Well Construction and Cementing Practices in Shale and Salt Water Disposal Wells

2017 Shale Network Workshop

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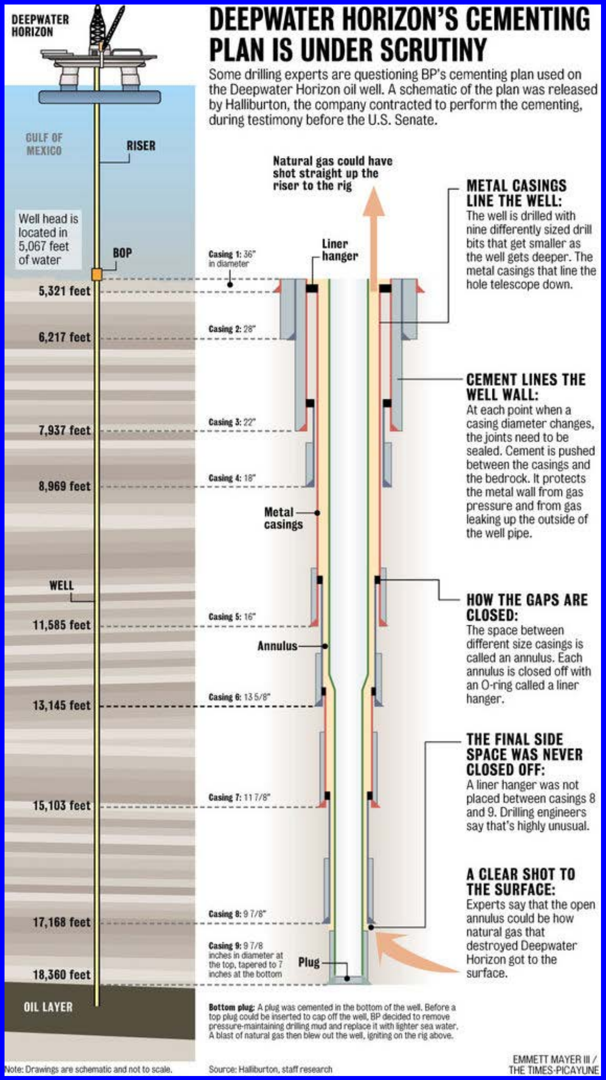
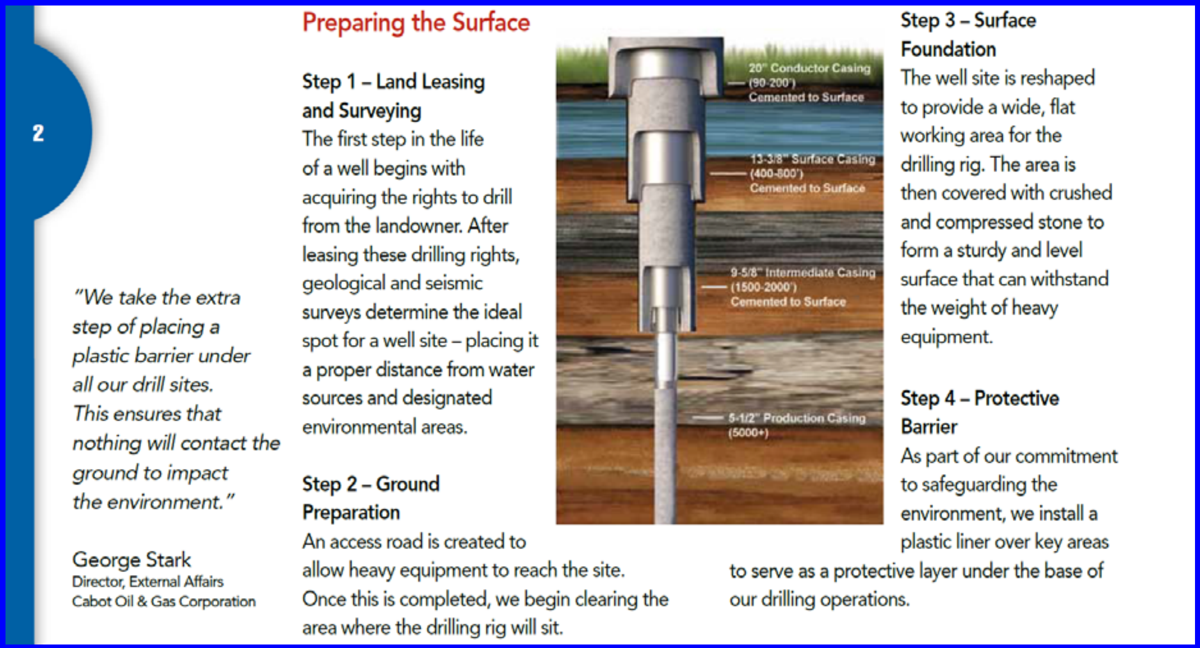
RRM Completions, LLC

