



Raptor Habitat in Relation to Oil Infrastructure in Weld County, CO

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Abstract

Weld County, Colorado is the 7th largest producer of oil and gas in the continental United States. Home to the Pawnee National Grassland, Weld county supports short grass prairie, riparian, and agricultural ecosystems. These ecosystems support several raptor species on the Bureau of Land Management (BLM) Sensitive Species list, indicating that their habitat requires special management considerations to minimize the likelihood of endangerment. In April of 2019 senate bill 19-181 was passed, directing the Colorado Oil and Gas Conservation Commission to regulate operations in Colorado in a manner that protects public health, safety, welfare, the environment, and wildlife resources. Following this framework, the Colorado Energy and Carbon Management Coalition (ECMC) created Rule 304.c.(17) requiring oil and gas operators to create and submit a wildlife protection plan to the ECMC if operations are located within a Colorado Parks and Wildlife (CPW) identified High Priority Habitat. CPW High Priority Habitat spatial data, as defined by the ECMC, includes those habitat areas identified by CPW on maps included as Appendix VII to the ECMC's rules. The purpose of this project is to identify ideal locations for future oil and gas development in Weld county to minimize potential use limitations and harm to wildlife. To do so, we performed a suitability analysis based on county hydrology, parcel data, CPW-mapped High Priority Habitat, and ECMC regulation. These components were individually weighted based on their suitability for new well placement, categorized into three layers: most suitable (1), intermediate suitability (2), and not suitable (3), then overlaid to create one feature layer containing our results. Our suitability results allowed us to create a map of suitable locations for new oil and gas development. We identified roughly 1,554 km² that is not eligible for new oil and gas locations, and 4,412 km² that is ideal placement. This spatial data can be used by oil and gas companies and related stakeholders to inform where new wells should be placed to comply with SB 19-181. Future considerations should account for Colorado wildlife as a whole by including all taxa with High Priority Habitat documented in Weld county. Logistical and monetary input from oil and gas companies could also benefit the expansion of this project. Incorporating those factors in the suitability analysis would improve accuracy of suitable areas.

Introduction

Weld County, Colorado is ranked as the 7th largest oil and gas producer in the country. Weld county is predominately a shortgrass prairie ecosystem, and contains the Pawnee National grassland- 193,000 acres of protected natural area famous for its birding, hiking, and camping (USDA). Since 1970, grassland bird populations collectively have declined by 53% ("Nearly 3 Billion Birds Gone"). Raptors, or birds of prey, are essential to grassland ecosystems due to their position at the top of the foodweb. Primarily feeding on small rodents and birds, they contribute to disease prevention and regulate prey populations. Additionally, raptors act as an indicator species for human and environmental health due to their sensitivity to habitat change (Hawk Watch International). In the well permitting process, oil and gas operators must submit a Cumulative Impact Assessment to the Colorado Energy and Carbon Management Coalition (ECMC). This report includes all environmental impacts, including wildlife impacts, affected waterways, topsoil sampling, and more depending on the site. Nesting raptors often delay site operations, sometimes

pushing work back for over a month. Additionally, follow-up surveys or consistent nest monitoring are usually required to clear the site. The purpose of this project is to create a resource for oil and gas companies, environmental consultants, and governing organizations to better inform future well placement. By strategically placing new well infrastructure, we can prevent potential environmental harm. The goal of this project was to create a map that clearly displays where Weld county is highly suitable, moderately suitable, and not suitable for new oil and gas development, primarily based on known raptor habitat for the selected species.

Background

For this project, we selected the following raptor species for habitat analysis: Bald Eagle (*Haliaeetus leucocephalus*), Burrowing Owl (*Athene cunicularia*), Ferruginous Hawk (*Buteo regalis*), Osprey (*Pandion haliaetus*), Prairie Falcon (*Falco mexicanus*), Peregrine Falcon (*Falco peregrinus*), and Golden Eagle (*Aquila chrysaetos*). This list was created from referencing the Colorado Parks and Wildlife (CPW) High Priority Habitat dataset and Colorado Bureau of Land Management (BLM) sensitive species list. To comply with the Bald and Golden Eagle Protection Act, both of those species were included despite maintaining stable populations. The study area was limited to Weld County because it is the highest exporter of oil and gas in Colorado, as well as the 7th largest exporter nationally. In April of 2019 senate bill 19-181 was passed, directing the Colorado Oil and Gas Conservation Commission to regulate operations in Colorado in a manner that protects public health, safety, welfare, the environment, and wildlife resources. Following this framework, the ECMC created Rule 304.c.(17) requiring oil and gas operators to create and submit a wildlife protection plan to the ECMC if operations are located within a CPW-identified High Priority Habitat. CPW High Priority Habitat spatial data, as defined by the ECMC, includes those habitat areas identified by CPW on maps included as Appendix VII to the ECMC's rules. The ECMC has compiled all rules and regulations for oil permitting, operation, and remediation in the *Code of Colorado Regulations*. These regulations provide detailed guidance on how to comply with state statutes and help guide state departments and agencies in their operations (ECMC).

