SPE · AAPG · SEG

CCUS

Carbon Capture, Utilization, and Storage

Advanced Resources International, Inc.

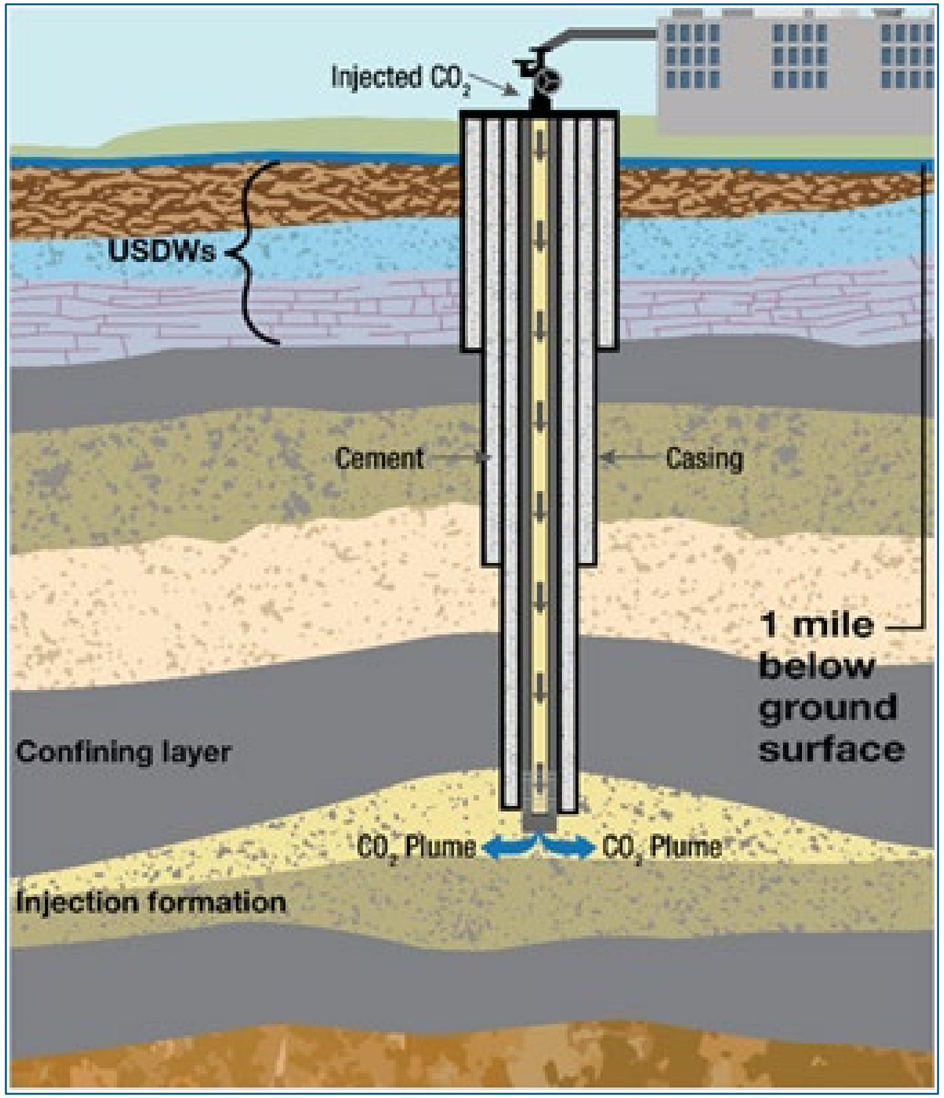
Utilizing Existing Wells for CO_2 Storage Characterization

Gabe Casanova , Karen Lechtenberg , George Koperna, Dave Riestenberg

Geologic Characterization for CO_2 Storage

Why is it so important?

- Ensures CO_2 can safely be stored in that geology
  - Assesses reservoir quality and seal integrity
- Identifies USDWs (Underground Safe Drinking Water)
- Provides data needed for project design
  - Injection pressure
  - Fracture pressure
  - Storage volumes
  - Plume growth projection
- Regulatory requirements
  - EPA Class VI requirements



Geologic Data Collection

What data is required?

