All Star Training, Inc.

Common Causes of Well Failure - Part 1 Video Slides

Major Causes of Controllable Well Problems

Well Construction Issues

Can include either well design decisions or actual well construction issues. State standards are generally the minimum requirement.

Incomplete Well Development

Can often be treated as an after-thought and is generally not given the attention, or time, it needs to be successful.

Pre-Mature Aging

Poor well design and/or lack of maintenance can substantially shorten the lifespan of a well.

Neglect

The "run to failure" model still prevails in the industry. Out of sight, out of mind!

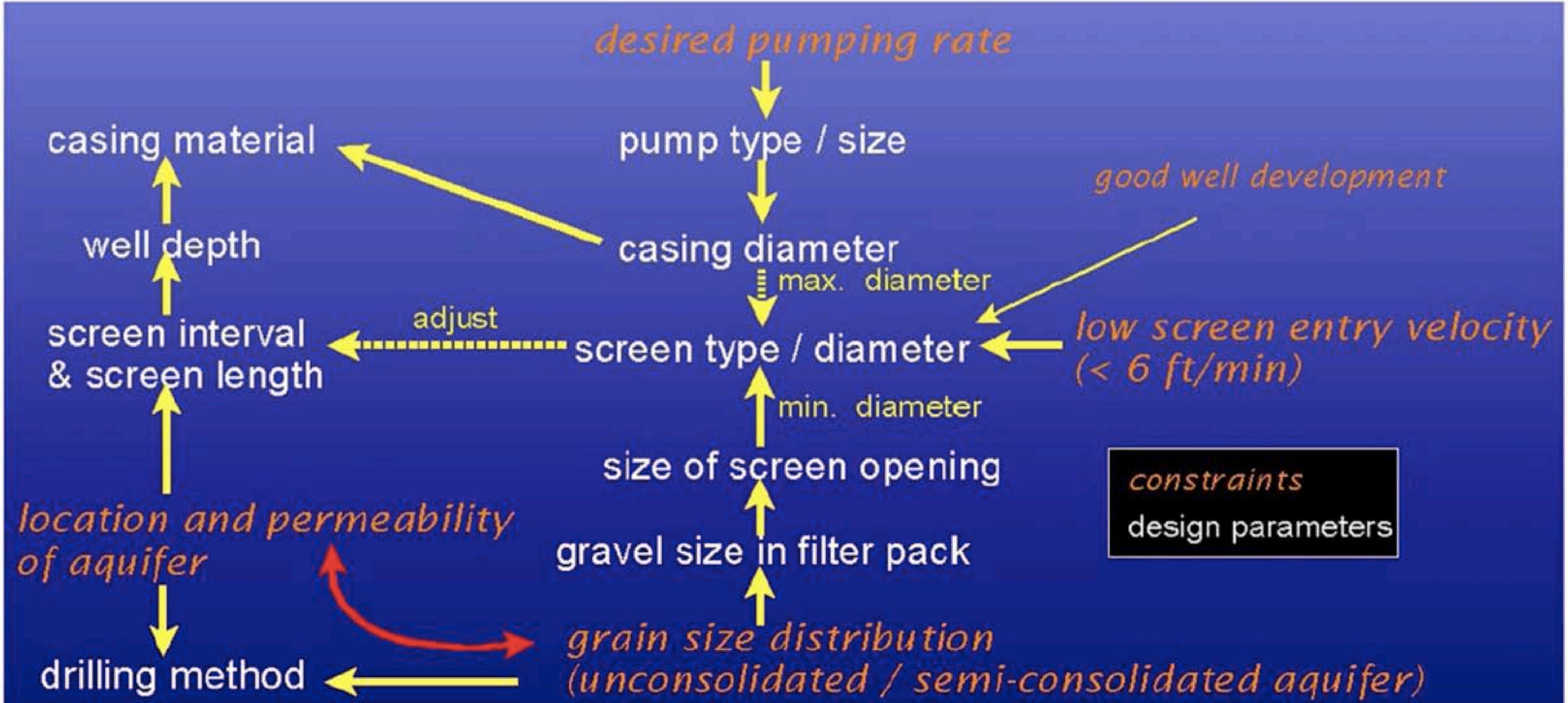
Contaminants

Many types of contaminants can be dealt with in well design and construction, but information is key here.

Location

The most convenient location is not often the best location for a productive well.

Well Decision Tree



Well Design and Construction Issues

Well Seals

Can include either well design decisions or actual well construction issues. State standards are generally the minimum requirement.

Gravel Pack Bridging/Settlement

Installation of gravel pack during well construction can result in voids due to bridging which can result in later sanding issues. Settling can have a similar effect.

The Wrong Materials for the Situation

Often, materials are chosen for well construction to save on up front costs without regard for long term health of the well.

Screen and Gravel Size

The wrong choices here can lead to a sanding well if too coarse and an inefficient well if too fine.

Welds

A common point of failure due to preferential corrosion and incomplete welds.

Plumbness and Alignment

The most convenient location is often times not the best location for a productive well.

AWWA A100-15 Water Well Standard

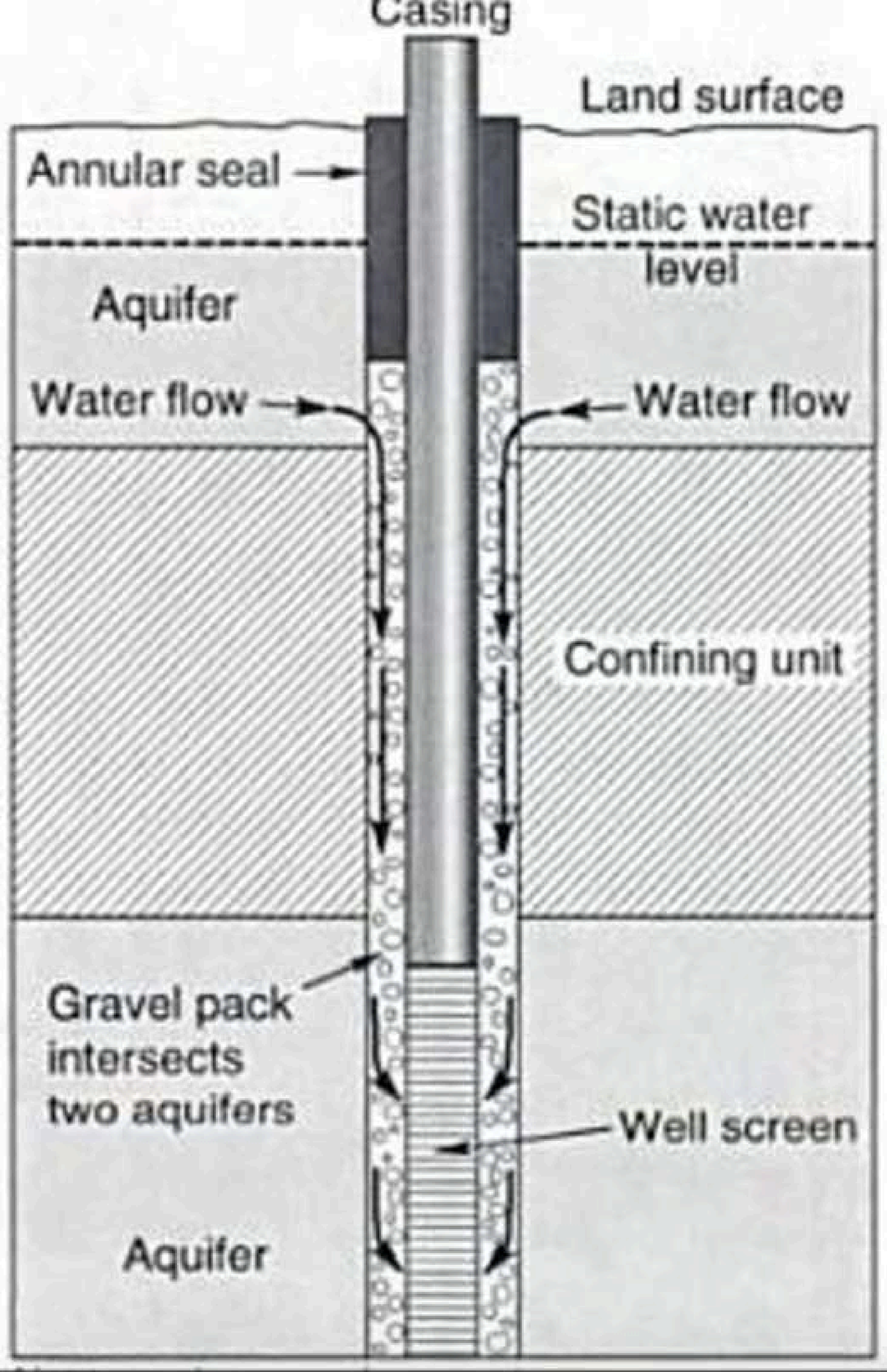
- Investigation of Geologic and Hydrologic Conditions and Groundwater Conditions
- Material Requirements
- Well Casing
- Well Screens
- Gravel Pack
- Well Construction
- Well Development
- Well Disinfection
- Decommissioning of Test Holes, Partially Completed Wells and Abandoned Wells
- Performance Testing
- Water Quality Testing
- Basis of Rejection