Location of Weld County in Colorado

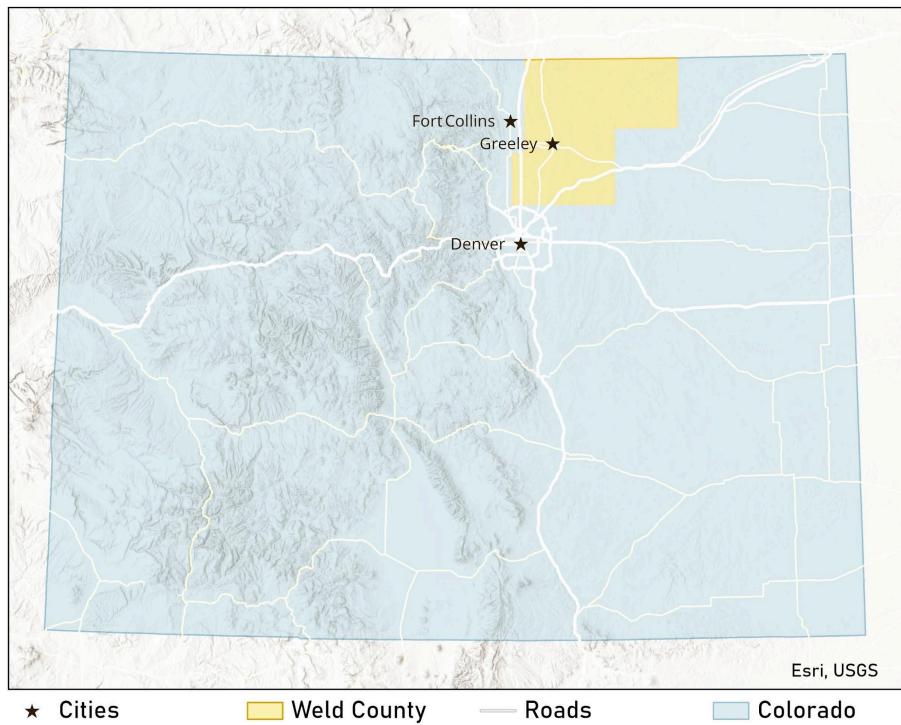


Figure 1: Map layout of study area within Colorado. Weld County is highlighted to display the extent of the project in relation to the rest of the state.

Methods and Analysis

Data Acquisition and Preparation

The data sets used in this project include oil and gas wells (`Filtered_well_data_`), Weld County Boundary (`weld_county_bndry`), Bird Habitat (`Bird_Data`), land use (`StateofColorado_Parcels`), hydrology (`NHD_Weld`), and schools (`Schools_Weld`). More information can be found in table 1. Despite the focus of raptor habitat protection in this class, additional data sets were included to allow for a comprehensive suitability analysis. The additional datasets were selected due to the restrictions of well implementation within specific distances of the feature as defined in the ECMC's *Colorado Code of Regulations*. All of the data was projected in NAD 1983 UTM Zone 13N to ensure accurate placement on the basemap. Initially, the eBird and Colorado State parcel data sets were in .csv format. Because of this, it was necessary to reformat and organize the .csv files then use the "table to point" tool to analyze this data spatially. The eBird data was easily converted to points; however the parcel data set needed additional steps to allow for the polygons to be added to the map. These steps included reformatting the dates to match the desired format in ArcGIS. The parcel data was then categorized based on tax land use description and divided into the following feature layers: Agriculture, Residential, Buildings, Vacant Land, Industrial, and Natural Areas.

Table 1: Project data categorized by name, origin dataset, source website, and file format.

Data Category	Name	Dataset	Source	Format
Oil and Gas Wells	Filtered_well_data	ECMC	Colorado ECMC	.csv
Weld County	weld_county_bndry	County Boundary	Weld GIS Hub	Shapefile
Bird Habitat	Bird_Data	CPW HPH	ArcGIS Online	File Geodatabase Feature
Bird Habitat	Bird_Data	EBird	eBird	.csv
Land Use	StateofColorado_Parcels	State of Colorado Public Parcels	ArcGIS Online	Feature layer
Hydrology	NHD_Weld	National Hydrography Dataset	USGS	File Geodatabase
Schools	Schools_Weld	CDPHE Open Data	ArcGIS online	Feature layer

