

# **Impacts of Oil and Gas Development on Indigenous Communities in New Mexico's Greater Chaco Landscape**



## **Technical Appendix to Determining Violations of Oil and Gas Well Permitting in New Mexico**

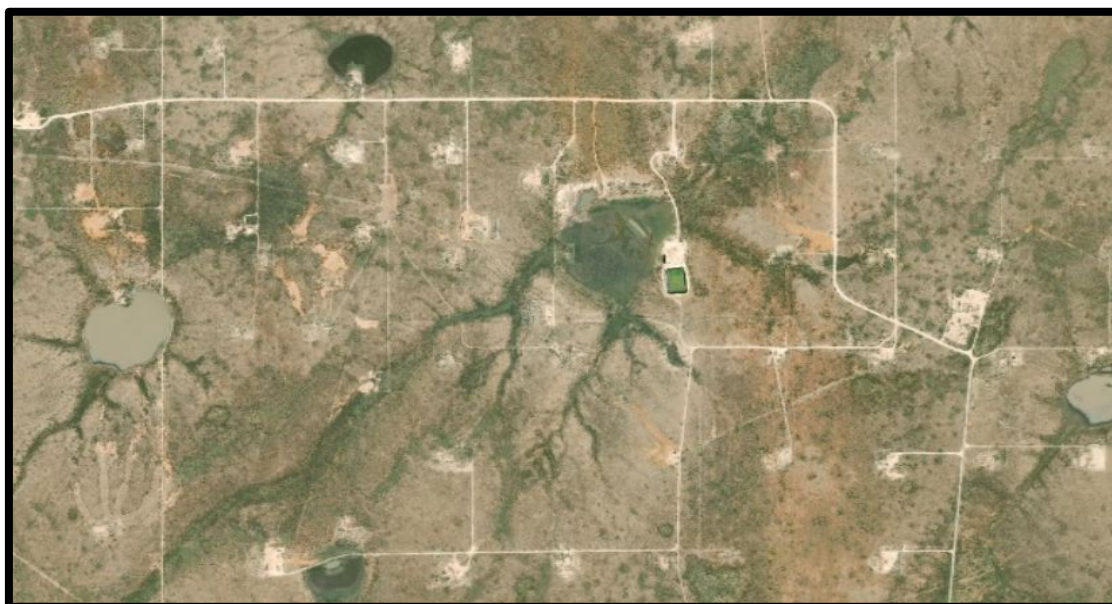
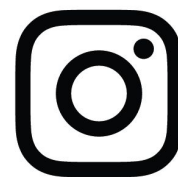
# Purpose

The purpose of this technical appendix is to detail the analysis performed by a 2019 - 2020 UCLA Institute of the Environment and Sustainability Environmental Science Practicum Capstone team for WildEarth Guardians. The technical appendix will cover the following topics:

- Project Setting and Results .....i
- Python Packages .....1
- Well and Facility Data Sources.....2-3
  - New Mexico Oil Conservation Division
  - New Mexico Environment Department
- Background and Exploratory Analysis of Oil and Gas Wells and Facilities.....4-6
- Well Clustering and Facility Association.....7-15
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- Mapping Wells, Facilities, and Emissions.....19-40

This technical appendix will not cover the exact 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 [repository](#) on GitHub.

All question regarding the analysis should be directed to [ioesnewmexico@gmail.com](mailto:ioesnewmexico@gmail.com).



# Project Setting and Results

The northwestern region of New Mexico, known as the Greater Chaco region, is rich with cultural sites and gathering spaces. The region is a checkerboard of federal, state, tribal, private, and Navajo allotment land, and while Navajo (or Diné) communities call this land home, the Chacoan Landscape is the homeland of the Ancient Puebloans, ancestors of the modern day Pueblos that still trace their lineage to this sacred area. Despite this, 91% of public lands in the region are leased for oil and gas drilling. These operations are often concentrated in and around Navajo communities, which are threatened by historical and continued rapid expansion of oil and gas development.

Regulations aiming to mitigate public health risks resulting from oil and gas development, including the federal Clean Air Act, are overseen by a variety of federal and state agencies, sometimes with complex, overlapping jurisdiction. But loopholes and shortcomings in tracking and enforcement of oil and gas activities, including well and facility construction, open the door to potential violations of state and federal law. Our research, detailed below, indicates that some stages of oil and gas development may be occurring before required permits or agency approvals have been obtained. Before any construction or activity of any kind can be undertaken by an oil company, including drilling wells or clearing land for an oil pad, the Clean Air Act requires that a proposed facility obtain a permit covering the air pollution emissions that will be released.

We analyzed 69 well-facility pairings, or wells drilled since 2010 that we could positively associate with a specific, permitted facility, in the Greater Chaco region of New Mexico. Of these, only 62 had sufficient data available for both the well and associated facility to determine their permitting timeline. We found that 35% of the wells in those pairings were constructed before required permits for their associated facilities were obtained.



# Python Packages

The majority of the analysis was performed using Python 3.8.3. The advantage of performing the analysis in Python is that the analysis is highly reproducible and can be easily updated as new data becomes available. In addition, the analysis can be scaled to larger areas beyond San Juan County if desired.

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](#)



# Well and Facility Data Sources

Data required for this analysis was obtained primarily from the New Mexico Environment Department (NMED) and the New Mexico Oil Conservation Division (NMOCD). The NMED houses facility information including the location, emissions, and permitting information. The NMOCD houses well information including the location, operating company, and the dates of major events such as spudding.



## 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

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The NMED maintains a 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. At the time this appendix was created, the Excel spreadsheet was hyperlinked with the name "Permitted Facilities Lat/Long as of 02/24/2020." The analysis for this project only focused on oil and gas facilities, although the provided data includes facilities from all industries.

While the NMED dataset of facilities provides information such as the location and emissions, it fails to include information about the permits such as the date they were deemed complete. In order to obtain permitting information about each facility, it is necessary to file public records request for specific facilities with the NMED. This step will be covered in greater detail later in the analysis.



# Exploratory Analysis of Wells and Facilities

Before beginning the analysis, it was important to first gain a stronger understanding of the oil and gas well data. The exploration of the data was guided by the following question:

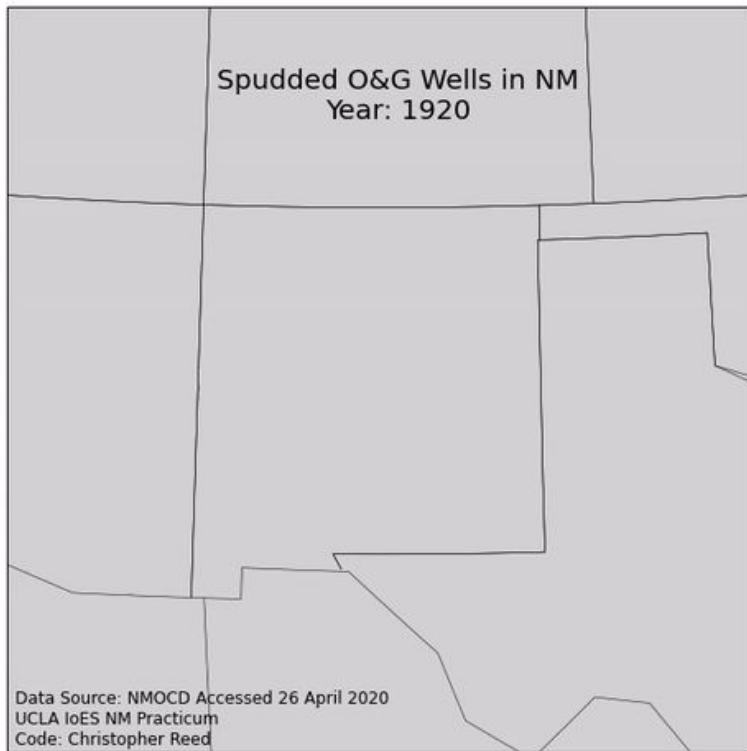
**How extensive is the development of oil and gas wells across New Mexico? San Juan county?**

**What is the trend in the number 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 in San Juan County, New Mexico since 2010?**

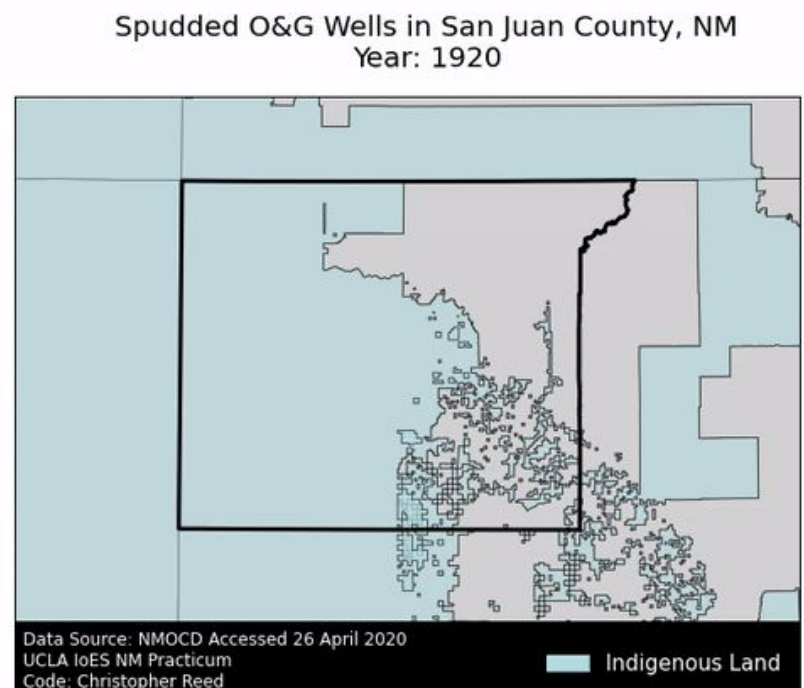
The code required to answer these questions is provided in the Google Colaboratory Notebook located in the GitHub [repository](#) referenced earlier in the appendix. The following figures depict the final outcome used to answer the above questions.



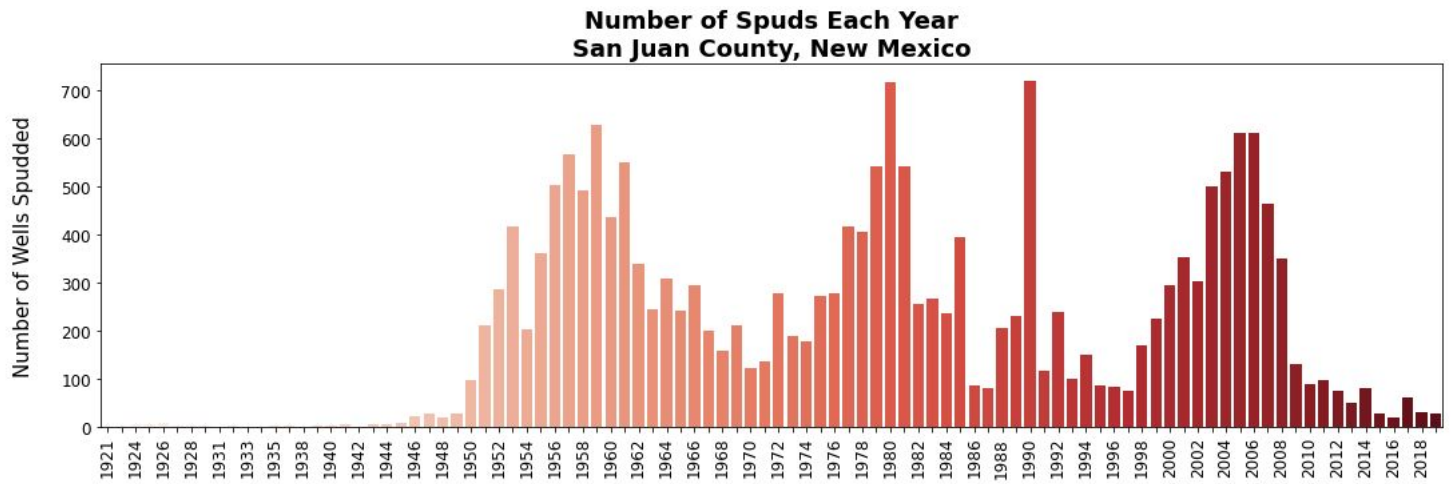


There has been extensive growth in oil and gas wells across New Mexico since 1900. There are two primary regions of development: the northwest and southeast corners. The northwest corner is where the San Juan Basin is located. The southeast corner is where the Permian Basin is located. This project focuses on the San Juan Basin.

