PLUGGING AND ABANDONMENT

UIC INSPECTOR TRAINING

JULY 2019

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OUTLINE

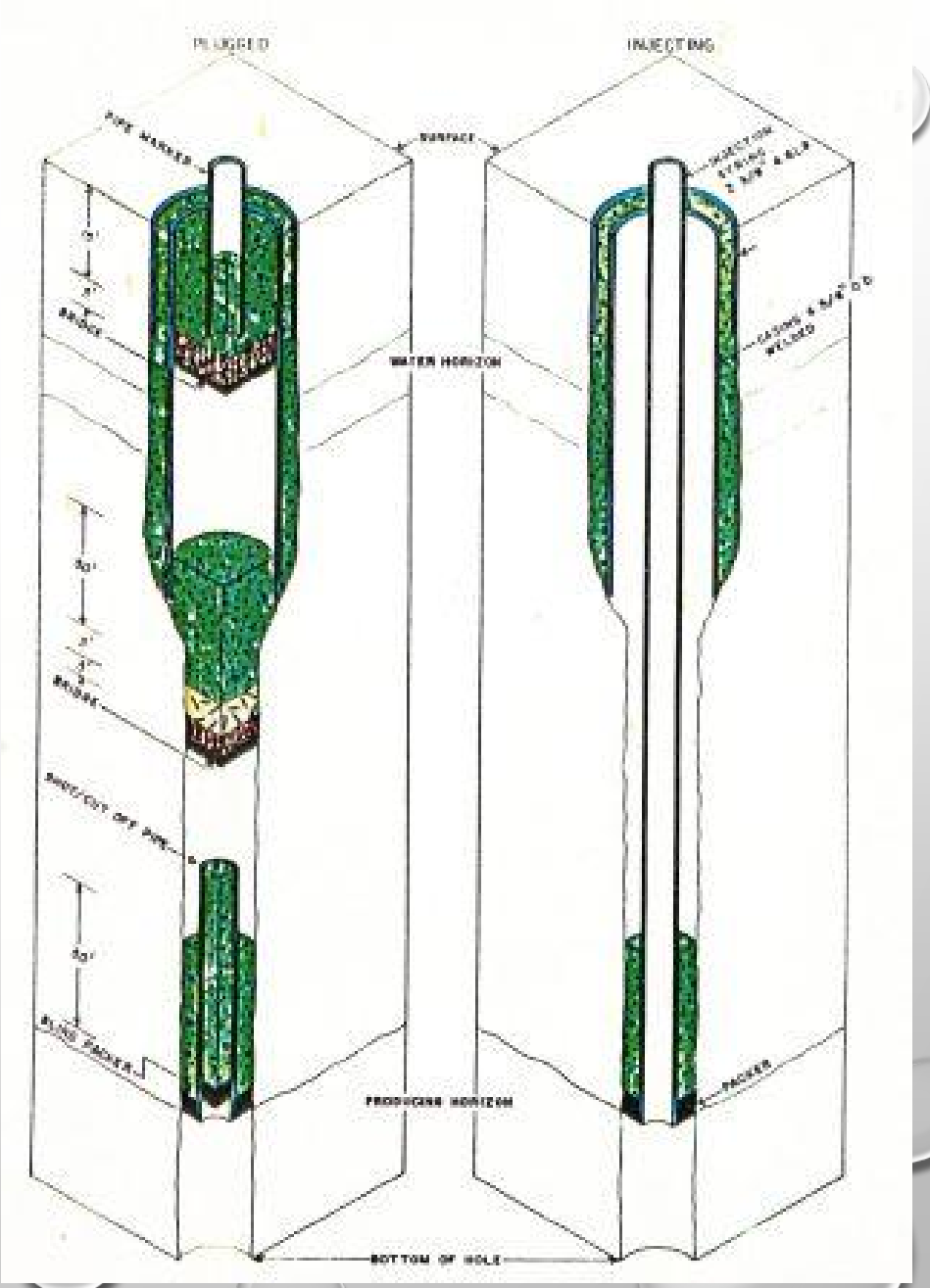
- PURPOSE OF PLUGGING
- PLANNING THE INSPECTION
- THE PLUGGING DESIGN
- PLUGGING MATERIALS
- PLACEMENT METHODS
- ABANDONMENT

PURPOSE OF P&A

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

PURPOSE OF P&A

- An unplugged well leaves pathways for fluid migration along the wellbore
- Proper plugging blocks potential pathways
- Identify ALL potential pathways place plugs to prevent unwanted fluid migration



P&A OPERATIONS

- IN THE OFFICE:
  - PLANNING
- IN THE FIELD:
  - WELL PREPARATION
  - SETTING THE PLUGS
  - 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
  - PAST MI ISSUES
  - CASING COLLAPSE? CEMENT CHANNELING?
  - JUNK IN THE HOLE?
  - REMEDIAL ACTION NECESSARY?

→ May have problems getting to some intervals

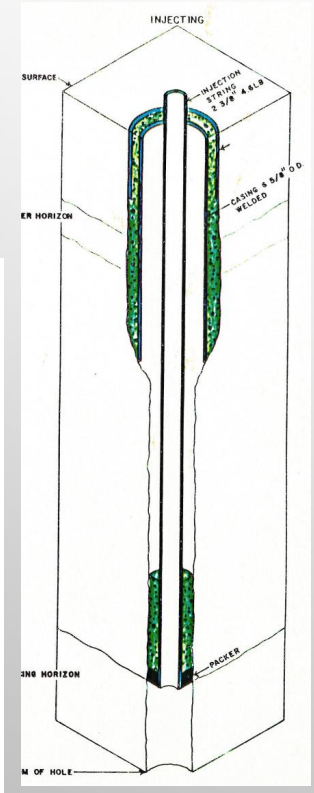
→ Additional depths may need to be isolated

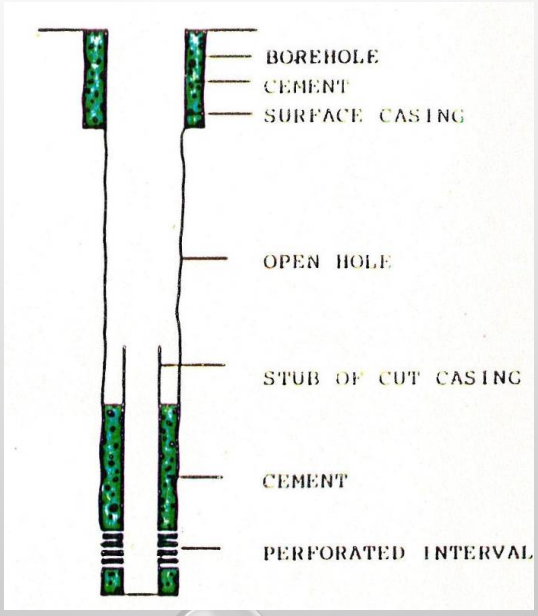
WELL PREP

- PERFORM ANY REQUIRED TESTING
- MOVE IN WORKOVER RIG AND REMOVE TUBING/PACKER, IF POSSIBLE
- REMEDIAL OPERATIONS
  - BIT/SCRAPER OR WIPER RUNS TO IMPROVE BONDING
  - PLUG-BACK THE INJECTION ZONE (IF NECESSARY OR DESIRABLE AT THIS STAGE)
  - CUT OR PULL CASING?
- CIRCULATE THE HOLE WITH WEIGHTED FLUID TO ACHIEVE STATIC EQUILIBRIUM

WELL PREP

- CUT & PULL, OR PERF AND SQUEEZE CEMENT BEHIND ANY FREE CASING
- DRESS THE TOP OF THE REMAINING PIPE



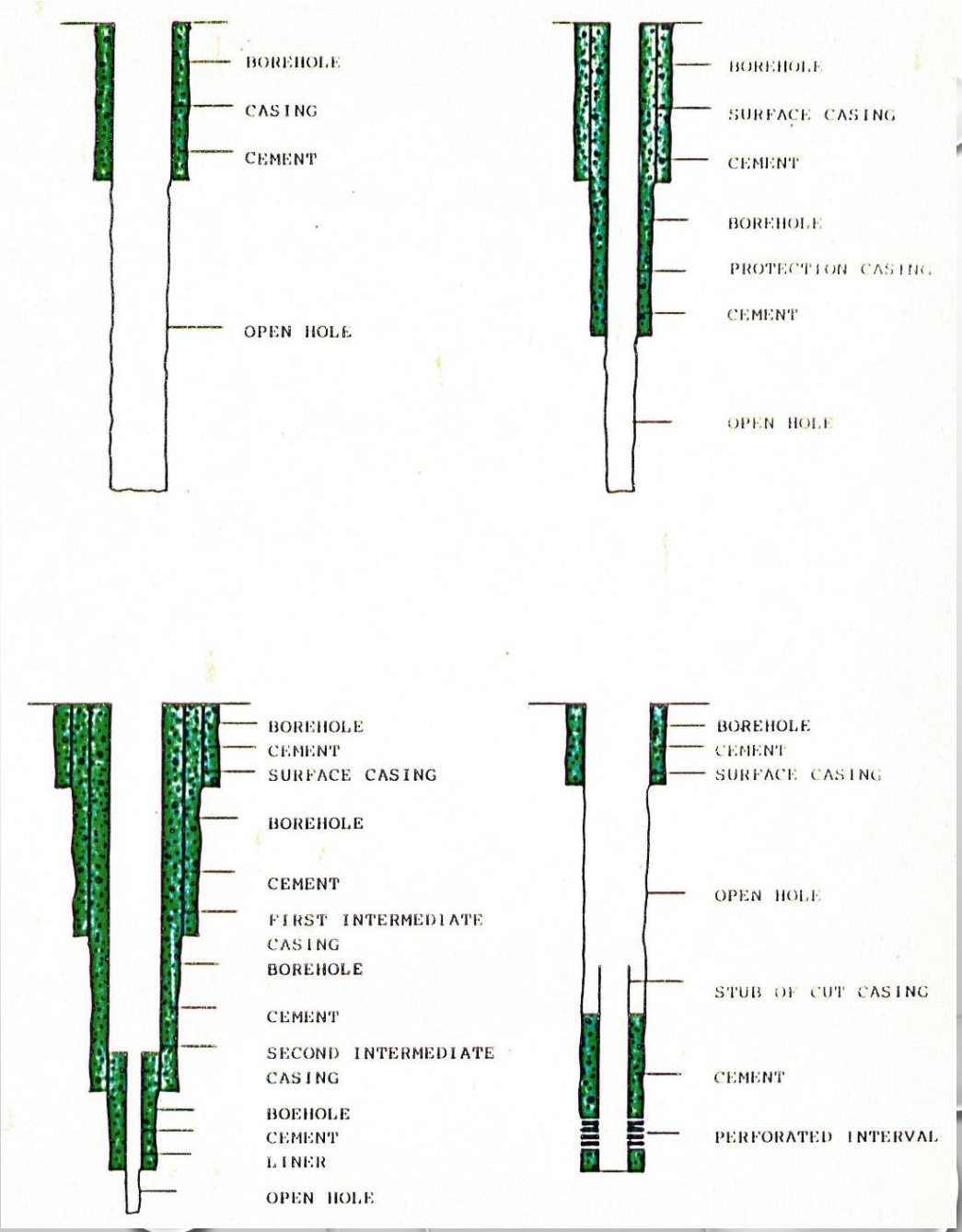


- Use tools to open tight places where casing is collapsed
- If cement voids or other loss of cement integrity is suspected, squeeze cementing may be necessary

