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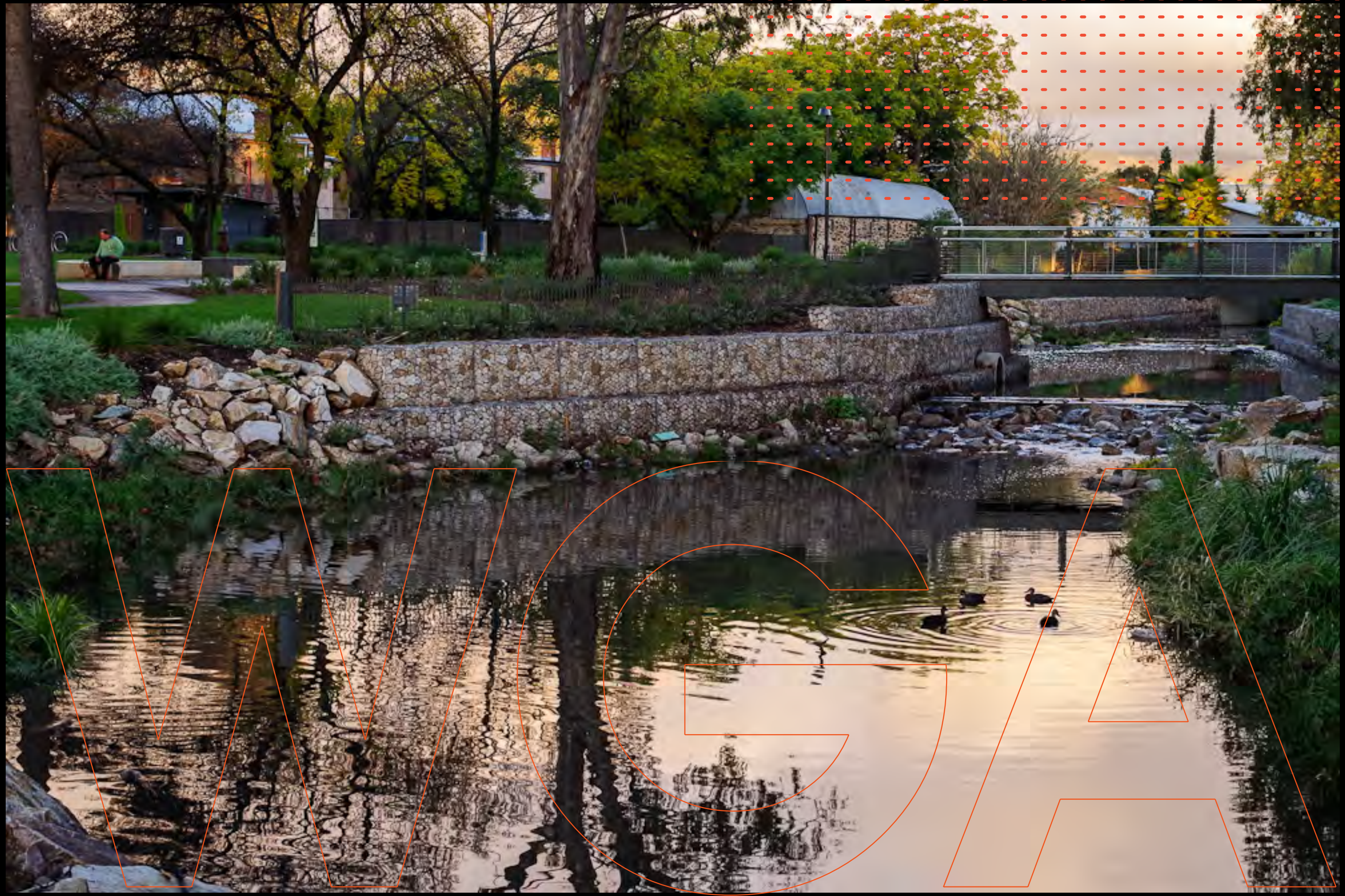
Clogging During Managed Aquifer Recharge

26 April 2018



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Clogging

- Why is clogging important?
  - Clogging causes impaired injectivity restricting the volume of water that can infiltrate or be injected into the target aquifer.
  - Severe clogging may lead to infiltration basins or injection bores being replaced.
  - It is the biggest risk to the successful and sustainable operation of any MAR scheme.

CLOGGING WILL HAPPEN!

CLOGGING CAN BE MANAGED!

- Mitigate, through
  - Water treatment
  - engineering design
  - operational management practices.

Clogging types

1. ***Physical Clogging***
2. ***Chemical Clogging***
3. ***Mechanical Clogging***
4. ***Biological Clogging***

