EMPLOYING THE LV-EMI™ UNIT IN THE GREATER ELK HILLS AREA

Larry Aldrich, California Resources

L.J. Guillotte Jr., Enio Oliveros, and Anne Marie Weaver

Lightning Production Services

ABSTRACT

The Greater Elk Hills Area boasts a substantial continuous rod population, introduced to the field due to loading requirements and casing restrictions. However, the existing continuous rod population is now comprised of older worn rod strings, with many of these strings exceeding ten years of service. When rod strings are pulled during service operations, it is common that sections of rod need replacement, highlighting the need for a precise and reliable inspection method.

In the past, visual inspection was utilized to assess the condition of continuous rod strings, determining when worn or corroded sections required replacement. This method can be imprecise and dependent on the rig operator's expertise. In California Resources Corporation's (CRC) case, the company would often encounter repeat failures after pulling the rod string to get the well back online. One barrier to widespread continuous rod adoption has been the inability to clearly identify and replace sections of corroded or damaged rods. In the past, when continuous rod was pulled during service operations, visual inspections sometimes resulted in defective rods being rerun, subsequently causing premature and repeated rod failures.

In 2020, electromagnetic inspection (EMI) technology for continuous rod was introduced to the industry with the Low Voltage Electromagnetic Inspection (LV-EMI™) unit. This unit allows for continuous inspection of the rod while it is being pulled out of the wellbore during service operations. By utilizing this unit, compromised continuous rod sections are accurately identified and replaced, minimizing failures, and optimizing wellbore performance. Since initial deployment, several advancements have been made to the LV-EMI™ unit, further refining its capabilities, and expanding its potential applications.

CRC took proactive steps by incorporating EMI scanning into workovers, employing specific criteria to guide their approach. The results of the approach they implemented, along with the lessons learned are presented in this paper.

CONTINUOUS ROD TECHNOLOGY

While the implementation of continuous rod offers a multitude of benefits, CRC utilized continuous rod to address the challenges of loading conditions at deep seat nipple depths and high fluid rates along with casing restrictions within wellbores. A steel sucker rod string is typically comprised of steel sucker rods interlinked by couplings in intervals of either 25 or 30 feet, whereas continuous rod eliminates the couplings. The couplings add weight to the rod string and can restrict the internal diameter of the tubing.

These couplings contribute additional weight to rod string, resulting in a conventional rod string that is approximately 8-10% heavier than its continuous rod string counterpart. Add reference to paper on weight. The disparity in weight allows more fluid to be lifted due to decreasing loads at surface and on the rod string.

The absence of couplings in continuous rod configurations offers the distinct advantage of accommodating larger rod sizes within smaller tubing dimensions. For example, consider 2-7/8” tubing. While the largest conventional rod size viable for this tubing size is 1”, the utilization of continuous rod permits the use of 1-1/8” rods. This translates to improved fluid lifting potential, facilitated by more manageable rod loading characteristics.

ELECTROMAGNETIC INSPECTION TECHNOLOGY

Electromagnetic testing is a form of nondestructive testing, involving the induction of electric currents, magnetic fields, or a combination of both. When a test is executed properly, a defect inside the test object generates a detectable response.

Electromagnetic inspection is utilized throughout the oil and gas industry. Specifically for inspection of oil country tubular goods including drill pipe, casing, tubing, and conventional sucker rods. Magnetic flux leakage (MFL) and magnetic flux density (MFD) are employed during electromagnetic inspection. Magnetic flux leakage (MFL) measures and assesses the presence of defects, anomalies, or corrosion on the object. Magnetic flux density (MFD) measures and assesses changes in the cross-sectional area and permeability of the object.

The thresholds for the EMI unit are loosely based on API 11BR standard for conventional sucker rods. The current magnetic flux leakage (MFL) threshold for removal is set at 6% of the rod diameter for continuous rod. For magnetic flux density (MFD), the current threshold to remove sections is when cross-sectional loss is greater than 15% of the rod diameter. These thresholds can also be adjusted based on operator’s preferences.

LV-EMI™ UNIT & OPERATIONS

Operation

To install and pull continuous rod strings, a special piece of equipment is required, a hydraulic injector. This can be utilized in tandem with a conventional workover rig. During service operations to pull a continuous rod string, the rod string travels through the injector before entering the guide arms. Prior to entering the guide arms, rubber strippers are employed to eliminate excess oil and paraffin. This step ensures that the scan occurs with optimal conditions, mitigating potential data interference. The rod then travels through the guide arms and an additional set of rubber strippers before entering the LV-EMI™ unit and collapsible service reel. An image of a continuous rod workover operation is displayed in Figure 1.

Compact in design, this unit allows for placement between the last guide arm and the collapsible service reel. The unit is comprised of two components that clamp around the rod allowing it to be easily installed or removed at any time during operation. The LV-EMI™ unit boasts a Class I, Div. II rating, making it suitable to be deployed near the wellhead, and employs magnets to induce magnetic fields for object testing. A prominent element within the unit, displayed in Figure 2, is the ring, which induces the magnetic field. This innovative configuration, patent pending technology, enables accurate inspection of continuous rod while also adhering to safety standards.

Software

With the previous software used for scanning continuous rod, the software captured screenshots at thirty second intervals, synchronized with a counter that monitored the footage. The number of feet per screenshot varied depending on how fast the rig was pulling the rod out of the wellbore. This data would then be employed to produce a graphical representation.

The new Zephyr™ software has been developed to capture data continuously. The software's architecture and commands are focused on one continuous element. Utilizing this software with the predefined thresholds mentioned in [1] will alert and trigger actions if there is an indication on the rod as it is traveling through the EMI unit. Should the EMI readings signify an indication, the software initiates immediate actions, including capturing a photo of the rod as it is traveling through the unit.

The counter will be incorporated into the software to aid in the precision of aligning the EMI scanning data to the correct footage. Furthermore, the software will aid in reducing the amount of time for the EMI scan results/report.

Fatigue in the Rod String

In addition to identifying wear and corrosion, the scanning process has also brought to light the occurrence of rod fatigue, shown in Figure 3. While initially uncertain on the nomenclature of this phenomenon, a pattern emerged: these fatigue indications were consistently present near areas where the rod string would part. This occurrence has now been identified as fatigue within the rod string. These types of indications in the rod string are termed as "MFD fluctuations".

These fluctuations are associated with hardness variations that alter the magnetic permeability properties of the rod string. This transformation is the result from the repetitive stretching and compression that the rod undergoes over time. These fluctuations can vary in magnitude depending on the frequency of strokes per minute and degree of deviation. Typically, the more cycles per day and the more severe the deviations, the EMI operator will observe a higher amplitude on the software. The density of the fluctuations and the length of the fluctuation section will determine how the EMI operator interprets the severity and inputs the data into the report for the customer.