State Regulations vs Geologic Reality

Most states specify a minimum seal depth

This minimum seal depth often gets treated as a de facto construction standard

In actuality, hydrogeologic conditions encountered during drilling should dictate the actual seal depth



Why Well Seals are Important

- Stabilize the upper portion of the boring and casing.
- Prevent the vertical migration of poor quality or contaminated groundwater.

Mystery Case

- Located in Lassen County, California
- 300 connection water system
- Volcanic rock bedrock
- 3 wells of approximately 100 deep
- Wells all located in a line within 300 ft of each other
- Outside wells had consistent E. coli detections
- Nearby septic systems as likely source of E. coli
- Looking at expensive water treatment system to solve problem
- Mystery of why only 2 of 3 wells were impacted

Lessons Learned

- A review of drill logs indicated fracture zones providing possible conduit to surface
- Drill appeared to have inadequately sealed wells with only a minimum seal
- Wood shavings. Really?
- Answer to extend wells to 200 ft with 100 ft of seal

Gravel Pack and Screen Size

- This well was a sander from the beginning
- Screen size is too large for the surrounding formation

Well #6

DUPLICATE
Driller's Copy

STATE OF CALIFORNIA
WELL COMPLETION REPORT

No. 439136

GEOLOGIC LOG

WELL OWNER

Name Daggett Community Services Dist

Mailing Address P O Box 308

Daggett Ca.

WELL LOCATION

City Daggett

County San Bernardino

APN Book 515 Page 151 Parcel 62

Township 9N Range 1E Section 16

LOCATION SKETCH

DRILLING METHOD Rotary FLUID Mud

WATER LEVEL & YIELD OF COMPLETED WELL

DEPTH OF STATIC WATER LEVEL 128 (Ft.) & DATE MEASURED 10-1-98

ESTIMATED YIELD 1500 (GPM) & TEST TYPE pump

TEST LENGTH 18 (Hrs.) TOTAL DRAWDOWN 57 (Ft.)

TOTAL DEPTH OF BORING 321 (Feet)

TOTAL DEPTH OF COMPLETED WELL 306 (Feet)

CASING(S)

ANNULAR MATERIAL

ATTACHMENTS (✓)

CERTIFICATION STATEMENT

Desert Empire Drilling

3850 Lenwood Rd. Barstow Ca. 92311

10-6-98

IF ADDITIONAL SPACE IS NEEDED, USE NEXT CONSECUTIVELY NUMBERED FORM

Well Development

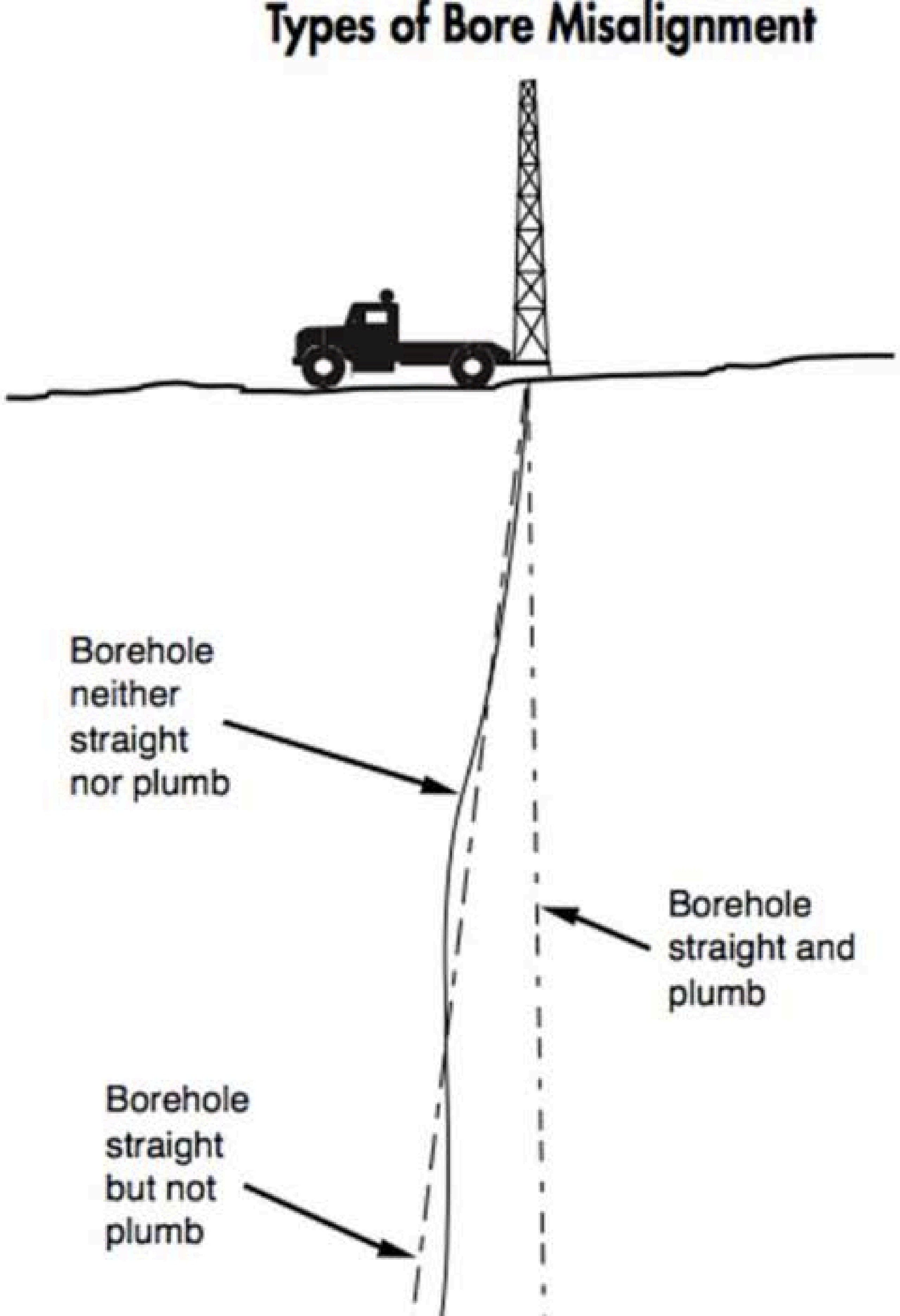
The act of repairing damage to the formation caused during drilling procedures and increasing the porosity and permeability of the materials surrounding the intake portion of the well.

