Results of the 2012 Range-wide Survey of

Lesser Prairie-chickens (*Tympanuchus pallidicinctus*)

Photo by Joel Thompson, WEST, Inc.

Prepared for:
Western Association of Fish and Wildlife Agencies
c/o Bill Van Pelt
WAFWA Grassland Coordinator
Arizona Game and Fish Department
5000 W. Carefree Highway
Phoenix, Arizona 85086

Prepared by:
Lyman McDonald, Jim Griswold, Troy Rintz, and Grant Gardner
WEST, Inc.
Western EcoSystems Technology, Inc.
200 South 2nd St., Suite B, Laramie, Wyoming
September 14, 2012

NATURAL RESOURCES • SCIENTIFIC SOLUTIONS

ABSTRACT

We flew aerial line transect surveys between March 30 and May 3, 2012, to estimate the abundance of lesser prairie-chickens (*Tympanuchus pallidicinctus*) and lesser prairie-chicken leks in four habitat regions in the Great Plains U.S. Estimates were supplemented with data from surveys conducted by Texas Tech University in two regions in the Texas Panhandle and surveys conducted by the Oklahoma Department of Wildlife Conservation in Oklahoma. We also estimated the number of mixed species leks which contained both lesser and greater prairie-chickens (*Tympanuchus cupido*) and the number of hybrid lesser-greater prairie-chickens. The study area for 2012 included four regions containing the 2011 estimated occupied lesser prairie-chicken range: 1) Shinnery Oak Prairie Region located in eastern New Mexico-southwest Texas panhandle, 2) Sand Sagebrush Prairie Region located in southeastern Colorado-southwestern Kansas and western Oklahoma Panhandle, 3) Mixed Grass Prairie Region located in the northeast Texas panhandle-northwest Oklahoma-south central Kansas area, and 4) Short Grass/CRP Mosaic located in northwestern Kansas and eastern Colorado. We created a sampling frame over the study area consisting of 536 blocks – each 15 km by 15 km. We flew 512 transects within a probabilistic sample of 256 blocks totaling 7,680 km. We observed 36 lesser prairie-chicken leks, 26 greater prairie-chicken leks, 5 lesser and greater prairie-chicken mixed leks and 85 prairie-chicken groups not confirmed to be lekking for a total of 152 prairie-chicken groups. Texas Tech University and the Oklahoma Department of Wildlife Conservation flew transects in an additional 27subjectively selected blocks and detected 10 lesser prairie-chicken leks and 7 groups not confirmed to be lekking. Combining these data we estimated a total of 3,174 lesser prairie-chicken leks (90% CI: 1,672 – 4,705) and 441 lesser and greater prairie-chicken mixed leks (90% CI: 92 - 967) in the study area. We estimated a total of 37,170 individual lesser prairie-chickens (90% CI: 23,632 – 50,704) and 309 hybrid lesser-greater prairie-chickens (90% CI: 191 - 456) in the study area.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

INTRODUCTION

Within the five states of its range (Texas, Oklahoma, Kansas, New Mexico, and Colorado), the lesser prairie-chicken (*Tympanuchus pallidicinctus*, LEPC) remains present on sand sagebrush (*Artemesia filifolia*), mixed- and short- grass prairies of western Kansas and eastern Colorado, through portions of northwest Oklahoma, the northeast Texas panhandle, and into the shinnery oak (*Quercus havardii*) and sand sagebrush habitat of eastern New Mexico and western Texas. Agencies in these states monitor LEPC breeding populations annually within the known occupied range of the species, however, monitoring efforts have differed markedly among agencies and inferences have been made about populations using a variety of methods. This variation in survey methods and effort complicates attempts to understand LEPC population size and trends, and makes comparisons among areas difficult. Our objectives were to develop common, statistically robust survey and analysis methods to monitor LEPC population size and trends within the region and apply those methods in a pilot study in spring of 2012.

SURVEY AREA

The 2012 survey area was an expansion of the 2011 estimated occupied LEPC range (Southern Great Plains Crucial Habitat Assessment Tool, http://kars.ku.edu/maps/sgpchat/. The 2011estimated occupied LEPC range was expanded in Kansas to include habitat with relatively high probability of lek occurrence based on a habitat suitability model developed for the Western Governors' Association (Online Lesser Prairie-chicken Habitat Mapping Tool, http://www.oklahomafarmreport.com/wire/news/2011/11/02055_LesserPrairieChicken11012011_132701.php. In addition, some small, convoluted areas in the 2011 occupied LEPC range were expanded by a 7.5 km buffer to better accommodate aerial survey logistics using 15 x 15 km survey blocks (Figure 1).

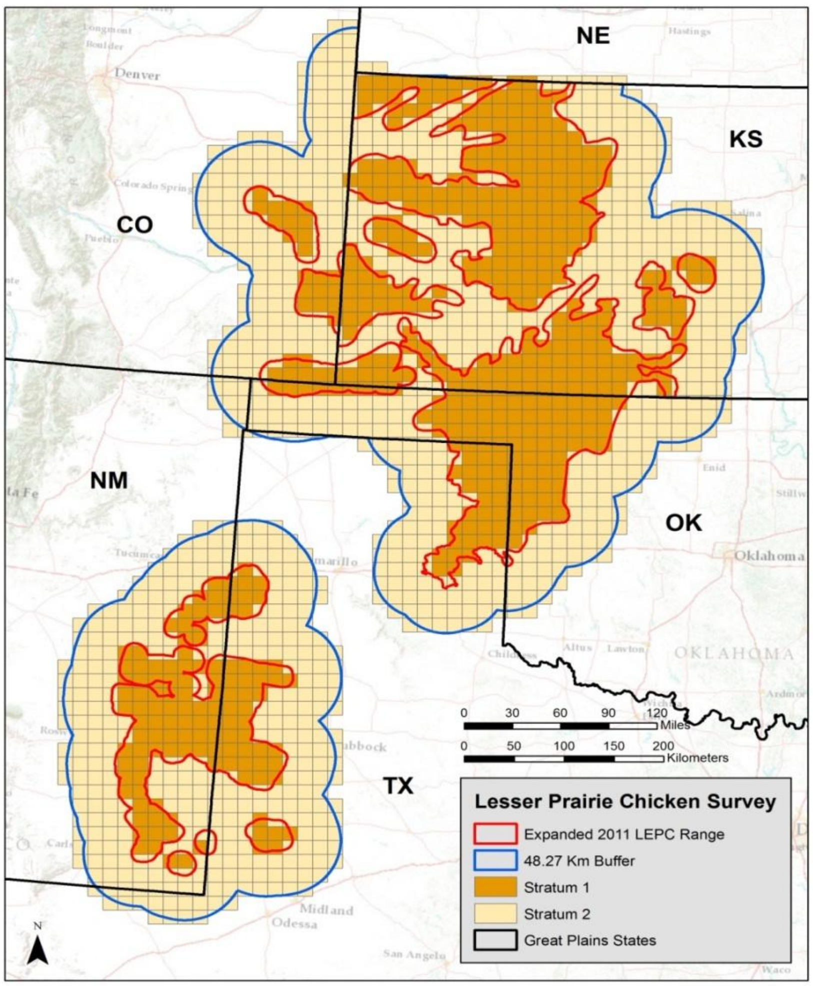

Figure 1. The 2012 study area (Stratum 1) consisted of 536 (15 × 15 km) blocks that overlap the expanded 2011 estimated occupied lesser prairie-chicken range by 50% or more. Stratum 2 consists of 979 additional blocks in approximately a 48.27 km (30 mile) buffer around Stratum 1. No probabilistically selected blocks were surveyed in Stratum 2 in 2012.

Stratum 1 was defined by the 536 blocks which overlap the expanded 2011 estimated occupied LEPC range by 50% or more. Stratum 2 was defined by the additional 979 (15 x 15 km) blocks which overlap the outer boundary of a 48.28 km buffer (30-mile buffer) around the 2011 estimated occupied LEPC range by 10% or more. Boundaries of the 15 x 15 km blocks were defined using the USA Contiguous Albers Equal Area Conic USGS projection.

The 2012 aerial survey was a sample survey of the 536 blocks in Stratum 1 and did not include survey of blocks in Stratum 2. Also, note that the outer boundary of Stratum 2 may be changed in future surveys depending on results of the 2012 study, funds available, predictions of suitable LEPC habitat based on the Western Governors' Association tool, or other new information.

OBJECTIVES

Our objectives were to estimate the numbers of LEPC and active LEPC leks in Stratum 1 in spring of 2012. We also estimated the number of leks which contained both LEPC and greater prairie-chicken (*Tympanuchus cupido*, GRPC) in northwestern Kansas and the number of hybrid lesser-greater prairie-chickens (HPC). Estimates of LEPC lek and population abundances were given for four habitat regions: 1) Shinnery Oak Prairie Region (SOPR) located in eastern New Mexico-southwest Texas panhandle, 2) Sand Sagebrush Prairie Region (SSPR) located in southeastern Colorado-southwestern Kansas-western Oklahoma Panhandle, 3) Mixed-Grass Prairie Region (MGPR) located in the northeast Texas panhandle-western Oklahoma-south central Kansas, and 4) Shortgrass/CRP Mosaic (SGPR) located in northwestern Kansas and eastern Colorado (Figure 2). Our data and estimates were supplemented with surveys conducted in subjectively selected blocks in Stratum 1: by Texas Tech University in two regions in the Texas Panhandle (Timmer 2012a) and by the Oklahoma Department of Wildlife Conservation in Oklahoma.

METHODS

Blocks in Stratum 1 were ranked from 1 to 536 by an equal probability sampling procedure known as Generalized Random Tessellation Stratified (GRTS) sampling (Stevens and Olsen 2004). Blocks selected by the GRTS procedure maintain spatial dispersion of a sample for aerial resources such that any contiguous subset, if taken in order, was an equal probability sample of the target population. Blocks can be dynamically removed from the ranked list and the next blocks on the list added to the sample as we discover non-target or inaccessible blocks (e.g., military lands), if any exist. The original sample of 180 blocks was supplemented by 40 additional blocks from the GRTS list in Kansas and 36 blocks from the GRTS list in Region 1 (SOPR) in New Mexico and western Texas for a total sample size of 256 probabilistically selected blocks for aerial survey. Data from these blocks were used in estimation of density and abundance of LEPC and LEPC leks.

All observers and pilots participated in a training session prior to the survey. All observers were experienced in conducting wildlife surveys. The goals of the training were threefold: 1) to standardize survey methodology, 2) to improve and standardize observers' abilities to identify prairie-chickens from the air, and 3) to provide each observer with safety training. Training flights were conducted March 30 and 31 on eight blocks not selected for the primary sample survey and on some blocks in the primary sample survey. These blocks were selected in areas where prairie-chickens and leks were likely to be present. Data collected on March 31 through

May 3 on primary survey blocks and training blocks were given equal weight in the software program DISTANCE 6.0 (Buckland et al. 2001, Thomas et al. 2010) for estimation of the average probability of detection of prairie-chicken groups. Data collected March 31 through May 3 on primary survey blocks were used in estimation of density and abundance of LEPC and LEPC leks.

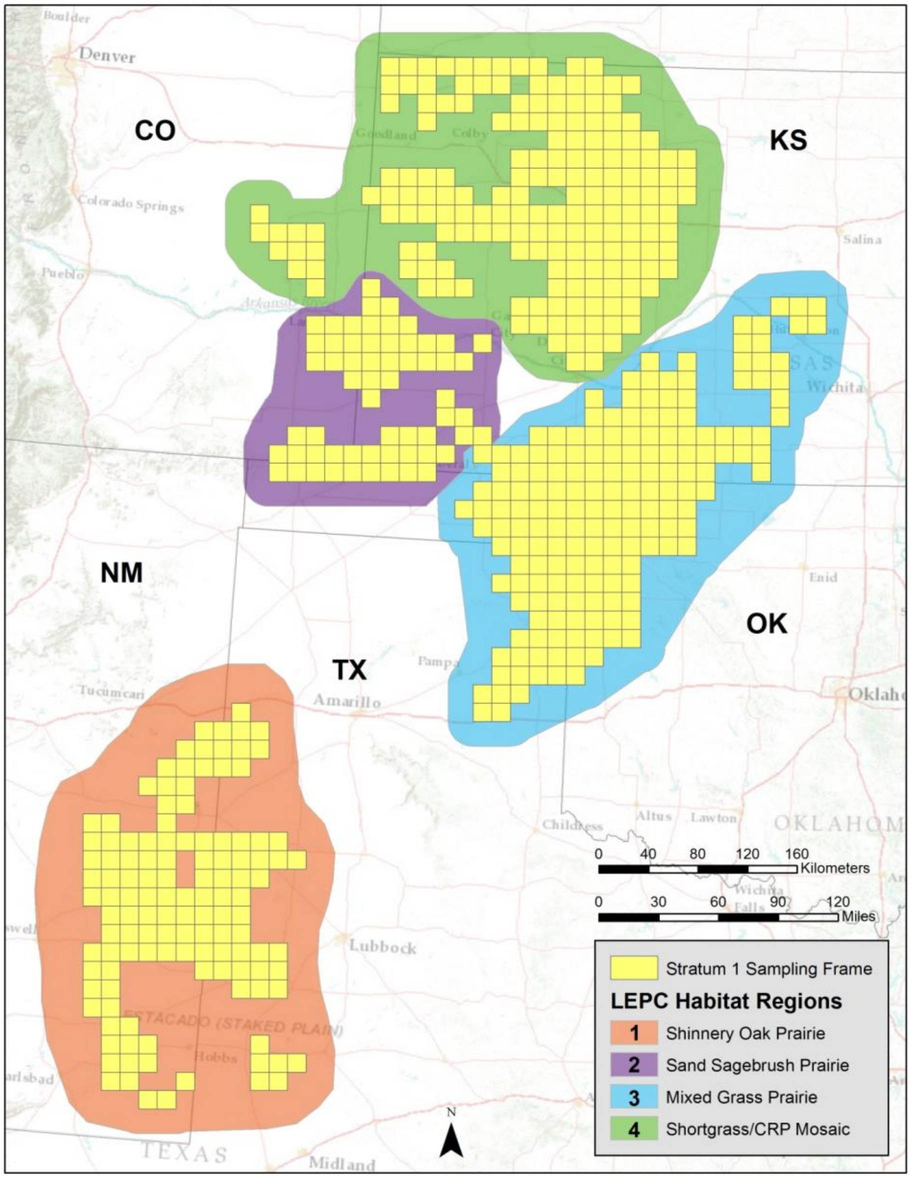

Figure 2. Potential survey blocks for the 2012 pilot study within Stratum 1 in four lesser prairie-chicken habitat regions. Areas not in blocks within the buffers were located in Stratum 2.

