Cooperative Assessment of Black-Tailed Prairie Dog Status in Eastern Wyoming: Final Report for Task I - Validation of Map Produced by the Wyoming Game and Fish Department

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INTRODUCTION

In 2002 the Wyoming Natural Diversity Database (University of Wyoming; hereafter WYNDD) entered into an agreement with the Wyoming State Office of the Bureau of Land Management (hereafter BLM) to assess the distribution and status of the black-tailed prairie dog (*Cynomys ludovicianus*; hereafter BTPD) in Wyoming. This project was established on the understanding that the Wyoming Game and Fish Department (hereafter WGFD) would produce and deliver to WYNDD and BLM a completed map of black-tailed prairie dog distribution and activity status covering all of the species' range in the state. This report presents the results from the first of three tasks outlined in the cooperative agreement. The complete list of project tasks and their associated sub-tasks is as follows:

Task I: Develop and apply a method of validating accuracy of the WGFD BTPD map by:
- A. Estimating omission error rate
- B. Estimating commission error rate
- C. Comparing the WGFD map to one provided by the BLM Newcastle Field Office

Task II: Evaluate conservation and management status of BTPD towns in Wyoming by:
- A. Analyzing activity status of mapped towns
- B. Analyzing burrow density on a sample of mapped towns
- C. Analyzing reproductive output on a sample of mapped towns
- D. Analyzing habitat characteristics of mapped towns at a landscape scale
- E. Exploring ways to assess effects of plague, poisoning, and shooting
- F. Mapping the boundary between the ranges of BTPD and white-tailed prairie dogs (*Cynomys leucurus*; hereafter WTPD) in Wyoming.

Task III: Create a computer database of mapped towns

Please note that in the above list and subsequently throughout this report we use the term prairie dog "town." We recognize that biologists and management agencies apply specific definitions to "town," versus "colony" and "complex," and that these definitions are somewhat variable depending on context. For example, in their Completion Reports, WGFD generally uses the term "colony." Throughout this report we use "town" to represent a geographically distinct area of contiguous prairie dog occupation, as delineated by a single polygon on the maps discussed in this report. This term is used for simplicity and does not imply any information on the size or status of the entity in question.

In 2002, WGFD began creating a comprehensive map of BTPD towns throughout the Wyoming range of the species. Their mapping procedure involved digitizing town boundaries from 1:40,000 scale, 2001/2002 National Aerial Photography Program (NAPP) color infrared photographs (Grenier et al. 2004). Prairie dog towns were digitized on roughly 70% of the photographs covering the range of BTPD in Wyoming by July 1, 2003. Between May and early July of 2003 WGFD and WYNDD conducted aerial survey flights to confirm the mapping accuracy and activity status of towns digitized by WGFD. WYNDD also conducted omission survey flights, conducted demographic surveys on selected BTPD towns, and developed a

questionnaire with which prairie dog experts throughout Wyoming assessed the impacts of plague, poisoning and shooting.

Beginning in 2003 the WGFD produced several maps of BTPD towns as a result of this effort, but all of them were described as "not quite final" and still requiring work and improvement. In their 2004 Completion Report, WGFD presented a formal analysis of BTPD distribution (Grenier et al. 2004). The map on which this analysis was based was still not complete, because about 700 aerial photos (representing about 30% of BTPD range in Wyoming) had not yet been interpreted. Total occupied acres estimated in the 2004 analysis did not include extrapolation to un-evaluated photos. At that time there was some uncertainty over whether or not the number and size of BTPD towns on the un-evaluated photos was significant. Although the geographic position of all un-evaluated photos was not available to WYNDD, it appeared that many occurred in areas known to support high densities of BTPD, such as the Thunder Basin National Grassland and areas near the town of Kaycee, Wyoming. To ensure that WYNDD-generated estimates of omission error (i.e., the number of existing BTPD towns that were not mapped by WGFD) were not inflated due to un-interpreted photos, BLM and WYNDD decided to postpone complete evaluation of the WGFD BTPD map until a final version was produced.

WYNDD received an updated BTPD map from WGFD in April 2005. This map was still incomplete and difficult to analyze. In the 2005 map, BTPD towns were not attributed with their activity status (i.e., whether they were active or inactive when surveyed); information which is needed to evaluate BTPD conservation and management status. The 2005 map included ca. 335 (17%) more towns than the 2004 map reported by Grenier et al (2004). We assumed this increase was due to WGFD processing some of the missing 700 photos, but the geographic position of the remaining un-evaluated photos was still not available to WYNDD, making meaningful analysis of the 2005 map difficult. Given these difficulties, BLM and WYNDD decided to conduct a preliminary analysis based on the 2005 map (Keinath et al. 2006), but not to conduct a final analysis until we received a complete map from the WGFD for which all aerial photographs had been evaluated.

WGFD reported statistics from a complete version of the BTPD map in their 2007 Completion Report (Grenier et al. 2007). According to Grenier et al. (2007), the new map contained 2,429 BTPD towns, which was 443 more than the 1,986 towns already delineated in the 2003 version of the map (an increase of 22%). WYNDD received a copy of the complete map in June 2007, which was then used to complete all WYNDD / BLM project tasks (as reported here, and in subsequent reports). June 2007 marked the beginning of WYNDD's 2007 field season, so analysis of the complete map was postponed until fall and finished in February of 2008. The following sections present the methods and results from the 3 sub-tasks of Task I: estimating the omission error rate of the WGFD BTPD map, estimating the commission error rate of the BTPD map, and comparing the WGFD BTPD map to that provided by the BLM's Newcastle Field Office.

ESTIMATING OMISSION ERROR RATE

Background and Methods

Omission error refers to BTPD towns that were missed by the WGFD mapping effort (i.e., actual BTPD towns that were somehow overlooked and not included in the 2007 WGFD map). An omission error rate was not estimated by WGFD, for various reasons stated in the 2004 Completion Report. The same report suggests that WGFD will undertake an estimation of omission error sometime after 2004; to our knowledge they have not done so to date.

In 2003 WYNDD flew objective (i.e., positioned without foreknowledge of mapped towns) transects across portions of BTPD range in Wyoming and recorded the position of all sighted towns. Transects were flown in a fixed wing plane (e.g. Cessna 210, 180 or Super Cub) with a pilot and one observer. Waypoints representing the northern and southern ends of transects were loaded into GPS units and used to maintain constant bearings. Flight speeds were maintained at about 100 mph and elevation was maintained at about 500 feet above the ground. To insure accurate identification of prairie dog towns, only towns falling within 700 feet of the plane were recorded. This recording distance was insured using a simple sighting scope cut from 2-inch diameter PVC pipe that, when held against the plane's window, resulted in a field of view extending 700 feet from the plane; only towns falling within this field of view were documented. If there was any question regarding the identification or status of a particular town, the pilot was instructed to circle back so the technician could re-evaluate.