Agenda

- Well Construction – Importance and Examples
- Well Cementing – Design and Chemistry
- Summary and Q & A

Why Well Construction?





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Preparing the Surface

Step 1 – Land Leasing and Surveying
The first step in the life of a well begins with acquiring the rights to drill from the landowner. After leasing these drilling rights, geological and seismic surveys determine the ideal spot for a well site – placing it a proper distance from water sources and designated environmental areas.

Step 2 – Ground Preparation
An access road is created to allow heavy equipment to reach the site. Once this is completed, we begin clearing the area where the drilling rig will sit.

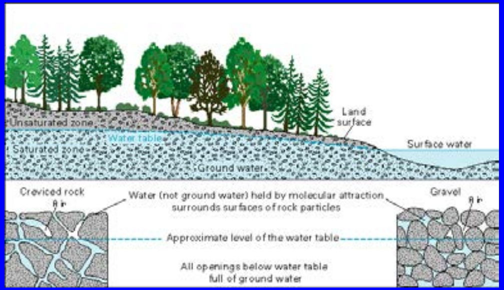
Step 3 – Surface Foundation
The well site is reshaped to provide a wide, flat working area for the drilling rig. The area is then covered with crushed and compressed stone to form a sturdy and level surface that can withstand the weight of heavy equipment.

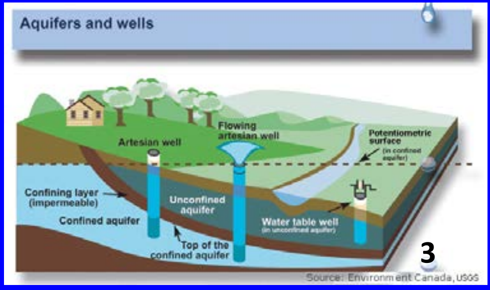
Step 4 – Protective Barrier
As part of our commitment to safeguarding the environment, we install a plastic liner over key areas to serve as a protective layer under the base of our drilling operations.

"We take the extra step of placing a plastic barrier under all our drill sites. This ensures that nothing will contact the ground to impact the environment."

George Stark
Director, External Affairs
Cabot Oil & Gas Corporation

Fact: A drill bit passes through strata containing fresh water on its way to Marcellus or Utica Shale!





Well Construction

Planning/engineering requires a drilling prognosis

- Information needed
  - Depths to all fresh water zones
  - Depth to coal
  - Depths to tops of all major formations
  - Pore pressures
  - Mud weight (or air)
  - Frac gradients
  - Geologic features – faulting, high perm matrix

Well Construction

Casing Design Considerations

- Casing Design
  - Internal (burst) yield
  - Collapse pressure
  - Joint strength
  - Axial loading
  - Connections
  - API 5T specs

