Comparative Methodology for USDW Determination to Support Abandonment of Offshore Rincon Oil Field*

Daniel Schwartz[1], Terence O'Sullivan[2], and Eric White[3]

[1]Daniel E Schwartz, LLC and Driltek Corp., Bakersfield, CA, United States (Dan.Schwartz@driltek.com)
[2]Vapor Condensation Technologies, LLC, Bakersfield, CA, United States
[3]Numeric Solutions, LLC, Ventura, CA, United States

Abstract

To develop part of the offshore Rincon Oil Field, wells were drilled from a coastal corridor in Ventura County. Abandonment of these wells required that cement be placed across the base USDW (transition from >10,000 mg/l TDS to <10,000 mg/l TDS). A blended Petrophysical / Geological approach was developed to create a base USDW surface map to intersect wells for abandonment. California State Regulations and Codes (Article 3.2. Oil and Gas Drilling Regulations 2128. Drilling Regulations); stipulate "a cement plug at least 200 feet long shall be placed across the intrazone freshwater/saltwater interface, so as to isolate fluids in the strata in which they are found and to prevent them from migrating into other strata." To determine water salinity and total dissolved solids (TDS); the traditional approach has been to utilize well logs run when the well was drilled. Commonly the Spontaneous Potential (SP) or the Resistivity-Porosity (RP) methods are used to estimate formation water salinity. In both cases, depth and log readings are needed in addition to drilling-mud properties (weight, resistivity, temperature, mud filtrate resistivity, and mud filtrate temperature), uninvaded-zone resistivity (in a wet sand) and the porosity of the wet sand are needed. Rincon wells were drilled between 1927 and 1988, and in general, digital log data was not available. Key parameters were not available for older wells, and this increases the uncertainty in salinity calculations, especially if only one well log method is used. For the present study, data was obtained from 30 corridor wells. Fifty-two SP and 54 RP readings were made from logs. TDS determinations for sample depths range from 4,000 to 40,000 mg/l with a R2 = 0.7415 but have a variance of 5000 mg/l to 10,000 mg/l around the 10,000 mg/l value. To generate a base USDW surface for abandonment cement placement, a four-step process was employed, resulting in a mapped surface with over 200 feet of variance in the corridor. The USDW map was overlaid with surface topography. Stream discharge appears to influence USDW distribution in the near subsurface along the shoreline. Wells of differing vintage and data quality require a more robust analysis to ensure consistent output. Mapping of statistically consistent salinity derived from both SP and RP methods improves stability, promotes the understanding of base USDW variance, and enables development of a most-likely depth-to-base USDW map that compares favorably to surface drainage patterns. When historical variations in watershed discharge are considered, there is strong support for adjusting depth of abandonment-cement placement in Rincon corridor wells.

Comparative methodology for USDW determination to support abandonment of offshore Rincon Oil Field
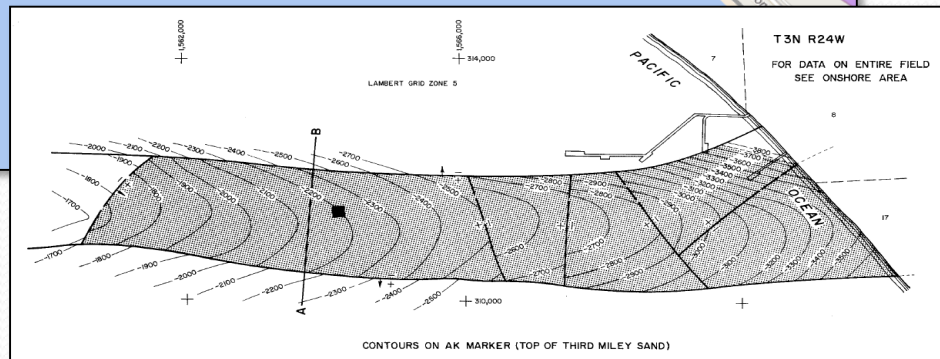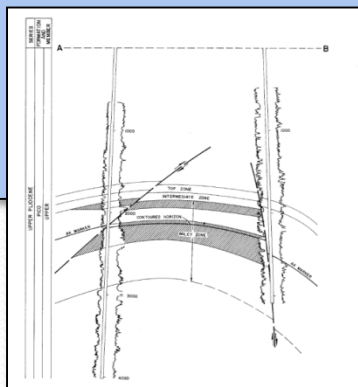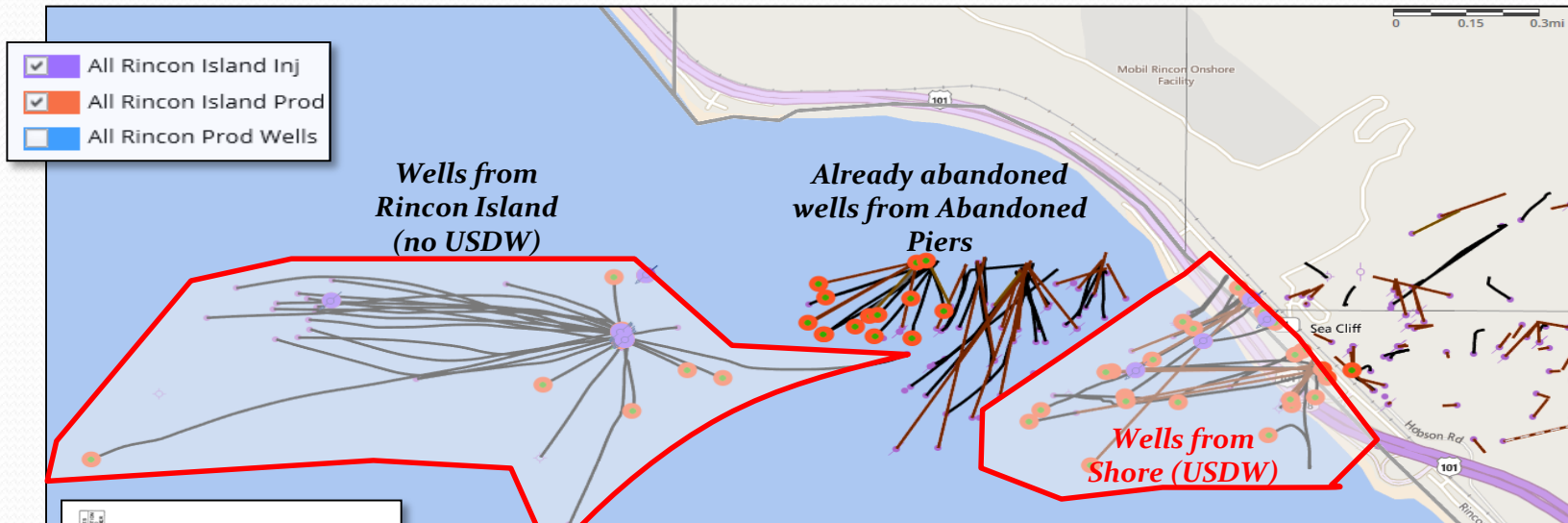
Daniel Schwartz; Daniel E Schwartz, LLC, Driltek Corp.
Terence O'Sullivan; Vapor Condensation Technologies, LLC
Eric White; Numeric Solutions, LLC

