HYDRAULIC FRACTURING - INDUSTRY ADVANCES IN WATER RECYCLING, AND REDUCTIONS IN CHEMICALS, NOISE, EMISSIONS AND TRUCK TRAFFIC

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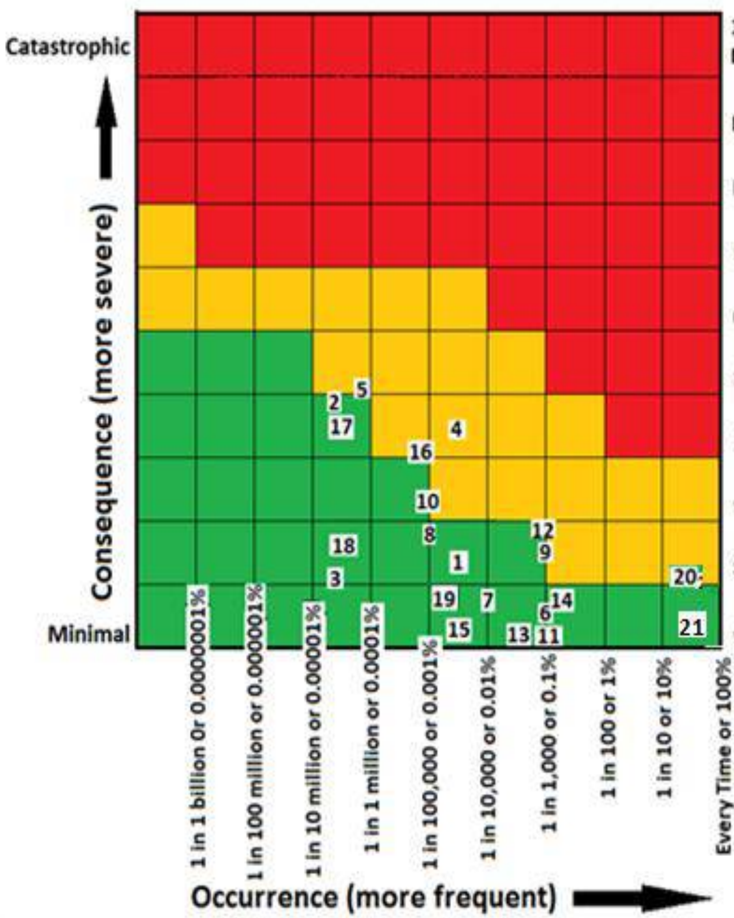
Post Oak Savannah Groundwater District's Burleson and Milam Counties Groundwater Summit, Caldwell TX. August 15, 2018

ACTUAL RISKS IN FRACTURING? VERY MINOR.

BUT EVEN MINOR RISKS CAN BE SERIOUS & EXPENSIVE.

Risk Matrix of Consequence vs. Occurrence For Events of Hydraulic Fracturing



10 - > 1 Mile Diam. Subsurface Pollution, Toxic, Not Recoverable. Similar to acid mine drainage.

9 - 100 ft to 1 Mile Diam. Pollution, Toxic, Not Recoverable. Similar to acid mine drainage.

8 - > 1 Mile Diam., Surface Pollution Toxic, Slow or No Biodegradation. Less toxic than acid mine drainage.

7 - 100 ft to 1 Mile Diam., Surface Pollution Toxic, Slow or No Biodegradation. Less toxic than acid mine drainage.

6 - <100 ft. Subsurface Pollution, Toxic but dispersible or recoverable. Similar to storage tank leak of oil or gasoline.

5 - < 100 ft. Diam. Surface Pollution, Toxic but dispersible. Similar to spill of fertilizer, ammonia or small diesel spill

4 - Spill or Leak of 50 to 500 gal (1.94M3) Non Toxic but persistent chemical, Similar to salt spredding on icy roads.

3 - Large volume (<5,000 gal) spill of raw fresh or salt water with low conc. chemicals, similar to partly treated sewage.

2 - Spill (<25,000 gal) of raw fresh water with no chemicals. Similar to a swimming pool draining on the ground.

1 - Small spills (<5 gal or 20 liter) of diluted, non toxic, quickly biodegradable, household or food grade chemical.

1. Spill clean fresh or salt water
2. Spill biocide
3. Spill dry additives
4. Spill of diesel from truck wreck
5. Spill of diesel -wrecked re-fueler
6. Spill frac tank water, no adds
7. Spill frac tank water w/adds
8. Spill diesel fuel while re-fueling
9. Spill of frac tank -flowback water 10. Frac press ruptures surface casing
11. Cooling pulls tubing out of packer (casing maintains integrity)
12. Mud channel, well < 2000 ft
13. Mud channel, well > 2000 ft
14. Intersects well in the pay zone
15. Intersect properly abandoned well
16. Intersects improperly abandoned well
17. Frac to surface through rock, well greater than 2000 ft deep.
18. Earthquake, mag. >5.0
19. Frac intersects a natural seep
20. Emissions > background
21. Normal frac operation – no problems.

