# The Art of Diagnosing a un-Healthy Water Bore and Rehabilitation techniques

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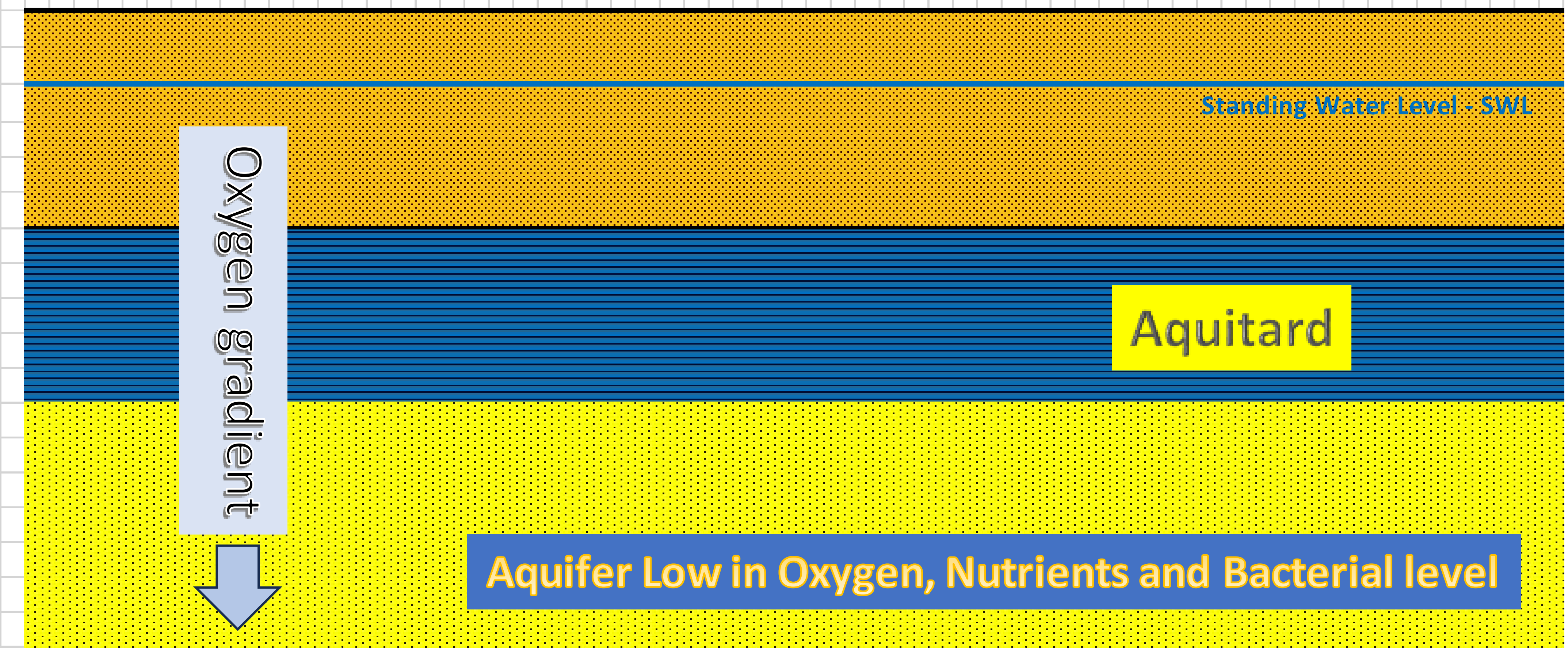
Water Resources Drilling

# TALK OUTLINE

- Describe the Interface between the Water Bore and Aquifer
- Identify Key Parameters to Monitor to allow identification of a Bores Health
- Some tips on Effective Bore Rehabilitation
- Method to calculate the Additional Pumping costs from bore biofouling

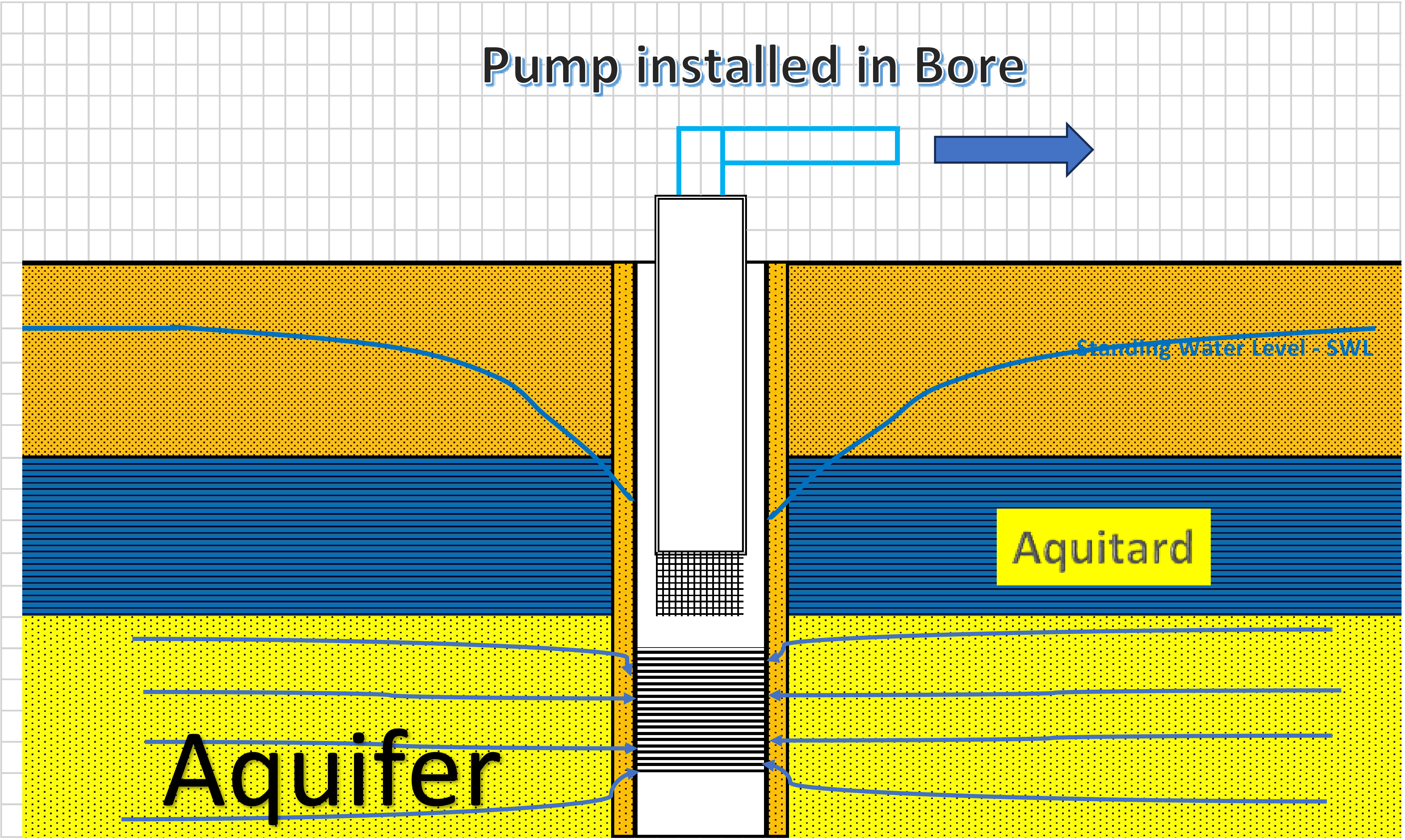
# Natural Groundwater Conditions No Bore installed.



