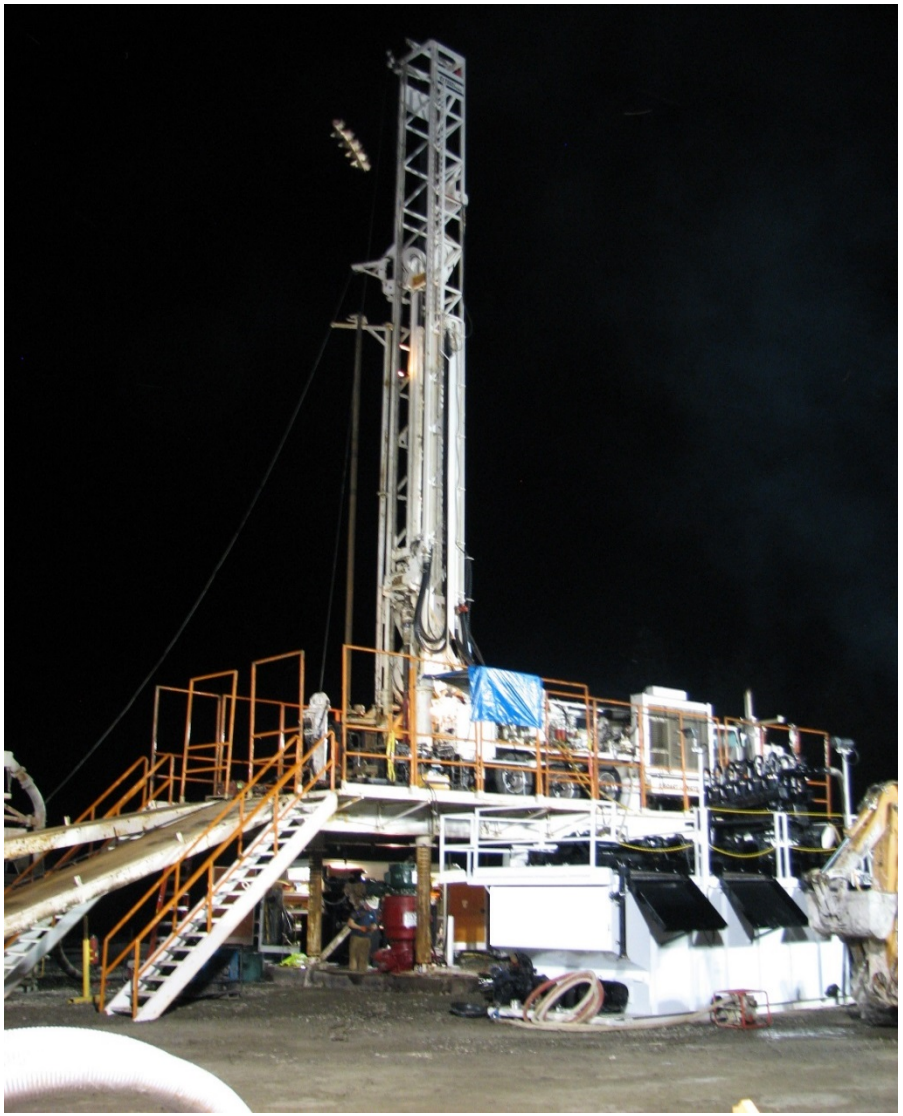
2018 BCGWA Trade Show
Convention and AGM

Planning for and Managing Artesian Well Conditions

Robert Stadeli



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Scope of Todays Discussion

- Planning Phase
- Execution Phase
- Geological Challenges
- Case Studies
- Conclusions

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Planning Phase

- Understanding the Flow and Pressure
- Planning for Adequate Seals
- Drilling Equipment and Tooling
- Site and Logistical Challenges

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Planning Phase

Understanding the Flow and Pressure

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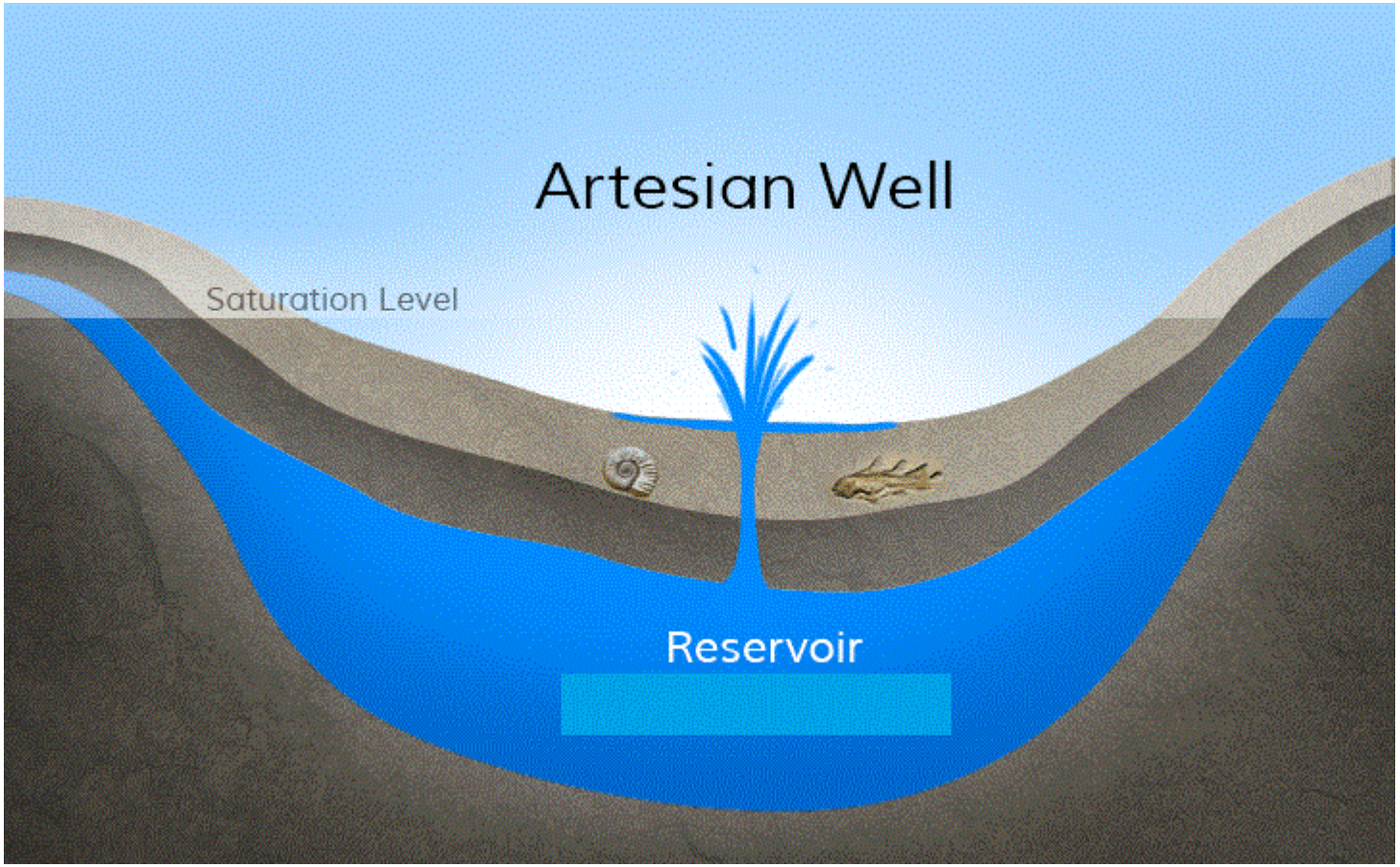
Understanding the Flow and Pressure