WELL PREP COMPLETE

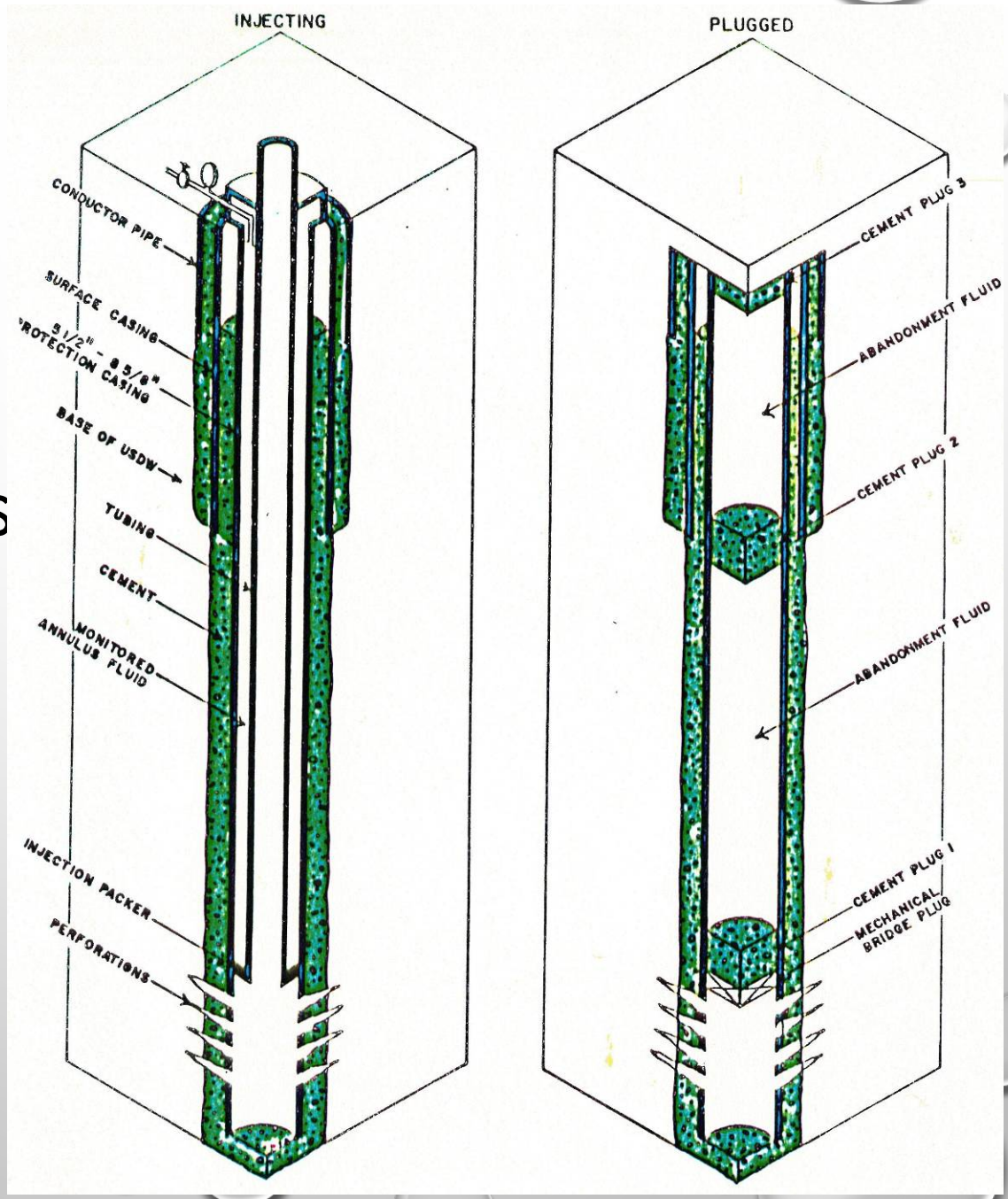
Prepared and ready for plugs!

But, where do they go?



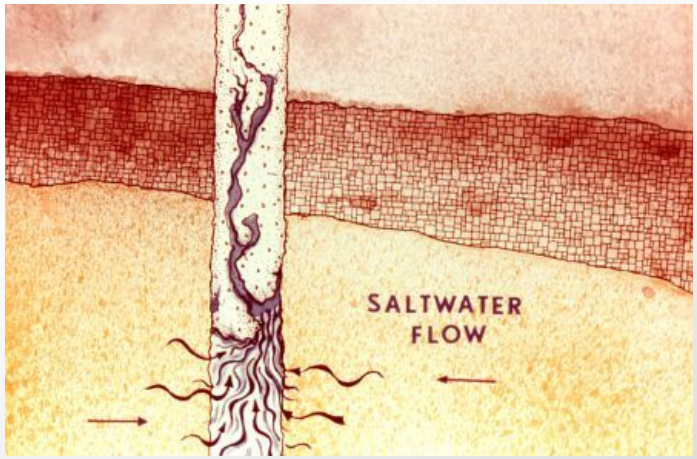
PLUG FUNCTIONS

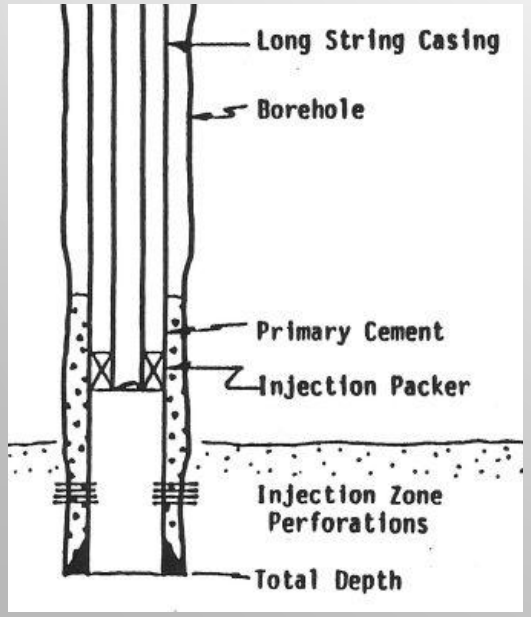
- ISOLATE THE SURFACE
- ISOLATE THE USDWS
- ISOLATE ANY MINERAL-BEARING FORMATIONS
- ISOLATE THE INJECTION ZONE

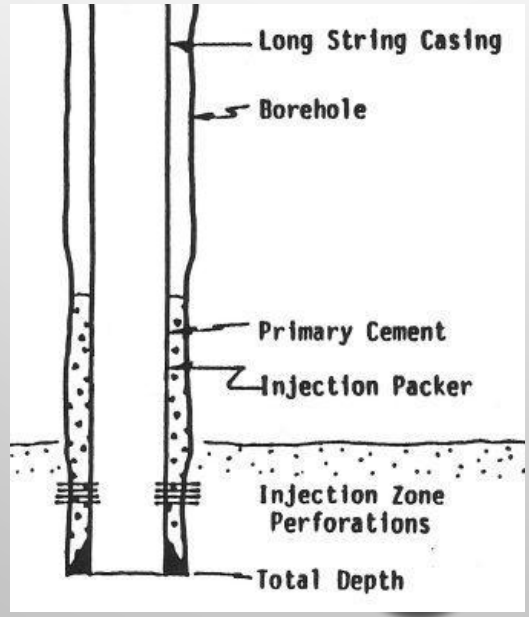


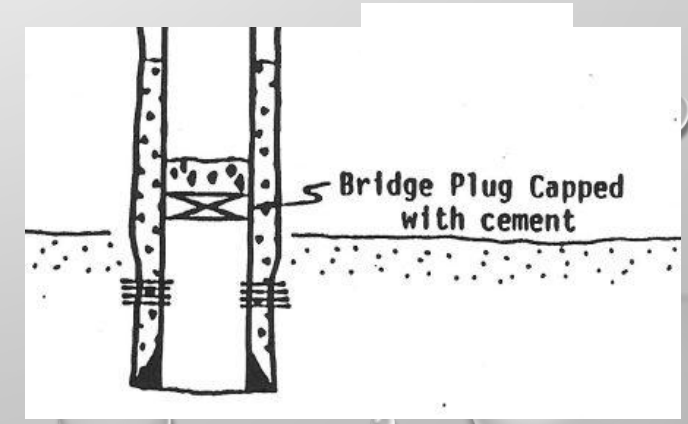
WELL PREP

- PLUG BACK THE LOWER ZONES (ESP. INJECTION ZONE)
- PREVENTS FLUID FROM ENTERING THE WELL
- MIGHT MAKE OTHER PREPARATORY STEPS EASIER