DRILTEK

Rincon Oil Field
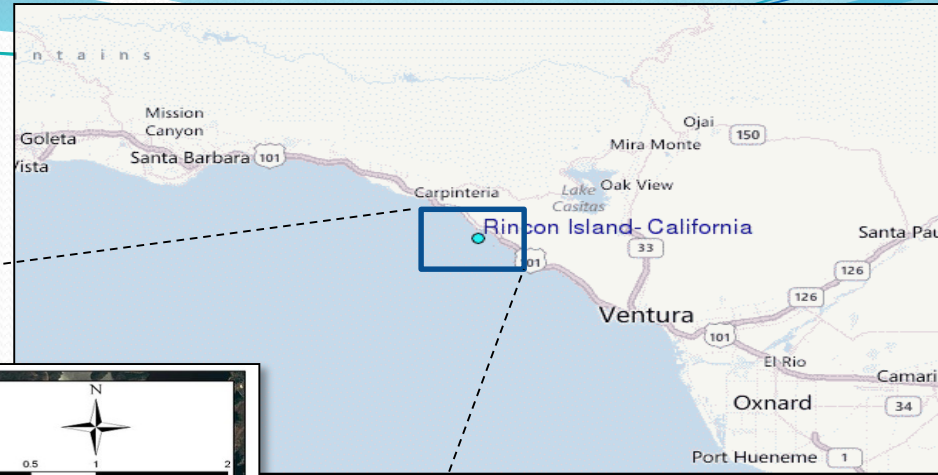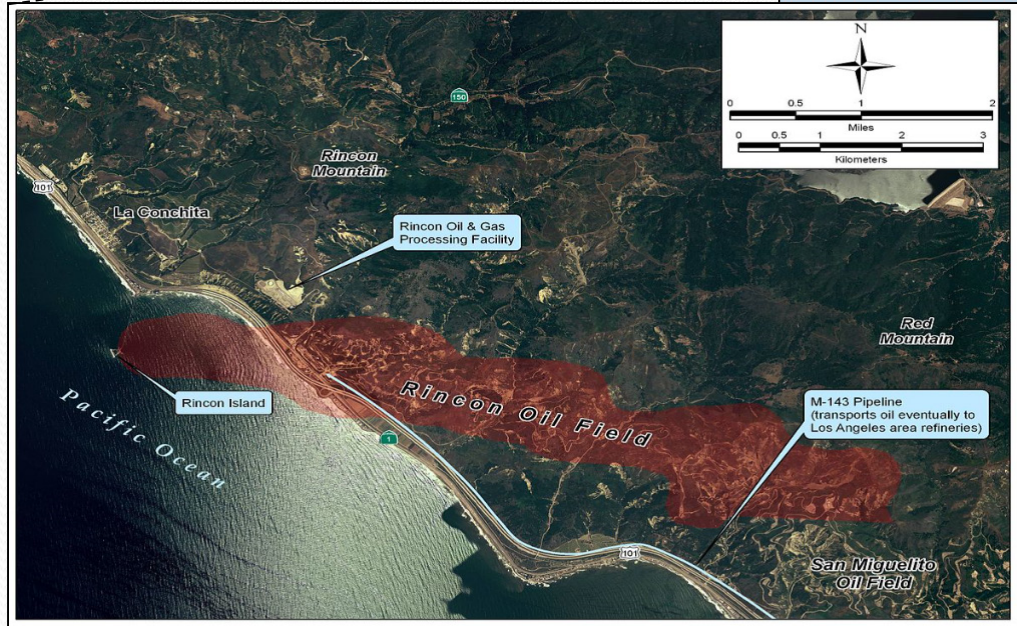
Rincon well abandonments

The Regulations and Codes

State of California, Public Resources Codes Sections 6103, 6108, 6216, 6301 and 6873(d; and Section 11152 of the Government Code with reference to: Sections 6005, 6216, 6301, 6871, and 6871.1, are the basis for State Lands Commission Oil and Gas Drilling Regulations with application to the abandonment of oil and gas wells, as follows:

- **Article 3.2. Oil and Gas Drilling Regulations 2128. Drilling Regulations.**
- (1) Permanent Abandonment.
- (A) Isolation of Zones in Open Hole. In open hole portion of the well, cement plugs shall be spaced to extend from 100 feet below to 100 feet above each oil or gas bearing zone or zone that is productive of hydrocarbons elsewhere in a field, and a cement plug at least 200 feet long shall be placed across the intrazone freshwater / saltwater interface, so as to isolate fluids in the strata in which they are found and to prevent them from migrating into other strata.

