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PRIMROSE/WOLF LAKE CSS 2019 WELL INTEGRITY PERFORMANCE Scheme Approval #9140

March 11, 2020

PREMIUM VALUE. DEFINED GROWTH. INDEPENDENT.

Agenda

1. Review 2019 Well Failure Statistics
2. 2019 Well Integrity Initiatives

CNRL's Well Integrity Philosophy

1. Reduce casing failures through proper well design, construction and operational practices

2. Continue to further our understanding of well failure mechanisms and reduce the frequency of future failures

3. Effectively apply monitoring resources to minimize risks to HSE, assets, and reputation

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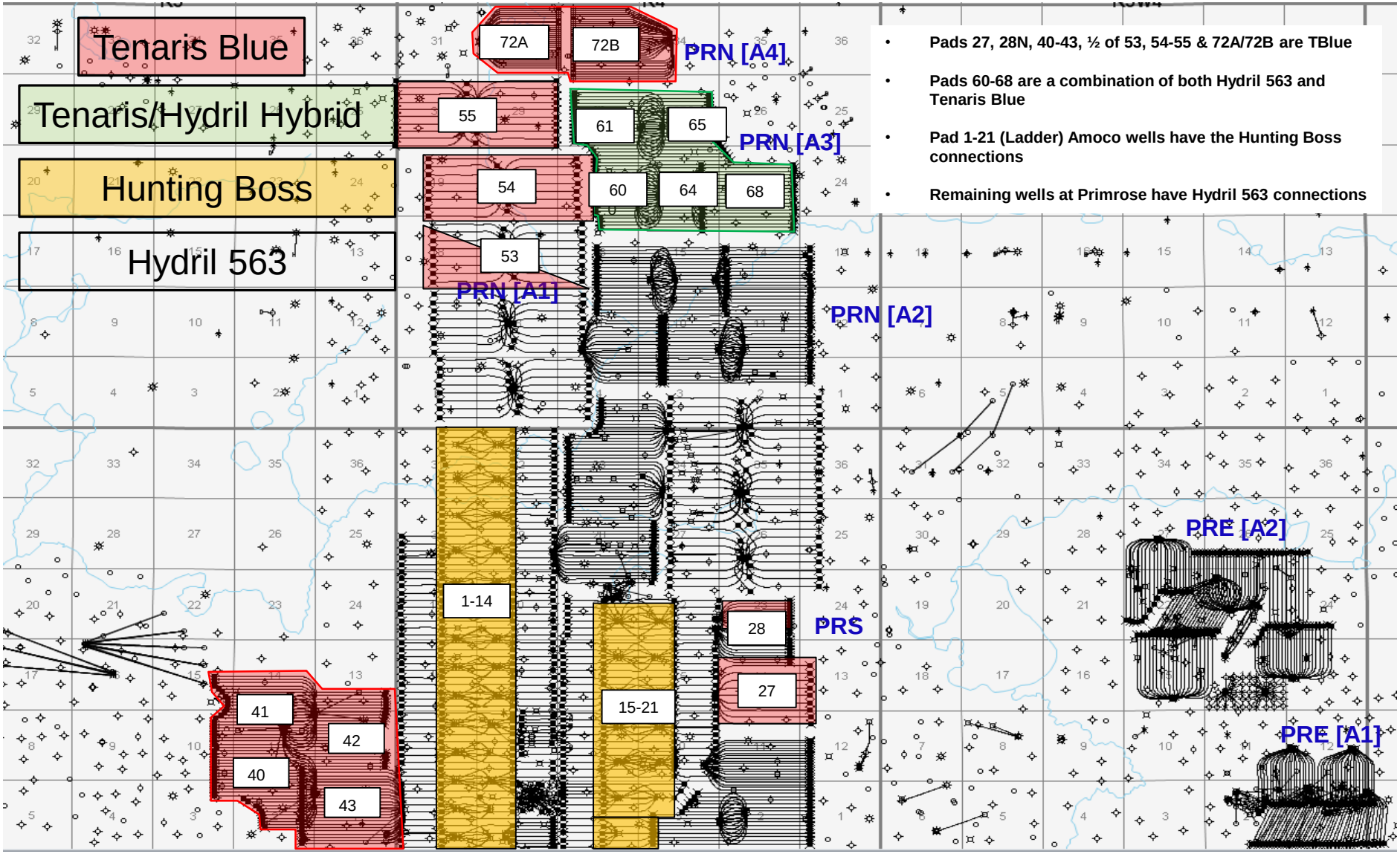
2019 PAW WELL FAILURE STATISTICS

PAW Casing Connection Grouping



- Pads 27, 28N, 40-43, ½ of 53, 54-55 & 72A/72B are TBlue
- Pads 60-68 are a combination of both Hydril 563 and Tenaris Blue
- Pad 1-21 (Ladder) Amoco wells have the Hunting Boss connections
- Remaining wells at Primrose have Hydril 563 connections

