Well Site Plugging & Abandonment Workshop

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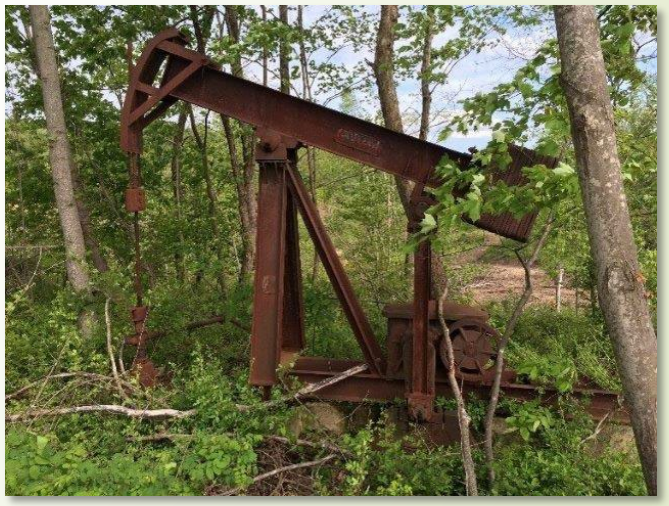
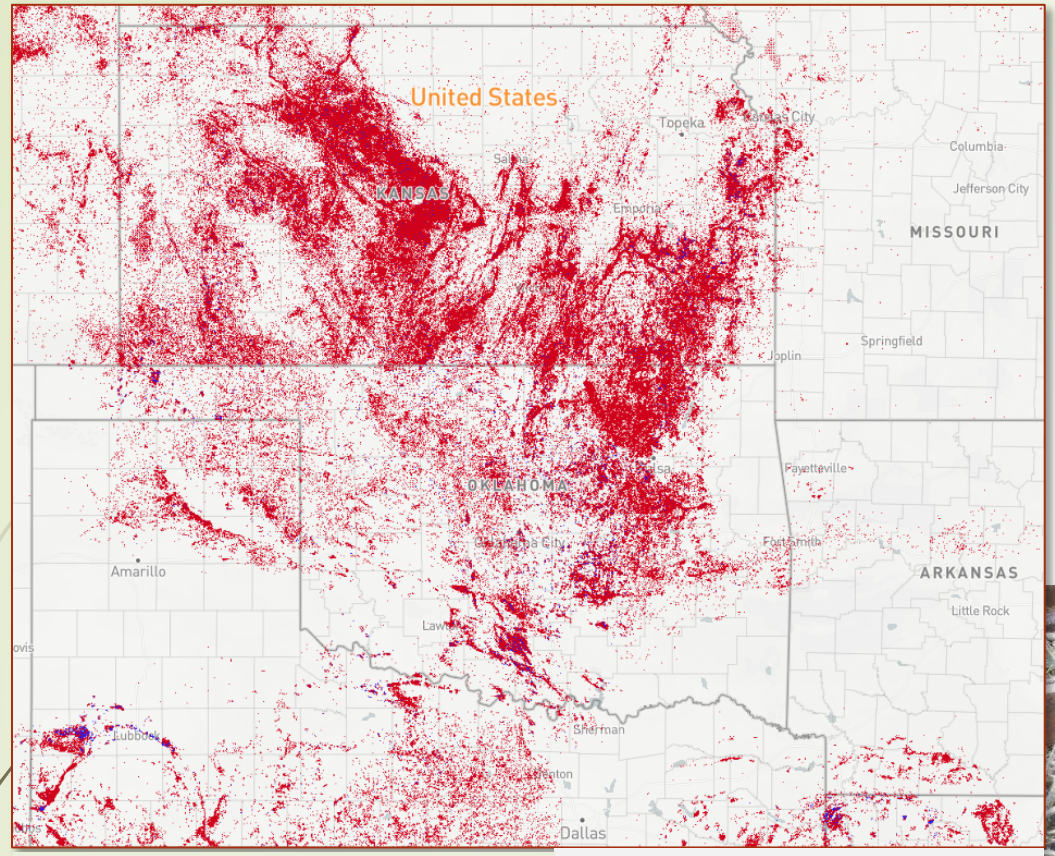
Overview

- *P&A General Considerations*
- *Historical Considerations*
- *Prioritizing Regulation of Well Plugging*
- *Brief History of Well Construction Methods*
- *Early Plugging Practices & Regulation*
- *Locating Orphan & Idle Wells*
- *Characterizing Methane Emissions*
- *Technical Considerations*
- *Well Plugging Methods*
- *Well Plugging Procedures & Execution*



Sources: ALL Consulting



Source: Eagle Environmental Group

- Inactive Oil and Gas Wells
- Inactive Injection Wells

P&A GENERAL CONSIDERATIONS

Source: ALL Consulting

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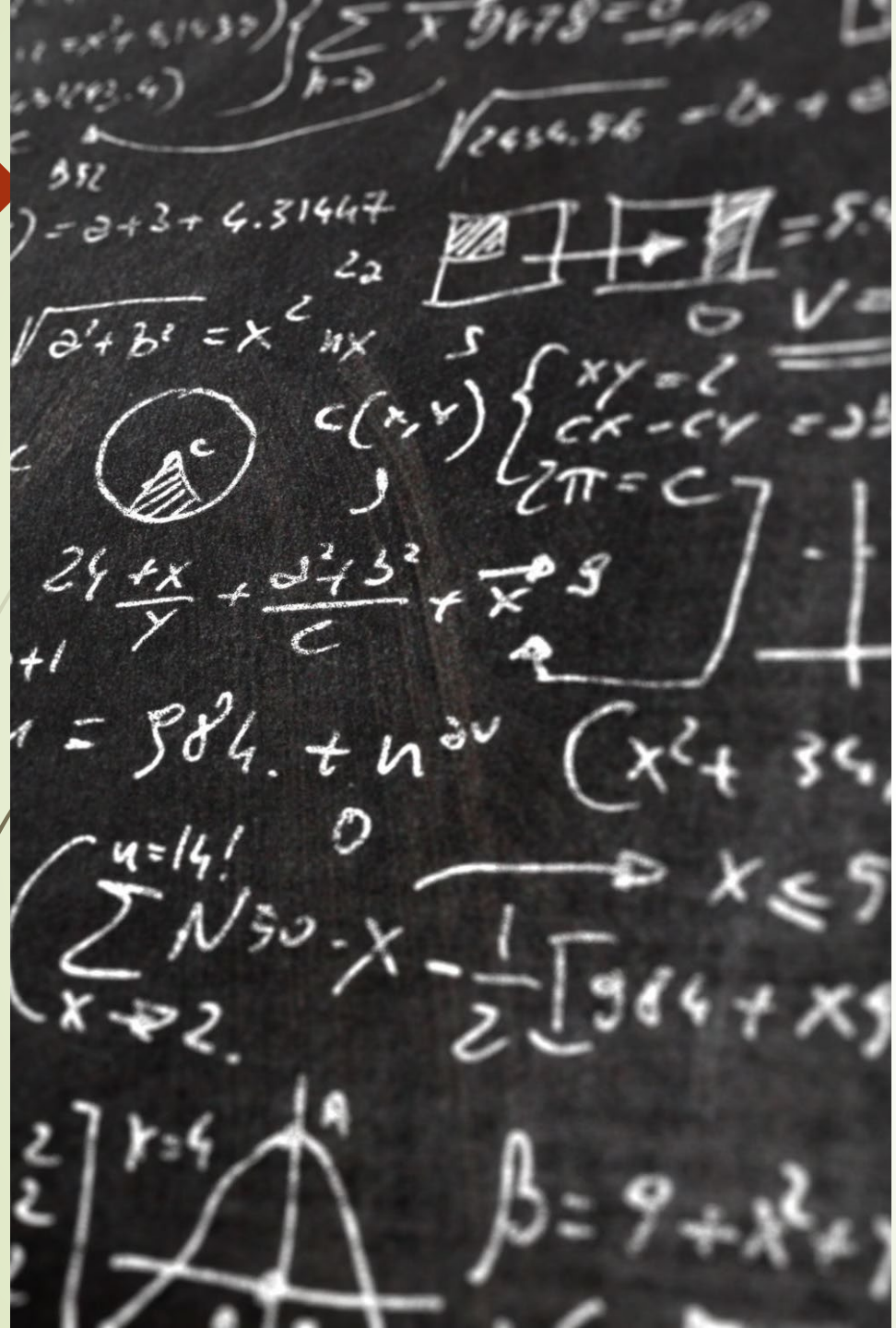

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Well Plugging Planning Details

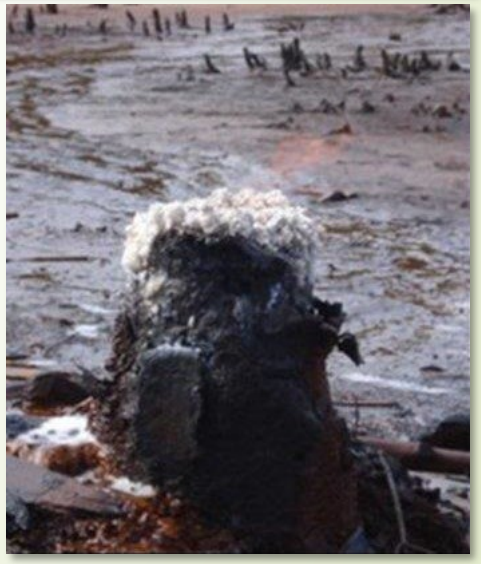
- Planning
  - Regulatory, Site Access, Testing, Safety, Area Issues/Developments, Past Issues (e.g., blowouts), Potential Re-Purposing, etc.
- Risk Management Planning
- Historic Well Records
  - Availability, Details, etc.
- Past/Historic Practices for the Area
- Area Characterization
- Well Types (e.g., Oil, Gas, EOR, Injection, etc.).
- Reservoir Details (e.g., Water Drive, etc.)
- Well Plugging Design
- Geology & Hydrogeology
- Locating Wells
- Quantifying/Characterizing Emissions

General Well Plugging Goals

- Assure plugging operations "permanently" abandon the well to eliminate risks to the environment.
- Quantify and eliminate emissions (Depending on the situation) through well plugging operations.
- Remediation & Reclamation of impacted soils.
- Remediate groundwater where impacted.
- Address current & future potential risks (e.g., stray gas, zombie wells, etc.).
- Manage historical equipment or other details (recommended).

Experience is critical!

Source: NY DEC



Considering Priorities

Greenhouse gas emissions, such as natural gas leaks from wells and facilities, appear to contribute to atmospheric warming. Orphan wells can leak natural gas and they also pose other environmental threats such as brine and oil flow into underground sources of drinking water or to the surface and into surface waters.

- Federal Legislation has a particular focus on identifying undocumented wells and reducing methane emissions.
- Various sources suggest there "may" be more than two million Orphan and Abandoned Wells (both documented & undocumented).
- Orphan and Abandoned Wells may present environmental risks, such as greenhouse gas emissions, soil & groundwater contamination, habitat impacts, etc.
- Successful well plugging can hinge on understanding the construction of the wells, their history, the development of the fields in which they are found, and the local geology.

Source: ALL Consulting

Modern Documentation Requirements

Regulatory Agencies

- Requirements vary depending on agency(s) involved (local, state, federal, Indian, etc.)
- Plugging Plan/Approval
- Logging/testing results
- Site restoration plan
- Plugging and site restoration confirmation
- Site restoration final report

Carbon Registries

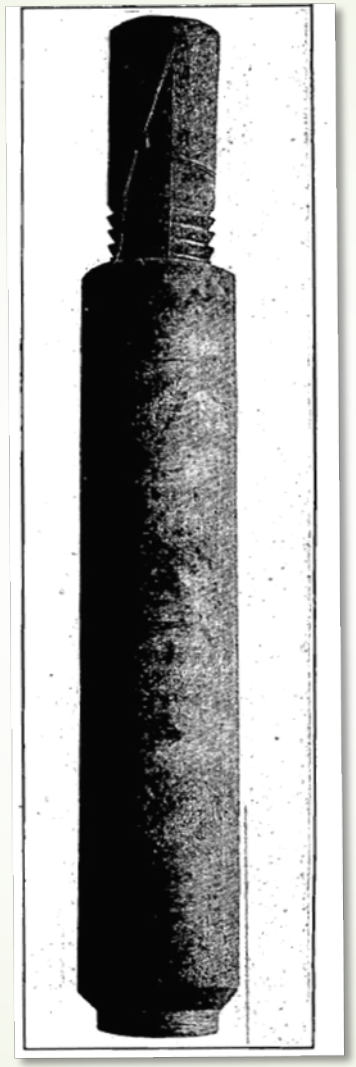
- Requirements vary depending on the Registry you're using.
- Common Requirements
  - Plugging plans & approvals
  - Leak confirmation, measurement, and gas analysis
  - Surface/Mineral ownership
  - Plugging confirmation
  - Documentation of project emissions

Historical Considerations

Source: Albertype Collection, OK Historical Society

Early Development of Oil & Gas

- During the early stages of oil and gas development in the 1800s, there were little to no regulations, let alone protocols for plugging and abandonment.
- Typically, on "dry holes" or plugged wells, all casing was removed when possible, and wells were plugged with brush, wood, rocks, lead, cannon or steel balls, and back filled with rock sediment, sand, or dirt.