Apache

HOW MUCH WATER IS NEEDED TO GENERATE ENERGY?

Energy Form	Gal. water per million BTUs	Water: Used (rapidly returnable), OR Consumed (tied up long term)?	Comments
Natural Gas (shale) (water used in fracturing & drilling)	1 to 5	Consumed, but 11 mm gal returned for each bcf of gas fuel burned. $CH_4 + O_2 \Rightarrow 2CO_2 + H_2O$	Fracturing dominates water use. Salt water is 40%+ of total fracture water use (increasing)
Oil	10 to 20	Consumed	
Coal	2 to 12	Used	
Ethanol (Corn)	2000+	Consumed/Used	water vol. much higher when irrigating
Biodiesel (Soy)	5500+	Consumed/Used	water vol. much higher when irrigating
Hydroelectric	30+	Used	Not counting evaporation (100's of billions of gallons per year)
Nuclear	28+	Consumed	Fuel prep only – not counting cooling.
Wind Turbine generated electricity	1 to 2	Consumed	450,000 to 720,000 gallons fresh water used in each 30,000 to 60,000 ton concrete foundation for wind turbines. Est. 120 million KWh by a single wind generator over 20 years for the power used in the calculations.
Solar (photoelectric)	0.003 to 0.3 (est.)	Used	Cleaning & cooling – highly variable with conditions

PRODUCED WATER: DISPOSAL OR REUSE? MAKING A CHOICE………

- Looked at cost/use of fresh water for fracturing and the problems of water disposal (seismic, over pressuring zones, etc.)
- Focused on recycling produced water instead of disposing into salt water injection wells.
- In 2016, 56% of our water withdrawals in a test region were replaced with recycled, reused or salty waters.
- We actually produced recycled water for fracturing for less than buying fresh water.

WATER RECYCLING

CHEMICALS - FRAC FLUID ADDITIVES

- Friction reducer (polyacrylamide or other polymer at 0.25 to 0.5 gal/1000 gal) AND
- Biocide (e.g., quaternary amine at 0.05 to 0.1 gal /1000 gal).

- Surfactants – only if lab tests shows need.
- Scale inhibitor – only if lab tests shows need.
- Acid & inhibitor – only if field tests show need.

By testing & removing un-needed chemicals, we saved up to ½ million $ per well.

CHEMICAL ADDITIVES – WHAT'S IMPACT OF SALT AND OTHER IONS?

Most Common Slick Water Frac Additives	Composition	CAS Number	My Estimates of Limit of salinity	Alternate Use
Friction Reducer	Polyacrylamide	9003-05-8	50,000 to 70,000 ppm is upper limit with decreasing friction reducing function	Adsorbent in baby diapers, flocculent in drinking water preparation
Biocide	Glutaraldehyde	111-30-8	Some decrease with increasing salinity – testing advised.	Medical disinfectant
Alternate Biocide	Ozone, Chlorine dioxide UV,	10028-15-6 10049-04-4	Turbidity and very high salinity are hindrances	Disinfectant in municipal water supplies
Scale Inhibitor	Phosphonate & polymers	6419-19-8 & others	Specific ions like calcium are a problem	Some cleaners and medical treatment for bone problems.
Gellants	Guar and Cellulose	9000-30-0 9004-62-0	Calcium content & high salinity are problems. Iron is detrimental to stability.	Thickening ice cream and soup

DUST CONTROL AND NOISE REDUCTION

- Old Method

- New Methods

EMISSIONS REDUCTIONS

- Emission reducing goals set in 2012 have reduced methane emissions by 43%.
- Target of methane leak reduction to a level below 0.36% (of produced gas volume) by 2025 => on track!
- LDAR (leak detection and repair) programs are in place and active in each region.

