Investigating Oversight of Oil and Gas Drilling in New Mexico

Well pads in Navajo Lake State Park, NM (Google Earth)

Technical Appendix to Investigating Oversight of Oil & Gas Development in New Mexico

UCLA IoES

WildEarth Guardians
A Force for Nature

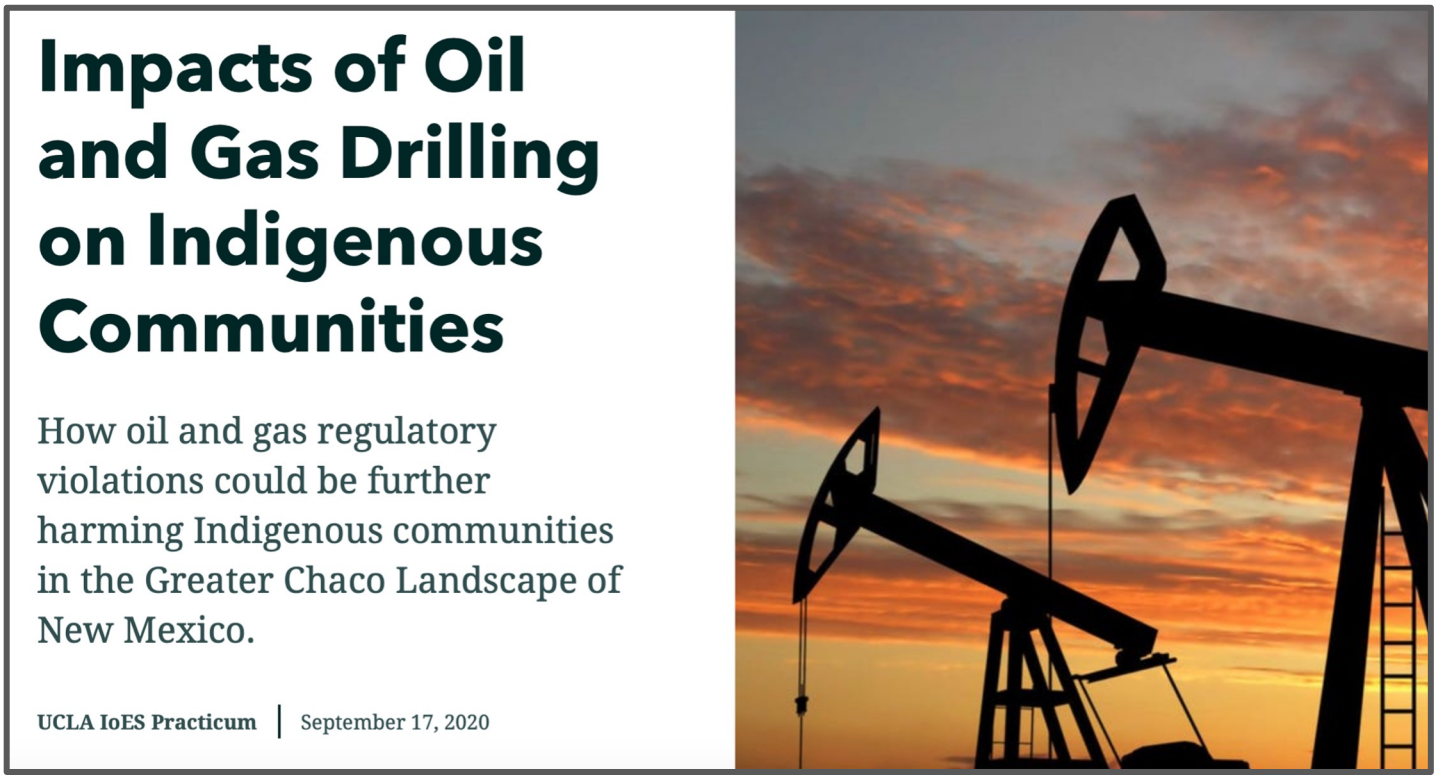
Purpose

The purpose of this technical appendix is to detail the analysis performed by a team of environmental science students in the Institute of the Environment and Sustainability (IoES) at the University of California, Los Angeles as part of the 2020-2021 Environmental Science Practicum. The technical appendix will cover the following topics:

This technical appendix will not cover the specific code required to perform the analysis, but rather the overarching methodology and outcomes. The complete set of data and code is available on the UCLA New Mexico Google Colab.
All question regarding the analysis should be directed to ioes.nm.fl@gmail.com.

Recognition of 2019-2020 Practicum Team

We would like to recognize the work of last year's team: the 2019-2020 IoES New Mexico Practicum Team. The 2019-20 team began this investigation into oil and gas well drilling in New Mexico with an analysis of permitting in the San Juan Basin. We were able to use their Python code, analysis from their final report, and details from their technical appendix to expand upon their investigation of potential permitting violations in the San Juan Basin. We have directly incorporated some sections of their work from the 2019-20 project here, including in the "Python Packages," "Expanded Analysis of Wells and Facilities in San Juan County," and "Justification for Permitting Violations" sections of this technical appendix. We also expanded on their work by including an analysis of the Permian Basin in southwestern New Mexico. We appreciate the work they've done, and wish to thank them for allowing us to use their previous Python code and technical appendix layout.



Python Packages

The majority of the San Juan Basin analysis was performed using Python 3.8.3. Performing the analysis in Python ensures that the process is highly reproducible and can be easily updated as new data becomes available.

The following analysis calls upon many of Python's standard data science packages. The most crucial of which were Pandas, NumPy, Matplotlib, and Scikit Learn. In addition to these standard packages, it was also necessary to use geospatial packages such as Geopandas and Fiona to read and process geospatial data. Documentation for the most prominent packages can be found below.

- Pandas
- NumPy
- Matplotlib
- Scikit-learn
- Geopandas
- Fiona

Legal Background

The New Mexico Environment Department (NMED), is responsible for administering the Clean Air Act (CAA) and enforcing CAA air quality standards in the state (NMED, n.d.), including issuing any required permits under Title V of the Act. NMED's regulatory authority stems from the New Mexico Environmental Improvement Act, the Air Quality Control Act, and its EPA-approved State Implementation Plans (SIPs). Under Title V of the CAA, oil and gas operators must submit a Notice of Intent (NOI) prior to beginning any construction on a facility that has the potential to emit more than 10 tons per year of a regulated pollutant (42 U.S.C. §7661(a); 42 U.S.C. §7412(a)(1)). NMED will then provide the operator with CAA permits or exemptions. Only after receiving a permit or exemption can facilities begin to build their infrastructure.

Our team interprets facility infrastructure to include the drilling of new wells, as each is dependent on the other – wells must have a facility to process the oil and natural gas, and facilities have no function without the products from wells. Thus, a facility would be in violation of the CAA if the well or wells supplying the facility are drilled prior to the facility operator's receipt of a CAA permit or exemption. However, since the drilling of wells is regulated by a separate department than the permitting for facility construction that releases emissions, it can be difficult to determine whether an operator begins drilling a well prior to obtaining a CAA permit or exception for a facility.

Well and Facility Data Sources

The data required for this analysis was primarily obtained from the NMED and the New Mexico Oil Conservation Division (NMOCD). The NMED has information including the location, emissions, and some permitting information of facilities. The NMOCD has information for wells including their location, operating company, and the dates of major events such as spudding. Wells are a component of the construction of a facility; they are the location of the actual drilling, with the natural gas or oil then piped to a facility.

Facility Information

- Location
- Name
- Unique ID
- Emissions
- Permitting Dates

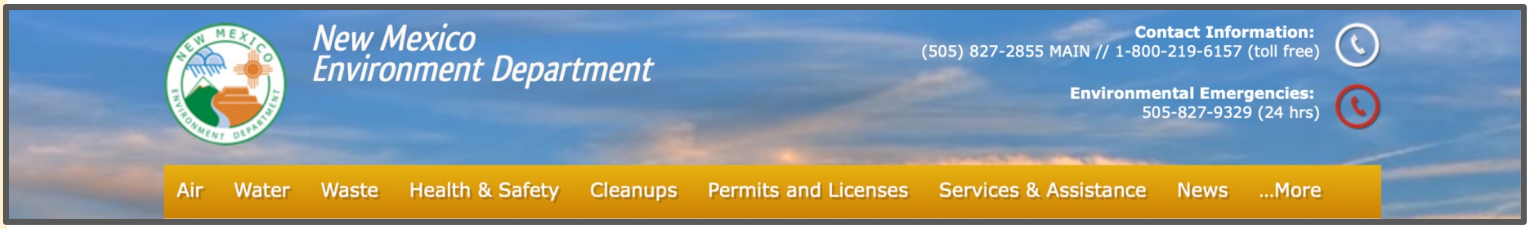
Well Information

- Location
- Name
- Unique ID
- Dates of major events (Spud, violations)

The New Mexico Oil Conservation Division

The NMOCD has a geospatial dataset of all the wells in New Mexico that is updated biweekly. The dataset is available for download on the NMOCD FTP website. The dataset is located under the Geodatabase folder. The NMOCD also provides metadata on the dataset as well as updates on the status of the FTP site.