Source: A Handbook of the Petroleum Industry

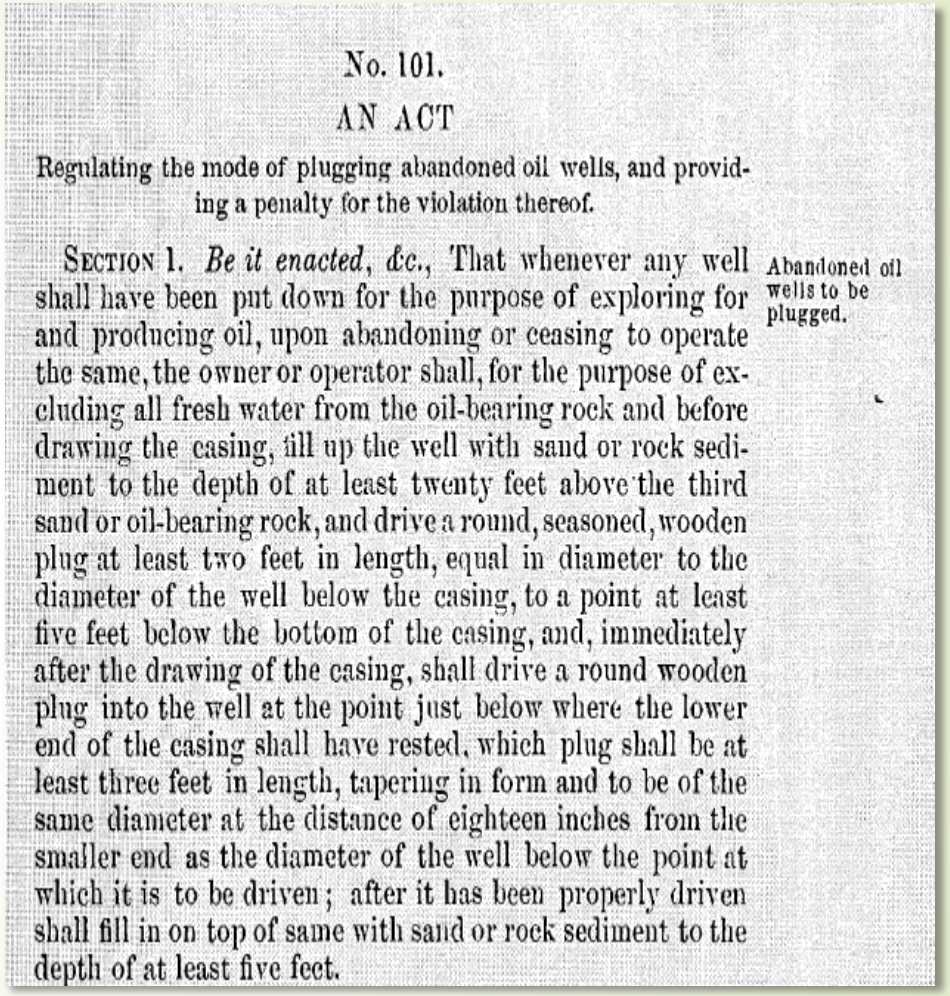
Source: PA DEP

Prioritizing Regulation of Well Plugging

Source: CSR Services

The Need for Plugging Regulations

- As more wells were abandoned, some states began to recognize the need for development of standards for well plugging.
- Pennsylvania enacted some plugging regulations in 1881.
- Texas RRC did not assume authority on well plugging until 1919.
- API published its first set of plugging standards and classes of cement in 1952.



No. 101.

AN ACT

Regulating the mode of plugging abandoned oil wells, and providing a penalty for the violation thereof.

Abandoned oil wells to be plugged.

SECTION 1. *Be it enacted, &c.*, That whenever any well shall have been put down for the purpose of exploring for and producing oil, upon abandoning or ceasing to operate the same, the owner or operator shall, for the purpose of excluding all fresh water from the oil-bearing rock and before drawing the casing, fill up the well with sand or rock sediment to the depth of at least twenty feet above the third sand or oil-bearing rock, and drive a round, seasoned, wooden plug at least two feet in length, equal in diameter to the diameter of the well below the casing, to a point at least five feet below the bottom of the casing, and, immediately after the drawing of the casing, shall drive a round wooden plug into the well at the point just below where the lower end of the casing shall have rested, which plug shall be at least three feet in length, tapering in form and to be of the same diameter at the distance of eighteen inches from the smaller end as the diameter of the well below the point at which it is to be driven; after it has been properly driven shall fill in on top of same with sand or rock sediment to the depth of at least five feet.

Source: PA DEP

Historic Regulations

- 1980 SDWA Amendments creates the UIC Program. This resulted in the ultimate development of an Underground Source of Drinking Water (or USDW). Or, a current or potential underground drinking water source, having 10,000 mg/L TDS or less.
- State oil & gas regulations vary. Some states had different terms (e.g., Base of Fresh Water). Definitions and time frames varied.
- Many historic regulations only protected water that may be used for irrigation and were focused on keeping water formations from contaminating oil producing zones.
- Historically, methods for assessing these zones, that we now strive to protect, were less than ideal. Some historic records might include notes such as "tastes salty".

Source: Dan Arthur

Source: Dan Arthur

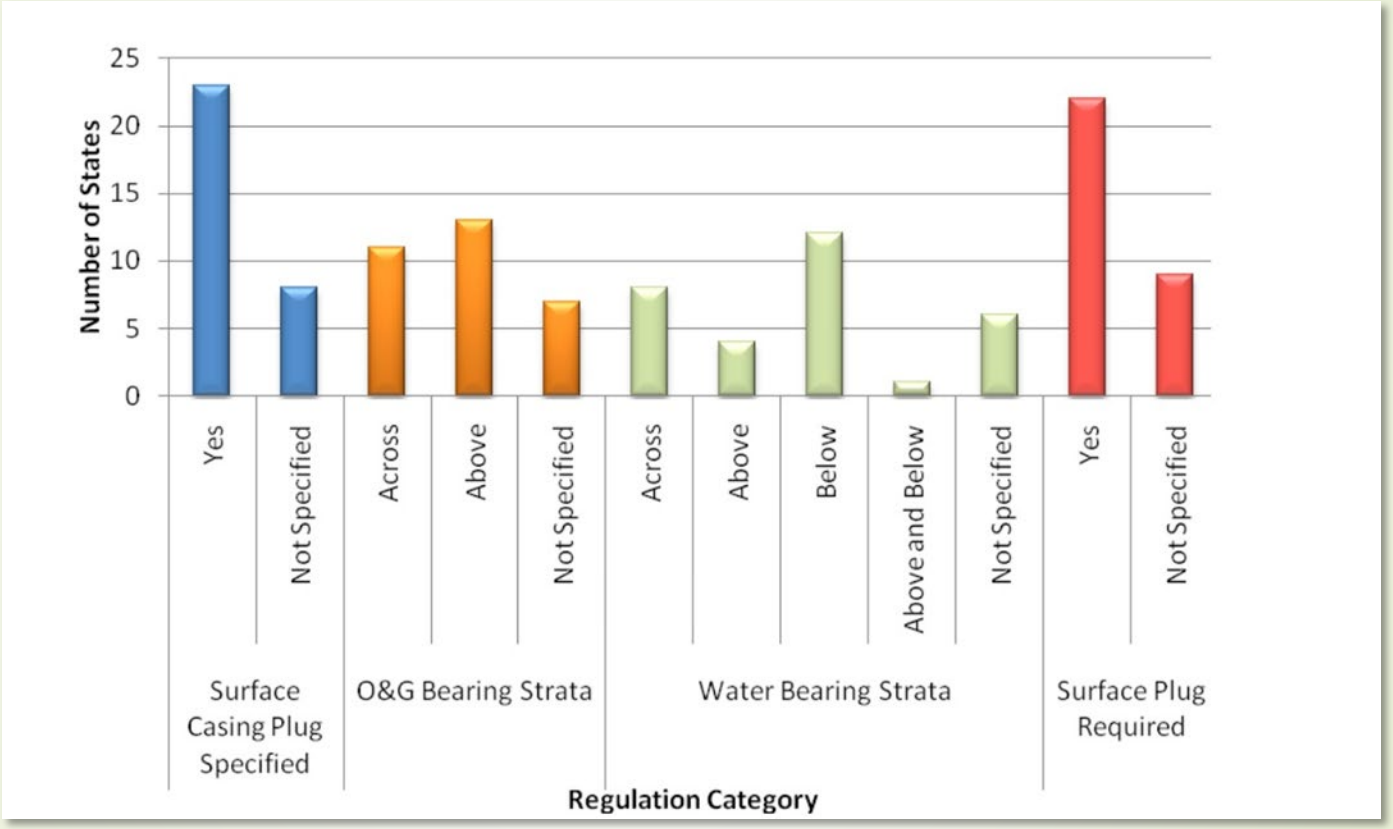
Plugging Regulations and Priorities

- Plugging requirements vary by jurisdiction but involve a combination of technical standards and administrative procedures.
- At least 30 states, Bureau of Land Management, and the U.S. Forest Service have developed plugging requirements for oil and gas wells.
- Wells are often scored with a matrix-type system to determine plugging priority.

Prioritization Factor	Number of States
Water resource impacts	21
Leaks and spills	18
Well depth, age, and/or condition	18
Threat to public health and safety	16
Threat to environment	13
Proximity to people	13
Impacts to other land use	11
Budgetary and technical considerations	8
Environmental justice	5
Impact to soils	3
Other	14

Source: IOGCC

Elements of State Plugging Regulations



Source: GWPC

Development Near Abandoned Wells

- Some oil and gas states have regulatory requirements for development around old wells including:
  - Notification,
  - Safety Precautions,
  - Permitting Requirements,
  - Monitoring Requirements, and
  - Financial Assurance.
- While other states have no regulatory guidelines regarding development and construction near or over top of old abandoned wells.

Source: Welldone Foundation

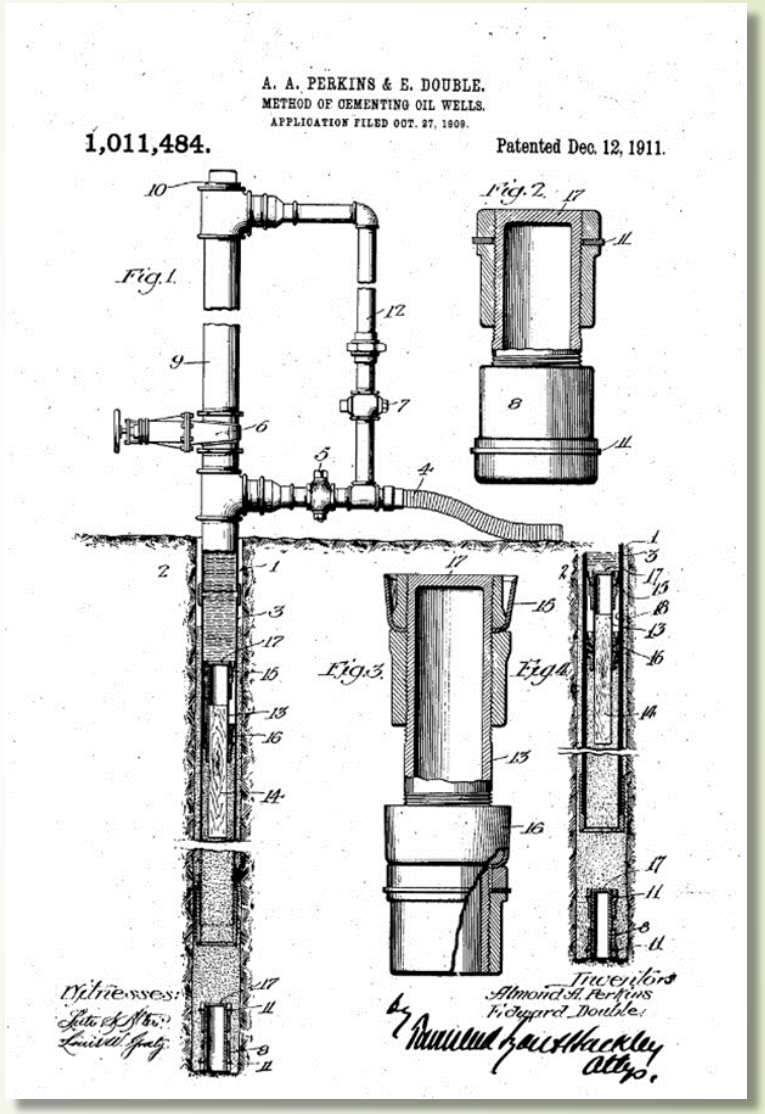
Brief History of Well Construction

- Very early drilling methods involved spring poles, but was quickly replaced by cable tool rigs, and then later by rotary tools which started in the 1880s but becoming prevalent by the 1920s.
- Today, most wells are drilled with rotary rigs, but cable tools still see some limited use in the Appalachian Basin.
- Early on, well casing was used exclusively to isolate water-bearing formations from impacting oil and gas producing formations.
- If a well was a dry hole or later abandoned, casing strings were normally withdrawn from these wells.
- During World War II many steel casings were pulled out of old oil and gas wells for the was effort.

Source: Oklahoma Historical Society

Historical Cementing Practices

- Prior to the early 1910s, oil and gas well casings were not cemented.
- Cement was first used in California in 1903.
- With the development of the Perkins two-plug method in 1911, cementing of casings started to be more common by the 1920s.
- Initially, all cements were Class A Portland cement, but later development by the 1930s led to the use of Class C, G, and H cement blends.


