Maryland Department of the Environment

Maintaining Well & Pump Efficiency

Neil Winner
Water Supply Program

September 29, 2010

MDE

MDE

Why Maintain System Efficiency?

- Save $$ in efficient operation and pumping
- Allow budgeting for future repairs
- Prevent emergency breakdowns
- Prevent more expensive repairs
- Drought-proof your system
- Preventive maintenance is the key

Maryland

MDE

Outline

- Well System Efficiency
- Well Development
- Step-Rate & Constant-Rate Pumping Tests
- Operational Expectations
- Record Keeping
- Periodic Maintenance
- Performance Loss
- Well Rehab Methods
- Pump Maintenance and Repair

MARYLAND

MDE

Well System Efficiency

- Starts with proper well design and pump selection
- Continues with proper well drilling, construction, and development
- Maintained by preventive maintenance and service

MARYLAND

MDE

Well Design

- Selection of the gravel pack must match formation characteristics
- Slot openings of the screen must match the water bearing formation or the gravel pack, if applicable
- Important in order to maximize well efficiency

MARYLAND

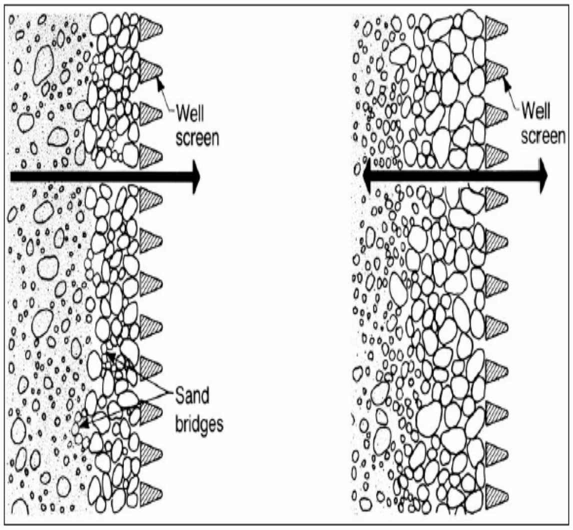
MDE

Well Development

- Removes fines from the water bearing formation adjacent to the screen and gravel pack
- Allows for the free entry of water into the well
- Maximizes the efficiency of the well

MARYLAND

MDE

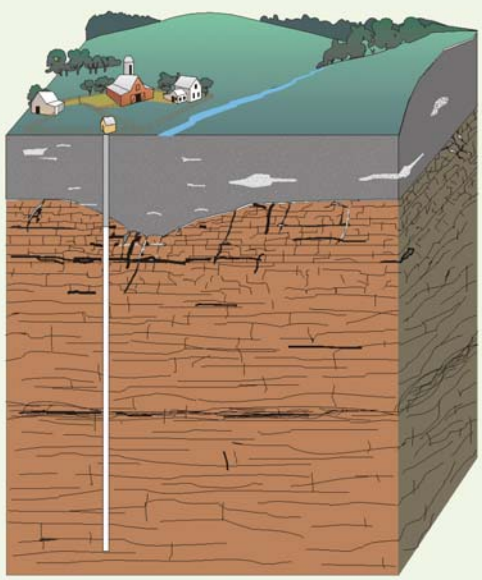


Effective development action requires movement of water in both directions through screen openings. Reversing flow helps break down bridging of particles. Movement in only one direction, as when pumping from the well, does not produce the proper development effect.

Development of Screened Wells in Unconsolidated Sediments

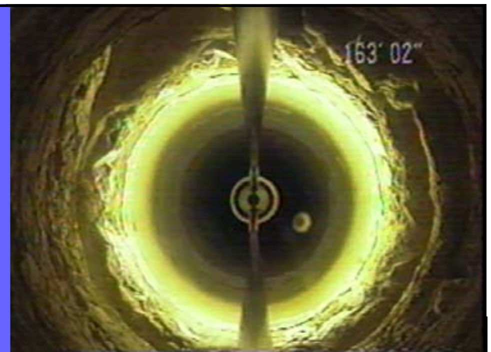
MARYLAND

Development of Bedrock Wells



- **Remove natural and drilling-induced fines from fractures**
- **Widen fractures near the well to prove hydraulic connection with nearby fractures**

