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# Salinity-Based Pump & Dump Strategy for Drilling Salt with Supersaturated Fluids

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### Abstract

Riserless drilling with weighted mud systems, commonly referred to as a "Pump & Dump" drilling strategy, is an established drilling technique used on deepwater wells with shallow hazards. Large holes and high flow rates result in very large volumes of fluid being required to drill to total depth (TD), circulate the well clean and cement the conductor casing string. Fluids management becomes a major issue in the riserless hole section. In the Gulf of Mexico, mud is often densified in excess of well requirements and then blended with seawater in a "Cut-Back" operation to reach the desired density to pump downhole.

When riserless drilling into salt, a Pump & Dump strategy is often used. Dilution with seawater, however, results in an undersaturated fluid. This fluid leaches the salt resulting in substantial hole enlargement. The hole enlargement can result in poor cementing jobs that require remediation or even an additional string of casing. A unique operation has been employed in the Santos Basin of Brazil where a supersaturated brine fluid was used to conduct a pump & dump operation with the goal of drilling with a saturated brine fluid and minimizing hole enlargement. This paper details the planning of the operation, fluid design, and pilot testing. Fluids management, equipment rig up, and results are discussed in detail. The operation has been successfully executed twice with both operations achieving the set objectives for the wells. Unforeseen complications that were encountered are discussed along with lessons learned that have been applied to subsequent operations.

### Introduction

The operator and co-venturers began exploration drilling on the block BM-S-22 in the offshore Santos Basin of Brazil in 2008. The location of the block is shown in **Fig. 1**. Water depths in the block range from 2100 to 2300 m. The entire block is thought to contain a thick layer of evaporite which overlies the prospective interval. The evaporite interval is encountered at approximately 600 to 1200 m below the mudline and consists of anhydrite and a variety of different salt chemicals including halite, carnalite, and tachyhydrite. A carbonate / anhydrite caprock of varying thickness overlies the evaporite. From the mudline to the caprock are sequences of soft to firm hemi-pelagic clays with interbedded silts, marls, and sands.

The conductor casing on which the high-pressure wellhead housing is connected is normally set some distance below the top of the evaporite interval. A protective casing string is often set near the base of the evaporite before drilling the objective section found immediately below the evaporite. The intent of the protective casing is to both obtain an increased formation integrity test (FIT) before drilling the objective interval and to also case off the evaporite section which has been considered prone to salt creep. By placing the casing shoes in the evaporite interval, the well design can take advantage of the elevated shoe integrity afforded by the higher Poisson's ratio in the evaporite interval. On the exploration drilling program, the depth of the base of the evaporite was not known with certainty, and the risk existed of potentially drilling into the objective interval with only conductor casing set. For this reason, obtaining a high conductor casing shoe FIT is critical to the well's success.

Available data from offset wells suggested the lack of consistent conductor casing shoe integrity tests. An offset with its conductor shoe 100 m below the top of evaporite may not have the shoe integrity of another offset with its shoe at a similar depth but only 50 m into the top of the evaporite. The operator concluded that it was not the formation that had variable integrity, but rather the quality of the cement jobs on the various wells. The most likely cause of poor cement job quality was thought to be borehole enlargement.

Offset well data also suggested the rate of penetration in evaporite could also be an issue. Rates of penetration were in the range of 5 to 6 m/hr for the run. With the lower rates of penetration, more time would be required to drill the evaporite to the desired shoe depth, leading to a bigger hole enlargement.

### Worldwide Practices

Riserless drilling into salt formations has been conducted in the U.S. Gulf of Mexico, West Africa, and Brazil. The techniques used vary by operator and region. Almost all published case histories, though, are wells in the Gulf of Mexico. Some advocate riserless drilling of salt with seawater, others with more saline yet still undersaturated brines, and others yet with saturated brines. Whitson and McFayden (2001) present a case history of a well in the Gulf of Mexico that drilled 167 m (500 ft) of salt riserless with seawater. When riserless drilling with prepared drilling fluids, the fluid is used to make one circulation in the well and then it is discharged at the seafloor. This strategy of using a mixed drilling fluid to only make one circulation in the well before disposal at the mudline has earned the moniker "Pump & Dump" drilling strategy. Pump & Dump operations were developed principally to deal with shallow water flows or shallow gas. Turner and Morales (2000), Schuberth and Walker (2000), and Roller, Magner and Drury (2001), all present case histories of using a Pump & Dump strategy to overcome shallow water flows, and they provide excellent information regarding logistics and equipment set-up. Rohleder, et al (2003) discuss the use of an undersaturated Pump & Dump fluid to drill into salt followed by a saturated spotting mud in the riserless hole. All of these case histories concern wells drilled in the United States Gulf of Mexico.

Pump & Dump operations involve large volumes of fluid that must be managed at the offshore well site. In one of the earlier papers regarding shallow water flows, Alberty et al (1999) did not find favor with the Pump & Dump strategy due to its costs and the logistical difficulties of handing large volumes of mud. Since most deepwater operations are far from their resupply point, all fluid for the operation must be at the well site in advance. Johnson and Rowden (2001) discuss the widely accepted practice of blending the premixed Pump & Dump fluid with seawater and/or fluids to augment the volume. By blending a weighted mud to a much higher density than what is planned to be pumped downhole, the higher-density premixed fluid can be diluted "on-the-fly" or "cut-back" with seawater to the appropriate mud density. This technique allows much more fluid to be pumped in the riserless operation than can be stored on location.

