Low-Risk Wind Energy Development Areas in the Central Great Plains
[revised 8/25/2017]

The Nature Conservancy (TNC)[1]. 2017. Low-risk wind energy development areas in the Central Great Plains. Central Great Plains Grasslands Initiative project office, Tulsa, Oklahoma, USA. http://www.nature.org/sitewindright

Introduction

The Nature Conservancy has developed a science-based siting assessment to facilitate responsible wind energy procurement and development in Kansas, Oklahoma and a portion of Texas. Power purchasers acquiring wind-generated electricity from the Central Great Plains may meet renewable energy objectives while helping to protect sensitive ecosystems by selecting projects sited in defined low-risk wind energy development areas. This analysis, which represents a practical application of concepts outlined in Obermeyer et al. (2011) and Fargione et al. (2012), identifies locations where conflicts between wind energy and wildlife are likely to be minimal. Notably, the assessment factors engineering and land use constraints so that sites with low development potential are excluded.

It is important to note that this assessment is a coarse-filter approach to the siting of wind energy; regarding potential impacts to protected species, developers should consult with relevant federal and state wildlife agencies including the U.S. Fish and Wildlife Service, the Kansas Department of Wildlife, Parks & Tourism, the Oklahoma Department of Wildlife Conservation, and the Texas Parks and Wildlife Department.

Methods

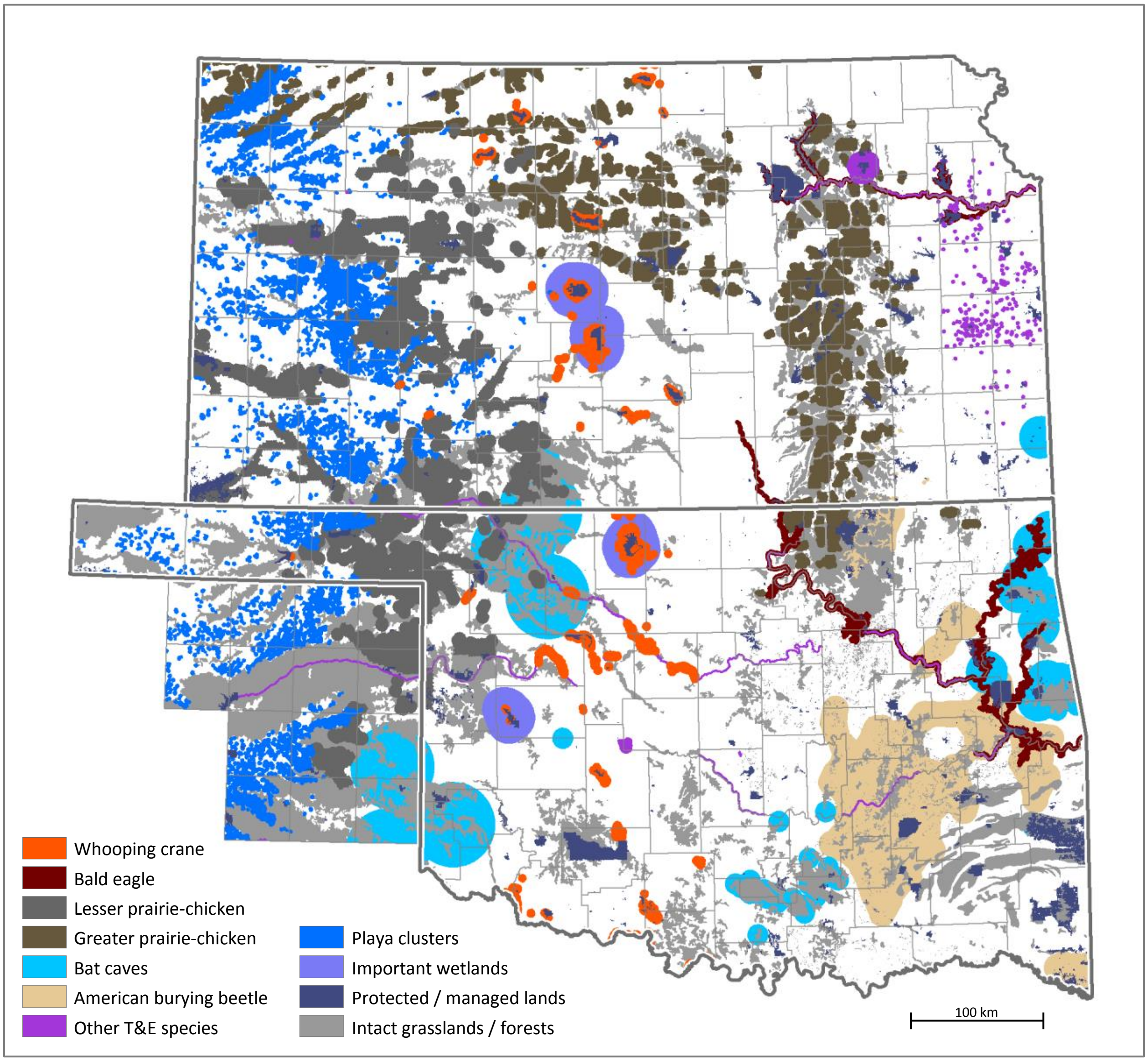
Key wildlife areas

We identified sensitive natural habitats and distributions of wildlife species that may be adversely impacted by wind energy development (Figure 1). Key wildlife areas include:

- Whooping crane stopover sites
- Bald eagle nesting areas
- Lesser prairie-chicken focal areas and lek complexes
- Greater prairie-chicken optimal habitat
- Bat caves
- American burying beetle priority areas
- Other threatened and endangered species (terrestrial)
- Playa clusters
- Globally important wetlands
- Protected and managed lands
- Intact grasslands and forests

[1] **Contacts**
Rob Manes, Kansas State Director | 2420 NW Button Rd., Topeka, KS 66618 | Tel. 785.233.4400 | rmanes@tnc.org
Mike Fuhr, Oklahoma State Director | 10425 S. 82nd E Ave., Ste. 104, Tulsa, OK 74133 | Tel. 918.585.1117 | mfuhr@tnc.org

Figure 1. Map of key wildlife areas



Potential engineering and land use restrictions

We identified areas considered to have low potential for wind development due to physical constraints or incompatible human activity (Figure 2). Potential engineering and land use restrictions include:

- Airfields
- Special use airspace
- NEXRAD stations
- Existing wind facilities
- Urban lands and other developed areas
- Excessive slope
- Water and wetlands
- Poor wind resource

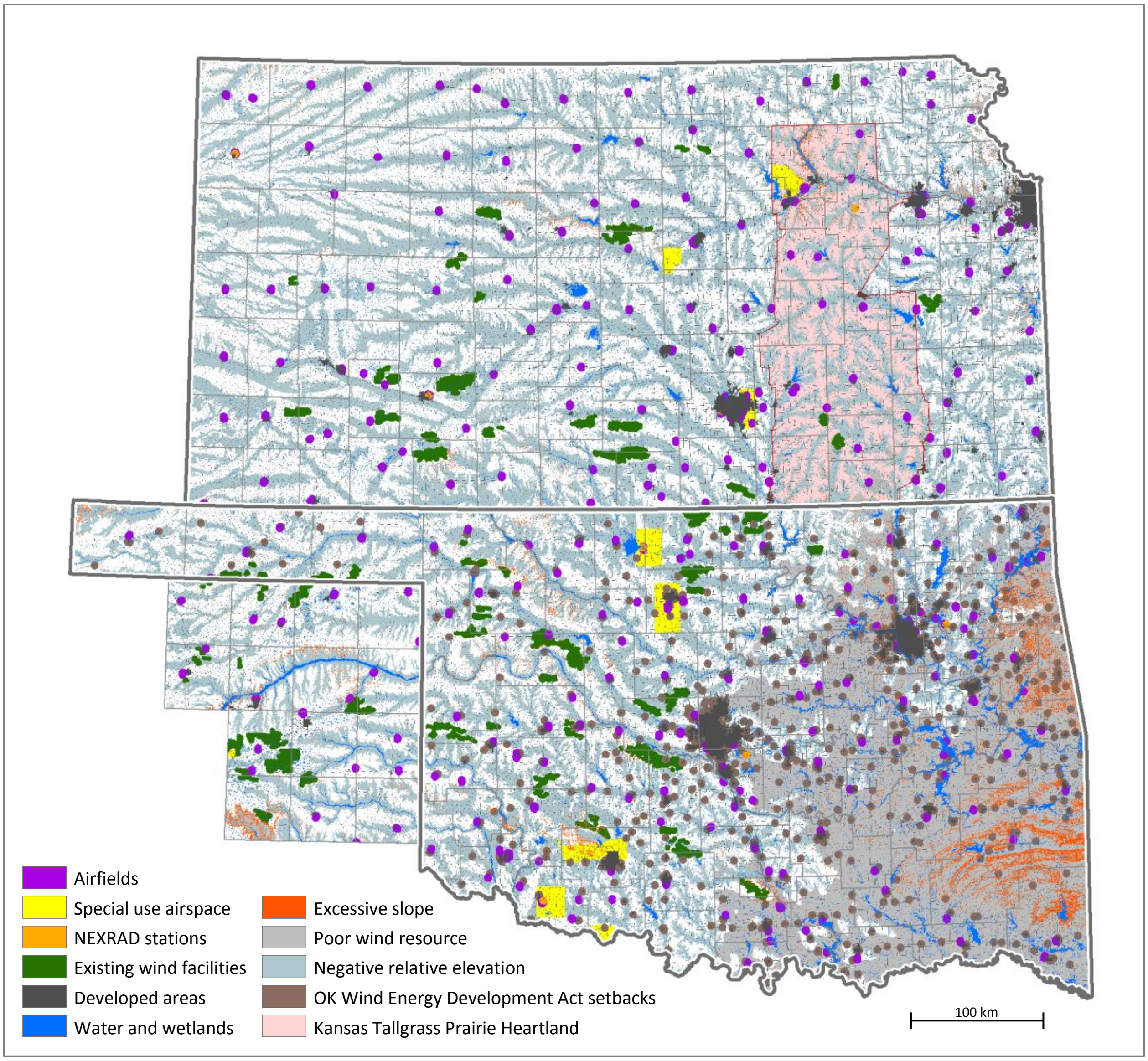
- Negative relative elevation
- Oklahoma Wind Energy Development Act setbacks
- Kansas Tallgrass Prairie Heartland

Delineation methods and data sources for component key wildlife areas and potential engineering and land use restrictions are detailed in the attached Appendix A.

Analysis

Input data were rasterized at a ground sample distance of 30 m. We generated a preliminary Boolean map of areas suitable for wind development by excluding lands with potential engineering and land use restrictions. To eliminate isolated areas too small to support commercial wind development, the results were smoothed using a 1 km radius moving window, and patches less than 20 km^2 in size were removed. The component engineering and land use restrictions layers were then subtracted from the remaining

Figure 2. Map of potential engineering and land use restrictions



smoothed patches to eliminate false positive values and other spatial artifacts introduced by the moving window analysis. To delineate suitable wind development areas with low risk of wildlife conflicts, key wildlife data layers were subtracted from the preliminary Boolean suitability map, and the analysis repeated as above.

For each state and for the analysis area as a whole, we quantified wind development potential on all suitable lands, as well as the subset of suitable lands identified as low-risk, based on a nameplate capacity density of 3 MW/km^2 (Denholm et al. 2009).

Results

Within the study area, approximately 13.1 million ha (32.4 million ac) of land may be suitable for development (based on wind speed and terrain, excluding previously developed sites, statutory

Figure 3. Map of low-risk wind development areas (existing wind facilities depicted for visual reference)

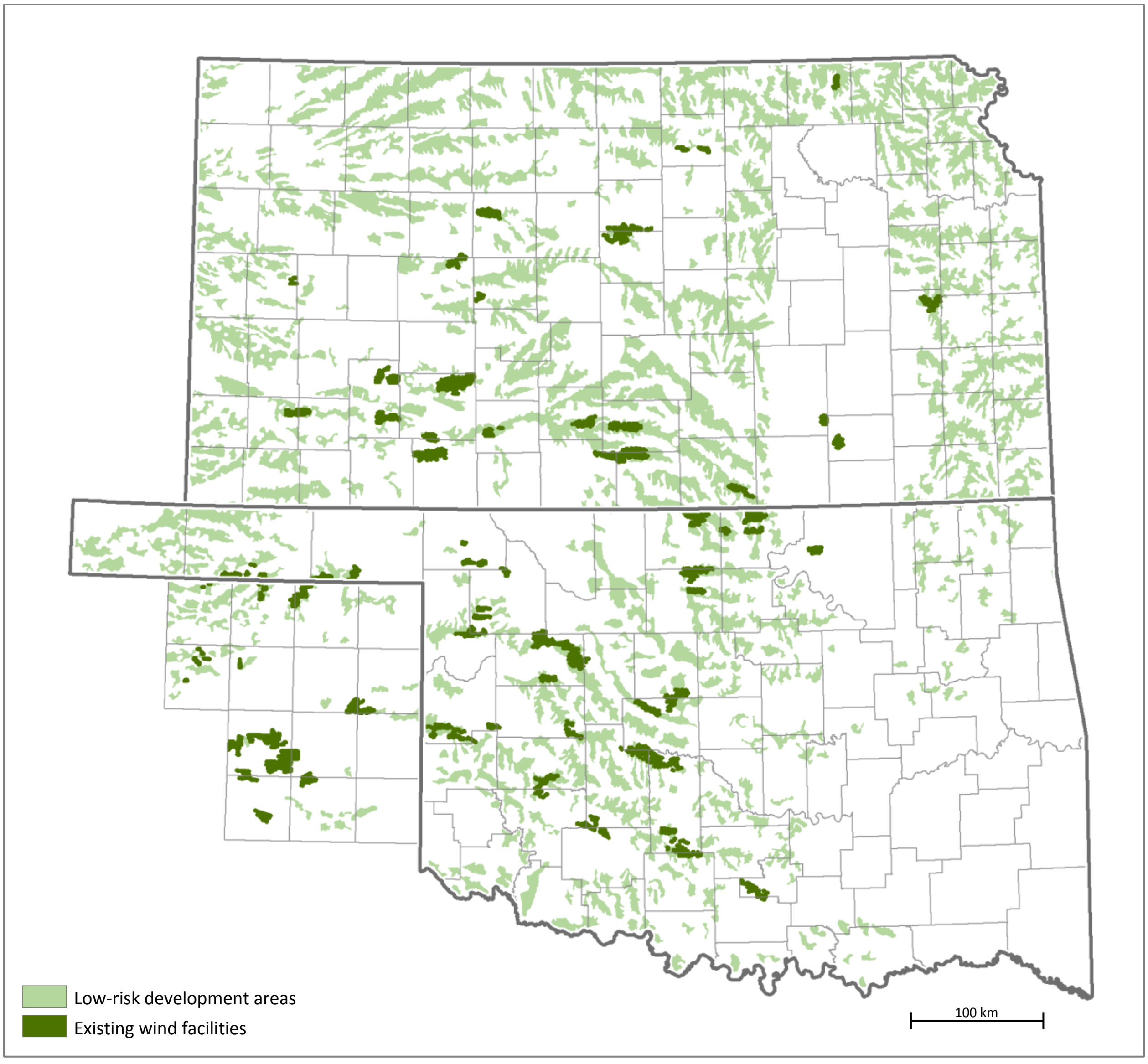


Table 1. Suitable land and low-risk development area statistics

State	Suitable land (ha)	Percent of region	Nameplate capacity (GW)	Low-risk suitable land (ha)	Percent of region	Nameplate capacity (GW)
Kansas	7,717,558	36%	232	4,378,719	21%	131
Oklahoma	3,886,284	21%	117	1,966,745	11%	59
Texas (selected counties)	1,507,191	45%	45	243,597	7%	7
combined area	13,111,033	31%	393	6,589,060	15%	198

setbacks, unsuitable land use, and small/isolated sites). If all of these areas were developed for wind energy, they could support approximately 393 GW of electrical capacity. After removing sensitive wildlife habitats, approximately 6.6 million ha (16.3 million ac) remain as suitable for development (15% of the region). These low-risk areas are capable of yielding approximately 198 GW of electrical capacity. For Kansas and Oklahoma, the low-risk development potential is more than 20 times greater than the combined state figures detailed in the U.S. Department of Energy 20% by 2030 Wind Vision Central Study Scenario (USDOE 2015).

Discussion

Our analysis suggests that large areas of the Central Great Plains could be developed for wind energy without significant negative impacts to wildlife (Figure 3; Table 1). Because the availability low-risk wind resources in the Central Great Plains far exceeds development projections, our results should be applicable to any reasonable development scenario. Moreover, our estimates of development potential are likely conservative, as some areas we consider to have engineering and land use restrictions may actually be viable for wind energy.

We note that our delineation of sensitive wildlife habitats is not exhaustive. Within the identified low-risk development areas, wildlife concerns should be addressed through careful micrositing. Operational mitigation may be required to reduce mortality, particularly for bats (Arnett et al. 2013).

To facilitate use of this assessment by interested parties, we created a web-based mapping application available at http://www.nature.org/sitewindright.

The engineering and land use information presented herein is intended to account for generalized areas of low development potential, in recognition that the wind industry faces many challenges related to project siting. This portion of the assessment is necessarily limited in scope and is not intended to replace detailed analyses of physical, social, and economic factors by knowledgeable project planners. If desired, component wildlife data may be used to evaluate ecological site characteristics separately from other concerns.