- **Where is the potential artesian zone?**



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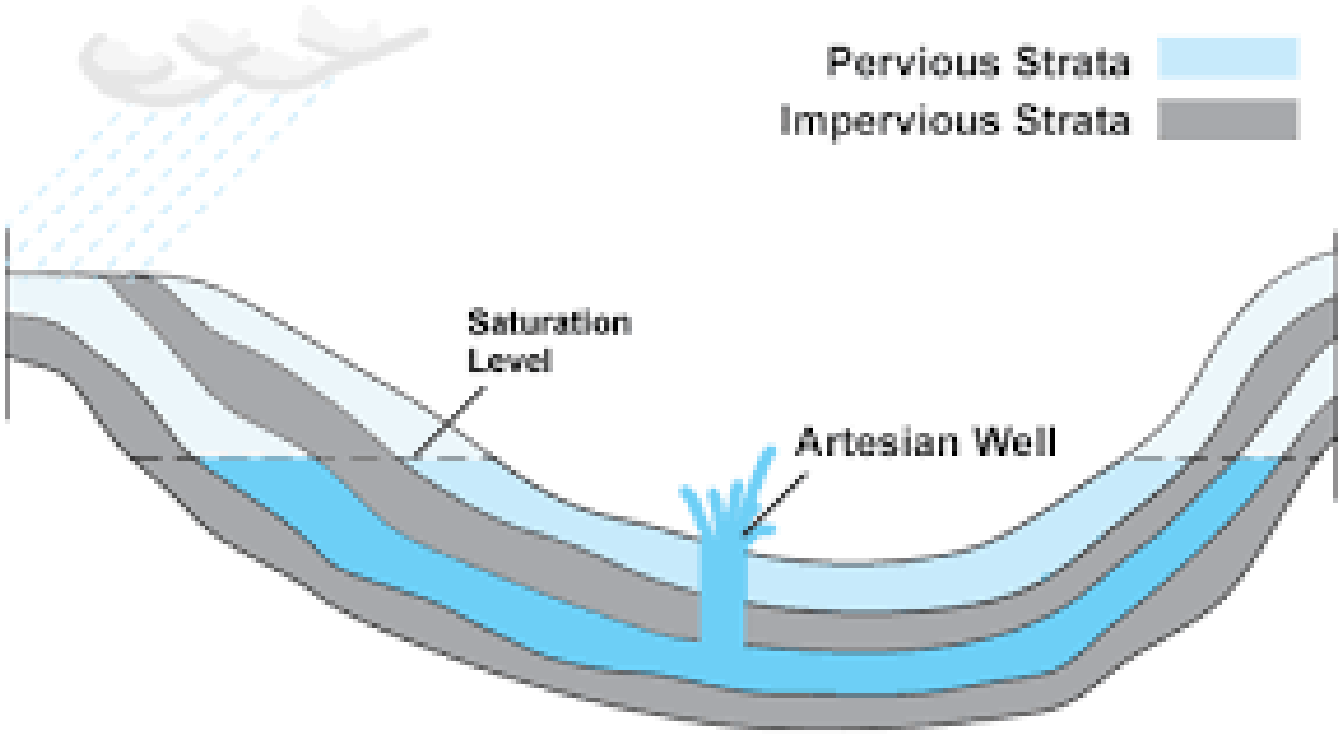
Understanding the Flow and Pressure

What if there are multiple zones



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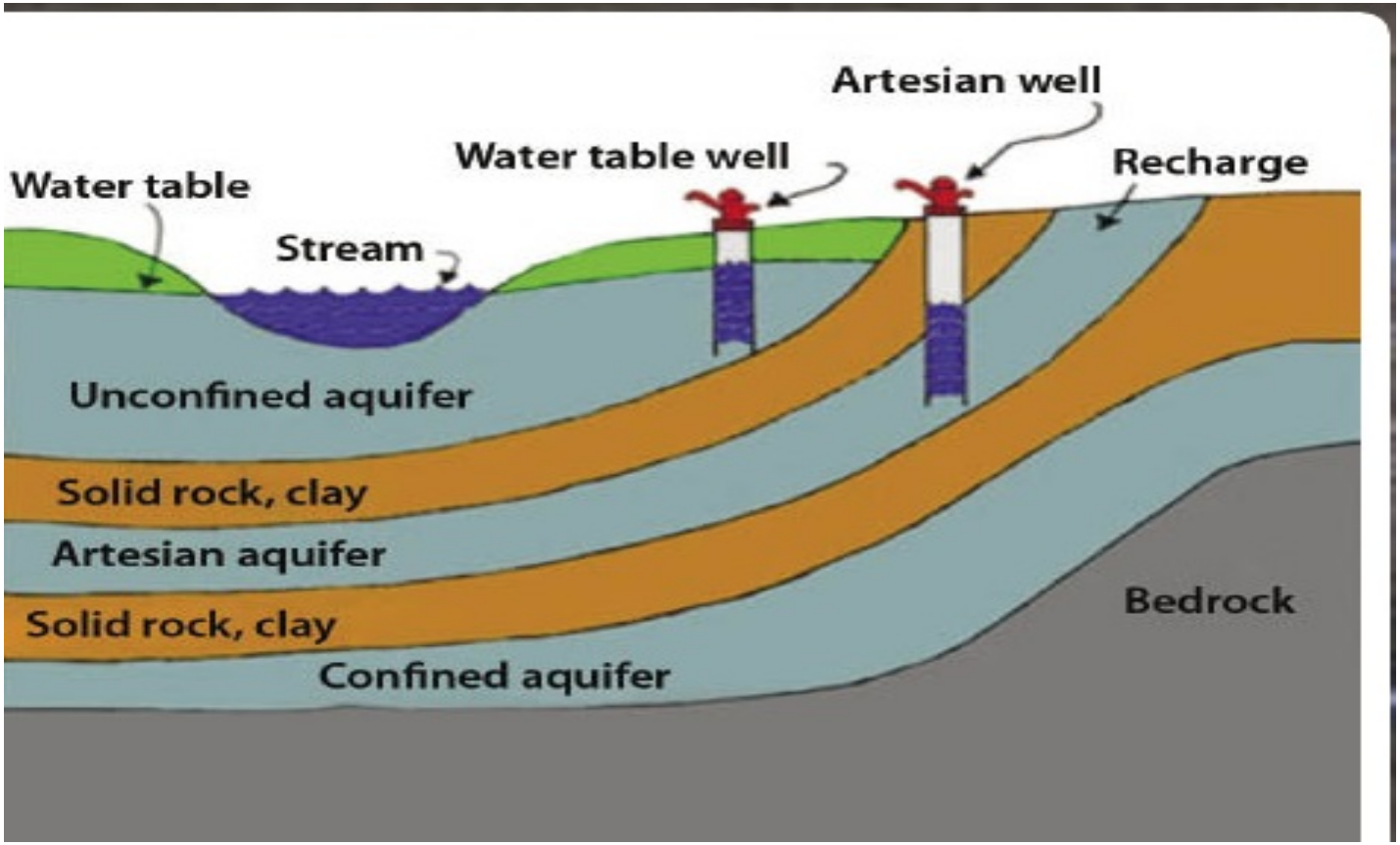
Understanding the Flow and Pressure

Do zones have different heads?