Examples of Typical and Extreme Bedrock Fractures



MDE

Pumping Tests

- Determine safe pumping rates
- Used to determine proper size pump
- Act as final well development phase

MARYLAND

MDE

Types of Pumping Tests

- Step Drawdown Test
- Constant Rate Flow Test

MARYLAND

MDE

Step Rate Pumping Test

- Determine flow for the constant rate test
- Calculate well efficiency
- Develop a baseline for future well rehabs
- 25, 50, 75, 100, 125, 150% of design flow
- Calculate specific capacity at set flows
- S.C.=GPM ÷ Ft of Drawdown

MARYLAND

MDE

Constant Rate Test

- Calculate long term safe yield
- Calculate interference between wells
- Indicate if any boundaries or recharge
- 100 to 150% of permitted pumping rate
- 24 to 72 hours (120 or more for bedrock)
- Design of pumping equipment

MARYLAND

MDE

Operational Expectations

- Wells often need to be cleaned and redeveloped after the first 7-10 years of operation
- Pump may need to be repaired 5-8 years after it is first installed
- BOTH often require service every 7-8 years thereafter
- Depends on formation and water quality
- Depends on how pump is operated

MARYLAND

MDE

Record Keeping

- Record well and pump daily operation
- Flow-GPM
- PSI @ discharge head of pump
- Water level in well during pumping
- Static water level in well
- Amperage reading of motor during operation
- Specific Capacity measured monthly or bimonthly

MARYLAND

MDE

Periodic Maintenance

- Maintain proper lubrication of bearings and motor - VTPs
- Keep packing properly adjusted - VTPs
- Refill oil reservoir on oil lube pumps - VTPs
- Not much to do on submersible pumps
- Yearly: step rate pump test with flow, water level, pressure (TDH) and amperage readings; change oil and packing on VTPs

MARYLAND

MDE

Performance Loss - Symptoms

- Decrease in yield
- Decrease in pump discharge pressure
- Increased drawdown
- Pump breaking suction
- Increased pump run time

MARYLAND

MDE

Performance Loss - Symptoms

- Change in water quality
- Pumping sand
- Vibration and/or noise
- Decrease in well depth
- Excessive seal leakage

MARYLAND

MDE

Performance Loss - Causes

- Encrustation with chemical precipitates of iron, calcium and manganese (typically)
- Biofouling of borehole, screen and pump by iron related bacteria, sulfate reducing bacteria, and slime forming bacteria-80% of wells now thought to be affected by this
- Plugging of formation and gravel pack by movement of fine-grained materials

MARYLAND

MDE

Performance Loss - Causes

- Screen wear
- Over-pumping of well
- Structural collapse of well, borehole or screen
- Wear of pump bearings, shafts, wear rings, impellers, etc. due to long usage

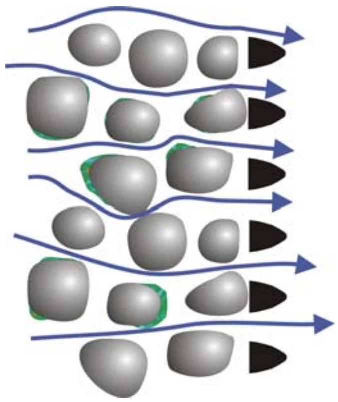
MARYLAND

Biologic and Precipitate Well Fouling

Original (Pre-well) Conditions

- Slow and predominantly horizontal groundwater flow velocities
- Results in a narrow redox front and limited food source for micro-organisms
- End result: Sparse and diffuse population of micro-organisms

Environment of a New and Efficient Well



- Relatively unobstructed laminar flow
- Only pre-existing micro-organisms are present

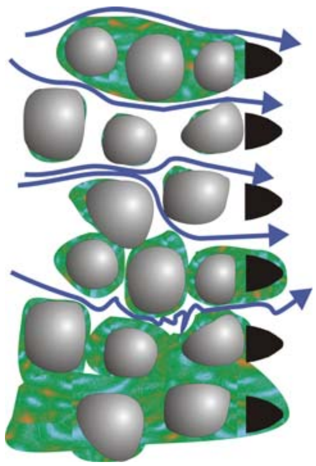
The Developing Near-Well Environment

Converging groundwater flow toward the well increases the supply of nutrients near the well