- Remove drilling fluids and formation damage
- Remove formation fines near the wellbore
- Establish optimal hydraulic contact between the well and the geologic formation
- Provide an acceptable level of sand and turbidity (based on field testing)
- Provide for an appropriate level of drawdown at the production pumping rate

Plumbness and Alignment

- Plumbness is the horizontal deviation from the well centerline and a true vertical centerline

- Alignment is the horizontal deviation between the actual well centerline and a straight line

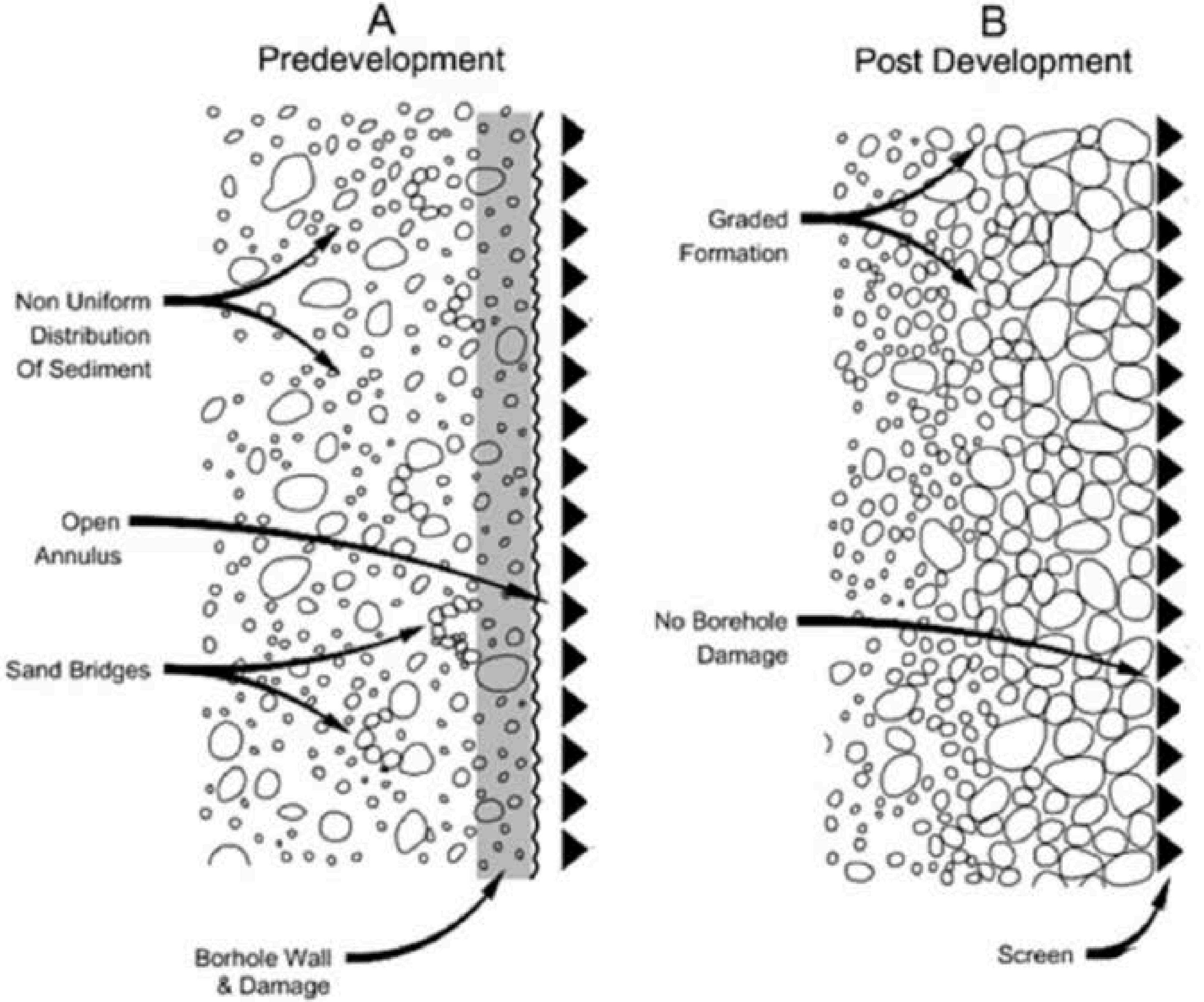


Well Development

The goal of well development is carry out activities to allow the groundwater reach the pump as easily and cost-effectively as possible.

Well Development Objectives

- Remove drilling mud and "skin" on borehole wall
- Settle filter pack and remove sand "bridges"
- Remove fines/sand from the well
- Reduce turbidity



Common Issues with Well Development

- Failure to establish and monitor well development parameters
- Failure to spend the proper amount of time on well development
- Failure to use proper techniques to remove drilling mud from borehole and formation

Drilling Mud

- Usually Wyoming bentonite clay-based
- Hydrated bentonite swells due to its molecular structure
- Designed to coat borehole wall to stabilize the hole
- Much of the development process consists of removing the drilling mud which impedes water flow into the well.

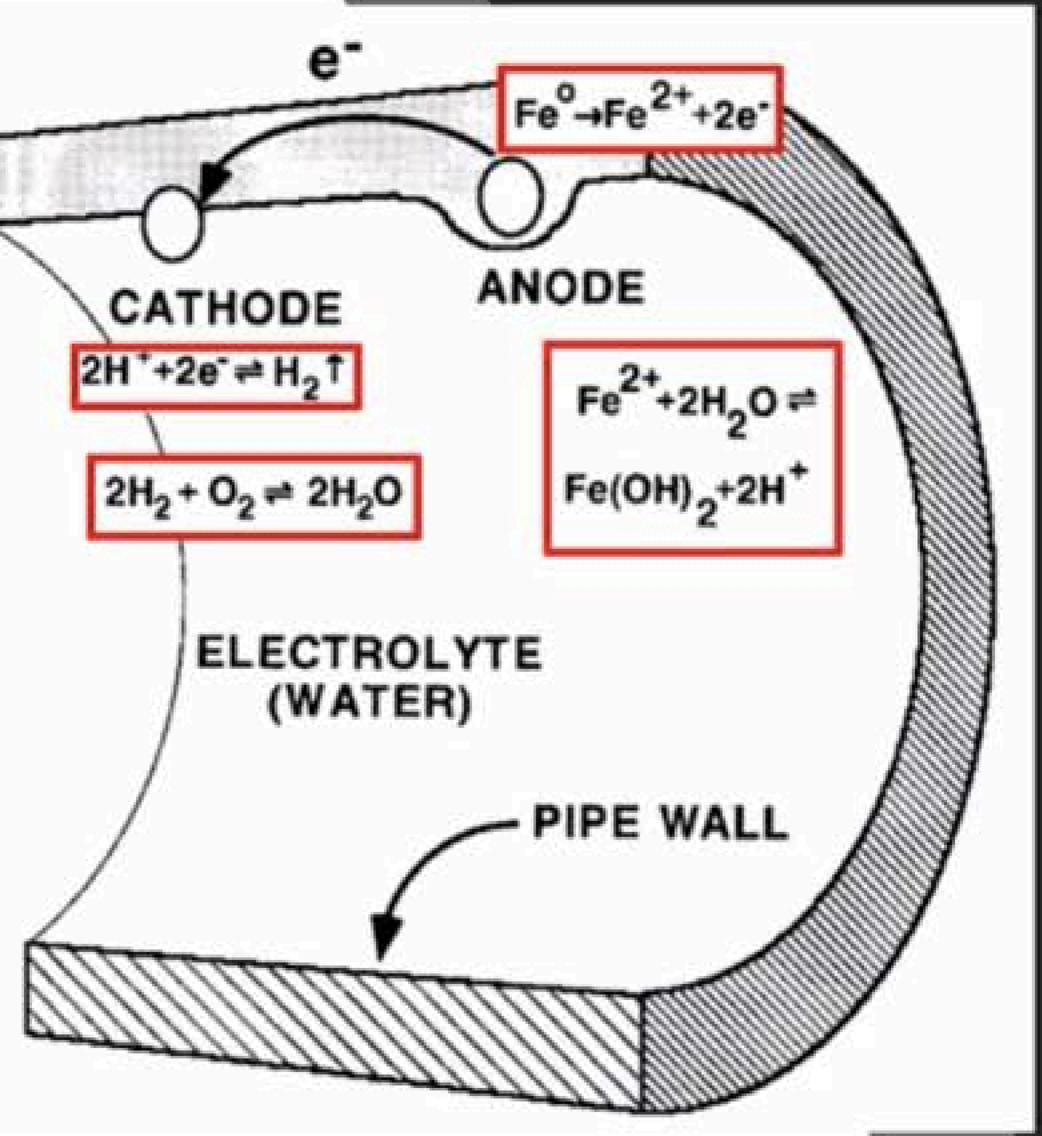
Another Reason Development is Important

- Drilling muds are generally bentonite clay-based
- Bentonite is a montmorillonite clay that is expandable when hydrated
- Montmorillonite clays are derived from volcanic tuff and glass deposits
- Volcanic deposits can often contain trace to high concentrations of heavy metals and other contaminants
- Not well studied, but bentonite can contain arsenic, lead, mercury, chromium, magnesium, etc.
- Drilling mud generally contains added polymers that require special treatment during development to remove them.