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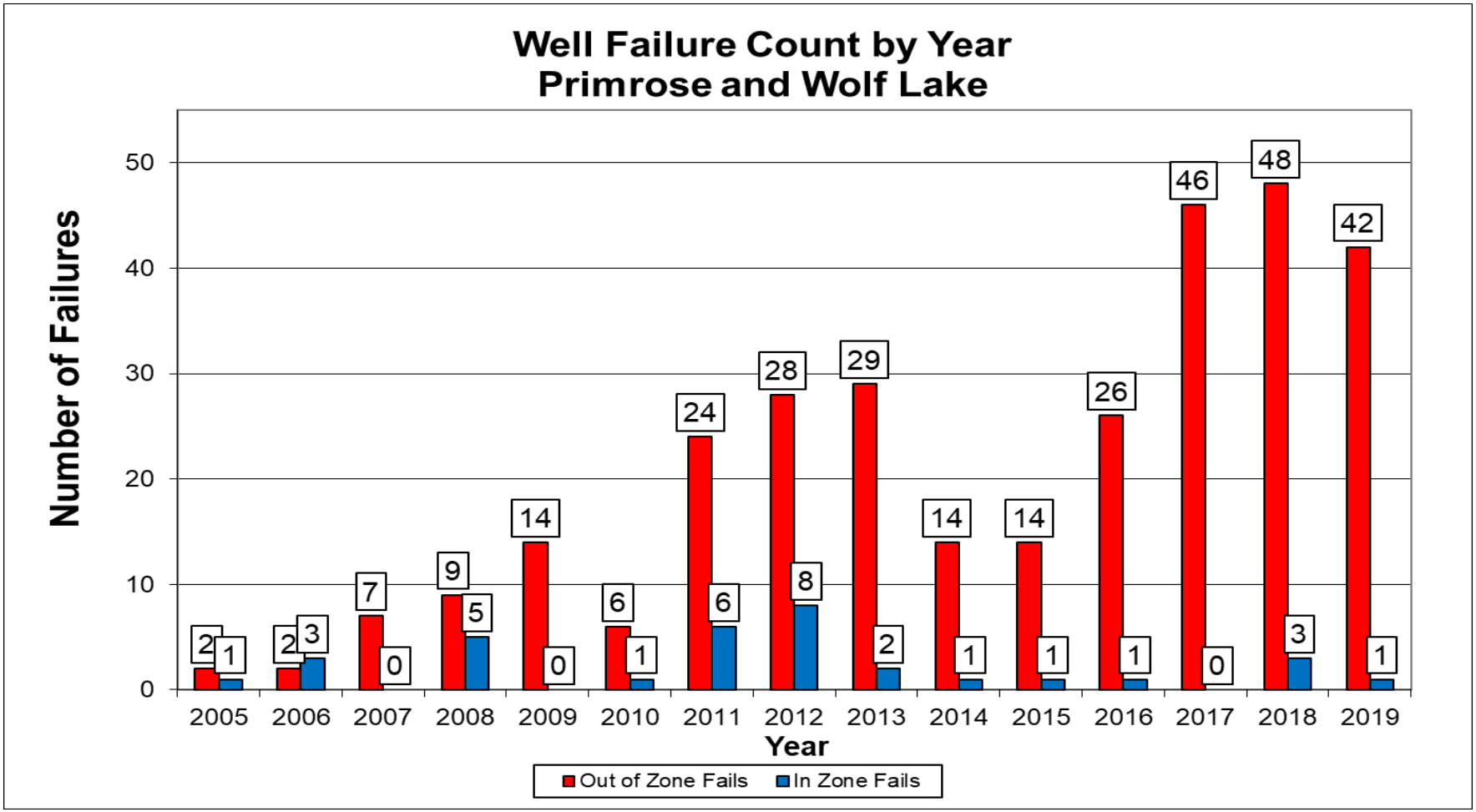
Well Failure Definitions

- **Near-surface failure**: 0 m – 25 m TVD
- **Out of zone failure**: failure depth is between 25 m TVD to the interface of Grand Rapid/Clearwater formation
- **In zone failure**: occurs within the Clearwater formation (includes failures within the capping shale)
- **Primary failure**: primary pressure-containing string in the wellbore (typically 9-5/8” intermediate casing)

