WELL PADS VS. DRILLING PERMITS for Predicting Spuds in the Permian Basin

sourcewater

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WELL PADS VS. DRILLING PERMITS for Predicting Spuds in the Permian Basin

Spatiotemporal Comparison of Well Pads Detected in Satellite Imagery with DirtWork Alert™ versus Drilling Permit Submissions for Predicting Permian Basin Drilling Events in Texas and New Mexico

SUMMARY

Sourcewater, Inc., an energy intelligence company in Houston, developed and patented DirtWork Alert™ (DWA), a system for detecting oilfield activity in satellite imagery. Sourcewater identified and analyzed every well pad, drilling permit and spud (drilling start) in the Permian Basin in 2018 and 2019 to quantify the time and probability relationships between these critical oilfield events and to assess the accuracy of the DWA model.

In Texas, the appearance of a well pad predicted a spud earlier than a drilling permit for about 1/3rd of spuds, and well pads predicted spuds with similar specificity and sensitivity compared to permits. A drilling permit collocated with a well pad indicated a stronger intention to drill a well sooner than a permit alone.

In New Mexico, the appearance of a well pad predicted a spud earlier than a drilling permit for over 1/3rd of spuds in 2019, and well pad detections predicted spuds with much higher specificity and somewhat higher sensitivity compared to permits alone, while drilling permits paired with a well pad indicated a far stronger intention to drill a well sooner than a permit alone. Satellite imagery detection of well pads is clearly an important enhancement to regulatory data for energy market participants who rely on early and accurate indications of oilfield activity, particularly in New Mexico.

KEY TAKEAWAYS

- For 1 in 3 spuds in both Texas and New Mexico, a well pad was detected in advance of any drilling permit. In these cases, the pad appeared on median 76 days before the permit in Texas and 100 days before the permit in New Mexico.
- In Texas, 1 in 5 approved drilling permits was never drilled. In New Mexico, 1 in 2 approved drilling permits was never drilled.
- In both states, 2 of 3 DWA-detected well pads led to a spud.
- An additional 14% of DWAs led to undrilled permits in Texas and 25% in New Mexico, suggesting DWA true well pad detection rates of at least 80% to 90%, probably higher.
- In both states, about 95% of spuds had a collocated DWA well pad, but in New Mexico, only 93% of spuds had a matching permit.
- After a well pad appeared in the same location as an undrilled permit, a Texas permit was 14% more likely to be drilled and a New Mexico permit was 53% more likely to be drilled.
- A permit with a matching DWA pad was drilled on median 31 days sooner in Texas and 36 days sooner in New Mexico than a permit without a pad.

INTRODUCTION

Conventional oilfield market intelligence – knowing who is drilling where and how much oil and gas they are producing – relies on the downloading, processing and mapping of state regulatory filings, such as drilling permit submissions and completion reports. However, many important oilfield activities are not subject to regulatory recordkeeping, while other data are submitted to or released by the regulator long after the relevant events on the ground have occurred. Moreover, much of the data submitted to regulators is self-reported by operators and unverified; errors, omissions and delays are common.

Analysis of oilfield activity data gleaned from independent, non-regulatory sources may enhance the timeliness, accuracy and completeness of market intelligence used for energy business decisions. One such independent source is satellite imagery. High cadence, high resolution satellite imagery has become commercially available from many competing sources in recent years, as have better software tools and processing power for analyzing imagery. One essential oilfield activity that is visible from the sky but that is not tracked in any regulatory record is the construction of well pads.

A well pad is a clear, level area on the ground where heavy equipment such as a drilling rig can safely operate. It is a physical necessity that all oil and gas wells must have a well pad in place before they can be drilled ("spudded".) However, because there are no regulatory records of well pads, the time and probability relationships between well pad construction, drilling permit submission, and drilling start date (or "spud") has never been measured – until now.

Sourcewater, Inc., an energy market intelligence technology company based in Houston, has developed, patented and applied new machine learning and artificial intelligence technologies to detect and analyze energy activity in satellite imagery. The company originally developed these systems to detect and measure frac water impoundments and has continued to expand its capabilities into other types of oilfield activity detection, such as well pads.

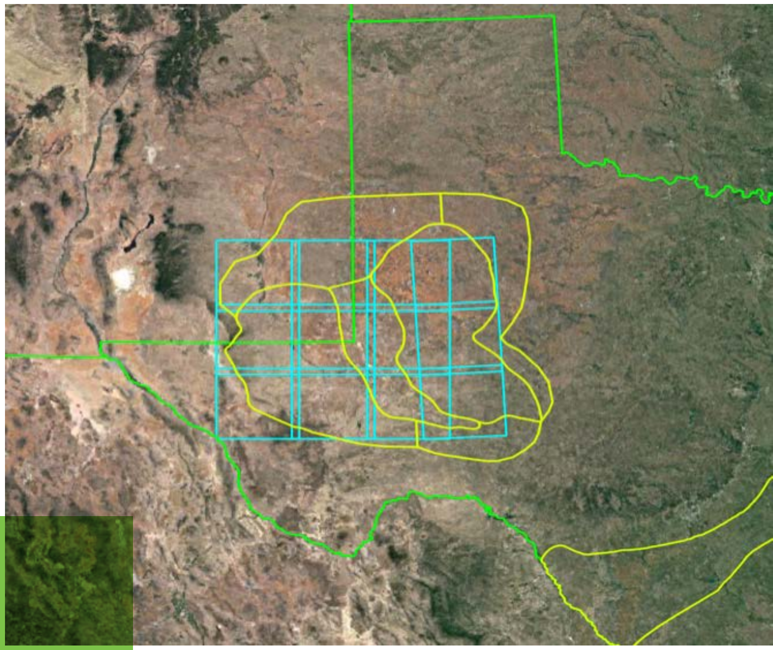


Figure 1: The Permian Basin study area is bounded by the outer bounds of the blue boxes

For this study, Sourcewater applied its DirtWork Alert™ product to detect every presumed well pad constructed in the Permian Basin of Texas and New Mexico from March 2017 through July 2020 on a five-day image cadence (See Figure 1 for the geographic study area.)