Vertical groundwater flow causes redox front to expand downward

Pressure drop into well liberates CO_2 which decreases carbonate solubility

Biomass Development



- Expansion of biofilm into pore spaces restricts flow
- Local environment evolves (Eh/O_2, pH, nutrients)
- Collection of micro-organisms evolves to take advantage of the new environments

MDE

Effects of Prolonged Biofouling

Biomass expands vertically and laterally, causing water to be channeled to other areas of the well

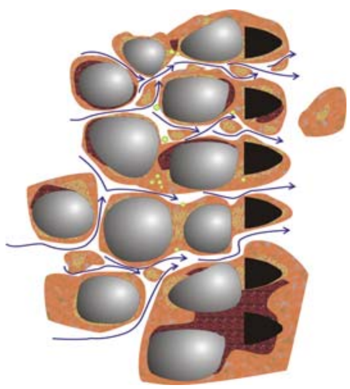
Reduced porosity near well causes higher and more turbulent velocities resulting in:

1) Increased food/nutrient availability

2) Greater pressure drop into well

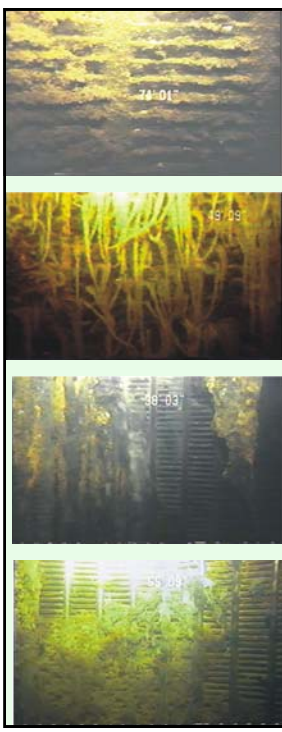
MARYLAND

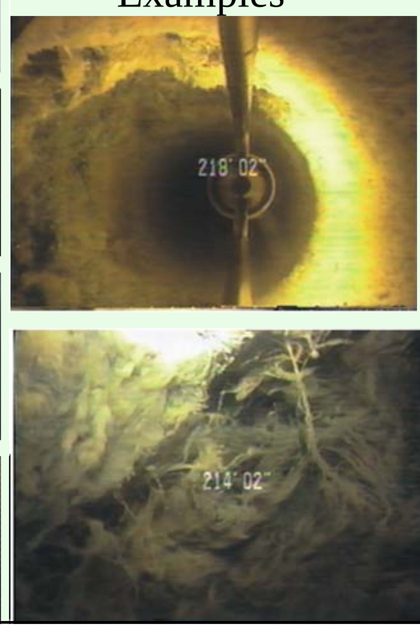
Mature Biomass

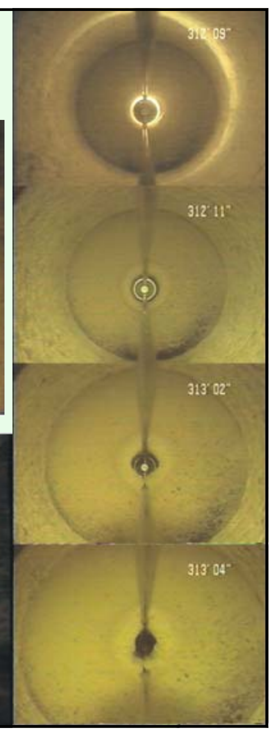


- Preferential flow through developed channels
- Many types of microorganisms, depending on localized environment
- Accumulation of inorganics within biomass
- Development of mineral deposits
- Development of gases
- Sloughing

Biofouling Examples







MDE

Determining Need for Service

- When the well's specific capacity at design flow has declined by 25% or more, it is time to rehab the well
- When the pump's total dynamic head (TDH) has declined by 10% or more at the design flow rate, the pump is in need of repair or service

MARYLAND

MDE

Short-Term Adjustments

- Cut back on flow with valve or VFD
- Adjust impellers (not recommended)
- Reduce Demand

MARYLAND

Well Rehabilitation Methods

Physical or Mechanical

- Break up mineral & biologic solids
- Remove materials from immediate vicinity of well
- Facilitate the application of chemicals