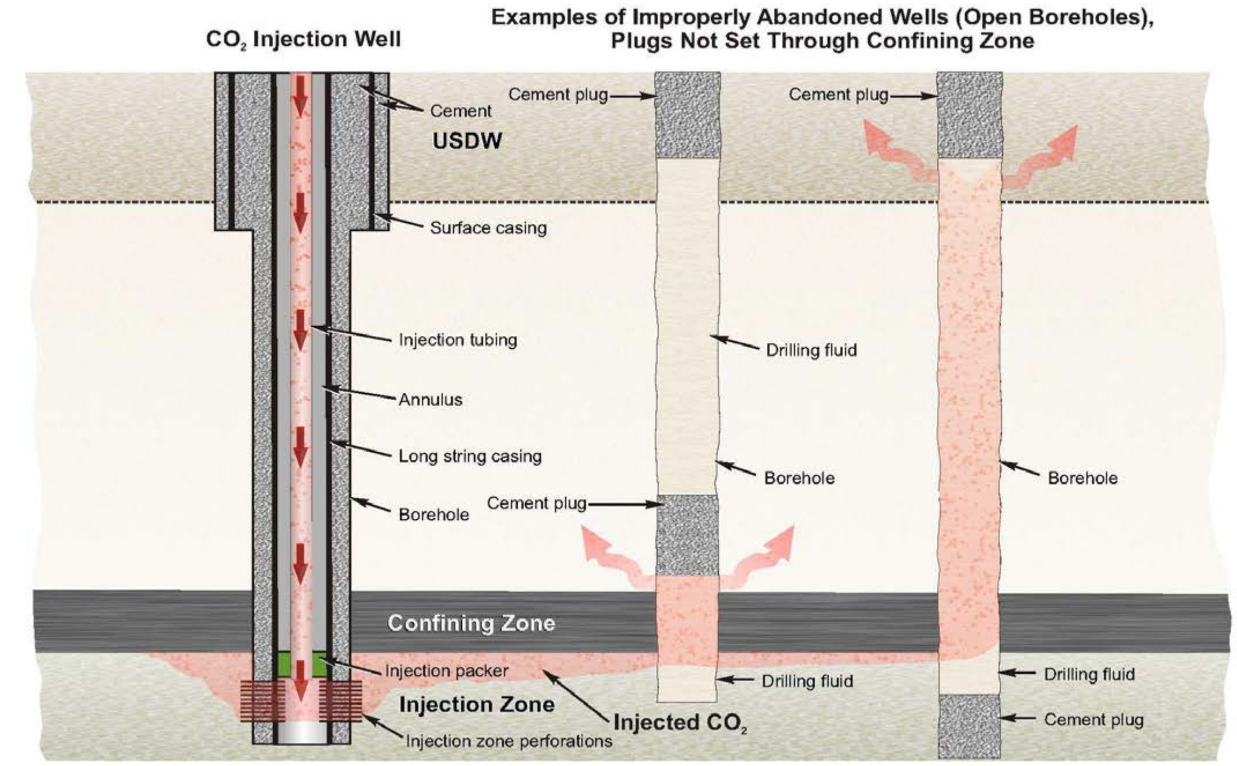
- Wireline Logs
  - Depth, thickness, porosity, permeability, lithology
  - Sonic, fracture finder
- Injection Zone Fluid Characterization
  - Temp, pH, Specific Conductivity, Salinity(TDS)
- Hydrogeologic Characteristics
  - Pressure Fall-off Test/Injectivity Tests and Fracture Pressure
- Core Analysis
  - Routine Core Analysis, Geomechanical, Special Core Analysis

CCUS
Carbon Capture, Utilization, and Storage
SPE
AAPG
SEG

Historical Legacy Well Perspective

Why are they often considered a bad thing?

- Potential leak path
  - Wells that penetrate the caprock in the project area could allow CO_2 or brine back to surface or into other zones
  - Especially if inadequately completed or abandoned
- Solutions to this risk
  - Avoidance
  - Corrective Action: plugging, re-plugging, or workover
  - Conversion to a monitor well



