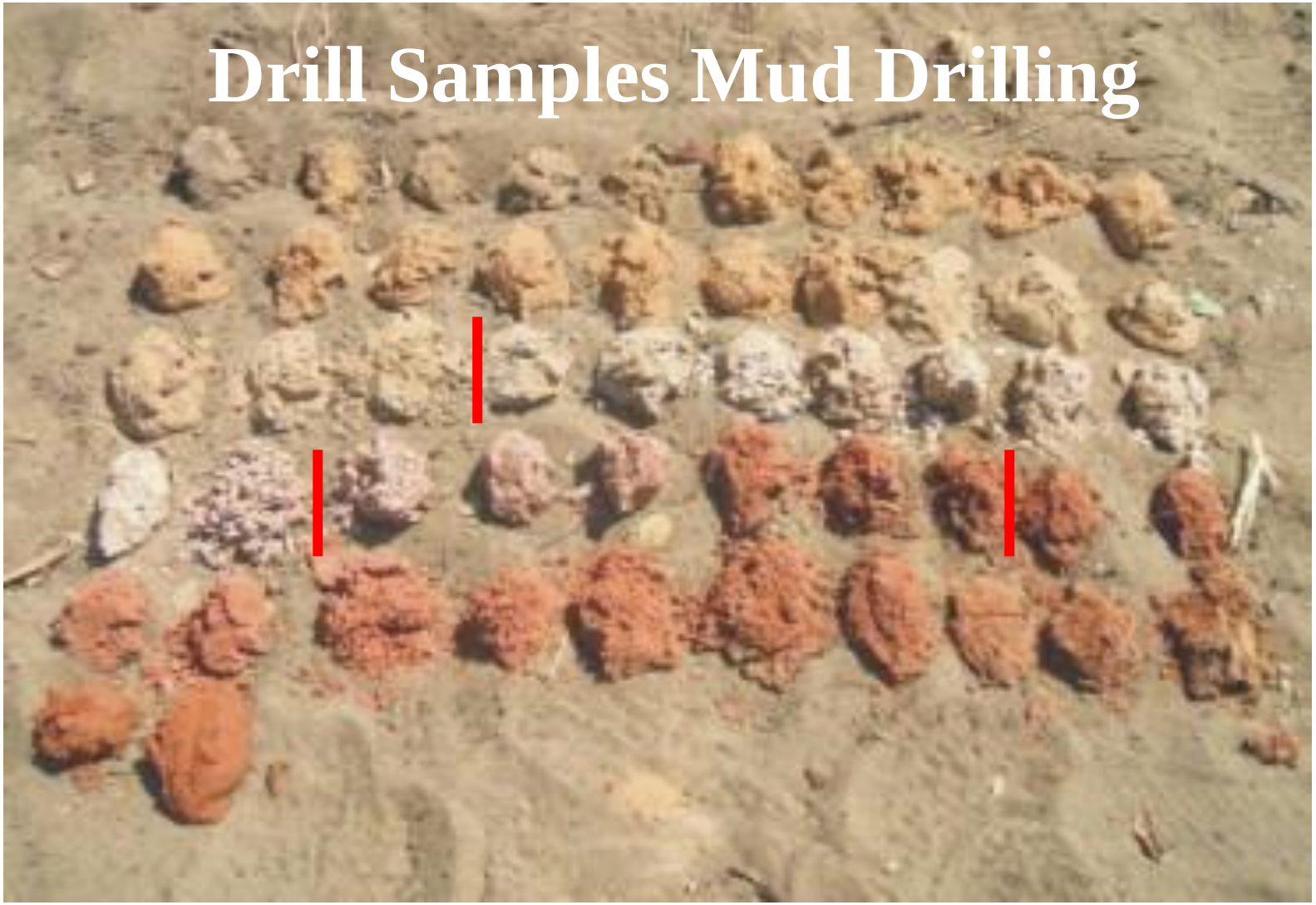
Date finished:

Km from last site: 24 Km.

Date	Drilling (Hours)	From (m)	To (m)	Other work	Remarks Geological log (Summary)
		0	9		Brown top with Soil
		10	15		Beige clay.
		16	23		Grey clay.
		24	51		upper saprolite
		52	56		Siltstone
		24			Start of Saturated zone.
					1st water: 24 mbgl
					2nd water: 38 mbgl
					Main water: 43 mbgl
					SWL: mbgl

Drilling Details			Construction Details		
Soft	0.00 m to	56 m	Mud Rotary (MR)		
Hard	m to	m	Air Percussion (AP) DTH		
			Cable Tool (CT)		
10" from	0.00 m to	56 m			
8" from	m to	m	Temporary casing used:	–	m
			Temporary casing recovered:	–	m
Bit diameter at start		254 mm			
Bit diameter at end		254 mm	PVC casing (4" mm ID):	43.9	m
			PVC screen (4" mm ID):	12	m
Final V-notch reading		mm	Total meters installed:	56.9	m
			PVC screen slot width:	0.5	mm
Water pH:					
Water EC:		ppm	Lost meter calculation (collapse)		m
Iron content		mg/l	Gravel Pack: 180 buckets		m^3

Drill Samples Mud Drilling



NORTH WESTERN PROVINCE RURAL WATER SUPPLY PROJECT - BOREHOLE COMPLETION REPORT

CODE		
KA 119A	Name:	Sota
	Ward:	Mpungu
	District:	Kasempa
	Depth(m):	65
	Drilling date:	28-Apr-07
Coordinates:	(Decimal Degrees, Arc1950)	
Easting:	26.02748	
Southing:	13.64935	

S - Soil (laterite, sand)
W - Weathered Bedrock
Fi - Fine Grained Rock (Mudstone\Siltstone)
Fc - Fresh Crystalline Rock (Granite, Gneiss)
UnS - Unconsolidated Sand
CoS - Consolidated Sand
Mix - Mictite

ClS - Clay rich sand
Oth - Other

PVC plain casing (Incl
PVC slotted casing
Cement sanit
Formati

Lithological Profile and Well Design