DRILTEK

Variables and Methods

Variable	Source or equation	Description
DepthSp	Log print	Depth of static SP pick
SSP	Log print	value of static SP
MudWt	Log header	mud weight
Rm	Log header	mud resistivity
TempRm	Log header	mud temperature
Rmf	Log header (not typically measured before 1960)	mud filtrate resistivity
TempRmf	Log header	mud filtrate temperature
Rt	Log print	uninvaded zone resistivity (in a wet sand)
Porosity	Log print, or estimated value	porosity of the sand
SP NaCl equivalent salinity evaluation, parameters and calculation.		
Rm_75	=Rm*(TempRm+6.77)/(75+6.77)	calculate Rm@75 degF
Km_LD	=IF(Rm_75>0,10^(0.396-(0.0475*MudWt)),"")	Lowe & Dunlop "K" factor
RmfEdit2	=IF(Rm_75>0,Km_LD*Rm_75,Rmf)	Lowe & Dunlop Rmf from Rm, or measured Rmf (if available)
MudWt	=MwPpg(MudWt)	MudWt, converted to pounds per gallon
FT	=0.0131*DepthSp_1+ 60	Formation temperature at DepthSP_1 from gradient, surface temperature = 60 degF
Rmf_75	=RmfEdit2*(TempRmf+6.77)/(75+6.77)	Rmf @ 75 degF
RmfEq_75	=IF(Rmf_75>0.1,0.85*Rmf_75,(146*Rmf_75-5)/(337*Rmf_75+77))	Rmf equivalent
R_	=IF(SSP=-9999,-9999,10^-(SSP/(60+0.133*FT)))	adjust SSP for Formation temperature
RwEq_75	=RmfEq_75/R_	Rw equivalent
Rw75lt.1	=0.03793+0.22248*RwEq_75+14.87084*RwEq_75^2-80.77638*RwEq_75^3	
Rw75gt.1	=0.02093+1.12581*RwEq_75-0.62131*RwEq_75^2+1.68355*RwEq_75^3	
Rw75Tl	=IF(RwEq_75<0.1,Rw75lt.1,Rw75gt.1)	estimated Rw @ 75 degF
RwTl	=Rw75Tl*82/(FT+7)	Rw @ Formation temperature
SP-Sal	=IF(NOT(SSP=-9999),10^((3.562-LOG10(Rw75Tl-0.0123))/0.955),-9999)	convert Rw to NaCl-equivalent salinity
RP (resisitivity-porosity) method for apparent formation water resisitivity, parameters and calculation.		
m	cementation exponent	1.08*
a	"a" archie coefficient	2.45*
Rwa	=(Rt * Porosity^m)/a	formation water resisitivity (in a wet sand)
RP-salinity	=10^((3.562-LOG10(Rwa-0.0123))/0.955)	convert Rwa to NaCl-equivalent salinity
*Value for Pliocene sands (Southern California), Carothers and Porter (1970).		

DRILTEK

Challenges

- Wells drilled over a wide time period
  - 1927 – 1929
  - 1945 – 1949
  - 1953 – 1958
  - 1986 – 1988

- Well logs of variable quality and often missing key data
  - Mud resistivity, temperature, weight
  - Mud filtrate resistivity, temperature
  - Porosity of wet zone