Locations of towns along omission transects (Figure 1) formed the basis for our estimates of the number of towns missed by the WGFD map (i.e., omission error). Because the 2007 WGFD BTPD map includes all towns mapped from all aerial photos across the entire range of BTPD in Wyoming, omission error estimated from our 2003 objective flight data should represent only those towns that were not detected by the WGFD mapping protocol (i.e., the earlier problem of un-interpreted photos does not apply).

To analyze omission error, we compared two spatial layers of BTPD towns: 1) town locations from WYNDD aerial omission transects (Figure 1); and 2) towns from the 2007 WGFD BTPD map (Figure 2). We compared these layers via a detailed, visual assessment of each WYNDD-observed town, with conclusions constrained by a pre-defined decision tree. See Appendix A for the full details of our methods. Following this comparison, all observations of BTPD towns identified on our omission transects were classified into the following 3 categories:

1. Omission: An observation where a BTPD town was clearly identified by WYNDD personnel, but was absent from the map developed by WGFD.
2. Concurrence: An observation where the same BTPD town was, beyond a reasonable doubt, represented in both the WYNDD omission transects and the map developed by WGFD.
3. Uncertain: An observation where there was some uncertainty of whether a BTPD town noted on a WYNDD omission transect referred to the same town on the map developed by WGFD.

Observations classified as uncertain were not included in calculating our best estimate of omission rate, making that estimate conservative. An observation was generally classified as

uncertain for two reasons, both of which were evaluated by comparing the mapped towns to 1:40,000 scale color infrared digital orthophotos taken in 2000 (available online from the Wyoming Geographic Information Science Center: http://www.wygisc.uwyo.edu/ data.htm). The first cause of uncertainty occurred when no town was clearly visible on orthophotos near the WYNDD observation. Since field personnel reported these towns, they probably refer to legitimately omitted towns, but they may be difficult to observe on the photographs used by the WGFD. The second cause of uncertainty occurred when the towns referred to by both the WYNDD observation and the WGFD were visible on orthophotos, but due to inaccurately mapped town boundaries it was not clear that they referred to the same town. See Figures A-2 through A-7 for specific examples of omission, concurrence, and uncertain situations.

Results and Discussion

WYNDD observed 304 BTPD towns along its omission transects (Figure 1). Based on the analysis described above and in Appendix A, 103 (34%) of the 304 towns do not appear on the 2007 WGFD BTPD map, while 124 (41%) overlap with towns on the 2007 WGFD BTPD map and 77 (25%) are classified as "uncertain", being neither clear omissions nor concurrences with the 2007 WGFD BTPD map (Figure 3).

Due to the nebulous nature of the "uncertain" points, our best estimate of omission error is made by simply removing these points from the analysis. Therefore, calculating omission error based solely on those points clearly classified as omissions or concurrences, the resulting omission error rate is 103 / (304 - 77) = 45%. An upper and lower bound for this value were determined by assuming that the uncertain points were either all captured by the 2007 WGFD map (omission error lower bound = 34%) or all missed by the 2007 WGFD map (omission error upper bound = 59%). Both of these scenarios are unrealistic and omission error likely does not reach either extreme, but they provide objective bounds for the actual omission error rate of the 2007 WGFD BTPD map.

The estimate of omission error reported in our preliminary analysis (Keinath et al. 2006) was 42% - 59%. That estimate was based on an unsupervised classification scheme using a 520 meter buffer around our omission observations. We concluded that this rather high preliminary estimate could have been due to a number of factors, including the fact that our omission flights occurred in 2003, two years after the base aerial photographs were taken (and BTPD towns could have shifted significantly in that time). Therefore we chose to implement a more rigorous evaluation and classification scheme in the final analysis (reported here), wherein we manually analyzed each BTPD observation from our omission transects relative to 1:40:000 scale color-infrared orthophotographs taken in 2000, within a year of the WGFD photographs. Furthermore, in the final analysis we removed all observations that were not clearly classifiable according to our decision tree, thus removing some of the error potentially introduced by the time lag between the WGFD photographs and when we conducted aerial surveys. However, despite the added rigor of the final analysis, our estimates of omission error remained relatively unchanged: 42%-59% from the preliminary analysis vs. 34% - 59% from the final analysis.

The 1:40:000 scale color-infrared orthophotographs that we used to evaluate omission error were of the same resolution as the photographs used by WGFD to create their BTPD map, and they were also taken at approximately the same time (summer 2000). Therefore, they should be very comparable to the data on which the WGFD map was based. Since most of the missed towns were clearly visible on the color-infrared orthophotographs (e.g., Appendix A, Figures A-

2 and A-4), the most likely source of omission was digitizing error - that is, technicians who digitized towns from photographs simply overlooked the towns in question. Further, since the field verification methods employed by WGFD were not designed to evaluate omission (crews flew to and evaluated only those towns that had been delineated by technicians on photographs, and did not attempt to locate additional towns from the air), there was no way to quantify omission or otherwise become aware of missed towns outside of re-evaluating the photographs.

Mapping technicians could have missed towns that were visible on photographs for many reasons. We do not know the exact digitizing procedures followed by WGFD technicians, but our analysis suggests some possible contributing factors. Of the 103 missed towns, about 42% were classified from the air by WYNDD observers as "small"; on the order of 40 acres or less. Clearly, small towns would be easier to overlook during visual scans of photographs than larger towns. Also, when evaluating each BTPD observation along our omission transects, we noted the relative visual distinctness of the towns on the color-infrared orthophotographs. Twenty-one percent of the missed towns were vague. It is likely that these towns, which included several of the aforementioned small towns, were missed because they did not show-up well on aerial photographs. Combining these two factors, 56% of omissions were either small, vague, or both. The remaining 44% of omitted towns were larger, often over 100 acres and sometimes approaching several square miles in size; 17% of omissions were classified by WYNDD observers as either large or very large towns.

ESTIMATING COMMISSION ERROR RATE

Background and Methods

Under ideal circumstances, commission error in the final BTPD map produced by the WGFD should be nil, because the mapping methods included field verification of all potential towns delineated on aerial photos. Potential towns delineated on aerial photos that were determined in the field to be something other than prairie dog towns were marked as such, and were not included in final map. Grenier et al. (2004) estimated that 16% of potential towns identified on aerial photos were actually errors of commission, which was revised to 23% on the updated version of the map (Grenier et al. 2007). WYNDD dedicated a substantial amount of effort and resources to help the WGFD evaluate mapped towns; roughly 27% of all mapped towns were evaluated from the air by WYNDD. Thus, WYNDD can investigate commission error estimates based on its sample of the study area.

Guided by GPS coordinates provided by WGFD, WYNDD flew commission error flights to 441 sites that were mapped as BTPD towns by WGFD. For each of these sites, technicians recorded whether the feature mapped was actually a prairie dog town. If the feature was not a prairie dog town, its actual identity was noted. Methods for these flights followed those specified by the WGFD (Grenier et al. 2004).