The cut-back operation works well for shallow water flow applications where the critical mud parameter of the resultant fluid is the mud density. For riserless drilling of salt, the salinity of the resultant fluid is the key mud property. By diluting the raw fluid with seawater, the salinity of the resultant fluid will be reduced. If the goal is to drill riserless with a high salinity fluid or a saturated fluid, the benefit of the cut-back operation becomes non-existent when the raw fluid starts as a saturated fluid.

### Salt Leaching by Undersaturated Fluids

When salt is drilled with an undersaturated water-base fluid, the salt is leached into the fluid. Durie and Hessen (June 1964, September 1964) and Kazemi and Jessen (1964) performed numerous experiments into salt leaching and developed mathematical models to simulate the salt leaching process. Their interests were mainly associated with the leaching of salt bodies to create storage caverns. The experiments and models were mostly associated with fluids in a laminar flow regime, although Durie and Jessen concluded that, with turbulent flow at the salt surface, the rate of salt removal could be increased several fold (10 to 20 times) over a similar fluid in laminar flow. They also concluded the rate of salt removal was controlled by the salinity of the fluid at the salt face. Whitfill et al (2002) looked at the effect of the drilling fluid properties on both penetration rate and hole enlargement while drilling salt. Whitfill et al built upon the work of the 1960s but continued with the assumption of laminar flow in the drilling fluid at the salt face. They also state that unsaturated seawater pills have been shown to improve significantly upon the rate of penetration (ROP) on a temporary basis.

Willson (2004) looks specifically at the use of seawater as the drilling fluid to drill salt formations. Willson's work was directed towards the development of an accurate leaching model under turbulent flow conditions. Laboratory models were constructed and data collected from turbulent flow leaching experiments scaled to simulate drilling conditions. An analytical model was developed based upon diffusion principles and fluid mechanics which correlated well with laboratory results.

### Development of Drilling Strategy

The operator had decided on a well design that would use a 28-in. riserless hole section to be drilled 200 m into the evaporite interval. 22-in. conductor casing would then be run and cemented. The primary goal of the 28-in. interval was to minimize hole enlargement in order to maximize the probability of a quality 22-in. cement job. A secondary objective for this interval, of only slightly less importance, was an increased ROP. Based on offset records, rates of penetration were not expected to be above 6 m/hr in the upper section of the evaporite.

The operator worked with the drilling fluids supplier to develop a simplified leaching model based upon the equations presented by Willson, et al. The final model utilized only one pipe size and assumed constant temperature (the solubility of salt varies little between 0° and 30°C). The model was used to analyze sensitivities to both drilling fluid salinity and flow rate. As shown in Fig. 2, hole enlargement did not exhibit significant sensitivity to the drilling fluid flow rate until very low rates are achieved. This conclusion suggests that an undersaturated drilling fluid has the ionic capacity to remain undersaturated despite the salt leaching at the studied flow rates. Since it was suspected that the top of the evaporite interval

was heterogeneous with layers of insoluble anhydrite, a flow rate of 1,000 gal/min was selected as a compromise of hole cleaning vs. fluid usage.

Use of an undersaturated drilling fluid was an attractive proposition due to both its potential for higher rate of penetration (ROP) and its lower cost as compared to a saturated fluid. The sensitivity of the 28-in. drilled hole size to salinity is displayed in **Fig. 3**. The simplified leaching model showed that even small levels of undersaturation in the drilling fluid could result in significant hole enlargement.

Hence, the following drilling strategy was developed:

<u>Interval</u>	<u>Drill Fluid</u>	<u>Logic</u>
1st 50 m	Seawater	Reduce fluid volumes required on rig. Highly heterogeneous interval with layers of caprock and anhydrite
Next 100 m	25-wt% NaCl	1-wt% undersaturated to minimize washout yet attempt some ROP gain
Final 50 m	26-wt% NaCl	Saturated NaCl fluid to maintain gauge hole around casing shoe

Using the theory of super-position, a hypothetical hole profile was developed with the leaching model. This hole profile is displayed in **Fig. 4**. With the strategy established, fluid volumes could be determined. In order to preserve the drilled hole at interval TD, saturated NaCl fluid would be needed to sweep the hole at TD, for the spotting mud left in the hole while running casing, and circulating prior to cementing. **Table 1** shows the total estimated volume required for the operation. Nearly 46,000 bbl of saturated or slightly undersaturated mud would be required for the proposed operation.

The exploration campaign was to be conducted with a state-of-the art drillship with 12,000 bbl of active and reserve mud capacity. The drillship logistics were provided by two (2) support vessels with 8,000 bbl each of mud storage capacity, resulting in a total storage volume of 28,000 bbl. This capacity was noticeably less than the 46,000 bbl required for the planned operation. Spot-hire vessels of sufficient mud capacity could not be located in Brazil and the 48-hr round trip travel time between well location and shore base prevented the support vessels from being able to empty their mud and re-supply the operation in sufficient time.