Well Construction

Primary Modes of Pipe Failure

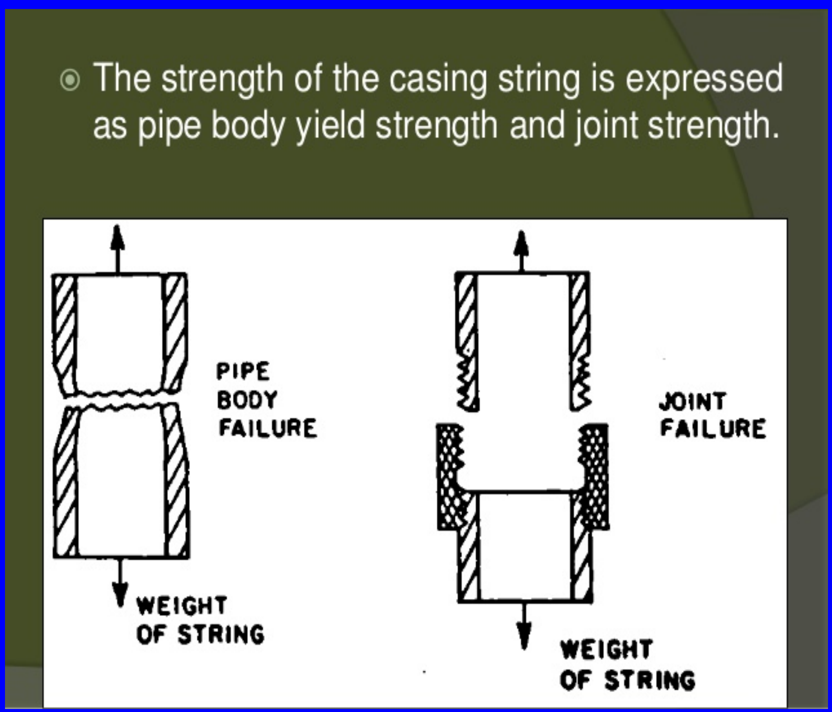
- Internal yield (burst)
  - $P_B = 0.875\ (2Ypt/D)$

- Collapse pressure
  - External pressure exceeds internal pressure (radial)

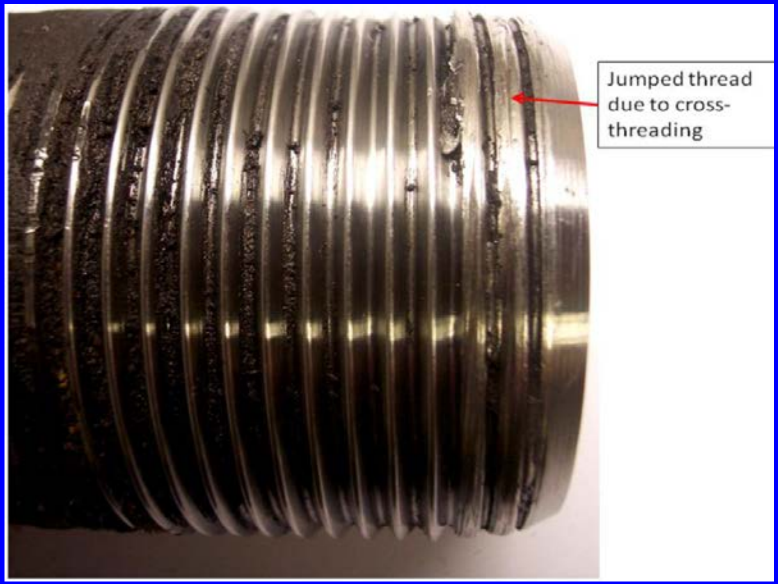
Well Construction

Primary Modes of Pipe Failure

- Joint strength – body failure



- Connection failure
  - Cross-threading
  - H_2S – rarely in NE



Well Construction

Shale Well vs. Salt Water Disposal

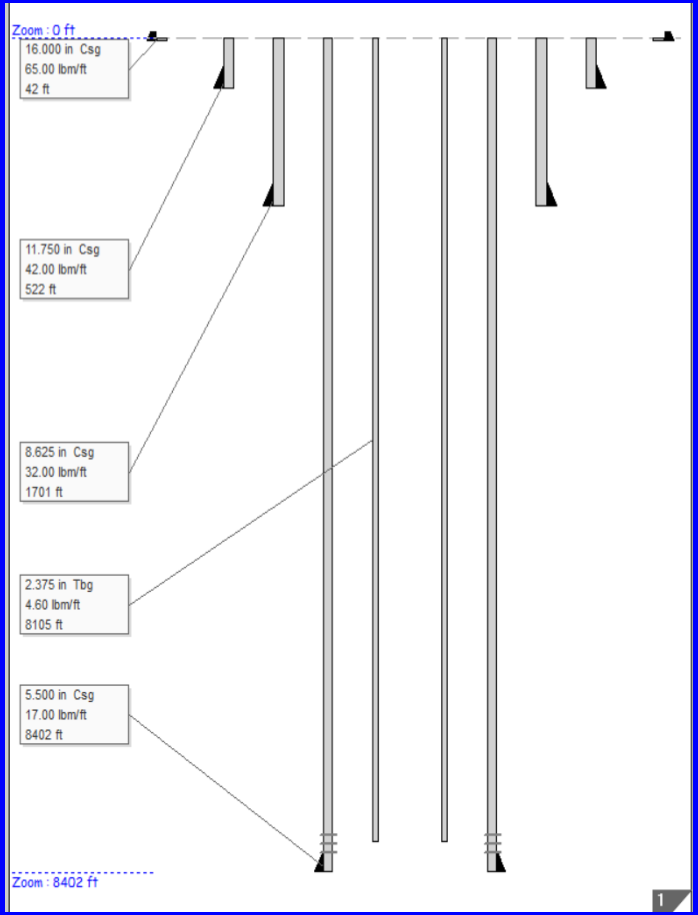
- Shale Well
  - Higher injection pressures (frac)
  - Higher pore pressures
  - Cased hole completions
  - Production casing based largely on frac pressures