Results and Discussion

Of the 441 sites visited by WYNDD staff, 162 were not prairie dog towns, resulting in a commission error rate of 37%. In other words, within the area sampled by WYNDD, 37% of the polygons identified by WGFD mapping technicians as potential BTPD towns were not actually prairie dog towns (and, again, were not included as towns on the final WGFD map). This

contrasts with the WGFD estimate for the complete map of 23%. Further, there is some disagreement between the commission numbers recorded by WYNDD and those reported by Grenier et al. (2004). For example, WGFD reported fewer errors in degree block 13 than were recorded by WYNDD (Table 1). These discrepancies are substantial, and perhaps worthy of resolving. Such resolution would require in-depth discussions between WYNDD and WGFD, and likely a re-examination of the flight data collected by both units.

In each case where a mapped potential town was determined to be something other than a BTPD town, both WGFD and WYNDD technicians recorded what landscape feature was mistaken for a prairie dog town. Of the 162 erroneously classified sites visited by WYNDD, we found that 108 (67%) were ant colonies; 35 (22%) were patches of bare ground; and the remaining 11% were miscellaneous features (e.g., mining operations, human disturbance, etc.) or were unspecified. These proportions of commission error types closely match those reported by WGFD (Table 1). Clusters of ant mounds are clearly confused with prairie dog towns on aerial photographs, so areas with high ant populations can expect high commission error. Similarly, landscapes containing much patchy bare ground can contribute to high commission error. Further, based on WYNDD's data, there seems to be geographic variation in the degree of commission error, with higher error rates in dense clusters of prairie dog towns, such as portions of Thunder Basin National Grassland and the Powder River Basin (e.g., Figure 2 and Table 1).

It is important to re-emphasize that the commission error rate in the 2007 WGFD BTPD map should be nil, given that all co-mitted potential towns were not included in the final map. Estimates of commission error apply to the accuracy of photo-interpretation. A more thorough understanding of commission error may be valuable to parties wishing to repeat prairie dog mapping in Wyoming, or to use similar procedures to map prairie dogs elsewhere.

COMPARING WGFD MAP AND BLM MAP FROM THE NEWCASTLE FIELD OFFICE

Background and Methods

We compared the 2007 WGFD BTPD map to a map developed by the Newcastle BLM based on field survey efforts in 1992. This was essentially two parallel analyses: 1) validating the WGFD map with the BLM map; and 2) validating the BLM map with the WGFD map. The following procedure was used to make this comparison.

The BLM map seemed to include only towns on or near BLM surface ownership, so comparisons outside this area are not valid. To standardize extent of the maps, we clipped both the WGFD and BLM maps to include only those towns within 2 sections of BLM surface ownership (i.e., about 3,200 meters). Additionally, both maps were clipped to the extent of the Newcastle BLM field office, which is essentially Crook, Newcastle and Niobrara Counties. All comparisons were made within this area.

Considering surface area, we can measure concordance between the WGFD and BLM maps by comparing total area of prairie dog towns on each map, and also by comparing the area that both maps have in common. Summary statistics were generated for each map (e.g., number and size of prairie dog towns). The maps were then intersected resulting in a new map showing

only the areas where towns on both maps overlapped. Summary statistics were generated for these areas of overlap and compared with those of the original maps to determine the degree to which the maps were in agreement.

Another measure of concordance between the WGFD and BLM maps is whether a particular town, regardless of its area, was identified by both. However, due to differences in methodology, errors in digitizing and transferring coordinates to maps, time lag between the production of each map, and vague boundaries of actual towns, it is reasonable to expect variation in the position of town boundaries on both maps. Thus, the "same" town could occur in slightly different locations on each map. Consultation with remote sensing professionals suggested that potential error due to digitizing from geo-rectified 1:40,000 scale aerial photos is on the order of meters, while error due to transferring features from 1:24,000 scale topographic maps is on the order of tens of meters. We assumed a worst-case scenario for both maps and buffered towns to account for this uncertainty. Specifically, towns from the Newcastle BLM map were buffered by 80 meters, while towns on the WGFD map were buffered by 50 meters, as discussed in Appendix A.

These buffered towns were then compared and any area of intersection was considered a "hit" (i.e., places where both maps predicted a town in roughly the same area). Towns from one map that did not intersect those of the other map were considered "misses," or "omissions." Hits and misses were tallied for both maps and summarized to obtain an estimate of difference between them.

Results and Discussion

A much larger area of BTPD occupation, and more BTPD towns, appeared on the WGFD map than on the Newcastle BLM map (Table 2). Specifically, the WGFD map predicted 144% more area of BTPD towns than the BLM map. There were roughly 13,000 acres in common between the two maps, which represents 54% of the BLM map and only 22% of the WGFD map. Further, the WGFD map predicted 104% more towns (265) than did the BLM map (130), and even after these towns were buffered to account for mapping error, less than half of them seemed to coincide. The BLM map generally had smaller towns, several of which often overlapped a single WGFD town, so although 78 BLM towns were coincident with WGFD towns, only 61 WGFD towns were coincident with BLM towns.

There are <u>many</u> possible explanations for why the two maps differ to such a great degree, which leaves us with the conclusion that they are simply not comparable. Perhaps most importantly, roughly 10 years separates the creation of these two maps. During that time there could have been significant changes in prairie dog abundance and distribution. In fact, we know that at least once during this period sylvatic plague spread through prairie dog towns in Wyoming, with a corresponding drop then subsequent rebound in numbers. Ten years of poisoning and shooting could also have had noticeable impacts, and there were several years of drought that could have easily affected BTPD occupation patterns. Further, the methods used to survey prairie dogs and generate the maps were very different. The WGFD identified potential prairie dog towns from aerial photographs and then flew to these towns to confirm their status. This is a rather objective and complete procedure that eliminates the limiting variables of ground-based observation, topographic obstructions, and land ownership and access issues. In contrast, the BLM effort was a ground-based survey where biologists were limited to what they could see from the fragmented BLM parcels and public roads within the field office.

Unfortunately, the relative contributions of these potential sources of error cannot be estimated. Moreover, the temporal and methodological differences between the maps are so substantial that one must conclude that they are not comparable with respect to population shifts in BTPD. Thus, we cannot determine if inconsistencies in the two maps are due to relative errors of the methods used to create those maps or if they are due to biologically meaningful shifts in the distribution of BTPD.

CONCLUDING REMARKS

The main focus of the report was validation of the map of BTPD towns created by the WGFD and provided to WYNDD in 2007. As discussed above, we estimated that omission error of the final map was on the order of 45%, with a possible range of 34% - 59%. We also found that although the commission error rate of the 2007 WGFD BTPD map should be nil, there is some uncertainty associated with the commission error rate for photo-interpretation. Resolution of this uncertainty is beyond the scope of this project, and would require further analysis and consultation.

From this information we draw two primary conclusions. First, although the conceptual approach taken by WGFD is valid, the methods used to delineate prairie dog towns from digital photographs have some significant flaws. The high omission error suggests that more attention needs to be paid to refining methods such that photo-interpreters "catch" more towns in their scans. Such refinements need to center on stricter digitizing protocols, including perhaps independent redundant digitizing of photos, formalized quality-control, more pre-digitizing training of technicians, and manipulations of technician numbers and shift durations to maximize attentiveness. Also, recent advances in automated image classification and pattern recognition software could be incorporated into the interpretation process to assist technicians in town recognition (e.g., Platt and Rapoza 2008).

