10.9 FORMATION INTEGRITY TESTS

The hesitation method shall be used for the conduct of all Formation Integrity Tests. This involves pumping a small amount, waiting for the pressure to stabilise before repeating the process until the maximum test pressure is achieved. The test pressure shall be limited to a maximum pressure that does not exceed the lowest of the following:

- Actual leak-off pressure.
- The pressure specified in the Drilling Programme (typically the pressure required to give required kick tolerance or 80% of casing burst pressure).
- The wellhead test pressure.
- The BOP test pressure.
- A maximum pressure of 0.8 psi/ft at the casing shoe.

10.9.1 Responsibilities

All responsibilities for Formation Integrity Testing are given in Section 10.2

10.9.2 Testing Preparation

The following equipment is recommended for execution of a Formation Integrity Test, for accuracy and control:

- Pumping unit with tanks calibrated in ¼ barrel increments.
- Calibrated gauges covering anticipated pressure ranges mounted on a manifold.
- Chart recorder.

10.9.3 Test Procedure

The following procedure shall be adhered to when performing a Formation Integrity Test:

1. Drill out cement plus 3 m of new formation.
2. Circulate clean to a balanced mud weight (use old mud from previous section).
3. Pull the bit back in casing shoe.
4. Make sure the hole is filled up and close the annular BOP (Hydril) around the drill pipe.
5. Rig up the pump to the drill pipe. Use a pressure gauge of appropriate range (0 - 1,500 psi.), mounted at the pump unit manifold.
6. Slowly pump mud until pressures begin to increase. Volume pumped will start from this point.
7. Pump 0.125 - 0.25 bbl and wait for 2 minutes or the time required for the pressure to stabilise in the case this takes longer.
8. Record the volume pumped, and the bleed back stabilised pressure.
9. Repeat items 6 & 7 and plot pressures versus cumulative mud volume
10. Continue procedure until either the final stabilised pressure, after the waiting time, deviates from the expected pressure from the plot or the required maximum pressure is reached.
11. Keep well closed in to verify that a constant pressure has indeed been obtained.
12. Release pressure and record volume recovered in tank.

10.9.4 Calculations

Formation Intake Gradient (FIG)

$$FIG = \frac{LOP + (CSD \times MG)}{(CSD - RKBE)} \text{ psi/ft}$$

Effective Mud Gradient (EMG)

$$EMG = \frac{LOP + (CSD \times MG)}{CSD} \text{ psi/ft}$$

Maximum Allowable Annular Surface Pressure (MAASP)

$$MAASP = LOP - (CSD \times MG) \text{ psi}$$

Formation Breakdown Pressure (FBP)

$$FBP = LOP + (CSD \times MG)$$

Where:

LOP	=	Leak-Off Pressure (psi), surface pressure recorded during the test
CSD	=	Shoe Depth of last casing set (TVD ft RKB)
MG	=	Mud Gradient (psi/ft)
RKBE	=	Rotary Kelly bushing elevation above ground level (ft)

APPENDIX 1: GENERAL WELL CONTROL FORMULAE

1. The Formation Pressure (P_0)

$$P_0 = P_{dp} + (D_h \times \rho_1) \text{ psi}$$

Po = Formation Pressure (psi)
Pdp = Shut in drill pipe pressure (psi)
Dh = Depth of hole (ft)
p_1 = Formation pressure gradient (psi/ft

2. The new mud gradient to balance P_0 (ρ_2)

$$\rho_2 = P_0 \div D_h \text{ psi/ft}$$

3. The height of the influx (h_{inf})

$$h_{inf} = V_{inf} \div CAP_{ann} \text{ ft}$$

Vinf = Volume of influx (bbl)
CAPann – Annular capacity (bbl/ft)

4. The gradient of the influx (ρ_{inf})

$$\rho_{inf} = \rho_1 - (P_{ann} - P_{dp}) \div h_{inf} \text{ psi/ft}$$

Pann = Shut in casing pressure (psi)

5. Type of influx

ρ_{inf} 〈 0.2 psi/ft is gas
ρ_{inf} 〈 0.35 - 0.39 psi/ft is crude oil
ρ_{inf} 〈 0.433 psi/ft is water
ρ_{inf} 〈 0.433 - 0.465 psi/ft is salt water

6. Volumes

Contents of string

$$V_{str} = CAP_{dp} \times (D_h - L_{dc}) + CAP_{dc} \times L_{dc} \text{ bbls}$$

Vstr = Volume of string (bbl)
CAPdp = Capacity of dp (bbl/ft)
Ldc = Length drill collars (ft)
CAPdc = Capacity of dc (bbl/ft)
Ldc-oh = Length dc in oh (ft)

Contents of annulus open hole section

$$V_{dc-oh} = CAP_{dc-oh} \times L_{dc-oh} \text{ bbls}$$

Vdc-oh = volume between oh and dc (bbl)
CAPdc-oh = Capacity between dc and oh (bbl/ft)

$$V_{dp-oh} = CAP_{dp-oh} \times L_{dp-oh} \text{ bbls}$$

Vdp-oh = volume between oh and dp (bbl)
CAPdp-oh = Capacity between dp and oh (bbl/ft)
Ldp-oh = Length dp in oh (ft)

Contents of annulus casing section

$$V_{csg-dp} = CAP_{csg-dp} \times D_{csg} \text{ bbls}$$

Vcsg-dp = volume between csg and dp (bbl)
CAPcsg-oh = Capacity between csg and oh (bbl/ft)
Dcsg = Depth of casing (ft)