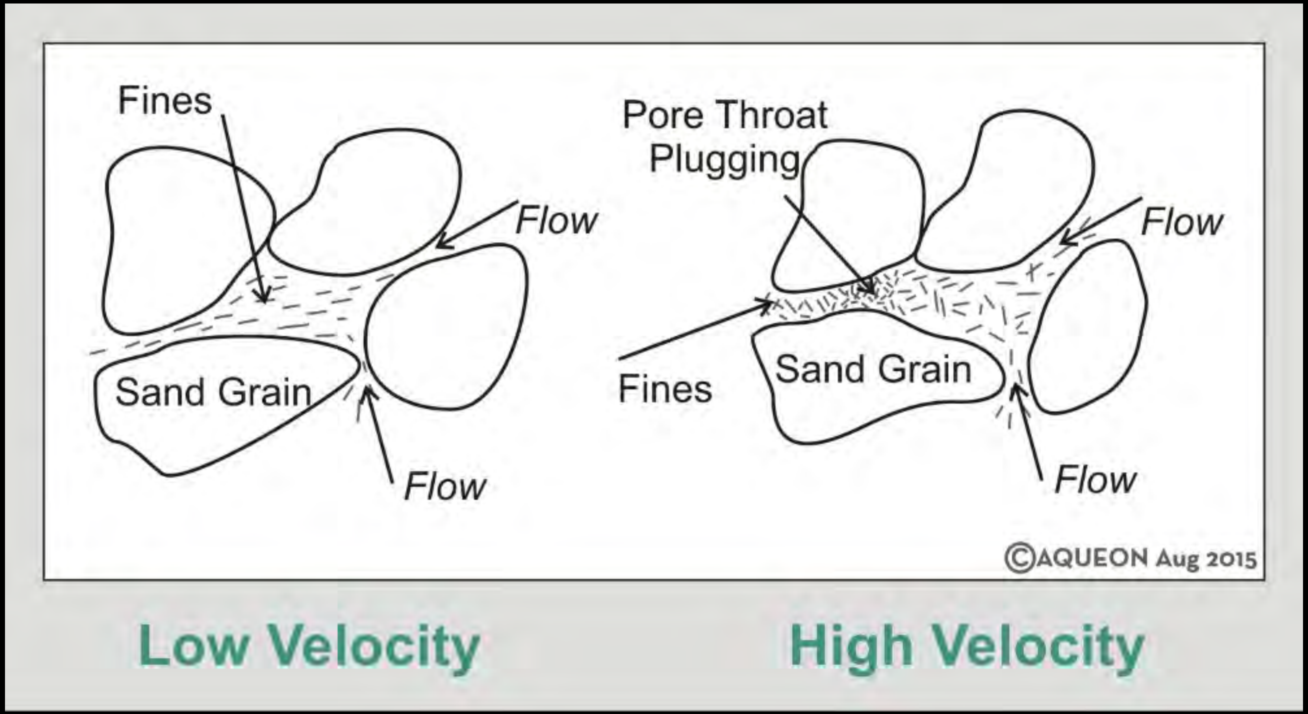
Clogging process

Clogging Types	Clogging Processes
Physical	• Accumulation / Injection of organic and inorganic suspended solids. • Velocity induced damage e.g. migration of interstitial fines such as illite or smectite. • Clay swelling (e.g. montmorillonite). • Clay deflocculation. • Invasion of drilling fluids (emulsifiers) deep into the formation. • Temperature
Chemical	• Geochemical reactions that result in the precipitation of minerals e.g. iron aluminium or calcium carbonate growth; • Aquifer matrix dissolution (can also work to increase hydraulic conductivity); • Ion exchange; • Ion adsorption; • Oxygen reduction. • Formation of insoluble scales. • Formation dissolution
Mechanical	• Entrained air/gas binding (includes nitrogen &/or methane from microbiological activity). • Hydraulic loading causing formation failure, aquitard failure or failure of casing around joints or seals.
Biological	• Algae growth and accumulation of biological flocs. • Microbiological production of polysaccharides. • Bacterial entrainment and growth

Source: R Martin, 2012. Clogging issues associated with managed aquifer recharge methods

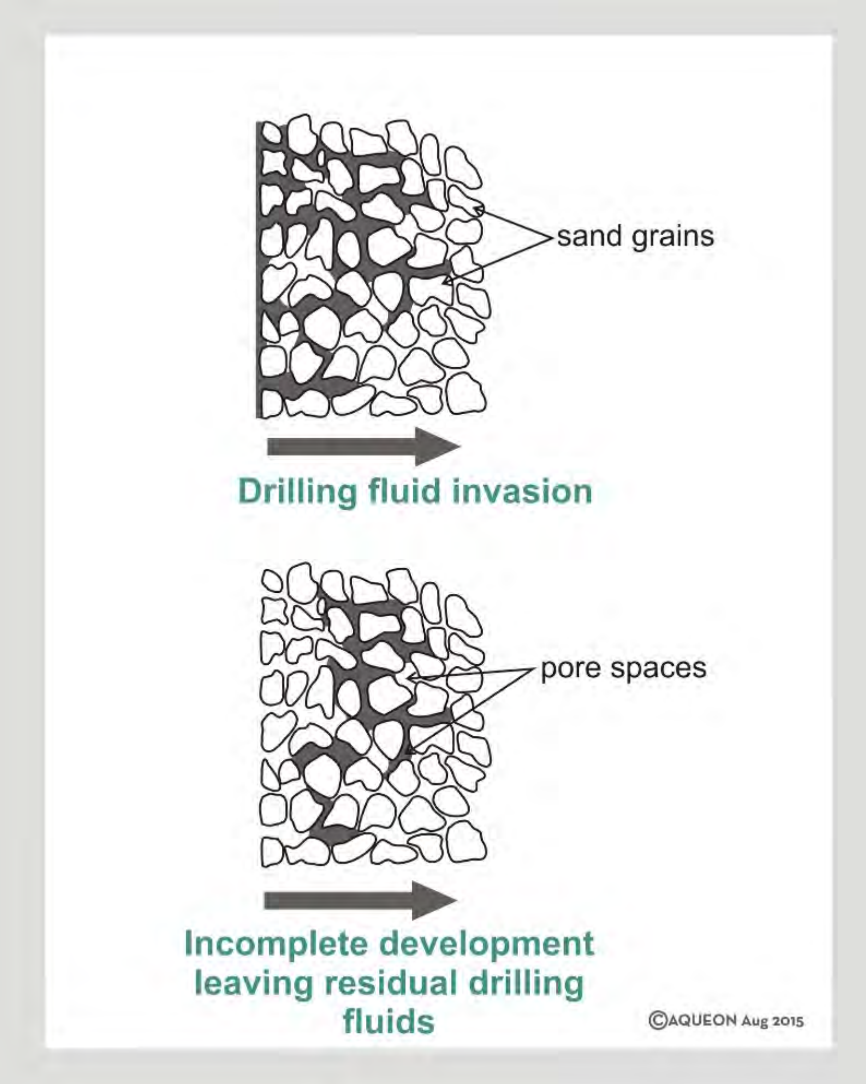
Physical clogging

- Energy sources include nutrients and carbon in recharge water, sulphur and iron.
- Accumulation / Injection of organic and inorganic suspended solids.
- Velocity induced damage e.g. migration of interstitial fines such as illite or smectite.