Procuring wind energy from low-risk development areas may provide power purchasers with several advantages over site-by-site application of the full mitigation hierarchy (i.e., avoid, minimize, mitigate/offset). Table 2 highlights our assessment of the comparative net benefits of a defined low-risk procurement area approach based on factors related to administration, risk profile, and cost.

Table 2. Comparative advantages of wind energy procurement from low-risk development areas

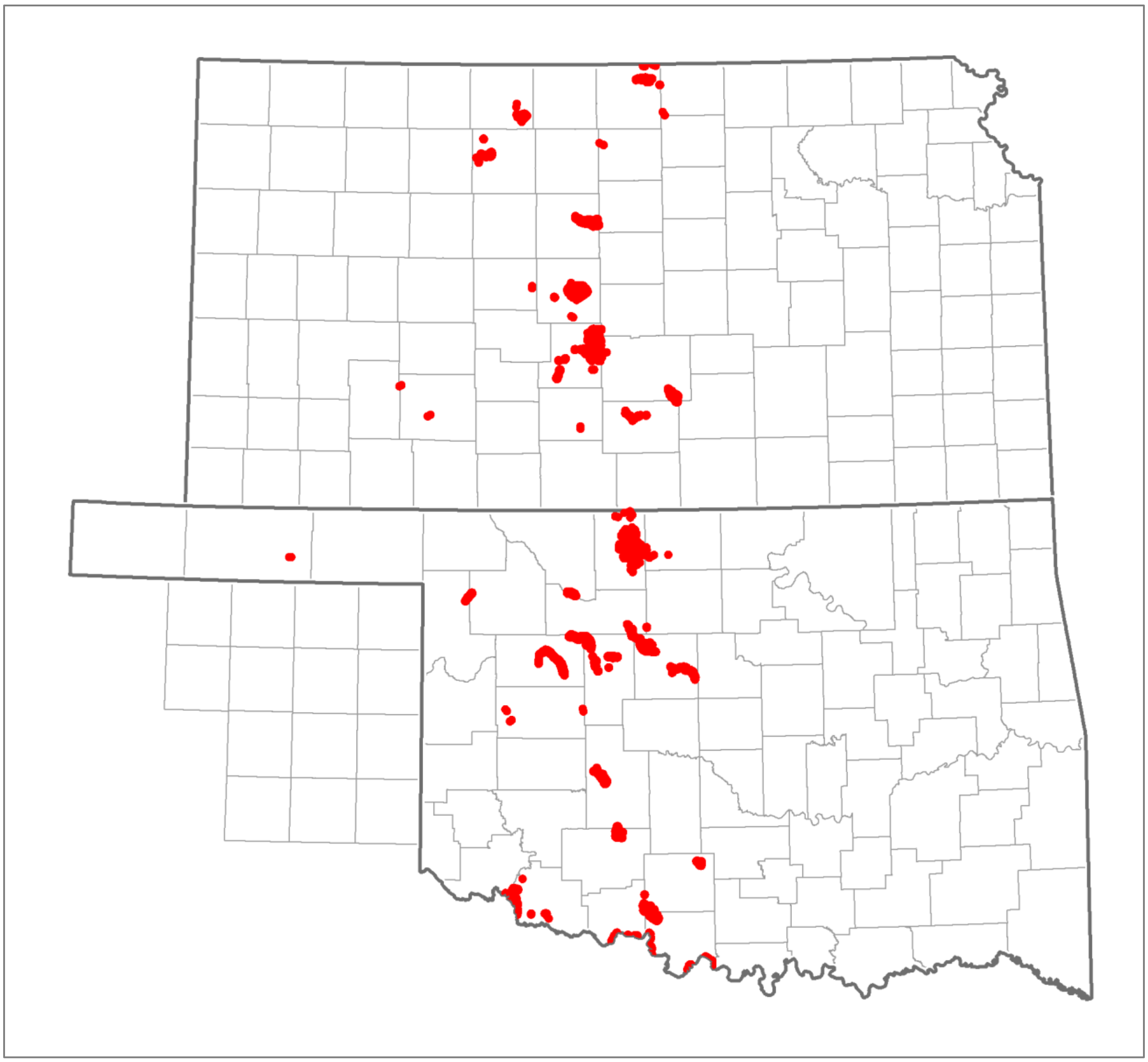
Business factors	Low-risk development areas	Mitigation hierarchy
Public relations and other disruptive risks	low	moderate - high
Regulatory and due diligence burdens	low	moderate - high
Complexity	low	high
Administrative burden and cost	low	high
Scientific certainty	high	low – moderate
Confidence in outcomes	high	mixed
Consistency relative to cost recovery	high	low – moderate
Impact of strong public commitment	high	moderate
“Bad actor” risk	low	moderate - high
Limitation of available wind resources	yes	yes (mitigation costs)
Renewable energy goals met	yes	yes

Appendix A – component element descriptions

Whooping crane stopover sites

The federally endangered whooping crane (*Grus americana*) depends on wetlands in the central Great Plains during migration (USFWS 2011a). Whooping cranes may be at risk of turbine collisions when ascending or descending from high altitude migration flights, or when travelling short distances between roost and foraging areas (USFWS 2009a). To address this concern, we delineated areas within 3.2 km of whooping crane stopover sites to be avoided by wind energy development. Stopover sites include locations with two or more confirmed whooping crane observations (USFWS 2010) since 1985, as well as modeled suitable habitat (cf. Austin and Richert 2001; Belaire et al. 2014) within portions of the migratory flyway frequently used by whooping cranes (Pearse et al. 2015).

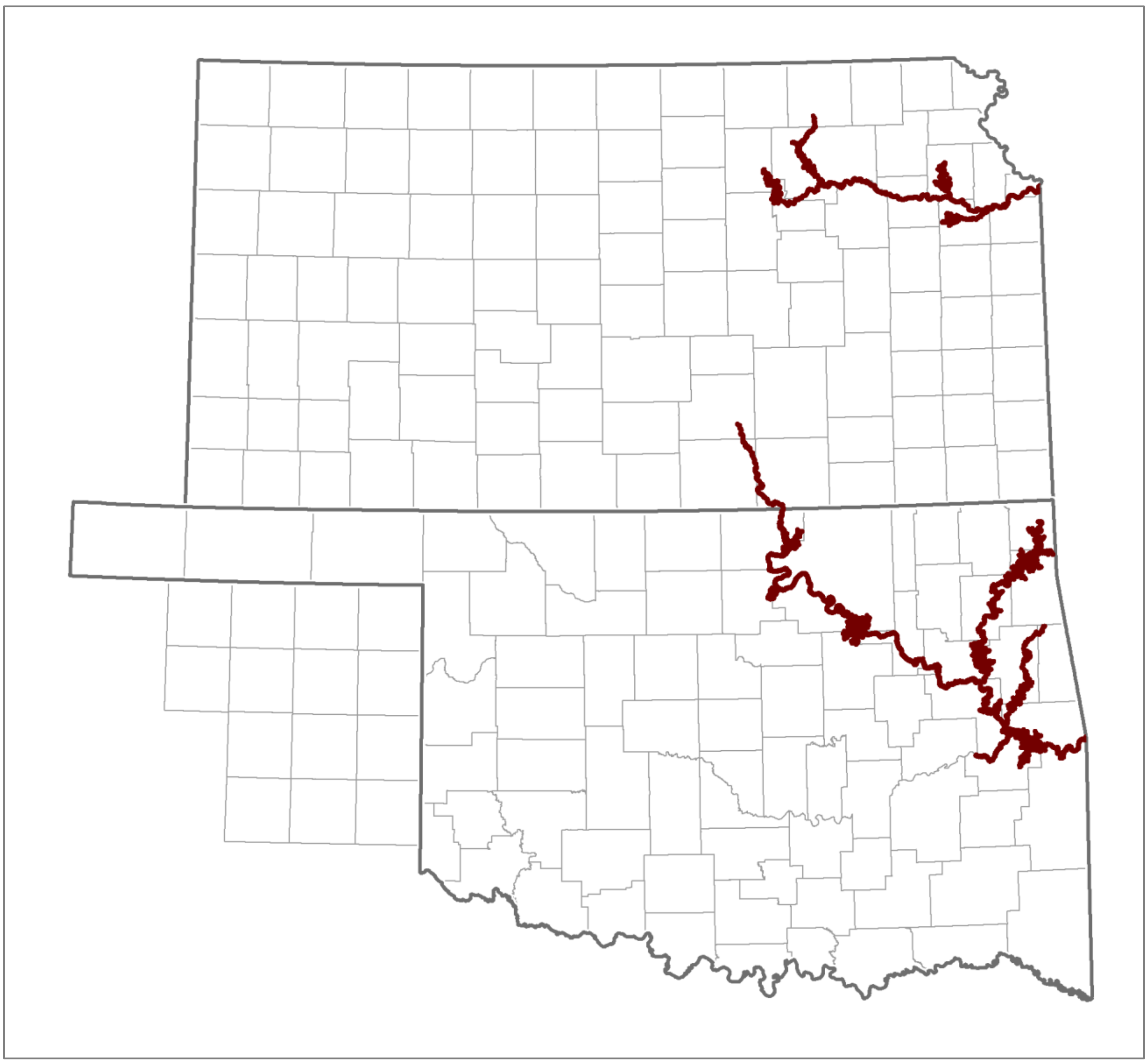
Sources: data - USFWS (2010, 2011c); Pearse et al. (2015); spatial analysis – TNC (2017).



Bald eagle nesting areas

Migrant bald eagles (*Haliaeetus leucocephalus*) are found across Kansas and Oklahoma during the winter months. An increasing number of nests have been located near lakes and rivers in the eastern portion of the area since 1989 (Reinking 2004, GMSARC 2015, GPNC 2015). Eagles may be injured or killed by collision with wind turbines, and the rate of mortality at commercial wind facilities may be underestimated due to lack of rigorous monitoring and reporting (Pagel et al. 2013). Following general habitat management guidelines established by USFWS (1989), we recommend that developers avoid placing landscape-altering structures within 1.6 km of nesting areas (including but not limited to sites depicted below). Mapped reaches of the lower Kansas and Arkansas River systems and avoidance buffers encompass approximately two-thirds of known nest locations in the region. It is important to note that migrant eagles concentrate near reservoirs and other areas which host high overwintering populations of waterfowl; this map depicts only the greatest risk associated with nesting bald eagles.

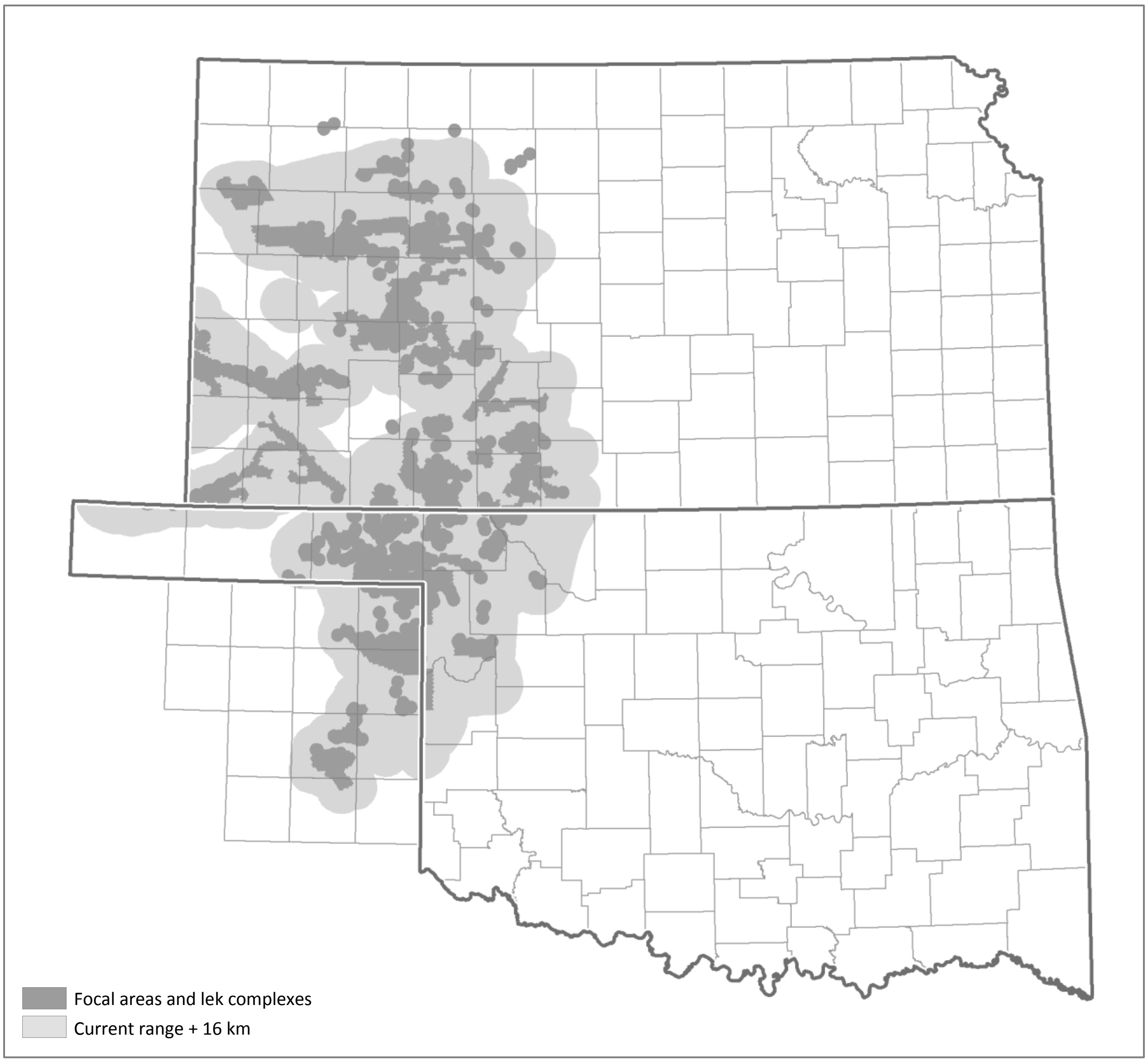
Sources: unpublished USFWS and TNC data



Lesser prairie-chicken focal areas and lek complexes

The lesser prairie-chicken (*Tympanuchus pallidicinctus*) is a species of prairie grouse endemic to the southern High Plains of the United States, including portions of Kansas, Oklahoma, and Texas. Evidence suggests that lesser prairie-chickens may avoid areas affected by wind development due to sensitivity to habitat fragmentation, human activity, and vertical structures (Hagen et al. 2004; Robel et al. 2004, Pitman et al. 2005; Pruett et al. 2009). We recommend that developers avoid siting wind facilities and associated infrastructure within conservation focal areas designated by the Western Association of Fish and Wildlife Agencies (Van Pelt et al. 2013). To ensure adequate protection of nesting habitat, we also recommend avoidance of development within 5 km of current and historical lek sites in close proximity to focal area polygons, and lek 'complexes' (3 or more leks within overlapping 5 km buffers). Outside of these areas, voluntary mitigation is encouraged for wind development projects situated within 16 km of the current lesser prairie-chicken range.

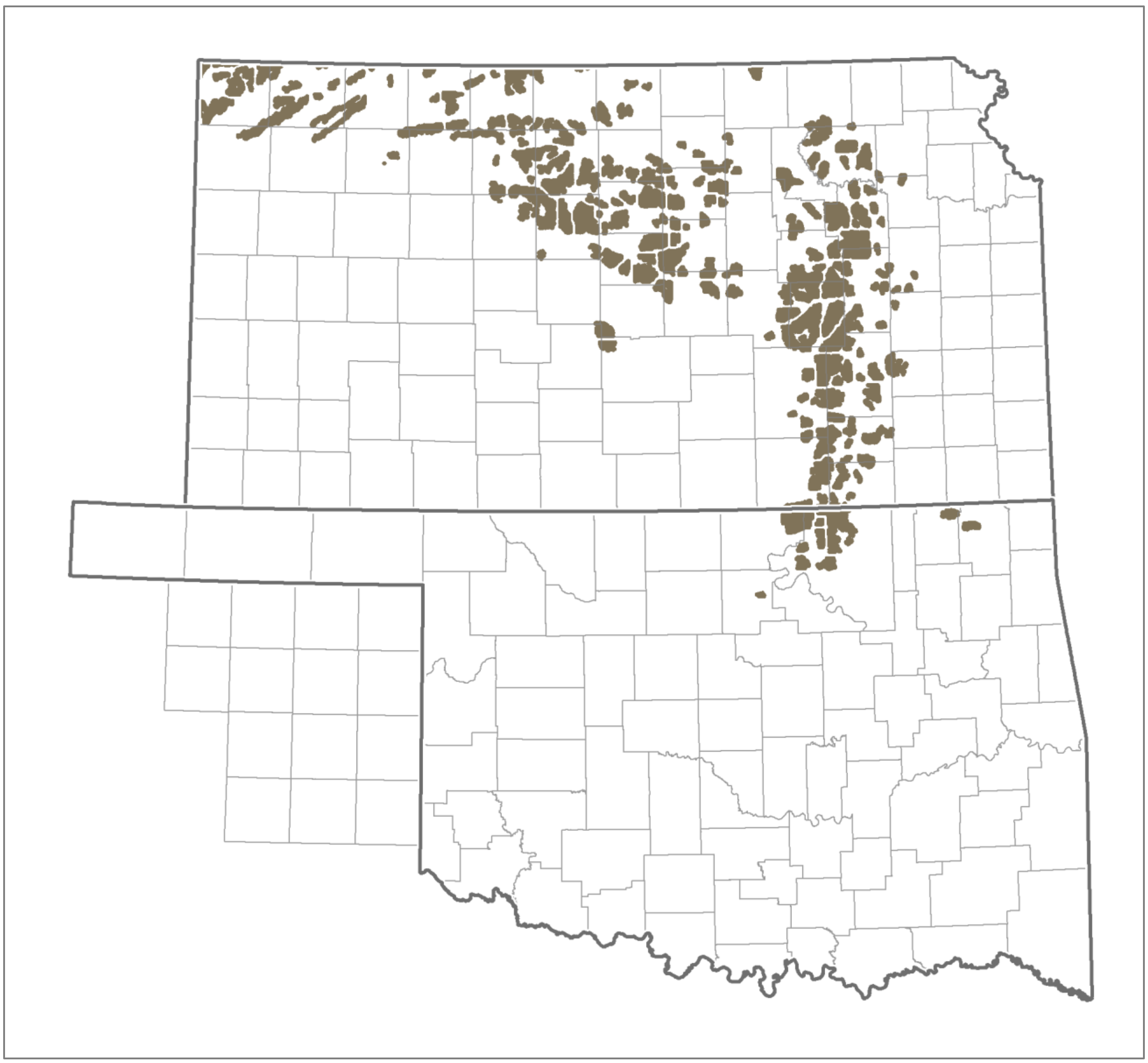
Source: SGPCHAT (2013)



Greater prairie-chicken optimal habitat

Greater prairie-chicken (*Tympanuchus cupido*) populations in Kansas and Oklahoma have been dramatically reduced since the early 20th century due to habitat degradation associated with human activity (Svedarsky et al. 1999; Johnsgard 2002). We recommend that developers avoid siting wind facilities within 1.6 km of native grasslands considered "optimal chicken habitat" (Obermeyer et al. 2011) due to the potential for abandonment of otherwise suitable habitat in close proximity to wind turbines (Robel 2011).