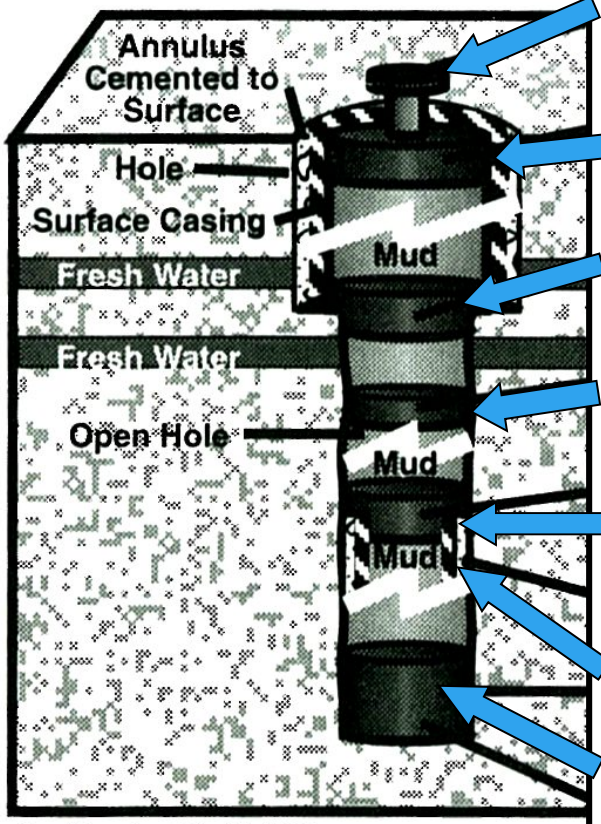






GENERIC REQUIREMENTS FOR WELL PLUGGING

TYPICAL PLUGGING REQUIREMENTS FOR OIL AND GAS WELLS IN MOST STATES

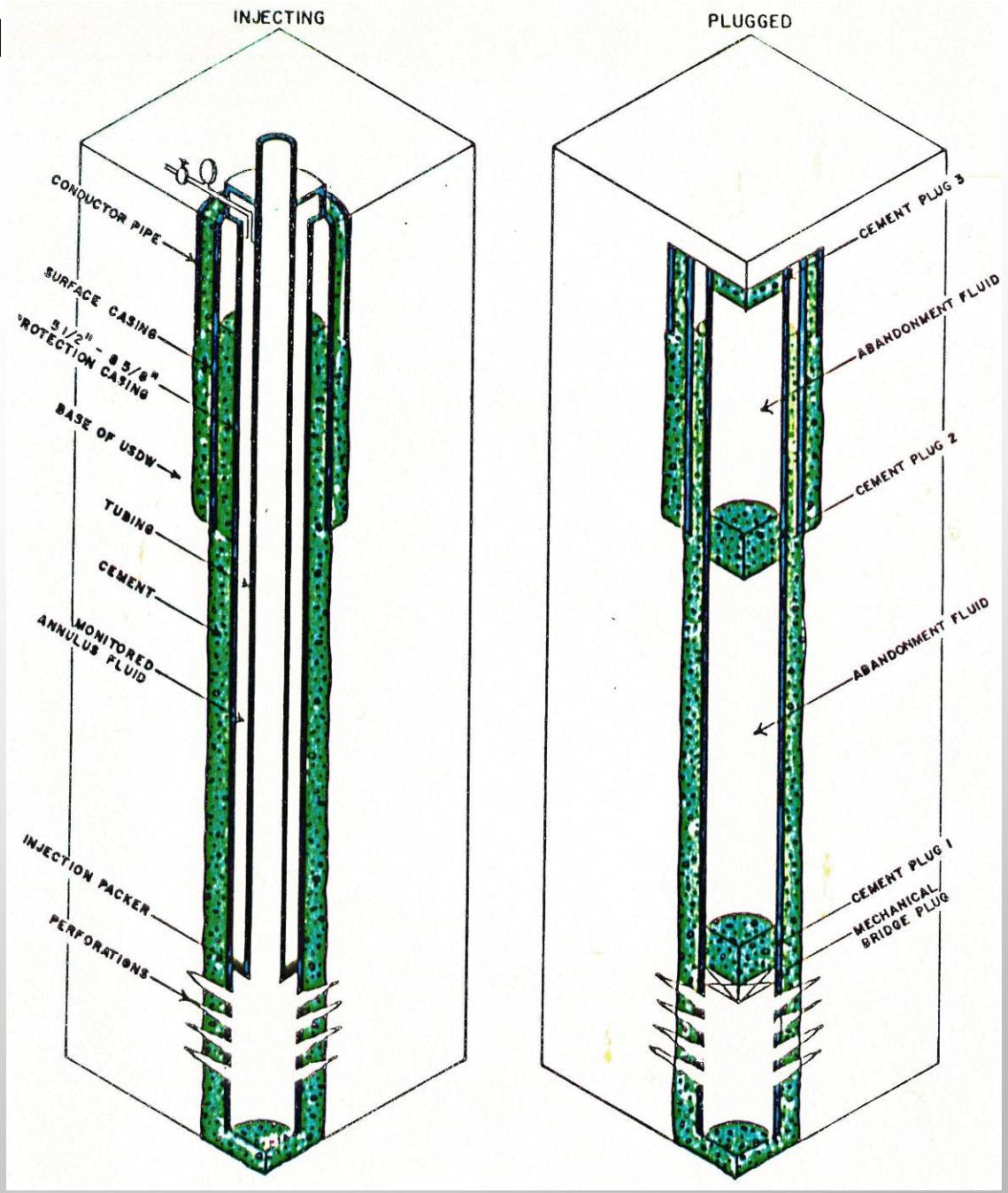


After Herndon & Smith 1976

- 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

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

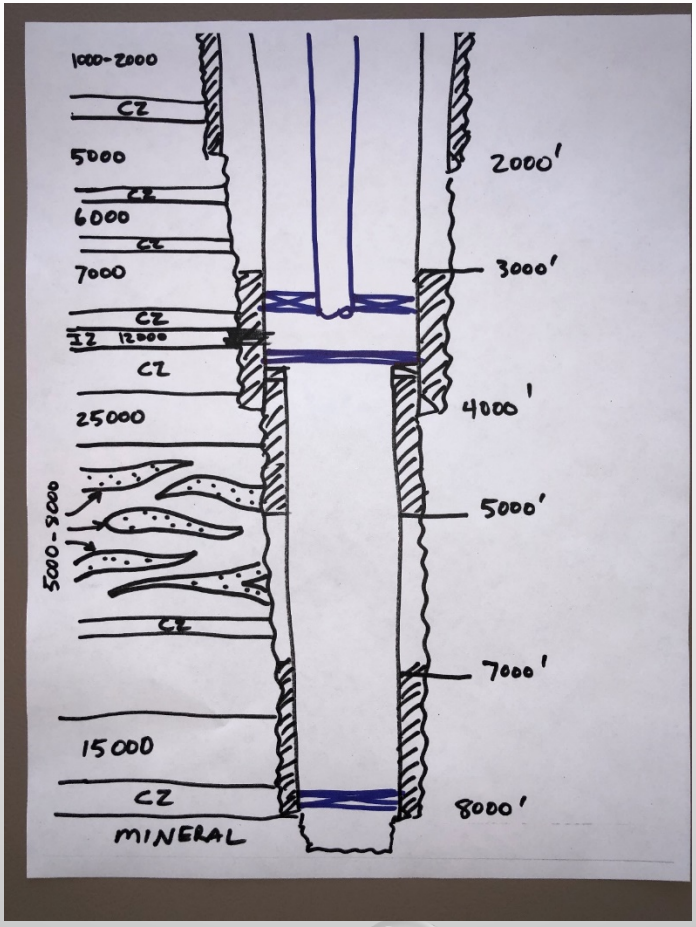
- BASIC CEMENTS: CLASS A, C, G, AND H (OFTEN DENSIFIED WITH A DISPERSANT)
- ADDITIVES: FOR HIGHER OR LOWER DENSITY, FASTER OR SLOWER THICKENING TIME, IMPROVED BOND, ETC.
- WATER: CLEAN & FRESH IS BEST
- CHECK THE SLURRY VOLUME IN FT^3/SACK
- PLUG DEPTH AND STRENGTH MUST BE VERIFIED
  - WAIT FOR CEMENT TO SET AND TAG THE PLUG
  - SET PLUG WITH A BRIDGE PLUG BELOW

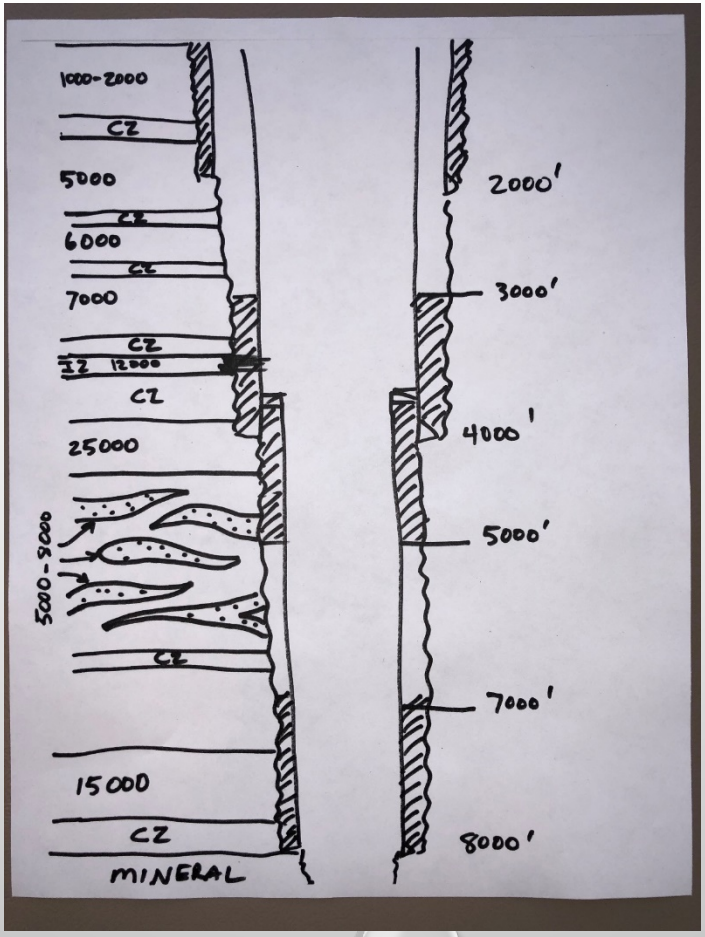
PLUG LOCATIONS

- 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 OPERTOR WANTS TO PLUG

HYPOTHETICAL P&A

WHERE TO SET PLUGS


1000-2000
CZ
5000
CZ
6000
CZ
7000
CZ
IZ 12000
CZ
25000
5000-9000
CZ
15000
CZ
MINERAL
2000'
3000'
4000'
5000'
7000'
8000'


1000-2000
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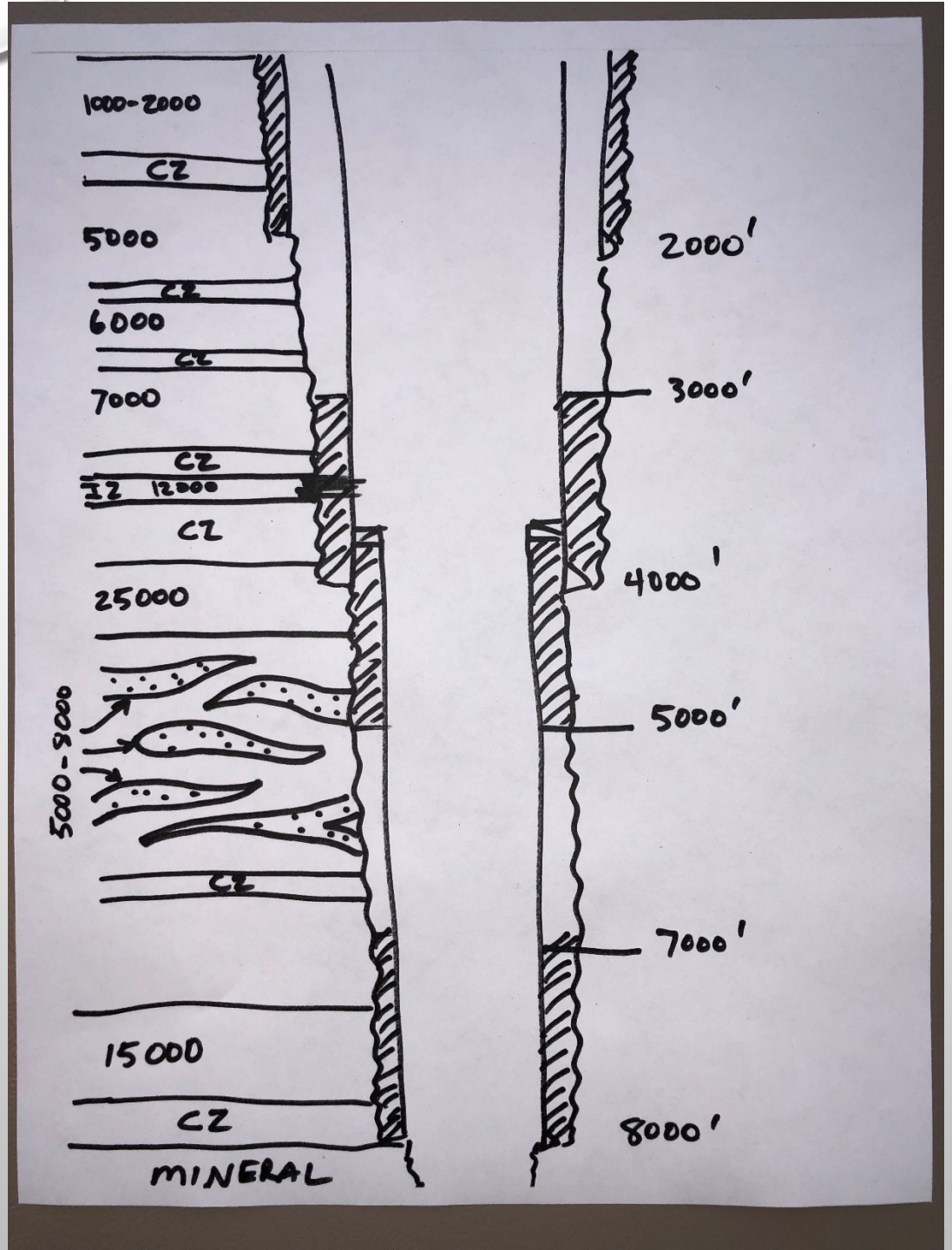
1000-2000
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15000
CZ
MINERAL
2000'
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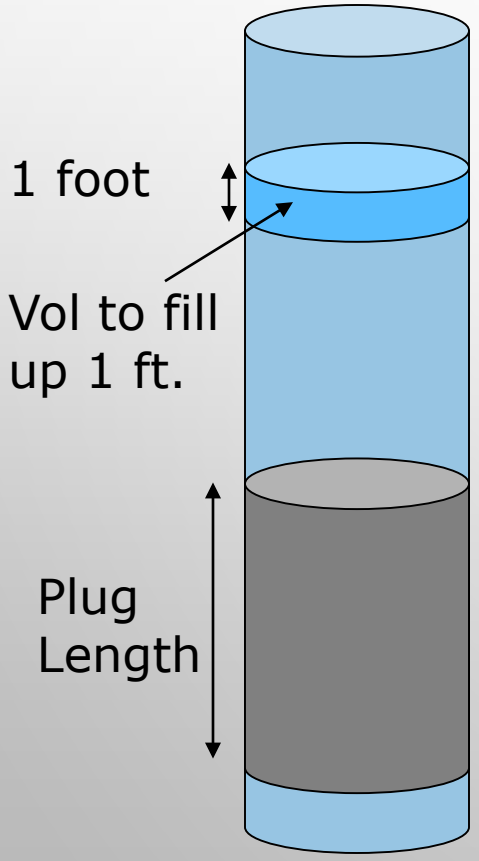
BASIC CEMENT CALCULATION



Variables	Source
Sacks of cement	
Thickness of plug, ft	State requirements or policy
Capacity of casing or hole (vol/linear ft)	Cementing tables
Excess cement required (percentage)	State requirements or policy
Slurry volume of the cement ft, cu. ft/sack	Cementing tables

CALCULATE SOME PLUG VOLUMES

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

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  CASING CAPACITY?