A. A. PERKINS & E. DOUBLE.
METHOD OF CEMENTING OIL WELLS.
APPLICATION FILED OCT. 27, 1909.
1,011,484. Patented Dec. 12, 1911.
Fig. 1.
Fig. 2.
Fig. 3.
Fig. 4.
Witnesses:
Inventors
Almond A. Perkins
Edward Double

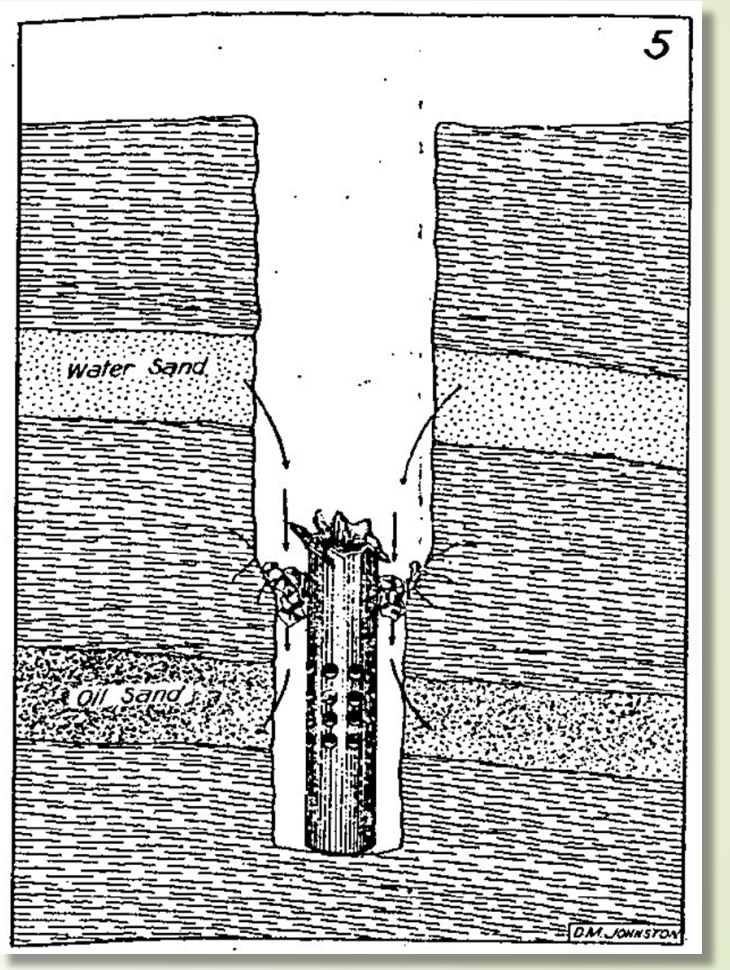
Source: Patent Images

Early Plugging Practices

Source: ODNR

Poor Plugging Methods

- During the early period of oil and gas development, hazards caused by pulling casing was either unrecognized or ignored.
- This led to "flooding" out of oil and gas reservoirs by shallower water zones.
- Early regulations in California, Gulf Coast, Pennsylvania, and Texas were passed to address this problem.



California Dept. Petroleum and Gas of State Mining Bureau

How These Old Wells Were Plugged

- The building of a "bridge" was the first step in plugging a well above the oil and gas zone.
- A bridge could be a lead plug or wooden plug driven down the wellbore directly above the oil or gas zone.
- Then rock sediment, dirt, cement or clay was typically dumped on top of the plug with a dump bailer.
- Another common method was a "brush and stone" bridge, where a small tree was cut down and driven down the wellbore and then large stones dropped on top of it to create the "bridge".

Source: PA DEP

Additional Plugging Methods

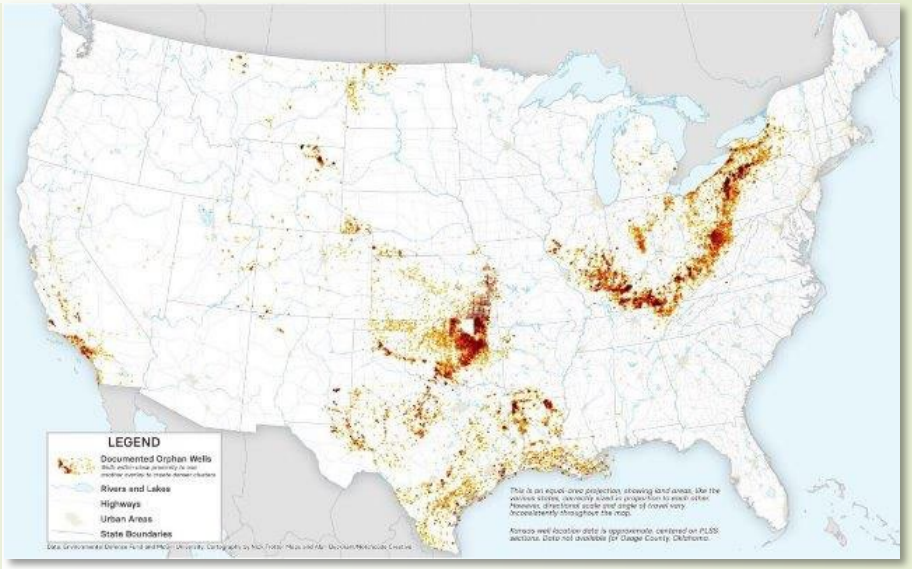
- Since cable tool holes were tapered (slim holed)as you went deeper after setting multiple water strings, pre-cast concrete plugs were used instead of other bridging material.
- These pre-case plugs would be dropped from the surface and seal on the casing seat and then clay or other plugging material was typically emplaced on top of them.

Source: Westernex

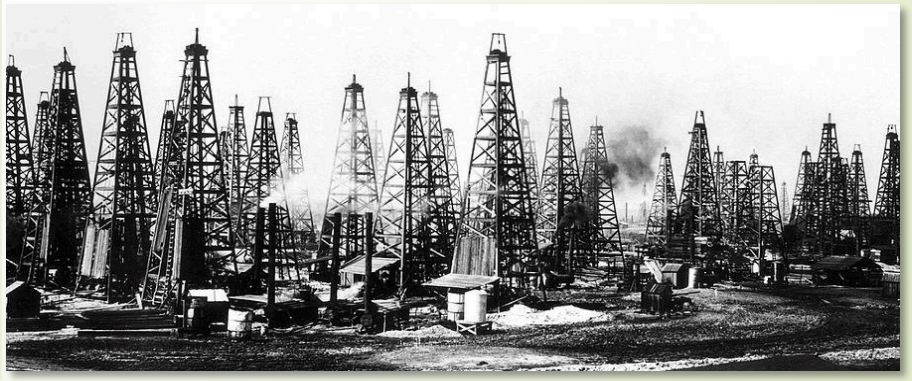
LOCATING ORPHANED & ABANDONED WELLS

Well Locations & Variations

- OAWs exist throughout the US have *MANY* different issues:
  - Surface Considerations (e.g., rural or city, etc.)
  - Ecosystems & Environments,
  - Geologic Settings,
  - Well Configurations,
  - Past Production Histories,
  - And more…
- Wells can also vary by age, drilling methods, area historic practices, downhole environment (e.g., highly corrosive environments), etc.
- Issues may vary widely and should be considered in planning safety & plugging operations.



Source: 81,000 wells per Environmental Defense Fund & McGill University, 2022



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Methods Used for Locating Orphan Wells

- Historic & Records Research
  - State and Federal Records
  - Published and unpublished historic maps
  - Published reports or documents
  - Historic & Public Records
  - Newspapers & Publications
- Field Surveys
  - Physical Searches
  - Magnetometer
  - Gas Detector and Resistivity/Conductivity Instruments
  - Infrared Imaging
  - Drones

Sources: NYDEC & ODNR

Historic Maps, State Records, Etc.

Historic & Records Research

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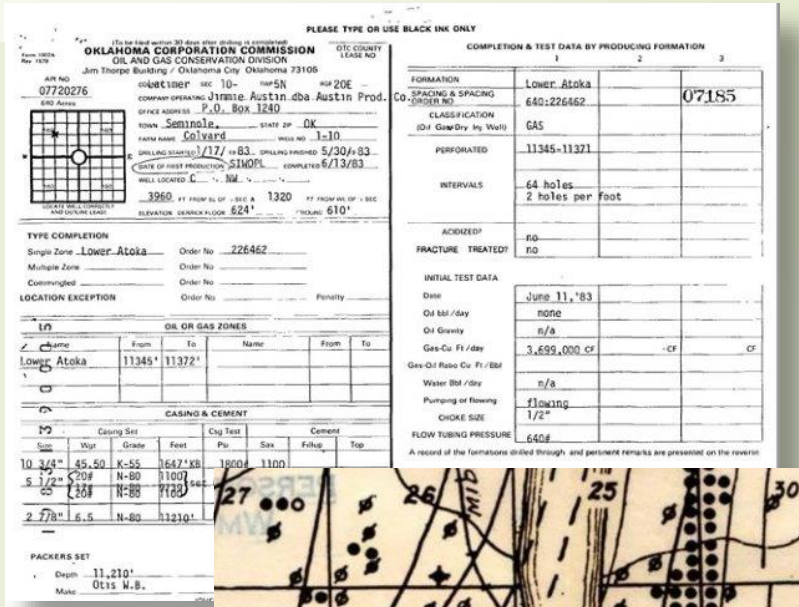
- Newspapers & Publications



PLEASE TYPE OR USE BLACK INK ONLY

OKLAHOMA CORPORATION COMMISSION
OIL AND GAS CONSERVATION DIVISION
Jim Thorpe Building / Oklahoma City, Oklahoma 73105

API NO 07720276

OPERATOR Jimmie Austin dba Austin Prod. Co.
OFFICE ADDRESS P.O. Box 1240
TOWN Seminole STATE OK ZIP
FARM NAME Colvard WELL NO 1-10
DRILLING STARTED 5/17/83 DRILLING FINISHED 5/30/83
DATE OF FIRST PRODUCTION SIWOPL COMPLETED 6/13/83
WELL LOCATED C NW
3960 FT FROM SL OF SEC & 1320 FT FROM WL OF SEC
ELEVATION DERRICK FLOOR 624' GROUND 610'

TYPE COMPLETION
Single Zone Lower Atoka Order No 226462
Multiple Zone Order No
Commingled Order No
LOCATION EXCEPTION Order No Penalty

OIL OR GAS ZONES

Name	From	To	Name	From	To
Lower Atoka	11345'	11372'			

CASING & CEMENT

Size	Wgt	Grade	Feet	Csg Test PSI	Cement Sax	Fillup	Top
10 3/4"	45.50	K-55	1647' KB	1800#	1100		
5 1/2"	20#	N-80	11007				
	17#	N-80	9728		562		
	20#	N-80	1169				
2 7/8"	6.5	N-80	11210'				

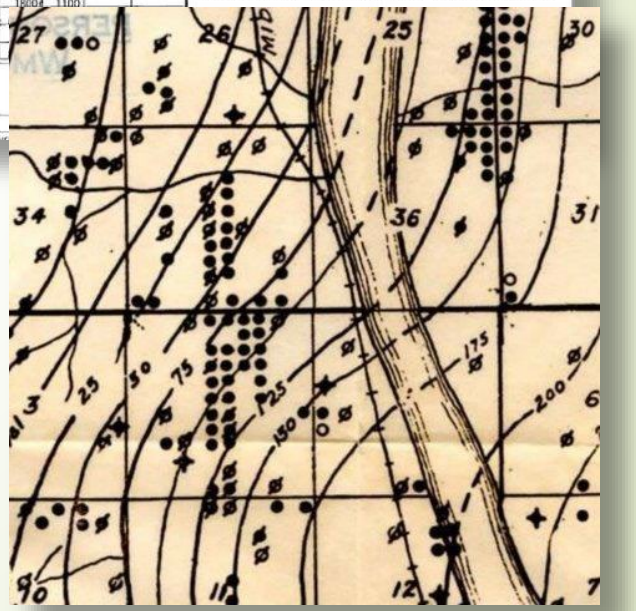
PACKERS SET
Depth 11,210'
Make Otis W.B.

COMPLETION & TEST DATA BY PRODUCING FORMATION

	1	2	3
FORMATION	Lower Atoka		07185
SPACING & SPACING ORDER NO	640:226462		
CLASSIFICATION (Oil, Gas, Dry, Inj, Well)	GAS		
PERFORATED	11345-11371		
INTERVALS	64 holes 2 holes per foot		
ACIDIZED?	no		
FRACTURE TREATED?	no		
INITIAL TEST DATA			
Date	June 11,'83		
Oil bbl/day	none		
Oil Gravity	n/a		
Gas-Cu Ft/day	3,699,000 CF	-CF	CF
Gas-Oil Ratio Cu Ft/Bbl			
Water Bbl/day	n/a		
Pumping or flowing	flowing		
CHOKE SIZE	1/2"		
FLOW TUBING PRESSURE	640#		

A record of the formations drilled through and pertinent remarks are presented on the reverse.