7. Pre kick calculations

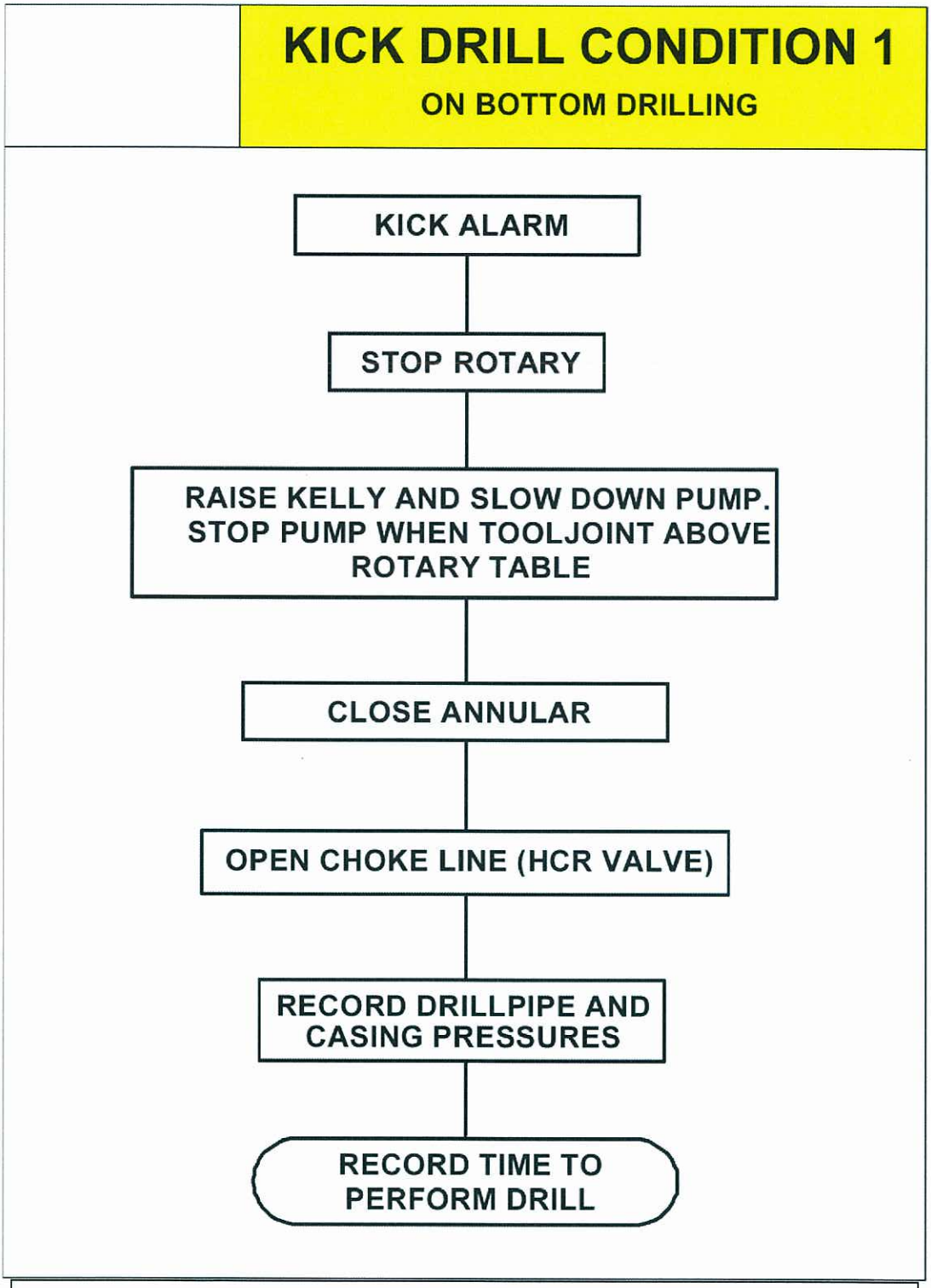
1. MAASP $= (\rho_{fs} - \rho_1) \times D_{csg}$ psi
2. $CAP_{str} = 9.7138 \times \varnothing^2_{id\ pipe} \times 10^{-4}$ bbls/ft

   Note: 1) $\varnothing_{id\ pipe}$ in inches. 2) $CAP_{str} = CAP_{dp} + CAP_{dc}$ + etc.
3. $CAP_{ann} = 9.7138 \times (\varnothing^2_{id\ hole} - \varnothing^2_{id\ pipe}) \times 10^{-4}$ bbls/ft

   Note: 1) $\varnothing$ in inches 2) $CAP_{ann} = CAP_{dc\text{-}oh} + CAP_{dp\text{-}oh} + CAP_{dp\text{-}csg}$ + etc.

Appendix II: Well Control Schematic Procedures

This Chapter contains the following schematic representations of the key well control procedures described in this Manual:



Fgure 12. Kick Drill Condition 1 (On Bottom Drilling)

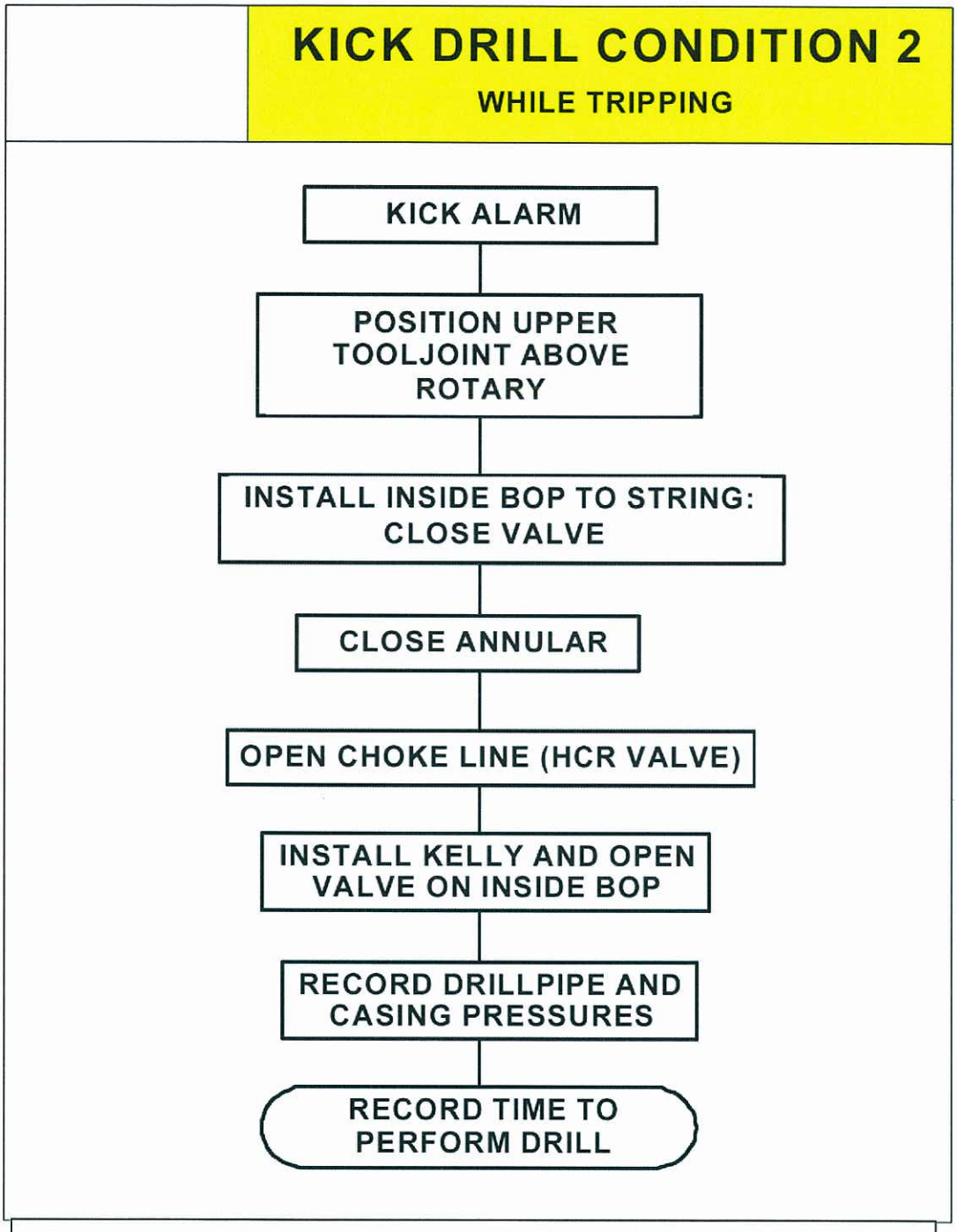


Figure 13. Kick Drill Condition 2 (Tripping)

