OUTLINE

- PURPOSE OF PLUGGING
- PLANNING THE INSPECTION
- EVALUATING PLUGGING DESIGN
- PLUGGING MATERIALS
- PLACEMENT METHODS
- ABANDONMENT
PURPOSE OF P&A

- FOR CLASSES I, II, AND III:
  - PREVENT THE MOVEMENT OF FLUIDS EITHER INTO OR BETWEEN USDWS
  - PLUGGING RESTORES THE ORIGINAL CONFINEMENT
  - ACCOMPLISHED BY SETTING CEMENT PLUGS IN THE WELL
  - PLUGS SHOULD LAST INDEFINITELY

- THE INSPECTOR WITNESSES THE PLUGGING ACTIVITIES TO ENSURE THEY WERE DONE PROPERLY
PURPOSE OF P&A

 buiten circuit well leaves pathways for fluid migration along the wellbore

Proper plugging blocks all potential pathways

Identify ALL potential pathways place plugs to prevent any fluid migration into USDWs
P&A OPERATIONS

IN THE OFFICE:
- PLANNING

IN THE FIELD:
- WELL PREPARATION
- WELL PLUGGING
- ABANDONMENT
PLANNING
KNOW THE WELL CONDITIONS

- CONSTRUCTION DETAILS
  - CASING STRING SIZES, GRADES, DEPTHS
  - CEMENTING PROGRAM – BOND LOGS
  - PERFORATED/OPEN HOLE SECTIONS
  - MECHANICAL EQUIPMENT IN THE WELL
  - LOST CIRCULATION ZONES

Plugging design will in part depend on these factors

- GEOLOGY
  - USDWS AND OTHER FLUID-BEARING ZONES
  - COMMERCIAL MINERAL RESERVES

Plugs required to isolate these zones

- MECHANICAL CONDITION
  - MECHANICAL INTEGRITY
  - CASING COLLAPSE? CEMENT CHANNELING?
  - JUNK IN THE HOLE?
  - REMEDIAL ACTION NECESSARY?

May perform MITs or other well logs to determine integrity

Additional depths may need to be isolated
WELL PREP

- Perform any required testing
- Move in workover rig and remove tubing/packer, if possible

Remedial Operations

- Bit/scraped or wiper runs to improve bonding
- Plug-back the injection zone (if necessary or desirable at this stage)
- Repair or remove damaged or uncedented/poorly cemented casing

- Circulate the hole with weighted fluid to achieve static equilibrium
WELL PREP

- Plug back the lower zones (esp. injection zone)
- Prevents fluid from entering the well
- Might make other preparatory steps easier
WELL PREP

- RIP & PULL, OR PERFORATE AND SQUEEZE CEMENT BEHIND ANY FREE CASING
  - SMOOTH THE TOP OF THE REMAINING PIPE

- Use tools to open tight places where casing is collapsed

- If cement voids or other loss of cement integrity is suspected, squeeze cementing may be necessary
WELL PREP COMPLETE

Prepared and ready for plugs!

But, where do they go?
PLUG FUNCTIONS

- ISOLATE THE SURFACE
- ISOLATE THE USDWS FROM OTHER FORMATIONS
- ISOLATE ANY MINERAL-BEARING FORMATIONS
- ISOLATE THE INJECTION ZONE
TYPICAL PLUGGING REQUIREMENTS FOR OIL AND GAS WELLS IN MOST STATES

- Steel pipe with marker or pipe cut off below plow depth
- 10-25 foot cement plug at the surface
- 100 foot cement plug – 50 foot below and 50 foot above the shoe of surface AND intermediate casing
- 50 foot cement plug set below, above, or across any fresh water or mineral-bearing zones in open hole
- 50-100 foot cement plug on top and in any casing left in hole
- Cemented casing stub (may or may not be in hole)
- 50-100 foot cement plug above injection/production zone; Often has a bridge plug or cement retainer + cement