The New Mexico Environment Department



The NMED maintains a monthly-updated running list of permitted facilities across New Mexico. The dataset is stored as an Excel file and is located on the "Current Permitting Activities" page on the NMED website. Although the provided data includes facilities from all industries, the analysis for this project only focused on oil and gas facilities.

While the NMED dataset of facilities provides information such as the location and emissions of individual facilities, it fails to include complete information about the facility permits, including the date permits were deemed complete. In order to obtain permitting information about each facility, it was necessary to file a Public Records Act (PRA) request for specific facilities with the NMED. This step will be covered in greater detail later in the analysis.

Expanded Analysis of Wells and Facilities in San Juan County

Our team sought to expand on the analysis performed by the 2019-2020 practicum team. To do this, we first began by conducting a review on these following three questions, to gain a stronger understanding of oil and gas development in San Juan County, New Mexico.

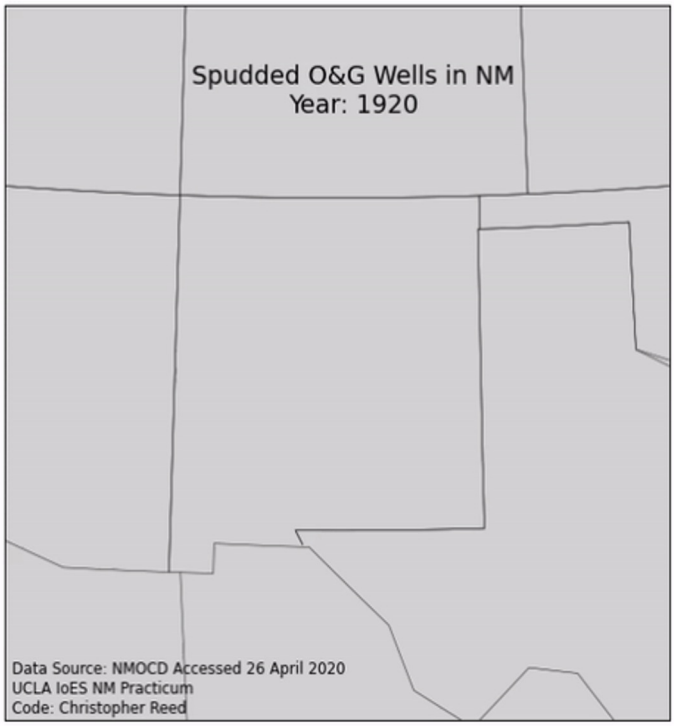
How extensive is the development of oil and gas wells across New Mexico? San Juan County?

What is the trend in the number of oil and gas wells beginning operation (spudding) across New Mexico? San Juan County?

What operating companies are responsible for the most oil and gas wells spudded in San Juan County since 2010?

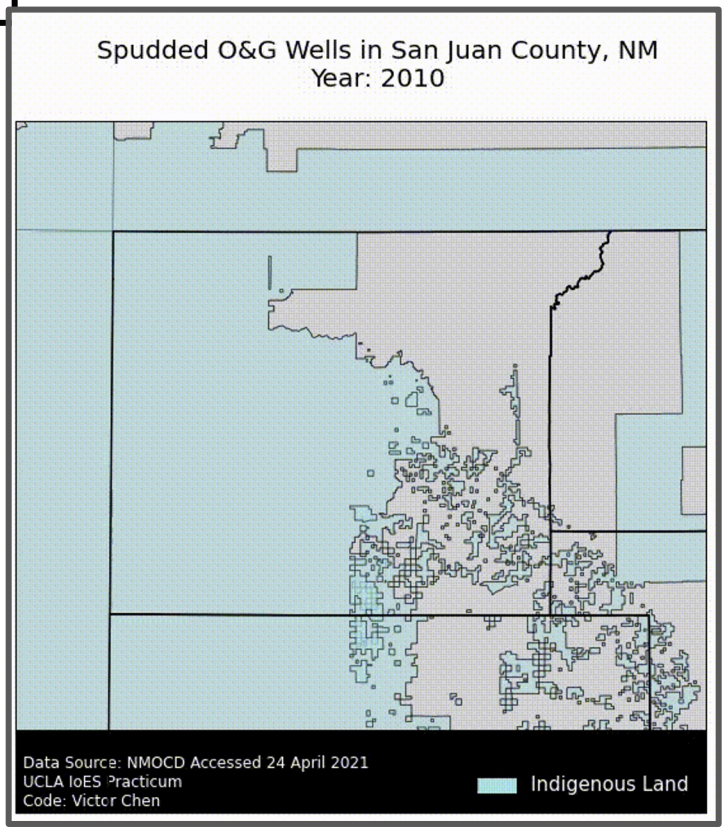
The code required to answer these questions is provided in the Google Colaboratory Notebook located in the GitHub repository. The following figures depict the final outcome used to answer the above questions.

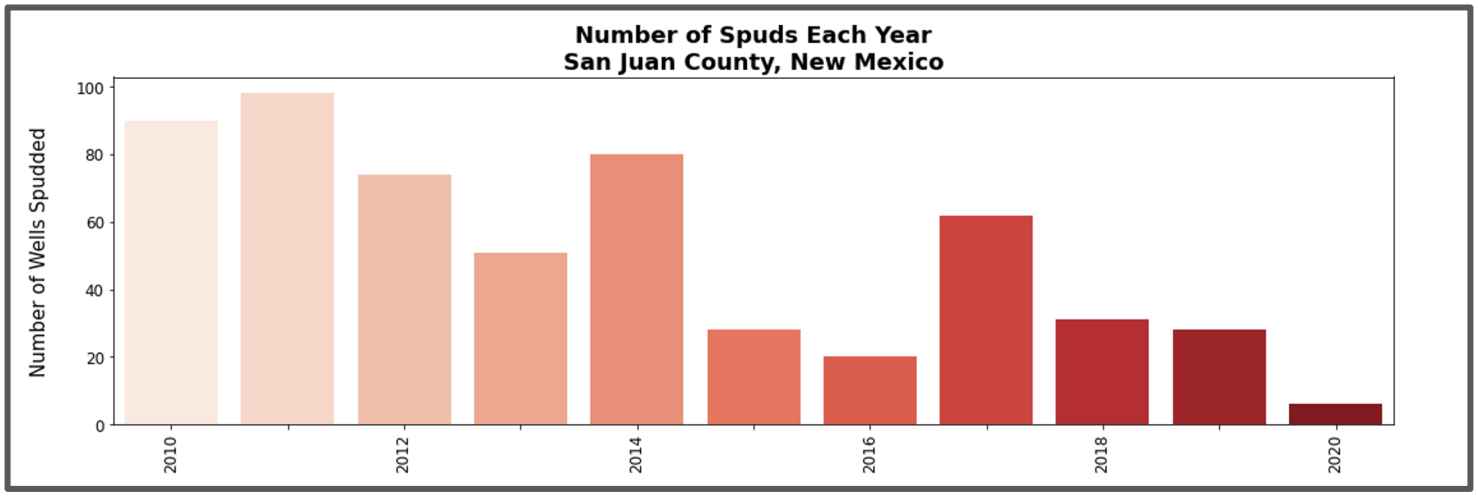
Expanded Analysis of Wells and Facilities in San Juan County



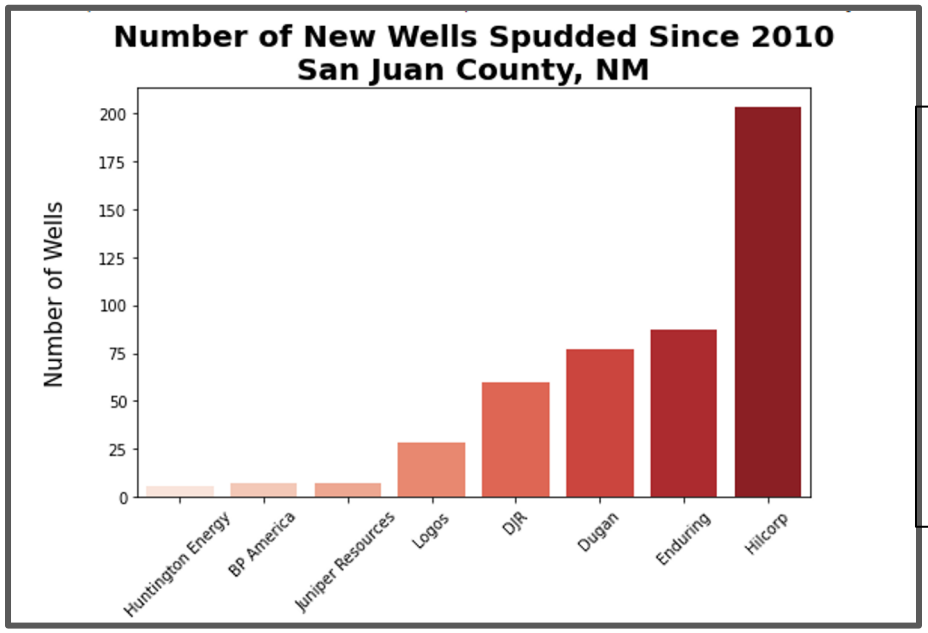
There has been extensive growth of oil and gas wells across New Mexico since 1900. There are two primary regions of development: the San Juan Basin, located in the northwest, and the Permian Basin located in the southeast. This project focuses on San Juan County in northwest New Mexico, as well as the Permian Basin. The map to the left was created by Christopher Reed of the 2019-20 Practicum Team.