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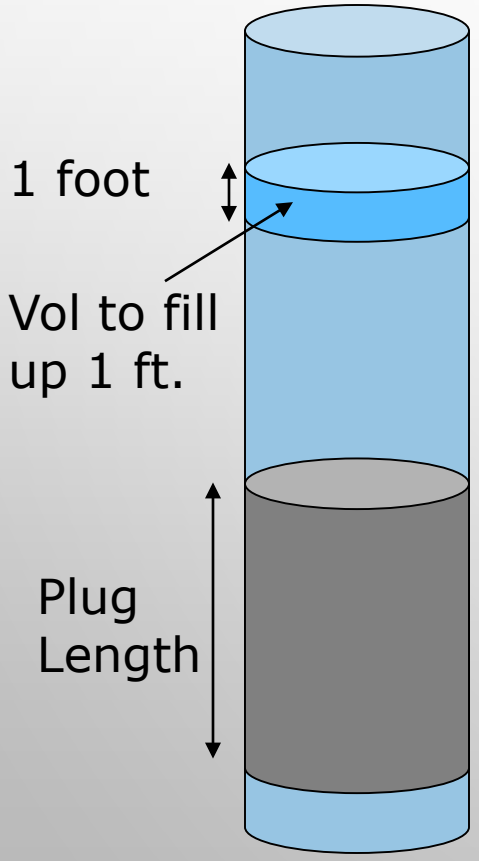

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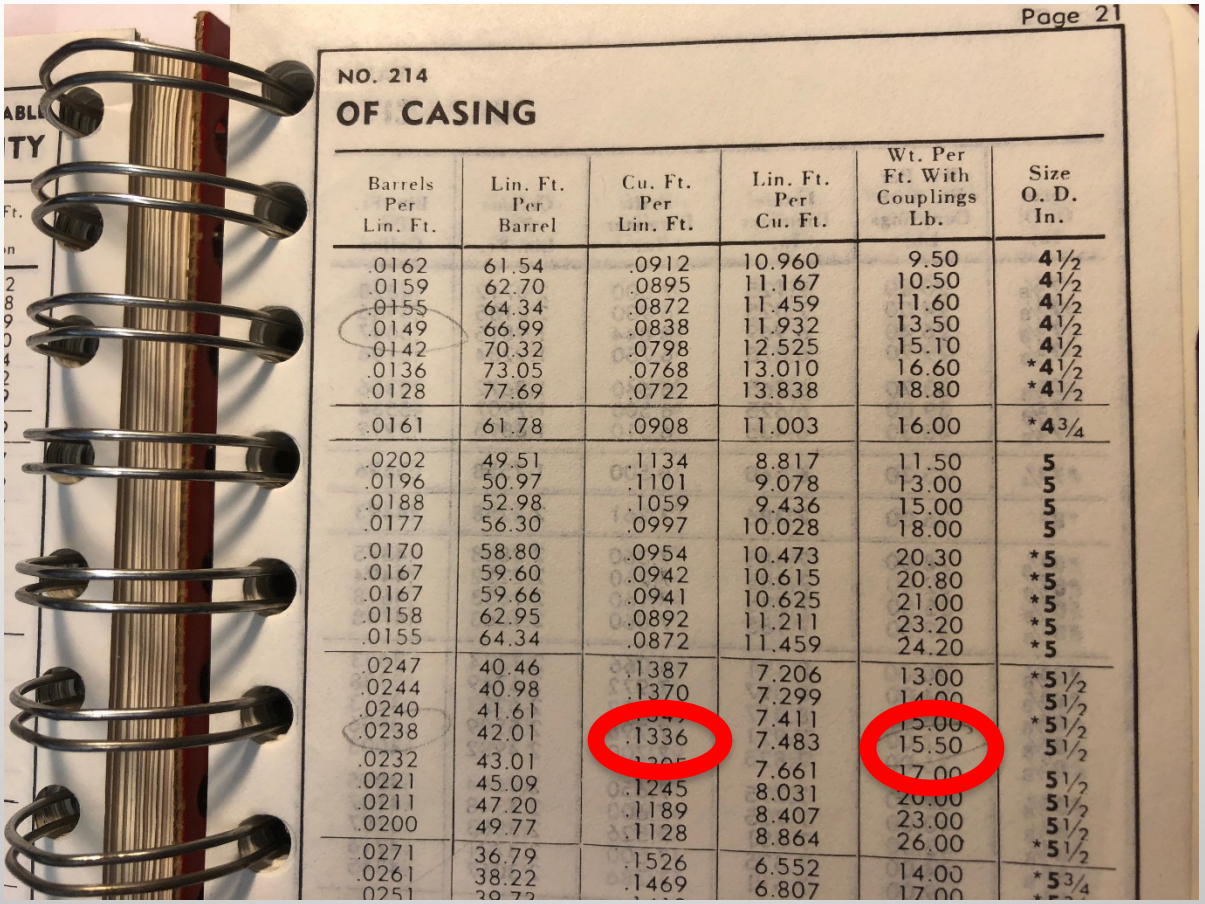
FROM REDBOOK



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OF CASING

Barrels Per Lin. Ft.	Lin. Ft. Per Barrel	Cu. Ft. Per Lin. Ft.	Lin. Ft. Per Cu. Ft.	Wt. Per Ft. With Couplings Lb.	Size O. D. In.
.0162	61.54	.0912	10.960	9.50	4½
.0159	62.70	.0895	11.167	10.50	4½
.0155	64.34	.0872	11.459	11.60	4½
.0149	66.99	.0838	11.932	13.50	4½
.0142	70.32	.0798	12.525	15.10	4½
.0136	73.05	.0768	13.010	16.60	*4½
.0128	77.69	.0722	13.838	18.80	*4½
.0161	61.78	.0908	11.003	16.00	*4¾
.0202	49.51	.1134	8.817	11.50	5
.0196	50.97	.1101	9.078	13.00	5
.0188	52.98	.1059	9.436	15.00	5
.0177	56.30	.0997	10.028	18.00	5
.0170	58.80	.0954	10.473	20.30	*5
.0167	59.60	.0942	10.615	20.80	*5
.0167	59.66	.0941	10.625	21.00	*5
.0158	62.95	.0892	11.211	23.20	*5
.0155	64.34	.0872	11.459	24.20	*5
.0247	40.46	.1387	7.206	13.00	*5½
.0244	40.98	.1370	7.299	14.00	5½
.0240	41.61	[illegible]	7.411	[illegible]	*5½
.0238	42.01	.1336	7.483	15.50	5½
.0232	43.01	[illegible]	7.661	17.00	5½
.0221	45.09	.1245	8.031	[illegible]	5½
.0211	47.20	.1189	8.407	23.00	5½
.0200	49.77	.1128	8.864	26.00	*5½
.0271	36.79	.1526	6.552	14.00	*5¾
.0261	38.22	.1469	6.807	17.00	[illegible]
.0251	39.72	[illegible]	[illegible]	[illegible]	[illegible]

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 (RED BOOK)

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  CASING CAPACITY = 0.1336 CU FT/LIN FT

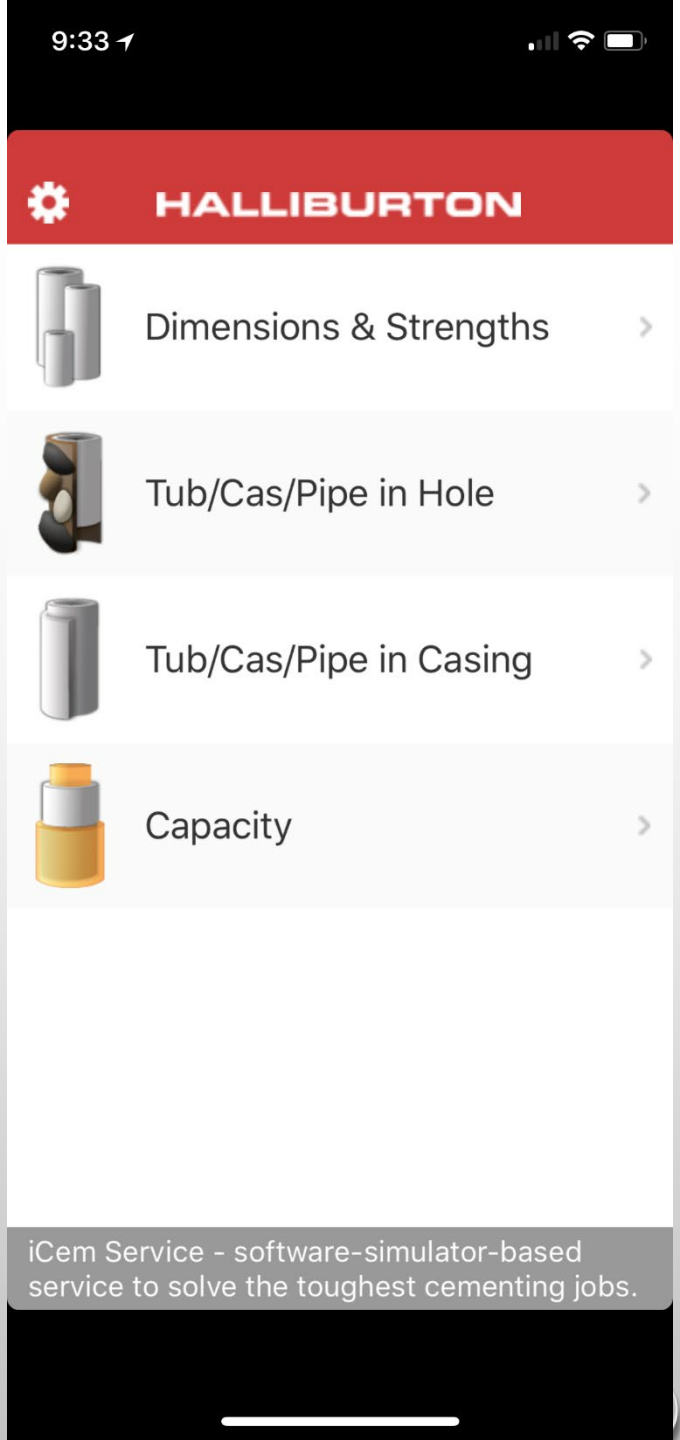
  PLUG VOLUME = (0.1336 CU FT/LIN FT) * (150 FT) = 20.04 CU FT