Second, we conclude that the final WGFD map substantially underestimates the extent of BTPD towns. The degree of omission error is sufficient to make the map of questionable use in determining the absolute coverage and distribution pattern of BTPD in Wyoming, or for use as a baseline with which to compare future estimates of distribution. Virtually half of all BTPD towns in Wyoming were likely omitted from the current map. Even if many of those omissions were small towns, which is likely the case, their cumulative area is probably substantial. If the extent or configuration of BTPD towns differs between the 2007 WGFD map and future maps, it will be difficult to determine whether those differences are due to biologically meaningful trends or are artifacts of mapping errors. In the context of monitoring, perhaps the best use of the 2007 WGFD BTPD map is to identify a representative subset of existing towns to monitor into the future as an estimate of statewide trends, as mentioned by Grenier et al. (2007).

Statewide mapping of BTPD towns with geo-referenced satellite or aerial imagery is worthy of pursuing as part of future efforts to evaluate BTPD status (e.g., Biggins et al. 2005, Sidle et al. 2002). However, for such efforts to be useful, key methodological issues must be rectified.

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TABLES

Table 1: Latilong summary of commission errors reported by the Wyoming Game and Fish Department in their 2004 completion report (WGFD; Grenier et al. 2004) compared to that estimated by the Wyoming Natural Diversity Database (WYNDD) for those blocks where effort overlapped.

Latilong Block	Percent of Block flown by WYNDD	Total Commission Errors as reported by WGFD / WYNDD			
		Ants	Bare Ground	Other	Total
13	~75%	39 / 91	15 / 31	3 / 15	57 / 137
14	<10%	15 / 1	6 / 2	1 / 1	22 / 4
21	100%	4 / 4	0 / 0	1 / 3	5 / 7
27	100%	3 / 2	1 / 1	0 / 0	4 / 3
28	100%	9 / 10	1 / 1	0 / 0	10 / 11

Table 2: Comparison of the Wyoming Game and Fish Department (WGFD) map of black-tailed prairie dog towns digitized from aerial photographs taken in 2001 and the map from USDI Bureau of Land Management - Newcastle Field Office (Newcastle BLM) developed from a field inventory in 1992.

	Newcastle BLM	WGFD	Area of Intersection *
Total Town Area (acres)	24,191	59,072	13,156
Total Number of Towns	130	265	-
Number of Towns Intersecting Other Map**	78	61	-
Omissions ***	204	52	-
Average Town Area (acres)	186	223	-

* The two maps were intersected, resulting in a set of polygons that were represented by both maps as being prairie dog towns.

** Sizes of towns on both maps were increased by their potential spatial errors (50m for WGFD and 80m for Newcastle BLM). Overlapping towns were counted to evaluate the how many were common between the two maps. 78 towns on the BLM map overlapped those of the WGFD map, but only 61 WGFD towns overlapped those on the BLM map.

*** Each map had towns that were not captured by the other: 204 WGFD towns were omitted by the BLM map and 52 BLM towns were omitted by the WGFD map.

FIGURES

Figure 1: Map of aerial omission transects flown by WYNDD in the summer of 2003, with locations of black-tailed prairie dog towns observed along those transects.

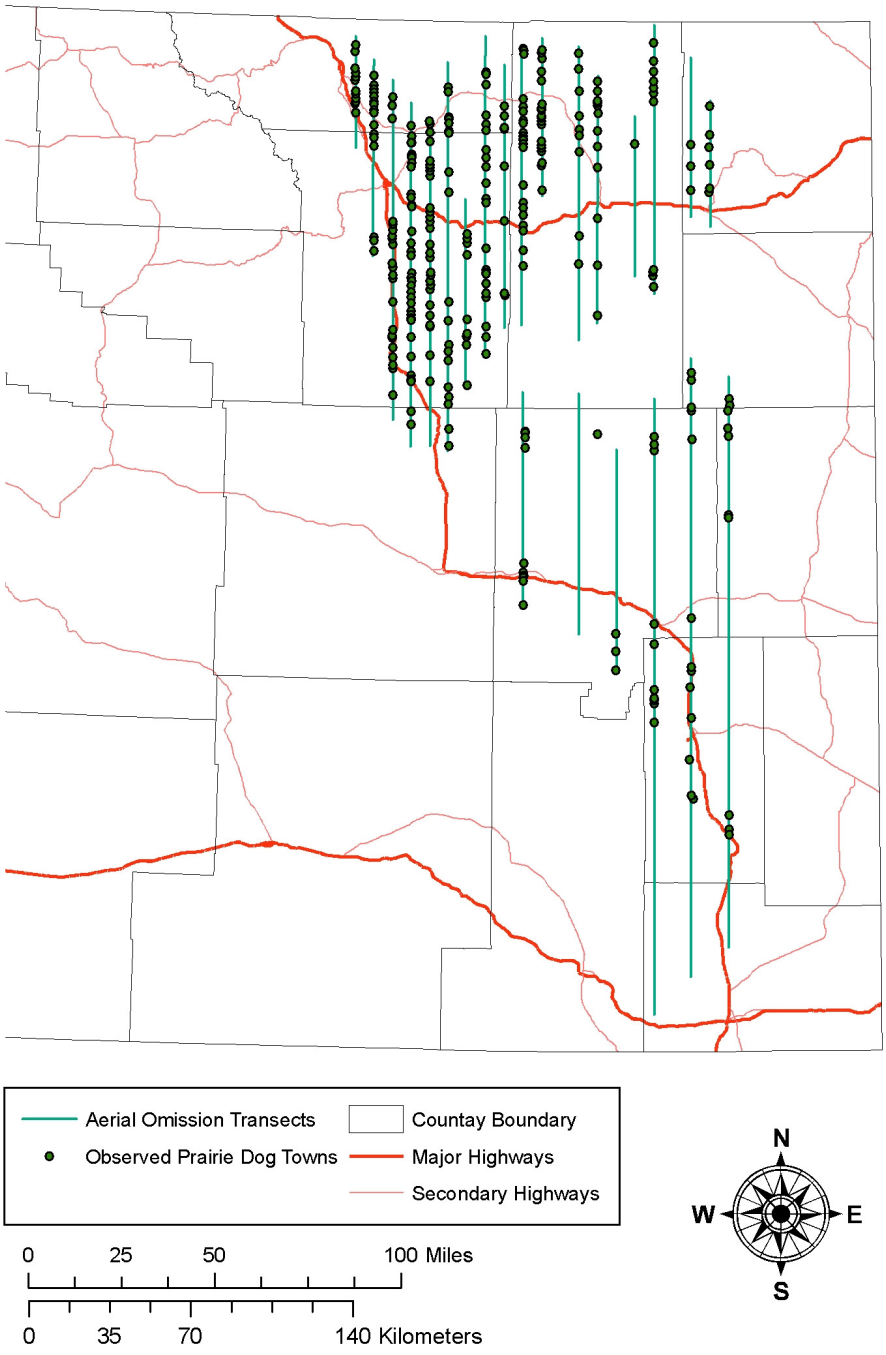


Figure 2: Map of prairie dog towns delineated by WGFD between 2002 and 2007 from 1:40,000 scale aerial photographs and subsequently field verified. Towns are shown in blue. Because most towns are too small to be seen at this scale, they have been buffered by about 500 meters for display purposes.