### **Supersaturated Fluids & Cutback Calculations**

In the Gulf of Mexico, mud used in riserless pump & dump operations is often densified in excess of well requirements and then blended with seawater in a "cut-back" operation to reach the desired density to pump downhole. A similar analogy was applied to the NaCl brine drilling fluid planned for the operation. The volume of fluid that could be stored on-site was fixed, but the capacity of the fluid to generate saturated brine drilling fluid could be extended by supersaturation of the fluid.

Some Gulf of Mexico pump & dump fluids are supersaturated such that the diluted fluid maintains some level of salinity when pumped downhole. The dilution of the pump & dump fluid is dictated by the density of the fluid rather than the salinity.

A supersaturation of 100 lbs of NaCl per bbl of brine was selected for the drilling fluid based upon a survey of levels of supersaturation that have been successfully used in other operations by the operator. **Fig. 5 and 6** illustrate the calculations for salt content in the supersaturated fluid and for the cutback of the supersaturated fluid back to the desired salinity. For these calculations, conservation of salinity is essential. It is not possible to make the dilution calculations using the densities of existing and desired fluids because salt does not behave like an ideal fluid with respect to density. As the NaCl salt goes into solution, it ionizes and in effect finds some amount of existing space between the water molecules. Hence, a barrel of supersaturated fluid mixed with a barrel of seawater will not result in two barrels of fluid because volume is not conserved. For example, a saturated sodium chloride brine supersaturated with 88.5 ppb sodium chloride has to be mixed in a 0.56:0.44 ratio with seawater to yield a simple saturated brine again.

With the ability to supersaturate the NaCl drilling fluid, the volume of fluid required on location was significantly reduced. **Table 2** illustrates the fluid volumes required to conduct the planned operation.

### **Formulation & Pilot Testing**

The formulation of the supersaturated drilling fluid was kept simple with the following components:

<u>Component</u>	<u>Purpose</u>
Water	Base Fluid
NaCl Salt (Coarse & Fine)	Salinity (Fluid Saturation & Supersaturation)
Xanthan Polymer	Viscosity / Suspension
Caustic Soda	pH Control
Soda Ash	Hardness ( $\text{Ca}^{++}$ , $\text{Mg}^{++}$ ) Control
Corrosion Inhibitor	Corrosion Inhibition
Bacteriocide	Bacterial Growth Control

The more expensive Xanthan polymer was selected over guar gum due to Xanthan gum's favorable suspension properties. Settling of the suspended NaCl was a major concern. A 14-day laboratory pilot test was performed by the drilling fluids contractor to determine the optimal Xanthan concentration to maintain suspension while still allowing pumpability of the

fluid. **Fig. 7** shows the appearance of the sample after 14 days of stagnation. A Xanthan concentration of 1.5 lb/bbl was selected based on the lowest concentration that still resulted in total suspension of the NaCl salt particles.

### Pit Planning / Logistics

Logistics and pit planning are paramount to the successful implementation of a large pump and dump operation. Planning an operation based on paper specifications is a sure way to fail. Pit planning began with gathering all pit and tank diagrams from the vessels and the rig. Vessel captains were consulted to obtain the practical or useable volume that could be stored in each tank. In general, a 5,000-bbl tank on paper will not hold 5,000 bbl. A dead volume survey was also conducted to determine the volume of fluid that remains stranded in each tank when suction is lost. Both the rig and the vessels had tank designs with recessed suction boxes, as shown in **Fig. 8 and 9**, which resulted in minimal losses to dead volume. The 12,000 bbl of mud pits on the drillship realistically only had about 10,500-11,000 bbl of useable pit volume, and the supply vessels had 7,300-7,500 bbl of useable volume of the 8,000 bbl listed in the specifications.

The mud mixing manifold selected for the cutback operation is shown in **Fig. 10**. It was located on top of the mud pits and had separate flow meters for each fluid stream. The discharge from the blending unit was planned to be checked every 5 to 10 minutes to ensure the blended fluid being pumped downhole was the proper density (hence salinity).

Storage of the supersaturated fluid had to compete with the other fluid needs in the riserless drilling intervals. Viscous seawater sweeps were needed for drilling above the evaporite interval and a densified seawater "spotting" mud was needed in the 42-in. structural casing hole while running 36-in. casing. While drilling the evaporite interval, a densified salt-saturated "spotting" mud also had to be prepared to place in the 28-in. hole. Brine for cementing mix water was removed from the pump & dump fluid requirements when the cementing service provider did not feel comfortable using the cutback, supersaturated drill fluid for mix water. A separate cementing brine was prepared and placed in the rig's dedicated clear brine tank.

Pit management diagrams were prepared for each phase of the riserless hole in order to communicate how the separate fluid needs were to coexist. An example of such a diagram is displayed in **Fig. 11**. These plans were reviewed with the drilling fluids engineers, rig management, and the operator's rig-site supervisors for input, upgrade, and final consensus.

Supersaturated salt fluids are highly hydrophilic and, while sodium chloride is more benign than other salts, emphasis was placed on personnel protection while mixing and working with the supersaturated fluid. All personnel working with the fluid were required to wear safety goggles and impermeable gloves and aprons in addition to standard personal protective equipment. No safety incidents occurred while mixing or handling the fluid.