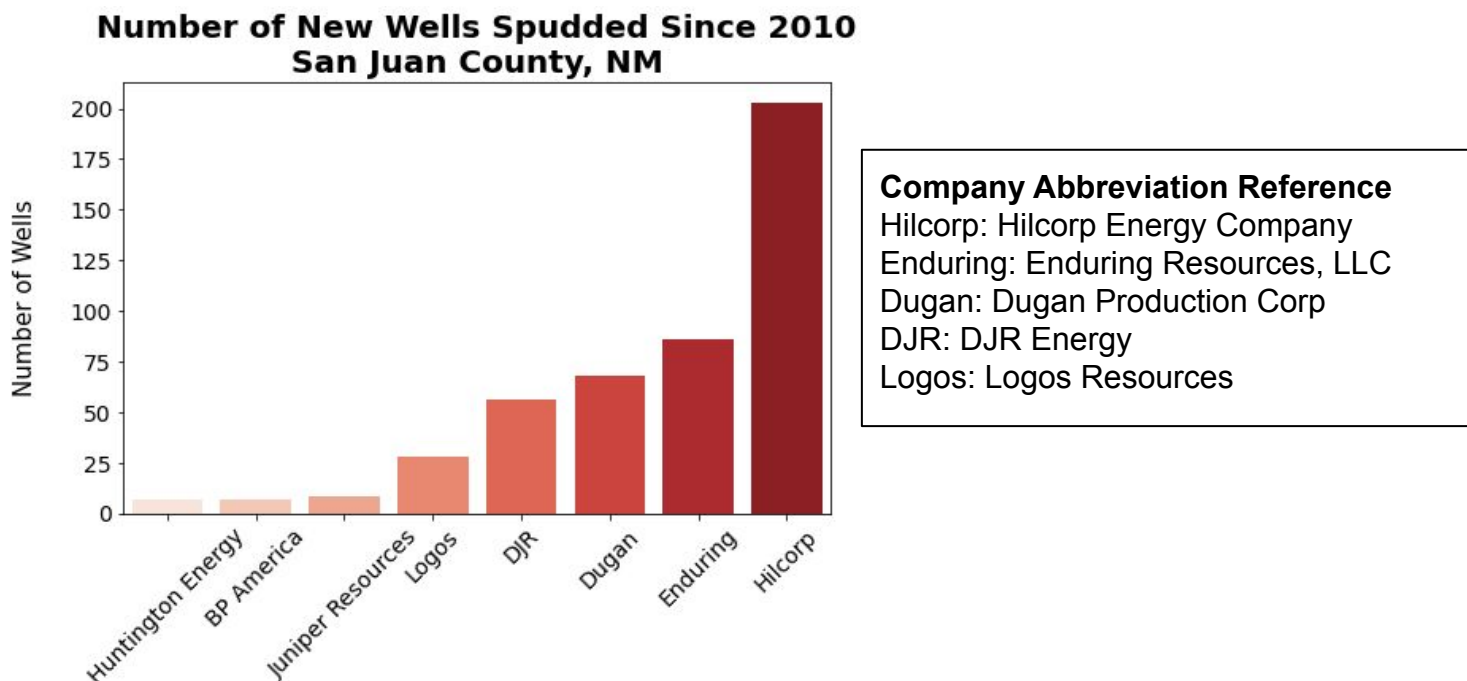
As visualized in the previous plot, there has been extensive oil and gas well development in San Juan County which is outlined in the bold black line. A significant portion of this development has occurred on or in close proximity to federally recognized Indigenous land. The proximity of development to indigenous land raises concerns over the health impacts in those communities.







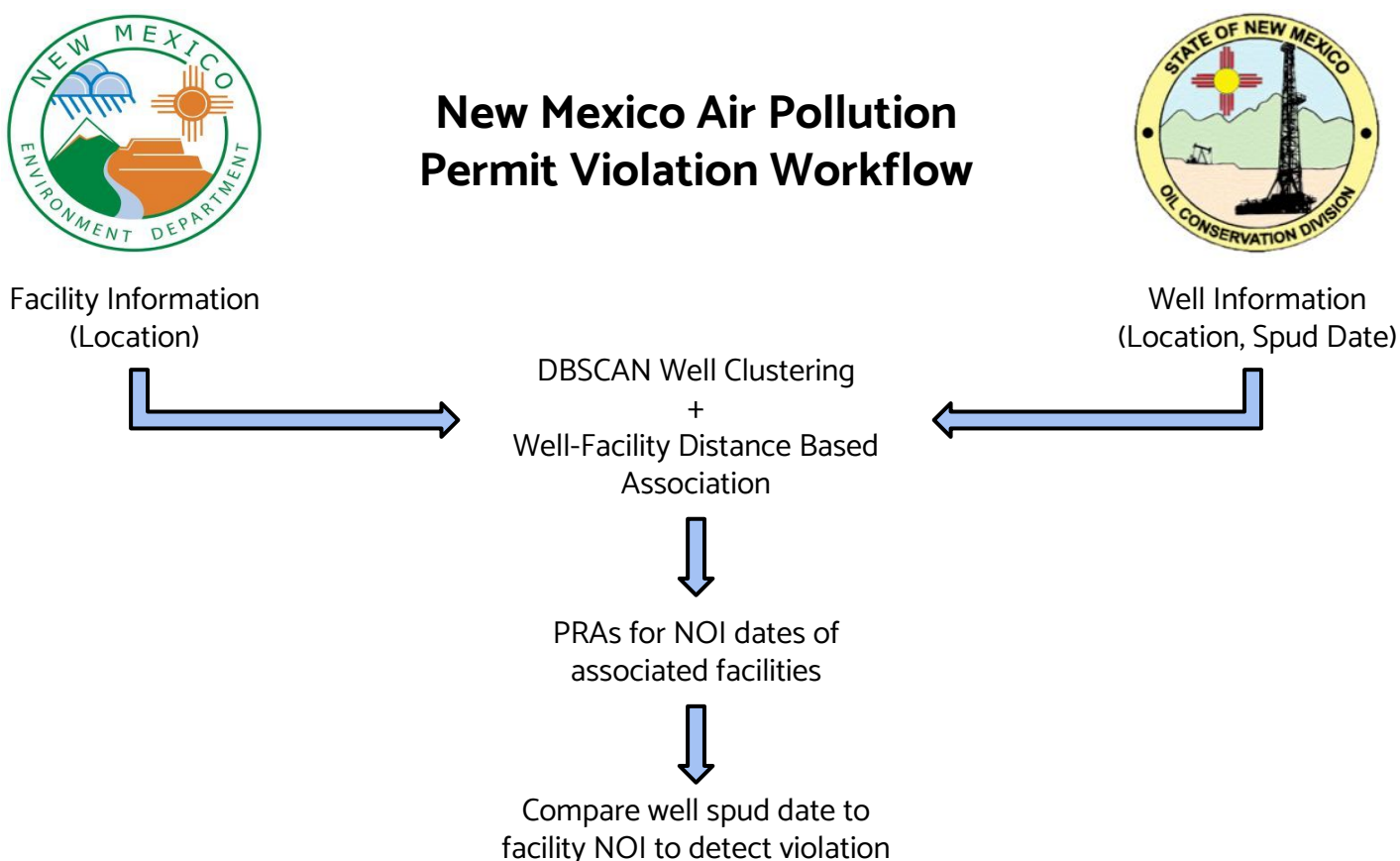
The above plot demonstrates that there have been three peaks in development in San Juan County. It appears as though oil and gas well development has slowed in the past 10 years. This is likely due to the recent explosion of development in the Permian Basin located in the opposite corner of New Mexico.



In order to determine which wells to focus on within San Juan County, it was necessary to identify which companies have spudded the most wells within the county since 2010. Hilcorp and Enduring are clearly the largest contributors to new well spuds in San Juan County since 2010 with 289 new oil and gas wells.

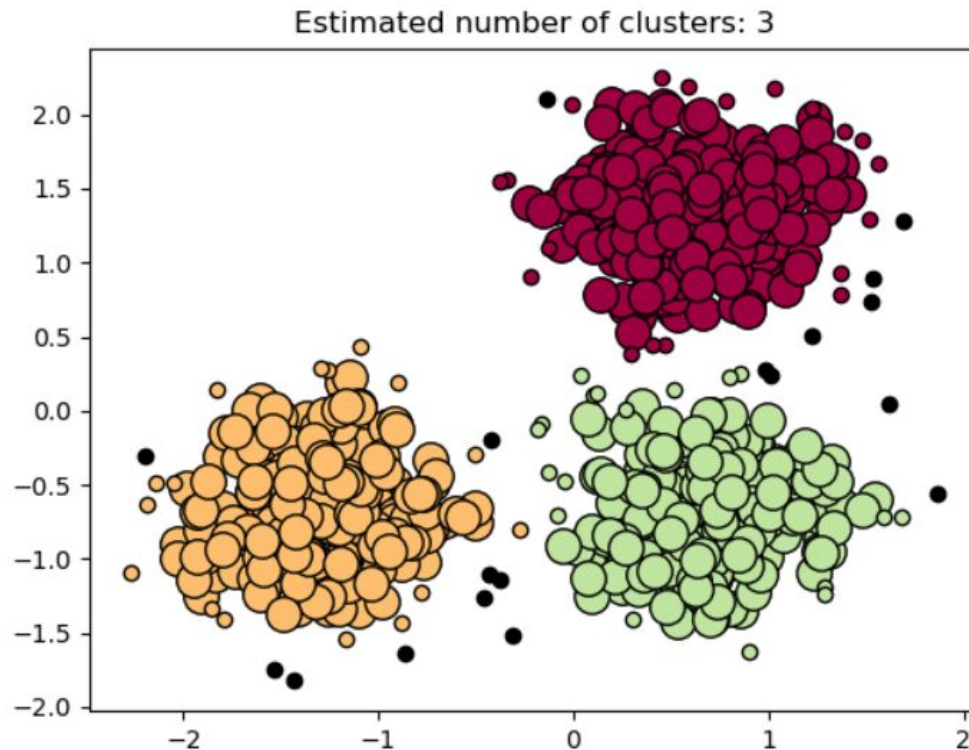
# Well Clustering and Facility Association

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 facilities that are close to dense clusters of wells are likely associated with all the wells in a 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 some pattern on a well pad which DBSCAN can detect and cluster together. The result of DBSCAN is one representative point for each well cluster.

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, if one wishes to expand this analysis to the some 120,000 wells across New Mexico it is critical to minimize the size of the dataset.