After Herndon & Smith 1976
PLUG LOCATIONS IN A SIMPLE CLASS II WELL

- CEMENT PLUG SET AT THE SURFACE PREVENTS FLUID MOVEMENT TO AND FROM THE SURFACE
- A CEMENT PLUG AT THE BASE OF THE SC PREVENTS FLUIDS FROM MIGRATING UPWARD TO THE USDW
- BOTTOM PLUG ISOLATES THE INJECTION ZONE WITH CEMENT ON A BRIDGE PLUG
TYPES OF CEMENT

- **BASIC CEMENTS**: CLASS A, C, G, AND H (OFTEN DENSIFIED WITH A DISPERSANT)
- **ADDITIVES**: FOR HIGHER OR LOWER DENSITY, FASTER OR SLOWER THICKENING TIME, IMPROVED BOND, ETC.
- **WATER**: CLEAN & FRESH IS BEST
- **CHECK THE SLURRY VOLUME IN FT³/SACK**
- **PLUG DEPTH AND STRENGTH MUST BE VERIFIED**
  - WAIT FOR CEMENT TO SET AND TAG THE PLUG
  - SET PLUG WITH A BRIDGE PLUG BELOW
PLUG LOCATIONS

- Start with required plugs from other agencies
  - Injection zone – other perfs
  - Minerals
  - Casing shoes/liner tops
- Isolate into/between USDWS >2000 mg/l
- Use CIBP as plug base or tag plugs
- Consider how the operator wants to plug
HYPOTHETICAL P&A
WHERE TO SET PLUGS
PLUG LOCATIONS

- START WITH REQUIRED PLUGS FROM OTHER AGENCIES
- INJECTION ZONE – OTHER PERFS
- MINERALS
- CASING SHOES/LINER TOPS

- ISOLATE INTO/BETWEEN USDWS >2000 MG/L
- USE CIBP AS PLUG BASE OR TAG PLUGS
- CONSIDER HOW THE OPERATOR WANTS TO PLUG
BASIC CEMENT CALCULATION

Variables

- Sacks of cement
- Thickness of plug, ft
- Capacity of casing or hole (vol/linear ft)
- Excess cement required (percentage)
- Slurry volume of the cement ft, cu. ft/sack

Source

- State requirements or policy
- Cementing tables
- State requirements or policy
- Cementing tables
CALCULATE SOME PLUG VOLUMES

- 5-1/2 INCH, 15.5 LB/FT CASING
- PLUG NEEDED = 150 FT
CALCULATE SOME PLUG VOLUMES

- 5-1/2 INCH, 15.5 LB/FT CASING
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- HOW MANY CU FT OF CEMENT IS NEEDED?
CALCULATE SOME PLUG VOLUMES

- 5-1/2 INCH, 15.5 LB/FT CASING
- PLUG NEEDED = 150 FT
- HOW MANY CU FT OF CEMENT IS NEEDED? CASING CAPACITY?
BASIC CEMENT CALCULATION

Variables

- Sacks of cement
- Thickness of plug, ft
- Capacity of casing or hole (vol/linear ft)
- Excess cement required (percentage)
- Slurry volume of the cement ft, cu. ft/sack

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CALCULATE SOME PLUG VOLUMES

• 5-1/2 INCH, 15.5 LB/FT CASING
• PLUG NEEDED = 150 FT
• HOW MANY CU FT OF CEMENT IS NEEDED?
  CASING CAPACITY?
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CALCULATE SOME PLUG VOLUMES

- 5-1/2 INCH, 15.5 LB/FT CASING
- PLUG NEEDED = 150 FT
- HOW MANY CU FT OF CEMENT IS NEEDED?
  CASING CAPACITY = .1336 CU FT/LIN FT
CALCULATE SOME PLUG VOLUMES