### Well 1:

Due to mobilization and start-up issues, the supersaturated fluid was loaded onto the supply vessels approximately three to four weeks prior to the actual pump & dump operation. During transfer from the supply vessels to the drillship, it was noted that fluid density had decreased 0.1 to 0.2 lb/gal, which indicated some settling of the salt. Upon reaching the top of the evaporite and drilling a sufficient distance with seawater, the pump & dump operation commenced. Realizing the salt sag had altered the chloride content of the supersaturated fluid from that assumed in the original cutback calculations, new calculations had to be done real time for varying densities (and hence, chloride content). By checking the density of the blending unit discharge every 5 to 10 min, the calculations were "field-checked." The supersaturated cutback blending and the pump & dump operation itself occurred without problems according to the plan. A saturated NaCl densified mud was spotted in the 28-in. hole, 22-in. casing run and cemented all without incident. Upon drill-out and testing of the 22-in. casing shoe, the formation integrity test (FIT) exceeded expectations.

Several minor issues were noted that could be improved in future operations. At the end of the pump and dump operation, settling of the salt was noted in both the vessels and the drillship despite the regular agitation and rolling of tanks. The photograph in **Fig. 12** shows the settling was relatively minor with about 6 to 8 in. of salt at the bottom of some tanks. To reduce salt settling on well 2, the Xanthan composition was increased from 1.5 to 2.0 lb/bbl and field tested with a 500 bbl batch of the supersaturated fluid. The drilling fluids service provider and the operator considered the larger volume test to be more indicative of actual conditions. The fluid was left stagnant in a tank for 24 days and then drained to check the settling characteristics of the fluid. **Fig. 13** shows the bottom of the tank upon draining. Some polymer-salt mixture remains on the tank bottom due to fluid viscosity vs. suction rate. Very little settling was actually observed.

As noted above, the NaCl settling resulted in the supersaturated drilling fluid having a variable Cl<sup>-</sup> content that varied from the original cutback calculations and had to be compensated for real time. Future operations should consider varying settling scenarios and have blending ratios already calculated and vetted. A blending chart was created for well 2, as shown in **Fig. 14**, that allowed quick reference to the proper blending ratios given the supersaturated actual density. The operation could also be improved by reducing the time between load-out of the supersaturated fluid and the start of the pump & dump operation.

Both the drilling jars and the rotor in the mud motor on well 1 exhibited signs of pitting corrosion when they were laid down and inspected. The pitting occurred in the chrome alloy. Pitting corrosion often indicates the presence of dissolved oxygen in the medium and the presence of chlorides is known to accelerate the pitting process. The untreated seawater is suspected as the primary culprit of supplying the dissolved oxygen. The supersaturated fluid composition could be enhanced

through the addition of an oxygen scavenger which when blended with the seawater would mitigate the effects of the dissolved oxygen.

One of the tenets of the pump & dump strategy was to use a slightly undersaturated fluid in the upper evaporite in order to gain improvements in the rate of penetration. While both seawater and a 25-wt% NaCl fluid (1% undersaturated) were used, no gains in ROP were realized. **Fig. 15** shows the ROP and weight on bit (WOB) as functions of depth and notes the fluid used in the interval.

## Well 2

Well 2 occurred immediately after well 1. The composition of the supersaturated fluid was modified with increased 1/2 lb/bbl of Xanthan polymer concentration and addition of oxygen scavenger. Time between load-out of the fluid and the start of the pump and dump operation was also reduced to approximately two weeks. The pump & dump strategy on well 2 was modified to also include an interval of 24-wt% NaCl drilling fluid in an attempt to observe the anticipated improvements in the rate of penetration.

Execution of the plan on well 2 also occurred without incident or problems. While some salt sag was still observed in the supersaturated fluid, the sag was anticipated and easily mitigated using the blending ratio chart. In addition, no corrosion was observed on downhole chrome alloy components, suggesting a correct diagnosis of the corrosion issue. As with well 1, the formation integrity test (FIT) of the 22-in. casing shoe exceeded expectations. **Fig. 16** shows the ROP and WOB as functions of depth and notes the fluid used in the interval. Again, no discernible improvement in ROP was observed at the lower fluid salinities.

On both wells, the formation integrity test was sufficient to not only eliminate an 18-in. contingency liner, but also contributed to the decision to eliminate the planned protect casing string at the base of the evaporite interval.

## Conclusions & Recommendations

1. A new type of pump & dump operation has been developed based upon fluid salinity rather than fluid density. Because fluid volumes are not ideal with salt solutions, rigorous cutback calculations should be based upon the resultant fluid salinity rather than resultant density.
2. Excellent hole conditions while running casing and casing shoe integrities that exceeded expectations indicate the salinity-based pump & dump strategy was a success.
3. The rate of penetration increase that was expected with the use of undersaturated drill fluids in the salt was not realized in field operations.
4. Highly saline solutions can exacerbate pitting corrosion where dissolved oxygen is present. Oxygen scavenger is recommended to be added to saline solutions that will be diluted with seawater.

