M E M O R A N D U M

To: Jay D'Ewart, June Wendlandt
CC: Paul Griffin (BLM), Ben Smith, Kimberlee Foster; Gavin Lovell; Robert Price; Bea Wade, John Niell (BLM)
From: Bruce Lubow, IIF Data Solutions
Date: 4 May 2016
RE: Statistical analysis for 2016 horse survey of Rock Springs area horse populations.

I. Summary Table

Survey areas and Dates:	April 4, 2016 Adobe Town HMA April 6, 2016 Salt Wells Creek HMA, Adobe Town HMA April 7, 2016 Salt Wells Creek HMA April 8, 2016 Salt Wells Creek HMA, Adobe Town HMA, Divide Basin HMA April 9, 2016 Divide Basin HMA April 12, 2016 White Mountain HMA, Little Colorado HMA April 13, 2016 Little Colorado HMA, Divide Basin HMA
Type of Survey	Simultaneous Double-observer
Aviation Company	Kim Ruble and Larry VanSlyke, pilots, Red Tail Aviation (Price, UT); Cessna 210, N367N
Agency Personnel	Kent Benson, James Price (BLM), Lou Arambel (in cooperation with the Rock Springs Grazing Association), Jay D'Ewart, aviation manager

Table 1. Estimated population sizes (Estimate) are for the numbers of horses in the surveyed areas at the time of survey. 90% confidence intervals are shown in terms of the lower limit (LCL) and upper limit (UCL). The coefficient of variation (CV) is a measure of precision; it is the standard error as a percentage of the estimated population. Number of horses seen (No. Seen) leads to the estimated percentage of horses that were present in the surveyed area, but that were not recorded by any observer (% Missed). The estimated number of horses associated with each HMA but located outside the HMA's boundaries or on checkerboard lands are already included in the total estimate for that HMA.

Area	**Age Class**	**Estimate (No. Horses)**	90% LCL[a]	90% UCL	Std Err	CV	No. Horses Seen	% Missed	Estimated # of Groups	Estimated Mean Group Size	Foals per 100 Adults	Est. No. Horses Outside HMA	Est. Horses on Checkerboard Lands
Little Colorado HMA	Total	328	279	411	47.0	14.3%	297	9.5%	37	9.0	7.2	43	0
	Foals	22	16	29	4.0	18.0%							
	Adults	306	259	387	44.2	14.4%							
White Mountain HMA	Total	237	189	329	51.1	21.6%	219	7.5%	18	13.4	6.9	0	120
	Foals	15	12	24	4.1	27.1%							
	Adults	221	176	307	47.1	21.2%							
Complex Total (White Mtn. / Little Colorado)	Total	565	494	707	72.2	12.8%	516	8.7%	54	10.4	7.1	43	120
	Foals	37	30	49	5.6	14.9%							
	Adults	528	464	662	67.4	12.8%							
Salt Wells Creek HMA	Total	709	669	750	24.0	3.4%	673	5.1%	111	6.4	1.9	51	187
	Foals	13	12	15	0.8	6.0%							
	Adults	696	658	736	23.8	3.4%							
Adobe Town HMA	Total	689	648	744	30.7	4.5%	657	4.7%	117	5.9	0.7	77	25
	Foals	5	5	6	0.2	4.6%							
	Adults	684	643	739	30.7	4.5%							
Complex Total (Adobe Town / Salt Wells)	Total	1398	1333	1463	42.2	3.0%	1330	4.9%	228	6.1	1.3	128	212
	Foals	18	17	20	0.8	4.5%							
	Adults	1380	1315	1445	42.0	3.0%							
Divide Basin HMA	Total	578	543	615	21.3	3.7%	554	4.2%	102	5.6	6.7	81	272
	Foals	36	31	41	2.7	7.3%							
	Adults	542	511	576	19.4	3.6%							

[a] 90% confidence interval based on percentiles of bootstrap simulation results. The lower 90% confidence interval limit (LCL) is actually less than the number of horses sighted during the survey for these estimates. This is a normal statistical result and reflects the fact that a confidence interval expresses what would likely happen if the survey were repeated. If repeated many times, some surveys would miss more horses and produce lower estimates, even after corrections, than were actually observed during this survey. Clearly, I conclude that there are at least as many horses as were observed during this survey, rather than using the lower confidence limit as a minimum number.