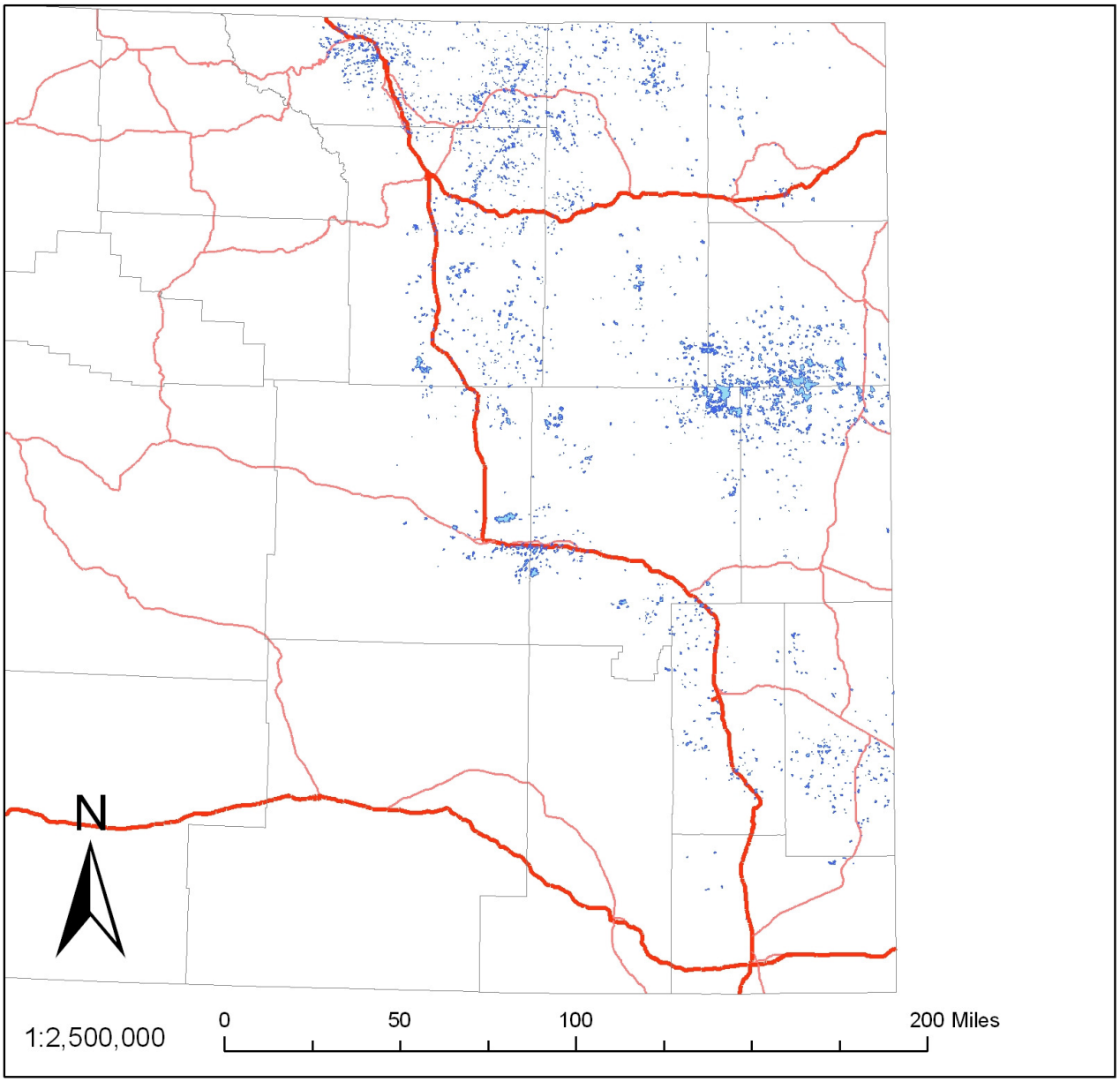
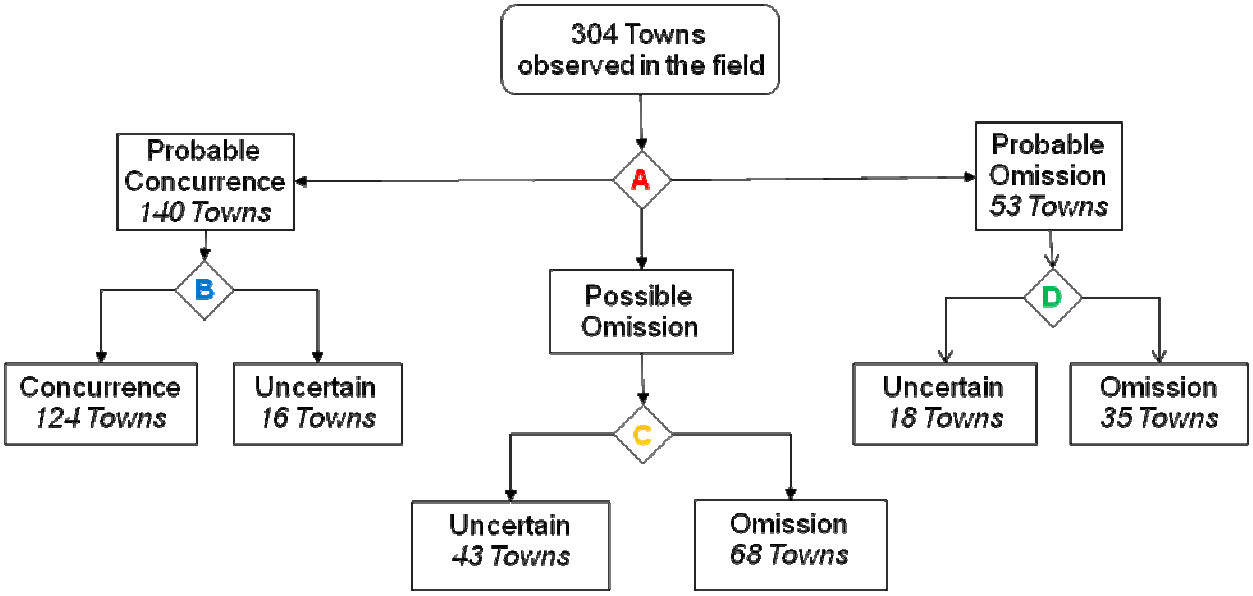


Figure 3: Summary of classification success of 304 black-tailed prairie dog towns observed along omission error transects flown in the summer of 2003. See Appendix A for description of the classification methods.