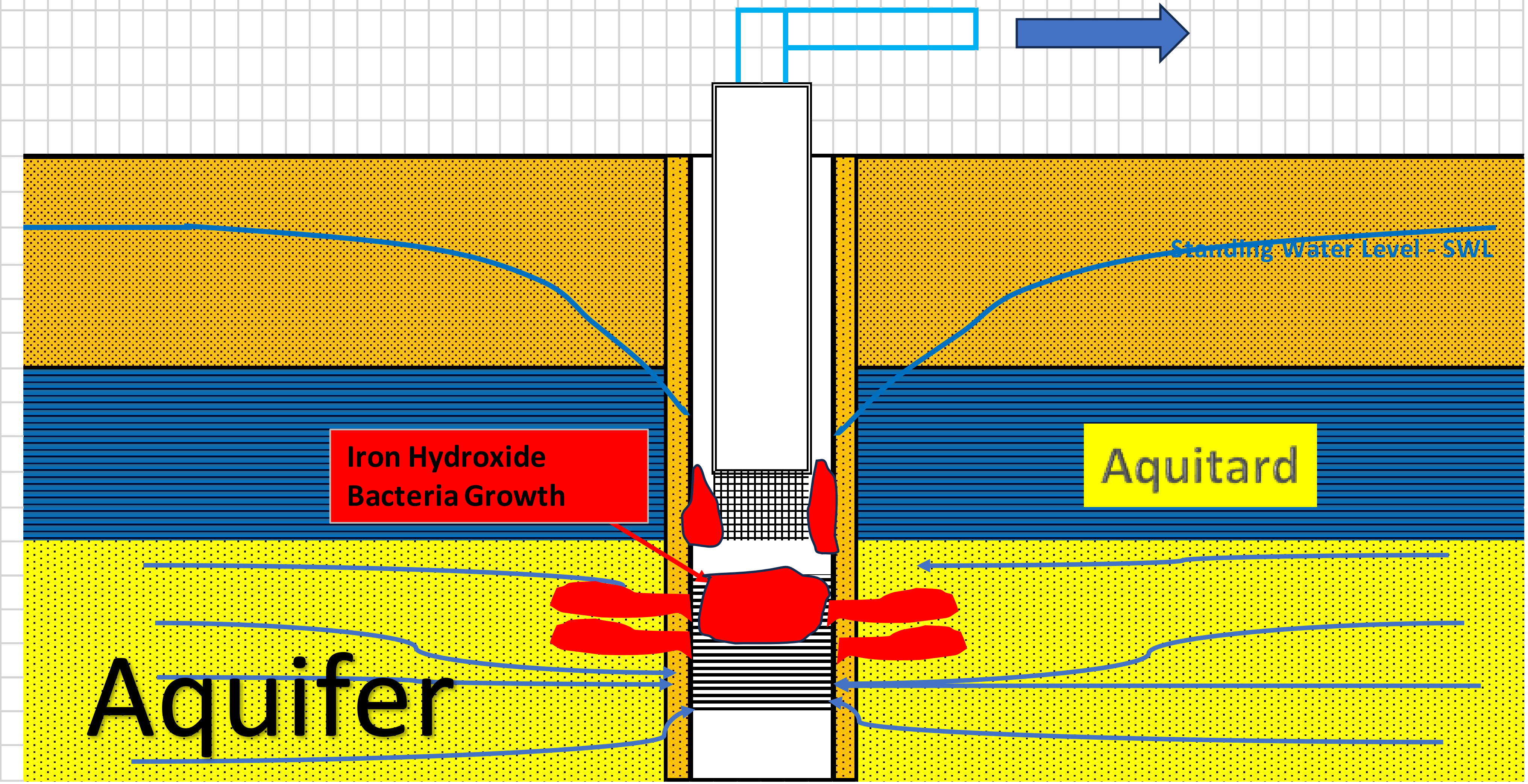
# Aquifer conditions prior to bore installation

- **Aquifer is low in oxygen and concentration reduces with depth**
- **Nutrient Levels are very low in concentration**
- **Bacterial levels are very low in concentration**
- **Where the water flow rate is highest is where bacteria concentration is highest as they can live on the nutrients in the groundwater as it flows past**