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## Nomenclature

BML	Below Mud Line
FIT	Formation Integrity Test
MD	Measured Depth
RT	Rotary Table (depth reference point)
ROP	Rate of Penetration
TD	Total Depth
TVD	True Vertical Depth
WOB	Weight on Bit

## SI Metric Conversion Factors

bbl x 1.589 873	E-01 = m <sup>3</sup>
cp x 1.0*	E-03 = Pa.s

ft x 3.048\* E-01 = m  
 in x 2.540\* E-02 = m  
 gal x 3.785 412 E-01 = m<sup>3</sup>  
 lbm x 4.535 924 E-01 = kg  
 psi x 6.894 757 E+00 = kPa  
 \* conversion factor is exact

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**Table 1: Fluid Volumes Required for Evaporite Pump & Dump Drilling (1,000 gal/min.)**

Activity	Total Mud Pumped (Bbl)
Drill 50 m into Evaporite with seawater drilling fluid	10,204
Drill 100 m into Evaporite with 25-wt% NaCl drilling fluid	20,408
Drill final 50 m of Evaporite with saturated (26 %wt) drilling fluid	10,204
Pump 1 hole volume of 26% saturated drill fluid (assume 36-in. hole)	4,059
12.0 ppg Saturated Spotting Mud	5,100
Cement Mix Water requirements	1,000
Saturated NaCl Mud for Circulating prior to Cementing	2,000
Contingency	3,000
Totals	56,138 bbl
Minus volume seawater used	45,934 bbl

**Table 2: Fluid volumes required for evaporite pump & dump drilling utilizing supersaturated salt mud (1000 gal/min.)**

Activity	Supersaturated Salt Mud (bbl)	Seawater (bbl)	Total Mud Pumped (bbl)
Drill 50 m into salt with SW	-	10,204	10,204
Drill 100 m into salt with 25-wt% NaCl drill fluid	10,204	10,204	20,408
Drill final 50 m with saturated drill fluid (26%wt)	5,714	4,592	10,204
Pump 1 hole volume of 26% saturated drill fluid (assume 36-in. hole)	2,273	1,826	4,059
12.0 ppg Saturated Spotting Mud	2,856	2,244	5,100
Cement Mix Water	1,000		1,000
Sat. Mud for Cementing	1,120	900	2,000
Contingency	3,000		3,000
Totals	26,167 bbl	29,970 bbl	56,138 bbl

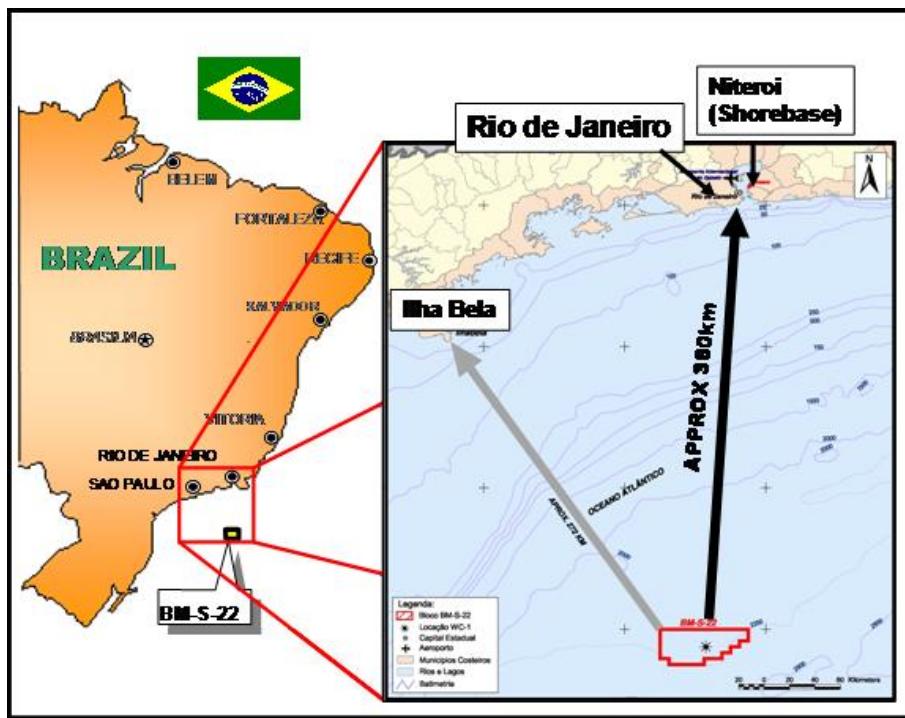


Fig. 1—Location of Block BM-S-22, Santos Basin Brazil.

