BW - 8

SOLUTION CAVERN CHARACTERIZATION

Chavez, Carl J, EMNRD

From: Chavez, Carl J, EMNRD
Sent: Friday, January 4, 2019 10:37 AM
To: 'Ayarbe, John'
Cc: 'Pieter Bergstein (pieter@bergsteinenterprises.com)'; Griswold, Jim, EMNRD
Subject: RE: [EXT] Salty Dog cone calculation

John:

Good morning!

Received. I will update the admin. record today with this information.

Thank you.

Mr. Carl J. Chavez, CHMM (#13099)
New Mexico Oil Conservation Division
Energy Minerals and Natural Resources Department
1220 South St Francis Drive
Santa Fe, New Mexico 87505
Ph. (505) 476-3490
E-mail: CarlJ.Chavez@state.nm.us
"Why not prevent pollution, minimize waste to reduce operating costs, reuse or recycle, and move forward with the rest of the Nation?" (To see how, go to: http://www.emnrd.state.nm.us/OCD and see "Publications")

From: Ayarbe, John <jayarbe@geo-logic.com>
Sent: Wednesday, December 26, 2018 7:16 AM
To: Chavez, Carl J, EMNRD <CarlJ.Chavez@state.nm.us>
Cc: 'Pieter Bergstein (pieter@bergsteinenterprises.com)' <pieter@bergsteinenterprises.com>; Griswold, Jim, EMNRD <Jim.Griswold@state.nm.us>
Subject: [EXT] Salty Dog cone calculation

Carl,

Attached is the cone calculation you requested. We are finalizing the closure plan and FA cost estimate, and expect to have those to you soon after the New Year.

Thanks,

John P. Ayarbe
Senior Hydrogeologist

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Calculation Cover Sheet

Daniel B. Stephens & Associates, Inc.

Project Name Salty Dog Cavern Characterization Project Number ES08.0118.06

Calculation Number 1 Discipline Hydrology No. of Sheets 2

PROJECT:

Salty Dog

SITE:

Salty Dog Brine Station, Lea County, New Mexico.

SUBJECT:

Brine Well Cavern Characterization

SOURCES OF DATA:

1. 2017 monthly fresh and brine water report forms
2. 2017 laboratory analytical reports for brine and freshwater sampling
3. Historical documents and information

The above data sources are referenced and summarized in DBS&A (2018).

SOURCES OF FORMULAE & REFERENCES:

Daniel B. Stephen & Associates, Inc. (DBS&A). 2018. 2017 *Annual Class III Well Report, Salty Dog Brine Station, DP BW-8, API No. 30-025-26307, Lea County, New Mexico.* Prepared for the New Mexico Energy, Minerals and Natural Resources Department Oil Conservation Division, Environmental Bureau, Santa Fe, New Mexico. May 1, 2018.

New Mexico Energy, Minerals and Natural Resources Department (NMEMNRD). Undated. Example Salt Cavern Characterization. Emailed to DBS&A from NMENMRD on December 7, 2018.

☐ Preliminary Calculation ☑ Final Calculation Supersedes Calculation No. _____

Rev. No.	Revision	Calculation By	Date	Checked By	Date	Approved By	Date

Project No. ES08.0118.00 Date 12/11/2018

Subject Brine Well Cavern Characterization Sheet 1 of 2

By J. Ayarbe Checked By B. Salvas Calculation No. 1

1. Purpose

Calculate the estimated height and estimated floor diameter of the brine cavern at the Salty Dog Brine Station.

2. Given

1. Volume of the brine cavern at the end of 2017:

Volume = 883,300 barrels (bbl)

Value based on historical and present brine production data, as presented in DBS&A (2018). Attachment 1 provides the relevant section from DBS&A (2018).

2. Equation for the volume of a cone (Attachment 2)

$$Volume = \frac{\pi \times radius^2 \times height}{3}$$

3. Brine well construction (Attachment 3):

Casing is set at 1,877 feet below ground surface (feet bgs). Tubing was set at 2,665 feet bgs between 2013 and 2017, and was moved to 2,610 feet bgs in 2018, when the brine well was repaired.

3. Method

Cavern height calculated from the 2013 to 2017 tubing depth (i.e., 2,665 feet bgs) because the tubing was only recently moved up to 2,610 feet bgs. Cavern height calculated as the difference between the bottom of the well casing and tubing depth (Attachment 2).

Floor diameter calculated by solving for radius in the cone-volume equation.