Wet and Dry Cycles in the Ventura River Watershed

The Ventura River watershed has long experienced cycles of wetter years and drier years. The storage capacity of Lake Casitas was designed by the Bureau of Reclamation based upon the longest dry period on record, the years 1944/45 to '65.
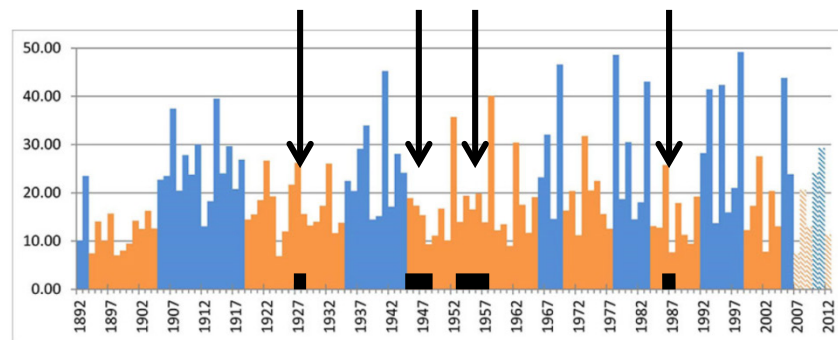
Wet (blue) and Dry (orange) Periods in the Ventura River Watershed
Source: Ventura River Watershed Management Plan
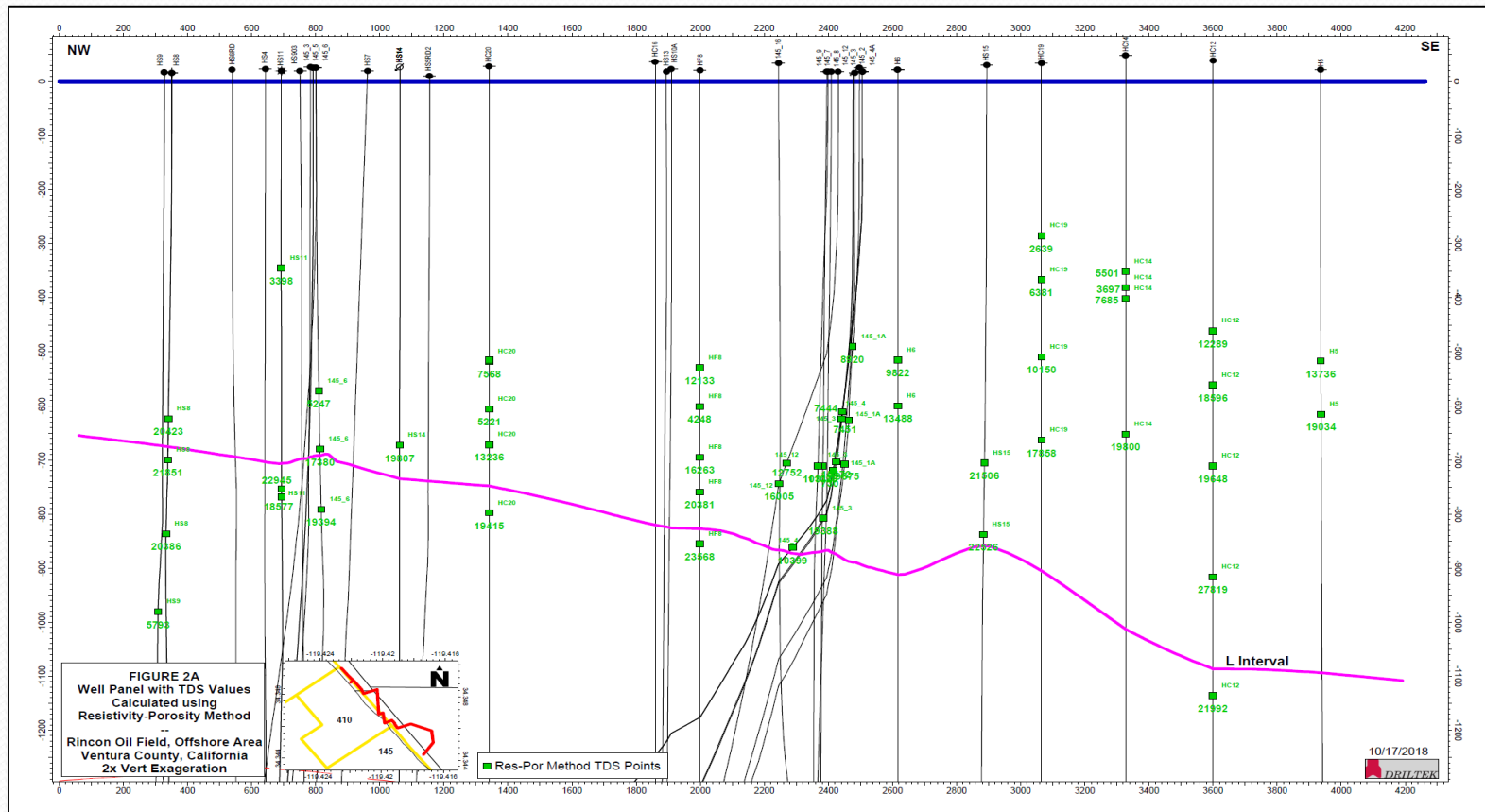
DRILTEK

Determining base USDW

To estimate the base of USDW, two geophysical log-based methods were used.

- The first utilized the spontaneous potential (SP) log while the second utilized the resistivity log and an estimate of porosity (RP).

- For both methods log readings were determined from a variety of strategically chosen depths with the goal of bracketing the 10,000 mg/l transition zone.

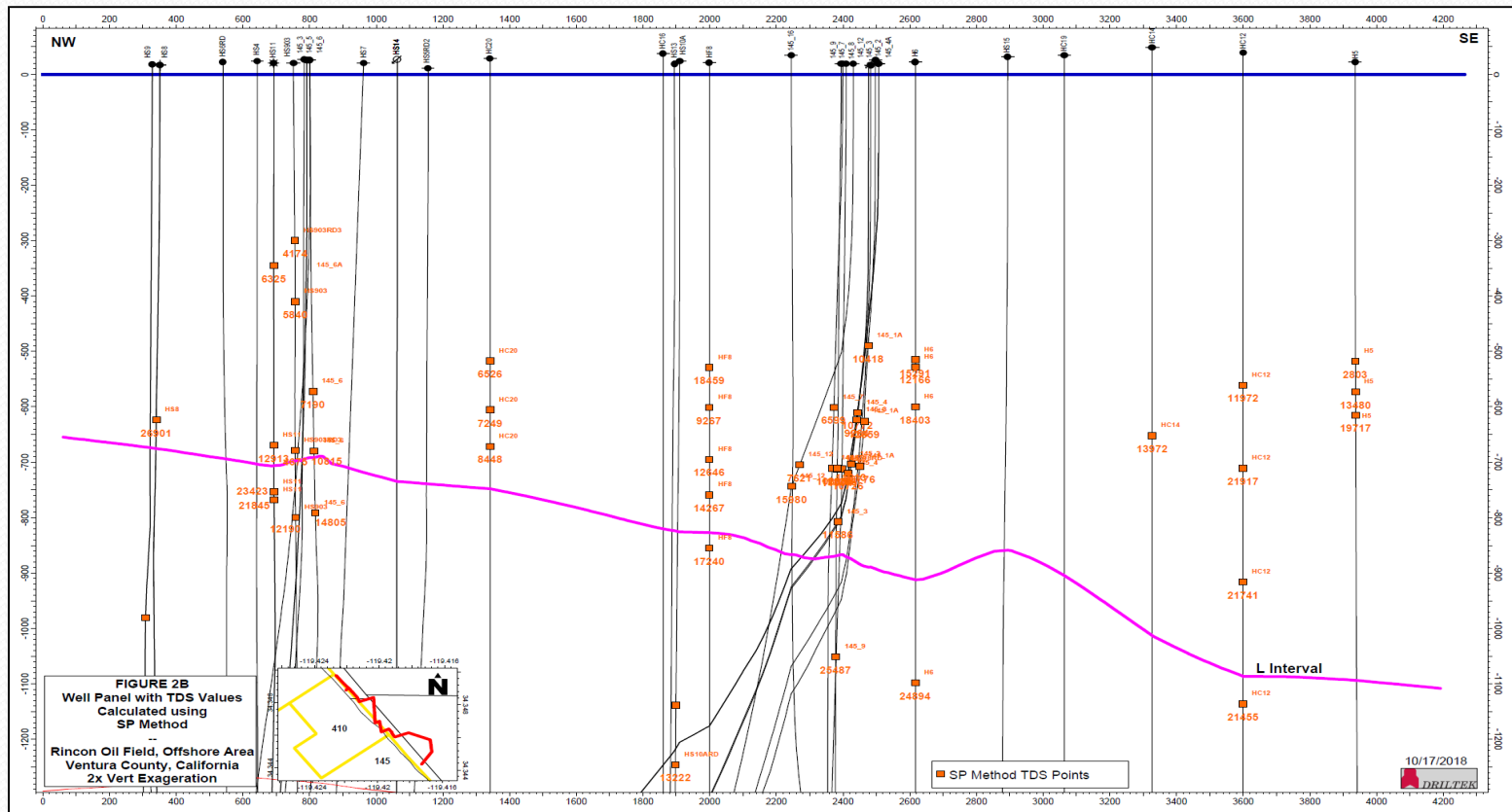- In total, 52 SP and 54 resistivity readings were taken from 30 wells