Source: Oklahoma Corporation Commission

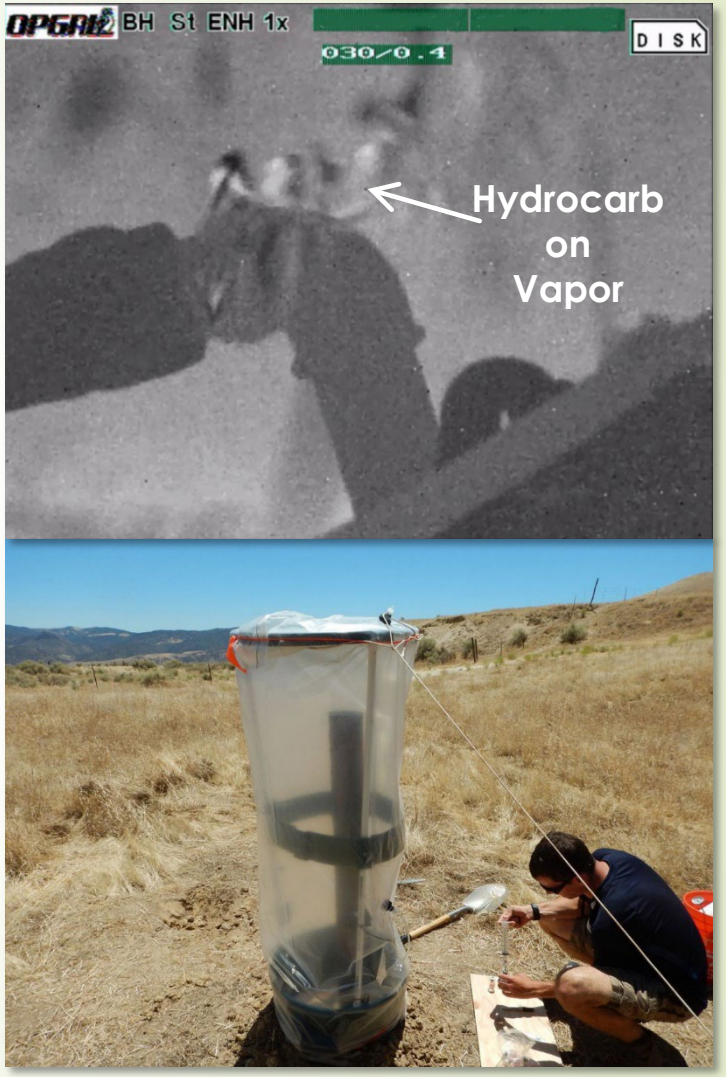


Source: Oklahoma Geological Survey

Characterizing & Measuring methane and other gas emissions or potential emissions

Greenhouse Gas Emissions

- Many wells may not be emitting 100% of what they could produce if and or when the existing equipment fails. Emissions could be greater!
- Emissions could be escaping the well below the top of the well and could be creating seeps through the ground.
- Connected piping could be leaking, away from the wellhead.
- Accurate measurements using standard methods may be required if Carbon Credits or Tax Credits will be pursued.



Sources: ALL Consulting, LLC and DOE NETL

Methane Emissions

- Methane can be observable and measurable
- Estimated to be several million metric tons per year across the U.S.
- May exceed lower explosive limits (LEL)
- Contributes to greenhouse gas emissions

LEL

Source: ALL Consulting

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Gas Measurement

- There are several quantification tools and methods available.
- Methods & equipment should align with the situation & may vary by project.
- If pursuing carbon credits, make sure the method you choose is accepted by the carbon registry you intend to use.

Source: DOE NETL

Source: Alicat Scientific

Source: Science Direct

Source: Ventbuster Instr.

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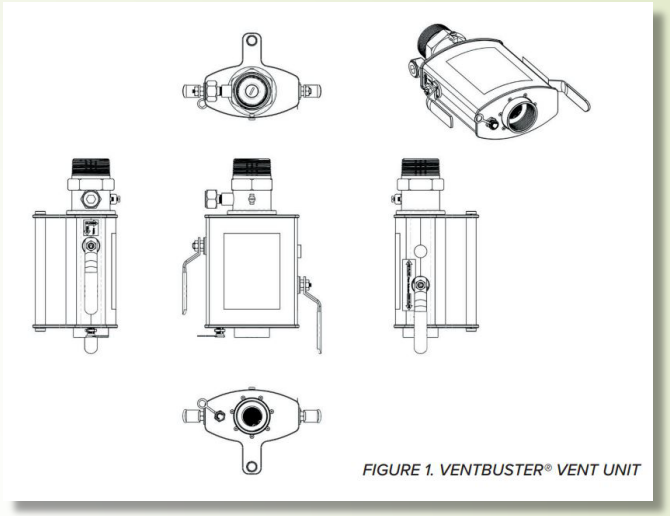
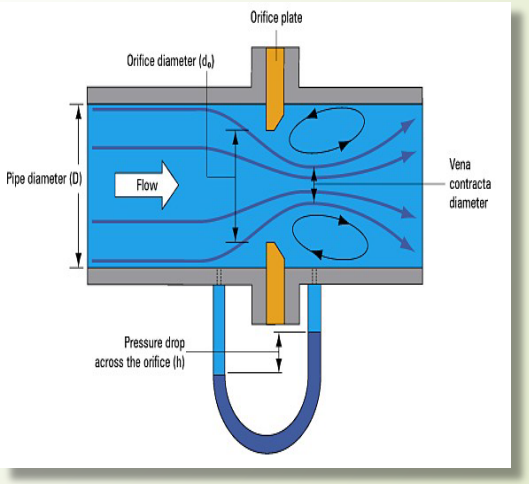
Flow Rate

- Ventbuster
  - Measures continuous and intermittent venting.
  - Data is collected electronically.
  - "One bubble in 10 minutes" to over 450 m3/day.
- Orifice Well Tester can use liquid manometers in very cold weather.
- These measurements should be repeated over time.
- Measurements following recent precipitation should be avoided.



Ventbuster flow measurement instrument
Source: Ventbuster



Orifice Well Tester diagram
Source: Refinery Supply

Methane Concentrations

- Non-Specific Gas instruments
  - Are used over time.
  - Are calibrated to the gas-specific instruments.
  - Used to determine methane concentrations over time.
- Gas-Specific instruments
  - Field *off-axis tunable diode laser absorption spectroscopy* or other field gas chromatography.
  - Grab samples used to calibrate the non-specific gas instruments.
- Importance of Calibration and Record Keeping

Teledyne PS 500 Non-Specific Gas Detector
Source: Teledyne

MicroGuard using Off Axis Integrated Cavity Output Spectroscopy
Source: ABB Measurement & Analytics

Well Emissions

- Annular cement can prevent fluid migration up or down borehole-casing interface.
- Methane Molecules
  - Much smaller and lighter than water molecules
  - Can move through smaller spaces.
  - Can move up the well.
  - Can even move away from the well.

Abandoned Well Surface Casing

Source: ALL Consulting

Quantifying Emissions

- Ground-based, methane-specific measurement methods offer a high degree of sensitivity (1 gram of methane per hour or less)
- Flow chamber may be utilized to capture and measure emissions.
- An appropriate monitoring duration should be used to accurately estimate a daily average flow rate over multiple seasons.

Flux Chamber with Flow Rate Measurement Instrument

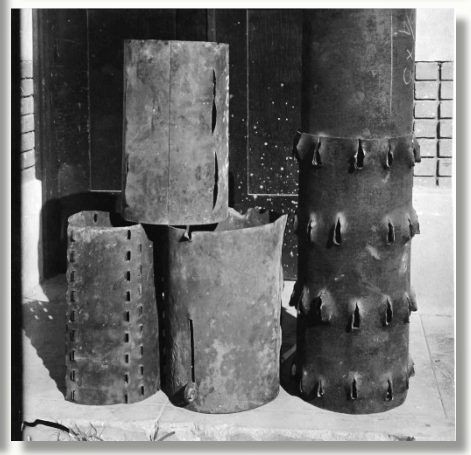
Source: Well Done Foundation

Infrared Imaging

During ground searches, infrared gas imagery helps find natural gas leaks in wells and in production equipment.

- Methane gas absorbs infrared radiation strongly at the wavelengths of 3.3 micrometers (μm) and 7.6 μm.
- The camera used features an optical narrow band pass filter at 3 μm to 5 μm.
- Background infrared radiation is absorbed by the escaping methane gas, causing it to appear as smoke or fog.

Hydrocarbons exceed the LEL



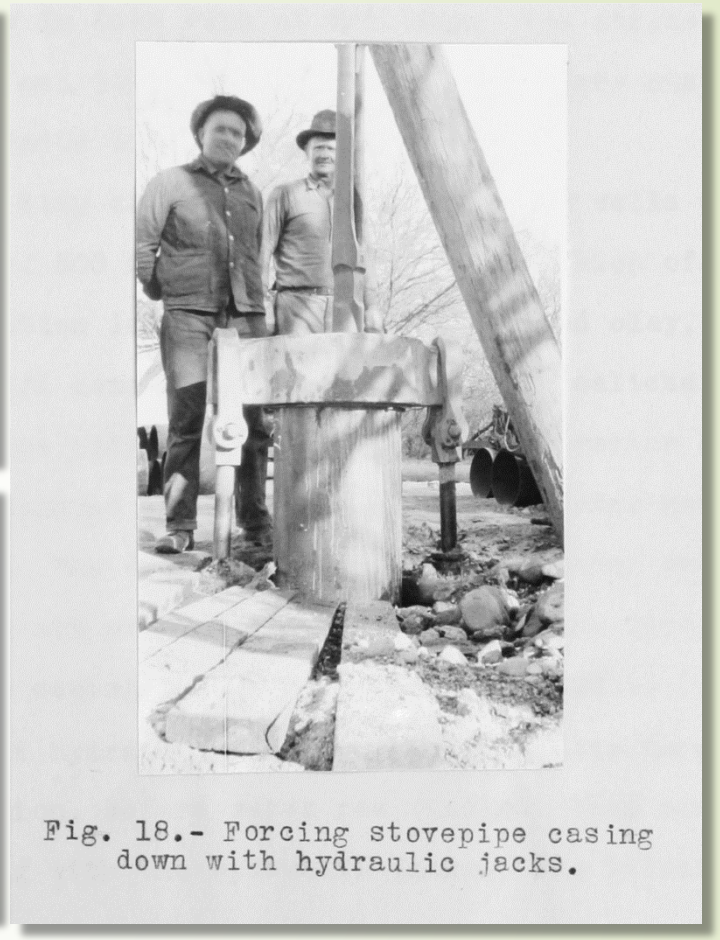


Fig. 18.- Forcing stovepipe casing down with hydraulic jacks.

PLANNING & MANAGING RISKS

Critical Risks & Considerations

Multi-disciplinary teams are needed to address numerous well field conditions:

- Methane is a highly flammable Volatile Organic Compound (VOC) and a Green House Gas (GHG).
- Hazards may exist for people and the environment at the surface.
- Understanding site geology plays a role in successful plugging operations.
- Past plugging operations and even current well plugging operations haven't always been designed to effectively eliminate VOC emissions (primarily methane).
- Failure to understand and effectively plan & implement plugging operations can create significant future risks/problems.
- Plugging only a few wells in a field may increase emissions from some remaining wells.

A former Clinton production well in Lorain County, Ohio, plugged in 1922 and found leaking Methane after development of an Apartment Complex. To address the leaking methane, a vent system was installed for safety purposes. The well has not been re-plugged.
Source: ALL Consulting, LLC

Risks at the Surface

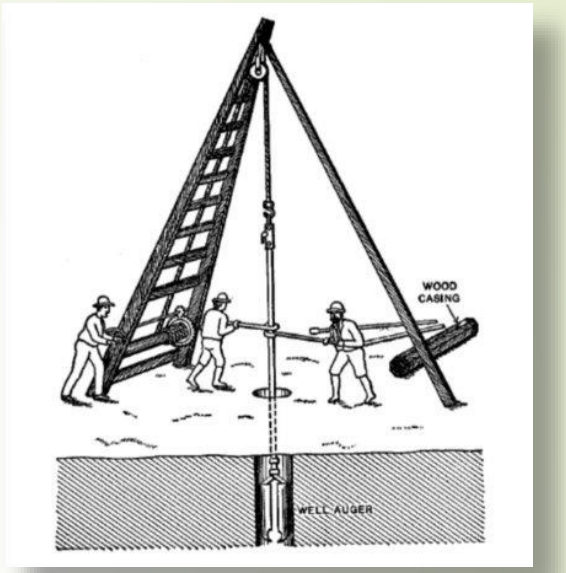
- Potential hazards to human health and safety
- Potential environmental hazards
- Value of Old Equipment
- Well location issues
  - Under Water
  - Under Structures
  - Adjacent to Gas Storage
  - Etc.

Sources: ALL Consulting and Source: Brian Best & Facebook Oil History Group

Early Development of Oil & Gas

Early well drillers had different interests than exploration and operating companies have today. In some instances, well casings were not cemented, and natural gas was purposely vented to the atmosphere.

- Surface casings were largely used to prevent fresh water (or even brackish/saline water) from contaminating oil reservoirs!
- With cable-tool holes casings were not cemented and gas vented to the atmosphere.
- Sometimes steel casings were removed, and wells were inadequately plugged or not plugged at all. Making well location using a magnetometer impossible! This is the case, for example, at Turkey Mountain here in Tulsa (but also many other places).



