Kansas Department of Health and Environment
Division of Environment

Water Quality and Compliance Issues in Kansas Drinking Water Wells

75th Annual Environmental Engineering Conference April 17, 2025

Special Thanks to:

Michael Schnieders, PG, PH-GW
Water Systems Engineering, Ottawa, Ks

Ned Marks, P.G.
Terrane Resources, Stafford, KS

Don Whittemore, P.G.
Kansas Geological Survey (Retired)

For the use of their data, images, photos and slides and consultation on well construction issues and biogeochemical fouling of water wells

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Today’s Topics

- Design Issues
- Well Hydraulics and associated WQ Issues
- Common biogeochemical induced issues
- What needs to change

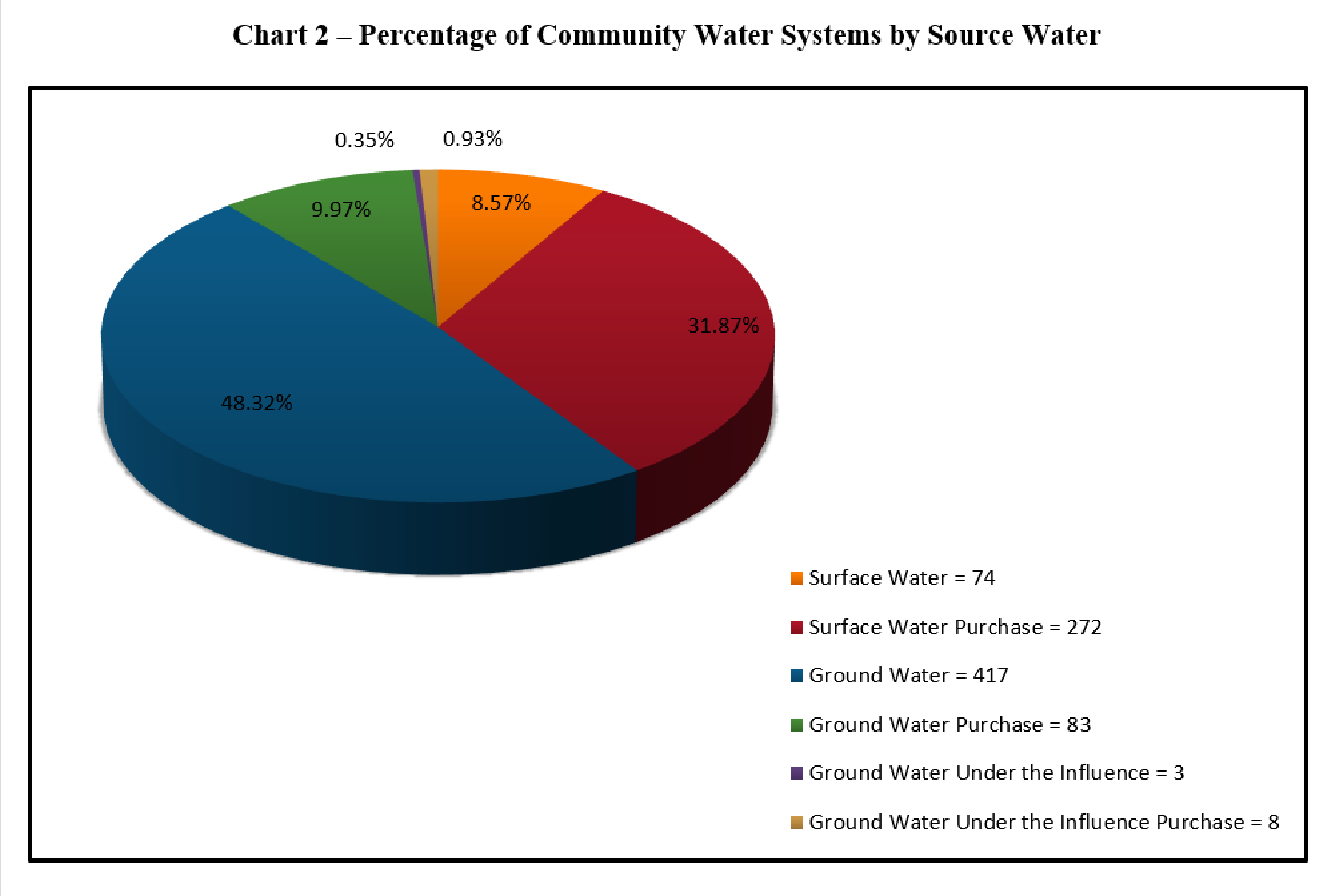
We as professionals must do better…

- In identifying possible water quality issues before a well is installed and…
- Apply known science to provide a long-term high-quality water supply to the public…
- While protecting our very limited and shrinking potable groundwater supplies…

Kansas Water Systems by Source:

GW = 48.3%
GWP= 9.97%

Almost 60% of Kansas Public Water supplies are from GW our most valuable resource



PWS Wells: *Suffer from the Forgotten Child Syndrome*

- Many water quality issues start at the well design phase
- Wells are often ignored as the source of a water quality issues
- Source protection plans are seldom recorded and lost in a dusty file cabinet
- Designers may not understand basic well hydrogeology and bio-geochemistry
- Boards and City Councils tend to opt for water well quantity over water quality
- Well design should give flexibility to the operator (i.e. variable speed drives)
- Proper well grouting is cheap compared to a new well or treatment plant
- Proper construction and well maintenance is key to long term water quality
- Treatment plants should be the last resort, especially for small systems <1000p

KDHE PWS Design Standards - Chapter 4 Source Development – Construction Criteria for Public Water Supply Wells

Grouting of Annular Space between the Casing and Drill Hole

- *3.g.1 Wells shall be sealed by grouting the annular space between the casing and the well bore from ground level to a minimum of 20 ft. (6.1 m) or to a minimum of 5 ft. (1.5 m) into the first clay or shale layer, if present, **whichever is greater.***

- *3.g.4 - Water from two or more separate aquifers **shall be separated** from each other in the boring by sealing the annulus between the aquifers with grout.*

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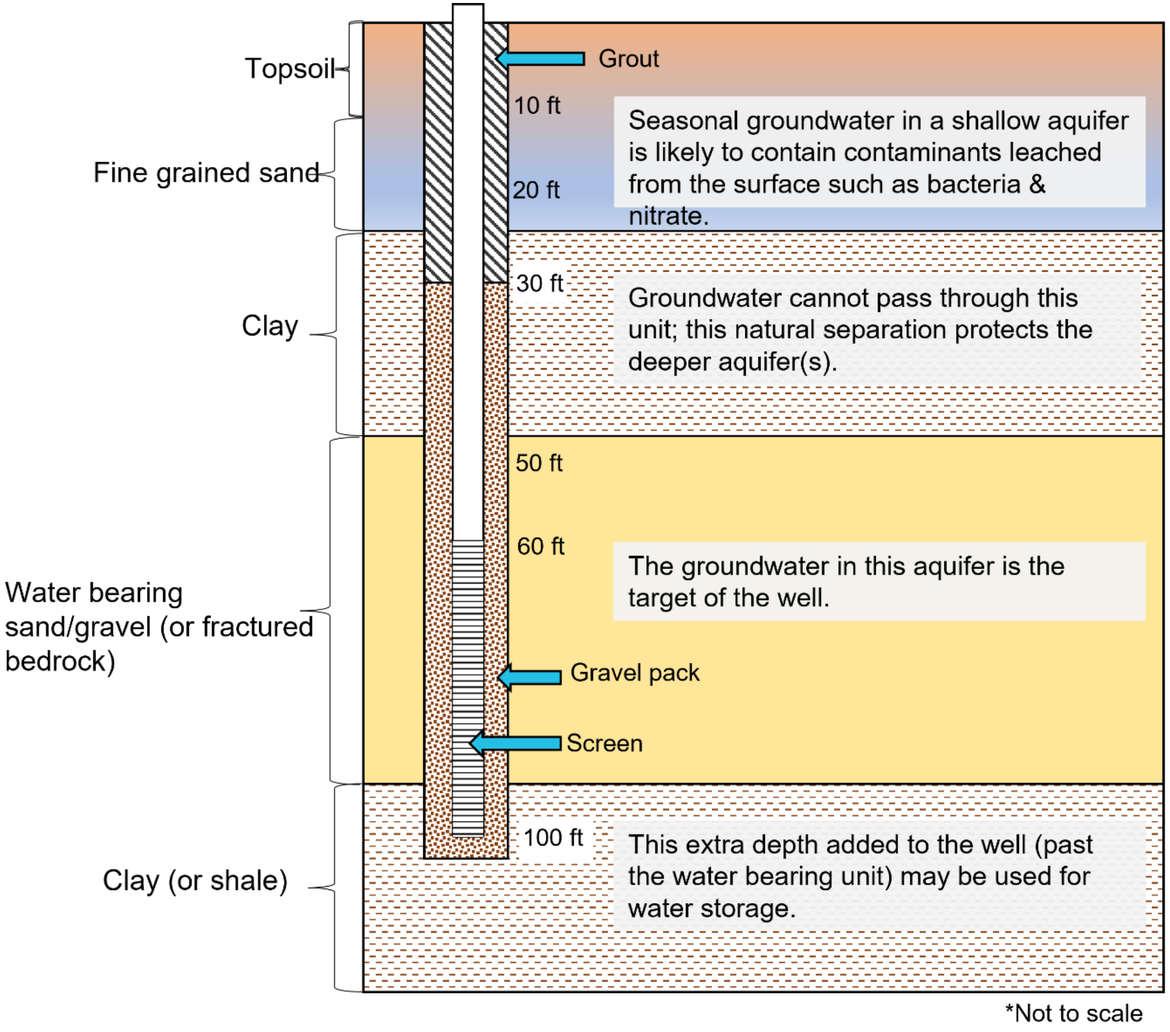
KANSAS STATUTES PERTAINING TO PUBLIC WATER SUPPLY

65-163. Public water supply systems and water treatment residues; regulation; permits; investigations.

- *(a) (1) No person shall operate a public water supply system within the state without a public water supply system permit from the secretary. An application for a public water supply system permit shall be submitted for review and approval <u>prior to construction</u>…*

- *Do not install a PWS well without an approved design and permit!*

Idealized Groundwater Well Design Is this Reality???



This well has been grouted through the topsoil, a potential shallow aquifer, and 5 feet into the underlying clay. This is the correct way to protect the deeper aquifer from potential shallow contamination.

This well required more than 20 ft of grout to reach the first clay layer (i.e., 30 ft), to meet KDHE regulations.