Sources: methods – Obermeyer et al. (2011); spatial analysis & data – TNC (2017).



Bat caves

Bat mortality has been documented at wind energy facilities across North America (Erickson 2002; USFWS 2003; Arnett and Baerwald 2013). Because bats concentrate in large numbers and have low reproductive rates, they are exceptionally vulnerable to population declines (Kunz and Fenton 2003). Therefore, caution is warranted when undertaking any activity that may adversely affect known bat populations.

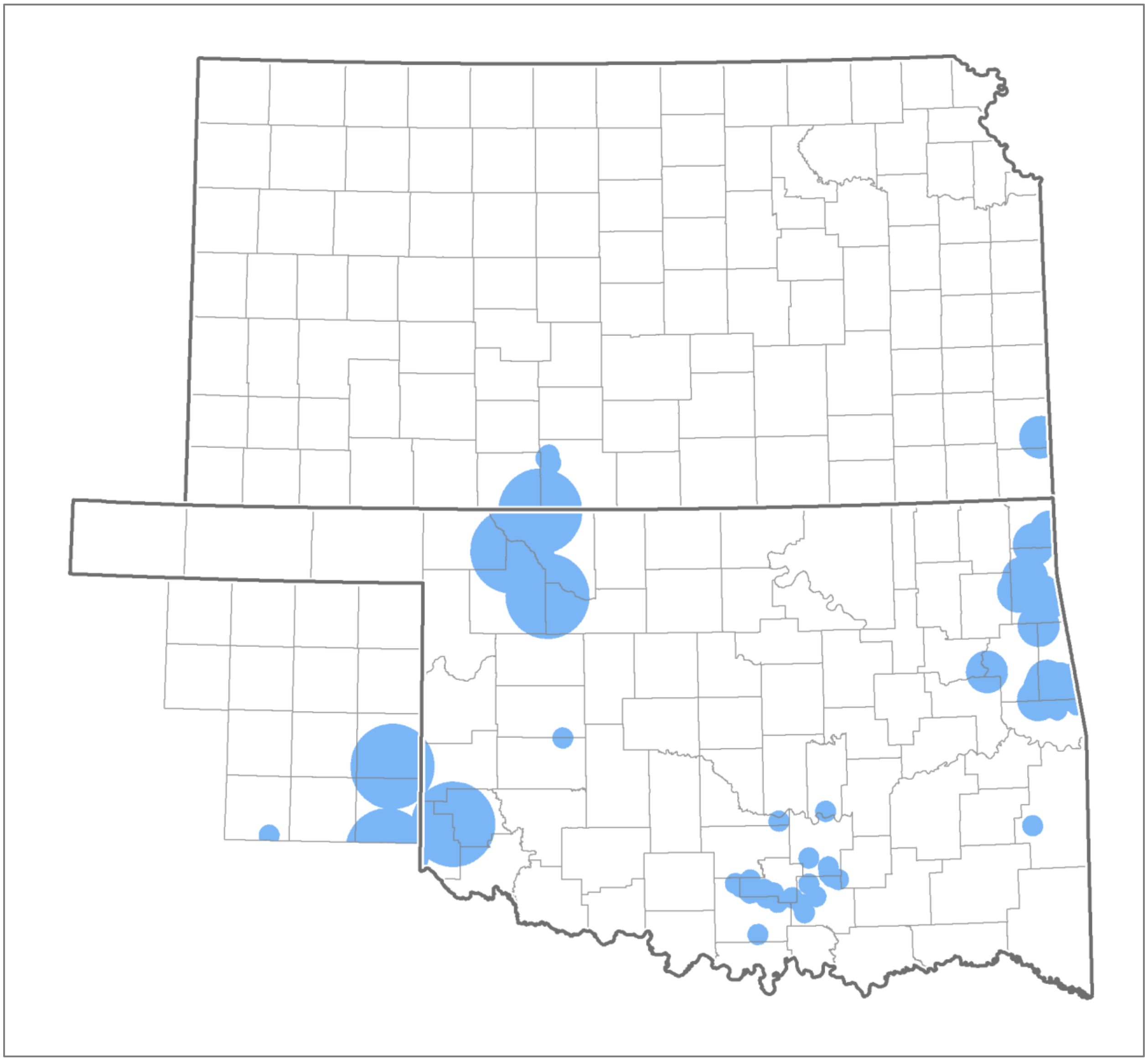
While knowledge of bat and wind turbine interactions in the central Great Plains is limited, evidence suggests that the Mexican free-tailed bat (*Tadarida brasiliensis*) may be particularly susceptible to fatal injury during encounters with turbine blades. This species accounts for a large percentage of documented wildlife mortality at wind facilities across the Southwestern U.S. (Kerlinger et al. 2006; Miller 2008; Piorkowski and O'Connell 2010). Moreover, regional populations in Oklahoma and Texas are comprised primarily of reproducing females (Caire et al. 1989; Schmidly 2004); as such, each adult fatality in the area is likely to result in the deaths of two individuals (mother and young). Recent population estimates in Oklahoma are markedly lower than historical figures, possibly indicative of declines related to wind development or other factors (Caire et al. 2013). Due to the large foraging range of this species (Best and Geluso 2003) and concerns regarding population-level impacts, we recommend that developers avoid siting wind facilities within 32 km of Mexican free-tailed bat maternity roosts. This distance is consistent with wind avoidance recommendations for large bat colonies in the Midwestern U.S. (USFWS 2016).

Based on foraging behavior (LaVal et al. 1977; Graening et al. 2011) and management guidelines for related species (PGC 2007; USFWS 2011b), we also recommend that developers avoid siting wind turbines within 16 km of maternity roosts of the gray bat (*Myotis grisescens*), and within 8 km of caves occupied by other bat species.

Sources: KSU (2002); TNC (2003, 2016); Graening et al. (2011); KBS (2015).

map on following page

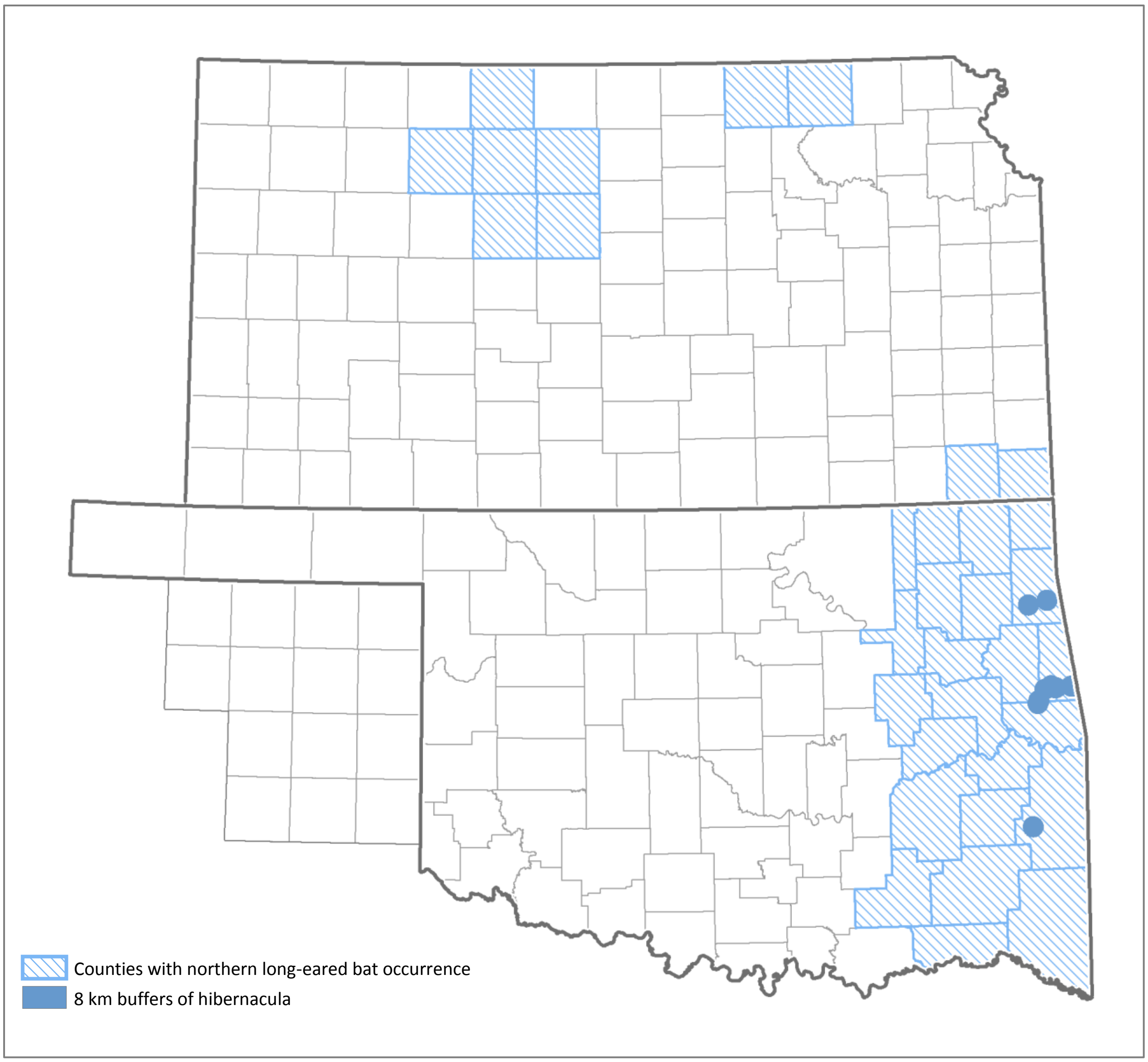
Bat caves (continued)



Bat caves (continued)

At the time of this writing, regional summer occurrence records for the northern long-eared bat (*Myotis septentrionalis*) are very limited. This species has been documented in wooded riparian habitat in north-central Kansas (Sparks and Choate 2000; Schmidt 2015) and in cave and forest habitats in far eastern Oklahoma (TNC 2017). Based on a typical maximum spring migration distance of 89 km (USFWS 2014b) and presence of suitable roosting habitat, northern long-eared bats may occur across a 25 county area in the eastern portion of the region. Higher concentrations of this species are likely to occur within 8 km of hibernacula during swarming and migration events (USFWS 2014b); said concentration areas are included in the avoidance map on the previous page.

Sources: Sparks and Choate (2000); Schmidt (2015); TNC (2017).



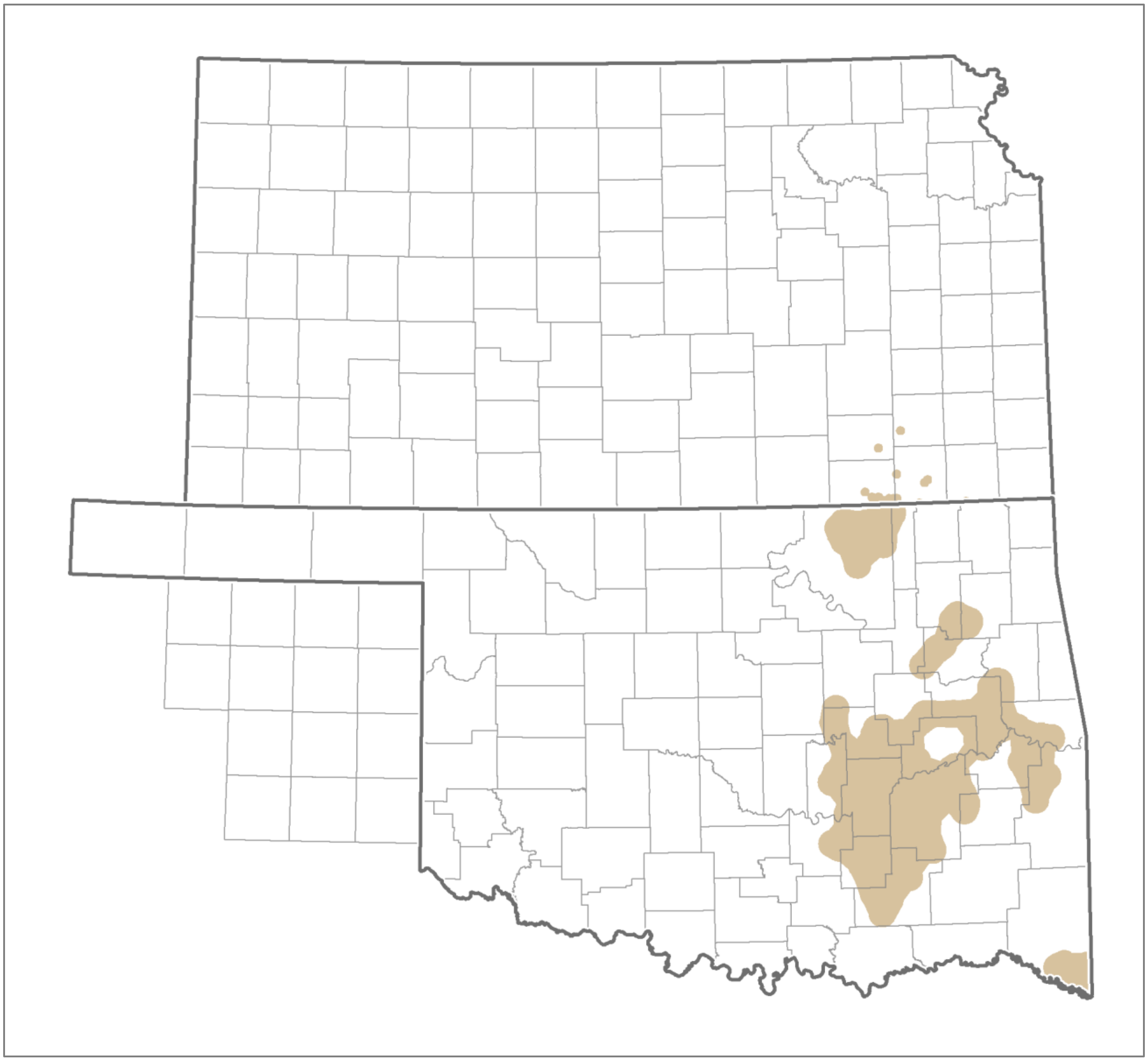
American burying beetle priority areas

The American burying beetle (*Nicrophorus americanus*, ABB) is a federally endangered carnivorous insect endemic to eastern North America. Primary threats to the species include habitat fragmentation and loss (USFWS 1991a). The potential effects of wind development on this species are poorly understood. A recent laboratory study suggests that turbine-induced seismic vibration may negatively impact behavior associated with feeding and reproduction (Moore et al. 2012).

The U.S. Fish and Wildlife Service has identified multiple ABB 'conservation priority areas' in Oklahoma. Mapped polygons include areas that are likely to contain important elements for ABB conservation, such as presence over multiple years, suitable breeding habitat, and carrion resources (USFWS 2014).

Sites in Kansas represent approximate locations of documented ABB occurrence (KBS 2015).

