Review of Borehole Failures: Causes and Remedies

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REVIEW OF BOREHOLE FAILURES: CAUSES AND REMEDIES

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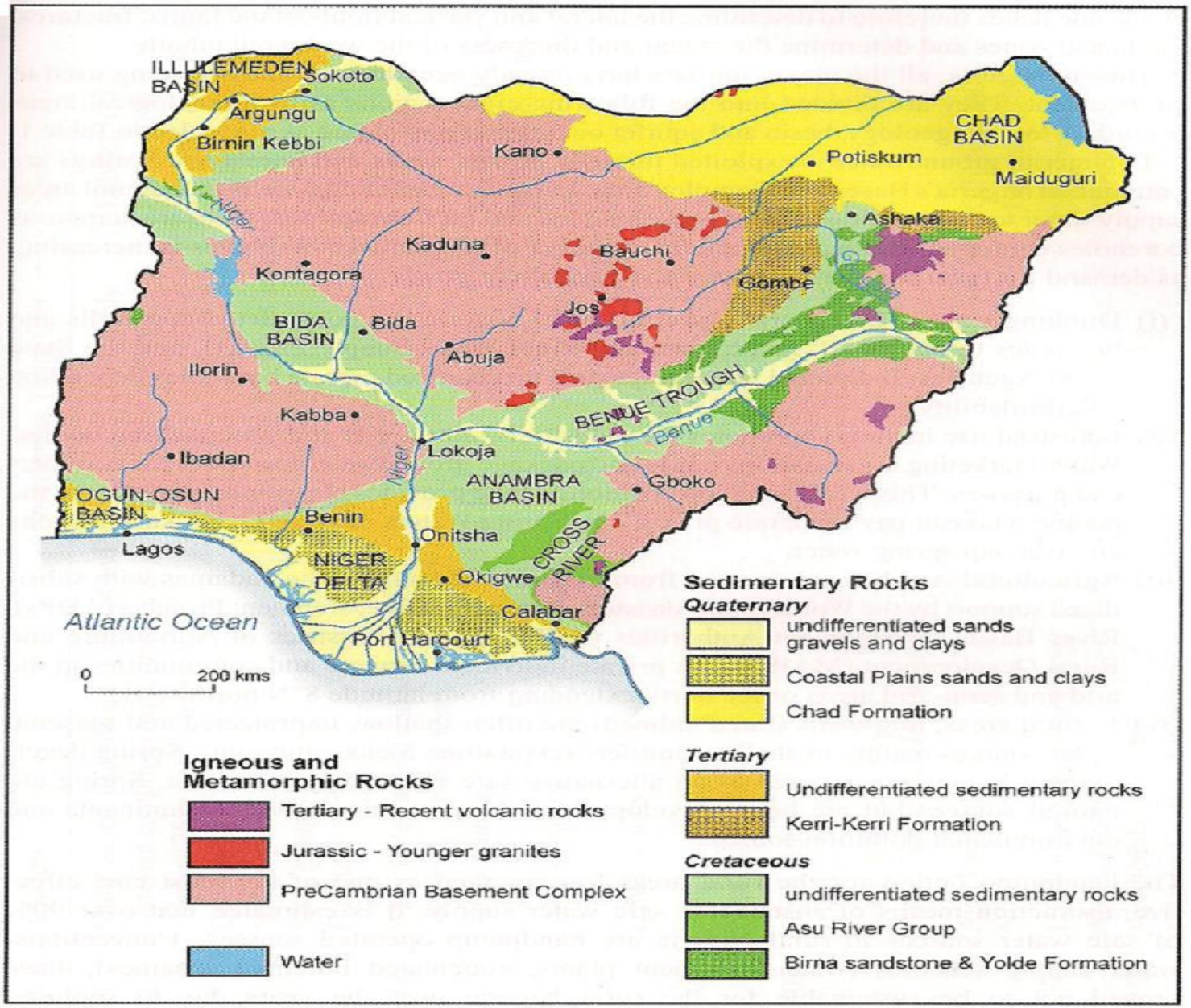
2017 NATIONAL CONVENTION OF ASSOCIATION OF WATER WELL DRILLING RIG OWNERS AND PRACTITIONERS (AWDROP)

HELD AT THE NATIONAL WATER

FEBRUARY 16, 2017

The Groundwater Regimes in Nigeria



National Borehole programmes:

- National Borehole Programme (1981) of President Shagari's Civilian Adminstration;
- Directorate of Food, Roads and Rural Infrastructure (DFRRI) Rural Water Supply Programme (1986 – 1992) of General Babangida's Military Government;
- Petroleum Trust Fund (PTF) Rural Water Supply Programme (1996 – 1998) of General Abacha's Military Government;
- Improved Access to Water Supply and Sanitation Programme (2000 – 2001) of President Obasanjo's Civilian Administration;
- National Rural Water Supply and Sanitation Programme through the MDGs Office (2010 – 2015) of Yar'Adua – Jonathan Administration
- Partnership for Expanded Water, Sanitation and Hygiene (PEWASH)– (2016 – date) of PMB

- In groundwater resources management, identifying the factors responsible for borehole failure is the first step towards strategic planning for sustainable borehole use and remedial measures.