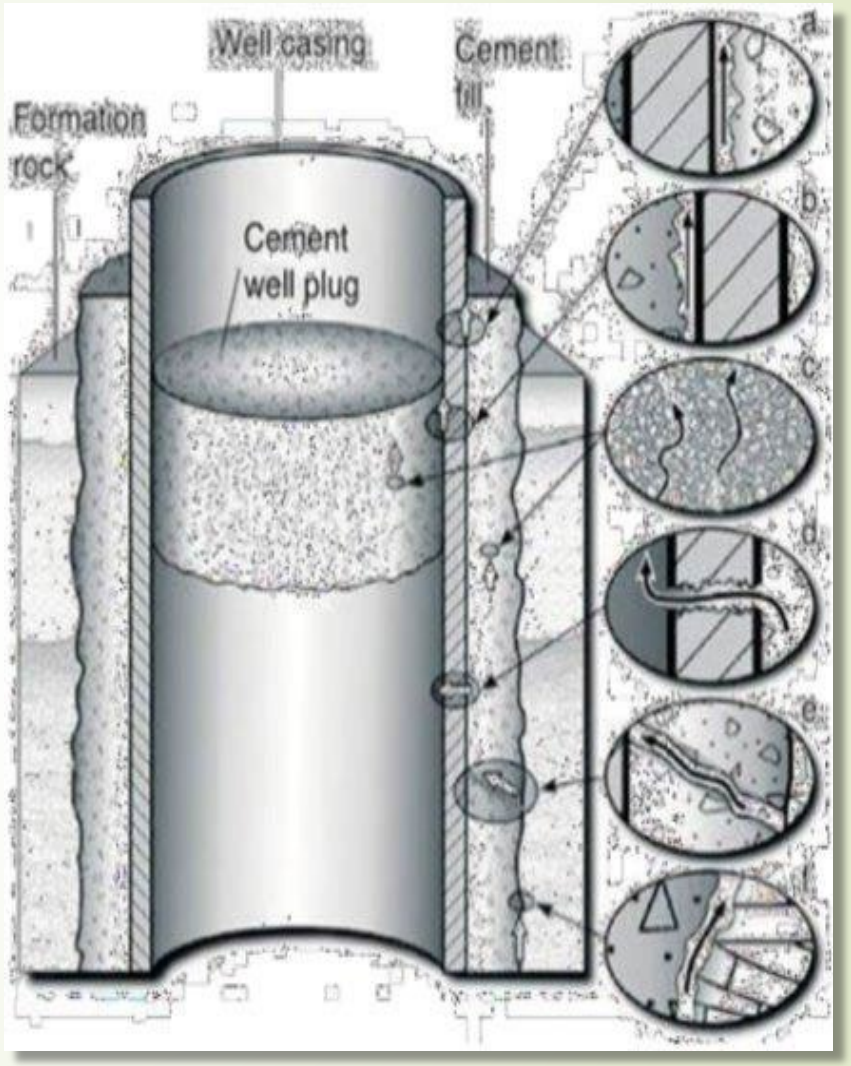
Source: Well Drilling Methods, Isaiah Bowman, 1911

Source: ALL Consulting

Recognizing Stray Gas Emission Potential

During well construction, potential stray gas issues can be reduced with an understanding of over-pressured and under-pressured zones in the vertical portion of the well and appropriate cementing to surface.

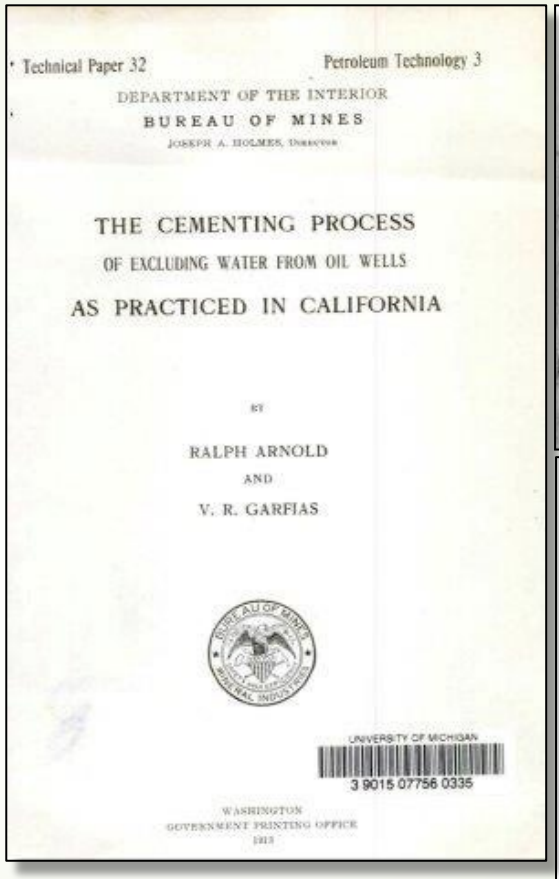
- Vertical Gas Migration
  - Gas Enters into Borehole
  - Gas Exits the Borehole (surface or into shallow formations)
- *Expanded plugging procedures may be required in some cases.*



Source: US DOE

Understanding History Is CRITICAL!

- Historic Practices are VERY different from those used today!
- API was not founded until 1919.
- Most States didn't have applicable regulations until the 1930s.
- Industry Practices varied substantially.
- Understanding history & historical practices can reduce risks.


Technical Paper 32 Petroleum Technology 3

DEPARTMENT OF THE INTERIOR
BUREAU OF MINES
JOSEPH A. HOLMES, Director

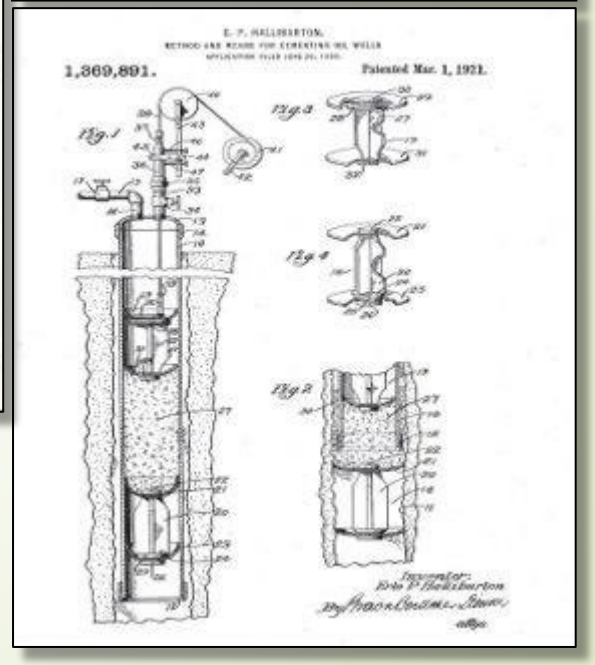
THE CEMENTING PROCESS
OF EXCLUDING WATER FROM OIL WELLS
AS PRACTICED IN CALIFORNIA

BY

RALPH ARNOLD
AND
V. R. GARFIAS

UNIVERSITY OF MICHIGAN
3 9015 07756 0335

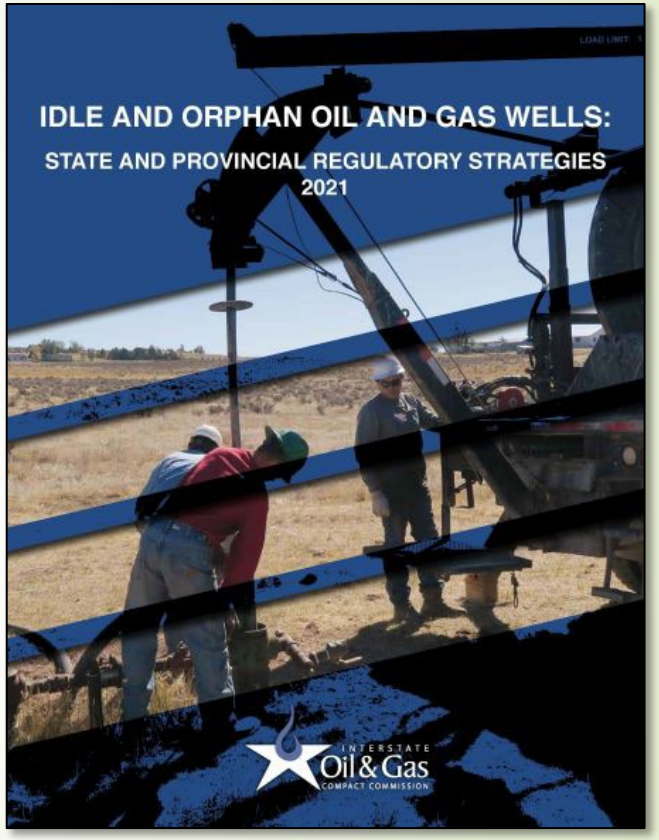
WASHINGTON
GOVERNMENT PRINTING OFFICE
1913


1,369,891. Patented Mar. 1, 1921.

Sources: Various

IOGCC & GWPC

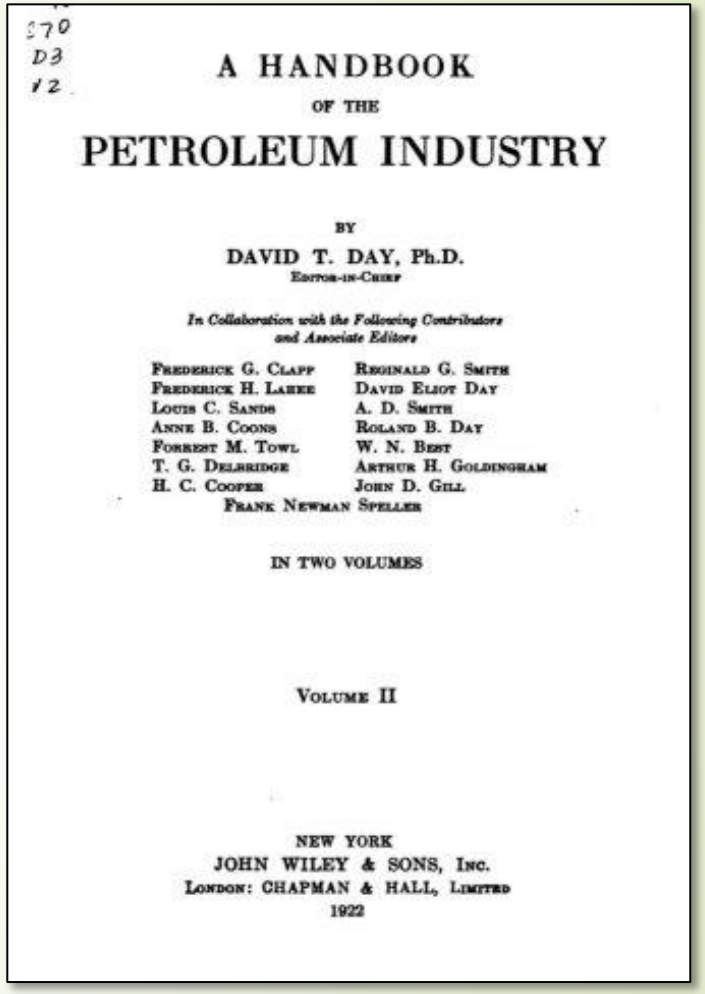
- The Interstate Oil & Gas Compact Commission (IOGCC) and Ground Water Protection Council (GWPC) represent member states and various regulatory programs applicable to Orphan Wells.
- These organizations have done training and collaboration regarding many issues, such as induced seismicity, gas storage, underground injection, public disclosure of hydraulic fracturing chemicals, and also orphan well plugging.
- Neither IOGCC nor GWPC are regulatory bodies, but they have facilitated evolutionary changes in state and federal regulations and practices.



Well Plugging from 1922

A Handbook of the Petroleum Industry, Vol. 1, 1922

- Wooden plugs 2-ft. to 4-ft. long driven to a point between the oil sand and the nearest water-bearing stratum above, with clay or cement placed on top.
- Cement alone, emplaced for some distance using a dump bailer or by tremie.
- Lead plugs in hard formations, battered into place using tools and expanded to form a bond with the borehole wall.
- Portion of casing above was sheared off using nitroglycerine and removed.



TN870 D3 v.2

A HANDBOOK
OF THE
PETROLEUM INDUSTRY

BY
DAVID T. DAY, Ph.D.
Editor-in-Chief

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H. C. Cooper — John D. Gill
Frank Newman Speller

IN TWO VOLUMES

VOLUME II

NEW YORK
JOHN WILEY & SONS, Inc.
London: CHAPMAN & HALL, Limited
1922

Source: A Handbook of the Petroleum Industry, Vol. II, 1922

National Petroleum Council

Plugging and Abandonment of Oil and Gas Wells, Paper #2-25, National Petroleum Council, 2011

- Prior to Modern Standards (1950):

  "Many wells were abandoned with plugs consisting of brush, wood, paper sacks, linen or any other material that could be pushed into a well to form a basis for the dumping of one or two sacks of cement to "plug" the well" *

- Modern cement additives enhance performance:

  Retarders, accelerators, Pozzaline, Lost Circulation Materials, Density/Weight additives, Light-Weight additives, and Water-Loss additives.