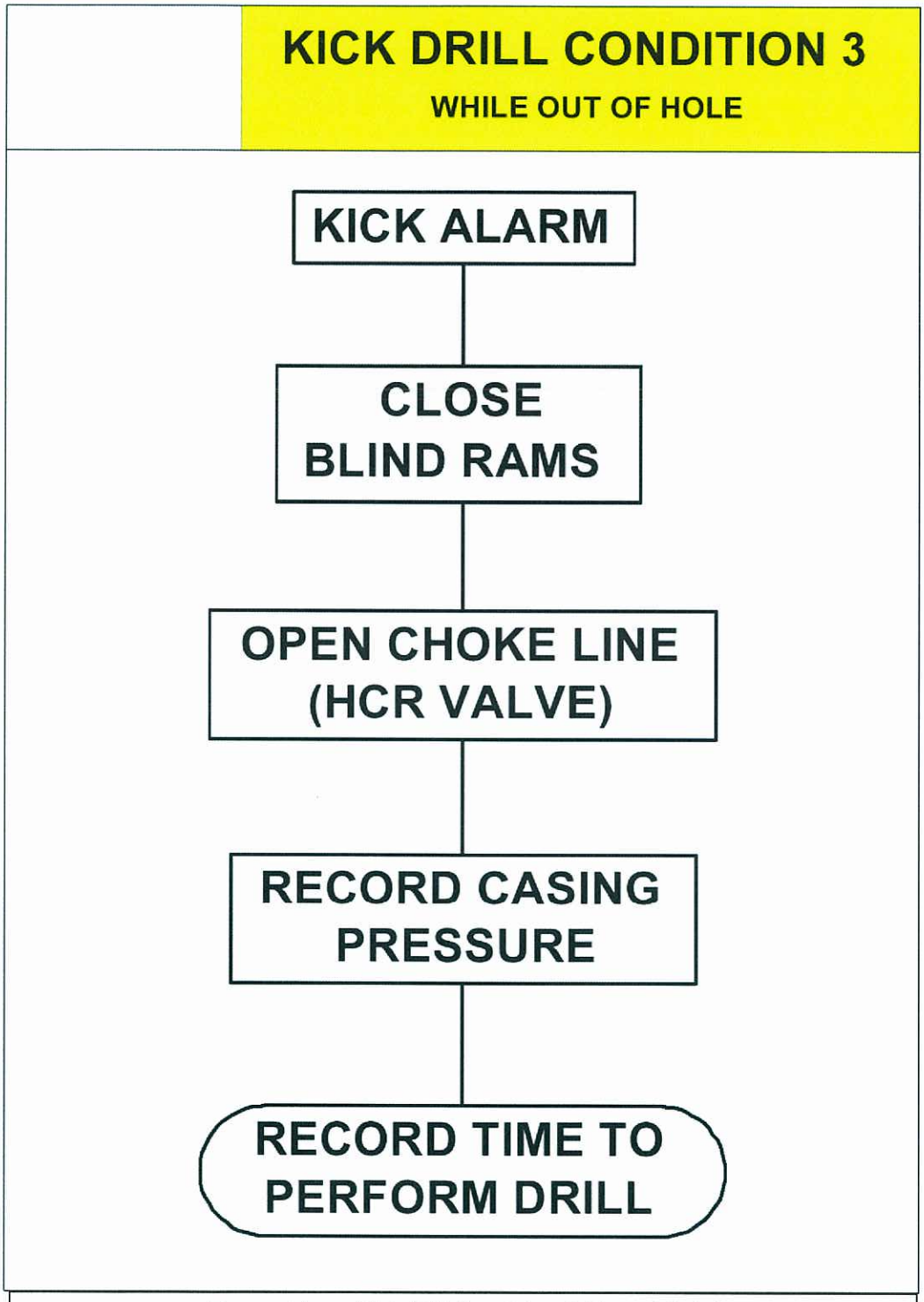


Figure 14. Kick Kill Condition 3 (Out of Hole)

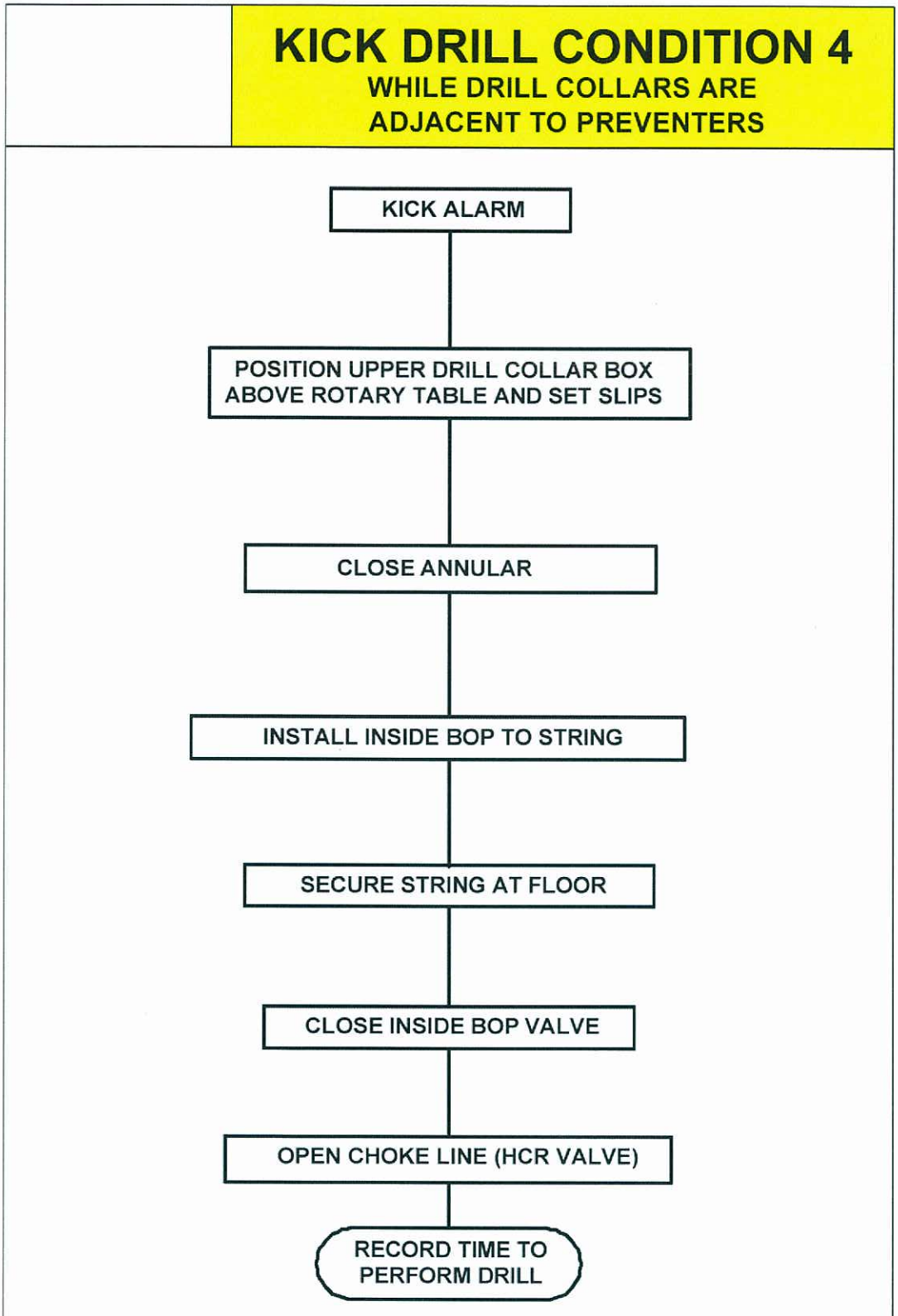


Figure 15. Kick Drill Condition 4 (Drill Collars Adjacent to Preventors)

