November 2019

WHITE PAPER

ESal
Engineered Salinity

THE SECRET IS IN THE WATER

Screening: Knowing when a technology doesn't work is as important as knowing when it can.

In this white paper, we summarize the findings of ESal research into the factors contributing to the effectiveness of the Engineered Salinity™ solution in oilfields.

The knowledge gained from this research was instrumental in developing a valid, fast and affordable screening tool for assessing the efficacy of Engineered Salinity in petroleum reservoirs.

THE PURPOSE OF SCREENING

The decision to employ specific technologies in the petroleum industry is usually aided by a technical screening process. Screening procedures traditionally consist of applying a series of rules to evaluate the likelihood that specific techniques will work on a candidate reservoir. Screening rules can be qualitative or quantitative and are based on experience where specific criteria can be related to the success or failure of a technique. Examples of screening criteria used include flow response, oil-in-place, temperature, salinity, depth, oil properties (API gravity, viscosity) rock properties (porosity, permeability, mineralogy, clay content), pay thickness and heterogeneity, among others.

Attributes of Valid Screening

A valid screening tool or procedure informs as to whether a technology is likely to work in a given situation. There are some other important variables, however, that a screening tool must possess:

Minimize false positives. A valid screening tool must minimize the probability of generating a false positive, giving the green light to a technology that will ultimately fail in the candidate scenario.

Minimize false negatives. Minimize the probability of generating a no-go decision when a technology would actually work in the candidate scenario.

Expensive. If the cost of screening is greater than the expected economic benefit, or consumes a substantial portion of it, it is cost prohibitive. In this situation, a potentially valuable technology is likely to be shelved or an operator may decide to take on excessive risk.

Timely. Screening results must be delivered within a reasonable amount of time. Waiting a year or longer for test results is too long in a cyclical industry vulnerable to macroeconomic volatility.

We considered these attributes when developing the ESal screening tool for Engineered Salinity, and provide discussion on them in this paper.

The Engineered Salinity Process of Identifying Key Variables

Over the past fifteen years, there have been over 350 laboratory and field studies of altering salinity to increase oil recovery. The figures below show the additional recovery for numerous carbonate (Figure 1) and sandstone (Figure 2) laboratory and field tests.

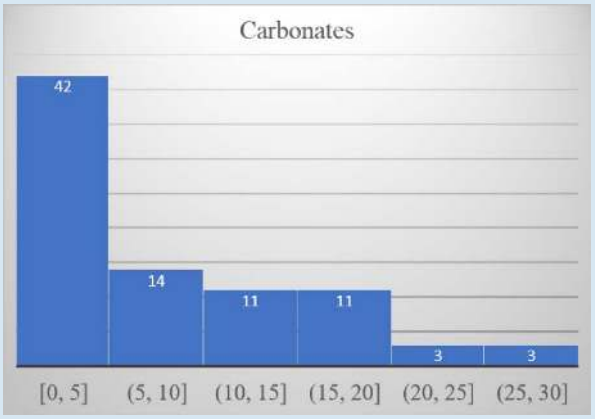

Figure 1

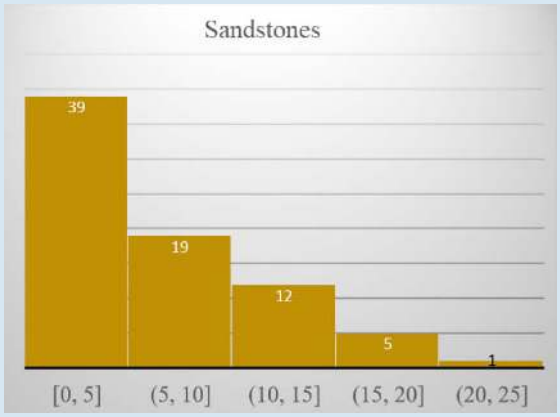

Figure 2

The data above show a wide range of success for increasing oil recoveries by altering salinity from both sandstone and carbonate reservoirs (0 to 25%), but most cases are between 0 and 10% additional oil recovery. These studies were used to formulate the initial screening tool for Engineered Salinity. The current tool uses 28 individual parameters, but we will limit the discussion to a few examples.

For example, careful review revealed that temperature is an important factor. For sandstones, there was only one successful case above 120°C (248°F), but many successful cases at lower temperatures. In contrast, there are no successful cases below 50°C (122°F) for carbonates.