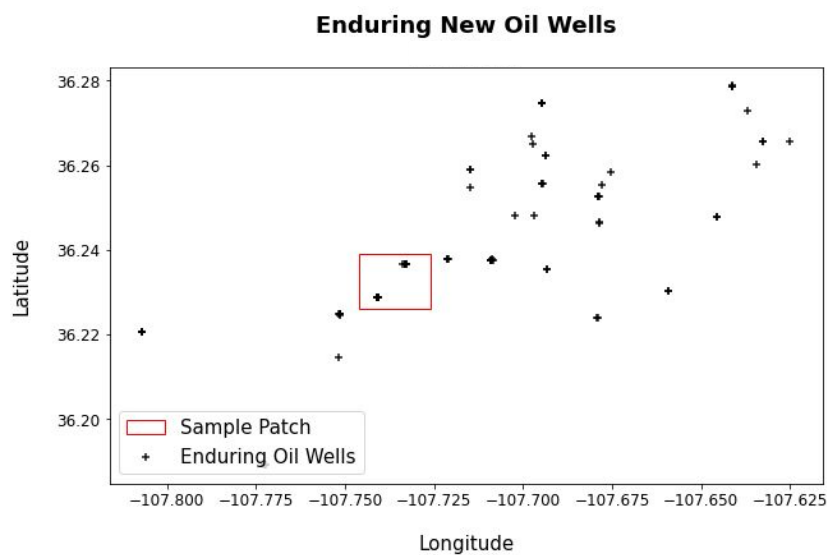
DBSCAN requires two input parameters to function: the minimum number of points in a cluster and the maximum distance between two samples for one to be considered as in the neighborhood of the other. Due to the potential of new well pads only having one well on them, the minimum number of points in a cluster was set to one. The distance between samples was set to 400 meters based on inspecting the typical distance between wells on a well pad in San Juan County using ESRI satellite imagery.

The following pages illustrate the end-to-end process of associating wells and facilities and then detecting potential permit violations. For simplicity, the visualizations only depict oil wells operated by Enduring Resources, but similar visualizations for Enduring Resources gas wells and Hilcorp gas wells can be found in the Google Colaboratory notebook in this project's [repository](#).



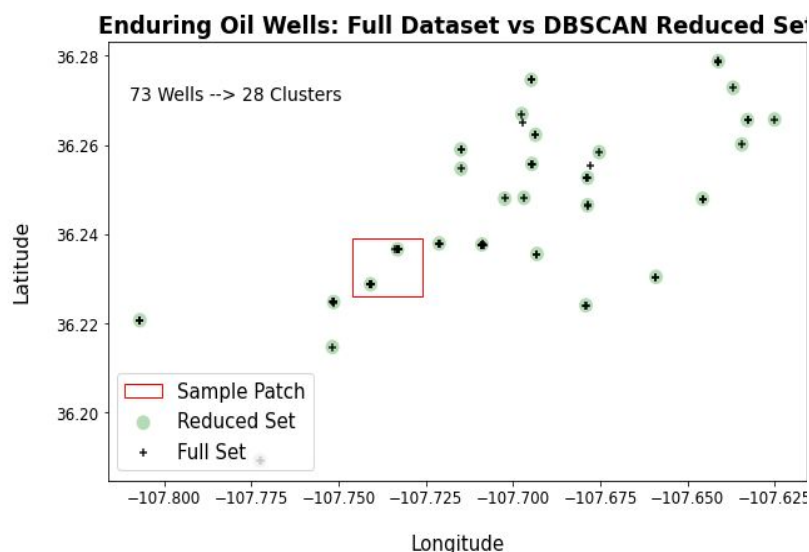
## STEP 1: Visualize wells

### Enduring Oil Wells in San Juan County, New Mexico



The first step of the analysis involves visualizing the distribution of wells. There are 69 oil wells, excluding gas wells, operated by Enduring in San Juan County that have been spudded since 2010. On the simple plot with no satellite imagery, it does not look like there are 69 points. This is because many of the wells are in close proximity and have overlapping points. The red patch labelled "Sample Patch" is zoomed in on with satellite imagery to demonstrate that oil wells are in dense clusters located on well pads. The dense clusters of wells will be critical for the next step in the analysis. Overall, the analysis considered 289 oil and gas wells in San Juan County spudded by Enduring Resources or Hillcorp Energy Company since 2010.

## STEP 2: Identify Well Clusters

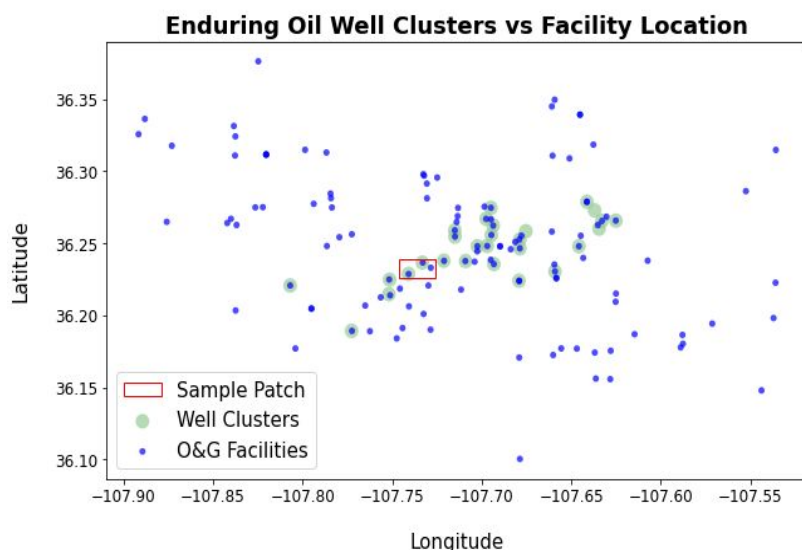


Enduring Oil Wells in San Juan County, New Mexico

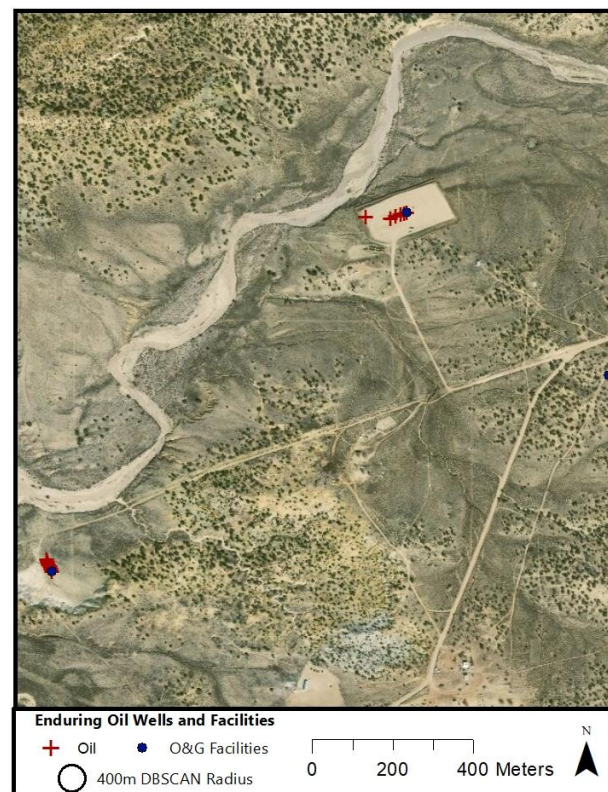


Step 2 applies DBSCAN to reduce the number of datapoints. DBSCAN is able to detect the well clusters, which can also be thought of as well pads, and associate all individual wells in cluster with a unique cluster label. In this subset of data, 69 wells are reduced to 28 clusters. The centroid of each cluster is found by averaging the longitude and then the latitude of all the wells in a cluster. The advantage in clustering instead of performing an operation with all 69 wells, such as calculating distance from nearby facilities, one can calculate the distance from 28 representative clusters to each facility.

## STEP 3: Visualize Facilities



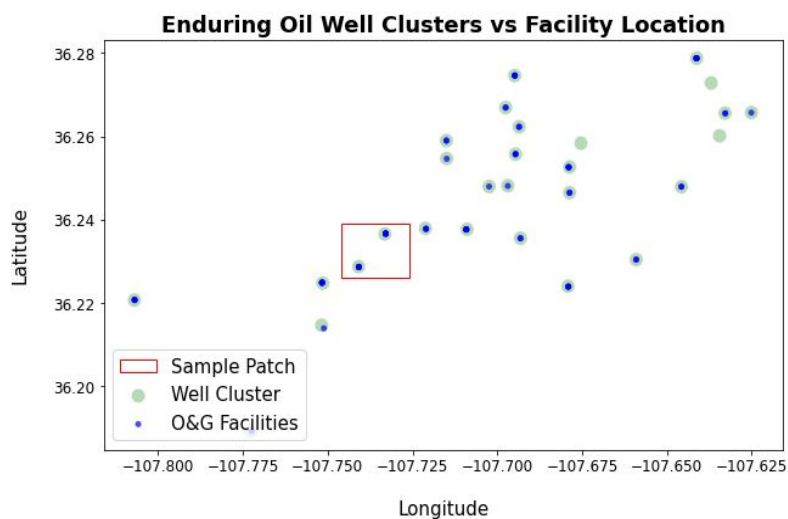
**Enduring Oil Wells in San Juan County, New Mexico**



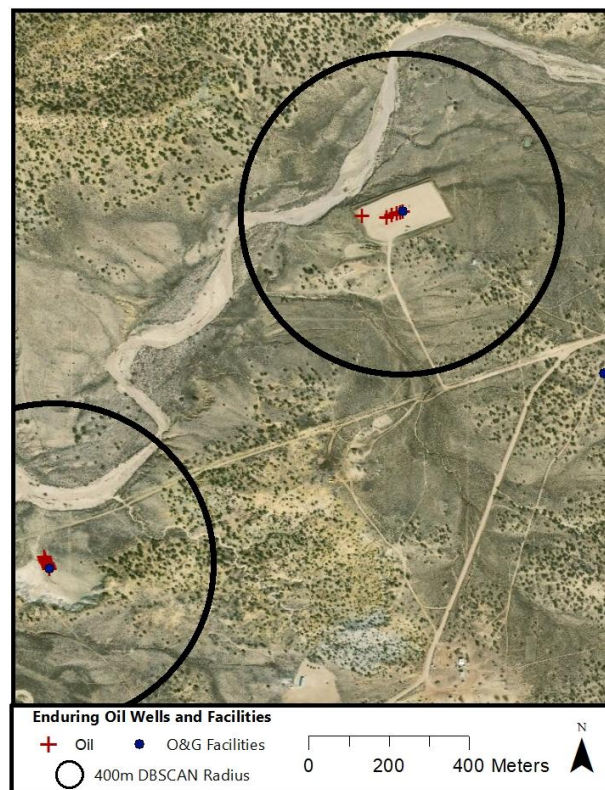
The next step in the analysis is to visualize the oil and gas facilities in the nearby area. As noted earlier, there is no data that explicitly links facilities to wells. Based on observing a sample of well pads such as those pictured in the sample patch, a facility was determined to be likely associated with wells if it was within 200 meters. It is possible that facilities can be located further than 200 meters away from wells, but it is unclear how to expand the search radius without including false positive associations. Overall, the analysis considered 602 facilities. Facilities were determined by creating a rectangle that encompassed all of the oil and gas wells considered in the analysis. If a facility was within this rectangle, it was considered in all subsequent analyses.



## STEP 4: Associate Wells and Facilities



**Enduring Oil Wells in San Juan County, New Mexico**



The facilities visualized above are the subset of facilities that remained after the 200 meter association was implemented, the remaining facilities in this subset of data were visualized. An important caveat is that there is no official data that can validate each well-facility pair. However, this research assumes that facilities are paired with a well cluster if it is less than 200 meters away. Many of the well-facility pairs identified by this project have similar names such as an Enduring well named RODEO UNIT #501H being paired with a facility named Enduring Resources - Rodeo UT No500, 501. While not an official way to validate well-facility pairs, fifty out of the 69 well-facility pairs identified in this project had similar well and facility names.