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

ITUNES STORE:
Halliburton eRedBook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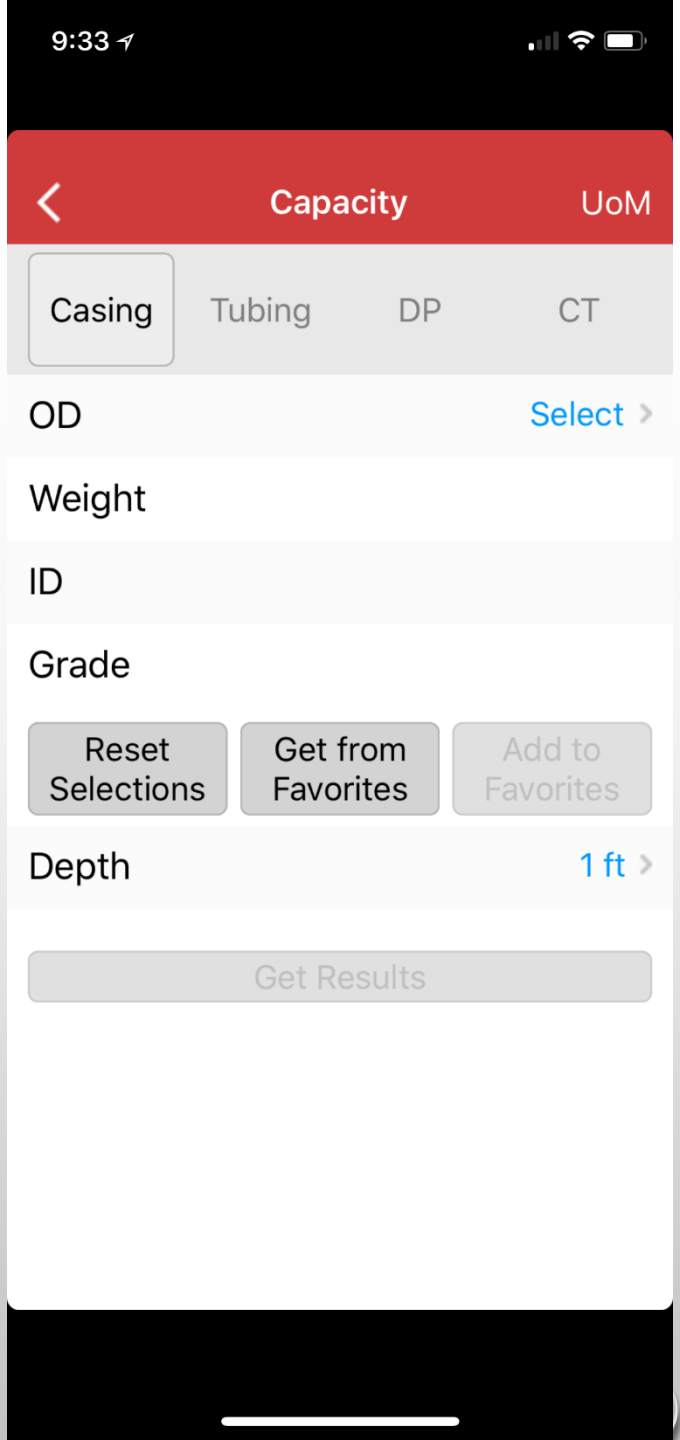
HALLIBURTON
Dimensions & Strengths
Tub/Cas/Pipe in Hole
Tub/Cas/Pipe in Casing
Capacity
iCem Service - software-simulator-based service to solve the toughest cementing jobs.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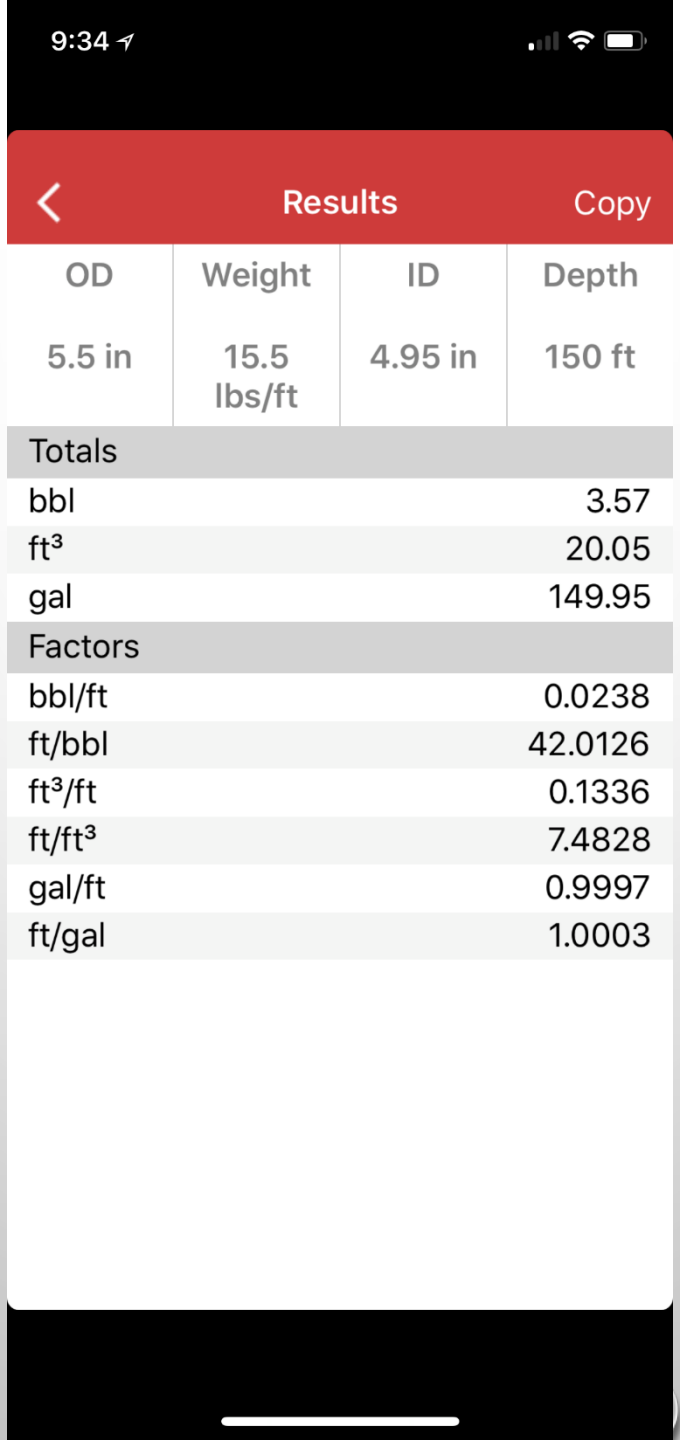
Capacity
UoM
Casing
Tubing
DP
CT
OD
Select
Weight
ID
Grade
Reset Selections
Get from Favorites
Add to Favorites
Depth
1 ft
Get Results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Results
Copy
OD
Weight
ID
Depth
5.5 in
15.5 lbs/ft
4.95 in
150 ft
Totals
bbl 3.57
ft³ 20.05
gal 149.95
Factors
bbl/ft 0.0238
ft/bbl 42.0126
ft³/ft 0.1336
ft/ft³ 7.4828
gal/ft 0.9997
ft/gal 1.0003

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?

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- PLUG NEEDED = 150 FT
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- HOW MANY SACKS OF CEMENT ARE NEEDED?
  SLURRY VOLUME (YIELD)

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  SLURRY VOLUME (YIELD) = 1.18 CU FT/SACK

CALCULATE SOME PLUG VOLUMES

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- 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
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- PLUG NEEDED = 150 FT
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- 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

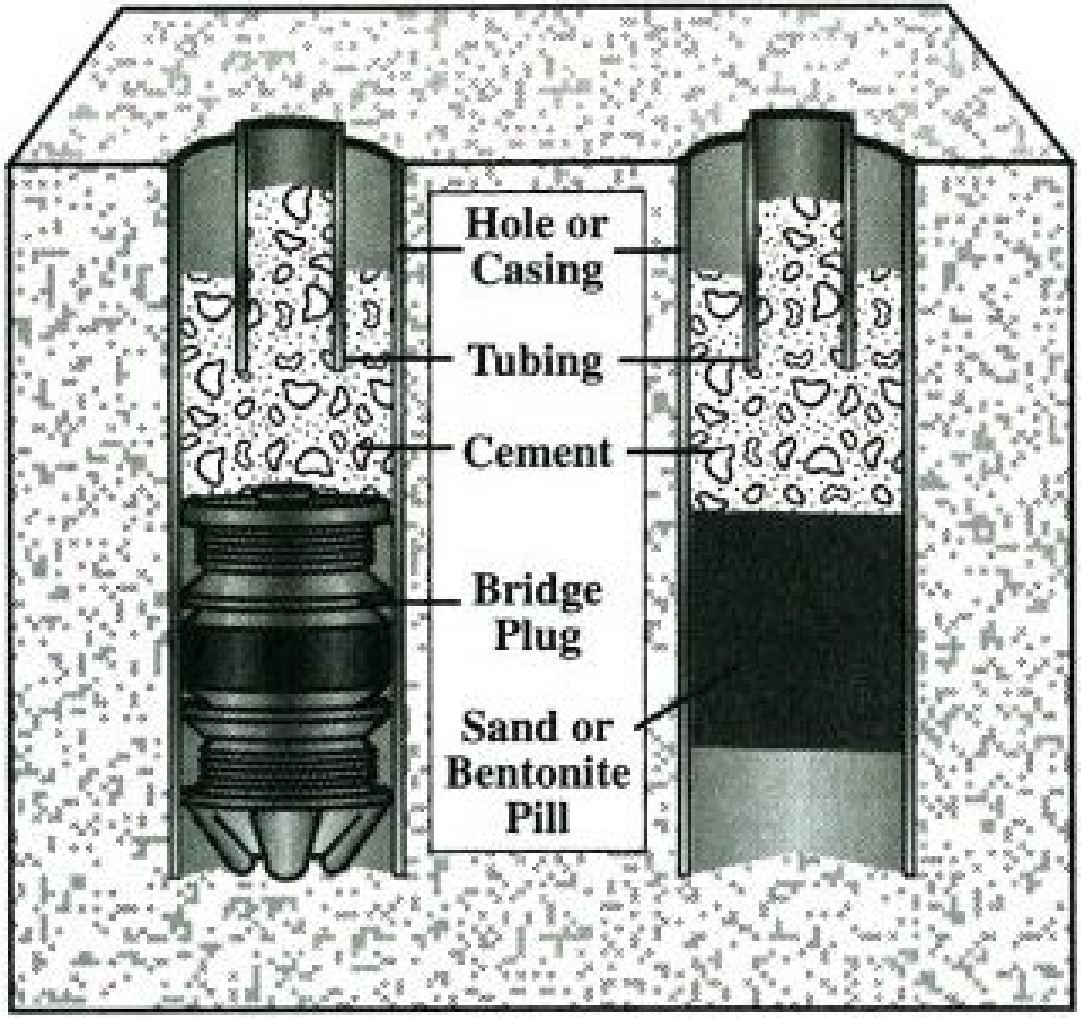
- 3 METHODS APPROVED IN THE FEDERAL UIC REGULATIONS
  - THE BALANCE METHOD
  - THE DUMP BAILER METHOD
  - THE TWO-PLUG METHOD

ALSO:

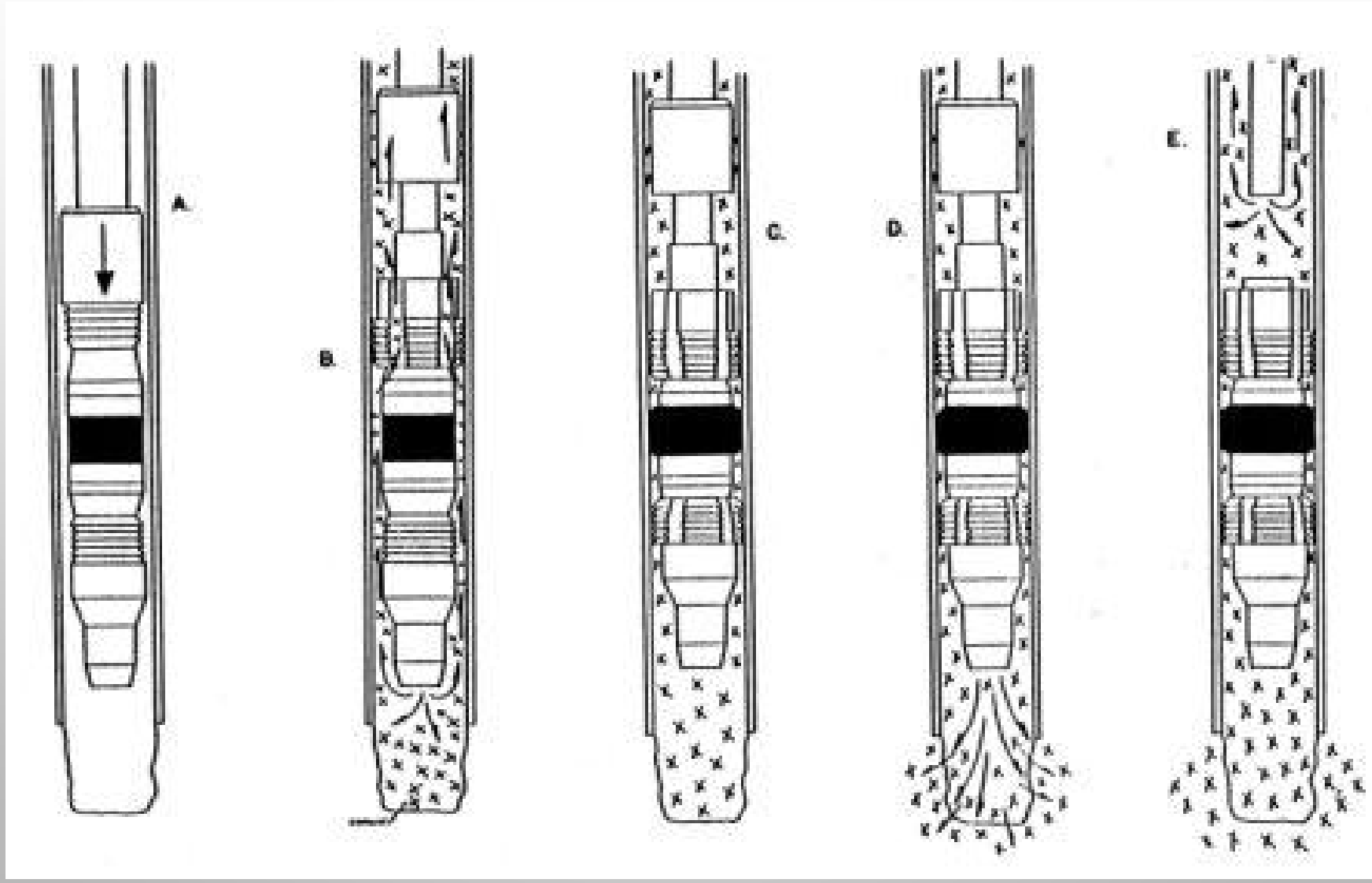
- AN ALTERNATE METHOD, APPROVED BY THE DIRECTOR, THAT WILL RELIABLY PROVIDE A COMPARABLE LEVEL OF PROTECTION MAY ALSO BE APPROVED

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

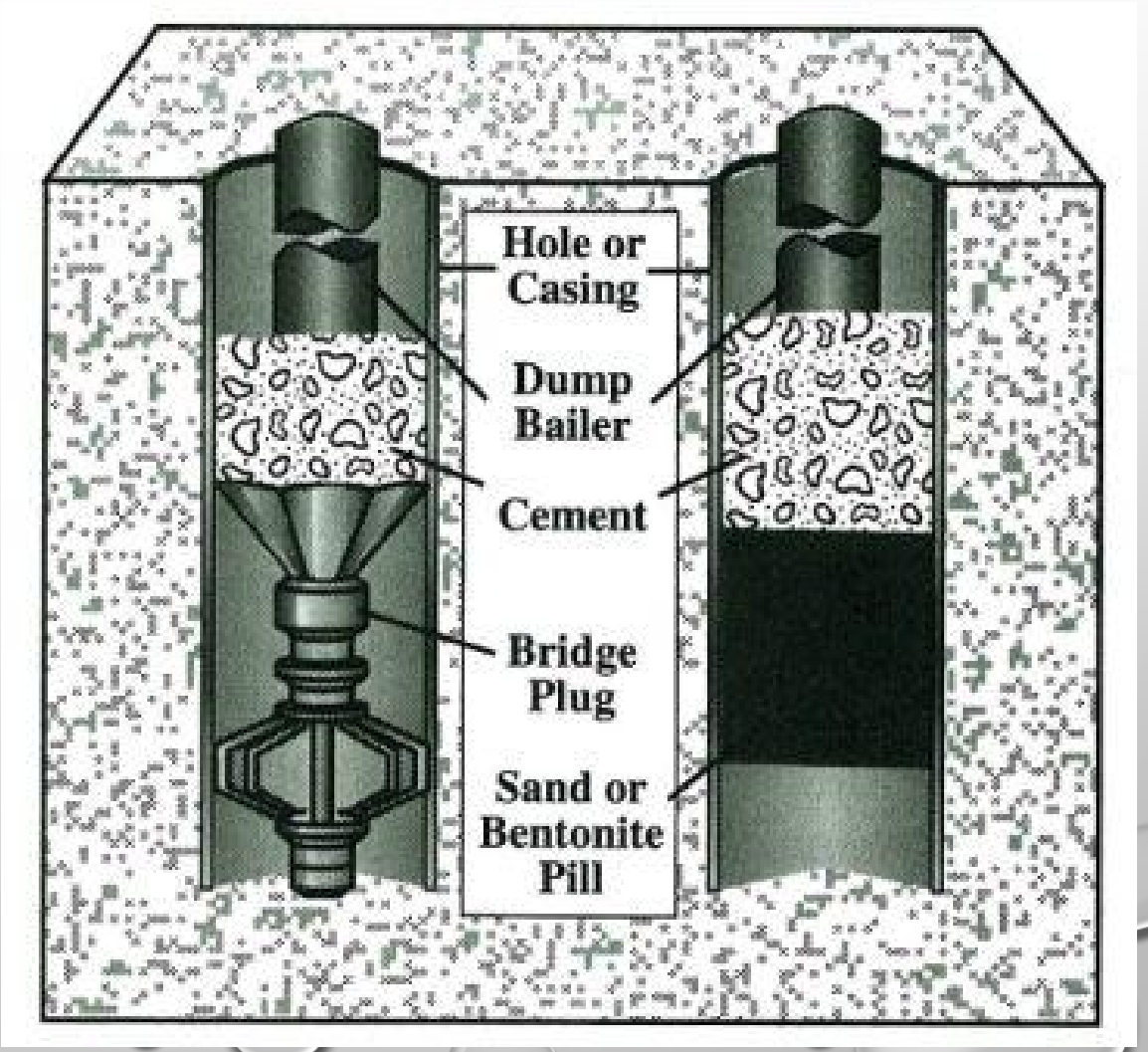


CEMENT RETAINER VARIATION



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 unforseen circumstances

FOR MORE INFORMATION

- HALLIBURTON CEMENTING TABLES (PRINT COPY)
- EREDBOOK IS AVAILABLE FOR DESKTOP AND SMARTPHONES

  GOOGLE “EREDBOOK”
- OILFIELD ACRONYMS:

  WIKIPEDIA

END

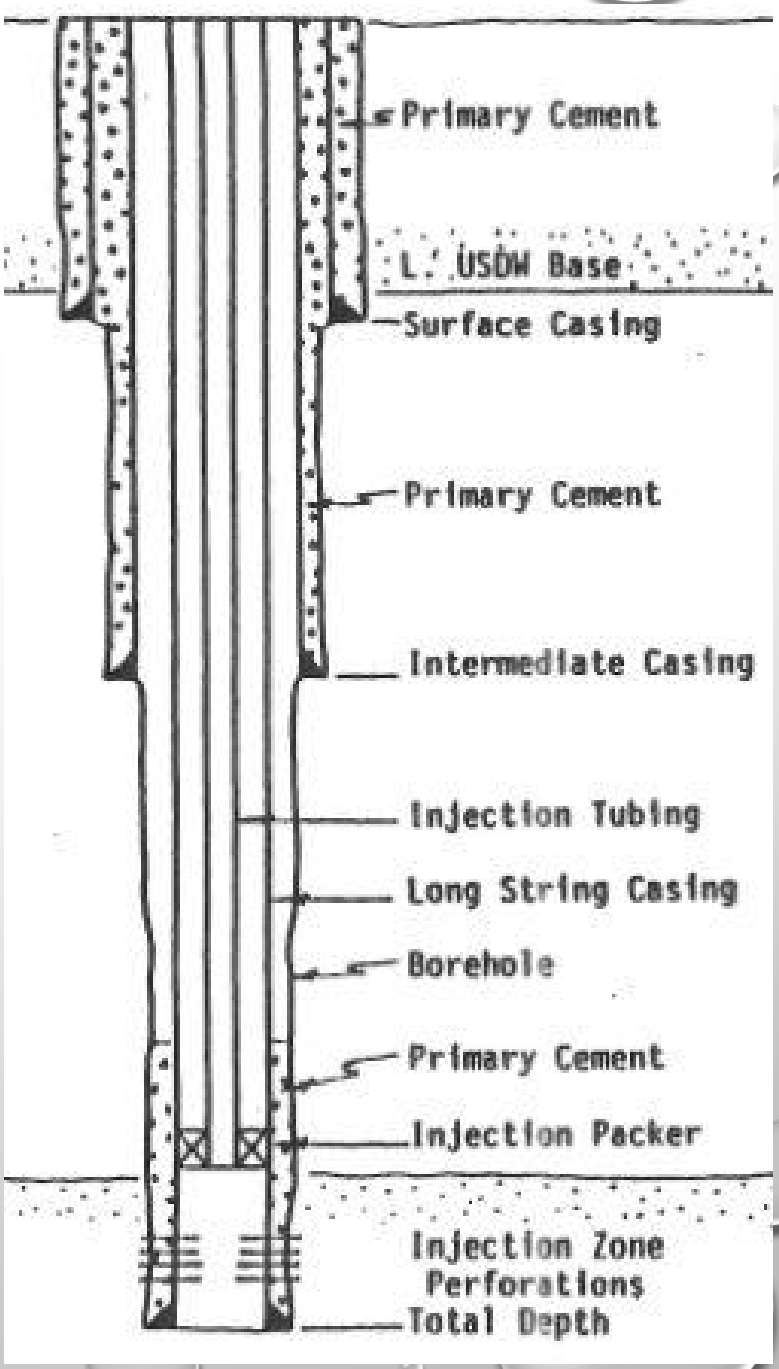
PLUGGING EXAMPLE

PREPARATION STEPS:

1) REMOVE TUBING, PACKER

2) CUT LSC ABOVE THE TOC AND PULL CASING

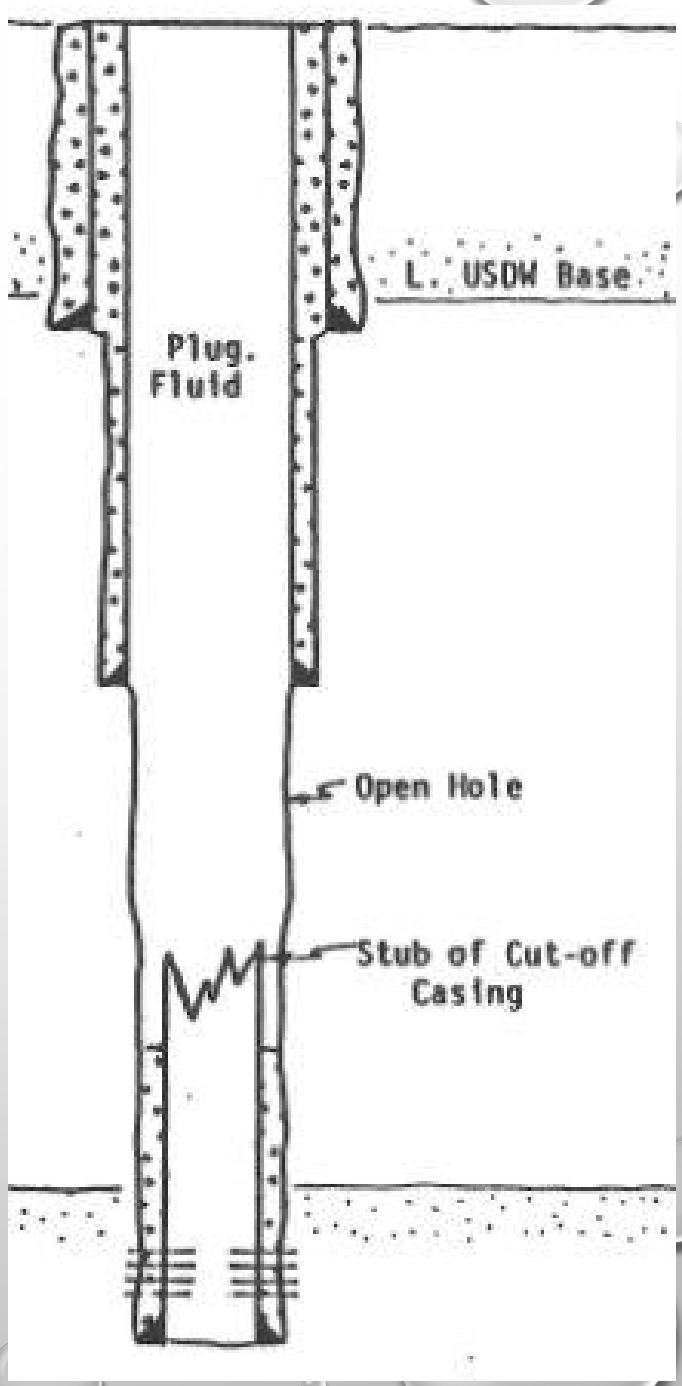
3) CIRCULATE MUD TO ACHIEVE STATIC EQUILLIBRIUM