ArcGIS Steps

To conduct this project ArcGIS Pro software was used to buffer and classify the data layers to display the most to least suitable areas. An image of the general workflow used can be found in figure 2. The initial step was to clip all of the layers to be located within the focus area of Weld County Colorado. This step allowed for a reduction in the processing time for future tools as the data sets were reduced to only contain data located within our project's spatial boundary. Once the layers were clipped to Weld County's extent, they were buffered based on the ECMC oil and gas well regulations. The ECMC *Colorado Code of Regulations* document includes the buffer distances that are advised for permitting, as well as the hard line buffers that are required for well placement. Using this document, buffers around residential areas (500ft), buildings (1000ft), schools (1000ft), natural areas (350ft), government buildings (1 mile), and water features (500ft) were created. For the raptor habitat buffers, the distances were sourced from CPW's *Best Practices and Recommended Buffers for Critical Raptor Habitats*. This document provides the minimum distance that well operation can be generally conducted without distressing the raptor(s). The recommended survey buffer for each raptor are: Bald Eagle ($\frac{1}{2}$ mile), Golden Eagle ($\frac{1}{2}$ mile), Ferruginous Hawk ($\frac{1}{2}$ mile), Peregrine Falcon ($\frac{1}{2}$ mile), Prairie Falcon ($\frac{1}{2}$ mile), Osprey ($\frac{1}{4}$ mile), and Burrowing Owl ($\frac{1}{8}$ mile). Buffers were created around individual (200ft) and grouped wells (100ft) to display areas where wells are already located and new wells can be placed without having to build large amounts of additional infrastructure.

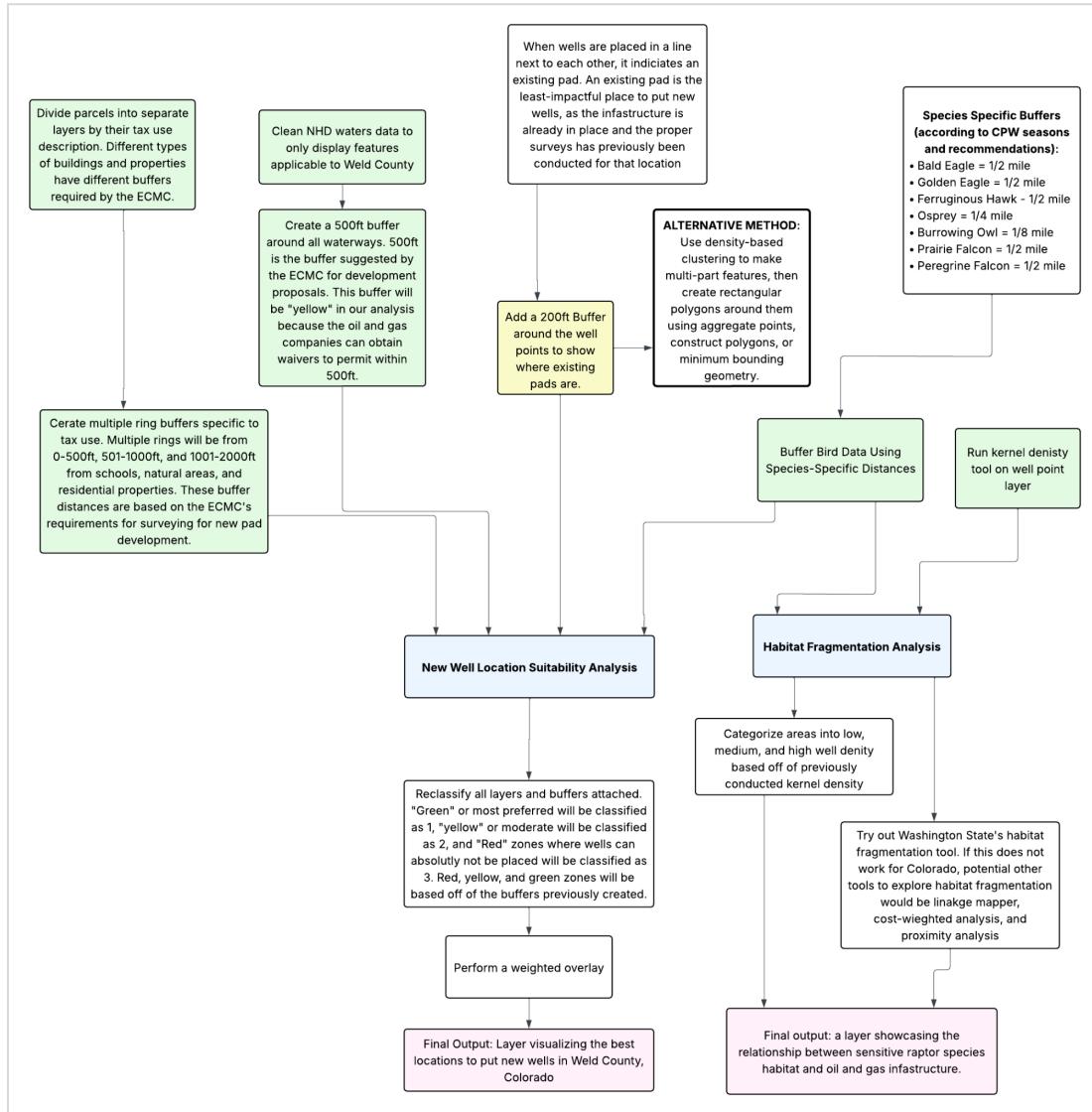


Figure 2: Project workflow including the reach goal of habitat connectivity analysis.