2019 Failure Statistics Summary

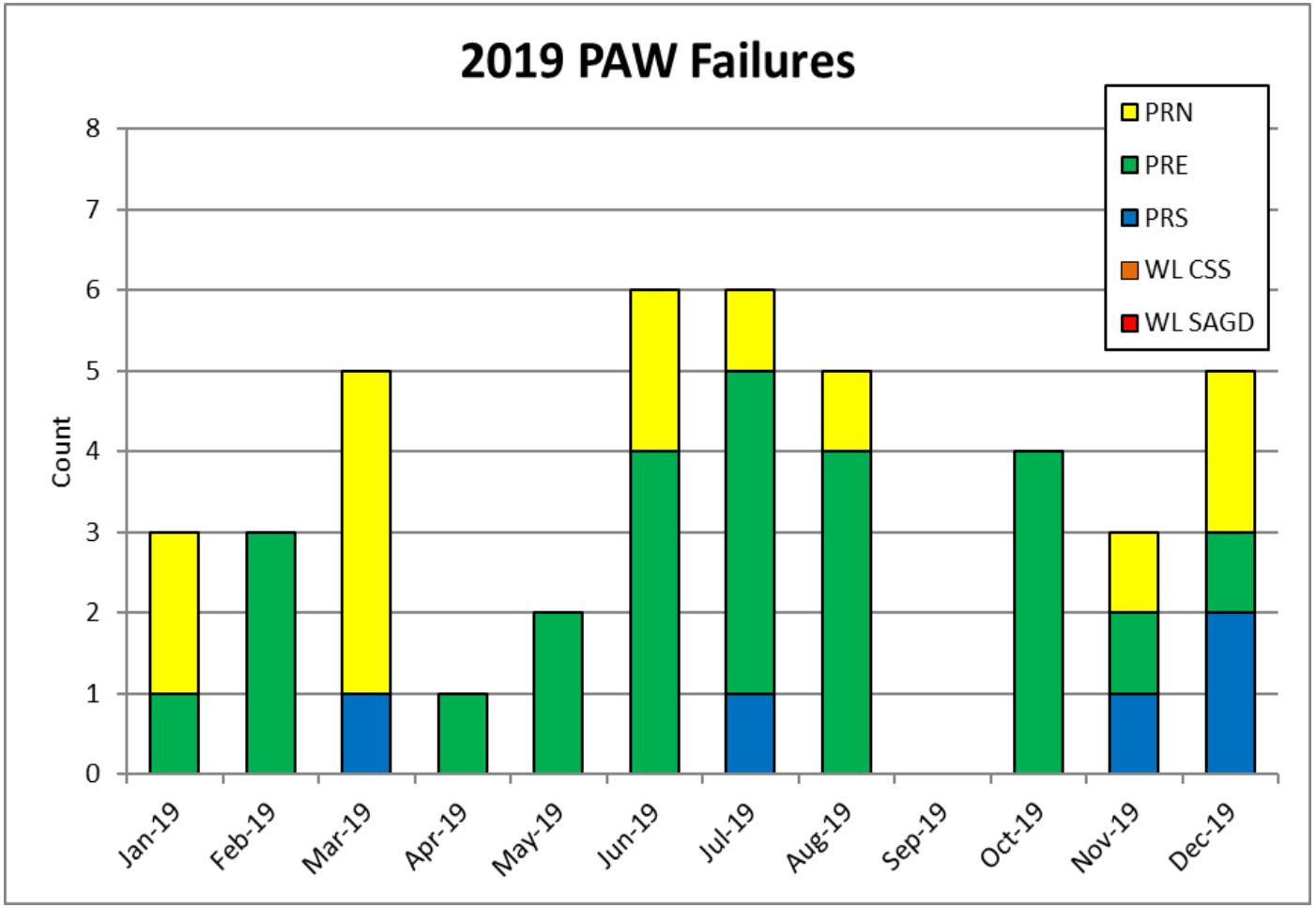
	Out of Zone	In Zone
Primary Casing Failures	42	1
Area	Concentrated in PRN A2, PRE A2	6A64
Connection/Pipe Body	1 Failure in Pipe Body 41 Connection Failures	Connection Failure
Cycle	1 CSS well on Cycle 7 41 wells on Steamflood	CSS Cycle 7
Formation	100% in Colorado Shale	Clearwater
Pressure During Failure	100% Failures at pressure < 5.0MPa	11.0Mpa
Status at time of Failure	58% associated w/ well shut-in 21% on production 21% on injection	Injecting

