Eagle Ford – Groundwater Protection and Enhance Recovery*

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The opinions expressed within the following are the authors and do not intended to reflect the policies or rules of the RRC.

Abstract

I. Groundwater Protection

Introduction

Since the 1930's the RRC has maintained an active program of groundwater protection in its regulated O&G operations. Historically, Texas has regarded protected groundwater as what is known as "useable-quality groundwater" (UQG). No regulatory or statutory definition of UQG exists, but RRC guidance is roughly 3,000 ppm total dissolved solids (TDS) and less. If groundwater of greater salinity is being used for agricultural and domestic purposes, the RRC will protect it as UQG.

In its early effort to protect UQG, the RRC sought unofficial advice on the occurrence of protected groundwater from the US Geological Survey and the old Texas Board of Water Engineers, predecessor to the Texas Commission of Environmental Quality (TCEQ). Since 1955, per RRC rules, the RRC has sought official groundwater protection advice from the TCEQ and its predecessors. On September 2012, the Legislature moved the TCEQ advisory geologists to the RRC and the group is known as the Groundwater Advisory Unit (GAU) under the RRC O&G Division.

Through the history of the RRC's groundwater protection program, three differing qualities of groundwater have developed: drinking-water quality (often referred to as "fresh or superior" quality groundwater), which is 1000 ppm TDS or less; the previously discussed UQG, which is 3000 ppm TDS or less; and lastly, underground sources of drinking water (USDW), which is defined by the US Environmental Protection Agency (EPA) as 10,000 ppm TDS – an outcome of the Federal Drinking Water Act.

Eagle Ford Groundwater Protection Criteria

The Eagle Ford play presents special considerations in groundwater protection. The principal aquifer of concern is the Carrizo and can be protected groundwater to 6,000-7,000 feet. Although many O&G and water wells have Carrizo water analyses available, this information is not abundant enough to make the necessary groundwater protection recommendations. Open-hole electric logs are the most common source of control for recommendations.

Given reasonable logging runs and an optimum 30% porosity, a rule-of-thumb guidance from open-hole deep induction curves follows: 1,000 ppm TDS (fresh/superior) - 20 ohms and greater; 3,000 ppm TDS (UQG) – 10 ohms and greater; 10,000 ppm TDS (USDW) – 4 ohms and greater. Water quality calculations should be from the spontaneous potential (SP), if high resistivity occurs from high bicarbonate dissolution in formation water, and/or aquifer sands having high carbonate cementation or detrital carbonate.

Eagle Ford Surface Casing Exceptions

For operational reasons, setting several thousand feet of surface casing and expecting adequate cementing returns to surface may not be feasible. In making a request to the district RRC office for an exception to the surface casing rule, the RRC may not wish to grant an exception for shallower casing (less than the base of the UQG), if the primary surface casing does not cover the Carrizo.

Equally problematic might be an exception requesting a surface casing setting of 200 feet or more below the base of UQG. An example might be where the Lower Wilcox is not UQG and the request is to set surface casing at the top of the Midway. This may make operational sense, but the RRC may not allow further drilling exposure to the Carrizo without surface casing protection.

Eagle Ford Waste Water (Produced or Flow-Back Water) Disposal Zones

Acceptable disposal zones present a challenge in the Eagle Ford play. In up dip counties, such as Wilson, Atascosa, Frio, Dimmit, and Zavala, the entire Wilcox section is protected from disposal. The Olmos is the principal disposal zone, but may present conflicts where the Olmos is productive of oil or gas. Down dip of these counties, the Olmos has little or no disposal-sand quality.

Down dip of these counties, disposal becomes more complicated in meeting the two geologic requirements for disposal: 1) No disposal is allowed into or above a USDW, and; 2) Geologic isolation from the UQG is required. That is to say 250 feet of net shale is needed and, included within that, a contiguous 100 feet of gross shale interval, which is unbroken by sand.

The Lower Wilcox sands can be fairly massive and optimum disposal zones, but meeting the disposal criteria is often difficult. Once the Lower Wilcox is no longer a USDW it may not have adequate geologic isolation from the UQG. Consequently, a large area, especially across LaSalle and McMullen Counties has no acceptable disposal zones, except the Edwards, which is very deep and a wildcat objective. The Austin Chalk is precluded from disposal, as it appears to have no geologic isolation from the Eagle Ford.

Eventually down dip and off the Cretaceous shelf edge, the Carrizo is no longer protected groundwater and is available for disposal. As the Cretaceous shelf narrows in Live Oak, DeWitt, Karnes, and Gonzales Counties, the Carrizo becomes a disposal objective within the down dip Eagle Ford play. In LaSalle and McMullen Counties, the shelf is broadened and the gas phase widens. Once the Carrizo is available for disposal, it is too far removed from the active liquid-phase of the Eagle Ford play to be an economic objective for disposal.

Eagle Ford Fracture-Water Supply Wells

The Eagle Ford has the advantage of abundant fracture-water sources. Middle to Lower Eocene sands (including the Yegua, Sparta, Queen City, Carrizo-Wilcox, and Lower Wilcox) offer varying water quality and yield. In DeWitt County limited water sources are from the Upper Eocene Jackson sands, because the Middle and Lower Eocene sands can be quite deep.

The Carrizo is the preferred aquifer for drinking water and agricultural use. With alternate Eocene sand sources of upwards of 1500-2,000 feet of section present throughout most of the Eagle Ford play, the Carrizo does not need to be stressed for fracture-water supply. Much of the Eocene section apart from the Carrizo can range from 1,000-3,000 ppm TDS. A standard RRC groundwater protection recommendation isolates these lesser water-quality sand sections from the Carrizo. These sources may require some treatment for fracturing. Nonetheless, these alternate source-water sands should be considered, where feasible, over the Carrizo.

Most groundwater conservation districts require permitting of these water supple wells for purposes of monitoring groundwater use. Although not required, dual permitting these water supply wells with the RRC assures a groundwater protection recommendation and best practices construction, operation, and plugging of the wells. This practice would reduce O&G operator-liability, especially where the well penetrates the base of UQG.

Earthquakes and Disposal Operations

Even faults that have been inactive for long periods of geologic time can retain some locked strain. High volume disposal directly into a fault plane can decouple locked strain and cause a small “dish-rattler” quake. The decoupled locked-strain is only associated with the small area of injection. Injection into an active fault zone may present a more complex and little understood problem. If the earthquake focus is not located within the injection zone, proving the injection is a causal factor remains highly speculative. The earthquake focus must be at the injection zone to be associated with disposal operations. Lastly, hydraulic fracturing into a fault zone does not have the composite energy to decouple locked strain.

II. Problems Affecting Groundwater Protection and Enhanced Recovery

Introduction

Whereas the hydraulic fracturing process itself is no threat to protected groundwater, shortcutting-drilling operations across shallow sections poses a threat to protected groundwater. Certainly, operators would be extremely pleased if hydraulic fracturing was half as effective as the claims of those opposed to the process. Unfortunately, the downside of the hydraulic fracturing process is its inherent limitations, which leave a large percentage of in-place oil unrecovered.

Drilling Operations and Mud Systems

The harsh reality of thin economics of source rock exploitation has led to cost-cutting drilling operations, which compromise protected groundwater. To reduce drilling time and costs, many operators are jetting through the protected groundwater section. At best, a gel mud system may be used in the deeper protected groundwater section. Huge water loss and drilling fluid invasion into porous sands occur. Moreover, no mud cake develops, which means there is no isolation between the well bore and the protected groundwater sands.