• 5-1/2 INCH, 15.5 LB/FT CASING
• PLUG NEEDED = 150 FT
• HOW MANY CU FT OF CEMENT IS NEEDED?
  CASING CAPACITY = 0.1336 CU FT/LIN FT
  PLUG VOLUME = (0.1336 CU FT/LIN FT) * (150 FT) = 20.04 CU FT
CALCULATE SOME PLUG VOLUMES

• 5-1/2 INCH, 15.5 LB/FT CASING
• PLUG NEEDED = 150 FT
• HOW MANY CU FT OF CEMENT IS NEEDED = 20.04 CU FT
USING E-REDBOOK
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CALCULATE SOME PLUG VOLUMES

• 5-1/2 INCH, 15.5 LB/FT CASING
• PLUG NEEDED = 150 FT
• HOW MANY CU FT OF CEMENT IS NEEDED = 20.04 CU FT
• HOW MANY SACKS OF CEMENT ARE NEEDED?
CALCULATE SOME PLUG VOLUMES

• 5-1/2 INCH, 15.5 LB/FT CASING

• PLUG NEEDED = 150 FT

• HOW MANY CU FT OF CEMENT IS NEEDED = 20.04 CU FT

• HOW MANY SACKS OF CEMENT ARE NEEDED?
  SLURRY VOLUME (YIELD)
CALCULATE SOME PLUG VOLUMES

• 5-1/2 INCH, 15.5 LB/FT CASING

• PLUG NEEDED = 150 FT

• HOW MANY CU FT OF CEMENT IS NEEDED = 20.04 CU FT

• HOW MANY SACKS OF CEMENT ARE NEEDED?
  SLURRY VOLUME (YIELD) = 1.18 CU FT/SACK
CALCULATE SOME PLUG VOLUMES

• 5-1/2 INCH, 15.5 LB/FT CASING

• PLUG NEEDED = 150 FT

• HOW MANY CU FT OF CEMENT IS NEEDED = 20.04 CU FT

• HOW MANY SACKS OF CEMENT ARE NEEDED?
  SLURRY VOLUME (YIELD) = 1.18 CU FT/SACK

  SACKS = (20.04 CU FT) / (1.18 CU FT/SACK) = 16.98 SACKS
CALCULATE SOME PLUG VOLUMES

- 5-1/2 INCH, 15.5 LB/FT CASING
- PLUG NEEDED = 150 FT
- HOW MANY CU FT OF CEMENT IS NEEDED = 20.04 CU FT
- HOW MANY SACKS OF CEMENT ARE NEEDED = 16.98 SACKS
CALCULATE SOME PLUG VOLUMES

- 5-1/2 INCH, 15.5 LB/FT CASING
- PLUG NEEDED = 150 FT
- HOW MANY CU FT OF CEMENT IS NEEDED = 20.04 CU FT
- HOW MANY SACKS OF CEMENT ARE NEEDED = 16.98 SACKS
TO REITERATE

1) CALCULATE THE VOLUME NEEDED TO FILL THE SPACE FOR YOUR PLUG

2) CALCULATE THE NUMBER OF SACKS NEEDED TO MAKE UP THAT VOLUME OF CEMENT
PLUGGING METHODS

- 3 METHODS APPROVED IN THE FEDERAL UIC REGULATIONS
  - THE BALANCE METHOD
  - THE DUMP BAILER METHOD
  - THE TWO-PLUG METHOD

**ALSO:**

- AN ALTERNATE METHOD, APPROVED BY THE DIRECTOR, THAT WILL RELIABLY PROVIDE A COMPARABLE LEVEL OF PROTECTION MAY ALSO BE APPROVED
BALANCE METHOD

- BRIDGE PLUG IS SET (OR OTHER SURFACE PREPARED)
- TUBING IS LOWERED
- CEMENT IS PUMPED DOWN INSIDE THE TUBING & COMES UP ON THE OUTSIDE
- PUMPING IS STOPPED WHEN THE LEVEL INSIDE AND OUTSIDE THE TUBING ARE EQUAL
- THE TUBING IS SLOWLY RAISED ABOVE THE TOP OF THE PLUG
- DOESN'T REQUIRE SPECIAL EQUIPMENT, BUT DOES REQUIRE SKILL
CEMENT RETAINER VARIATION
DUMP BAILER METHOD