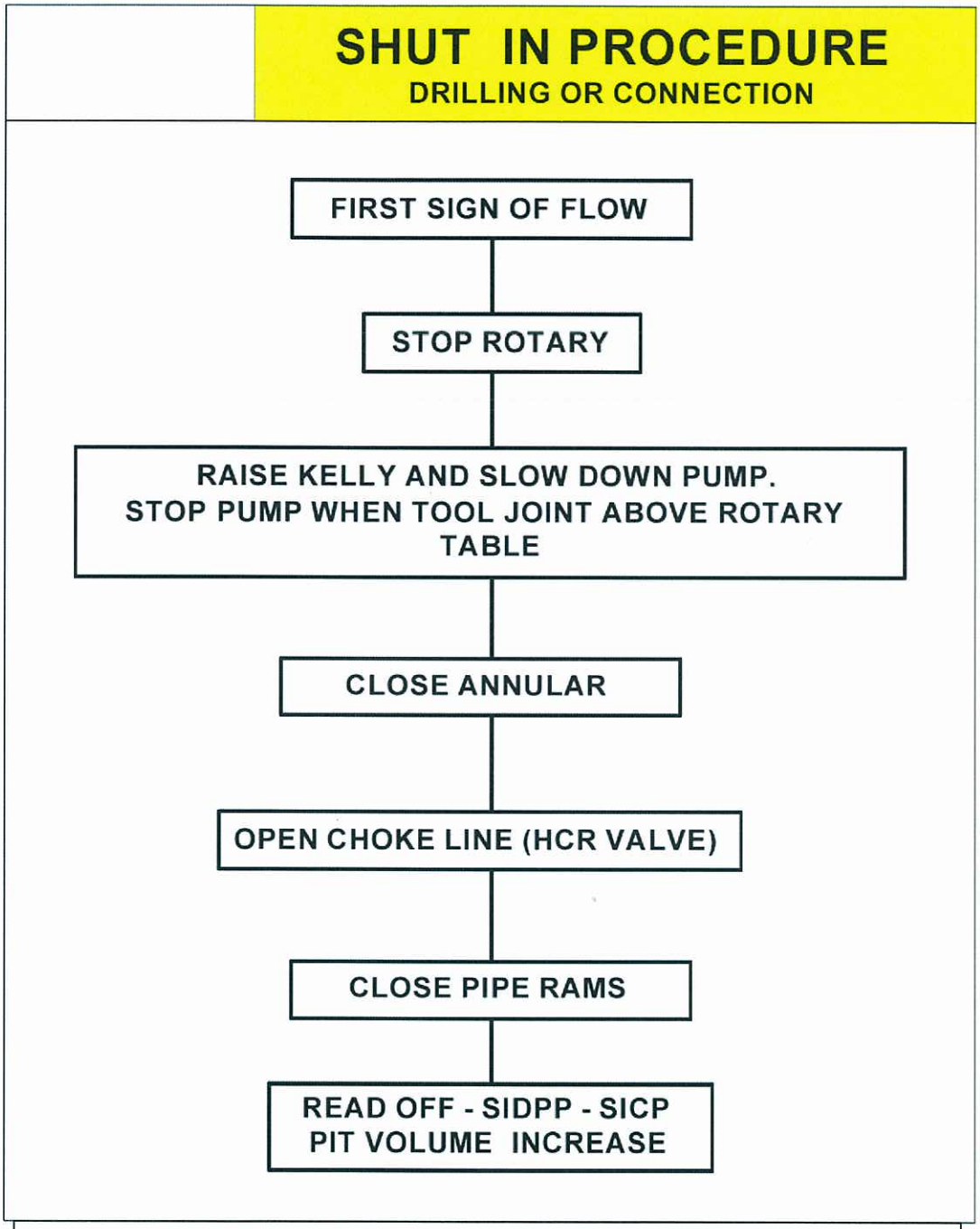


Figure 16. Well Shut-in Procedure (Drilling or Connection)