Consequently, even when cement is circulated to surface, groundwater may not be adequately protected. A good, bentonite mud-cake assures isolation of protected groundwater from drilling fluids and from comingling with lesser quality groundwater. In addition, good mud cake prevents annular gas migration, which can move into protected groundwater. Without a good mud cake, a cement job is inadequate in protecting groundwater. Oil-based mud systems may speed mud-motor drilling and yield a slick, even-gauged hole; however, over time without bentonite, it is a poor seal for fluid migration behind cemented pipe.

Drilling Hazards

Within the Eagle Ford Play, the Wilcox is the principal groundwater section and it does present some drilling challenges. First, the Carrizo Aquifer of the Upper Wilcox can be extremely underbalanced due to high drawdown by the agricultural industry. These partially depleted sands create drilling, pipe-setting, and cementing problems. Lost circulation, stuck pipe, and failed cement jobs are common, especially in the Eagle Ford up-dip counties, where the Carrizo is shallowest and greatly stressed by agriculture.

Thin, Middle Wilcox sands are known for small, random stratigraphic traps. The gas traps do occur within the protected groundwater section. Without a good mud system, the sands can easily be swabbed-in by collars and stabilizers upon tripping the hole or with an open-hole logging tool. Blowouts to surface and underground blowouts are known to happen, contaminating and gas charging protected groundwater sands.

Gas-charged shallow sands from old surface and underground blowouts can be a particularly bad drilling and cementing hazards. Old underground blowouts may have been controlled and not reported, leaving an unknown drilling hazard. Recently, one such hazard in northern Live Oak County requires 12-15 pound mud to control at a depth of 1,000 feet and less.

Enhanced Recovery

From discussions with operators, the nano-fracture sets from adjoining laterals do not communicate. Mega-fractures communicate between laterals, but not the nano-fracture sets. This problem seems reminiscent of a common reservoir stimulation nemesis - migration-of-fines. In my view, when wedging open the nano-fractures a fines migration front is created. The front is pushed by the fracturing fluids and eventually occludes the developing fracture, both halting the fracturing process and forming a permeability barrier. The front is likely debris consisting of nano-particles rock, clay, and even the organic carbon itself. More research needs to be done to understand what is really happening at the fracture front. Probably, coring the fracture front is the best way to see what is happening.

Nonetheless, this is very disappointing for enhanced recovery. The reservoir energy is the free gas. If an internal lateral cannot be used to restore and maintain reservoir energy by produced-gas injection, only a small percentage of in-place oil can be produced. This problem with enhance recovery puts a cloud over recovery economics and questions how companies are calculating recoverable reserves.

Another observation by several operators is the disappearance of freshwater used in fracturing fluids. Some water losses are up to 100%. Two advantages are reduced disposal/recycling costs and observed increases in production when water is allowed to be “soaked-up” by the formation. The question quickly becomes, “What happened to the water?” If clays are taking the water, obstructed fractures and limited production would be expected. Apparently, this is not the case. The only other explanation would be that the freshwater is replacing adsorbed gas, which becomes free gas and adds to reservoir energy. Again, this is another area of needed research.

Many companies are not using freshwater in fracturing fluids. Instead, they are using brackish or moderately saline water. The reasons for not using freshwater vary, but the result is to limit the stress on the principal Eagle Ford fracture-water source, the Carrizo. Some companies have tried both fresh and saline fracture-water with mixed results. If freshwater becomes preferred in fracturing fluid, then the Carrizo will bear the added usage stress.

Inexperienced Staff

The learning curve is slowly improving. As I have pointed out in my previous discussion, the hardest thing for operators and their staff is “reinventing-the-wheel” in drilling onshore through several thousand feet of unconsolidated, protected groundwater section. The thinking is that if the operations meet the rules, then all is great. Although Texas has the most comprehensive rules for O&G operations does not mean that doing the minimum, per the rules, works best for groundwater protection. Operators are ethically bound to follow prudent operations and best practices, which always exceed the rules of regulation.

The biggest mistake the industry has made in groundwater protection is having lost the ability to drill through protect groundwater with old-fashioned, bentonite mud systems. Designer gel-mud systems, used offshore, are not suitable in protecting groundwater. Oil-based mud systems and mud motors have spoiled drilling staff expertise.

My concern is that many wells drilled without proper mud systems will come to haunt the regulatory agencies and the industry with behind-pipe groundwater contamination. Studies have already shown increased natural gas in groundwater in highly drilled areas of the Marcellus. The hydraulic fracturing process is not the cause. Poor drilling procedures are most likely responsible by increasing pathways for shallow, naturally occurring background-gas to migrate into protected groundwater.

Lastly, the open-hole electric logs tell the story of mud systems and groundwater protection. It is a very simple interpretation. When all induction curves are tracking, regardless of known sand water-quality, the mud system is not protecting groundwater even with an acceptable cement bond log. If the mud filtrate is reading the same as the deep induction, there is a definite problem in isolating sands from mud filtrate invasion and fluid migration behind cemented pipe. Cemented pipe alone does not protect groundwater. A good mud system in conjunction with a good cement job is the best groundwater protection.

Earthquakes and Disposal Operations

Even faults that have been inactive for long periods of geologic time can retain some locked strain. High volume disposal directly into a fault plane can decouple locked strain and cause a small "dish-rattler" quake. The decoupled locked-strain is only associated with the small area of injection. Injection into an active fault zone may present a more complex and little understood problem. If the earthquake focus is not located within the injection zone, proving the injection is a causal factor remains highly speculative. The earthquake focus must be at the injection zone to be associated with disposal operations. Lastly, hydraulic fracturing into a fault zone does not have the composite energy to decouple locked strain.

III. Conclusions

1. The RRC has in place an official GAU, which prepares specific groundwater protection recommendations for regulated O&G operations.

2. The RRC GAU has established criteria for determining protected groundwater and for geologic isolation in disposal operations.

3. In the Eagle Ford play area, fracture source-water is available in thick sand sections apart from the Carrizo.

4. Dual-permitting fracture water supply wells through the local groundwater conservations districts and the RRC may be advisable to assure prudent operations and groundwater protection.

5. More research is needed to understand what really happens at the nano-fracture level of hydraulic fracturing, especially regarding fracture-front permeability barriers and disappearing fracturing water.

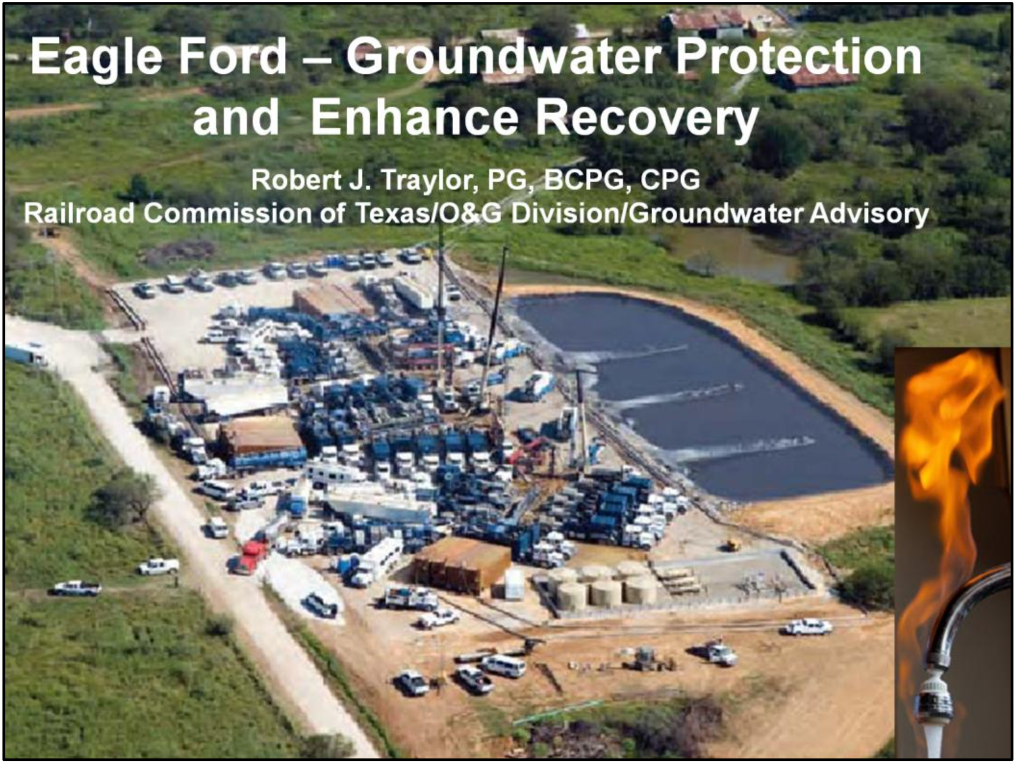
6. Without a viable enhanced recovery program, liquid-phase source rocks have extremely disappointing recoverable reserves.