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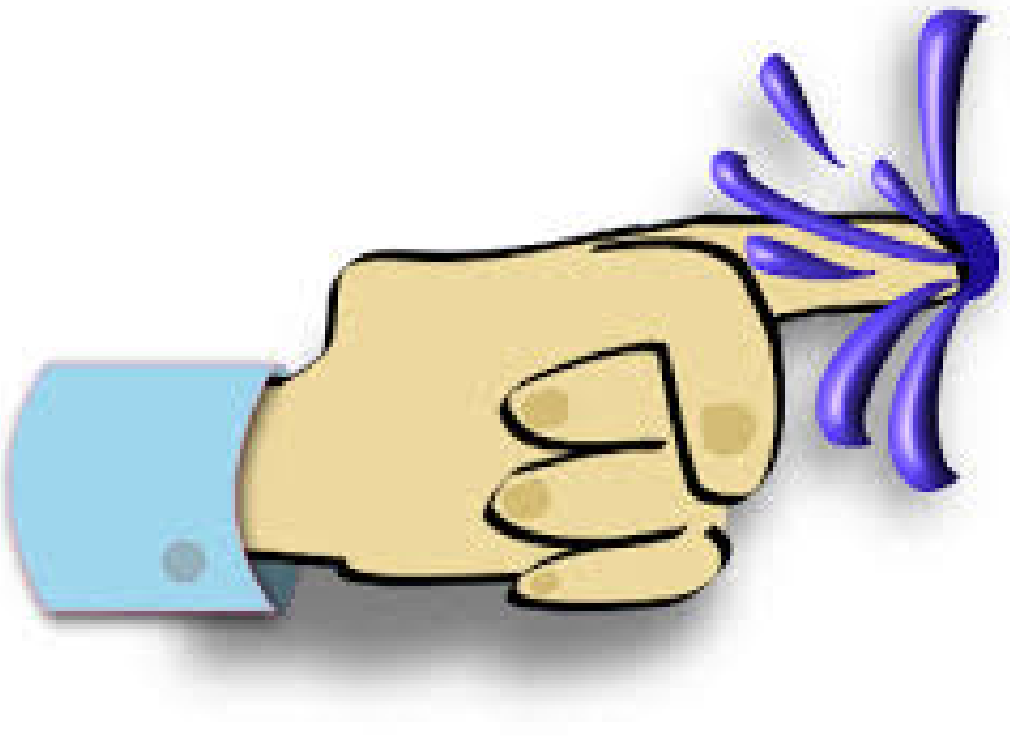
Planning Phase

Planning Adequate Seals



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Planning Adequate Seals

When is a Test Well a Good Idea

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Planning Adequate Seals

- Written Sealing Plan (Regulatory Requirement)
- Alternative Construction Plan
- Emergency Contingency
- How do they all effect cost

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Planning Adequate Seals

Include Enough Cost for Extra Grout and Additives

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Planning Adequate Seals

Reliable Grout Supply is a Must

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Planning Adequate Seals

- Proper grouting equipment in good working condition with backup available onsite
- Positive displacement pumps
- Subcontracted concrete pumpers can be a good option if pumps are in good shape.

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Planning Adequate Seals

- Plan to start large enough for multiple casing points and seals if needed for unexpected conditions
- Seal as close to the top of the artesian zone as possible (Regulator requirements are minimum)
- Communicate the need for this to the client prior to cost estimates or bids so everyone is bidding the same requirement

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Planning Phase

Drilling Equipment and Tooling

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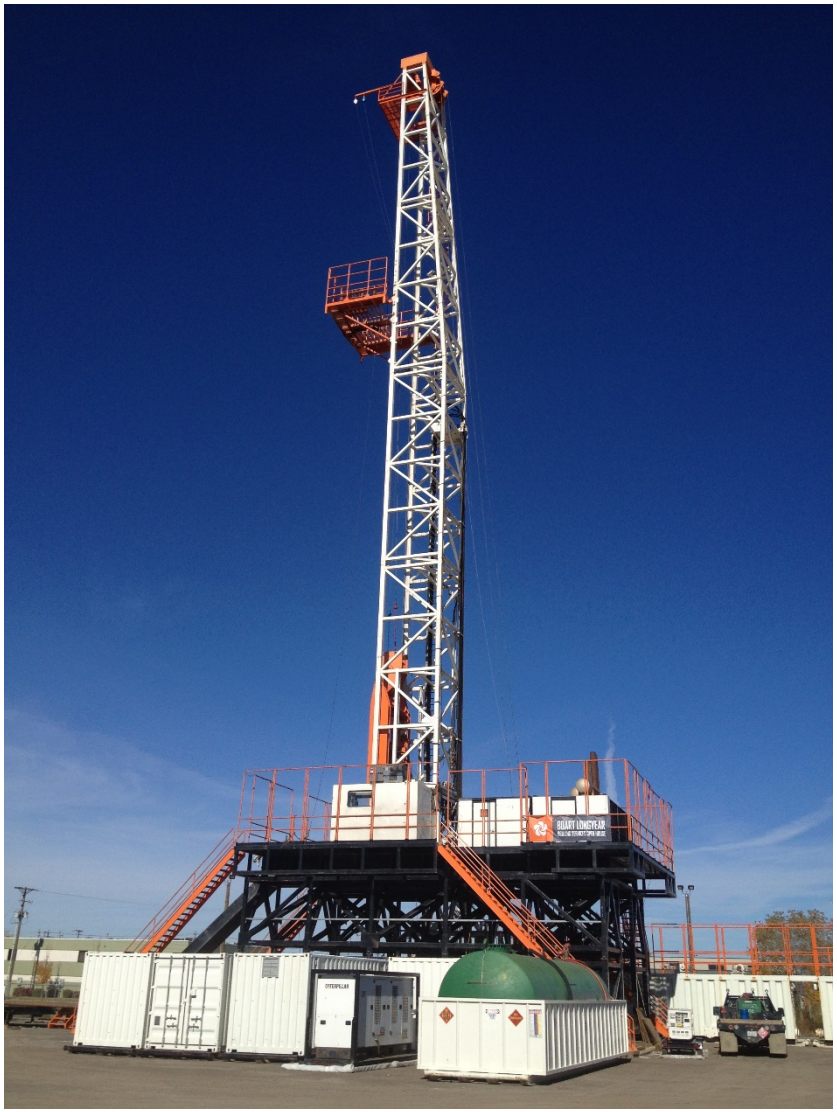
Drilling Equipment and Tooling

Rig Capabilities

- Plan for Increased string weights
- Plan for additional casing and sealing points



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Drilling Equipment and Tooling

Fluid Capabilities

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Drilling Equipment and Tooling

Casing Advance Capabilities

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Drilling Equipment and Tooling

Well Killing Capabilities

- Well Head control Equipment
- Kill fluids
- High pressure/volume pumps

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Drilling Equipment and Tooling

Adequate Tooling Available and Built into Your Cost

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Planning Phase

Site and Logistical Challenges

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Site and Logistical Challenges

Do you have enough space?