DRILTEK

Rincon Field Offshore wells with USDW

Wells requiring cement to cover USDW

The offshore area is developed from five subsurface leases, including PRC 145, PRC 410, PRC 427, PRC 429, and PRC 1466.

Rincon cross section with TDS values from resistivity-porosity (RP) methodology

FIGURE 2A
Well Panel with TDS Values
Calculated using
Resistivity-Porosity Method
--
Rincon Oil Field, Offshore Area
Ventura County, California
2x Vert Exageration

Res-Por Method TDS Points

10/17/2018

Rincon cross section with TDS values from spontaneous potential (SP) methodology

FIGURE 2B
Well Panel with TDS Values
Calculated using
SP Method
--
Rincon Oil Field, Offshore Area
Ventura County, California
2x Vert Exageration

TDS from resistivity-porosity versus spontaneous potential

$R^2 = 0{,}7415$
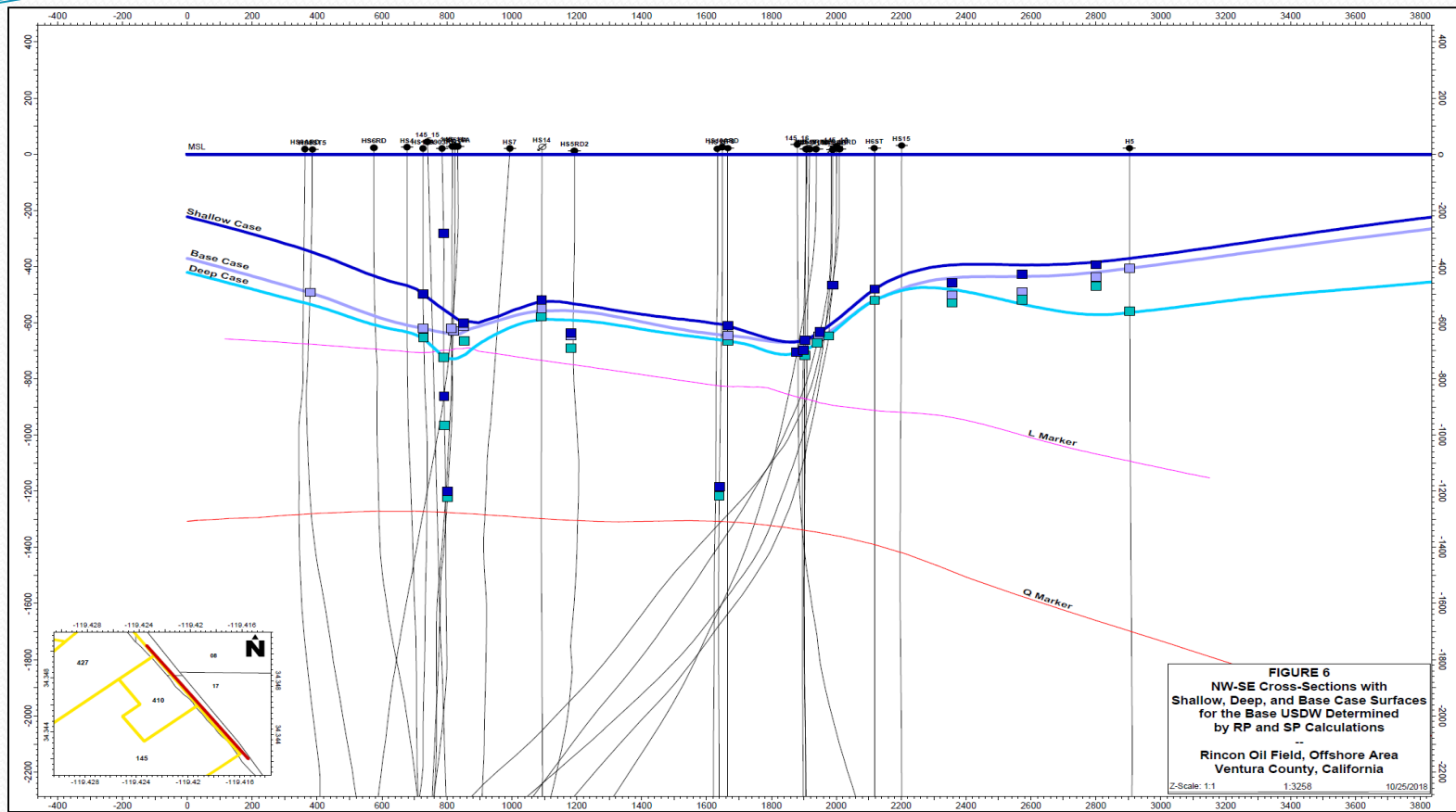
10,000 mg/l variance

DRILTEK
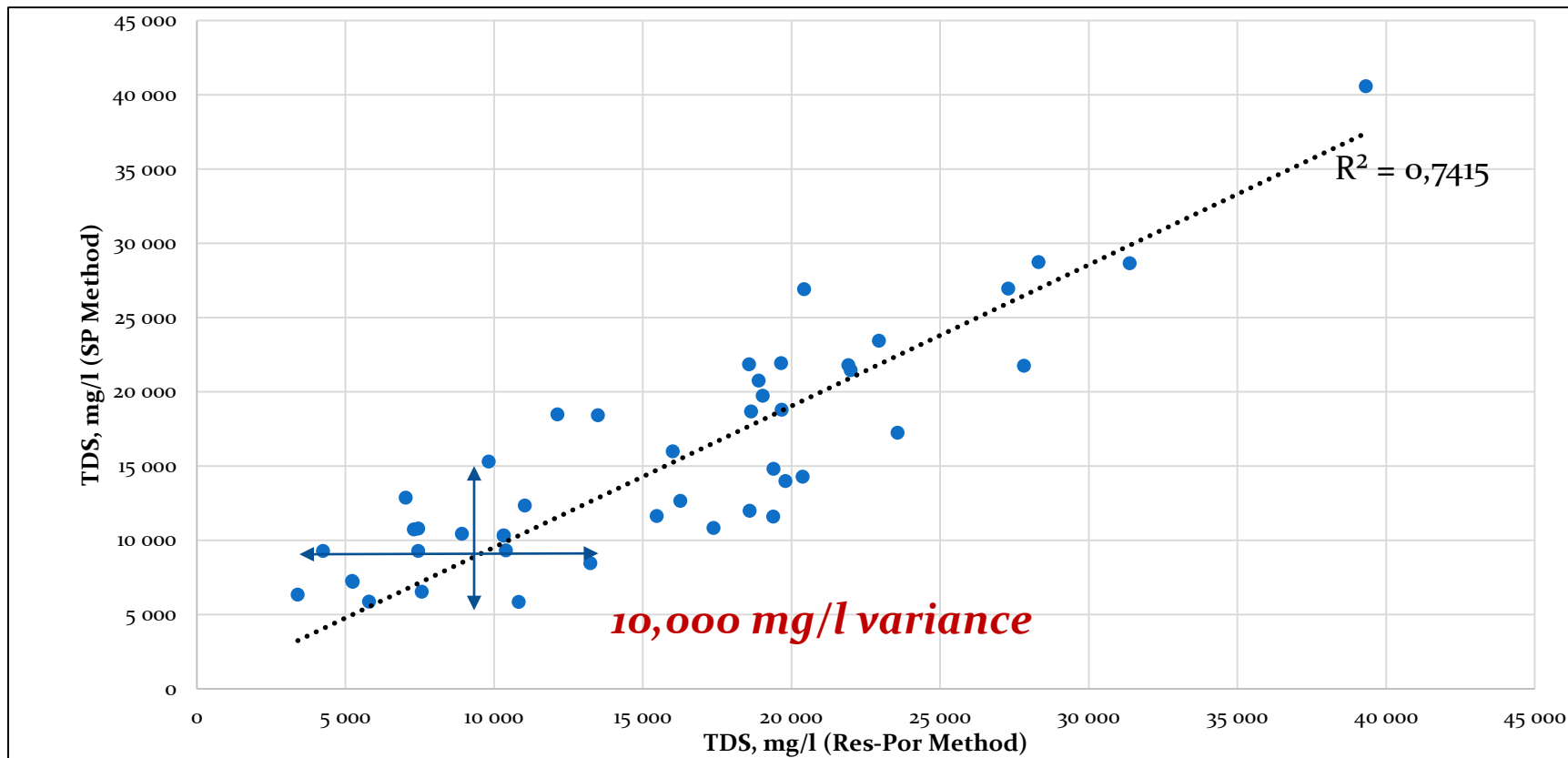
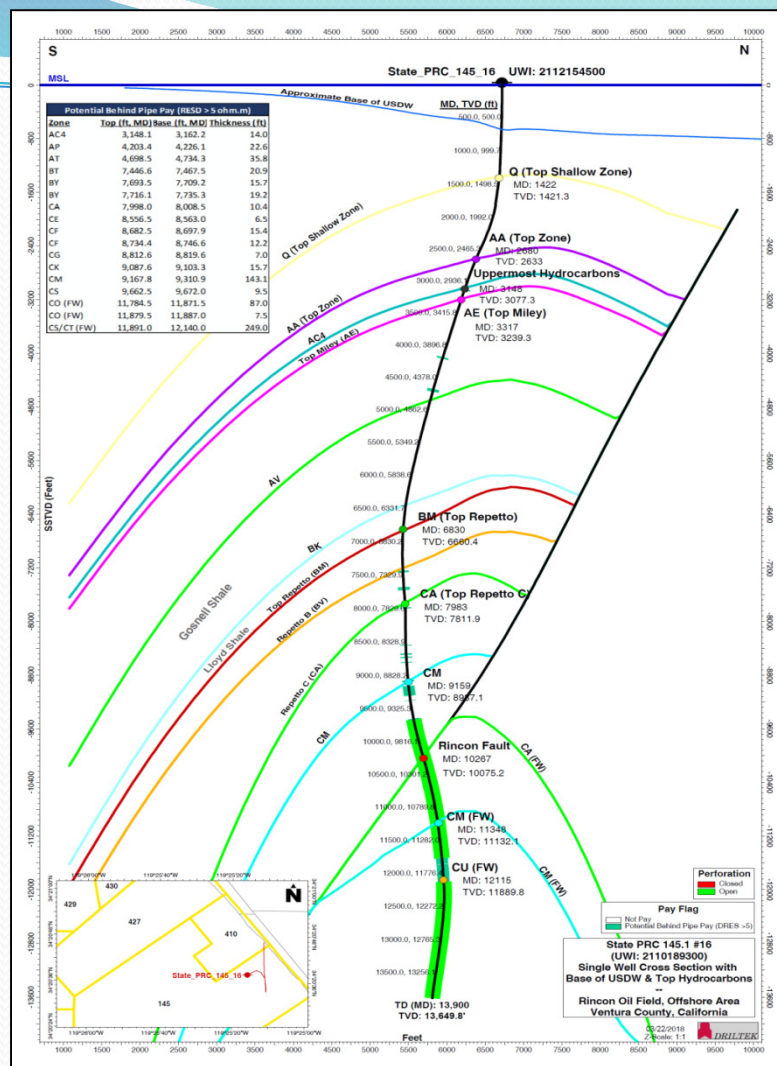# *Estimating the depth of the transition to waters > 10,000 mg/l TDS*