Detections were compared to Texas Railroad Commission (RRC) and New Mexico Oil Conservation Division (OCD) drilling permit filings and completion reports for every drilling permit and every spud reported during this same period to measure the time and probability relationships between these key oilfield indicators. Results were narrowed to the full years of 2018 and 2019 to allow time buffers for complete data on either side. Drilling permits and wellbores records that lacked either a date or a location were excluded from the study.

BACKGROUND

Oilfield business activity is traditionally tracked and predicted through the use of regulatory filings such as W-1 drilling permits and W-2 completion reports received from operators and then published by the Texas Railroad Commission (RRC), or similar forms submitted to and published by government agencies in other states.

While reliance on these regulatory filings is an essential component of oilfield market intelligence, there are a number of shortcomings in regulatory sources: they can be incomplete, inaccurate or untimely. For example, of the 1,163,434 unique wellbores in the RRC database, 472,931 (40.6%) have no matching drilling permit, and 193,317 RRC wellbores (16.6%) have no associated location. Of 250,883 RRC wellbores in the section of the Texas Permian analyzed herein, only 116,671 (46.5%) of them had an associated spud date. It seems likely that many wellbore records have an incorrect location or date. Reporting lag is also an issue.

While Texas drilling permit submissions and New Mexico drilling permit approvals are typically published online within a few days of their respective submission or approval, spud reports lag the spud event by up to 150 days in Texas and up to 190 days in New Mexico, creating uncertainty about current numbers of drilled but uncompleted wells, completions, production and other facts essential for energy businesses, investors and regulators to make well-informed, timely decisions.

Regulatory forms were not intended to capture all aspects of oilfield activity, including some indicators that might occur earlier, more accurately or with more significance than regulatory data alone. For example, well pad construction must physically precede new drilling but is not reported to the RRC.

Since 2017, data scientists at Sourcewater, Inc., have been developing machine learning methods to analyze satellite imagery for oilfield activity that when contextualized with regulatory data may provide earlier, more accurate and more complete market intelligence than regulatory data alone.

This work has produced seven granted U.S. patents, with many more pending. The resulting product is called DirtWork Alert™ because it may detect many types of oilfield dirtwork or sitework activity, not only well pad construction, though the model is trained and intended to detect well pads specifically. For this study, we trained models to detect every Permian Basin well pad appearing in five-day cadence satellite imagery for the period from March 24, 2017 through August 8, 2020, then spatiotemporally correlated each presumed well pad with any drilling permit submission and or spud reported if the permit and or spud included both a date and a location. (Figure 2 shows a typical satellite image with well pads and wellbores marked.) Permits and spuds were matched by API number.

OUR STUDY PURPOSE WAS FOUR-FOLD:

▶ **1** First, to rigorously quantify the time and probability relationships between drilling permit submissions and spuds in the Permian Basin, distinguishing Texas regulatory outcomes from New Mexico outcomes. Original new drilling permit submissions (Texas) and approvals (New Mexico) and spud dates from completion reports were matched by API number to measure false positive and false negative rates and time distributions from permit to spud.

For study purposes we only included 2018 permits for permit-to-spud false-positive calculations and made December 31, 2019 the outside date for matching a spud to a 2018 permit.

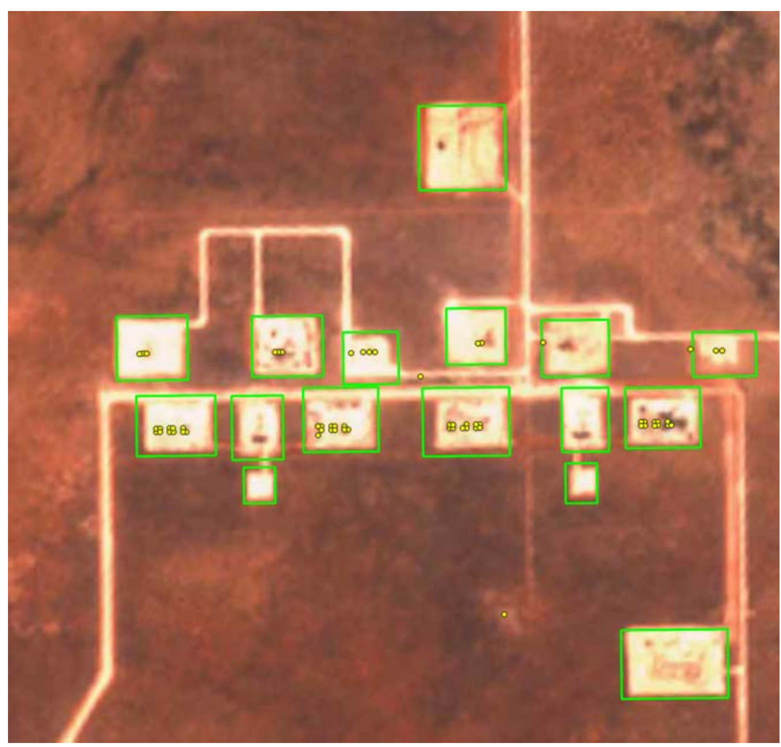


Figure 2: A typical satellite image with well pads and wellbores marked.