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Site and Logistical Challenges

Do you have good access?

- **Consider Cold/Wet Weather Access**

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Site and Logistical Challenges

Do you have adequate discharge location?

- Do you have a good discharge location for disposal of fluids?
- Will wet weather reduce discharge capability?

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Execution Phase

- Controlling the Flow and Pressure
- Proper Installation of Seals
- Use of Kill Fluids
- Development and Testing of Flowing Well

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Controlling the Flow

- Execute what you have already planned to be needed
- The more unknown the more casing and seal points will be required
- Install well control that you can drill through or operate through

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Installation of Proper Grout Seals

- Start with the correct diameter from the start
- Case and seal quickly and continuous if possible
- If artesian flow is present, kill the well before and during the seal placement

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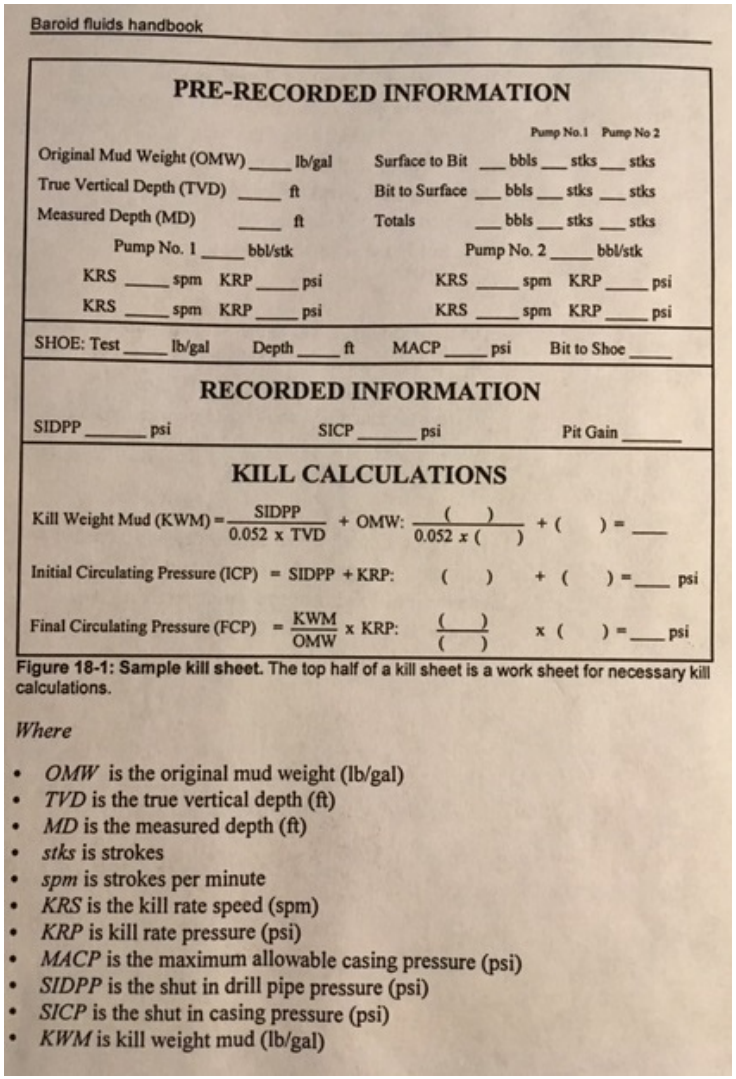
Installation of Proper Grout Seals

Use proper sealing material and additives

- Cement grout
- Avoid bentonite seals that could erode under increased pressure
- Use additives that will reduce shrinkage
- Accelerators cause shrinkage and increase the risk of flashing
- Bentonite up to 5% can be helpful to reduce shrinkage and increase fluidity and pump ability
- Retarders and or water loss additives a must if pumping under high pressure or for extended durations

Use of Kill Fluids

Baroid Red Book Kill Weight Work Sheet



Baroid fluids handbook

PRE-RECORDED INFORMATION

		Pump No.1	Pump No 2
Original Mud Weight (OMW) ____ lb/gal	Surface to Bit	___ bbls	___ stks ___ stks
True Vertical Depth (TVD) ____ ft	Bit to Surface	___ bbls	___ stks ___ stks
Measured Depth (MD) ____ ft	Totals	___ bbls	___ stks ___ stks
Pump No. 1 ____ bbl/stk	Pump No. 2 ____ bbl/stk		
KRS ____ spm KRP ____ psi	KRS ____ spm KRP ____ psi		
KRS ____ spm KRP ____ psi	KRS ____ spm KRP ____ psi		

SHOE: Test ____ lb/gal Depth ____ ft MACP ____ psi Bit to Shoe ____

RECORDED INFORMATION

SIDPP _____ psi SICP _____ psi Pit Gain _____

KILL CALCULATIONS

Kill Weight Mud (KWM) = $\frac{\text{SIDPP}}{0.052 \times \text{TVD}}$ + OMW: $\frac{(\quad)}{0.052 \times (\quad)}$ + ( ) = ____

Initial Circulating Pressure (ICP) = SIDPP + KRP: ( ) + ( ) = ____ psi

Final Circulating Pressure (FCP) = $\frac{\text{KWM}}{\text{OMW}}$ x KRP: $\frac{(\quad)}{(\quad)}$ x ( ) = ____ psi

Figure 18-1: Sample kill sheet. The top half of a kill sheet is a work sheet for necessary kill calculations.

