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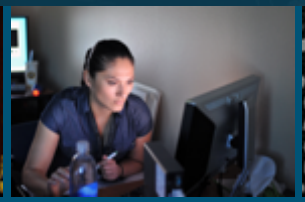
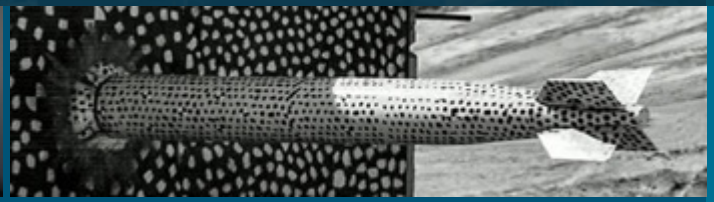
Sandia National Laboratories

Casing Deformation at the Big Hill SPR Site





PRESENTED BY

Barry L. Roberts – Sandia National Labs

U.S. DEPARTMENT OF ENERGY | NNSA

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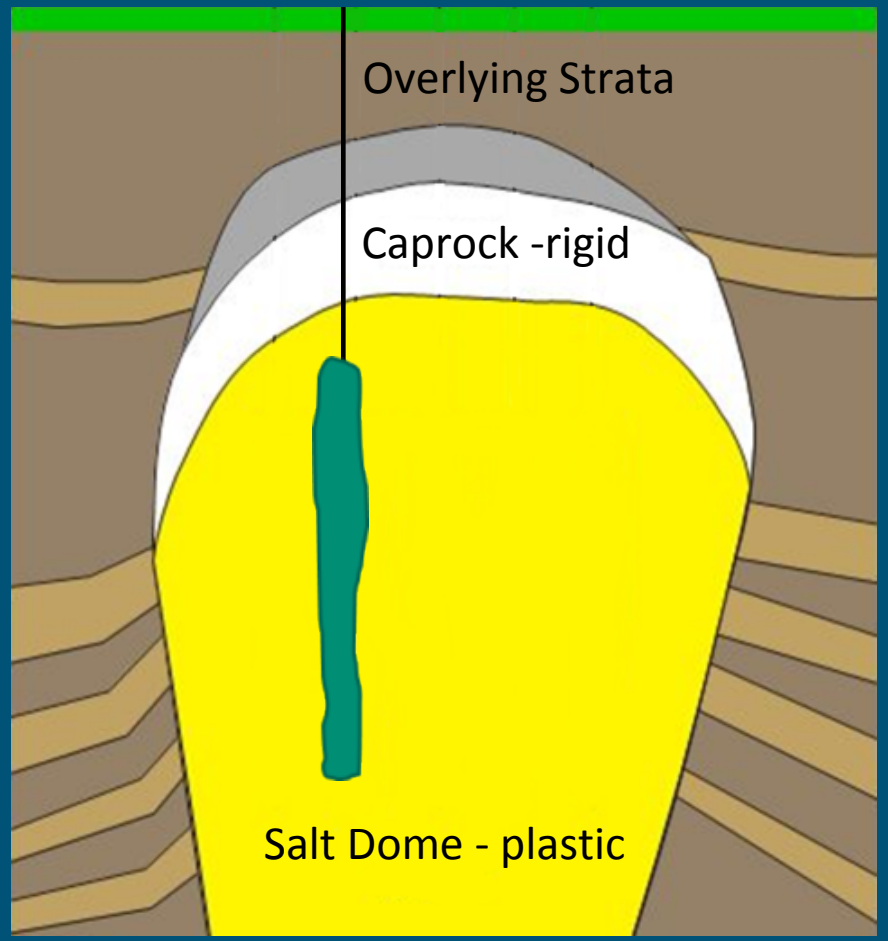
Talk Overview

1. Introduction/review of the U.S. Strategic Petroleum Reserve
2. General storage cavern operations
3. Recognition of integrity issues from pressure signature
4. Multi-arm Caliper data analysis
5. Case study – BH-105B
6. Why is this happening?
7. What is our best path forward?
8. Summary