2&3 Our second and third purposes were to spatially associate presumed well pad detections (also called DirtWork Alerts or DWAs) with permit and spud locations, in order to: a) quantify the time and probability between well pads and spuds; and b) gauge the performance of the evolving ML detection model.

This challenge is far more complex than matching API numbers, because the true time and probability between spuds and well pads on the ground is different from the evolving DWA model performance in detecting well pads. Cloud-cover or occasional satellite imagery defects may delay or prevent detection of a new well pad, but that does not mean that the well pad does not yet exist. Moreover, the "ground truth" of regulatory data such as wellbore locations is shaky at best.

Most regulatory information is self-reported by operators and is never independently verified. As noted earlier, 40.6% of all RRC wellbores appear to have no drilling permit, and 16.6% of wellbores have no recorded location. It seems likely that many other permit and wellbore records have recorded locations that are present but erroneous, and therefore a well pad detected in a satellite image might in fact be a true location for a wellbore, even though the wellbore record with the regulator shows a slightly different location. A single missing or rounded thousandth place decimal in one GPS coordinate could move a wellbore about 50-feet off its true well pad. Likewise, many dates recorded on drilling permits and in completion reports may be missing or false. 53.5% of all Texas Permian wellbores have no associated spud date.[1]

In such cases however, the satellite imagery detection is always presumed wrong if it differs from the date or location on the permit or the completion report. Finally, it is difficult to quantify the detection performance for the ML model because even if all true well pads were observed, and even if all permit and wellbore records were correct, some true well pads are simply never permitted or drilled, just as some permits are never drilled. Just because something that looks like a well pad does not have a collocated permit or wellbore does not mean it is not a true well pad, built with a yet-unfulfilled intention of permitting and drilling on it.

[1] Missing permits, location and dates are vastly more common in older RRC records versus recent years. We made no presumptions in our study about probabilities for missing or erroneous regulatory records, we simply excluded any spud or permit that had no associated date or location from the study, and assumed all dates and locations on remaining regulatory records were correct.

4 The fourth purpose of the study was to compare the relative performance of drilling permits versus well pads in predicting spud events, and to see if the combination of a well pad and a permit was a stronger predictor of drilling than either alone.

DWA users always have access to current regulatory records in addition to the satellite intelligence, but conventional market intelligence sources do not provide the enhancement of satellite intelligence and rely on regulatory records alone. Does the addition of satellite intelligence to conventional intelligence provide an advantage to energy market decisionmakers?

As further discussed below, our analysis found that false negatives for both permits and pads in Texas were negligible, but New Mexico permits had a significant false negative rate. False positive rates for permits leading to a spud or pads leading to a spud or permit were almost identical at 80% in Texas, but false positive rates for New Mexico permits were much higher than for DWA well pads detected.

The appearance of a well pad predicted a spud earlier than a drilling permit in about 1/3rd of cases in both states. A drilling permit collocated with a well pad indicated a 14% stronger intention to drill 31 days sooner on median than a permit alone in Texas, and a 53% stronger intention to drill 36 days sooner on median in New Mexico.

METHOD

The sample was constructed using two sources of data: (i) regulatory data for permits and wellbores available from the Texas Railroad Commission (RRC) and New Mexico Oil Conservation Division (OCD) websites, and (ii) European Space Agency Sentinel-2 satellite images, processed by Sourcewater's proprietary machine learning (ML) algorithms. Each well was uniquely identified by API number, which was used to match permits and spud reports from the RRC and OCD.

Well pad detection consisted of several stages. First, Sentinel-2 satellite imagery for the Permian Basin was analyzed by machine learning algorithm to detect well pad boundary boxes. This required building a geospatial data pipeline for downloading and assembling and annotating non-overlapping, edge-matched images of the full Permian Basin from an irregular stream of partial images from the satellites on a five-day cadence and applying various image enhancement methods. Human experts (Geology and GIS students from Texas universities) annotated well pads in tens of thousands of images in a custom annotator, with quality-control review of all images by managers, in order to create the initial ML training sets (Figure 3). External visual and regulatory data sets were also used to train the model. These methods are now the subject of seven granted U.S. patents.[2]

Archival satellite images beginning on March 24, 2017 and up through present were fed through the model, covering the complete Permian Basin every five days. The model outputs were analyzed for Mean Average Precision relative to the training set, and using other methods, and several models were trained, tested, discarded and replaced before we achieved the current level of performance.

Because the boundaries and detected locations of the same well pad could vary over time, whether because of cloud cover obscuring a previously detected pad, or from light, rain or soil conditions or further construction expanding the boundaries of the pad, additional processing matched pads over time to create a single persistent identity for each pad.

The regulatory and well pad detection datasets were merged into a database with one row for each location of a spud, permit or well pad. Permits and spuds with no associated date or location were excluded from the study and probably account for some portion of well pads with no spatial match.