Once the buffers were made, they were assigned suitability values based on if the buffered feature had strict regulations or only required additional permitting. The suitability values consisted of 0 and 1 (highly suitable), 2 (intermediate suitability), and 3 (unsuitable). The highly suitable area included the value of 0 to ensure that all areas within Weld County with no overlapping buffers were classified as suitable. Well pad buffers were assigned a value of 1 in their attribute table. The intermediate suitability areas included residential areas, buildings, government buildings, individual wells, and water which were all assigned a value of 2 in their attribute tables. The unsuitable areas included all the bird habitat buffers, school buffers, and natural areas. Each suitability attribute also had a corresponding weight with high suitability having the lowest weight and unsuitable having the highest weight. This allowed for the unsuitable areas to overwrite the high suitability areas. Once these assignments were applied, the calculated field function was used to separate the buffers with different suitability values. The equation used for the highly suitable areas can be referenced in equation 1. The intermediate suitability equation can be referenced in equation 2. The unsuitable area equation can be referenced in equation 3.

$$(!Weld_Suitability!*!Weld_Weight!) + (!Clusters_buffered_suitability!*!Clusters_buffered_Weight!)$$

Equation 1: Calculate field equation used to create the high suitability layer.

$(!Residential_Buffer_Suitability!*!Residential_Buffer_Weight!) + (!Buildings_Buffer_Suitability!*!Buildings_Buffer_Weight!) + (!Single_Well_Suitability!*|Single_Well_Weight!) + (Water_Suitability!*|Water_Weight!).$ The unsuitable equation was $(!All_Birds_Suitability!*!All_Birds_Weight!) + (!Schools_Weld_Suitability!*!Schools_Weld_Weight!) + (!Natural_Areas_Suitability!*!Natural_Areas_Weight!)$

Equation 2: Calculate field equation used to create the medium suitability layer.

$$(All_Birds_Suitability!*|All_Birds_Weight!)+(Schools_Weld_Suitability!*!Schools_Weld_Weight!) + (!Natural_Areas_Suitability!*!Natural_Areas_Weight!)$$

Equation 3: Calculate field equation used to create the unsuitable layer.

Using these calculations, three layers were made based on each suitability value and weight. The medium suitability and high suitability layers were then cut to exclude lower suitability. This resulted in three layers that have no overlap, with the lowest suitability areas overwriting both the medium and high suitability, and the medium suitability layer overwriting the high suitability. The final suitability layers were styled to look appealing and display contrast for people with color vision deficiency as seen in Figure 3. To perform analysis on the suitable area layers, the area of each suitability class was calculated. Maps of suitability, well density, and raptor habitat were created for visual analysis. Additional deliverables include this final summary report, a final presentation, and an experience builder page.