Used courtesy of KDHE Geology Unit

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More Realistic Water Well Scenario

2865 gsl

S.W.L = 30 bgs

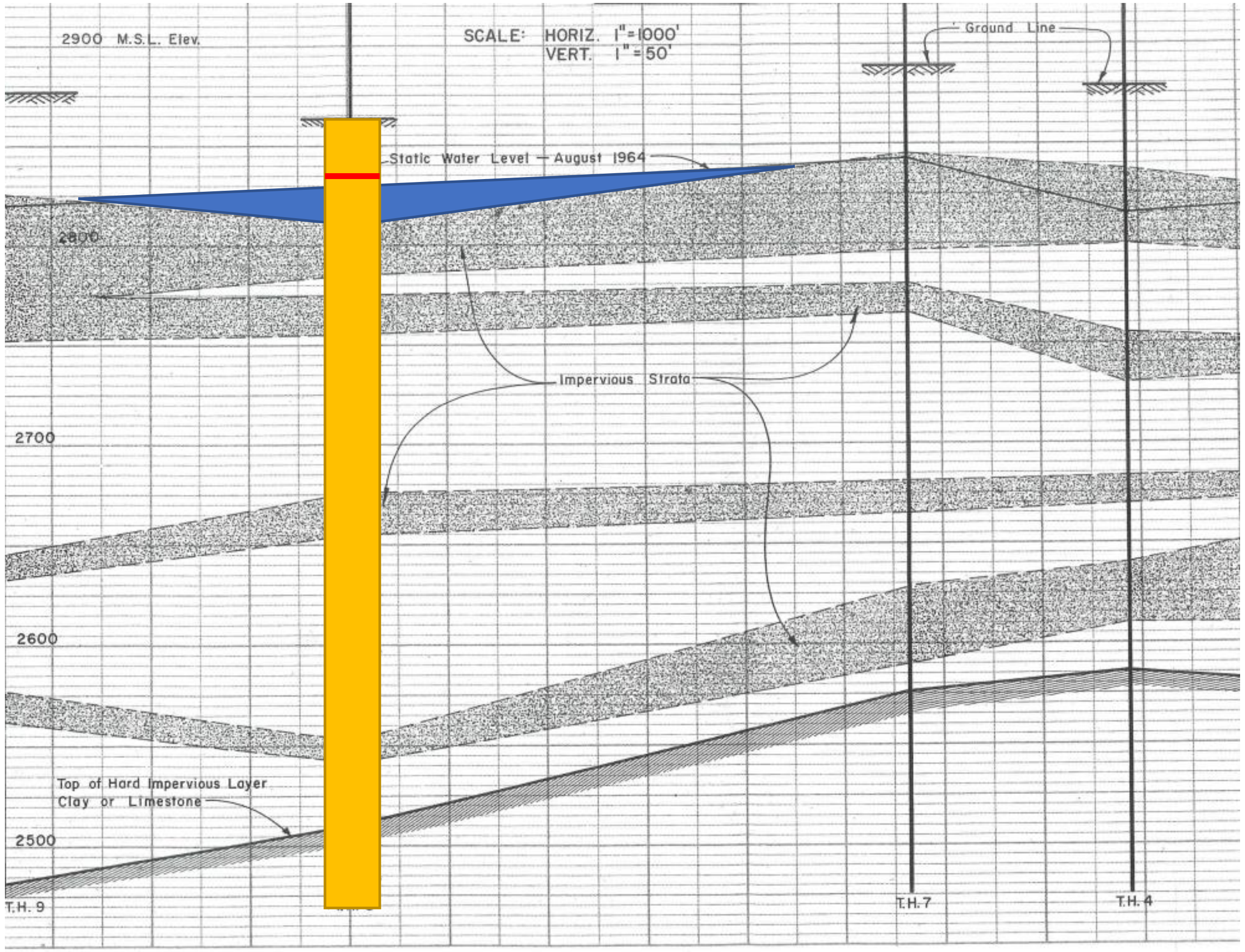
45 bgs

150 bgs

220 bgs

290 bgs

bgs = Below Ground Surface



Clay Layer Aquitard

Water Bearing Sand

Clay Layer Aquitard

Water Bearing Sand

Clay Layer Aquitard

Water Bearing Sand

Clay Layer Aquitard

Water Bearing Sand

Bottom Aquitard

ENGINEERS - ARCHITECTS
VAN DOREN-HAZARD-STALLINGS-SCHNACKE

KDHE PWS Design Standards - Chapter 4 Source Development – Construction Criteria for Public Water Supply Wells

- 3.l - **ABANDONED WELLS AND TEST HOLES** - *Before any well or test hole drilled in connection with a water supply is abandoned, it* ***shall be plugged in such a manner as to prevent the pollution of the groundwater*** *by contaminating substances. Abandoned water wells and test holes, whether cased or uncased,* ***shall be plugged*** *in accordance with the requirements of KAR 28-30-7.*

- How many systems still have test holes (PVC Pipe with cap) near active wells?
- Possibly gravel-packed to 10-feet bgs? (Causing WQ issues)

Kansas Knows Better:

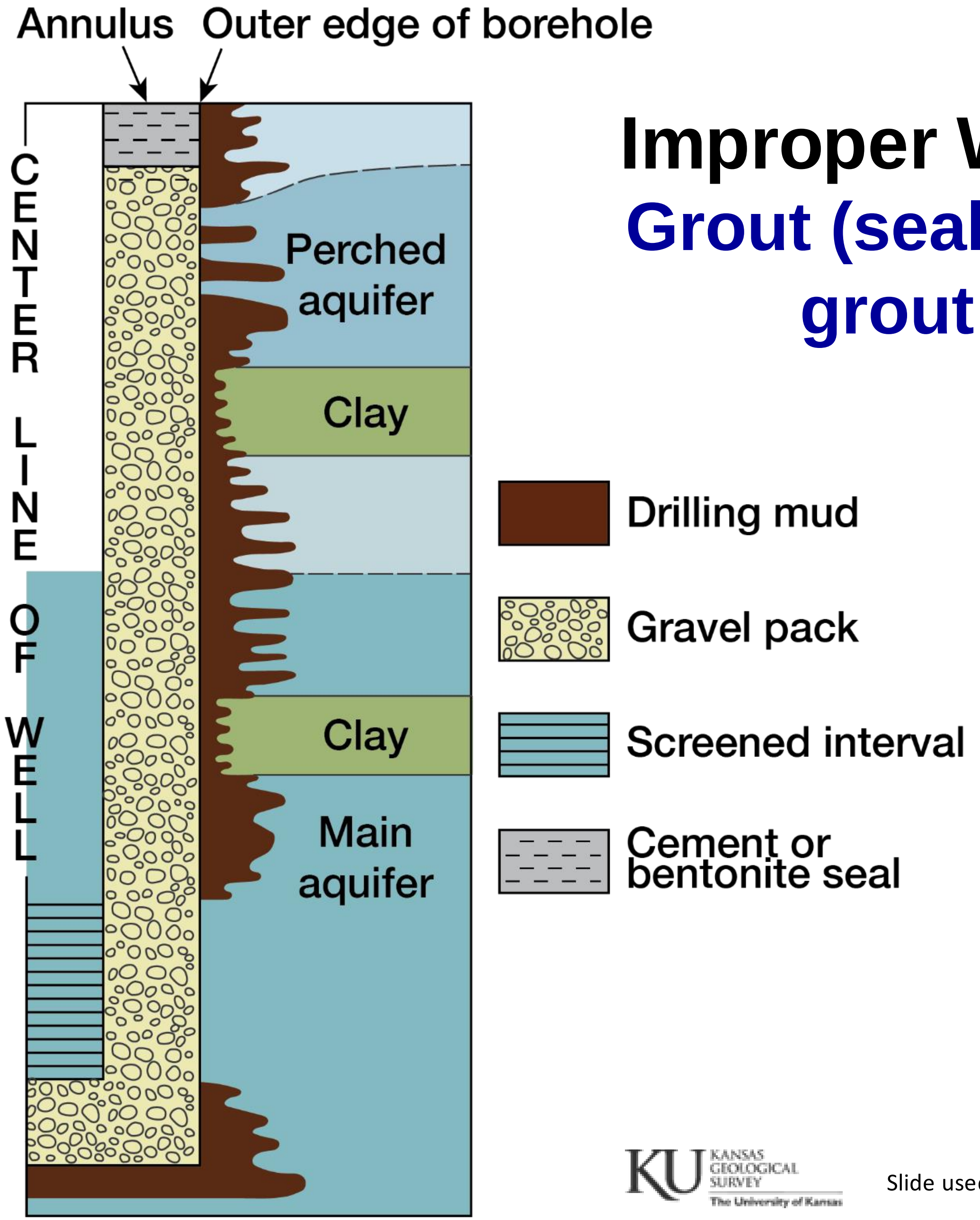
- Kansas has documented that proper grout placement is key for water quality more than 75-years ago!

- If you don't grout off low-quality shallow water bearing units, you cannot protect the high-quality deeper water.

- Conversely if you mix deep water of low quality with shallow high-quality water…all will become lower quality

Improper Well Construction

Grout (seal) at surface but no grout across clays



KANSAS GEOLOGICAL SURVEY
The University of Kansas

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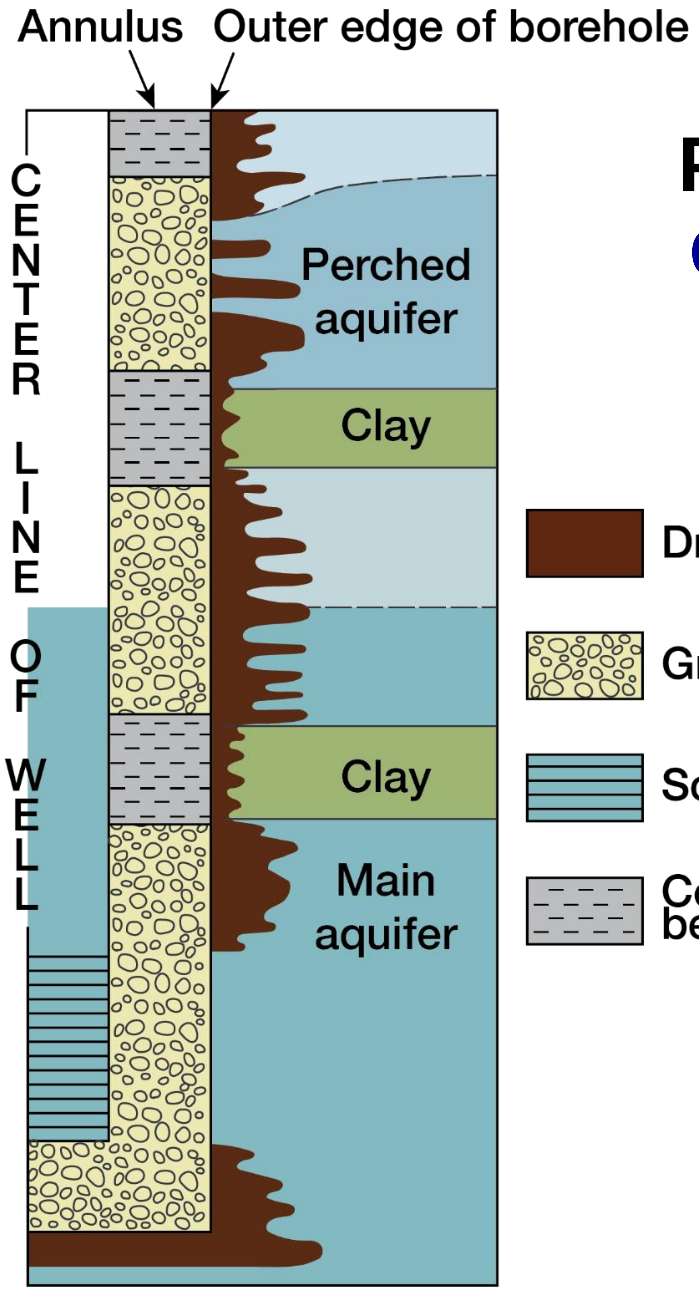
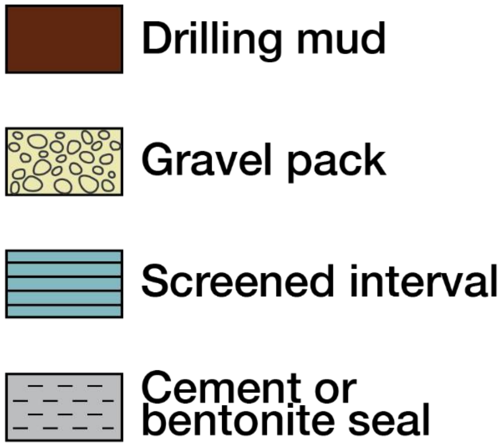
Proper Well Construction