4. Solution

Cavern Height

$height = 2{,}665 \text{ feet} - 1{,}877\ feet = 788\ feet$

Cavern Floor Diameter

$1\ bbl = 5.614584$ acre-feet

Project No. ES08.0118.00 Date 12/11/2018

Subject Brine Well Cavern Characterization Sheet 2 of 2

By J. Ayarbe Checked By B. Salvas Calculation No. 1

$$radius = \sqrt{\frac{3 \times Volume}{\pi \times height}} = \sqrt{\frac{3 \times 883{,}300 bbl}{\pi \times 788\ feet} \times \frac{5.614584 ft^3}{bbl}} = 77.52\ feet$$

$$diameter = 2 \times radius = 2 \times 77.52\ feet = 155.0\ feet$$

Attachment 1

2017 Annual Class III Well Report

Salty Dog Brine Station

DP BW-8, API No. 30-025-26307

Lea County, New Mexico

Prepared for **New Mexico Energy, Minerals and Natural Resources Department Oil Conservation Division**

May 1, 2018

Daniel B. Stephens & Associates, Inc.

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2.1 Fluid Injection and Brine Production

Except for an approximately 2-year shutdown between 2011 and 2013 and temporary interruptions for routine maintenance and testing (e.g., February 2009 sonar survey [SOCON, 2009]), the brine well has been in continuous operation since 1980, producing an average of approximately 10,500 barrels per month (bbl/mo) of brine between 1980 and 2009. This production rate is based on 1987, 1996–1999, and 2009 brine production and sales records (Salty Dog, 1988, 1999, and Undated).

Both fluid injection and brine production volumes are metered, and daily volumes are recorded on monthly fresh and brine water report forms (Appendix B). Table 1 summarizes monthly injection and production volumes for the reporting period. Injection water for the brine well comes from two fresh water wells (FWS-1 and FWS-2) and a groundwater remediation well (RW-2) (Figure 4). In 2017, monthly ratios of injected water to produced brine ranged from 0.97 to 1.08.

Table 1. Monthly Water Injection and Brine Production Volumes, 2017

Month	Volume (bbl)		Ratio (injection:production)
	Water Injection	Brine Production	
January	56,015	54,959	1.02
February	45,679	42,556	1.07
March	57,170	55,689	1.03
April	53,925	50,131	1.08
May	51,520	51,083	1.01
June	45,752	46,009	0.99
July	64,910	64,007	1.01
August	57,886	57,863	1.00
September	81,711	80,409	1.02
October	48,785	47,366	1.03
November	50,360	48,747	1.03
December	15,753	16,321	0.97
Annual total	629,466	615,140	—

bbl = Barrels

Based on the data reported in Table 1 and previously reported production records (Salty Dog, 1988, 1999, and Undated; DBS&A, 2014), the estimated cumulative volume of brine production is 6,096,795 bbl.

In 2017, brine production activities at the site dissolved an estimated 89,500 bbl of Salado Formation. This estimate is based on the brine production data reported in Table 1, the average total dissolved solids (TDS) concentrations of the produced brine and injection water reported in Table 2, and an assumed density of the Salado Formation of 2.17 grams per cubic centimeter (g/cm^3). The total estimated size of the brine solution cavern is approximately 883,300 bbl, based on the historical and present brine production data. In 2012, OCD estimated a volume of 1,022,196 bbl for the Salty Dog solution cavern (NMEMNRD, 2012).

Table 2. Injection Water and Produced Brine Chemical and Physical Characteristics

Constituent	Average Concentration (mg/L [a])	
	Injection Water	Produced Brine
pH (s.u.)	7.76	7.37
Specific gravity (unitless)	0.997	1.19
Chloride	270	180,000 [b]
Sodium	NM	79,500
TDS	775	316,500

[a] Unless otherwise noted
[b] During the second semiannual monitoring event, the chloride concentration of the brine water was not analyzed.
mg/L = milligram per liter
nm = Not measured
s.u. = Standard units
TDS = Total dissolved solids