As visualized in the plot to the right, a large portion of wells drilled in San Juan County during the past decade have been located on the eastern side of the county. Many of the wells spudded are close to or within designated indigenous lands, which potentially poses health issues for communities in these areas.





The plot above visualizes the number of oil and gas wells spudded in San Juan County each year from 2010 to 2020. There has been a general decline in wells drilled outside of a peak in 2017. The decline in wells spudded may be due to increased opportunities in the Permian Basin.



Company Abbreviation Reference

Hilcorp: Hilcorp Energy Company

Enduring: Enduring Resources, LLC

Dugan: Dugan Production Corp

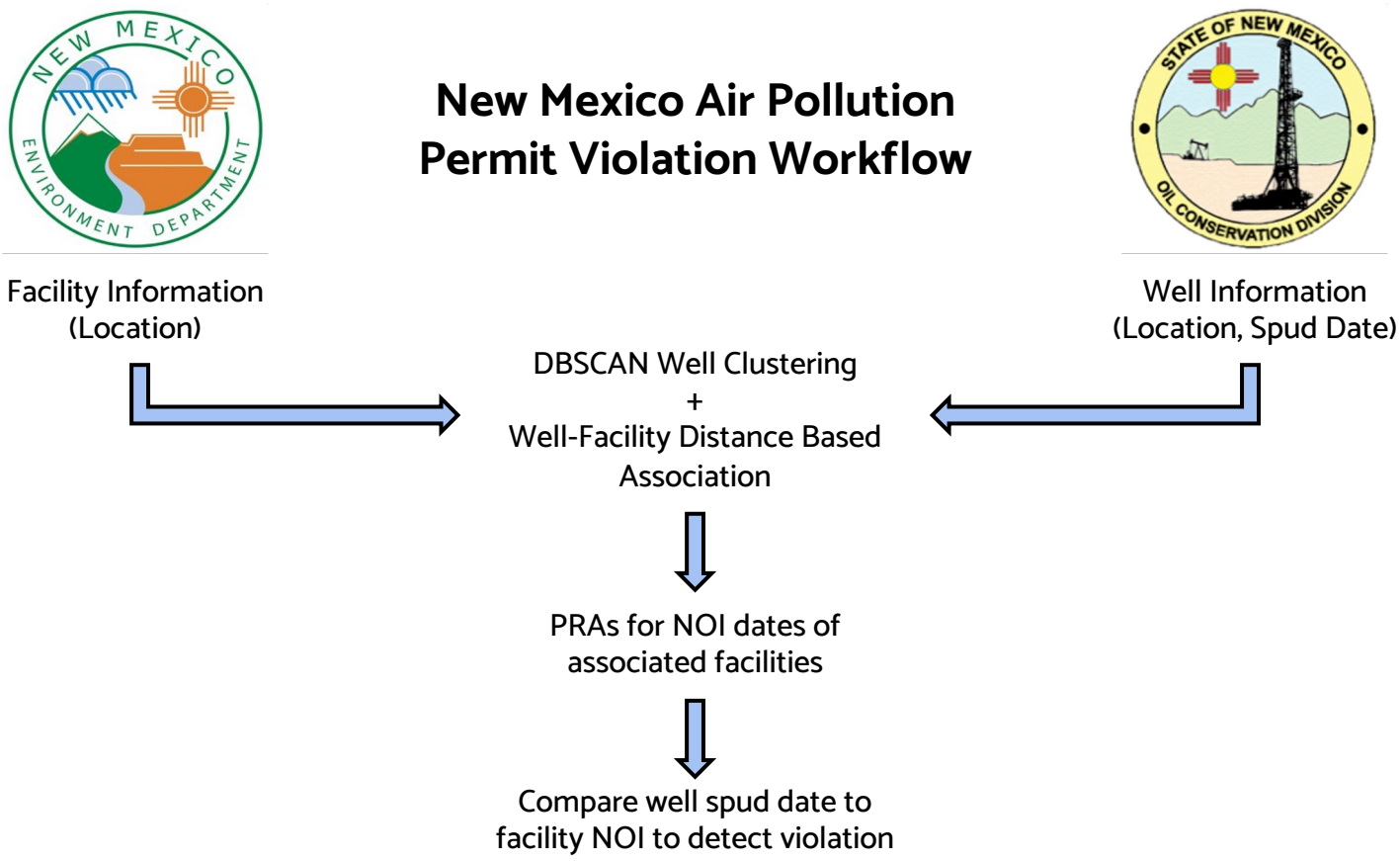
DJR: DJR Energy

Logos: Logos Resources

In order to determine which wells to focus on within San Juan County, we reviewed the number of wells spudded by different companies in the county since 2010. Hilcorp Energy Company leads in wells drilled by more than double the next most prominent company in the area. Enduring Resources, Dugan Production Corp, and DJR Energy have drilled over 50 wells each.

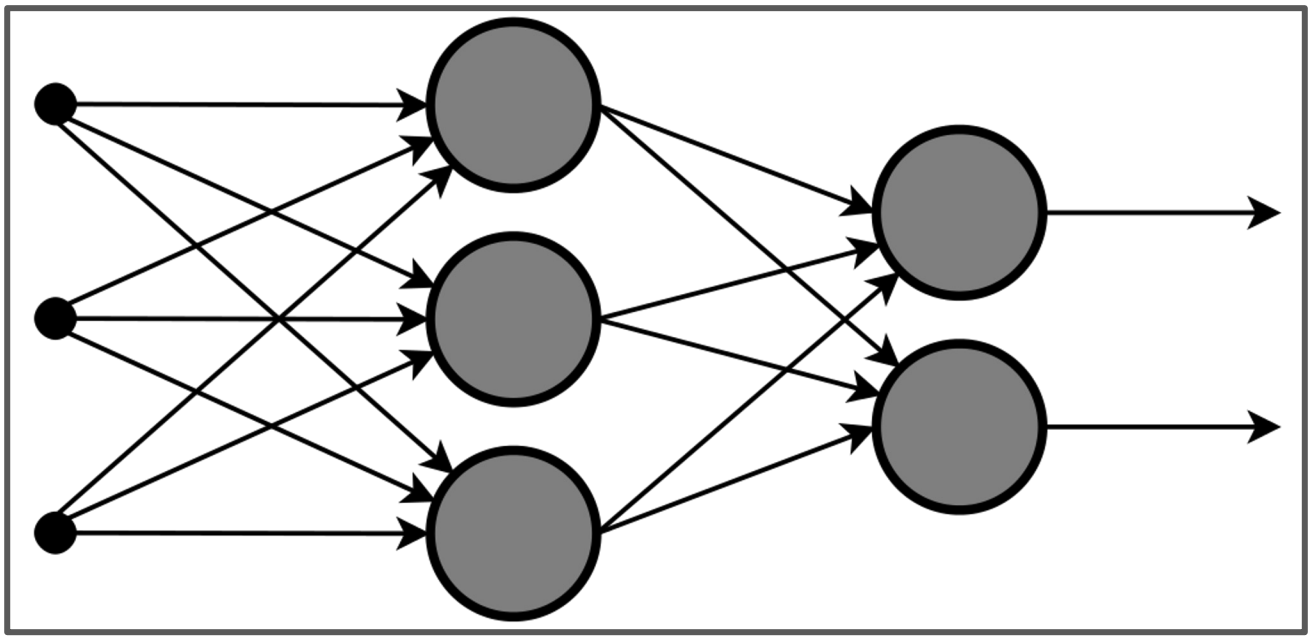
Well Clustering and Facility Association

The following workflow was developed in order to join oil and gas wells to supporting facilities.



The joining between the NMED and NMOCD data occurs through a process best described as DBSCAN Well Clustering and Well-Facility Distance Based Association. In essence, the process rules that a facility that is close to a dense cluster of wells is likely associated with all the wells in that cluster.

DBSCAN stands for Density Based Spatial Clustering of Applications with Noise. DBSCAN is an unsupervised machine learning classification algorithm that clusters points together based on density as illustrated below.



In terms of its geospatial applications, DBSCAN is particularly effective at handling irregular cluster shapes as is the case with oil and gas wells. Oil and gas wells are typically arranged in a loose pattern on a well pad which DBSCAN can detect and cluster together. The result of DBSCAN is one representative point for each well cluster.