CASE STUDY: CALIFORNIA RESOURCES, GREATER ELK HILLS AREA

CRC implemented the use of electromagnetic inspection utilizing the following criteria on high failure rate wells: in cases where the cause of failure is related to the rod string, CRC will scan the rod string utilizing the LV-EMI™ unit. Additionally, if the well has a high failure rate and has a previous history of rod failures, CRC employs the LV-EMI™ unit to scan the rod string regardless of the reason for the pull. CRC has employed the LV-EMI™ unit on more than 115 continuous rod strings meeting the above-mentioned criteria. The following cases highlight instances of pulling continuous rod strings, conducting visual inspections, and deeming these rod strings as suitable to run back in the wellbore. CRC pulled these wells again shortly after rerunning the rod strings back into the wellbore and scanned the rod strings with the EMI unit, revealing contrasting findings on the condition of the rod string compared to the previous visual inspection.

Well No. 1

Well No.1 features a semi-elliptical continuous rod taper. This rod string was originally installed in December 2019 and experienced a rod part in September of 2021 at a depth of 869' in the SE#8 taper. During this workover, the rod string underwent visual inspection by the rig crew, who observed mild corrosion pitting and mild rod wear, leading them to conclude that the rod string was in acceptable condition to re-run.

In January of 2022, the rod string was pulled due to pump failure. At this time, CRC decided to scan the rod string using the LV-EMI™ unit. The corresponding MFL and MFD indications for this rod string can be observed in Figures 4 and 5. According to the EMI scan results, the entire rod string exhibited moderate to severe corrosion. The rod string is graded from blue to red according to the scan. Images of the rod string with severe corrosion and moderate wear can be seen in Figures 6 and 7, marked based on the EMI readings. Based on this scan, CRC decided to retire the string and install a new rod string. It is noteworthy that CRC has not experienced a rod failure to date. Scanning this rod string with the EMI unit likely prevented a repeat rod failure.

Well No. 2

Well No. 2 features a semi-elliptical continuous rod taper. This rod string was originally installed in January of 2020. After nearly two years of operation, the rod string parted in January of 2022 at the transition between the SE#4 taper and SE#3 taper at a depth of 7,252'. During this workover, the rod string underwent a visual inspection by the rig crew, who concluded that the rod string was in acceptable condition for redeployment.

In August of 2022, the rod string was pulled due to a rod pump failure. This prompted CRC to scan the rod string utilizing the EMI unit. The corresponding MFL and MFD indications for this rod string can be observed in Figures 8 and 9. According to the EMI scan, the top 1,500' of the rod string experienced stress cracking. Additionally, possible injector damage was detected throughout the entire rod string, with severe damage between 4,500’ to 6,500’. MFD fluctuations were also observed from 4,500’ to 5,500’, indicating rod fatigue. Images of the rod string with stress cracking can be seen in Figure 10, marked based on the EMI readings. Considering these findings, CRC decided to retire the string and run a new rod string in the well. CRC has not experienced a rod failure to date. Scanning the rod string instead of relying solely on a visual inspection likely prevented a repeat rod failure.

Well No. 3

Well No. 3 features a semi-elliptical continuous rod taper. This rod string was originally installed in May of 2019. In November of 2023, the rod string was pulled for elective well work. During this workover, the rod string underwent a visual inspection by the rig crew, who concluded that the rod string had light pitting and wear but was in acceptable condition for redeployment.

One week later, in November of 2023, the well failed due to a rod part. This prompted CRC to scan the rod string utilizing the EMI unit. The corresponding MFL and MFD indications for this rod string can be observed in Figures 11 and 12. According to the EMI scan, the top 650’ of the rod string experienced severe pitting. Additionally, the bottom section of the rod string experienced moderate wear. Images of the rod string with severe pitting can be seen in Figure 13, marked based on the EMI readings. In light of these findings, CRC decided to replace the top 650’ of rod. By relying on visual inspection instead of an EMI scan, CRC could have prevented a failure.

Well No. 4

Well No. 4 features a semi-elliptical continuous rod taper. This rod string was originally installed in April of 2013. After over ten years of operation, the rod string parted in August of 2023 at a depth of 950’ in the SE#6 taper. During this workover, the rod string underwent a visual inspection by the rig crew, who concluded that the rod string had light pitting but only needed to cut 60’ above and below the failure but was in acceptable condition for redeployment.

In October of 2023, the well failed again due to a rod part. This prompted CRC to scan the rod string utilizing the EMI unit. The corresponding MFL and MFD indications for this rod string can be observed in Figures 14 and 15. The failure occurred in the transition weld between the SE#6 and SE#7 taper, but per the EMI scan results, the rod string was highly compromised, with evidence of pitting and wear dedicated along its entire length. Images of the rod string with moderate to severe scale and wear on the minor side can be seen in Figures 16 and 17, marked based on the EMI readings. Considering these findings, CRC decided to retire the string and run a new rod string in the well. By relying on visual inspection during the first rod part instead of an EMI scan, CRC could have prevented a repeat failure.

Well No. 5

Well No. 5 features a semi-elliptical continuous rod taper. This rod string was originally installed in December of 2014. In February of 2022, the rod string was pulled for a tubing failure. During this workover, the rod string underwent a visual inspection by the rig crew, who concluded that the rod string had heavy wear and corrosion throughout and that the rod string should be replaced. CRC replaced with a surplus semi-elliptical continuous rod string that had previously been deemed acceptable to use.

Ten months later, in December of 2022, the well failed due to a rod part. This prompted CRC to scan the rod string utilizing the EMI unit. The corresponding MFL and MFD indications for this rod string can be observed in Figures 18 and 19. The rod failed at a depth of 1017’ in the SE #7 taper. According to the EMI scan, there are several sections of the rod string that experienced significant corrosion and wear. Additionally, the EMI scan detected mechanical damage on the rod string. Images of the rod string with moderate scale can be seen in Figure 20, marked based on the EMI readings. In light of these findings, CRC decided to retire this string and install a new rod string. CRC has not experienced a rod failure to date.

CONCLUSION

As displayed in the case study, the integration of electromagnetic inspection technology during well workovers with continuous rod can significantly reduce failure rates, translating to substantial cost savings long term.

