ASR Well Maintenance:

What Happens When ASR Wells Stop Giving: Idaho Case Histories

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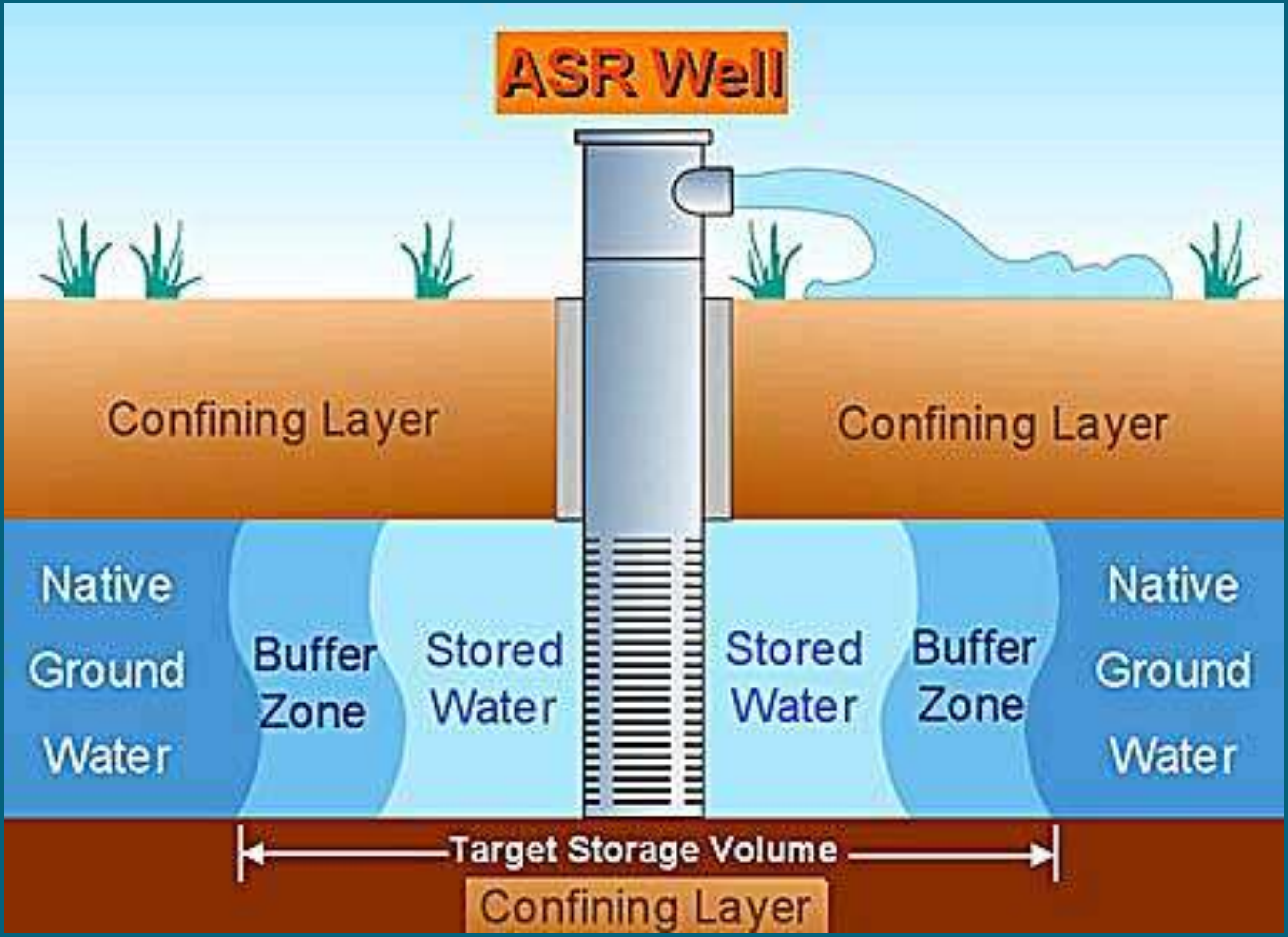
ASR Technology Overview

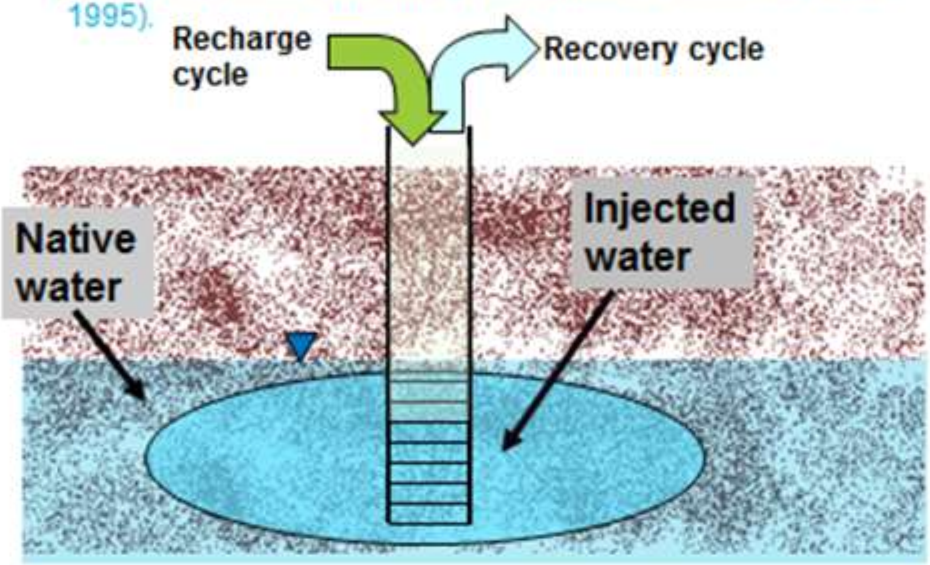
What is Aquifer Storage and Recovery?

- Water supply management tool
- Remediation for poor water quality
- Alternative to reservoirs and holding tanks
  Temporary underground storage of potable water
- Recovery of water to meet peak demands
- Water is injected during wet or surplus periods and pumped during dry or peak need periods

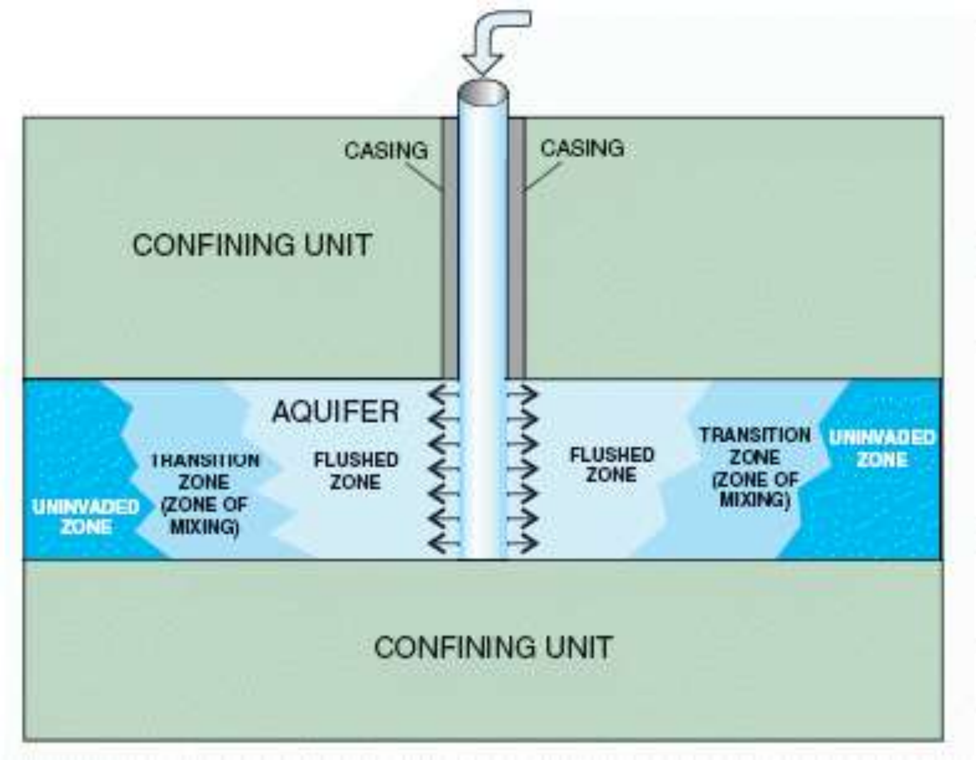
What is ASR?


ASR Well
Confining Layer
Confining Layer
Native Ground Water
Buffer Zone
Stored Water
Stored Water
Buffer Zone
Native Ground Water
Target Storage Volume
Confining Layer

ASR: Storage of water in a suitable aquifer through a well during times when water is available, and recovery of the water through the same well during times when it is needed (Payne, 1995).