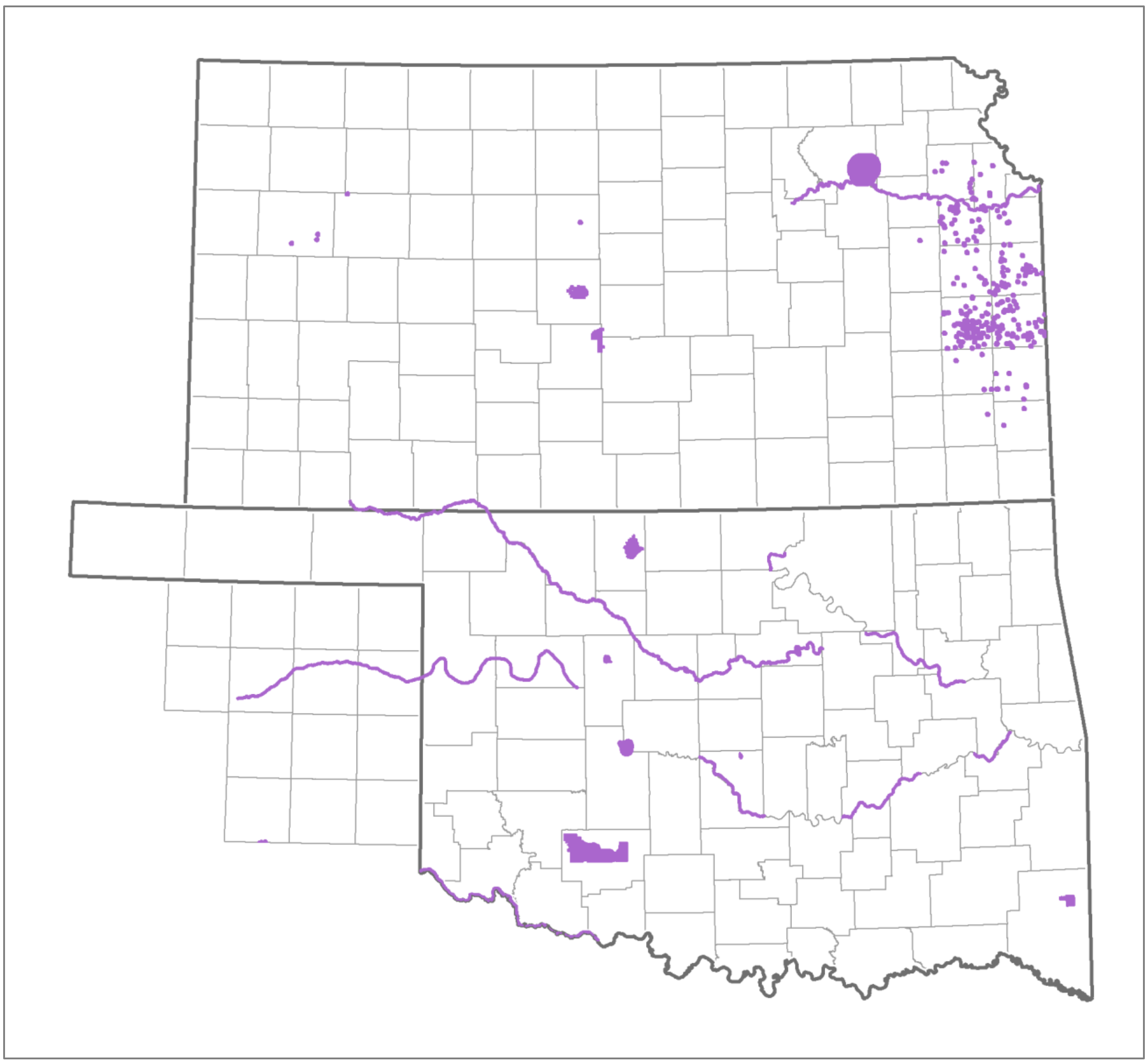
Source: USFWS (2014a); KBS (2015)



Other threatened and endangered species (terrestrial)

Terrestrial threatened and endangered species that may be adversely impacted by wind development in Kansas, Oklahoma, and Texas include least tern (*Sternula antillarum*), piping plover (C*haradrius melodus*), black-capped vireo (*Vireo atricapilla*), red-cockaded woodpecker (*Leuconotopicus borealis*), black-footed ferret (*Mustela nigripes*), western prairie fringed orchid (*Platanthera praeclara*), and Mead's milkweed (*Asclepias meadii*). Development projects with a federal nexus (i.e. is carried out, funded, licensed or permitted by a federal agency) that have potential to impact these species require consultation with the U.S. Fish and Wildlife Service under Section 7 of the Endangered Species Act (USFWS 2009b). Mapped sites include critical habitats designated by state and federal agencies, current/recent species distributions, and historical occurrence records.

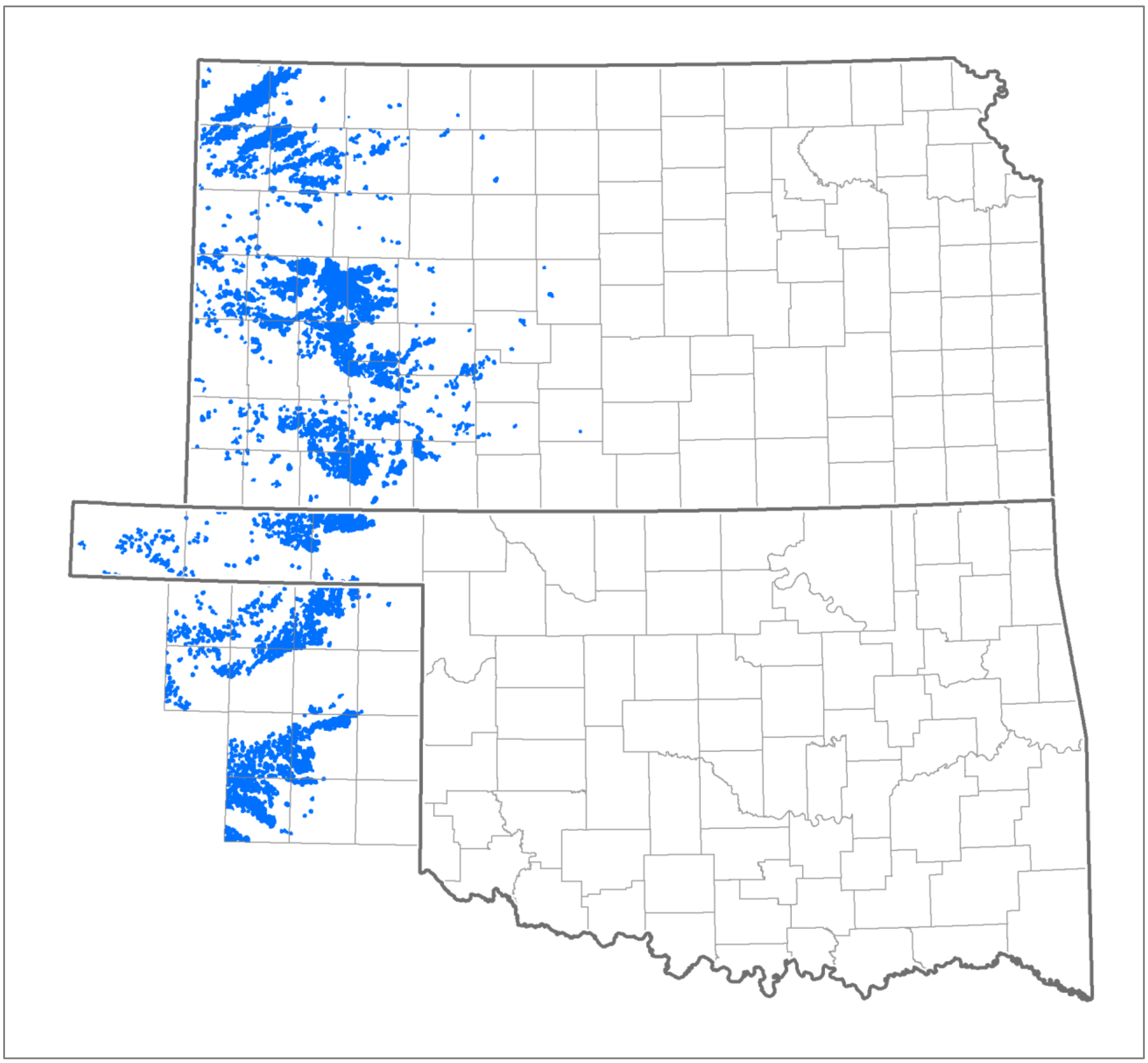
Sources: Masters et al. (1989); USFWS (1990, 1991b); Wilkins et al. (2006); KBS (2015); KDWPT (2015); ODWC (2015).



Playa clusters

In the southern High Plains of the United States, migratory waterbirds rely on ephemeral, closed basin wetlands known as playas (PLJV 2015a). Placement of wind turbines and associated infrastructure in areas of high playa density may cause adverse impacts on species protected by the Migratory Bird Treaty Act, and otherwise degrade wetland function (PLJV 2017). Following guidance from the Playa Lakes Joint Venture, we recommend that developers avoid placing wind turbines and associated infrastructure within defined playa clusters.

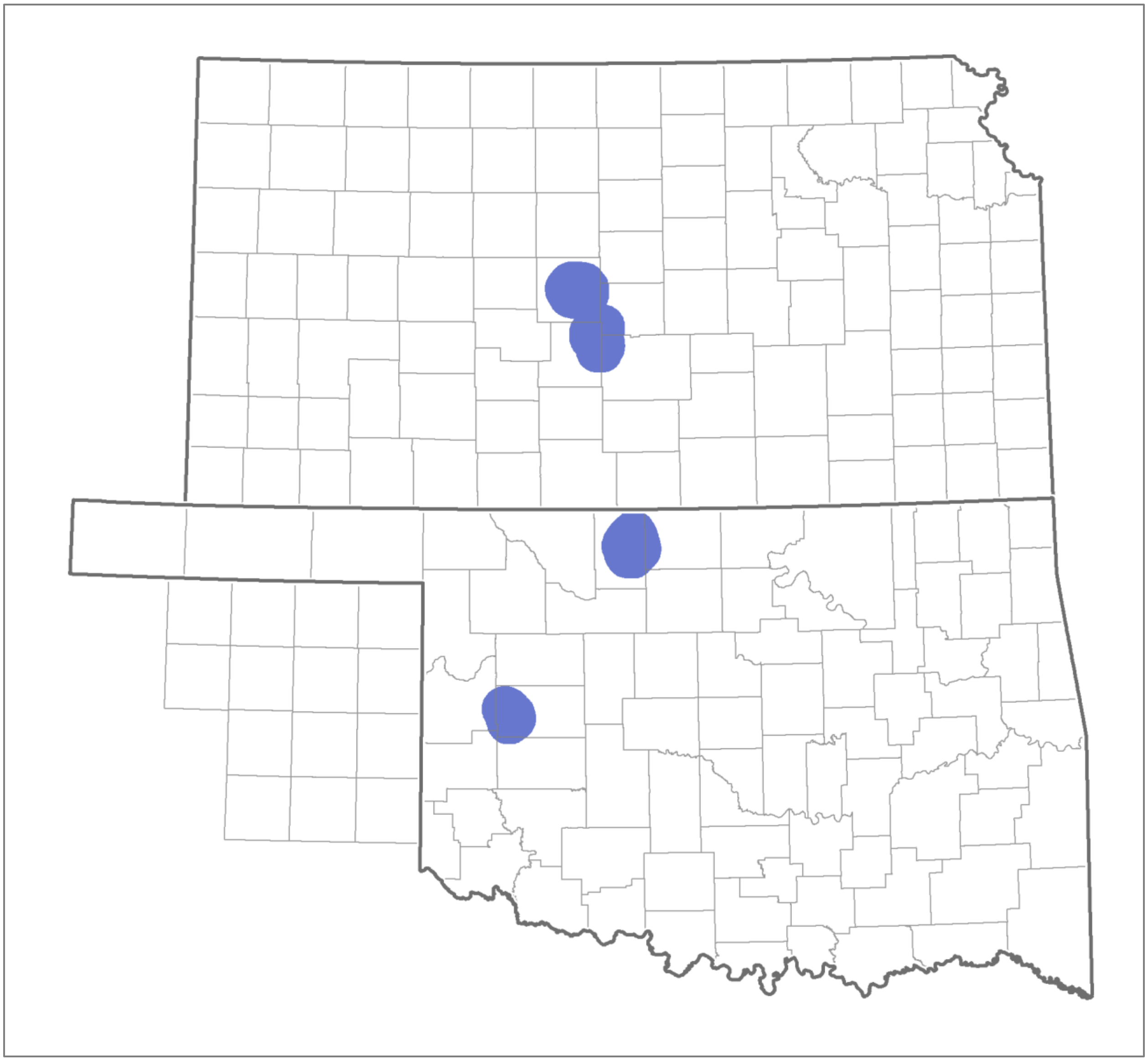
Source: PLJV 2015(b)



Globally important wetlands

Wetland complexes in Kansas and Oklahoma are among the most important shorebird migration stopover sites in the Western Hemisphere (WHSRN 2015), and may host large numbers of wintering waterfowl (USFWS 2015). Because the legal boundaries for these sites do not include adjacent areas of ecological importance, we recommend that wind developers avoid areas within 16 km of the Cheyenne Bottoms wetland complex and Quivira, Great Salt Plains, and Washita National Wildlife Refuges. These wetlands and associated uplands are also frequently used by whooping cranes and other species of concern.

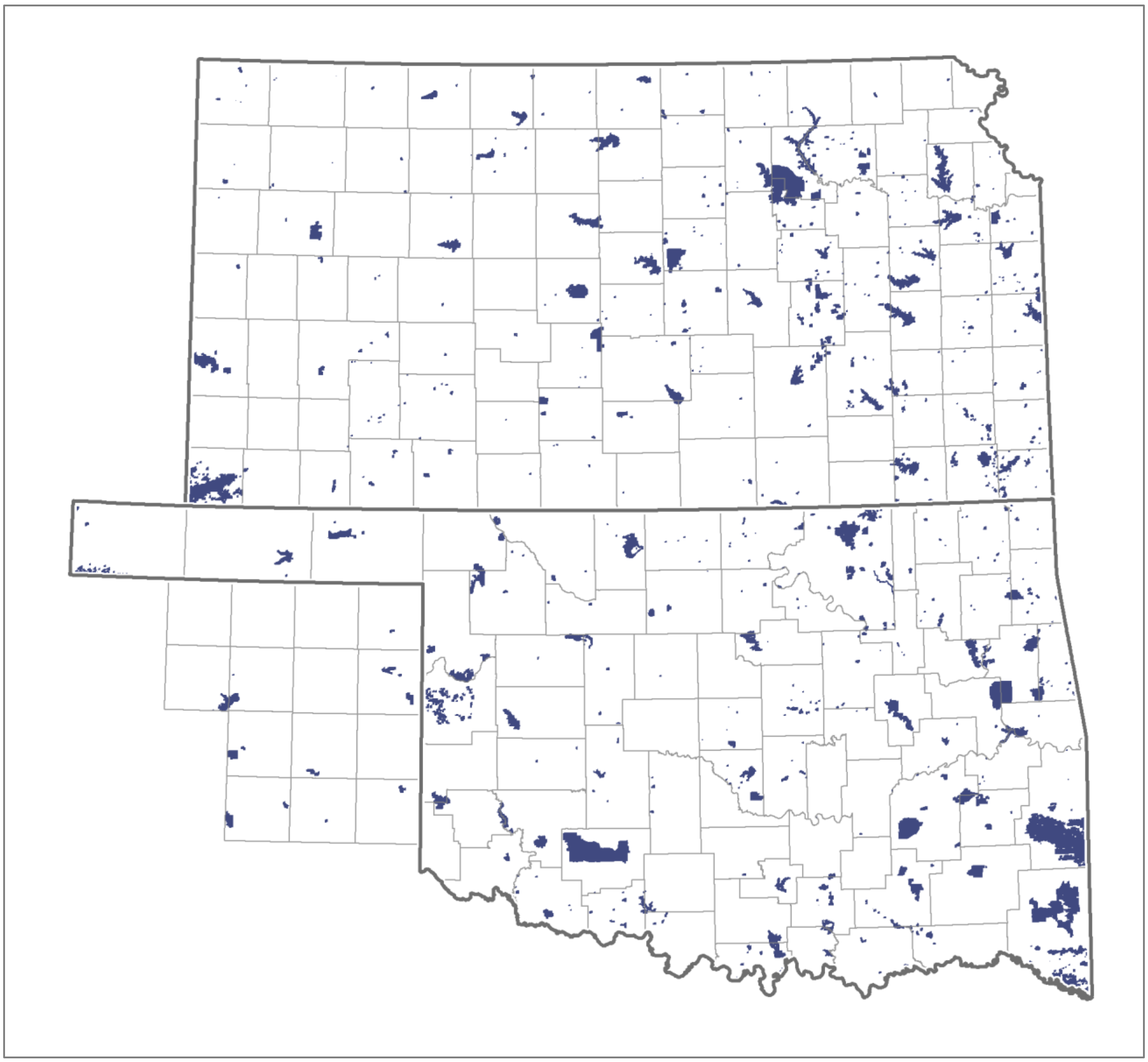
Sources: Obermeyer et al. (2011); ABC (2015); TNC (2017).



Protected and managed lands

Areas managed for long-term conservation of natural features include state parks and wildlife management areas; national parks, grasslands/forests, and wildlife refuges; military installations; TNC preserves; and private lands subject to conservation easements.

Sources: KBS (2015); NCED (2016); TNC (2017).