- Water well problems result from many causes: including equipment failure, geological/geophysical constraints, depletion of the aquifer, corrosive qualities of the water and improper well design and construction. Correctly identifying the cause enables you to select appropriate treatment or maintenance to fix the problem rather than abandon the well

Borehole failure: classification:

(Inability to achieve minimum water requirement in terms of quality & quantity)

- 1. Inappropriate Design and Construction:
  - Improper well design and construction
  - Incomplete well development

2. Groundwater potential and Hydrogeological factors:
   - Poor groundwater potential, Borehole stability problems,
   - Incrustation build-up
   - Biofouling
   - Corrosion
   - Aquifer problems (low recharge, seasonal water level variations due to climatic factors, over-pumping called groundwater mining)

3. Operation and Maintenance Challenges:
   (Equipment and Personnel-related problems)

- The integrity of drilling equipment and its maintenance are major factors in minimizing drilling problems plus the "human" element.

- **Improper well design and construction**
  When designing a well, the licensed water well contractor must match the type of well construction with the characteristics of the producing aquifer. Decisions must be made about:
- Perforated well casing/liner vs. well screen (see Figure 1, Perforated Well Liner and Well Screen)
- Slot size of well screen
- Placement of well screen or perforated liner
- Size and amount of gravel pack around the well screen (if required)
- Location of the pump in the well (pump setting).
- If poor choices are made, you may experience problems with sediment in your water or reduced well yield. Regulations require that a well must be completed to ensure no damage will be incurred to the pumping system, plumbing or fixtures due to sediment in the water.

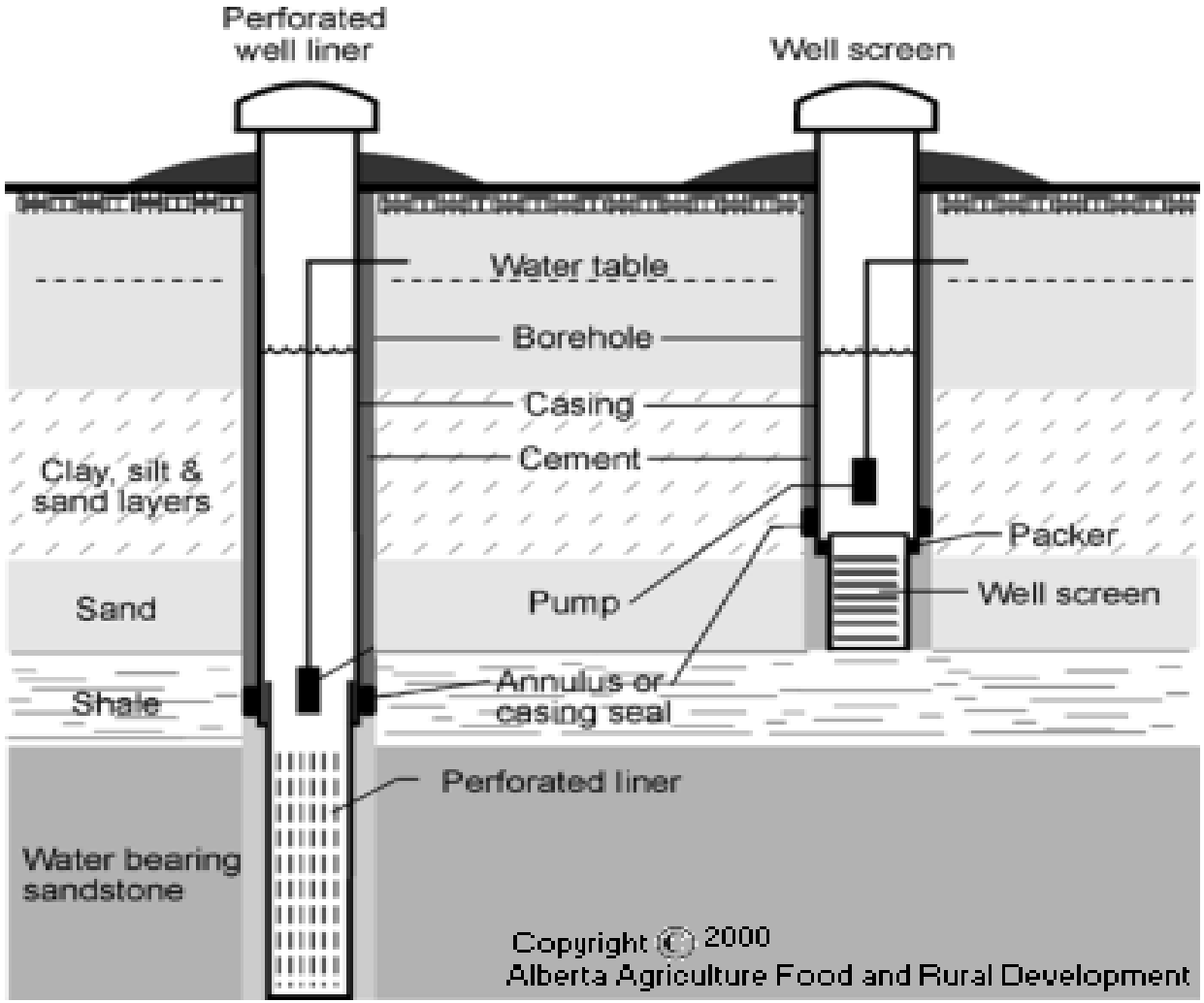


Fig. 1. *Perforated Well Liner and Well Screen*

- **Mineral incrustation**

  Mineral incrustation is a common problem in some shallow water table type aquifers where there is an abundance of dissolved minerals including calcium, magnesium and iron, as well as iron bacteria. When water is pumped from the well, changes in pressure and temperature occur. This creates ideal conditions for minerals to precipitate or settle out, causing scale formation on the casing, liner and screens. A combination of good preventive maintenance and good management practices can minimize the effect of incrustation. Management practices that reduce water pumping rates can reduce the effects of mineral incrustation. A strategy of reduced pumping rate with longer pumping intervals helps prevent incrustation of screens and perforated liners.