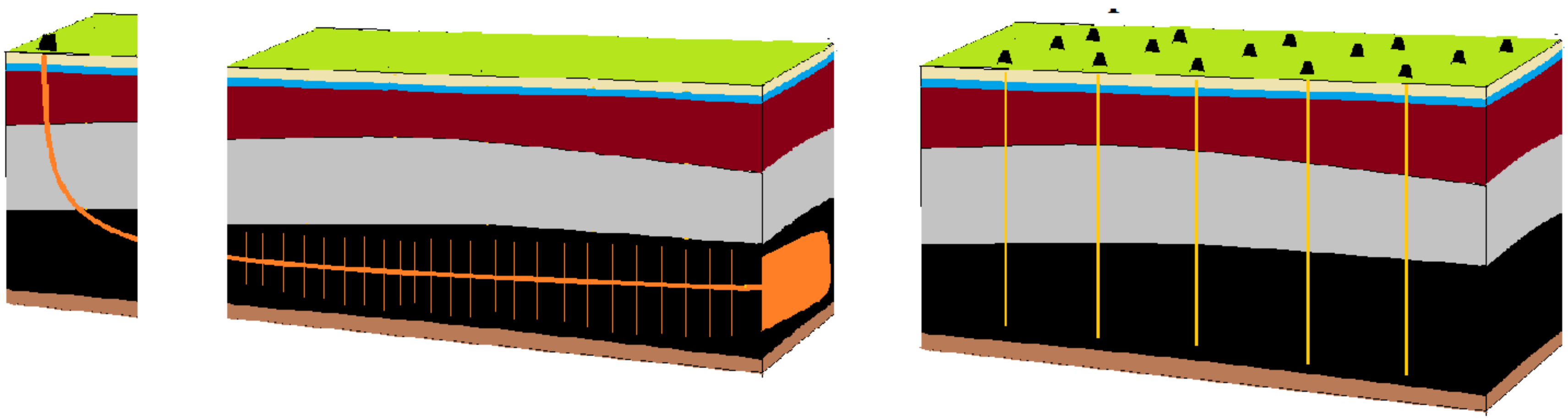
TRUCKING AND TRUCK TRAFFIC

- Often the biggest single objection from communities is truck traffic.
- About 2,000 semi truck loads of water, sand and materials may be used on a single, long well.
- Advances:
  - Central recycling of water with repurposed and temporary pipelines took 80,000 truck loads of water off the road in a multi-well project.
  - Using sand silos for storage minimized traffic problems by staggering deliveries in non-busy hours.

REDUCING THE "FOOT PRINT" BY OVER 90%

1 horizontal well - 1 water penetration
1 shared 4 to 6 acre pad, remote location
1 tank battery - shared w/ 3 to 4 wells
1 road + 100 ft. of gathering line
Total footprint ~ 6 to 7 acres

15 vertical wells - 15 water penetrations
1 well per 2 or 3 acre pad
2 to 4 tank batteries + roads
1 to 2 miles surface gathering line
Total footprint = ~ 50 to 70 acres



- Sharply reduced footprint and groundwater penetrations
- More formation access area per well.

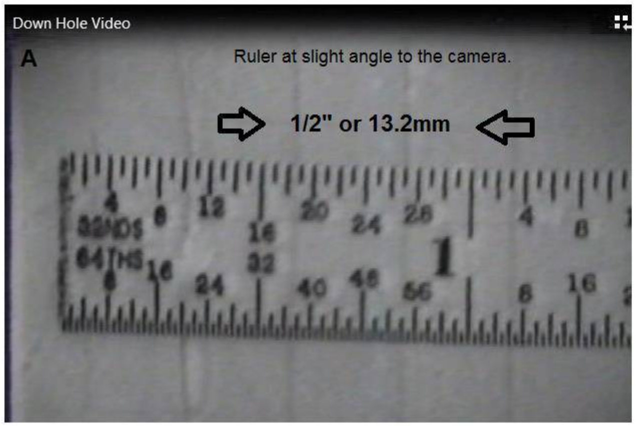
VERTICAL FRACTURES – WHERE DO THEY STOP?

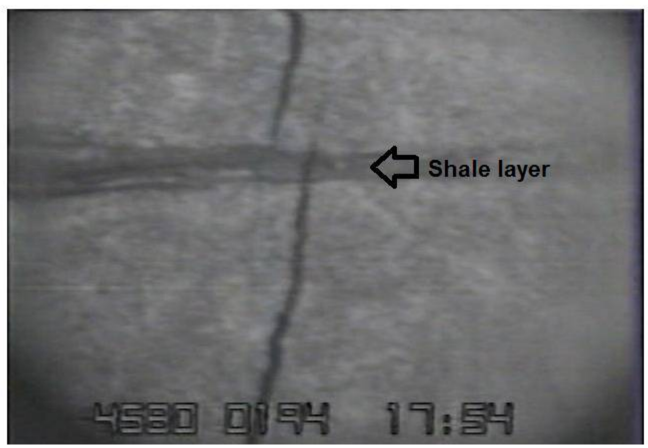
Fractures are naturally limited by many factors.

- Natural formation barriers.
- Tectonic stresses in the rock
- Leakoff into the hydrocarbon-charged reservoir.
- Natural fractures that form complexity or network fractures.

Two inch by 1.5" view from a downhole TV camera run in clear water. Amoco - Circa 1971.