- Mechanical bridge plug/cement basket assembly is placed at plugging depth
- The dump bailer is a cylindrical container holding a fixed amount of cement
- The cement is dumped on the mechanical plug
- Seldom used
ABANDONMENT

- May include post-closure care (required for Class I hazardous wells and Class VI wells)
- Surface remediation
  - Removing all equipment
  - Restoring vegetation
  - May be other special requirements
- You may not witness these activities, but you should know what is planned
SUMMARY

- Prepare for the inspection
  - Know the well construction, the geology, and the plan
- Did your agency approve the plan?
  - Communicate with permit writers
- Ensure that the plan is appropriate for the conditions and that it is followed
  - Choice of plugging fluids, cement slurry, placement method, etc.
- No cutting corners in well preparation!
- Be prepared to adapt to unforeseen circumstances
FOR MORE INFORMATION

- HALLIBURTON CEMENTING TABLES (PRINT COPY)
- EREDBOOK IS AVAILABLE FOR DESKTOP AND SMARTPHONES
  - GOOGLE “EREDBOOK”
- OILFIELD ACRONYMS:
  - WIKIPEDIA
END
PLUGGING EXAMPLE

PREPARATION STEPS:

1) REMOVE TUBING, PACKER

2) CUT LSC ABOVE THE TOC AND PULL CASING

3) CIRCULATE MUD TO ACHIEVE STATIC EQUILLIBRIUM
PREPARED FOR PLUGGING

IDENTIFY ZONES WHICH MUST BE ISOLATED WITH CEMENT:

1) INJECTION ZONE
2) CASING STUB
3) ANY PRODUCING OR FLUID-BEARING ZONE IN THE OPEN HOLE
4) BASE OF THE INTERMEDIATE CASING
5) BASE OF THE SURFACE CASING AND USDW
6) GROUND SURFACE
APPROVED PLAN

ASSUME:

- 9 5/8 IN., 36# INTERMEDIATE CASING
- 7 IN., 26# LSC IN A 8 3/4 IN. HOLE
- PLUG THICKNESSES FOLLOW THESE STATE REQUIREMENTS:
  1) 100’ CEMENT ISOLATING THE IZ IF NO BRIDGE PLUG/CEMENT RETAINER IS USED
  2) 50’ CEMENT ON A BRIDGE PLUG, IF USED
  3) 50’ CEMENT ABOVE AND BELOW A RIP POINT OR SURFACE CASING SHOE
  4) 50’ CEMENT ISOLATING PRODUCING ZONES
  5) 25’ CEMENT AT THE SURFACE
PLUGS NUMBERED

ASSUME:

1. 9½ IN., 36# INTERMEDIATE CASING
2. 7 IN., 26# LSC IN A 8¾ IN. HOLE
3. PLUG THICKNESSES FOLLOW THESE STATE REQUIREMENTS:
   1) 100’ CEMENT ISOLATING THE IZ IF NO BRIDGE PLUG/CEMENT RETAINER IS USED
   2) 50’ CEMENT ABOVE AND BELOW A RIP POINT OR SURFACE CASING SHOE
   3) 50’ CEMENT ISOLATING PRODUCING ZONES
   4) 25’ CEMENT AT THE SURFACE
PLUG #1

- 9\(\frac{5}{8}\) IN., 36# INTERMEDIATE CASING
- 7 IN., 26# LSC IN A 8\(\frac{3}{4}\) IN. HOLE
- CLASS A CEMENT (1.18 FT\(^3\)/SACK)
- \(S_C = L \times C \times (1+E_C) \div V_{SL}\)

**PLUG 1:**

\(L = 100\) FEET

\(C = 0.2148\) FT\(^3\)/FT

\(E_C = 0\)