II. Narrative

In April of 2016, Bureau of Land Management (BLM) personnel conducted simultaneous double-count aerial surveys of the wild horse populations in: White Mountain HMA, Little Colorado HMA, Adobe Town HMA, Salt Wells Creek HMA, and Divide Basin HMA (Figure 1). For management purposes White Mountain HMA and Little Colorado HMA are considered to be a complex; similarly, Adobe Town HMA and Salt Wells Creek HMA are considered to be a complex.

I analyzed these data to estimate sighting probabilities, which I then used to correct the raw counts for systematic biases (undercounts) that are known to occur in aerial wildlife surveys, and to provide confidence intervals (which are measures of uncertainty) associated with the estimated population sizes for the HMAs and surrounding areas that were surveyed (Lubow and Ransom 2016).

On the whole, 2016 surveys followed my previous (2015 memo) suggestions in terms of limiting the number of skilled observers, with a single front seat observer and proper seat rotation by only 2 back seat observers, and making frequent use of photography. Unfortunately, weather disrupted the survey, although observers would have been prepared to survey the area without interruption if not for the unanticipated weather. Suggestions for improving future surveys are offered in the Recommendations section.

Population Results

The estimated total horse populations (Table 1) within these areas provided a relatively large sample size of observations (364 horse groups, Table 2, Figure 1), of which 360 were recorded according to protocol and usable in the statistical estimation of sighting probability. All observations made during aerial surveys were used to inform the total estimates of population size, so long as those horses were associated with one of the target populations.

Average sighting probability for this survey was high (94.4%), an increase over the 2014 survey (92.3%), and substantially higher than the 2015 survey (79.1%). The high sighting probability lead to excellent confidence intervals and coefficients of variation in Adobe Town, Salt Wells, and Divide Basin HMAs, but somewhat lower average sighting probabilities in Little Colorado and White Mountain HMAs lead to lower than desirable precision (Table 1). In addition to the estimated errors, biases in the estimates could still exist due to heterogeneity of sighting probabilities that were not fully accounted for in this dataset.

I estimate the mean size of detected horse groups, after correcting for missed groups, to be 6.6 horses/group across surveyed areas, with a median of 4 horses/group, and a composition of 3.8 foal horses per 100 adults at the time of these surveys, but these vary substantially among areas (Table 1). Given the springtime dates of the surveys, these values are very unlikely to represent all foal horses born in either 2015 or 2016.

<u>Sighting Probability Results</u>

The front observers saw 59.1% of the groups (59.1% of the horses) seen by any observer, whereas the back seat observers saw 94.5% of all groups (96.7% of horses) seen (Table 2). There were undoubtedly additional groups not seen by any observer; I address this issue in the analysis that follows. These results demonstrate that simple raw counts do not fully reflect the true population without statistical corrections for missed groups, made possible by the double observer method and reported here.

The analysis method used for the surveyed areas were based on simultaneous double-observer data collected during these surveys. Informed by preliminary analyses and *a priori* reasoning, all models used in the double-observer analysis contained:

1. An estimated parameter for an intercept common to all observations.
2. A parameter in all models to account for the lower sighting probability for the front-seat observers when a group was on the pilot's side of the flight path due to the pilot's focus on flying and the obstructed view from the opposite side. This is a well-established effect.
3. Individual parameters for each unique back-seat observer based on a preliminary analysis that indicated virtually no support for models with only a common effect of back seat location relative to the individual effect by observer (i.e., there was very strong evidence for differences in sighting acuity among the back-seat observers).

No groups were recorded on the centerline, so I did not included a parameter to account for the inability of back-seat observers to see this type of group. 20 groups were recorded as seen spread across both sides of the flight path and visible from both sides of the airplane so I examined the effect of this group position on front observers, but found virtually no support for any effect and dropped it from consideration. Back seat observers, on the other hand, each have an independent chance to see a group that is available on both sides, so the estimated probability for them is increased accordingly without the need for an additional model parameter. I did not consider parameters for effects of vegetation, snow, topography, or lighting conditions because conditions were too uniform to obtain sufficient data for meaningful estimates of these effects.

In addition to the 3 parameters listed above that were included in all models, I tested 4 possible effects on sighting probability by fitting models for all possible combinations of these effects, resulting in 16 alternative models. The 4 effects were: (1) horse movement, (2) horse group size, (3) distance from observer to horse group, and (4) unique effects for each survey area (HMA).

The effect of movement was the most strongly supported (74.3% of AIC_c model weight) followed by the effect of distance (59.4%). Effects of group size (34.8%) and differences among the 5 survey areas (30.5%) were only weakly supported.