* - Ide, S., Friedmann, S., and Herzog, H. (2006) CO2 Leakage through Existing Wells: Current Technology and Regulations, 2006

Surface Environments

Risk assessments are necessary to plan for potential hazards:

- Potential hazards to human health and safety
- Potential environmental hazards
- Value of Old Equipment
- Well location issues
  - Under Water
  - Under Structures
  - Adjacent to Gas Storage
  - Etc.

Sources: ALL Consulting and Source: Brian Best & Facebook Oil History Group

WELL PLUGGING CONCEPTS & STRATEGIES

Sources: ALL **Consulting**

Well & Plugging Efforts

- U.S. Department of the Interior recently awarded $560 million to 24 states.*
- Registered contractors:
  - 158 in Pennsylvania*
  - 133 in New York*
  - 170 in Texas**
  - 44 in Ohio***
- Each orphan well requires significant effort by staff.***

Source: New York DEC

Source: Pennsylvania DEP

* - Bloomberg Law July 25, 2022
** - Texas RRC August 2022
*** - Ohio DNR Orphan Well Program Performance Audit, August 2022

Considerations & Resources

- Research & Due Diligence
- Accessibility Considerations
- Historic well construction and integrity issues
- Geologic considerations
- Well control issues
- Fluid/Waste Management
- Controlled venting or flaring if necessary
- Plugging methods

Sources: Dan Arthur/ALL Consulting

Zonal Isolation Methods

Isolating an Uncased Hole, for example a dry hole or when production casing was removed.

- Isolate casing stub, if any
- Balanced cement plugs across producible hydrocarbon zones and injection/disposal zones
- Balanced cement plug below the lowermost freshwater aquifer
- Balanced plugs typical for isolating intermediate zones of concern
- Cement plugs extend 50 feet above and below the zone being isolated
- Balanced cement plugs should extend 50 feet above and below casing shoes found at the top of a long, uncased interval

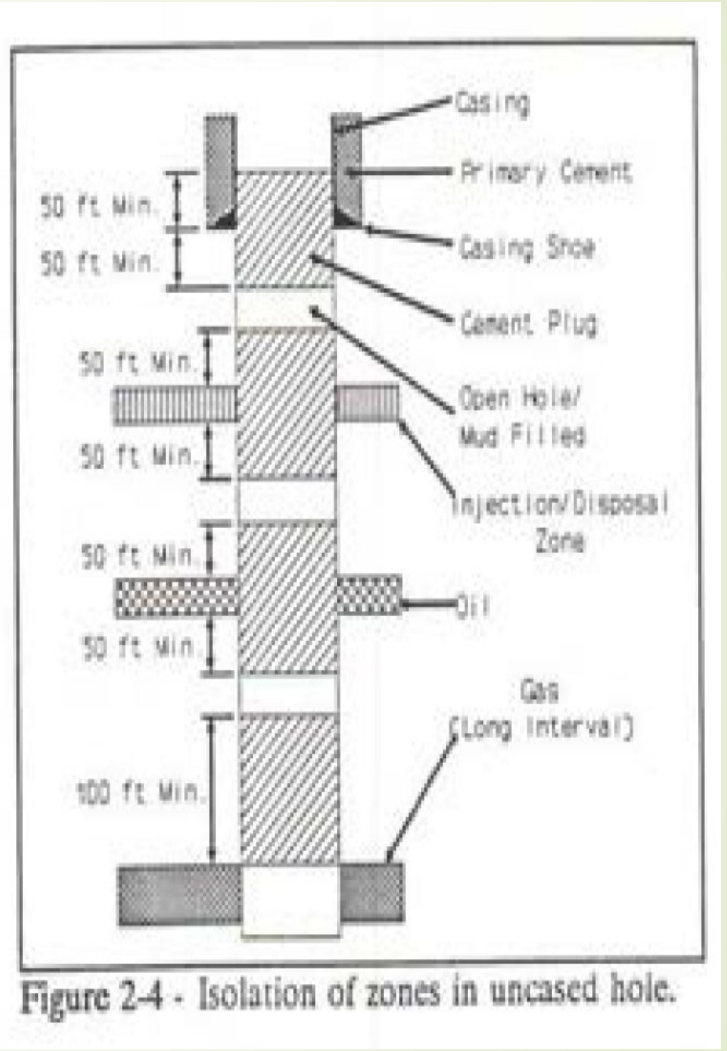

Figure 2-4 - Isolation of zones in uncased hole.

Source: Environmental Guidance Document – Well Abandonment and Inactive Well Practices for U.S. Exploration and Production Operations, 1992, American Petroleum Institute

General Plugging Guides

States provide guidance for well plugging that may differ from one another and from the federal government's guidelines:

- Plugging Intervals
  - Above perforated Intervals
  - Where casing has been cut
  - Base of the lowermost freshwater aquifer
  - Across the surface casing shoe
  - At the surface.
- Plug lengths may be specified locally
- Generally, the minimum plug length is 100 ft.
- Historically, has not addressed plugging materials to mitigate gas migration or stray gas issues.

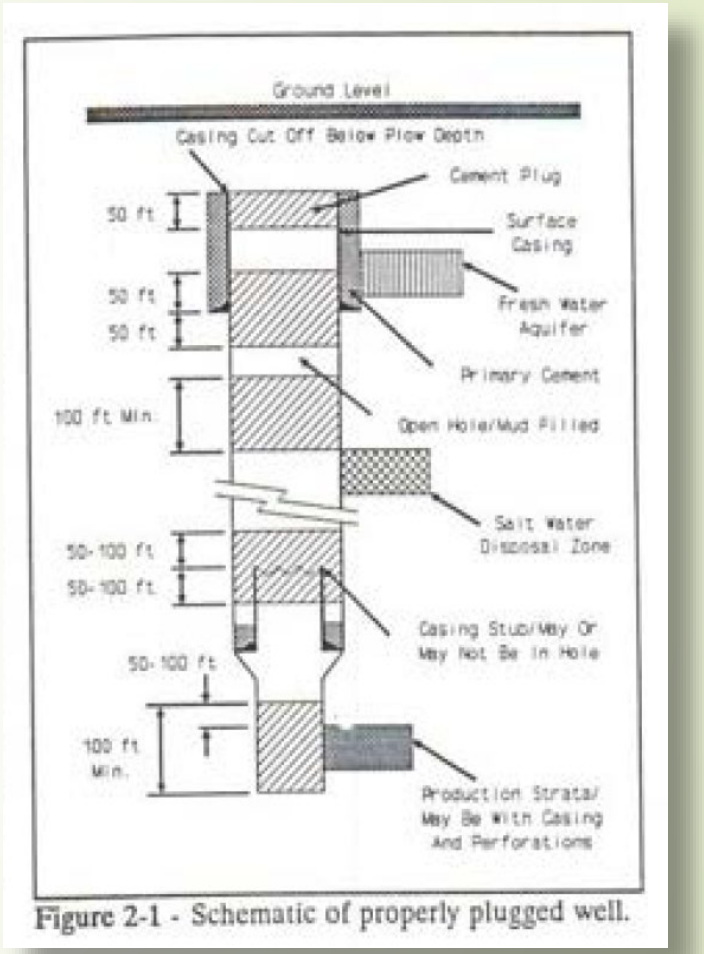

Figure 2-1 - Schematic of properly plugged well.

Source: Environmental Guidance Document – Well Abandonment and Inactive Well Practices for U.S. Exploration and Production Operations, 1992, A

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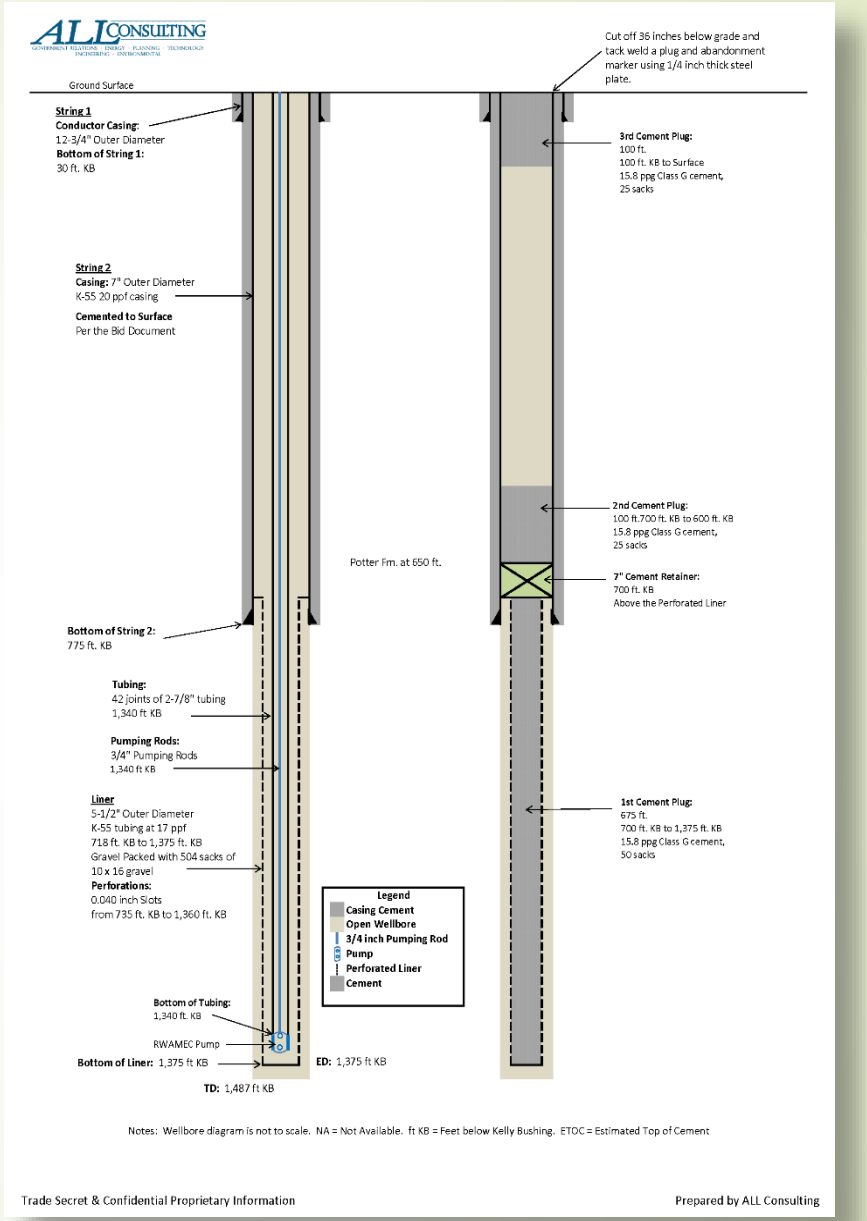
Federal Lands

- Bureau of Land Management Plugging Program:
  - Federal Orphan Well Program funded by the Infrastructure Investment and Jobs Act, 2021
  - Plug wells on Federal lands.
- Site Examination and Inventory
- Field Sampling and Testing
- Site Clean-up
- Wellbore and Well Schematics
- Well Plugging Design
- Execution
- Documentation



Source: ALL Consulting

Biomineralization - Technology

"The only technology proven to fill micro annuli, sealing off the flow of gas and permanently repairing the well."

-- BioSqueeze, 2023

Impervious to Gas Cut

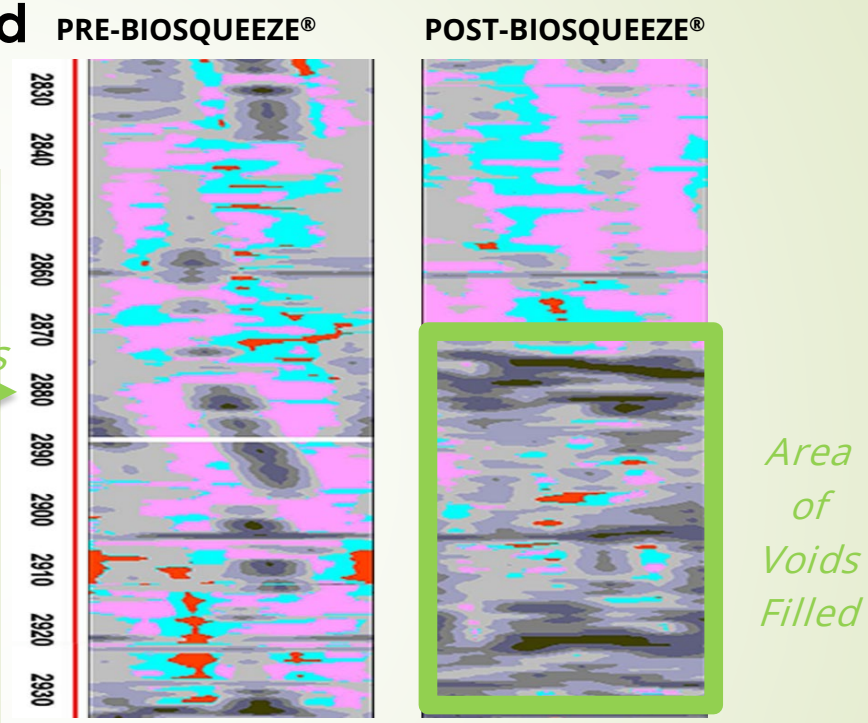
Solids grow crystal by crystal, creating a gas-tight barrier stronger than cement

Low Viscosity

Fluids composed of micron-sized particles, pumped with similar viscosity as water, ideal for sealing long distances vertically along the wellbore.