Where

- *OMW* is the original mud weight (lb/gal)
- *TVD* is the true vertical depth (ft)
- *MD* is the measured depth (ft)
- *stks* is strokes
- *spm* is strokes per minute
- *KRS* is the kill rate speed (spm)
- *KRP* is kill rate pressure (psi)
- *MACP* is the maximum allowable casing pressure (psi)
- *SIDPP* is the shut in drill pipe pressure (psi)
- *SICP* is the shut in casing pressure (psi)
- *KWM* is kill weight mud (lb/gal)

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Use of Kill Fluids

Weight-Up Calculation with Barite

$$\text{Lbs. of Barite Required (B)} = \left[\frac{35.05 \times (W_f - W_I)}{35.05 - W_f} \right] \times V_I$$

Where:

B	**=**	**Amount of Barite to Add, lbs.**
V_I	**=**	**Starting Volume of Mud, gallons**
W_f	**=**	**Desired Mud Weight, lb/gal**
W_I	**=**	**Starting Mud Weight, lb/gal**

Rule of Thumb:
For Weighted Drilling Fluids up to 12 lbs./gal using Barite.
For every 140 pounds of Barite added to 100 gallons (U.S.) the weight will rise 1 lb/gal
Prior to weighting up fluid the Funnel Viscosity must be raised with
AQUA-GEL® or QUIK-GEL® to four times the final mud weight

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Well Development and Testing of Flowing Well

Specialized Well Development

- Even flowing wells require proper well development
- How to operate if well must be shut in

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Geological Challenges

- Expect The Unexpected!
- Local knowledge is king but can also be a curse
- Be ready to adapt designs and plans
  - The subsurface is never an exact science

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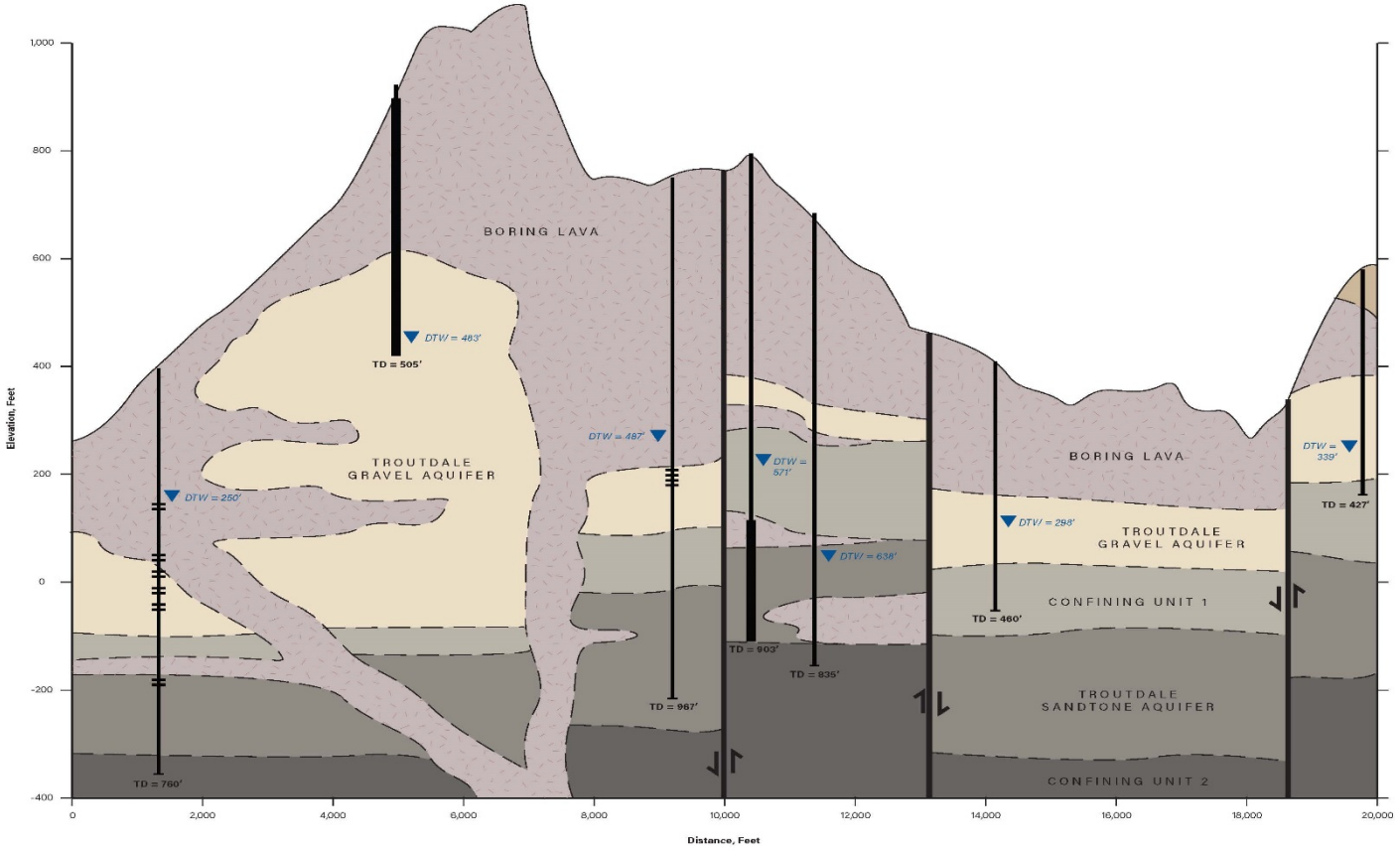
Geological Challenges

Expect The Unexpected!



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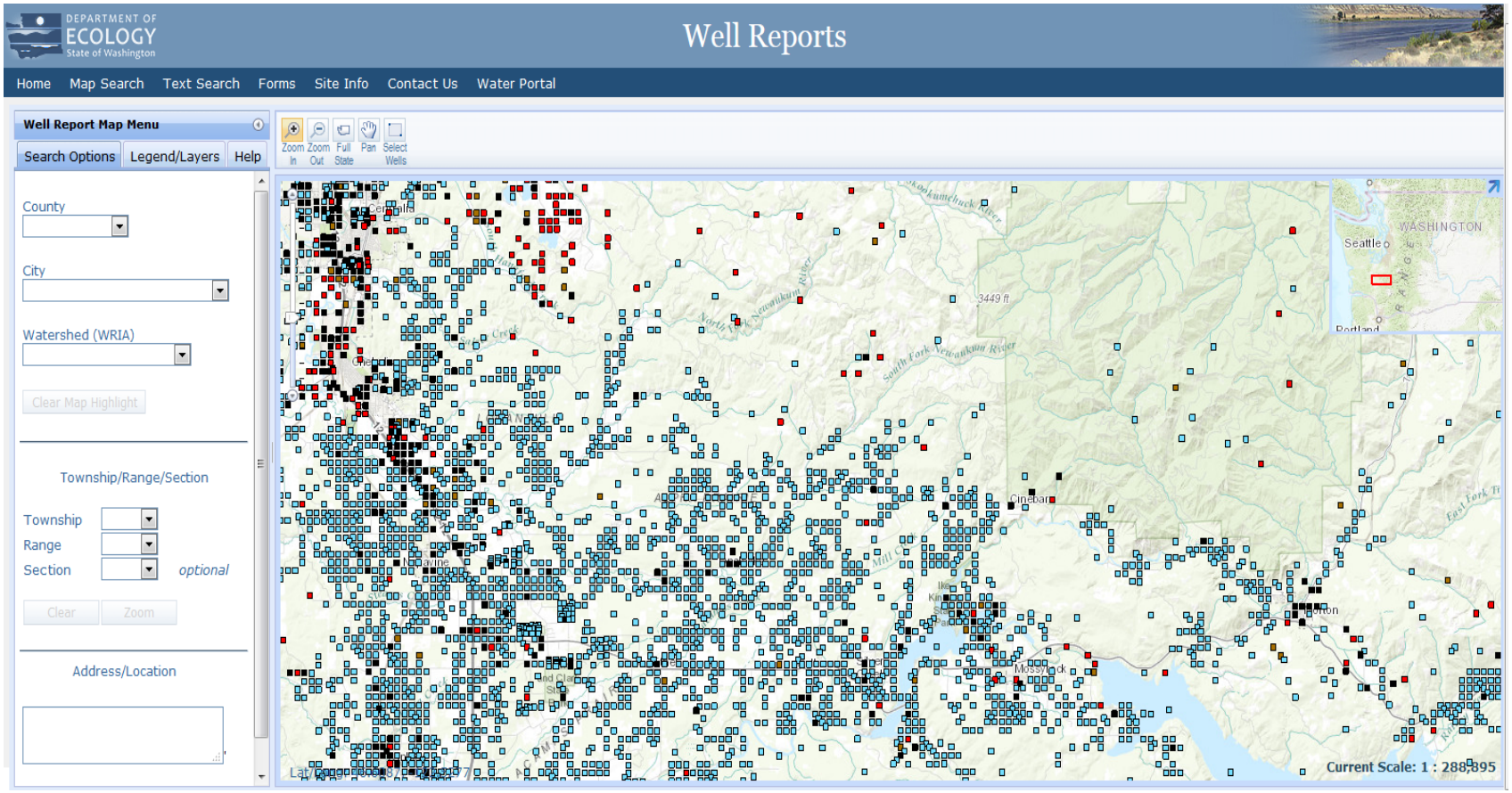
Geological Challenges