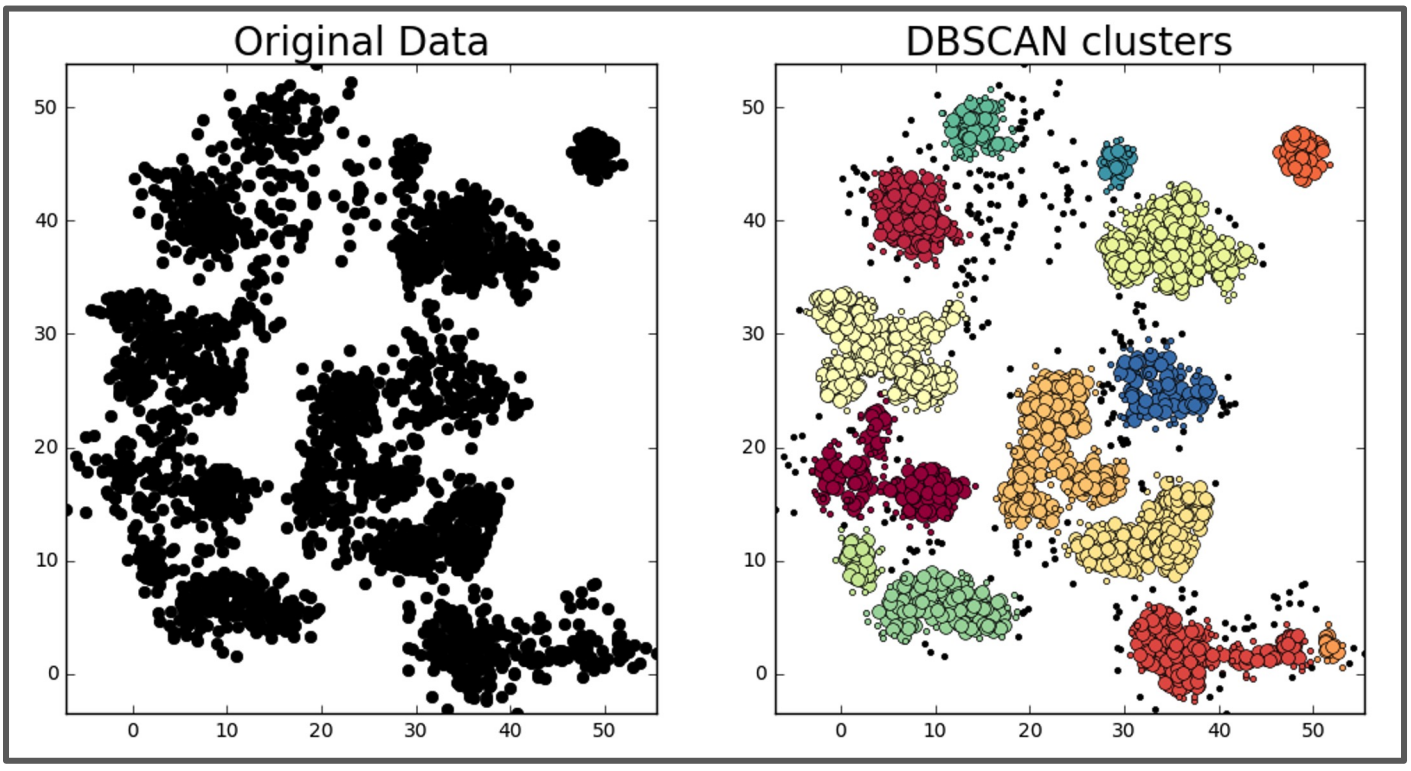


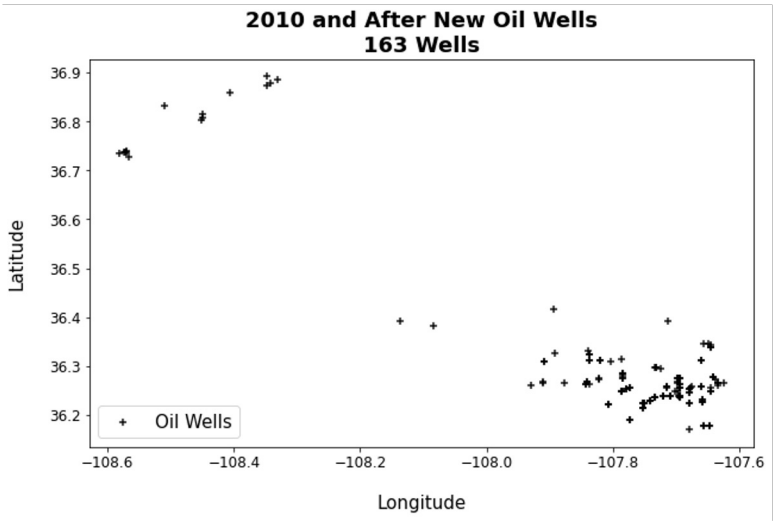
Image from Chris Wernst

Identifying clusters of wells is crucial because it decreases the number of data points for subsequent analysis. Although the dataset used in this project is manageable without DBSCAN, to expand this analysis to the roughly 120,000 wells across New Mexico it would be critical to minimize the size of the dataset.

DBSCAN requires two input parameters to function: the minimum number of points in a cluster and the maximum distance between two samples for one to be considered “in the neighborhood” of the other. Due to the potential for new well pads to only have one well on them, the minimum number of points in a cluster was set to one. The distance between samples was set to 200 meters based on inspecting a representative distance between wells on a well pad and the distance between well pads in San Juan County using ESRI satellite imagery.

The following pages illustrate the end-to-end process of associating wells and facilities, and subsequently detecting potential permit violations. For simplicity, the visualizations only depict oil wells, but similar visualizations for gas wells can be found in the Google Colaboratory notebook and in this project’s repository.

STEP 1: Visualize wells



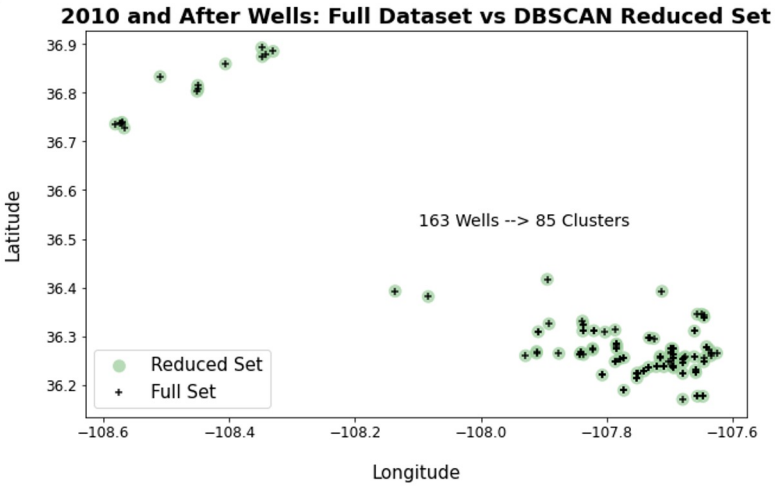
San Juan County Oil Wells

Victor Chen

The following steps highlight only the process for oil wells.

The first step of the analysis involves visualizing the distribution of wells. There are a total of 504 active oil and gas wells that have been spudded since 2010 in San Juan County, of which 163 wells are for oil production. On the simple plot with no satellite imagery at top left, many of the wells are in close proximity and appear to overlap at the given resolution. The satellite image on the right shows a zoomed in visual of multiple oil wells on a single pad. The dots representing oil wells are still in close proximity to each other at this scale, causing them to overlap.