Suitable Locations for New Oil and Gas Wells in Weld County

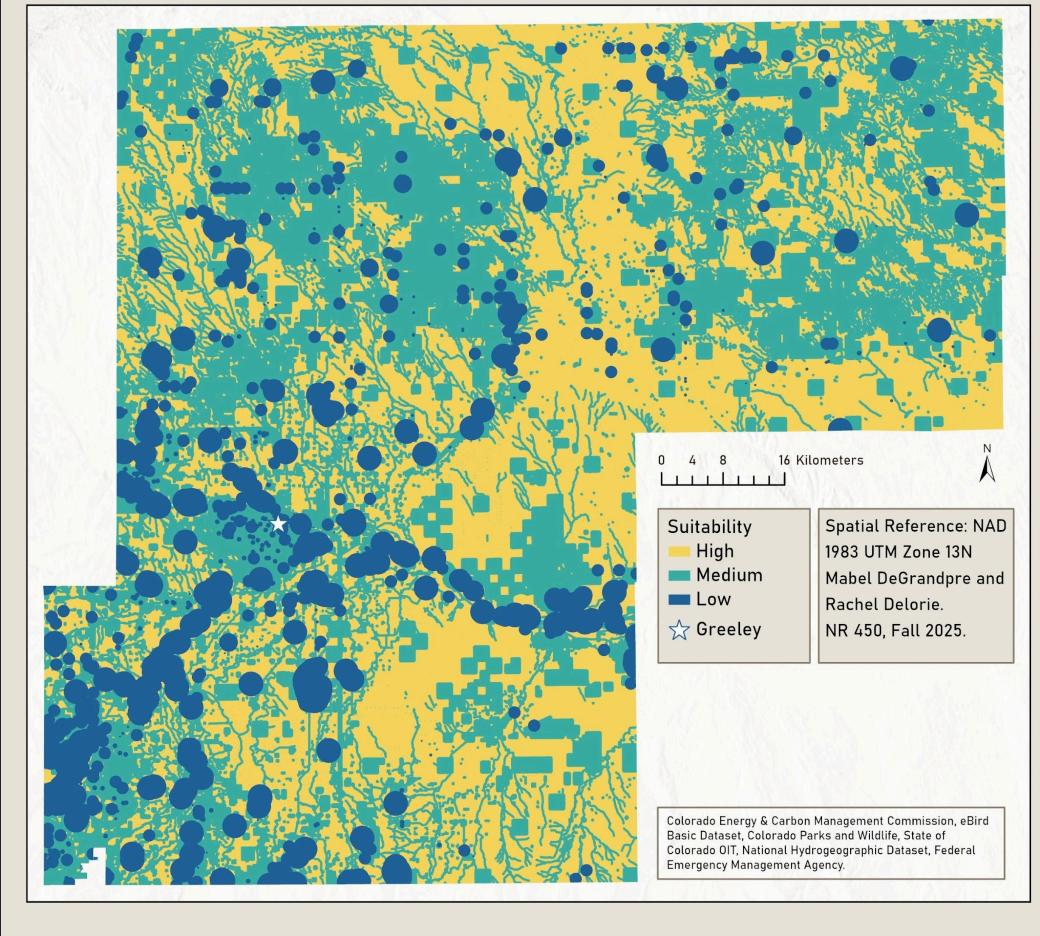


Figure 3: Final map displaying the sarees with different suitability classifications with unsuitable areas taking up 1,554 km² and medium and high suitability areas taking up 4,412 km².

Challenges and Limitations

The most significant limitation of this project was data acquisition. This issue came up when retrieving raptor data, parcel data, and well pad polygons. When searching for raptor species habitat, it was difficult to find observational data. The majority of data layers were potential, such as "species range" or "migrational range", and spanned the entire area of Weld County. This caused us to source eBird data for additional data points. This dataset has the potential for flaws and inaccuracies, as it is a citizen science platform. This means that observations were limited to areas with high human traffic, such as natural areas and highly populated cities such as Greeley. In addition to the raptor species data being difficult to retrieve, there were issues finding parcel data with a full attribute table. This required us to use the Colorado State parcel dataset despite it having missing attributes, which limited us to rely solely on tax land use description to divide the parcels by use. Lastly, there was no accessible data on well pads. We worked around this limitation by using density based clustering of our well layer to identify groupings of wells. This layer was

then buffered by 200ft to generalize the area of well pads. If this project were to be replicated, either in Weld County or not, it would be important to allot a significant amount of project time toward obtaining more extensive data on raptor species, editing the parcel table, and ensuring accuracy of well pad polygons.

Results

Upon completion of the ArcGIS Pro workflow three map layouts were created. The three maps are Suitability Assessment (figure 3), Well Density (figure 5), and Raptor Habitat (figure 6). These maps allow for visual analysis. Calculating the area of each suitability ranking revealed that the medium suitability layer covered the most area in Weld County, with 4,698 km². High suitability was a close second with an area of 4,144 km², and the unsuitable areas had the lowest area of 1,554 km², as shown in figure 4.

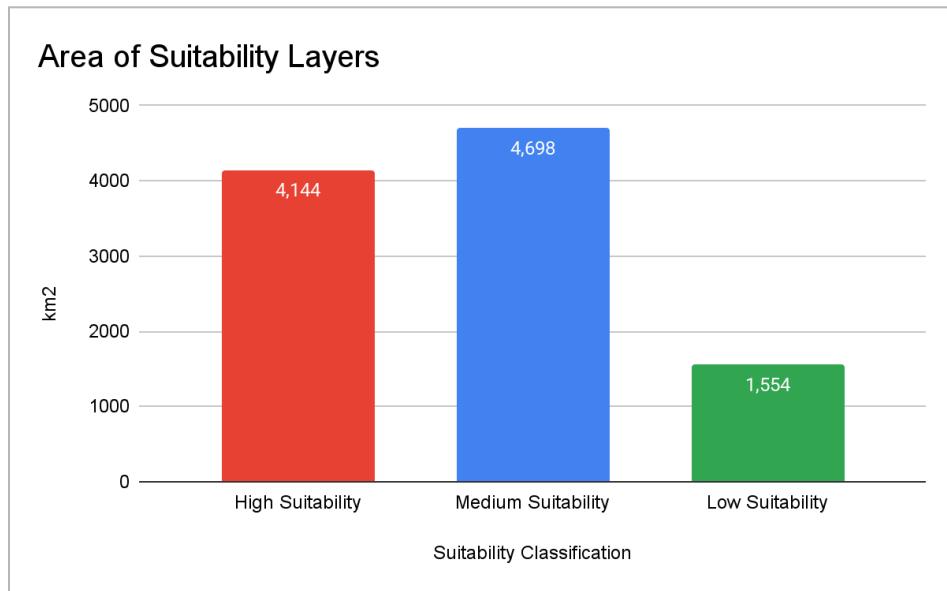


Figure 4: Bar chart showing the total area of each suitability layer in square kilometers.