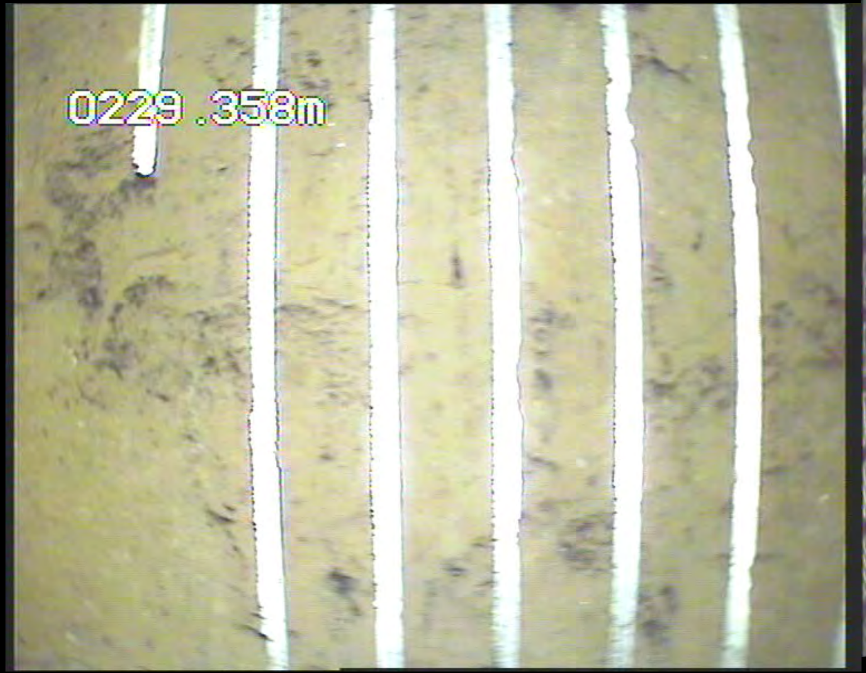


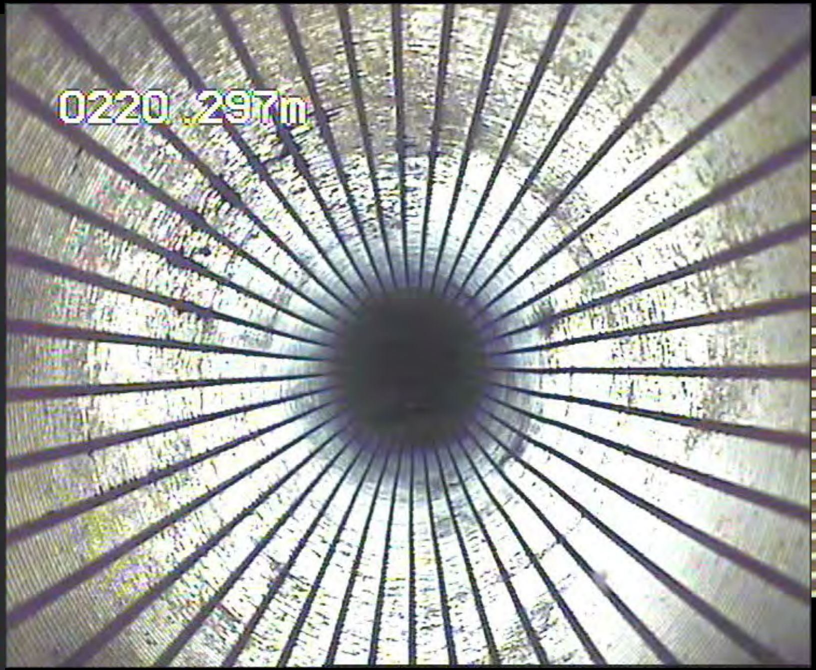
Mud invasion

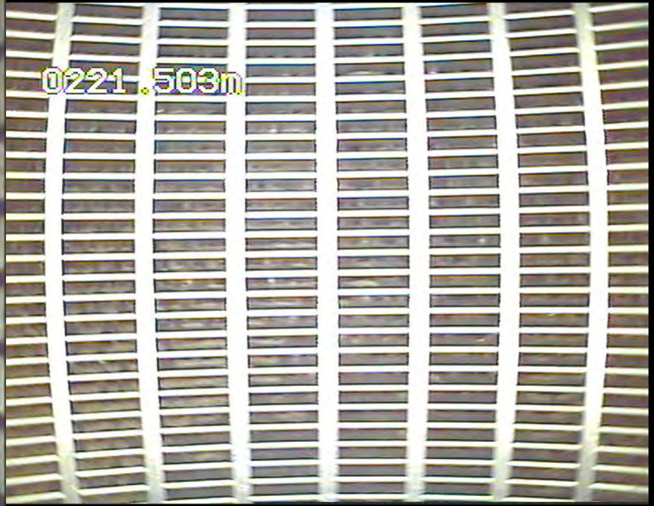
- Invasion of drilling fluids (emulsifiers)
- Muds are designed to bridge the pores to form a filter cake to keep pore fluids in place and stabilise the hole.
- Smaller particles can invade further into the pore spaces driven under the differential hydrostatic pressures between the drilling mud and aquifer.