Well Failure Count by Year



Out-of-zone failures ↑ since 2015 due to cumulative damage as wells age

2019 Primary Casing Failure Count by Area

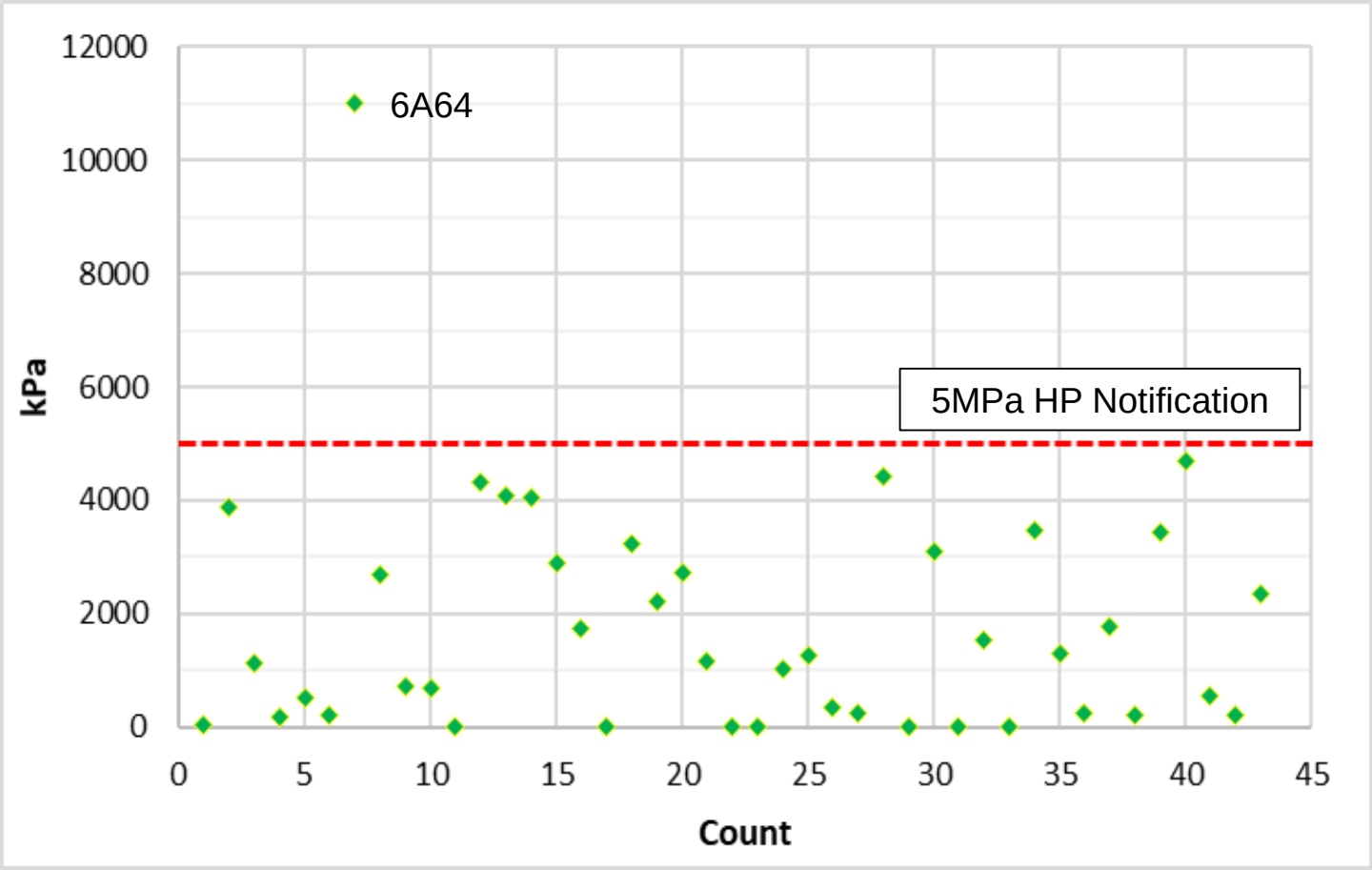


In 2019:

- PRN, 13 Failures
  - PRN A2, 11 Failures
  - PRN A3, 2 Failures
- PRE, 25 Failures
  - PRE A1, 12 Failures
  - PRE A2, 13 Failures
- PRS, 5 Failures