At this point, there is a much more manageable number of facilities to work with. Unfortunately, there is no way to automate the next step in the analysis: obtaining facility permitting documents. In order to obtain a Notice of Intent (NOI) for the construction of a facility, one must submit a [public records request](#) to the NMED asking for any and all permitting documents associated with the construction of the facility.

After these documents have been received, the analysis is further hindered because the documents are returned as non-machine searchable scanned pages. This means that, barring computer vision or optical character recognition, the information must be collected by hand. This is a major hindrance to the analysis because it is not feasible to perform this step for some 120,000 wells across New Mexico.

The public records requests should request all documents regarding the Notice of Intent (NOI) for the paired facilities. The documents should include a NOI application completed by the operating company as well as a letter from NMED to the operating company stated that the NOI has been processed. The letter from the NMED back to the company is the most crucial document because it includes the date the application was filed which means that the company can begin constructing the facility and all wells associated with it.

The following page contains a sample image of the first page of the NMED's response to a company's NOI application. Box 1 highlights the date the NMED is responding to the application, box 2 highlights important identifying information about the facility, and box 3 highlights the date the NMED received the company's application. As noted earlier box 1 is the most important date because it demarcates the completion of the NOI and the date the company can begin constructing or altering their facility. Based on the information provided in NMED's response, it is possible to create a permitting timeline for each facility.

# Sample NMED Response Letter With Annotations



SUSANA MARTINEZ  
GOVERNOR

JOHN A. SANCHEZ  
LIEUTENANT GOVERNOR

## New Mexico ENVIRONMENT DEPARTMENT

*Air Quality Bureau*  
1301 Siler Road, Building B  
Santa Fe, NM 87507-3113  
Phone (505) 476-4300  
Fax (505) 476-4375  
[www.nmenv.state.nm.us](http://www.nmenv.state.nm.us)



DAVE MARTIN  
CABINET SECRETARY

BUTCH TONGATE  
DEPUTY SECRETARY

March 6, 2012

CERTIFIED MAIL NO.: 7005 1820 0001 5770 6739

Randy Poteet  
Principal Environmental Consultant  
ConocoPhillips Company  
P.O. Box 4289  
Farmington, NM 87499-4289

2

Notice of Intent No. 4695  
IDEA ID No. 31155 - PRN20120001  
Sandia Federal 1F  
AIRS No. 35-045-0501

Dear Mr. Poteet:

3

This letter acknowledges the receipt of your Notice of Intent (NOI) application dated February 3, 2012 to construct and operate the Sandia Federal 1F facility in Township 30N, Range 11W, Section 29 in San Juan County, New Mexico. The Department received the application on February 9, 2012.

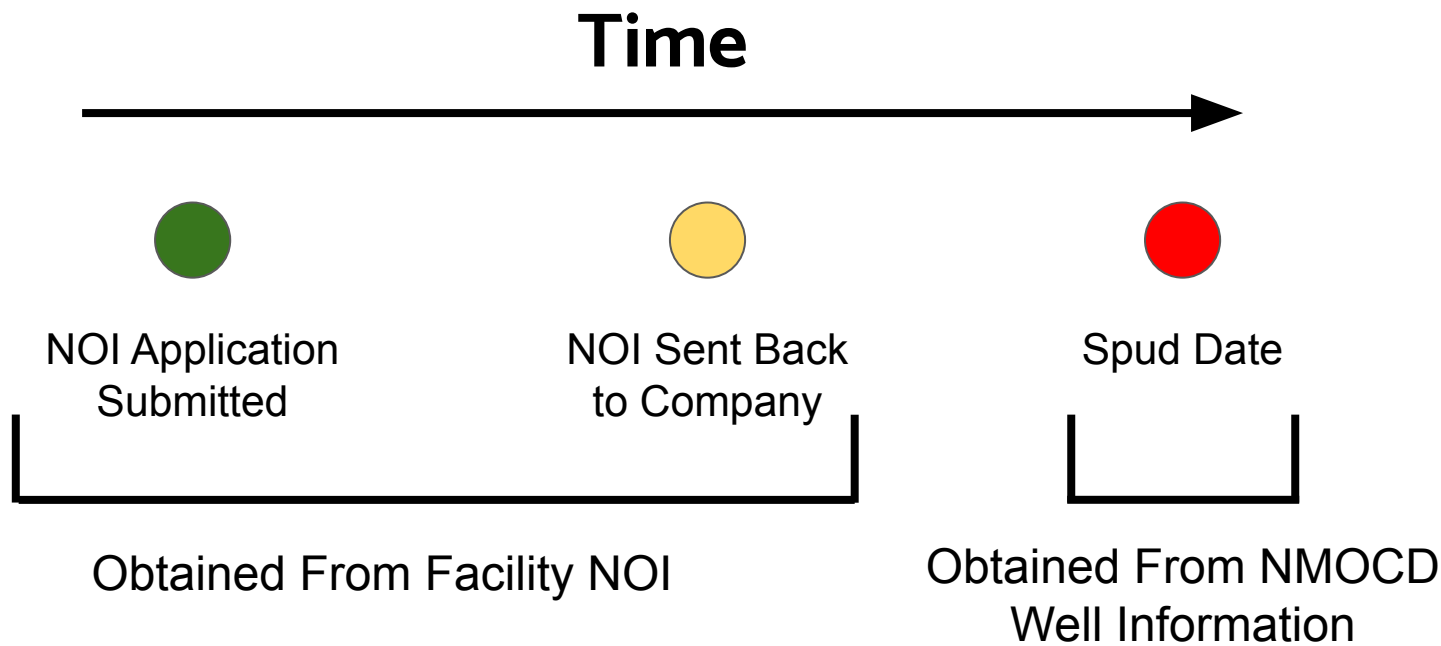
This facility shall consist of the following regulated equipment: natural gas-fired heaters with a combined total maximum heat input of 2.0 MMBtu/hr (unit AUXH); two (2) condensate / oil storage tanks with a maximum capacity of 500 barrels each (units TK-1 and TK-2); two (2) pit sump liquids storage tanks with a maximum capacity of 120 barrels each (units BGT-1 and BGT-2); two (2) produced water tanks with a maximum capacity of 400 barrels each (units PWT-1 and PWT-2); truck loading activities (unit TL-1); and one (1) pump jack engine (unit PJ-1) from the following preapproved list of engines:

Arrow C-46, 11 hp	Diadema KNG-1600E, 16 hp
Arrow C-66, 15.8 hp	Diadema KNG-3200E, 32 hp
Arrow C-96, 21.4 hp	Kubota DG972, 24.1 hp
Arrow C-106, 34 hp	Kohler CH18S, 18 hp
Arrow L-795, 65 hp	Oilwell E-20RC, 20 hp
Ajax E-42, 40 hp	Zenith ZPP428, 64 hp
Ajax DP-60, 58 hp	

### NMED Response Letter Components

- 1: Date NMED Responding to NOI Application
- 2: Identifying information about the facility
- 3: The date the NMED received the NOI application

## STEP 5: Construct Permit Timelines



The final step in this analysis is to construct permitting timelines for well-facility pairs. The ideal permitting timeline is diagrammed below: a company submits an NOI, the NMED processes the NOI and sends it back to the company, and the company can then begin to spud wells associated with those facilities.

After constructing the permitting timeline for a facility, it is necessary to join the facility permitting dates to the oil and gas wells it support. This join is performed based on the well-facility association created in step four of this analysis. After performing the join, each well facility has all three components of a permitting timeline.

# Justification for Permitting Violations

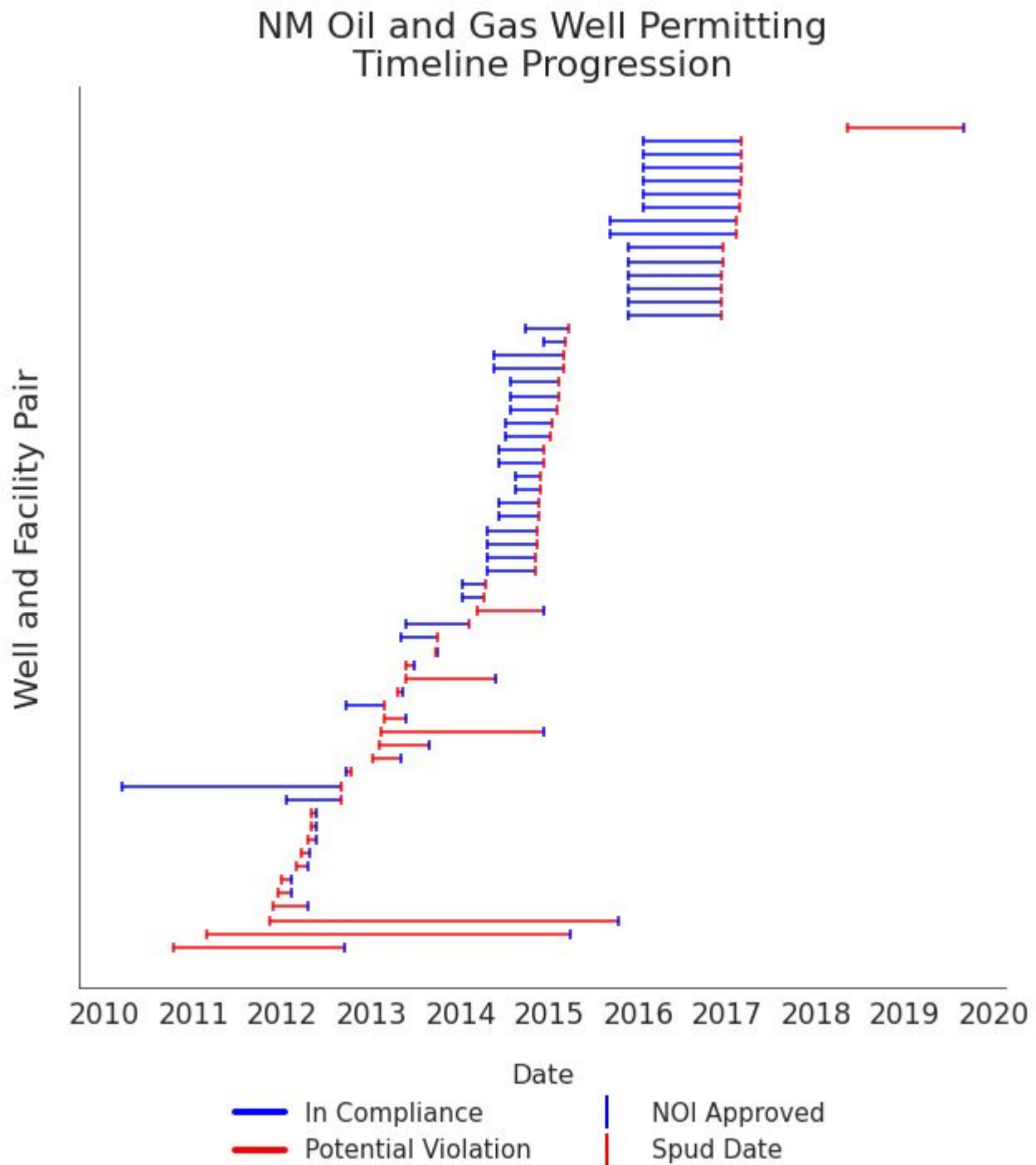
## **New Mexico Administrative Code (NMAC) 20.2.73.200 A4:**

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 analysis relies on the definition of the term “construction” in the above statute to include any and all construction activity on a) a facility on behalf of which an NOI is submitted or b) any well associated with a facility that is the subject of an NOI. WildEarth Guardians operates under this definition of the statute. Under this interpretation, no drilling can occur prior to the date of NMED’s letter of response to 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, the day in which construction (i.e. drilling) could begin is the date on the letter sent to the back to the company from NMED stating that the NOI has been processed.