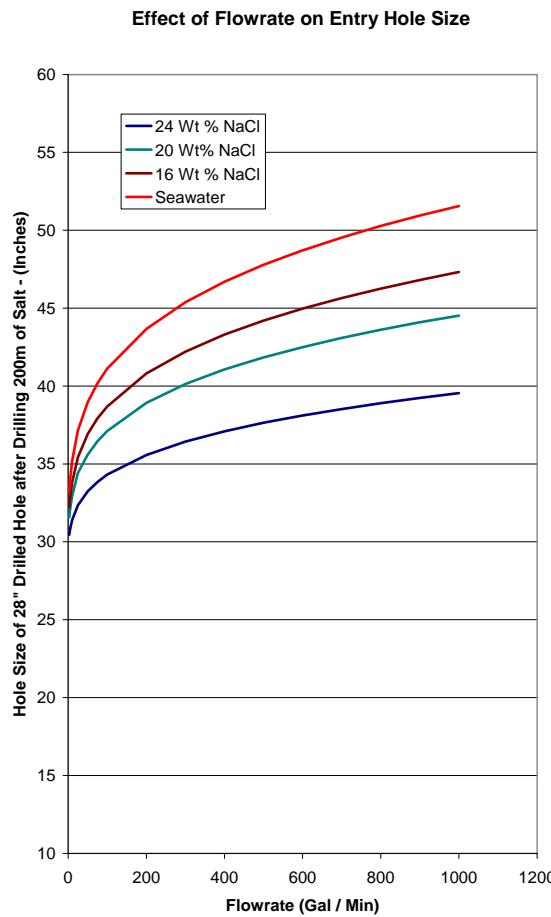


Fig. 2—Effect of flow rate on hole size.

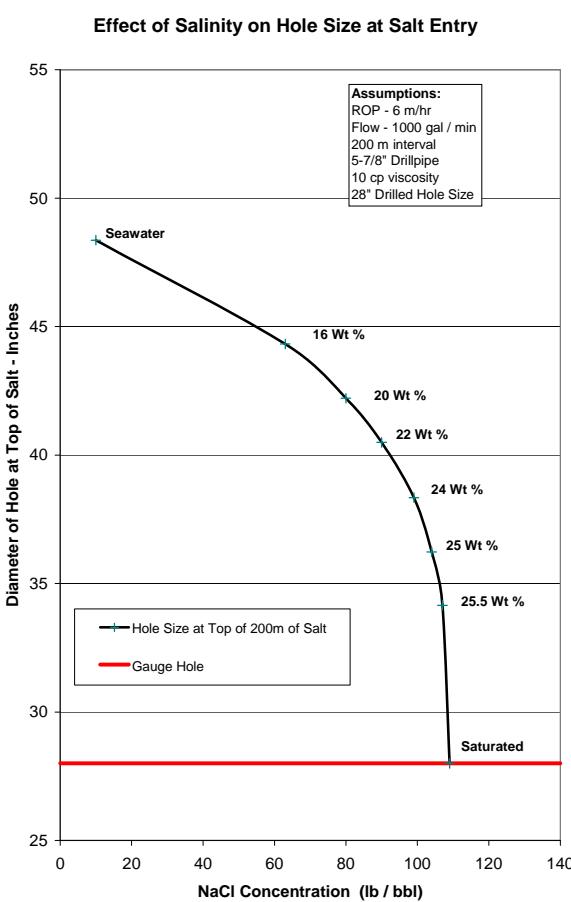


Fig. 3—Effect of salinity on hole size at salt entry.

Predicted Salt Washout for Planned Pump & Dump  
Strategy - 1000 GPM @ 18 ft/hr ROP

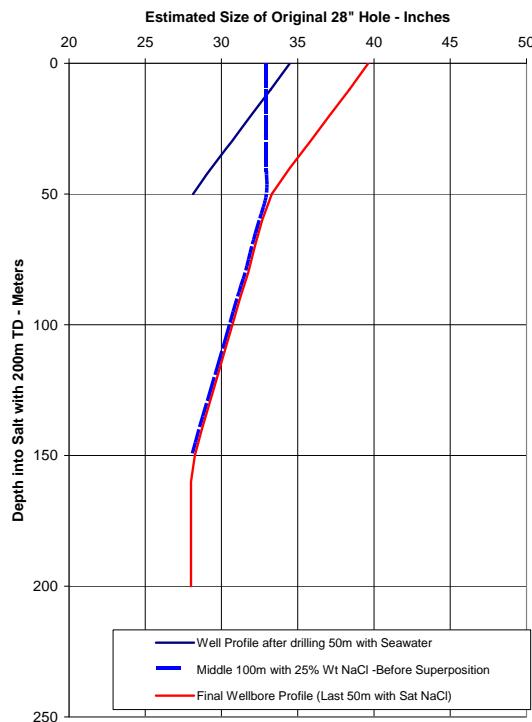


Fig. 4—Predicted salt washout for selected drilling strategy.

Supersaturated NaCl Solution Chloride Content

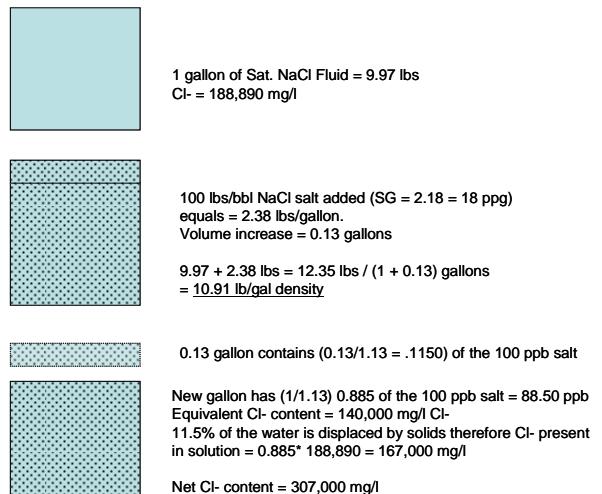
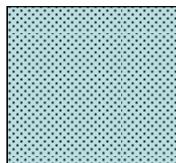


Fig. 5—Chloride content determination of a supersaturated brine.