7. Hydraulic fracturing does not threaten protected groundwater; however, a lack of prudent operations and best practices when drilling through protected groundwater sections present a real threat.

8. Hydraulic fracturing does not cause earthquakes; however, high volume disposal operations into a fault zone can cause small "dish-rattler" earthquakes.

Eagle Ford – Groundwater Protection and Enhance Recovery

Robert J. Traylor, PG, BCPG, CPG
Railroad Commission of Texas/O&G Division/Groundwater Advisory



Summary of Eagle Ford Problems

1. Tight Economics and Over-Leasing – Counterproductive Shortcuts
   A. Inexperienced Staff
   B. Jetting the Shallow Section (Protected Groundwater)
   C. Poor to Non-Existent Mud Cake Across Protected Groundwater
   D. Poor Cementing Across Protected Groundwater

2. Incomplete Cementing of Intermediate String – Annular Gas Migration Into Protected Groundwater

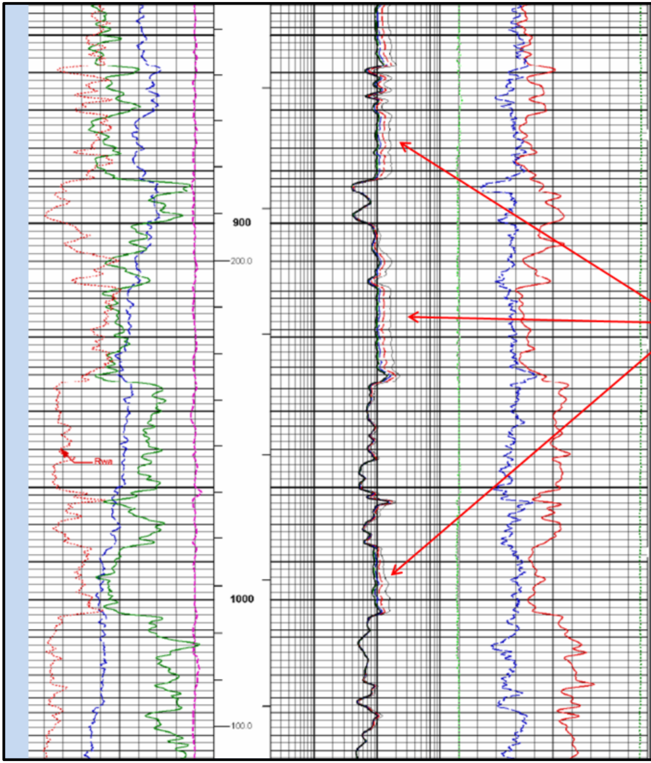
3. Drilling Hazards
   A. Under-Balanced Carrizo Aquifer Due to High Ag Use
   B. Old Blowouts and Over-Pressured Shallow Sands
   C. Middle Wilcox Strat-Trap Blowouts

4. Sequence Stratigraphy and Over-Steering the Lateral

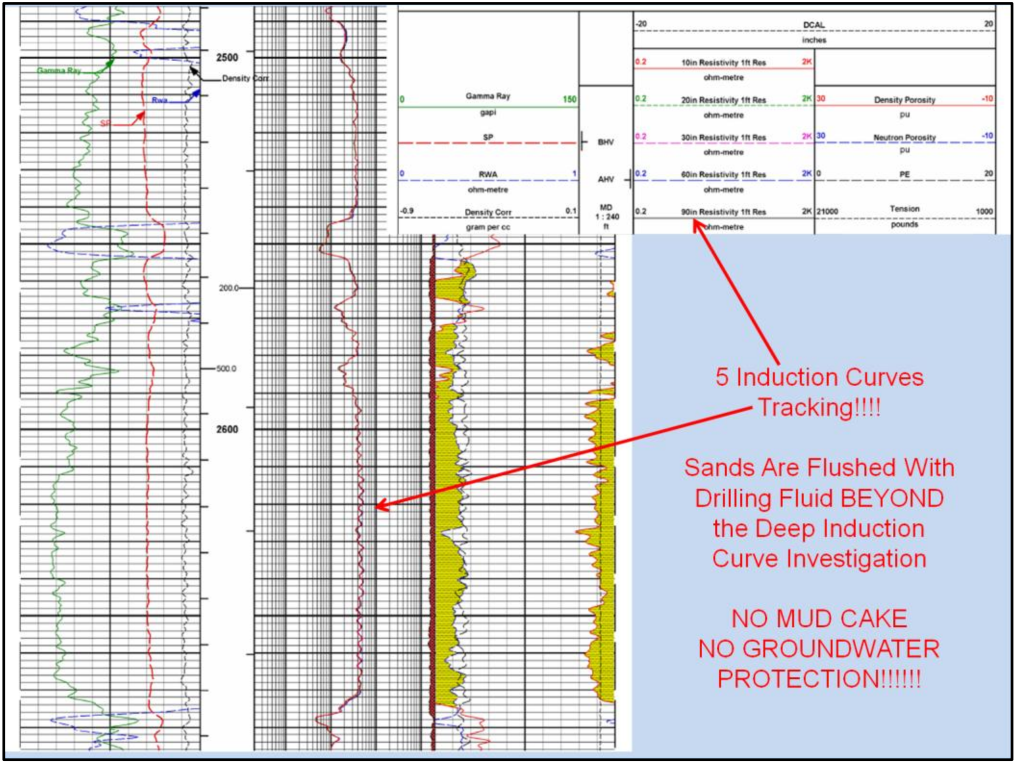
5. Enhanced Recovery
   A. Migration of Fines - No Offsetting Nano-Fracture Communication
   B. Frack-Water Loss Replacing Adsorbed Gas