When suitability was assessed in comparison to well density, the areas where well density is the highest are generally not suitable for future oil and gas infrastructure (figure 5). Well density appears to correlate to population density, with more urban areas of Weld County being located in or South-West of Greely, CO. The primary factors leading to unsuitability are schools and bird habitat. The region with the highest suitability is rural Weld County where there are lots of agricultural fields. This is due to the lack of raptor habitat, residential areas, and infrastructure that creates restrictions for well placement. Additionally, we observed that Bald Eagle habitat closely follows the South Platte River, which runs horizontally in the lower portion of Weld County. As shown in figure 6, the pink polygons run along the entirety of the river.

Distribution of Existing Oil and Gas Wells in Weld County

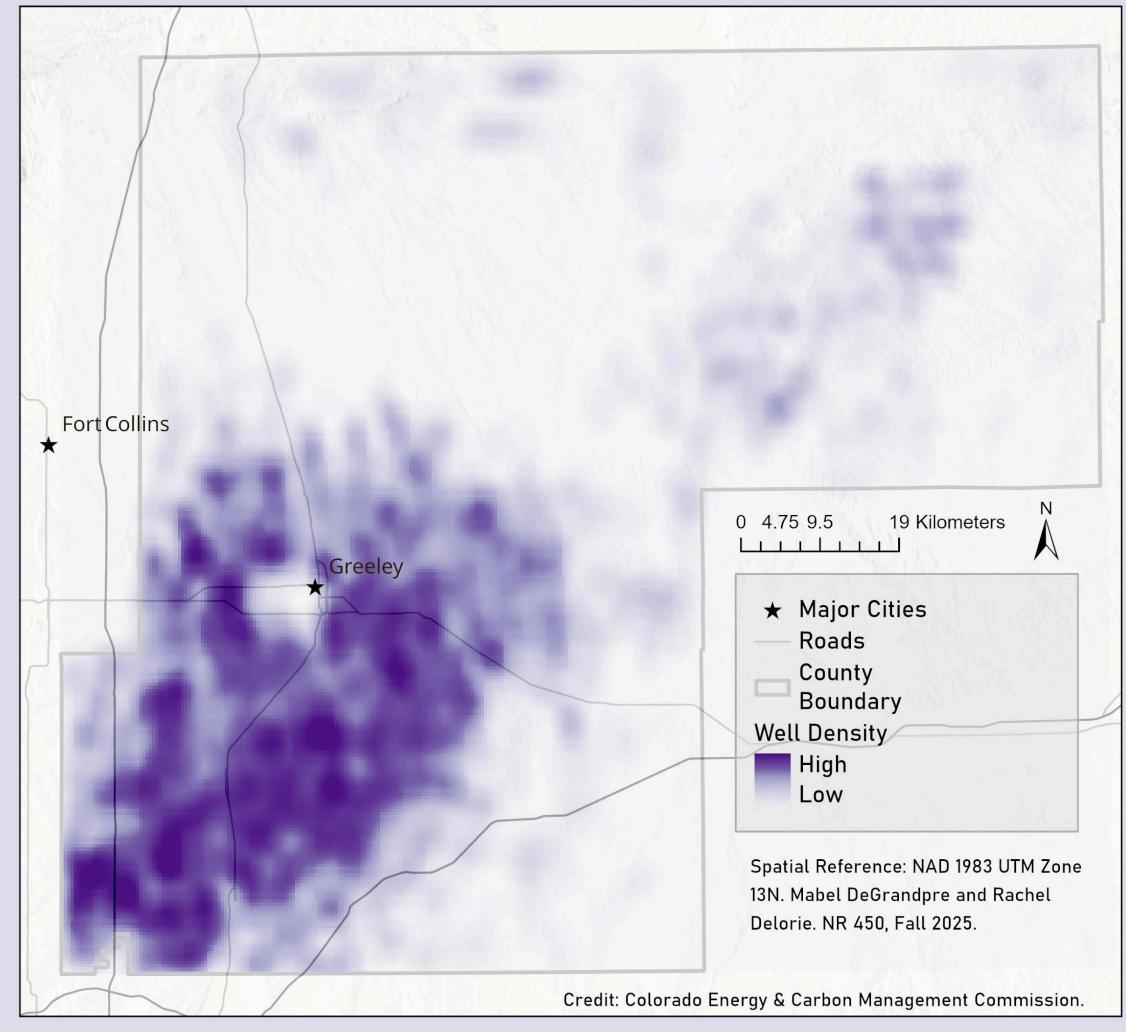


Figure 5: Map layout illuminating the highest well density areas in Weld County Colorado.