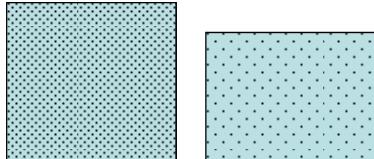
Supersaturated NaCl Solution Cutback Calculations



Salt Solid in Suspension = 88.50 ppb  
Equivalent Cl- content = 140,000 mg/l Cl-  
11.5% of the water is displaced by solids therefore Cl- present  
in solution = 0.885\* 188,890 = 167,000 mg/l

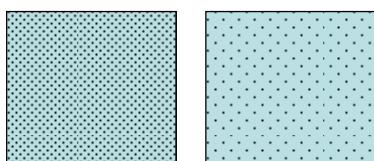
Net Cl- content = 307,000 mg/l  
Density = 10.91 ppg

Dilution to Saturation:



1 barrel Supersaturated Brine has:  
- 0.885 barrels of saturated brine  
- 88.5 lbs of solid salt in suspension  
88.5 bbls of salt can saturate \_\_\_\_\_ bbls seawater?  
- seawater contains approximately 3-wt% NaCl equiv.  
- approximately 112 lbs NaCl required to saturate 1 bbl seawater  
- suspended salt can saturate 88.5 / 112 = 0.79 bbls seawater  
- Ratio = 1/(1+0.79) = 0.56 / 0.44

Dilution to 25-wt % Brine:



1 barrel Supersaturated Brine has:  
- 0.885 barrels of saturated brine  
- 88.5 lbs of solid salt in suspension  
88.5 bbls of salt can saturate to 25-wt% \_\_\_\_\_ bbls seawater?  
- seawater contains approximately 3 Wt% NaCl equiv.  
- approximately 106 lbs NaCl required to increase SW saturation to 25-wt%  
- suspended salt can saturate 88.5 / 106 = 0.84 bbls seawater  
- Ratio = 1/(1+0.84) = 0.54 / 0.46

Fig. 6—Seawater dilution calculations.

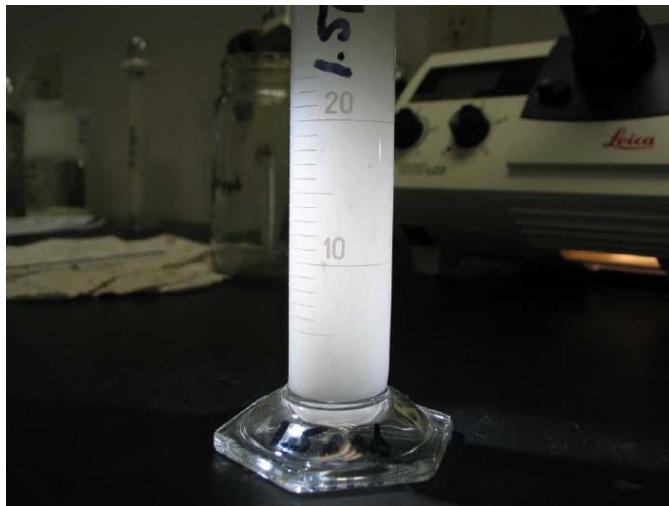


Fig. 7—Laboratory settling test - 14 days stagnation.



Fig. 8—Recessed suction box - rig tank.



Fig. 9—Recessed suction box - supply vessel tank  
(Note suction box in lower right of picture).



Fig. 10—Blending manifold.



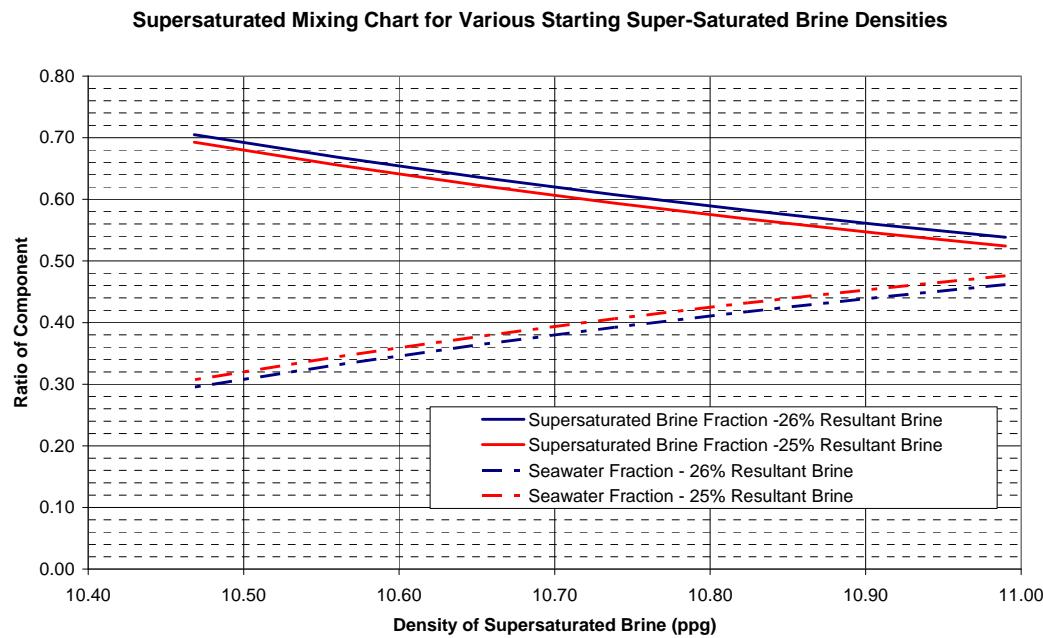
Fig. 11—Pit layout during mobilization/drilling 42-in. hole.