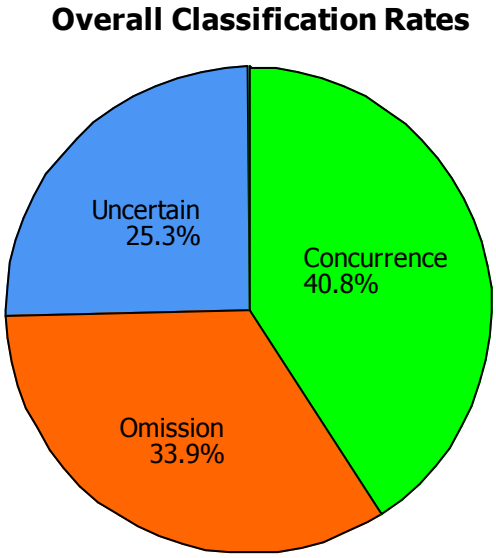


Figure 4: Map of locations evaluated by the Wyoming Natural Diversity Database for commission error. Each point represents a potential black-tailed prairie dog town mapped by the WGFD. Red, yellow and brown points were errors of commission (ant colonies, bare ground, or other features respectively).

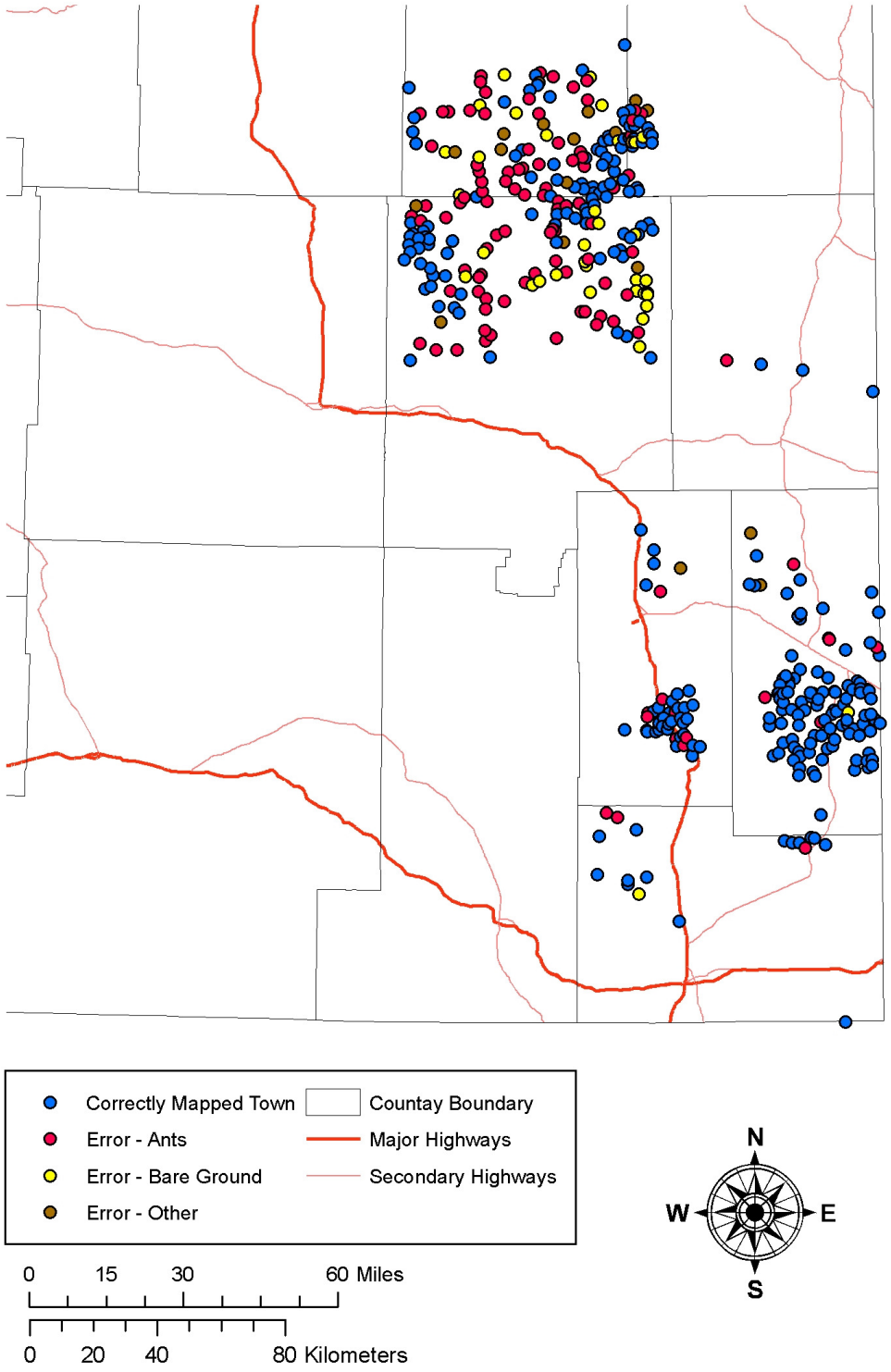
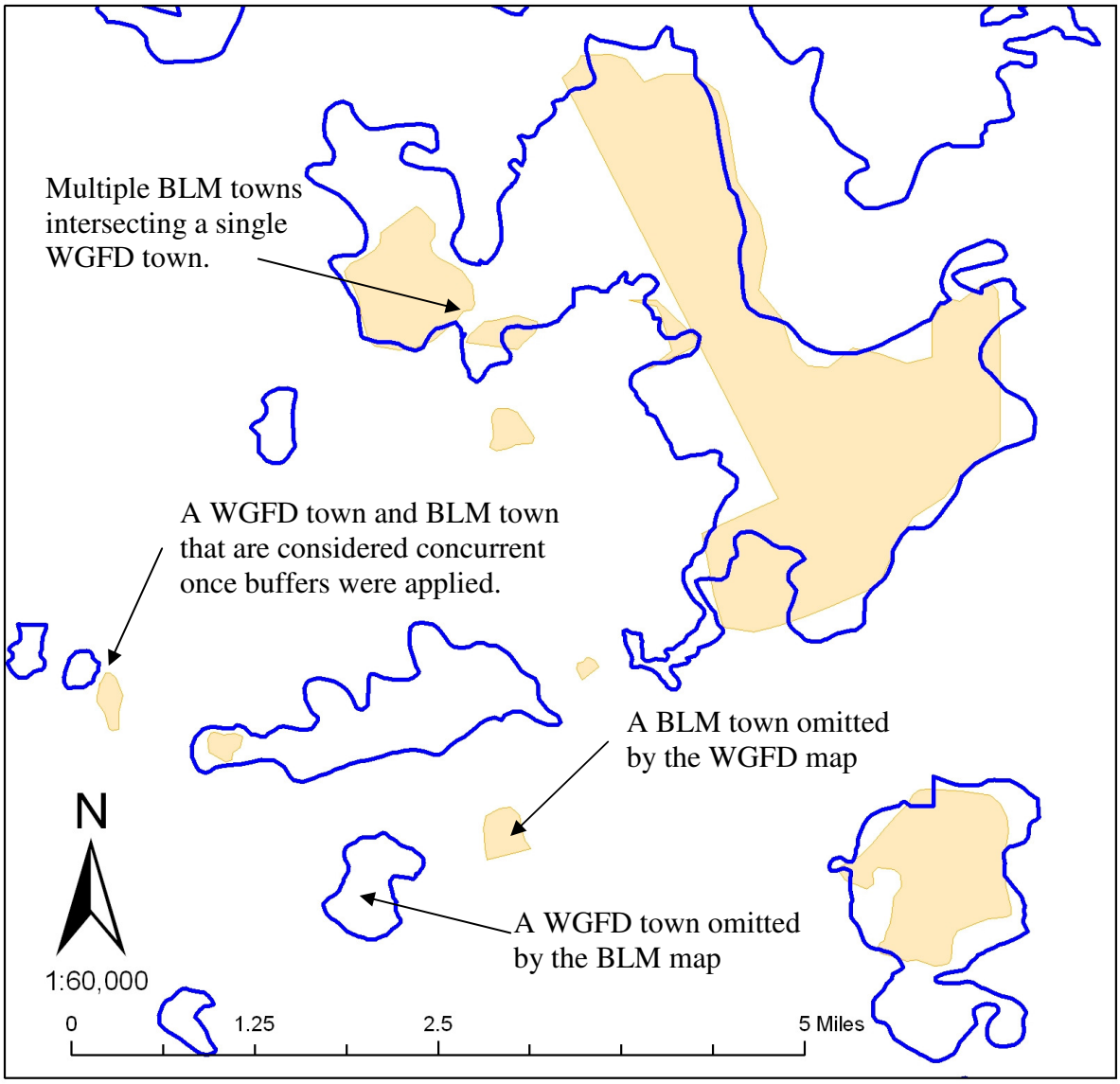