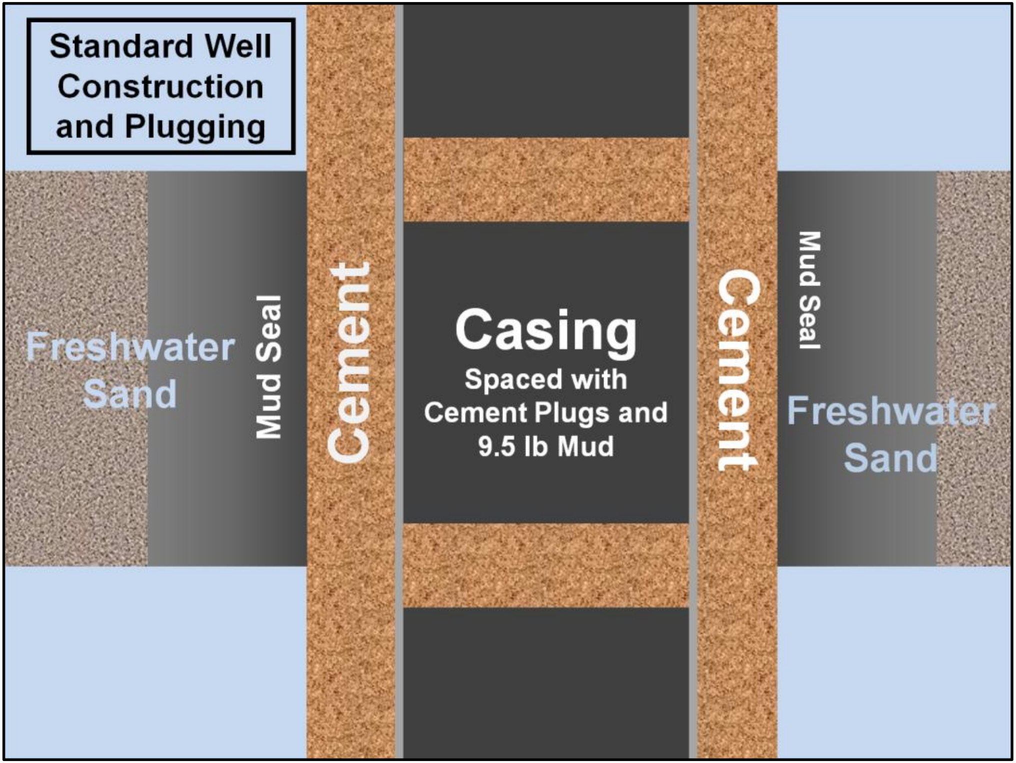
6. Permit Frack-Water Supply Wells with the RRC

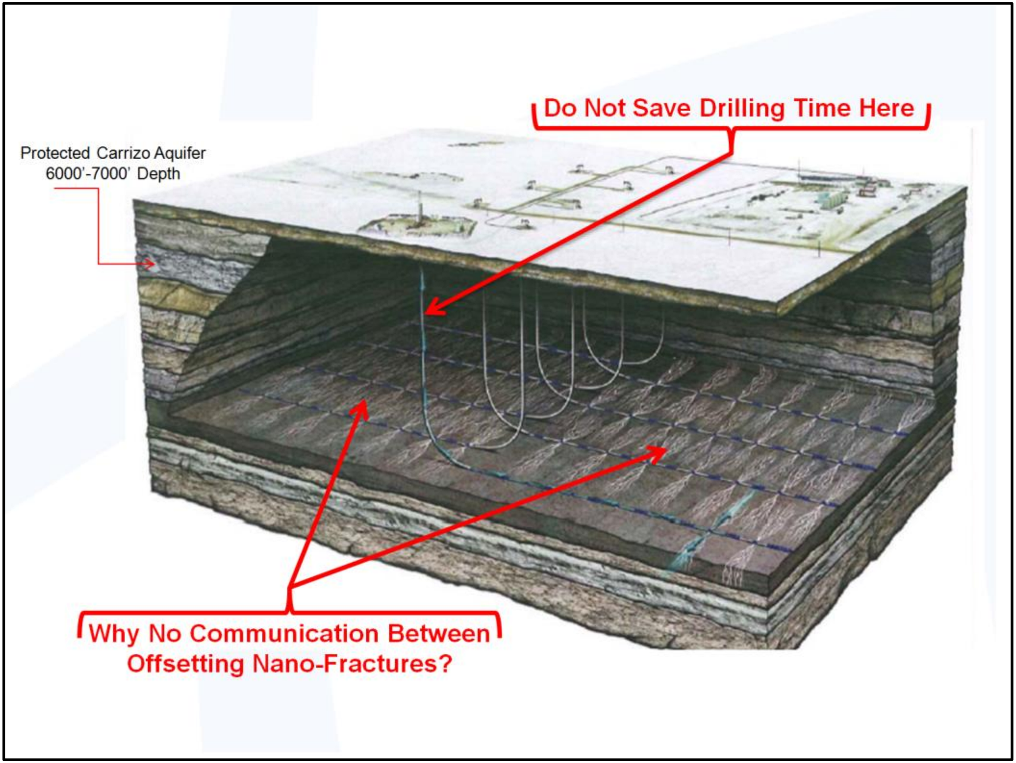
Creating a Drilling Hazard with No Mud System



Flushed Saltwater Sands With No Mud Cake

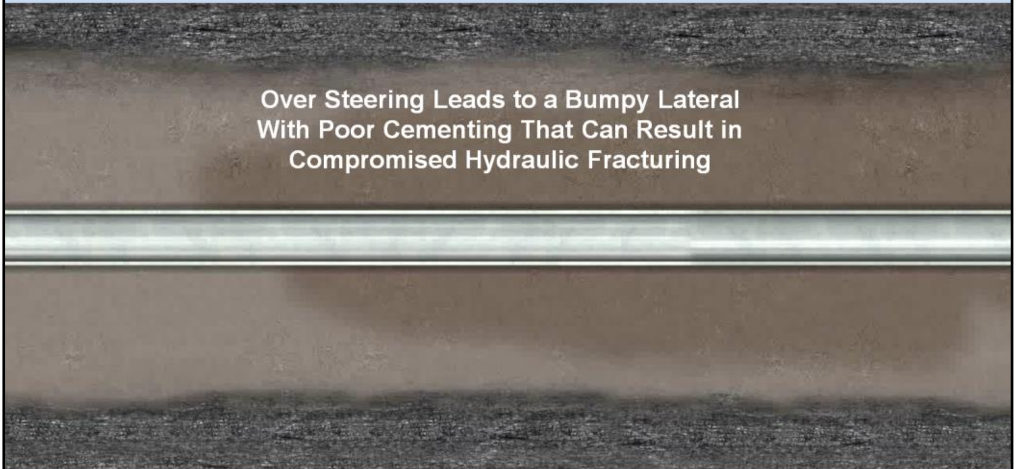

Gamma Ray
SP
Rwa
Density Corr
2500
200.0
500.0
2600
-20
DCAL
20
inches
0.2
10in Resistivity 1ft Res
2K
ohm-metre
0
Gamma Ray
150
gapi
0.2
20in Resistivity 1ft Res
2K
ohm-metre
30
Density Porosity
-10
pu
SP
BHV
0.2
30in Resistivity 1ft Res
2K
ohm-metre
30
Neutron Porosity
-10
pu
0
RWA
1
ohm-metre
AHV
0.2
60in Resistivity 1ft Res
2K
ohm-metre
0
PE
20
-0.9
Density Corr
0.1
gram per cc
MD
1 : 240
ft
0.2
90in Resistivity 1ft Res
2K
ohm-metre
21000
Tension
1000
pounds
5 Induction Curves Tracking!!!!
Sands Are Flushed With Drilling Fluid BEYOND the Deep Induction Curve Investigation
NO MUD CAKE
NO GROUNDWATER PROTECTION!!!!!!