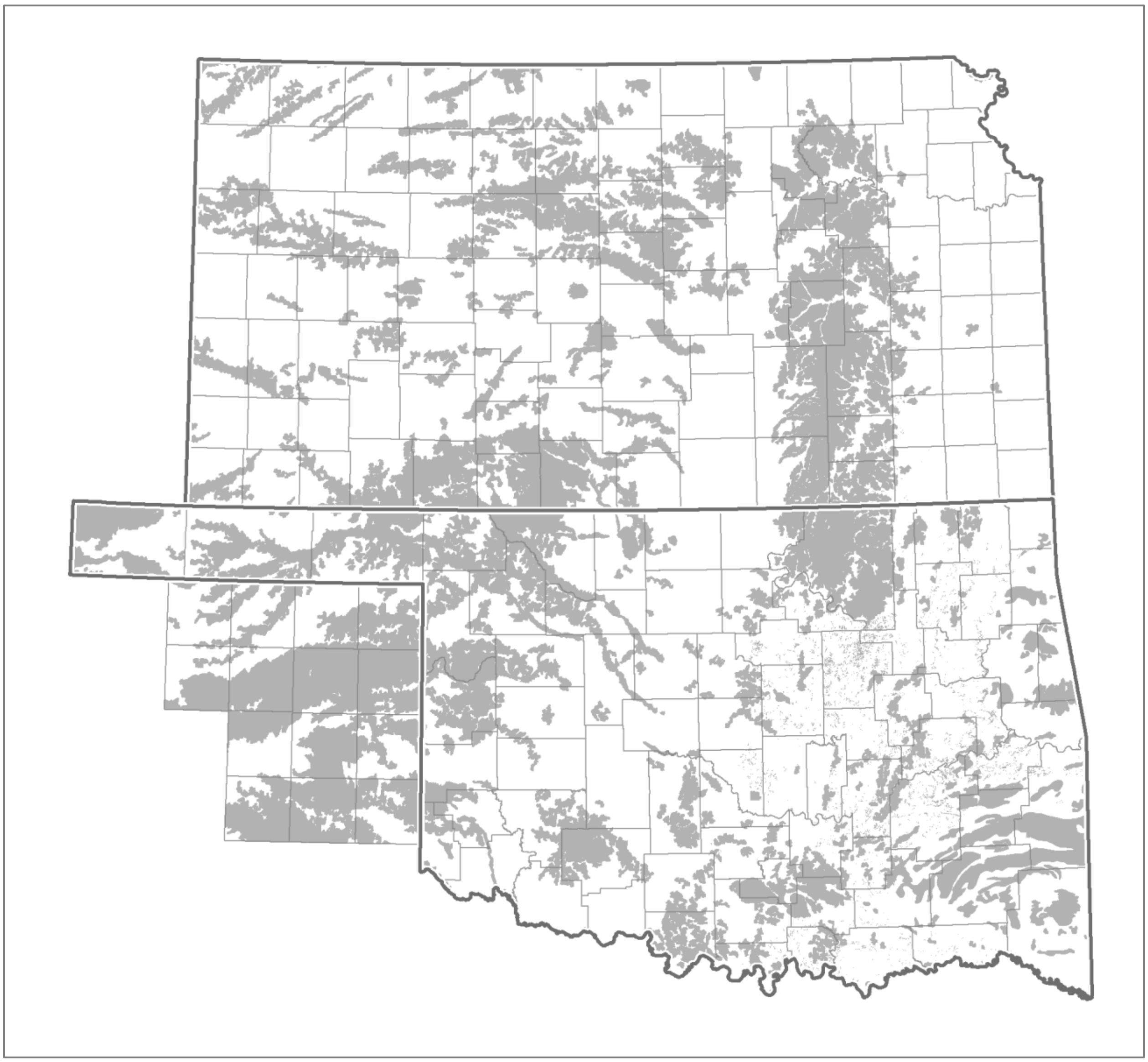


Intact grasslands and forests

Agricultural conversion and other land use changes across the Midwestern U.S. have resulted in a significant reduction in the spatial extent of prairie and woodland ecosystems and the loss of many associated species; relatively few areas capable of supporting fundamental ecological processes remain in the region. As a means of prioritizing conservation projects in the Great Plains, sites with largely intact natural vegetation were identified through an interpretation of early 1990's Landsat Thematic Mapper (TM) satellite imagery. These intact, 'untilled' landscapes provide the basis for long-term viability of many species of conservation concern (Ostlie 2003).

Mapped areas include landscape polygons delineated by TNC, and a predictive old-growth forest model for the Crosstimbers region developed by Stahle et al. (2003).

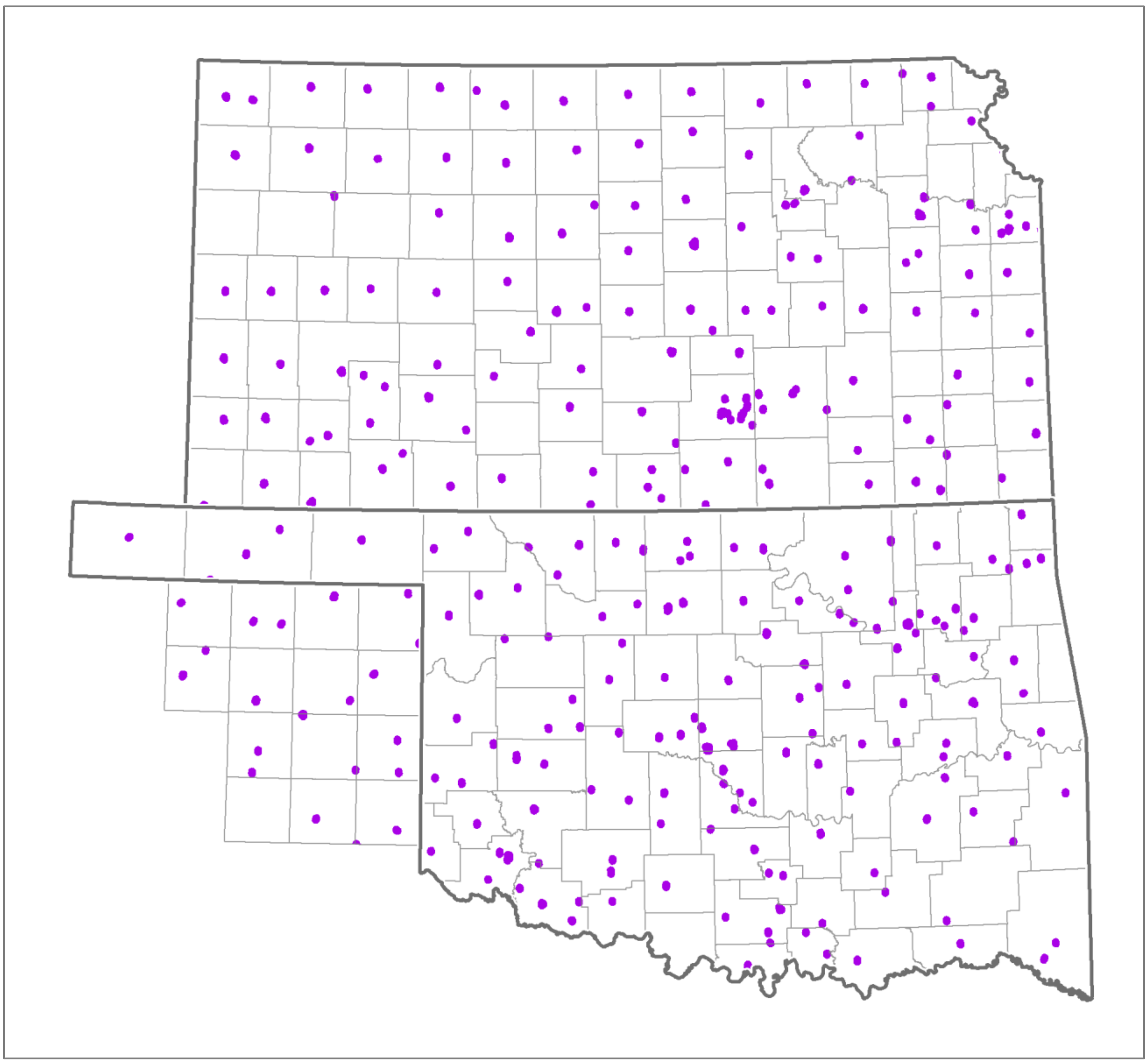
Sources: Ostlie (2003); Stahle et al. (2003); TNC (2017).



Airfields

Commercial wind turbines require undisturbed airspace for operation and may present hazards to air travel. Areas within 3 km of public use and military airfield runways are considered unsuitable for wind development (USDOE 2008).

Source: USDOT (2015)

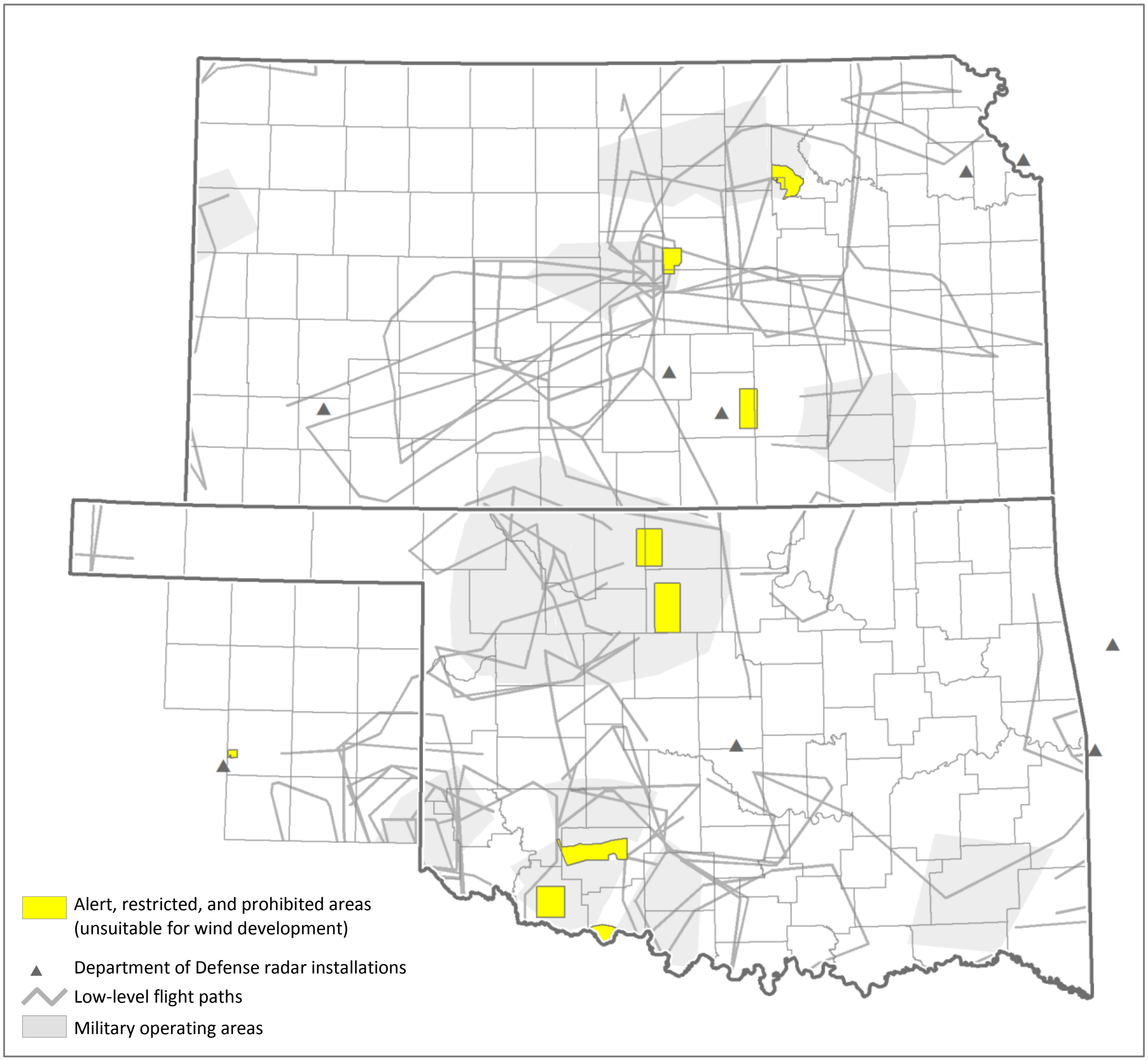


Special use airspace

Special use airspace areas managed by the Federal Aviation Administration contain unusual aerial activity, generally of a military nature. These include 'alert' areas which experience high volumes of training flights, 'restricted' areas near artillery firing ranges, and 'prohibited' areas with significant national security concerns (FAA 2010). Placement of wind turbines within these areas may create hazardous flight conditions and compromise military readiness (NRDC and USDOD 2013).

We consider alert, restricted, and prohibited airspace unsuitable for wind energy development. Outside of these areas, consultation with the U.S. Department of Defense may be required prior to constructing wind turbines within defined military operating areas, near low-level flight paths, and in areas that penetrate defense radar lines of sight.

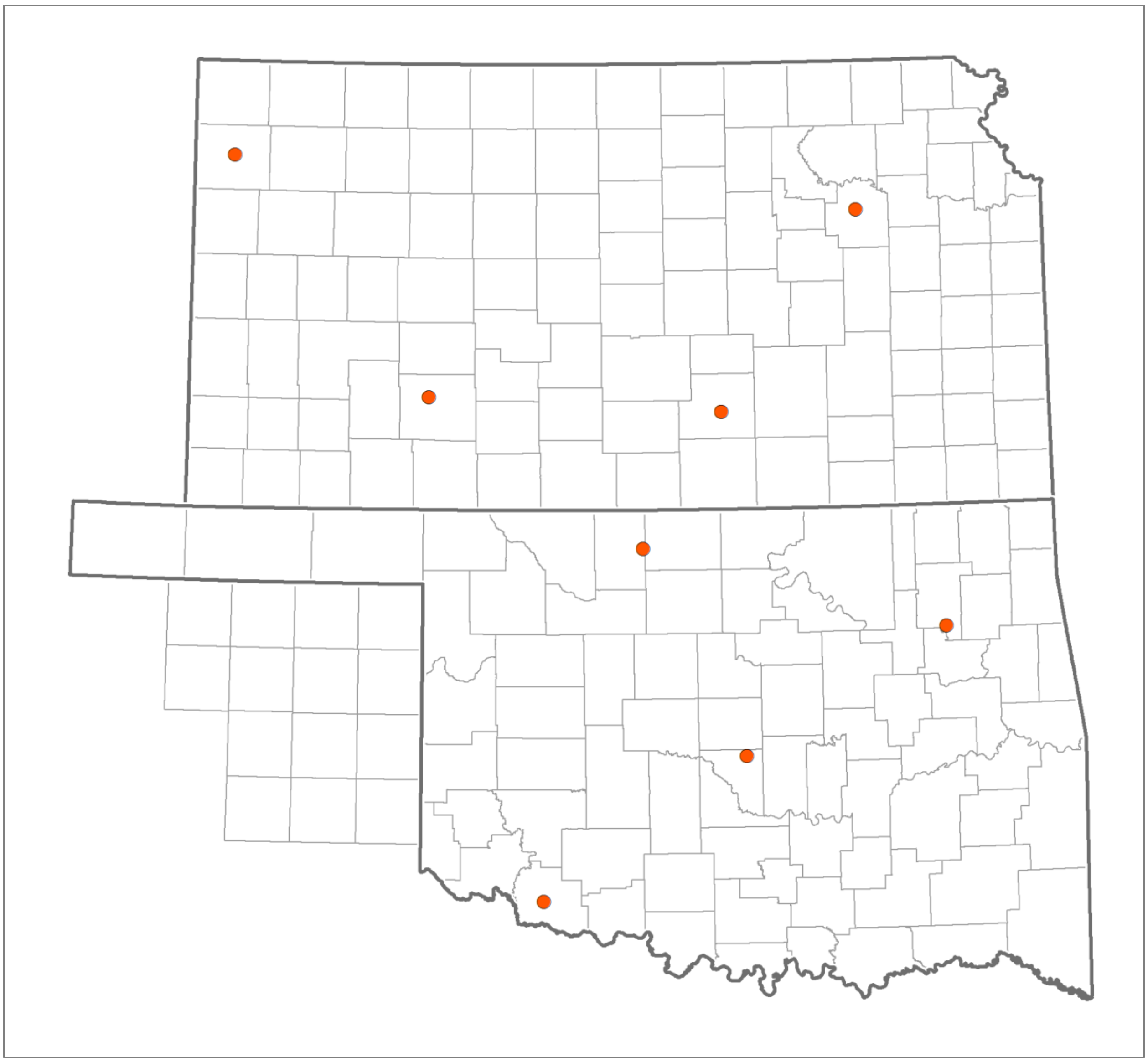
Sources: FAA (2011); FAA (2015a); NASA (2015).



NEXRAD stations

Wind turbines may cause interference with Doppler radar signals when sited in close proximity to weather stations, potentially compromising public safety during severe weather events. The National Oceanic and Atmospheric Administration (NOAA) requests that developers avoid constructing wind turbines within 3 km of NEXRAD radar installations (FAA 2015b). Outside of these areas, mitigation may be required for wind turbines that penetrate radar lines of sight, particularly for structures within 18 km (Vogt et al. 2011).