REFERENCES

1. Oliveros, E., Guillotte, L.J., Weaver, A., Vacek, B., Jensen, J. “Continuous Rod Scanning Using LV-EMI™ Proprietary Technology”, 2022 Southwestern Petroleum Short Course, Lubbock, TX

Appendix

Figure 1: Continuous rod workover operation

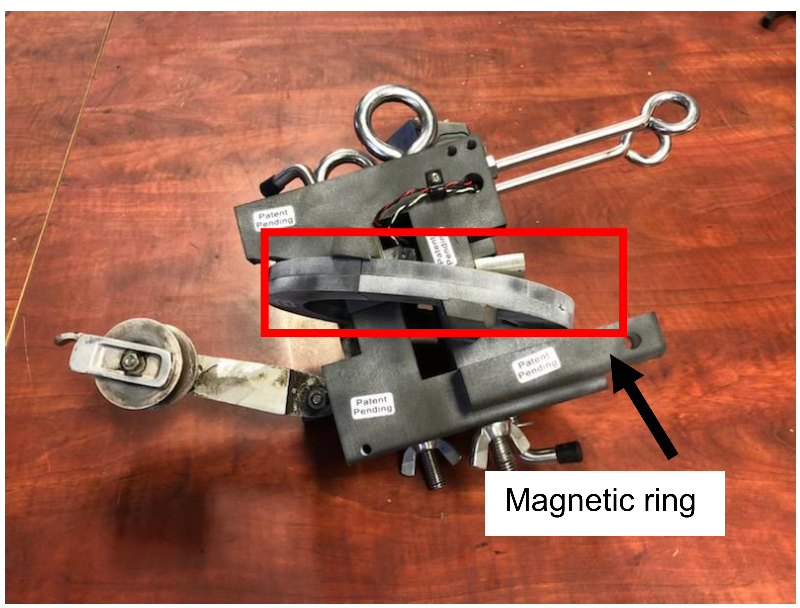

Figure 2: Patented LV-EMI Unit

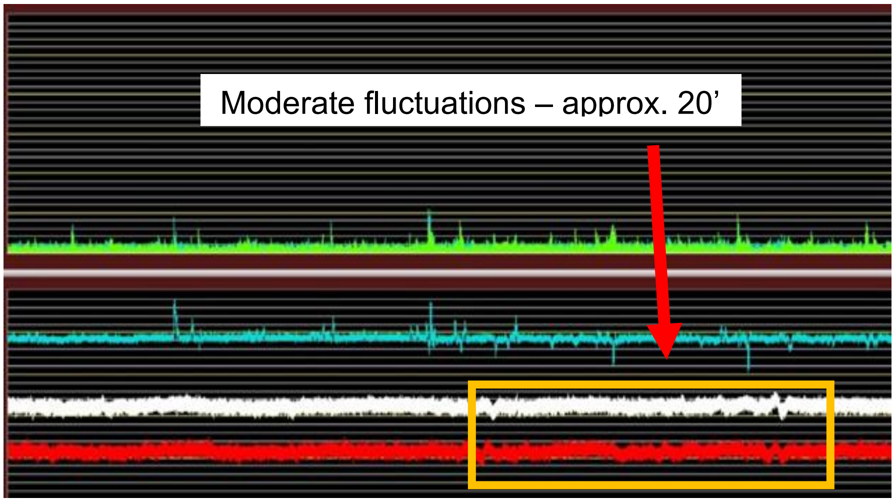

Figure 3: Rod Fatigue

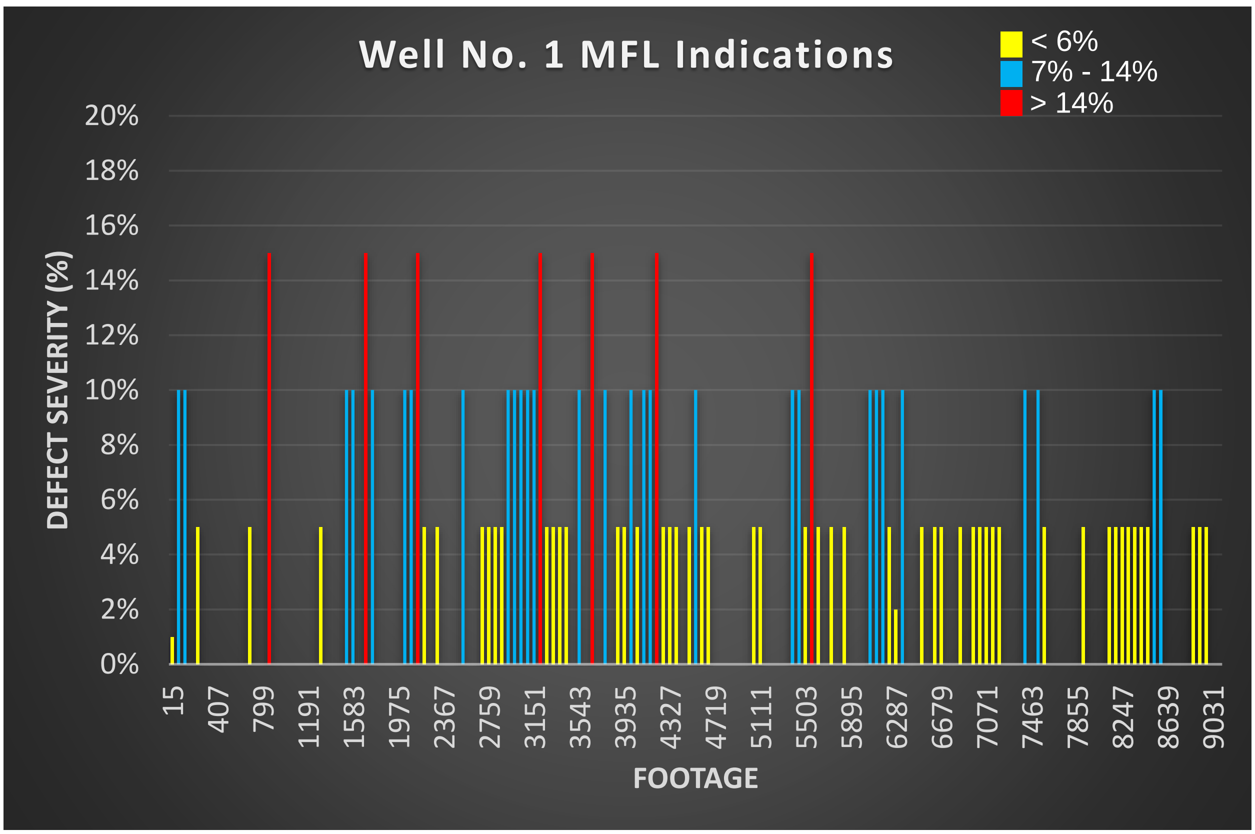

Figure 4: Well No. 1 MFL Indications

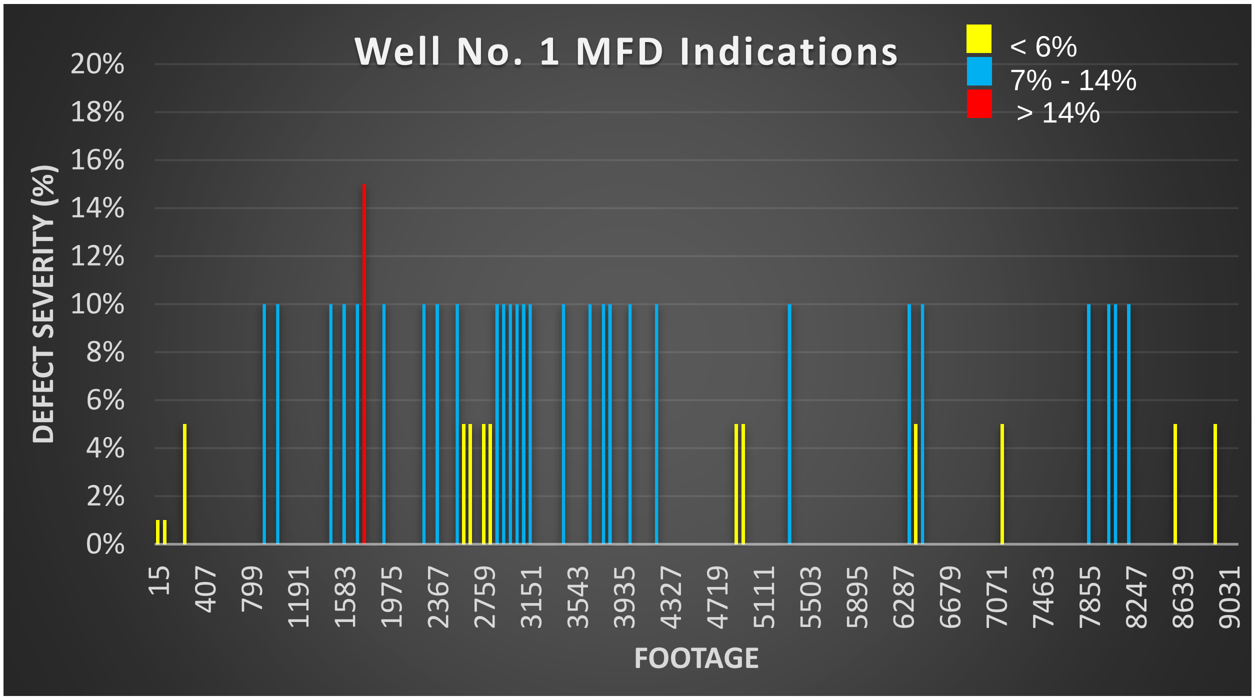