Steps to generating USDW surface:

- Step 1; Linear interpolation in each well that had TDS reading above and below 10,000 mg/l TDS.

- Step 2; From interpolated points, a surface was generated in Petrel using the convergent interpolation algorithm with a 1st degree polynomial trend.

- Step 3; Adjust the surface where needed to ensure it did not extend below values greater than 10,000 mg/l in wells that did not have calculated values less than 10,000 mg/l.

- Step 4; Map the surface and display the intersection of the surface on well diagrams with stratigraphic surfaces and oil shows.
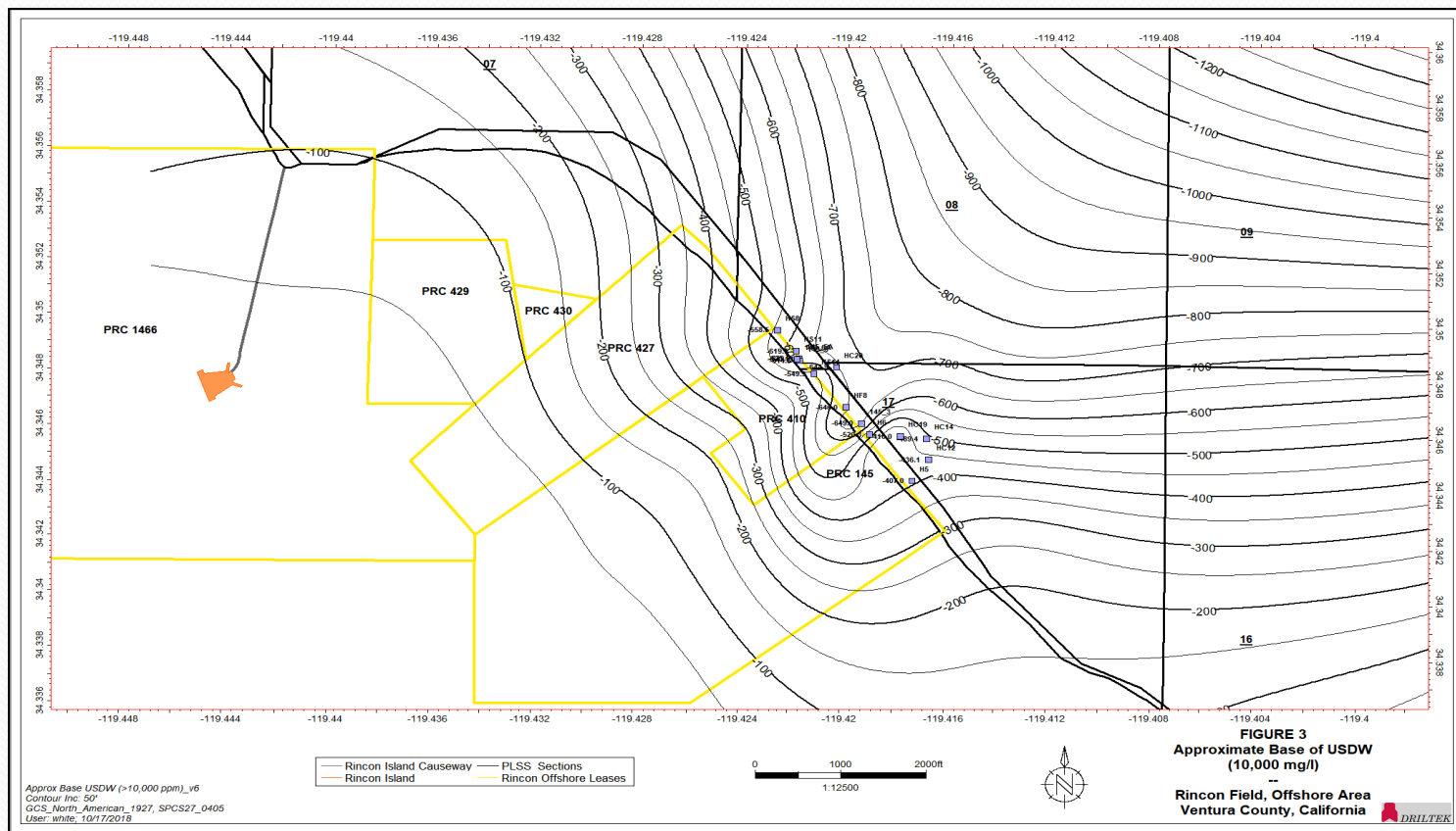
DRILTEK