\(V_{SL} = 1.18\) FT\(^3\)/SACK

\(S_C = \frac{100\ \text{FT} \times 0.2148\ \text{FT}^3/\text{FT}}{1.18\ \text{FT}^3/\text{SACK}}\)

\(= 18\) SACKS
**PLUG #2**

- 9½ IN., 36# INTERMEDIATE CASING
- 7 IN., 26# LSC IN A 8¾ IN. HOLE
- CLASS A CEMENT (1.18 ft³/SACK)
- \( S_c = L \times C \times (1 + E_c) \div V_{sl} \)

**Plug 2 bottom:**
- \( L = 50 \text{ feet} \)
- \( C = 0.2148 \text{ ft}^3/\text{ft} \)
- \( E_c = 0 \)
- \( V_{sl} = 1.18 \text{ ft}^3/\text{sack} \)

\[
S_c = \frac{50 \times 0.2148}{1.18} = 9.1 \text{ sacks}
\]

**Plug 2 top:**
- \( L = 50 \text{ feet} \)
- \( C = 0.4176 \text{ ft}^3/\text{ft} \)
- \( E_c = 0.2 \)
- \( V_{sl} = 1.18 \text{ ft}^3/\text{sack} \)

\[
S_c = \frac{50 \times 0.4176 \times (1 + 0.2)}{1.18} = 21.2 \text{ sacks}
\]

**TOTAL = 31 SACKS**
PLUG #3

- 9½ IN., 36# INTERMEDIATE CASING
- 7 IN., 26# LSC IN A 8¾ IN. HOLE
- CLASS A CEMENT (1.18 FT³/SACK)
- \[ S_c = L \times C \times (1+E_c) \div V_{sl} \]

**Plug 3 bottom:**

- L = 50 feet
- C = 0.4176 ft³/ft
- \( E_c = 0.2 \)
- \( V_{sl} = 1.18 \) ft³/sack

\[ S_c = 50 \times 0.4176 \times (1 + 0.2) \div 1.18 \]
\[ = 21.2 \text{ sacks} \]

**Plug 3 top:**

- L = 50 feet
- C = 0.4340 ft³/ft
- \( E_c = 0 \)
- \( V_{sl} = 1.18 \) ft³/sack

\[ S_c = 50 \times 0.4340 \div 1.18 \]
\[ = 18.4 \text{ sacks} \]
PLUG #4

- 9½ IN., 36# INTERMEDIATE CASING
- 7 IN., 26# LSC IN A 8¾ IN. HOLE
- CLASS A CEMENT (1.18 FT³/SACK)
- \( S_C = L \times C \times (1+E_C) \div V_{SL} \)

**PLUG 4:**

- \( L = 100 \text{ FEET} \)
- \( C = 0.4340 \text{ FT}^3/\text{FT} \)
- \( E_C = 0 \)
- \( V_{SL} = 1.18 \text{ FT}^3/\text{SACK} \)

\[
S_C = \frac{100 \text{ FT} \times 0.4340 \text{ FT}^3/\text{FT}}{1.18 \text{ FT}^3/\text{SACK}}
\]

\[
= 37 \text{ Sacks}
\]
PLUG #5

- 9 ⅝ IN., 36# INTERMEDIATE CASING
- 7 IN., 26# LSC IN A 8 ¾ IN. HOLE
- CLASS A CEMENT (1.18 FT³/SACK)
- \[ S_C = L \times C \times (1+E_C) \div V_{SL} \]

**PLUG 5:**

\( L = 25 \) FEET

\( C = 0.4340 \) FT³/FT

\( E_C = 0 \)

\( V_{SL} = 1.18 \) FT³/SACK

\[ S_C = \frac{25 \text{ FT} \times 0.4340 \text{ FT}³/\text{FT}}{1.18 \text{ FT}³/\text{SACK}} \]

= 9 SACKS