Self-Diverting Fluids, Superior Radial Distribution

The only fluid technology that continuously reduces permeability throughout injection.



Technology	Minimum Fracture Gap
Bismuth	Can't be pumped
Cement	400 µm
Polymer Resin	310 µm
Nanosealant	200 µm
Epoxy Resin	120 µm
Micro-Fine Cement	120 µm
BioSqueeze®	1 µm

Typical Human Hair is 60 µm Wide

Source: BioSqueeze, 2023

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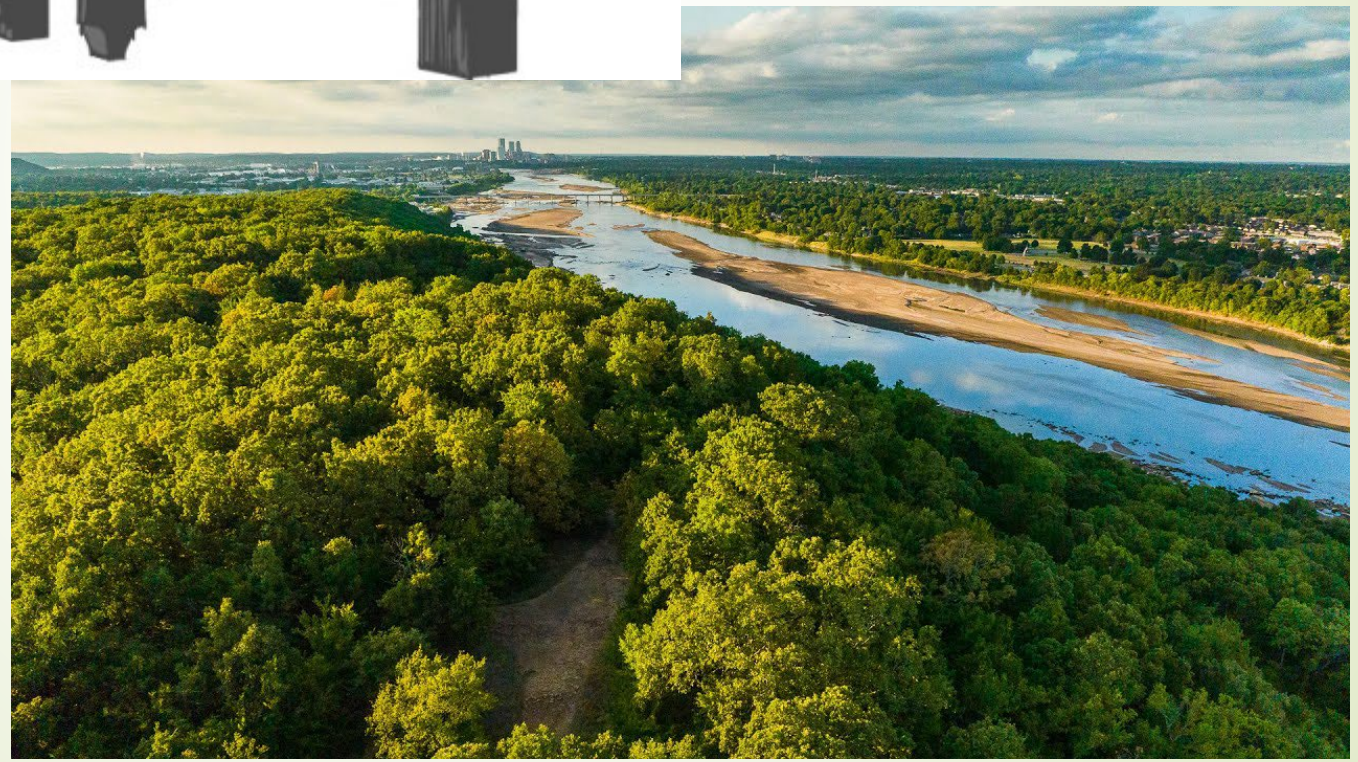
TURKEY MTN
URBAN WILDERNESS AREA



Turkey Mountain Development

- Oklahoma Energy Resources Board
  - Address environmental issues at historical exploration and production sites.
  - Wells that are abandoned with no responsible party and are under the jurisdiction of the Oklahoma Corporation Commission.
- Tulsa Metropolitan Utility Authority and Board
  - Authorized closure of wells between 51st St. and 71st St. South, the Arkansas River and Elwood Ave., in 1997
- Turkey Mountain Urban Wilderness
  - 300 acres
  - Specialty retailer REI to build store at the northwest corner of 71st St and Elwood Ave, next to the Turkey Mountain Urban Wilderness.

Source: Michael Van Valkenburgh Associates

Turkey Mountain

The first drilling attempts pre-dated statehood, and the two most significant drilling programs occurred in the early 1910s and the early 1920s.

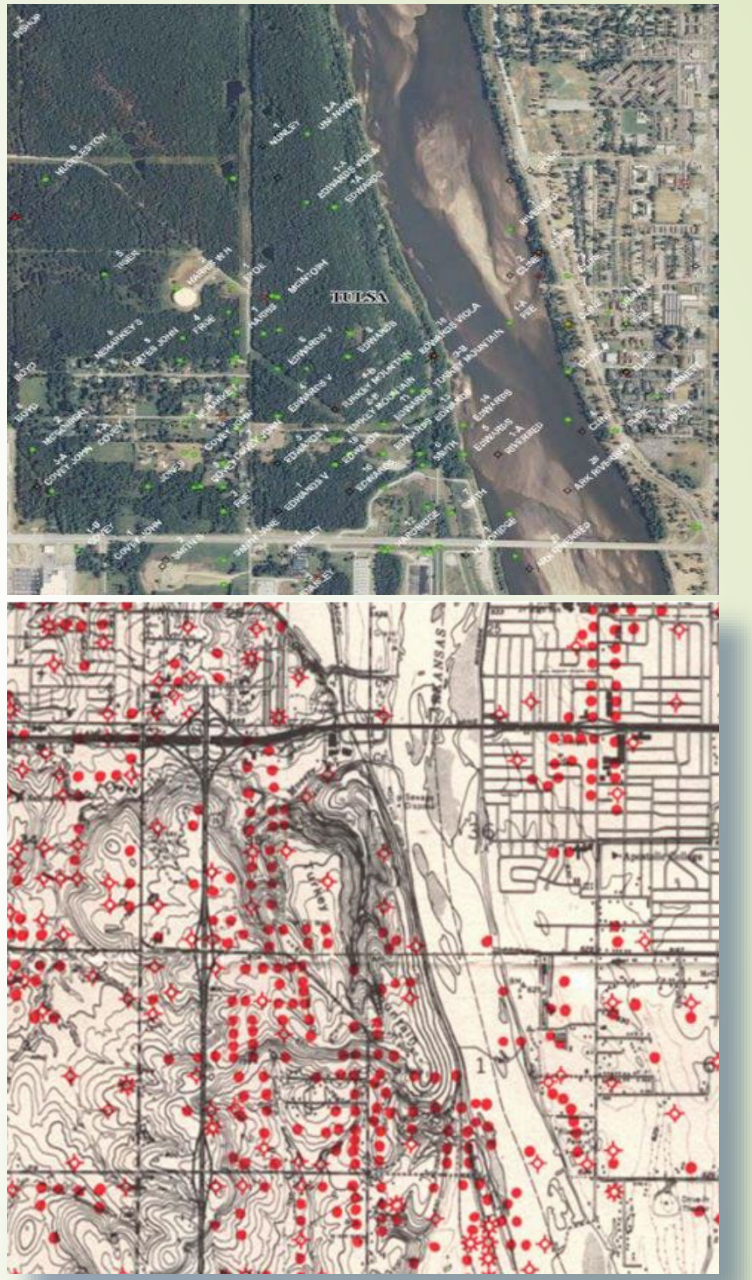
Cable tools, open hole completions, and total depths <2500 feet

Casings not cemented in dry holes.

Most of the wells pre-dated World War II, all of them are now abandoned, although not necessarily properly plugged by modern standards.

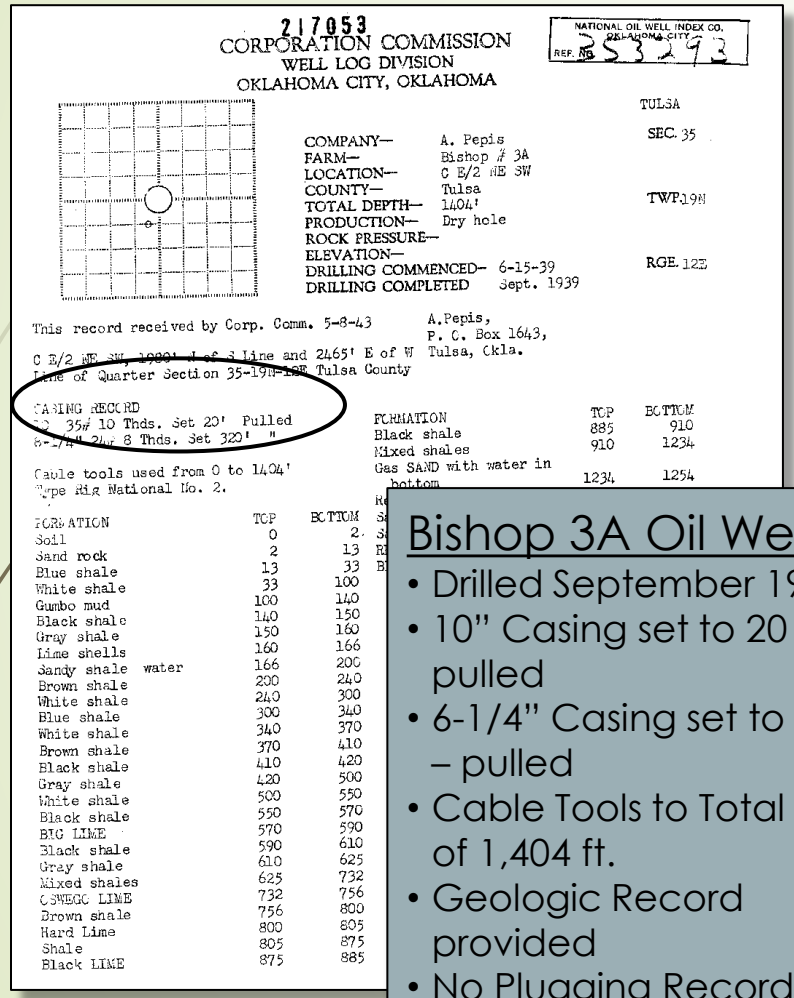
200+ historical well bores, with 75+ within the planned TMUW park outline, an effective well spacing of <10 acres/well.

Source: Ray Sorenson June 20, 2019



Source: Tulsa Geological Society 1972, Tulsa's Physical Environment

Historical Records are often incomplete and contain errors



217053
CORPORATION COMMISSION
WELL LOG DIVISION
OKLAHOMA CITY, OKLAHOMA

NATIONAL OIL WELL INDEX CO.
OKLAHOMA CITY
REF. No. 353293

TULSA
SEC. 35
TWP. 19N
RGE. 12E

COMPANY— A. Pepis
FARM— Bishop # 3A
LOCATION— C E/2 NE SW
COUNTY— Tulsa
TOTAL DEPTH— 1404'
PRODUCTION— Dry hole
ROCK PRESSURE—
ELEVATION—
DRILLING COMMENCED— 6-15-39
DRILLING COMPLETED Sept. 1939

This record received by Corp. Comm. 5-8-43

A.Pepis,
P. O. Box 1643,
Tulsa, Okla.

C E/2 NE SW 1980' N of S line and 2465' E of W line of Quarter Section 35-19N-12E Tulsa County

CASING RECORD
10" 35# 10 Thds. Set 20' Pulled
6-1/4" 24# 8 Thds. Set 320' "

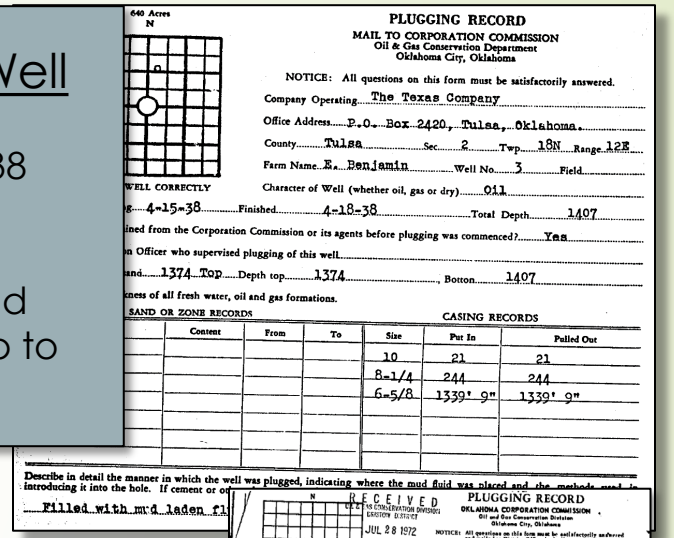
Cable tools used from 0 to 1404'
Type Rig National No. 2.