Aerial Survey Methods

The survey platform used for the 2012 LEPC survey was the Raven II (R-44) (Robinson Helicopter Company, Torrance, CA) helicopter accommodating two observers in the left and right rear seats, and a third observer in the front left seat. Three survey crews operated simultaneously within the study area. Transects were flown north to south or south to north at nominal values of 60 km per hour and 25 m above ground. Surveys were conducted between March 30 and May 3 2012 from sunrise until 2.5 hours after sunrise during the peak period of lek attendance. McRoberts et al. (2011a) reports that when flushed by a helicopter, LEPC in Texas returned to the lek and resumed pre-disturbance behavior within an average of 7 minutes, suggesting that aerial surveys can be conducted using a helicopter with minimal disruption to the LEPC lek dynamic.

Two 15 km north-south transects, separated by 7.5 km, were selected in each of the survey blocks. The starting point of the first transect was randomly located in the interval [200 m, 7300 m] on the base of the block and the second transect was located 7500 m to the right of the first transect. Appendix A contains the GPS waypoints for the beginning and ending of each of the 512 transects surveyed in the 256 primary survey blocks.

Each crew consisted of three observers. Two of the observers were seated side-by-side in the back seats, and the third observer sat in the front left seat of the aircraft. Double observer (mark-recapture) sampling trials following Seber (1982), Manly et al. (1996), and McDonald et al. (1999), were conducted on the left side of the aircraft to help estimate the probability of detection of prairie-chicken groups. To help ensure independence of observers, we installed a cardboard wall that served as a visual barrier between front left and back left observers. Observers recorded the approximate perpendicular distance to the center of a group of prairie-chickens from the transect line, counted any observed prairie-chickens, and remained quiet until confident that the other observer either saw or missed the group. The detection was then announced by one or both of the observers and the helicopter returned to the original observed location of prairie-chickens so the GPS coordinates of the center could be recorded for more accurate computation of the perpendicular distance from the transect. Communication of all observations during the surveys ensured that observers did not confuse two different prairie-chicken groups for the same observation. In addition to the number of individuals counted, other covariates recorded for each observation included: number of prairie-chickens sighted, date of the observation, activity (strutting or flushed), whether leks were man-made or natural, and habitat type: crop land, short-grass grassland, tall-grass grassland (with little or no shrubs), sand-sage prairie, shinnery oak (including other shrub dominated land), and bare ground.

Surveys were conducted at 25 m above ground level (AGL), except when necessary to avoid obstacles. At 25 m AGL there was an area beneath the aircraft 6.9 m to the left or right side of the transect line that was not visible to the rear seat observers. The front left seat observer focused on detection of prairie-chickens on and close to the transect line and also made observations of prairie-chickens detected in the field of view of the back left seat observer. The observer in the front left seat was also responsible for helping to guide the pilot to survey transects and recording flight paths and observations into a laptop computer. Observers alternated seats between flights in order to rotate observer positions throughout the survey. This allowed for estimation of an “average probability of detection by the average observer” for each position in the helicopter.

We estimated perpendicular distances from the transect line to observed prairie-chickens by flying off transect and recording the location of each prairie-chicken group where it was first detected using a Global Positioning System (GPS). All GPS coordinates, including the actual flight path, were recorded in a laptop computer using Garmin's nRoute software (Garmin International, Inc., 1200 E. 151st St., Olathe, KS 66062).

Detection of five or more prairie-chickens in a group were classified as an active lek. This criterion was verified during helicopter aerial and ground surveys conducted in Texas 2010 and 2011 (Jennifer Timmer, personal communication). If fewer than 5 individuals were observed, ground surveys were conducted to idenfity whether the birds were associated with a lek. If lekking birds were not found during ground surveys at the specified location of the group of less than 5 birds, the observation was classified as a "non-lek". If the observation was in Region 4 where LEPC, GRPC, and HPC were found, locations of all prairie-chicken observations were visited on the ground to determine if the observed groups of birds were all LEPC, all GRPC, or a mixture of lesser and greater prairie-chickens. No attempt was made to identify hybrid prairie-chickens during our ground surveys. A more detailed description of the methods is contained in the Appendix of Standard Operating Procedures (McDonald et al. 2011).

Texas Tech University and Oklahoma Department of Wildlife Conservation Survey Methods

Some blocks in Stratum 1, not selected for survey by Western EcoSystems Technology, Inc. (WEST), were subjectively selected by the Texas Parks and Wildlife Department and surveyed using helicopters by Texas Tech University (Timmer 2012a) in the Texas portions of Region 1 and Region 3. Similarly, the Oklahoma Department of Wildlife Conservation surveyed subjectively selected blocks in the Oklahoma portion of Region 3 (Doug Schoeling, personal communication). Nineteen blocks were surveyed by Texas Tech University and 8 blocks were surveyed by the Oklahoma Department of Wildlife Conservation. We treated the 19 blocks in Texas as a separate Stratum T and the 8 blocks in Oklahoma as a separate Stratum O (Figure 3). We reported Texas Tech University and Oklahoma Department of Wildlife Conservation estimates for LEPC density and lek density in strata T and O.

Standard operating procedures for these aerial surveys were similar to those conducted by WEST, with the following exceptions. Texas Tech University utilized a Robinson R-22 helicopter (Robinson Helicopter Company, Torrance, CA) with one observer and pilot responsible for detection of prairie-chickens. The Oklahoma Department of Wildlife Conservation utilized an Air Ranger helicopter with two observers and pilot – one observer in the left front seat and one in the right rear seat. Both of these supplemental surveys were conducted on eight transects per block, a higher sub-sampling intensity compared to two transects per block flown by WEST in the remainder of Stratum 1.

We denote the area in Stratum 1 minus the 27 blocks in Strata T and O by the phrase "Stratum 1^{-}". We estimate density and abundance of LEPC and LEPC leks in Stratum 1^{-} using the sample survey data collected by WEST and combine the estimates with those reported by Texas Tech University and the Oklahoma Department of Wildlife Conservation for Strata T and O. Texas Tech University and the Oklahoma Department of Wildlife Conservation conducted aerial surveys in other blocks whose corresponding data were not used to estimate parameters in Stratum 1. Also, Texas Tech University and the Oklahoma Department of Wildlife Conservation resurveyed six of WEST's original sample of 256 blocks. We used data from the WEST surveys on those six blocks in our analysis to maintain equal sub-sampling intensity with the other 250 blocks surveyed by WEST.

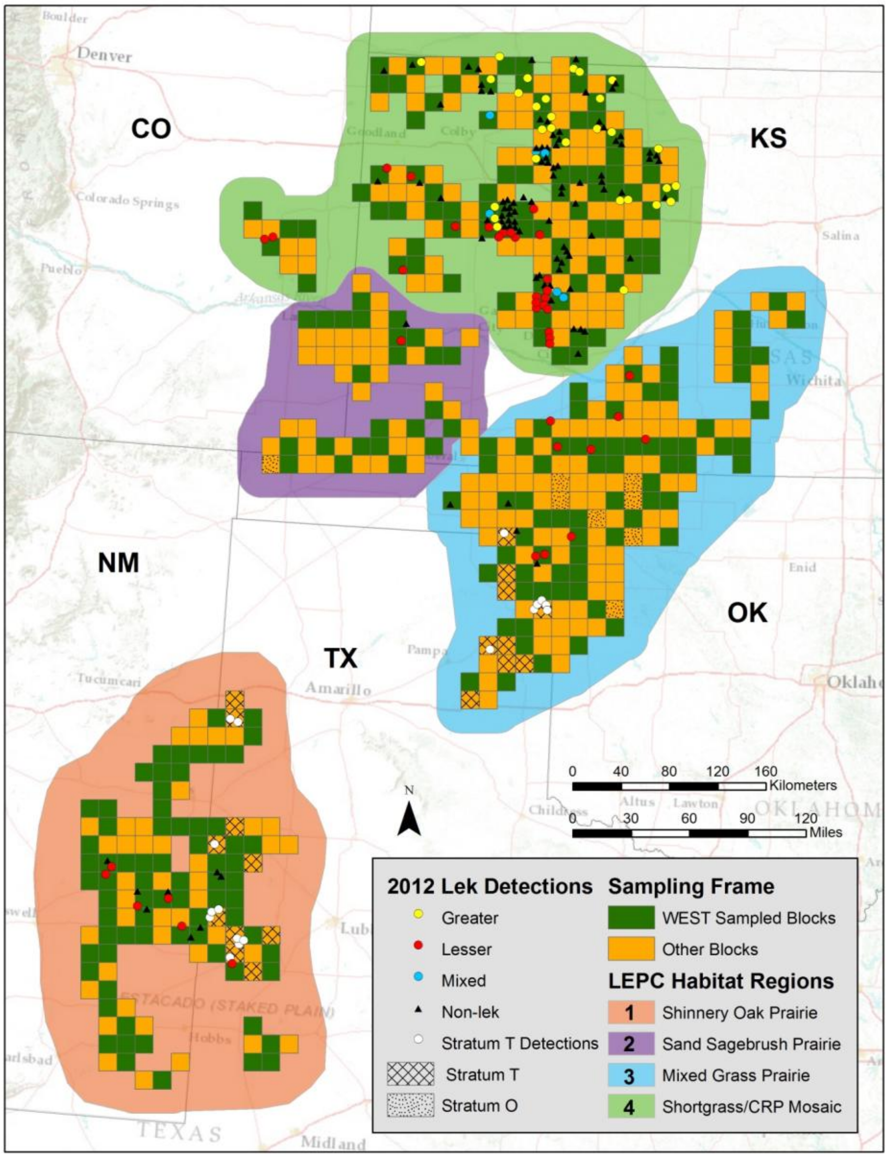

Figure 3. Locations of prairie-chickens observed in the 2012 survey, including training exercises. Exact locations of the symbols have been shifted to show all detections. Texas Tech University detections of leks and non-leks were plotted in Stratum T. Prairie-chickens were not detected in Stratum O in Oklahoma.

Statistical Methods

We investigated the assumption that probability of detection of prairie-chicken groups was 1.0 on or near the transect line by analyzing the double observer observations of prairie-chickens. Analysis of the double observer observations involved estimating the probability of detection $p_1(x_i)$ by the front left seat observer (observer 1) given the back left seat observer (observer 2) detected prairie-chickens at distance x_i. Vice versa, probability of detection $p_2(x_i)$ by the back seat observer given detection by the front seat observer was also estimated. Logistic regression (McCullagh and Nelder 1989) was used to estimate $p_1(x_i)$ and $p_2(x_i)$ using an equation similar to

$$p_j(x_i) = \frac{\exp(\beta_{0j} + \beta_{1j}x_i + \beta_{2j}x_i^2)}{1 + \exp(\beta_{0j} + \beta_{1j}x_i + \beta_{2j}x_i^2)}, \quad (1)$$

where β_{0j} was the intercept coefficient for observer j, β_{1j} was the slope coefficient of distance x_i m for observer j, and β_{2j} is the coefficient for distance squared.

We considered the following logistic regression models for the double observer data: 1) intercept term only (i.e., probability of mark-recapture success was constant at all distances), 2) intercept term and a slope coefficient for distance from the transect line, and 3) model 2) with an additional coefficient for distance squared. For each observer position we chose the model with the lowest value of the second-order variant of Akaike's Information Criterion (AICc; Burnham and Anderson 2002).