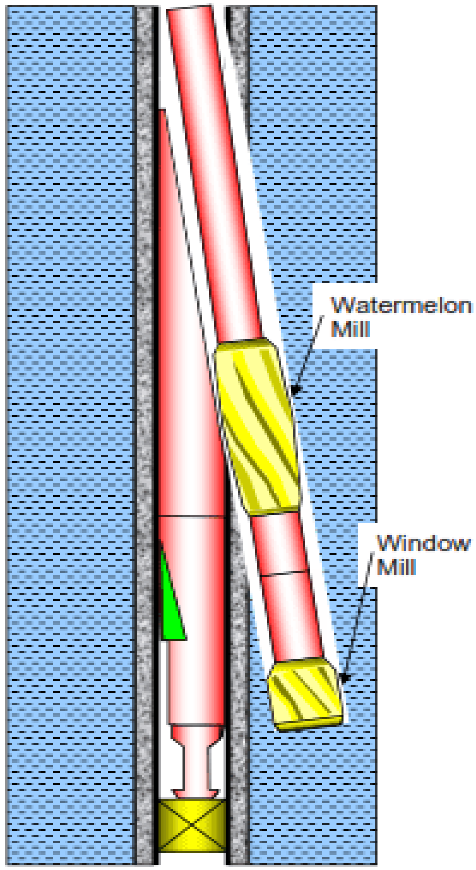
Note: *Figure not to scale*
Source: *Daniel B. Stephens & Associates, Inc.*

Alternative Legacy Well Perspective

What if we used these wells to characterize the geology?

- The majority of characterization well cost is new well/site construction
  - ~70% of the cost of a characterization well is from constructing the well and well site(Mob/Demob, Rig, Casing, Cement, Mud, etc.)
- We can collect 100% of the data at 30% of the cost
  - Eventually an injection or monitor well will need to be constructed for the project if the geology is proven suitable
- The technology for re-entering these wells is mature and has been used for similar applications in Oil and Gas
  - Casing exits or section mills often used for sidetracks or abandonment operations
  - Slim hole logging tools available in 2.125" Diameter
  - Whole core collection on workover rigs or mineral coring rigs
- May not be applicable to all projects
  - Wells must be available in the project area and in usable condition
  - Low risk projects may wish to collect this data during Injection well construction

Section Mill



Casing Exit

Well Size Considerations

Some wireline tools won't fit in smaller wells

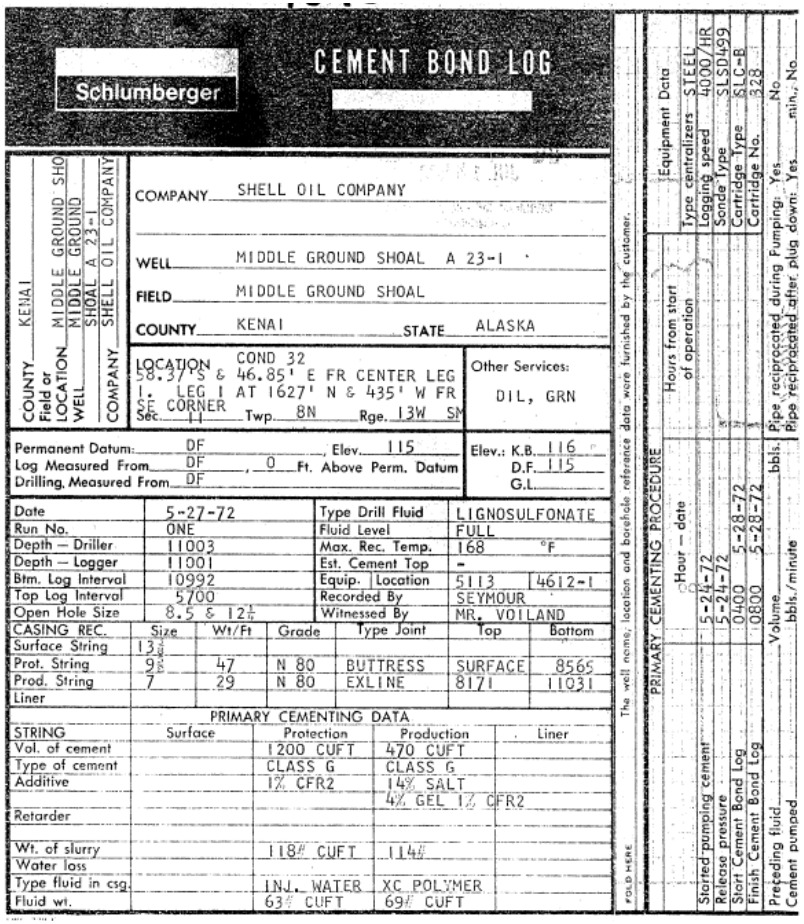
- Many of the advanced wireline (NMR, MDT, Rotary Sidewall Core) > 4.75" Diameter
- Quad Combo, FMI, Sonic available in ~2.125"Diameter
- Whole core collected on workover rig with power swivel or mineral coring rig
- Tubing deployed straddle tools could be used for injection testing, stress testing, and fluid sampling
  - These test take more time on tubing, but can collect the same data