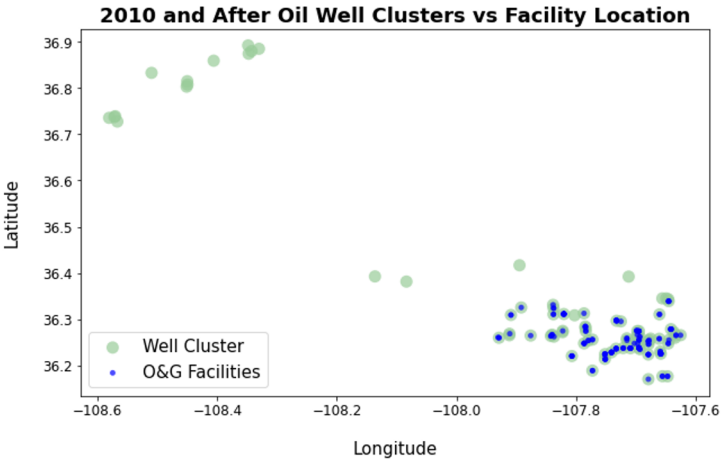
STEP 2: Identify Well Clusters



Victor Chen

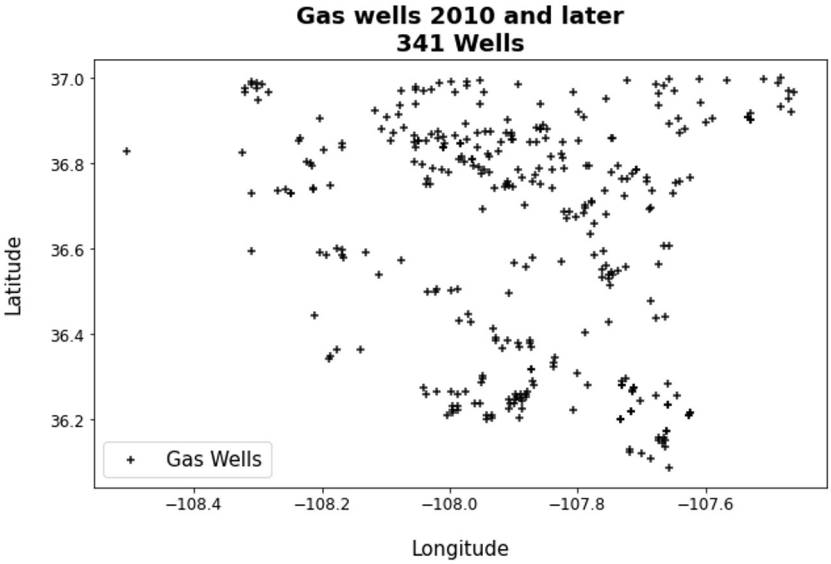
The second step of the analysis applies DBSCAN to reduce the number of datapoints. DBSCAN is able to detect the well clusters - a group of wells on a well pad - and associate all individual wells in a cluster with a unique cluster label. The minimum number of wells in a cluster is one. The maximum number of wells in a cluster is unrestricted - as long as the wells are located within 200 meters of each other, they will be clustered together. In this subset of data, 163 wells were reduced to 85 clusters. The centroid of each cluster is found by averaging the longitude and latitude of all the wells in the cluster. The advantage in clustering instead of performing an operation, such as calculating distance from nearby facilities, with all 163 wells is that the distance from all 85 representative clusters to each facility can be calculated.

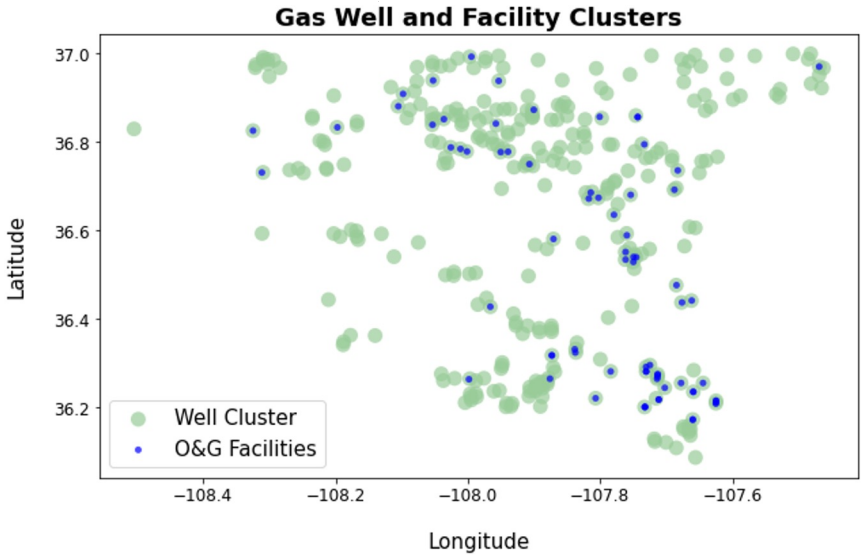
STEP 3: Visualize Facilities



The next step in the analysis is to visualize oil and gas facilities in close proximity to a cluster. As noted earlier, there is no data that directly links facilities to wells. A facility was calculated to be likely associated with a well or wells if it was located within 200 meters of the well. It is possible that associated facilities can be located farther than 200 meters away from wells, but expanding the search radius beyond this radius risks including false positive associations. Overall, we considered 852 facilities in San Juan County, which were selected based on their proximity to all of the oil and gas wells considered in the analysis. We ultimately paired 58 oil well clusters were with 63 facilities.

Final Well to Facility Pairings





A total of 341 gas wells and 163 oil wells (504 total wells) were considered for this portion of the analysis. The 341 gas wells were grouped into 319 clusters. Of the 319 clusters, we were able to pair 62 gas well clusters with 62 facilities. (As mentioned in the previous page, 63 facilities were paired with 58 oil well clusters.) However, when concating the gas and oil well clusters and their facility pairings, some of the 125 facilities overlapped. Therefore, when duplicate facilities are removed, a total of 117 unique facilities were paired with 120 oil and gas well-clusters.

Cumulatively, 207 of 504 oil and gas wells were paired with 125 facilities.

Once wells and facilities were clustered under the analysis, we then requested Notice of Intent (NOI) documents from NMED for all facilities receiving a permit between 2010 and 2020. This was done to compare the spud dates of all wells in the identified clusters against the NOI permit issue date for their associated facility.

Rather than transmitting the NOI documents directly, NMED instead sent the data from the NOIs in a Microsoft Excel spreadsheet, including NOI approval dates, enabling easy Python code implementation. The NOI issue dates were compared with spud dates in well-facility pairs. If the spud date of an individual well occurred before the listed facility permit issue date, the well-facility pairing was marked as having potential violations.

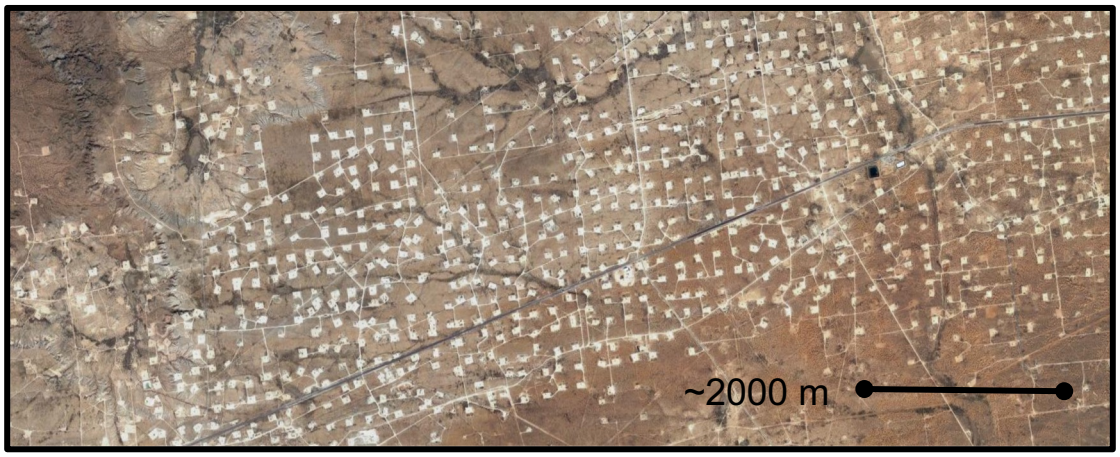
Analysis of Drilling in the Permian Basin

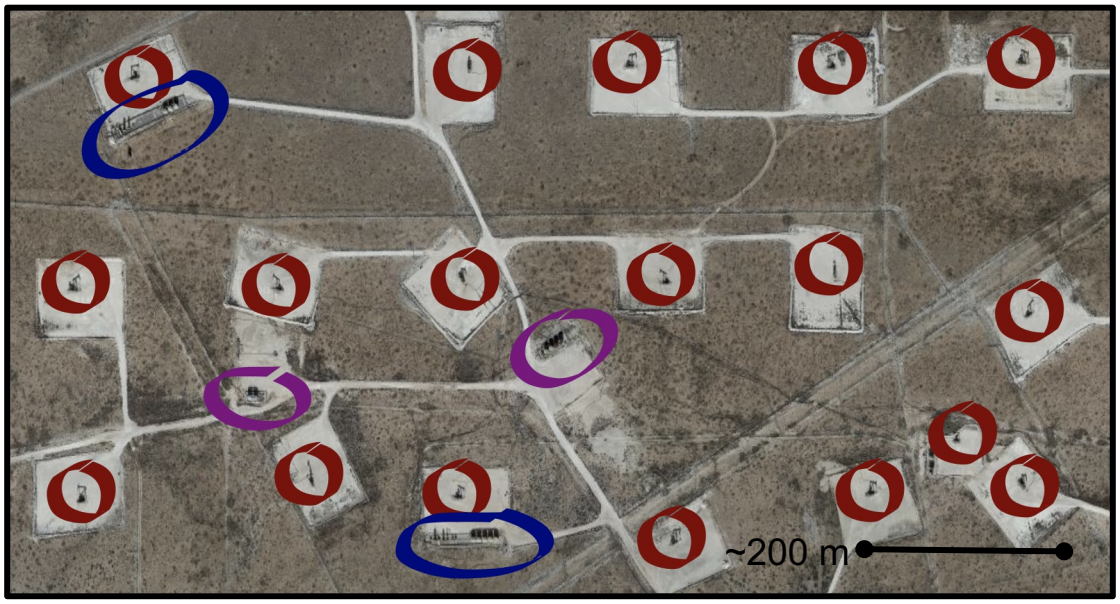
In addition to expanding the project's San Juan Basin analysis, we also attempted to determine whether potential permitting violations were occurring in the Permian Basin, located in the southeastern part of New Mexico. The layout of Permian Basin oil and gas development differs significantly from that in the San Juan Basin. Rather than multiple wells on a single well pad, the vast majority of well pads in the Permian Basin contain only a single well. Facilities may be located on a pad with a single well, but many pads contain only a well, with facilities then interspersed among separate pads. Well pads are generally laid in a grid-like pattern, in which wells could be located roughly equidistantly from more than one facility. Storage tanks were also dispersed in a non-orderly pattern throughout. We attempted to pair wells with facilities through several different methods. The approaches are outlined below,