Figure 5: Well No. 1 MFD Indications

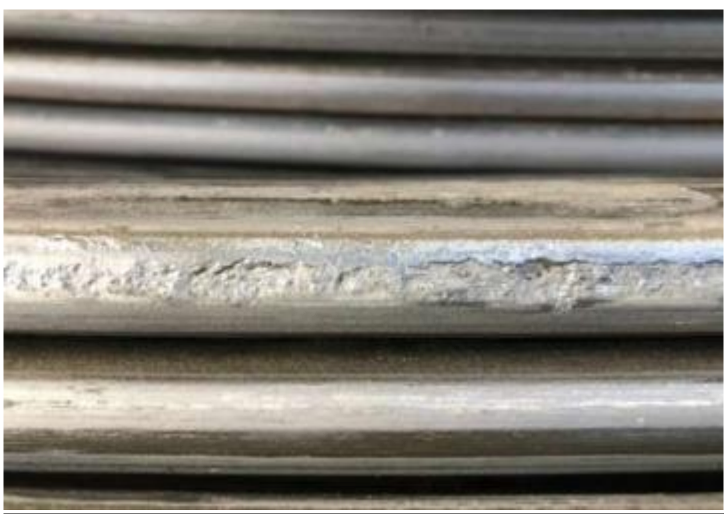

Figure 6: Well No. 1 - Moderate to Severe Pitting

Figure 7: Well No.1 - Moderate Wear

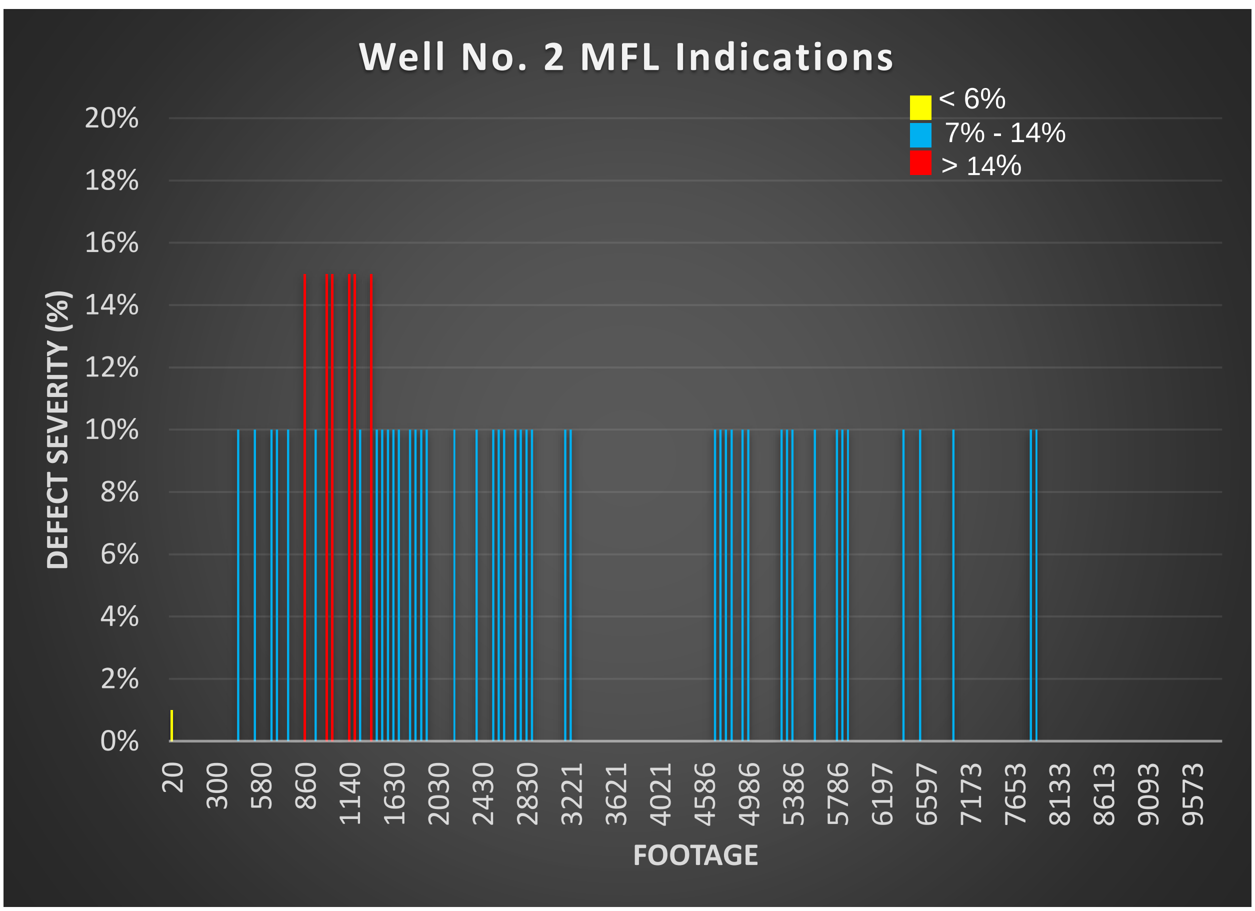

Figure 8: Well No. 2 MFL Indications

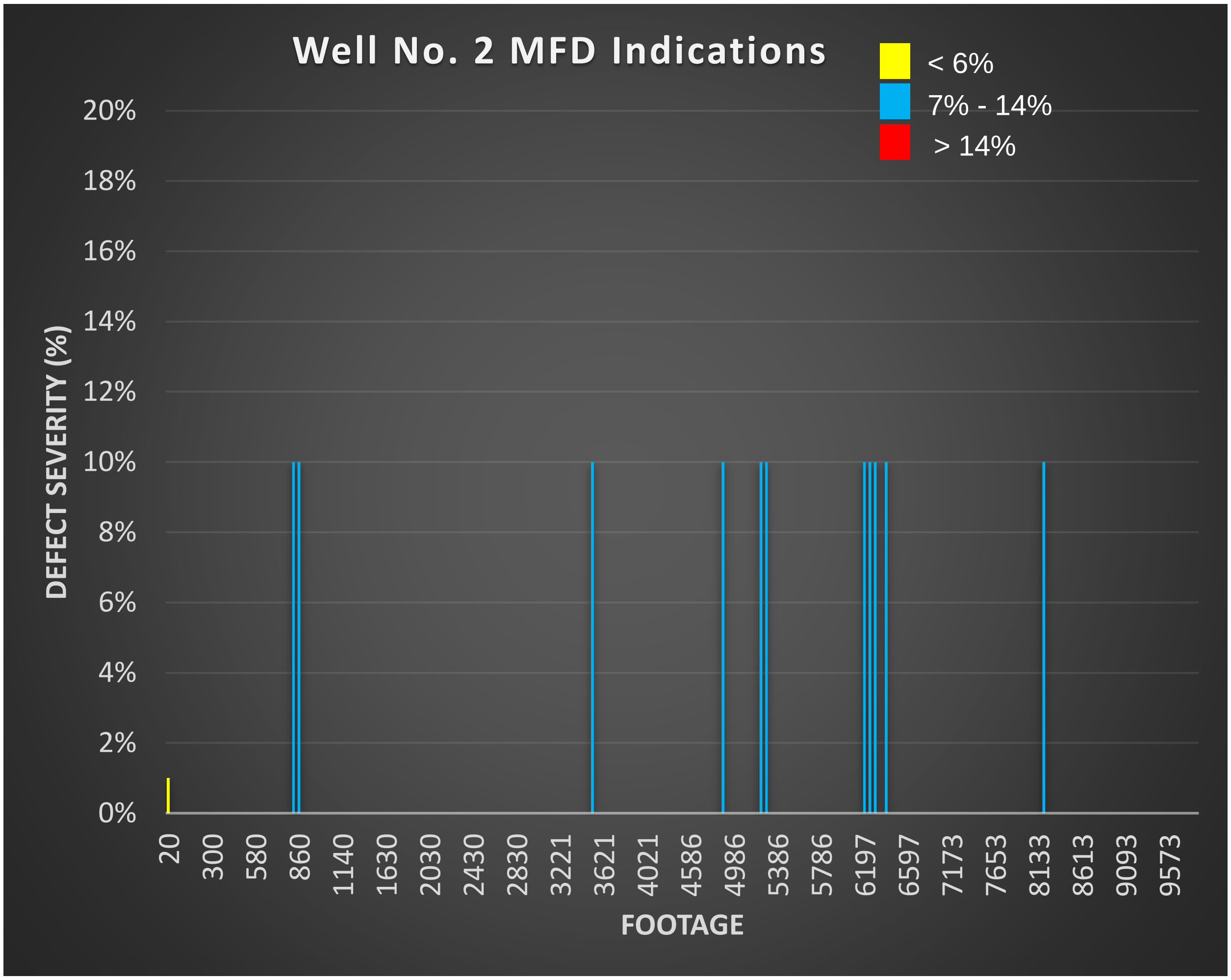