- **Biofouling**
  Installing and pumping a well increases the level of oxygen and nutrients in the well and in the surrounding aquifer. Bacteria, such as iron bacteria, may thrive under these conditions. They can form a gel-like slime or biofilm that captures chemicals, minerals and other particles such as sand, clays and silts. Minerals, such as iron, oxidize and get trapped in the biofilm. "Biofouling" occurs where biofilm accumulations are sufficient to reduce water flow. This can mean reduced well yield and water quality.
- Shock chlorination is effective as a regular maintenance technique to kill bacteria and limit its ability to create biofilm. However, shock chlorination is not effective at penetrating biofilm. If biofilm buildup is suspected, the introduction of appropriate chemicals and physical agitation is required to remove the biological plugging material.

- **Corrosion**
  Chemical substances found in water can eat away or corrode metal well casings. To avoid corrosion, the licensed water well contractor must choose a casing material that is suitable for the water supply. For example, licensed water well contractors usually select plastic casing liners and stainless steel well screens for corrosive water. Sulfate-reducing bacteria can also cause corrosion. Shock chlorination can keep these bacteria in check.

  Over-pumping
  A well is over-pumped if water is withdrawn at a faster rate than the well was designed for or the aquifer is able to produce. Over-pumping is the most common well problem that leads to premature well failure. Over-pumping not only depletes the groundwater aquifer (or source), but it rapidly increases the rate of corrosion, incrustation and biofouling related problems. Over-pumping also increases the rate of sediment particles moving toward the well, causing plugging of the perforated area where water flows into the well. It can also cause the aquifer to settle and compact which further restricts water flow to the well.

- **Dissolved Gas in Water**

  The presence of gas in water wells occurs in some places. Oxygen, carbon dioxide, nitrogen, methane and hydrogen sulphide may occur naturally in some of the aquifers in which water wells are drilled (e.g. coal seams, fractured shales and sandstones). When gas is present, it is held in groundwater under pressure. Pumping water wells completed in such aquifers can reduce the pressure, releasing the gas. Sometimes gas in groundwater can affect the operation of your well. Even if gas is present, it may still be possible to use your well in a safe manner.

- **Aquifer Problems**
  While most well problems are related to the construction, development or operation of the well, the formation can also be a source of problems. Reduced aquifer yield can be caused by lack of recharge. For example, the amount of water withdrawn can exceed the recharge from rain and snow melt. This is referred to as "mining the aquifer". Sometimes the decline in water level is seasonal. Typically water levels are higher in rainy season and lower in the dry season. Extended dry periods can also impact water levels, especially in shallow water table type aquifers. Checking the water level in your well is an important maintenance procedure. You will be able to identify water level trends and identify well problems or aquifer depletion before the problem becomes serious.

- **Difficult geological terrains** pose a challenge to groundwater exploitation. Groundwater is usually the first option to be considered for water supply and in most cases, the exploration and exploitation encounter very challenging terrains, especially in some areas underlain by Crystalline Basement rocks. For example, to meet the minimum yield requirement of 15 l/min for handpump boreholes in some parts of the Basement Complex of Northern Nigeria, has become a difficult task to achieve due to the poor permeability of the Formations.
- **Uncoordinated and unregulated development** of groundwater may result in water quality issues which appear when the scale of the problem has reached a catastrophic level. The case of high concentration of Lead (Pb) and other radioactive compounds in groundwater due to informal mining activities in some communities in zamfara and Niger States provides a good example.

A CASE EXAMPLE OF FUNCTIONAL STATUS OF BOREHOLES IN FCT (64%)

	Gwagwalada A.C.	Kuje A.C.	A.M.A.C.	Abaji A.C.	Bwari A.C.	Kwali A.C	Total No.
No. of funct. BH	62	135	45	97	11	8	358
No. of non-funct. BH	42	74	21	11	27	23	198
Total No. of BH	**104**	**209**	**66**	**118**	**38**	**31**	**556**
No. of HP BH	39	25	26	38	19	20	167
No. of BH (Electric/ Solar)	65	184	40	70	19	11	389