# Pump installed in Bore

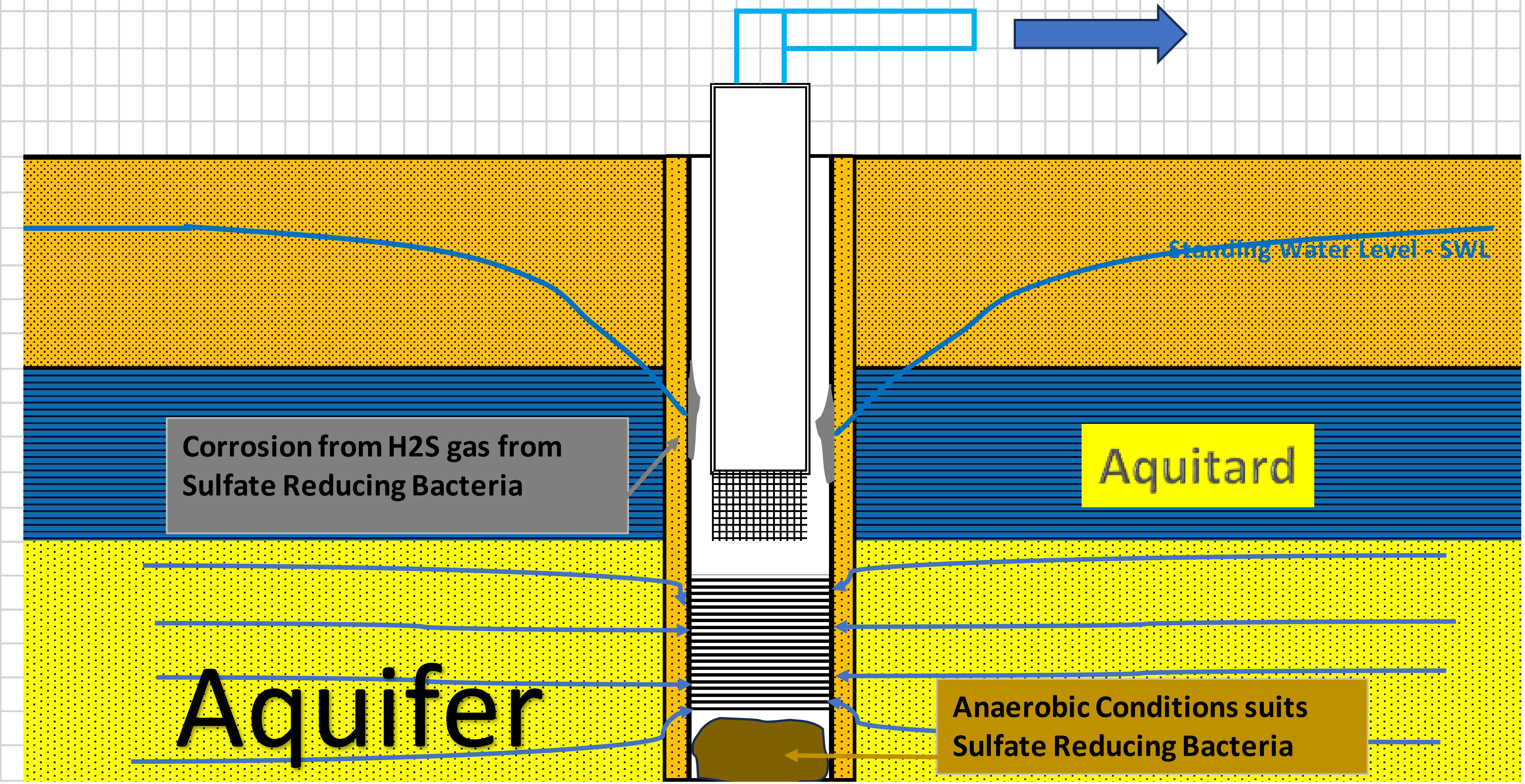


# Impacts of Iron Hydroxide Bacteria

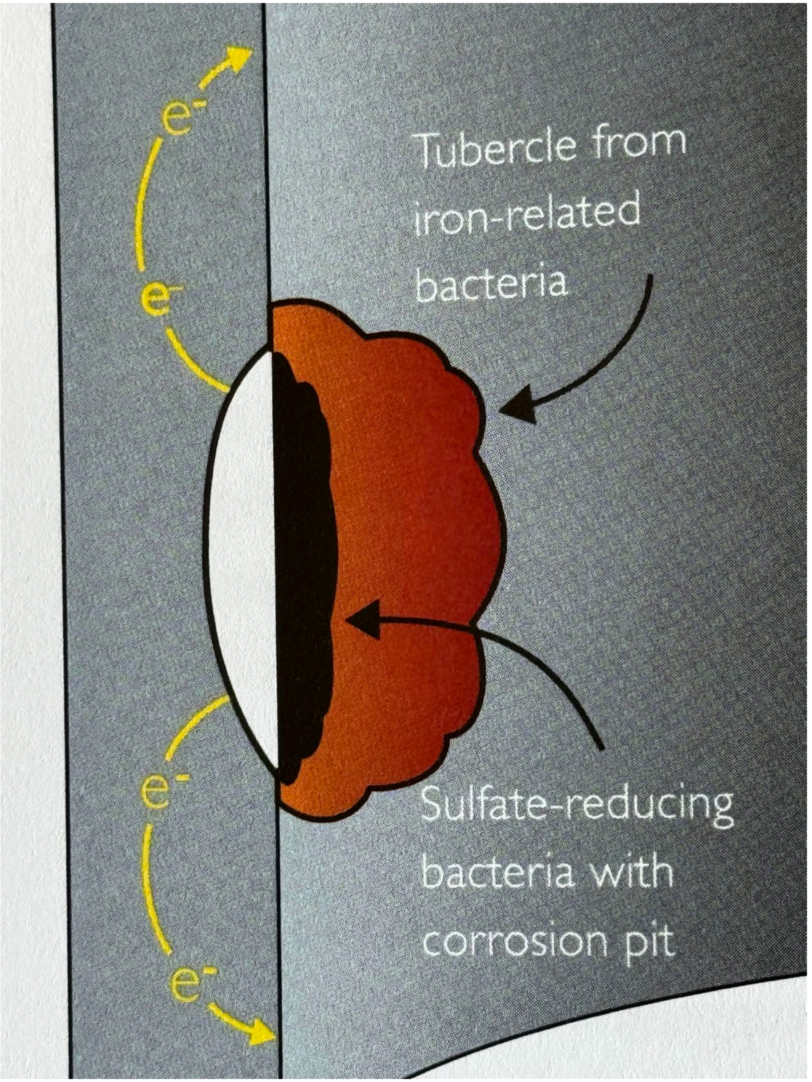


# Iron Bacteria Biofouling on Bore Pump

# Impacts of Corrosion from Anaerobic Bacteria



# Mechanism for Corrosion Pitting from Sulfate Reducing Bacteria




Source : M Glofelty The Art of Water Wells

# Corrosion due to dis-similar metals mild steel casing and stainless Steel Screen

# Installation of a Water Bore changes to ecosystem bore interface

- A bore changes the ecosystem in the aquifer by
- Pumping provides high water movement and turbulence in the well provide ideal conditions for bacteria to grow
- Introduces oxygen to assist growth of Iron and Slime producing bacteria ( Aerobic Bacteria)
- Oxidation of Ferrous ions $Fe^{2+}$ to Iron hydroxide $Fe(OH_3)$ can occur. Either biological or chemical encrustration
- Natural and Drill Mud clays can contaminate the well interface
- Low Oxygen conditions favour anaerobic bacteria produce Hydrogen Sulfide gas and induce corrosion of steel bore casing