Following logistic regression analysis, we estimated the probability of detection by at least one observer on the left side of the helicopter. Let 1, and 2 denote observer positions in the front left and back left of the helicopter, respectively. Assuming independence between observers 1 and 2, the probability of detection on the left side of the helicopter at distance x_i by at least one observer was calculated as

$$\hat{p}.(x_i) = \hat{p}_1(x_i) + \hat{p}_2(x_i) - \hat{p}_1(x_i)[\hat{p}_2(x_i)]. \quad (2)$$

Following logistic regression analysis, we estimated the probability of detection by each of the observers at 6.9 m (minimum observable distance by back-seat observers) and by at least one observer on the left side at 6.9 m to help evaluate whether probability of detection of prairie-chicken groups was close to or equal to 1.0 on the transect line (perpendicular distance = 0.0). We assumed that the estimated probability of detection of prairie-chickens by the back right observer was the same as the probability of detection by the back left observer, because the fields of view were similar and we rotated observers among the three seats throughout the survey.

Buckland et al. (2001) recommend dropping up to 5% of observations with the largest distances to the transect line to remove the influence of outliers prior to estimation of the average probability of detection. We dropped two observations greater than 300 m from the transect line when using program DISTANCE 6.0 to estimate average probability of detection of leks and non-leks.

We separated our data into two groups for the estimation of $\hat{P}$ – the average probability of detecting a prairie-chicken group, given that it was available for detection. Separate analyses were conducted for leks and non-leks, because group sizes for leks were greater than those of non-leks and were thus likely to be observed with higher probability. The influence of other covariates on probability of detection (e.g., habitat type and type of lek) was investigated using the computer program DISTANCE 6.0.

We used the multiple-covariate software in program DISTANCE 6.0 to analyze our data for the purpose of model selection. Akaike's Information Criterion corrected for small sample size (AIC_c) was used to select among competitive models (Burnham and Anderson 2002). Covariates considered included group size, lek type, activity, survey date, survey date squared and habitat type. Candidate models included the negative exponential, hazard-rate and half-normal key functions. Adjustment terms used were the simple polynomial, cosine and Hermite polynomial. The hazard- rate and half-normal key functions were considered with and without adjustment terms and covariates.

We estimated the proportions of LEPC and HPC in leks and non-leks observed in the Kansas portion of Region 4 where the species overlap. Estimates of the proportions of lesser, greater and hybrid prairie-chickens in the Kansas portion of Region 4 were obtained from ground surveys conducted by the Kansas Department of Wildlife, Parks and Tourism. The resulting data set included 874 counts on 741 leks (553 GRPC, 152 LEPC and 46 mixed) across Kansas from 2007-2011. Kriging (Cressie 2012) was used to interpolate the species proportions across all sampled survey blocks (Figures 4 and 5; Jim Pitman, personal communication).

Upon selection of a model for probability of detection, we used the Rdistance package in the R language and environment (v2. 13.0; R Development Core Team 2011) to estimate population parameters. We estimated densities of LEPC leks and mixed lesser-greater leks, as well as LEPC and HPC population totals in each habitat region and the entire study area. Estimation of the average probability of detection of a lek ($\hat{P}_{lek}$) and density ($\widehat{D}_{lek}$) were carried out using the F.dfunc.estim and ESW functions in the Rdistance package which applied the formulas (Buckland et al. 2010)

$$\hat{P}_{lek} = \frac{\int_0^w g(x)\,dx}{w}, \tag{3}$$

and

$$\hat{D} = \frac{n}{2wL\hat{P}_{LEK}} \tag{4}$$

where $g(x)$ was the probability of detection function, x was the perpendicular distance to observations, *w* was the maximum search distance, $\hat{D}_{lek}$ was the estimated density of LEPC or mixed leks, *n* was the number of the given type of lek detected, and *L* was the total length of transects flown. Thus, the observed density of leks ($n/2wL$) was corrected for less than 100% probability of detection by dividing the observed density by the average probability of detection. To be consistent with other recent work (Timmer 2012b) we reported our estimated density as the number of leks per 100 square kilometers (km^2).

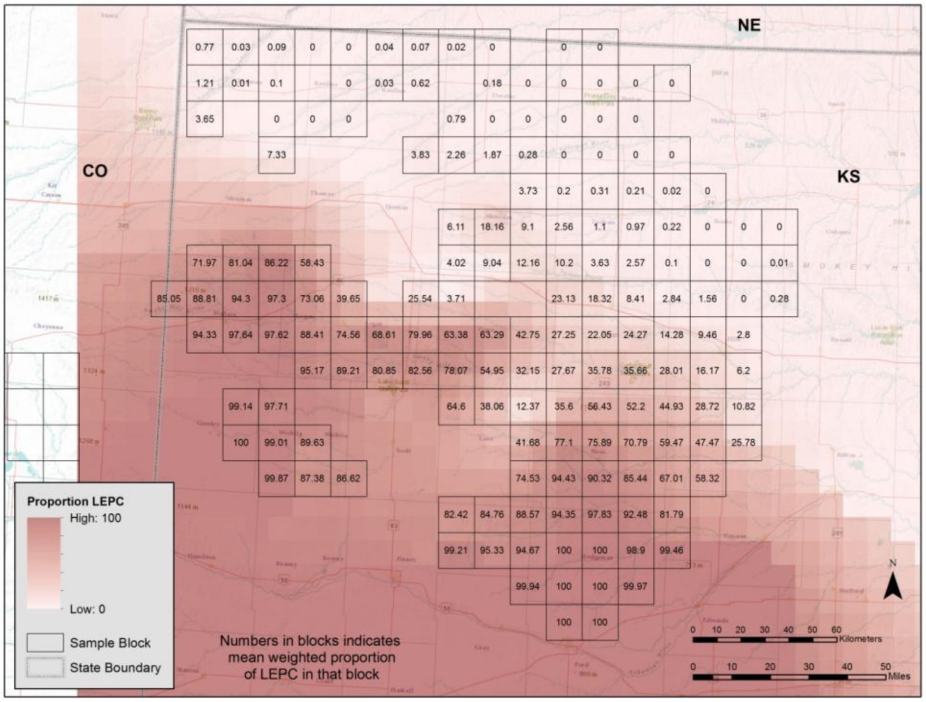

Figure 4. Estimated proportions of lesser prairie-chickens in (15 x 15 km) blocks in Region 4 (SGPR) located in northwestern Kansas.

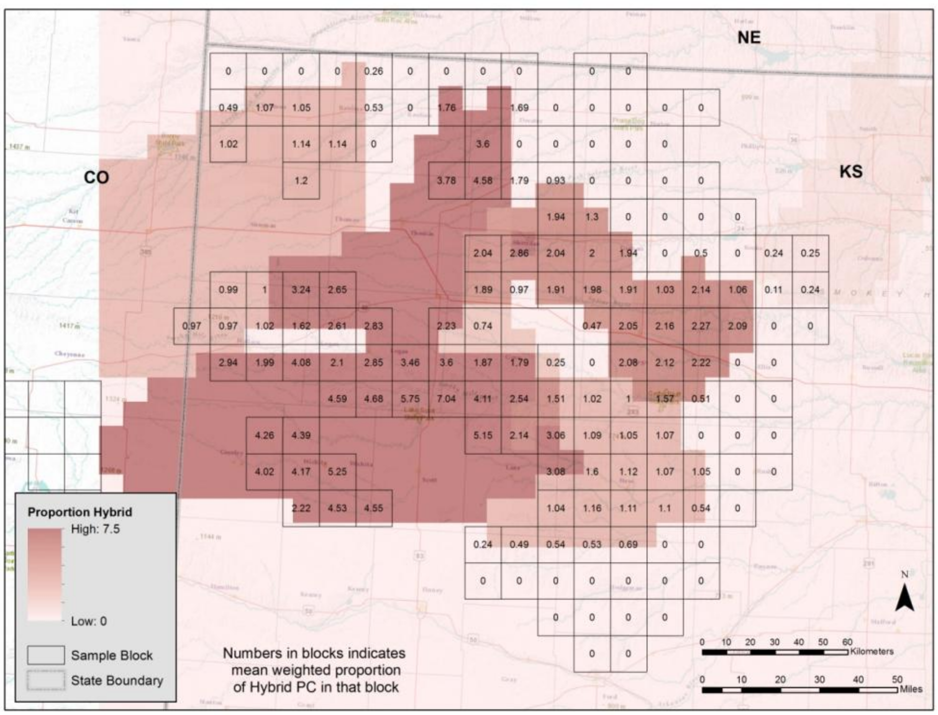

Figure 5. Estimated proportions of lesser prairie-chicken/greater prairie-chicken hybrids in 15 x 15 km blocks in Region 4 (SGPR) located in northwestern Kansas.

Similarly, we estimated the density of non-leks using probability of detection of non-leks computed using equation (3). Density of non-leks was estimated using the probability of detection for non-leks (equation 4).

Density of LEPC in Stratum 1¯ was estimated separately for leks and non-leks and then combined to obtain a total density of all individuals. Density of LEPC associated with leks was estimated as the product of three statistics: (habitat region specific mean group size of leks) × (proportion of LEPC in leks) × (density of leks). Similarly, density of LEPC in non-leks was estimated as the product of three statistics: (habitat region specific mean group size of non-leks) × (proportion of LEPC in non-leks) × (density of non-leks). The proportions of LEPC in leks and non-leks were assumed to be 1.0 except in the Kansas portion of Region 4, where we estimated the proportion of LEPC in a lek as the average of the proportions in surveyed blocks in Figure 4. Hybrid prairie-chicken density was estimated using similar formulas except that the proportions of HPC in leks and non-leks were estimated as the average of the proportions in surveyed blocks in Figure 5. To be consistent with other recent work (Timmer 2012b) we reported our estimated LEPC and HPC densities as the number of LEPC and HPC per 100 square kilometers (km^2).

Habitat region totals of LEPC leks or mixed leks in Stratum 1¯ were estimated as the product of the total area of the region and the density of leks or mixed leks per km^2. Estimated totals of LEPC leks and mixed leks were estimated as the sum of the four habitat regions estimates in the study area.

Habitat region totals of LEPC and HPC in Stratum 1¯ were estimated as the product of the total area of the region and the appropriate density estimate per km^2. Estimated population totals for LEPC or HPC were estimated as the total of the four habitat regions population estimates in the study area.

Bootstrapping (Manly 2006) was used to estimate 90% CIs for densities and population totals of LEPC leks, mixed leks, LEPC and HPC within each habitat region and Stratum 1¯. This process involved taking 1,000 simple random samples with replacement from the 256 surveyed blocks. The entire analysis was repeated on each bootstrapped sample including: re-computation of region specific lek and non-lek group sizes, estimated average probabilities of detection, number of LEPC leks, mixed leks and non-leks in the bootstrapped sample, and average proportions of LEPC and HPC in Region 4 of Kansas. Each bootstrapped sample produced new estimates of densities and population totals. We calculated confidence intervals based on the central 90% of the bootstrap distribution (the "Percentile Method") for each estimated parameter in Stratum 1¯.

Total abundance estimates for the study area (Stratum 1) were obtained by summing estimates from Stratum 1¯, Stratum T, and Stratum O. Confidence intervals for parameters in Stratum 1 were estimated by approximating the standard error of the totals for Stratum 1¯, Stratum T and Stratum O (Casella and Berger 2002). For example, the coefficient of variation $CV_{SOPR\,Total}$ for estimated total leks in Region 1 (SOPR), was estimated by computing a weighted average of the CV for Region 1 based on WEST's data and the CV of Texas Tech University's estimate for the portion of Stratum T in Region 1, where weighting was by area of Region 1 (minus the portion of Stratum T in Region 1) and the area of the portion of Stratum T in Region 1.

The standard error ($SE_{SOPR\,Total}$) for total leks in Region 1 was estimated as the product of $CV_{SOPR\,Total}$ and the estimated total number of leks. Finally, a 90% CI for the Region 1 total leks was computed as

$$90\%\ CI : LEKS_{SOPR\,Total} = LEKS_{SOPR\,Total} \pm 1.65 \times SE_{SOPR\,Total}. \quad (5)$$

RESULTS

We observed 40 lesser prairie-chicken leks, 29 greater prairie-chicken leks, 6 mixed leks and 100 non-leks for a total of 175 prairie-chicken groups in 264 blocks, including observations detected during training exercises in 8 blocks (Table 1). The percentage of LEPC leks detected - classified by habitat type at the location were: crop land (2.8%), short-grass grassland (75%), tall-grass grassland (little or no shrubs; 5.6%), sand-sage prairie (5.6%), shinnery oak (including other shrub dominated land; 8.3%), bare ground (2.8). The percentage of LEPC non-leks detected (not including Region 4 – because Region 4 non-leks may include GRPC and HPC) - classified by habitat type at the location were: crop land (0%), short-grass grassland (38.5%), tall-grass grassland (little or no shrubs; 30.8%), sand-sage prairie (7.7%), shinnery oak (including other shrub dominated land; 23.1%), bear ground (0%). The location of one observation of LEPC in Region 1 was not accessible for ground confirmation and was included in Table 1 and in further analysis as a non-lek. One of the blocks in the original sample of 256 was on the Cannon Air Force Base, New Mexico, in Region 1 (SOPR) and not accessible for aerial survey. The block was replaced by the nearest accessible block not scheduled for survey.