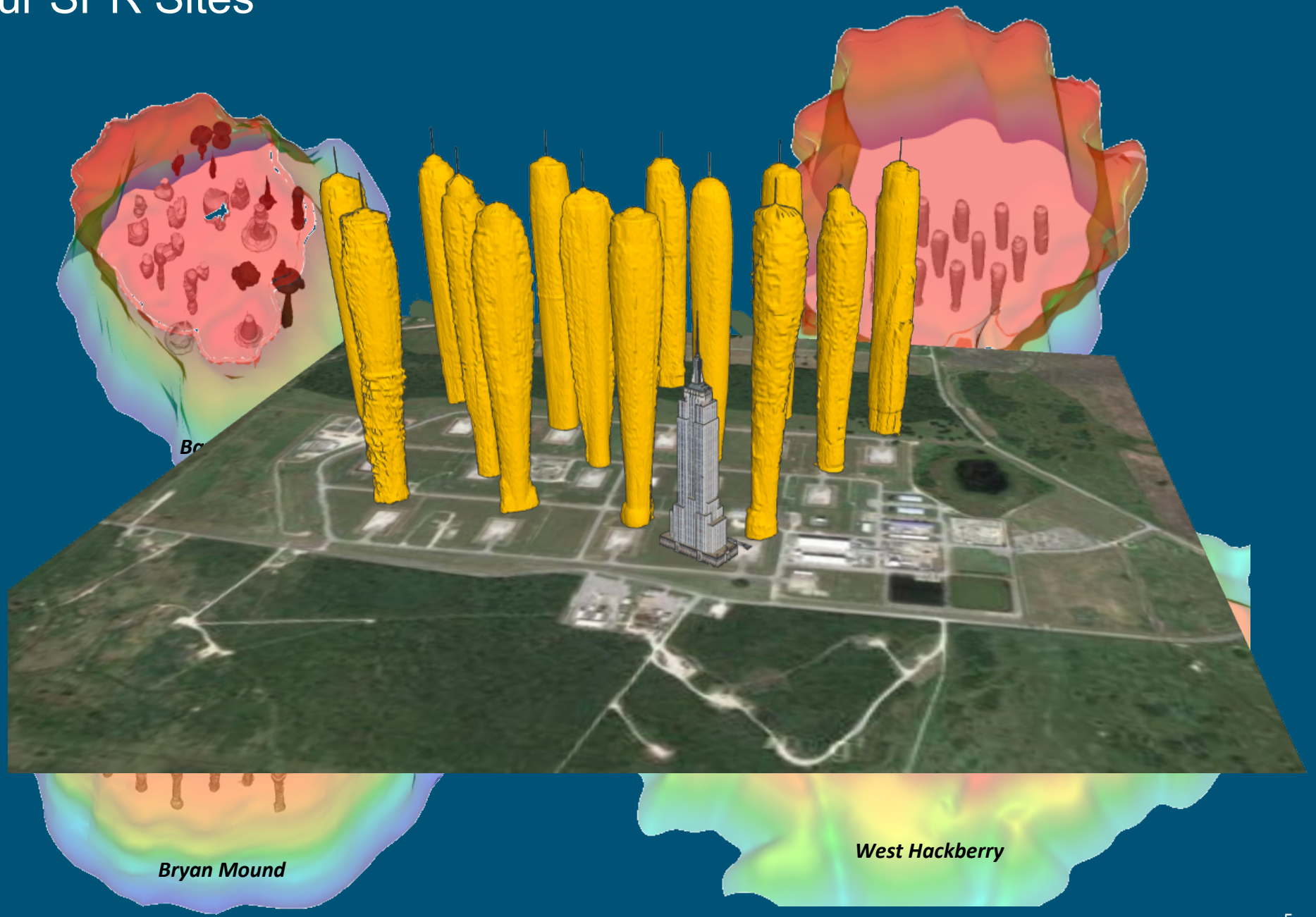
The U.S. Strategic Petroleum Reserve

- SPR is spread across 4 Gulf Coast site locations
- Current oil inventory of about 700 million barrels
- Composed of 62 solution mined caverns
- About 120 cavern access wells – differing completions
- Mixture of pre-existing and purpose-built caverns
- Length of cased well sections range from ~1400 to ~2500 feet
- SPR – owned by DOE
  - Managed/operated by FFPO
  - SNL geotechnical advisors