- In Florida and California the aquifers near the ocean have intrusions of natural salty brine
- Freshwater pumped into aquifer will have zone of mixing
- Freshwater will create a “bubble”… Keeps Brine away



ASR Technology Overview

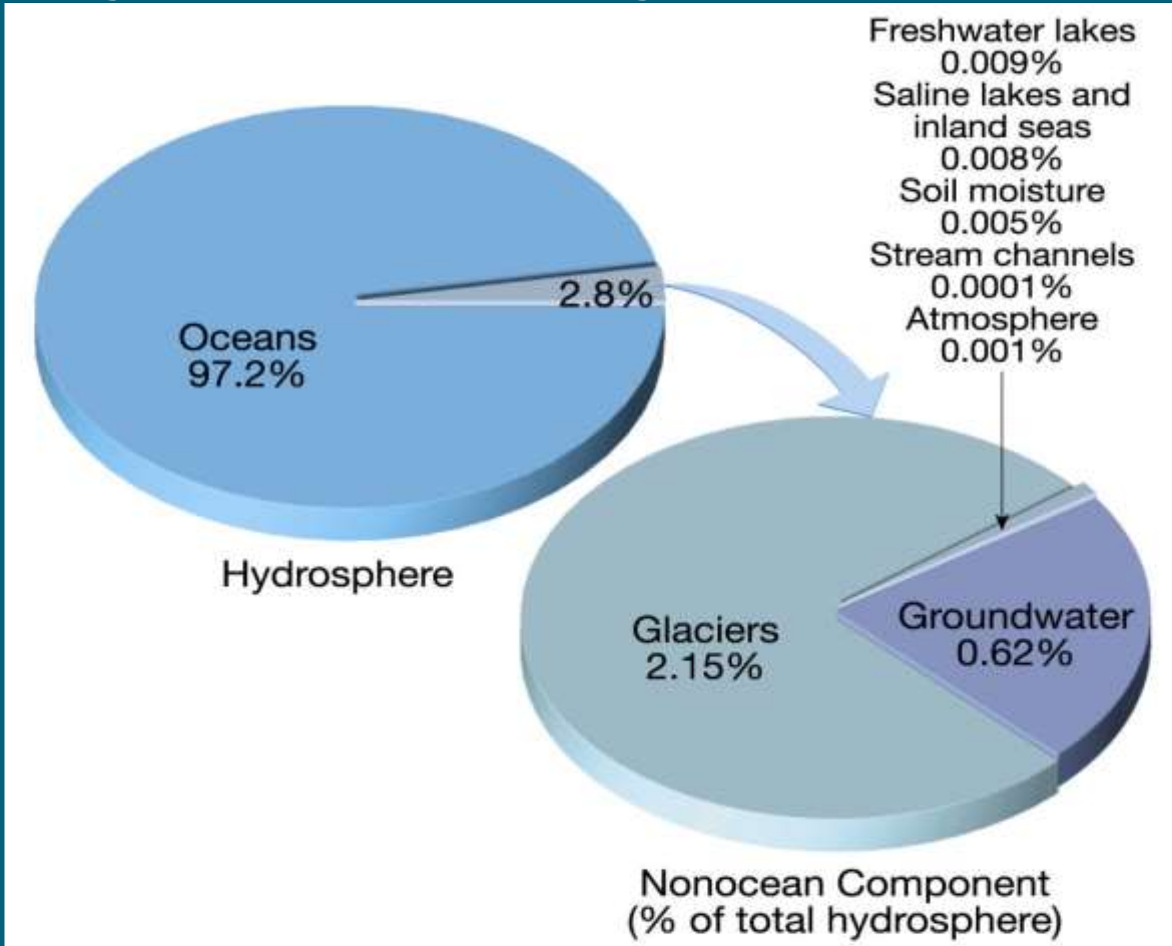
Key Factors in Boise

- In Boise, ASR wells are used to remediate problems with iron, manganese, arsenic and other negative chemicals
  - UWID has 6 ASR wells
  - Have a 100 day window to inject water
  - 40 to 60 MG injected per well

- Mac Well Study
  - Aging study found 7000 year old water
  - Recovery Percentage: 30%. Usually put in 3X the water we get back out before quality gets bad

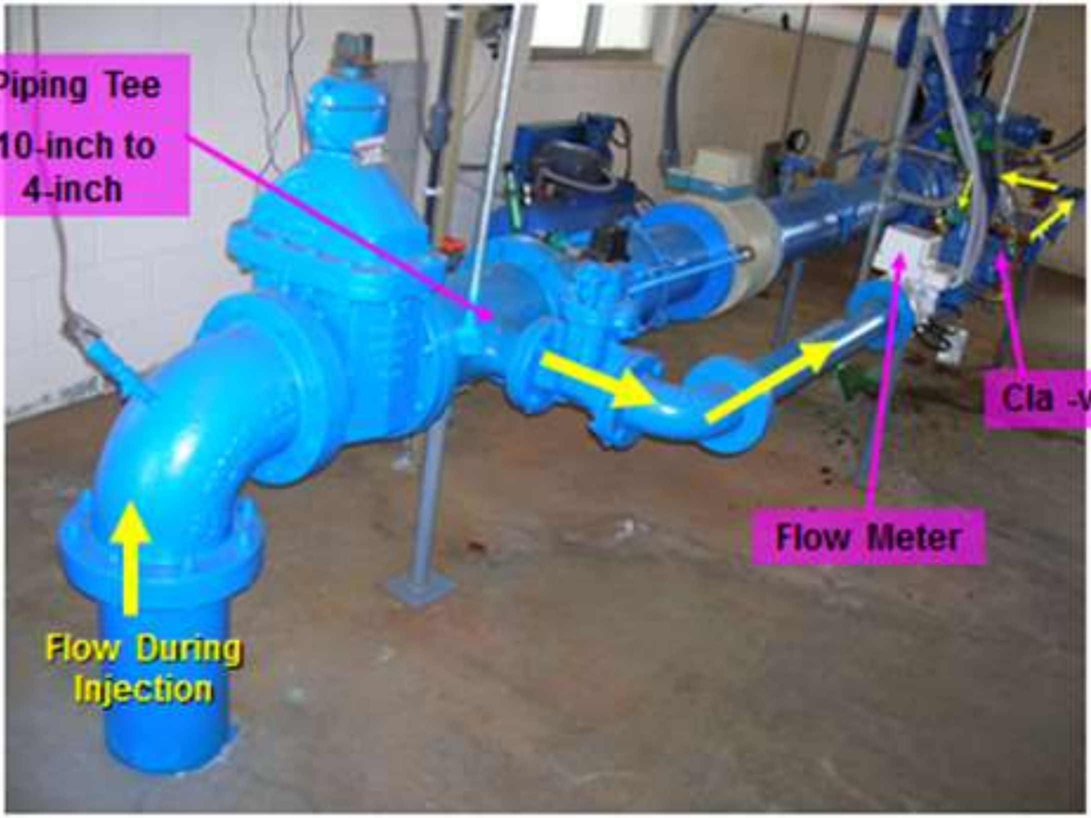
Groundwater

- **Largest reservoir of fresh water that is readily available**
- **Relatively Constant Quality and Production**



Typical ASR Piping at Wells

MODIFICATION TO EXISTING PIPING FOR RECHARGE



Idaho's Story

Ground water supplies 95% of Idaho's drinking water
6.3 Billion gallons per day production (1980 figures)
Public and rural use: 3% of total, but serves 90% of public water supplies

Although water quality is generally good, certain areas of the state have been specifically degraded by man with nitrates, heavy metals and SOC's , & VOC's

Nature contributes iron, manganese, arsenic and fluoride

Why do ASR wells clog and need periodic cleaning?

- Clays, silts and physical debris in the distribution system go back into the well
- Inappropriate pumping and use
  - Mineral precipitation
  - Milky water
- Microbial populations in distribution system
- Corrosion from both chemistry and biology

Well fouling begins as soon as the well is drilled and placed into operation

Mechanical and Physical Incrustation

- Drilling fluids and muds left from poor well development
- Plugging with natural silt and clay
- Debris fills screens and gravel pack
- Poor well development leads to inefficient wells
- Early clogging = early failure

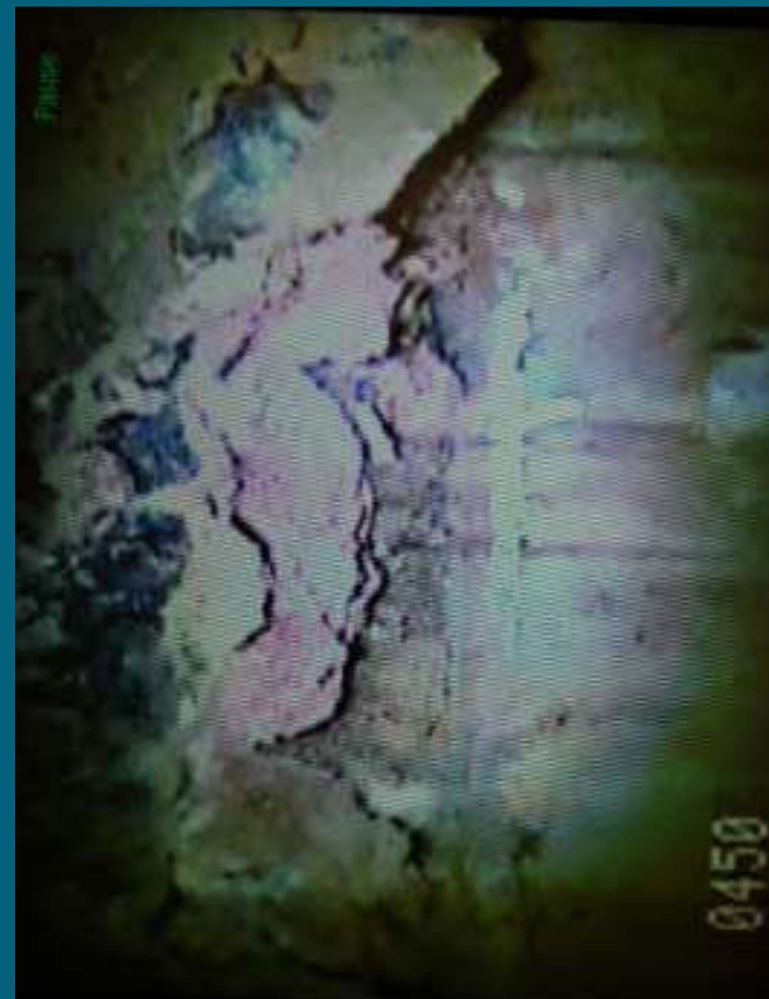
Drill Muds

Not easily removed

Mineral Incrustation

- Mineral scale forms around well bore and screens
- Caused by well inefficiency and high water velocities
- Inorganic chemical mineral deposits
    - Carbonates, sulfates