		Casing Size			
Wireline	**Data/Purpose**	**4.5"**	**5.5"**	**7"**	**9.625"**
Gamma Ray	Lithology/ Formation Tops	Yes	Yes	Yes	Yes
Resistivity	Fluid Saturation/Salinity	Yes	Yes	Yes	Yes
Neutron Porosity	Porosity/Storage Volume	Yes	Yes	Yes	Yes
Dipole Sonic	Geomechanical Properties	Yes	Yes	Yes	Yes
Monopole Sonic	Porosity/Geomechanical	Yes	Yes	Yes	Yes
Bulk Density	Density/Porosity	Yes	Yes	Yes	Yes
Spontaneous Potential	Formation Tops/Salinity	Yes	Yes	Yes	Yes
Cement Bond Log	Well Integrity	Yes	Yes	Yes	Yes
Formation Micro Imager	Fractures/Faults	Yes	Yes	Yes	Yes
Nuclear Magnetic Resonance	Permeability/Mobility	No	No	Yes	Yes
Rotary Sidewall Core	Porosity, Permeability, etc.	No	No	Yes	Yes
Wireline Formation Tester	Fluid sample/Mobility, Press.	No	No	No	Yes
Wireline Stress Test(Mini Frac)	Fracture Pressure	No	No	No	Yes
Tubing	**Data/Purpose**				
Whole Core	Porosity, Permeability, etc.	Yes	Yes	Yes	Yes
Injection Testing(Straddle Tools)	Permeability/Injectivity	Yes	Yes	Yes	Yes
Stress Testing(Straddle Tools)	Fracture Pressure	Yes	Yes	Yes	Yes
Fluid Sampling (Straddle Tools/Slickline	Fluid sample/Mobility, Press.	Yes	Yes	Yes	Yes

Legacy Well Screening Process

How do we mitigate the risk of using an existing well?

- Well records
  - Well diagram, drilling report, completion report, and well history are critical
- Status of well
  - Ideally late production life, temporarily abandoned, or shut in
  - Previously abandoned wells are still potential candidates with sufficient well history and abandonment records
- Well size
  - 5.5" 17# and larger wells provide the most flexibility for necessary tools i.e. casing exits, whole coring tools, slim hole logging tools
  - 9.625" have no limitations on characterization tools
- Well depth
  - Wells need to penetrate the confining zone and the injection zone or be close to the injection zone top


Schlumberger
CEMENT BOND LOG

COMPANY SHELL OIL COMPANY
WELL MIDDLE GROUND SHOAL A 23-1
FIELD MIDDLE GROUND SHOAL
COUNTY KENAI STATE ALASKA
LOCATION COND 32 58.37' S & 46.85' E FR CENTER LEG 1. LEG 1 AT 1627' N & 435' W FR SE CORNER
Sec. 11 Twp. 8N Rge. 13W SM
Other Services: DIL, GRN

Permanent Datum: DF Elev. 115
Log Measured From DF 0 Ft. Above Perm. Datum
Drilling Measured From DF
Elev.: K.B. 116 D.F. 115 G.L.