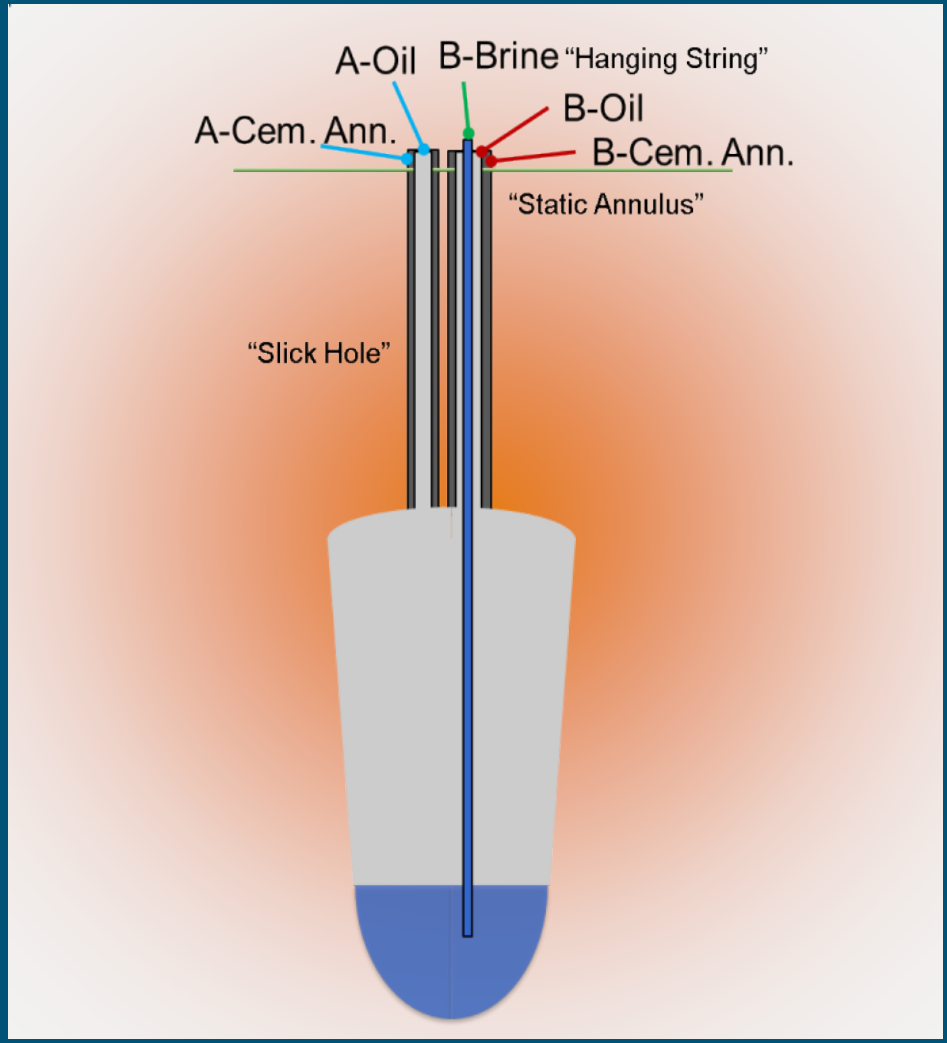
The U.S. Strategic Petroleum Reserve



The Four SPR Sites

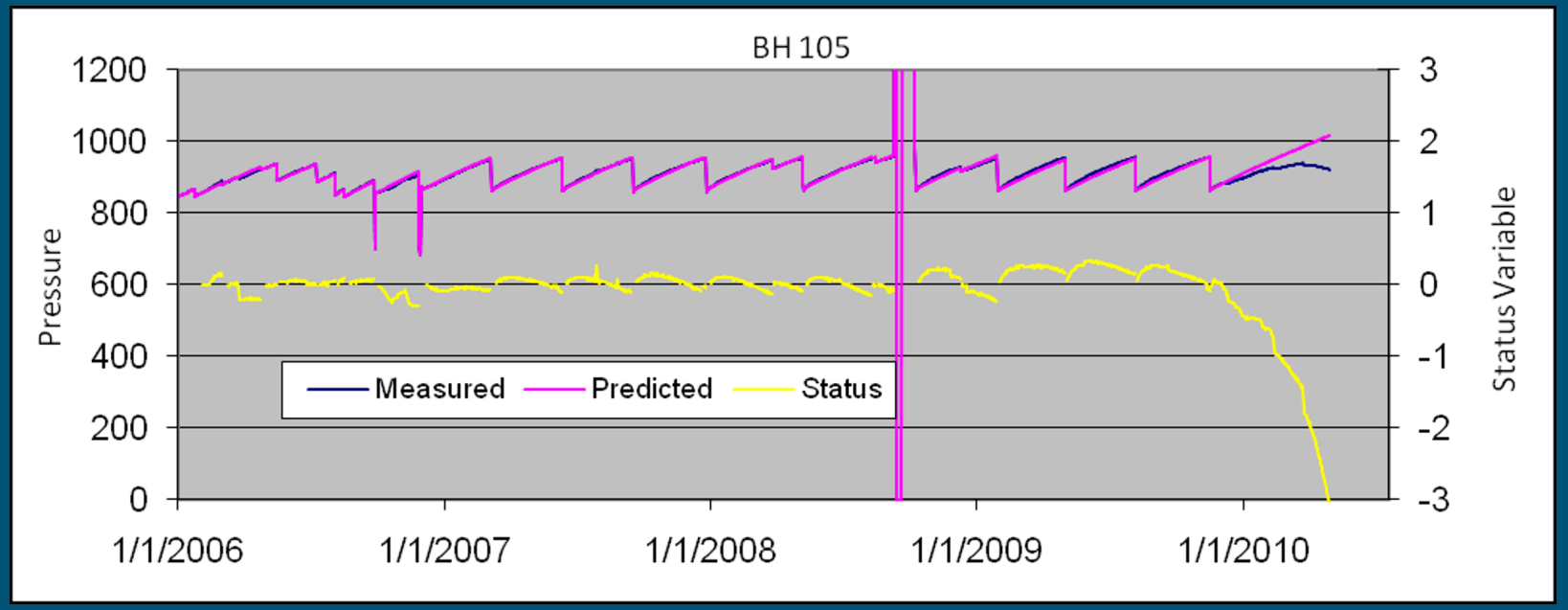


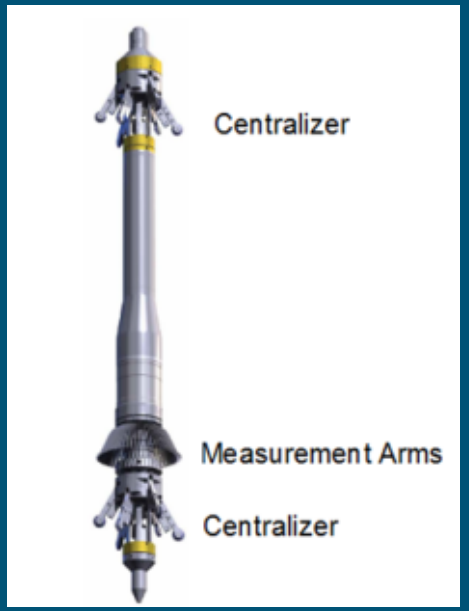
SPR Cavern Operations – How Oil is Moved In and Out



Recognition of Well Integrity Issues at Big Hill

- 2009 - Recognition of loss of pressure integrity for BH-105B and BH-109B
- Wells subsequently remediated via liner installation
- Multi-Arm Caliper (MAC) Surveys of SPR wells started in 2010



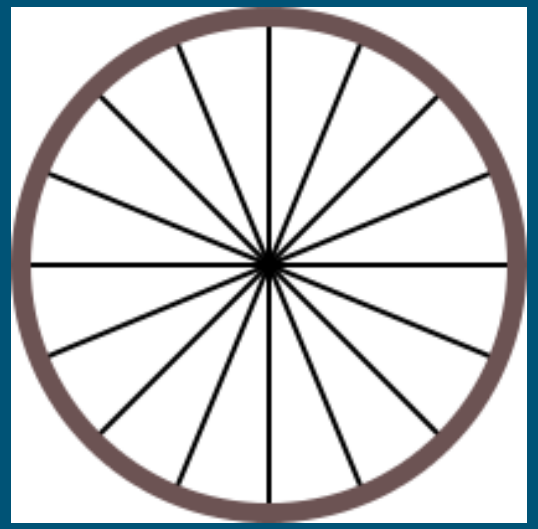


Analysis of Multi-Arm Caliper Data

Use raw radial arm measurement data to compute a summary parameter that describes radial casing deformation as a function of depth

Investigations show that the coefficient of variation – Cv – of the diameter values provides a robust indicator of casing deformation suitable for differing well configurations

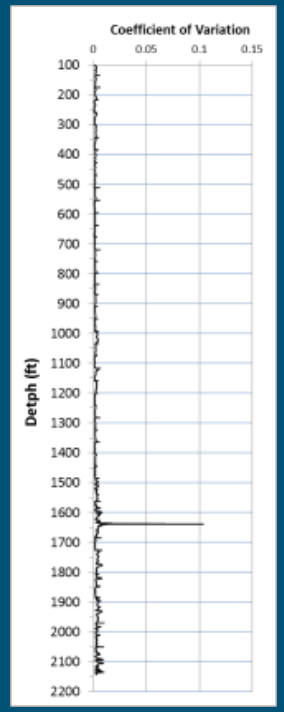
Nearly Circular Cross Section



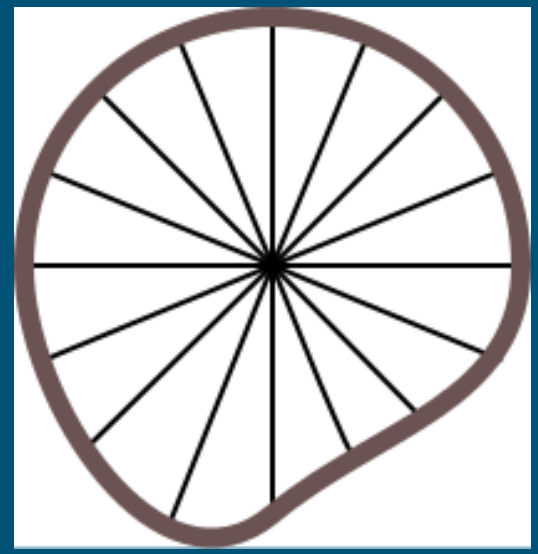
Diameter values nearly equal
Low Cv values