One observation of a GRPC lek and one observation of a non-lek in Table 1 were greater than 300 m from the transect line and dropped from further analysis. The remaining 74 LEPC, GRPC, and mixed leks were pooled among all habitat regions and given equal weight for estimation of the average probability of detection of leks. Similarly, the remaining 99 non-leks were pooled and given equal weight for estimation of the average probability of detection of non-leks.

Table 1. Leks and non-leks observed in survey of 264 blocks in Stratum 1¯, including eight blocks surveyed during training exercises.

Habitat Region	Blocks in Survey	LEPC Leks Detected	GRPC Leks Detected	Mixed Leks Detected	Non-leks Detected
1 - SOPR	75	6	NA	NA	8
2 - SSPR	24	1	NA	NA	1
3 - MGPR	72	9	NA	NA	4
4 - SGPR	93	24	29	6	87
Total	264	40	29	6	100

We fitted the negative exponential, hazard-rate and half-normal key functions with and without adjustment terms and covariates to the perpendicular distances of 74 leks using program DISTANCE 6.0. Based on AICc values, the exponential detection function with no adjustment terms was tied with the hazard-rate model with no covariates and no adjustment terns (both had

AIC_c = 352). Following the principle of parsimony, we selected the model with the fewest number of parameters and estimated densities and abundance based on the exponential model (Figure 6). The estimated average detection probability for leks was $\hat{P}_{lek} = 0.296$ (90% CI: 0.233 – 0.374).

The exponential detection function with no adjustment terms was the best fitting model for perpendicular distances to 99 non-leks (AIC_c =456). The next best model was the hazard-rate with no covariates and no adjustment terms (AIC_c = 461). Using the negative exponential model, the estimated average probability of detection for non-leks was 0.271 (90% CI: 0.226 – 0.324) (Figure 6).

We estimated the probability of detection of leks or non-leks at 6.9 m from the transect line to help investigate the assumption that probability of detection of leks or non-leks was 1.0 on or near the transect line. Using logistic regression and data from the two independent observers on the left side of the helicopter, we estimated the probability of detection of a lek or non-lek by one or both of the observers in the interval 6.9 m to 300 m. At 6.9 m the estimated probability of detection of a lek or non-lek by one or both of the observers was 0.89 (Table 2). Using the fitted negative exponential models in Figure 6, the estimates of probability of detection at 6.9 m for leks and non-leks were estimated to be 0.928 and 0.922 respectively.

Table 2. The estimated probability of detection at distance 6.9 m from the transect line, $\hat{P}_{6.9}$. BL indicates the observer seated in the back left position of the helicopter while FL denotes the front left observer.

Observer	$\hat{P}_{6.9}$	**90% CI Low**	**90% CI High**
BL	0.79	0.62	0.95
FL	0.46	0.29	0.63
At least one of FL, BL	0.89	0.83	0.94

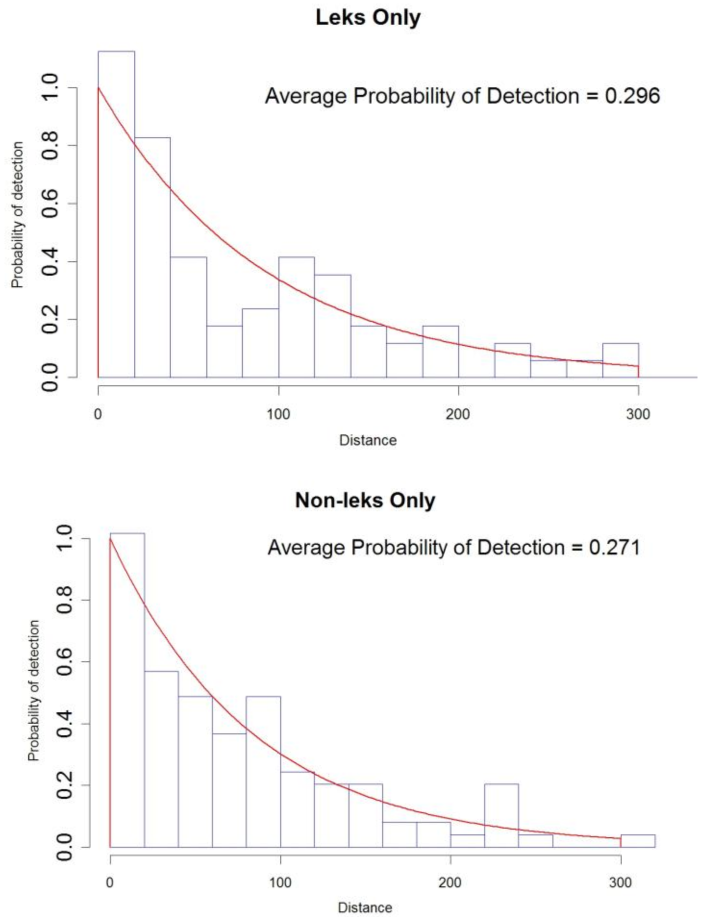

Figure 6. Plots of the negative exponential models with histograms of observed perpendicular distances to leks and non-leks. The histograms were scaled so that the models intersect the vertical axis at 1.0. Estimated average probabilities of detection for leks and non-leks were $\hat{P}_{lek} = 0.296$ and $\hat{P}_{non-lek} = 0.271$ respectively.

Estimated Densities and Abundances of LEPC Leks

We observed 36 lesser prairie-chicken leks, 26 greater prairie-chicken leks, 5 mixed leks and 85 non-leks for a total of 152 prairie-chicken groups less than 300 m from the transect lines during surveys of 256 blocks in Stratum 1¯ (Table 3).

Table 3. Leks and non-leks detected in survey of 256 blocks in Stratum 1¯, excluding blocks flown for training exercises.

Habitat Region	Blocks In Survey	LEPC Leks Detected	GRPC Leks Detected	Mixed Leks Detected	Non-leks Detected
1 - SOPR	75	6	NA	NA	8
2 - SSPR	24	1	NA	NA	1
3 - MGPR	72	9	NA	NA	4
4 - SGPR	85	20	26	5	72
Total	256	36	26	5	85

We post stratified the survey data into Regions: 1, 2, 3, and 4 and estimated the density of LEPC leks in each Region and the overall density for Stratum 1¯ giving equal weight to blocks surveyed within regions (Table 4). The estimated densities of LEPC leks in Stratum 1¯, unadjusted for probability of detection, were computed using the area surveyed per block (2×15 km×0.6 km = 18 km^2), the number of blocks flown, and number of LEPC leks detected (Table 3 and 4). For example, in Region 1 (SOPR) the unadjusted estimated density was [6/(75×18)]×100 = 0.44 leks/100 km^2. To adjust for the probability of detection, the unadjusted estimates were divided by the estimated average probability of detection, $\hat{P}_{lek} = 0.296$. Continuing the example in Region 1, the adjusted estimate of LEPC density was 0.44/(0.296) = 1.50 leks/100 km^2. We provide 90% confidence intervals on the estimates using bootstrap re-sampling methods. Estimated densities ranged from 0.78 LEPC leks per 100 km^2 in Region 2 (SSPR) to 4.43 leks per 100 km^2 in Region 4 (SGPR) with an estimated density of 2.64 leks per 100 km^2 in Stratum 1¯.

The estimated total abundances of LEPC leks were computed using the estimated densities from Table 4 and the total areas of the Regions (Table 5). Continuing the example, the estimated total abundance of LEPC leks in Region 1 (SOPR) was (1.50 leks per 100 km^2)×(25,425 km^2)/100 = 381 leks.

Table 6 contains estimated abundances of LEPC leks in Regions 1 and 3 of Stratum T in Texas, based on results provided in Timmer (2012a). No LEPC leks were detected in Stratum O in Oklahoma. Finally, estimated total abundances of LEPC leks were provided in Table 7 for the original study area (Stratum 1) by summing estimates in Tables 5 and 6. Coefficients of variation and confidence intervals on the estimated total abundances were computed by an approximate combination of the bootstrapped estimates in Table 5 for Stratum 1¯ and the statistics provided by Timmer (2012a). We estimate a total of 3,174 LEPC leks in the study area (Stratum 1).

Table 4. Estimated density of LEPC leks in Stratum 1¯. Adjusted estimates of densities are computed by dividing unadjusted statistics by $\widehat{P}_{lek} = 0.296$ the average probability of detection of prairie-chicken leks. Confidence intervals are based on bootstrap re-sampling methods.

Habitat Region	Blocks in Survey	LEPC Leks Detected	LEPC Leks/ 100 km^2 Estimate Unadjusted	LEPC Leks/ 100 km^2 Estimate Adjusted	LEPC Leks/ 100 km^2 90% CI Low	LEPC Leks/ 100 km^2 90% CI High
1 - SOPR	75	6	0.44	1.50	0.57	2.70
2 - SSPR	24	1	0.23	0.78	0.12*	2.28
3 - MGPR	72	9	0.69	2.33	1.03	4.03
4 - SGPR	85	20	1.31	4.43	1.96	7.90
Total	256	36	0.78	2.64	1.57	4.07

*The lower limit of the 90% bootstrapped confidence interval was 0.00, an impossible value, computed because only one LEPC lek was detected in Region 2. The known minimum value for density of LEPC leks in Region 2 was 0.12 leks/100 km^2 based on ground surveys conducted by State wildlife biologists (Pitman 2012, Smith 2012).

Table 5. Estimates of abundance of LEPC leks in Stratum 1¯. Coefficients of variation (CV) and confidence intervals were computed using bootstrap re-sampling methods.

Habitat Region	Area of Blocks in Stratum 1¯ (km^2)	LEPC Leks Estimate	LEPC Leks CV	LEPC Leks 90% CI Low	LEPC Leks 90% CI High
1 - SOPR	25,425	381	0.43	144	687
2 - SSPR	13,500	105	0.99	16*	307
3 - MGPR	35,775	834	0.39	370	1,440
4 - SGPR	39,825	1,764	0.40	856	3,145
Total	114,525	3,084	0.28	1,803	4,659

*The lower limit of the 90% bootstrapped confidence interval was 1.0, an impossible value, computed because only one LEPC lek was detected in Region 2. The known minimum value for abundance of LEPC leks in Region 2 was 16 based on ground surveys conducted by State wildlife biologists (Pitman 2012, Smith 2012).

Table 6. Estimated abundance of LEPC leks in Stratum T and confidence intervals based on statistics provided in Timmer (2012a).

Habitat Region	Area of Blocks in Stratum T (km^2)	LEPC Leks/ 100 km^2 Estimate	LEPC Leks Estimate	LEPC Leks 90% CI Low	LEPC Leks 90% CI High
1 - SOPR	2,250	2.10	47	25	92
3 - MGPR	2,025	2.10	43	22	83
Total	4,275	2.10	90	47	175

Table 7. Estimated total abundance of LEPC leks in Stratum 1. Coefficients of variation and confidence intervals were computed as an approximation combining statistics from Stratum 1¯ and Stratum T (Tables 5 and 6).

Habitat Region	Area of Blocks in Stratum 1 (km^2)	LEPC Leks Estimate	LEPC Leks CV	LEPC Leks 90% CI Low	LEPC Leks 90% CI High
1 - SOPR	27,675	428	0.43	125	736
2 - SSPR	13,500	105	0.99	16*	278
3 - MGPR	39,600	877	0.38	339	1,432
4 - SGPR	39,825	1,764	0.40	610	2,923
Total	120,600	3,174	0.29	1,672	4,705

*The lower limit of the 90% bootstrapped confidence interval was 1.0, an impossible value, computed because only one LEPC lek was detected in Region 2. The known minimum value for abundance of LEPC leks in Region 2 was 16 based on ground surveys conducted by State wildlife biologists (Pitman 2012, Smith 2012).

We estimated densities and abundances of mixed LEPC-GRPC leks in Region 4 using the same methods as for LEPC leks. Our estimate of density of mixed leks was 1.11 leks per 100 km^2 (90% CI: 0.18 - 2.38) in Region 4 with an estimated abundance of 441 mixed LEPC-GRPC leks (90% CI: 92 – 967) (Table 8). Combining LEPC leks and mixed LEPC-GRPC leks, we estimate that lesser prairie-chickens were present on a total of 3,615 active leks in the study area during spring 2012.

Estimated Densities and Total Abundances for LEPC and HPC

Using the habitat region-specific mean group sizes for leks (Table 9) we estimated total abundance of LEPC and HPC. The mean size of leks detected in Stratum 1¯ ranged from 5.83 LEPC per lek in Region 1 to 9.00 LEPC per lek in Region 2 (Table 9). Mean lek size in Region 4 was 7.2 (GRPC, LEPC and HPC) per lek. Mean size of non-leks detected ranged from 2.00 in Region 1 to 3.57 in Region 4.

Table 8. Estimates of density of mixed LEPC-GRPC leks and total abundance of mixed LEPC-GRPC leks in Region 4 (SGPR). Coefficients of variation (CV) and confidence intervals were computed using bootstrap re-sampling methods.