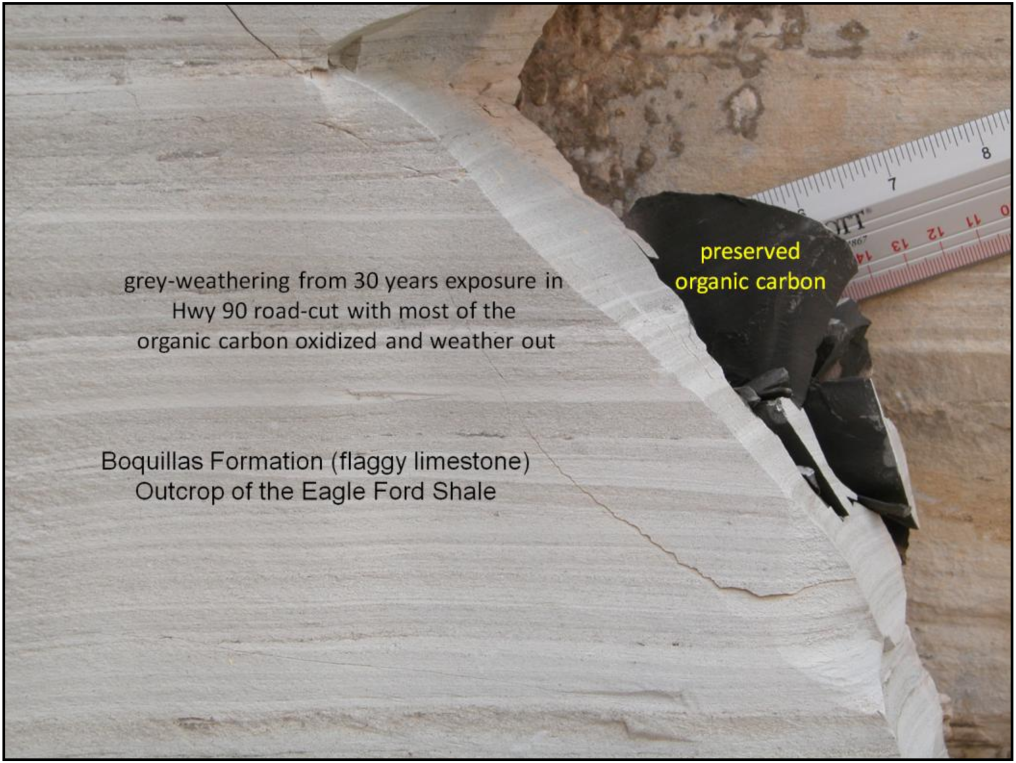

Standard Well Construction and Plugging
Freshwater Sand
Mud Seal
Cement
Casing
Spaced with Cement Plugs and 9.5 lb Mud
Cement
Mud Seal
Freshwater Sand



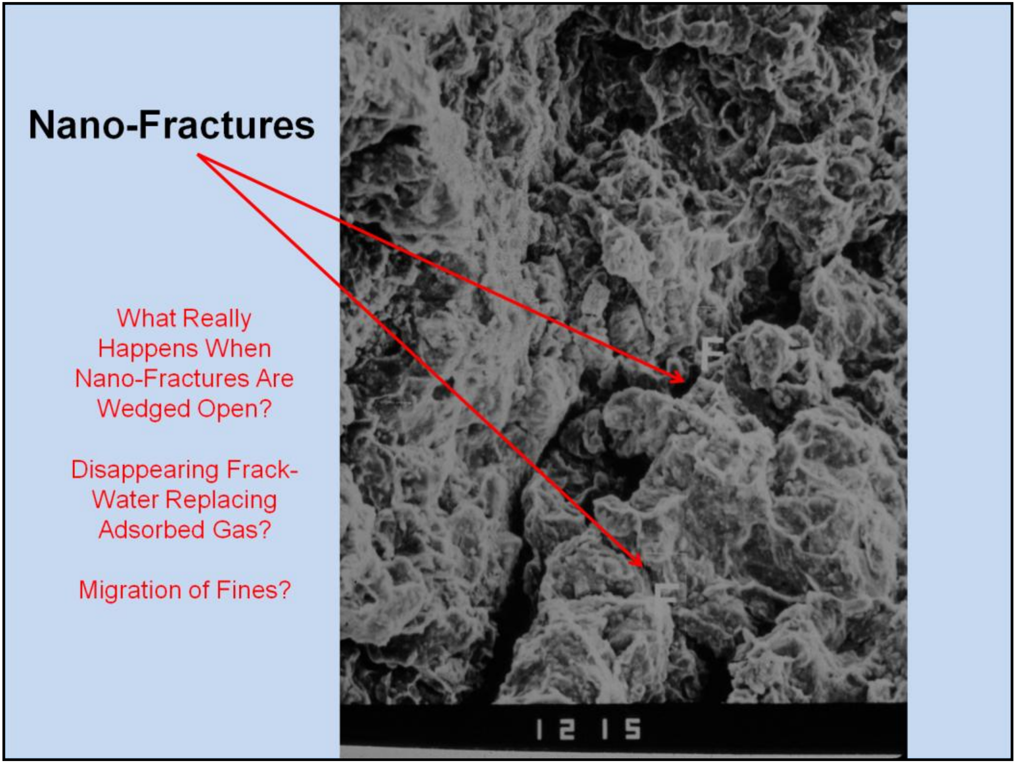
Do Not Save Drilling Time Here
Protected Carrizo Aquifer
6000'-7000' Depth
Why No Communication Between
Offsetting Nano-Fractures?

If You Think Your Lateral Looks Like This
You Are Nuts

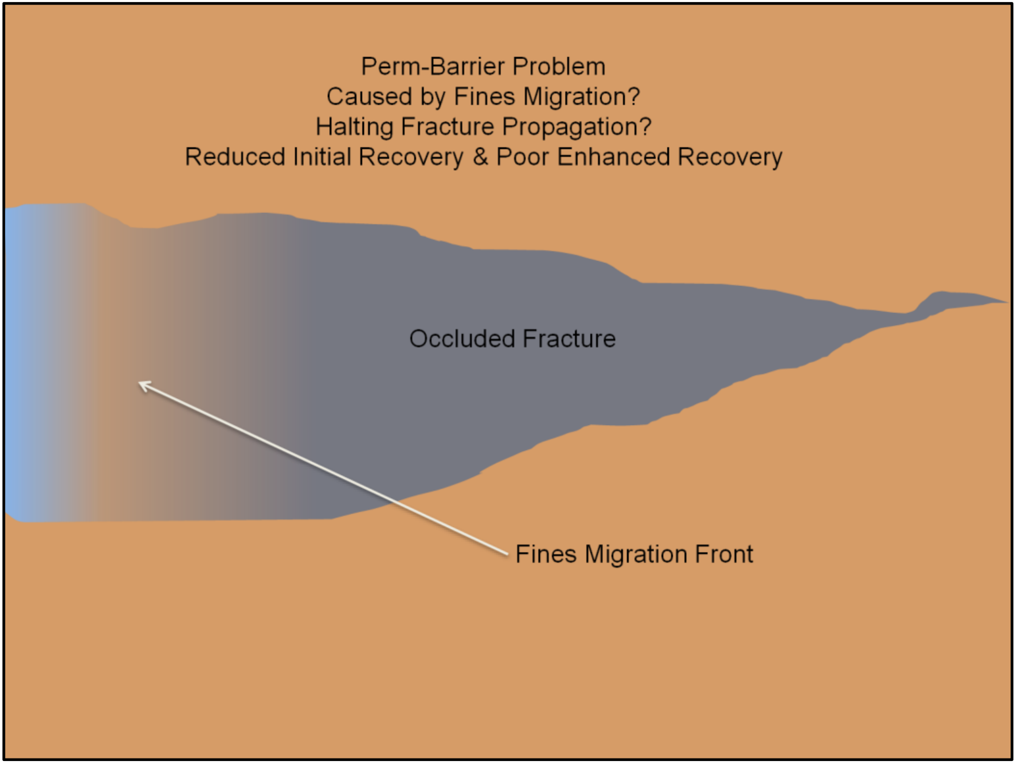




Presenter's notes: Boquillas Hwy 90 Road Cut - courtesy of Brian Lock, Prof of Geol, University of Louisiana, Lafayette