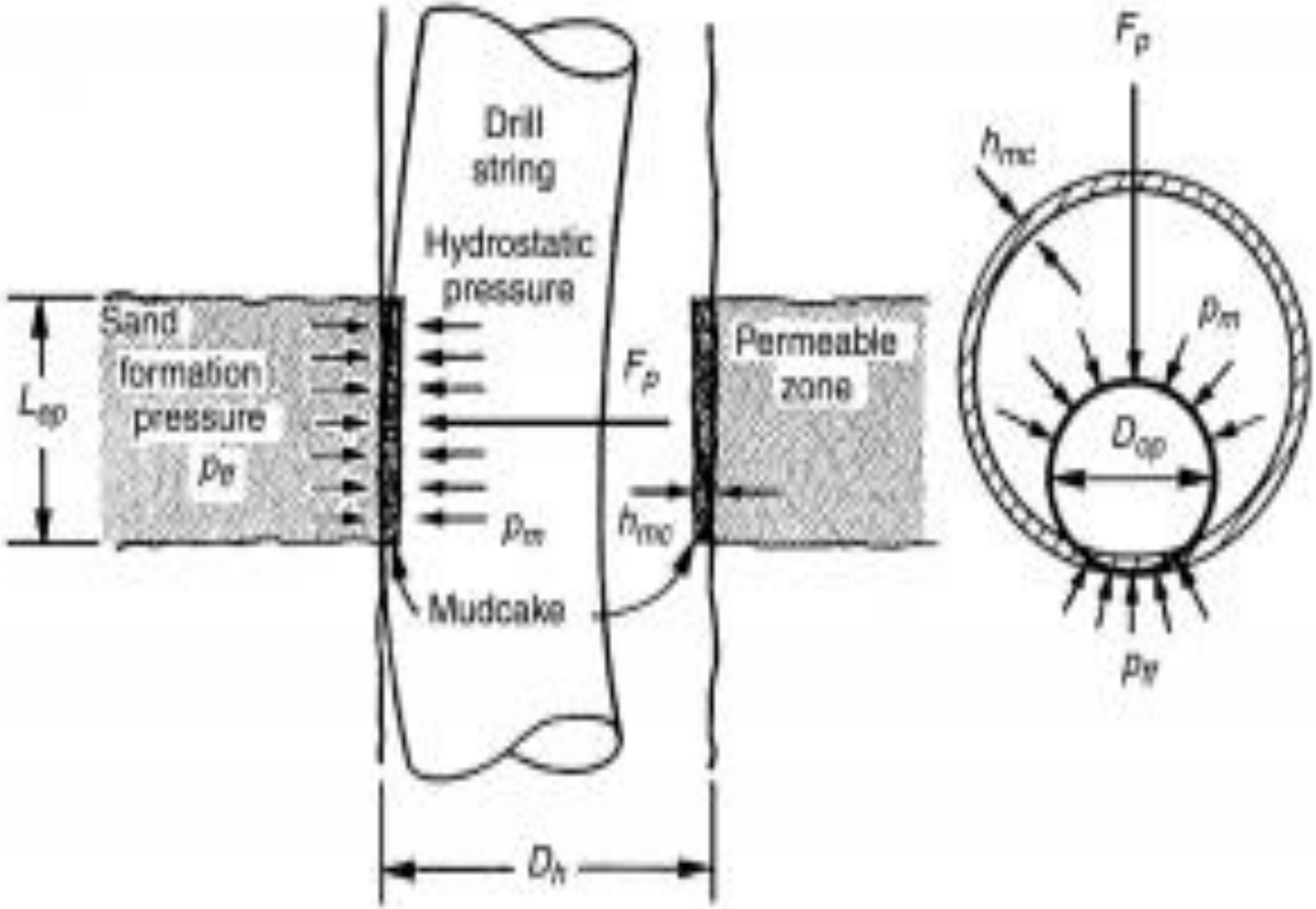
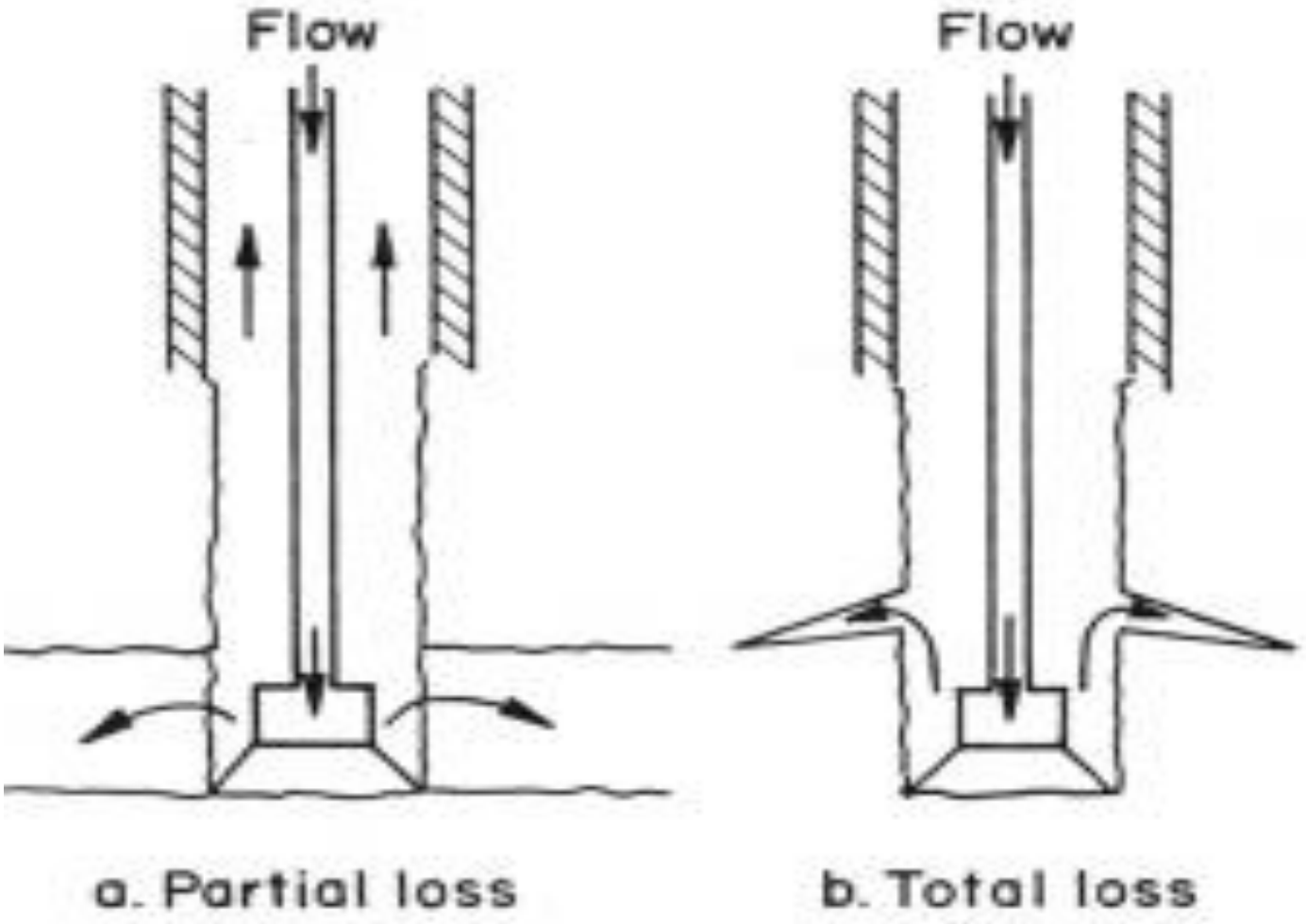