Visibility in the front for groups on the pilot's side was markedly lower, as expected (Table 3). Visibility was greater for larger groups and groups closer to the flight path, also as expected. In contrast to the 2015 survey, sighting probability was lower for moving groups in this survey. Sighting probability differed substantially between the 2 back seat observers but was good for both of them.

Correction for sighting probability resulted in a statistically estimated 5.6% of horses present in the surveyed areas not being observed, on average, although the percentage missed was as high as 9.5% at Little Colorado HMA. Estimated sighting probabilities for individual groups ranged from 5.2-92.0% for the front observers and 63.9-99.6% of the back observers and 65.8-100% for the combined observers. The very low sighting probabilities (<25%) for the front observers were all cases when the group was on the pilot's side. Even in these survey areas with excellent sighting conditions characterized by very open and relatively smooth terrain, adjustment to raw counts for those groups not seen by any observer are needed. This underscores the importance of using a statistical method for correcting raw counts.

Assumptions and Caveats

The results obtained from these surveys are estimates of the horses present in the areas surveyed at the time of the survey and should not be used to make inferences beyond this context. The reliability

of results from any population survey that is based on the simultaneous double-observer method rests on several important assumptions.

First, I must presume that pre-flight planning by the district specialists and BLM research coordinator led to the surveyed areas including as much as possible of the areas used by each population of horses using the surveyed HMAs, HAs, and WHTs. Although some fences, highways, mountain ranges, and dry lake beds provide deterrents to animal movement that help to contain them within the areas surveyed, these barriers are not always continuous, unbroken or impenetrable. Consequently, the numbers of animals found within the survey areas at another time could differ substantially. It is possible that temporary emigration from the surveyed areas may have contributed to some animals of a given population not being present in the surveyed areas. Also, the estimated distribution of animals between different subareas of any complex should only be considered specific to the times of this survey; that spatial distribution almost certainly varies throughout the year.

Second, simultaneous the double-count method assumes that all groups of animals are flown over once during a survey period, and thus have exactly one chance to be counted by the front and back seat observers, or that groups flown over more than once are identified and considered only once in the analysis. Groups counted more than once would constitute 'double counting,' which would lead to estimates that are biased higher than the true number of groups present. Additionally, groups that were never available to be seen (for example, due to temporary emigration from the study area or due to moving, undetected, from an unsurveyed area to one already surveyed) can lead to estimates that are negatively biased compared to the true population size. Although attempts were made to minimize the potential for horse movement among survey days by making use of highways, rivers, and topographic barriers, inter-day horse movements during a multi-day survey could potentially bias results if those movements result in unintentional double counting or unavailability of groups. This could have been a problem, in particular, at Divide Basin HMA, where there was a 2 day break caused in part by inclement weather. The identification of 'marker' horses (horses with unusual coloration) in each group, use of photography for reference, and variation in group sizes, helped to reduce the risk of double counting during aerial surveys, and the results presented here are based on a survey design and methods that assume that any unobserved movements were random, so the effects would cancel each other out.

Third, this method assumes that all horse groups with identical sighting covariate values have equal sighting probability. If there is additional variability in sighting probability not accounted for in the sighting models, such heterogeneity could lead to a negative bias (underestimate) of the population. This is of greater concern when sighting probabilities are lower, so this concern is minimal in the Adobe Town, Salt Wells, and Divide Basin estimates but remains a caveat worth noting in interpreting the White Mountain and Little Colorado results.

A fourth assumption is that the number of horses in each group is counted accurately. In very large groups it may be common to miss a few horses unless photographs are taken and scrutinized after the flight. Relying on raw counts made from the airplane could lead to biased low estimates of population size. Observers in this survey made good use of photography to check group size, except in cases where very windy conditions precluded access.

Given these potential sources of bias, it is more likely that the estimates are somewhat lower, rather than higher, than the true population. However, given the high sighting probabilities and precision estimated for these surveys, the population estimates I present here provide a sound and reliable basis for management decisions, although appropriate caution should be used in applying results for specific areas with lower precision.