PRE had higher failure count due to more mature pads

Estimated Pressure at Failure Depth

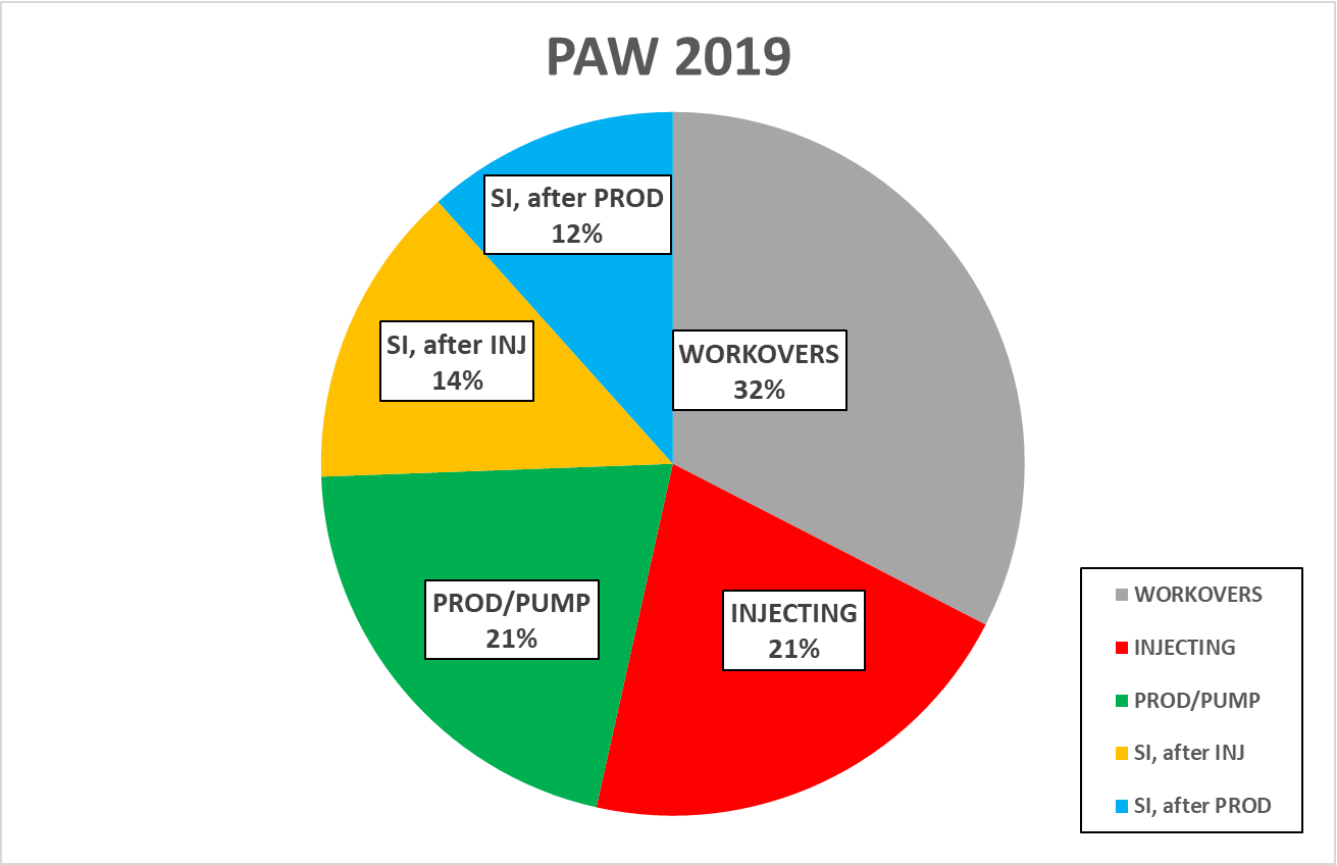


6A64

- In Zone
- Injecting at time of alarm

In 2019, there has not been any reported out of zone HP failures

Operating Stage at Time of Failure



Failures primarily occurred when wells were cooling:

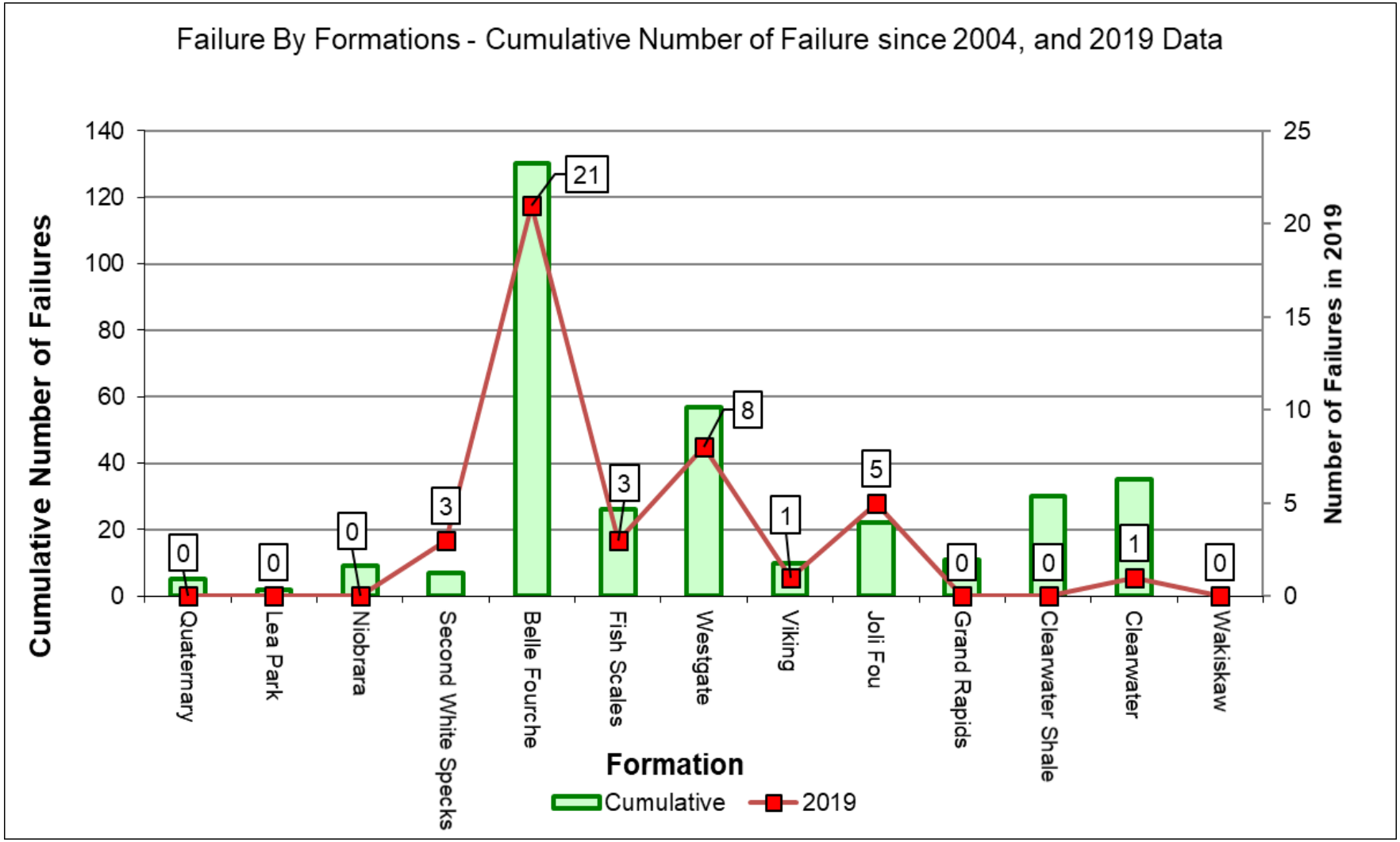
- changes in casing stress (compression to tension)
- cumulative effect of other ageing effects (caustic, thermal cycling, etc.)