Local Knowledge is Key but Can Also Be a Curse



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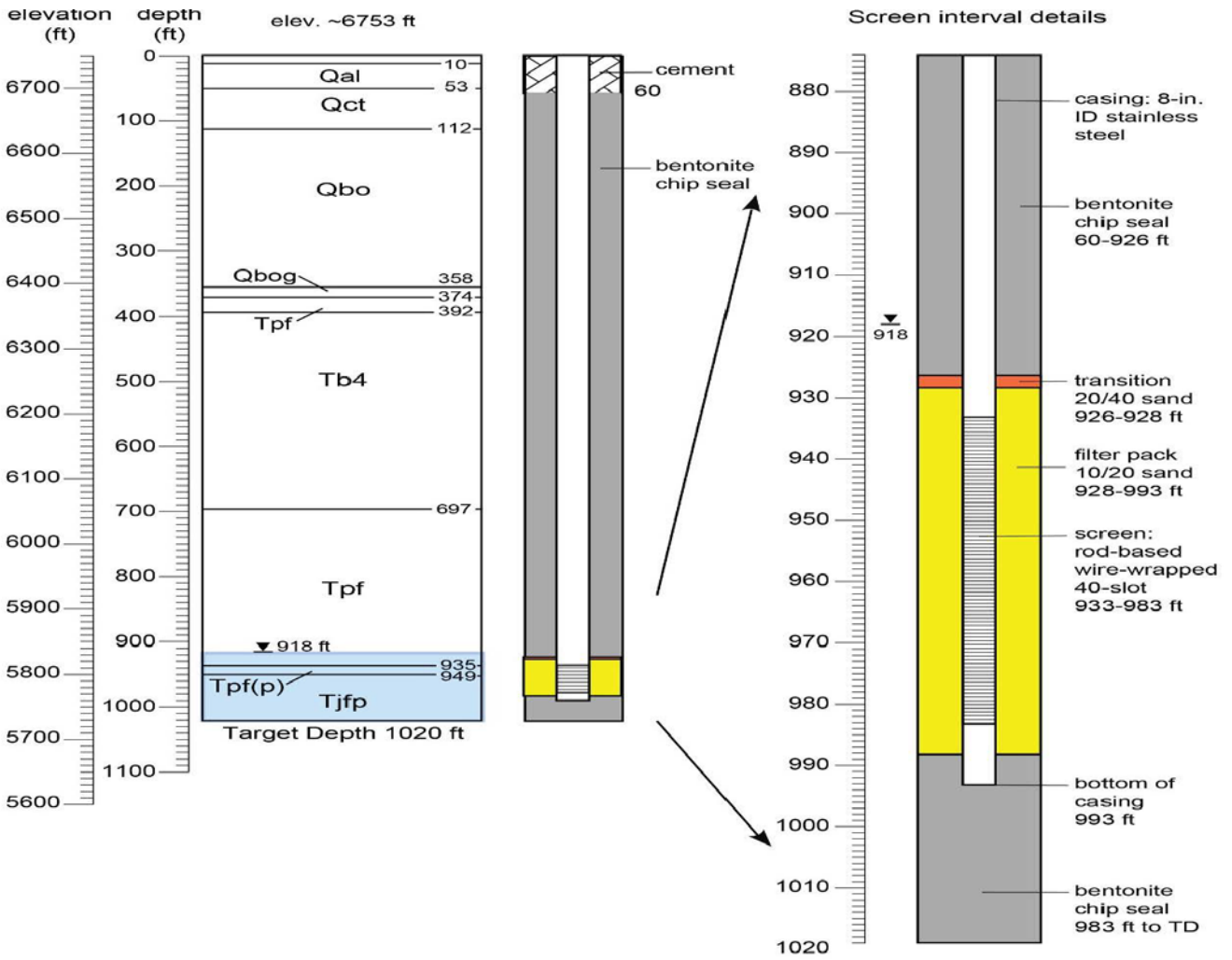
Geological Challenges

Existing Wells May Not Tell the Complete Story



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Geological Challenges

Be Ready to Adapt Designs and Plans

- The subsurface is never an exact science

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Case Studies
Uncontrolled Flows and Impacts

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Mosier Oregon

- Wells primarily in confined basalt aquifers
- Primary water supply aquifer is Priest Rapids for domestic, muni and ag users (cherries, grapes) – flowing artesian in lower part of watershed.
- Upper aquifer (Pomona) generally doesn't flow
- Water level declines of over 150 feet (50 meters) in Priest Rapids in past 40 years
- Commingling from lower to upper (Pomona) aquifers identified as the primary contributor of declines – of 71 wells located in highest priority area (lower portion of basin), 45 identified as potentially commingling now or in past