$$C_v = \frac{\sigma}{\mu}$$

Standard Deviation / Mean



Deformed Cross Section



Diameter values vary significantly
Higher Cv values

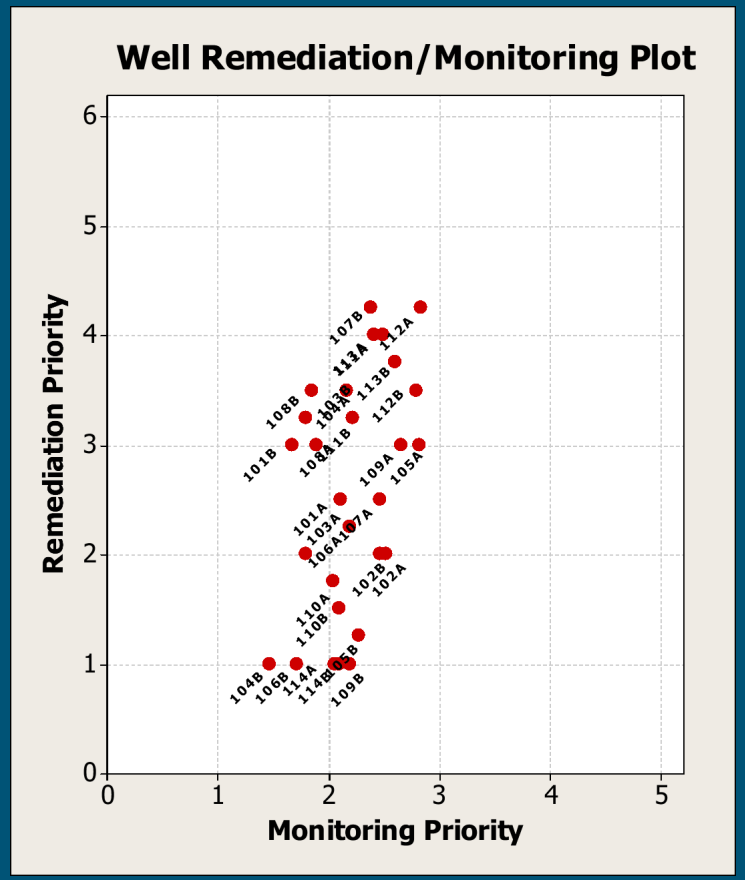
SPR Well Grading System

- Well grading framework developed for SPR
- Considers geology, simulation results, cavern geometry, well history, etc.
- Main driving components are MAC survey data and pressure history

	A	D	E	F	G	H	I	J	K	P
1		Remed.	Pressure for Monitoring	MAC for Monitoring	Geomech.	Well Info.	Geology	Cavern Geo.	Offsite Act.	Monitor Axis
2	*Weight*	*(MAC, Press)*	*0.20*	*0.20*	*0.20*	*0.15*	*0.10*	*0.10*	*0.05*	**1.00**
4	BH101A	2.5	2	4	1	1.83	2.40	1.33	1	1.30
5	BH101B	3	2	2	1	1.55	2.40	1.33	1	1.26
6	BH102A	3	3	3	4	1.84	2.40	1.33	1	2.10
7	BH102B	3	3	2	4	1.55	2.40	1.33	1	2.06
8	BH103A	4	4	3	4	2.27	3.20	1.67	1	2.48
9	BH103B	4.5	4	4	4	2.26	3.20	1.67	1	2.48
10	BH104A	2.5	1	3	5	2.12	2.40	1.33	1	1.94
11	BH104B	5	1	5	5	1.54	2.40	1.33	1	1.85
12	BH105A	2.5	1	2	5	2.58	2.40	1.33	1	2.01
13	BH105B	1	1	2	5	2.21	2.40	1.33	1	1.95
14	BH106A	2	1	3	2	2.14	2.40	1.67	1	1.38
15	BH106B	5	1	5	2	1.57	2.40	1.67	1	1.29
16	BH107A	2.5	1	3	3	2.45	2.00	1.33	1	1.55
17	BH107B	4.5	1	4	3	1.88	2.00	1.33	1	1.46
18	BH108A	3	1	4	2	2.01	2.60	1.67	1	1.38
19	BH108B	3.5	1	3	2	1.72	2.60	1.67	1	1.33
20	BH109A	3	1	3	5	2.44	2.60	1.67	1	2.04
21	BH109B	1	1	1	5	1.91	2.60	1.67	1	1.96
22	BH110A	1.5	1	2	3	1.86	2.60	1.33	1	1.52
23	BH110B	1.5	1	3	3	1.57	2.60	1.33	1	1.48
24	BH111A	4	1	4	2	2.42	1.60	1.67	2	1.39
25	BH111B	3.5	1	4	2	1.84	1.60	1.67	2	1.30
26	BH112A	4	4	3	3	2.54	2.20	1.67	1	2.22
27	BH112B	4	4	5	3	2.26	2.20	1.67	1	2.18
28	BH113A	4.5	3	4	2	2.11	2.40	1.67	1	1.77
29	BH113B	4	3	4	2	1.54	2.40	1.67	1	1.69
30	BH114A	1	1	1	4	1.58	3.20	1.67	2	1.82
31	BH114B	1	1	1	4	1.87	3.20	1.67	2	1.87