Grout at surface and grout across clays





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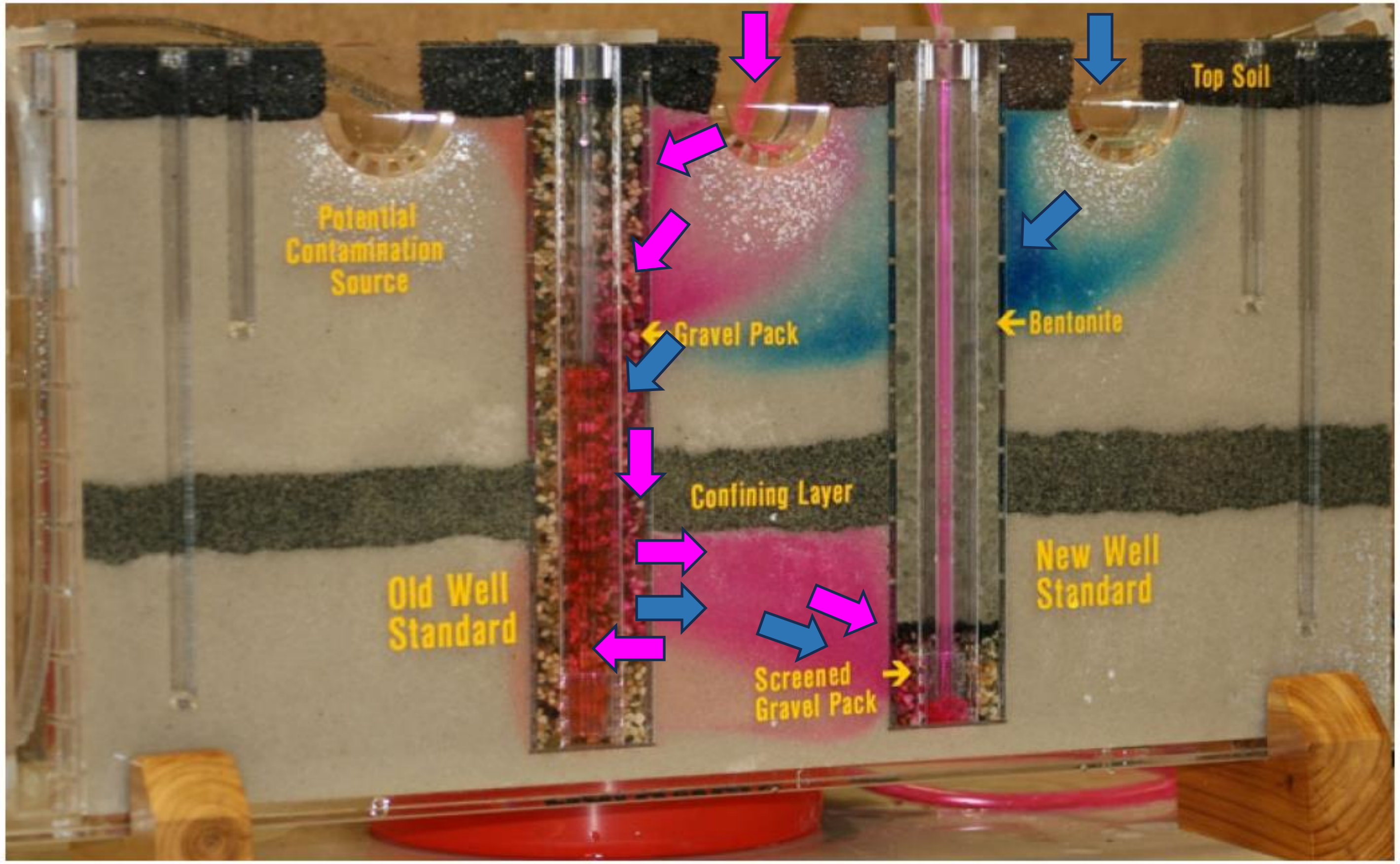
Nebraska Grout Study Model

- Contamination flow to improperly grouted well

- Contamination flow to properly grouted well caused by adjacent improperly grouted well

Research Shows Bentonite-Packed Well Annulus Can Prevent Contamination of Confined Aquifers



"A pumping well constructed using the new state well design standards can become contaminated by pulling in surface contamination through old wells"

By Sharon Skipton and Bruce Dvorak, University of Nebraska-Lincoln

Modified by TERRANE RESOURCES CO. 0CT., 2014 KANSAS GROUND WATER: STRAIGHT FROM THE ROCKS!

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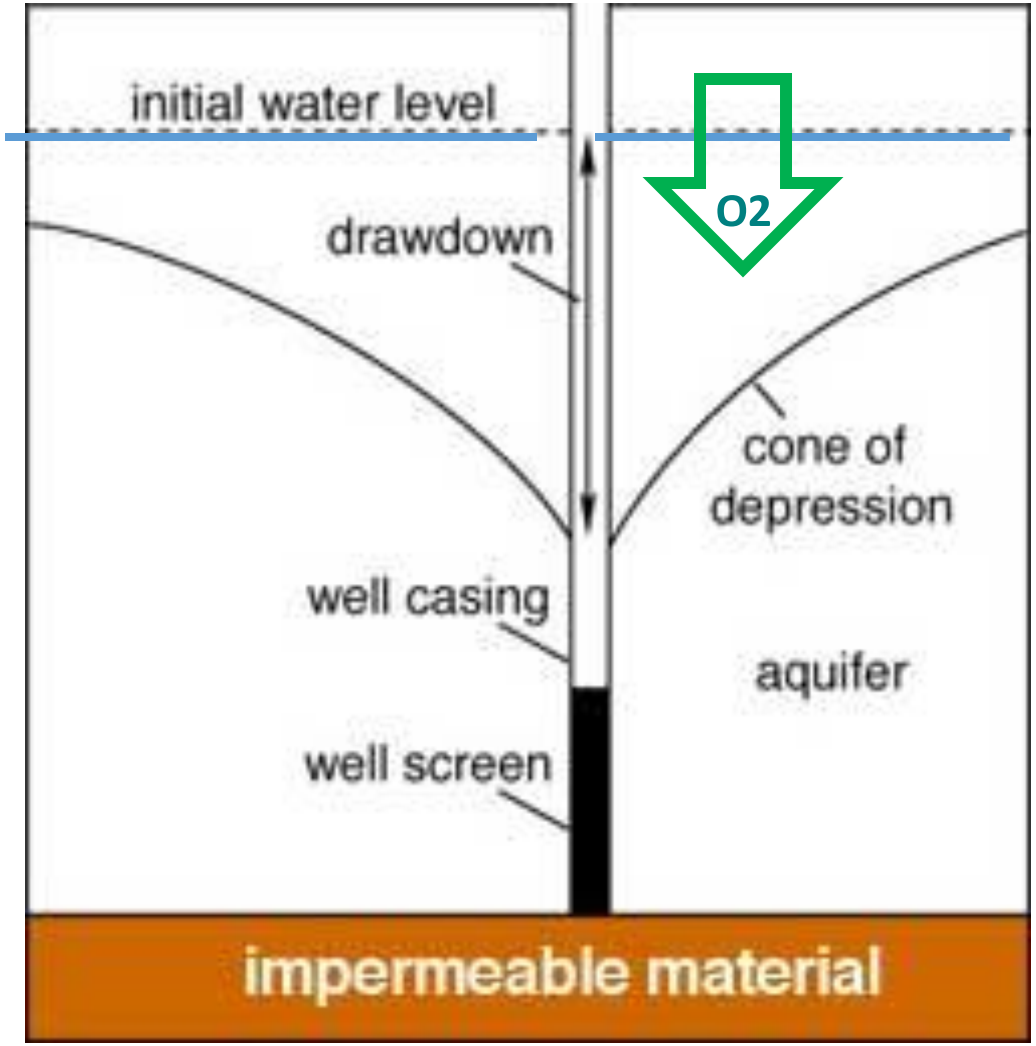
Issues Caused by Well Hydraulics

Cone of Depression

- When a well is pumped, the ground-water level near the well forms a cone of depression

- Minerals can be oxidized within the cone of depression and then mobilized into GW when pumping stops

- Maybe we look at reducing the drawdown in areas of mineralization?



Pumping Well
Screen Flow hydraulics

- When a well is pumped, flow to the screen is not uniform.
- Screen slots load to capacity then next slot loads
- Depends on pump intake placement in well
- Sump is stagnant, probably anoxic

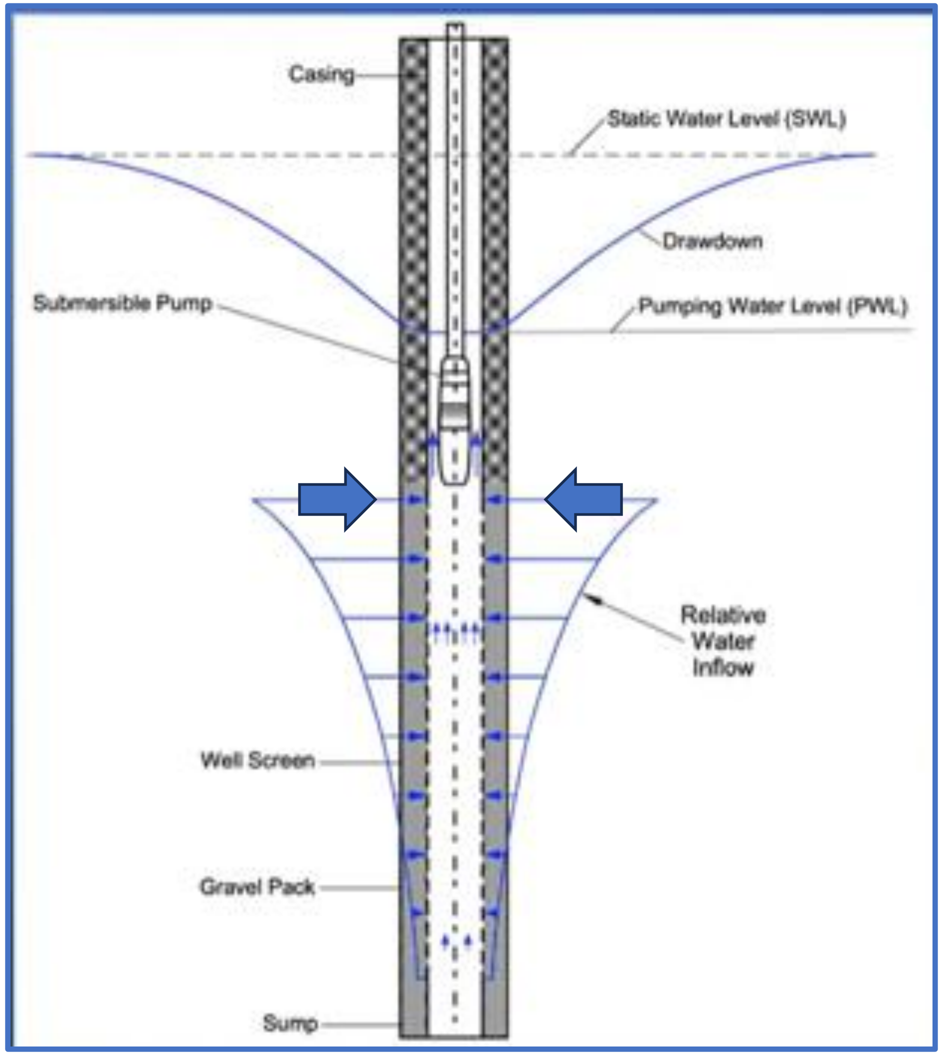


Image courtesy of Tom Ballard

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Pumping Well Redox Zones

- When a well is pumped, aerated water flows to flowing part of screen (aerobic/oxic)
- Zone of slow or non-moving water in bottom of screen (anaerobic/anoxic)
- Depends on pump intake placement in well or shroud configuration