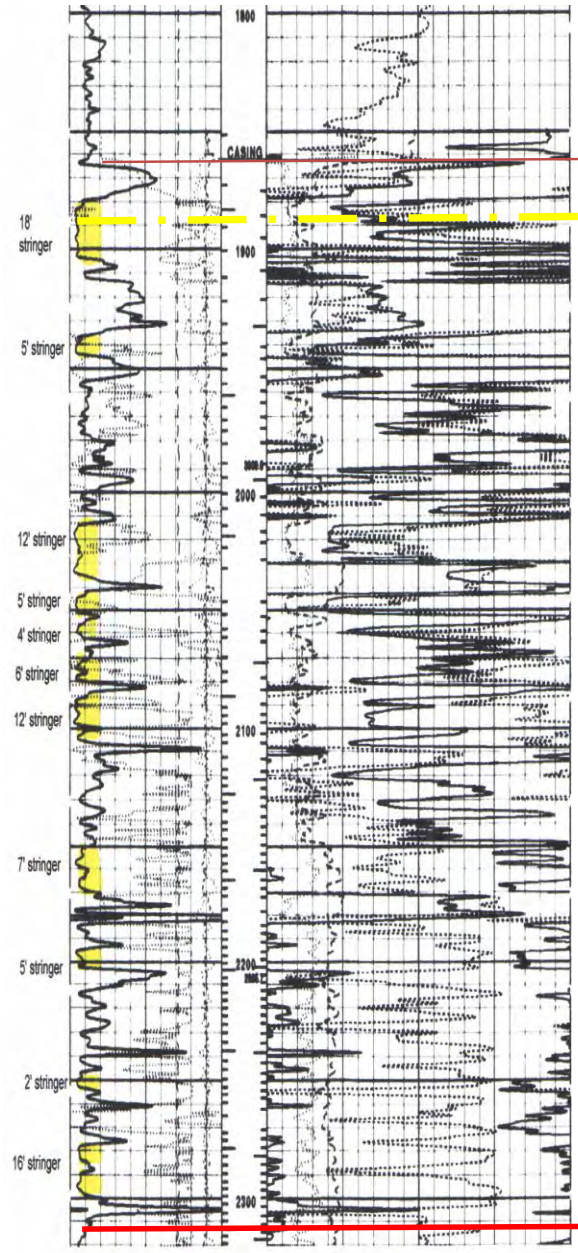
2.2 Injection Pressure

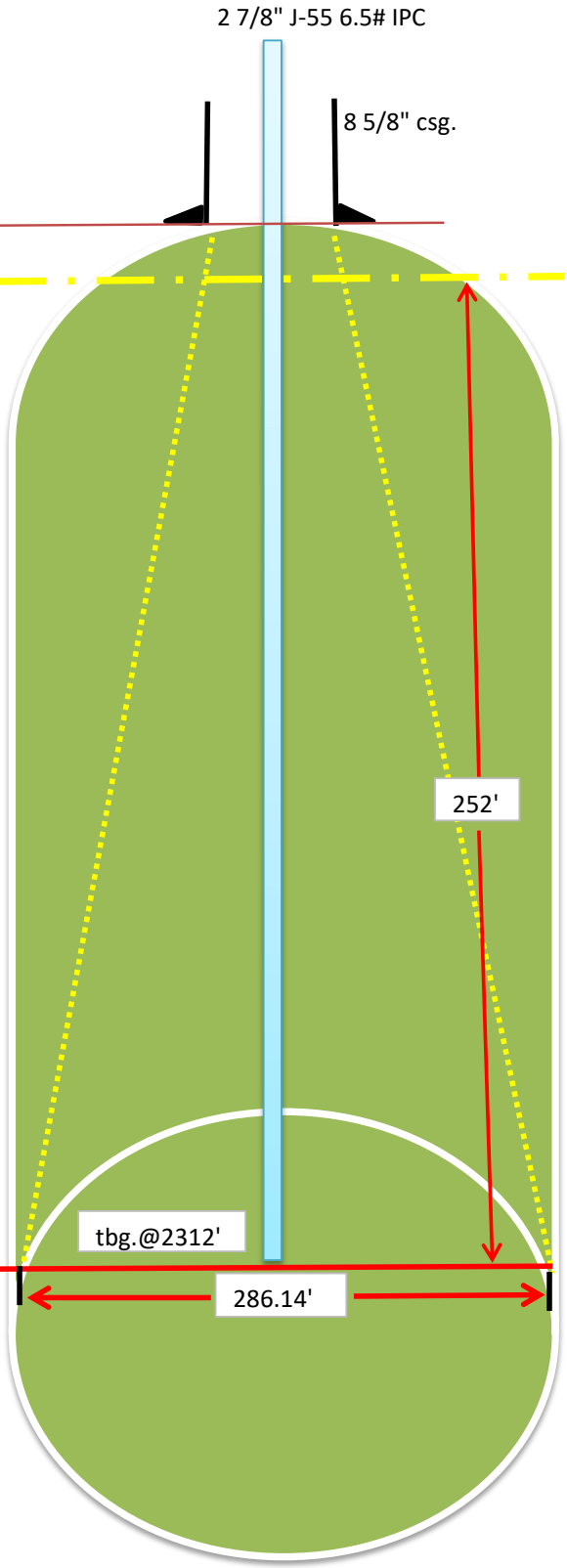
Pressure is monitored on the well tubing and on the annulus between the inner tubing and outer casing. These measurements are recorded on the monthly fresh and brine water report forms (Appendix B). In 2017, recorded daily tubing pressure was 100 pounds per square inch (psi), while annulus pressure was 375 psi.