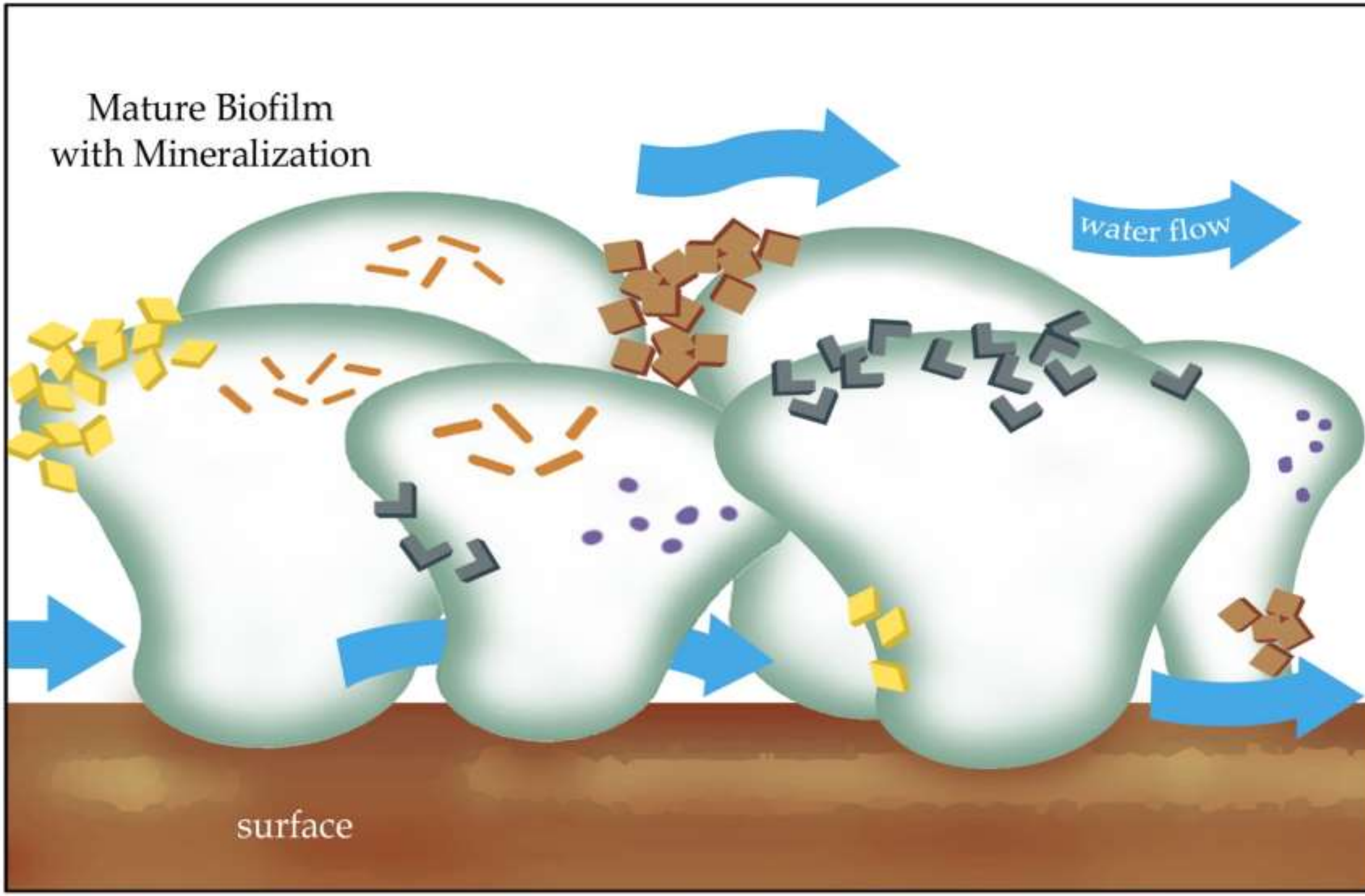
Before



After Cleaning

Water flow area virtually eliminated

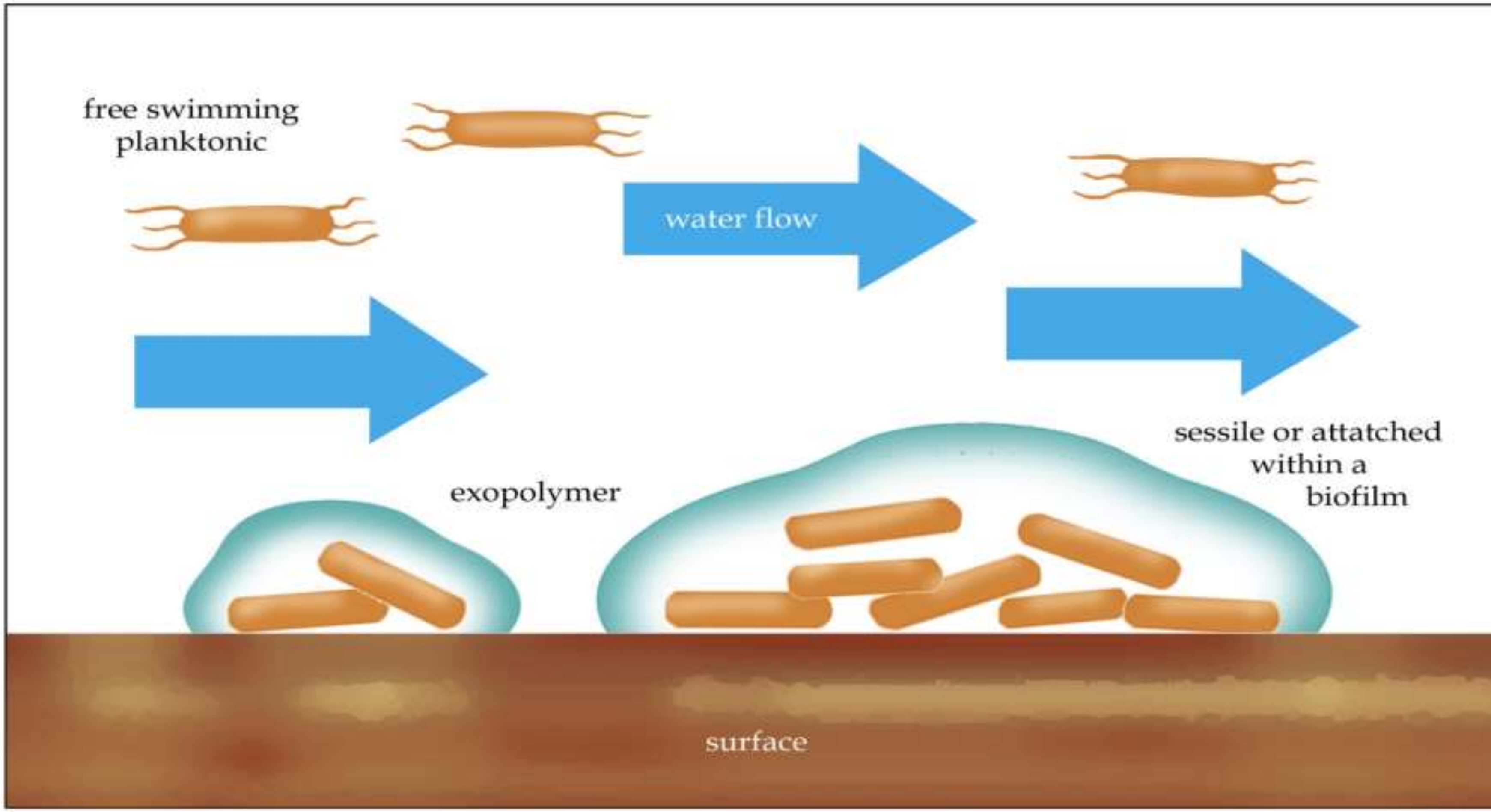
Mineral Attachment

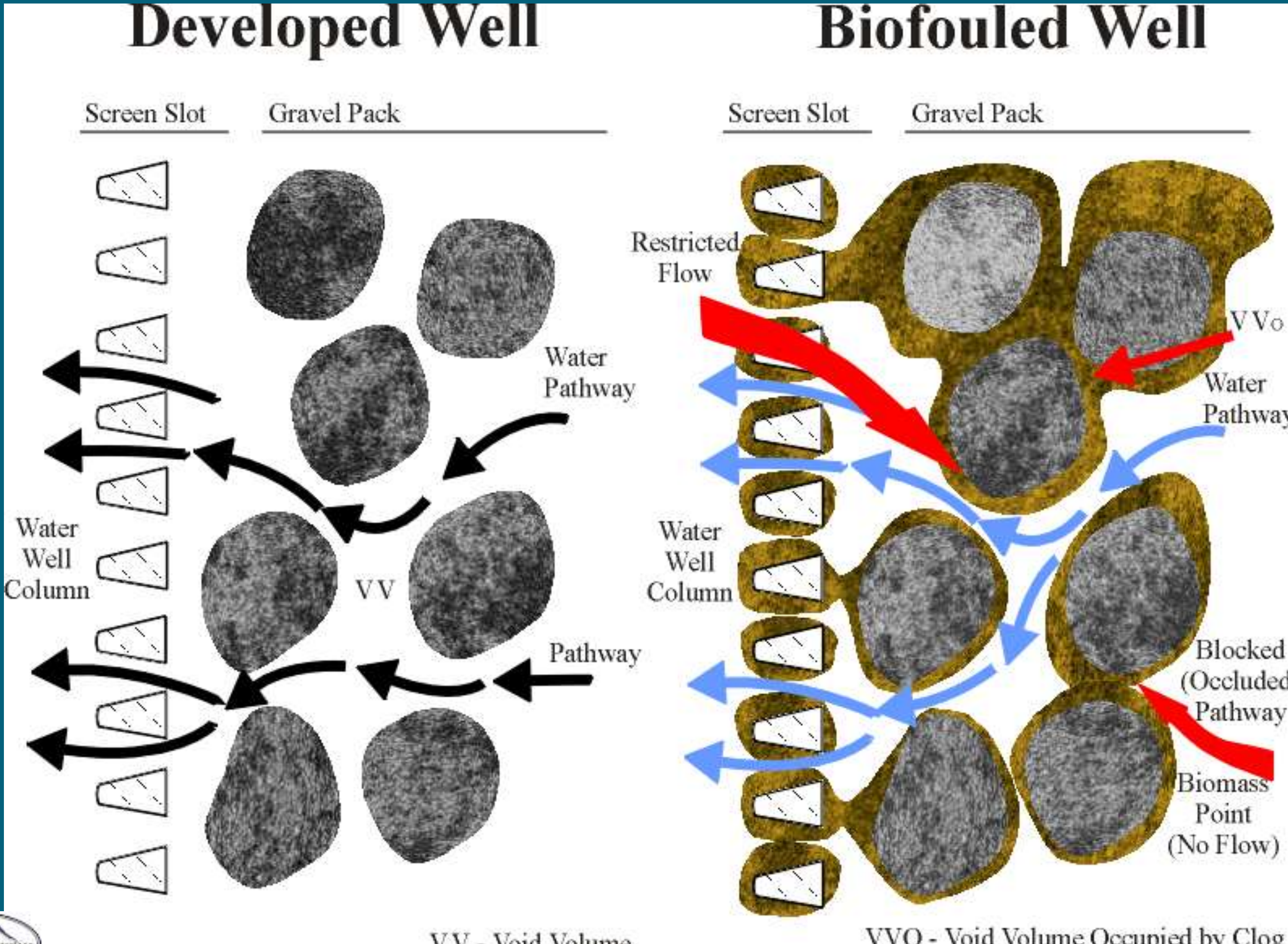


Biological Incrustation

- Plugging occurs due to biofilm buildup
- Microbial Organisms
  - Iron related bacteria
  - Slime related bacteria
  - Sulfate reducing bacteria
  - Anaerobic bacteria
  - Coliforms

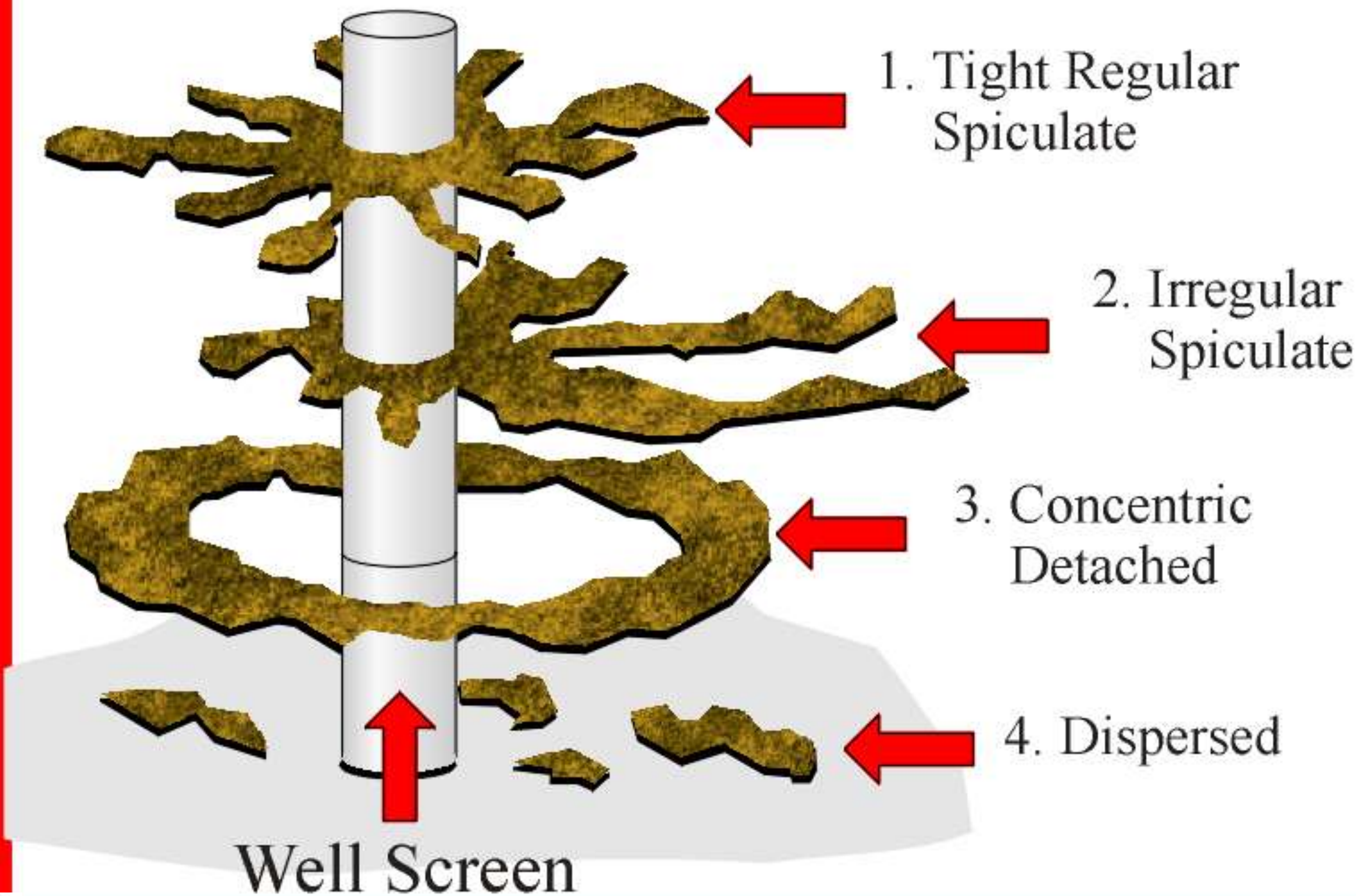
Biofilm formation, free cells to attached cells





Developed Well
Screen Slot
Gravel Pack
Water Pathway
Water Well Column
VV
Pathway
VV - Void Volume
Biofouled Well
Screen Slot
Gravel Pack
Restricted Flow
VVo
Water Pathway
Water Well Column
Blocked (Occluded) Pathway
Biomass Point (No Flow)