Of the 69 well-facility pairs sampled in this project, 62 had the necessary data to construct timelines. Of the 62 well-facility pairs with complete data, 35% of the wells were spudded before the NMED had processed the company's NOI.

# Mapping Wells, Facilities, and Emissions

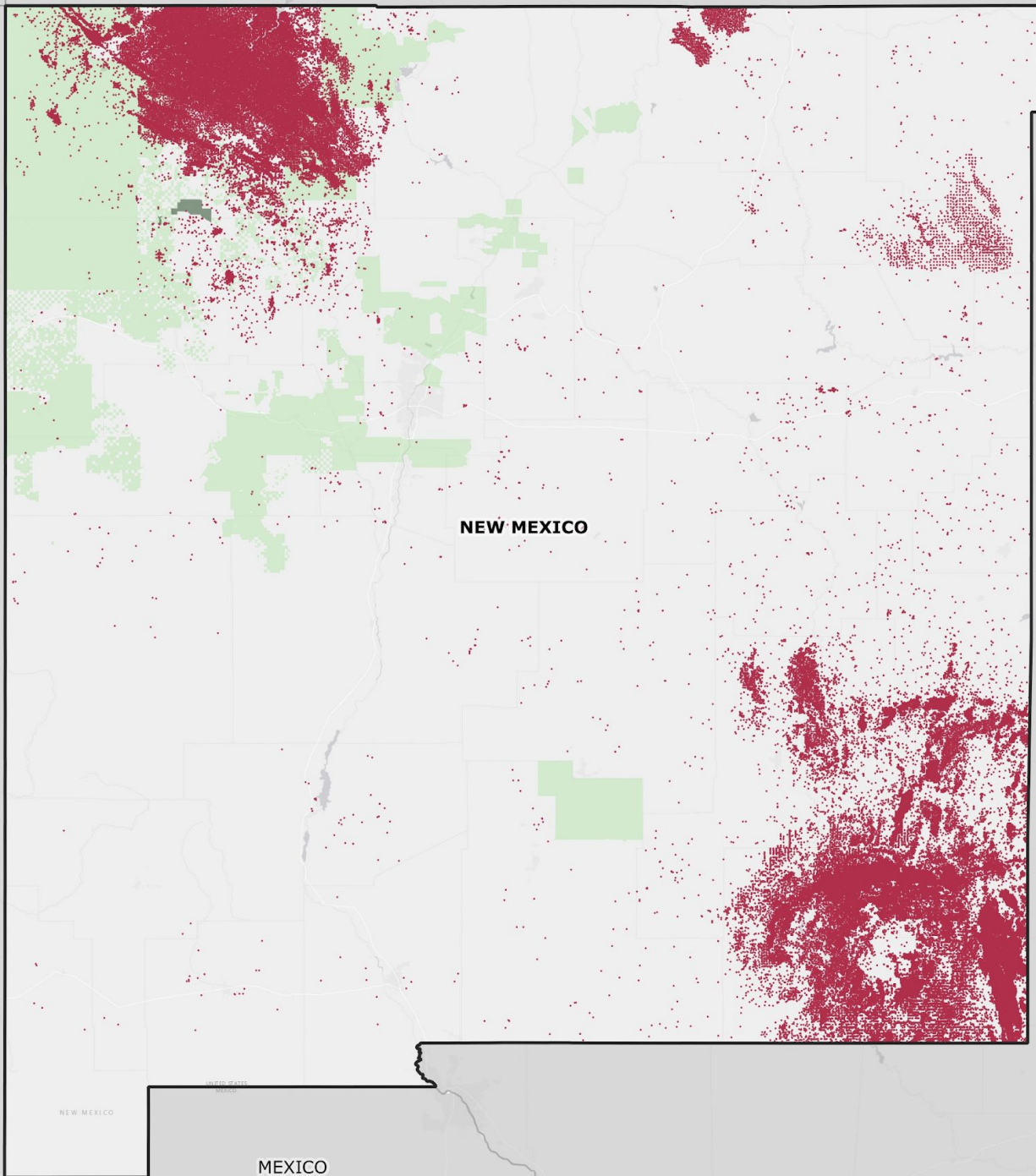
The following section includes three general maps of oil and gas wells and facilities in New Mexico and San Juan County. It also includes four visualizations of air pollution emissions within a smaller area of San Juan County.

## Section Breakdown

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- Oil and Gas Wells in New Mexico
- Oil and Gas Wells in San Juan County
- Active Oil and Gas Facilities in San Juan County
- Air Emissions Buffer Analysis
- Nitrogen Oxides (NO<sub>x</sub>) Emissions
- Carbon Monoxide (CO) Emissions
- Volatile Organic Compound (VOC) Emissions
- Particulate Matter (PM) Emissions

# Oil and Gas Wells in New Mexico



0 25 50 75 100 mi



Map Scale 1 : 4,000,000

Sources: NMOCD, US Census Bureau,  
NM RGIS, iGIS, ESRI

Cartography by Molly Schaner

• Wells

Indigenous Land

Chaco Culture National Historical Park

NM State Boundary

# Oil and Gas Wells in New Mexico

## Map Breakdown

### Description

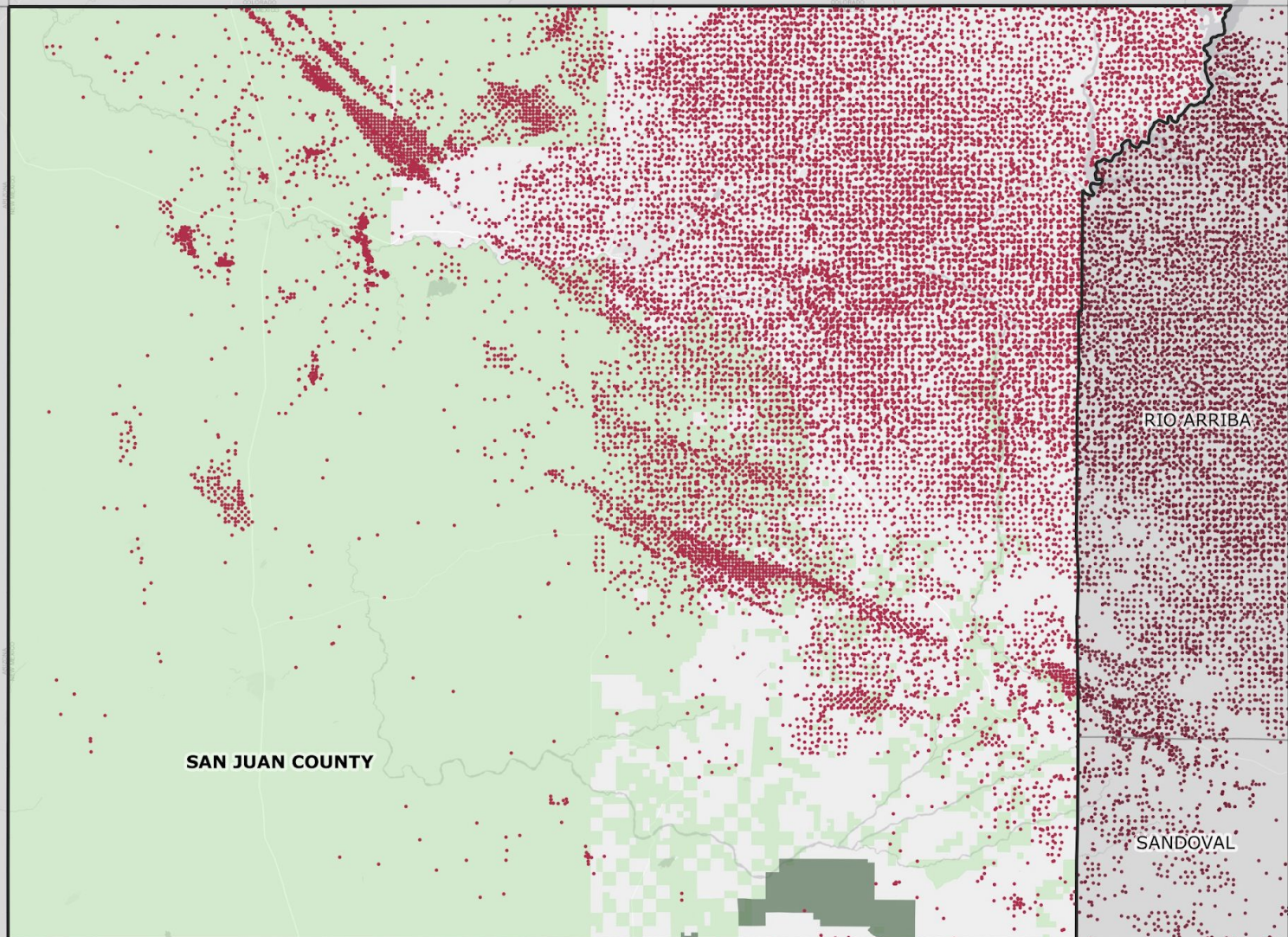
The Oil and Gas Wells in New Mexico map on page 20 depicts the location of all oil and gas wells in New Mexico in relation to federally recognized indigenous land. The two clusters in the northwest and southeast are located over two oil and gas hotspots in New Mexico: the San Juan Basin and the Permian Basin respectively. In addition, the borders of Chaco Culture National Historical Park, an epicenter of indigenous culture, is outlined in a dark green just south of the San Juan Basin well clusters. A time lapse of the development of oil and gas wells can be seen on page 7 of this technical appendix.

### Data Sources

Layer	Owner	Original Source	Date Downloaded
New Mexico Border	United States Census Bureau	<a href="#">United States Census Bureau</a>	April 2020
Federally Recognized Indigenous Land	United States Census Bureau	<a href="#">United States Census Bureau</a>	April 2020
Chaco Culture National Historical Park	University of New Mexico	<a href="#">University of New Mexico</a>	April 2020
NMOCD Well Locations	NMOCD	<a href="#">NMOCD</a>	April 2020



# Oil and Gas Wells in San Juan County, NM



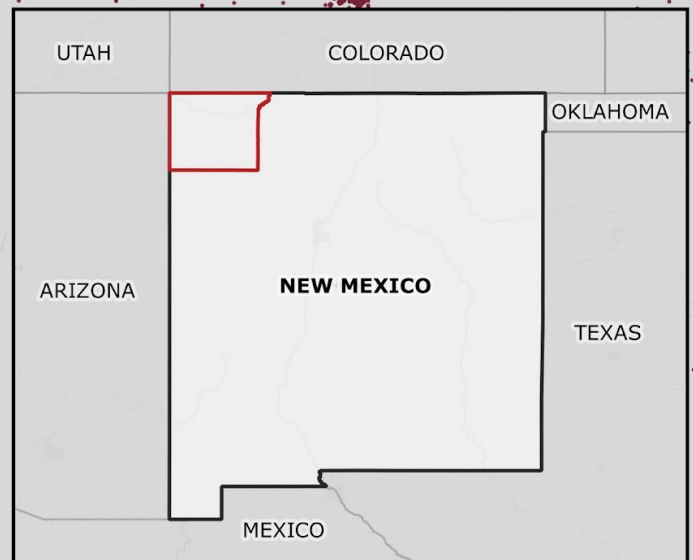
0 5 10 15 20 25 mi



Map Scale 1 : 930,000

Sources: NMOCD, NM RGIS,  
US Census Bureau, ESRI  
Cartography by Molly Schaner

- Wells
- Indigenous Land
- Chaco Culture National Historical Park
- San Juan County Boundary