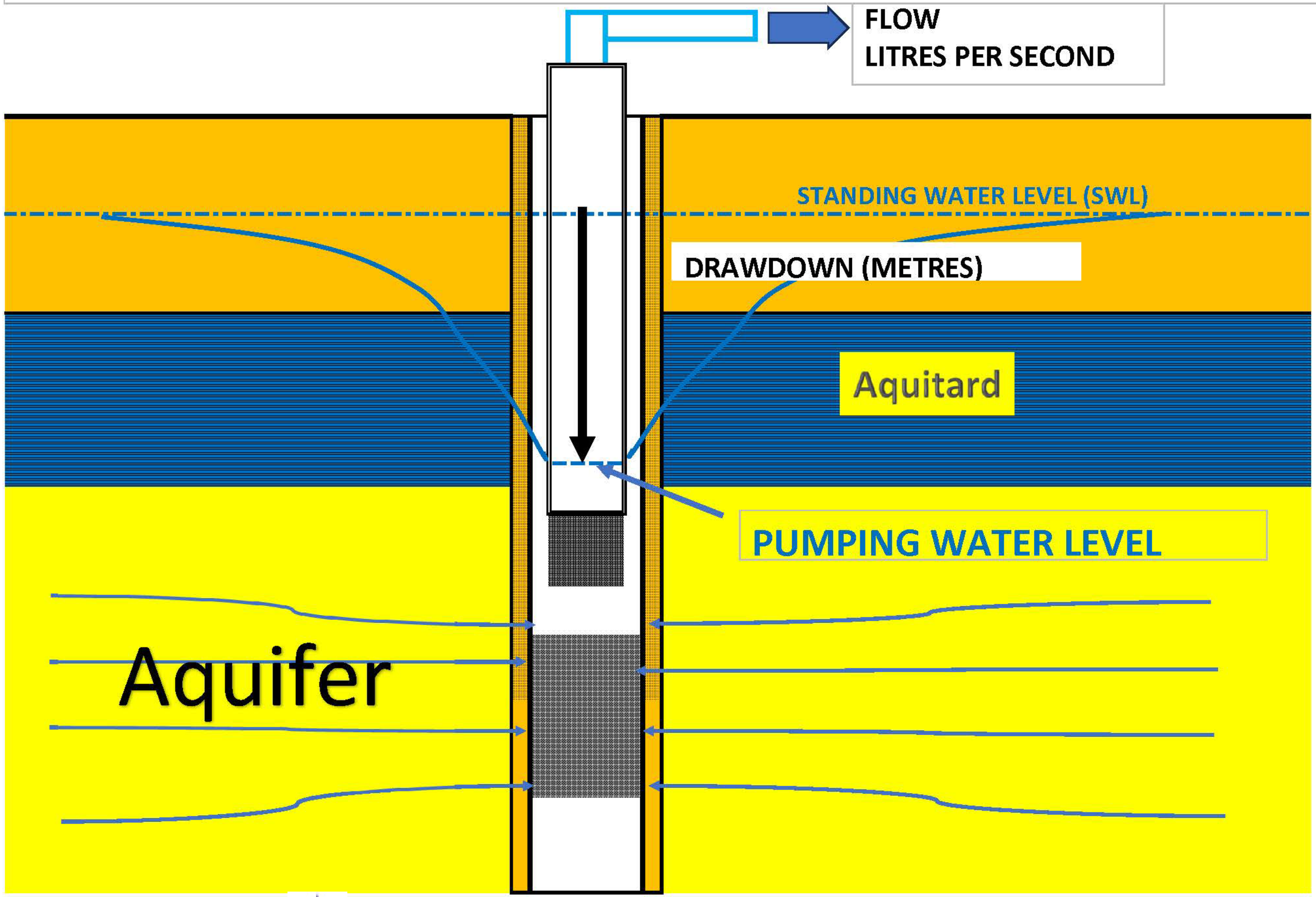
# Iron Bacteria characteristics

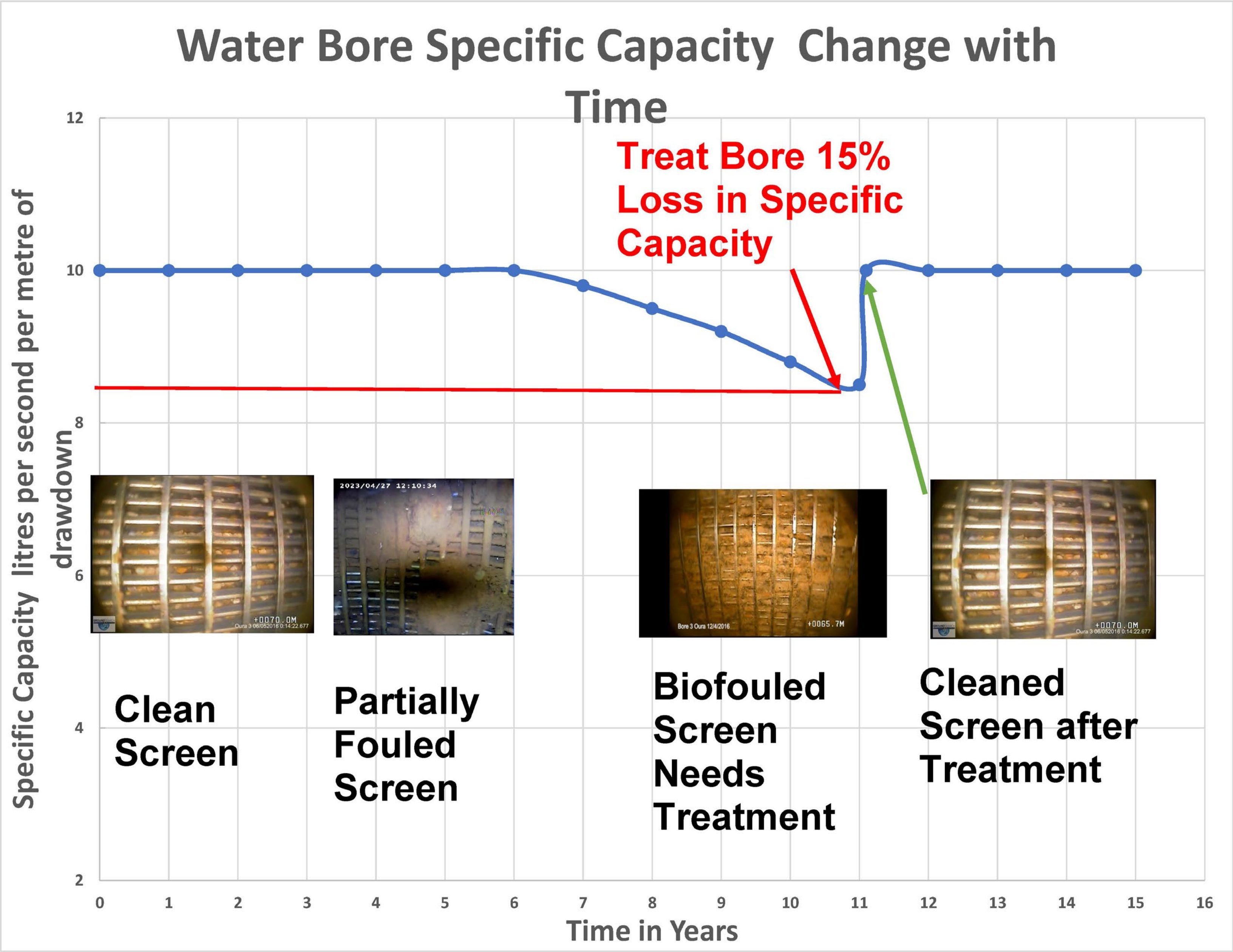
- 80 percent of bores that require bore rehabilitation is due to Iron bacteria as a rule
- Iron bacteria growth rate is highest near the pump interface and the top of screen or where the flow rate through the screen is highest
- Iron Bacteria will grow tubercles or finger like growth that grow into the gravel pack and into the aquifer from 15 centimetres up to a metre.
- The tubercules will eventually clog the water flow and then a new area of the well will open up to maintain the flow rate
- If left untreated eventually the well will clog up and severely impact on the flow rate or it may cause other problems like sand pumping

# Key WPI – Well Performance indicators

1. Specific Capacity- Flow rate vs drawdown  eg litres per second per metre
2. Biological indicators BART KITS
3. Hydrochemistry Measuring changes with time in pH, Eh, Iron, Manganese, Alkalinity
4. Geophysical cased hole assessment
   - CCTV bore camera videos
   - Optical Televiewer
   - Acoustic Imager
   - Calliper Log

# SPECIFIC CAPACITY = FLOW (LITRES/SEC) / DRAWDOWN (M.)



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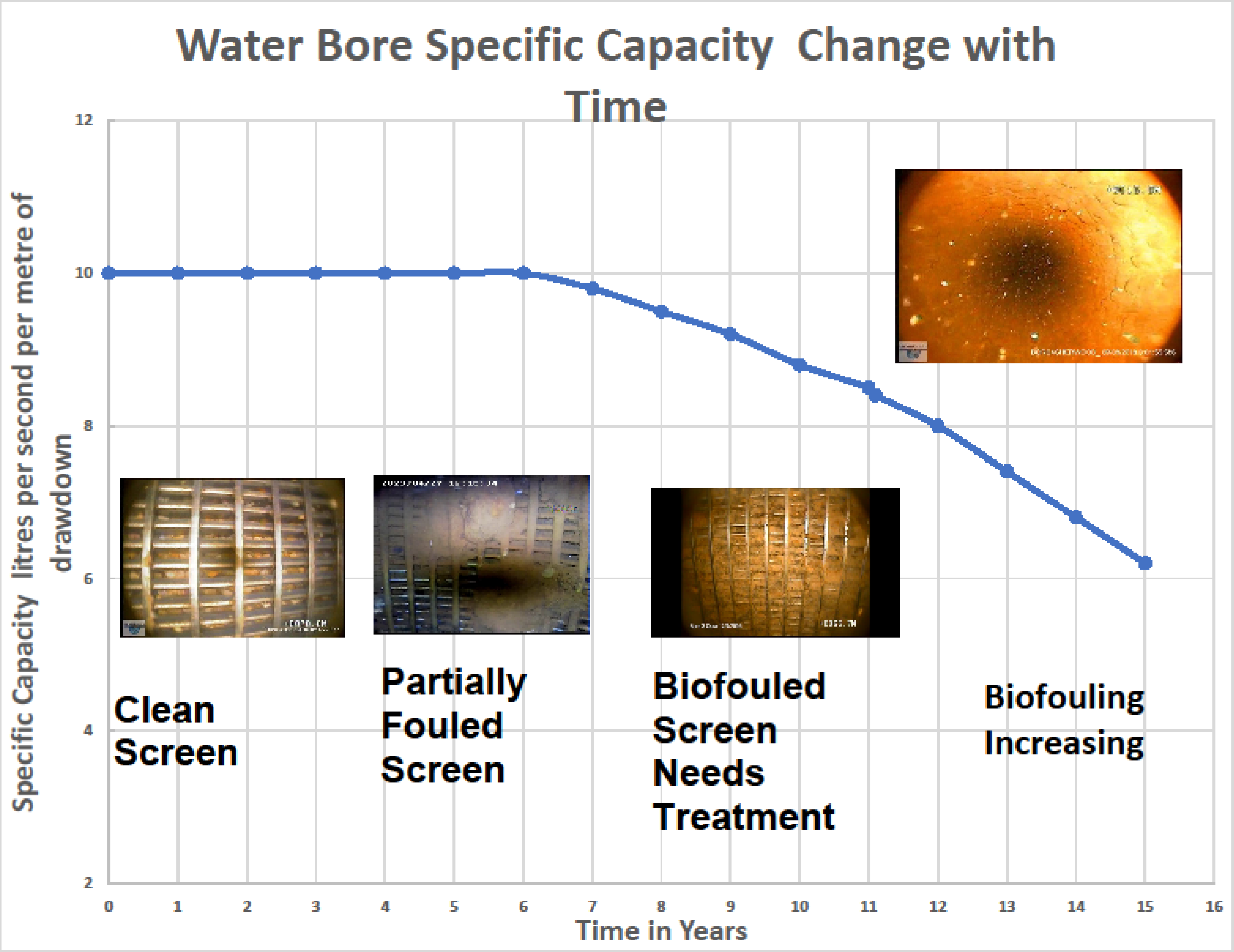