- Salt Water Disposal
  - Lower injection pressures (MAIP)
  - Lower pore pressures (depletion)
  - Cased and open hole completions
  - Production casing/tubing larger to avoid friction losses

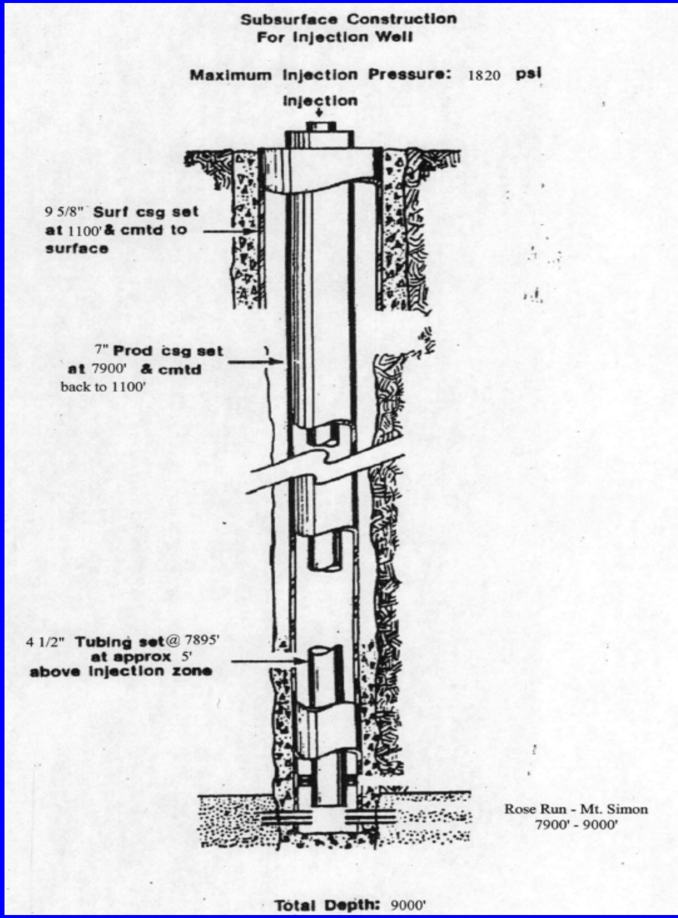
Well Construction

Shale Well vs. Salt Water Disposal

- **Shale Well**



- **SWD Well**



Courtesy of Seahorse Operating, LLC

Well Construction
Primary Containment

Well Construction
Secondary Containment

Well Construction

Cellars

Well Construction

Conductor Pipe – 0 – 300’

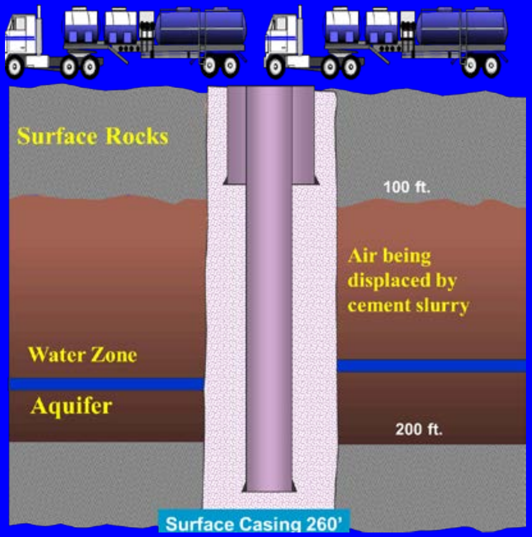
- Purpose
  - Prevent sides of hole collapsing
  - Restricts drilling returns
  - Stops artesian water flow and lost circulation