Recommendations for Future Surveys

Below, I comment on the appropriateness of the survey planning and execution with notes about improvement that have been implemented this year and possible additional incremental improvements to be considered in for future surveys:

1. There is a substantial benefit to maximizing the sighting probabilities and minimizing the number of different factors that cause variation in sighting probability. By far the most potent means to accomplish both objectives is to drastically limit the number of observers used, as was done in 2016. Using a single pilot is also preferred. 2 pilots were used in these surveys, but sometimes on long surveys that is necessary because of pilot duty-hour limitations. Back seat observers must be rotated, as they were in 2016. Most important, observers should be carefully selected based on their past performance and ability to spot horses, which appears to have been the case in 2016. It is especially important to use the best possible observer in the front seat. The changes adopted in 2016 led to a dramatic improvement in the precision and reduced the risk of undetected biases, compared with results from 2014 and especially 2015. The personnel and procedures employed in 2016 should be retained for future surveys to the greatest extent possible
2. Group sizes ranged from 1 to 76 horses in this survey with 60 groups (16.5%) containing >10 horses (19 or 5.2% of those groups had >20 horses), so inaccurate counting would have been a substantial risk for some groups had photography not been employed. Observers circled over large groups to get as accurate a count as possible and routinely used photography to record group size of large groups. Using photography is in the drafted standard operating procedures for BLM double-observer aerial surveys for horses, when group size is 20 or more – this was done in almost all cases in 2016. I emphasize the importance of continuing to use photography for large horse groups (>10 preferable, >20 is extremely important) to ensure that such groups are counted accurately. Given the tendency for horses in this area to form large groups, all future surveys should use photography so that group sizes recorded in flight can be validated with reference to photographs after the flight. Surveys should continue to use a reliable, high-resolution camera with an adequate telephoto or zoom lens for the distance between observer and horses for this purpose.
3. The pilot followed predetermined transect lines that were loaded into the pilot's GPS unit quite well during most of the fight. The flight lines were spaced at regular distances approximately 1.5 miles apart, reflecting the fact that there was little variation in topography or vegetation and sighting conditions were favorable. The pilot followed largely the same pattern of planned flight lines (Figure 1) as was used for these surveys in 2014. Both pilots did an excellent job of staying close to the pre-planned transect lines and succeeded in maintaining uniform spacing throughout the survey area.
4. Temporary emigration into or out of the surveyed areas was unlikely to have been a significant problem, because the survey lines extended well beyond the HMA boundaries, especially where fencing, highways, and other barriers were not present, such as west of the Divide basin HMA. Compared with 2015, the 2016 surveys extended survey lines for Little Colorado HMA and Divide Basin HMA several miles to the north, as I had recommended in 2015. Even with those extensions, a number of groups were observed at the northern extent of those two HMAs and beyond at least one line of fencing – this suggests that future surveys may need to have survey lines that extend even further north there, to encompass and adequately survey the horse populations using those areas. Fencing can be a deterrent to horse movement, but does not ensure containment.

5. The assumption of no movement within the survey area during the survey (potentially leading to double counting or unavailable animals) may have been violated in the Divide Basin HMA; there, the survey had to be suspended for 2 days because a storm interrupted the survey on April 10-11. This storm would have been hard to predict when the surveys started on April 4. To the extent possible, future inventories should continue to include single HMAs, and all the HMAs in any complex together, on consecutive days, in a consistent season, and using as many of the same observers across all HMAs as possible. If it is likely that a storm will disrupt a survey and the aircraft will continue to be available, it may be better to wait to begin the survey of a given HMA or complex until the storm has passed.

Literature Cited

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Table 2. Tally of raw counts of horses and horse groups by observer (front and back) and survey year for combined HMAs. This table is based on raw counts (not statistical estimates) and, therefore does not address groups not seen by any observer.

Observer	Groups Seen (Raw Count)	Horses Seen (Raw Count)	Actual Sighting Rate[a] (groups)	Actual Sighting Rate[a] (Horses)
Front	215	1,418	59.1%	59.1%
Back	344	2,320	94.5%	96.7%
Both	195	1,338	53.6%	55.8%
Combined	364	2,400		

[a] Percentage of all groups seen that were seen by each observer.