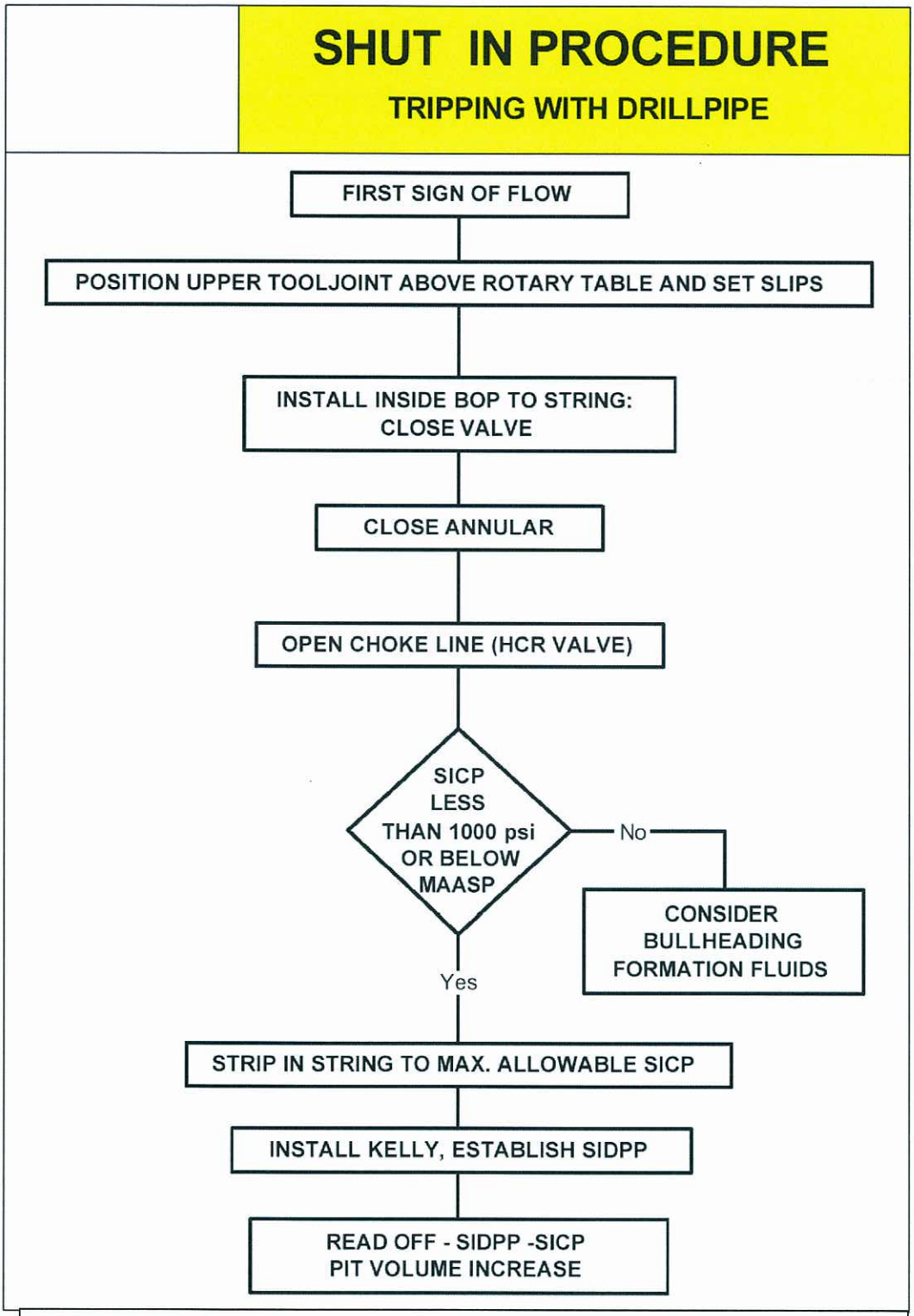


Figure 17. Well Shut-in Procedure (Tripping with Drill Pipe)

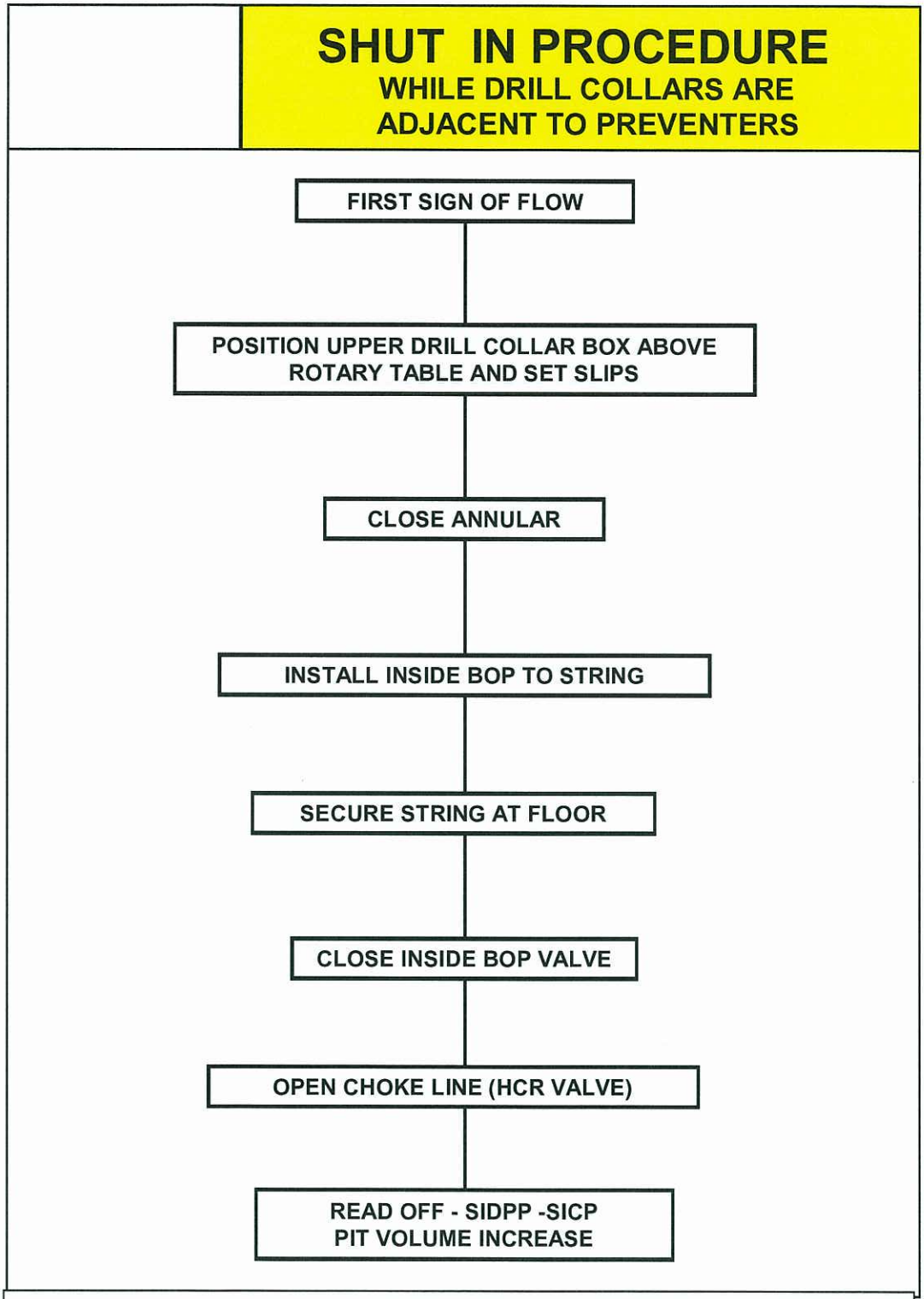


Figure 18. Well Shut-in Procedure (Drill Collars Adjacent to Preventors)