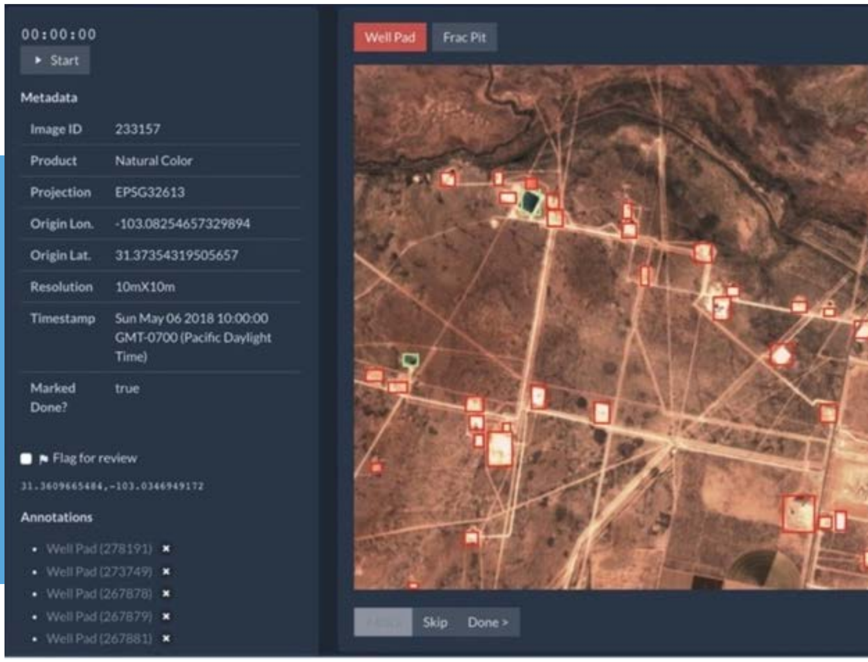


Figure 3: Custom imagery annotation screen

[2] *During the model training we found that experienced, trained geology graduate students achieved an average peak image annotation rate of 5 images per hour, with each image representing a 10 square-mile area at a 10m resolution, and second-pass quality assurance took the same amount of time. At this rate, a company would need a team of 100 people working 8-hours shifts, 7-days per week, without breaks, to review the 100,000 square mile Permian Basin for all new well pads every five days.*

For false positive and false negative analysis, only permits and pads detected in calendar 2018 were analyzed, even though data was available up through August 8, 2020, to leave large buffers of time around the comparison period to capture pads or permits detected prior to spud and spuds occurring or reported after a permit or pad. Some significant amount of time must be allowed after a well pad or permit is detected to allow for the possibility that the well will be drilled before declaring a false positive.

In addition, since spuds dates and locations are released by the RRC up to 150 days after they occur, and by OCD up to 190 days after they occur, additional outside time must be allowed to avoid missing a spud that was drilled but not yet reported. We included spuds reported up through the end of 2019 when matching permits and pads detected any time in 2018.

DISCUSSION & CONCLUSIONS

SUMMARY OF KEY FINDINGS FOR TEXAS

- In the Texas Permian, 100% of spuds reported in 2018-2019 that include a date and a location (n=10,426) were associated with an API-number matched permit. 94.4% were collocated with a spatially matched well pad.[3]
- Well pads preceded spuds by a mean of 150 days and a median of 41 days. Permits preceded spuds by a mean of 96 days and median of 62 days.
- 33.6% (1 in 3) of well pads were detected ahead of the drilling permit submission, by a median advantage of 76 days before the permit in those cases.
- 79.5% (4 in 5) of drilling permits submitted in 2018 led to a spud. 20.5% (1 in 5) of permits filed in 2018 were never drilled (as of December 31, 2019.)

[3] Since all spuds require a well pad, spud locations without matching well pad detections may be caused by detection model failures, by persistent cloud cover, or by errors in the GPS coordinates submitted on drilling permit and completion reports. 16.6% of all RRC wellbores have no reported location – the locations of 193,317 wells in Texas are unknown. Erroneous regulatory location data for spuds and permits may be common, and therefore a significant contributor to spuds seemingly drilled without a well pad. Even a single digit missing or rounded to the thousandth place after the decimal in a GPS coordinate would move the regulatory location of the well far enough from its true location to take it off a correctly located well pad. We did not attempt to identify wellbore or permit records with inaccurate locations, we simply assumed all regulatory locations were accurate, and excluded wellbores and permits that had no regulatory location or date from this study.7-days per week, without breaks, to review the 100,000 square mile Permian Basin for all new well pads every five days.

- 66% (2 in 3) of well pad detections in 2018 led to a spud. An additional 14% of pads led to a permit that was not spudded. Therefore at least 80% of satellite DirtWork Alerts in Texas were true well pads, and the true positive rate for DWA well pads may have been much higher if some permit or spud records had inaccurate GPS coordinates (see footnote.)

- 90.3% of Permits collocated with a pad led to a spud. In other words, a permit with a pad was 14% more likely to be drilled than a permit without a pad after the pad appeared.

- Permits collocated with a well pad led to a spud 31 days sopermits and pads detected any time in 2018

Overall in Texas, the appearance of a well pad predicted a spud earlier than a drilling permit in about 1/3 of cases, and well pads predicted spuds with similar specificity and sensitivity compared to permits, while drilling permits collocated with a well pad indicated a stronger intention to drill a well much sooner than a permit alone.

SUMMARY OF KEY FINDINGS FOR NEW MEXICO

- In the New Mexico Permian, only 93.2% of spuds reported in 2018-2019 (n=2,428) had a matching API-number permit. 6.8% of spuds had no permit record.

- 95.8% of spuds were collocated with a spatially-matched well pad. A person relying only on permit filings to predict new drilling would miss more spuds than a person relying only on DirtWork Alerts (though a DirtWork Alert user would also have access to permits.)