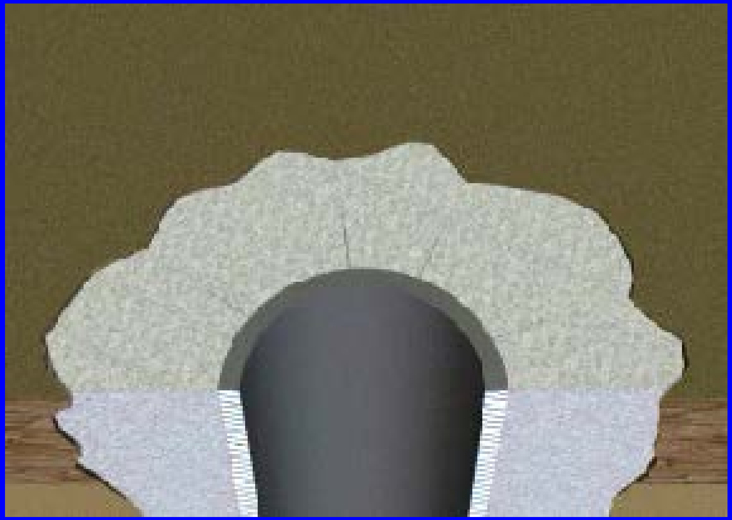
Concentric Casing Drilling Rig: inner drill pipe rotates an air percussion hammer/bit inside 94# 20” which is locked in place with a lock ring swivel and rotated independently of the inner drill pipe

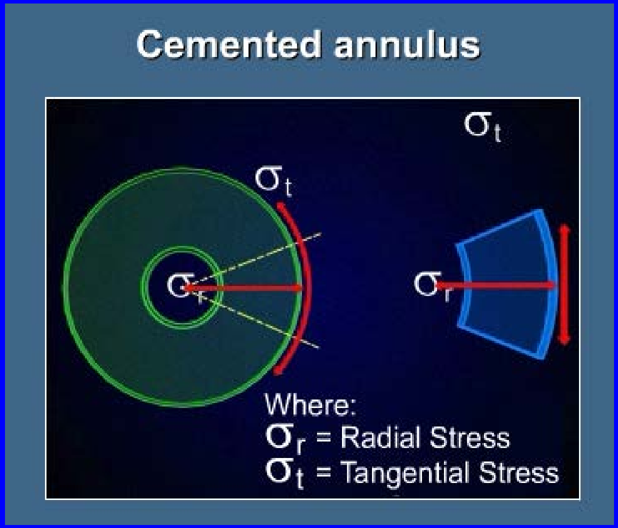
Well Construction

Surface Casing - to 800'

- Purpose
  - Prevent contamination of fresh water zones
  - Isolates coal seams
  - Supports BOPs and other casing strings