Habitat Region	Area of Blocks in Region 4 (km^2)	Mixed Leks/ 100 km^2	Mixed Leks/ 100 km^2 90% CI Low	Mixed Leks/ 100 km^2 90% CI High	Mixed Leks Est.	Mixed Total Leks CV	Mixed Leks 90% CI Low	Mixed Leks 90% CI High
4 - SGPR	39,825	1.11	0.18	2.381	441	0.61	92	967

Table 9. Mean group size for LEPC leks, LEPC non-leks, and mixed GRPC-LEPC leks. Confidence intervals were based on bootstrap re-sampling methods.

Habitat Region	Mean LEPC Lek Group Size	90% CI Low	90% CI High	Mean LEPC Non-Lek Group Size	90% CI Low	90% CI High	Mean Mixed Lek Group Size
1 - SOPR	5.83	3.60	7.88	2.00	1.22	2.83	NA
2 - SSPR	9.00	0.00	9.00	3.00	0.00	3.00	NA
3 - MGPR	8.56	5.50	11.17	2.25	1.00	3.00	NA
4 - SGPR	7.20	4.80	11.25	3.57	1.22	2.83	9.20
Stratum 1¯	7.36	5.76	9.34	3.35	2.81	3.90	NA

We estimated densities and abundances of LEPC in Stratum 1¯ (Tables 10 and 11). Estimated abundance of LEPC in Regions 1 and 3 of Stratum T were computed based on results in Timmer (2012a) (Table 12). Totals for the original study area (Stratum 1) were obtained by summing values in Tables 10 and 11 (Table 13). No LEPC were detected in Stratum O in Oklahoma.

We estimated total abundance of 37,170 LEPC (90% CI: 23,632 – 50,704) (Table 13) in the study area, Stratum 1. In addition, we estimated an additional 309 (90% CI: 191 - 456) hybrid LEPC-GRPC individuals in Region 4 - SGPR (Table 14).

Table 10. Estimated density of LEPC in Stratum 1¯. Density of LEPC was estimated using region-specific mean lek size, region-specific mean non-lek size and mixed lek estimated species composition. Estimates adjusted for probability of detection were a combination of LEPC from leks and non-leks adjusted by $\hat{P}_{lek} = 0.296$ and $\hat{P}_{non-lek} = 0.271$, respectively. Confidence intervals were computed using bootstrap re-sampling methods.

Habitat Region	Blocks in Survey	LEPC Detected	LEPC / 100 km^2 Estimate Unadjusted	LEPC / 100 km^2 Estimate Adjusted	LEPC / 100 km^2 90% CI Low	LEPC / 100 km^2 90% CI High
1 – SOPR	75	51	3.78	13.16	2.77	16.31
2 – SSPR	24	12	2.78	9.62	0.81*	23.49
3 – MGPR	72	86	6.64	22.71	9.47	40.45
4 – SGPR	85	260**	17.01	59.58	37.86	87.01
Total	256	409	8.88	31.87	22.11	44.11

*The lower limit of the 90% bootstrapped confidence interval was 0.00, an impossible value, computed because only one LEPC lek was detected in Region 2. The known minimum value for density of LEPC in Region 2 was 0.81 LEPC/100 km^2 based on ground surveys conducted by State wildlife biologists (Pitman 2012, Smith 2012).

**LEPC detected in Region 4 (SGPR) was an estimated total based on the estimated proportion of LEPC in sampled blocks.

Table 11. Estimated abundance of LEPC in Stratum 1¯. Abundance of LEPC was estimated using estimated adjusted densities in Table 10 and areas of Regions in Stratum 1¯. Coefficients of variation and confidence intervals were computed using bootstrap re-sampling methods.

Habitat Region	Area of Blocks in Stratum 1¯ (km^2)	LEPC Estimate	LEPC Total CV	LEPC Total 90% CI Low	LEPC Total 90% CI High
1 - SOPR	25,425	3,346	0.40	1,438	5,734
2 - SSPR	13,500	1,299	0.77	110*	3,172
3 - MGPR	35,775	8,125	0.41	3,388	14,470
4 - SGPR	39,825	23,728	0.25	15,076	34,651
Total	114,525	36,498	0.21	25,318	50,514

*The lower limit of the 90% bootstrapped confidence interval was 0.00, an impossible value, computed because only one LEPC lek was detected in Region 2. The known minimum value for abundance in Region 2 was 110 LEPC based on ground surveys conducted by State wildlife biologists (Pitman 2012, Smith 2012).

Table 12. Estimates of abundance of LEPC in Stratum T and confidence intervals based on statistics provided in Timmer (2012a).

Habitat Region	Area of Stratum T (km^2)	LEPC Estimate	LEPC 90% CI Low	LEPC 90% CI High
1 - SOPR	2,250	353	178	709
3 - MGPR	2,025	318	160	638
Total	4,275	671	338	1347

Table 13. Estimates of total abundance of LEPC in the study area, Stratum 1. Coefficients of variation and 90% confidence intervals were computed as an approximation combining statistics from Stratum 1¯ and Stratum T (Tables 10 and 11)

Habitat Region	Area of Blocks in Stratum 1 (km^2)	LEPC Estimate	LEPC Total CV	LEPC 90% CI Low	LEPC 90% CI High
1 - SOPR	27,675	3,699	0.40	1,254	6,144
2 - SSPR	13,500	1,299	0.77	110*	3,172
3 - MGPR	39,600	8,444	0.42	2,637	14,250
4 - SGPR	39,825	23,728	0.25	15,076	34,651
Total	120,600	37,170	0.22	23,632	50,704

*The lower limit of the 90% bootstrapped confidence interval was 0.00, an impossible value, computed because only one LEPC lek was detected in Region 2. The known minimum value for abundance in Region 2 was 110 LEPC based on ground surveys conducted by State wildlife biologists (Pitman 2012, Smith 2012).

Table 14. Estimates of density and total abundance of Hybrid LEPC-GRPC (HPC) in Region 4 (SGPR).

Habitat Region	Area of Blocks in Region 4 km^2	HPC/ 100 km^2 Est.	HPC/ 100 km^2 90% CI Low	HPC/ 100 km^2 90% CI High	HPC Est.	HPC Total CV	LEPC 90% CI Low	LEPC 90% CI High
4 - SG/CRP	39,825	1.12	0.48	1.14	309*	0.18	191	456

*Bootstrapped estimate of the mean was reported because the bootstrapped sampling distribution was skewed toward high values.

DISCUSSION AND RECOMMENDATIONS

We modeled probability of detection of double observers on the left side of the helicopter in the field of view of the left rear observer, i.e., in the interval [6.9 m, 300 m]. The estimated probability of detection at 6.9 m from the transect line by at least one of the two observers was

0.89. Using the fitted negative exponential model for leks and non-leks (Figure 6), the estimated probabilities of detection of leks and non-leks at 6.9 m were 0.928 and 0.922 respectively, values that agree well with the estimate based on the double observers.

The left front observer was instructed to “guard the transect line”, particularly in the 13.8 m area under the helicopter that was not visible by the rear seat observers. This attention to the area under the helicopter resulted in reduced probability of detection of prairie-chickens by the front seat observer in the interval [6.9 m, 300 m] (Table 3). Although the pilots were not official observers, they were instructed to announce any prairie-chickens missed by the WEST observers. There were no occasions when the pilots detected prairie-chickens under the helicopter that were missed by the left front observer. In fact, there was only one lek detected by a pilot that was missed by the observers and it was greater than 100 m from the transect line. In more controlled experimental surveys of lesser prairie-chickens in Texas using a R-44 helicopter, McRoberts et al. (2011b) were comfortable with the assumption that they had 100% probability of detection on the transect line. We believe that the probability of detection of prairie-chickens on the transect lines was close to 100% in our surveys. However, we admit the possibility of not detecting all prairie-chicken groups on the transect line, particularly for non-lekking birds in small groups. Thirty-two percent of detections of non-leks were groups that did not flush and birds that do not flush were difficult to detect, particularly if they were in heavy cover. If the probability of detection on the transect lines was less than 100% then the resulting estimates of abundance of LEPC and LEPC leks should be conservative underestimates of the population parameters in the study area.

Our conclusions were that estimates of totals for the study area were conservative underestimates and precision of estimates were in a useful range. These estimates were: 3,174 lesser prairie-chicken leks (90% CI: 1,672 - 4,705), 441 mixed lesser and greater prairie-chicken leks (90% CI: 92-967), 37,170 individual lesser prairie-chickens (90% CI: 23,632 – 50,704), and 309 hybrid lesser-greater prairie-chickens (90% CI: 191 – 456) in the study area during Spring 2012.

Point estimates of total abundance of LEPC and LEPC leks for the study area (Stratum 1) had coefficients of variation of 22% and 29%, respectively. In our experience, point estimates with coefficients of variation in this range of precision are useful to management agencies. However, point estimates of abundance of LEPC and LEPC leks in some of the sub-regions had coefficients of variation in the range of 40% to 99% resulting in confidence intervals which were relatively wide. The exception was Region 4 (SGPR) in northwest Kansas and eastern Colorado where the coefficient of variation on the abundance of LEPC was 25%. Originally, we were planning to provide point estimates of abundance of LEPC and LEPC leks for each state, however we do not feel comfortable in breaking the data into smaller pools than the four habitat regions considered in this report.

Models for the probability of detection that included habitat type had AIC_c values that were close to the AIC_c of the negative exponential model; however there were few detections of leks or non-leks for some of the habitat types. Accuracy and precision of estimates based on models with covariates such as habitat type were questionable. If the survey platform and standard operating procedure remain the same in future surveys with experienced observers then detections of leks and non-leks can be pooled among years to better model the probability of detection as a function of covariates such as habitat type. Improved estimates of probability detection would be used to update estimates from 2012 and provide estimates in future surveys with smaller coefficients of variation.

Recommendations for Future Surveys

We recommend continued use of the R-44 helicopter, or equivalent seating arrangement for observers, in future surveys. We judge that data from double observers on the left side of the platform provide valuable information to help evaluate the validity of the assumption that probability of detection was 100% on the transect lines. For safety reasons, we prefer that the pilots do not have responsibility for detection of prairie-chicken groups.

The 2012 aerial survey was designed to estimate LEPC and LEPC lek densities and abundance. Little evidence was obtained for distribution of LEPC outside of or on the edge of Stratum 1, our extension of the 2011 estimated occupied range. In so far as we were aware, ground and aerial monitoring outside Stratum 1 by the five State wildlife agencies did not locate LEPC. For these reasons, we recommend that surveys for the study of trends in population size in the immediate future be conducted only in Stratum 1. Further research and information is needed to improve the outer boundary and size of Stratum 2 before extending the survey beyond Stratum 1. For example, we understand that improvements are being made in the Western Governor's Association's Southern Great Plains Crucial Habitat Assessment Tool which may guide efficient and economical survey effort in a new definition for Stratum 2.

Two hundred and fifty-six blocks (sample size = 256 out of 536 in Stratum 1) together with the 27 blocks surveyed by Texas Tech University and Oklahoma Department of Wildlife Conservation was about the correct total sampling effort for estimation of total abundance parameters in the study area, assuming two transects were flown in each block. Coefficients of variation in the neighborhood of 22% and 29%, for annual estimates of total LEPC and LEPC leks should be useful for making management decisions concern size and trends of the overall LEPC population in future surveys. Our professional judgment is that the coefficients of variation cannot be decreased much below these values without a substantial increase in survey effort, for example, by flying two transects in all 536 blocks or three transects in each of 256 blocks.

We recognize two basic alternatives for study design and selection of blocks in future sample surveys. There are advantages and disadvantages of each. First, we assume it is critical to obtain information on LEPC population trends as quickly as possible for the study area and for each of the four habitat regions. Under this assumption we recommend the same study design and sample blocks as in 2012 with the addition of sample blocks in habitat regions with high coefficients of variation (alternative 1). Precision for total abundance of LEPC was in an acceptable range for the study area in 2012 as was the precision in Region 4) SGPR, i.e., 22 % and 25% respectively. Coefficients of variation were about equal for regions 1) SOPR and 3) MGPR, i.e., 40% and 42% respectively. Region 2) SSPR was the outlier with relatively low estimated abundance and consequently, a relatively high CV = 77%. In alternative 1, we recommend maintaining about the same sampling effort in Regions: 1) SOPR and 3) MGPR as in 2012, including the sampling effort provided by Texas Tech University and Oklahoma Department of Wildlife Conservation in Regions1 and 3. However, the sample blocks should be selected by the GRTS sampling procedure without regard to state boundaries. Some additional survey effort should be expended in Region 2) SSPR, either by increasing the overall sampling effort or shifting some of the effort in Region 4) SGPR to Region 2. Under alternative 1, the same blocks and transects within blocks would be surveyed in 2013 as in 2012 – to the extent possible. In 2014 or future surveys, the same blocks and transects would be surveyed as in 2013 - to the extent possible. Future studies and sampling effort would be shifted from region to region under a stratified design with equal probability sampling in each stratum.