Measuring Well Development

Parameter	Target
Specific Capacity	Development should continue with 10-15 percent SC improvement
Turbidity	Less than 5 NTU
Sand	Less than 5 ppm

Galvanic Corrosion



- The electrochemical process in which one metal corrodes preferentially when it is in contact with a different type of metal and both metals are in an electrolyte.
- When different types of metals come into contact in the presence of an electrolyte, a galvanic couple is set up as different metals have different electrode potentials.
- The electrolyte provides a means for ion migration from the anode to the cathode.
- In the case of a water well, the electrolyte is the water in the well; the anode is the lower potential metal (low carbon steel); and, the cathode is the higher potential metal (stainless steel).

A Neglected Well Leads To:

- Development of Mineral Incrustations
- Biofouling
- Silt/Clay Plugging
- Corrosion

Microbially-Induced Corrosion

- Iron-related bacteria (IRB) can grow rapidly in aerobic conditions at well screens and clog wells.

- Iron-related bacteria can also allow the growth of sulfur-reducing bacteria below the IRB colonies where there is little oxygen.

- Sulfur-reducing bacteria (SRB) are corrosive to wells due to hydrogen sulfide byproduct.

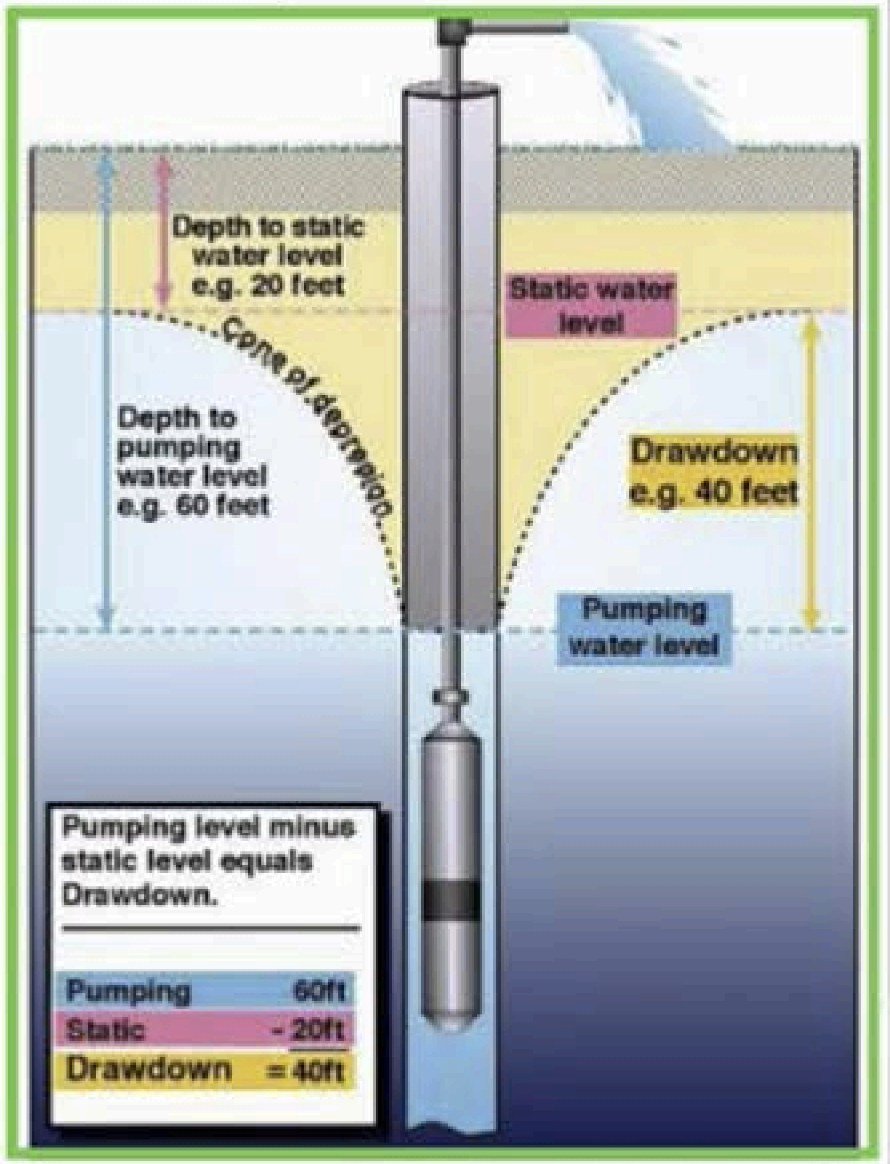
Maintaining a Healthy Well

At a minimum, track Specific Capacity.

If you are prone to biofouling, track iron-related bacteria and sulfur-reducing bacteria.

The more parameters you track, the better.

Specific Capacity



An expression of the productivity of a well.

SC = Q/ds

SC = specific capacity

Q = discharge

ds = drawdown

Biological Activity Reaction Test (BART)

- **Colorimetric test for:**
  - Iron-Related Bacteria
  - Sulfate-Reducing Bacteria
  - Heterotrophic Aerobic Bacteria
  - Slime-Forming Bacteria
- **Time for color change indicates population size and activity**
- **Oxygen gradient differentiates aerobic vs anaerobic**
- **2-8 day test time**

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Common Causes of Well Failure - Part 2 Video Slides

Measuring the Health of a Well

Key Performance Indicators (KPI) are a powerful tool to indicate the health of a water supply well and determine the optimal schedule for rehabilitation.

Key Performance Indicators

Chemical Parameters

- Iron (+2, +3, total)
- Manganese
- Hardness (Ca, Mg)
- Total Dissolved Solids
- Turbidity
- pH
- Total Cations/Anions
- Oxidation-Reduction Potential (ORP)
- Specific Contaminants

Biological Parameters

- Coliform Bacteria (presence/absence)
- Total Bacteria
- Anaerobic Bacteria (as a percent of total bacteria)
- Iron-Related Bacteria
- Sulfate-Reducing Bacteria
- Speciate Bacteria (may be helpful in diagnostics)

Physical Parameters

- Specific Capacity
- Energy Usage
- Sand Production
- Well Efficiency
- Water Levels

Based on Studies by Water Systems Engineering, Inc., Ottawa, Kansas

KPI Triggers – Biological Parameters

KPI	Green Zone	Yellow Zone	Red Zone
Coliform	ND		present
Total Bacteria (ATP or HPC)	<30,000 ATP <500 HPC	30,000–100,000 ATP 500-1,000 HPC	>100,000 ATP >1,000 HPC
Anaerobic Bacteria	<10%	10-20%	>20%
IRB	ND	moderate	heavy
SRB	ND	moderate	heavy