# Oil and Gas Wells in San Juan County, NM

## Map Breakdown

### Description

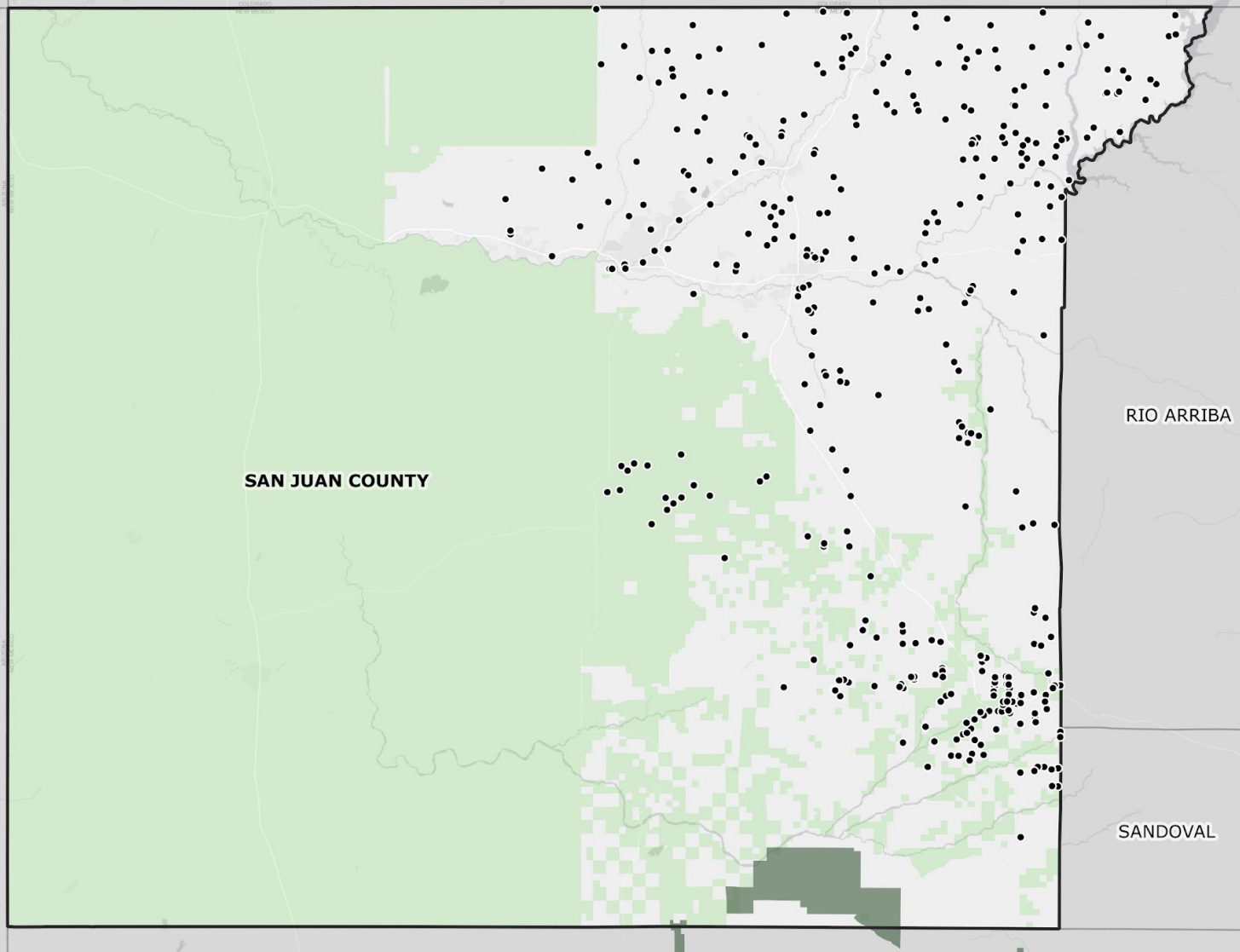
The Oil and Gas Wells in San Juan County, NM map on page 22 depicts the location of all oil and gas wells in San Juan County, New Mexico in relation to federally recognized indigenous land. Chaco Culture National Historical Park is highlighted in dark green in the southeast corner of San Juan County. A timelapse of oil and gas well development in San Juan County, New Mexico can be seen on page 7 of this technical appendix.

### Data Sources

Layer	Owner	Original Source	Date Downloaded
New Mexico Border	United States Census Bureau	<a href="#">United States Census Bureau</a>	April 2020
Federally Recognized Indigenous Land	United States Census Bureau	<a href="#">United States Census Bureau</a>	April 2020
Chaco Culture National Historical Park	University of New Mexico	<a href="#">University of New Mexico</a>	April 2020
NMOCD Well Locations	NMOCD	<a href="#">NMOCD</a>	April 2020
San Juan County, NM	University of New Mexico	<a href="#">University of New Mexico</a>	April 2020



# Active Oil and Gas Facilities in San Juan County, NM



0 5 10 15 20 25 mi

Map Scale 1 : 930,000  
Sources: NMED, NM RGIS,  
US Census Bureau, ESRI  
Cartography by Molly Schaner

Active Facilities OLD

- Indigenous Land
- Chaco Culture National Historical Park
- San Juan County Boundary



# Active Oil and Gas Facilities, San Juan County Map Breakdown

## Description

The Active Oil and Gas Facilities in San Juan County, NM map on page 24 depicts the location of all active oil and gas facilities in San Juan County, New Mexico. These oil and gas facilities are a subset of all permitted facilities across multiple industries tracked by NMED.

## Data Sources

Layer	Owner	Original Source	Date Downloaded
New Mexico Border	United States Census Bureau	<a href="#">United States Census Bureau</a>	April 2020
Federally Recognized Indigenous Land	United States Census Bureau	<a href="#">United States Census Bureau</a>	April 2020
Chaco Culture National Historical Park	University of New Mexico	<a href="#">University of New Mexico</a>	April 2020
NMOCD Well Locations	NMOCD	<a href="#">NMOCD</a>	April 2020
San Juan County, NM	University of New Mexico	<a href="#">University of New Mexico</a>	April 2020
Permitted Oil and Gas Facilities	NMED	<a href="#">NMED</a>	May 2020

# Air Emission Buffer Analysis

The remaining maps depict air emissions reported to the NMED from oil and gas facilities in San Juan County, New Mexico. The emissions represent the maximum potential emissions from each facility. This study opted to use buffer analysis to depict the impact of emissions from each facility.

The study constructed buffers using a 1500 ft (0.28 mi) radius around each oil and gas facility to visualize the immediate area impacted by air emissions. This radius was based on literature on setback distances: the minimum distance away from unsafe infrastructures to mitigate public health hazards. Setback distances are most often a compromise between local or state governments, land developers, land owners, and communities<sup>1</sup>. There is often a large discrepancy between the implemented setback distance and the scientifically supported setback distance<sup>2</sup>.

Setback distances in San Juan County, New Mexico are left to the jurisdiction of municipalities. Farmington implements a minimum of 200 ft from any residential, commercial and industrial buildings, Aztec implements a minimum of 400 ft, and Bloomfield implements a minimum of 300 ft. However, growing literature has found that unconventional oil and gas (UOG) drilling sites, at minimum, must be set at a distance of 1350 to 2500 ft from residences and any location of human activity to lessen exposure and impacts from UOG induced polluted air, noise, and odor<sup>3,4,5</sup>. Although uncertainty remains due to gaps in long term health and exposure data, setback distances implemented by San Juan County municipalities are smaller than those recommended by the scientific community. This suggests that residents living close to UOG sites may suffer greater from the health hazards these sites create.

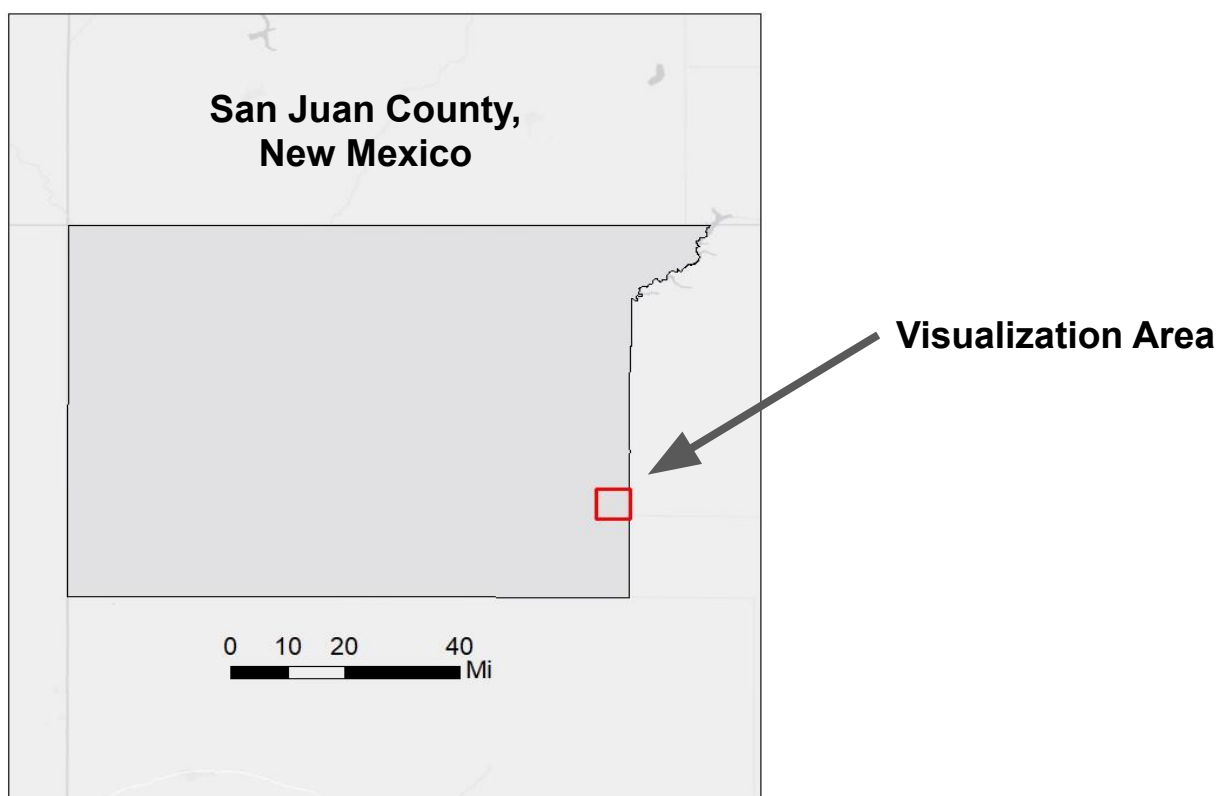
Due to the unavailability of street address and residency information through US Census data, our team was unable to include the proximity of indigenous communities to emission sources. Research conducted by the Clean Air Task Force, Earthworks, and FracTracker, however, suggests that residents of San Juan County are at high risk of health impacts due to the density of UOG sites.<sup>6</sup>



# Air Emission Site Selection

While the buffer analysis was performed on all active oil and gas facilities in New Mexico, only a subset of facilities are included in the following maps. The study opted to visualize one particular area instead of all of San Juan County for a number of reasons:

- The small scale allows one to visualize individual facilities
- Facilities in this region displayed a variety in both the type and rate of air emissions
- The site includes both facilities that were analyzed during this project and unanalyzed facilities
- The site includes a balance between facilities with and without permitting violations