- Well pads preceded spuds by a mean of 165 days and a median of 50 days. Permits preceded spuds by a mean of 158 days and median of 75 days.

- 30.5% of well pads were detected ahead of the drilling permit submission for a spud (26.5% in 2018, 34.2% in 2019), by a median advantage of 100 days before the permit in those cases.

- Only 51.1% (1 in 2) of New Mexico drilling permits approved in 2018 led to a spud. 48.9% of permits approved in 2018 were never drilled (as of December 31, 2019.)

- 65% (2 in 3) of New Mexico well pad detections in 2018 led to a spud. An additional 25% of pads led to a permit that was not drilled. Therefore at least 90% of satellite DirtWork Alerts in New Mexico were true well pads, and a DirtWork Alert was 27% more likely than a drilling permit to lead to a spud. This probably understates the DWA accuracy since some permit and spud records probably have inaccurate GPS coordinates (see footnote).

- 78.4% (4 in 5) of permits collocated with a pad led to a spud. In other words, a permit with a pad was 53% more likely to be drilled than a permit without a pad.

- Permits collocated with a well pad led to a spud 36 days sooner on median than a permit without a collocated well pad (39 days v. 75 days.)

Overall in New Mexico, the appearance of a well pad predicted a spud earlier than a drilling permit in over 1/3 of cases in 2019, and well pad detections predicted spuds with much higher specificity and somewhat higher sensitivity compared to permits alone, while drilling permits paired with a well pad indicated a far stronger intention to drill a well much sooner than a permit alone. Satellite imagery detection of well pads is clearly an important enhancement to regulatory data for energy market participants who rely on early and accurate indications of oilfield activity, particularly in New Mexico.

Returning to our four study purposes, what did we find? In each case we have to consider sensitivity, specificity and timing. Sensitivity is the chance that a future outcome is missed – a false negative. Specificity is the chance that a detected outcome is true – or is not a false positive. Timing in this case is the timing of the outcome after a true event detection.

All of the key outcomes are described in the Key Findings above. With respect to the first question, the permit-to-spud relationship, we found that sensitivity of

permits to spuds in Texas was essentially 100%. Virtually all spuds had a permit. (This was not true until 2010. In prior decades many wellbores lacked permit records.) In New Mexico, however, close to 7% of spuds did not have a permit record. New Mexico permits had a sensitivity of only 93.2% for spuds, lower even than satellite-detected well pads. For specificity, 79.5% of 6,543 Texas drilling permits led to a spud. 20.5% of Texas drilling permits were essentially false leads. But for New Mexico, in what might be the most surprising result of this study, only 51.1% of 2,117 approved drilling permits led to a drilling event. The chance that a New Mexico drilling permit is ever drilled is about 50/50. It turns out that a satellite-imagery detected well pad is 27% more likely to predict a spud than an approved drilling permit.

In Texas, the time distribution from permit to spud, in the 80% of cases where a spud followed, look like this:

Variable	Mean	StdDev	Min	P5	Q1	Median	Q3	P95	Max	N
PermitToSpud	96.0331	106.319	0	12	34	62	115	305	1403	10418

In New Mexico, the time distribution from permit to spud, in the half of cases where a spud followed, look like this:

Variable	Mean	StdDev	Min	P5	Q1	Median	Q3	P95	Max	N
PermitToSpud	158.379	317.926	1	9	34	74.5	179	541	7831	2264

In Texas, permits tend to come before spuds by a range of 34 days to 115 days in the middle quartiles, with a median of 62 days. In New Mexico that variance is much larger. The 25-75 range is 34 days to 179 days with a median of 74.5 days. (Clearly in both cases there may be some defective dates on permits causing some unlikely max numbers, but these few outliers had no significant impact on the median and 25-75 ranges.)

Our second and third big questions relate to the true relationship between well pads, permits and spuds, and the accuracy of our particular detection model. These are different questions, and the second is harder to answer than the first. As discussed earlier, a well pad may exist on the ground, even if our model did not detect it for some reason. We tried to answer the first part of this question by starting with spud locations and working backward in time to pad detections.

Since we know all spuds must physically have a pad, if there were any spuds in our time range for which we did not see a pad, we know this was probably a false negative. 94.3% of 10,426 Texas spuds showed a collocated well pad and 95.8% of New Mexico spuds showed a well pad. This suggests a sensitivity rate of well pad detection of spuds of about 95%. The missing 5% might be caused by persistent cloud cover for a pad built close to the time of the spud, or might be caused by model failures. But in fact, the question is more complicated. As discussed earlier, given the high prevalence of missing information in the permit and wellbore records for both states, it seems likely that some location coordinates on some wellbore records might be at least a little bit inaccurate. A missing or rounded digit in the thousandths place of a GPS coordinate on a wellbore record would be enough to move a wellbore location about 50-feet – even more considering the +/- 10m resolution of the imagery – thereby causing a well pad false negative and a separate well pad false positive, when in fact it was the wellbore record that was incorrect, not a missing or wrong well pad detection. It is entirely possible that all of the ~5% of well pad false negatives were actually the result of slightly erroneous wellbore GPS coordinates, or false-false-negatives, and if so, this would have also added an equal number of well pad false-false-positives. We did not try to assess the accuracy of the GPS coordinates on wellbore records, though this could be an interesting future subject of study.

Anecdotally, it is not unusual for a human to look at wellbore locations overlaid on recent satellite imagery and see dots that are clearly nowhere near any well pad or road. Regardless, it seems that well pad sensitivity of detection for spuds was very high at around 95% – even higher than the 93% permit sensitivity of detection in New Mexico: 100% wells are supposed to have a permit.