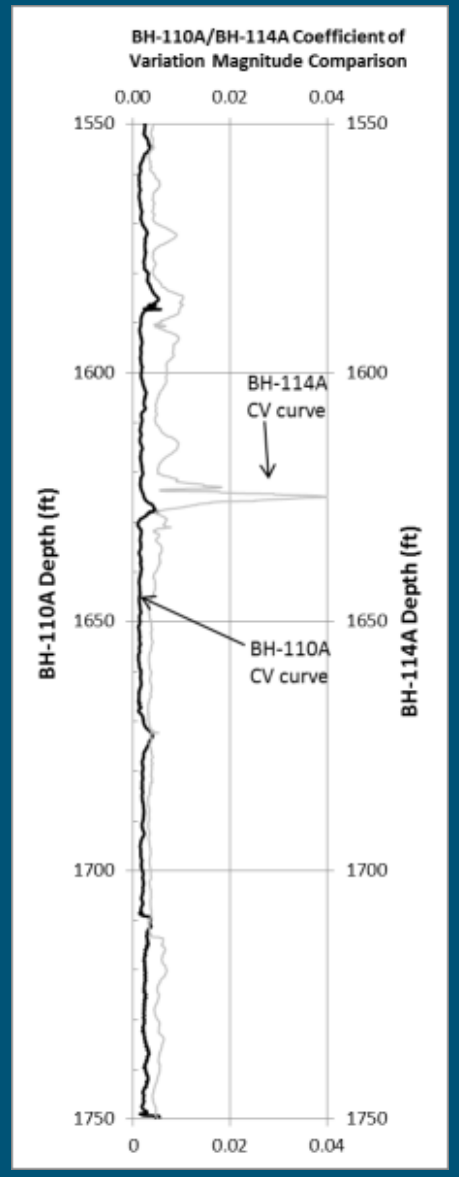
ALL Post_Rmdtn | MAC_Post_Rmdtn | Pressure | Geomech | Geology | Well | Cavern Geometry | Offsite Act.