Cross section showing initial and revised surfaces

Base USDW depth cases based on dual TDS methodologies

FIGURE 6
NW-SE Cross-Sections with
Shallow, Deep, and Base Case Surfaces
for the Base USDW Determined
by RP and SP Calculations
--
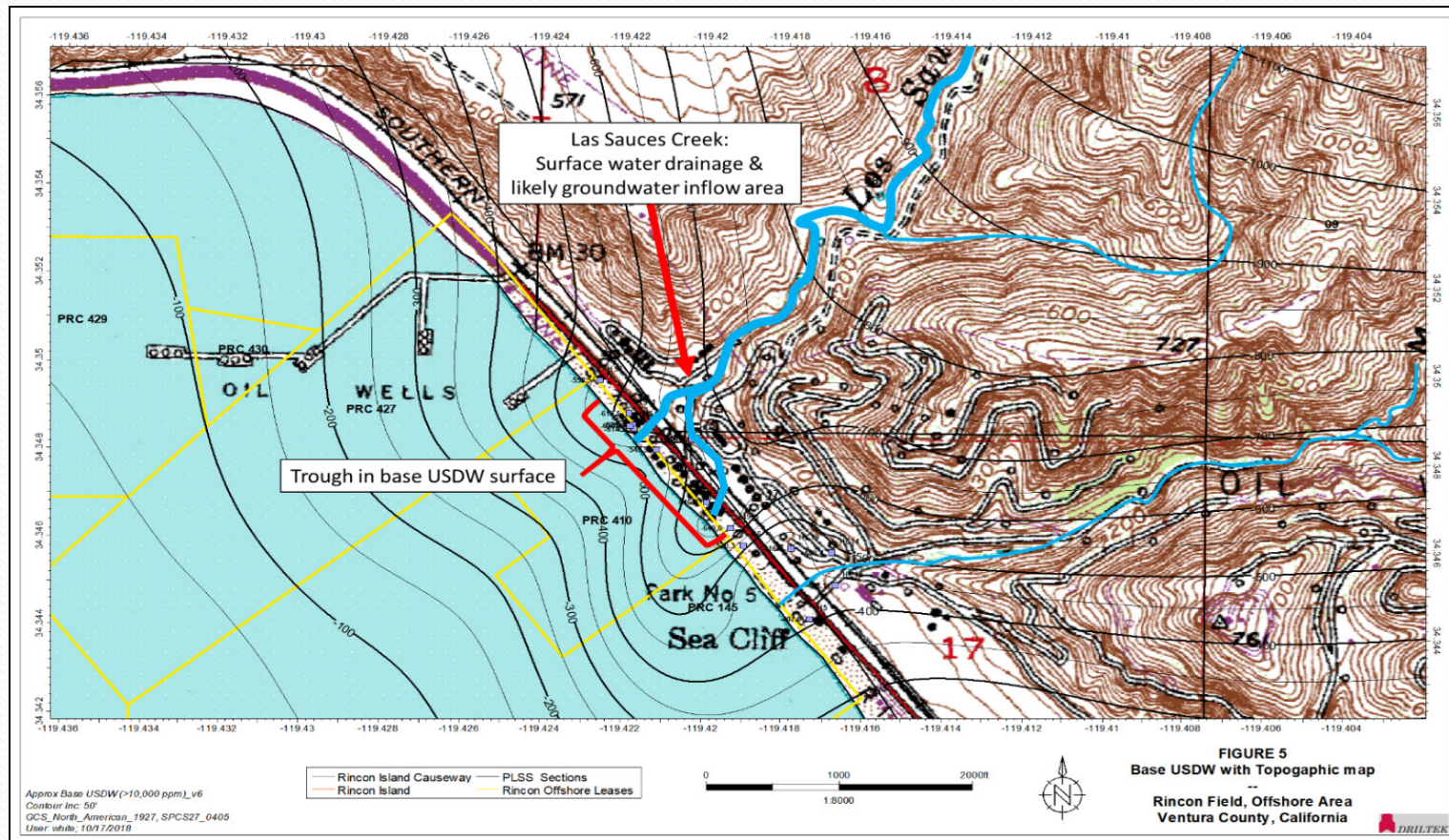Rincon Oil Field, Offshore Area
Ventura County, California

Well diagram provided to abandonment team and regulator to display USDW, uppermost hydrocarbons, behind pipe pay, and open intervals to define cement placement for abandonment

Map of most likely base USDW surface for Rincon

FIGURE 3
Approximate Base of USDW
(10,000 mg/l)
--
Rincon Field, Offshore Area
Ventura County, California

FIGURE 5
Base USDW with Topogaphic map
--
Rincon Field, Offshore Area
Ventura County, California

Conclusions

- Having wells of different vintages and input parameters requires a more robust analysis of TDS from well logs

- Using both the SP and RP methods provides ranges of USDW depth

- Assessing the results from a statistical perspective improves understanding of variance

- Surface discharge influences base USDW contours

DRILTEK