KPI Triggers – Chemical Parameters

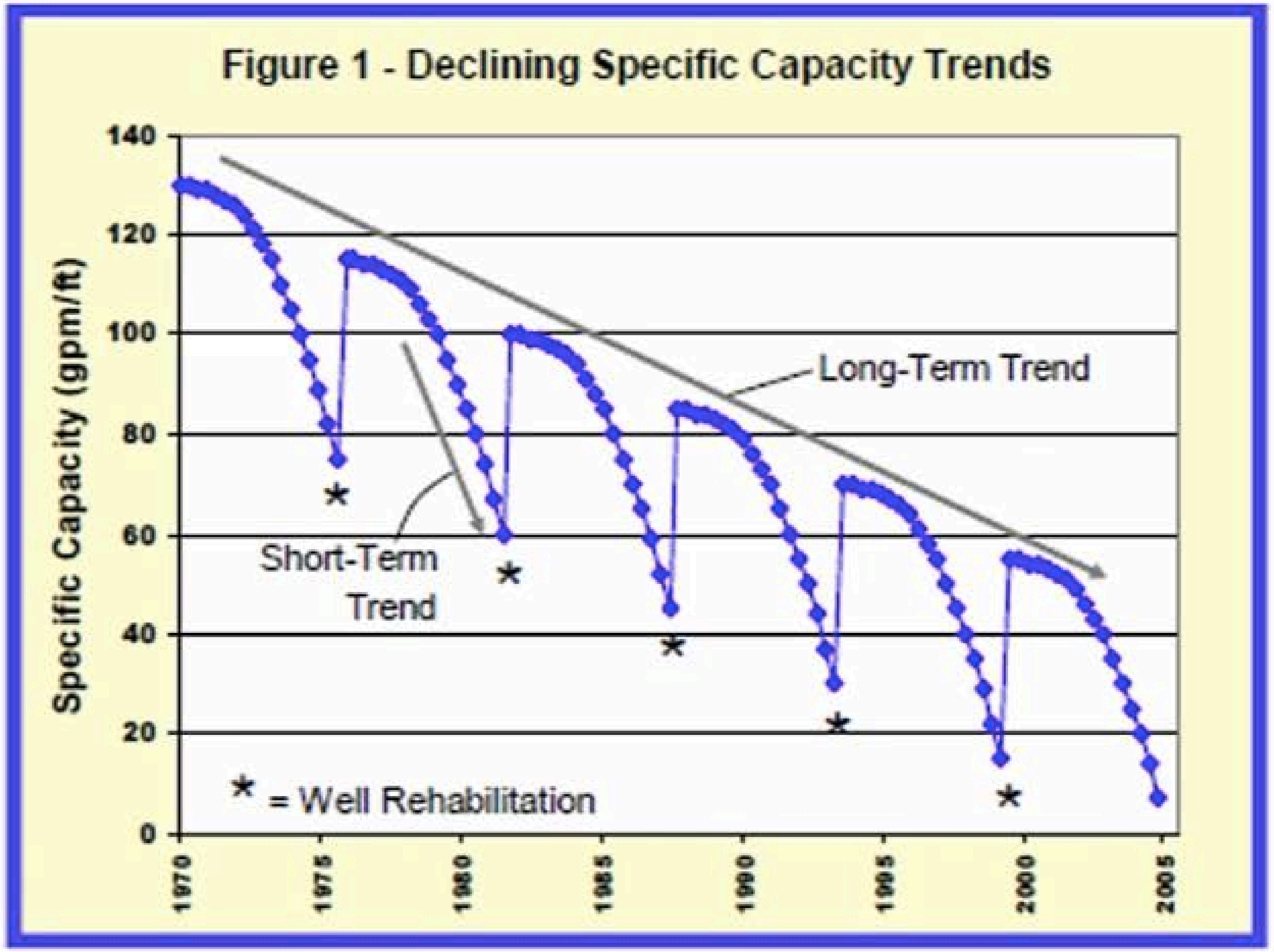
KPI	Green Zone	Yellow Zone	Red Zone
Fe^{+2} (ferrous)	<0.02 mg/L	Relative	Changes
Fe^{+3} (ferric)	Relative	Changes	>0.75 mg/L
Fe (total)	<0.3 mg/L	0.3-1.0 mg/L	>1.0 mg/L
Mn	<0.05 mg/L	0.05-0.2 mg/L	>0.2 mg/L
Hardness (Ca, Mg)	0-120 mg/L	120-250 mg/L	>250 mg/L
TDS	< 500 mg/L	500-1,000 mg/L	>1,000 mg/L
Turbidity	<5 NTU	5-10 NTU	>10 NTU
pH	6.5-7.5	5.5-6.5 or 7.5-8.5	<5.5 or >8.5
Cations/Anions	Monitor	Relative	Changes
ORP	Near zero	Moderate + or -	High + or -
Specific Contaminant	<½ MCL	½ MCL - MCL	>MCL

KPI Triggers – Physical Parameters

KPI	Green Zone	Yellow Zone	Red Zone
Gallons/KWH	<5% decline	5-15% decline	>15% decline
Sand	<5 ppm	5-10 ppm	>10 ppm
Specific Capacity	<5% decline	5-10% decline	>10% decline
Efficiency	<5% decline	5-10% decline	>10% decline
Water Levels	<5% decline	5-10% decline	>10% decline

KPI Changes Over Time

- KPI changes over time can allow troubleshooting
- Using multiple KPIs is more reliable than a single KPI
- To be effective, must track KPIs at regular intervals over time



Develop a KPI Dashboard

- Determine appropriate KPIs to track for each well
- Wells can vary – even those close together
- Small operators can use a graphical spreadsheet as a dashboard
- Larger operators can develop web interface to share
- Relative changes are often the best measure
- ***KPI changes provide data to determine optimal rehabilitation schedule***

Contaminants Can Be Challenging to Deal With

- Arsenic
- Uranium
- Nitrates
- Fluoride
- Methane
- 1,2,3-TCP
- PFAS

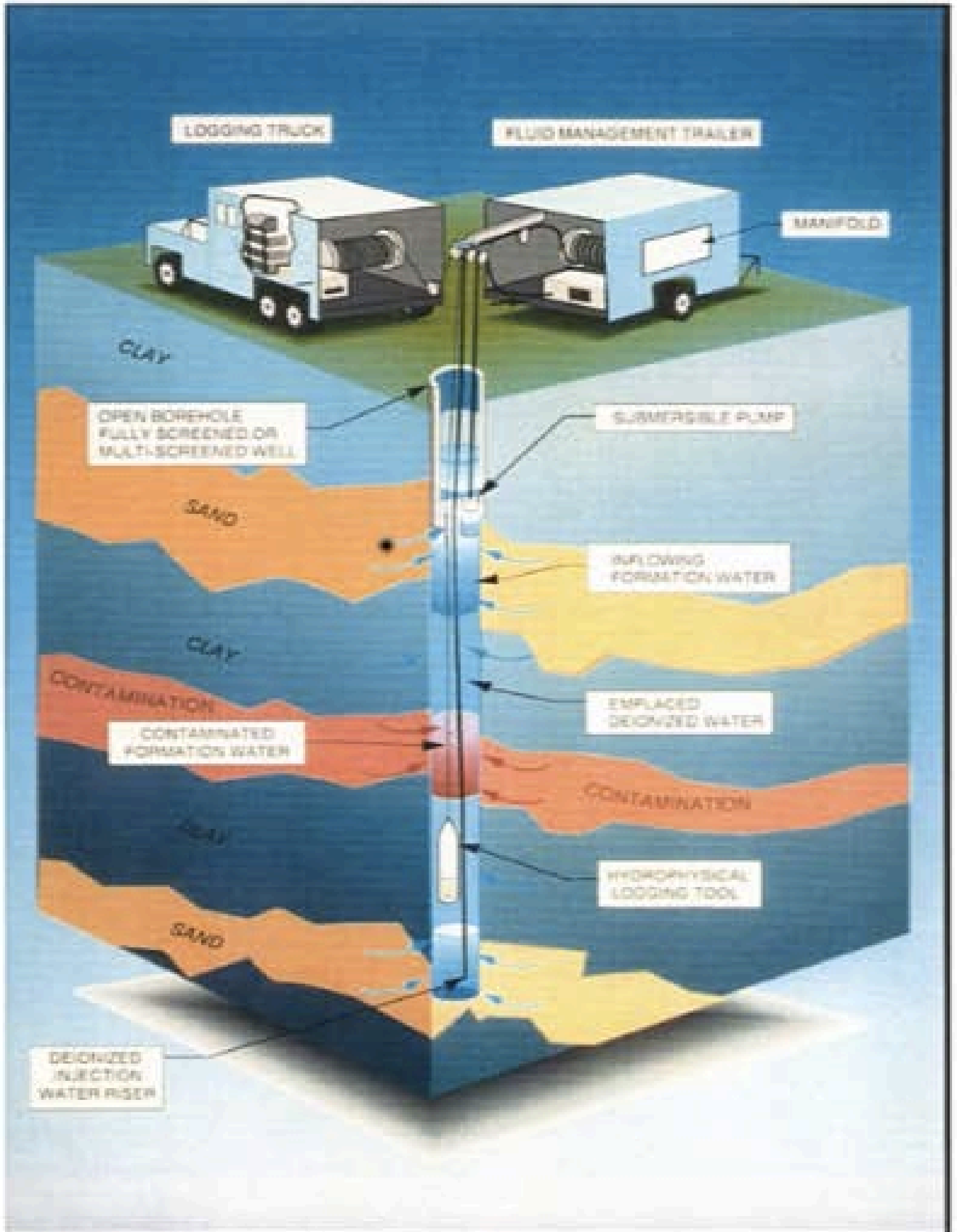
- Often, treatment systems are presumed to be the only option.
- Well profiling can often pinpoint problem intervals in wells that are often geology related.
- Well modification can be much less expensive than treatment systems.