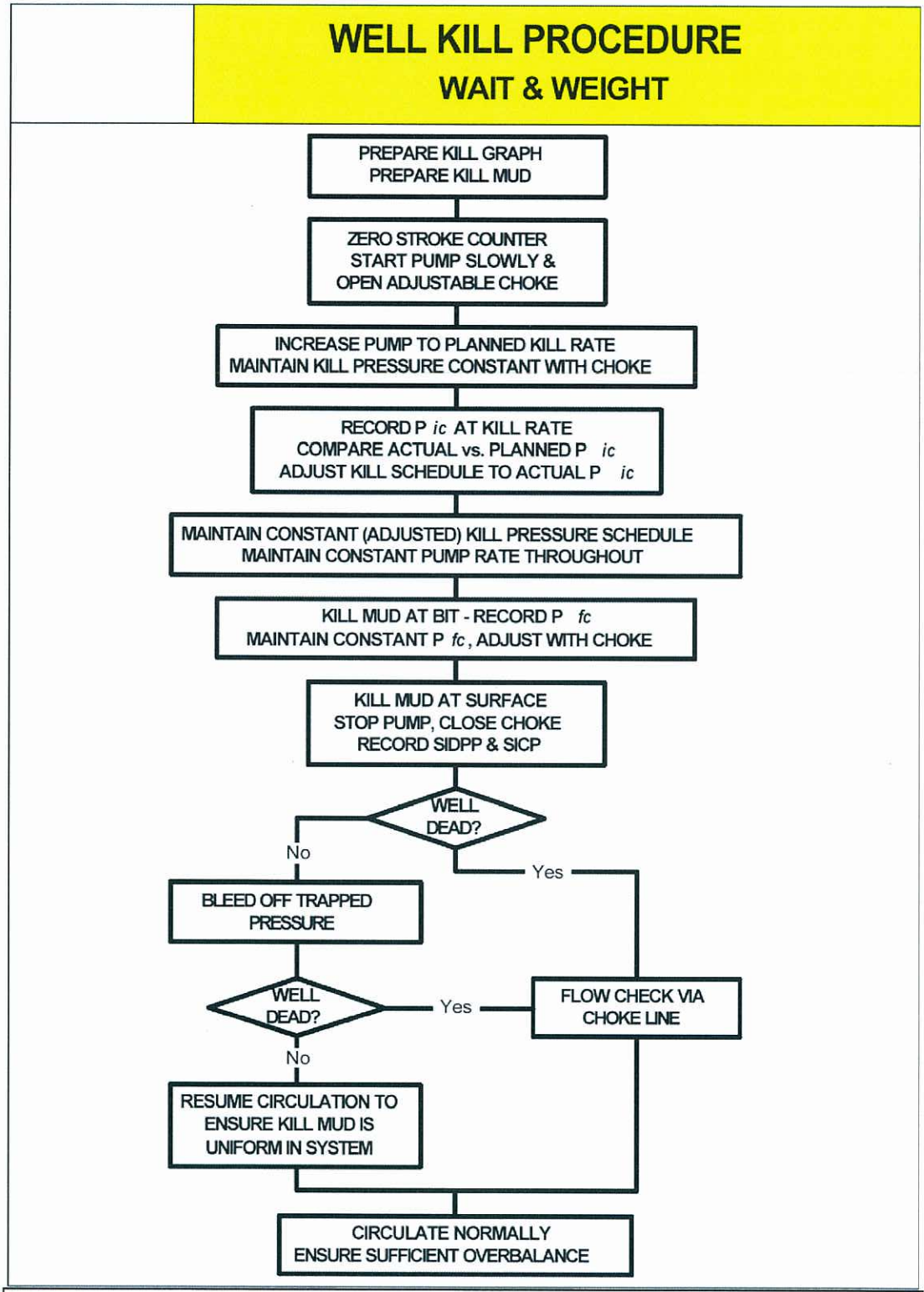


Figure 19. Well Kill Procedure - Wait and Weight Method

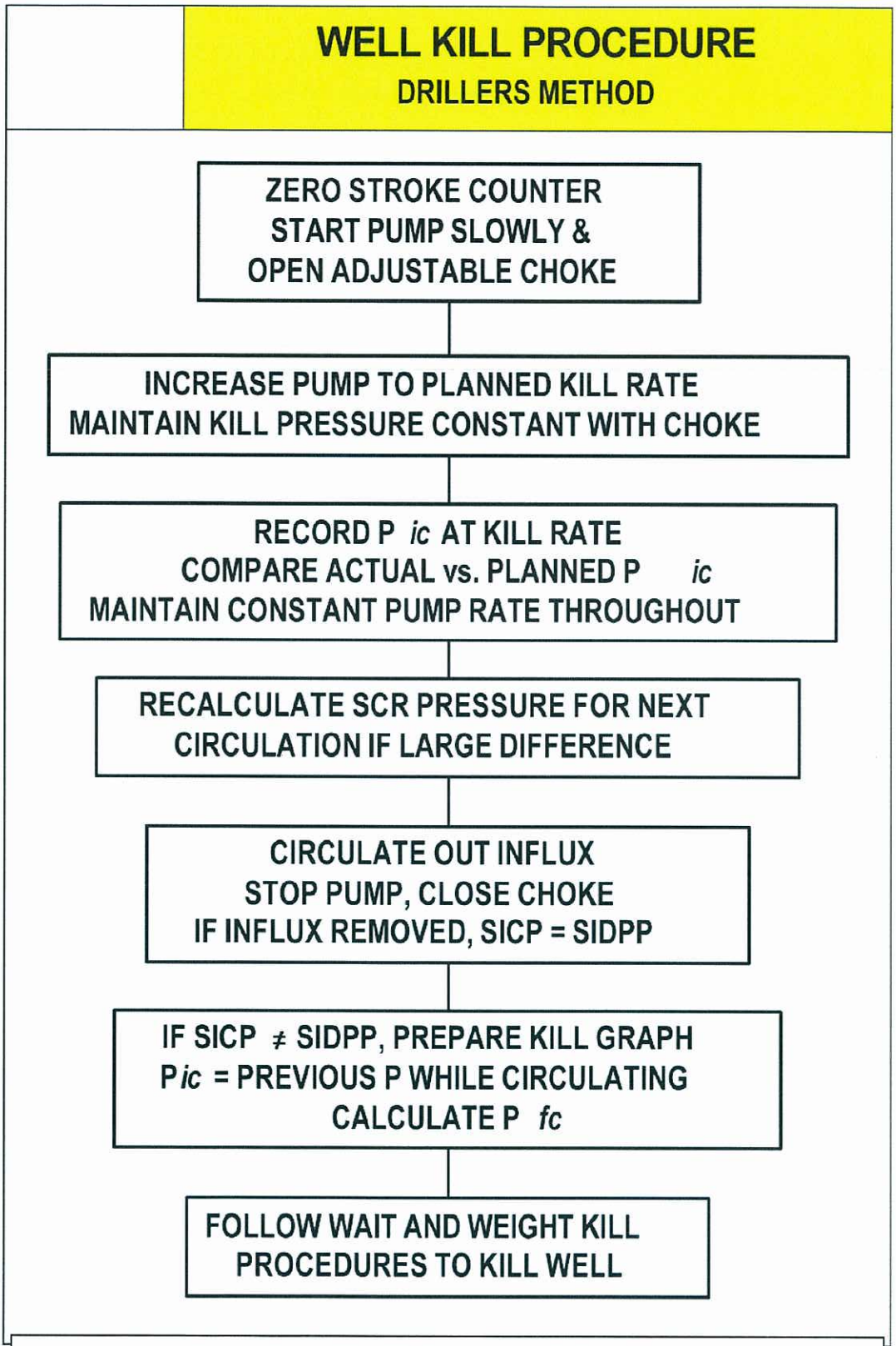
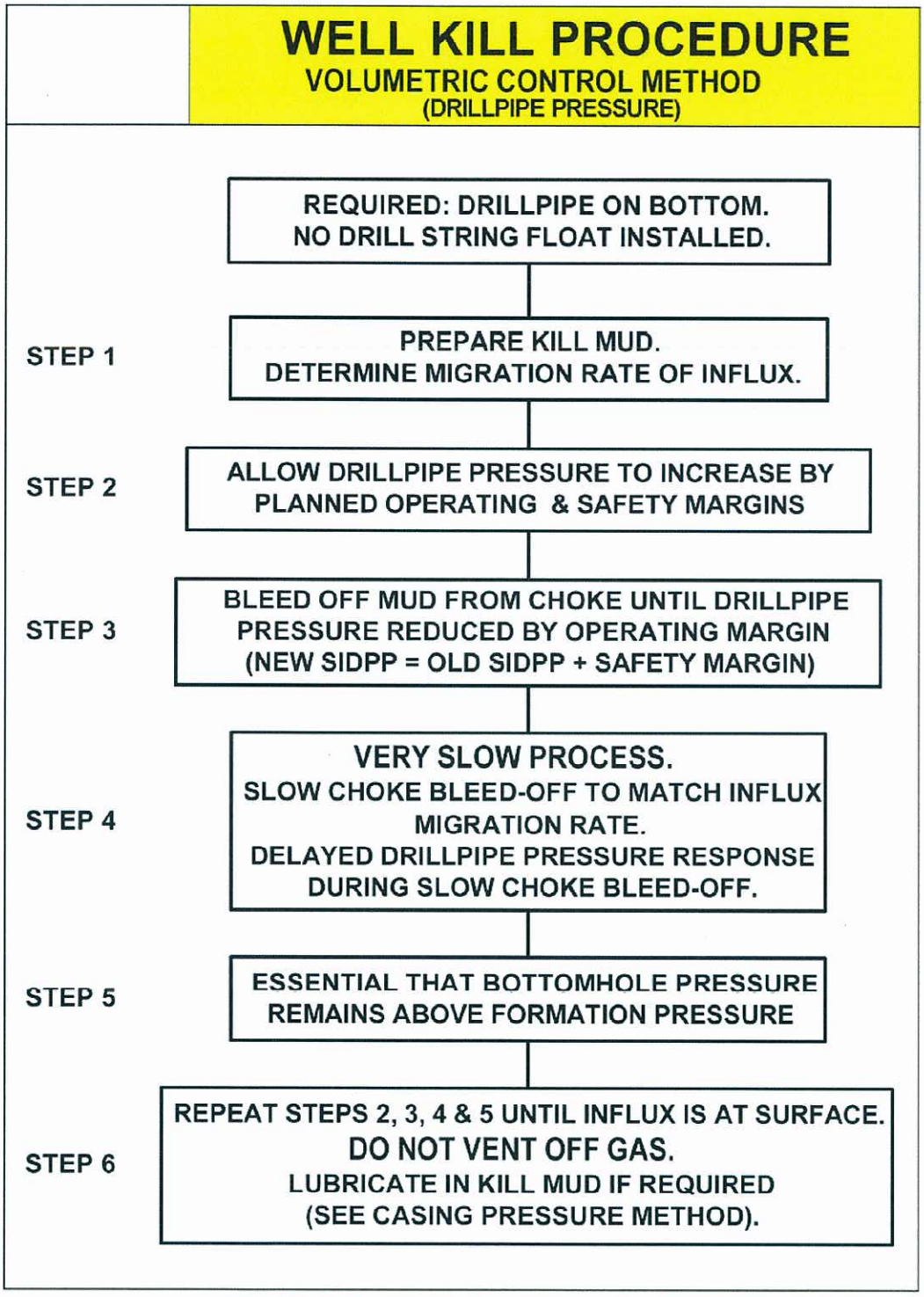