VVO - Void Volume Occupied by Clog

Forms of Well Biofouling



Non Pathogenic
Common Soil Bacteria

Slime problems

- Pseudomonas
- Aerobacter
- Flavobacter
- Acinetobacter

88% slime problems in over 2000 tests

Plugging problems w/stalks
Produce a corrosive enzyme

Most common iron bacteria families

- Gallionella
- Crenothrix
- Leptothrix
- Siderocapsa

8% of problems found in wells or systems

Corrosion, & Odors

Sulfate Reducing Bacteria
Iron Bacteria families

Well fouling occurs through the activity of iron oxidizing bacteria…

One of the most important and commonly observed issues

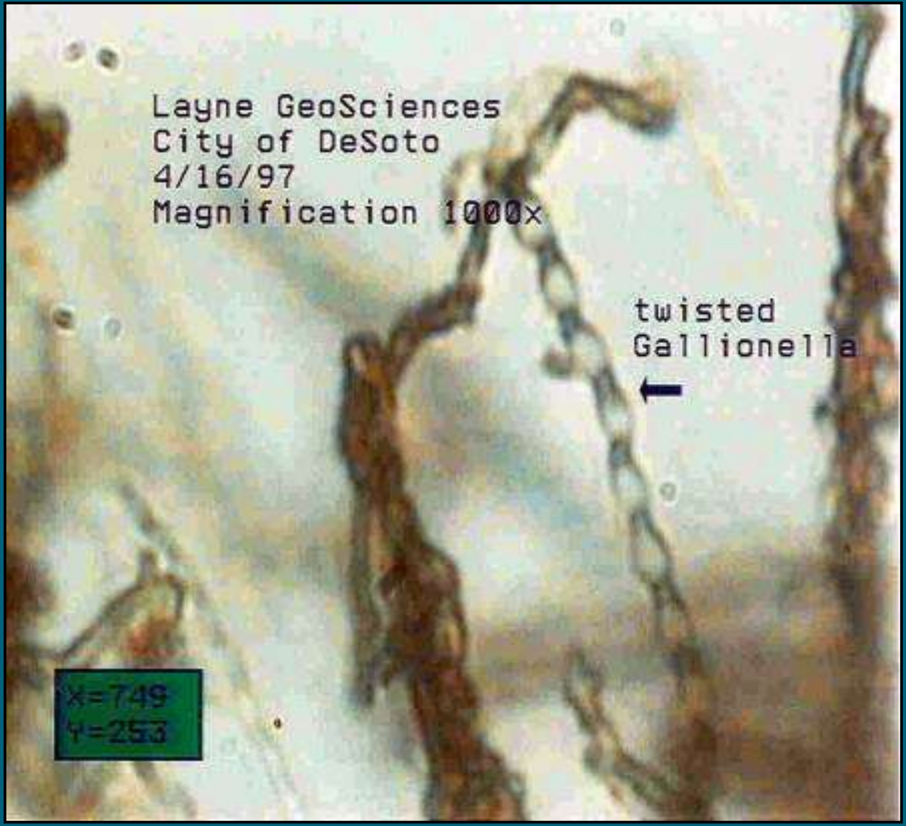
Iron oxidizing bacteria are found in a variety of soil and aquatic habitats associated with iron