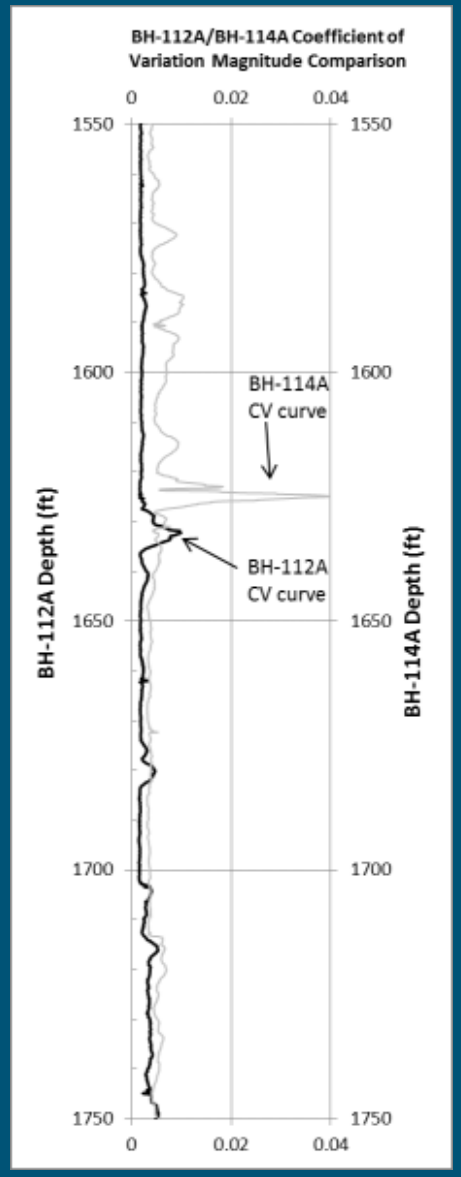
Grading Data Tabulation

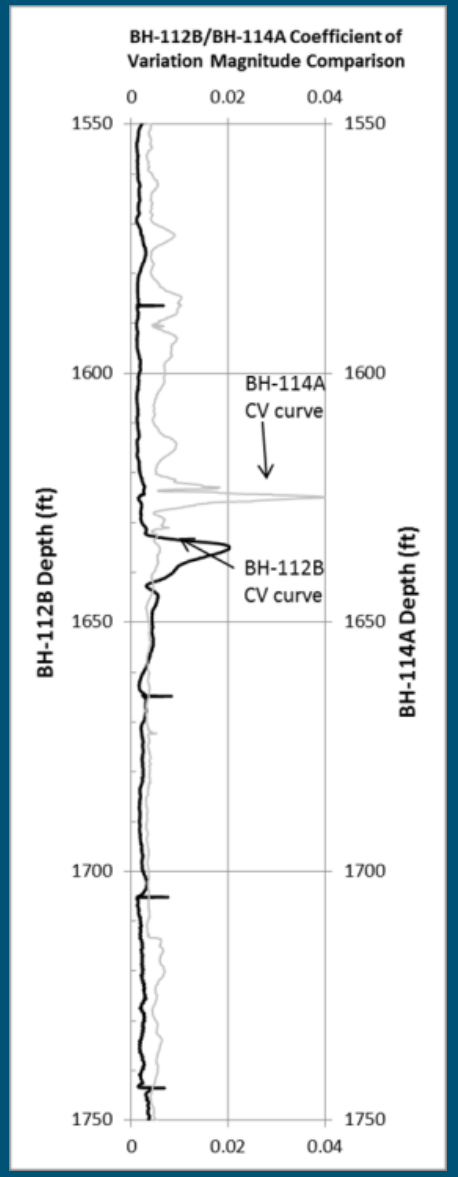


Summary Plots

Cv Values Allows for Well-to-Well Comparisons

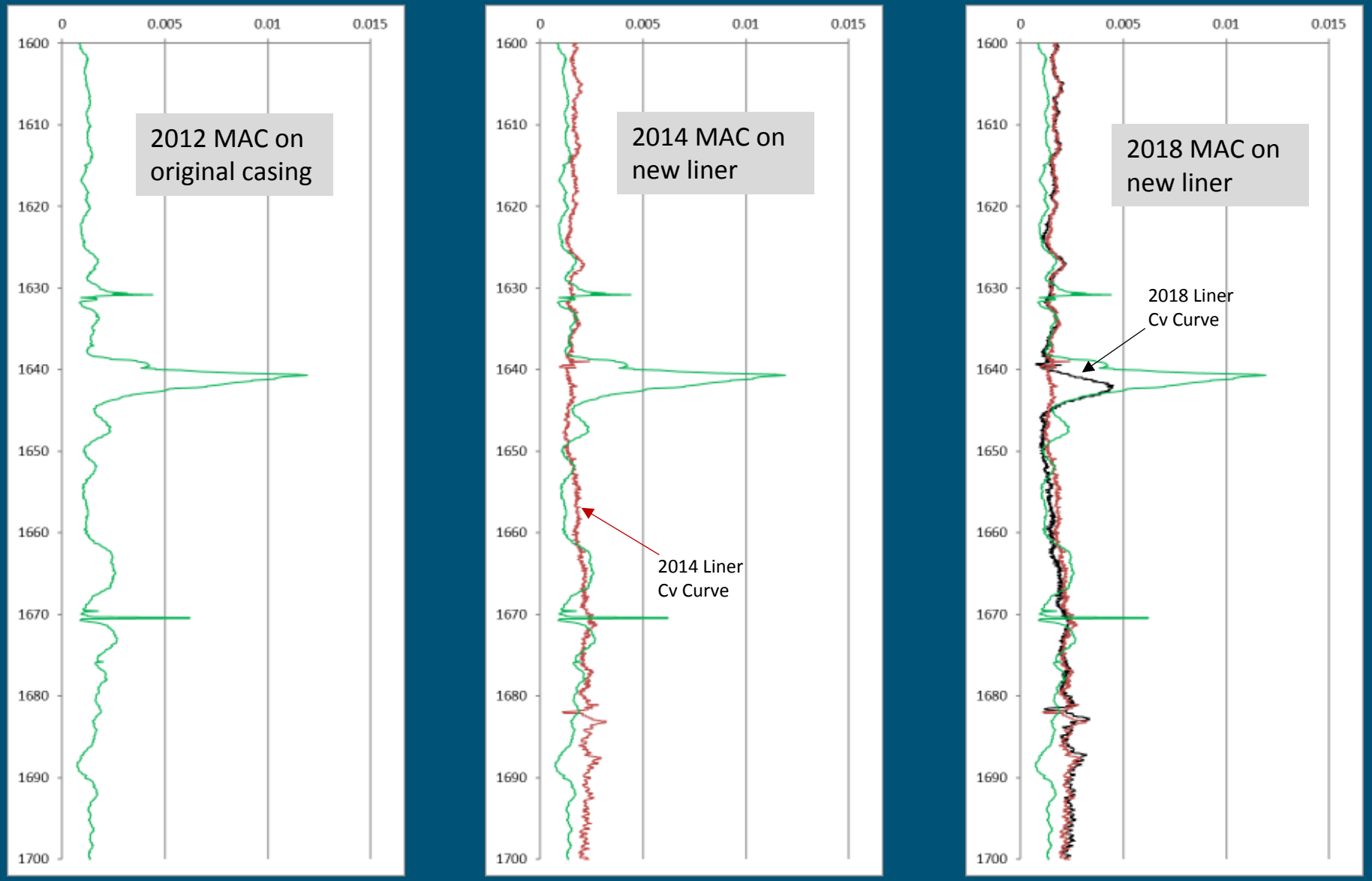




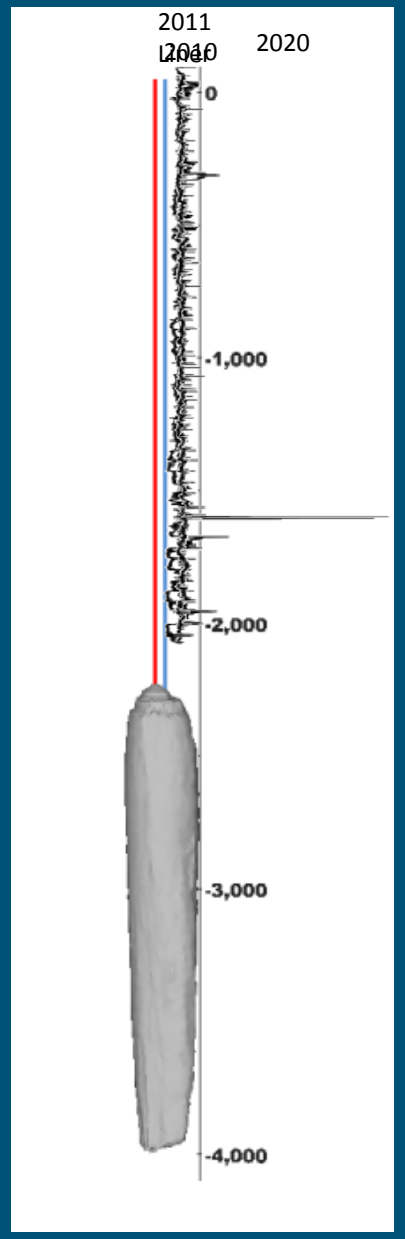


Cv Values Provide Basis for Time-Dependent Analysis

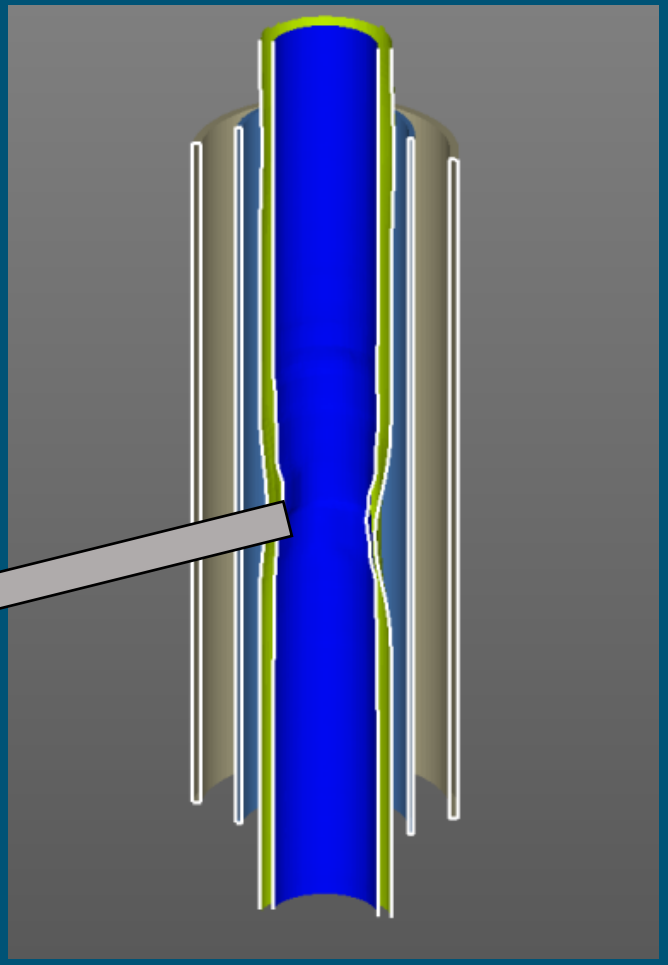
BH-103B Cv Values through time



BH-105B Case Study

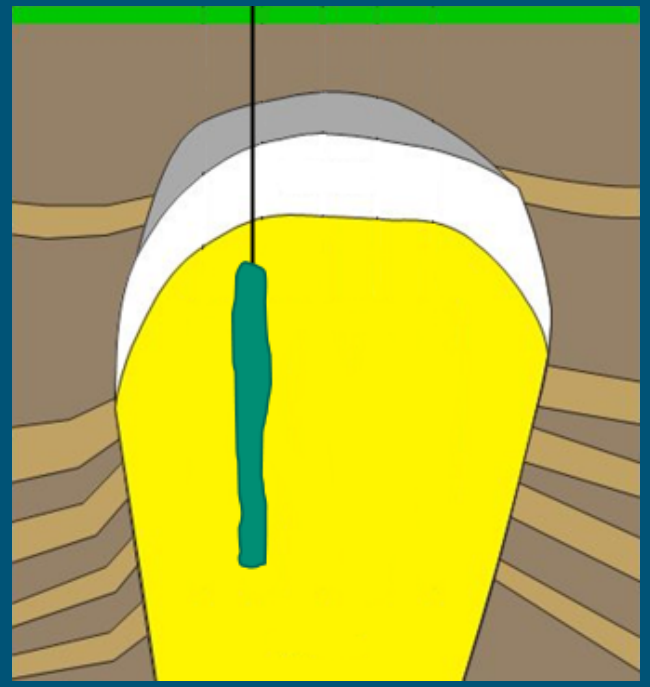


- BH-105B completed in Dec. 1984