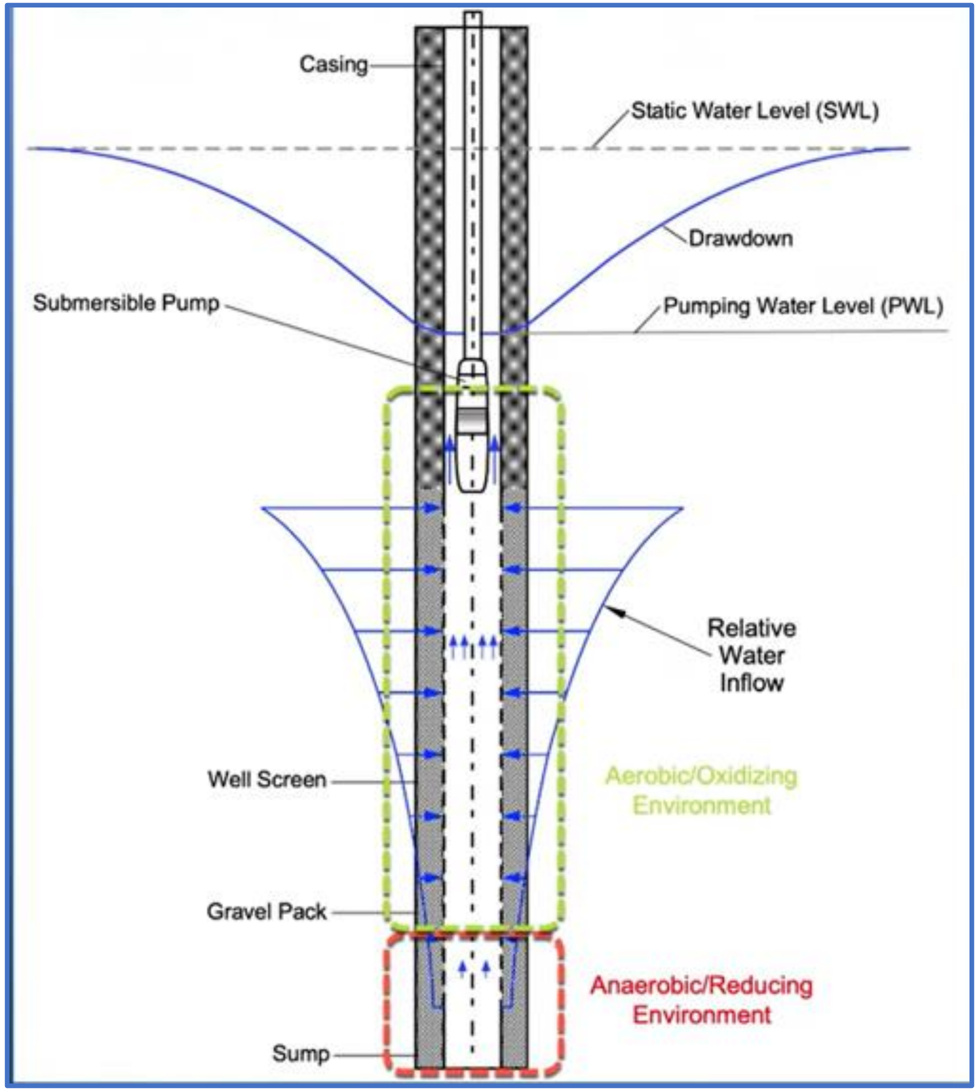

Image courtesy of Tom Ballard

Mobilization of Contaminants
Kansas Public Water Supply Wells

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Most Common Inorganic (IOC) Compliance Contaminants

- NITRATE
- ARSENIC
- SELENIUM
- MANGANESE
- IRON
- BROMIDES

Radiological Contaminants

- URANIUM
- RADIUM 226 & 228

Table 1 – 2022 Health-based Compliance Rates for All Rules

Rule	Systems Sampled	Population Served	% Comp Systems	% Comp Population	% Comp Samples
CONSUMER CONFIDENCE RULE (CCR) (Mon*)	863	2,843,358	96.2%	99.6%	96.2%
DISINFECTION BYPRODUCT RULE (DBPR)					
Bromate 1011	10	927,931	100%	100%	100%
Chlorite 1009	18	330,519	100%	100%	100%
Haloacetic Acids (HAA5) 2456	747	2,826,828	99.7%	99.9%	99.8%
Total Organic Carbon (TOC)(TT*) 2920	76	1,722,229	97.4%	99.8%	99.7%
Total Trihalomethanes (TTHMs) TT 2950	747	2,826,828	98.1%	98.9%	98.5%
GROUND WATER RULE (GWR)					
Monitoring	64	674,215	89.1%	98.9%	98.9%
Treatment Technique	64	674,215	95.3%	94.1%	98.8%
INORGANIC CHEMICAL GROUP (IOC)	210	1,970,571	100%	100%	100%
Arsenic 1005	218	1,972,670	98.6%	99.9%	98.6%
Asbestos 1094	24	373,734	100%	100%	100%
Fluoride1925	221	1,968,425	100%	100%	100%
Nitrate 1040	633	2,511,391	97.8%	99.6%	97.1%
Selenium 1045	216	1,973,606	100%	100%	100%
LEAD AND COPPER RULE 5000					
Monitoring	402	446,185	97.8%	99.3%	99.7%
Action Level Lead	402	446,185	99.2%	97.5%	99.9%
Action Level Copper	402	446,185	97.0%	92.9%	99.4%
RADIONUCLIDE RULE					
Gross Alpha Including Radon and Uranium 4002	137	822,384	100%	100%	100%
Gross Alpha Excluding Radon and Uranium 4000	21	175,040	95.2%	97.8%	97.2%
Combined Uranium 4006	21	175,040	100.0%	100%	100%
Combined Radium 4010	137	975,561	91.7%	99.6%	96.3%
SURFACE WATER TREATMENT RULE (SWTR)					
Monitoring	78	1,722,679	100%	100%	100%
Treatment Technique	78	1,722,679	98.7%	99.7%	99.9%
SYNTHETIC ORGANIC CHEMICAL GROUP (SOC)	207	1,833,226	100%	100%	100%
Atrazine (Mon*) 2050	229	1,869,451	99.6%	99.8%	100%
REVISED TOTAL COLIFORM RULE (RTCR)					
Acute MCL (1A)**	946	2,839,301	99.8%	99.9%	99.9%
Level 1 Assessment Triggered (TT)*	946	2,839,301	96.9%	91.6%	99.9%
Level 1 Assessment Violation (2A)** (TT)*	946	2,839,301	99.7%	98.2%	99.9%
Level 2 Assessment Triggered (TT)*	946	2,839,301	98.7%	98.2%	99.9%
Level 2 Corrective Expedited Action (2C)** (TT)*	946	2,839,301	99.7%	99.9%	99.9%
Level 2 Assessment Violation (2B)** (TT)*	946	2,839,301	100%	100%	100%
Routine Monitoring (3A)***	946	2,839,301	92.4%	98.7%	99.7%
Additional Routine Monitoring (3B)***	946	2,839,301	100%	100%	100%
VOLATILE ORGANIC CHEMICAL GROUP (VOC)	175	503,228	100%	100%	100%

*Denotes compliance rate is not MCL based.
** See Table 12, Page 21
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Signs of Biogeochemical Reactions

- Do black or red stains form on your sink or toilet bowl or on laundry?
- Does you water smell like rotten eggs?
- Your hot water tank is filled with clear slimy goo?
- Do your water tests indicate high concentrations of uranium, selenium, nitrate, iron, manganese or arsenic?
- Is your well screen, pump or drop-pipe clogged with scale or mineralization?

Reasons Your Water Well may Develop Water Quality Issues After Many Years

- Change in aquifer chemistry / contamination
- Redox reaction activated due to changes in recharge / pumping Rates
- Flooding or drought conditions
- The changed conditions now support biological activity
- Well materials with age may develop corrosion and structural problems, such as cracked/leaking casings or collapsed casings that allow cascading water, and contaminants into the well.
- Galvanic corrosion of low-carbon steel casing

Redox Chemistry Primer

Remember "OIL-RIG"

- Oxidation is loss (**OIL**) of Electrons
- Oxidizing agent pulls electrons from another substance
- Reduction is gain of electrons (**RIG**)
- Reducing agents give/lose electrons