COMMON UNPROPPED HYDRAULIC FRACTURE WIDTHS



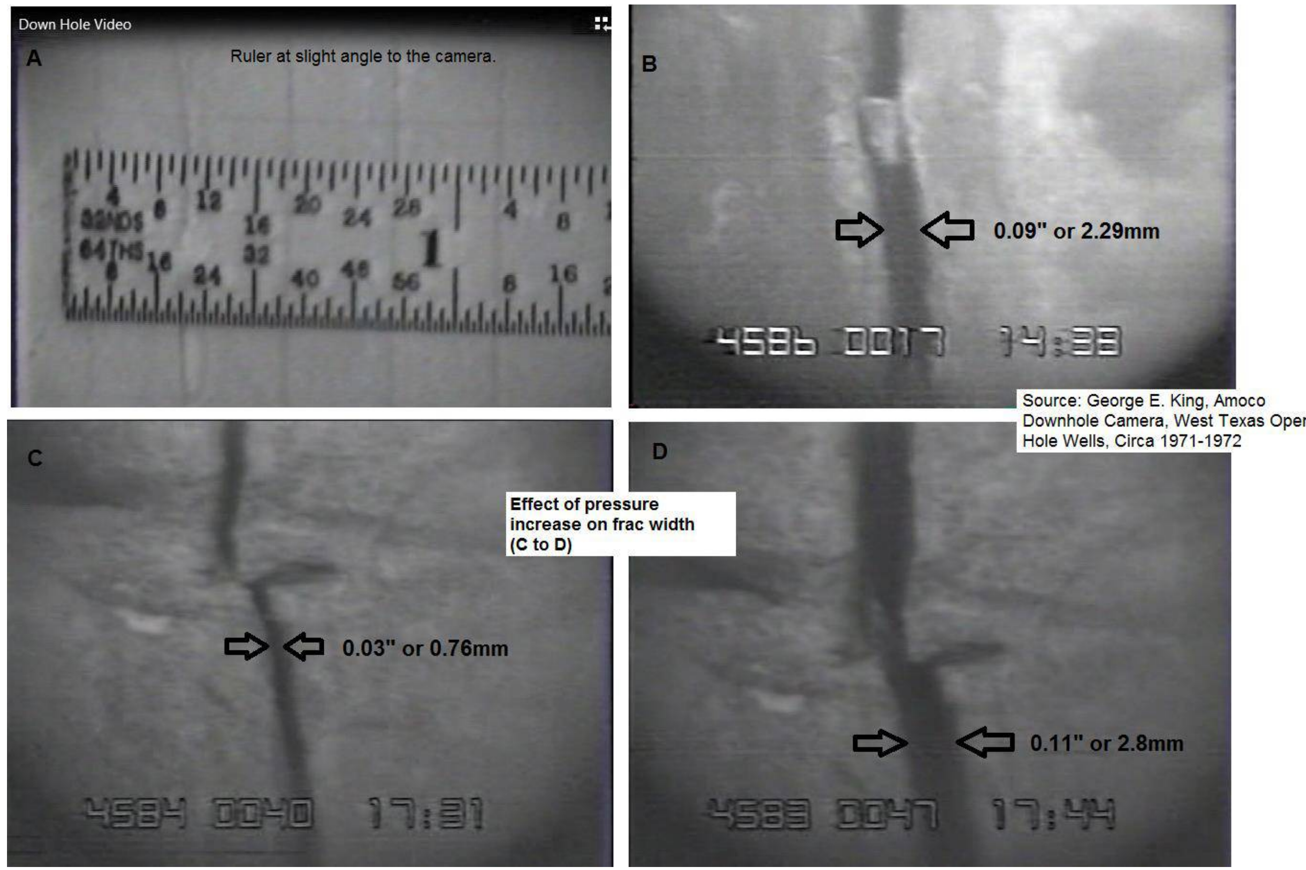


Source: George E. King, Amoco Downhole Camera, West Texas Open Hole Wells, Circa 1971-1972

COMMON HYDRAULIC FRACTURE WIDTHS

AND

EFFECT OF INJECTION PRESSURE ON FRACTURE WIDTH.



COMMUNITY RELATIONS & IMPACT EXAMPLES FROM 2016 BALMOREA AREA

- Set up a community advisory council – anyone can call the hot line, held regular public meetings.
- Partnered with schools, First Responders, city and county governments to support new programs.
- Support the local economy – in 2016 we increased our local-national hiring to about 97%. Our local vendor spending increased to 29%.

CONCLUDING SLIDE - HOW WE USED DEVELOPMENTS IN CANADA – 6000 ACRES ACCESSED FROM A 6 ACRE PAD

Apache Horn River L34 Pad.
6000 acres of shale from 6 acre pad
95% of frac water from brine source
Closed loop fracturing
12 wells, 154 fracs