The Alternative 2 study design is a rotating panel design in future surveys with the same transects being flown each year. For example, in 2012 we surveyed approximately 280 blocks including the blocks surveyed by Texas Tech University and Oklahoma Department of Wildlife Conservation. Define the first 140 blocks to be Panel 1 which would be supplemented by Panel 2, the next 140 blocks in the GRTS list: GRTS numbers 141 – 280. For future surveys, panel 1 might be retained for the survey in 2013 and supplemented with Panel 3 containing 140 new blocks: GRTS numbers 281 to 420. For the third survey, Panel 1 might be retained and supplemented with Panel 4: GRTS numbers 421 – 540. In such a design, Panel 1 would be repeated each year with the same transects surveyed to help provide information on trends in the population of lesser prairie-chickens. In three years, survey effort would have been conducted in every block to improve information on distribution of LEPC. Starting with the fourth survey, Panels 1 and 2 could be surveyed with Panel 2 contributing to more precise information on trends in population size. Surveying exactly the same transects when blocks are re-surveyed should allow earlier detection of important trends in the abundance of leks and population size than is the case if new transects are selected.

Advantages of the first design are the simplicity of a stratified design with direct comparison of LEPC and lek counts on the same units and more freedom to shift sampling effort from region to region without complicating the analysis excessively. The disadvantage is that there is less information on distribution and range of LEPC. The benefit of the rotating panel design is that it helps provide better long term information on distribution and range. But, the disadvantage is the expense of more complex design and analysis and less power to quickly determine trends in population parameters.

Considering the issues, our professional judgment is that the first alternative is best, a stratified design with equal probability sampling within strata (the four habitat regions) and survey of the same blocks and transects each year - to the extent possible. If Texas Tech University and Oklahoma Department of Wildlife Conservation participate in future surveys, we recommend that the R-44 helicopter be used with three observers and that the standard operation procedures in McDonald et al. (2011) be followed.

ACKNOWLEDGEMENTS

The recommended study design and methods were developed with the assistance of the following members of the Lesser Prairie-chicken Interstate Working Group: Bill Van Pelt, WAFWA Grassland Coordinator, Arizona Game and Fish Department; Jim Pitman, Kansas Department of Wildlife, Parks and Tourism; Sean Kyle, Texas Parks and Wildlife Department, David Klute, Colorado Division of Parks and Wildlife; Grant Beauprez, New Mexico Department of Game and Fish; and Doug Schoeling, Oklahoma Department of Wildlife

Conservation. Valuable assistance was also received from Michael Houts, GIS/Remote Sensing Specialist, Kansas Biological Survey. We also wish to acknowledge the assistance of the aerial survey crew members and pilots.

This work was accomplished by the financial support of the Great Plains Landscape Conservation Cooperative through a grant to the Western Association of Fish and Wildlife Agencies.

REFERENCES CITED

Buckland, S. T., D.R. Anderson, K.P. Burnham, J.L. Laake, D.L. Borchers, and L. Thomas. 2001. *Introduction to Distance Sampling*, Oxford: Oxford University Press.

Burnham, K. P., and D. R. Anderson. 2002. *Model selection and multimodel inference: a practical information-theoretic approach*. Second edition. Springer, New York, New York, USA.

Casella, G., and Berger, R. L. 2002. *Statistical inference*. Duxbury Press.

Cressie, Noel 2012. *Statistics for spatio-temporal data*. Hoboken, N.J.: Wiley.

Manly, B. J. F. 2006. *Randomization, Bootstrap and Monte Carlo Methods in Biology*, Third Edition, London: Chapman and Hall.

Manly, B. F. J., L. L. McDonald, and G. W. Garner. 1996. Maximum likelihood estimation for the double-count method with independent observers. *Journal of Agricultural, Biological, and Environmental Statistics* 1:170-189.

McCullagh, P., and Nelder, J. A. 1989. *Generalized Linear Models*. Second Edition, Chapman & Hall.

McDonald, L. L., G. W. Garner, and D. G. Robertson. 1999. Comparison of aerial survey procedures for estimating polar bear density: results of pilot studies in northern Alaska. Pages 37–51 *in* G. W. Garner, S. C. Amstrup, J. L. Laake, B. F. J. Manly, L. L. McDonald, and D. G. Robertson, editors. *Marine Mammal Survey and Assessment Methods: proceedings of the Symposium on Surveys, Status & Trends of Marine Mammal Populations*, Seattle, Washington, USA, 25-27 February 1998. CRC Press/Balkema, Rotterdam, The Netherlands.

McDonald, L.L., J. Griswold, T. Rintz. 2011. Range-wide Population Estimation and Monitoring for Lesser Prairie-chickens: Sampling Design and Pilot Implementation. Technical report prepared for the Western Association of Fish and Wildlife Agencies, c/o Bill Van Pelt, WAFWA Grassland Coordinator, Arizona Game and Fish Department, 5000 W. Carefree Highway, Phoenix, Arizona 85086.

McRoberts, J.T., M.J. Butler, W.B. Ballard, M.C. Wallace, H.A. Whitlaw, and D.A. Haukos. 2011a. Response of lesser prairie-chickens on leks to aerial Surveys. *Wildlife Society Bulletin* 35: 27-31.

McRoberts, J.T., M.J. Butler, W.B. Ballard, H.A. Whitlaw, D.A. Haukos, and M.C. Wallace. 2011b. Detectability of Lesser Prairie-chicken Leks: A Comparison of Surveys From Aircraft. *The Journal of Wildlife Management* 75:771–778.

Pitman, J. 2012. Prairie-chicken lek survey – 2012. Performance report, Statewide wildlife research and surveys. Kansas Department of Wildlife, Parks, & Tourism.

R Development Core Team. 2011. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria.

Seber, G. A. F. 1982. *The estimation of animal abundance and related parameters*. Second Edition. MacMillan, New York, New York, USA.

Smith, M. 2012. Colorado lesser prairie-chicken breeding survey 2012. Colorado Division of Parks and Wildlife, Colorado Department of Natural Resources.

Stevens, D. L., Jr., and Olsen, A. R. 2004. Spatially Balanced Sampling of Natural Resources. *Journal of the American Statistical Association*, 99, 262-278.

Thomas, L., R. Williams, S. T. Buckland, E. A. Rexstad, J. L. Laake, S. Strindberg, S. L. Hedley, J. R. B. Bishop, T. A. Marques, K. P. Burnham. 2010. Distance software: design and analysis of distance sampling surveys for estimating population size. *J Appl Ecol* 47(1):5-14.

Timmer, J.M. 2012a. Texas Tech University 2012 aerial lek surveys. Technical report to the Texas Parks and Wildlife Department, Lubbock, Texas.

Timmer, J.M. 2012b. Relationship of lesser-prairie chicken density to landscape characteristics in Texas. M.S. Thesis, Wildlife Science, Texas Tech University, Lubbock, Texas.

APPENDIX A.

Start and stop waypoints of transects surveyed in 256 blocks in Stratum 1¯, 2012. Block numbers are the original ranking from the GRTS sample list (McDonald et al. 2011).

Block Number	Transect East/West	State	Start North Longitude	Start North Latitude	End South Longitude	End South Latitude
1	West	KS	-101.988	39.974	-101.977	39.840
1	East	KS	-101.900	39.978	-101.889	39.844
2	West	KS	-99.229	37.664	-99.223	37.531
2	East	KS	-99.143	37.667	-99.138	37.533
3	West	OK	-100.566	36.818	-100.558	36.684
3	East	OK	-100.481	36.821	-100.473	36.687
4	West	TX	-102.758	33.219	-102.746	33.085
4	East	TX	-102.677	33.224	-102.665	33.090
5	West	KS	-99.623	39.394	-99.617	39.261
5	East	KS	-99.536	39.397	-99.529	39.263
6	West	KS	-101.220	37.193	-101.211	37.059
6	East	KS	-101.135	37.197	-101.126	37.063
7	West	TX	-100.314	36.157	-100.306	36.023
7	East	TX	-100.230	36.160	-100.222	36.026
8	West	NM	-103.514	34.519	-103.501	34.385
8	East	NM	-103.432	34.524	-103.419	34.390
9	West	KS	-100.325	39.640	-100.317	39.506
9	East	KS	-100.237	39.643	-100.229	39.509
10	West	KS	-99.804	38.853	-99.797	38.719
10	East	KS	-99.717	38.856	-99.710	38.722
11	West	KS	-98.685	37.410	-98.680	37.276
11	East	KS	-98.599	37.412	-98.594	37.278
12	West	CO	-102.514	38.338	-102.502	38.204
12	East	CO	-102.427	38.342	-102.416	38.209
13	West	KS	-100.300	38.837	-100.292	38.703
13	East	KS	-100.213	38.840	-100.205	38.706
14	West	OK	-99.498	36.585	-99.491	36.451
14	East	OK	-99.413	36.588	-99.407	36.454
15	West	TX	-102.365	32.568	-102.354	32.434
15	East	TX	-102.285	32.573	-102.274	32.438
16	West	KS	-101.997	37.694	-101.986	37.560
16	East	KS	-101.911	37.698	-101.900	37.564
17	West	KS	-99.857	39.655	-99.850	39.522
17	East	KS	-99.769	39.658	-99.762	39.524
18	West	KS	-99.524	37.254	-99.517	37.121
18	East	KS	-99.438	37.257	-99.432	37.123
19	West	TX	-100.511	36.417	-100.503	36.284
19	East	TX	-100.427	36.421	-100.419	36.287

Block Number	Transect East/West	State	Start North Longitude	Start North Latitude	End South Longitude	End South Latitude
20	West	TX	-102.929	34.824	-102.917	34.690
20	East	TX	-102.846	34.829	-102.834	34.695
21	West	KS	-101.576	39.590	-101.566	39.457
21	East	KS	-101.488	39.594	-101.478	39.461
22	West	KS	-99.562	38.459	-99.555	38.325
22	East	KS	-99.475	38.461	-99.469	38.327
23	West	OK	-99.469	35.916	-99.463	35.782
23	East	OK	-99.385	35.918	-99.379	35.785
24	West	NM	-103.917	33.280	-103.904	33.146
24	East	NM	-103.837	33.285	-103.823	33.151
25	West	KS	-101.215	38.936	-101.205	38.802
25	East	KS	-101.127	38.939	-101.118	38.806
26	West	KS	-100.099	38.710	-100.091	38.576
26	East	KS	-100.012	38.713	-100.004	38.579
27	West	KS	-98.189	37.955	-98.185	37.821
27	East	KS	-98.103	37.957	-98.099	37.823
28	West	CO	-102.934	38.583	-102.921	38.450
28	East	CO	-102.847	38.588	-102.835	38.454
29	West	KS	-99.931	38.046	-99.924	37.912
29	East	KS	-99.845	38.048	-99.838	37.915
30	West	OK	-99.040	36.866	-99.035	36.732
30	East	OK	-98.955	36.868	-98.950	36.734
31	West	NM	-103.647	33.702	-103.634	33.568
31	East	NM	-103.565	33.708	-103.552	33.574
32	West	CO	-102.300	37.142	-102.289	37.008
32	East	CO	-102.215	37.146	-102.204	37.013
33	West	KS	-99.812	39.255	-99.805	39.121
33	East	KS	-99.724	39.257	-99.717	39.124
34	West	KS	-100.199	37.367	-100.192	37.233
34	East	KS	-100.114	37.370	-100.107	37.236
35	West	OK	-101.024	36.799	-101.015	36.666
35	East	OK	-100.939	36.803	-100.930	36.669
36	West	TX	-102.859	34.156	-102.847	34.022
36	East	TX	-102.777	34.160	-102.765	34.026
37	West	KS	-101.295	39.871	-101.285	39.737
37	East	KS	-101.206	39.874	-101.197	39.741
38	West	KS	-100.129	38.307	-100.122	38.173
38	East	KS	-100.043	38.310	-100.036	38.176

Block Number	Transect East/West	State	Start North Longitude	Start North Latitude	End South Longitude	End South Latitude
39	West	OK	-99.827	36.173	-99.820	36.039
39	East	OK	-99.743	36.176	-99.736	36.042
40	West	NM	-104.140	33.803	-104.126	33.669
40	East	NM	-104.059	33.809	-104.045	33.675
41	West	KS	-100.301	38.301	-100.294	38.167
41	East	KS	-100.215	38.304	-100.207	38.170
42	West	OK	-99.866	36.440	-99.859	36.306
42	East	OK	-99.782	36.443	-99.775	36.309
43	West	NM	-103.832	32.611	-103.819	32.477
43	East	NM	-103.752	32.617	-103.739	32.483
44	West	KS	-101.683	38.513	-101.672	38.379
44	East	KS	-101.596	38.517	-101.586	38.383
45	West	KS	-99.068	37.936	-99.062	37.803
45	East	KS	-98.981	37.938	-98.976	37.805
46	West	OK	-99.345	36.724	-99.339	36.590
46	East	OK	-99.260	36.726	-99.254	36.592
47	West	NM	-103.665	33.836	-103.652	33.702
47	East	NM	-103.584	33.841	-103.571	33.707
48	West	KS	-101.760	37.169	-101.750	37.035
48	East	KS	-101.675	37.173	-101.665	37.039
49	West	KS	-99.861	39.789	-99.853	39.655
49	East	KS	-99.772	39.792	-99.765	39.658
50	West	KS	-101.517	37.984	-101.507	37.851
50	East	KS	-101.431	37.988	-101.421	37.855
51	West	TX	-100.487	35.480	-100.479	35.346
51	East	TX	-100.404	35.483	-100.396	35.349
52	West	NM	-103.621	33.973	-103.608	33.839
52	East	NM	-103.540	33.979	-103.527	33.845
53	West	KS	-100.772	40.026	-100.763	39.892
53	East	KS	-100.684	40.029	-100.675	39.895
54	West	KS	-99.608	38.859	-99.602	38.725
54	East	KS	-99.521	38.862	-99.515	38.728
55	West	KS	-98.392	37.951	-98.387	37.818
55	East	KS	-98.305	37.953	-98.301	37.819
56	West	NM	-104.053	34.348	-104.039	34.214
56	East	NM	-103.971	34.354	-103.957	34.220
57	West	KS	-101.188	38.401	-101.179	38.267
57	East	KS	-101.101	38.404	-101.092	38.271