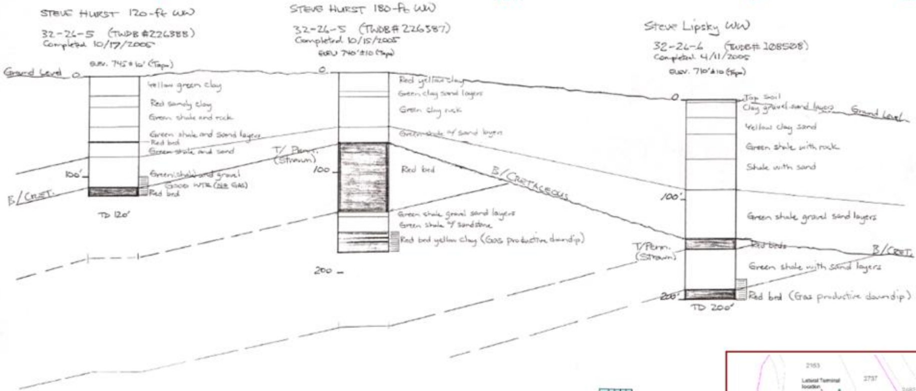


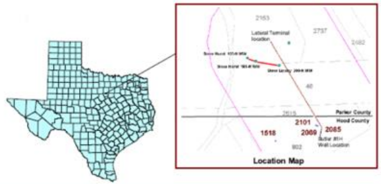
Presenter’s notes: Micro-Fracture in Mature Shale – SEM from personal collection


Perm-Barrier Problem
Caused by Fines Migration?
Halting Fracture Propagation?
Reduced Initial Recovery & Poor Enhanced Recovery
Occluded Fracture
Fines Migration Front

Water Well Driller's Log Cross Section in Proximity of Butler #1H Well

Water Well Completions in the Gas-Prone Strawn Wrongly Associated with Barnett Hydraulic Fracturing





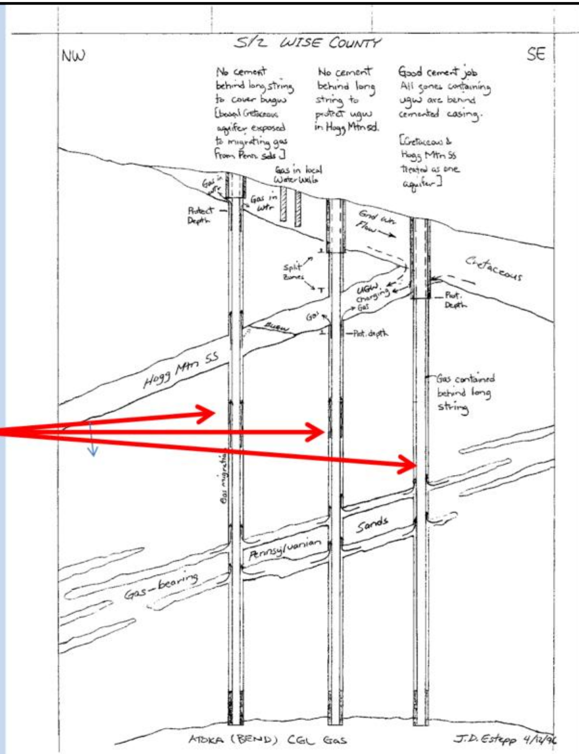
Texas Commission on Environmental Quality
Surface Casing Team