Chemical

- Dissolve solids
- Mobilize solids and hydrocarbons that cannot be effectively removed by physical methods alone
- Kill biologic growth

Physical Methods

- Air Lifting & Over-Pumping
- Bailing
- Wire Brushing
- Surge Blocks
- Jetting
- Compressed Gases (N_2 and air)
- Small percussive charges
- Dynamite (not recommended)

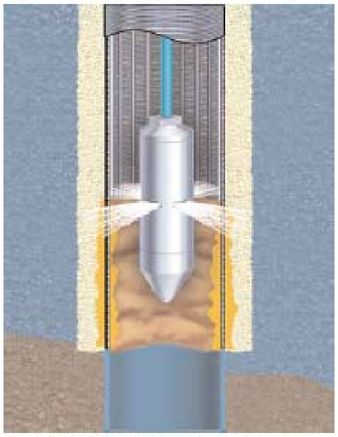
MDE

Surge Block with Compressed Gases

MARYLAND

MDE

High Pressure Compressed Gases

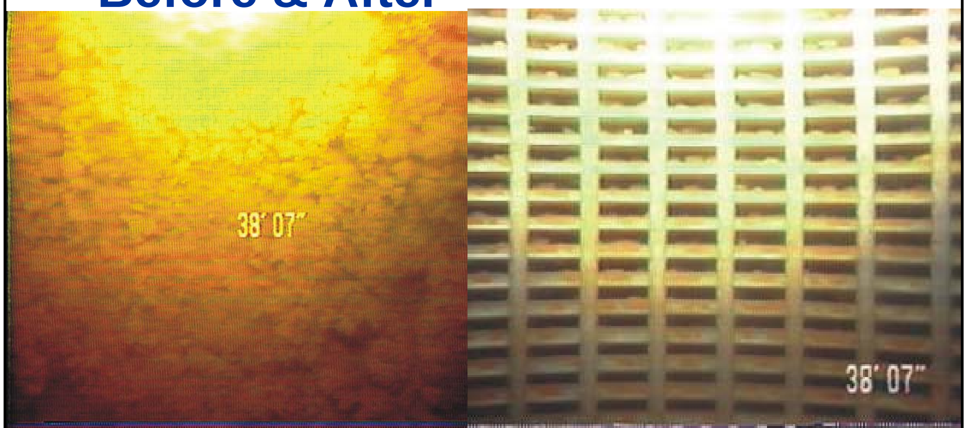


The Air Impulse Generator can deliver pressure pulses of up to 3500 psi, agitating and scouring away chemical and biological buildup.