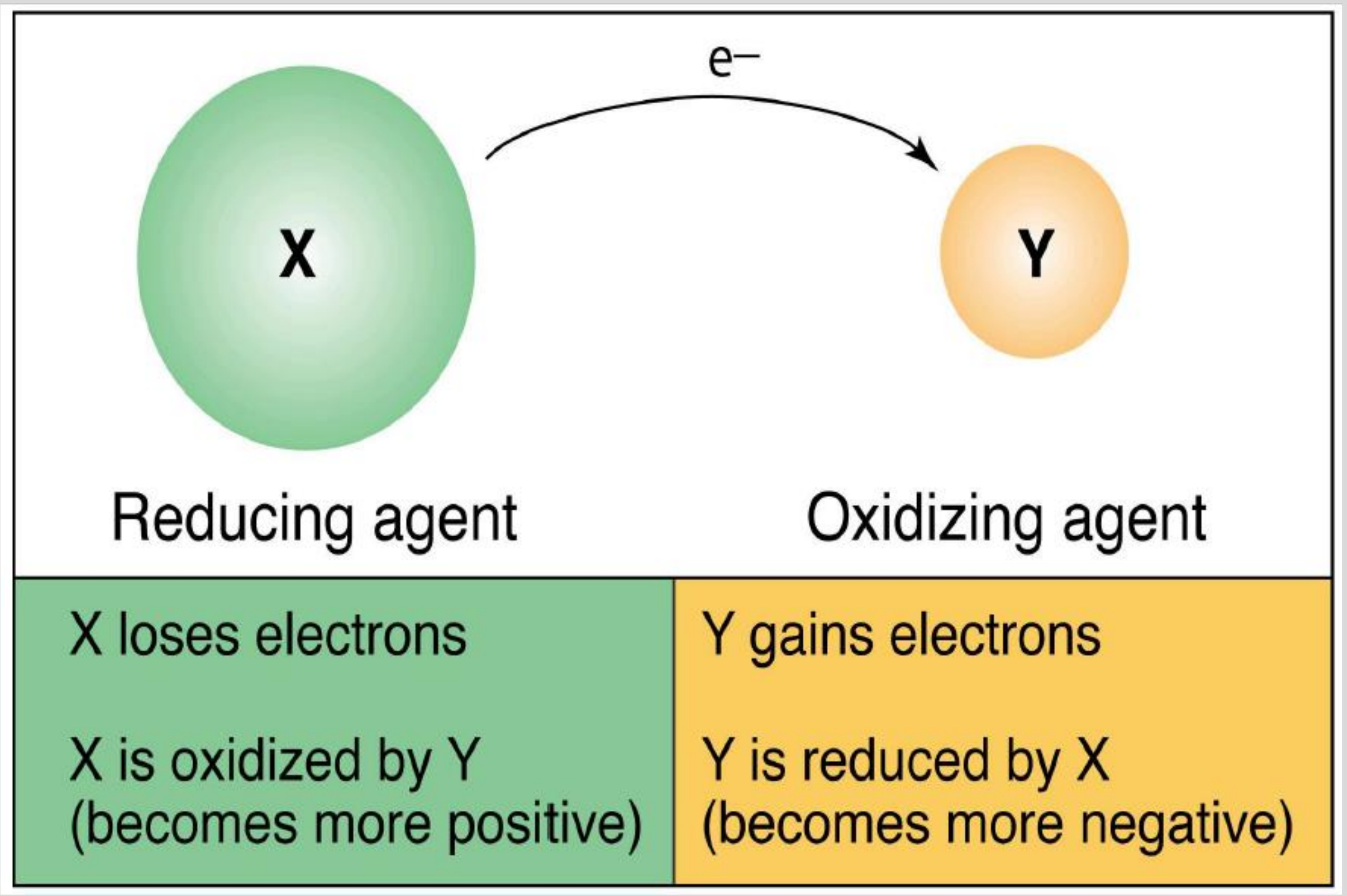


Image courtesy of KGS

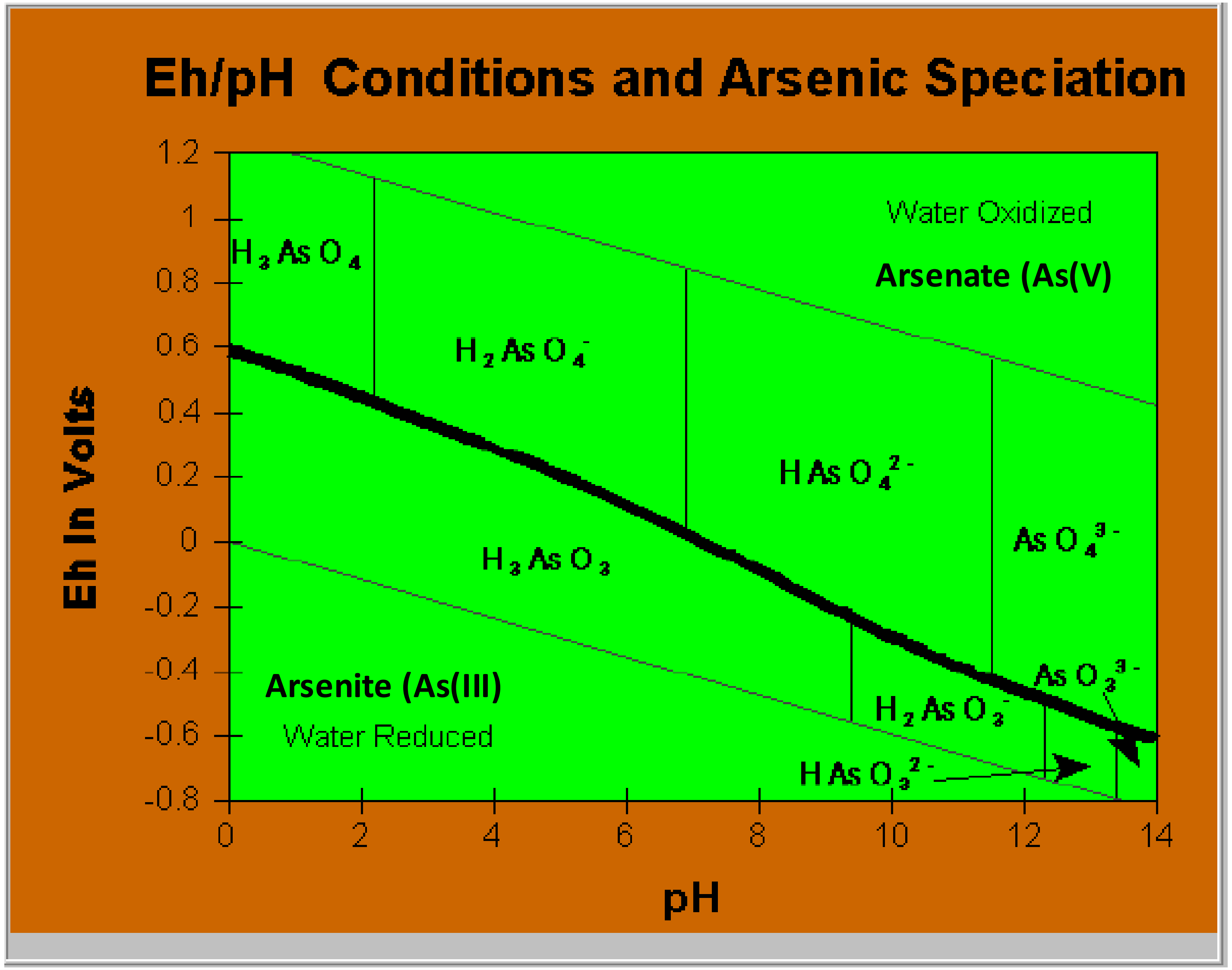
Oxidation Reduction Potential (ORP)

- Oxidation reduction potential (ORP) is an important method for testing water reactivity. ORP is expressed as Eh.
- May be used to evaluate the water's disinfection potential for chlorination
- <u>Testing redox conditions helps predict the potential for contaminant mobilization and transport of naturally occurring metals and radionuclides within an aquifer.</u>
- A negative ORP value in well water may imply reduction of nitrate to N2 gas. Arsenic is also more likely to be mobilized.
- A positive ORP indicate Oxic conditions and may support elevated selenium or uranium levels.

ORP (Eh) / pH Diagram

- Indicates stability of chemical or mineral species based on the activity of hydrogen ions (pH) and the activity of electrons (Eh)

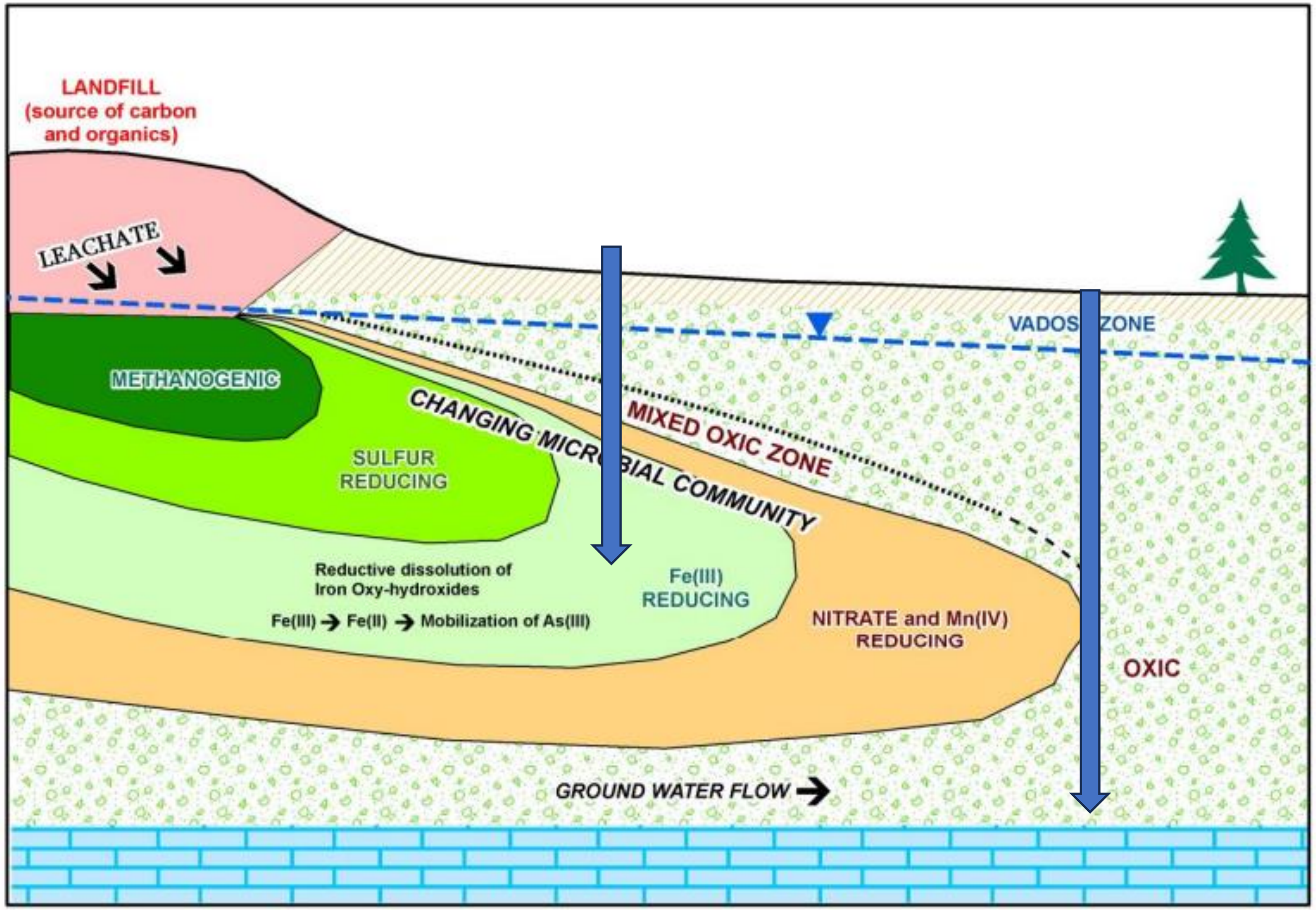
- Used to predict speciation of minerals for determine what processes are occurring in wells arsenate (AsV) and arsenite (AsIII)



Redox Zonation

Sources:

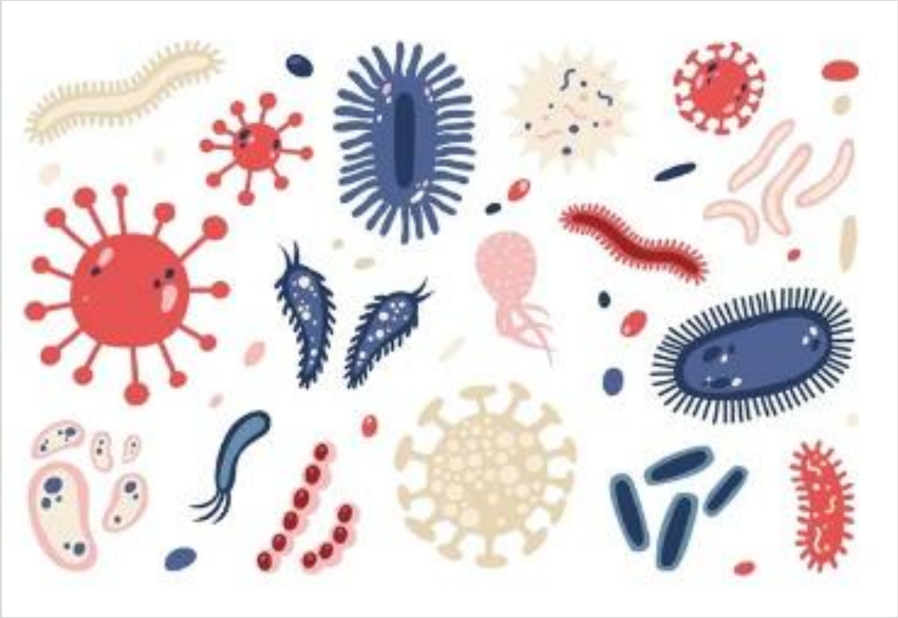
- Oil Field Brines
- Nitrates from Agricultural Activities
- Waste Lagoons
- Petroleum Spills
- Landfill leachate



Graphic used courtesy of the Ohio Division of Drinking and Ground Waters Technical Series on Ground Water Quality November 2014

Microorganisms can also Drive Redox Reactions

- Microorganisms drive oxidation-reduction reactions forward.
- Microorganism use redox reactions obtain energy for life functions and to obtain nutrients needed to make biomass.
- Regulators are just beginning to realize the importance of these biochemical reactions in relation to water quality and long-term water well health.



Microorganisms Inorganic Reduction Progression

- Dissolved oxygen (DO) will accept electrons quite readily and oxygen-reducing microorganisms will out-compete all others to utilize this easily accessible electron sink. If we create it, they will come!
- Oxygen-reducing reactions will continue until all available DO is depleted, Then nitrate becomes available, and the water becomes more reducing.
- This well-established pattern of **reducing reaction** preferences for common inorganic constituents is as follows:

$$O_2 > NO_3 > Mn(IV) > Fe(III) > SO_4^{2-} > CO_2.$$

Well Fouling What to look for:

- Water quality impairment, scale accumulations, biomass build-up, sediment infiltration, corrosion, pathogen occurrence, taste, odors, discoloration…

…any changes that impact the use ***and*** usability of the well over its operational life