Raptor Critical Habitat Areas Weld County, CO

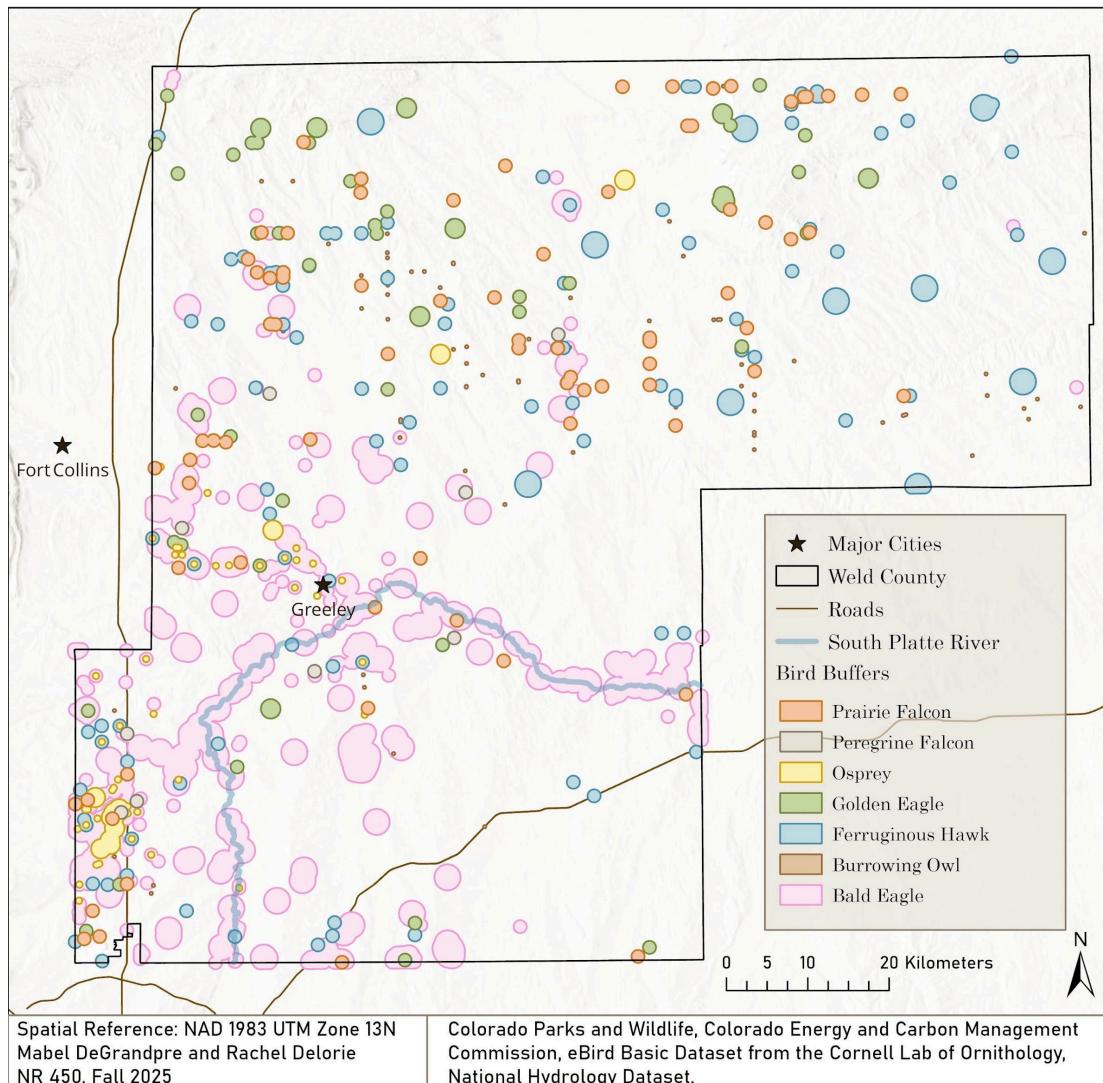


Figure 6: Map layout illustrating the buffered raptor habitat based on ECMC *Colorado Code of Regulations* and CPW *Best Practices and Recommended Buffers for Critical Raptor Habitats* documents.

When analyzing the oil and gas well owners and operators, the company with the most wells in Weld County was Kerr McGee Oil and Gas Onshore LP. This company owns 22.1% of the wells in Weld County operating under a status code indicating their physical presence. The second largest owner of wells in Weld County was Bonanza Creek Energy Operating Company LLC, owning 19.67% of the wells shown (figure 7). These companies represent the goal audience for this project, as they could potentially benefit from the suitability analysis that was performed.