Mud invasion





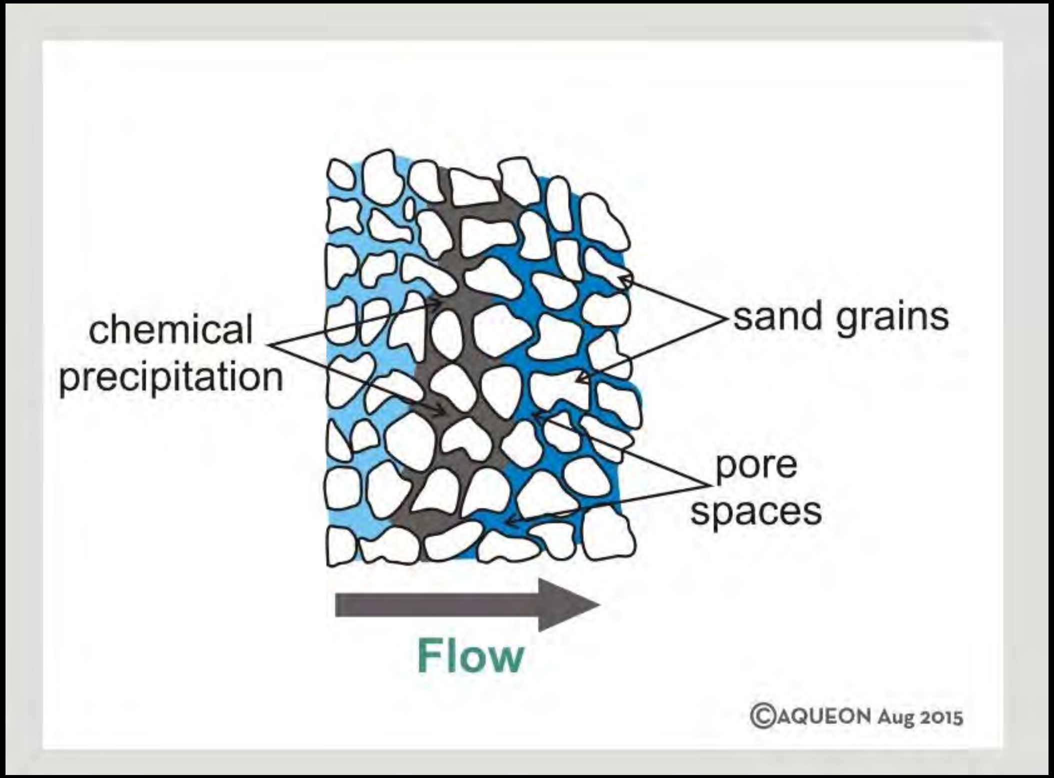


Poor mud control and development resulting in clogging of screen

Correct development of screen following construction

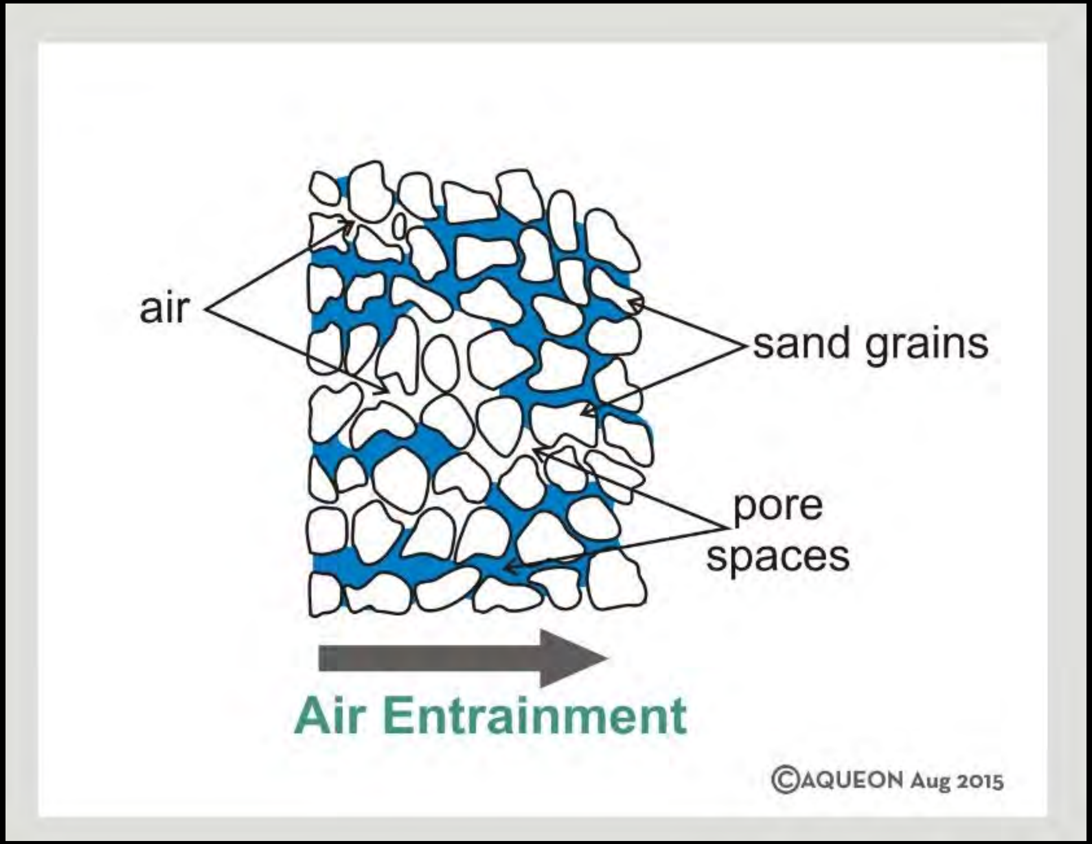
Chemical clogging

- Geochemical reactions that result in:
  - The precipitation of minerals e.g. iron, aluminium or calcium carbonate growth
  - Aquifer matrix dissolution (can also work to increase hydraulic conductivity)
  - Ion exchange
  - pH
  - Ion adsorption
  - Oxygen reduction; or
  - Formation of insoluble scales.