John D. Estepp, P.G.
December 21, 2010

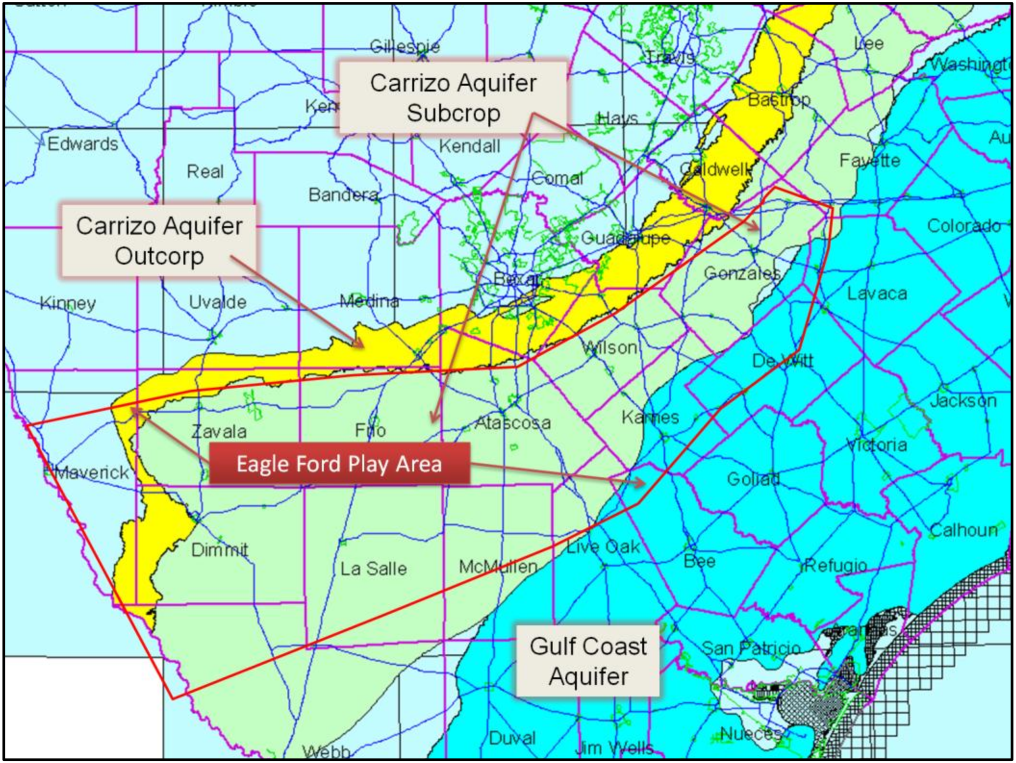
John D. Estepp
Geology
4191

Gas Contamination Pathways into Protected Groundwater Fort Worth Basin

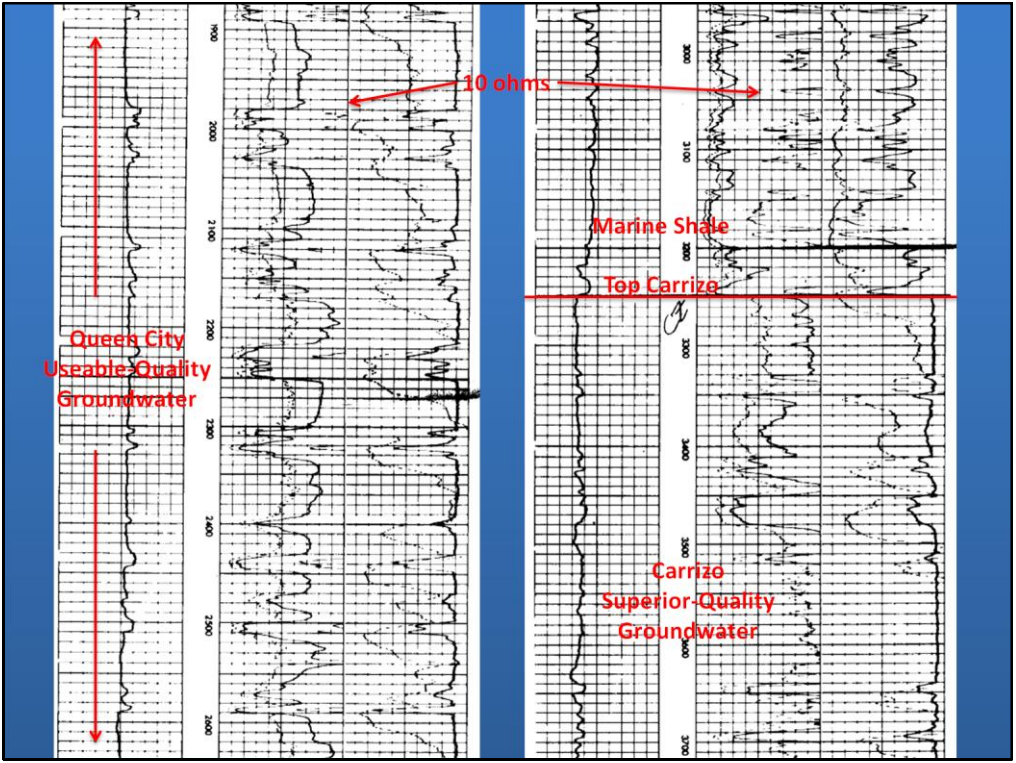
Poor Mud Systems and Cementing Can Allow Annular Migration of Gas Into Protected Groundwater



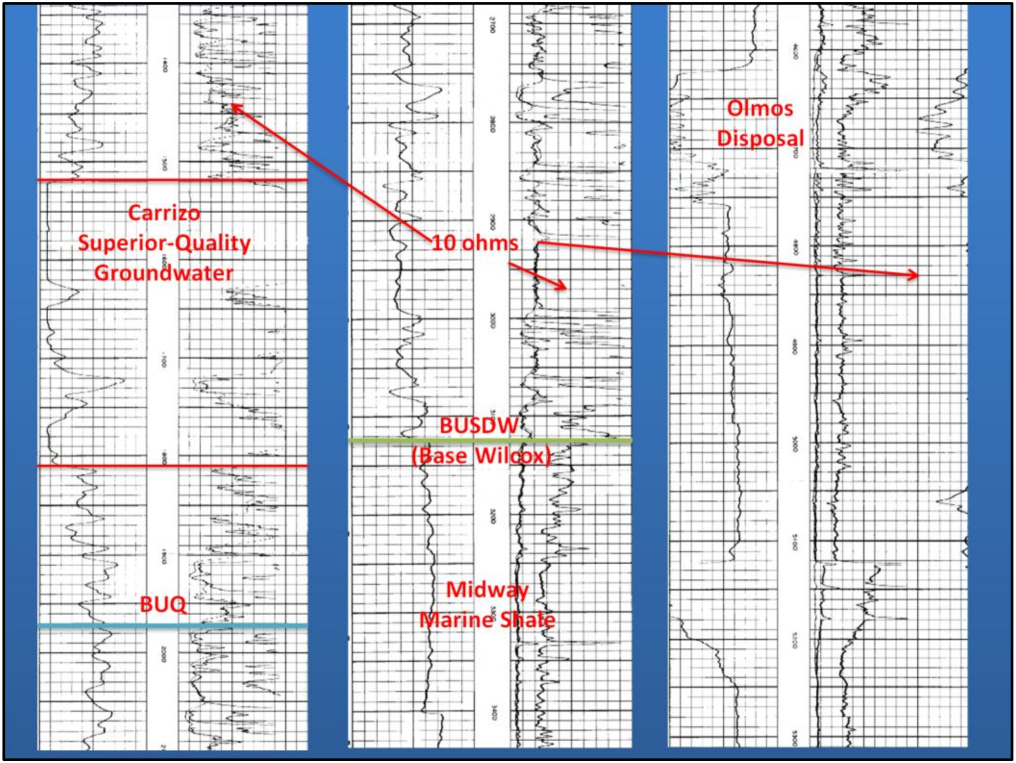
Presenter's notes: Natural Gas Groundwater Contamination Pathways in Ft Worth Basin via Cretaceous/Pennsylvanian Unconformity and Well Construction – courtesy of John Estepp, TCEQ



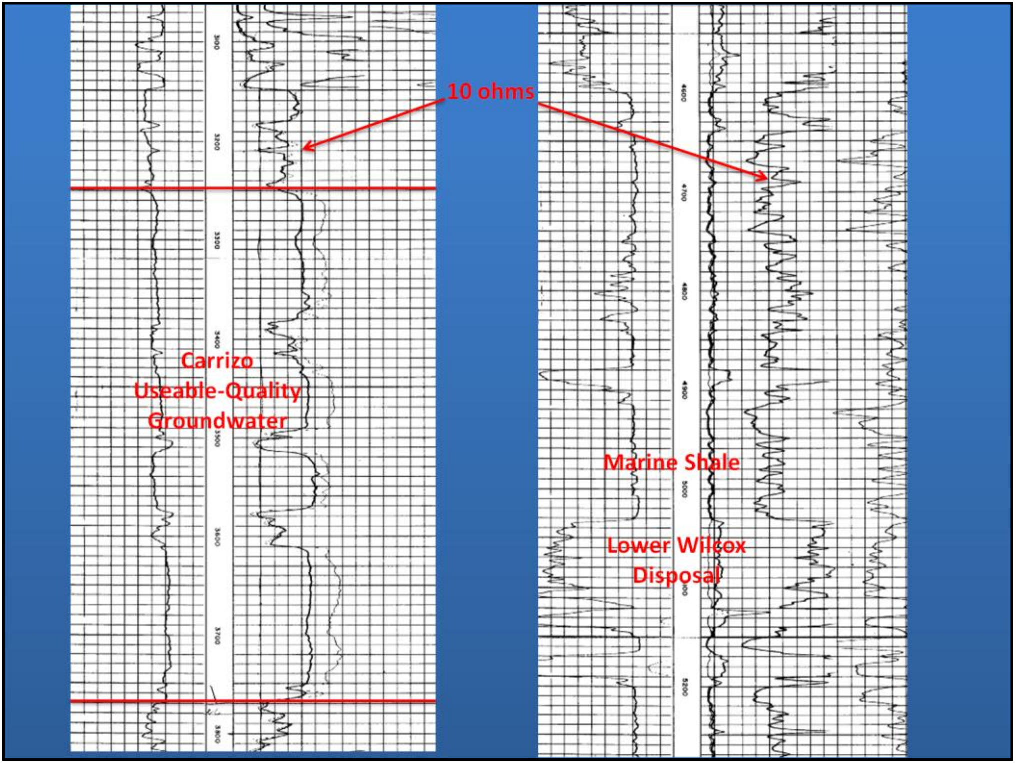
Carrizo Aquifer Subcrop
Carrizo Aquifer Outcorp
Eagle Ford Play Area
Gulf Coast Aquifer
Gillespie
Travis
Lee
Bastrop
Hays
Kendall
Edwards
Real
Bandera
Comal
Caldwell
Fayette
Colorado
Guadalupe
Gonzales
Bexar
Kinney
Uvalde
Medina
Lavaca
Wilson
De Witt
Jackson
Zavala
Frio
Atascosa
Karnes
Victoria
Maverick
Goliad
Calhoun
Dimmit
La Salle
McMullen
Live Oak
Bee
Refugio
San Patricio
Duval
Jim Wells
Nueces
Webb