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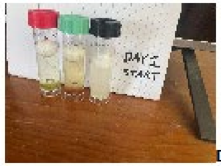
# BART KITS

- **Biological Activity Reaction Test**
- Red – Iron Bacteria
- Green – Slyme Bacteria (Aerobic)
- Black – Sulfate Reducting Bacteria (Aneorobic)

- Sample a few minutes after starting pump and then observe over 8 days provides a semi quantitative assessment of bacteria


DAY1


DAY 2


DAY 3


DAY 4


DAY 5

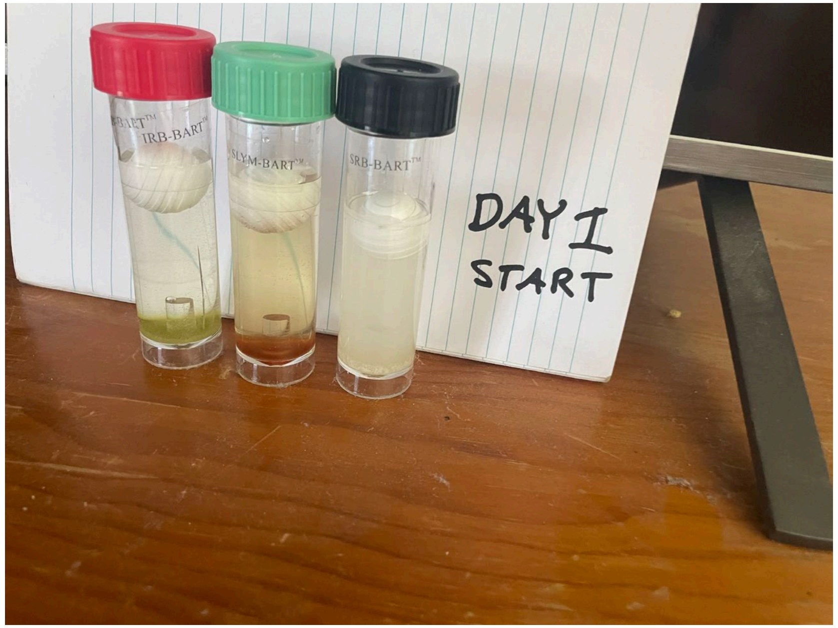

DAY 6


DAY7


DAY 8

# BART COMPARISON

DAY 1




DAY 5

# BART COMPARISON

## DAY 5


## DAY 8


**BART Nabiac Town Water bore Day 1**


**BART Nabiac Town Water bore Day 8**

# Monitoring Chemistry of Water Bore

- Purpose of chemistry monitoring is to detect changes that may indicate or reflect bore deterioration
- Basic Water Chemistry include
- Soluble $Fe^{2+}$, Total Fe, Total Mn, Sulphur, pH, Eh ( Redox Potential)
- Turbidity

- A Significant change with time of any above parameter indicates possible well fouling

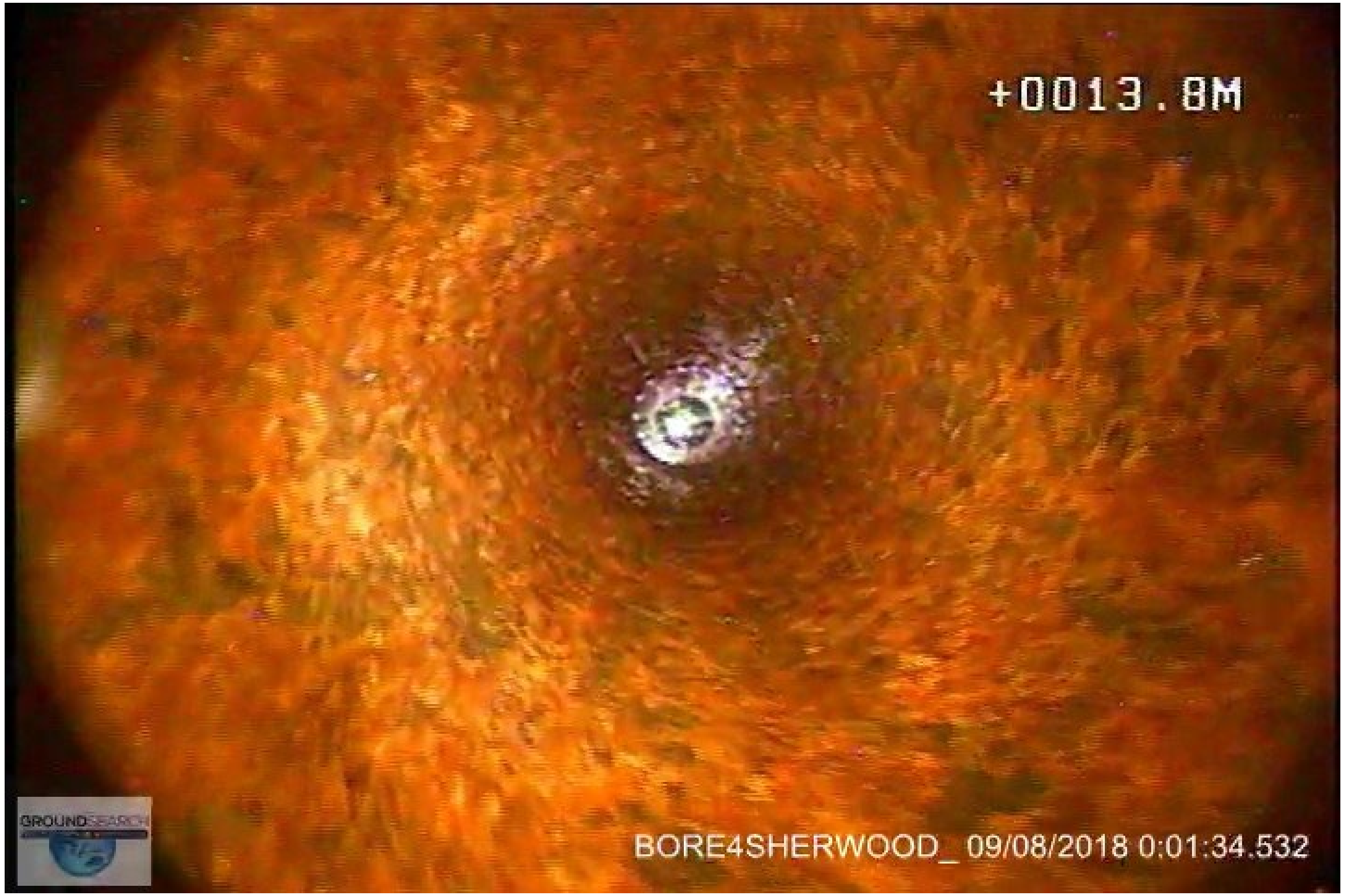
# Chemistry Changes Summary

- Iron Fe2+/Fe3+ indicates clogging potential
- Mn indicates clogging potential possible biofouling
- Sulphur S, $S_{2-}$ and $SO_{4-}$ indicates potential corrosion, incrustation and clogging potential
- pH likelihood of corrosion or mineral encrustation
- Turbidity indicates change in particle pumping or biofouling
- Major Ions indication of type of incrustation mineral or a surrogate is hardness

# When to Withdraw Pump and inspect Casing Condition

- When Specific Capacity has reduced by fifteen percent
- When BART sample indicates semi to aggressive bacteria present within first few days or with time increases in bacteria levels from Test
- Change in Chemistry noted with time
- Possibly at routine pump removal for maintenance.