Figure 3 to the right illustrates the linear relationship between temperature and oil recovery for sandstones.

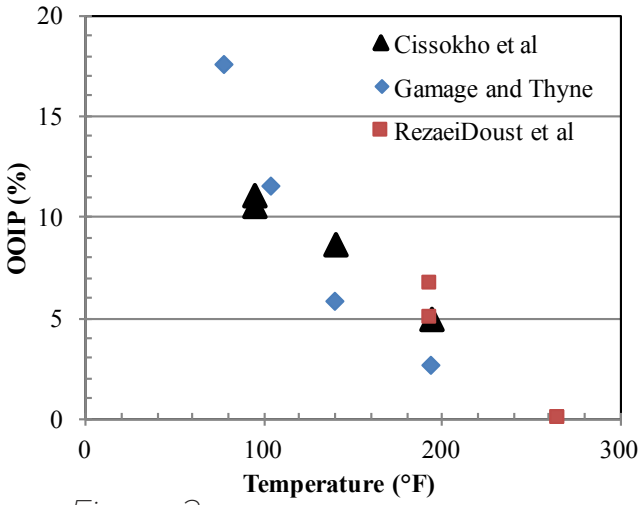

Figure 3

Another important factor is the clay content of sandstones. While the type of clay was initially proposed to be an essential component, later work demonstrated this is not the case. In fact, as shown in Figure 4, the amount of additional recovery is directly related to the amount of clay.

This is an example of a quantitative relationship that can be incorporated into a screening tool. Similar relationships can be derived for oil composition and dilution factor of injected versus formation water.

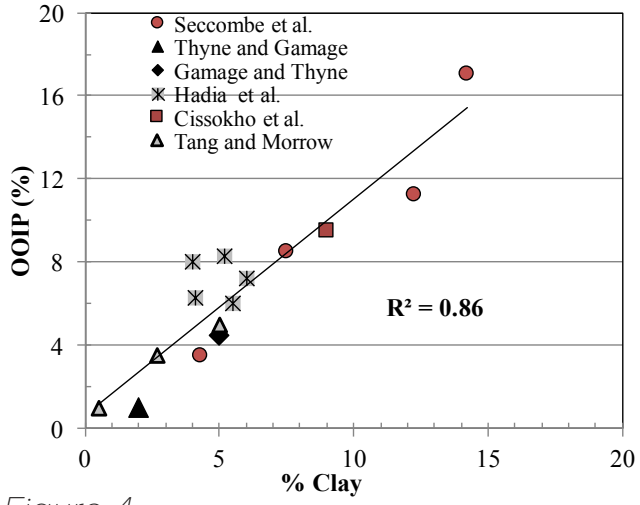

Figure 4

Temperature and clay content are only two independent variables out of many used in the ESal screening tool. We use empirically-based criteria to evaluate the suitability of Engineered Salinity for candidate reservoirs as step one in our process. Examples of successes and failures provided further insight into the links between reservoir factors such as water salinity, rock and oil composition, and reservoir characteristics with increased recovery as the basis for calculation.

For example, we found that clay content, oil composition, waterflood performance and temperature of reservoir were the most important factors for screening Alaskan oil fields, and we further defined the relative importance of each to the success case.

Incorporating these factors significant to predicting success into the ESal screening tool minimizes the risks of false positives or false negatives.

Combining these factors into a complex mathematical expression allows us to calculate a numerical score for candidate fields. The required data include reservoir oil and water chemistry, reservoir mineralogy and reservoir performance. An example of the output from the screening tool is shown in Figure 5 below.

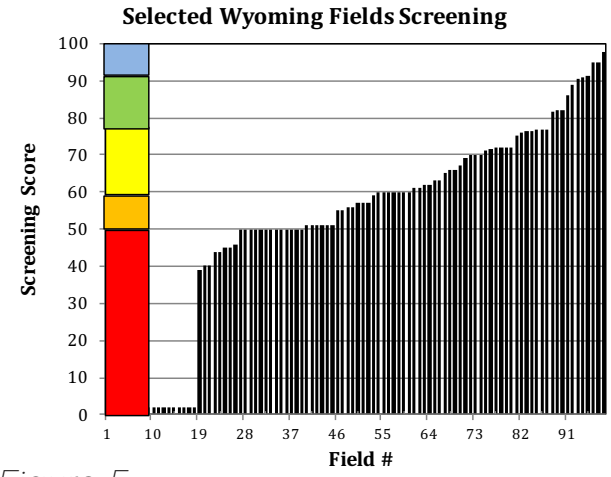

Figure 5

The basic information for the 100 candidate fields in Wyoming was taken from public sources and input to the ESal screening tool. The results indicated that approximately half the fields evaluated are Average to Good candidates (scores between 60 and 91), while five fields were ranked as Excellent candidates for Engineered Salinity.