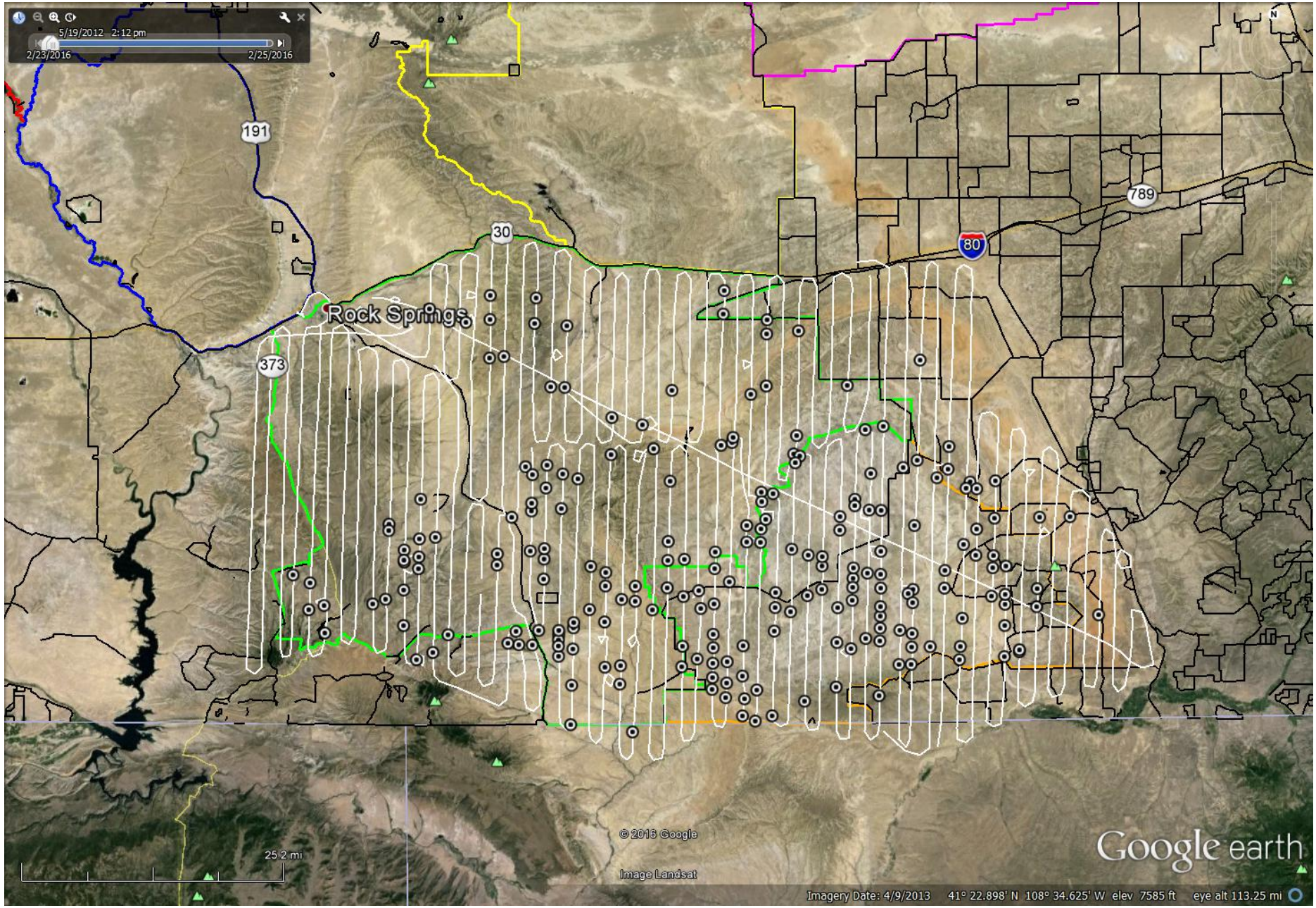
Table 3. Effect of observers and sighting condition covariates on estimated sighting probability of horse groups for both front and rear observers. Baseline case (**bold**) is for observers in the indicated seat computed for groups not on pilot's side, at Adobe Town, with no activity, group size=4 horses (the median value), distance 0-½ miles (the most common value), and for observer JP in the back. Other cases vary a covariate, one effect at a time, as indicated. Sighting probabilities for each row should be compared to the baseline (first row) to see the effect of the change in observer or condition. Baseline values are shown in bold wherever they occur. Sighting probabilities are calculated from weighted averaged model parameters across all 16 models.

	Sighting Probability, Front Observer[a]	Sighting Probability, Back Observer
Baseline	**91.1%**	**84.7%**
Effect of group size (N=1)	91.0%	84.5%
Effect of group size (N=10)	82.1%	71.2%
Effect of active group	81.6%	70.4%
Effect of distance (1/4-1/2 mile)	89.3%	81.9%
Effect of Salt Wells	89.9%	82.7%
Effect of White Mountain	91.8%	85.7%
Effect of Little Colorado	93.2%	88.1%
Effect of Divide Basin	91.2%	84.8%
Effect of Pilot's Side	12.8%	**84.7%**
Effect of observer LA in back	**91.2%**	97.2%

[a] Sighting probability for the front observers acting as a team when the horses were on the pilot's side of the flight path, regardless of which of the front observers saw the horses first.