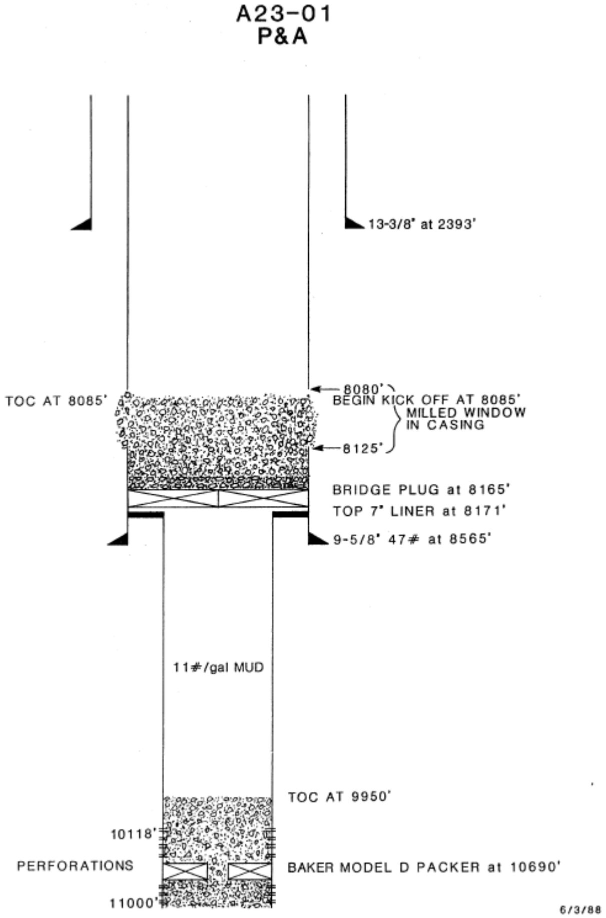
Date	5-27-72	Type Drill Fluid	LIGNOSULFONATE
Run No.	ONE	Fluid Level	FULL
Depth – Driller	11003	Max. Rec. Temp.	168 °F
Depth – Logger	11001	Est. Cement Top	-
Btm. Log Interval	10992	Equip. Location	5113 4612-1
Top Log Interval	5700	Recorded By	SEYMOUR
Open Hole Size	8.5 & 12¼	Witnessed By	MR. VOILAND

CASING REC.	Size	Wt/Ft	Grade	Type Joint	Top	Bottom
Surface String	13⅜					
Prot. String	9⅝	47	N 80	BUTTRESS	SURFACE	8565
Prod. String	7	29	N 80	EXLINE	8171	11031
Liner						

PRIMARY CEMENTING DATA

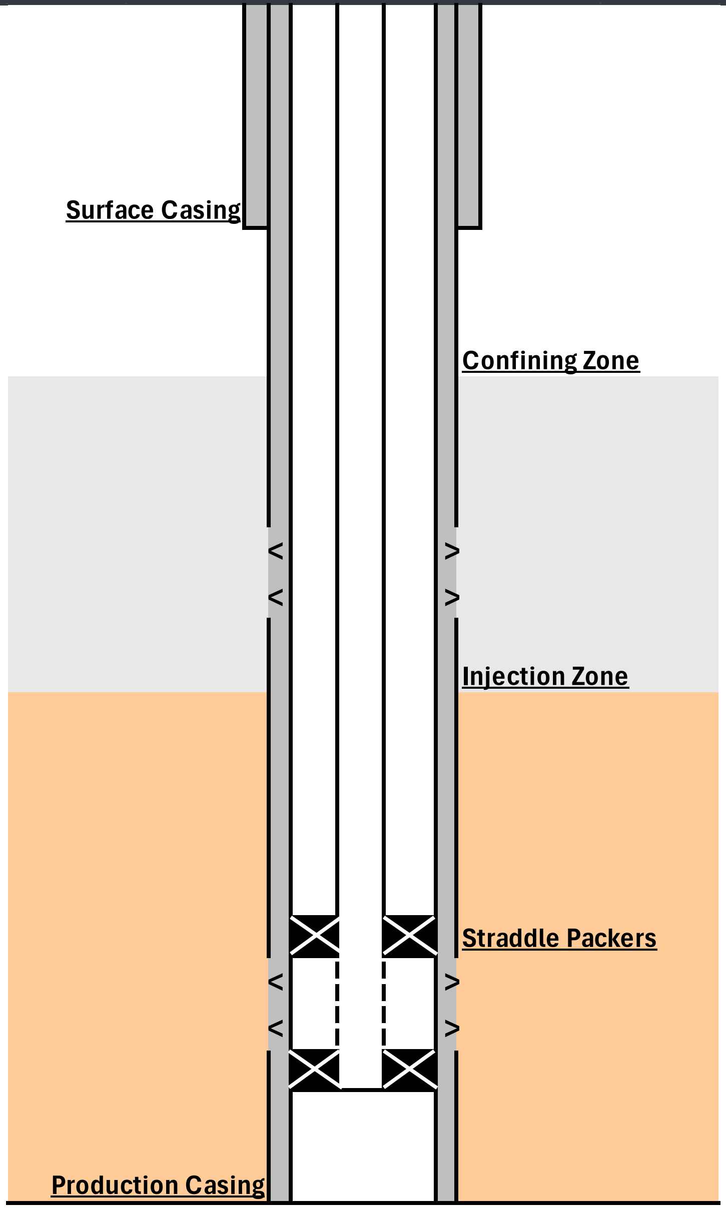
STRING	Surface	Protection	Production	Liner
Vol. of cement		1200 CUFT	470 CUFT	
Type of cement		CLASS G	CLASS G	
Additive		1% CFR2	14% SALT 4% GEL 1% CFR2	
Retarder				
Wt. of slurry		118# CUFT	114#	
Water loss				
Type fluid in csg		INJ. WATER	XC POLYMER	
Fluid wt.		63# CUFT	69# CUFT	