Attachment 2

EXAMPLE SALT CAVERN CHARACTERIZATION

John Doe Well No6
API 30-015-#####
SEC36 T18S R38E LAT: 32.##### LONG:-103.#####





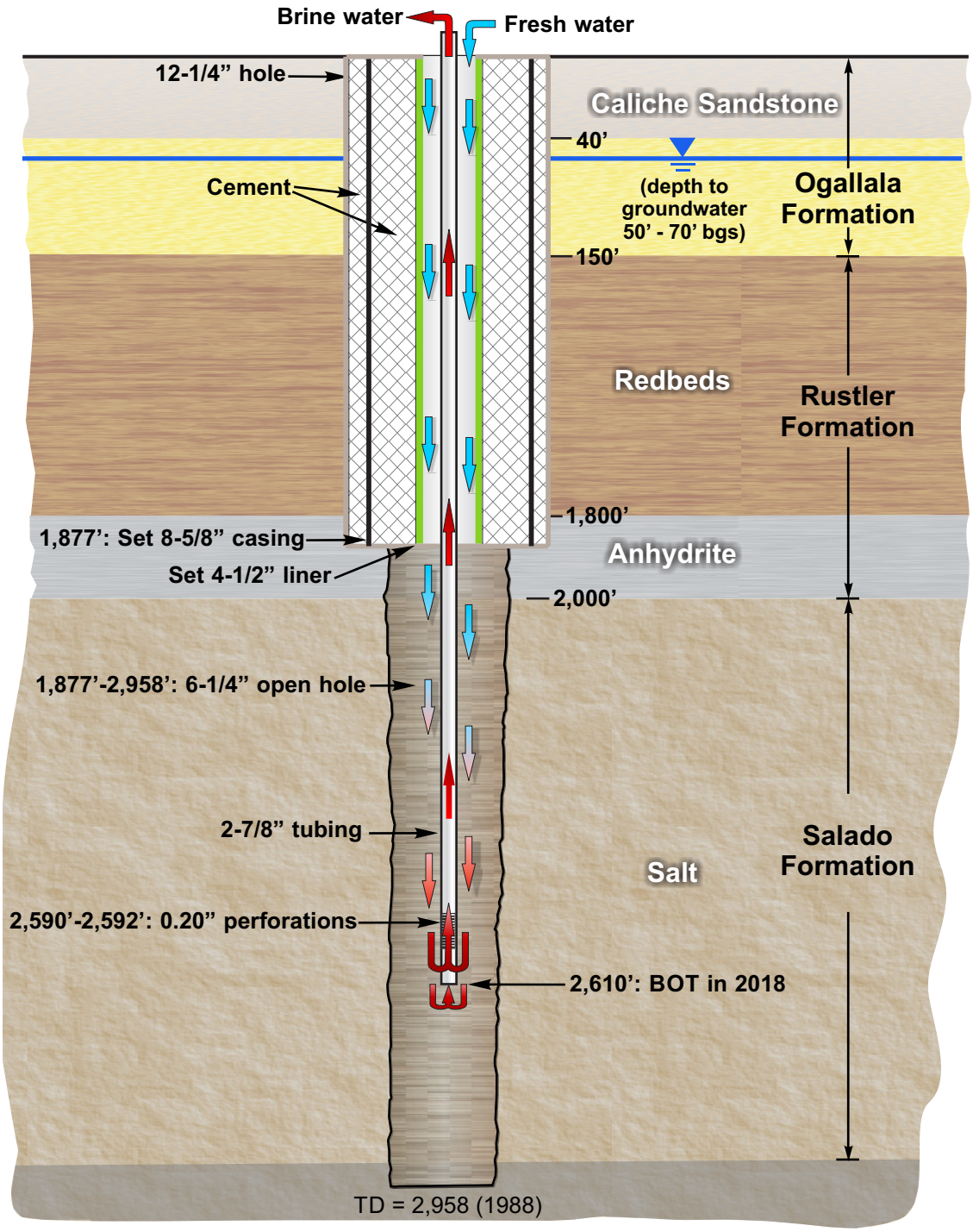
PPG 9.97 brine
PPG 8.34 fresh
SG 1.1951
2006 to 2017 Total Brine bbl. 3,538,154
122.136 LBS / BBL = 432,135,977 LBS HALITE
(432,135,977 LBS) / (80BLS per ft³) = 5,401,700 ft³

$V = \prod R^2 h / 3$
$V = (3.14159 * 143.07^2) * (252') / 3$
$V = 5,401,648.6\ ft.^3$

Est. hight is 252'
Est. cavern floor diameter is 286.14'

Attachment 3

Salty Dog Brine Well



Notes:

1. BOT = Bottom of tubing
2. Figure not to scale

Sources:

1. Completion data based on OCD well reports
2. Lithology from Salty Dog (1988)

SALTY DOG BRINE STATION

Generalized Brine Well Schematic

Daniel B. Stephens & Associates, Inc.

12-6-18 JN ES08.0118.06

S:\Projects\ES08.0118.06_Salty_Dog_2016\GIS\VR_drawings\Fig03_Generalized_brine_well_schematic.cdr