Figure 1A. Map of April 4-8, 2016 survey of Adobe Town HMA (orange) and Salt Wells Creek HMA (green). Circles are GPS waypoints at the locations where observers saw groups of animals. Black lines are fences.

Figure 1B. Map of April 8-13, 2016 survey in Divide Basin HMA (yellow), Little Colorado HMA (red), and White Mountain HMA (blue) and GPS recordings of actual flight paths (white lines). Circles are GPS waypoints at the locations where observers saw groups of animals. Black lines are fences. Adjacent management areas not included in this survey are shown for reference: Lost Creek, HMA (magenta) and Antelope Hills (purple).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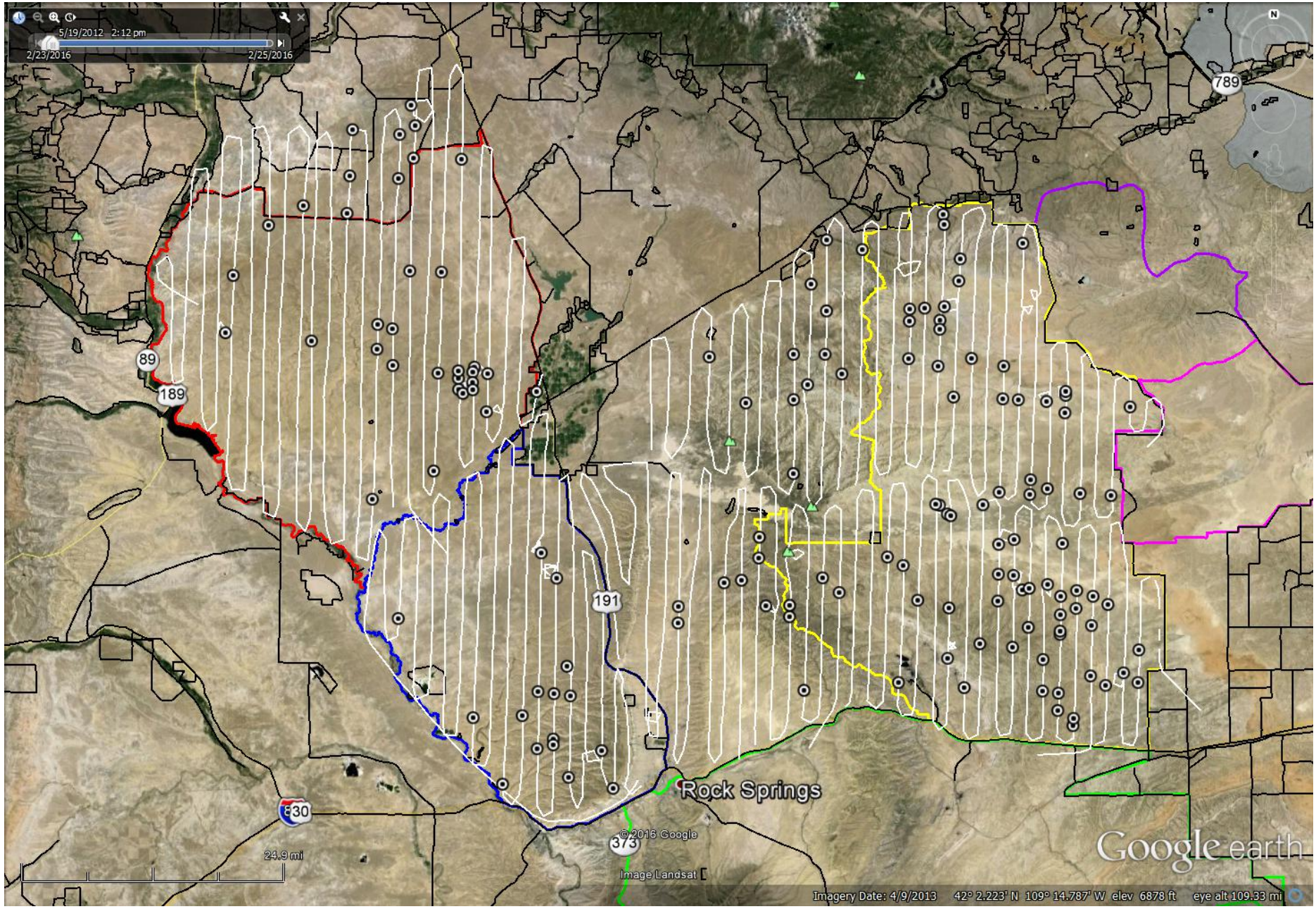
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