Figure 5: Examples of errors when comparing the 2007 WGFD map of black-tailed prairie dog towns (blue polygons; based on 2001 data) to the 1992 BLM Newcastle Field Office map of prairie dog towns (beige polygons). This is an image of towns occurring in northern Niobrara County on the southern edge of Thunder Basin grassland.



APPENDIX A: EVALUATING OMISSION ERROR

To evaluate omission error, we compared two shapefiles: Prairie dog town locations from aerial omission transects conducted by WYNDD (Figure 1 of main report) and prairie dog towns mapped by the WGFD and provided to WYNDD in 2007 (Figure 2 of main report).

Data Preparation

We modified both shapefiles to account for uncertainties in the data. All modifications were designed to make the omission error calculations as forgiving as possible. In other words, each modification increased acceptable buffers zones and caused towns that would otherwise have been called omissions to be considered accurately mapped. Modifications were made, as follows:

1. **Buffer WGFD polygons**: Towns on the WGFD map were buffered by 50 meters to account for random variation in location due to errors in digitizing and geo-rectification of photos and uncertainties associated with town boundaries. This is based upon summation of the following potential errors.
    a. Digitizing errors < 10 m: Errors associated with manual digitizing on 1:40K photos is on the order of meters; we assumed 10 meters as a worst-case scenario.
    b. Geo-rectification < 10 m: If geo-rectification is done appropriately, errors at specific locations on the photos are usually less than a couple meters; we assumed 10 meters as a worst-case scenario.
    c. Indistinct burrows < 30 m: Town boundaries are often indistinct at the scale of individual burrows, resulting in uncertainty in the mapped polygons, which we assumed to be 30 meters or less.

2. **Adjust placement of WYNDD observations:** Technicians performing the WYNDD omission observations from aircraft were instructed to include comments on their data sheets when they felt their recorded GPS coordinates should be shifted to more accurately represent the centroid of the associated town. We used such comments to shift observation points as follows.
    a. No comment: If no comment was provided, we assumed that the waypoint accurately captured the location of the town and did not change the coordinates.
    b. Easting corrections: If observer comments said the town was "on left", "on right", "east", "west", etc., we move the recorded waypoint 350 meters in the indicated direction, which is based upon our estimate of how far town centroids were from recorded points when comparing them to towns evident on 2001 ortho-rectified, color infrared aerial photographs. Because it appears that observers generally underestimated the distance of town centroids from the plane, we moved waypoints twice the specified distance, when a distance was indicated. For example, if the observer noted the town to be 200 meters to the west, we moved the recorded waypoint 400 meters to the west.
    c. Northing corrections: If observer comments said the town was "behind", "behind waypoint", etc., we moved the point 150 meters in the indicated direction. This

distance was determined as the approximate distance that the plane traveled in 4 seconds at a flight speed just over 80 miles per hour. If observer comment indicated the waypoint was, for example, on the "North edge of town", we moved the waypoint 75 m south, which is half the distance noted above.

3. **Minimum Buffer of WYNDD observations:** We established a minimum buffer to determine instances of Possible Concurrence in the two data sets. The minimum buffer distance of 470 meters represents a conservative estimate of possible errors in the locations of WYNDD observations that accounts for random variation in location of observed towns caused by a summation of the following potential errors:
    a. GSP error = 20 m: GPS error from the Garmin units used in this study is usually less than 20 m.
    b. Waypoint timing error = 150 m: Even when observers didn't note that their waypoint was not at the town center (see above), they may have been a few seconds off in taking waypoint information relative to the actual center of the town. We assumed that this lag-time would generally be very small; on the order of a few seconds and chose 4 seconds to be a reasonable estimate of average lag-time. Given a rough flight speed of just over 80 miles per hour this equates to about 150 m traveled by the plane.
    c. Plane pitch and altitude error = 50 m: The pilot tried to maintain a constant altitude and course during aerial surveys, but there are inevitable variations (e.g., due to weather or topography). Further, adjustments to altitude and course cause the pitch of the plane to vary periodically. Such variations would alter the field of view for the observer, resulting in location uncertainty of the GPS point with respect to the observed town. We assume that this error is on the order of 50 meters.
    d. Centroid estimation error = 250 m: Observers tried to collect observation points at the centroids of observed towns, but irregular town shape, topography and visibility considerations could have conspired to make such estimates inaccurate. It is difficult to estimate the potential size of this error, but we assume that such estimates would not be off less than half the width of the observed town. 95% of mapped towns were < 200 hectares, which translates to a circular radius of roughly 250 m.