# Rusted Casing above Water table

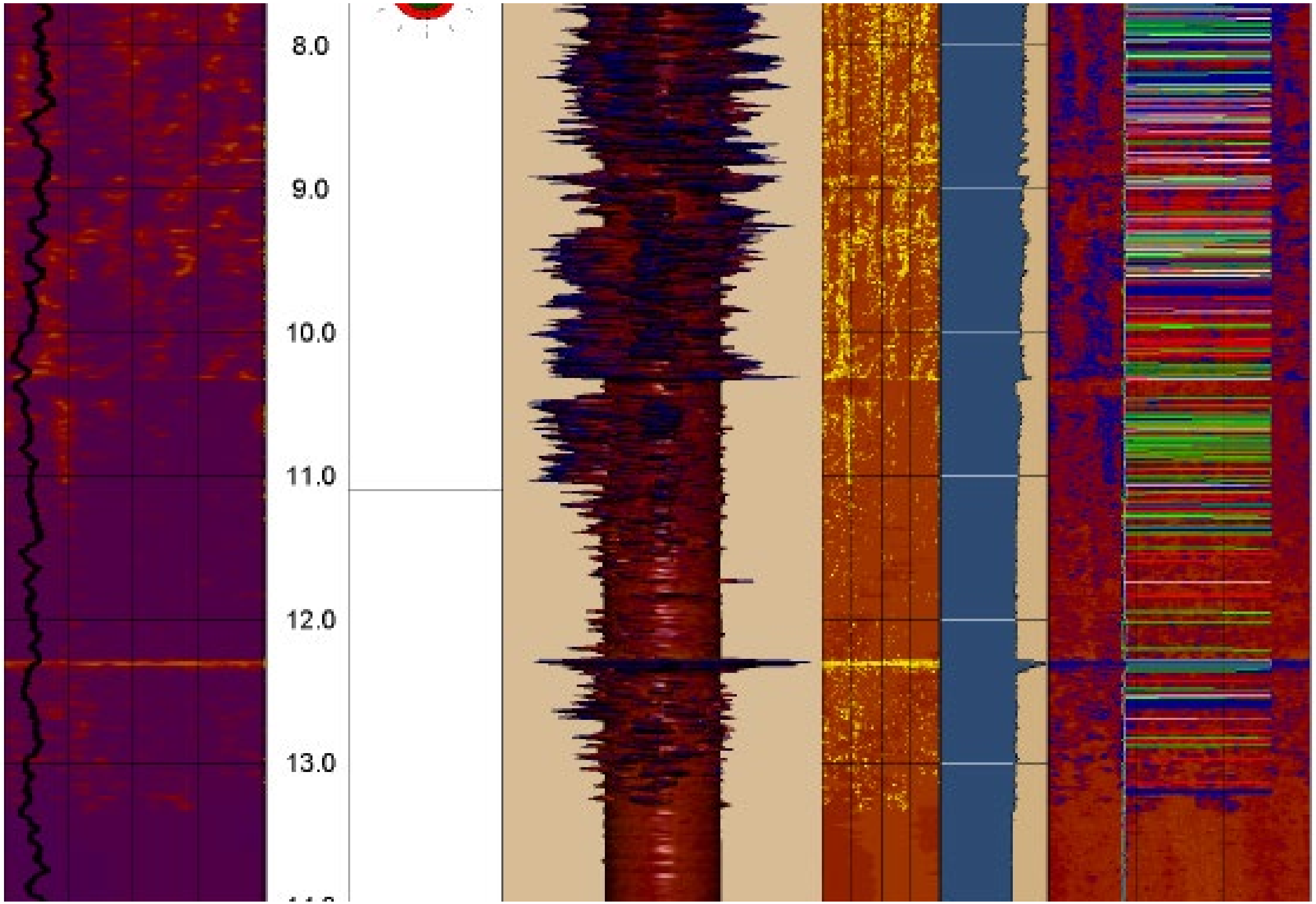


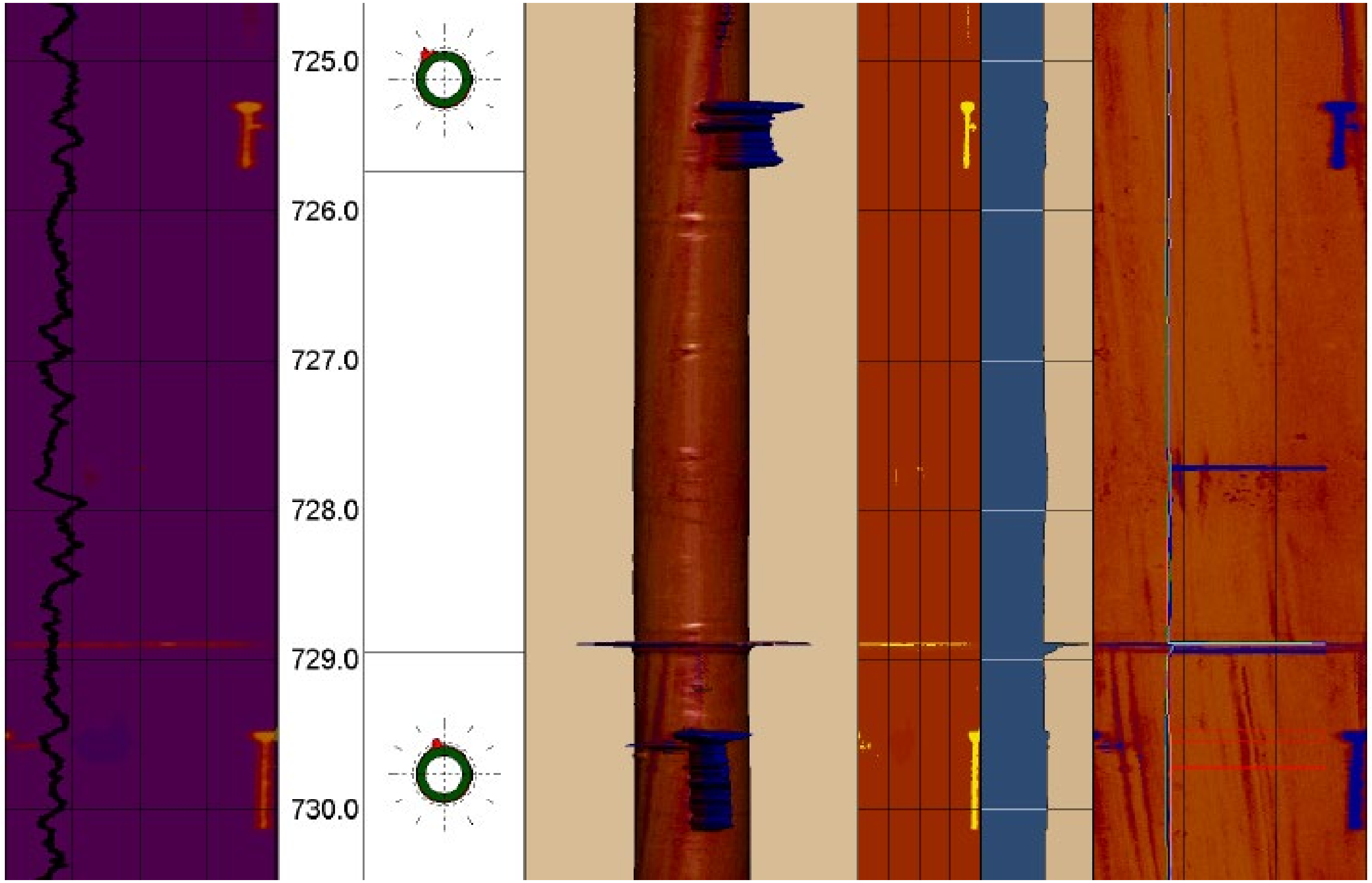
# Iron Bacteria Early Stages Video Camera inspection