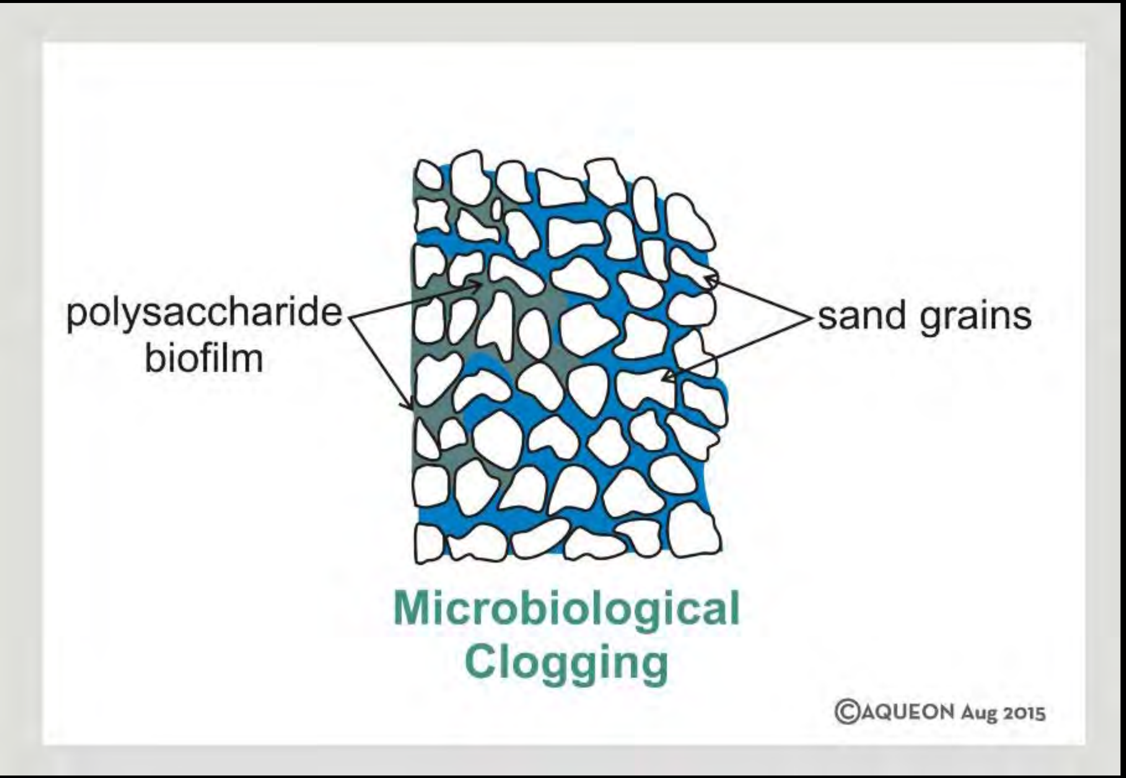
Mechanical clogging

- Entrained air/gas binding (includes nitrogen &/or methane from microbiological activity).
- Hydraulic loading causing formation failure, aquitard failure or failure of casing around joints or seals.



Biological clogging

- Microbiological production of polysaccharides.
- Bacterial entrainment and growth.
- Algae growth and accumulation of biological flocs (mainly associated with infiltration basins).



Management of clogging

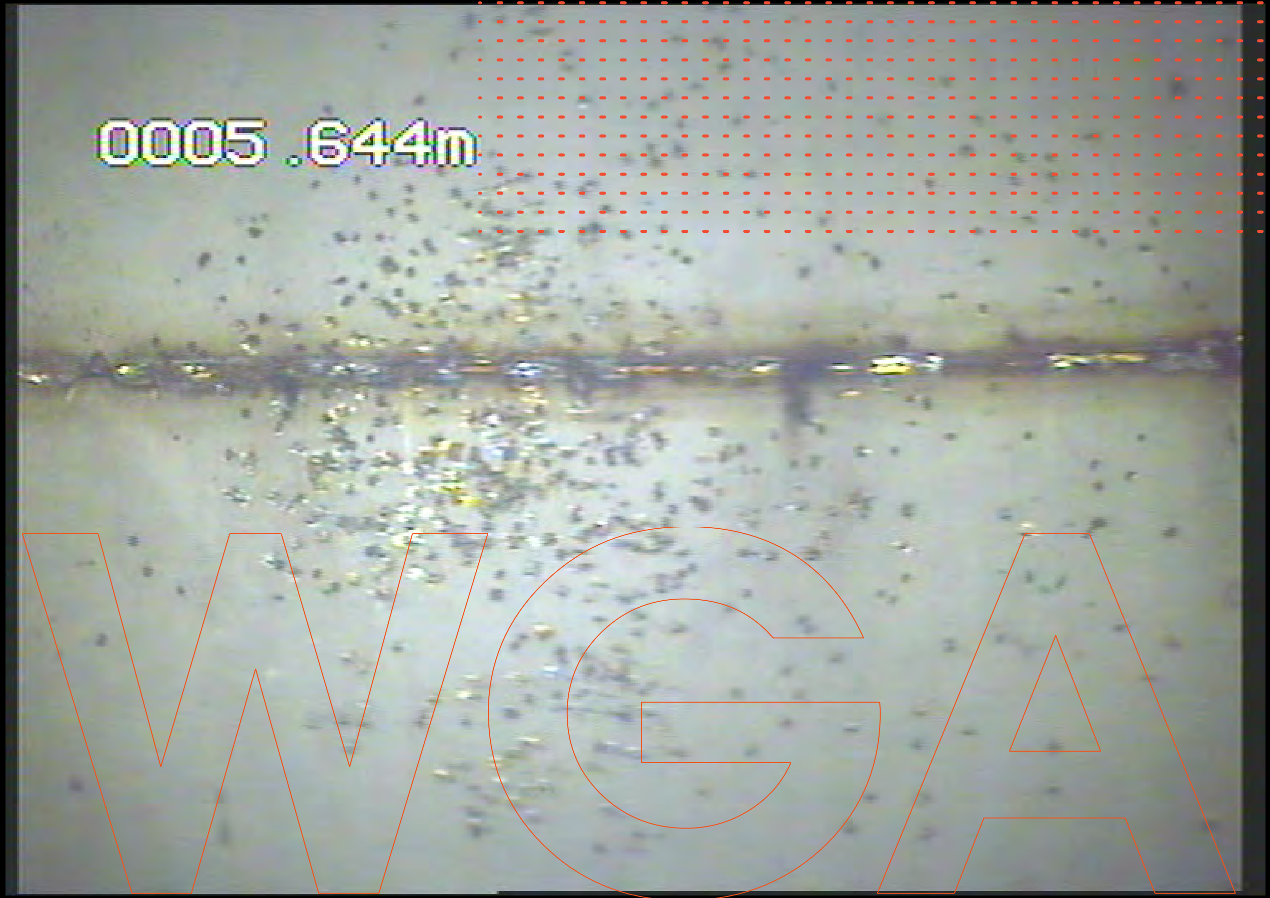
- Management of clogging starts with:
  1. Effective characterisation of the receiving aquifer and ambient groundwater quality.
  2. Engineering design.
  3. Chemical intervention.
  4. Monitoring of scheme performance.
  5. Modifications/adjustments to operational practices.