Sulphur – A Big Issue in Middle Tennessee

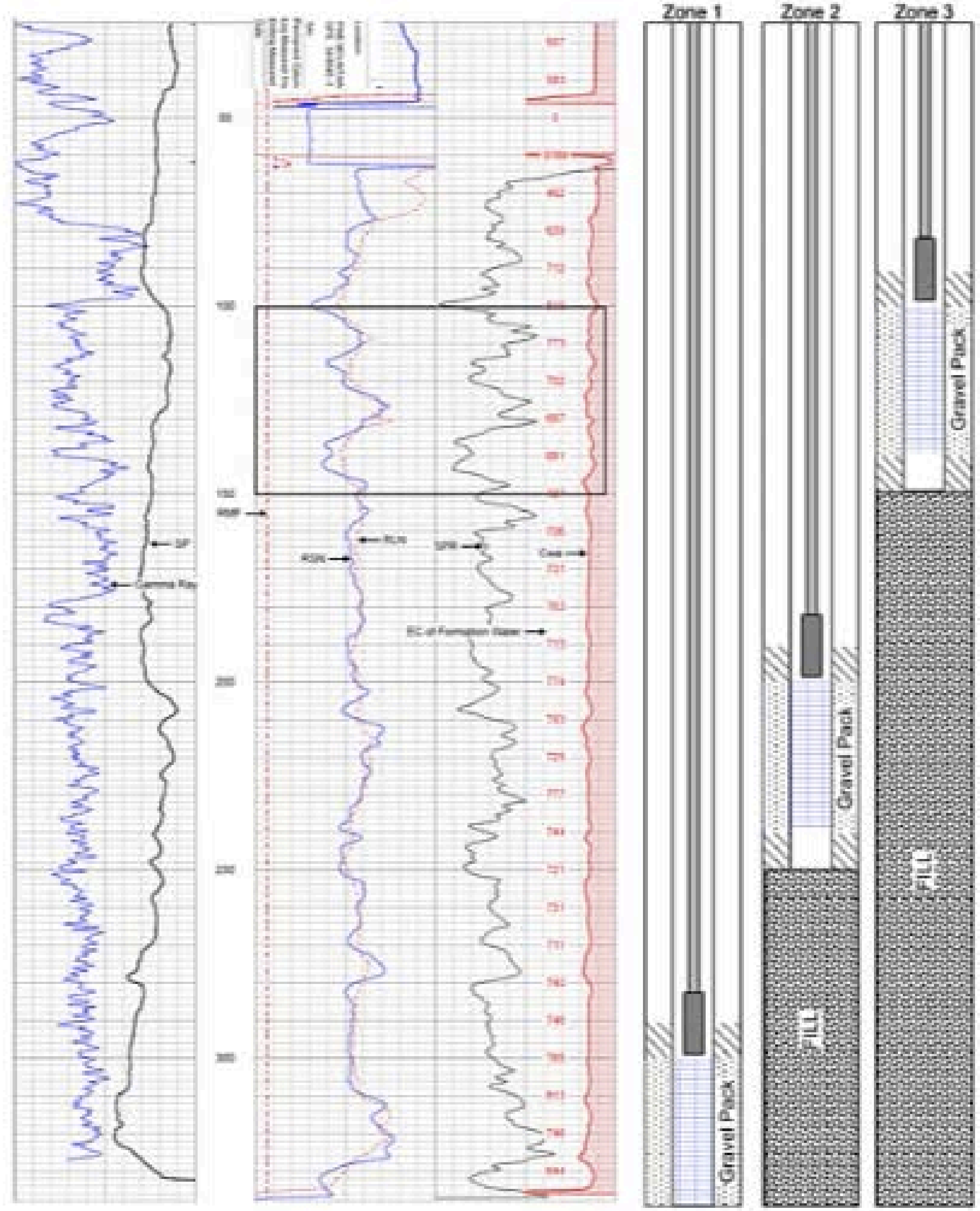
- TDEC Estimates that 20% of wells in Central Basin contain Sulfur
- Sulfur occurs in some ground water as a dissolved sulfate (SO_4^{2-}) or hydrogen sulfide gas (H_2S)
- Petroleum deposits or shows can indicate sulfur potential
- Another source is evaporite (gypsum and anhydrite) beds in the Fort Payne Formation – especially where Chattanooga Shale confining bed has been breached.