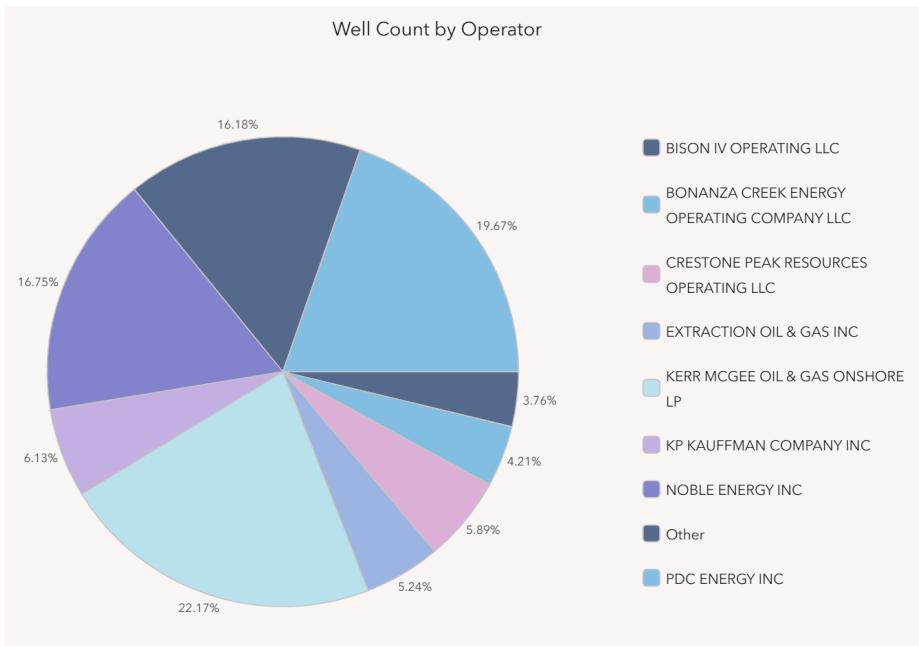


Figure 7: Pie Chart illuminating the different oil and gas well operators in Weld County, displayed in percentages.

Discussion

Interpretation and Significance

Medium suitability covered the most area in Weld County, with $4,698\text{km}^2$ identified for ideal well pad placement. This is hypothesized to be the case because of the dependent nature of medium suitability. It does not necessarily mean that wells cannot be placed in this area, but further permissions, surveys, and jurisdictional determinations are needed. Highly suitable area was the next largest portion of Weld County, only 554km^2 behind medium. This was an important finding as it shows that despite the regulations on well placement there is still opportunity for growth without disrupting raptor habitat. When suitability was assessed in comparison to well density, the areas where well density is the highest are generally not suitable for future oil and gas infrastructure (figure 5). These findings display a need to prioritize alternative areas for well placement, but may also signify that additional requirements for well placement were not taken into account. These additional requirements include driving distance, proximity to corporate offices, and access roads. A relationship between the South Platte River and Bald Eagle habitat was discovered during preliminary analysis of figure 6. Bald Eagle habitat closely follows the South Platte, allowing us to draw the conclusion that riparian areas are highly suitable for Bald Eagle nesting. We hypothesize that riparian areas support the growth of large, mature trees, which are ideal nesting habitats. This relationship displays the importance of the South Platte River for the preservation of Bald Eagles.

Future Recommendations

Several raptor species prevalent in Weld County were excluded from this analysis, either to limit the scope of the project or due to a lack of spatial data for the species. Replications of this

project should include the Northern Goshawk, American Kestrel, Red-Tail Hawk, Sharp-Shinned Hawk, and Northern Harrier. Additionally, this suitability could be expanded to account for taxa outside of birds. CPW High Priority Habitat includes data for sensitive species such as the Prairie Chicken, Swift Fox, and Preble Meadows Jumping Mouse. Exploring habitat fragmentation using Linkage Mapper tools was initially included in our workflow (figure 2), but unfortunately was not implemented due to time restraints. We would have liked to include road infrastructure in our analysis. Based on our results, we have reason to believe that access is an important consideration for well placement. Finally, input from oil and gas companies would be highly beneficial to the expansion of this project. Incorporating factors in the suitability analysis that are important to them for monetary or logistical reasons would increase the likelihood of our placement suggestions being implemented in the future.

References

- Brown, Julie. "Raptors at Risk." *Raptor Population Index*, <https://www.rpi-project.org/raptors-at-risk/>. Accessed 7 Dec. 2025.
- Colorado Energy and Carbon Management Coalition. *Code of Colorado Regulations*.
https://ecmc.colorado.gov/sites/ecmc/files/documents/Complete%20Rules_%28100%20Series-1300%20Series%29_Effective%20October%2030%202025_.pdf. 100 Series.
- Colorado Parks and Wildlife. *RECOMMENDED BUFFER ZONES AND SEASONAL RESTRICTIONS FOR COLORADO RAPTORS*. <https://cpw.widencollective.com/assets/share/asset/fqmg4ds76b>. Accessed 8 Dec. 2025.
- Hawk Watch International. *The Importance of Raptor Research*. 4 Dec. 2025,
<https://hawkwatch.org/importance-of-raptor-research/>.
- "Nearly 3 Billion Birds Gone." *Birds, Cornell Lab of Ornithology*,
<https://www.birds.cornell.edu/home/bring-birds-back/>. Accessed 7 Dec. 2025.
- Senate Bill 19-181*. <https://ecmc.state.co.us/sb19181.html#/overview>. Accessed 7 Dec. 2025.
- USDA. Arapaho and Roosevelt National Forests & Pawnee National Grassland | Pawnee National Grassland | Forest Service.
<http://www.fs.usda.gov/r02/arp/recreation/pawnee-national-grassland>. Accessed 9 Dec. 2025.