# ACOUSTIC TELEVIEWER 3D IMAGE

Moree Baths bore 1896

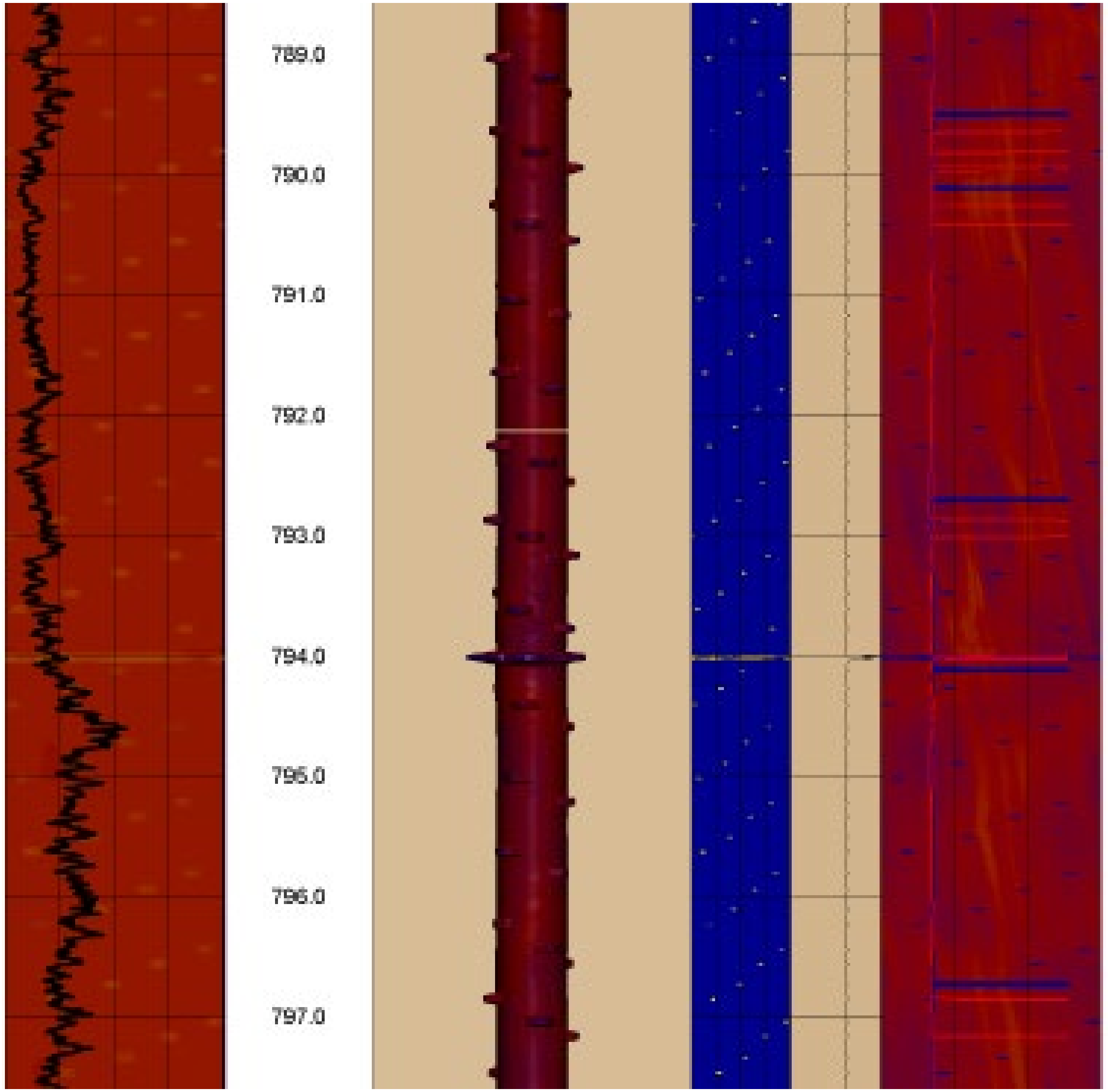
8 to 14 metres depth showing surface corrosion but no evidence of Holes in casing