Fig. 2. Pipe sticking (stuck pipe)



- Fig. 3. Loss of Circulation

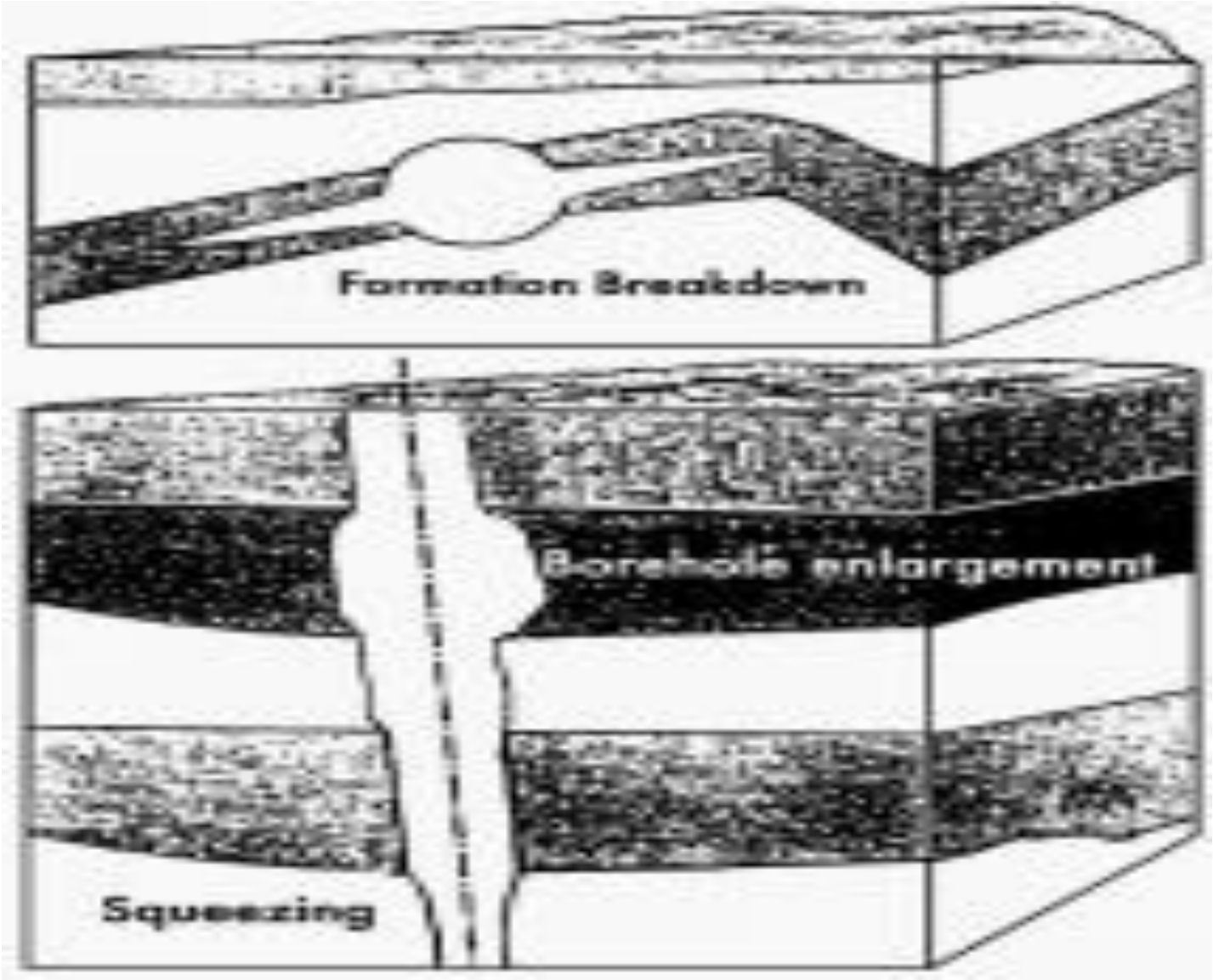
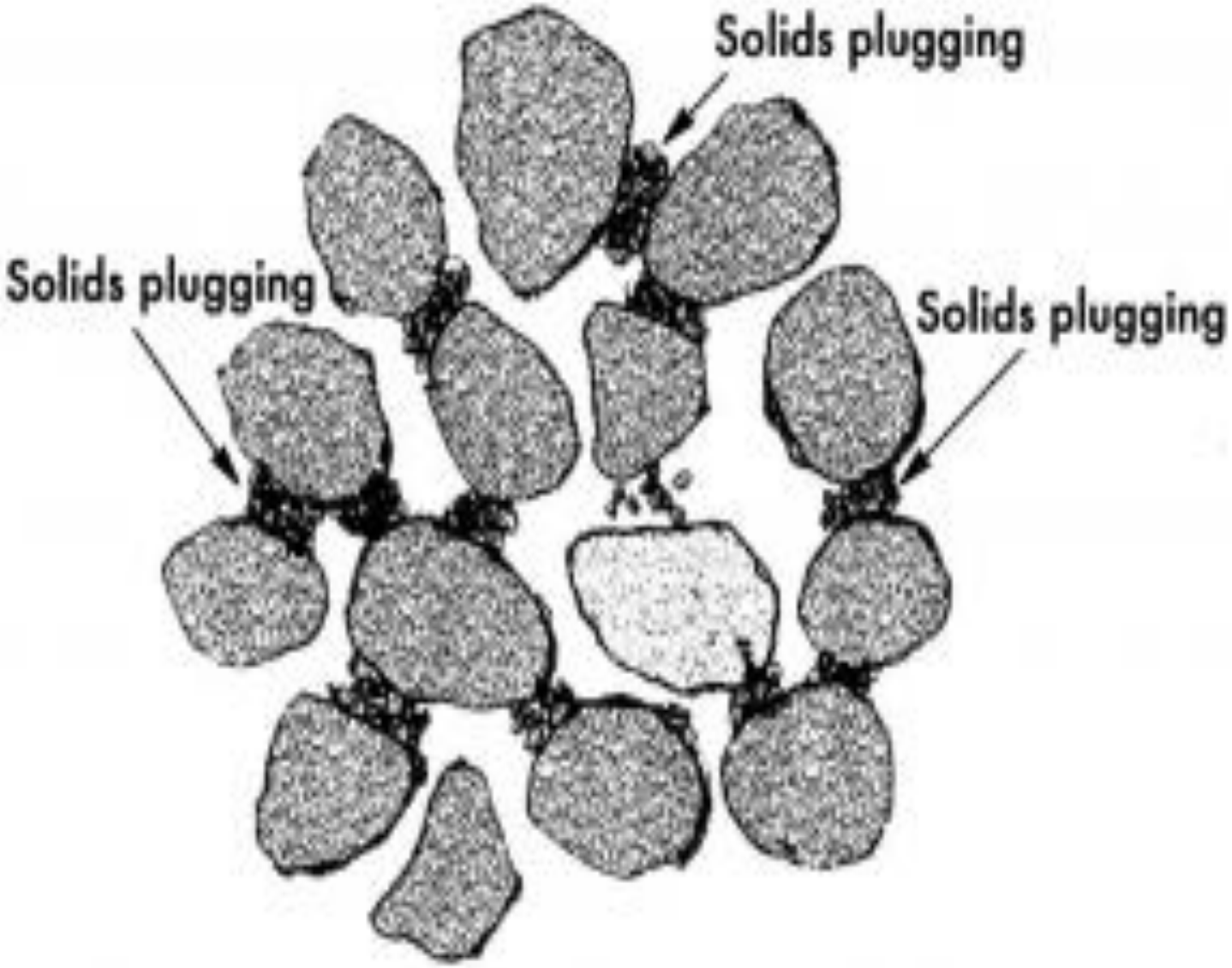


Fig. 4. Hole instability & drill pipe failures (Oturkpo case)



- Fig. 5. Formation damage & Mud contamination

Operation and Maintenance Factors:

- Equipment and Personnel-Related Problems
- **Equipment**
- The integrity of drilling equipment and its maintenance are major factors in minimizing drilling problems. Proper rig hydraulics (pump power) for efficient bottom and annular hole cleaning, proper hoisting power for efficient tripping out, proper derrick design loads and drilling line tension load to allow safe overpull in case of a sticking problem, and well-control systems (ram preventers, annular preventers, internal preventers) that allow kick control under any kick situation are all necessary for reducing drilling problems. Proper monitoring and recording systems that monitor trend changes in all drilling parameters and can retrieve drilling data at a later date, proper tubular hardware specifically suited to accommodate all anticipated drilling conditions, and effective mud-handling and maintenance equipment that will ensure that the mud properties are designed for their intended functions are also necessary.
-
- **Personnel**
- Given equal conditions during drilling/completion operations, personnel are the key to the success or failure of those operations. Overall well costs as a result of any drilling/completion problem can be extremely high; therefore, continuing education and training for personnel directly or indirectly involved is essential to successful drilling/completion practices.