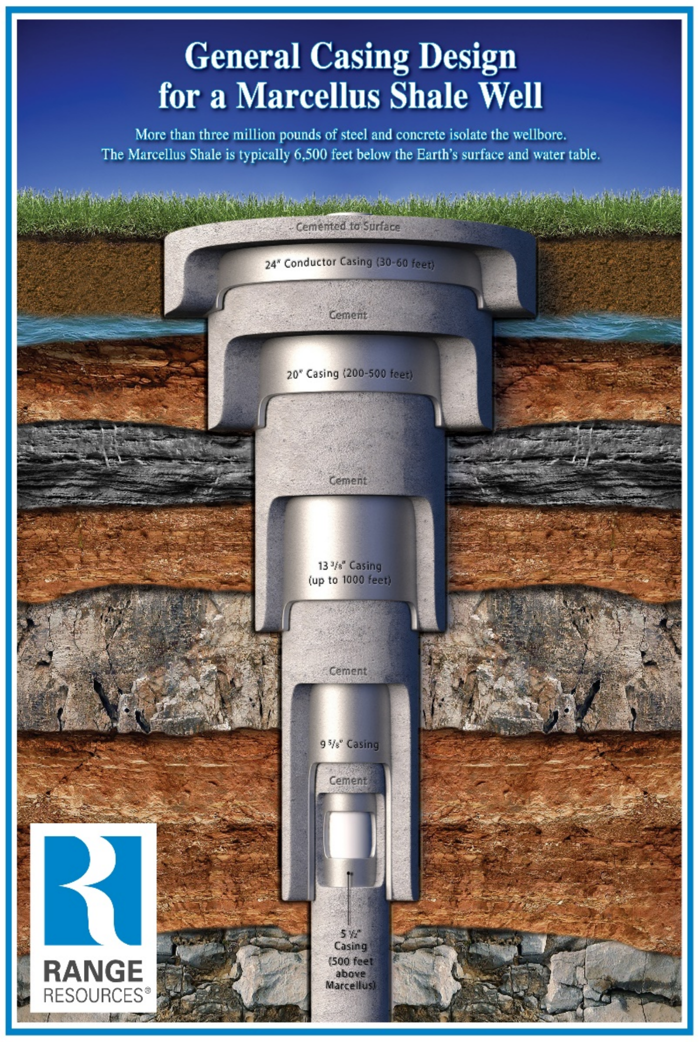




Well Construction

Intermediate Casing - to 9500’

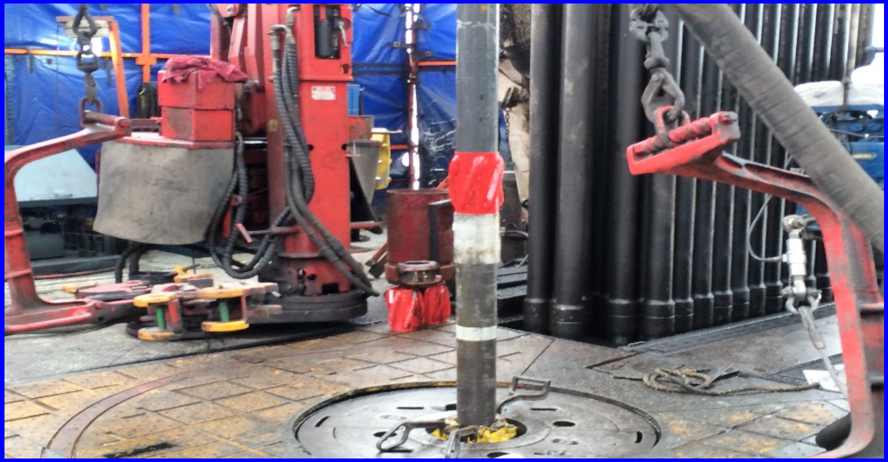
- Purpose
  - Prevents corrosion of production casing
  - Protects against hole caving of weak zones
  - Helps resist high pressure zones below



Well Construction

Production Casing - to 20,000'+

- Purpose
  - Selectively allows for oil & gas production
  - Isolates and prevents gas and brine migration
  - Provides well control



Well Cementing

Primary Cementing Planning

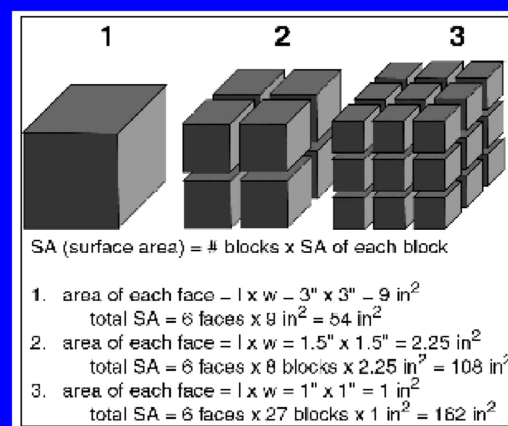
- Critical Factors
  - Wellbore
  - Drilling Fluid
  - Casing
  - Rig Operations
  - Cement Properties
  - Cement Service Equipment
  - Personnel
  - Lab Testing