Equipment Data: Type centralizers STEEL; Logging speed 4000/HR; Sonde Type SLSD499; Cartridge Type SLC-B; Cartridge No. 328
Pipe reciprocated during Pumping: Yes No; Pipe reciprocated after plug down: Yes min., No
PRIMARY CEMENTING PROCEDURE: Hours from start of operation; Hour – date; Started pumping cement 5-24-72 0400; Release pressure 5-24-72 0800; Start Cement Bond Log 5-28-72; Finish Cement Bond Log 5-28-72; Preceding fluid bbls.; Cement pumped Volume bbls./minute
The well name, location and borehole reference data were furnished by the customer.
FOLD HERE



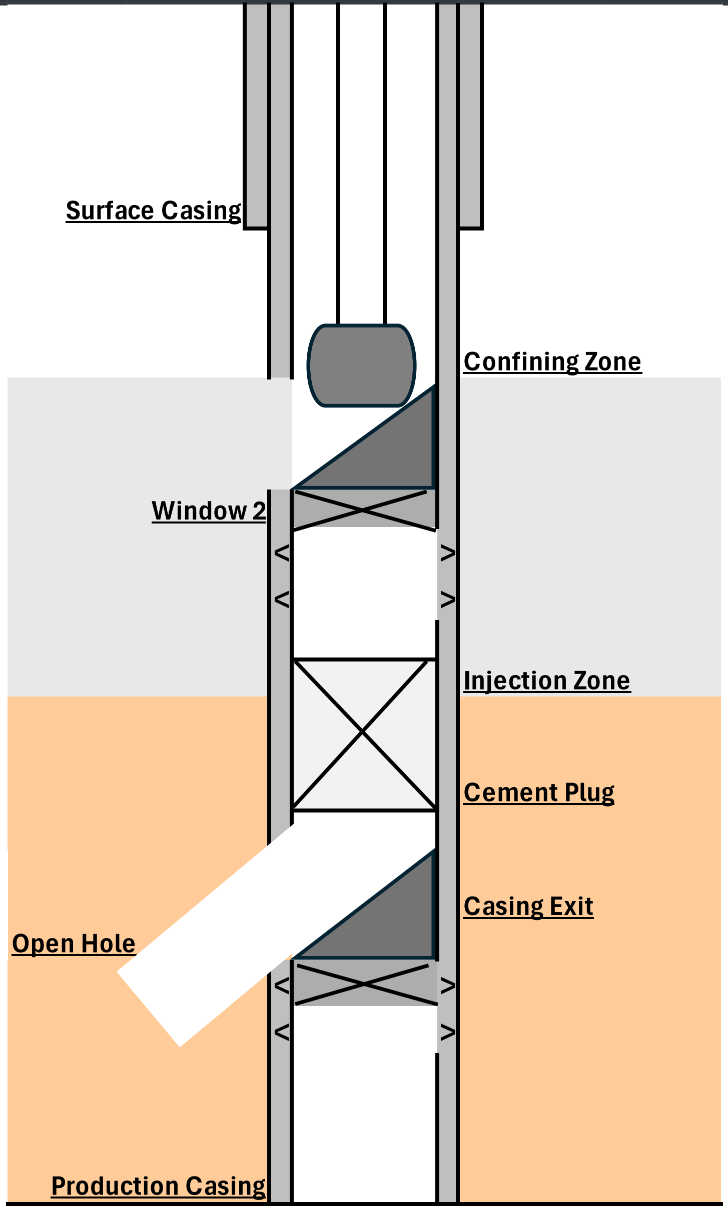
Legacy Well Characterization Procedure

1. Perform clean out run to injection zone depth(may need to plug off/abandon deeper zones)
2. Perform casing inspection run and cement bond log
3. Perforate injection zone and confining zone for fluid sampling and pressure test
4. Run in hole with straddle packers and pressure gauge
5. Perform fluid sampling with swabbing unit
6. Perform pressure fall off test
7. Come up hole with straddle packers and perform stress test