FORMATION	TOP	BOTTOM
Soil	0	2
Sand rock	2	13
Blue shale	13	33
White shale	33	100
Gumbo mud	100	140
Black shale	140	150
Gray shale	150	160
Lime shells	160	166
Sandy shale water	166	200
Brown shale	200	240
White shale	240	300
Blue shale	300	340
White shale	340	370
Brown shale	370	410
Black shale	410	420
Gray shale	420	500
White shale	500	550
Black shale	550	570
BIG LIME	570	590
Black shale	590	610
Gray shale	610	625
Mixed shales	625	732
OSWEGO LIME	732	756
Brown shale	756	800
Hard Lime	800	805
Shale	805	875
Black LIME	875	885

FORMATION	TOP	BOTTOM
Black shale	885	910
Mixed shales	910	1234
Gas SAND with water in bottom	1234	1254

Benjamin 3 Oil Well

- Drilled in 1911
- "Plugged" April 1938
- All Well Casings Removed
- Hole filled with "mud laden fluid from top to bottom"



640 Acres
N

PLUGGING RECORD
MAIL TO CORPORATION COMMISSION
Oil & Gas Conservation Department
Oklahoma City, Oklahoma

NOTICE: All questions on this form must be satisfactorily answered.

Company Operating The Texas Company
Office Address P.O. Box 2420, Tulsa, Oklahoma.
County Tulsa Sec. 2 Twp. 18N Range 12E
Farm Name E. Benjamin Well No. 3 Field
Character of Well (whether oil, gas or dry) Oil
WELL CORRECTLY
4-15-38 Finished 4-18-38 Total Depth 1407
lined from the Corporation Commission or its agents before plugging was commenced? Yes
n Officer who supervised plugging of this well
and 1374 Top Depth top 1374 Botton 1407
ness of all fresh water, oil and gas formations.

SAND OR ZONE RECORDS

Content	From	To

CASING RECORDS

Size	Put In	Pulled Out
10	21	21
8-1/4	244	244
6-5/8	1339' 9"	1339' 9"

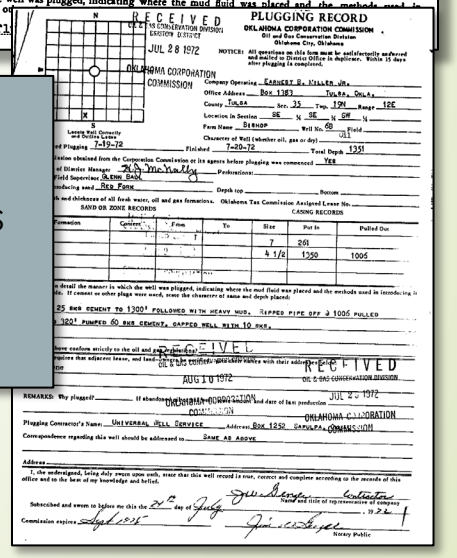
Describe in detail the manner in which the well was plugged, indicating where the mud fluid was placed and the methods used in introducing it into the hole. If cement or ot
Filled with mud laden fl

Bishop 3A Oil Well

- Drilled September 1939
- 10" Casing set to 20 ft. - pulled
- 6-1/4" Casing set to 320 ft. – pulled
- Cable Tools to Total Depth of 1,404 ft.
- Geologic Record provided
- No Plugging Record

Bishop 6B Oil Well

- Dry Hole, Production Casing Cut and 3 Plugs Emplaced in 1972
- No construction record
- No Geologic Record



RECEIVED
OKLAHOMA CORPORATION COMMISSION
JUL 28 1972

PLUGGING RECORD
OKLAHOMA CORPORATION COMMISSION
Oil and Gas Conservation Division
Oklahoma City, Oklahoma

NOTICE: All questions on this form must be satisfactorily answered and mailed to District Office in duplicate. Within 15 days after plugging is completed.

Company Operating Kennedy E. Killen, Jr.
Office Address Box 1383 Tulsa, Okla.
County Tulsa Sec. 35 Twp. 19N Range 12E
Location in Section SE W SE N SW
Farm Name Bishop Well No. 6B Field
Character of Well (whether oil, gas or dry) Oil
Date of Plugging 7-19-72 Finished 7-20-72 Total Depth 1351
Name of Director Manager J.D. McNally Productions:
Field Supervisor Glenn Bass
Producing sand Red Fork Depth top Bottom
Size and thickness of all fresh water, oil and gas formations. Oklahoma Tax Commission Assigned Lease No.
SAND OR ZONE RECORDS
CASING RECORDS

Formation	Content	From	To	Size	Put In	Pulled Out
				7	268	
				4 1/2	1350	1005

Describe in detail the manner in which the well was plugged, indicating where the mud fluid was placed and the methods used in introducing it into the hole. If cement or other plugs were used, state the character of same and depth placed.

25 SKS CEMENT TO 1300' FOLLOWED WITH HEAVY MUD. RIPPED PIPE OFF @ 1005 PULLED
320' PUMPED 60 SKS CEMENT, CAPPED WELL WITH 10 SKS.

RECEIVED
AUG 10 1972
OKLAHOMA CORPORATION COMMISSION

RECEIVED
JUL 28 1972
OKLAHOMA CORPORATION COMMISSION

REMARKS: Why plugged? If abandoned, give date of last production
Plugging Contractor's Name: Universal Well Service Address: Box 1252 Garnett, Kansas
Correspondence regarding this well should be addressed to: Same as above
Address
I, the undersigned, being duly sworn upon oath, state that this well record is true, correct and complete according to the records of this office and to the best of my knowledge and belief.
Subscribed and sworn to before me this 21st day of July, 1972
Commission expires Sept. 1975
Notary Public

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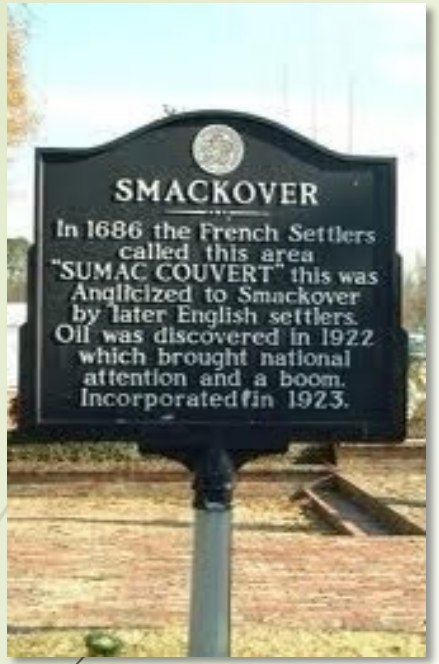
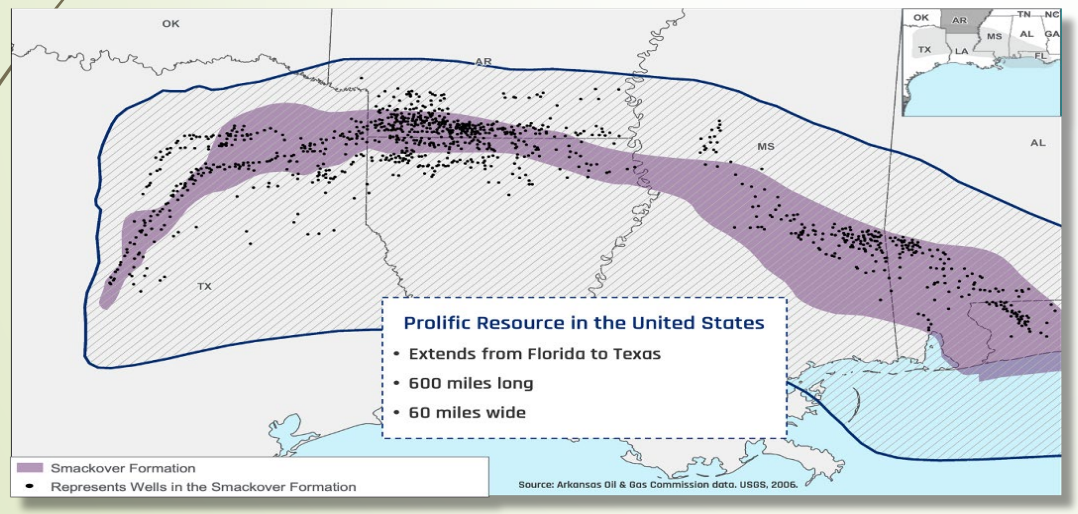
Repurposing Opportunities & options





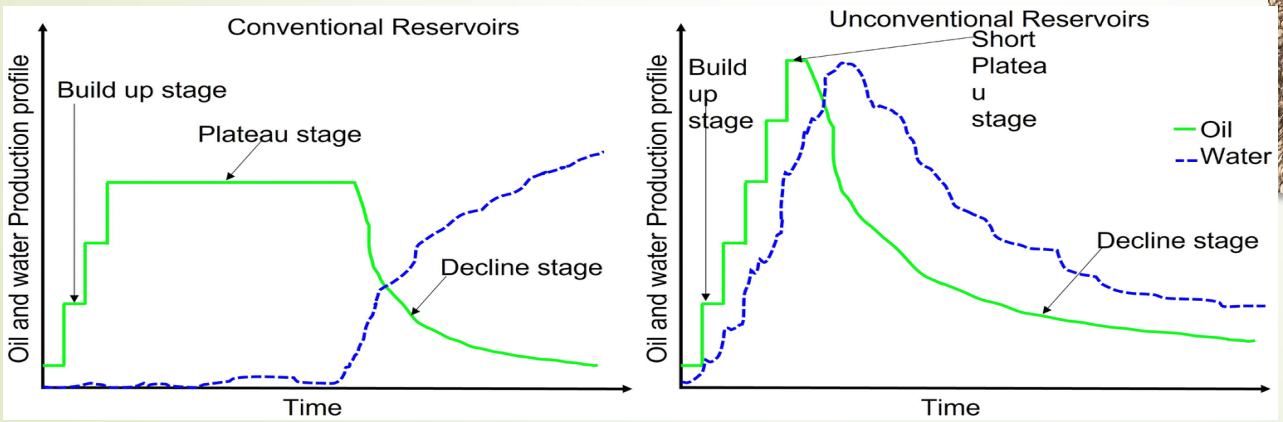
The Smackover FMTN & Lithium

- Some of the highest concentrations of Lithium in groundwater exist in the Reynolds Member of the Smackover Formation.
- Concentrations exceeding 600 mg/L have identified.
- Exxon recently purchased Brine Leases in Lower Arkansas for Lithium Development.

Prioritizing future production potential and mineral owners

Economic life of an oil and/or

- The economic life of an oil and/or gas well can vary by location, well type, conventional vs unconventional, and more.
- Many wells, however, reach their economic life and are made idle for a variety of reasons.
  - Water handling costs
  - Operational costs
  - Hydrocarbon production levels
  - Commodity pricing
  - A lack of alternate producing zones/options
  - Well disrepair/integrity issues
- Economic lifespans of wells has historically avoided considerations such as well plugging and site restoration costs.
- Orphan wells and many (if not most) idle or inactive wells are also past their productive life, especially when plugging and clean-up liabilities are considered.



Long Lasting economics

In Tulsa, Oklahoma, the Sue Bland well has been producing since 1901 and still produces about ¼ BOPD. This was the first well discovered in Tulsa County and has cumulatively produced in excess of a million barrels of crude oil.

However… Wells that have continuously produced for over 100 years are few and far between and most become shut-in, idled, and orphaned. Thus, providing NO economic benefit to the mineral owner and serving as a problem to the surface owner.

Carbon offset considerations related to affected parties

Source: Dan Arthur

Carbon Registry Considerations

Registry	Description	Application
American Carbon Registry (ACR)	The ACR method is currently focused (only) on orphan wells with existing leaks. Methane measuring/metering is a significant component of this methodology and is used to quantify emissions both the before and after well plugging operations.	Orphan wells only, although ACR does plan to include Idle (or "Abandoned") wells at some point in the future.
BCarbon	BCarbon's approach uses traditional Decline Curve Analysis (DCA) combined with a 3-stage leak model to forecast an estimated Methane leak volume over 20 years. Alternative methods of methane emission projection need to be approved by BCarbon.	Both idle and orphan wells qualify.
Carbon Path (High Vol)	CarbonPath's "Low Volume" methodology applies to both oil and gas wells and relies heavily on DCA and reservoir engineering principles.	Idle and producing wells qualify.
Carbon Path (Low Vol)	CarbonPath's "High Volume" methodology generally similar to the ACR methodology and can include both pre- and post- well plugging methane quantification.	Orphan wells qualify. Idle wells may qualify.
Onyx/Systemiq	Onyx Transition and Systemiq (OTS) have partnered to create a carbon credit system focused on limiting oil supply by awarding carbon credits for plugging oil and gas wells. The OTS method is still very new and refinements in the methodology should be expected.	Producing wells qualify, but neither idle nor orphan wells are specifically precluded.
ZeroSix	The ZeroSix methodology focuses on "supply side" reserves by awarding carbon credits for plugging existing production.	Producing wells qualify, but idle wells are not specifically precluded.
Others	There are other organizations, such as Verra, that are also in the process of developing protocols to incentivize well plugging through the issues of Carbon Credits.	N/A

***Note**: Specific information related to various Carbon Registry requirements, applicability, and other details can change rapidly. Further details on protocols, guidance documents, processes, and other information are generally available from each of the Registry's Web Sites. Please visit the web sites for further details.*

Well Plugging & Site Restoration is Complicated and HARD Work!

Source: CSR Services, LLC

Source: ALL Consulting

Source: HillTex

Source: Well Done Foundation

Source: Dan Arthur

CONTACT INFORMATION

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