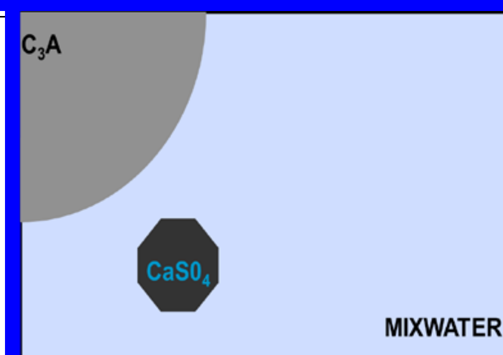
Well Cementing

Cementing Chemistry

- Hydration
  - Complex Reaction
  - Accelerators
  - Fluid Loss
  - Retarding Agents
  - Lost Circulation
  - Dispersants
  - Friction Reducers
  - Specialty Chems
    - Gas Migration
    - Zero Free Water

API Class	ASTM Type	Official Description	C_3S	β-C_2S	C_3A	C_3AF	Minimum Fineness Sq cm/g
A	I	General use	45	27	11	8	1,500
B	II	Moderate heat of hardening	44	31	5	13	1,600
C	III	High early strength	53	19	11	9	2,200
--	IV	Low heat of hydration	28	49	4	12	1,600
--	V	Sulfate resisting	38	43	4	9	1,600
G	(II)	--	50	30	5	12	1,800
H	(II)	--	50	30	5	12	1,600





Gas and Oil Well Cementing

Fluid & Gas Migration/Sustained Casing Pressure

- Why?
  - Early time failures (hours/days)
    - Borehole enlargement/poor mud removal
    - Equipment failure/unplanned job shutdowns
    - Slurry design – horizontal wells – free water
    - Unknown factors – overpressured shallow rocks
  - Late time failures (weeks/months/years)
    - Bulk volume reduction of cement
    - Pressure cycling

Gas and Oil Well Cementing

Fluid & Gas Migration/Sustained Casing Pressure

- Prevention
  - Drilling practices – reduce washout hole size
  - Rethink casing program
  - Strict adherence to job standard practices
  - Lab testing with all critical test parameters
  - Gas migration additives
  - Packer collars or mechanical seals
  - Flexible cement
  - Cement expanding agents

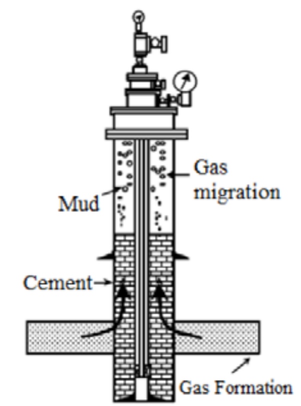


Figure 1.1: Mechanism of sustained casing pressure [4]

Remediation: Tubing workovers are easy; cement sheath failure is difficult to fix and is very expensive