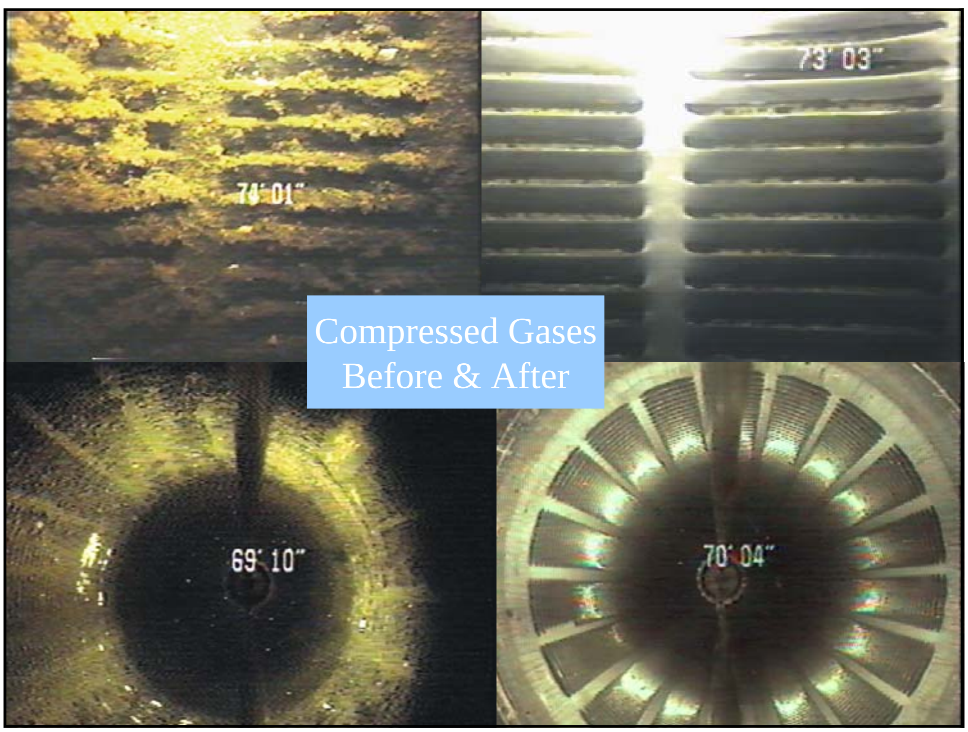
MARYLAND

MDE

Compressed Gases Before & After

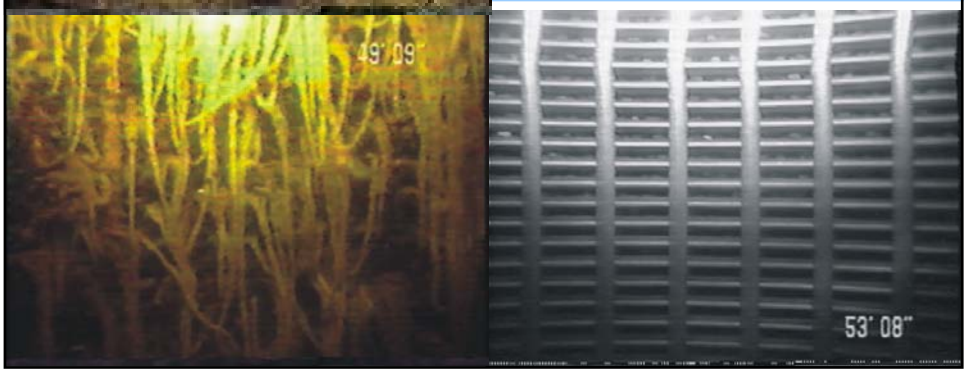


MARYLAND



Compressed Gases
Before & After

Compressed Gases
Before & After
(Biologic Growths)



MDE

Summary of Physical Methods

Several types of physical energy are typically needed for effective well treatment

<u>Percussive energy (high energy, low volume)</u>

- fragments precipitates & dislodges biosolids, but
- provides limited penetration and washing action needed to distribute chemicals and mobilize dislodged solids.

<u>Surging and jetting energy</u>

- more effective at penetration and washing action
- but, less effective at fragmenting precipitates.

MARYLAND

MDE

Chemical Methods

- Acids
- Surfactants/Wetting Agents
- Dispersants/Sequestering Agents
- Caustics
- CO_2 – Gas & Liquid
- Disinfectants

MARYLAND

MDE

Chemical Methods

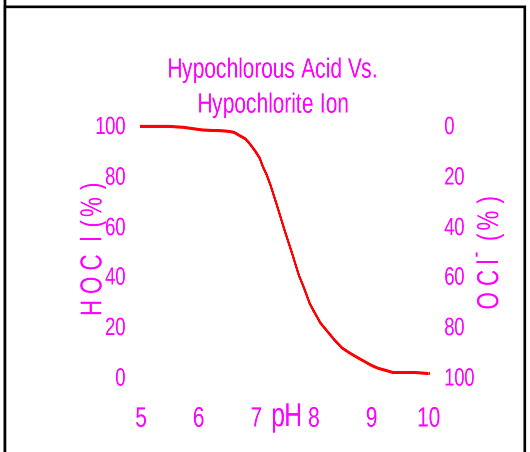
Polymer Chemistry-New Approach

- **Bioacid dispersant: surface active penetrant, suspension agent, increases dissolving power of acid, metal passivation, dissolves bacterial slime layer**
- **Clay dispersant**
- **Non-ionic surfactant**
- **Chlorine enhancer: acids and polymers**
- **Test Kits – IRB, SRB, SLYM**
- **Full chemical and biological analysis**
- **Anoxic Zone Creation**

MARYLAND

MDE

Slowing Down New Biologic Growth



- pH Buffered Disinfection
- Acid
- Polymer Chlorine Enhancer
- Hypochlorous Acid is **100x** more effective a bactericide than Hypochlorite Ion