Clogging in injection bores

- Clogging generally occurs close to the screen and gravel pack
- The same clogging processes occur in bores where open hole construction is used but open hole completion presents simpler and quicker remediation options.
- Remediation methods to address clogging are very site specific:
  - what works in one hydrogeological setting may not always be successful in another location;
  - remediation approaches may differ between injection bores across the same scheme and in the same aquifer.
- Remediation methods include:
  - Mechanical techniques
  - Physical techniques
  - Chemical techniques

Design Considerations

- Materials consideration (plastic vs steel).
- Bore completion methods
- Bore development
- Operation and maintenance – clogging.
- Management of artesian pressures or waterlogging.



Water treatment to minimise clogging

- Various methods of mechanical pre-treatment can be applied:
  - Passive (wetlands, biofiltration)
  - Filtration ranging from simple sand filters to membrane filters
  - Coagulation and flocculation
  - Activated charcoal
  - UV treatment
  - Chlorination
- Water sourced from RO may require additional buffering before recharge.
- Water sourced from wastewater treatment also may require additional treatment prior to recharge (e.g. algae management chlorination – THM?).

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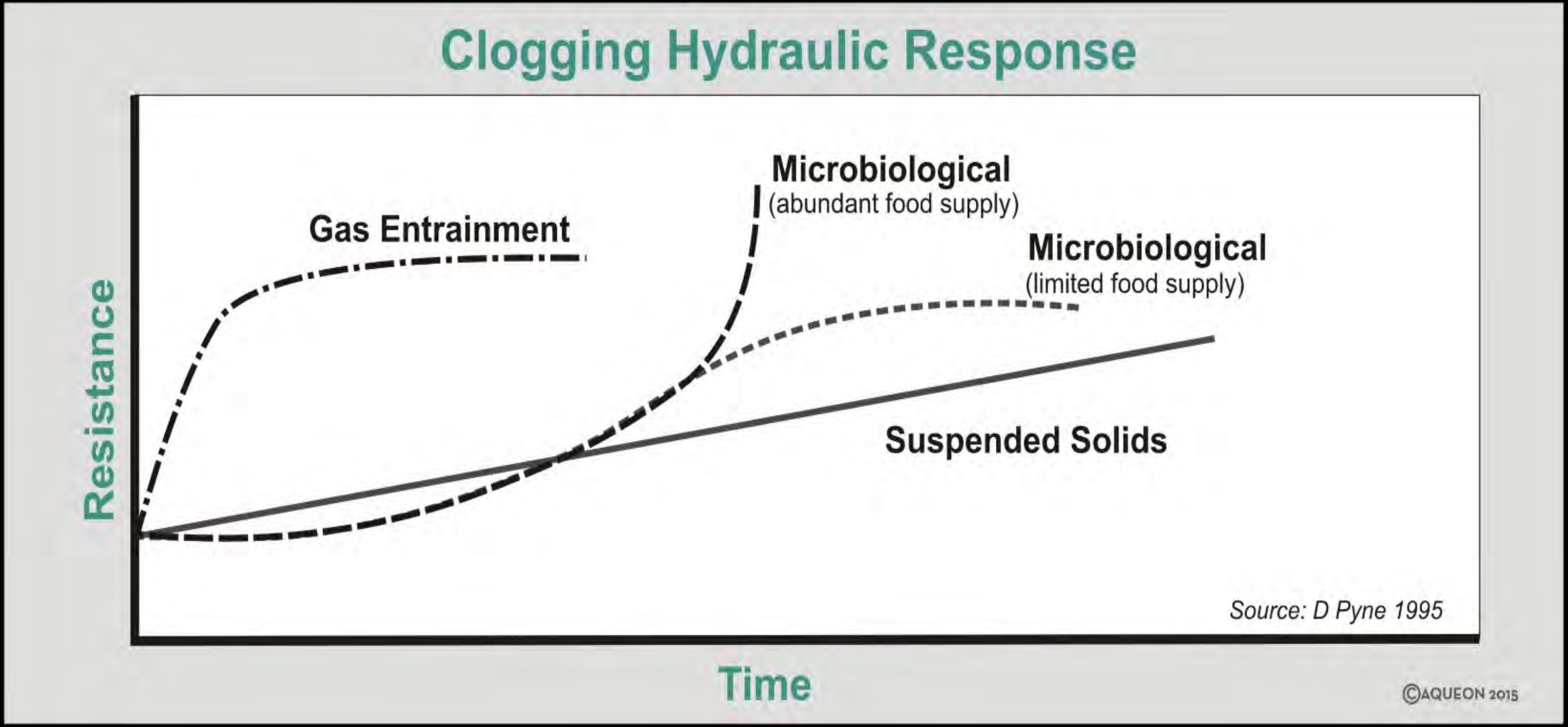
Operational measures to mitigate clogging

- Proper conditioning of the bore prior to commencing recharge
- Flush wellhead piping and well to waste prior to recharge and at beginning of recovery for a few minutes to an hour.
- Periodically backwash well to waste for a few minutes to an hour to remove accumulated solids.
- Typical backflush frequency is every few weeks to every month (depending on source water quality).
- Use same pump for backflush and recovery.
- Prevent clogging by treating water to acceptable standards – often necessary to meet regulatory requirement for protecting groundwater quality and/or existing third party users.