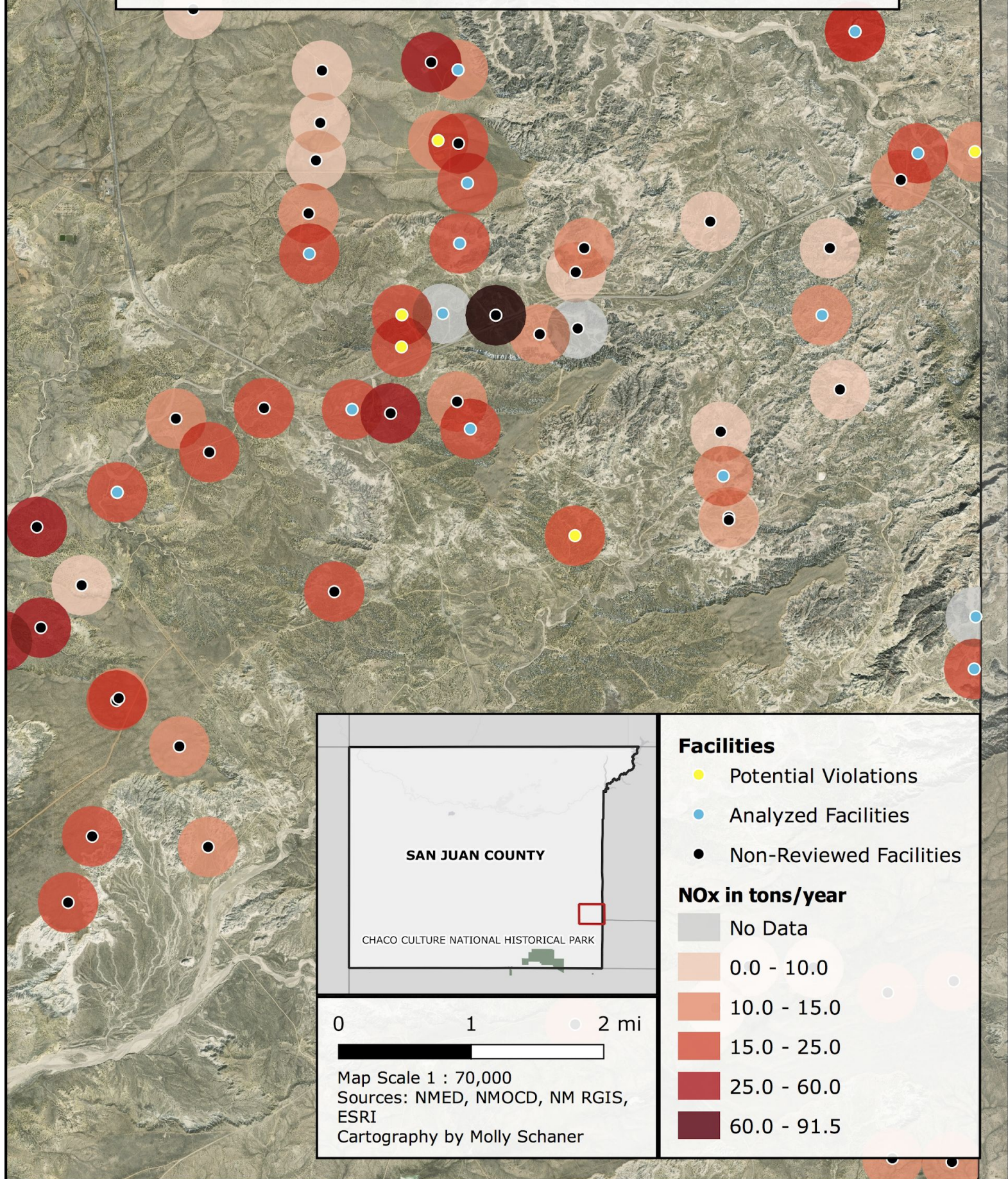
# Data Sources

The data sources used to construct the buffer analysis are listed in the table below. Potential violations were derived from NMED facility data and NMOCD well data, as previously described on pages 9 - 17. The shapefiles for the buffer analysis can be found in the [repository](#).

Layer	Owner	Original Source	Date Downloaded
New Mexico Border	United States Census Bureau	<a href="#">United States Census Bureau</a>	April 2020
Federally Recognized Indigenous Land	United States Census Bureau	<a href="#">United States Census Bureau</a>	April 2020
Chaco Culture National Historical Park	University of New Mexico	<a href="#">University of New Mexico</a>	April 2020
NMOCD Well Locations	NMOCD	<a href="#">NMOCD</a>	April 2020
San Juan County, NM	University of New Mexico	<a href="#">University of New Mexico</a>	April 2020
Permitted Oil and Gas Facilities	NMED	<a href="#">NMED</a>	May 2020



# Nitrogen Oxides (NOx) Emissions in a 1500 ft Facility Buffer





# Nitrogen Oxides (NOx) Emissions Map Breakdown

## Description

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The Nitrogen Oxides (NOx) Emissions in a 1500 ft Facility Buffer map on page 29 depicts the NOx emissions from a subset of oil and gas facilities in San Juan County, New Mexico. There are three types of oil and gas facilities on the map: those with potential permitting violations, facilities analyzed by this project that had no permitting violations, and facilities not analyzed by this project.

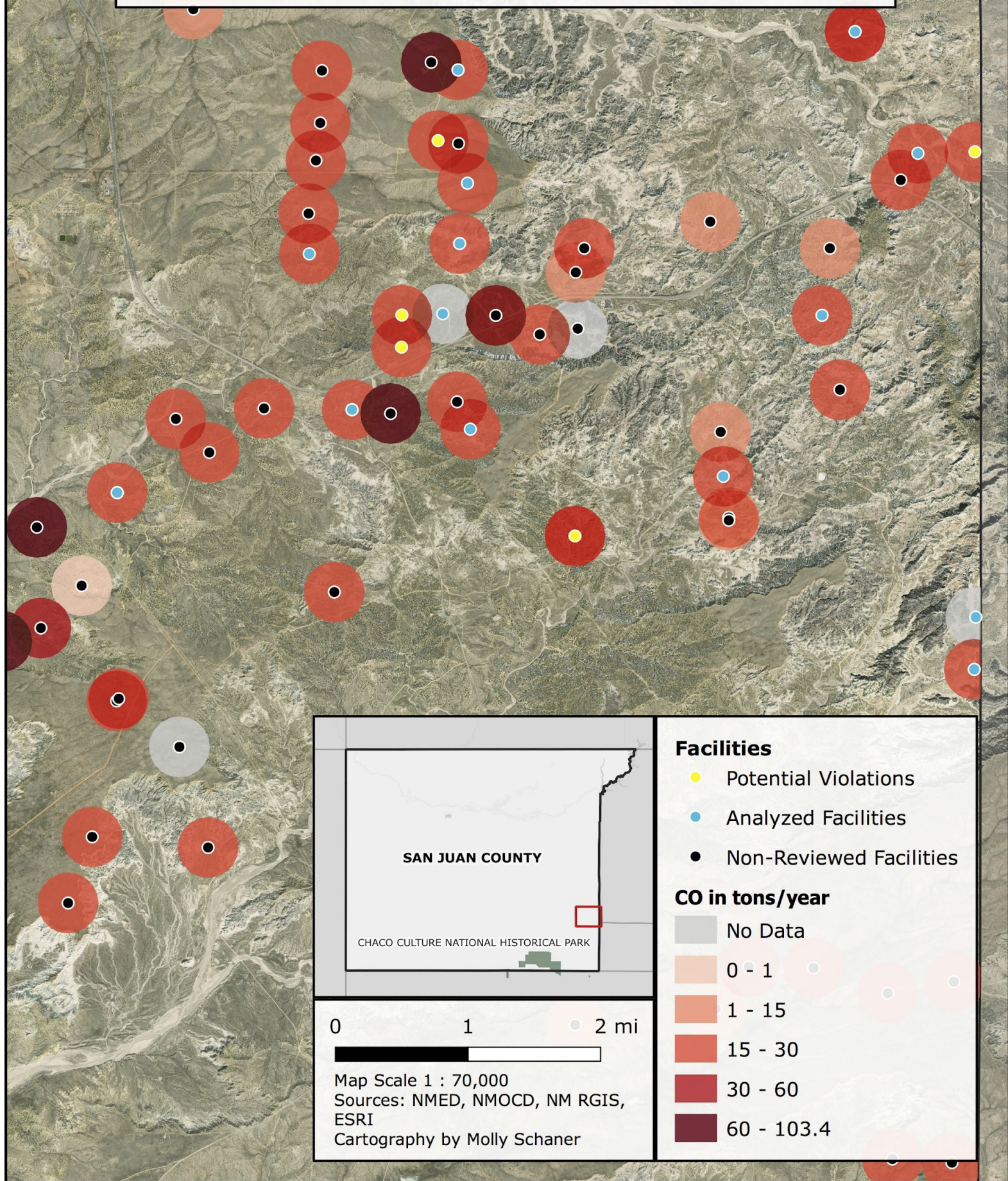
# Nitrogen Oxides (NOx) Emissions

Analyzed refers to facilities throughout San Juan County that were investigated in this project. All facilities refers to all compressor stations, production facilities, tank battery / bulk fuel storage, and well heads in San Juan County. There are additional types of oil and gas facilities beyond these four that are not included in this table.

	Facility Type	Count	Total (tons/year)	Median (tons/year)
Analyzed (violations)	Compressor Station	3	49.70	14.10
	Production Facility	11	84.53	6.35
	Tank Battery/Bulk Fuel Storage	3	55.00	20.40
	Well Head	6	0.00	0.00
Analyzed (no violation)	Compressor Station	3	77.00	31.80
	Production Facility	32	481.10	16.70
	Tank Battery/Bulk Fuel Storage	8	55.00	21.00
	Well Head	3	0.00	0.00
All Facilities	Compressor Station	449	27389.92	22.05
	Production Facility	183	2239.43	11.15
	Tank Battery/Bulk Fuel Storage	25	207.76	13.17
	Well Head	46	109.08	9.17



# Carbon Monoxide (CO) Emissions in a 1500 ft Facility Buffer





# Carbon Monoxide (CO) Emissions Map Breakdown

## Description

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The Carbon Monoxide (CO) Emissions in a 1500 ft Facility Buffer map on page 32 depicts the CO emissions from a subset of oil and gas facilities in San Juan County, New Mexico. There are three types of oil and gas facilities on the map: those with potential permitting violations, facilities analyzed by this project that had no permitting violations, and facilities not analyzed by this project.