**Acoustic Televiewer Moree Bore Bath Bores slots at 725metre and 730 metres**

# Moree Baths bore illustrating original downhole perforations 790 to 796m

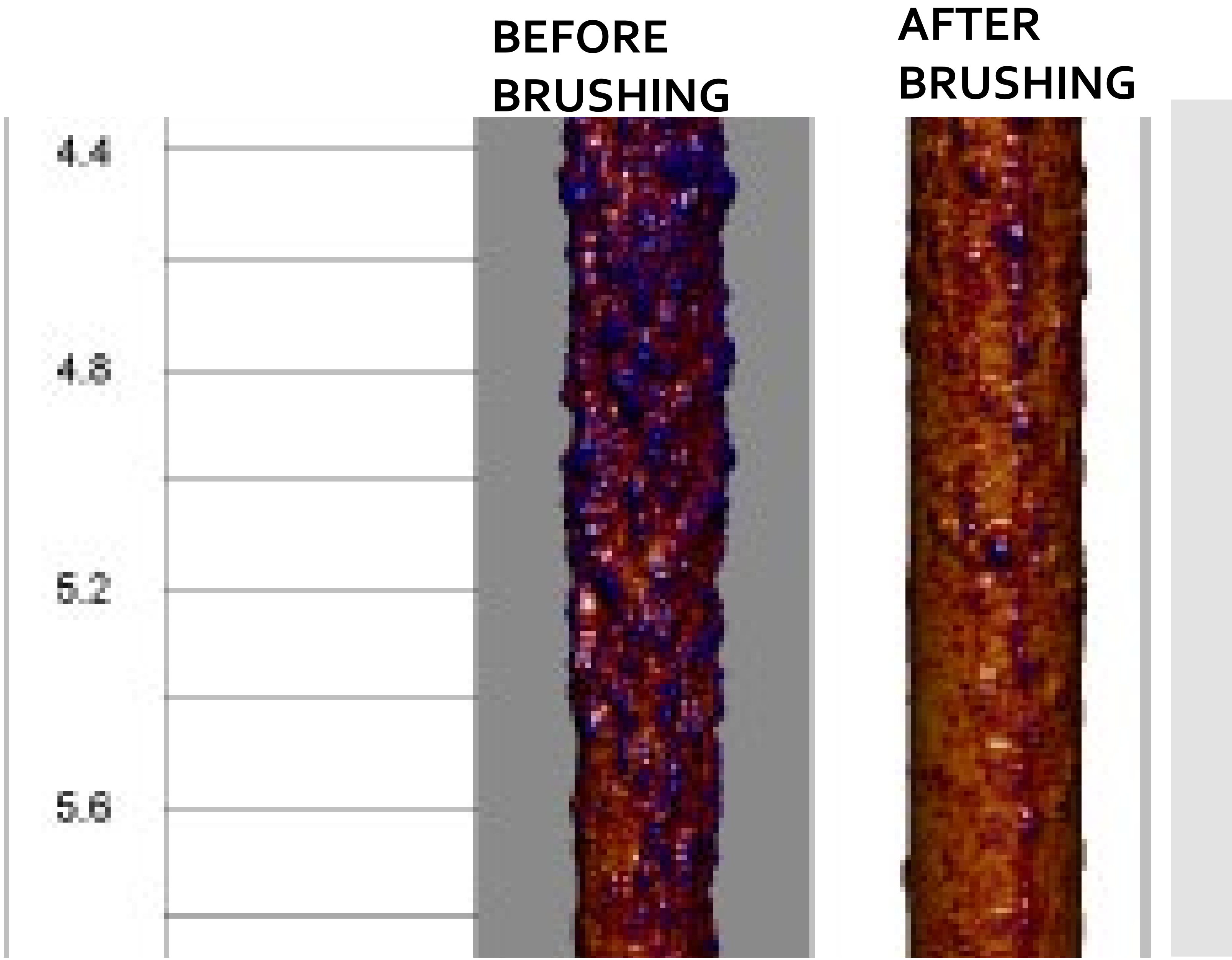


# Acoustic Televiewer image South West Rocks Town Bore

Depth 4 to 6 metres

On left Before showing surface rust prior to Cleaning

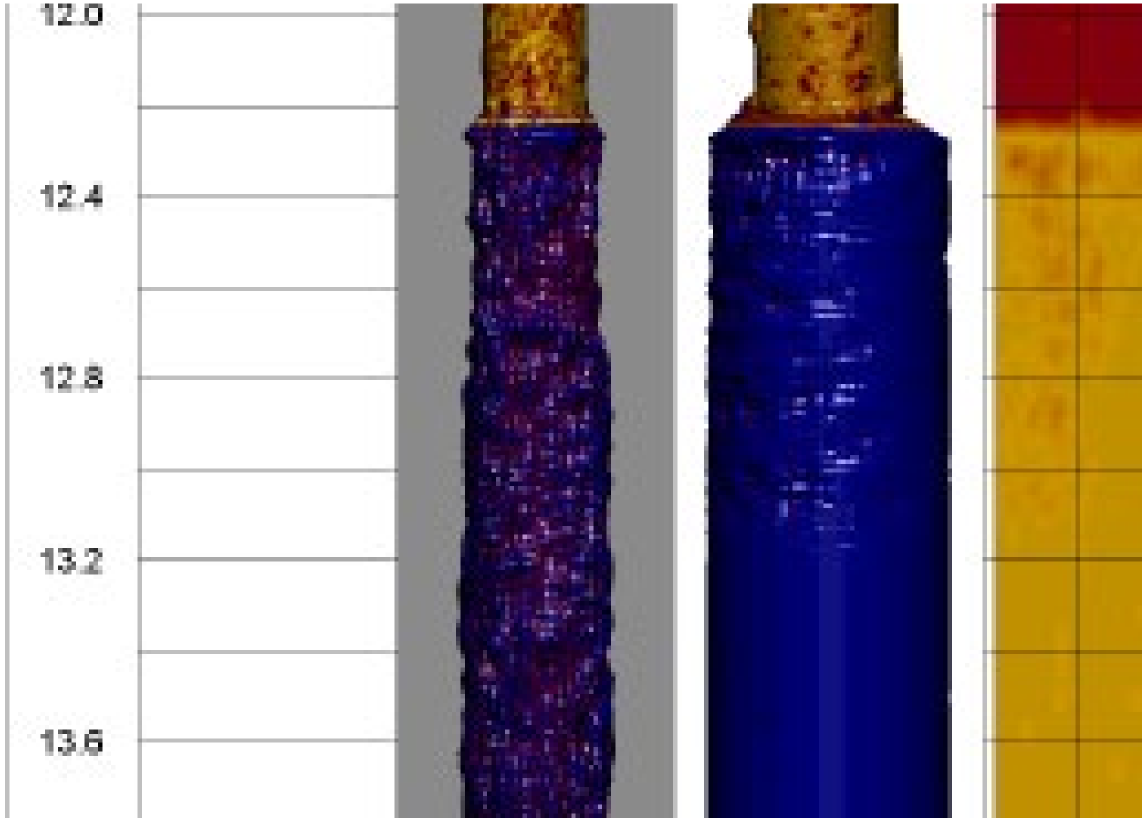
On Right Majority of rust removed after cleaning.



# SOUTH WEST ROCKS TOWN BORE ACOUSTIC TELEVIEWER IMAGE of SCREEN

SCREEN BEFORE CLEANING

SCREEN AFTER CLEANING



# Well Rehabilitation a Drillers Perspective

- If Iron Hydroxide Fouling is severe mechanical and chemical treatment will be required
  - Surging and Bailing
  - Brushing casing and screens
  - Jetting requires large volumes of water
  - Air Surging ( careful not directly in the screen)
  - Chemical Treatment

Surge Tool and Bailer

Jetting Tool

Combined Surge and Air Eductor tool

# Casing and Screen Brush

# CHEMICAL TREATMENT

- Chemical Treatment is important in Cleaning up Biofouling
- -Inorganic Acids
- Organic Acids
- Propietory Chemical with Acid and Surfactant is often best
- Important to know what the biofouling type is example Iron Hydroxide, Manganese or Calcium Carbonate
- Consult Chemical Company for best Chemical for the application.
- Chemical Treatment strongly recommend combine with Mechanical Treatment
- Key point is Acid reduces pH to very low levels to kill Bacteria and dissolve Bacteria Slyme , Sludge

# Relining of Bore casing design considerations

- If casing is rusted  from video camera inspection does not necessarily mean the bore will fail
- Need to consider bore design, casing thickness type of corrosion, whether pitting evident, Sulfate Reduction Bactera presence, the geological formation, is the annulus comprised of cement grout among other issues and the capability of the contractor
- Need to consider how long will the screen last before the expense of lining just the casing above the screens.
- A value judgement based on experience may well be required whether to reline or replace or just leave.

# Has Rehabilitation been Successful and ongoing monitoring

- **Economic Monitoring Methods**
- 1) Conduct a Specific Capacity Test to see if a significant improvement
- 2) Conduct a BART Test to see if reduction in bacteria levels
- **Costly Monitoring**
- 3) Water Chemistry routine monitoring
- 4) Repeat Video or Casing Condition Assessment with Geophysics tools

# How to calculate the power cost of not Rehabilitating a bore

- Energy Cost Per hour = $\frac{Q \times p \times g \times H \times C}{3.6 \times 10^6 \times u_p \times u_m}$
- Q = Flow (Cubic metres per hour)
- p = Density ( 1000kg/m3)
- g = Acceleration due to gravity ( 9.81 m/s²)
- H = Differential head ( drawdown)
- C = Electricity Cost in $ per kWhr
- g = acceleration due to gravity ( 9.81 m/s2)
- $u_{p}$ = Pump Efficiency
- $u_{m}$ = Motor Efficiency
- Source www.engineeringtoolbox.com

# Typical Additional Costings

**<u>Assumptions</u>**
**Motor Efficiency 90%**
**Pump Efficiency 75%**
**Energy Cost Average 30 cents per kilowatt hour**

| Flow Rate | Drawdown | Energy Cost /hour | Biofouling Additional cost over 200 days/yr |
|---|---|---|---|
| 100l/sec | 25 m | $10.89 | |
| 100 l/sec 15% SC reduction | 29.4 m | $12.81 | $9,198 /year |
| 100 l/sec 30% SC reduction | 35m | $15.24 | $20,902/year |

# Energy Cost Per hour

| Flow Rate | Drawdown m | Energy Cost per hour | Biofouling Additional Power pumping Cost per year |
|---|---|---|---|
| 50 l/sec | 50m | $21.77 | |
| 50 l/sec<br>15 % loss SC | 57.5m | $25.04 | $15,280 |
| 50 l/sec<br>30% loss SC | 65m | $28.31 | $31,360 |

# Conclusion

- Identified how a water bore impacts on the Ecology of the Aquifer system and can increase chance of biofouling, encrustation and corrosion
- Identified some key well indicators to utilise to monitor with time to determine a bores health
- Importance of combined Mechanical and Chemical combined methods in bore rehabilitation
- Identified potential pumping cost increases with reduction in specific capacity due to biofouling, encrustation of screens

# QUESTIONS?

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