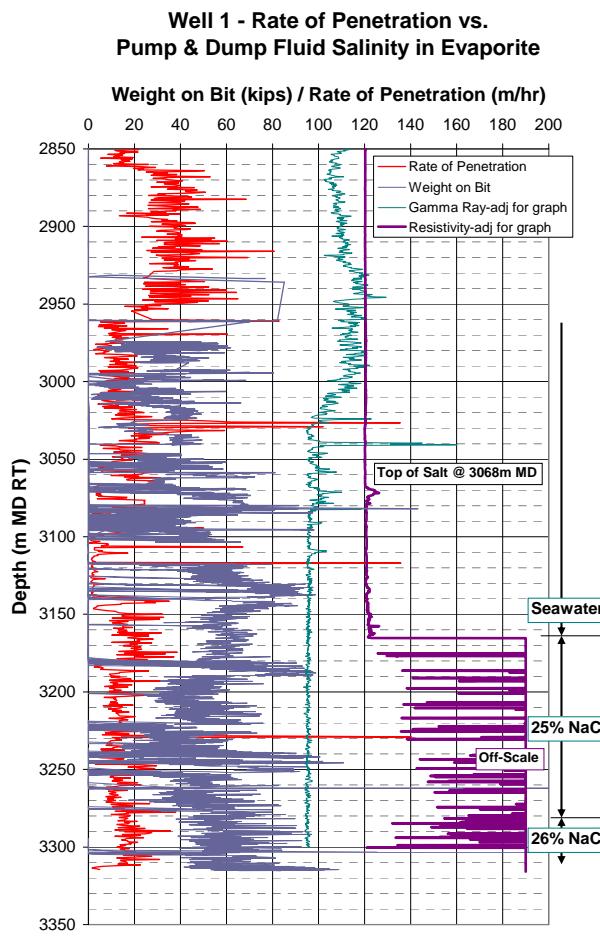
Fig. 12—Settled salt in mud tank after well 1.



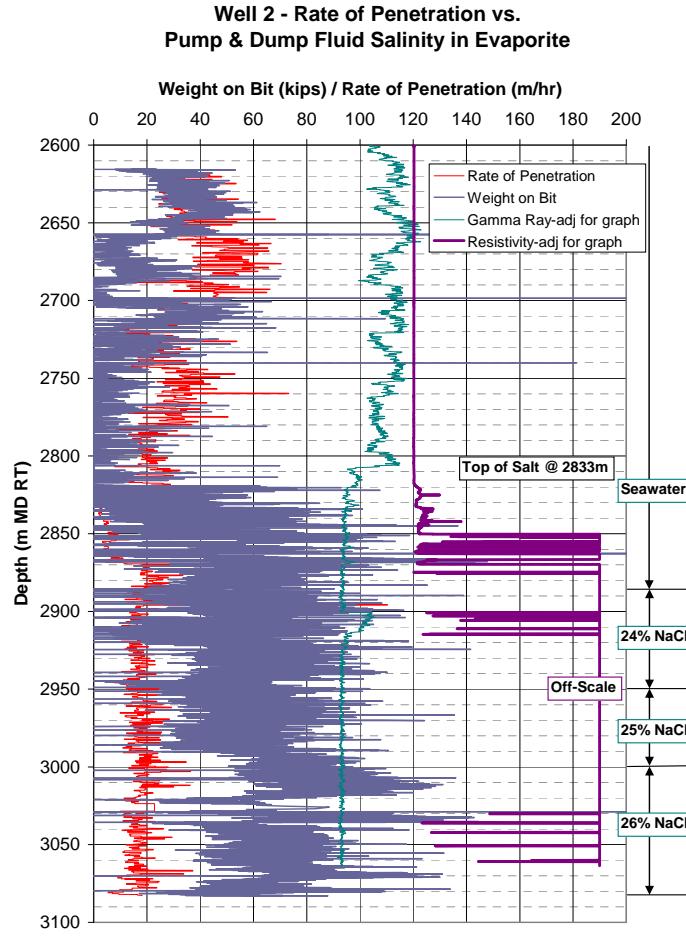
Fig. 13—24-day settling test of supersaturated brine.



**Fig. 14—Supersaturated brine dilution chart considering salt settling.**



**Fig. 15—Well 1 rate of penetration vs. fluid salinity.**



**Fig. 16—Well 2 rate of penetration vs. fluid salinity.**