PREPARED FOR PLUGGING

IDENTIFY ZONES WHICH MUST BE ISOLATED WITH CEMENT:

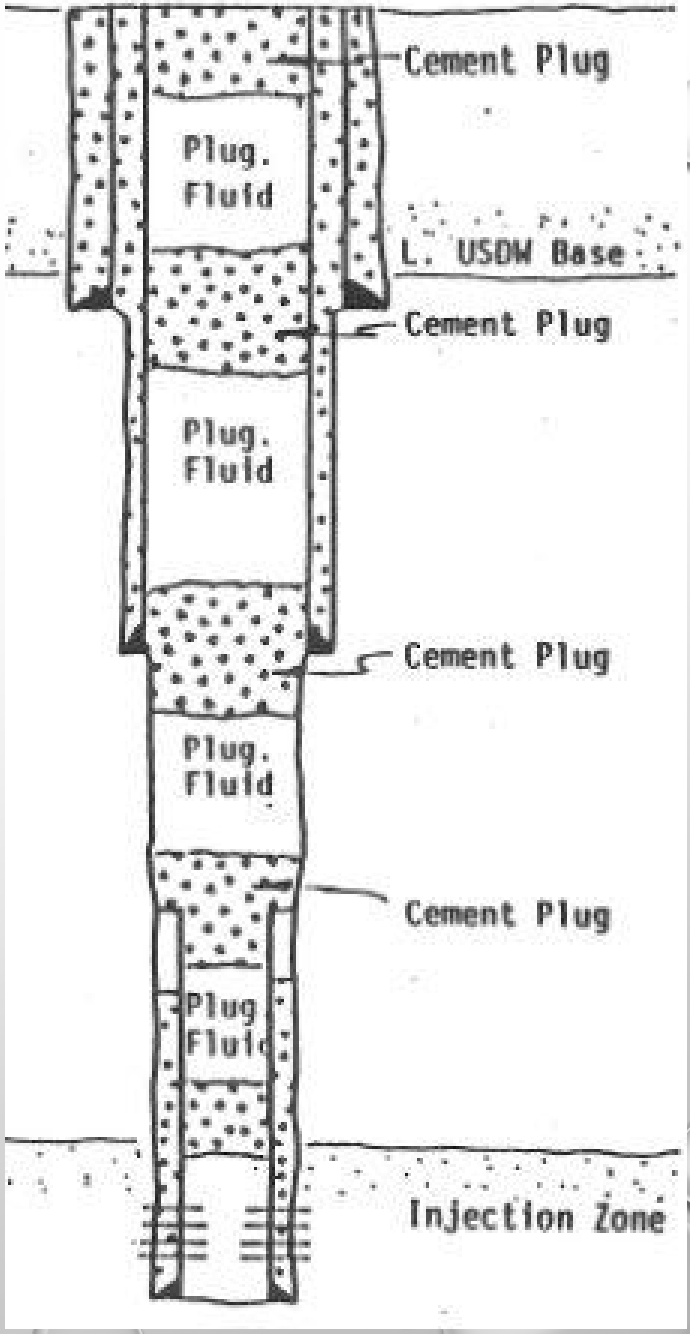
1) INJECTION ZONE
2) CASING STUB
3) ANY PRODUCING OR FLUID-BEARING ZONE IN THE OPEN HOLE
4) BASE OF THE INTERMEDIATE CASING
5)BASE OF THE SURFACE CASING AND USDW
6) GROUND SURFACE



APPROVED PLAN

ASSUME:

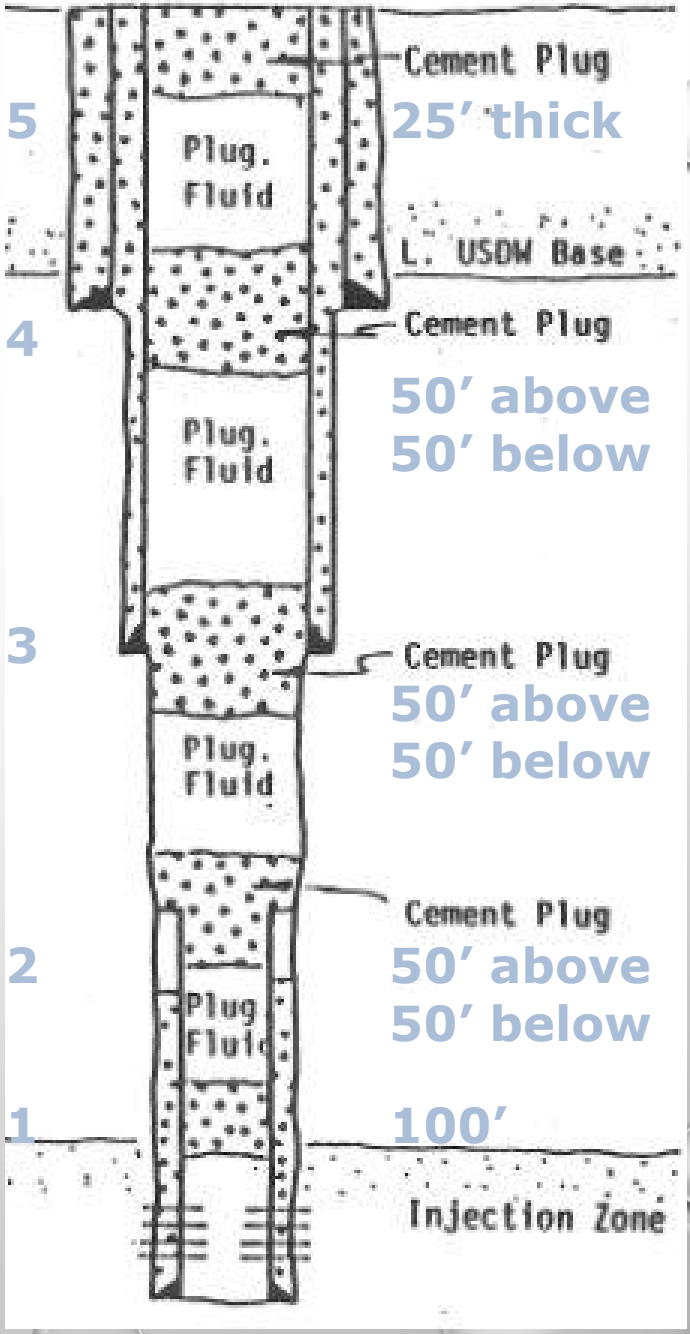
- 9⅝ IN., 36# INTERMEDIATE CASING
- 7 IN., 26# LSC IN A 8¾ IN. HOLE
- PLUG THICKNESSES FOLLOW THESE STATE REQUIREMENTS:
  1) 100’ CEMENT ISOLATING THE IZ IF NO BRIDGE PLUG/CEMENT RETAINER IS USED
  2) 50’ CEMENT ON A BRIDGE PLUG, IF USED
  3) 50’ CEMENT ABOVE AND BELOW A RIP POINT OR SURFACE CASING SHOE
  4) 50’ CEMENT ISOLATING PRODUCING ZONES
  5) 25’ CEMENT AT THE SURFACE



PLUGS NUMBERED

ASSUME:

- 9⅝ IN., 36# INTERMEDIATE CASING
- 7 IN., 26# LSC IN A 8¾ 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 ABOVE AND BELOW A RIP POINT OR SURFACE CASING SHOE
  3) 50’ CEMENT ISOLATING PRODUCING ZONES
  4) 25’ CEMENT AT THE SURFACE



PLUG #1

- 9⅝ IN., 36# INTERMEDIATE CASING
- 7 IN., 26# LSC IN A 8¾ 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