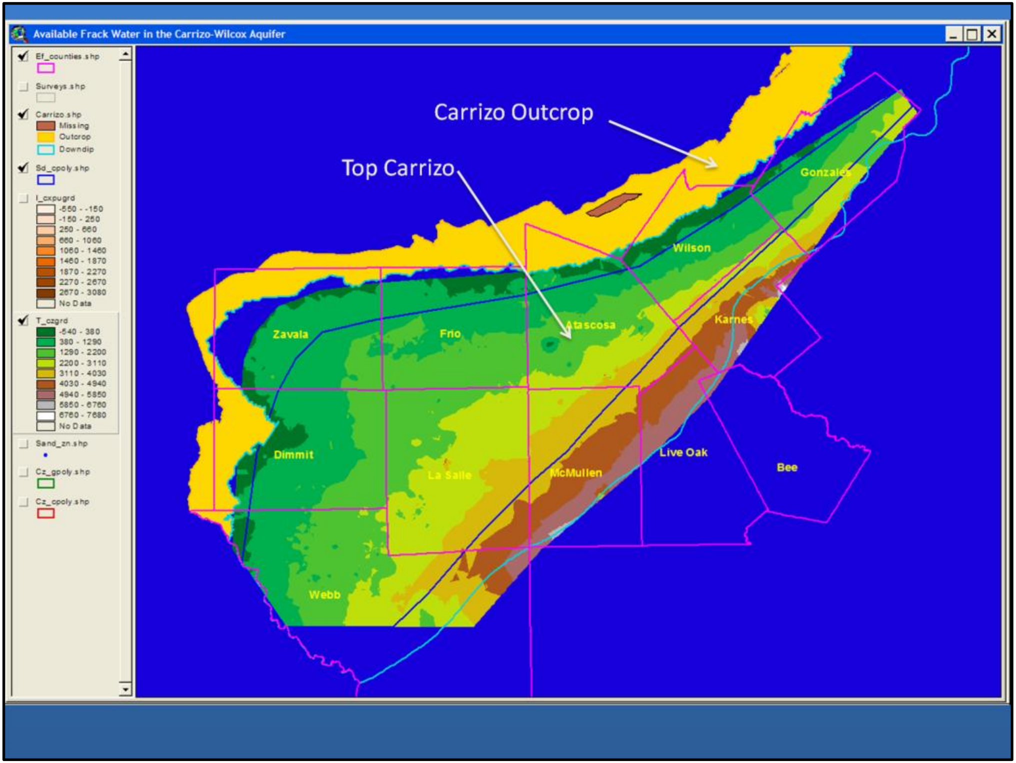


10 ohms
Marine Shale
Top Carrize
Queen City
Useable-Quality
Groundwater
Carrizo
Superior-Quality
Groundwater
1900
2000
2100
2200
2300
2400
2500
2600
3000
3100
3200
3300
3400
3500
3600
3700

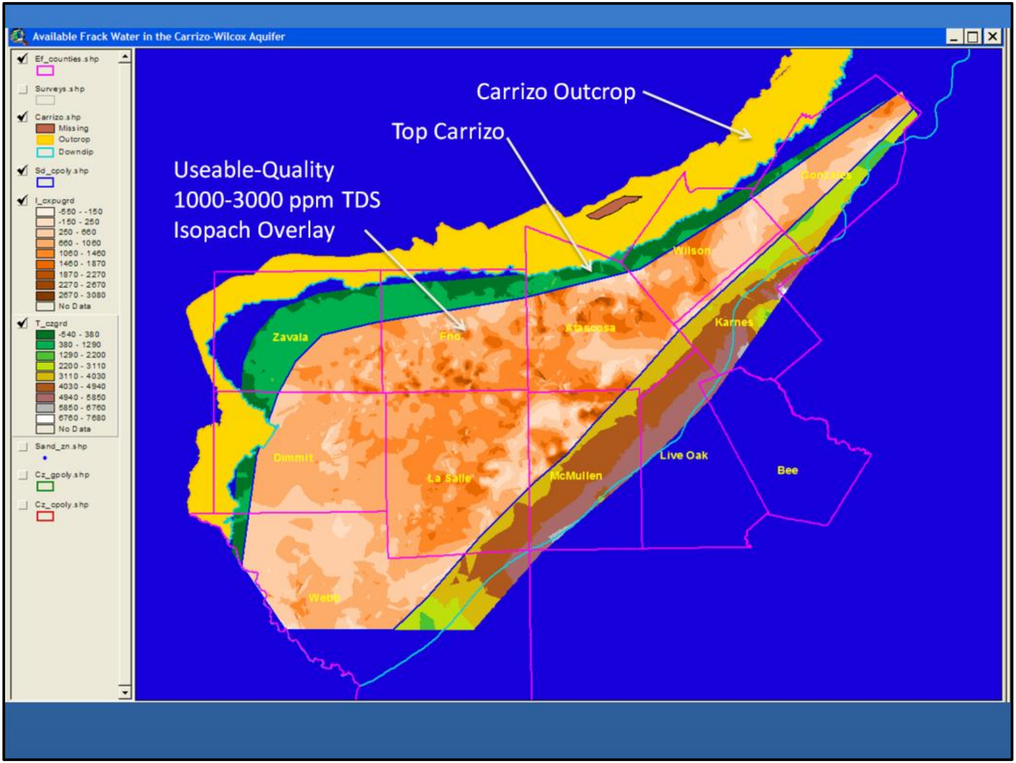


Olmos
Disposal
Carrizo
Superior-Quality
Groundwater
10 ohms
BUSDW
(Base Wilcox)
BUQ
Midway
Marine Shale


10 ohms
Carrizo
Useable-Quality
Groundwater
Marine Shale
Lower Wilcox
Disposal



Available Frack Water in the Carrizo-Wilcox Aquifer
Ef_counties.shp
Surveys.shp
Carrizo.shp
Missing
Outcrop
Downdip
Sd_cpoly.shp
I_cxpugrd
-550 - -150
-150 - 250
250 - 660
660 - 1060
1060 - 1460
1460 - 1870
1870 - 2270
2270 - 2670
2670 - 3080
No Data
T_czgrd
-540 - 380
380 - 1290
1290 - 2200
2200 - 3110
3110 - 4030
4030 - 4940
4940 - 5850
5850 - 6760
6760 - 7680
No Data
Sand_zn.shp
Cz_gpoly.shp
Cz_cpoly.shp
Carrizo Outcrop
Top Carrizo
Gonzales
Wilson
Zavala
Frio
Atascosa
Karnes
Dimmit
La Salle
McMullen
Live Oak
Bee
Webb



Available Frack Water in the Carrizo-Wilcox Aquifer
Ef_counties.shp
Surveys.shp
Carrizo.shp
Missing
Outcrop
Downdip
Sd_cpoly.shp
I_cxpugrd
-550 - -150
-150 - 250
250 - 660
660 - 1060
1060 - 1460
1460 - 1870
1870 - 2270
2270 - 2670
2670 - 3080
No Data
T_czgrd
-540 - 380
380 - 1290
1290 - 2200
2200 - 3110
3110 - 4030
4030 - 4940
4940 - 5850
5850 - 6760
6760 - 7680
No Data
Sand_zn.shp
Cz_gpoly.shp
Cz_cpoly.shp
Carrizo Outcrop
Top Carrizo
Useable-Quality
1000-3000 ppm TDS
Isopach Overlay
Zavala
Frio
Atascosa
Wilson
Gonzales
Karnes
Dimmit
La Salle
McMullen
Live Oak
Bee
Webb