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Well Screen Plugging

Photo courtesy of Aegis GW Consulting, Fresno, CA

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Photo courtesy of Layne, OK

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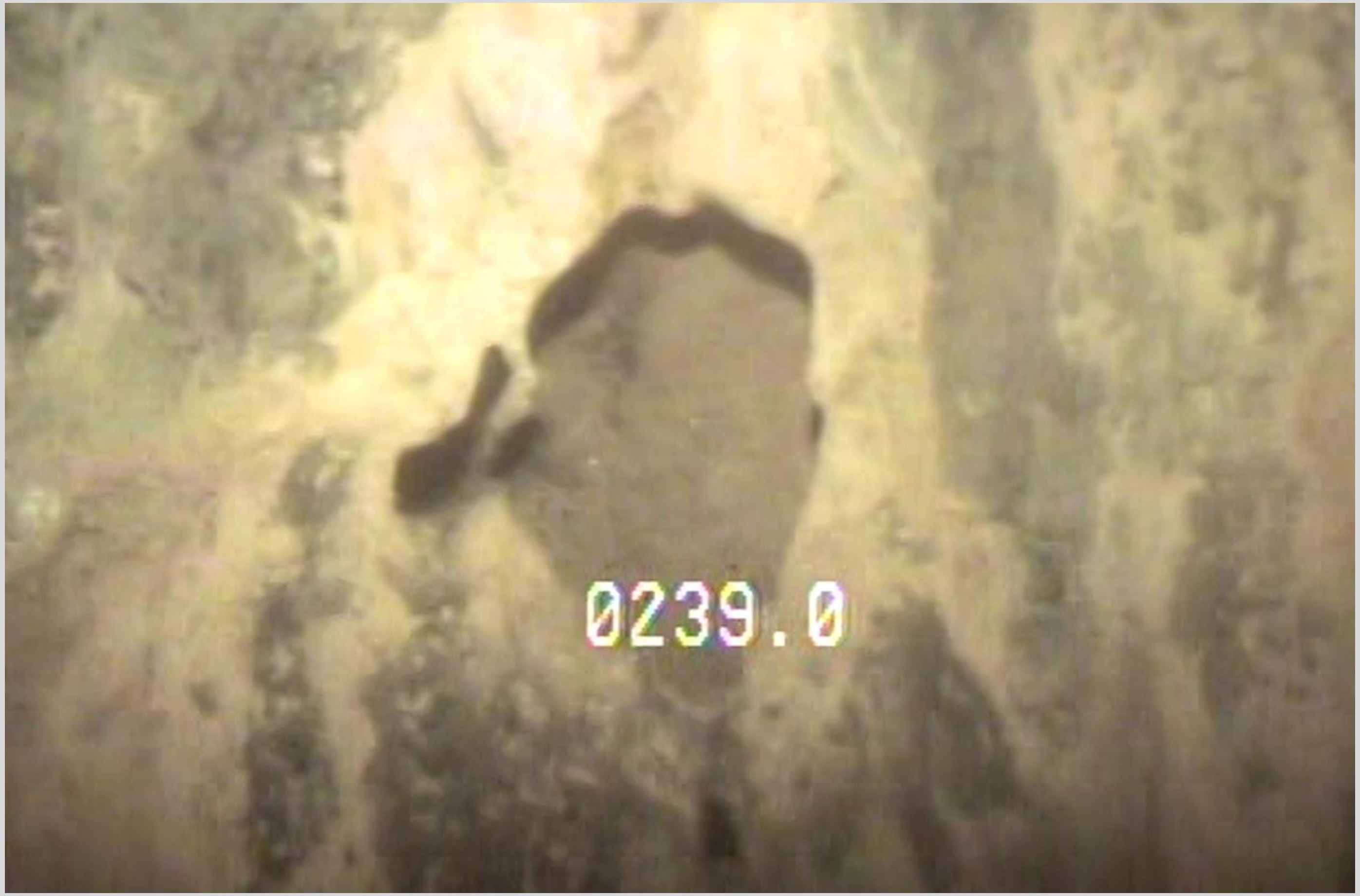

Photo courtesy of Aegis GW Consulting, Fresno, CA

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Future Problems ?

Water Quality Results

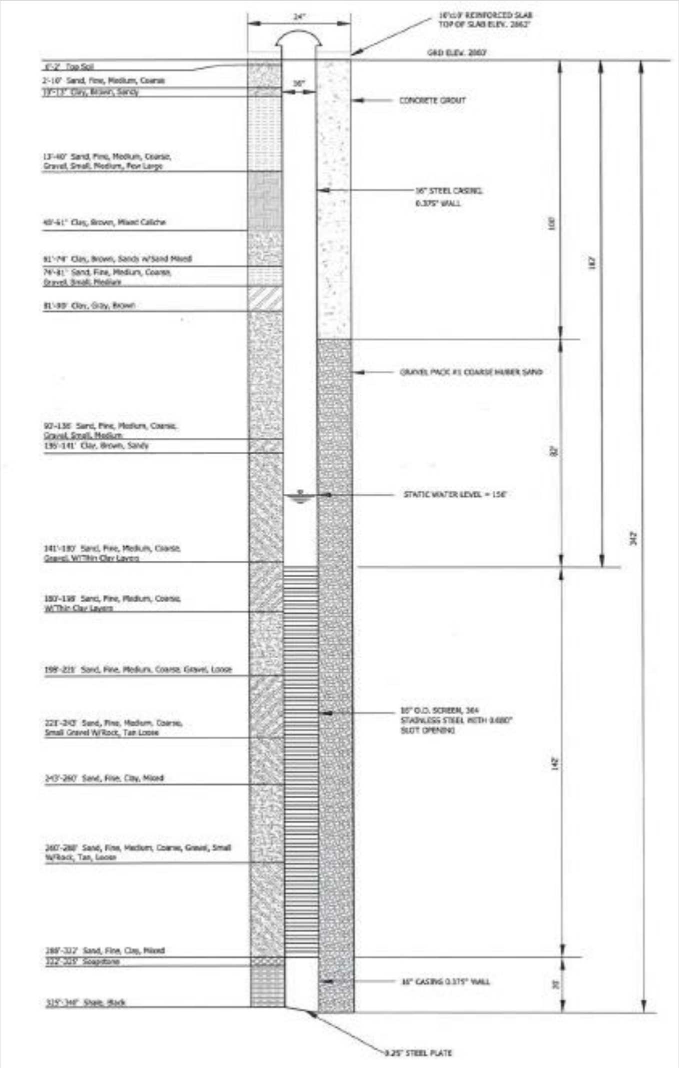
Total Hardness = 1200 mg/L
Dissolved Solid = 1800 mg/L
Calcium = 350 mg/L
Corrosivity = 0.82 LSI
Conductivity = 2100 umho/cm
Chloride = 97 mg/L
Sulfate = 1000 mg/L
Gross Alpha = 9.5 pCi/L

Well Materials

LCS Casing
SS Screen

Lithology

From	To	Lithology Intervals
0	2	topsoil
2	10	sand,fine to coarse
10	13	clay,brown
13	40	sand & gravel,fine to coarse,gravelly
40	61	clay,caliche stringers,brown
61	74	clay,sandy,brown
74	81	sand,fine to coarse,gravelly
81	90	clay,brownish,gray
90	136	sand,fine to coarse,gravelly
136	141	clay,sandy,brown
141	180	sand,fine to coarse,gravelly
180	198	sand,fine to coarse,clayey
198	221	sand,fine to coarse,gravelly
221	243	sand & gravel,fine to coarse,gravelly
243	260	sand,fine,clayey
260	288	sand & gravel,fine to coarse,gravelly
288	322	sand,fine,clayey
322	325	clay
325	340	shale,slightly weathered,black



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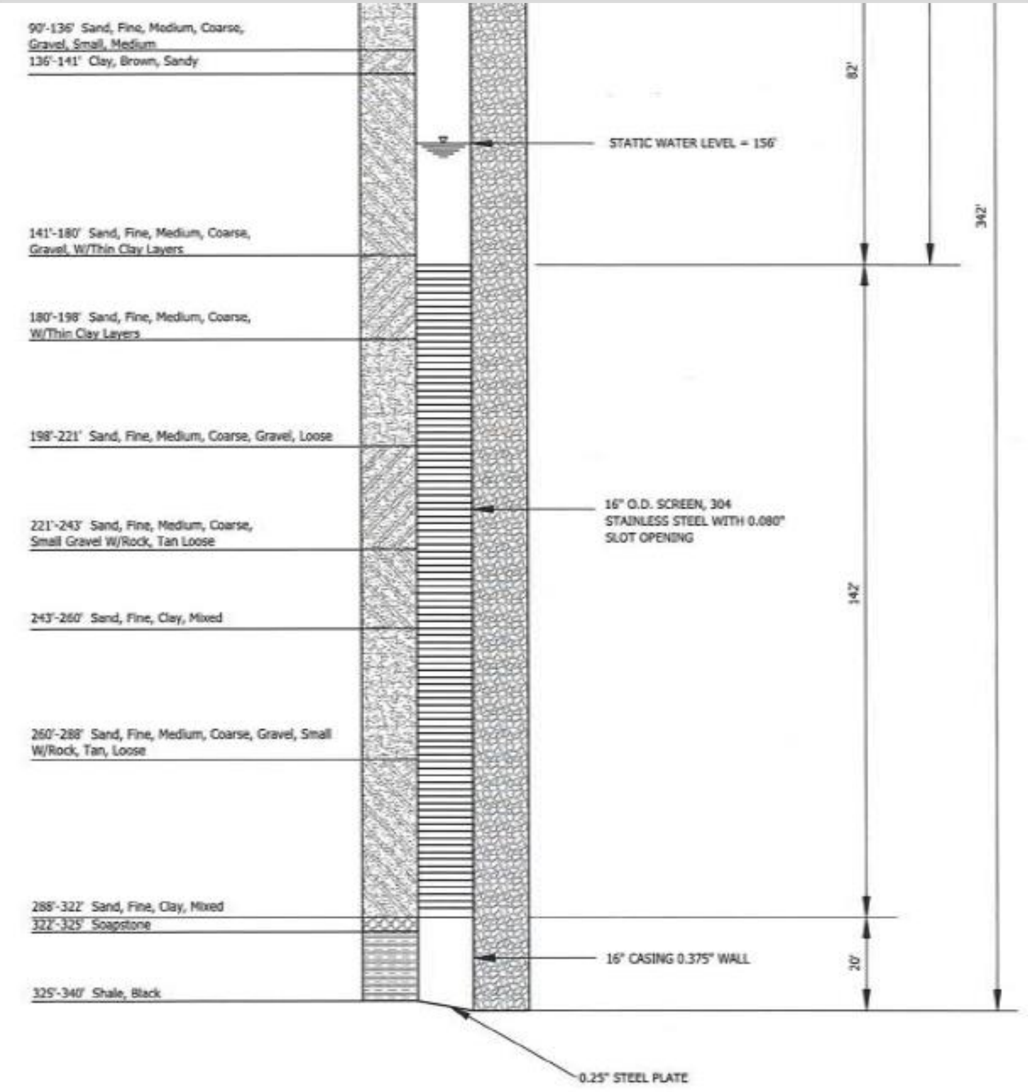
Well Materials

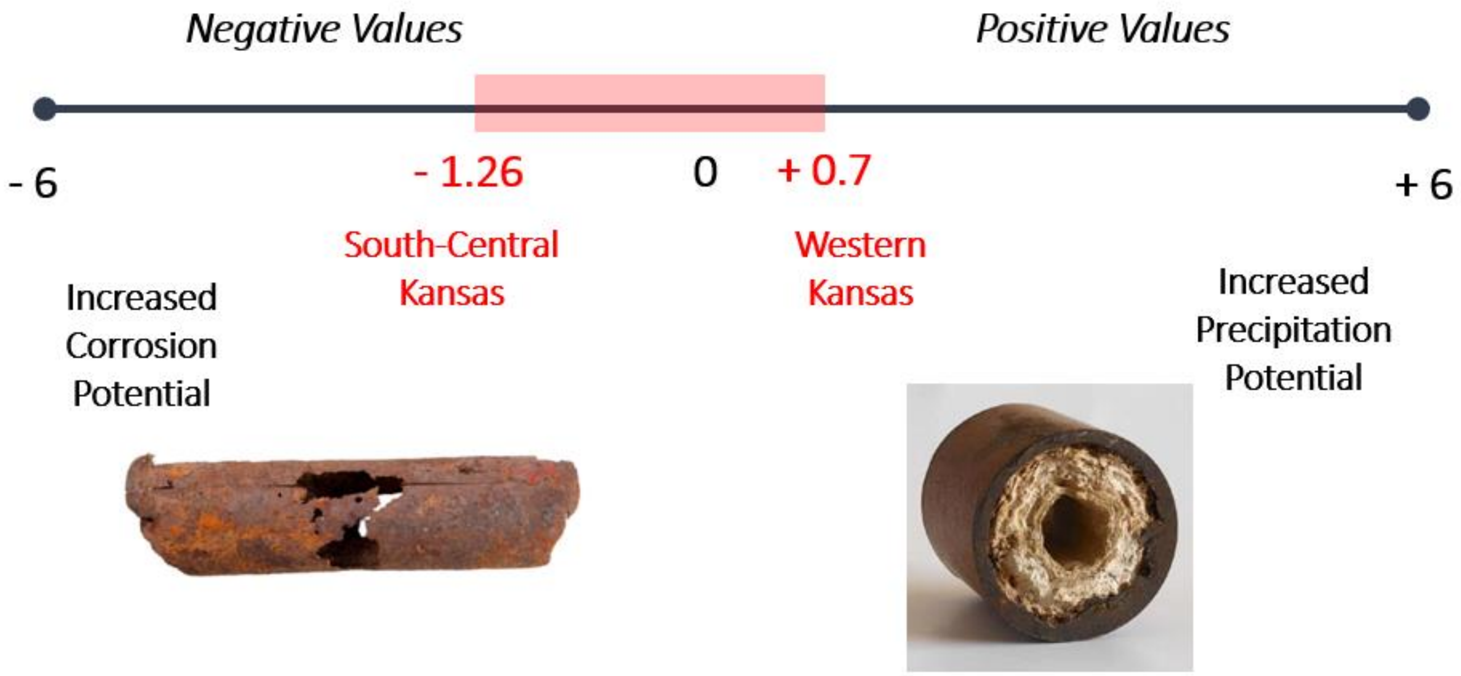
LCS Casing
SS Screen Elev. 180’ - 322
Pump Elev. = 300ft
LCS Sump = 320’- 340’
Cement grout = 0 – 100’