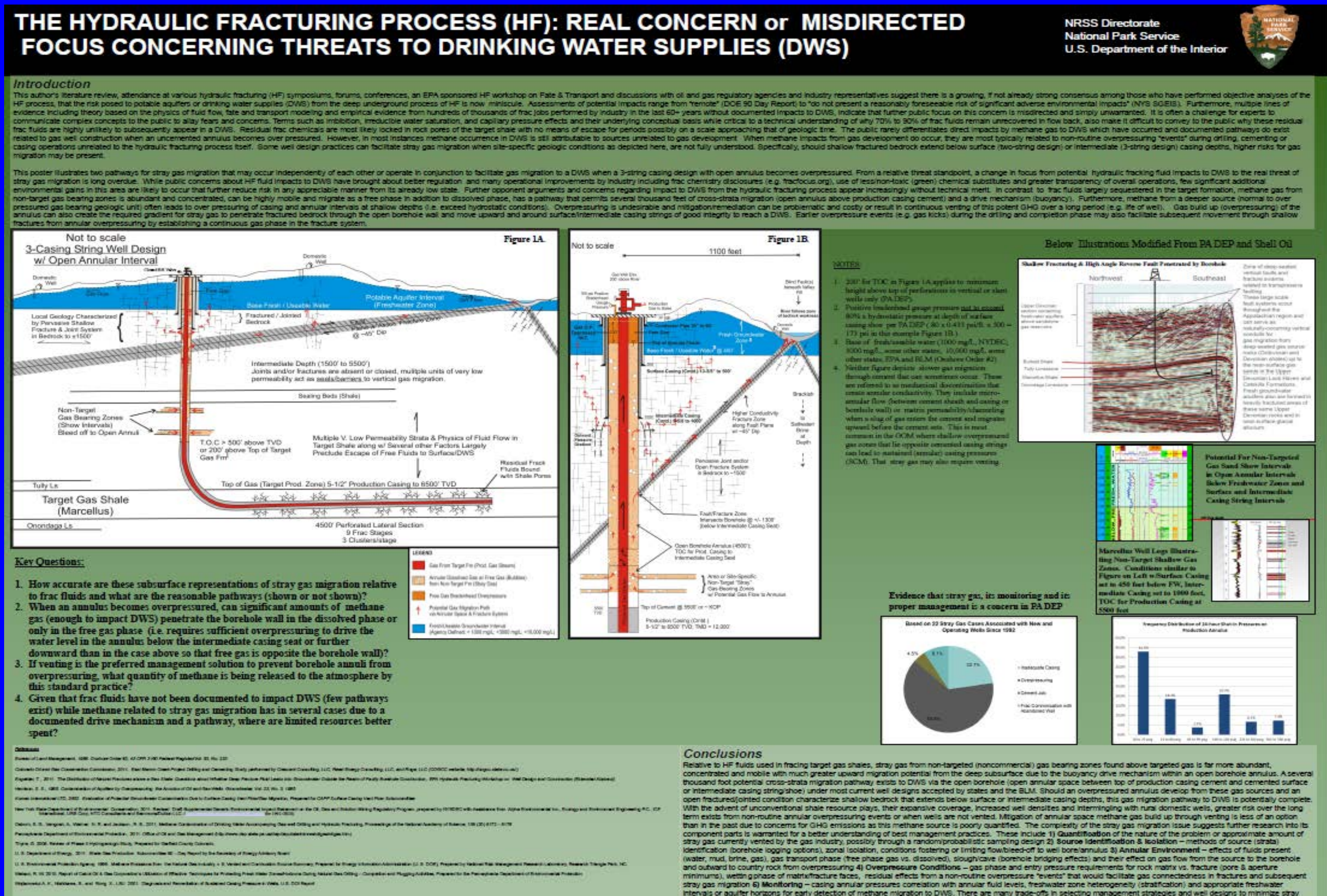
Gas and Oil Well Cementing

Fluid & Gas Migration/Sustained Casing Pressure

- What about backside or annular pressure?
  - Plumb annuli up with piping to ground level
  - Monitor pressure or open to stock tank
  - Poses minimal risk with a deeper intermediate casing set below properly cemented naturally fractured strata[21]

Hydraulic Fracturing

Fluid & Gas Migration/Sustained Casing Pressure



Summary

- Water wells and oil & gas wells drill into strata containing fresh drinking water
- Well construction planning is critical to success of both shale and salt water disposal wells
- Well cementing is of primary importance but doesn't get the attention it deserves
- Long term zonal isolation and prevention of fluid and gas movement

Bibliography - References

- Slide 3
  - John Turley, An Engineering Look at the 2010 Cause of Macondo Blowout, AADE, Butte, MN, 4-24-14
  - Cabot Oil & Gas, Life of a Natural Gas Well, 2010?
  - https://water.usgs.gov/edu/earthgwaquifer.html
- Slide 5 – personal photo

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- Slide 6
  - http://gekengineering.com/Downloads/Free_Downloads/Casing_Design_Hand_Calculation_Design_Example.pdf
- Slide 6 - http://casingcollapse.com/
- Slide 7 - https://www.slideshare.net/akincraig/petroleum-engineering-drilling-engineering-casing-design

Bibliography - References

- Slide 9 – Schematics property of Seahorse Oilfield Services, LLC
- Slide 6 - http://casingcollapse.com/
- Slide 7 - https://www.slideshare.net/ akincraig/petroleum-engineering-drilling-engineering-casing-design
- Slides 8 – 19 – Personal photos and slides from personal archives

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- Slide 20 – Removal of Sustained Casing Pressure by Gravity Displacement, E. Demirci, LSU, 2014, Master's Thesis
- Slide 21,22 – http://efdsystems.org/pdf/Stray_Gas_Migration_-_National_Park_Service_-_Peter_Penoyer.pdf; Peter Penoyer, US Department of Interior, National Park Service, Water Services Group, "Stray Gas Migration Issues in Well Design and Construction; Considerations in Avoiding Methane Impacts to Drinking Water Aquifers and/or Air Emissions", private communication