14 wells had a service rig on the hole at time of failure when wells were SI

- 10 wells had alarm during well kill
- 2 well during tubing repairs
- 1 wells while seating pump
- 1 well during acid stim

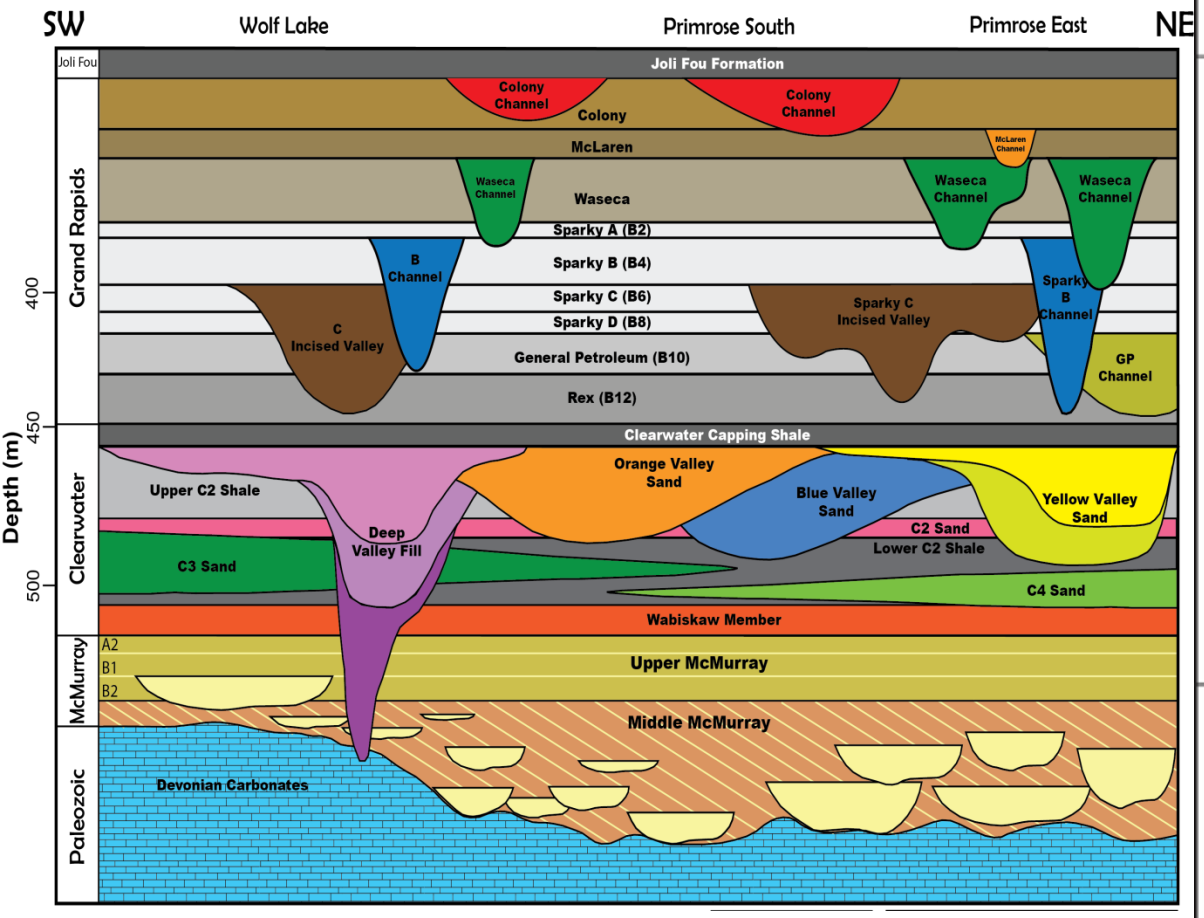
Up to 58% of failures were on ”cooler” wells that were SI