We also used only the confirmed spud locations to develop the backward timing from spuds to pads, thereby avoiding any questions about the ML model performance in quantifying this relationship. In this, we finally answered the age-old oilfield question: which comes first, the permit or the pad? Many people express opinions on this question, but as far as we know, no one has ever definitively answered it, until now. The answer is, in both Texas and New Mexico, about 1 in 3 well pads for confirmed spuds are detected before the drilling permit is made available from the RRC or OCD. This ratio is probably a little higher in reality on the ground, because our satellite image processing relies on 5-day imagery cadence and clear skies. Some pads are might have been detected up to five days after they were built because of the cadence, and some pads were detected long after construction because of extended cloud cover. Of equal note is that when a pad is built before the permit is available, it tends to be built a long time before the permit is available. The median of pad-before-permit in Texas is 76 days, and in New Mexico it is 100 days.

In Texas, the time distribution of pads that came before collocated permits for a spud looks like this:

Variable	Mean	StdDev	Min	P5	Q1	Median	Q3	P95	Max	N
DWA Detection to Permit	309.965	400.131	0	2	15	76	545	1189	1482	3303

In New Mexico, the time distribution of pads before permits looks like this:

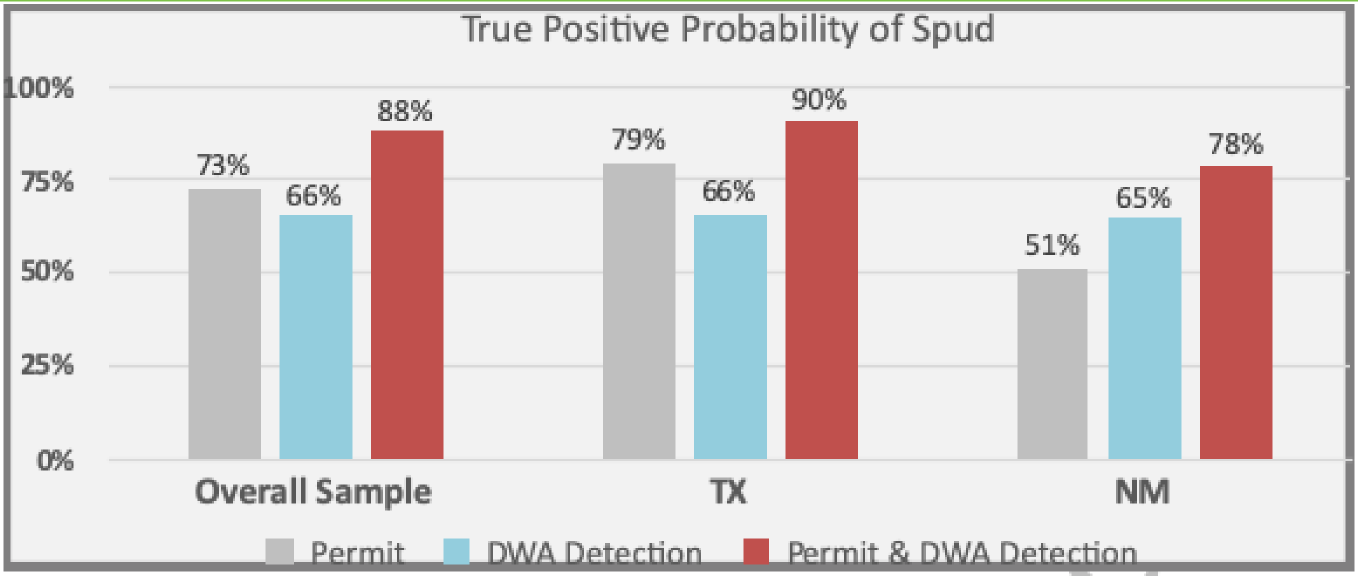
Variable	Mean	StdDev	Min	P5	Q1	Median	Q3	P95	Max	N
DWA Detection to Permit	306.132	380.885	0	2	18.5	100	493	1147	1473	660

With regard to specificity of well pad detection of spuds, we are limited by the ML model performance, because there is no way to know definitively if we failed to detect a well pad, since there is no ground truth for well pad locations. There are no regulatory records for comparison. What we found is that in both states, about 65%, or 2/3rds (65.7% in TX, 64.8% in NM) of well pads preceded a spud in the same location during the study period. The consistency of both specificity and sensitivity for detected well pads across state lines makes sense, since well pads look the same on the ground regardless of the state. The same companies are doing the same sitework on both sides of the state line. Although 2/3rds of presumed well pads led to a spud, that does not mean that the other 1/3rd were not true well pads.

These other 1/3 might have been pads that were never drilled, just as many permits are never drilled. Or they might be other types of oilfield dirtwork, such as for a frac pit or a central processing facility or an equipment yard. Or they might be sitework for non-oilfield construction, such as a home lot. Or they might be some other pad-like feature, such as a road intersection, a harvested field, a surface mine, or just erosion. Or, as discussed above, these might be true well pad locations that were indeed drilled, but the location reported on the drilling permit or wellbore was erroneously different from the true GPS coordinates of that wellbore to the thousandth place or more.