Legacy Well Characterization Procedure

8. Remove test packer assembly
9. Run in hole with casing exit for injection zone characterization
10. Cut window in production casing
11. Pick up coring assembly and collect qty2 30ft cores
12. Run in hole with slim hole logging tools
13. Abandon lower zone with cement plugs
14. Repeat steps 9-13 for confining zone characterization



CCUS Carbon Capture, Utilization, and Storage
SPE AAPG SEG

Legacy Well vs New Well Cost Comparison

- Cost estimates based on 5000 ft well in Midwest US and does not include drilling contingency
- $1.5M for Workover vs $5.07M for New Drill
- 28 days for workover vs 31 days for drill
- The New Well is assumed cased and will be converted to an injector
- The Legacy well is assumed to have 5.5” production casing

Workover Days (12 Hr Ops)

Mob/Demob	2
Well Re-Entry	2
Well Clean Out	2
Fluid Sampling	2
Stress Test	2
Injection Test	2
Casing Exit	4
Coring	6
Logging	4
P&A	2
Total Rig Days	**28**

New Well Days (24 Hr Ops)

Mob/Demob	8
Drilling	10
Casing/Cementing	3
Fluid Sampling	1
Stress Test	1
Injection Test	2
Logging Pre-TD	1
Coring	3
Logging Post-TD	1
T&A	1
Total Rig Days	**31**

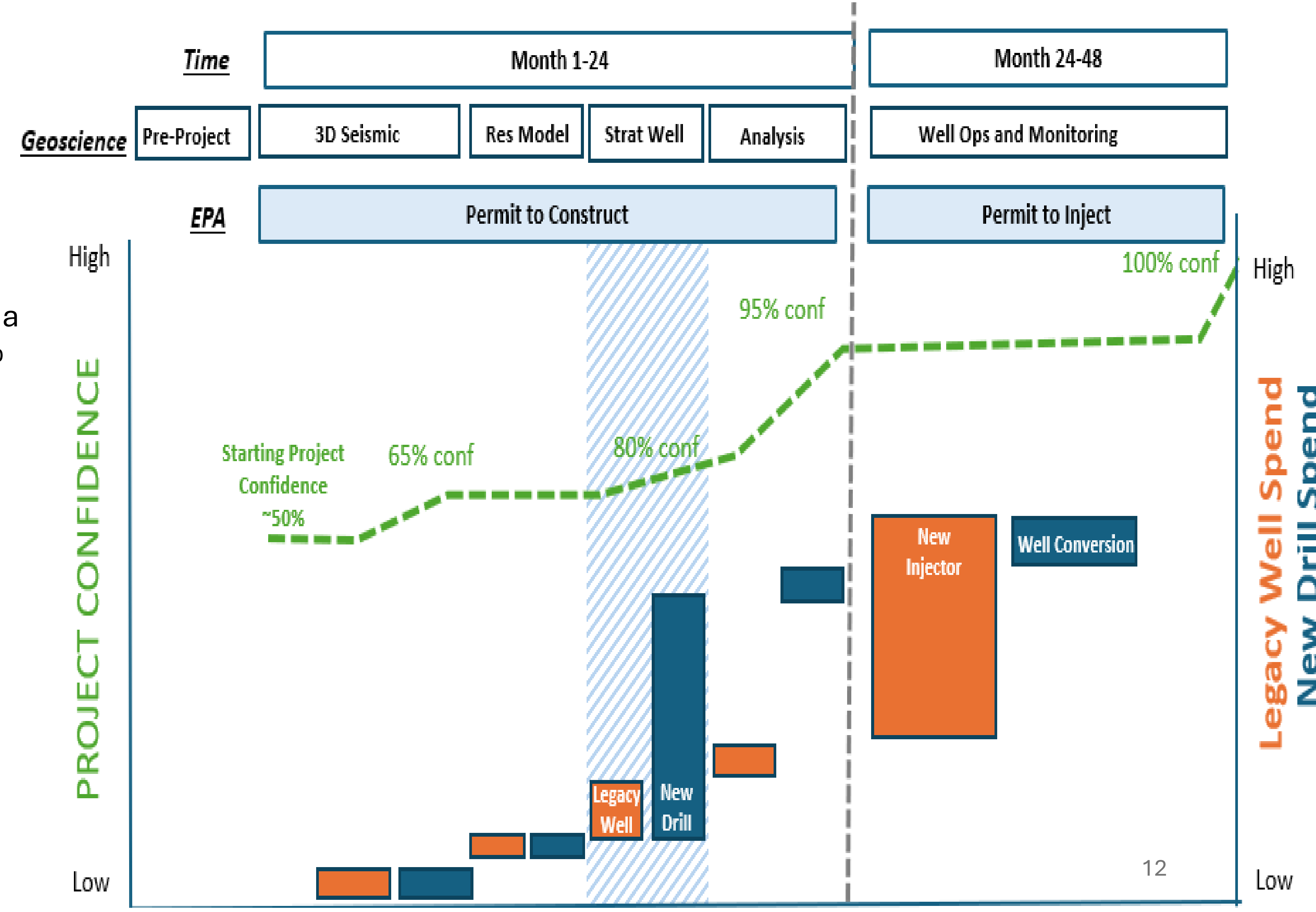
Description	Workover Cost	New Drill Cost
Site Preparation (Conductor Casing, Pad, Mob/Demob., Water Well)	$75,000	$1,100,000
Drilling and Workover Operations (Rig, Fluids, Casing Exits, Tubing, Drill Pipe)	$494,300	$1,478,500
Formation Evaluation (Coring, Logging, Fluid Samples, Injection Test)	$735,000	$1,115,000
Completion (Casing, Cement, Perforating, Cased Hole Logs)	$50,000	$924,700
Plugging and Abandonment (Cement and Bridge Plugs)	$60,000	$0
General (Supervision, Trucking, Sleeping Quarters, Rentals)	$89,600	$454,550
Total Cost	**$1,503,900**	**$5,072,750**