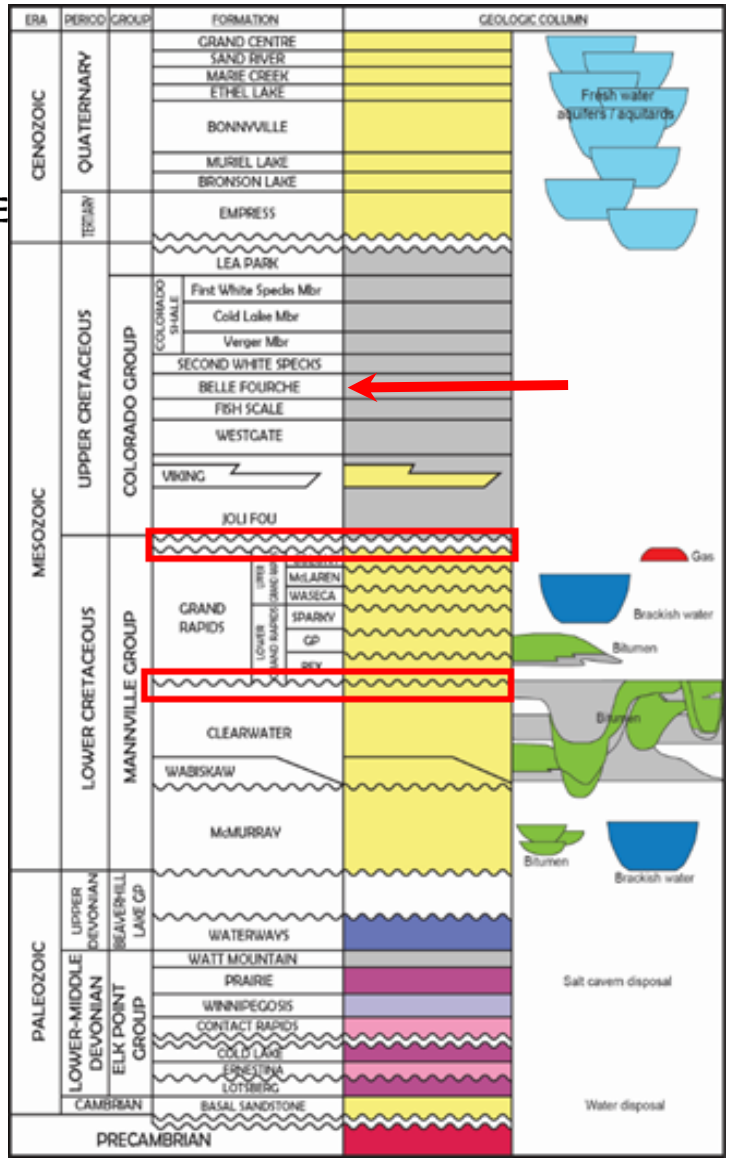
Out of Zone Failures by Formation



50% of casing failures were in the Belle Fourche formation

PAW Regional Schematic and Strat Column





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2019 PAW Casing Failures Table

Well Name	Area	Sub-Area	License #	Failure Of	Detection Method	Comfrimation Date	Depth (mkB)	Depth (mTVD)	Formation
8A59	PRN	PRN A2	401743	CONN	PS	4-Jan-19	308	305	Westgate
16A77	PRE	PRE A1	378166	CONN	PS	11-Jan-19	356	348	Joli Fou
8A58	PRN	PRN A2	396754	CONN	PS	23-Jan-19	333	328	Joli Fou
19A77	PRE	PRE A1	378784	CONN	PS	7-Feb-19	273	268	Belle Fourche
7A74	PRE	PRE A1	380835	CONN	PS	9-Feb-19	265	260	Belle Fourche
20A90	PRE	PRE A2	430523	CONN	PS	11-Feb-19	285	283	Belle Fourche
16A64	PRN	PRN A3	445701	CONN	PS	5-Mar-19	330	315	Belle Fourche
6A64	PRN	PRN A3	378168	CONN	PS	6-Mar-19	581	487	ClearWater
4A24	PRS	PRS	424512	CONN	PS	13-Mar-19	310	306	Westgate
20A63	PRN	PRN A2	409755	CONN	PS	14-Mar-19	265	258	Fish Scale
3A62	PRN	PRN A2	402524	CONN	PS	26-Mar-19	320	313	Westgate
15A93	PRE	PRE A2	432687	CONN	PS	3-Apr-19	260	260	Belle Fourche
5A94	PRE	PRE A2	433084	CONN	PS	12-May-19	266	264	Belle Fourche
6A90	PRE	PRE A2	430342	CONN	PS	28-May-19	290	285	Belle Fourche
2A66	PRN	PRN A2	396917	CONN	PS	7-Jun-19	251	248	White Specks
4A66	PRN	PRN A2	396919	CONN	PS	8-Jun-19	251	250	Belle Fourche
11A95	PRE	PRE A2	433418	CONN	PS	15-Jun-19	262	262	Belle Fourche
13A93	PRE	PRE A2	432685	CONN	PS	21-Jun-19	254	254	Belle Fourche
16A74	PRE	PRE A1	380851	CONN	PS	22-Jun-19	348	342	Joli Fou
17A77	PRE	PRE A1	378782	CONN	PS	27-Jun-19	337	328	Joli Fou
8A92	PRE	PRE A2	432910	CONN	PS	5-Jul-19	265	264	Belle Fourche
16A75	PRE	PRE A1	381921	CONN	PS	8-Jul-19	265	264	Belle Fourche
5A95	PRE	PRE A2	433412	CONN	PS	10-Jul-19	265	264	Belle Fourche