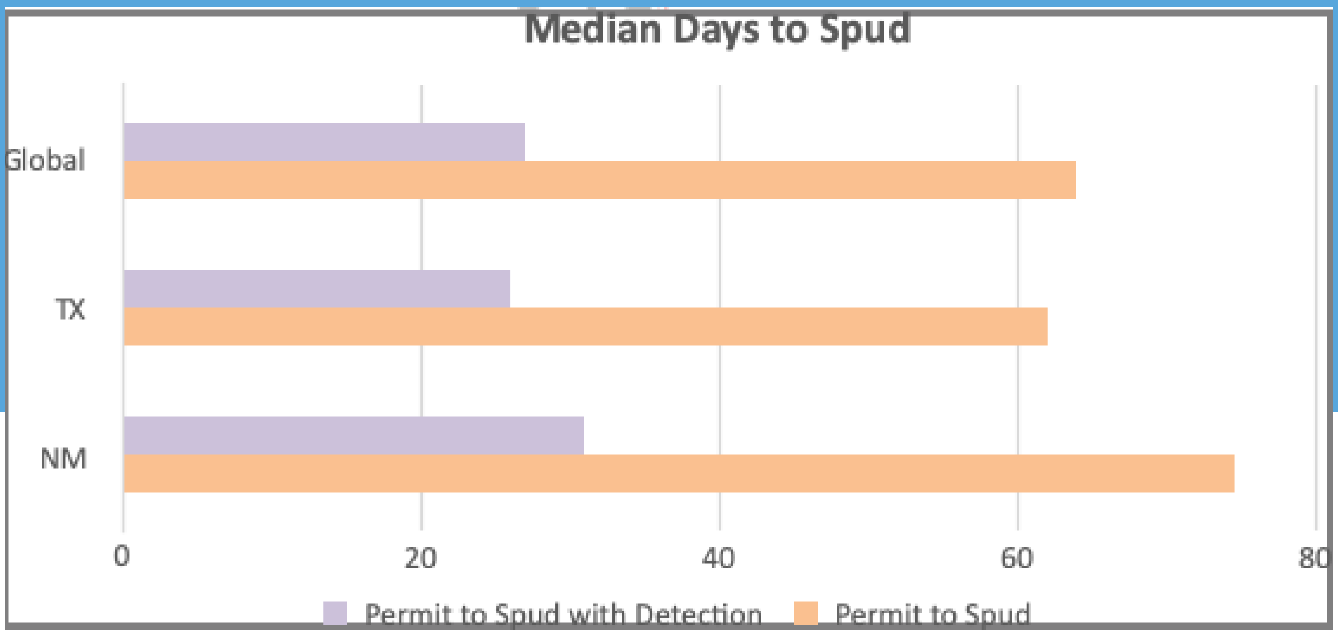
We gain a better understanding of the ML model accuracy by overlaying undrilled permit locations. What we find form this is that an additional 14.1% of DirtWork Alert presumed pads in Texas also had a collocated undrilled permit, and an additional 25.1% of DWA pads had a collocated undrilled permit in New Mexico. This means that at bare minimum, 80% of DWA ML model detections in Texas had to be true oil and gas well pads on the ground, and 90% of DWA ML model detections in New Mexico had to be true well pad detections on the ground. Considering how many other activities on the ground in these areas look like sitework for new oil and gas wells, this specificity outcome seems quite good – particular considering only 80% of Texas permits become spuds and only 50% of New Mexico permits become spuds.

Moreover, one of the key values of the DWA system is not just to predict specific drilling events – it is to alert energy market players that a potential customer, competitor or neighbor is preparing to drill on their lease. An early detection on a dormant lease of roadwork or of a dirtwork site that is not specifically for a new oil well could have just as much value for this purpose as an exacting detection of a new oil well pad.



Our final big question was whether adding satellite-imagery detected well pads might enhance the results of conventional regulatory intelligence. In other words, are pads plus permits better than permits alone. One clear example of this benefit is the fact that about 1/3rd of spuds are predicted earlier by the appearance of a well pad than by the publication of a permit. Companies that rely on early determination of drilling plans, such as mineral investors, offset operators planning for frac hits and oilfield service companies seeking early bidding opportunities all have a strong interest in this material edge.

But a second interesting advantage of adding the satellite intelligence is our finding that drilling permits are much more likely to be drilled, and drilled much sooner, once a well pad is detected in the same location as the drilling permit. In Texas, only 79.5% of drilling permits are ever drilled, but when a well pad is detected in the same location as an existing undrilled permit, the odds that the permit will be drilled increase by 13.7% to 90.3% in Texas, and by 53.3% to 78.3% in New Mexico. Moreover, permits are drilled much sooner once a well pad appears, moving from 62 days to 31 days in advance on median in Texas and from 75 days to 39 days on median in advance in New Mexico. In other words, someone whose business depends on placing timely bets on which oil and gas wells will be drilled and how soon they will be drilled benefits tremendously by adding well pad detections to drilling permit data, especially in New Mexico.



PRODUCT

All data and results in this study can be accessed through Sourcewater's DirtWork Alert cloud-based geospatial intelligence platform. DirtWork Alert scans satellite imagery of the full Permian Basin every 5-days to identify every new well pad and frac pond, reaching back to early 2017, and contextualizes this satellite intelligence with extensive, quality-assured regulatory data. Some of the data gathered in the platform is listed below:

Proprietary Data Coverage

Satellite Imagery / DirtWork Alert

Permian Basin well pads, weekly

Permian Basin frac ponds, weekly

Permian Basin flares, weekly

Global satellite imagery, weekly, back to March 2017

Public Regulatory Data Coverage

Oil & Gas Permits, Wellbores & Infrastructure

Oil & gas drilling permits, wellbore statuses, daily

Allocated production of oil, gas & water, monthly

Crude oil & natural gas pipelines

Wellbore locations & operators, 22 U.S. states

Water Activity & Infrastructure

Produced water transfers mapped between producing leases and SWDs, monthly (P-18s)