Vertical Profiling for Contaminants

Hydro-Physical Logging



Traditional Zone Testing



Dynamic vs. Ambient Testing

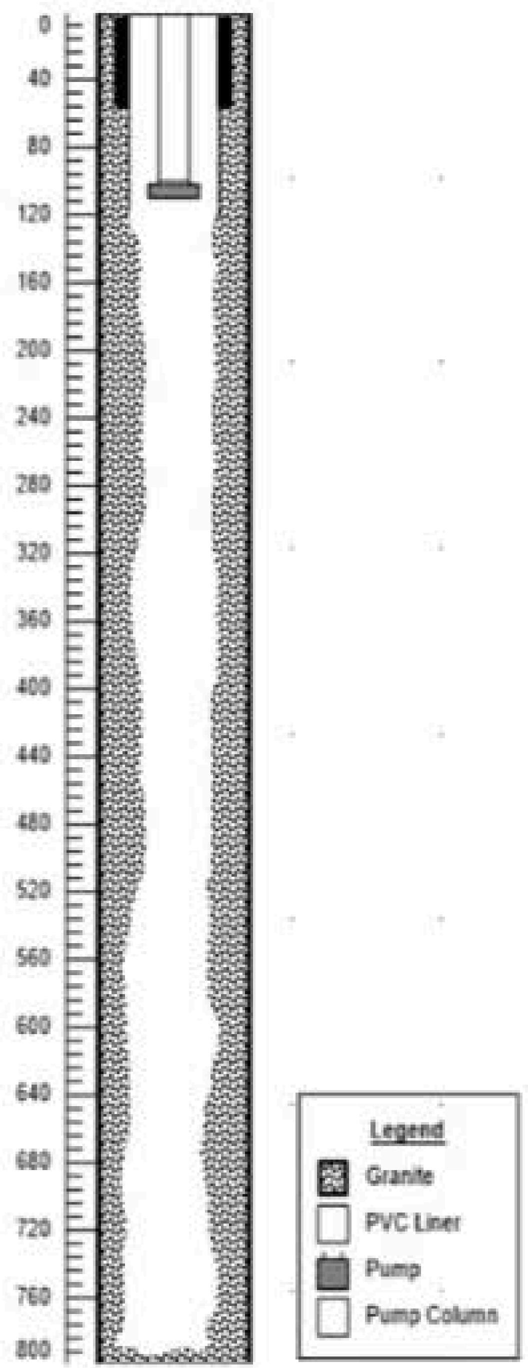
Ambient Testing

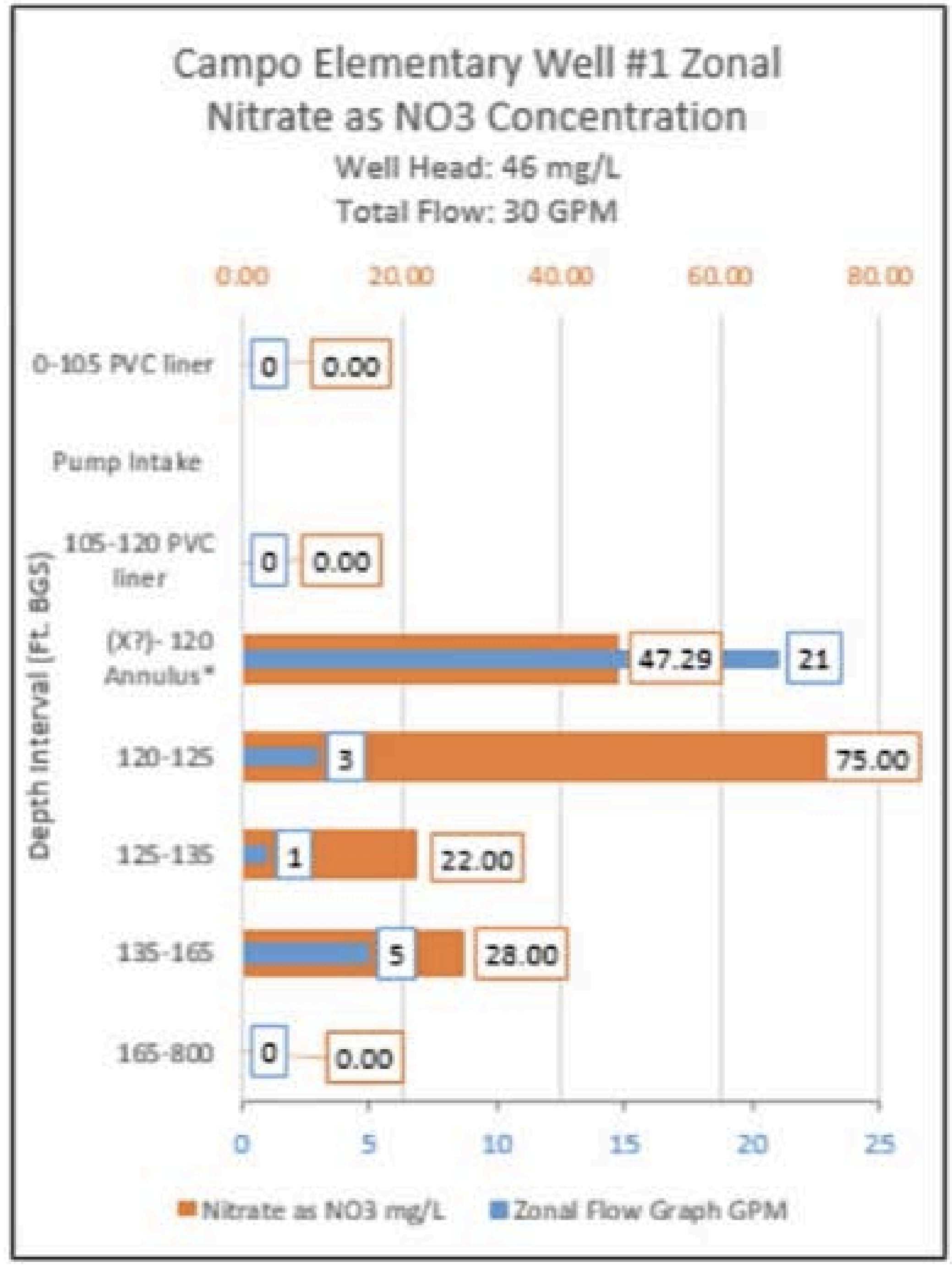
- Measures natural flow into the well – non-pumping conditions
- Usually requires removing the pump
- May be harder to interpret if ambient flow is low

Dynamic Testing

- Measures flow into the well under pumping conditions
- Most accurately simulates well production in terms of flow and chemistry
- More challenging to perform
- May require multiple trips in and out with the pump

Nitrate Profiling Example





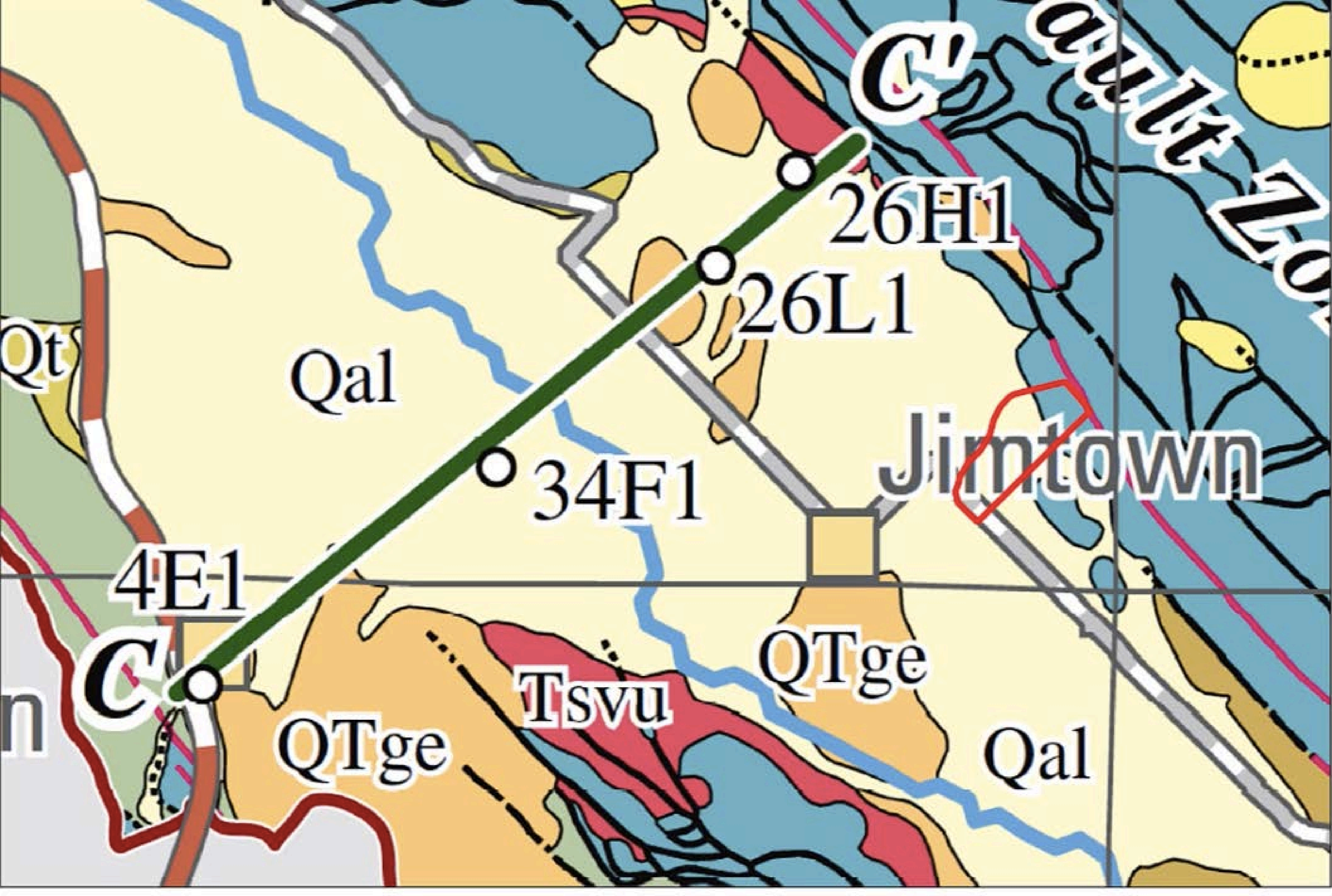
BESST, Inc.

Components of Well Profiling

1. **Review** — Review Geology and Well Logs
2. **Video** — Video Log Well (optional but recommended)
3. **Perform** — Perform Vertical Flow Characterization
4. **Conduct** — Conduct Depth Discrete Sampling
5. **Perform** — Perform Mass Balance Analysis
6. **Modify** — Modify Well, as appropriate, to address problems

Well Site Selection

- Review area geology and nearby well logs
- Alluvial vs. bedrock wells
- Well interference potential
- Potential contamination/water quality issues
- Desired yield
- Water rights
- Vulnerability to natural risks
- Property boundaries and set backs
- Utility interference
- Accessibility for drill rig, power source proximity and other logistical issues
- Safety issues