Widespread occurrence in groundwater and well systems

- The secreted stalks are often shed during cycling of the well resulting in surges of red water and spikes in total iron readings
- Can alter the physiochemical properties of pipe surfaces which then serve as nutritional substrates

Iron Oxidizing Bacteria

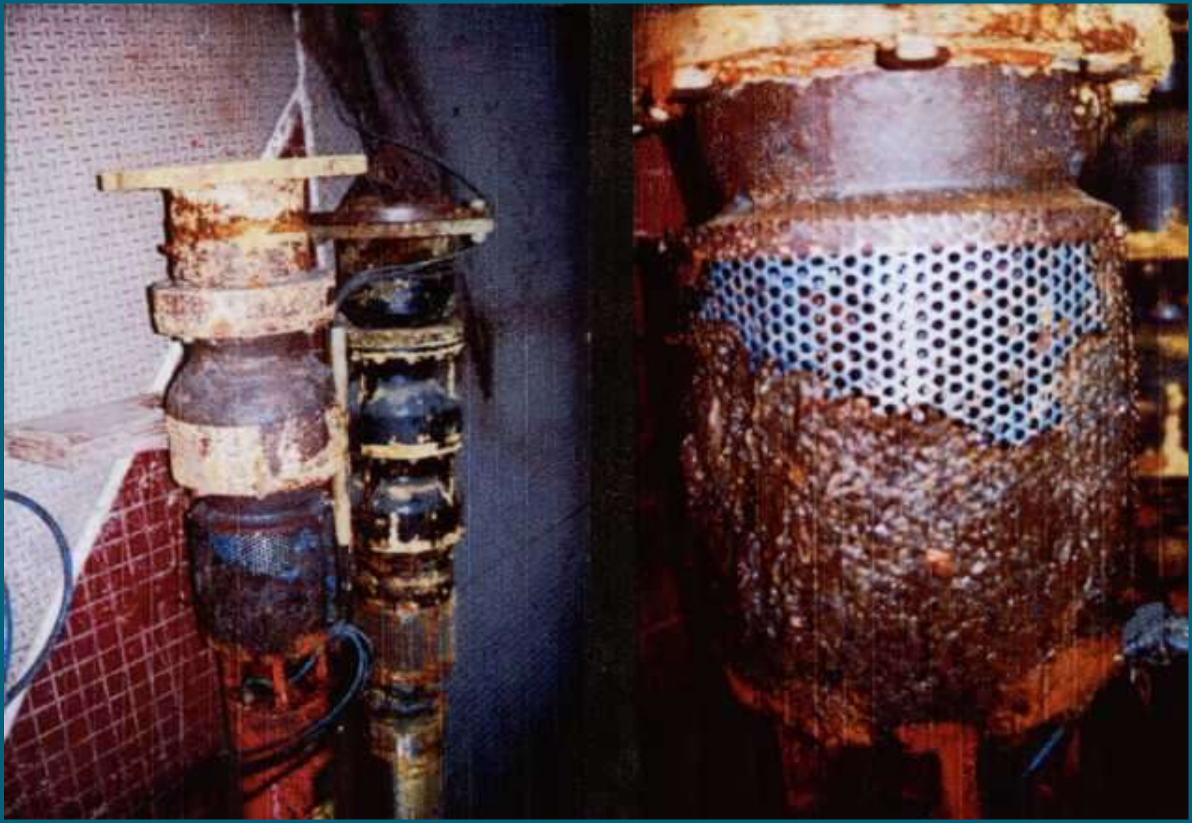
- Bacteria that deposit iron or manganese oxides
- Identified under the light microscope based on morphology



Gallionella ferruginea

Iron Oxide Entrained Biomass

Chronic bio-fouling caused by Iron bacteria



Many wells have been abandoned because of biofouling.

- Gallionella are a principal form of microbiologically influenced corrosion (MIC)
- As it attaches to iron bearing surfaces, Gallionella pits the metal in an effort to secure the iron necessary for energy

All iron bearing structures, including stainless steel, are susceptible to this form of pitting

Rehabilitation Treatments

- Many different methods
- Must effectively remove deposits
- Must penetrate into surrounding formation
- Must have good agitation
- Must be custom tailored for specific well problems

Selecting a Treatment Strategy

- **Physical and Mechanical**
- **Chemical Cleaning**
- **Disinfection**

The Diagnosis

Get all the facts first!

Tools

- Video Camera
- Geophysical
- Chemical and Biological

Well & Pump Inspection Record

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Well Owner: ______________________
Well Name or ID#: ______________________
Type Pump/Manf: Vertical Turbine: ______________________
Type Pump/Manf: Submersible: ______________________
Horsepower: ______________________

Month, Day, Year						
Readings before operating						
Static Water Level (SWL), in feet & inches*						
Voltage, each leg/ not operating L1/I2/L3						
Readings/after startup						
Voltage, each leg/operating L1/L2/L3						
Amp Readings, each leg L1/L2/L3						
GPM (Gallons per minute) @_______minutes**						
Head, above ground oe PSI reading on system						
Pumping Water Level (PWL), in feet & inches**						
Specific Capacity (SC) (GPM/ft of dd) *** PWL minus SWL= drawndown (dd) GPM divided by drawndown = SC Monitor & compare closely						
OTHER NOTES:						
Notes/Vertical Turbine Pumps						
Changes in vibration/ bearing noises						
OTHER NOTES:						
Notes/Submersible Pumps						
Meg Ohm readings per leg in starter box. If low						
or zero, take Meg Ohm readings at well head						
OTHER NOTES:						

* Always take static level before turning pump on. If taken after pump is off, let the well set for a minimum of 60 Minutes prior to recording the static level

** When measuring pumping levels, always take readings at least 30 minutes after the pump starts. Be consistent, one test to another, on whatever time (in minutes after pump starts) when recording the pumping level.

*** If Specific Capacity declines 10-20% (original SC x .80), maintenance should be schedualed for off peak times. Bacterial or water analysis should be considered.

Laboratory Services: Complete Well Profile

- One casing sample and one aquifer sample
- Includes inorganic chemistries
  - pH, alkalinity, bicarbonate, chloride, etc
- Bacterial assessment
  - Adenosine Triphosphate (ATP)
  - 2 major bacteria populations
  - Aerobic vs. anaerobic growth
  - Iron bacteria
  - Coliform bacteria

Monitor Wells with History of Iron Bacteria and Production Loses

- Collect startup and running samples
- Water samples to lab

- Monitor fouling before significant levels occur

Effective Treatment Includes

- Identification
- Treatment
- Monitoring

Biological Analysis Results and Ranges: Potable Wells

Clean Well

- ATP < 1,000--60,000
- HPC < 100
- SRB: Negative
- Anaerobic < 10%
- Coliform: Negative

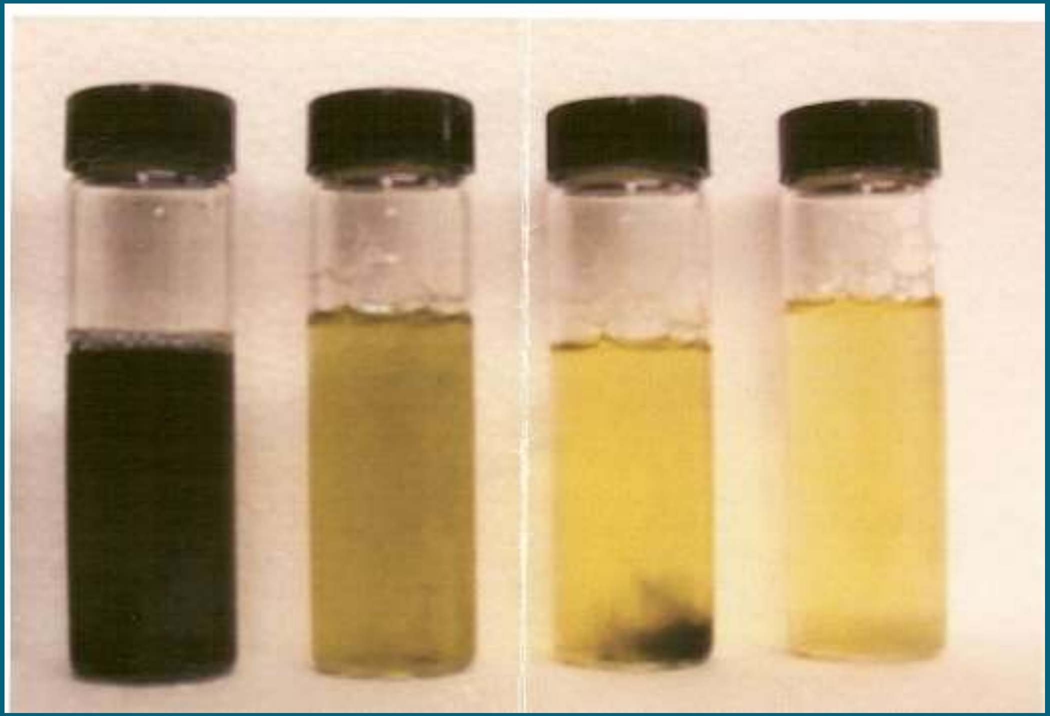
Fouled Well

- ATP > 100,000
- HPC > 300
- SRB: Positive
- Anaerobic > 20%
- Coliform: Positive or
- Negative

BacTeCheck:

A tube culture used to assess the bacterial condition in a water well.

Mfg. by Water Systems Engineering Inc.