Figure 20. Well Kill Procedure - Drillers Method



Well Control Procedure - Volumetric Control Method (Drill pipe pressure)

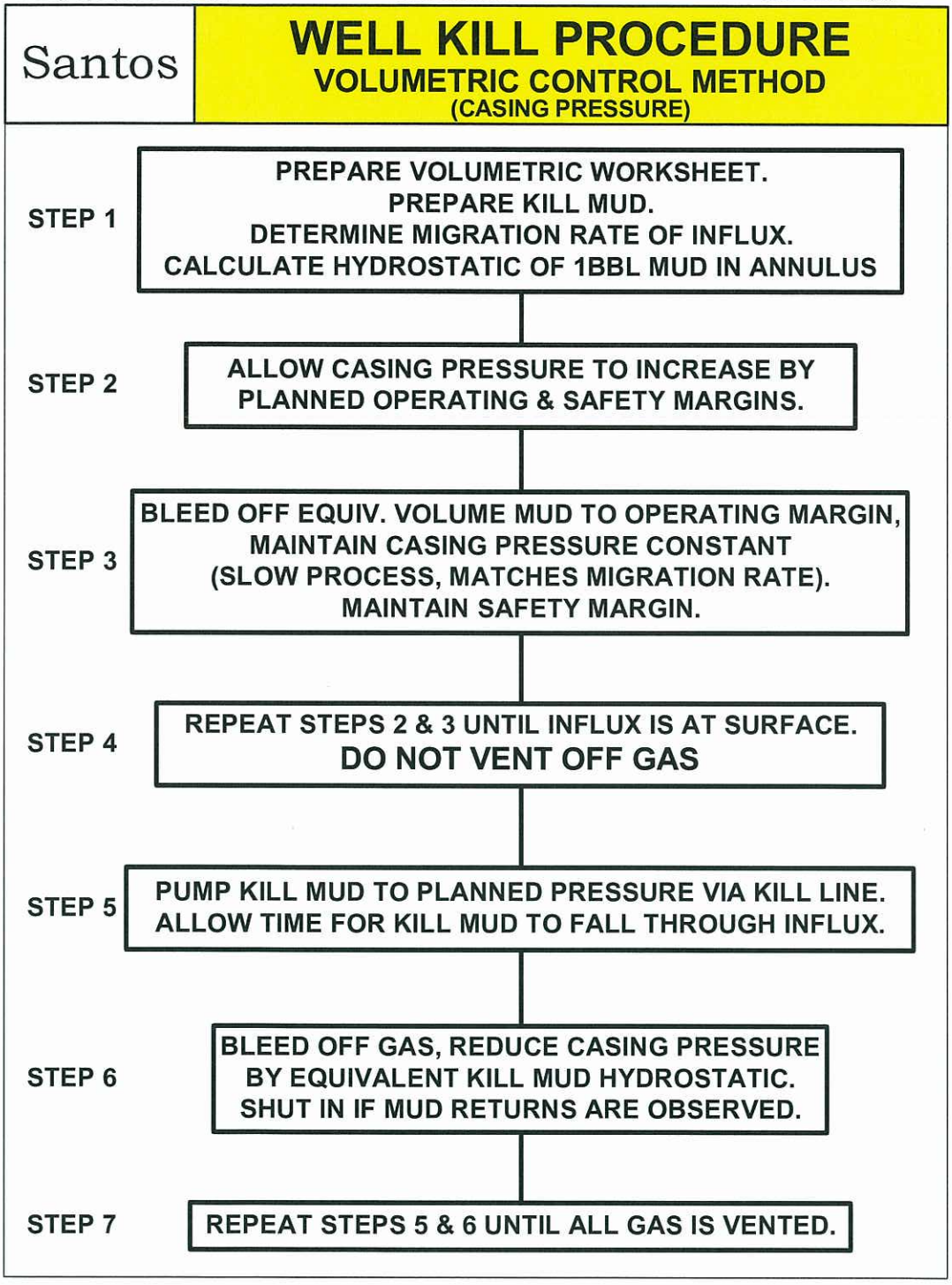


Figure 21. Well Kill Procedure – Volumetric Control Method (Casing Pressure)