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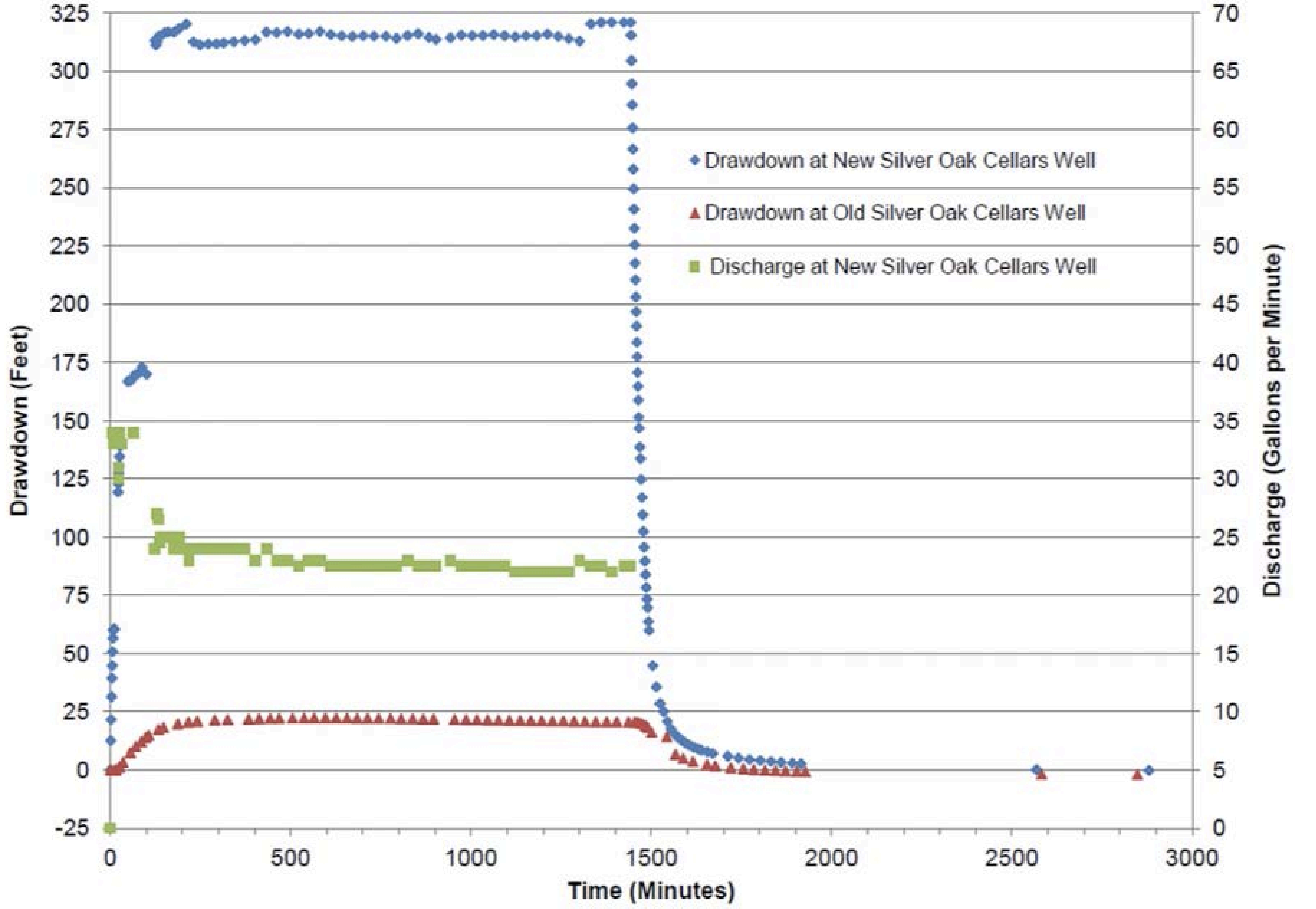
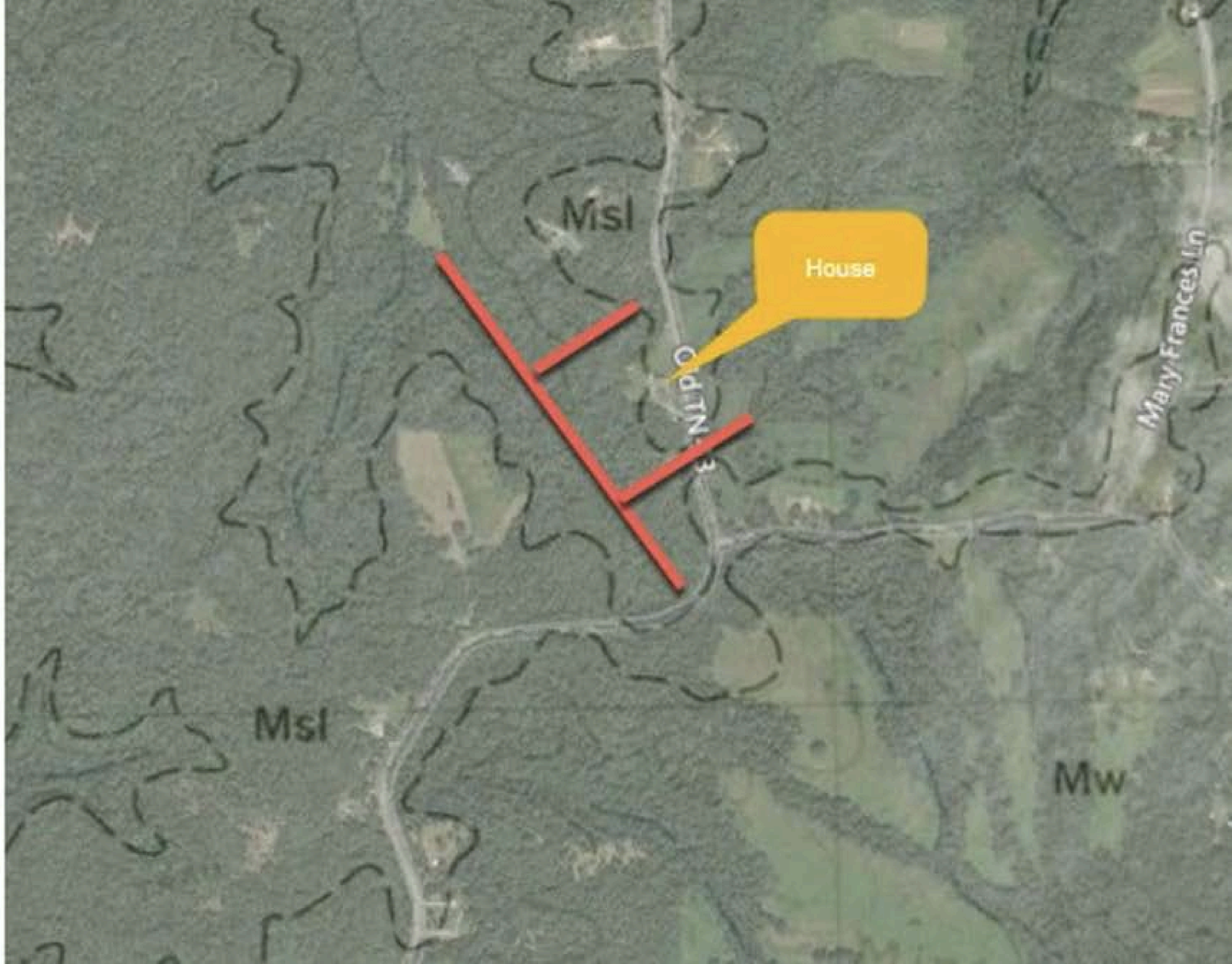

Drawdown at New Silver Oak Cellars Well
Drawdown at Old Silver Oak Cellars Well
Discharge at New Silver Oak Cellars Well
Drawdown (Feet)
Discharge (Gallons per Minute)
Time (Minutes)
325
300
275
250
225
200
175
150
125
100
75
50
25
0
-25
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
500
1000
1500
2000
2500
3000

Lessons Learned

- No well siting study done for locating the well
- Well was ultimately sited near power source
- Bedrock dipping under the site only provided a relatively thin wedge of sediment for water production
- Extended well development failed to produce more than 30 gpm
- Extended pumping test yielded a bit more than 20 gpm
- **Conclusion**: Well location needed to take geology and production potential into account, not just convenience

Karst and Fractured Bedrock

- Residential Property in Middle Tennessee
- Mapped out fracture traces and identified best locations to locate well
- Property owner did not like any of the locations



Residential Well in Middle Tennessee

With the Proper Approach, We Can Deal With All These Well Problems

- Well Construction Issues
- Incomplete Well Development
- Pre-Mature Aging
- Neglect
- Contaminants
- Location