2019 PAW Casing Failures Table cont.

Well Name	Area	Sub-Area	License #	Failure Of	Detection Method	Comfrimation Date	Depth (mkB)	Depth (mTVD)	Formation
8A90	PRE	PRE A2	430480	CONN	PS	20-Jul-19	255	254	Verger Mbr
16A66	PRN	PRN A2	396911	CONN	PS	27-Jul-19	300	297	Westgate
8A22	PRS	PRS	424750	CONN	PS	31-Jul-19	321	319	Viking
10A62	PRN	PRN A2	402531	CONN	PS	7-Aug-19	280	279	Westgate
10A90	PRE	PRE A2	430482	CONN	PS	8-Aug-19	279	279	Belle Fourche
9A77	PRE	PRE A1	378150	CONN	PS	20-Aug-19	308	306	Westgate
3A95	PRE	PRE A2	433410	CONN	PS	22-Aug-19	255	254	Belle Fourche
4A92	PRE	PRE A2	432906	CONN	PS	31-Aug-19	268	265	Belle Fourche
9A75	PRE	PRE A1	381913	CONN	PS	1-Oct-19	257	257	Belle Fourche
7A94	PRE	PRE A2	433086	CONN	PS	5-Oct-19	265	264	Belle Fourche
6A75	PRE	PRE A1	381910	CONN	PS	13-Oct-19	357	351	Joli Fou
10A75	PRE	PRE A1	381914	CONN	PS	28-Oct-19	266	266	Fish Scale
16A78	PRE	PRE A1	375423	CONN	PS	1-Nov-19	224	233	White Specks
16A42	PRS	PRS	455693	CONN	PS	4-Nov-19	254	253	Belle Fourche
8A66	PRN	PRN A2	396923	CONN	PS	27-Nov-19	336	331	Westgate
8A78	PRE	PRE A1	375387	CONN	PS	9-Dec-19	228	228	White Specks
10A43	PRS	PRS	454857	CONN	PS	12-Dec-19	234	234	Belle Fourche
1A62	PRN	PRN A2	402522	CONN	PS	15-Dec-19	322	312	Westgate
2A62	PRN	PRN A2	402523	CONN	PS	18-Dec-19	264	262	Fish Scale
17A23	PRS	PRS	424442	BODY	PS	31-Dec-19	267	265	Belle Fourche

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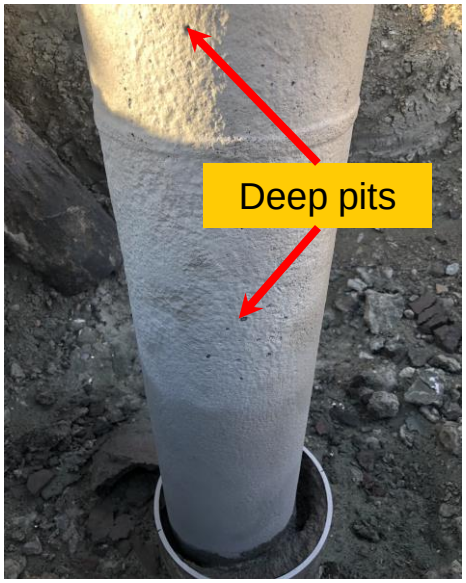
2019 WELL INTEGRITY INITIATIVES

Well Integrity Initiatives

- External Casing Corrosion Monitoring
  - Casing Integrity Assessment Methodology
  - Risk Based Re-Inspection Program
  - Coating Specification

External Casing Corrosion - PAW

- 80 wells randomly inspected in 2019 on a scoping basis (identify if a problem exists). Follow up from 2018 program where:
  - Some pads had not had at least one well inspected
  - Observed wall losses were variable across the pad
  - Quarterly bentonite top-up program in place
- 2019 inspection results as followed:
  - **70%** wells coated with the high temperature metallic Intertherm 751CSA coating (20-45% wall loss)
    20% wells do not require any coating due to significantly lower wall losses (< 20% wall loss)
  - **10%** wells flagged for casing stub cut-out and replacement due to future plan to steam these pads (60% wall losses).



External Casing Corrosion – Integrity Assessment

- **Phase 1**: New methodology for casing integrity assessment and repair decision making
  - New approach provides a more accurate estimation of the pressure rating of the casing as a result of the corrosion observed.
  - Level 1 analysis conducted (most common) as a function of temperature and wall loss
  - Develop a casing integrity decision tree for repair/remediation options
  - 7 wells will not require any casing stub cut-out and replacement.
- **Phase 2**: Risk based approach of the re-inspection interval
  - Build a long term casing integrity plan which will include a revised maintenance and inspection schedule
- **Phase 3**: Coating selection and specification
  - Evaluate current metallic coating used on the intermediate/production casing if fit for service (FFS)
  - Compare with peers and industry standard

External Casing Corrosion Management Protocol will be updated

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