The Average to Good candidates are likely to yield 5% or greater increased recovery, while the Excellent candidates will likely reach the higher end of the additional recovery range. Screening is the first step, an inexpensive step, to evaluate the potential of your existing properties or help evaluate potential acquisition and divestment strategies. The next step is laboratory testing and economic modeling to quantify the benefit.

Screening for A&D Opportunities

The ESal screening tool can be employed to guide acquisition and divestment strategies. In Figure 6, we show a map view of the Queen sandstone in the Permian Basin. The scores show that fields on the edges of the basin have the greatest potential to benefit from Engineered Salinity. These test results can help high-grade acquisition targets or guide divestment strategies.

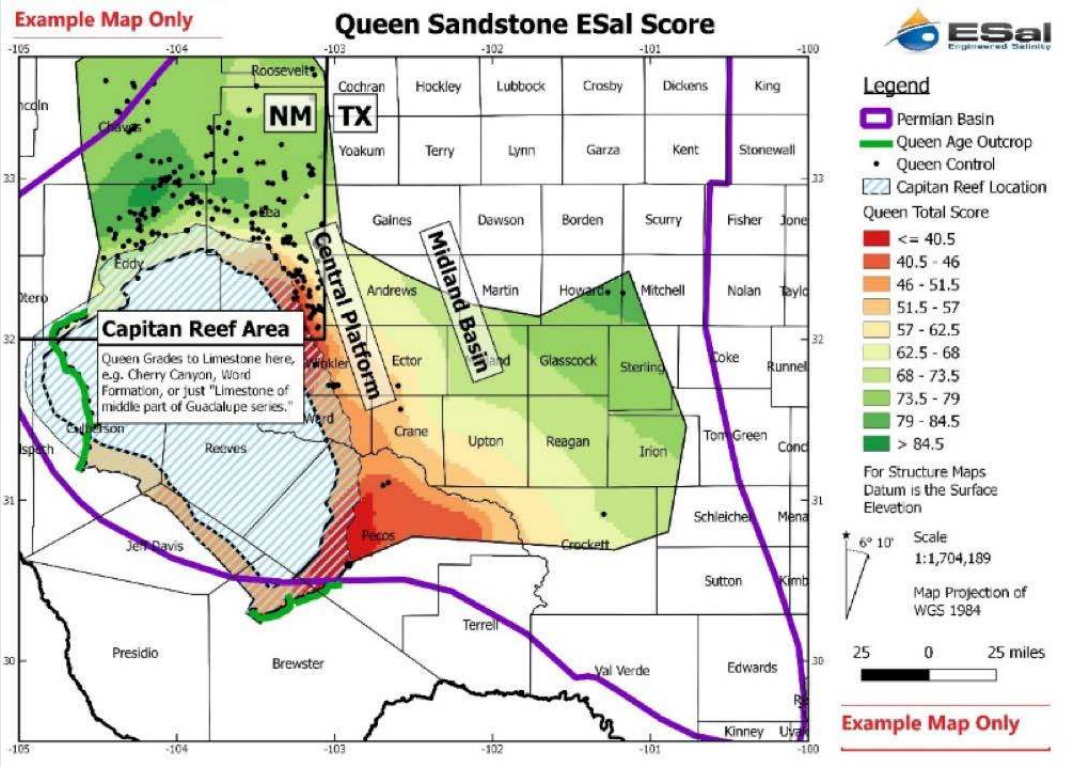

Figure 6

SUMMARY

The ESal screening tool has proven to be a valid indicator of the probability of success for applying Engineered Salinity to specific petroleum reservoir candidates. Importantly, the screening tool is affordable and provides timely results. **Typical cost is minimal and a comprehensive analysis usually requires less than six weeks.** It is not uncommon for other screening methodologies to cost millions of dollars and years of work to make an informed assessment.

At ESal, we are constantly refining the screening tool with new laboratory and field results to provide better answers for our customers. Combined with our laboratory testing to verify and quantify the potential improvement in recovery from the screening procedure, we minimize the risk and maximize the reward for our clients. Most importantly, we get results fast.

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