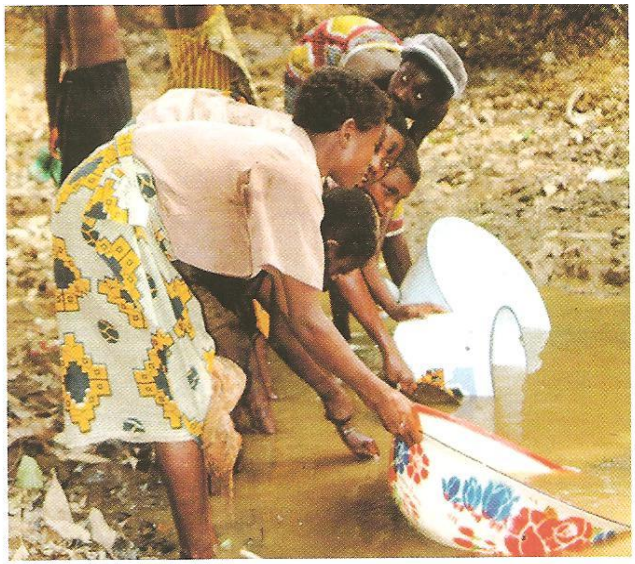
- **Lack of Community Ownership** of rural water supply schemes has been a major threat to operation and maintenance coupled with the non-involvement of women in planning and implementation of rural water supply projects (Dan-Hassan, 2001).
- **Technical Challenges** due to inappropriate technology for exploration and exploitation of the groundwater resource. This includes inadequate participation of professionals, issues of epileptic power supply, high cost of diesel fuel for electric generators, inappropriate sizing of solar panels/pumps, etc.

- The frequent **vandalism** and **theft** of borehole water scheme components have been militating against the smooth operation and maintenance of rural water supply facilities. Therefore, there is the need to provide extra security measures and components to the borehole facility in order to ensure safety and sustainability of the water scheme.

Wrong Design concept and inappropriate technology

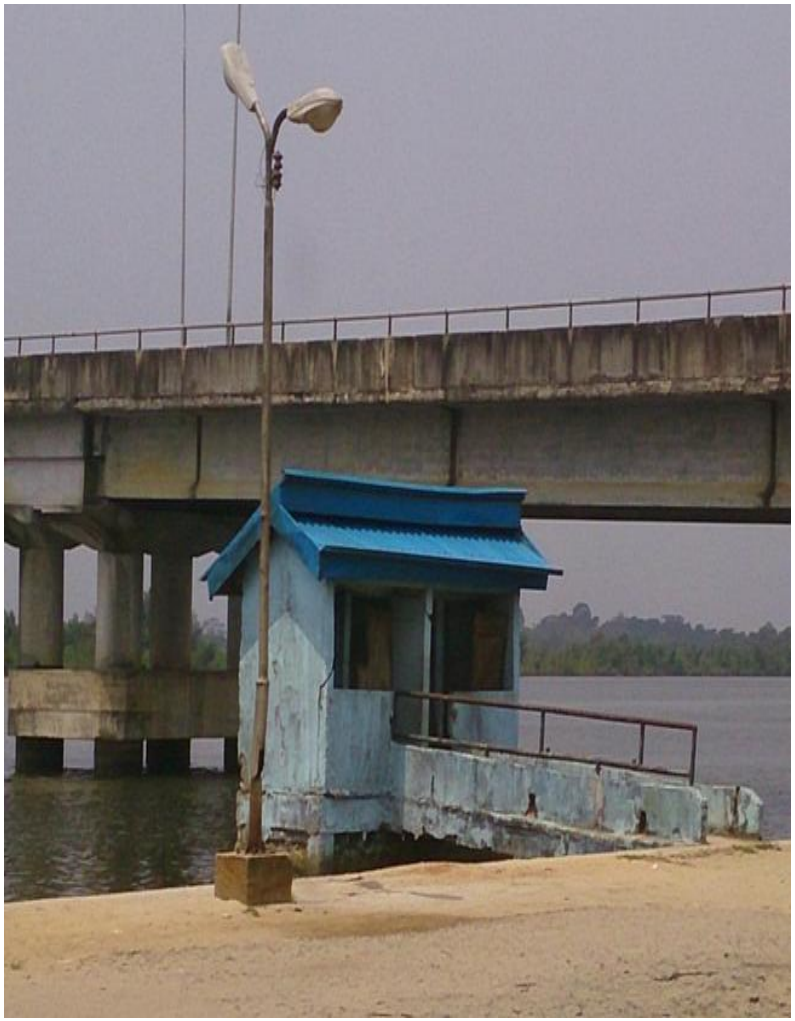
Challenges…

POINT OF DEPARTURE: IT'S ALL ABOUT WATER!



Rural Water Supply Scheme

Challenges.. Hanging Toilets in Riverine areas



ARE WE THERE YET?

What to check for and How to correct them:

- Pump and/or water system:
- Low pump production in spite of normal water level in well. Leak in system; worn pump impeller.
- Have a licensed water well contractor or plumber check the pump and water system.
- Biofilm build-up in well casing, well screen or pump intake.
- Slime build-up on household plumbing fixtures and livestock "waterers".
- Inspect pump and use down-hole camera to check for slime build-up.
- Shock chlorinate the well and water system as required - usually once or twice a year.