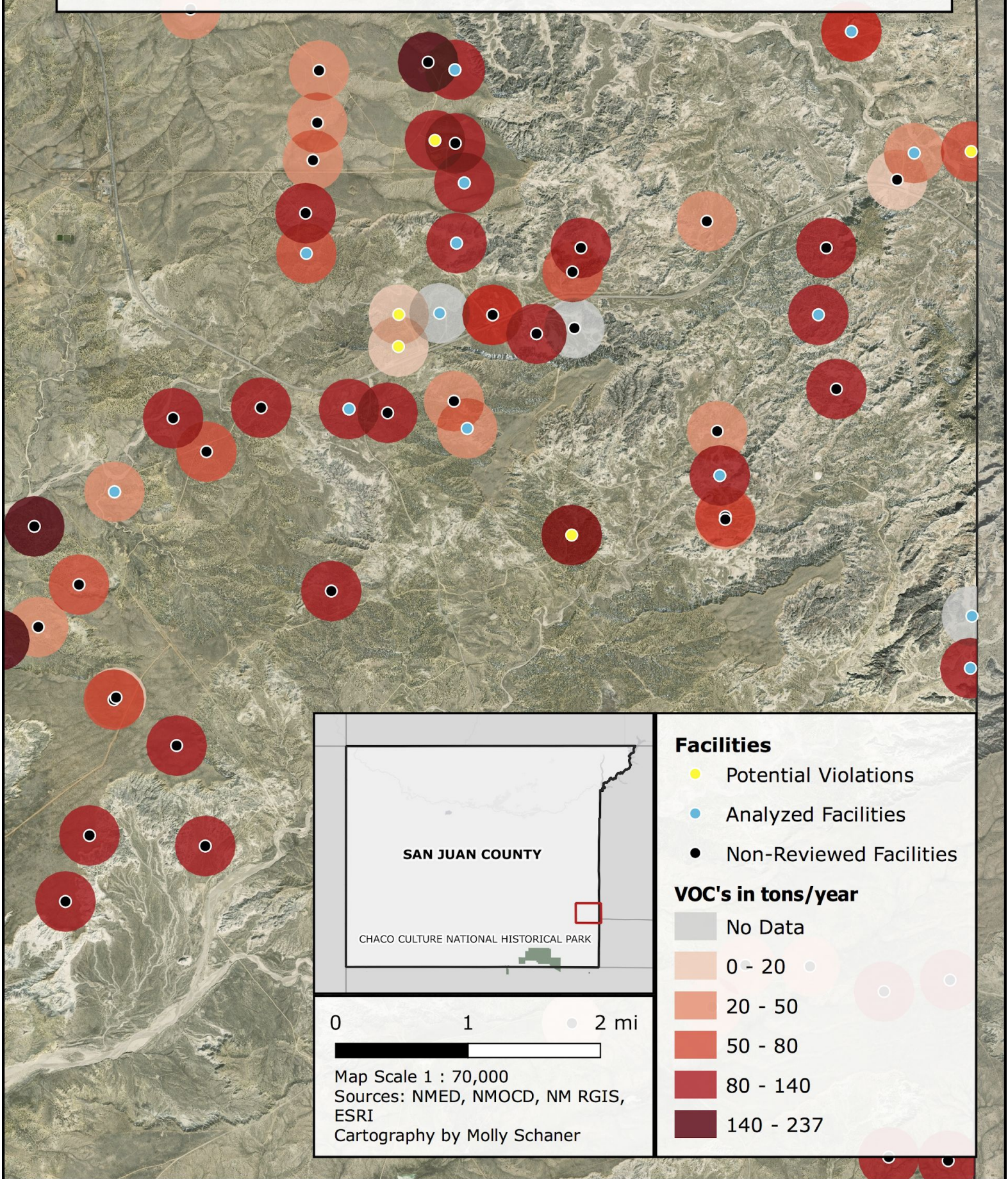
# Carbon Monoxide (CO) Emissions

Analyzed refers to facilities throughout San Juan County that were investigated in this project. All facilities refers to all compressor stations, production facilities, tank battery / bulk fuel storage, and well heads in San Juan County. There are additional types of oil and gas facilities beyond these four that are not included in this table.

	Facility Type	Count	Total (tons/year)	Median (tons/year)
Analyzed (violations)	Compressor Station	3	61.80	18.90
	Production Facility	11	120.72	11.04
	Tank Battery/Bulk Fuel Storage	3	73.50	24.40
	Well Head	6	0.00	0.00
Analyzed (no violation)	Compressor Station	3	86.70	31.20
	Production Facility	32	704.30	24.30
	Tank Battery/Bulk Fuel Storage	8	171.40	24.50
	Well Head	3	0.00	0.00
All Facilities	Compressor Station	449	19096.03	17.24
	Production Facility	183	2897.96	16.09
	Tank Battery/Bulk Fuel Storage	25	250.90	16.97
	Well Head	46	125.01	17.58



# Volatile Organic Compound (VOC) Emissions in a 1500 ft Facility Buffer





# Volatile Organic Compound (VOC) Emissions Map Breakdown

## Description

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The Volatile Organic Compound (VOC) Emissions in a 1500 ft Facility Buffer map on page 35 depicts the VOC emissions from a subset of oil and gas facilities in San Juan County, New Mexico. There are three types of oil and gas facilities on the map: those with potential permitting violations, facilities analyzed by this project that had no permitting violations, and facilities not analyzed by this project.

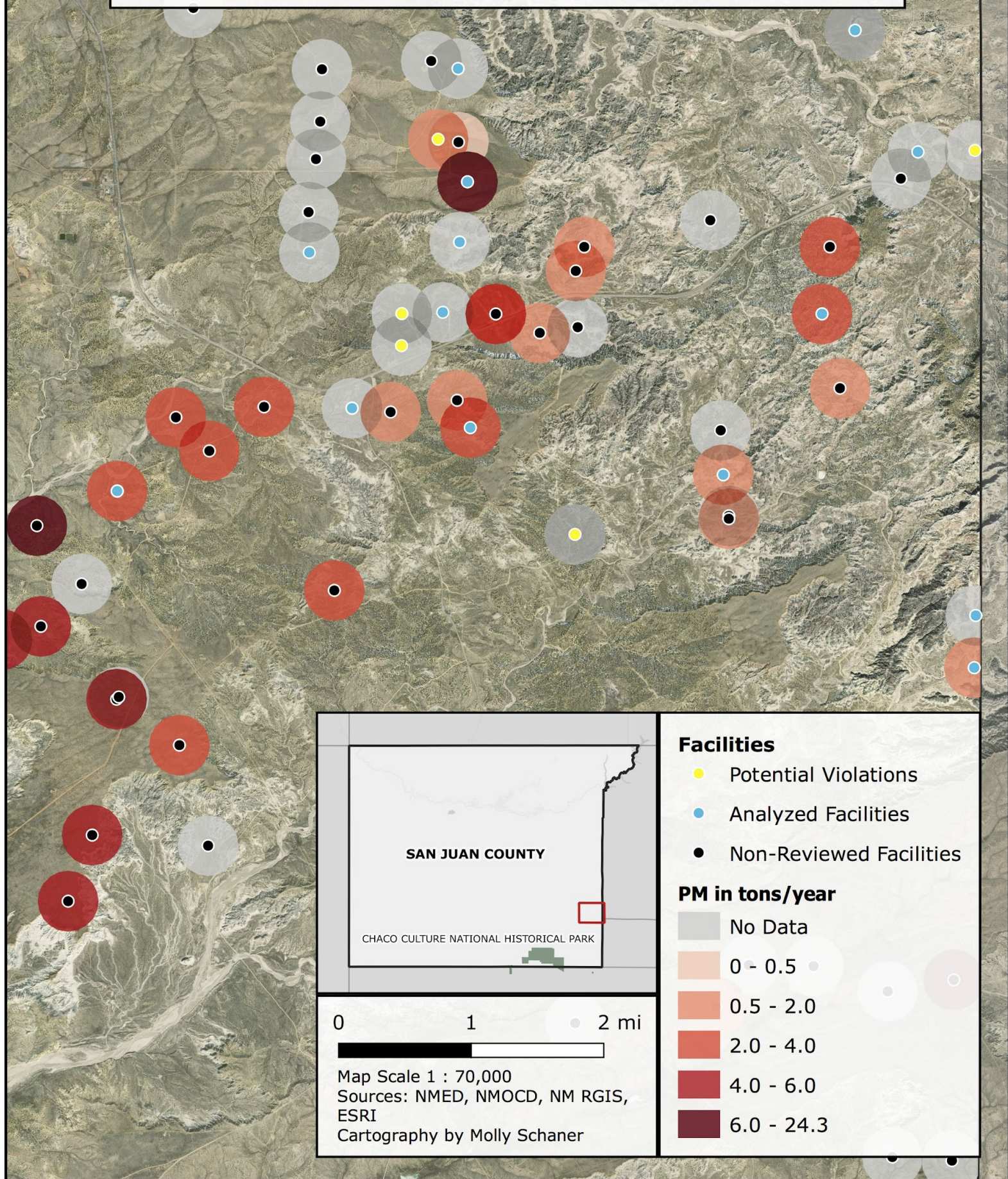
# Volatile Organic Compound (VOC) Emissions

Analyzed refers to facilities throughout San Juan County that were investigated in this project. All facilities refers to all compressor stations, production facilities, tank battery / bulk fuel storage, and well heads in San Juan County. There are additional types of oil and gas facilities beyond these four that are not included in this table.

	Facility Type	Count	Total (tons/year)	Median (tons/year)
Analyzed (violations)	Compressor Station	3	185.80	63.90
	Production Facility	11	226.25	10.3
	Tank Battery/Bulk Fuel Storage	3	109.10	8.10
	Well Head	6	0.00	0.00
Analyzed (no violation)	Compressor Station	3	171.60	39.20
	Production Facility	32	2324.00	87.60
	Tank Battery/Bulk Fuel Storage	8	256.80	27.20
	Well Head	3	0.00	0.00
All Facilities	Compressor Station	449	10981.61	13.16
	Production Facility	183	8266.29	44.50
	Tank Battery/Bulk Fuel Storage	25	817.89	35.33
	Well Head	46	202.23	36.91



# Particulate Matter (PM) Emissions in a 1500 ft Facility Buffer





# Particulate Matter (PM) Emissions Map Breakdown

## Description

The Particulate Matter (PM) Emissions in a 1500 ft Facility Buffer map on page 38 depicts the PM emissions from a subset of oil and gas facilities in San Juan County, New Mexico. PM refers to all particulates There are three types of oil and gas facilities on the map: those with potential permitting violations, facilities analyzed by this project that had no permitting violations, and facilities not analyzed by this project.



# Particulate Matter (PM) Emissions

Analyzed refers to facilities throughout San Juan County that were investigated in this project. All facilities refers to all compressor stations, production facilities, tank battery / bulk fuel storage, and well heads in San Juan County. There are additional types of oil and gas facilities beyond these four that are not included in this table.

	Facility Type	Count	Total (tons/year)	Median (tons/year)
Analyzed (violations)	Compressor Station	3	1.70	0.00
	Production Facility	11	10.10	0.00
	Tank Battery/Bulk Fuel Storage	3	0.00	0.00
	Well Head	6	0.0	0.0
Analyzed (no violation)	Compressor Station	3	2.9	0.6
	Production Facility	32	65.3	0.00
	Tank Battery/Bulk Fuel Storage	8	17.4	2.9
	Well Head	3	0.0	0.0
All Facilities	Compressor Station	449	144.48	1.60
	Production Facility	183	202.66	2.90
	Tank Battery/Bulk Fuel Storage	25	5.53	1.13
	Well Head	46	0.0	0.0

# Works Cited

Hyperlinks to data sources were provided throughout the appendix and are also available on the [repository](#). The works cited below represent a subset of sources that were not appropriate to include as hyperlinks.

1. Haley et al., “Adequacy of Current State Setbacks for Directional High-Volume Hydraulic Fracturing in the Marcellus, Barnett and Niobrara Shale Plays.” (2016).
2. Macey, G. P., et al., “Air concentrations of volatile compounds near oil and gas production: a community-based exploratory study. Environmental Health, 13(1), 82.” (2014)
3. Haley et al., “Adequacy of Current State Setbacks for Directional High-Volume Hydraulic Fracturing in the Marcellus, Barnett and Niobrara Shale Plays.” (2016).
4. Macey, G. P., et al., “Air concentrations of volatile compounds near oil and gas production: a community-based exploratory study. Environmental Health, 13(1), 82.” (2014).
5. Shamasunder et al., “Community-Based Health and Exposure Study around Urban Oil Developments in South Los Angeles.” (2017).
6. LA County Department of Public Health, “Public Health and Safety Risks of Oil and Gas Facilities in Los Angeles County.” (2018).
7. Lewis et al., “Setback distances for unconventional oil and gas development: Delphi study results.” (2018).
8. Oil and Gas Threat Map. Retrieved from:  
<https://oilandgasthreatmap.com/about/>.

*The views and positions expressed in this report are those of the authors, and do not necessarily reflect those of WildEarth Guardians.*