1,700+ water midstream pipelines

1,000+ market prices for water & disposal

SWD Pre-Permit Alert Legal Notices, daily

Drilling rig locations, weekly

Subsurface Insights

Active injection intervals and true formations of injection for all Permian injection and disposal wells.
1,783 Permian geologic fault lines mapped

Oilfield Water & Disposal

Disposal & injection well pressures, volumes and capacity utilizations, monthly

Permitted injection intervals & formations

Disposal well permit statuses

Seismicity events, daily

Water treatment facilities

Injected completions water

Groundwater well locations, depths, flow rates, quality reports

Complete land parcel ownership, TX & NM

Other Water & Land Data

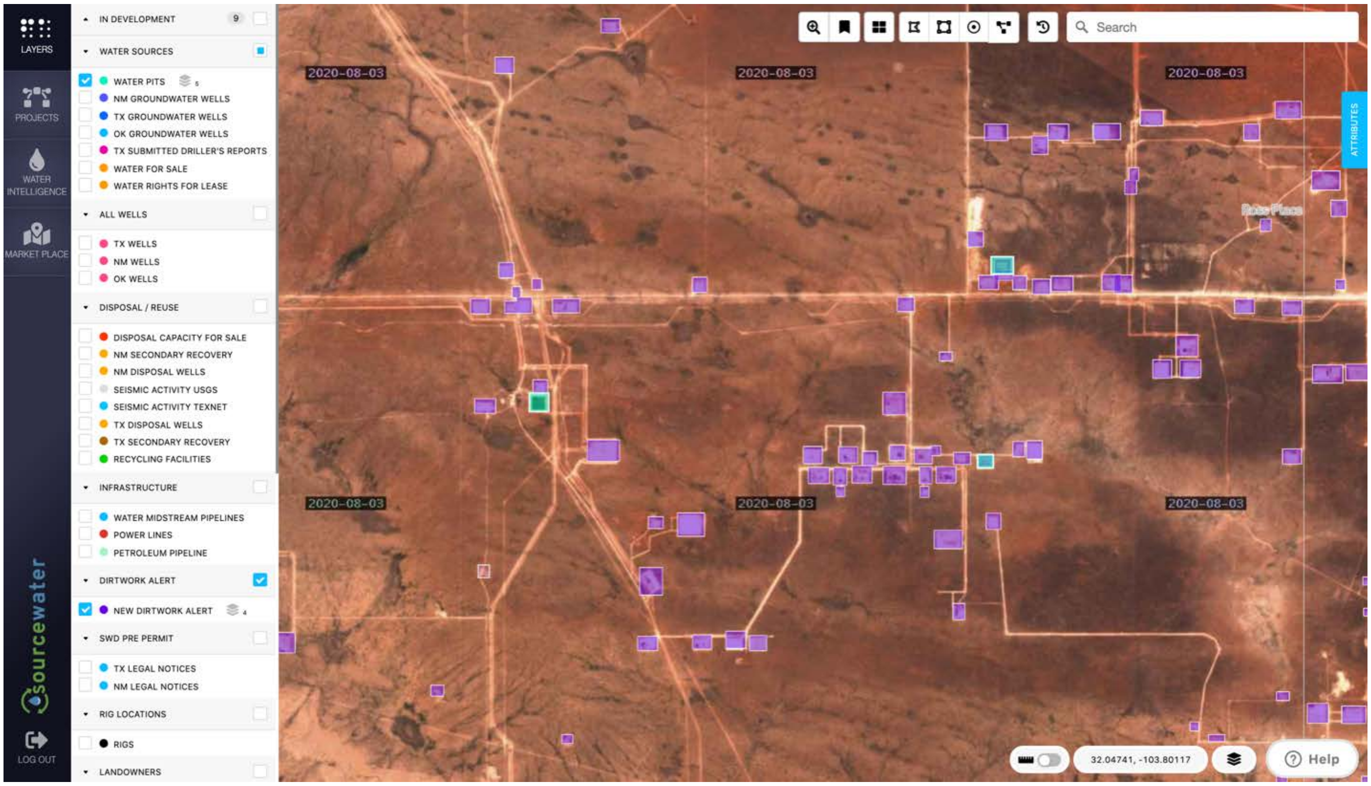
Power grid

PLSS Land Survey

Groundwater basins & districts

Aquifers

An example screen of the DirtWork Alert Interface is shown below:



ABOUT SOURCEWATER, INC.

Sourcewater, Inc. (www.sourcewater.com), is the technology leader in holistic upstream energy intelligence. Sourcewater launched from MIT's Energy Ventures program in 2014 as the first online marketplace for water. Today, Sourcewater gathers, analyzes and visualizes omnichannel data in the industry's best geospatial intelligence platform to show oilfield activity earlier, more completely and more accurately than any other source.

Our data science innovations combining satellite imagery AI/ML, mobile GPS tracking and regulatory big data infrastructure have earned nine U.S. patents with more pending. Sourcewater has been honored by IHS CERAWeek as an Energy Innovation Pioneer, by Frost & Sullivan as Enabling Technology of the Year, by the Oil & Gas Awards as New Technology of the Year, and by Tudor Pickering Holt as an Energy Disruptor.

FOR FURTHER INFORMATION ABOUT THIS STUDY, SOURCEWATER OR DIRTWORK ALERT PLEASE CONTACT:

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