Block Number	Transect East/West	State	Start North Longitude	Start North Latitude	End South Longitude	End South Latitude
58	West	OK	-100.056	36.702	-100.049	36.568
58	East	OK	-99.971	36.705	-99.964	36.571
59	West	TX	-102.574	32.826	-102.563	32.692
59	East	TX	-102.494	32.830	-102.483	32.696
60	West	KS	-101.656	37.978	-101.646	37.844
60	East	KS	-101.570	37.982	-101.560	37.848
61	West	KS	-99.885	37.243	-99.878	37.110
61	East	KS	-99.799	37.246	-99.793	37.112
62	West	OK	-100.356	36.825	-100.349	36.692
62	East	OK	-100.272	36.828	-100.264	36.695
63	West	TX	-102.796	33.755	-102.785	33.622
63	East	TX	-102.715	33.760	-102.704	33.626
64	West	OK	-101.570	37.043	-101.560	36.910
64	East	OK	-101.485	37.047	-101.476	36.914
65	West	KS	-101.995	39.839	-101.984	39.706
65	East	KS	-101.907	39.843	-101.896	39.710
66	West	KS	-99.042	37.669	-99.037	37.535
66	East	KS	-98.957	37.671	-98.951	37.538
67	West	TX	-100.387	36.556	-100.379	36.422
67	East	TX	-100.302	36.559	-100.295	36.425
68	West	TX	-102.642	33.495	-102.631	33.361
68	East	TX	-102.561	33.500	-102.550	33.366
69	West	KS	-99.617	39.261	-99.610	39.127
69	East	KS	-99.529	39.263	-99.523	39.129
70	West	KS	-101.248	37.460	-101.238	37.326
70	East	KS	-101.162	37.464	-101.153	37.330
71	West	TX	-100.148	36.162	-100.141	36.029
71	East	TX	-100.064	36.165	-100.057	36.032
72	West	NM	-103.727	34.639	-103.713	34.506
72	East	NM	-103.645	34.645	-103.631	34.511
73	West	KS	-100.927	39.618	-100.918	39.484
73	East	KS	-100.839	39.621	-100.830	39.487
74	West	KS	-100.184	39.109	-100.177	38.975
74	East	KS	-100.097	39.112	-100.089	38.978
75	West	KS	-98.899	37.271	-98.893	37.137
75	East	KS	-98.813	37.273	-98.808	37.139
76	West	KS	-102.055	39.032	-102.044	38.898
76	East	KS	-101.968	39.036	-101.957	38.902

Block Number	Transect East/West	State	Start North Longitude	Start North Latitude	End South Longitude	End South Latitude
77	West	KS	-100.460	38.965	-100.452	38.832
77	East	KS	-100.373	38.968	-100.365	38.835
78	West	OK	-99.020	36.598	-99.014	36.464
78	East	OK	-98.935	36.600	-98.930	36.467
79	West	TX	-102.534	34.174	-102.523	34.040
79	East	TX	-102.453	34.179	-102.441	34.045
80	West	KS	-101.991	38.096	-101.980	37.963
80	East	KS	-101.905	38.100	-101.894	37.967
81	West	KS	-99.982	39.651	-99.975	39.518
81	East	KS	-99.894	39.654	-99.887	39.520
82	West	KS	-99.356	37.259	-99.350	37.125
82	East	KS	-99.271	37.261	-99.265	37.128
83	West	TX	-100.671	36.277	-100.662	36.143
83	East	TX	-100.586	36.280	-100.578	36.147
84	West	TX	-102.695	34.165	-102.684	34.031
84	East	TX	-102.614	34.170	-102.602	34.036
85	West	KS	-101.412	39.732	-101.402	39.598
85	East	KS	-101.324	39.735	-101.314	39.602
86	West	KS	-100.098	38.576	-100.090	38.442
86	East	KS	-100.011	38.579	-100.004	38.445
87	West	OK	-99.816	35.771	-99.809	35.637
87	East	OK	-99.732	35.774	-99.725	35.640
88	West	NM	-103.734	33.427	-103.721	33.293
88	East	NM	-103.653	33.432	-103.640	33.298
89	West	KS	-101.365	38.929	-101.355	38.796
89	East	KS	-101.278	38.933	-101.268	38.800
90	West	OK	-99.819	36.307	-99.812	36.174
90	East	OK	-99.735	36.310	-99.728	36.176
91	West	KS	-98.004	38.360	-98.001	38.226
91	East	KS	-97.918	38.361	-97.914	38.228
92	West	CO	-102.716	38.729	-102.703	38.596
92	East	CO	-102.629	38.734	-102.617	38.601
93	West	KS	-99.719	38.052	-99.712	37.918
93	East	KS	-99.632	38.055	-99.626	37.921
94	West	OK	-99.169	36.862	-99.163	36.729
94	East	OK	-99.084	36.865	-99.078	36.731
95	West	NM	-103.633	33.568	-103.620	33.434
95	East	NM	-103.552	33.574	-103.539	33.440

Block Number	Transect East/West	State	Start North Longitude	Start North Latitude	End South Longitude	End South Latitude
96	West	CO	-102.598	37.126	-102.586	36.992
96	East	CO	-102.513	37.130	-102.502	36.997
97	West	KS	-100.189	39.243	-100.181	39.109
97	East	KS	-100.101	39.246	-100.094	39.112
98	West	KS	-100.392	37.226	-100.384	37.092
98	East	KS	-100.307	37.229	-100.299	37.095
99	West	TX	-100.826	35.466	-100.818	35.332
99	East	TX	-100.743	35.470	-100.735	35.336
100	West	NM	-103.384	34.258	-103.372	34.124
100	East	NM	-103.303	34.263	-103.290	34.129
101	West	KS	-100.393	39.772	-100.385	39.638
101	East	KS	-100.304	39.775	-100.296	39.641
102	West	KS	-99.287	38.734	-99.281	38.600
102	East	KS	-99.200	38.736	-99.194	38.603
103	West	OK	-99.651	36.045	-99.644	35.911
103	East	OK	-99.567	36.047	-99.560	35.913
104	West	NM	-103.952	33.681	-103.939	33.548
104	East	NM	-103.871	33.687	-103.858	33.553
105	West	KS	-100.292	38.435	-100.284	38.302
105	East	KS	-100.206	38.438	-100.198	38.305
106	West	OK	-99.878	36.574	-99.872	36.440
106	East	OK	-99.794	36.576	-99.787	36.443
107	West	NM	-103.700	32.485	-103.687	32.351
107	East	NM	-103.620	32.491	-103.607	32.356
108	West	CO	-102.388	38.076	-102.376	37.943
108	East	CO	-102.302	38.081	-102.290	37.947
109	West	KS	-99.034	37.803	-99.029	37.670
109	East	KS	-98.948	37.805	-98.943	37.672
110	West	OK	-99.547	36.852	-99.541	36.718
110	East	OK	-99.462	36.854	-99.456	36.720
111	West	NM	-103.308	33.455	-103.296	33.321
111	East	NM	-103.227	33.460	-103.215	33.326
112	West	CO	-103.079	38.843	-103.067	38.710
112	East	CO	-102.992	38.848	-102.980	38.715
113	West	KS	-99.656	39.929	-99.649	39.795
113	East	KS	-99.567	39.932	-99.561	39.798
114	West	KS	-101.116	37.868	-101.107	37.734
114	East	KS	-101.030	37.871	-101.021	37.738

Block Number	Transect East/West	State	Start North Longitude	Start North Latitude	End South Longitude	End South Latitude
115	West	TX	-100.348	35.753	-100.340	35.619
115	East	TX	-100.264	35.756	-100.257	35.622
116	West	NM	-103.149	34.138	-103.137	34.004
116	East	NM	-103.067	34.143	-103.055	34.009
117	West	KS	-100.934	39.886	-100.924	39.752
117	East	KS	-100.845	39.889	-100.836	39.755
118	West	KS	-99.461	38.729	-99.455	38.596
118	East	KS	-99.374	38.732	-99.368	38.598
119	West	KS	-98.349	37.818	-98.345	37.685
119	East	KS	-98.264	37.820	-98.259	37.686
120	West	NM	-104.176	33.935	-104.161	33.802
120	East	NM	-104.094	33.941	-104.080	33.807
121	West	KS	-100.660	38.958	-100.652	38.824
121	East	KS	-100.573	38.961	-100.565	38.827
122	West	OK	-99.822	36.709	-99.815	36.576
122	East	OK	-99.737	36.712	-99.730	36.578
123	West	NM	-103.520	32.632	-103.508	32.498
123	East	NM	-103.440	32.637	-103.428	32.503
124	West	KS	-101.625	38.114	-101.615	37.980
124	East	KS	-101.539	38.117	-101.529	37.984
125	West	KS	-99.730	37.248	-99.723	37.114
125	East	KS	-99.645	37.251	-99.638	37.117
126	West	OK	-100.160	36.698	-100.152	36.564
126	East	OK	-100.075	36.701	-100.068	36.567
127	West	TX	-102.969	33.745	-102.957	33.611
127	East	TX	-102.888	33.750	-102.876	33.616
128	West	OK	-102.089	37.018	-102.078	36.885
128	East	OK	-102.004	37.023	-101.993	36.889
129	West	KS	-101.813	39.848	-101.802	39.714
129	East	KS	-101.725	39.852	-101.714	39.718
130	West	KS	-98.997	37.269	-98.991	37.135
130	East	KS	-98.912	37.271	-98.906	37.137
131	West	TX	-100.202	36.429	-100.194	36.295
131	East	TX	-100.118	36.432	-100.110	36.298
132	West	TX	-102.744	34.969	-102.732	34.835
132	East	TX	-102.661	34.974	-102.649	34.840
133	West	KS	-99.642	39.528	-99.635	39.394
133	East	KS	-99.554	39.530	-99.547	39.397

Block Number	Transect East/West	State	Start North Longitude	Start North Latitude	End South Longitude	End South Latitude
134	West	KS	-99.416	38.597	-99.409	38.463
134	East	KS	-99.329	38.599	-99.323	38.465
135	West	TX	-100.483	35.882	-100.475	35.748
135	East	TX	-100.400	35.885	-100.392	35.751
136	West	NM	-103.402	34.526	-103.389	34.392
136	East	NM	-103.320	34.531	-103.307	34.397
137	West	KS	-100.716	39.224	-100.707	39.090
137	East	KS	-100.628	39.227	-100.619	39.093
138	West	KS	-99.787	39.122	-99.780	38.988
138	East	KS	-99.700	39.124	-99.693	38.990
139	West	KS	-98.171	37.554	-98.167	37.420
139	East	KS	-98.085	37.555	-98.081	37.422
140	West	KS	-101.733	38.913	-101.723	38.779
140	East	KS	-101.646	38.917	-101.636	38.783
141	West	KS	-100.659	38.824	-100.650	38.690
141	East	KS	-100.572	38.827	-100.563	38.694
142	West	OK	-99.210	36.995	-99.205	36.861
142	East	OK	-99.125	36.997	-99.120	36.864
143	West	TX	-102.421	33.373	-102.410	33.239
143	East	TX	-102.340	33.378	-102.329	33.244
144	West	CO	-102.144	38.089	-102.133	37.955
144	East	CO	-102.058	38.093	-102.047	37.959
145	West	KS	-100.181	39.511	-100.174	39.377
145	East	KS	-100.093	39.514	-100.086	39.380
146	West	KS	-100.246	38.035	-100.238	37.901
146	East	KS	-100.160	38.038	-100.152	37.904
147	West	TX	-100.369	36.289	-100.362	36.155
147	East	TX	-100.285	36.292	-100.278	36.158
148	West	TX	-103.027	34.280	-103.015	34.146
148	East	TX	-102.945	34.285	-102.933	34.151
149	West	KS	-101.067	40.014	-101.057	39.881
149	East	KS	-100.978	40.018	-100.969	39.884
150	West	KS	-99.987	38.446	-99.980	38.312
150	East	KS	-99.901	38.448	-99.893	38.315
151	West	OK	-99.991	36.168	-99.984	36.034
151	East	OK	-99.907	36.171	-99.900	36.037
152	West	NM	-104.095	33.132	-104.081	32.998
152	East	NM	-104.014	33.138	-104.001	33.004