MARYLAND

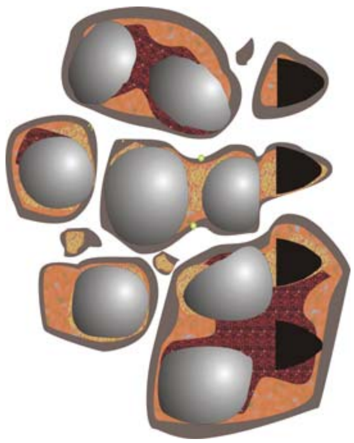
MDE

Components of Effective Cleaning

- Freeing & breaking up solids (physical methods & acids)
- Enabling water penetration. (surfactants/wetting agents)
- Dissolving solids (usually using organic or mineral acids)
- Suspending & dispersing loosened particles
- Preventing chemical re-deposition (sequestering/chelation)
- Slowing down new biogrowth

MARYLAND

Effects of Incomplete Treatment



- Limited "Kill Zone"
- Dead biomass dehydrates and collapses, providing protection for remaining micro-organisms
- Stressed micro-organisms develop protective neutral charge and reproduce
- Remaining micro-organisms become more resistant to future treatment
- Dead biomass becomes food for remaining micro-organisms

MDE

Considerations for Developing an Effective Well Rehabilitation Program

- **Types of deposits**
- **Geology & geochemistry**
- **Microbiology**
- **Groundwater quality**
- **Symptoms of blockage (lost capacity, odors, red water, unsafe samples, taste, etc.)**
- **Track-record of well**
- **Common problems with other nearby wells**

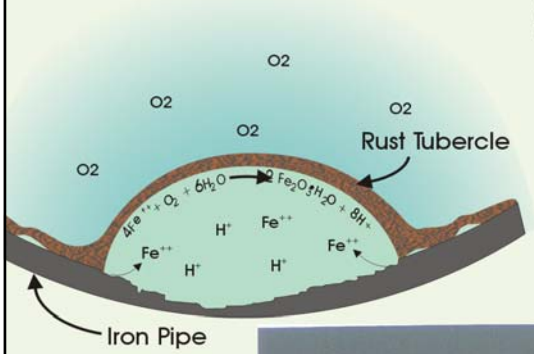
MARYLAND

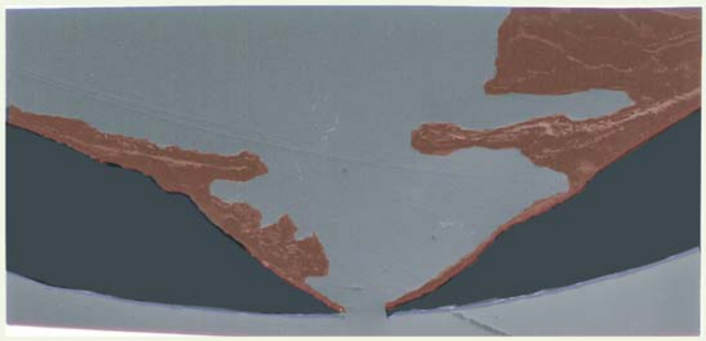
Pump Repairs

- Replace wear rings, bowl bearings, impeller shaft, shaft seals
- Replace lineshafts, lineshaft bearings, stuffing box bushing, packing
- Inspect motor; clean, coat, and balance armature; replace top thrust bearing and lower guide bearing

Examples of Scaling in Well Systems

Scale-Induced Corrosion





MDE

MARYLAND

MDE

Pump Condition Checklist

1. Pump operating on orig. design curve
2. Excessive heating of motor
3. Change in bearing noise level
4. Change in motor oil consumption
5. Excessive vibration
6. Amperage or voltage changes
7. Cavitation or other noises
8. Cracking or uneven settling of pad

MARYLAND

MDE

Benefits of Well Rehabilitation

- Improve transmission of water into well to restore lost capacity/pumping level
- Decrease pumping costs (**$$**)
- Improve water quality (unsafe samples, “red water”, taste, odors, turbidity & sand pumpage)
- Extend life of well & pumping equipment

MARYLAND