Monitoring for clogging

- Monitoring during recharge includes:
  - Inline parameters pH, temperature salinity, turbidity
  - Pressure heads in the injection bores and monitoring bores
  - Flow rates

Recognising clogging by hydraulic response



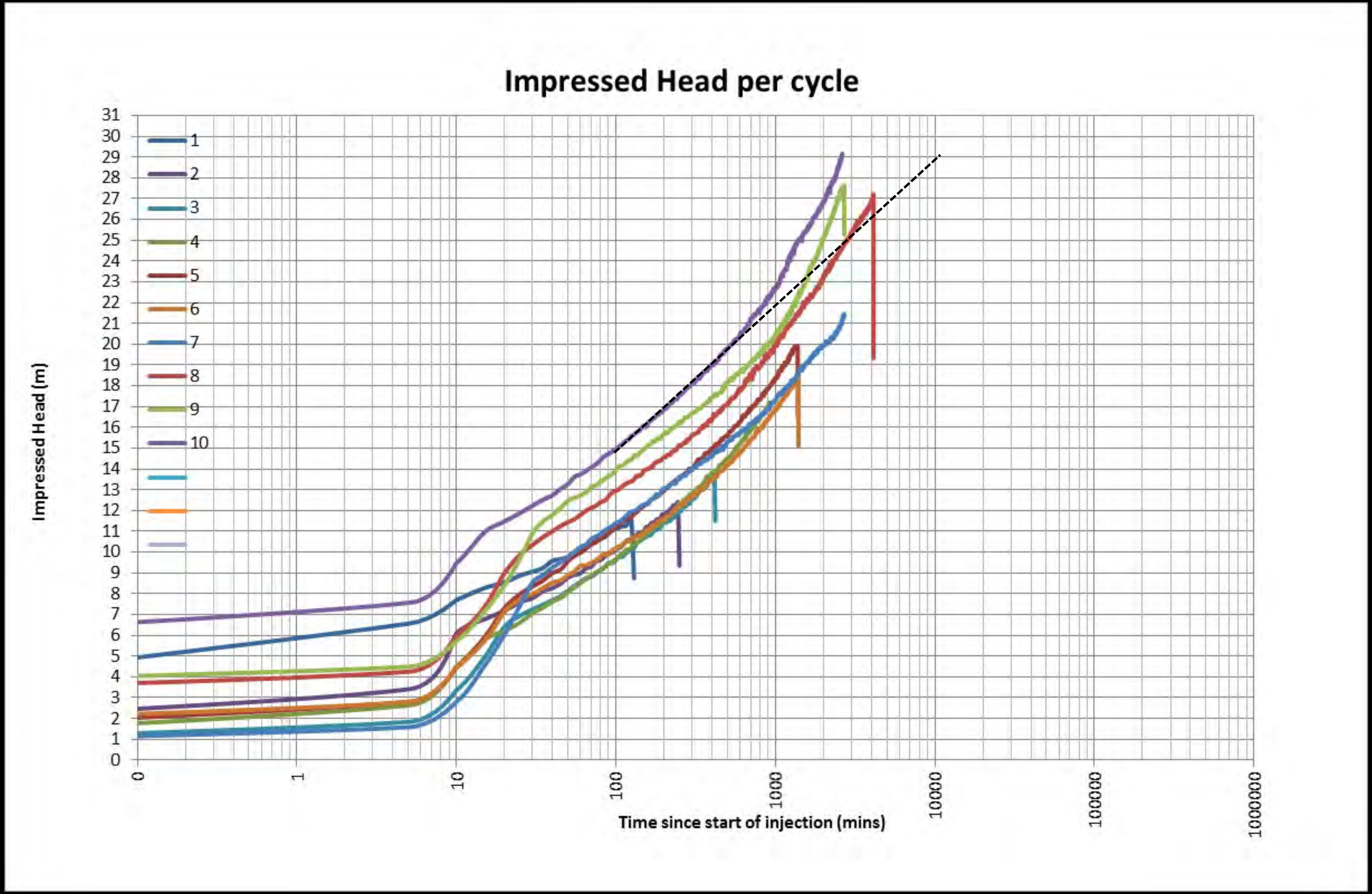
Specific Capacity

- Applied to Injection bores, SC is used to review the need for back flushing or the optimal injection flow rate or prioritising well performance