Figure 9: Well No. 2 MFD Indications

Figure 10: Well No. 2 - Stress Cracking

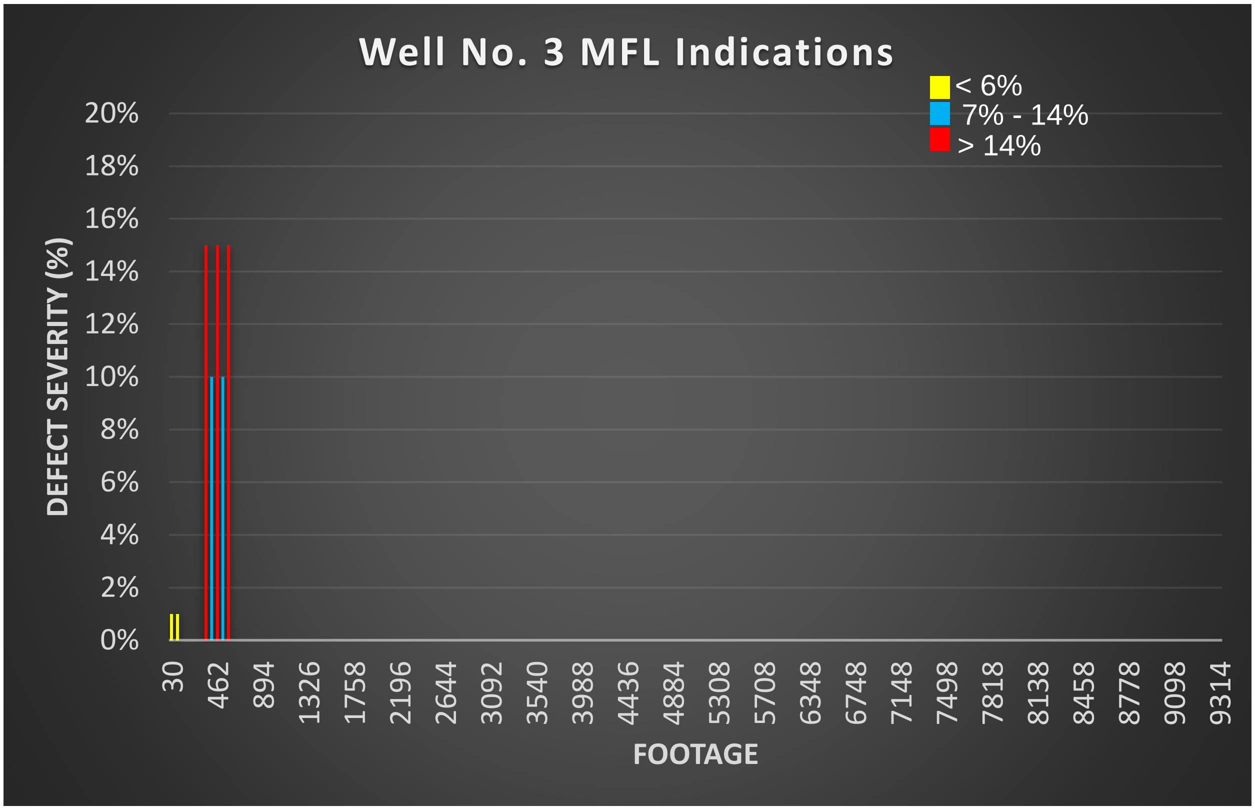

Figure 11: Well No. 3 MFL Indications

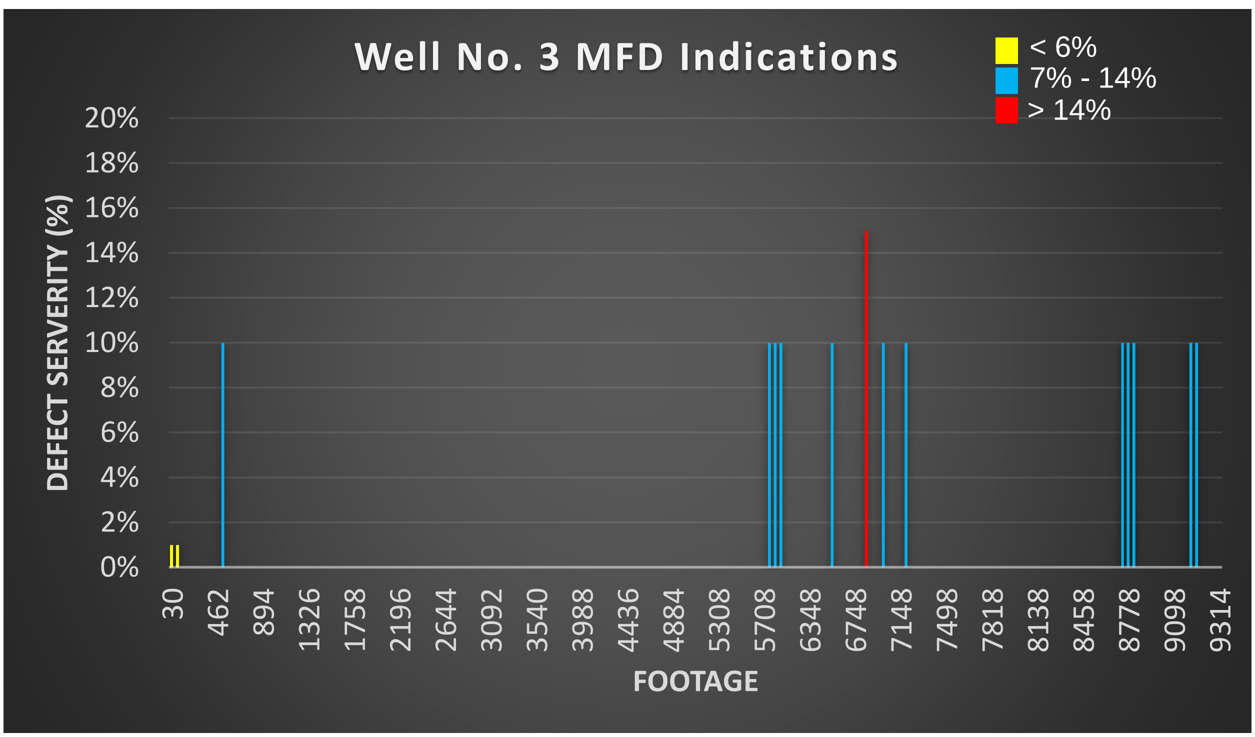

Figure 12: Well No. 3 MFD Indications