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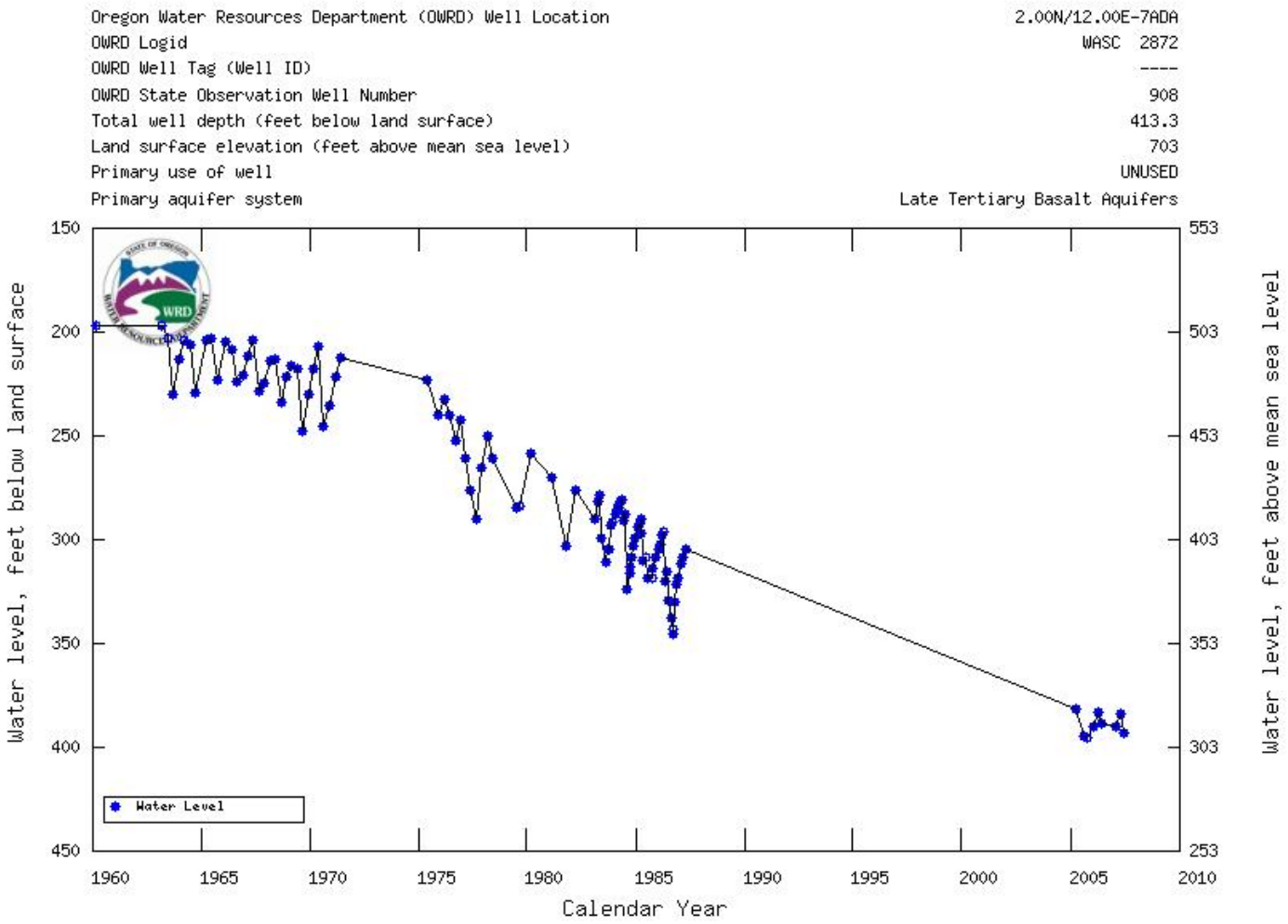
Mosier Oregon



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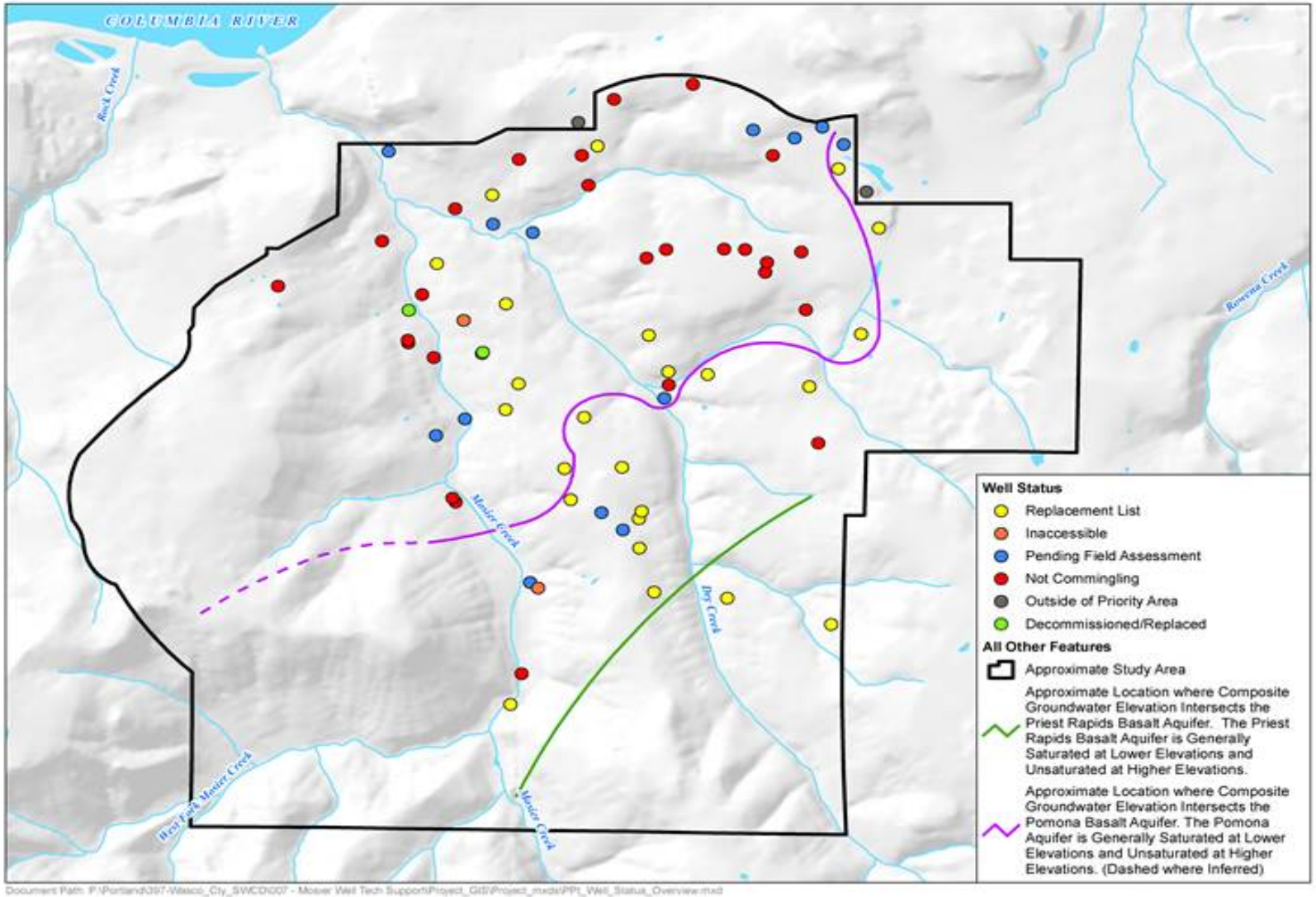
Mosier Oregon



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Mosier Well 3 Case Study

- Drilled in 1971 and deepened in 1974. Initial shut-in pressure – 80 PSI
- Washed out grout seal – uphole flow 24/7 from lower (Priest Rapids) around lower part of casing to Pomona – tremied in grout in annulus – likely washed out immediately
- Repaired with packer set in open basalt borehole a couple of times – failed each time (evidenced by drop in shut-in pressure).