What to Monitor for Well Health

- pH
- Total Dissolved Solids (TDS)
- Alkalinity
- ORP
- Langelier Saturation Index (LSI)
- Water Quality Parameter Lab Testing (IOCs, SOCs, VOCs)
- Pumping Rates over time
- Take sample post chlorination and observe for a day or two
- Adenosine triphosphate (ATP) test to measure the presence of bacteria in a well

Langelier Saturation Index (LSI)



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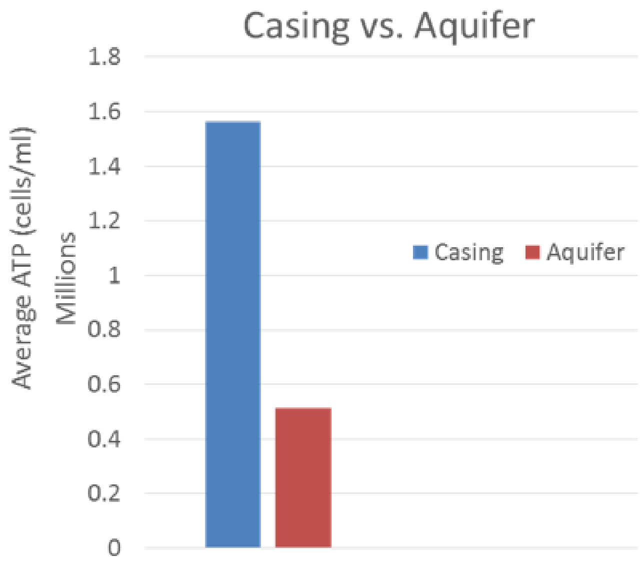
ATP – Total Bacterial Population Assessment

Average ATP Level (cells/ml)	
Casing	**Aquifer**
1,561,654	511,711



Observation: most wells appear to benefit from active operating schedules which deter bacterial growth, propagation, and cell attachment to surfaces

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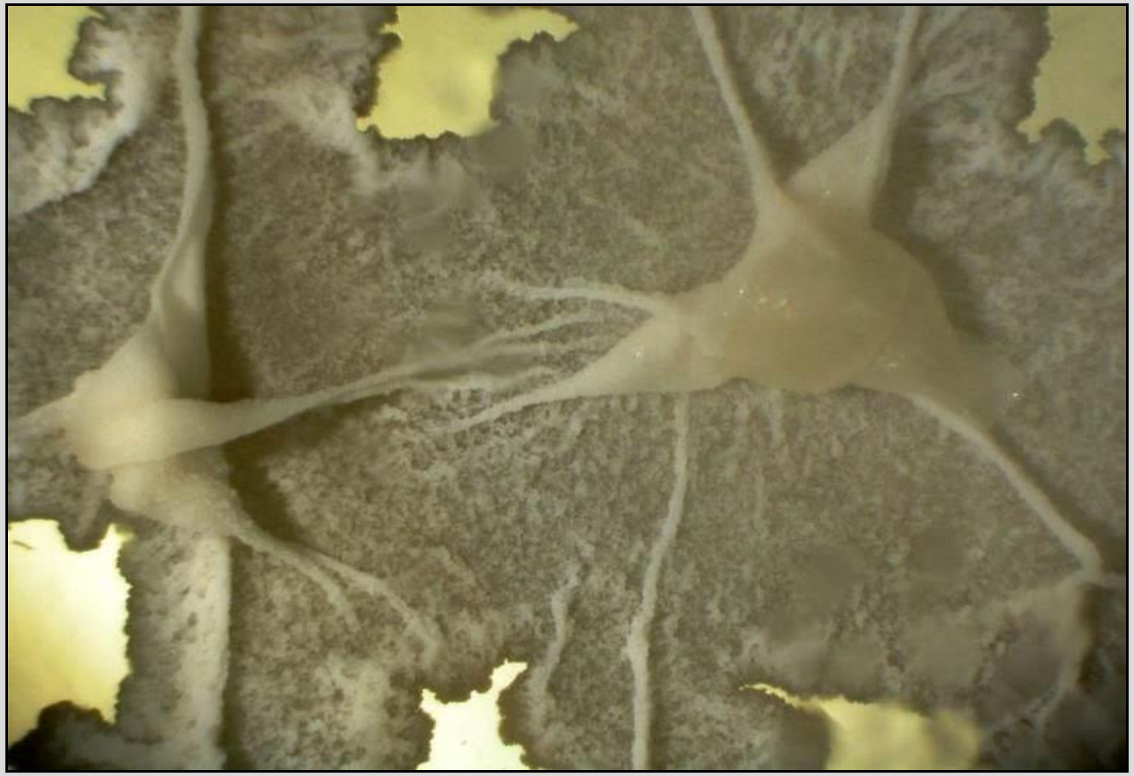
Slime Formers

- Produce excessive amounts of exopolymer

- Natural expression of bacteria to attach to surfaces to capture nutrients/protection etc.

- Key component of biofilm



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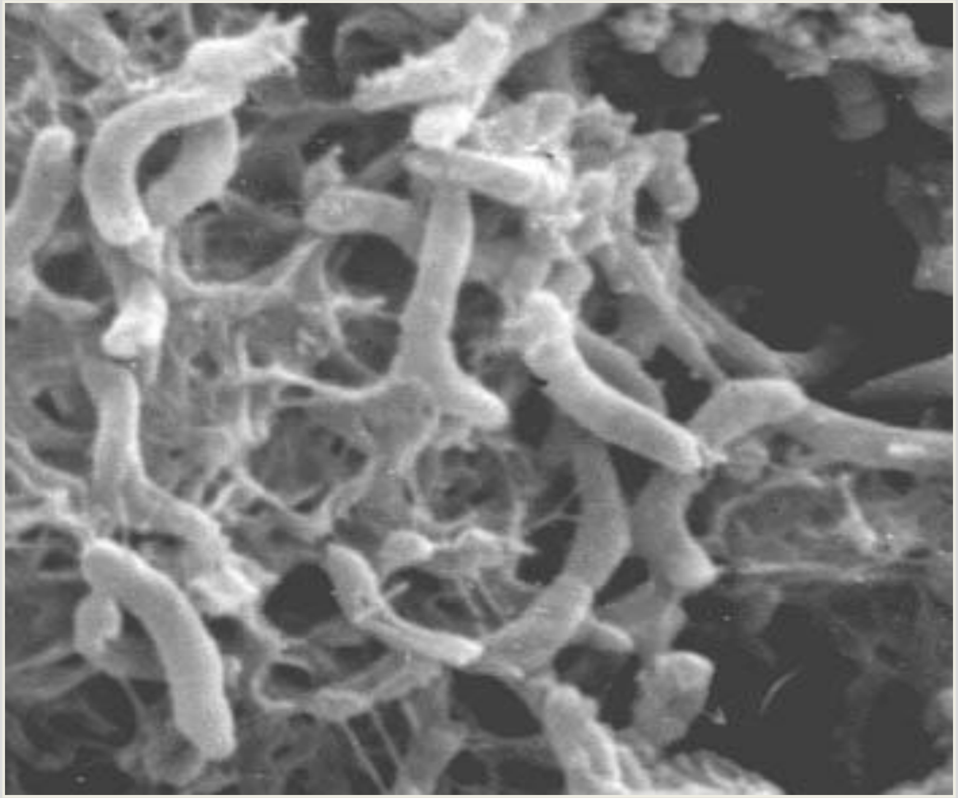
Anaerobic Bacteria

- Produce very dense biofilm
- Inhabit deep portions of the well and gravel pack
- Severely limit water flow
- Stratification of biofilm
- Include Sulfate Reducing Bacteria (SRB's)- Hydrogen Sulfide Gas



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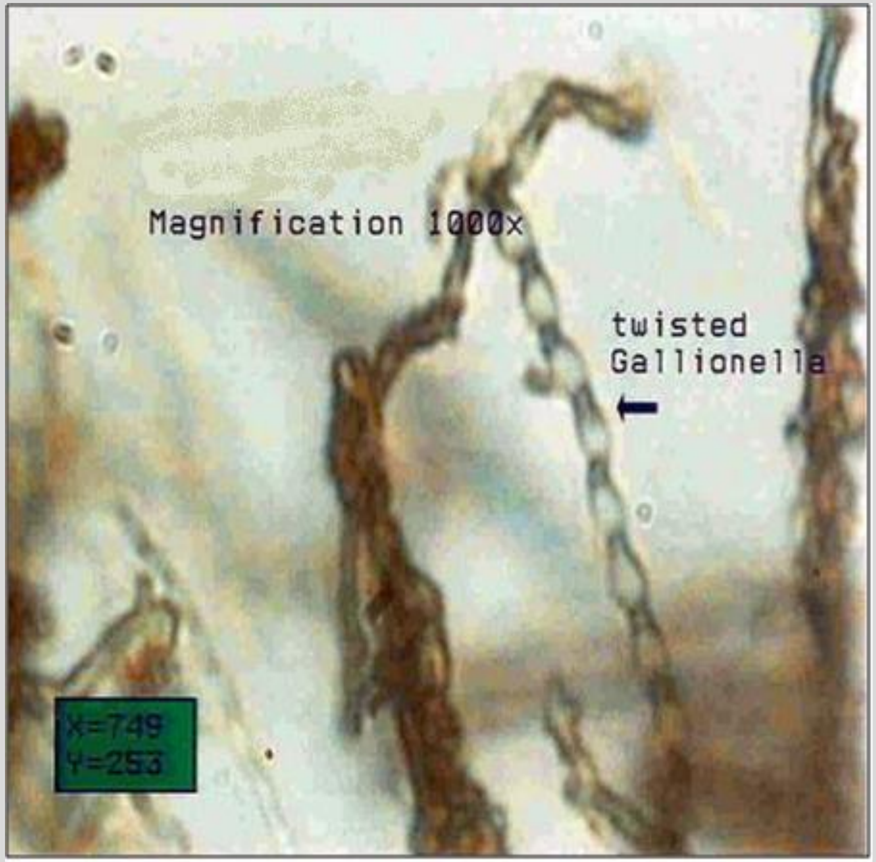
Iron Oxidizing Bacteria

- Bacteria that derive energy needed to live by oxidizing iron or manganese
- Deposit iron or manganese oxides
- Most common form of Microbially Induced Corrosion (MIC)
- Best identified with a microscope based on morphology