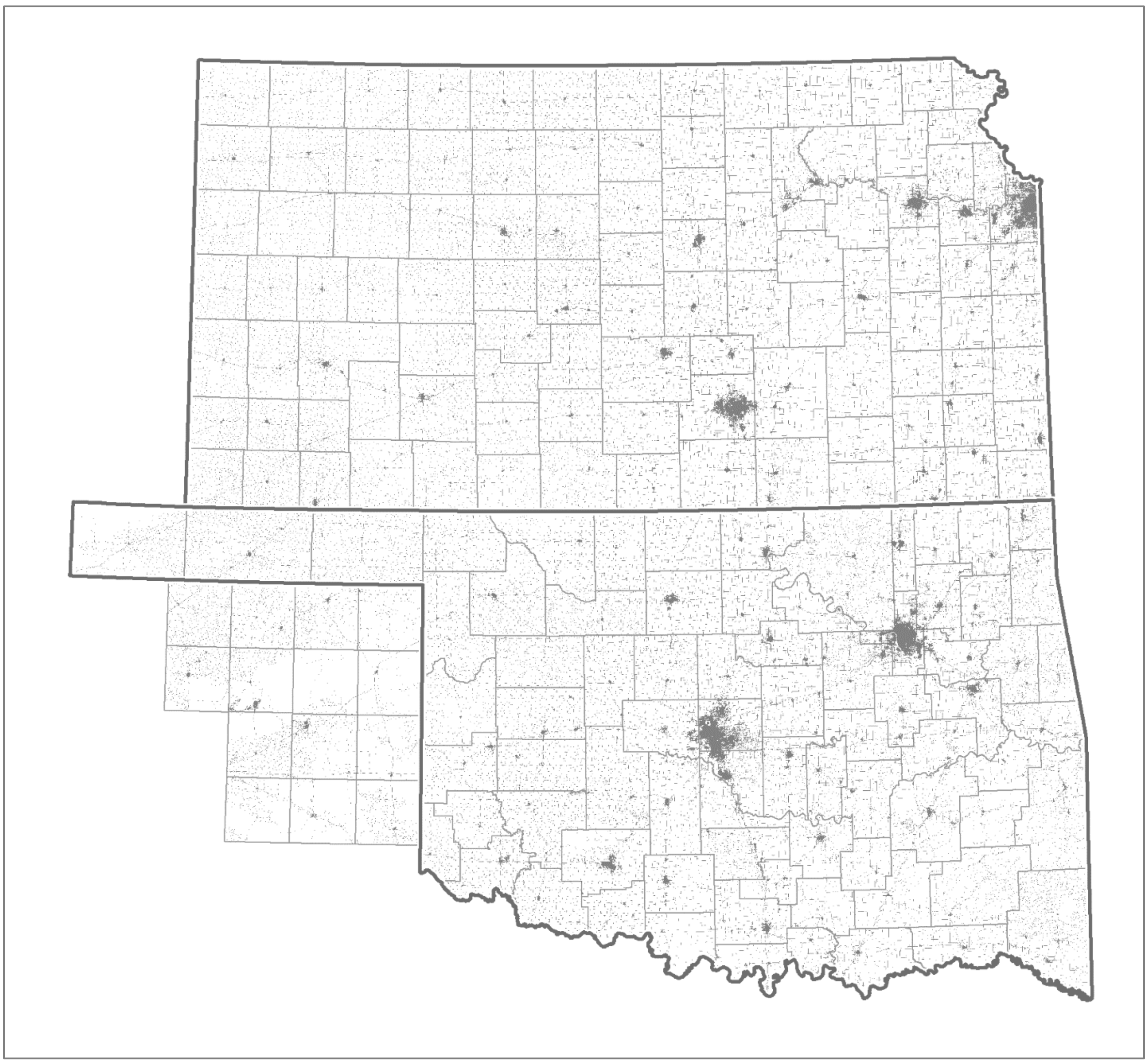
Source: NOAA (2015)



Urban lands and other developed areas

Urban lands and other developed areas (including roads, industrial sites, etc.) are considered unsuitable for commercial wind development (USDOE 2008).

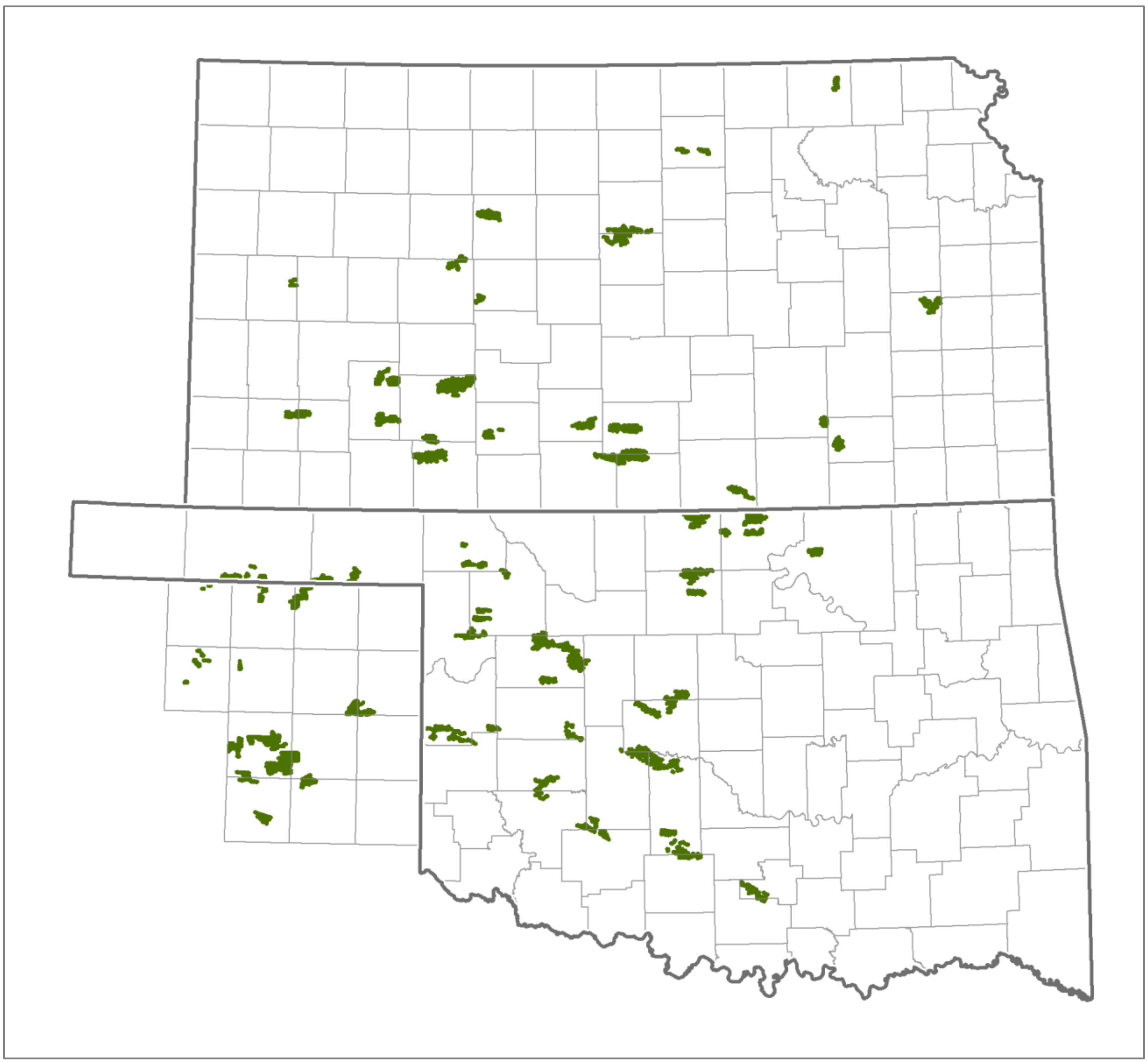
Sources: ESRI (2008); Fry et al. (2011).



Existing wind facilities

Areas within 1.6 km of existing wind turbines are considered unsuitable for development. This distance represents the typical spacing of turbine strings oriented perpendicularly to prevailing winds in Oklahoma and Kansas.

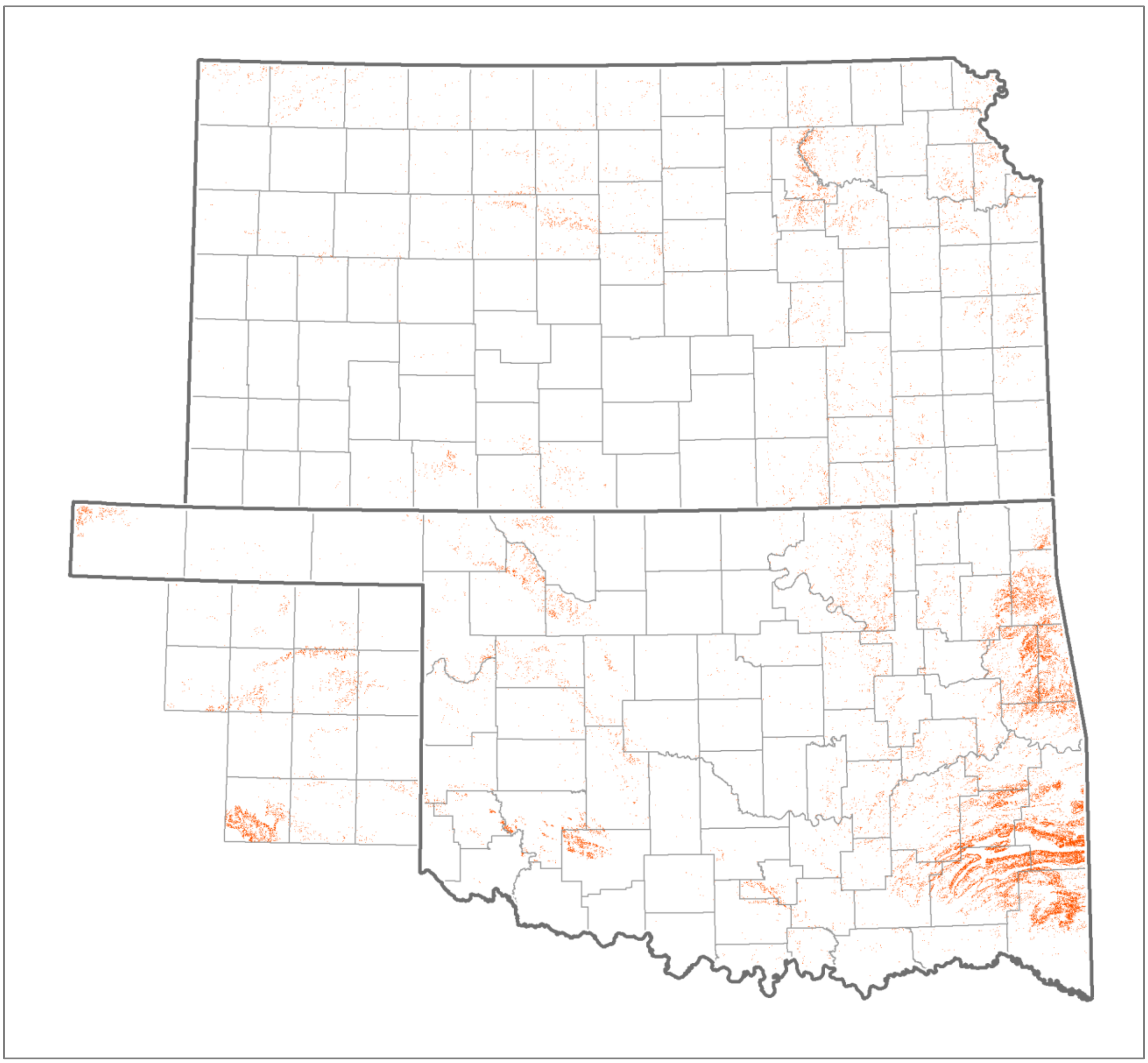
Source: FAA (2017)



Excessive slope

Steeply sloping terrain may significantly increase capital costs associated with turbine construction. Areas of slope exceeding 20% are considered unsuitable for wind development (USDOE 2008).

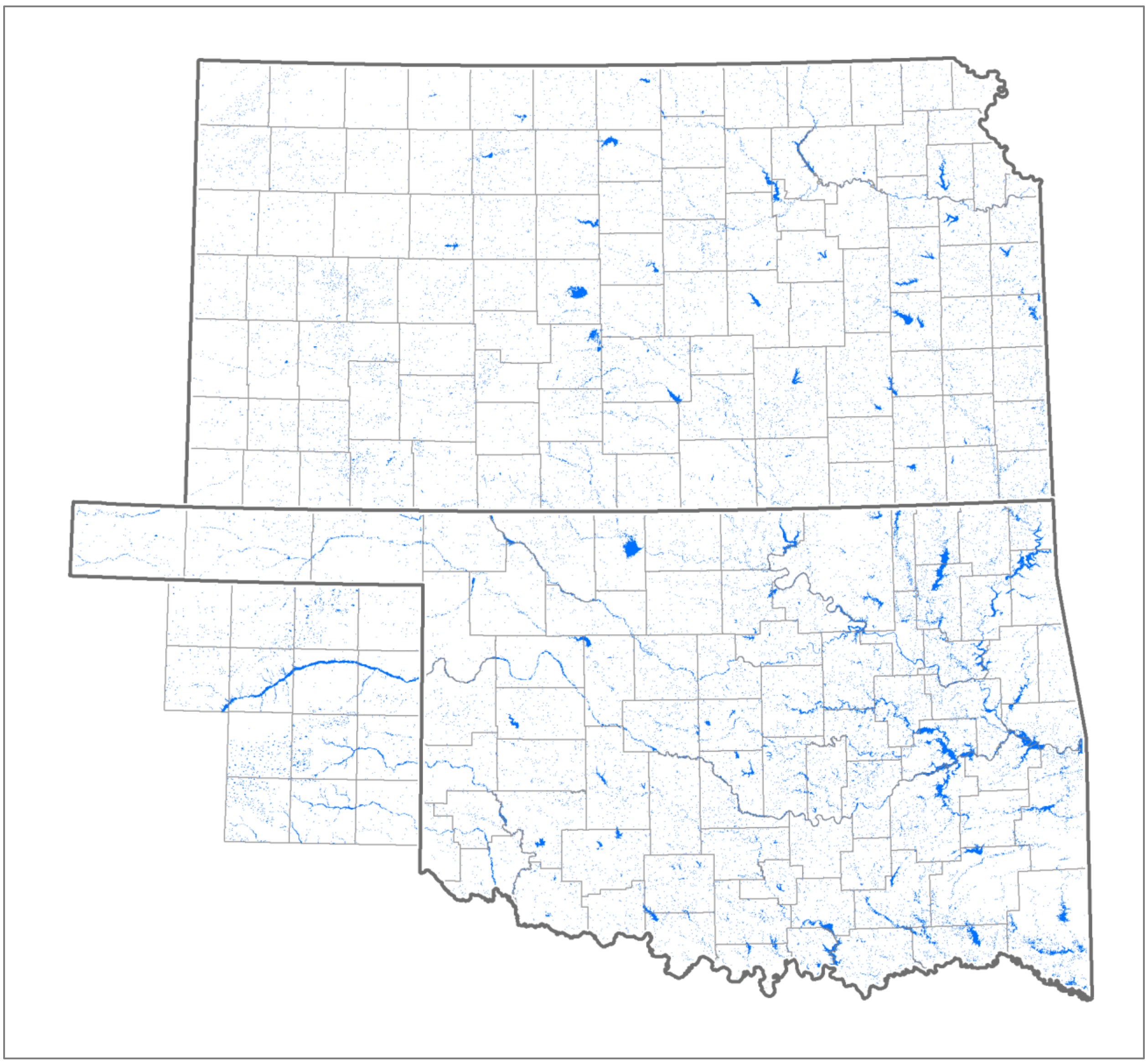
Source: USGS (2015a)



Water and wetlands

Open water and wetland areas are considered unsuitable for wind development (USDOE 2008).

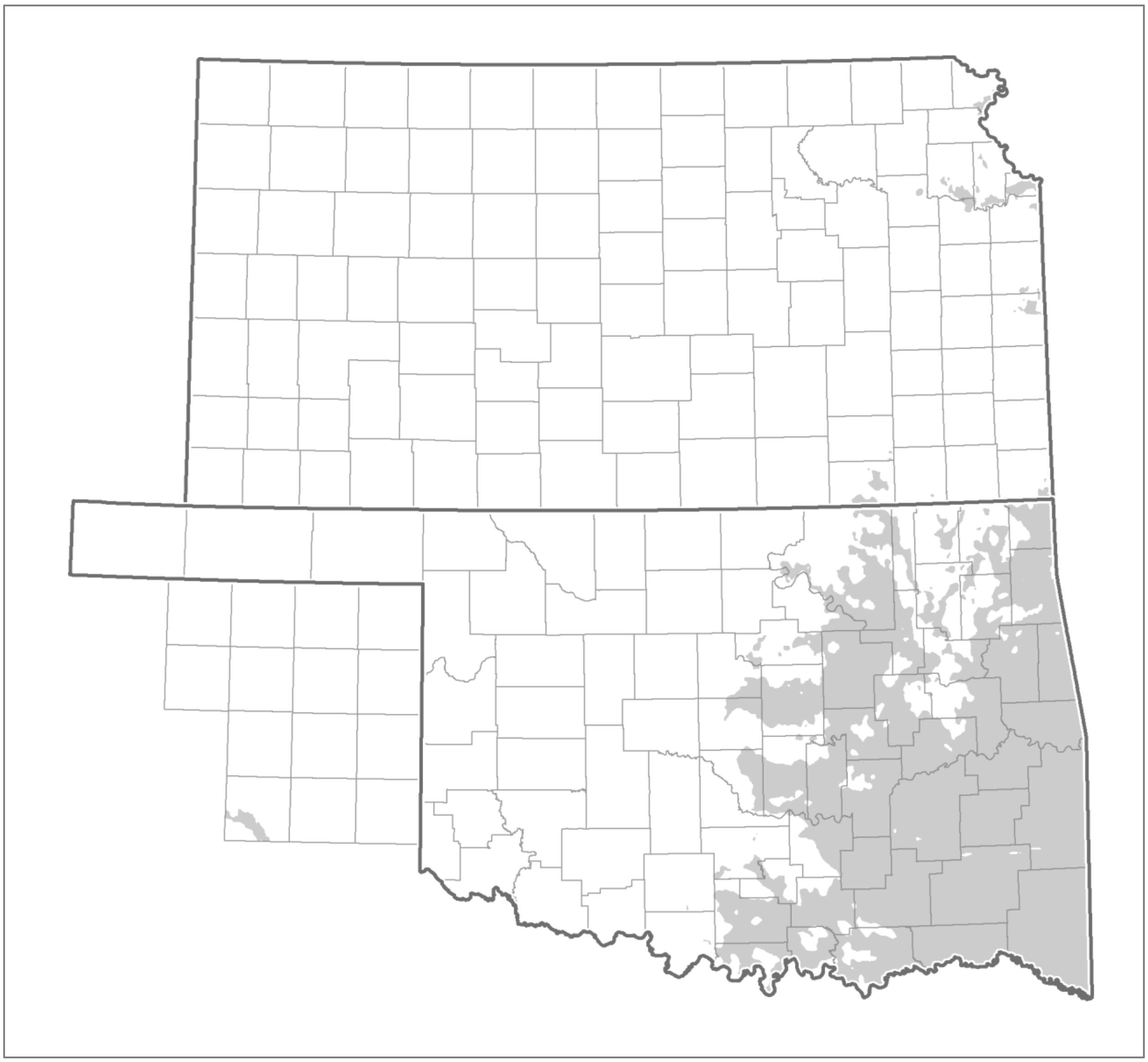
Source: Fry et al. (2011); USFWS (2011c); PLJV (2015b).