Mechanical and chemical cleaning, with disinfection of the well

1. Physical cleaning / agitation very important
   - Brushing, Scrubbing or swabbing well with biocide
   - Full evacuation—especially the well bottom
2. Properly selected acids and a good bio-dispersant
   - Proper concentrations based upon extent of infestation and overall water chemistry
   - Can add a biocide to the acid cleaning step
3. If fouling is limited: Minimally invasive treatments effective
   - Used as preventive maintenance
   - Light chemical treatment
   - Finish with pH enhanced chlorine disinfection, redevelopment

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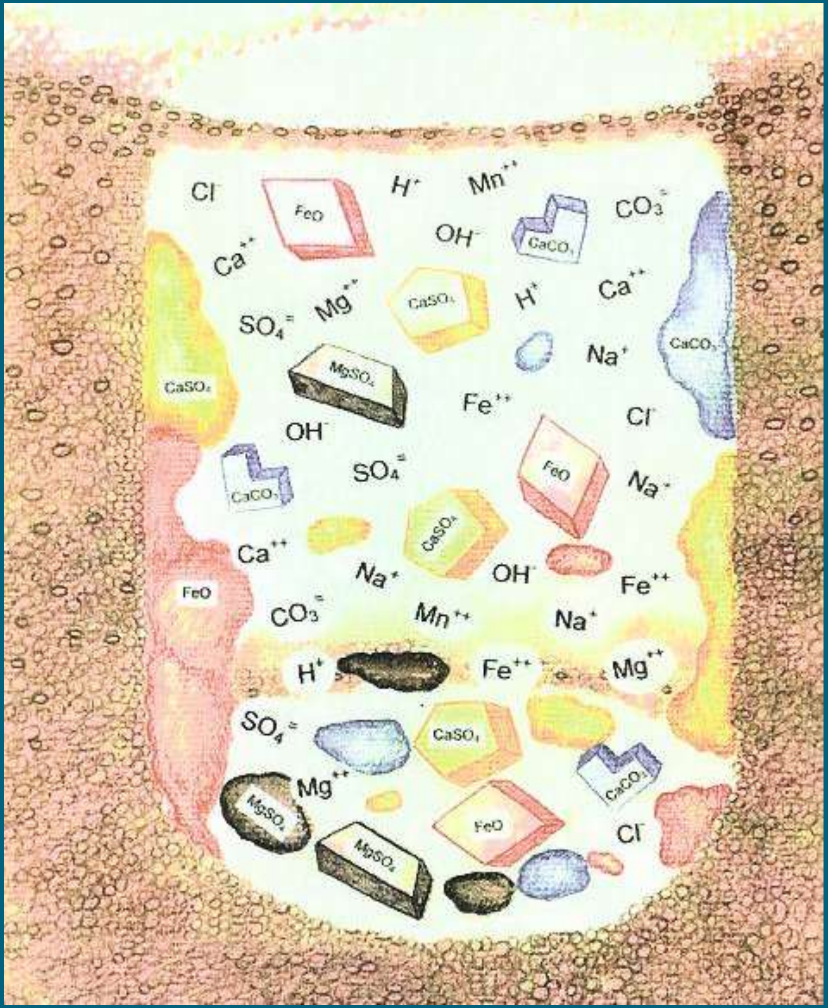
Characteristics of common well cleaning acids

Characteristics	Sulfamic	Hydrochloric	Phosphoric	Hydroxyacetic	Citric	Oxalic
Appearance	White crystal	Slight yellow liquid	Clear liquid	Clear liquid	White crystal	White crystal
Type	Mineral	Mineral	Mineral	Organic	Organic	Organic
Hazardous Fumes	None	High	None	Some	None	None
Relative Strength	Strong	Strong	Strong	Weak	Weak	Moderately Strong
pH @ 1%	1.2	0.6	1.5	2.33	2.6	1.25
Relative Reaction Time 1=Fast 10=Slow	<2	1	4 - 5	4 - 5	4 - 5	2
Corrosivenes metals skin	 Moderate Moderate	 Very High Severe	 Slight Moderate	 Slight Slight	 Slight Slight	 High Severe
Reactivity vs: Carbonate Scale Sulfate Scale Fe/Mn Oxides Biofilms	 Very good Good Fair Poor	 Very good Good-poor Very good Poor	 Very good Good-poor Good Poor	 Poor-fair Very poor Good Moderate good	 Poor Very poor Chelates Poor	 Very good Good Good Moderate good
Pounds of Acid (100%) Required to Dissolve 1 lb of Calcium Carbonate	2.0	0.73	0.65	4.5	4.0	2.0

Polymeric Dispersants

- Dispersant chemistry uses polymers
  - Blocks attraction of negative and positive charges
- Results:
  - Stops the formation of crystals
  - Stops re-deposition on well screens

The water in the well can be very congested with both soluble and insoluble debris (ions, crystals, granules, and colloidal masses)



From: Chemical Cleaning, Disinfection & Decontamination of Water Wells
John H. Schnieders

Without Dispersion Chemistry

- HCL at pH ≤ 3.0 – carries 12,000 ppm TDS

    As acid is spent, pH will rise…..

- HCL at pH 4.0- 2,400 ppm TDS

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With Dispersion Chemistry

- HCL at pH ≤ 3 – 120,000 ppm TDS

  As acid is spent and pH rises…….

- HCL at pH 7.0 – 108,000 ppm TDS

We are able to maintain approximately 90% of dissolved solid carrying capacity even at pH 7.0

Chlorination Problems

Super chlorination levels of 1000, 2000 and 5000 mg/L may not be effective

500 mg/L failed about 50% of the time

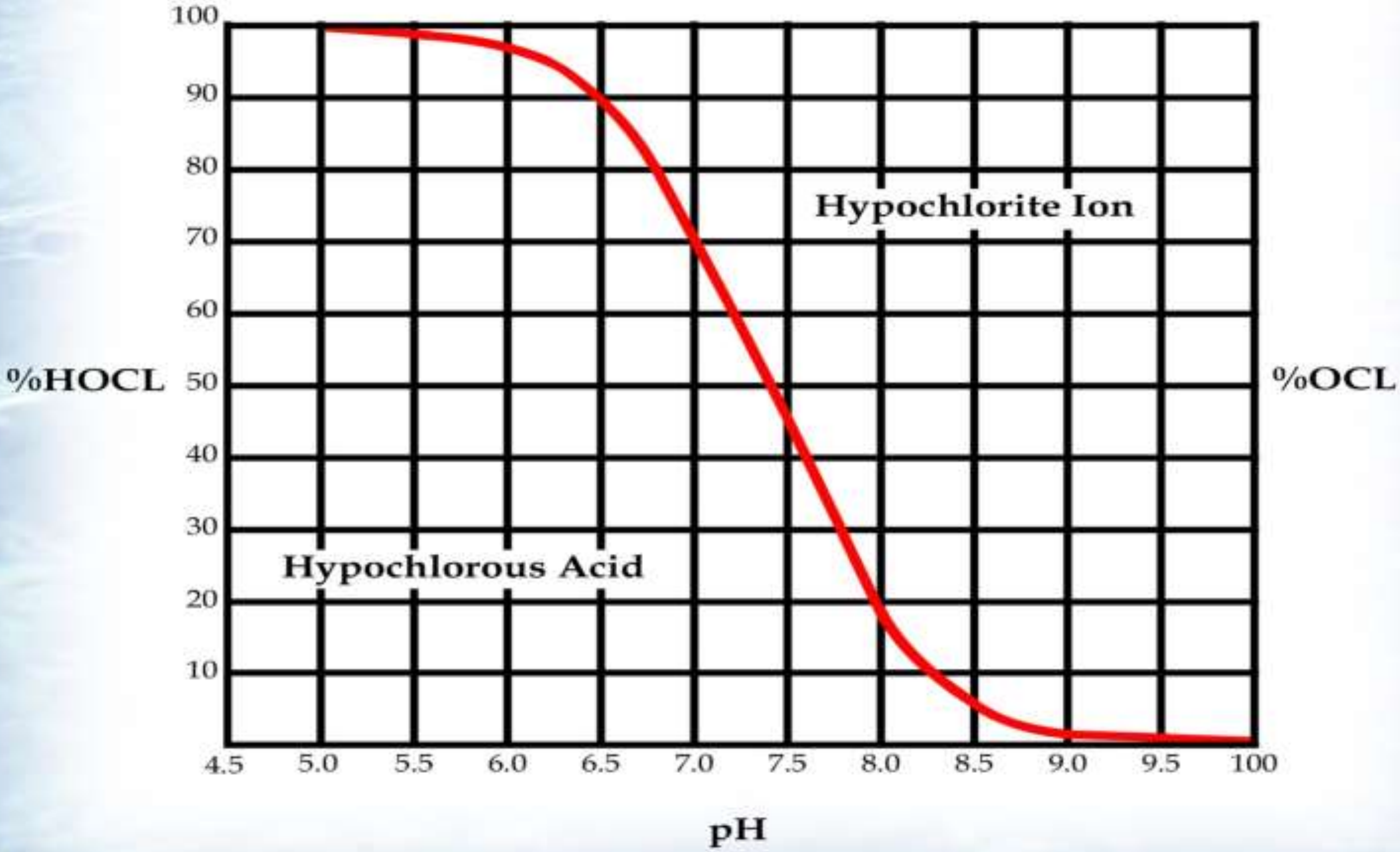
Most effective levels were the 50 mg/L and the 200 mg/L of Chlorine

Why Did Chlorine Fail at the Higher Dosages?