1. Permian Basin Python Script
2. Naming Conventions
3. County, Type, Date, Ownership

Spatial Layout of Permian Basin

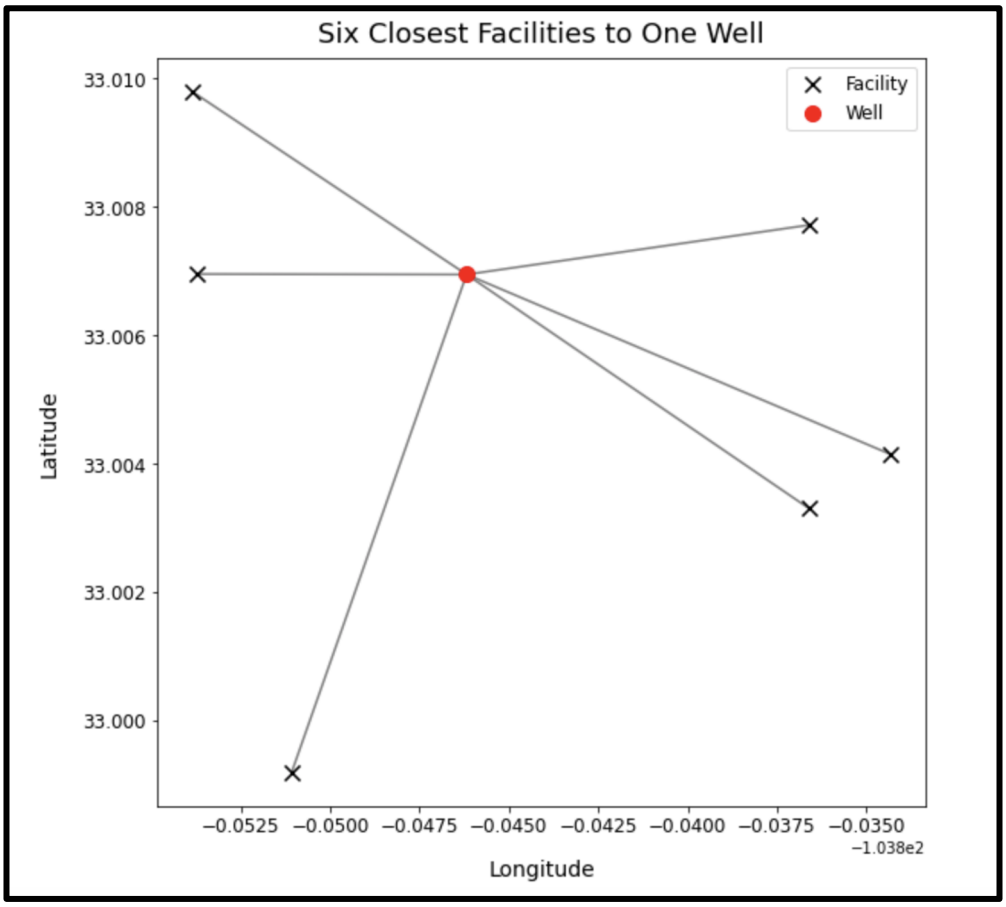
The aerial photos below show the grid-like layout of oil and gas development of the Permian Basin, as well as the spacing of wells, storage tanks, and other facilities.





As stated above, unlike the San Juan Basin, well pads in the Permian Basin rarely contain multiple wells and a permitted facility. The aerial photo of the Permian Basin above shows, at finer scale, single wells circled in red, facilities circled in blue, and storage tanks circled in purple.

Approach 1: Python Script



The first step of the analysis for the Permian Basin was to attempt to tie wells to facilities by using the same Python script we used for the San Juan Basin, with several small modifications for the change in county. For example, the Permian Basin code attempts to pair a well with a facility if it is located less than 500 meters away. However, many of the wells we assessed are relatively equidistant from multiple facilities, which rendered it difficult to definitively assess which facility a well in this scenario was associated with, assuming it could be definitively declared to be associated with any of them. The image above is a visualization of six facilities paired to one well, with their coordinates. Five of the six would be considered close enough to potentially pair, demonstrating that a distance-based approach is not reliable. Therefore, this method did not yield definitive results.

Approach 2: Naming Conventions

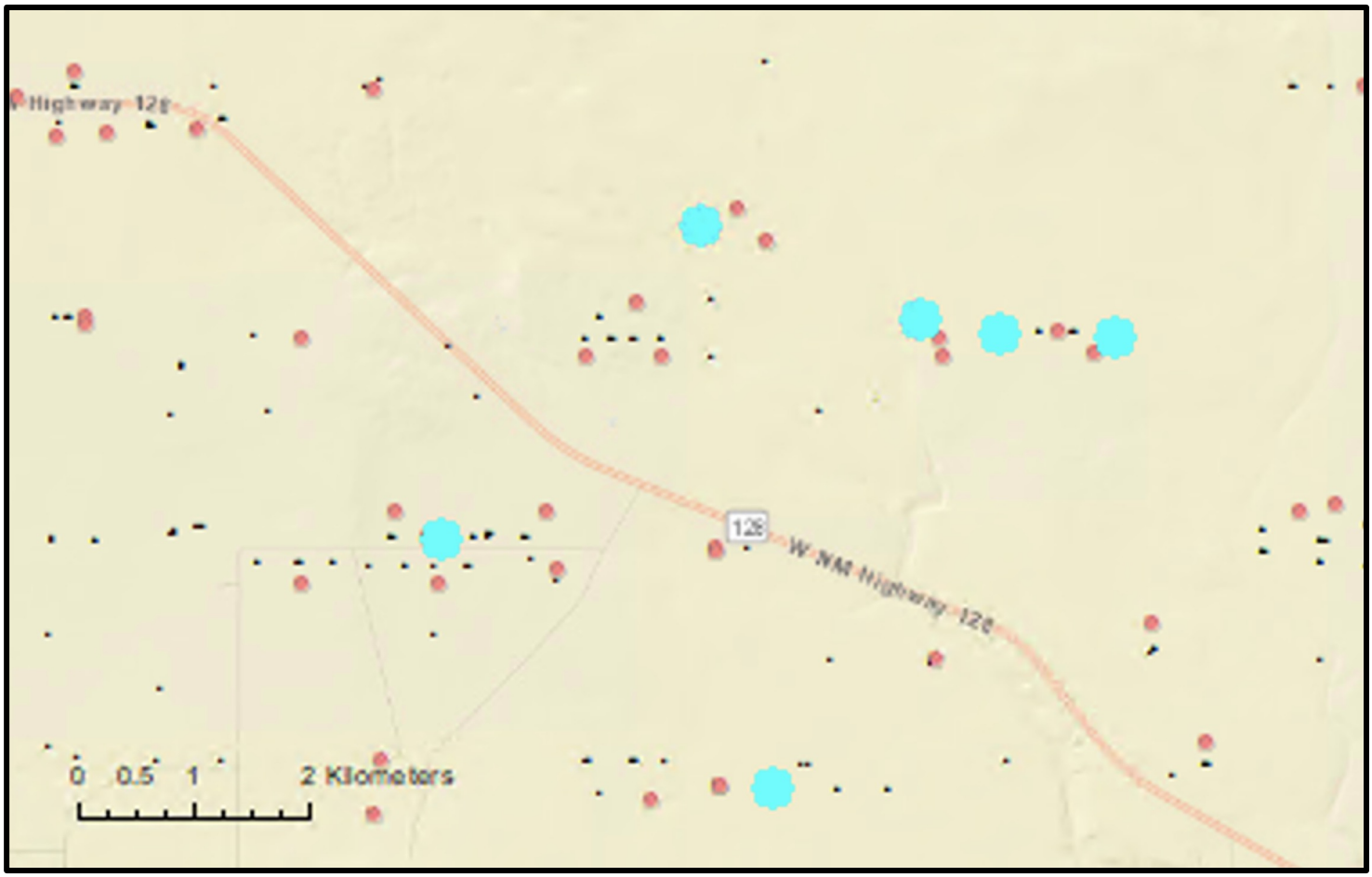
We next attempted to assess whether naming conventions for wells and facilities might allow us to pair groups together. For example, where wells or facilities were named after similar local geographic, geologic, or other features, it might suggest an association. We attempted to identify names that covered a set of wells that were within the same county, owned by the same company, and had a facility using the same convention. However, this effort proved to be fruitless for several reasons. First, certain names were found in several hundred wells and facilities. Second, many wells had unique names that were not shared with any facilities and vice versa. Third, whenever a small group of wells and facilities had the same name, the coordinates or site location for the group of wells often did not match coordinates or sites for the similarly named facilities within a reasonable distance that would allow for any definitive conclusion regarding association. Occasionally, this third approach resulted in a possible well grouping that could be paired to a facility. That said, this approach was not reliable and could not be used to suggest an association for the vast majority of wells and facilities in the Permian Basin. Examples of the failed efforts to find pairings are detailed on the following page.