$$SC = Q/s$$

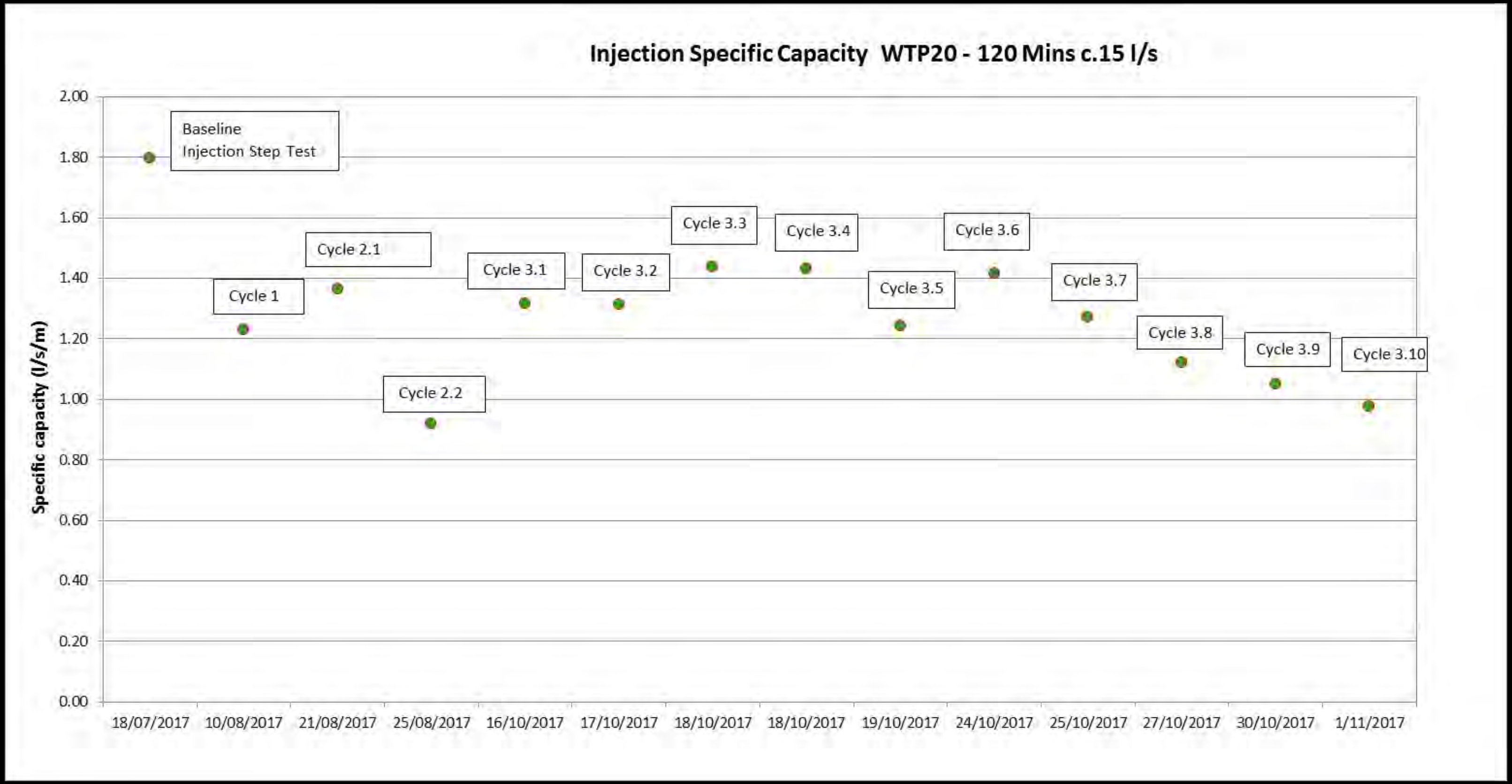
- where
  - Q = the rate at which injection is occurring (in traditional sense rate at which drillhole is pumped)
  - s = the change in head at a specified time e.g. 100 minutes.

Case study



Impressed Head per cycle
Impressed Head (m)
Time since start of injection (mins)
0
1
10
100
1000
10000
100000
1000000
31
30
29
28
27
26
25
24
23
22
21
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
1
2
3
4
5
6
7
8
9
10

Calculated specific capacity for different cycles



Intervention measures to restore clogged bores - 1

Mechanical techniques

- Back flushing (pumping)
- Intermittent pumping (surging)
- Juttering
- Over pumping
- Sectional pumping
- Vacuum
- Under reaming
- Ramping up & down of submersible pumps
- Incremental pack redevelopment (Tom Morris ASR Systems)
- High pressure jetting
- Air jetting
- Hydrodynamic fracturing
- Brushing
- High frequency vibration

Intervention measures to restore clogged bores - 2

Physical techniques

- Pasteurization
- Disruption by freezing + pumping
- Ionizing radiation: gamma radiation
- Explosives and ultrasonic

Chemical techniques

- Chlorine & chlorine containing agents
- Acids (hydrochloric acid, sulphamic acid, hydrofluoric acid).
- First chlorine then acid
- Polyphosphates
- Carbon dioxide
- High pressure water jet + hydrogen peroxide + hydrochloric acid to aid enlargement of well diameter.

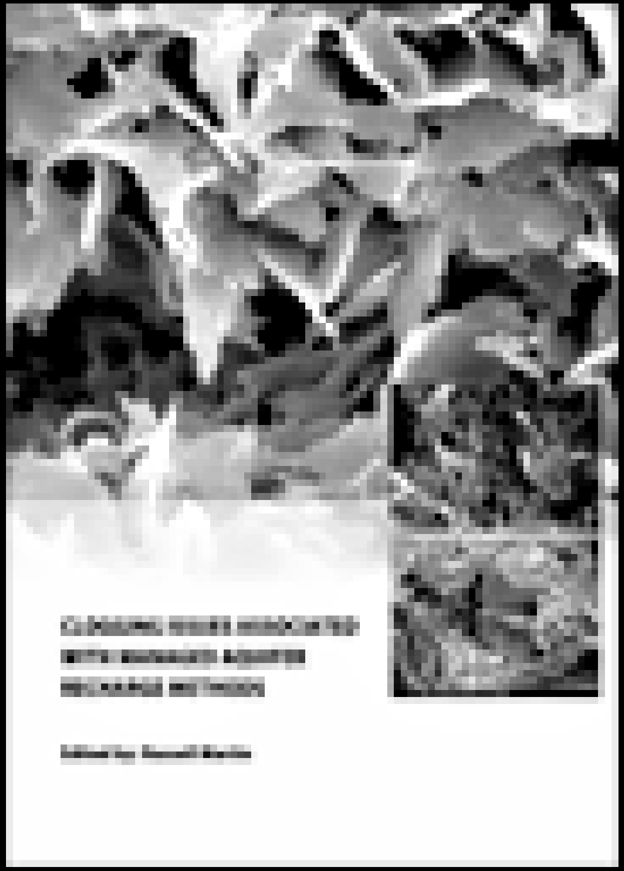
Summary

Clogging will happen

Clogging can be controlled

- Manage water quality
- Detailed characterisation of the aquifer
- Proper bore construction and development
- Proper conditioning of the bore prior to injection
- Monitoring during operations
- Remediation methods

Clogging reference



More information
https://recharge.iah.org/working-groups/clogging-and-its-management

Seeking articles and clogging case studies for volume 2.

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Questions

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