Poor wind resource

Areas with annual average wind speeds of less than 6.5 m/s at 80 m height may be unsuitable for wind development (AWS Truepower 2010).

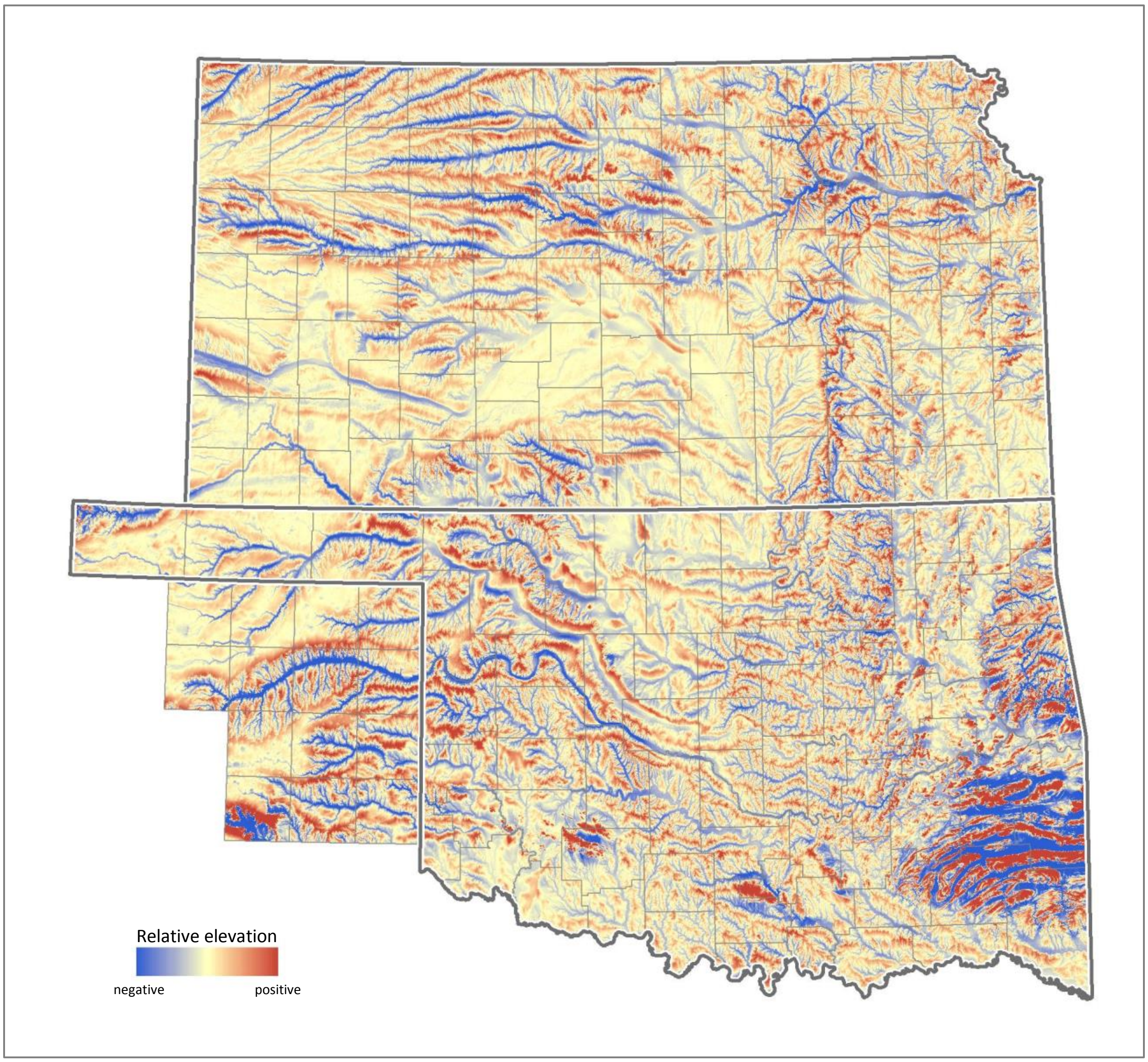
Source: AWS Truepower (2010)



Relative elevation

Mesoscale wind maps are often generalized and may not accurately depict wind energy potential at a given site (Bailey et al. 1997; Tennis et al. 1999). Wind developers employ a variety of computational models to assess local wind resources based on orography, measured wind speed, and other factors (Langreder 2010; Hau and von Renouard 2013). Most commercial wind facilities in the central Great Plains are situated on topographic ridges which experience higher winds than the general surroundings. To identify terrain conducive to development, we calculated relative elevation (Hughes et al. 2002) based on the mean elevation of 10 km radial wedges subtending to the north and south of a given point. Approximately 90% of wind energy potential in Oklahoma is derived from prevailing northerly and southerly winds (Hughes et al. 2002) and a similar distribution is apparent throughout much of Kansas (WRCC 2015). Positive values represent areas that lie above the adjacent landscape and thus have increased wind exposure (White et al. 2014).

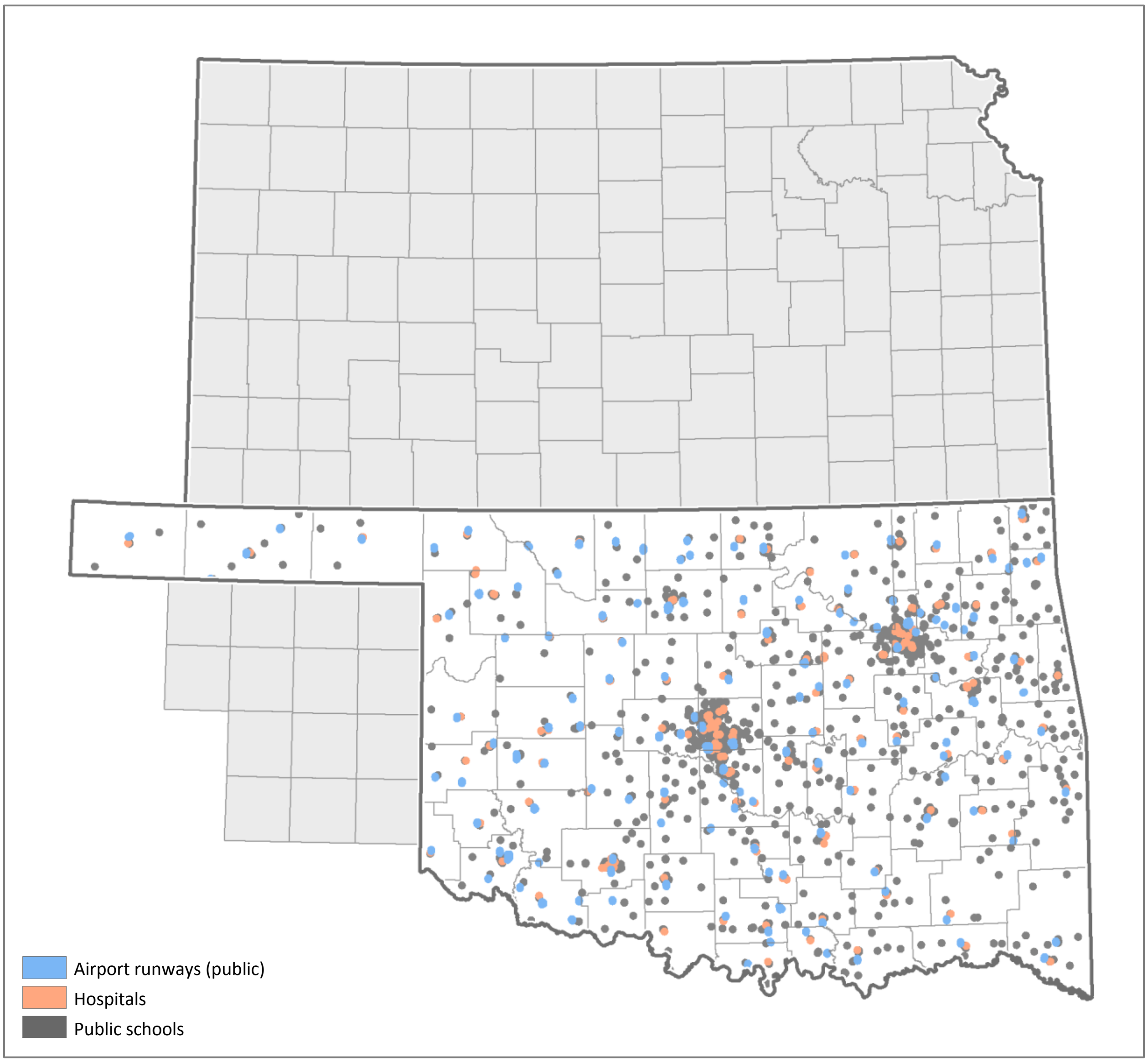
Sources: methods – Hughes et al. (2002); data – USGS (2015a); analysis – TNC (2017).



Oklahoma Wind Energy Development Act setbacks

The 2015 Oklahoma Wind Energy Development Act (17 O.S., Section 160. 20, as amended) mandates wind turbine setbacks of 1.5 nautical miles from airport runways, public schools, and hospitals. Line and point features representing structures of interest were buffered by 3 km (approximately 1.6 nautical miles) to account for potential spatial inaccuracies in the source data.

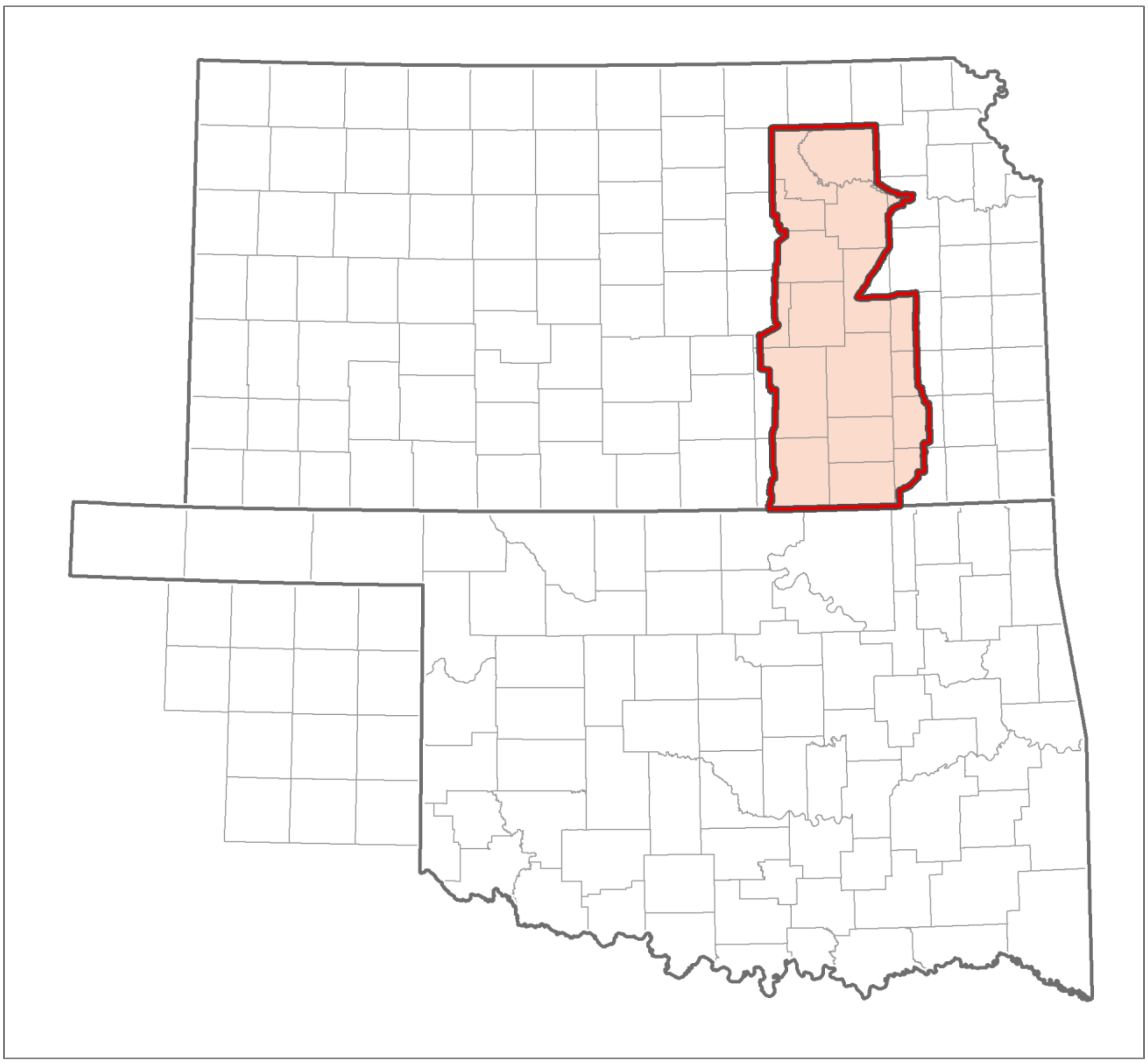
Sources: OKSDE (2015); USDOT (2015); USGS (2015b).



Kansas Tallgrass Prairie Heartland

Development of wind energy in the Flint Hills region of Kansas has been controversial due to landowner opposition and concerns regarding impacts to sensitive wildlife habitats. In a 2004 statement, Governor Kathleen Sebelius discouraged development of wind energy within a designated "Heart of the Flint Hills" area delineated in consultation with environmental advisors (Rothschild 2005). The region was expanded in 2011 by Governor Sam Brownback to be bounded by roads and administrative boundaries (KBS 2015). The updated “Tallgrass Heartland” area includes portions of 18 counties.

Source: KBS (2015)



Literature cited

American Bird Conservancy (ABC). 2015. Wind risk assessment maps for Kansas and Oklahoma. http://abcbirds.org/program/wind-energy/wind-risk-assessment-map/, accessed March 13, 2015.

Arnett, E.B. and E.F. Baerwald. 2013. Impacts of wind energy development on bats: implications for conservation. *In* Bat evolution, ecology, and conservation. Springer Science & Business Media, New York. Pp. 435-456.

Arnett, E.B., G.D. Johnson, W.P. Erickson, and C.D. Hein. 2013. A synthesis of operational mitigation studies to reduce bat fatalities at wind energy facilities in North America. A report submitted to the National Renewable Energy Laboratory. http://www.batsandwind.org, accessed June 22, 2016.

AWS Truepower. 2010. Utility-scale land-based 80 m wind maps for the United States. http://apps2.eere.energy.gov/wind/windexchange/wind_maps.asp, accessed December 14, 2013.

Austin, J.E. and A.L. Richert. 2001. A comprehensive review of observational and site evaluation data of migrant whooping cranes in the United States, 1943–99. U.S. Geological Survey, Northern Prairie Wildlife Research Center, Jamestown, North Dakota.

Bailey, B.H., S.L. McDonald, D.W. Bernadett, M.J. Markus, and K.V Elsohlz. 1997. Wind resource assessment handbook: fundamentals for conducting a successful monitoring program. Report prepared for the National Renewable Energy Laboratory. AWS Scientific, Inc., Albany, New York. http://www.nrel.gov/wind/pdfs/22223.pdf, accessed March 13, 2015.

Belaire, J.A., B.J. Kreakie, T. Keitt, and E. Minor. 2014. Predicting and mapping potential whooping crane stopover habitat to guide site selection for wind energy projects. Conservation Biology 28(2): 541-550.

Best, T.L., and K.N. Geluso. 2003. Summer foraging range of Mexican free-tailed bats (*Tadarida brasiliensis mexicana*) from Carlsbad Cavern, New Mexico. The Southwestern Naturalist 48(4): 590-596.

Caire, W., J.D. Tyler, B.P. Blass, and M.A. Mares. 1989. Mammals of Oklahoma. University of Oklahoma Press, Norman. Pp. 147-150.