Naming Conventions, Continued

For example, the name “Cedar Lake” was found in at least 400 wells in Eddy County, yet only one facility. Many wells do not share a name with any facility, or only share a name with a single, geographically unrelated facility. For example, there is only one well and one facility with “Helena” in the name in Eddy County. However, the two are located 60 kilometers apart.

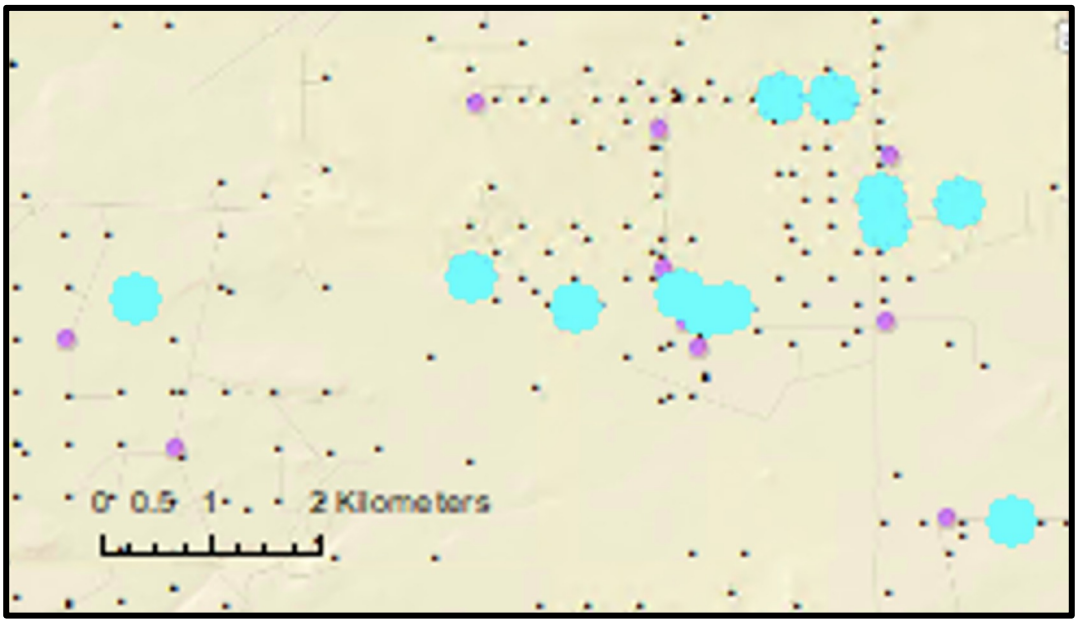
There are some small, spatially close groupings of wells with the same base name, and sometimes a facility with the same name is geographically proximate. For instance, four facilities and six wells in Eddy County have the name “Dark Canyon” as their base convention. Within that group, four of the wells are owned by Chisholm Energy, as is one of the facilities. Three of these wells also have very similar coordinates (within 100 meters of each other) and so there is a strong potential that they could be associated. The facility mentioned is also located about 100 meters away, meaning it could be associated with our potential Dark Canyon well cluster. However, this was a best-case scenario, and overall this methodology could not be considered reliable.

Approach 3: County, Type, Date, or Ownership



Finally, we attempted to connect wells or groups of wells to facilities in the Permian Basin by filtering by county, type (oil or gas), spud date or permit date, or ownership, on ArcMap. Unfortunately, this still did not result in any clearly delineated clusters of wells or any pairings between wells or well groups and facilities. As an example of this method, we mapped all oil and gas wells in Lea County spudded in 2017 and owned by COG Operating, LLC. Those wells are highlighted in light blue in the above map, with other wells shown as black dots, and facilities shown as pink dots. The map also includes a scale bar to demonstrate the significant distance between each highlighted well. This image is typical of the region in that the highlighted wells cannot be easily grouped together or grouped with a given facility.

County, Type, Date, or Ownership, Continued



The above map shows another example of an attempted grouping. This time we chose to highlight oil wells in Eddy County owned by COG Operating, LLC. Permitted facilities are shown by the purple dots. Unfortunately, there were still no reliable groupings of wells or pairings of wells and facilities. There are various potential well groupings or well grouping and facility pairings, but none of the results were conclusive. The potential well clusters are often surrounded by other wells that may or may not be associated. The facilities geographically near to a cluster are often owned by a different company than the well cluster or may be associated with another well grouping. Possible clusters we identified had no clear relationship or reliable basis to determine well grouping and facility pairing. The unclear spatial relationships were too unreliable for us to conclusively determine associations between individual wells or well groupings and facilities.

New Mexico Inspection of Public Records Act

Public Record Request

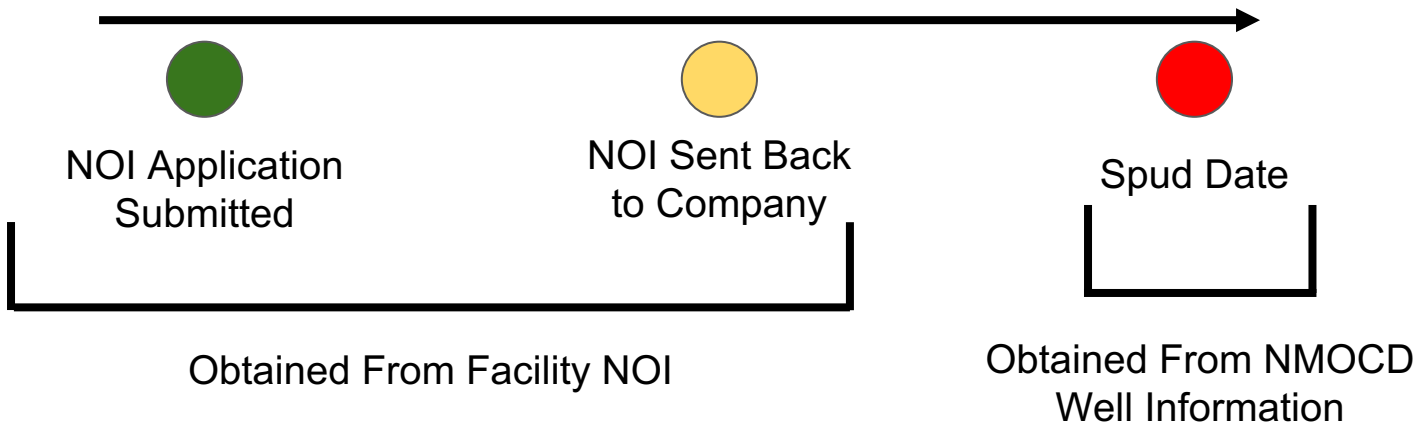
"Every citizen has a fundamental right to have access to public records."
Board of Com'rs of Dona Ana County v. Las Cruces Sun-News, 2003-NMCA-012, 134 N.M. 283.

The Inspection of Public Records Act (IPRA), NMSA 1978, §§ 14-2-1 to -12, embodies New Mexico's policy of open and transparent government by providing the public with a broad right to inspect public records. The New Mexico Environment Department is fully committed to honoring both the letter and spirit of IPRA. To request to inspect records from this office please send a request to:

Inspection of Public Records Officer
New Mexico Environment Department
1190 St. Francis Drive, Ste. N-4050
PO Box 5469
Santa Fe , New Mexico 87502
tel. (505) 827-2855
fax. (505) 827-1628
Environment.records@state.nm.us

The New Mexico Inspection of Public Records Act (NM IPRA) requires disclosure of government records to the public upon request. We made several public records requests to the NMED for the dates NOI permits were issued for all active facilities within specified counties in the last 10 years. For us to complete our analysis, we needed NOI data from NMED and well spud data from OCD. We used this data, in conjunction with our spatial clustering analysis, to assess potential violations in the San Juan Basin. As discussed above, completing a spatial clustering analysis of wells and facilities in the Permian Basin was not feasible.

Public Records Act, Continued



To assess whether potential drilling violations had occurred, our team compared the dates that NOI permits were issued with dates that wells were spudded. NOI dates are not publicly available, so we requested these from NMED through the NM IPRA. Well spud dates are provided on the NMOCD website.

In response to our public record requests, NMED provided our team with a spreadsheet of the dates that NOI permits were issued (rather than the actual NOI letters). In addition, NMED provided information including the agency interest numbers, permit numbers, ownership, company names, dates NOI permits were received by NMED, facility status, facility identification numbers, names of the facility, facility classifications, physical addresses, and coordinates for all of the facilities requested in our PRA. However, there are no common identifying variables between the NMED and NMOCD data sets that would allow our team to directly connect facilities and wells. Information provided by NMOCD includes wells' identification number, status, coordinates, name, spud date, plug date, county, district, and type. For the San Juan Basin, we were able to assess potential permitting violations through comparing the NOI and spud data with our well cluster and facility pairings.

While our team has both the spud date of wells and permit dates for facilities located in the Permian Basin, an analysis of potential permitting violations could not be completed given that we were unable to reliably pair wells and facilities.