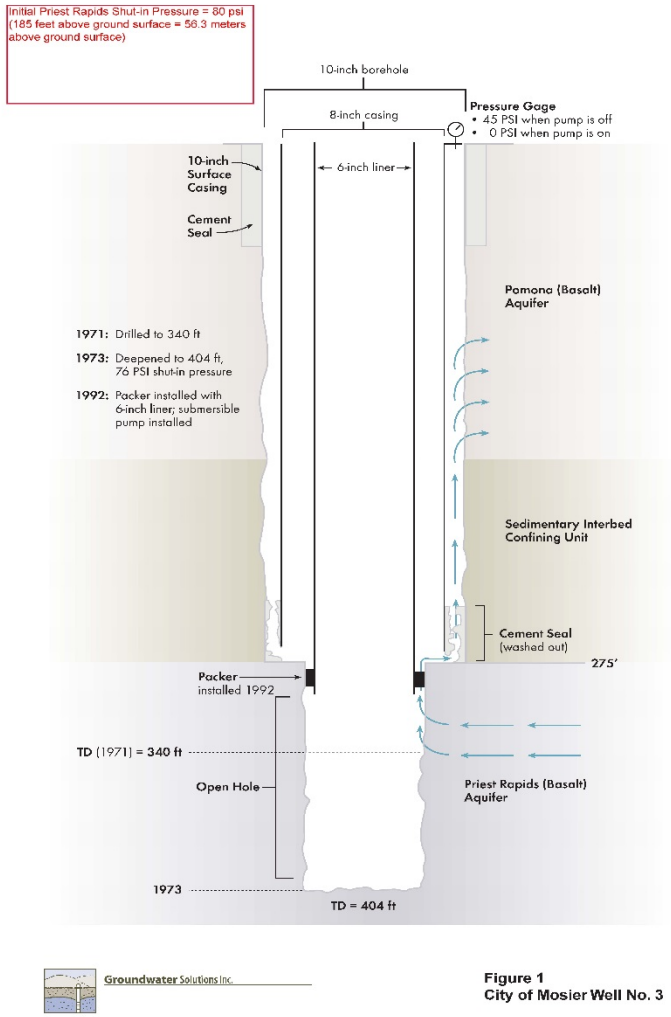

Figure 1
City of Mosier Well No. 3

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Mosier Well 3 Case Study

- 2006 – completed repair with packer and riser pipe. Repair appeared to work.
- Some indication that might be failing later, so well was decommissioned.
- Well decommissioned by killing first with weighted mud and LCM to shut off artesian flow. Once pressure maintained for period of several days, grouted up lower borehole, perforated casing and grouted upper borehole.

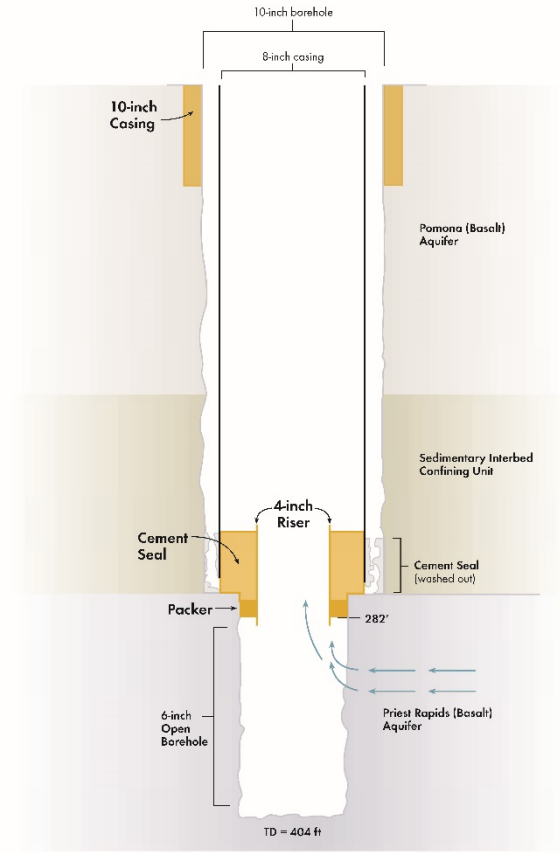

Figure 1
City of Mosier Well No. 3
Repair

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Mosier Replacement Well

- 2017 drilled deeper well to replace shallower irrigation well
- Encountered thick, very productive zone at bottom of Frenchmen Springs – drilled into sedimentary interbed (vantage) – no head change.
- Decision made to drill through vantage to set casing on next basalt flow – tagged next flow, no apparent head change.
- Advanced hole a few feet further and hit high-pressure, productive zone.
- Uphole flow across interbed and into high production zone above, took 3 months to control, with engineered fluids, etc.

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Slippery Rock Ranch Santa Barbara CA
Initial Findings

- Local driller drilled irrigation well, cased and perforated first zone, drilled deeper to 800 feet and encountered high pressure zone.
- installed smaller casing and attempted to grout up but cement flashed and grout job failed with grout pipe stuck inside casing.
- Resulted in maintaining connection of upper low pressure zone with lower high pressure zone, including a surface spring that has increased in flow by 3-4 times. Combined water level in the well was approximately 150 feet BGS after failed grout job
- Local regulators forced owner to repair well to seal escaping resource

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Slippery Rock Ranch Santa Barbara CA Repair

- Well was repaired by wash-over drilling production casing with failed grout job and removing.
- Well was then reamed and new larger production casing set with new grout seal. Isolating upper low pressure zone from lower high pressure zone
- Well was then deepened to re-encounter lower high pressure flow zone and completed flowing at the surface 350 GPM with 90 PSI shut in pressure and surface spring back to original flow

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Other Artesian Success Stories

- **Bull Run Water Shed City of Portland OR**
  - 6-inch test well flowing 2,000 GPM with 75-80 PSI shut-in
  - 16-inch test production well flowing 2,000 GPM with 75-80 PSI shut-in

- **Deschutes Valley Water District Culver OR**
  - 12/10-inch well flowing at 3,500 GPM with 50 PSI shut in
  - 2- 16-inch production wells flowing at 6,000 GPM with 50 PSI shut in

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Conclusions

- **Avoid Resource Disaster With Proper Planning and Approach Up Front.**
- **Artesian Issues are Only As Complicated as We Make/Plan Them.**

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Conclusions

- Plan, Plan, Plan with Contingency & Flexibility
- Price it Appropriately, be Comfortable and Confident
- Go With The Flow

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Thank You

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