- Mineral scale (incrustation) build-up on perforated well casing, well or pump screen.
- Scale formation on plumbing fixtures and livestock "waterers". Inspect pump. Use down- hole video camera to check for mineral build- up
- Once the type of mineral scale has been identified, the well should be cleaned by a licensed water well treatment specialist. Treatment could include both physical agitation and chemical/acid treatment.

- Sediment plugging on outside of perforated casing or screen.
- Sediment in water, followed by a sudden decline in yield.
- Have a licensed water well contractor redevelop the well.
- Collapse of well casing or borehole due to age of well.
- Sediment in water. Compare current depth of well with original records. A collapsed well will show a shallower depth than the original well.
- Recondition the well. If repair is not economical, plug the well and redrill.

- Neighbouring well interference.
- Check for significant drop in water levels in nearby wells.
- Identify other nearby wells located in the same aquifer. Reduce pumping rates as required.

- Aquifer depletion
- rate of withdrawal exceeds rate of recharge
- periods of drought can temporarily deplete
- shallow groundwater zones
- Compare current non-pumping static water level with the level at the time of well construction. A lower level confirms aquifer depletion. Contact Regulatory Authorities to see if water levels are declining.
- Reduce the water use. Install additional storage to meet peak water requirements. Drill a deeper well or one that taps into another aquifer.

Sediment in Water

- Improper well design or construction.
- Sediment appears in water shortly after well completion. Well production does not improve with pumping.
- Have the licensed water well contractor return to assess and repair the construction problem.
- Insufficient well development after construction.
- Sediment appears shortly after well completion. Well production may improve with pumping.
- Have the licensed water well contractor return to redevelop the well.
- Continuous over-pumping of well.
- Sediment appears in water. Compare current discharge rate of well with the recommended rate at the time of construction.
- If the current flow rate is higher than the recommended rate, install a flow restrictor on pump. If required, install additional storage to meet peak water requirements.
- Corrosion of well casing, liner or screen causing holes.

- Failure of the annular or casing seal.
- Sudden appearance of sediment, coupled with a change in water quality. Test water quality regularly and investigate when quality changes occur.
- Consult a licensed water well contractor. It may be possible to re-establish the seal. If repair is not economical, plug the well and redrill.

Change in Water Quality

- Corrosion of well casing, liner or screen, causing holes. Holes can allow water of undesirable quality to enter the well.
- Change in water quality, may be coupled with sudden appearance of sediment in water.
- Consult a licensed water well contractor. Depending on the well construction, repair or replace well using alternate construction materials. Plug old well.
- Failure of the annulus or casing seal.
- Sudden appearance of sediment, coupled with a change in water quality. Test water quality regularly and investigate when quality changes occur.
- Consult a licensed water well contractor. It may be possible to re-establish the seal.
  If repair is not economical, plug the well and redrill.
- Iron-related bacteria or sulfate-reducing bacteria (biofouling).
- Change in water quality such as colour, odour (e.g., rotten egg) or taste. Check inside of toilet tank for slime build-up and inspect pump.
- Shock chlorinate the well

- Contamination sources:
- Changes in water quality such as colour, odour or taste. Compare results from regular water analyses for changes.*
- Identify and remove contamination source. Continue to monitor water quality through regular water testing.
- Over-pumping the well:
- Malfunctioning pump (gas-locking). Refer to your pump manual to troubleshoot for your pumping system. Compare the rate at which you are pumping the well with the rate recommended by the driller on the drilling report.
- Have a licensed water well contractor or plumber check the pump and pressure system equipment for malfunction. Make sure any new pumping equipment is sized correctly to meet the production capability of the well. Reduce well pumping rate if necessary and install additional storage to meet peak water requirements if required.

WAY FORWARD..

- i. **Management strategy** must be formulated and implemented for sustainable groundwater resources development using the appropriate mechanism that ensures community ownership, efficient/effective operation and maintenance.
- ii. **Capacity Development** to improve knowledge and skills of professionals in the groundwater industry and also advocate for attitudinal change for people to take responsibility of managing the water facilities in their communities.

- Promotion of **Water Quality Standards and Surveillance** ensures safe water provision.
- **Collaboration** between the different stakeholders to understand and address the general and peculiar issues of sustainability with emphasis on the impact of groundwater resources in ensuring **national water security, poverty alleviation and improving the health conditions of the people.**

CONCLUSION:

- The elimination of borehole failures in Nigeria requires urgent **practical reforms** to ensure adherence to **best practices** in the exploitation of the groundwater resources without undermining its **sustainability**. This requires the involvement of all **stakeholders** at all levels.

CONCLUDING PHRASE:

"KNOWLEDGE AND CAPACITY" ARE KEY TO EFFECTIVELY SOLVE WATER ISSUES AT ALL SCALES AND LEVELS

- "WATER HAS THE POWER TO MOVE PEOPLE. SINCE THE BIRTH OF CIVILISATION, PEOPLE HAVE MOVED TO SETTLE CLOSE IT. PEOPLE MOVE WHEN THERE IS TOO LITTLE OR TOO MUCH OF IT. PEOPLE WRITE, SING OR DANCE ABOUT IT. PEOPLE FIGHT OVER IT. ALL PEOPLE, EVERYWHERE AND EVERYDAY NEED IT."– ---Mikhail Gorbachev, President of Green Cross International

Thank You