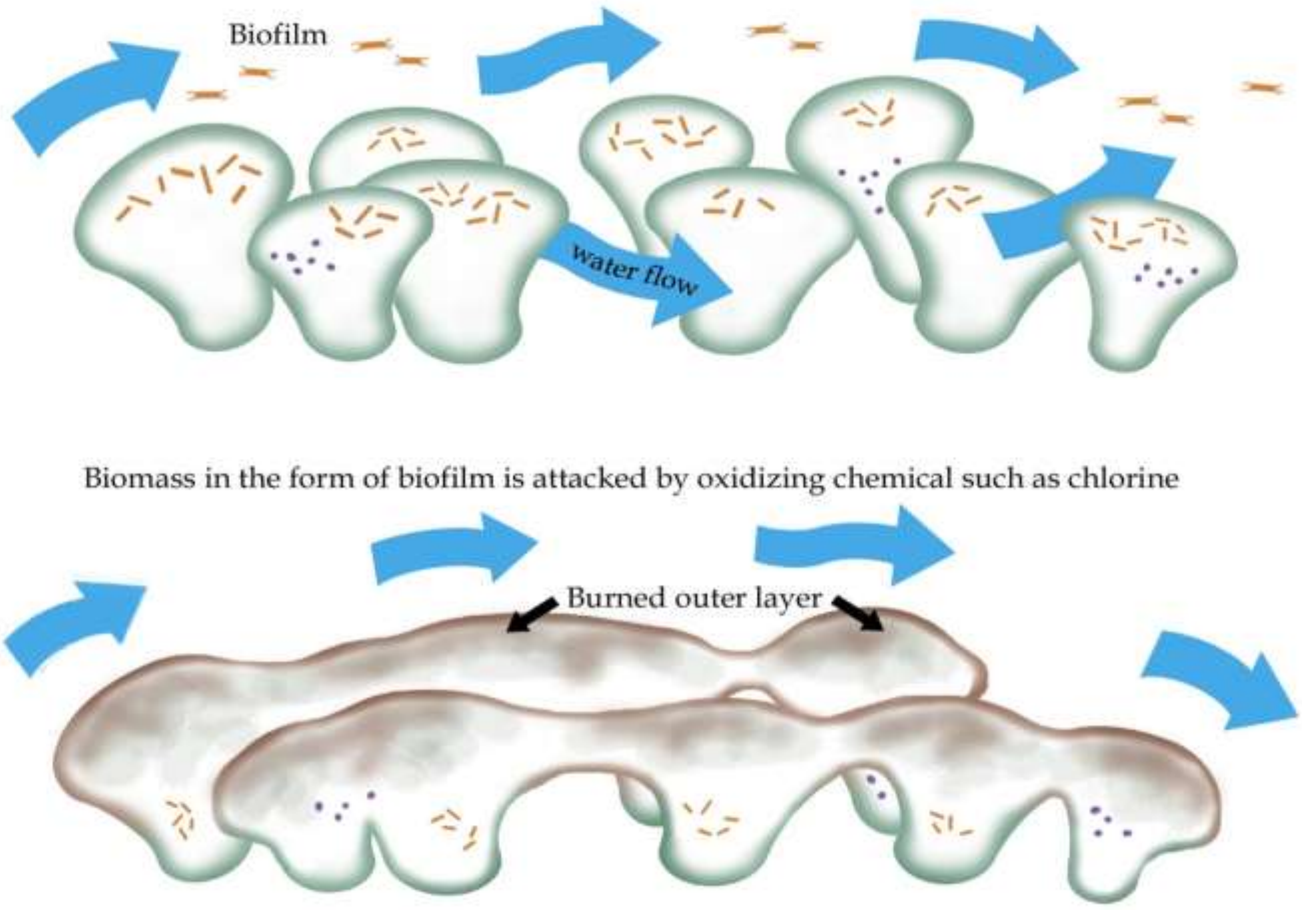
- High concentrations are very oxidative
- Higher levels can be greater than pH 10
- High pH promotes mineral precipitation
- Strong oxidation changes the polysaccharide…