Rationale for Permitting Violations

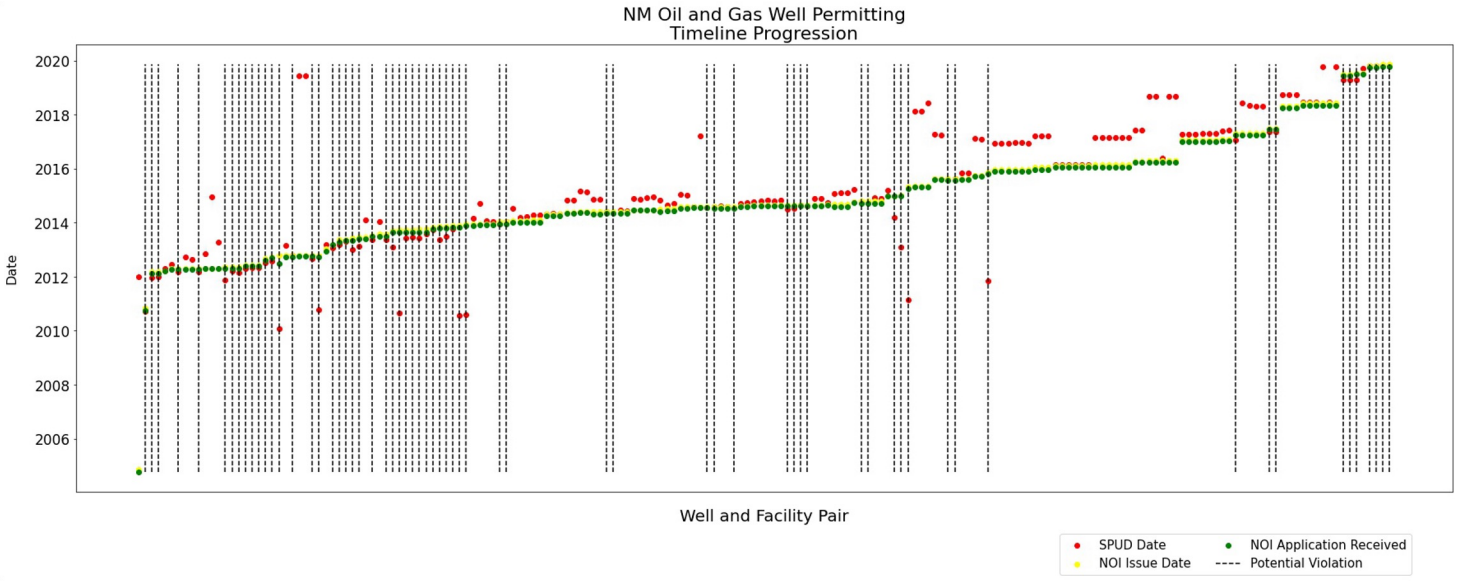
New Mexico Administrative Code (NMAC) 20.2.73.200 A4:

The notice of intent shall be filed prior to the commencement of construction. Construction shall not begin prior to issuance of a written determination by the department that a permit is not required, or if a permit is required, prior to the issuance of the permit under 20.2.72 NMAC, 20.2.74 NMAC or 20.2.79 NMAC.

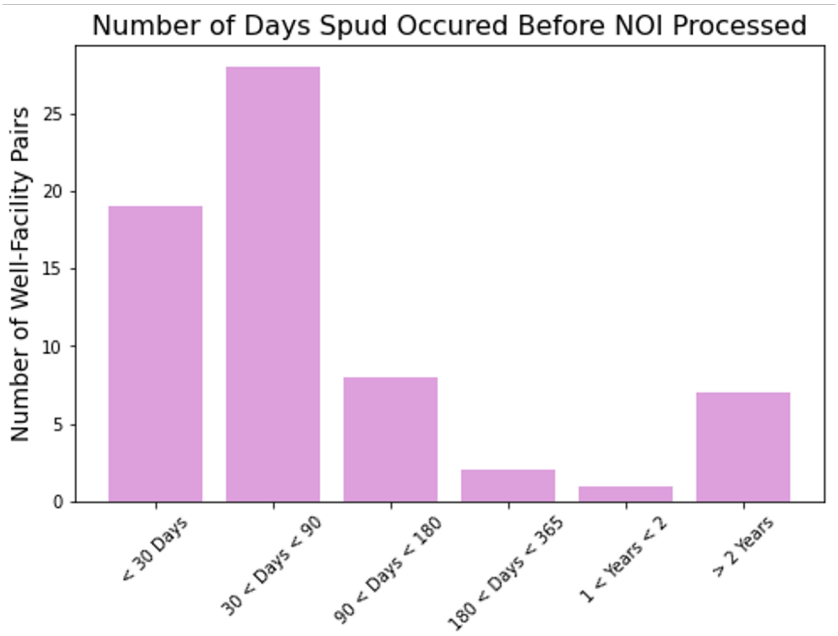
The definition of the term "construction" in the above statute includes any and all construction activity of a facility of which an NOI has been submitted. We interpret this to include construction of any well associated with a facility that is the subject of an NOI. Under this interpretation, no drilling can occur prior to the date of the NMED letter of response to the company indicating that the NOI has been processed and that no air permit is required. If an air permit is determined to be required, the company must wait until the air permit is issued before beginning any construction.

None of the facilities in the analysis projected air emissions large enough to require an air permit; therefore, we interpret the day in which construction (i.e. drilling) could begin as the date on the letter sent back to the company from NMED stating that the NOI has been processed.

Results



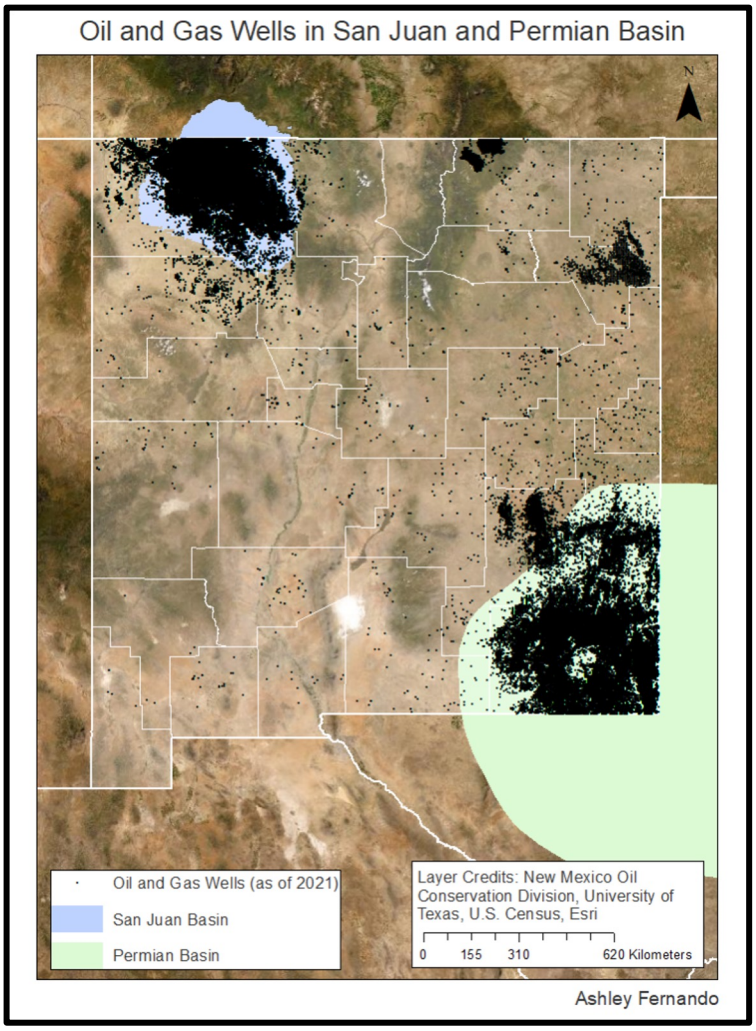
NOI permits were matched with the well-facility pairings resulting in 188 matches. The NOI issue dates were compared with spud dates of wells. If spud dates occurred before issue dates, the well-facility pairings were marked for potential violations. In total, 66 well-facility pairings were listed for having potential violations (35%).



66 well-facility pairs of 188 have **potential violations**

To the left, a graph visualizes the trend in the number of days spudding occurred before the associated facility NOI was issued.

Results, Continued



After using Python code, naming conventions, ArcMap spatial analysis, and information provided from NMED, we have not identified a clear way to pair facilities and wells in the Permian Basin. Without this association, the public cannot assess whether owners and operators are not preemptively drilling before obtaining the required permits under the CAA.

We recommend that NMED and OCD either track these permit applications and drilling dates conjointly or create a common variable that will make well-facility association a more feasible option. Having NMED and OCD maintain unrelated sets of data hindered our analysis of potential violations. This obstacle can be averted by adopting similar naming conventions throughout both governing agencies. We also recommend that NOI permit applications be made available to the public so that public records requests do not have to be filed. With these suggestions, management and enforcement of the CAA can be better upheld and explored for those interested.