Block Number	Transect East/West	State	Start North Longitude	Start North Latitude	End South Longitude	End South Latitude
153	West	KS	-101.354	39.064	-101.344	38.930
153	East	KS	-101.267	39.068	-101.257	38.934
154	West	OK	-99.996	36.302	-99.989	36.168
154	East	OK	-99.912	36.304	-99.905	36.171
155	West	KS	-98.827	37.139	-98.822	37.005
155	East	KS	-98.742	37.141	-98.737	37.007
156	West	CO	-102.548	38.738	-102.536	38.605
156	East	CO	-102.461	38.743	-102.449	38.609
157	West	KS	-100.082	37.907	-100.075	37.773
157	East	KS	-99.996	37.910	-99.989	37.776
158	West	KS	-99.543	37.120	-99.537	36.986
158	East	KS	-99.458	37.122	-99.452	36.989
159	West	NM	-103.280	33.726	-103.267	33.592
159	East	NM	-103.198	33.731	-103.186	33.597
160	West	KS	-101.913	37.161	-101.902	37.028
160	East	KS	-101.827	37.165	-101.817	37.032
161	West	KS	-100.018	40.052	-100.010	39.918
161	East	KS	-99.929	40.055	-99.922	39.921
162	West	KS	-100.744	37.213	-100.736	37.079
162	East	KS	-100.659	37.216	-100.651	37.082
163	West	TX	-100.129	35.627	-100.122	35.493
163	East	TX	-100.046	35.630	-100.039	35.496
164	West	NM	-103.529	34.249	-103.516	34.115
164	East	NM	-103.447	34.254	-103.435	34.120
165	West	KS	-100.574	39.899	-100.565	39.765
165	East	KS	-100.485	39.902	-100.477	39.769
166	West	KS	-99.274	39.002	-99.268	38.868
166	East	KS	-99.187	39.005	-99.181	38.871
167	West	KS	-98.394	38.085	-98.389	37.951
167	East	KS	-98.307	38.087	-98.303	37.953
168	West	NM	-103.919	33.549	-103.905	33.415
168	East	NM	-103.838	33.555	-103.824	33.421
169	West	KS	-100.631	38.289	-100.622	38.155
169	East	KS	-100.544	38.292	-100.536	38.159
170	West	KS	-99.687	37.116	-99.681	36.982
170	East	KS	-99.602	37.118	-99.596	36.984
171	West	NM	-103.734	32.753	-103.721	32.619
171	East	NM	-103.654	32.758	-103.641	32.624

Block Number	Transect East/West	State	Start North Longitude	Start North Latitude	End South Longitude	End South Latitude
172	West	CO	-102.496	38.070	-102.484	37.937
172	East	CO	-102.409	38.075	-102.398	37.941
173	West	KS	-99.918	37.644	-99.911	37.510
173	East	KS	-99.833	37.647	-99.826	37.513
174	West	KS	-100.699	37.080	-100.690	36.947
174	East	KS	-100.614	37.084	-100.605	36.950
175	West	NM	-103.141	33.465	-103.129	33.331
175	East	NM	-103.060	33.470	-103.048	33.336
176	West	OK	-102.618	36.990	-102.607	36.857
176	East	OK	-102.534	36.995	-102.522	36.862
177	West	KS	-99.268	39.404	-99.262	39.270
177	East	KS	-99.180	39.406	-99.174	39.273
178	West	KS	-101.053	37.334	-101.044	37.201
178	East	KS	-100.968	37.338	-100.959	37.204
179	West	TX	-100.282	35.890	-100.275	35.756
179	East	TX	-100.199	35.893	-100.191	35.759
180	West	NM	-103.217	34.806	-103.205	34.673
180	East	NM	-103.135	34.811	-103.123	34.678
181	West	KS	-100.517	39.231	-100.508	39.097
181	East	KS	-100.429	39.234	-100.421	39.101
182	West	KS	-99.614	39.127	-99.607	38.993
182	East	KS	-99.527	39.129	-99.520	38.996
183	West	KS	-98.513	37.280	-98.508	37.146
183	East	KS	-98.427	37.281	-98.423	37.147
184	West	NM	-104.011	33.947	-103.997	33.813
184	East	NM	-103.929	33.952	-103.916	33.819
185	West	KS	-100.833	39.085	-100.824	38.952
185	East	KS	-100.746	39.089	-100.737	38.955
187	West	NM	-103.346	32.374	-103.334	32.240
187	East	NM	-103.266	32.379	-103.254	32.245
188	West	KS	-101.631	37.845	-101.620	37.712
188	East	KS	-101.545	37.849	-101.535	37.715
189	West	KS	-100.044	37.238	-100.036	37.104
189	East	KS	-99.958	37.241	-99.951	37.107
191	West	TX	-102.812	33.889	-102.801	33.755
191	East	TX	-102.731	33.894	-102.719	33.760
192	West	TX	-102.746	35.103	-102.734	34.970
192	East	TX	-102.663	35.108	-102.651	34.974

Block Number	Transect East/West	State	Start North Longitude	Start North Latitude	End South Longitude	End South Latitude
193	West	KS	-101.890	39.174	-101.880	39.040
193	East	KS	-101.803	39.178	-101.792	39.044
194	West	KS	-99.211	37.263	-99.205	37.129
194	East	KS	-99.126	37.265	-99.120	37.132
196	West	NM	-103.047	34.817	-103.035	34.683
196	East	NM	-102.965	34.822	-102.953	34.688
197	West	KS	-101.574	39.188	-101.564	39.055
197	East	KS	-101.487	39.192	-101.477	39.059
198	West	KS	-99.260	38.601	-99.254	38.467
198	East	KS	-99.173	38.603	-99.167	38.469
200	West	NM	-103.855	33.014	-103.841	32.880
200	East	NM	-103.774	33.020	-103.761	32.886
201	West	KS	-101.556	38.653	-101.545	38.519
201	East	KS	-101.469	38.657	-101.459	38.523
202	West	KS	-99.965	38.982	-99.958	38.848
202	East	KS	-99.878	38.985	-99.870	38.851
203	West	KS	-97.820	38.229	-97.817	38.095
203	East	KS	-97.734	38.230	-97.731	38.096
204	West	KS	-101.869	38.907	-101.858	38.773
204	East	KS	-101.781	38.911	-101.771	38.777
205	West	KS	-99.884	37.913	-99.877	37.779
205	East	KS	-99.798	37.916	-99.791	37.782
206	West	KS	-99.065	37.133	-99.060	36.999
206	East	KS	-98.980	37.135	-98.975	37.001
207	West	TX	-102.425	33.238	-102.414	33.104
207	East	TX	-102.344	33.243	-102.333	33.109
209	West	KS	-100.018	39.248	-100.010	39.115
209	East	KS	-99.930	39.251	-99.923	39.117
210	West	KS	-100.267	38.168	-100.259	38.035
210	East	KS	-100.181	38.171	-100.173	38.038
212	West	TX	-102.998	34.013	-102.986	33.879
212	East	TX	-102.916	34.018	-102.904	33.884
213	West	KS	-101.620	39.991	-101.609	39.857
213	East	KS	-101.531	39.995	-101.521	39.861
214	West	KS	-99.762	38.587	-99.755	38.453
214	East	KS	-99.675	38.589	-99.668	38.456
216	West	NM	-103.943	33.817	-103.929	33.683
216	East	NM	-103.861	33.822	-103.848	33.689

Block Number	Transect East/West	State	Start North Longitude	Start North Latitude	End South Longitude	End South Latitude
217	West	KS	-101.198	38.802	-101.189	38.669
217	East	KS	-101.111	38.806	-101.102	38.672
219	West	KS	-98.354	37.149	-98.350	37.015
219	East	KS	-98.269	37.150	-98.265	37.017
220	West	KS	-102.040	38.228	-102.029	38.094
220	East	KS	-101.943	38.099	-101.943	38.099
221	West	KS	-99.386	37.794	-99.380	37.660
221	East	KS	-99.300	37.796	-99.294	37.663
223	West	NM	-103.288	33.860	-103.275	33.726
223	East	NM	-103.206	33.865	-103.194	33.731
224	West	KS	-101.749	37.303	-101.739	37.170
224	East	KS	-101.664	37.307	-101.654	37.174
225	West	KS	-99.999	39.919	-99.992	39.785
225	east	KS	-99.911	39.922	-99.903	39.788
226	West	KS	-101.255	37.862	-101.246	37.728
226	East	KS	-101.169	37.866	-101.160	37.732
228	West	NM	-103.480	33.982	-103.468	33.849
228	East	NM	-103.399	33.988	-103.386	33.854
229	West	KS	-100.536	40.035	-100.528	39.901
229	East	KS	-100.448	40.038	-100.440	39.904
230	West	KS	-99.091	39.141	-99.085	39.007
230	East	KS	-99.004	39.143	-98.998	39.009
231	West	KS	-98.364	38.220	-98.360	38.086
231	East	KS	-98.278	38.221	-98.273	38.088
232	West	NM	-104.158	34.341	-104.144	34.207
232	East	NM	-104.076	34.346	-104.062	34.213
233	West	KS	-101.542	38.519	-101.532	38.386
233	East	KS	-101.456	38.523	-101.446	38.390
235	West	TX	-102.532	32.559	-102.521	32.424
235	East	TX	-102.452	32.563	-102.441	32.429
237	West	KS	-99.919	37.510	-99.912	37.376
237	East	KS	-99.833	37.513	-99.826	37.379
239	West	NM	-103.564	33.438	-103.551	33.304
239	East	NM	-103.483	33.444	-103.470	33.310
241	West	KS	-99.297	39.269	-99.291	39.136
241	East	KS	-99.210	39.272	-99.204	39.138
242	West	KS	-101.443	37.317	-101.434	37.184
242	East	KS	-101.358	37.321	-101.348	37.188

Block Number	Transect East/West	State	Start North Longitude	Start North Latitude	End South Longitude	End South Latitude
244	West	NM	-103.395	34.795	-103.382	34.662
244	East	NM	-103.313	34.800	-103.300	34.667
245	West	KS	-100.369	39.370	-100.361	39.237
245	East	KS	-100.281	39.373	-100.273	39.240
246	West	KS	-99.464	39.131	-99.458	38.997
246	East	KS	-99.377	39.133	-99.371	39.000
247	West	KS	-98.374	37.282	-98.370	37.149
247	East	KS	-98.288	37.284	-98.284	37.150
248	West	NM	-103.836	33.959	-103.822	33.825
248	East	NM	-103.754	33.964	-103.741	33.831
249	West	KS	-100.524	38.829	-100.516	38.695
249	East	KS	-100.437	38.832	-100.429	38.698
251	West	TX	-102.369	32.703	-102.358	32.568
251	East	TX	-102.289	32.707	-102.278	32.573
253	West	KS	-99.566	37.521	-99.559	37.387
253	East	KS	-99.480	37.524	-99.474	37.390
254	West	KS	-100.245	37.097	-100.237	36.964
254	East	KS	-100.160	37.100	-100.152	36.966
255	West	TX	-102.955	33.342	-102.944	33.208
255	East	TX	-102.874	33.347	-102.863	33.213
256	West	NM	-103.096	35.083	-103.084	34.949
256	East	NM	-103.014	35.088	-103.001	34.954
260	West	NM	-103.542	34.651	-103.529	34.518
260	East	NM	-103.460	34.657	-103.447	34.523
263	West	TX	-102.355	34.184	-102.344	34.050
263	East	TX	-102.273	34.189	-102.263	34.055
268	West	NM	-103.949	33.412	-103.935	33.278
268	East	NM	-103.868	33.418	-103.854	33.284
271	West	NM	-103.452	33.715	-103.440	33.581
271	East	NM	-103.371	33.720	-103.358	33.586
276	West	TX	-102.839	34.022	-102.827	33.888
276	East	TX	-102.758	34.027	-102.746	33.893
279	West	NM	-103.669	32.622	-103.656	32.488
279	East	NM	-103.589	32.628	-103.576	32.494
284	West	NM	-104.035	34.215	-104.021	34.081
284	East	NM	-103.954	34.220	-103.940	34.086
287	West	TX	-102.784	33.622	-102.773	33.488
287	East	TX	-102.703	33.626	-102.692	33.492

Block Number	Transect East/West	State	Start North Longitude	Start North Latitude	End South Longitude	End South Latitude
292	West	NM	-103.427	34.659	-103.414	34.525
292	East	NM	-103.345	34.664	-103.332	34.530
295	West	TX	-102.549	34.308	-102.537	34.174
295	East	TX	-102.467	34.313	-102.455	34.179
300	West	NM	-104.065	33.269	-104.052	33.135
300	East	NM	-103.985	33.275	-103.971	33.141
303	West	NM	-103.098	33.603	-103.086	33.469
303	East	NM	-103.017	33.608	-103.005	33.474
308	West	NM	-103.158	34.272	-103.146	34.138
308	East	NM	-103.077	34.277	-103.064	34.143
311	West	NM	-103.855	32.879	-103.842	32.745
311	East	NM	-103.775	32.885	-103.762	32.751
316	West	NM	-104.186	34.069	-104.172	33.936
316	East	NM	-104.104	34.075	-104.090	33.941
319	West	TX	-103.008	33.877	-102.996	33.744
319	East	TX	-102.926	33.882	-102.915	33.748
324	West	NM	-103.598	34.782	-103.584	34.649
324	East	NM	-103.515	34.788	-103.502	34.654