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Well Review Example

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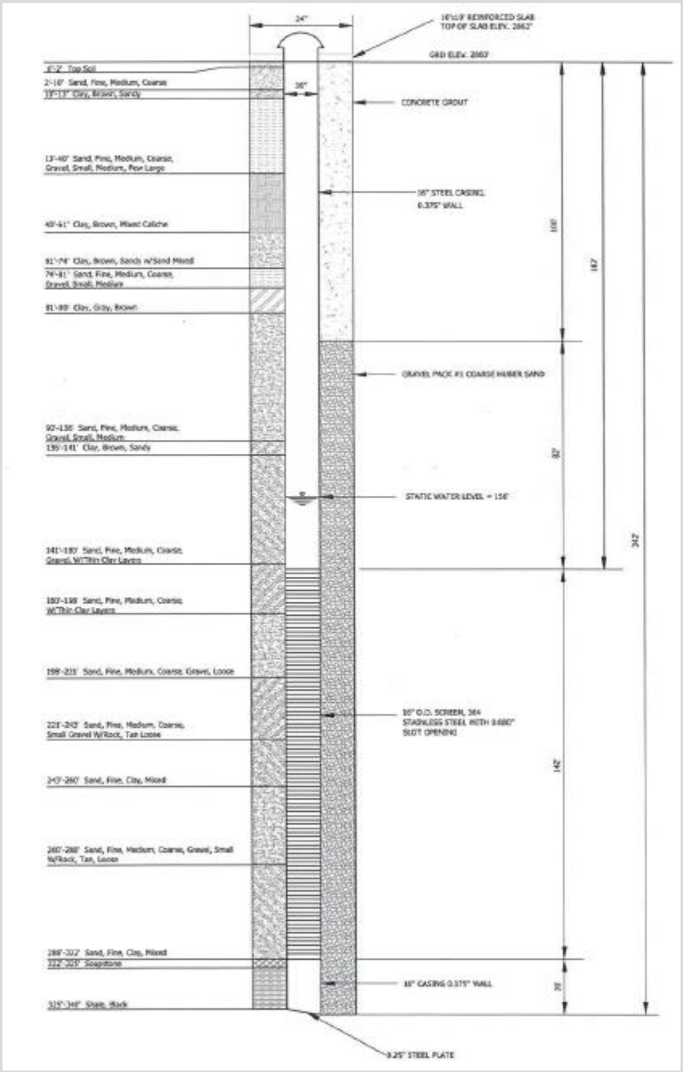

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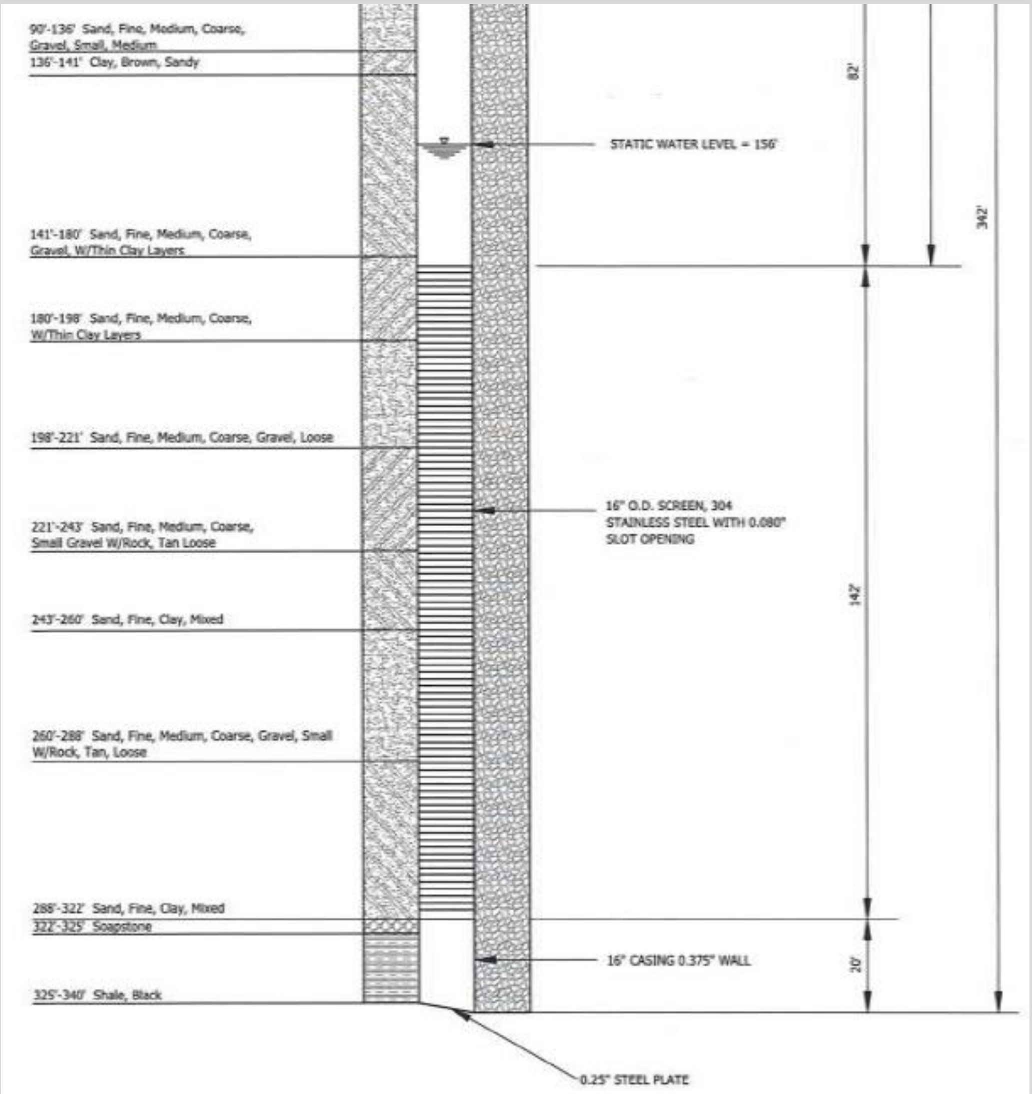

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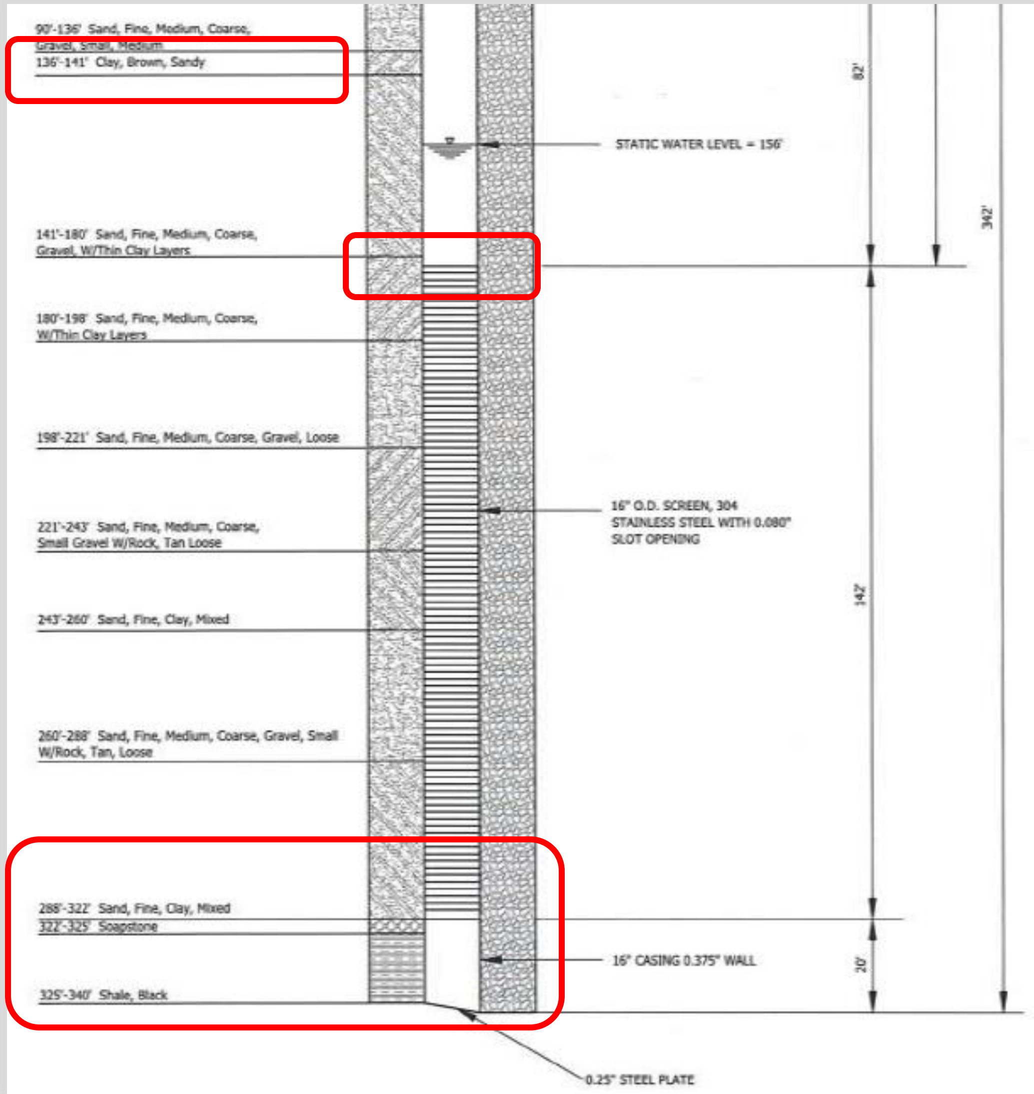
Dissolved Solid = 1800 mg/L
Calcium = 350 mg/L
Corrosivity = 0.82 LSI
Conductivity = 2100 umho/cm
Chloride = 97 mg/L
Sulfate = 1000 mg/L
Gross Alpha = 9.5 pCi/L

Well Materials

LCS Casing = 0 - 180’
Cement grout = 0 – 100’
SS Screen Elev. 180’ - 322
Pump Elev. = 300’
LCS Sump = 320’- 340’



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Identified Well Issue – Now What?

Key Water Well Rehab Techniques

- **Down-hole camera evaluation** - Pull Pump and drop pipe, and insert camera to log condition of well, casing pipe and screen
- **Removal -** of any foreign object or residuals in bottom of well
- **High-pressure jetting** - Using a high-pressure stream of water to blast away sediment and mineral deposits from the well screen and casing.
- **Surging** - A mechanical process where a plunger is moved up and down inside the well casing to dislodge debris and sediment.
- **Air surging** – Similar to mechanical surging but uses compressed air to dislodge deposits.

Key Water Well Rehab Techniques

- **Swabbing** - Using a large diameter bailer to remove sediment and debris from the well by repeatedly lowering and raising it.
- **Wire brushing** - Running a specialized brush down the well casing to scrape off deposits on the inner surface.
- **Static tank flush** - Allowing the well to fill a holding tank and then rapidly emptying it to flush out sediment.
- **Chemical treatment** - In some cases, specialized chemicals may be used to dissolve certain types of mineral buildup. Usually, an acid treatment followed by flushing and disinfection. Type of acid depends on type of accumumlations.

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What need to Change?

What needs to Change?

- When water quality issues arise, start by evaluating the wells first.
- Regulators must enforce the drinking water well construction design regulations
- Source Water Protection Plans need to be applied and enforced
- Design for long-term water quality not just quantity, using know science.
- Professionals must certify wells were constructed as designed
- We as an industry have to help PWS systems succeed!

Our Industry Needs Change

- Regulatory WQ Testing is only the minimum needed for protection of public health

- Identify geological areas of know water quality issues and disseminate knowledge to the industry

- Request targeted testing for wells based upon known areas of biogeochemical issues to identify precursors that may cause future water quality issues.

- PWS operators must be trained to evaluate water quality or aquifer changes

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Preventative Maintenance

- Mindset Change – Run to Failure not a good option
- Regular, targeted testing
- Evaluate how and when the sample is collected
- Document maintenance work and effectiveness
- Periodically review the data for trends

Contact Info

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Questions ???