Figure 13: Well No.3 - Moderate to Severe Pitting

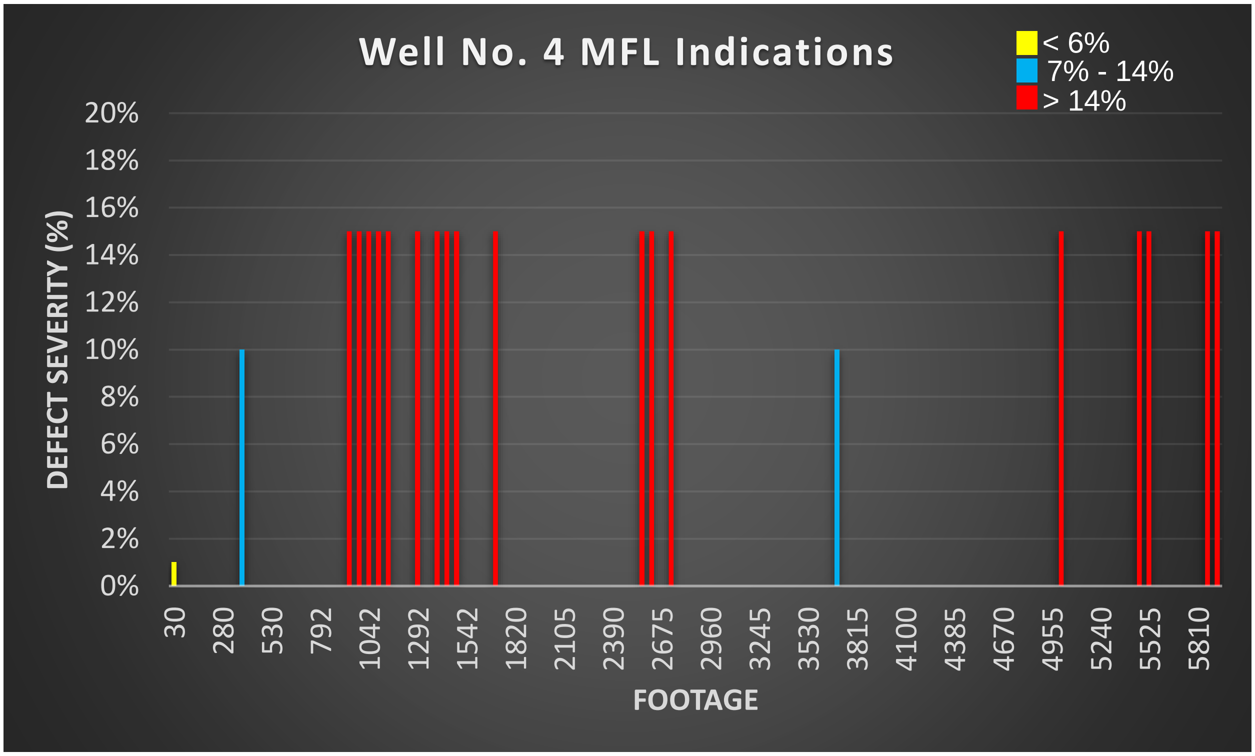

Figure 14: Well No. 4 MFL Indications

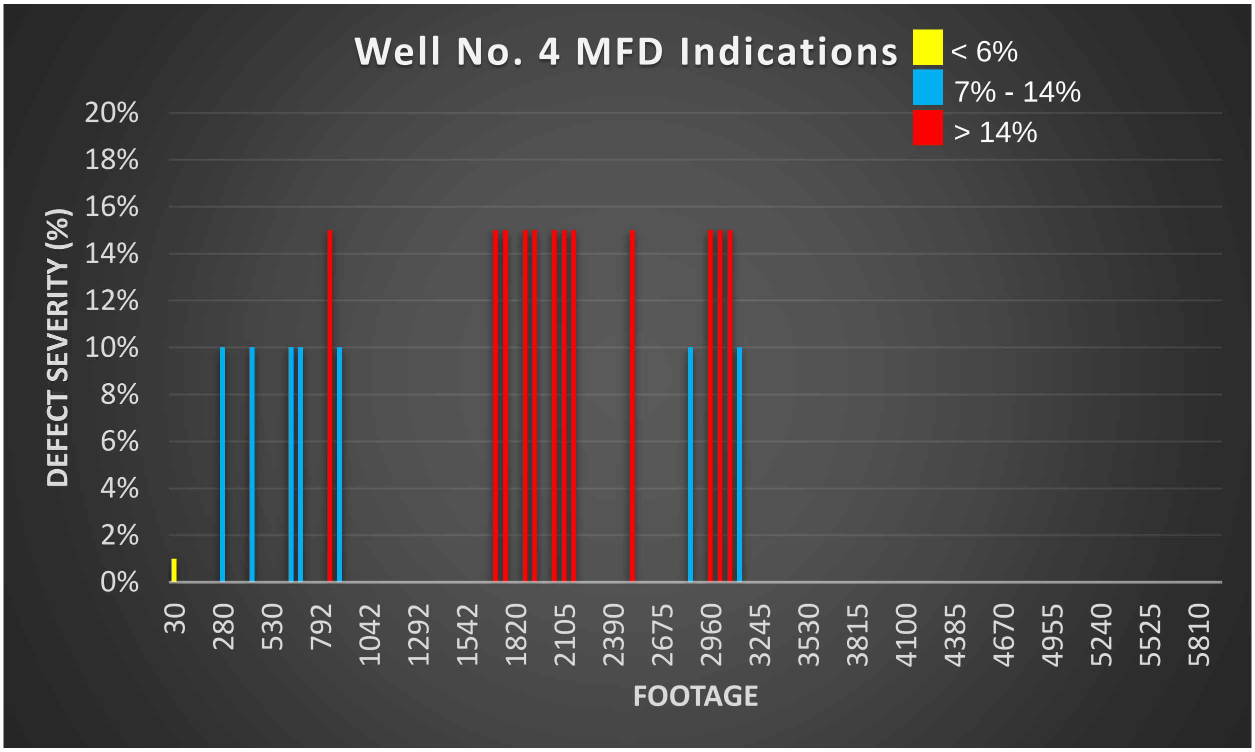

Figure 15: Well No. 4 MFD Indications

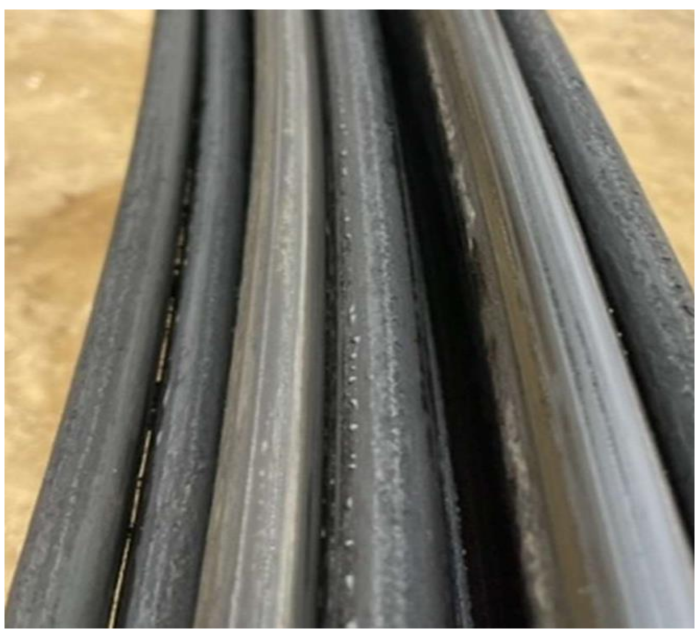