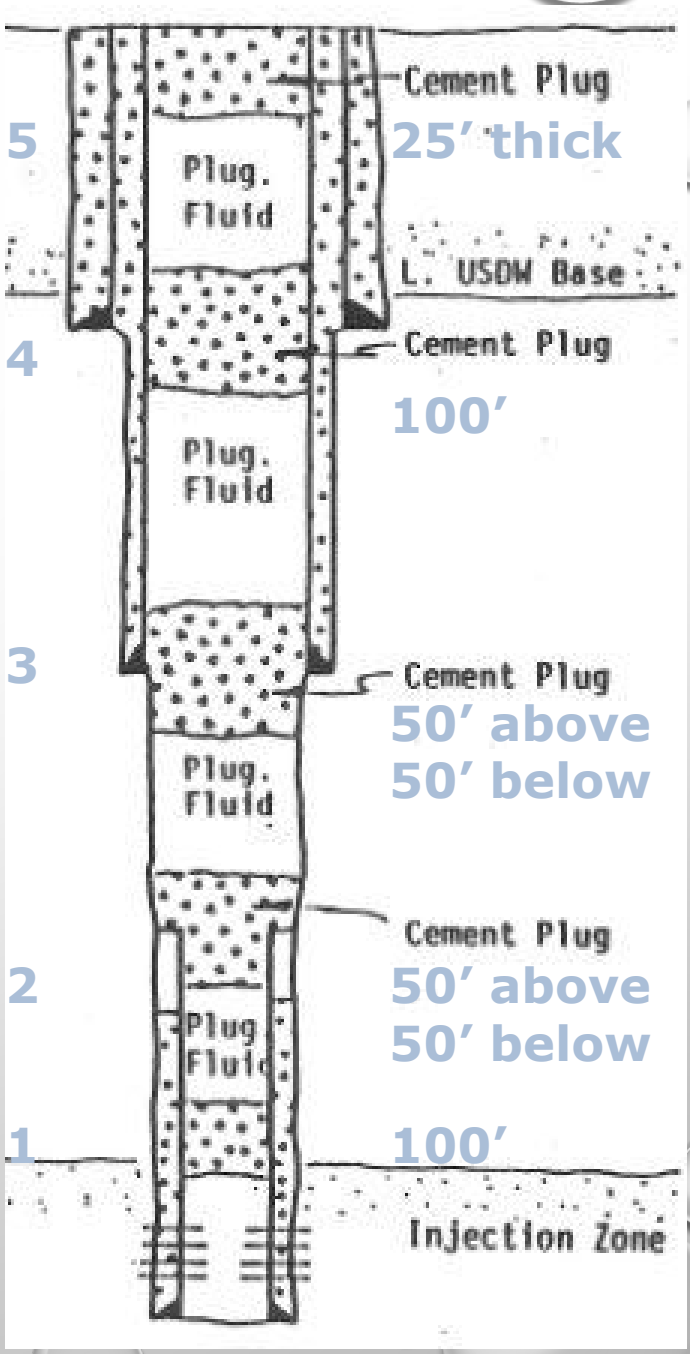
C = 0.2148 FT^3/FT

E_C= 0

V_{SL} = 1.18 FT^3/SACK

$$S_C = \frac{100\ FT \times 0.2148\ FT^3/FT}{1.18\ FT^3/SACK}$$

= **18 SACKS**

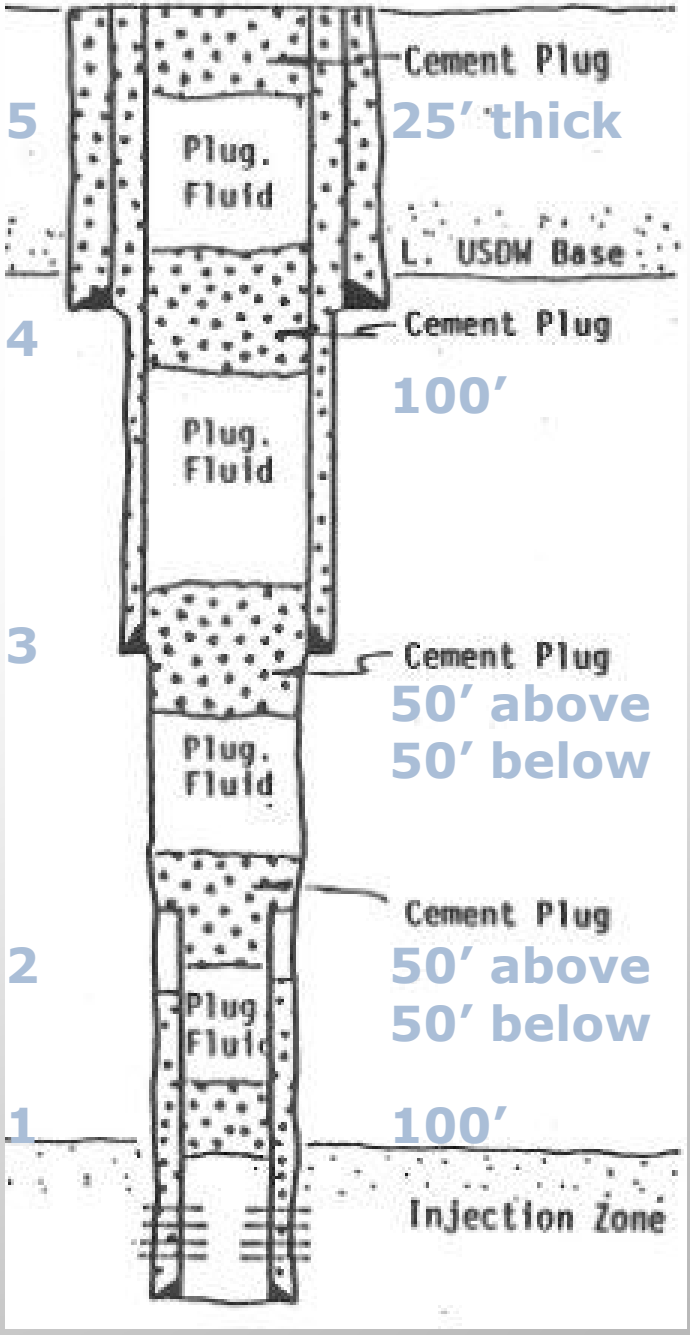


PLUG #2

- 9⅝ IN., 36# INTERMEDIATE CASING
- 7 IN., 26# LSC IN A 8¾ IN. HOLE
- CLASS A CEMENT (1.18 FT^3/SACK)
- $S_C = L \times C \times (1+E_C) \div V_{SL}$

Plug 2 bottom:	Plug 2 top:
L = 50 feet	L = 50 feet
C = 0.2148 ft^3/ft	C = 0.4176 ft^3/ft
E_c= 0	E_c= 0.2
V_{sl} = 1.18 ft^3/sack	V_{sl} = 1.18 ft^3/sack
$S_c = \frac{50 \times 0.2148}{1.18}$ = **9.1 sacks**	S_c = 50 × 0.4176 × (1 + 0.2) ÷ 1.18 = **21.2 sacks**

TOTAL = 31 SACKS

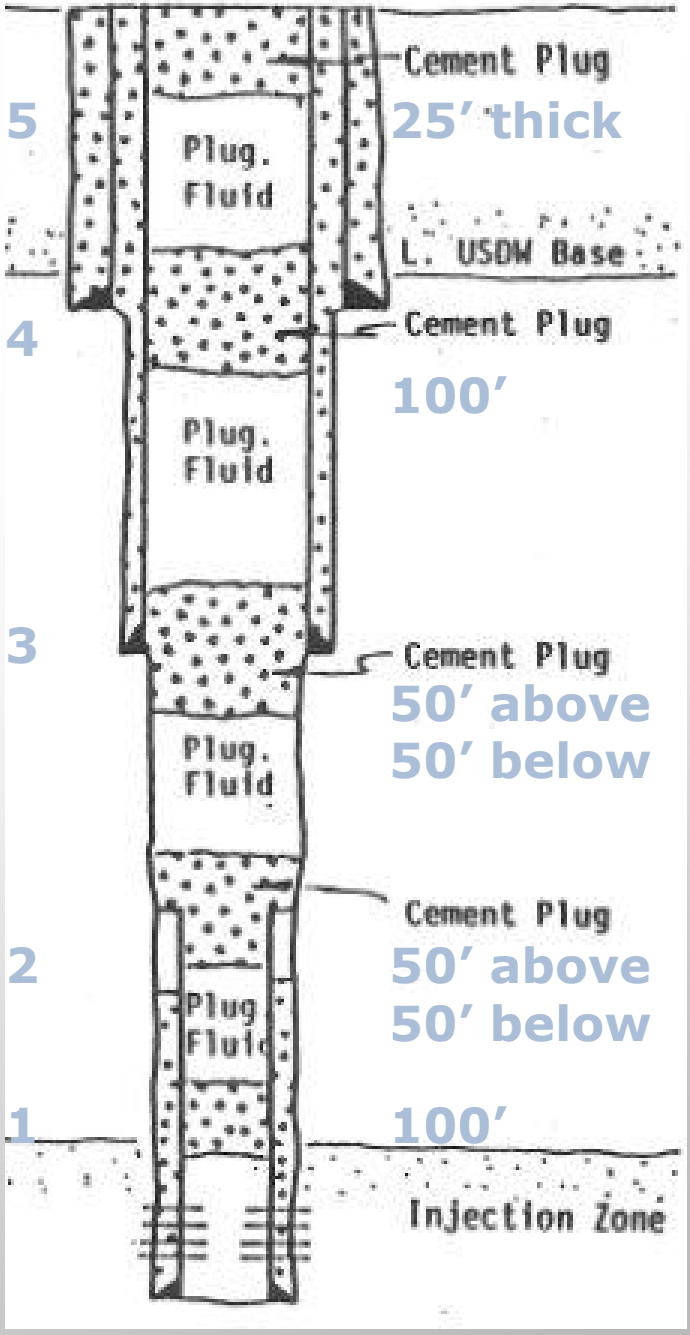


PLUG #3

- 9⅝ IN., 36# INTERMEDIATE CASING
- 7 IN., 26# LSC IN A 8¾ IN. HOLE
- CLASS A CEMENT (1.18 FT^3/SACK)
- $S_C = L \times C \times (1+E_C) \div V_{SL}$

Plug 3 bottom:	Plug 3 top:
L = 50 feet	L = 50 feet
C = 0.4176 ft^3/ft	C = 0.4340 ft^3/ft
E_c= 0.2	E_c= 0
V_{sl} = 1.18 ft^3/sack	V_{sl} = 1.18 ft^3/sack
$S_c = 50 \times 0.4176 \times (1 + 0.2) \div 1.18$ = **21.2 sacks**	$S_c = \frac{50 \times 0.4340}{1.18}$ = **18.4 sacks**

TOTAL = 40 SACKS



PLUG #4

- 9⅝ IN., 36# INTERMEDIATE CASING
- 7 IN., 26# LSC IN A 8¾ IN. HOLE
- CLASS A CEMENT (1.18 FT^3/SACK)
- $S_C = L \times C \times (1+E_C) \div V_{SL}$

<u>PLUG 4</u>:

L = 100 FEET

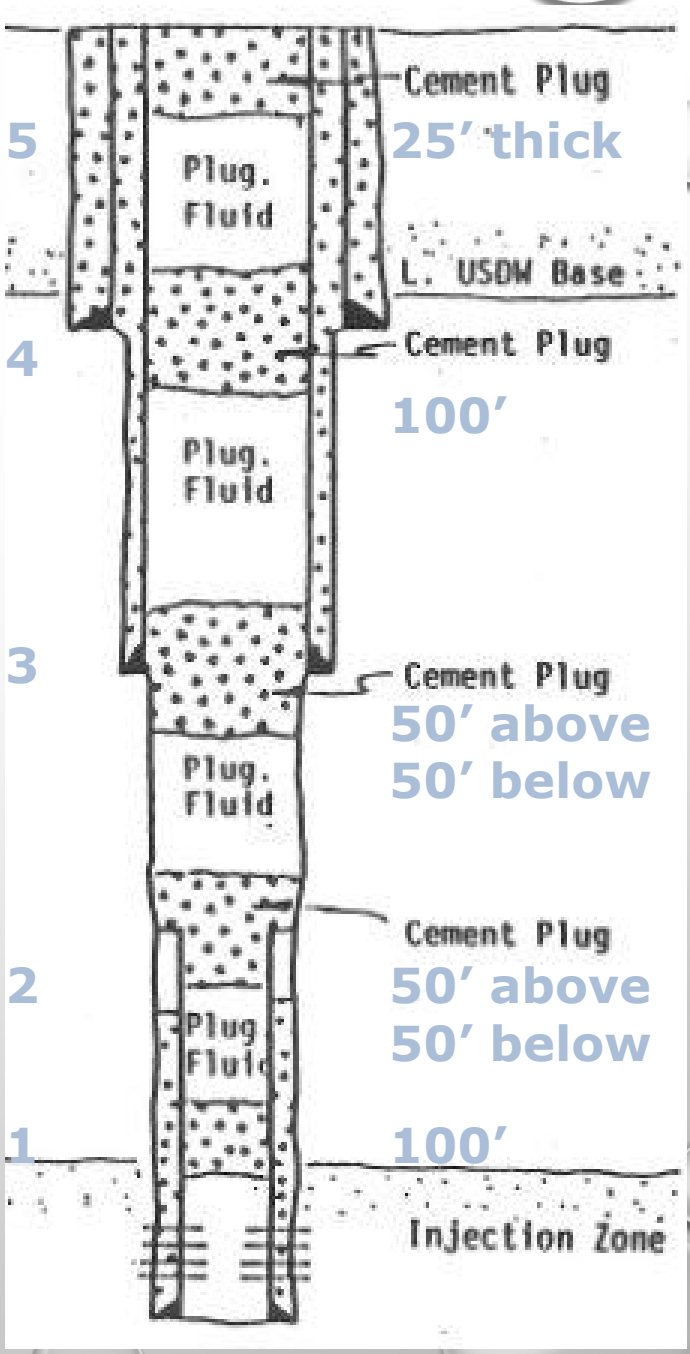
C = 0.4340 FT^3/FT

E_C= 0

V_{SL} = 1.18 FT^3/SACK

$$S_C = \frac{100\ FT \times 0.4340\ FT^3/FT}{1.18\ FT^3/SACK}$$

= **37 SACKS**



PLUG #5

- 9⅝ IN., 36# INTERMEDIATE CASING
- 7 IN., 26# LSC IN A 8¾ IN. HOLE
- CLASS A CEMENT (1.18 FT^3/SACK)
- $S_C = L \times C \times (1+E_C) \div V_{SL}$

PLUG 5:

L = 25 FEET

C = 0.4340 FT^3/FT

E_C= 0

V_{SL} = 1.18 FT^3/SACK

$$S_C = \frac{25\ FT \times 0.4340\ FT^3/FT}{1.18\ FT^3/SACK}$$

= **9 SACKS**