…which hardens the biofilm covering

Effects of pH on Hypochlorite Ion

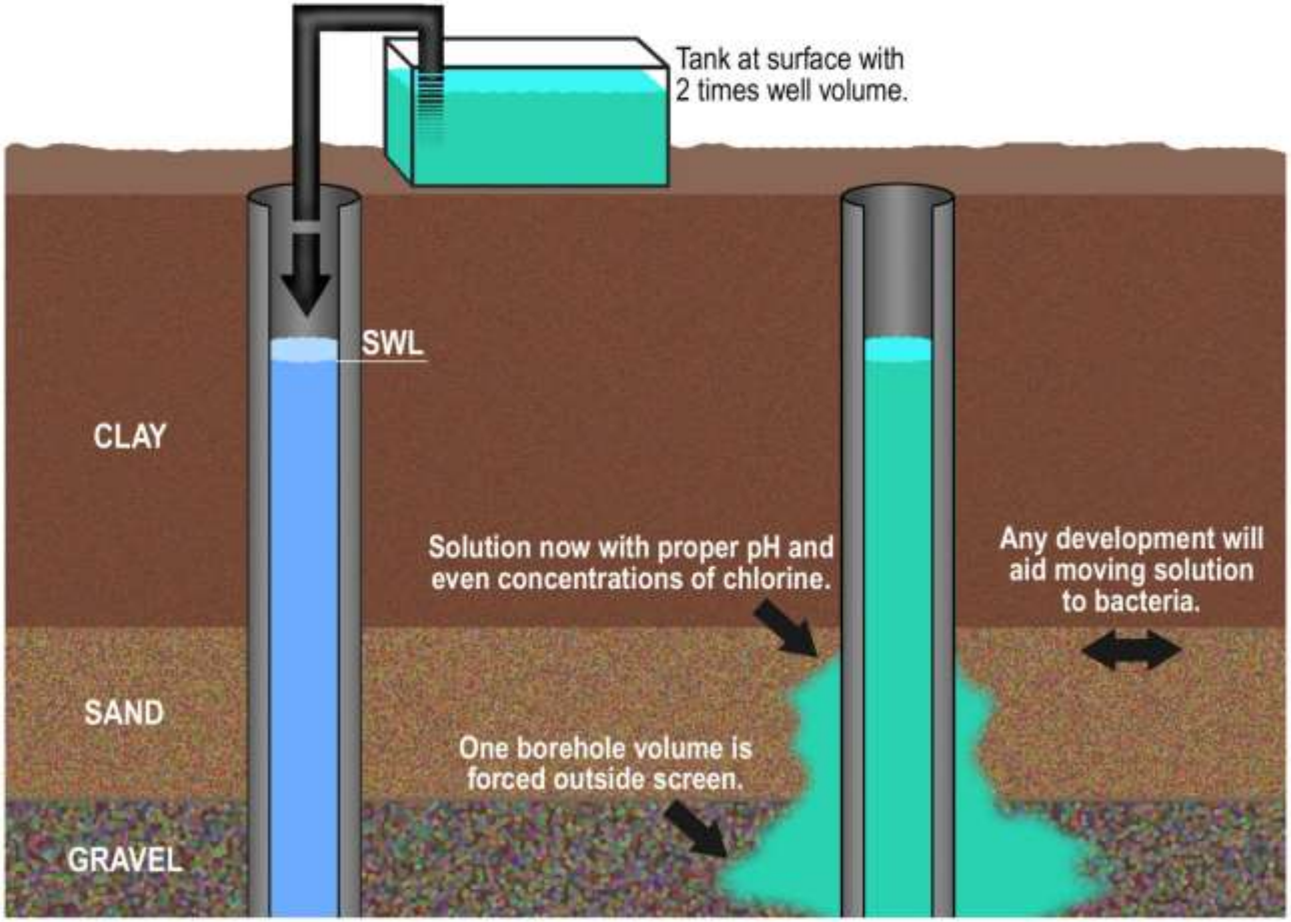


Effect of excessive Chlorine use

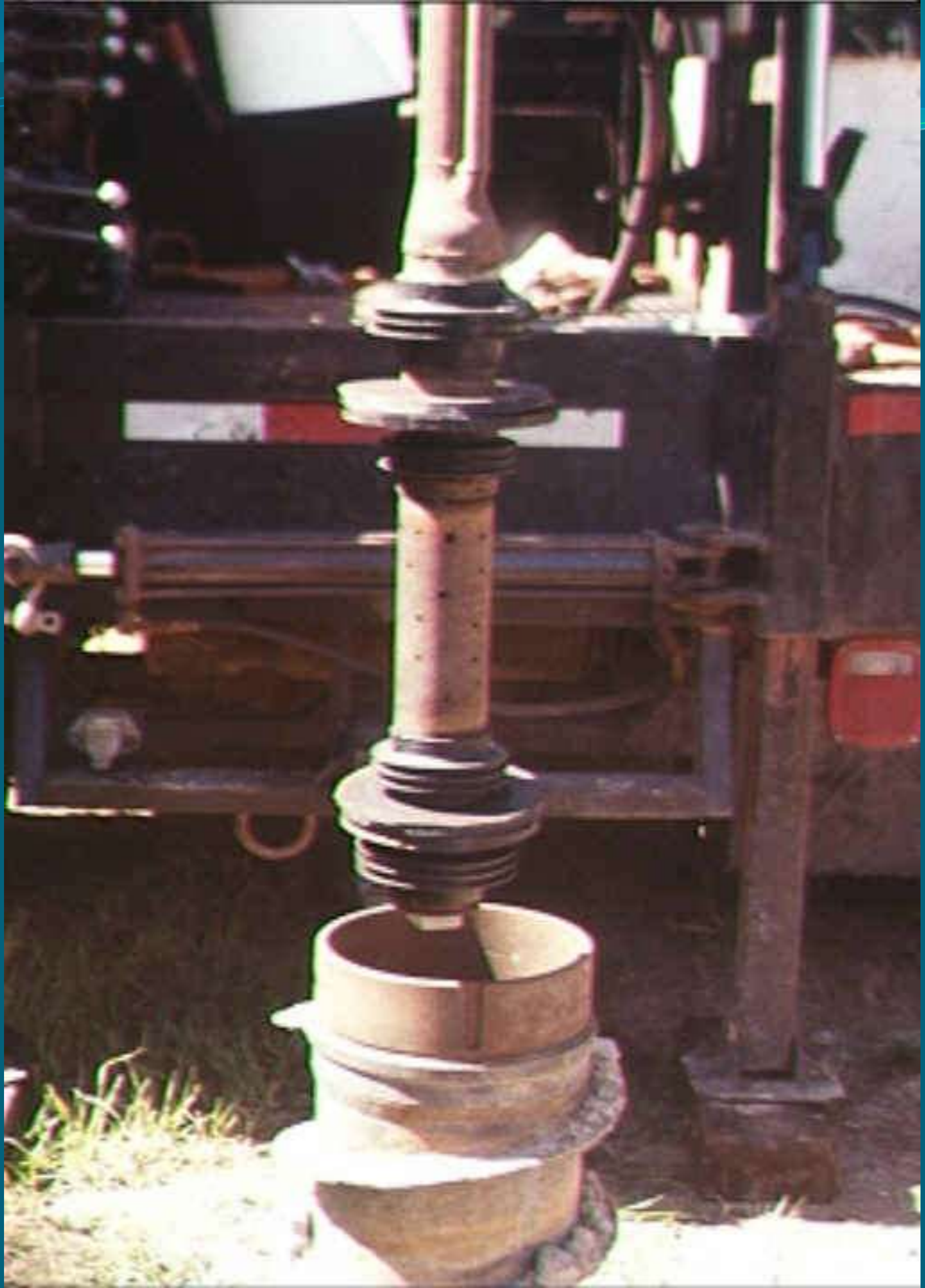


Proper Chlorination

Step 1: Calculate 2 times volume of well.
Step 2: Monitor and adjust pH, if necessary.
Step 3: Use proper concentration of chlorine and mix thoroughly. Pump or pour into well. Surge. let set overnight. Pump til pH returns to normal. Take sample.



Large Scale Chemical Treatment



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Large Scale Chemical Treatment debris is pumped from well and neutralized

Large Scale Chemical Treatment

Acid reacting in the well and foaming up to the surface

On a Smaller Scale

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WARNING

Boise City Schools, Case Study 1

- Used as an injection well for heating & cooling
- When New: 150 GPM but had dropped to 50 GPM
- Did a physical cleaning but did not change
- Before and After Well Physical Cleaning:
  - Pumping 50 GPM

- After Well Cleaning in August 2013 With AmeriWest supplying the chemicals:
  - Pumping 150 GPM

  That's a 200% improvement in pumping production

  A savings in electricity

  More efficient

Boise City Schools, Case Study

Boise City Schools, Case Study

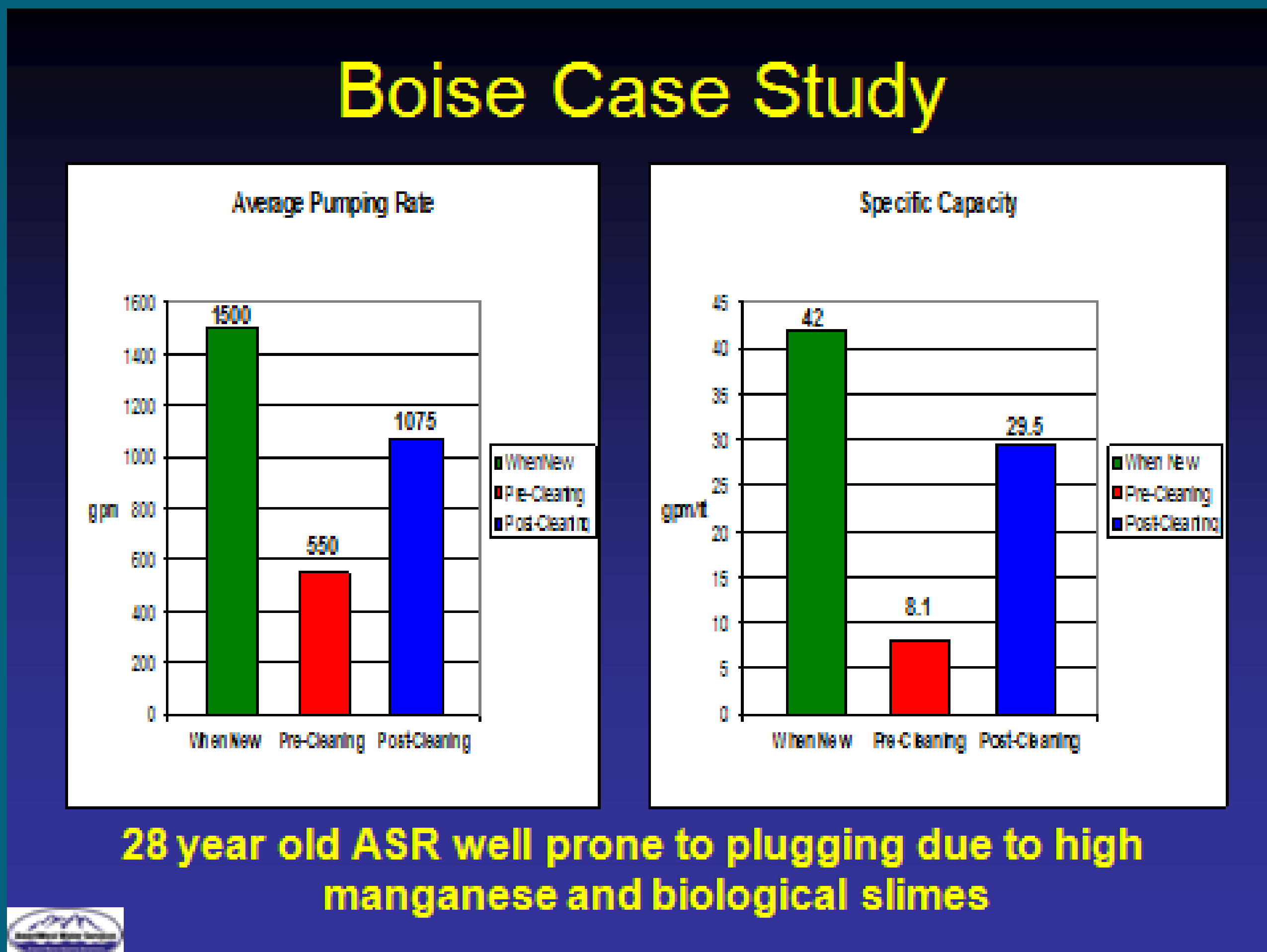
United Water Idaho Swift Well, Case Study 2

- When New in 1978: 1500 GPM with SC of 42
- Converted to ASR in 1999 to deal with Manganese, Pump reduced from 1000 to 600 GPM
- Before Well Cleaning:
  - Pumping 550GPM
  - Specific Capacity of 8.1
- After Well Cleaning in 2006
  - Pumping 1075 GPM
  - Specific Capacity of 29.5

That's a 95% improvement in pumping production

Providing additional revenue of $1212 per day.

United Water Idaho Swift Well, Case Study 2



United Water Idaho Roosevelt #3 Well, Case Study 3

- When New 650 GPM with Specific Capacity of 9
- Before Well Cleaning:
  - Pumping 465 GPM
  - Specific Capacity of 4.8

- After Well Cleaning in 2005
  - Pumping 618 GPM
  - Specific Capacity of 8.3

That's a 33% improvement in pumping production

Providing additional revenue of $587 per day.

United Water Overland Well, Case Study 4

- In 2004: 650 GPM with SC of 17
- Converted to ASR to deal with Iron & Manganese,
- Before Well Cleaning:
  - Pumping 600 GPM
  - Specific Capacity of 10

After Well Cleaning in 2012

- Pumping 650 GPM
- Specific Capacity of 19

That’s a 10% improvement in pumping production limited by pump, but 90% improvement of Spec. Capacity

Drawdown improved by 34 feet = more efficient = less pumping costs.

City of Layton Utah, Non-ASR Case Study 5

- When New: 2400GPM with SC of 126
- Before Well Cleaning:
  - Pumping 1200GPM
  - Specific Capacity of 15
- After Well Cleaning in March 2012
  - Pumping 2500 GPM with a drawdown of 15 feet
  - Specific Capacity of 166

That's a 1006% improvement in Specific Capacity and a 108% improvement in pumping capacity

A 15% savings in electricity = $1000 per month

A potential sales of $2500 per day in additional production

So. Salt Lake City Utah, Case Study 6 7th East Well Non-ASR

- Before Well Cleaning:
  - Pumping 890 GPM with a drawdown at 230 ft
  - Specific Capacity of 3.9
- After Well Cleaning in May 2013
  - Pumping 1475 GPM with a drawdown of 170 feet
  - Specific Capacity of 8.5

That's a 118% improvement in Specific Capacity and a 66% improvement in pumping capacity

A savings in electricity has been reported

A potential sales of $2246 per day in additional production at $2.00/100 cubic feet

Preventative Maintenance

- The most neglected part of well care

- *Make preparations when new*

  or when refurbishing a well for chemical injection down the well
  - Tremie line in well
  - Method for injecting down pump column

Consider a Car Care Approach to Well Maintenance

You don’t wait for the check engine light to come on in your car to make you get an oil change.

Why maintain your wells any differently?

Long term well maintenance is probably the most neglected part of well field operations.

Benefits of ASR Maintenance Well Rehabilitation

- Extend the useful life of the well
- Maintain good water reinjection and production

  Sell more water

- Lower energy costs

  Save Money... Reduced pumping costs

Fig. 11-3, p. 240

Any questions?