- 2010 MAC shows significant casing deformation
- 2011 new well liner cemented in place
- 2020 evidence of deformation of the brine string
- MAC survey of the brine string indicated it deformed
- 2020 removal of the brine string and MAC survey of the liner showed severe deformation
- Geologic forces had deformed:
  - 20” outer casing
  - 13.375” original inner casing — 27 years
  - 10.75” liner
  - 8.625” hanging string — 9 years



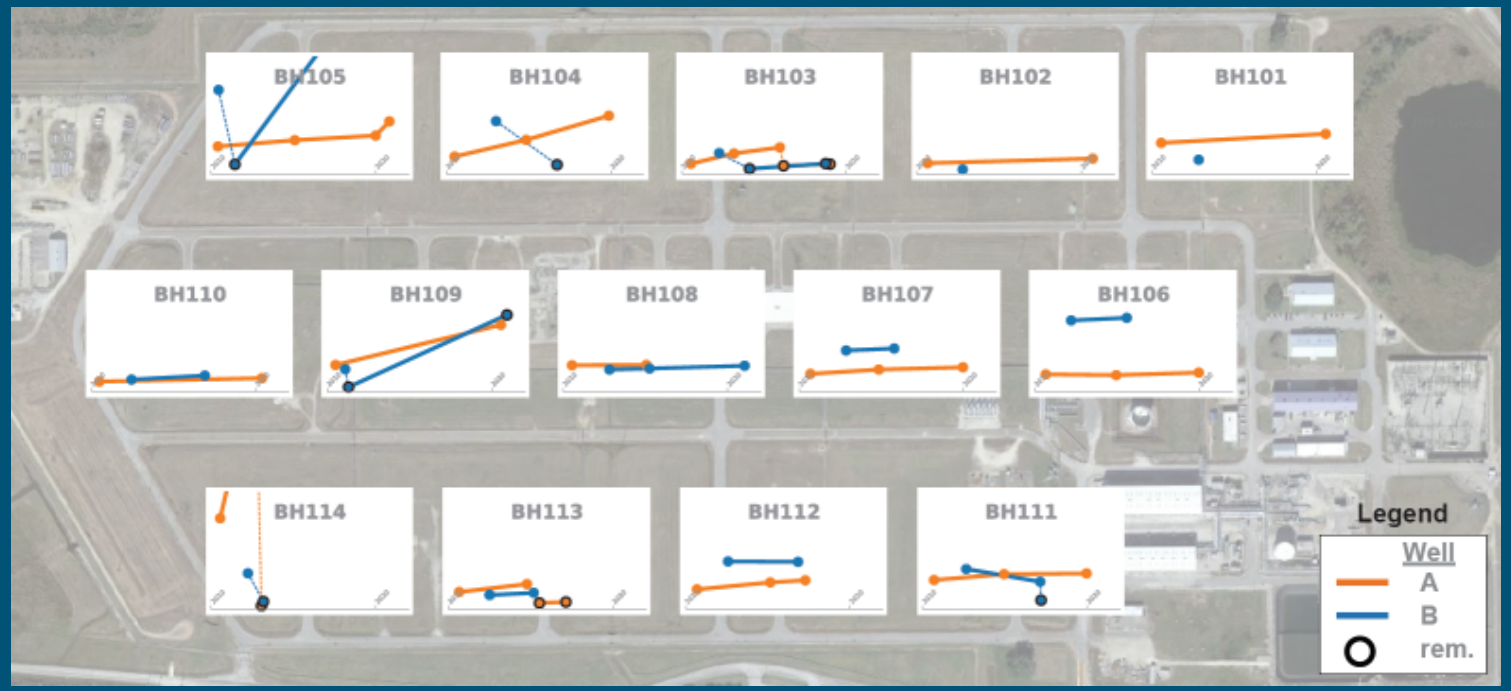
Why is this Happening?