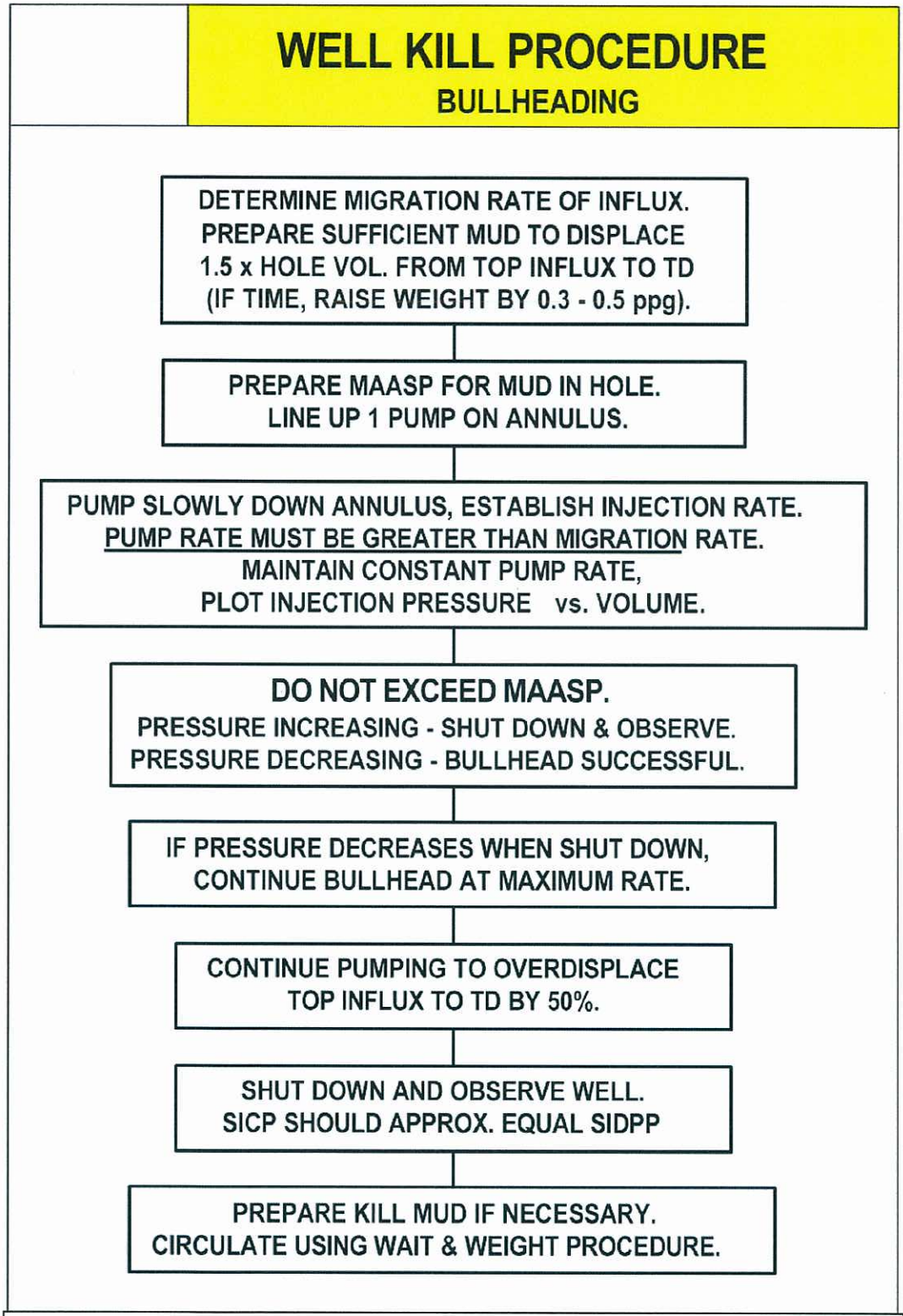


Figure 23. Well Kill Procedure - Bullheading

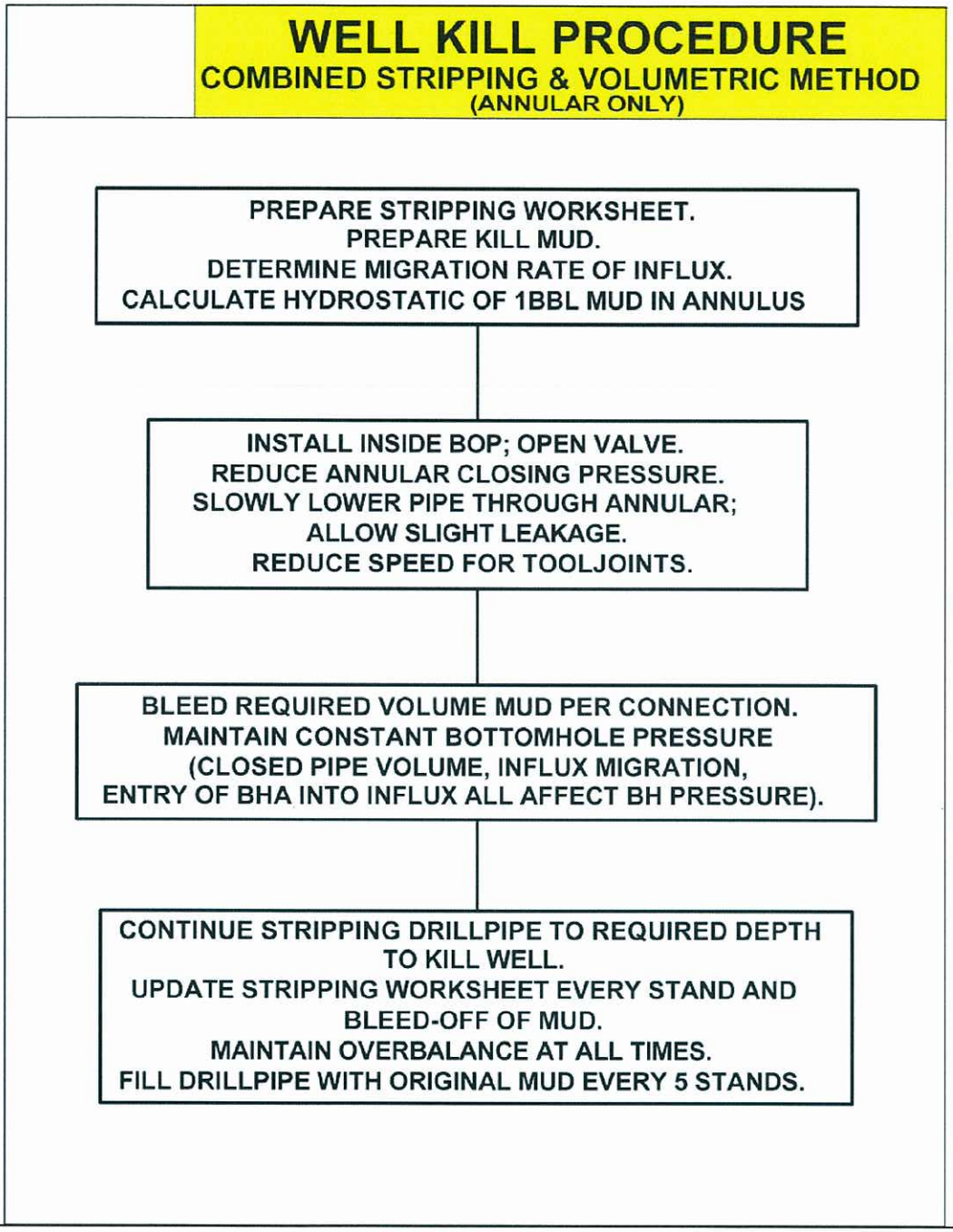


Figure 24. Well Kill Procedure – Combined Stripping & Volumetric Method (Annular only)