Legacy Well vs New Well Cost Comparison

Description	Workover Cost	New Drill Cost	Notes
Site Preparation (Conductor Casing, Pad, Mob/Demob., Water Well)	$75,000	$1,100,000	Minimal mobilization cost associated with workover rig, uses existing well site, and conductor casing
Drilling and Workover Operations (Rig, Fluids, Casing Exits, Tubing, Drill Pipe)	$494,300	$1,478,500	Most of the cost difference is from the drilling rig itself, drilling mud, solids control, rig fuel, and cuttings disposal
Formation Evaluation (Coring, Logging, Fluid Samples, Injection Test)	$735,000	$1,115,000	The new drill example use higher cost open hole wireline sampling /testing tools that are not available for small wellbores, the same data was collected in both scenarios
Completion (Casing, Cement, Perforating, Cased Hole Logs)	$50,000	$924,700	The higher new drill cost comes mainly from casing and cementing the wellbore, workover rig cost is cased hole logging and perforating
Plugging and Abandonment (Cement and Bridge Plugs)	$60,000	$10,000	The legacy well workover cost will be abandoned after data collection, the new drill will be left cased with a retrievable bridge plug for temporary abandonment
General (Supervision, Trucking, Sleeping Quarters, Rentals)	$89,600	$454,550	The higher new drill cost comes mainly from two onsite supervisors(day/night), equipment rentals, and onsite housing.
Total Cost	**$1,503,900**	**$5,082,750**	

Conclusions

- Legacy well characterization allows for lower upfront capitol cost for projects with medium to high-risk geologic uncertainty
- Performing geologic characterization in a legacy well can cost approximately 70% less than drilling a new well for characterization
- Both operations take roughly the same time, however the legacy well characterization could be done faster with 24-hour operations at higher cost
- Well data and well condition are critical for project success



For more information, please contact:

Gabe Casanova [gcasanova@adv-res.com]
Karen Lechtenberg [klechtenberg@adv-res.com]
George Koperna [gkoperna@adv-res.com]
Dave Riestenberg [driestenberg@adv-res.com]

Office Locations
Washington, DC
4501 Fairfax Drive, Suite 910
Arlington, VA 22203
Phone: (703) 528-8420

Columbus, OH
1840 Mackenzie Dr., Suite 100
Columbus, OH 43220

Knoxville, TN
4110 Sutherland Ave.
Knoxville, TN 37919