Caire, W., R.S. Matlack, and K.B. Ganow. 2013. Population size estimations of Mexican free-tailed bat, *Tadarida brasiliensis*, at important maternity roosts in Oklahoma. Final performance report, federal aid grant F10AF00236 (T-55-R-1). Oklahoma Department of Wildlife Conservation.

Denholm, P., M. Hand, M. Jackson, and S. Ong. 2009. Land-use requirements of modern wind power plants in the United States. Technical Report NREL/TP-6A2-45834. National Renewable Energy Laboratory, Golden, Colorado.

Erickson, W., G. Johnson, D. Young, D. Strickland, R. Good, M. Bourassa, K. Bay, and K. Sernka. 2002. Synthesis and comparison of baseline avian and bat use, raptor nesting and mortality information from proposed and existing wind developments. A final report submitted to the Bonneville Power Administration. WEST, Inc., Cheyenne, Wyoming.

ESRI. 2008. U.S. Census urbanized areas. Data & maps 2008. ESRI, Redlands, California.

Fargione, J., J.M. Kiesecker, M.J. Slaats, S. Olimb. 2012. Wind and wildlife in the Northern Great Plains: identifying low-impact areas for wind development. PLoS ONE 7(7): e41468.

Federal Aviation Administration (FAA). 2010. Airspace, special use airspace, and temporary flight restrictions. https://www.faasafety.gov, accessed December 9, 2015.

Federal Aviation Administration (FAA). 2011. See and avoid portal. http://www.seeandavoid.org/, accessed December 9, 2015.

Federal Aviation Administration (FAA). 2015(a). Visual flight reference raster charts for Dallas-Ft. Worth, Kansas City, Memphis, and Wichita. https://www.faa.gov/air_traffic/flight_info/aeronav, accessed December 9, 2015.

Federal Aviation Administration (FAA). 2015(b). DoD preliminary screening tool. https://oeaaa.faa.gov/, accessed December 9, 2015.

Federal Aviation Administration (FAA). 2017. Digital obstacle file. https://www.faa.gov/air_traffic/flight_info/aeronav/digital_products/dof/, accessed August 3, 2017.

Fry, J., G. Xian, S. Jin, J. Dewitz, C. Homer, L. Yang, C. Barnes, N. Herold, and J. Wickham. 2011. Completion of the 2006 National land cover database for the conterminous United States. Photogrammetric Engineering and Remote Sensing 77(9):858-864.

G.M. Sutton Avian Research Center (GMSARC). 2015. Bald eagle restoration efforts. http://www.suttoncenter.org/pages/bald_eagles_restoration_efforts, accessed March 13, 2015.

Graening, G.O., M.J. Harvey, W.L. Puckette, R.C. Stark, D.B. Sasse, S.L. Hensley, and R.K. Redman. 2011. Conservation status of the endangered Ozark big-eared bat (*Corynorhinus townsendii ingens*) – a 34-year assessment. Publications of the Oklahoma Biological Survey 11: 1-16.

Great Plains Nature Center (GPNC). 2015. Bald eagle. http://www.gpnc.org/eagleB.htm, accessed March 13, 2015.

Hagen, C.A., B.E. Jamison, K.M. Giesen, and T.Z. Riley. 2004. Guidelines for managing lesser prairie-chicken populations and their habitats. Wildlife Society Bulletin 32(1): 69-82.

Hau, E. and H. von Renouard. 2013. The wind resource. *In* Wind turbines: fundamentals, technologies, application, economics. Springer Science & Business Media, Berlin. Pp. 505-548.

Hughes, T.W., M. Shafer, T. Simonsen, J. Traurig, N. Mirsky, S.J. Stadler, and P.G. Earls. 2002. Using environmental data to attract development: the Oklahoma Wind Power Assessment Initiative. Proceedings of the 3rd Symposium on Environmental Applications, American Meterological Society, Orlando, Florida, January 12-17, 2002.

Kansas Biological Survey (KBS). 2015. Kansas Natural Resource Planner. http://kars.ku.edu/maps/naturalresourceplanner/, accessed February 20, 2015.

Kansas Department of Wildlife, Parks, and Tourism (KDWPT). 2015. Threatened and endangered wildlife. http://kdwpt.state.ks.us/Services/Threatened-and-Endangered-Wildlife, accessed February 20, 2015.

Kansas State University (KSU). 2002. Habitat model for gray myotis (*Myotis grisescens*). http://www.k-state.edu/kansasgap/KS-GAPPhase1/finalreport/SppModels/Mammals/Gray_Myotis.pdf, accessed February 20, 2015.

Kerlinger, P., R. Curry, L. Culp, A. Jain, C. Wilkerson, B. Fischer, and A. Hasch. 2006. Post-construction avian and bat fatality monitoring study for the High Winds Wind Power Project, Solano County, California: two year report. Curry and Kerlinger LLC, McLean, Virginia.

Kunz, T.H. and M.B. Fenton (eds). 2003. Bat ecology. University of Chicago Press.

Johnsgard, P.A. 2002. Grassland grouse and their conservation. Smithsonian Institute, Washington, D.C.

Langreder, W. 2010. Wind resource and site assessment. *In* Tong, W. (ed.) Wind power generation and wind turbine design. WIT Press, Billerica, Massachusetts. Pp. 49-87.

LaVal, R.K., R.L. Clawson, M.L. LaVal, and W. Caire. 1977. Foraging behavior and nocturnal activity patters of Missouri bats, with emphasis on the endangered species *Myotis grisescens* and *Myotis sodalis*. Journal of Mammology 58(4): 592-599.

Masters, R.E., J.E. Skeen, and J.A. Garner. 1989. Red-cockaded woodpecker in Oklahoma: an update of Wood's 1974-77 study. Proceedings of the Oklahoma Academy of Science 69: 27-31.

Miller, A. 2008. Patterns of avian and bat mortality at a utility-scaled wind farm on the southern High Plains. Master's thesis, Texas Tech University, Lubbock.

Moore, C.L., C.H. Johnson, C.L. Hall, and D.R. Howard. 2012. The effect of wind turbine induced vibration on the reproductive behavior of the endangered American burying beetle (*Nicrophorus americanus*). Entomological Society of North America, North Central Branch Annual Meeting, June 4, 2012, Lincoln, Nebraska.

National Aeronautics and Space Administration (NASA), Ames Research Center. 2015. Special use airspace .kml file. http://sggate.arc.nasa.gov:9518/GoogleEarth/sua.kmz, accessed December 9, 2015.

National Conservation Easement Database (NCED). 2016. Central region NCED dataset. http://conservationeasement.us/, accessed August 3, 2017.

National Oceanic and Atmospheric Administration. 2015. Climate data online radar mapping tool. https://gis.ncdc.noaa.gov/map/viewer/#app=cdo, accessed February 28, 2015.

Natural Resources Defense Council (NRDC) and U.S. Department of Defense (USDOD). 2013. Working with the Department of Defense: siting renewable energy development. http://docs.nrdc.org/nuclear/files/nuc_13112001a.pdf, accessed December 9, 2015.

National Wind Coordinating Collaborative (NWCC). 2010. Wind turbine interactions with birds, bats, and their habitats: a summary of research results and priority questions. http://www.nationalwind.org, accessed September 1, 2010.

Obermeyer, B., R. Manes, J. Kiesecker, J. Fargione, and K. Sochi. 2011. Development by design: mitigating wind development's impacts on wildlife in Kansas. PLoS One 6(10): e26698.

Oklahoma Department of Wildlife Conservation (ODWC). 2015. Oklahoma's threatened and endangered species. http://www.wildlifedepartment.com/wildlifemgmt/endangeredspecies.htm, accessed February 20, 2015.

Oklahoma State Department of Education (OKSDE). 2015. Oklahoma Public Schools 2014-2015 shapefile. http://okmaps.org, accessed December 9, 2015.

Oklahoma Statutes. 2017. Oklahoma Legislature, Constitution and Statues. Title 17, § 160.20

Ostlie, W. 2003. Untilled landscapes of the Great Plains. The Nature Conservancy, Minneapolis, Minnesota.

Pagel, J.E., K.J. Kritz, B.A. Milsap, R.K. Murphy, E.L. Kershner, and S. Covington. 2013. Bald eagle and golden eagle mortalities at wind energy facilities in the contiguous United States. Journal of Raptor Research 47(3): 311-315.

Pearse, A.T., D.A. Brandt, W.C. Harrell, K.L. Metzger, D.M. Baasch, and T.J. Hefley. 2015. Whooping crane stopover site use intensity within the Great Plains. U.S. Geological Survey Open-File Report 2015–1166. http://dx.doi.org/10.3133/ofr20151166, accessed August 3, 2017.

Pennsylvania Game Commission (PGC). 2007. Pre- and post construction monitoring of bat populations at industrial wind turbine sites. http://www.dcnr.state.pa.us/wind/index.aspx, accessed August 22, 2007.

Pitman, J.C., C.A. Hagen, R.J. Robel, T.M. Loughin, and R D. Applegate. 2005. Location and success of lesser prairie-chicken nests in relation to vegetation and human disturbance. Journal of Wildlife Management 69: 1259-1269.

Piorkowski, M.D and T.J. O'Connell. 2010. Spatial pattern of summer bat mortality from collisions with wind turbines in mixed-grass prairie. The American Midland Naturalist 164(2): 260-269.

Playa Lakes Joint Venture (PLJV). 2015(a). Regional birds. http://pljv.org/about/birds, accessed March 13, 2015.

Playa Lakes Joint Venture (PLJV). 2015(b). Playa decision support system. http://pljv.org/playa-dss, accessed February 20, 2015 and August 3, 2017.

Playa Lakes Joint Venture (PLJV). 2017. Energy development siting recommendations for playas. http://pljv.org/documents/PLJV_Energy_Development_Siting_Recommendations_Playas.pdf, accessed August 3, 2017.

Pruett, C.L., M.A. Patten, and D.H. Wolfe. 2009. Avoidance behavior of prairie grouse: implications for wind and energy development. Conservation Biology 23: 1253-1259.

Reinking DL (ed.) 2004. Oklahoma breeding bird atlas. University of Oklahoma Press, Norman.

Robel, R.J. 2011. Comments to the U.S. Fish and Wildlife Service on the land-based wind energy guidelines. http://www.fws.gov/windenergy/wind_comments/robel.pdf, accessed March 13, 2015.

Robel, R.J., J.A. Harrington, C.A. Hagen, J.C. Pitman, and R.R. Recker. 2004. Effect of energy development and human activity on the use of sand sagebrush habitat by lesser prairie chickens in southwestern Kansas. Transactions of the North American Wildlife and Natural Resources Conference 69: 251-266.

Rothschild, S. 2005, January 15. Flint Hills may not get wind of power plan. Lawrence Journal World, pp. 1B, 3B.

Schmidly, D.J. 2004. The mammals of Texas (revised edition). University of Texas Press, Austin. Pp. 123-129.

Schmidt, C.J., T.W. Taggart, and J.R. Choate. 2015. Kansas Mammal Atlas: an on-line reference. http://webcat.fhsu.edu/ksfauna/mammal, accessed December 11, 2015.

Southern Great Plains Crucial Habitat Assessment Tool (SGPCHAT). 2013. http://www.kars.ku.edu/maps/sgpchat/, accessed March 13, 2015 and August 3, 2017.

Sparks, D.W., and J.R. Choate. 2000. Distribution, natural history, conservation status, and biogeography of bats in Kansas. Pp. 173-228 *in* Choate, J.R. Reflections of a naturalist: papers honoring Professor Eugene D. Fleharty. Fort Hays State University, Hays, Kansas.

Stahle, D.W., M.D. Therrell, and K.L. Clements. 2003. The ancient cross timbers consortium for research, education, and conservation. University of Arkansas, Department of Geosciences, Fayetteville.

Svedarsky, W.D., R.H. Hier, and N.J. Silvy (eds). 1999. The greater prairie chicken: a national look. Minnesota Agricultural Experiment Station Publication 99-1999, Saint Paul.

Tennis, M.W., S. Clemmer, and J. Howland. 1999. Assessing wind resources: a guide for landowners, project developers, and power suppliers. Union of Concerned Scientists briefing paper. http://www.ucsusa.org/sites/default/files/legacy/assets/documents/clean_energy/wind_resource_assessment.pdf, accessed March 13, 2015.

The Nature Conservancy (TNC). 2003. Ozarks ecoregional conservation assessment. TNC, Midwestern Resource Office, Minneapolis, Minnesota.

The Nature Conservancy (TNC). 2017. Oklahoma Chapter geographic information system database. TNC, Tulsa, Oklahoma.

U.S. Department of Energy (USDOE). 2008. 20% wind energy by 2030: increasing wind energy's contribution to U.S. electricity supply. http://www.nrel.gov/docs/fy08osti/41869.pdf, accessed August 22, 2010.

U.S. Department of Energy (USDOE). 2015. Wind vision: a new era for wind power in the United States. http://www.energy.gov/sites/prod/files/WindVision_Report_final.pdf, accessed July 1, 2015.

U.S. Department of Transportation (USDOT). 2015. National transportation atlas database airport runways shapefile. http://www.rita.dot.gov, accessed December 6, 2015.

U.S. Geological Survey (USGS). 2015(a). National elevation dataset. http://ned.usgs.gov/, accessed February 20, 2015.

U.S. Geological Survey (USGS). 2015(b). 2015 geographic names information system text file for Oklahoma. http://viewer.nationalmap.gov, accessed December 9, 2015.

U.S. Fish and Wildlife Service (USFWS). 1989. Southeastern states bald eagle recovery plan. http://ecos.fws.gov, accessed March 13, 2015.

U. S. Fish and Wildlife Service (USFWS). 1990. Recovery plan for the interior population of the least tern (*Sterna antillarum*). http://ecos.fws.gov, accessed December 12, 2010.

U.S. Fish and Wildlife Service (USFWS). 1991(a). American burying beetle (*Nicrophorus americanus*) recovery plan. http://ecos.fws.gov, accessed December 12, 2010.

U.S. Fish and Wildlife Service (USFWS). 1991(b). Black-capped vireo (*Vireo atricapillus*) recovery plan. http://ecos.fws.gov, accessed December 12, 2010.

U.S. Fish and Wildlife Service (USFWS). 2003. Interim guidelines to avoid and minimize wildlife impacts from wind turbines. http://www.fws.gov/habitatconservation/wind.pdf, accessed August 22, 2007.

U.S. Fish and Wildlife Service (USFWS). 2009(a). Whooping cranes and wind development – an issue paper. http://www.fws.gov/southwest/es/library, accessed December 10, 2010.

U.S. Fish and Wildlife Service (USFWS). 2009(b). ESA basics fact sheet. http://www.fws.gov/endangered/, accessed December 10, 2010.

U.S. Fish and Wildlife Service (USFWS). 2010. Cooperative Whooping Crane Tracking Project GIS Database. USFWS, Grand Island, Nebraska.

U.S. Fish and Wildlife Service (USFWS). 2011(a). Species profile for whooping crane (*Grus americana*). http://ecos.fws.gov, accessed March 13, 2015.

U.S. Fish and Wildlife Service (USFWS). 2011(b). Indiana bat Section 7 and 10 guidance for wind energy projects. http://www.fws.gov/midwest/endangered/, accessed February 20, 2015.

U.S. Fish and Wildlife Service (USFWS). 2011(c). National wetlands inventory. http://www.fws.gov/wetlands/, accessed February 20, 2015.

U.S. Fish and Wildlife Service (USFWS). 2014(a). American burying beetle conservation priority areas shapefile and metadata. http://www.fws.gov/southwest/es/oklahoma/, accessed February 20, 2015.

U.S. Fish and Wildlife Service (USFWS). 2014(b). Northern long-eared bat interim conference and planning guidance. http://www.fws.gov/northeast/virginiafield, accessed March 18, 2016.

U.S. Fish and Wildlife Service (USFWS). 2015. Washita National Wildlife Refuge wildlife & habitat. http://www.fws.gov/refuge/Washita/wildlife_and_habitat/index.html, accessed March 13, 2015.

U.S. Fish and Wildlife Service (USFWS). 2016. Midwest wind energy multi-species habitat conservation plan (public review draft). http://www.midwestwindhcp.com/, accessed April 22, 2016.

Van Pelt, W.E., S. Kyle, J. Pitman, D. Klute, G. Beauprez, D. Schoeling, A. Janus, and J. Haufler. 2013. The lesser prairie-chicken range-wide conservation plan. Western Association of Fish and Wildlife Agencies, Cheyenne, Wyoming.

Vogt, R.J., E.J. Ciardi, and R.G. Guenther. 2011. New criteria for evaluating wind turbine impacts on NEXRAD weather radars. NEXRAD Radar Operations Center, Norman, Oklahoma. http://www.roc.noaa.gov/wsr88d/Publicdocs/WINDPOWER2011_Final.pdf, accessed December 9, 2015.

Western Hemisphere Shorebird Reserve Network (WHSRN). 2015. WHSRN sites. http://www.whsrn.org, accessed March 13, 2015.

Western Regional Climate Center (WRCC). 2015. Wind rose data for weather stations in Kansas. http://www.wrcc.dri.edu/, accessed February 20, 2015.

White, T., J. Kuba, and J. Thomas. 2014. Data driven generation siting for renewables integration in transmission planning. Proceedings of the ESRI User Conference, July 14-18, 2014, San Diego, California.

Wilkins, N., R.A. Powell, A.T. Conkey, and A.G. Snelgrove. 2006. Population status and threat analysis for the black-capped Vireo. Texas A&M University, College Station.