Figure 16: Well No. 4 - Moderate to Severe Scale Pitting

Figure 17: Well No. 4 - Wear on Minor

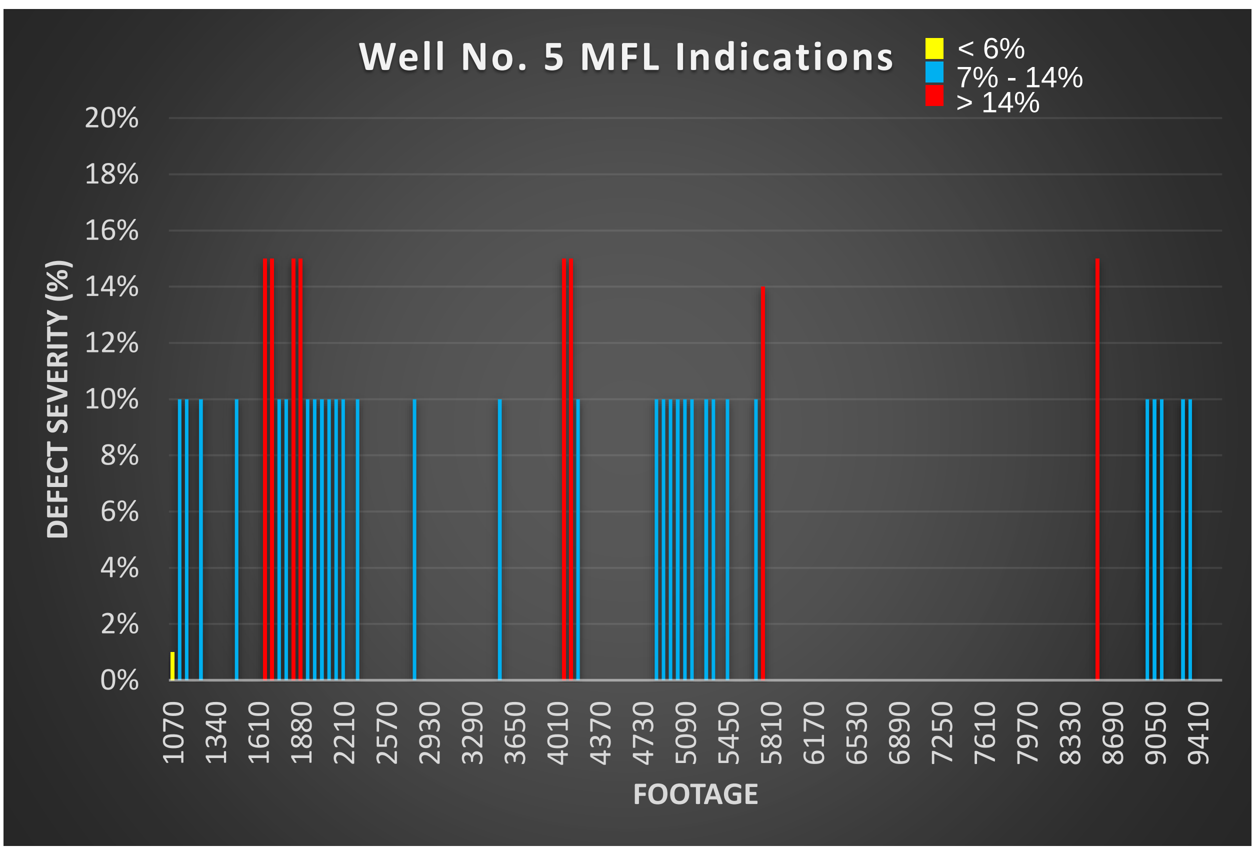

Figure 18: Well No. 5 MFL Indications

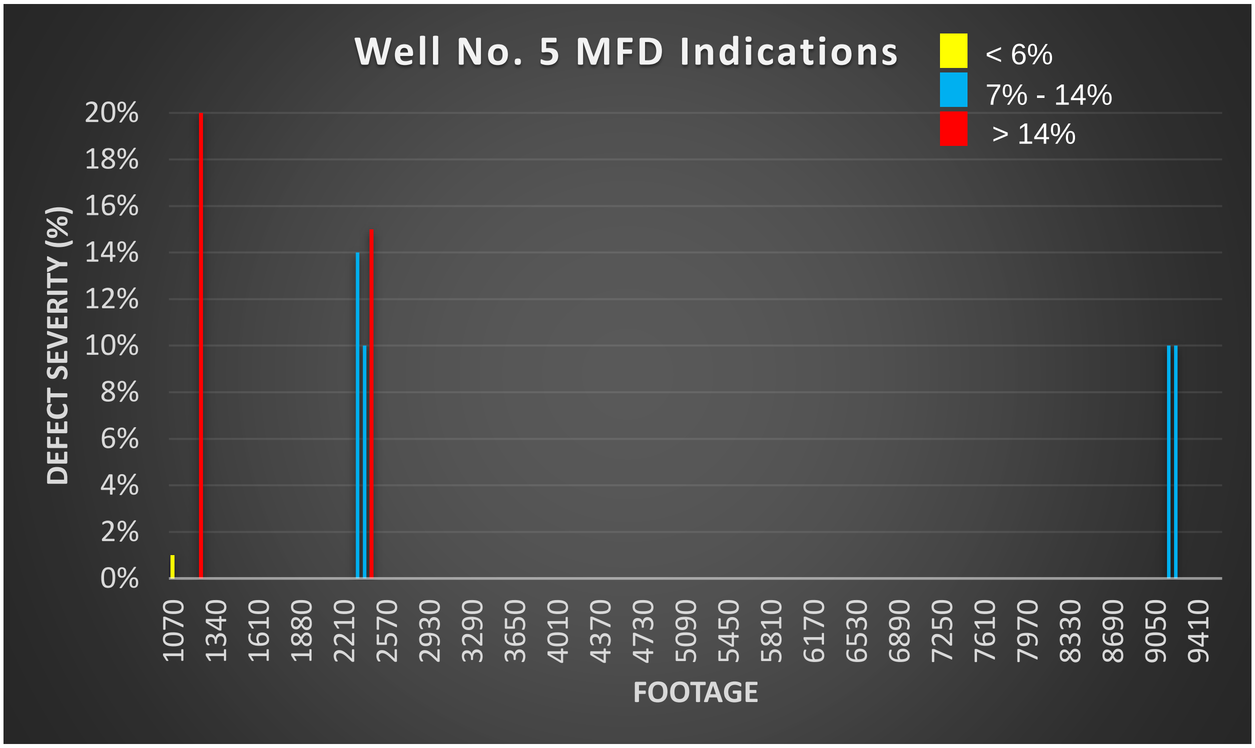

Figure 19: Well No. 5 MFD Indications

Figure 20: Moderate Scale