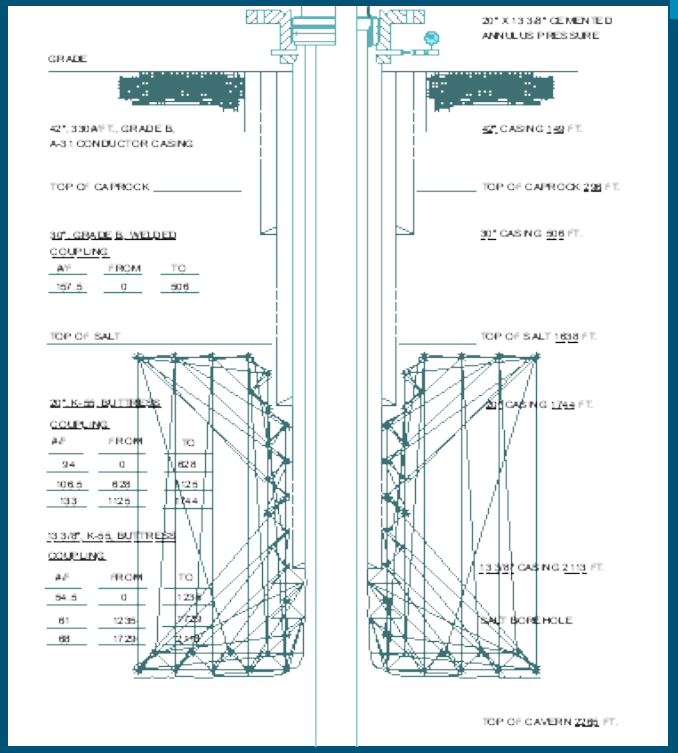
- Severe, rapid casing deformation at the salt-caprock interface is limited to the Big Hill SPR site.
- What is different about the Big Hill site?
- Cavern operations are similar, caverns have desirable shape
- Wells have well designed completions
- Each dome has unique geology
- Site nominal caprock thicknesses
  - Bayou Choctaw 200 – 300 feet
  - Bryan Mound 400 – 200 feet
  - West Hackberry 350 400 feet
  - Big Hill 850 – 1300 feet

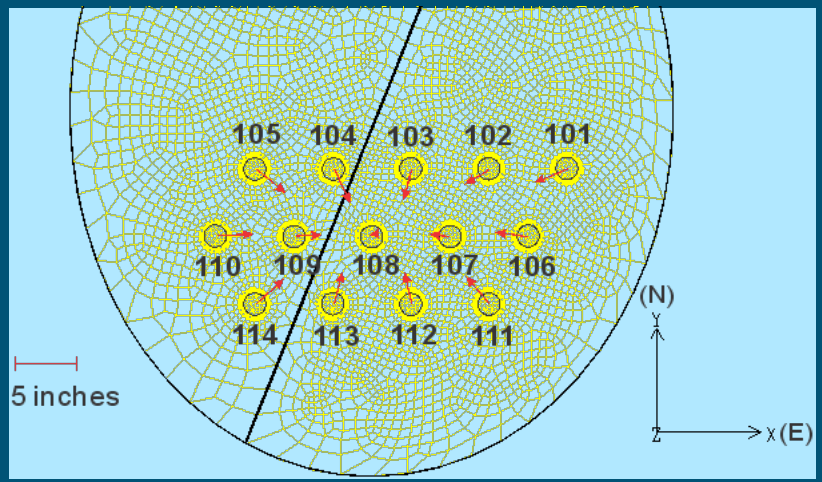


Why is this Happening? Is there a spatial pattern?

- Deformation is always at the salt-caprock interface
- Deformation occurs over a narrow vertical interval
- Greatest level of deformation typical on western side of site
- No clear correlation to surface subsidence
- Some correlation to results from geomechanical modeling
- Maybe associated with different salt spines?







What is the best path forward?

- Current wells and remediations use cemented steel casings
- Are there other completion techniques and/or materials better suited to this dynamic environment
  - Packer and tubing completion
  - Deformable annular materials
- How do we know which completion and materials are best
- Mechanical/Geomechanical simulations of different options
  - Challenges in parameterizing simulations
  - Pull information from previous MAC surveys
- Going forward, MAC surveys will have absolute orientations to allow for better understanding of forces and comparisons with simulations

Summary, Conclusions, and Further Questions…

- The DOE SPR is a strategic resource currently storing 637 million barrels of crude oil
- The Big Hill site currently holds 144 million barrels stored in 14 caverns
- Certain cavern access wells at Big Hill are experiencing severe deformation at the salt-caprock interface due to geologic forces
- These geologic forces are on-going and can not be stopped
- Remediation of the deformed casings is necessary to assure cavern integrity
- Historic liner installation remediations have demonstrated that liners may succumb to geologic forces within 10-11 years requiring further remediation
- *What are the specifics of the geologic mechanism causing this deformation?*
- *Are classic cemented-liner type remediations still the best option?*
- *Are there well completions and remediation options that will increase well longevity?*
  - *Packer and tubing type completions*
  - *Deformable or more plastic annular materials*
  - *Larger diameter wells*
  - *Thicker casing material*
  - *Combination of the above?*
- *Is there anyway to predict when this type of phenomena will arise?*
- <u>These questions need to be answered in order to move forward in an informed manner</u>

Thank you

Questions?

Albuquerque Balloon Fiesta