4. **Maximum Buffer of WYNDD observations**: We intentionally over-estimated possible location errors associated with WYNDD observations with the idea that if WGFD did not map a town within these large buffers, those observations were Probable Omissions. For this case, observations were buffered by 2,650 meters to account for the largest possible uncertainty based on the following potential errors:
    a. GSP error = 50 m: This is more than double the estimate calculated for the minimum buffer. GPS error from the Garmin units used in this study is usually less than 20m, but for this analysis we assumed a worst-case scenario of extreme error in position or operator usage (e.g., incorrect assignment of project or datum).
    b. Waypoint timing = 300 m: We doubled the conservative estimate of 4 seconds flight time noted above for the minimum buffer, and assumed observers were off 8 seconds in recording the waypoint, which equates to roughly 300 m.

c. Plane pitch and altitude = 500 m: In the absence of a concrete estimate of maximum error due to the position and motion of the plane, we assumed that the multiplication of errors due to pitch and altitude could, under worst case scenario, be an order of magnitude greater than the estimate of 50 meters noted above for the minimum buffer.
d. Centroid estimation error = 1800 m: As above, we assumed that errors locating town centroids would, at most, be off by half the width of the observed town. However, for the maximum buffer, we based this distance on large towns rather than "typical" towns. About 1% of mapped towns are more than 1,000 hectares, which we considered "large." This roughly translates to a circular radius of 1,800 m.

Map Comparison

We intersected WYNDD observations (repositioned and buffered as noted above) with WGFD polygons (buffered as noted above). This intersection divided the towns into three categories, noted below and on Node A of Figure A-1.

1. Probable Concurrence: If a WGFD polygon fell within the minimum buffer distance of a WYNDD observation, that observation was considered a "Probable Concurrence," and was further evaluated as noted in Node B of Figure A-1.
2. Possible Omission: If WGFD polygons fell between the maximum and minimum buffer distances from a WYNDD observation, that observation was considered a "Possible Omission," and was further evaluated as noted in Node C of Figure A-1.
3. Probable Omission: If no WGFD polygons fell within the maximum buffer distance of a WYNDD observation, that observation was considered a "Probable Omission", and was further evaluated as noted in Node D of Figure A-1.

Each of the 304 WYNDD observations was then viewed in a GIS in conjunction with digital orthophotographs to further refine the above classifications. All instances in which the orthophotographs did not confirm a particular classification were reclassified as "Uncertain". All remaining points were classified as either "Omission" or "Concurrence", based on orthophotograph interpretation. Figures A-1 through A-7 show typical examples of all possible situations in this regard. In summary:

1. Concurrence: The WGFD map and the WYNDD observation clearly referred to the same BTPD town. These were accurately mapped towns that did not contribute to omission error.
2. Omission: The WYNDD observation clearly referred to a BTPD town that was omitted from the WGFD map. These were formally called errors of omission.
3. Uncertain: It was unclear whether the WYNDD observation referred to the same town mapped by the WGFD. Such situations often involved multiple, complexly shaped towns in close proximity or towns that were vague and/or small. These towns were removed from the dataset before we calculated our best estimate of overall omission error (45%), but were used to estimate upper (59%) and lower (34%) bounds of that estimate.

Appendix A Figures

Figure A-1: Decision tree showing how towns observed by WYNDD were evaluated to determine if they represented errors of omission on the WGFD map of black-tailed prairie dog towns.

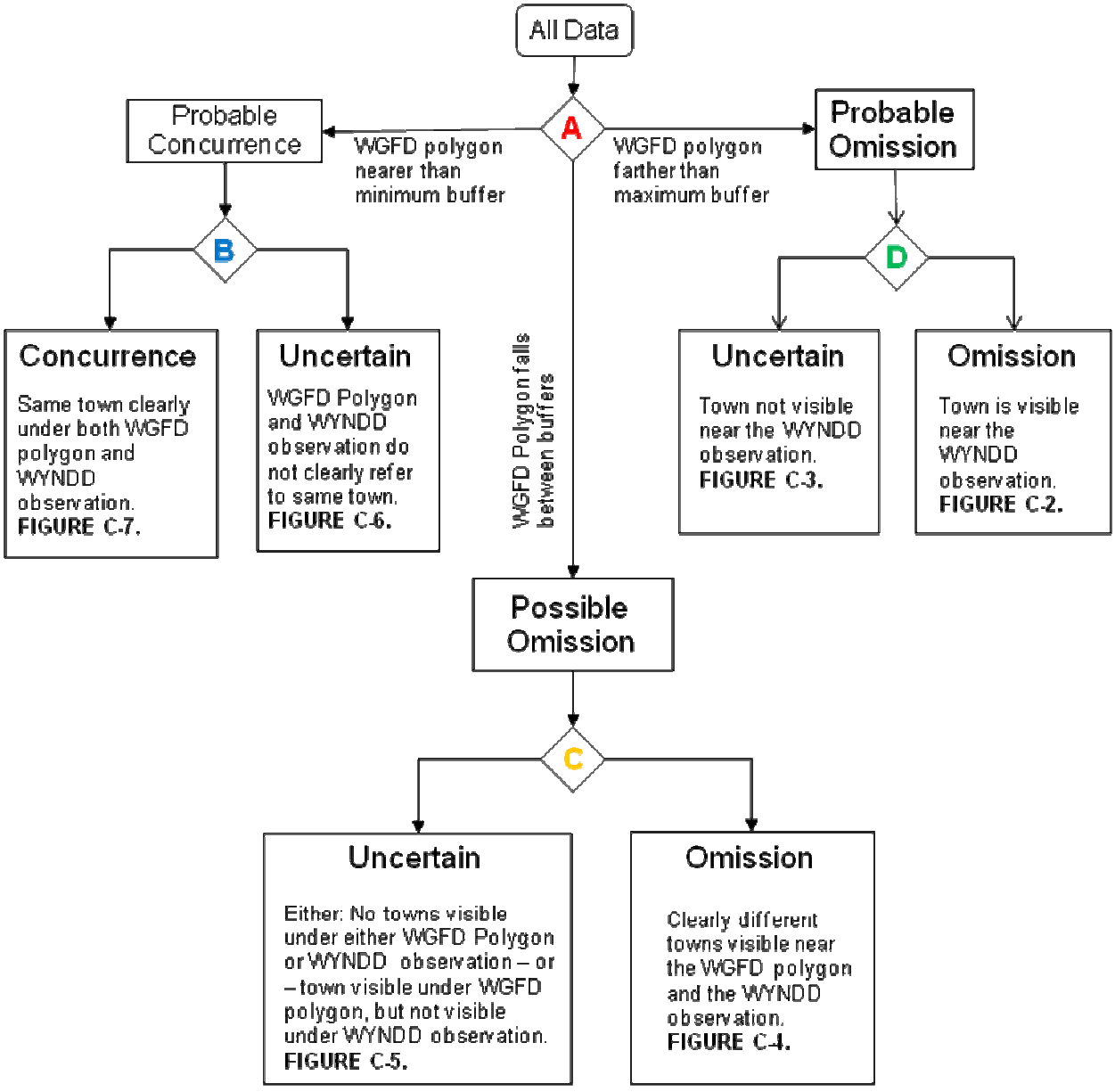


Figure A-2: Example of an omission error where no town mapped by the WGFD was within the maximum buffer distance of WYNDD Observation Number 291. The approximate boundary of the observed town is outlined in blue based on color infrared digital orthophotos taken in 2000.

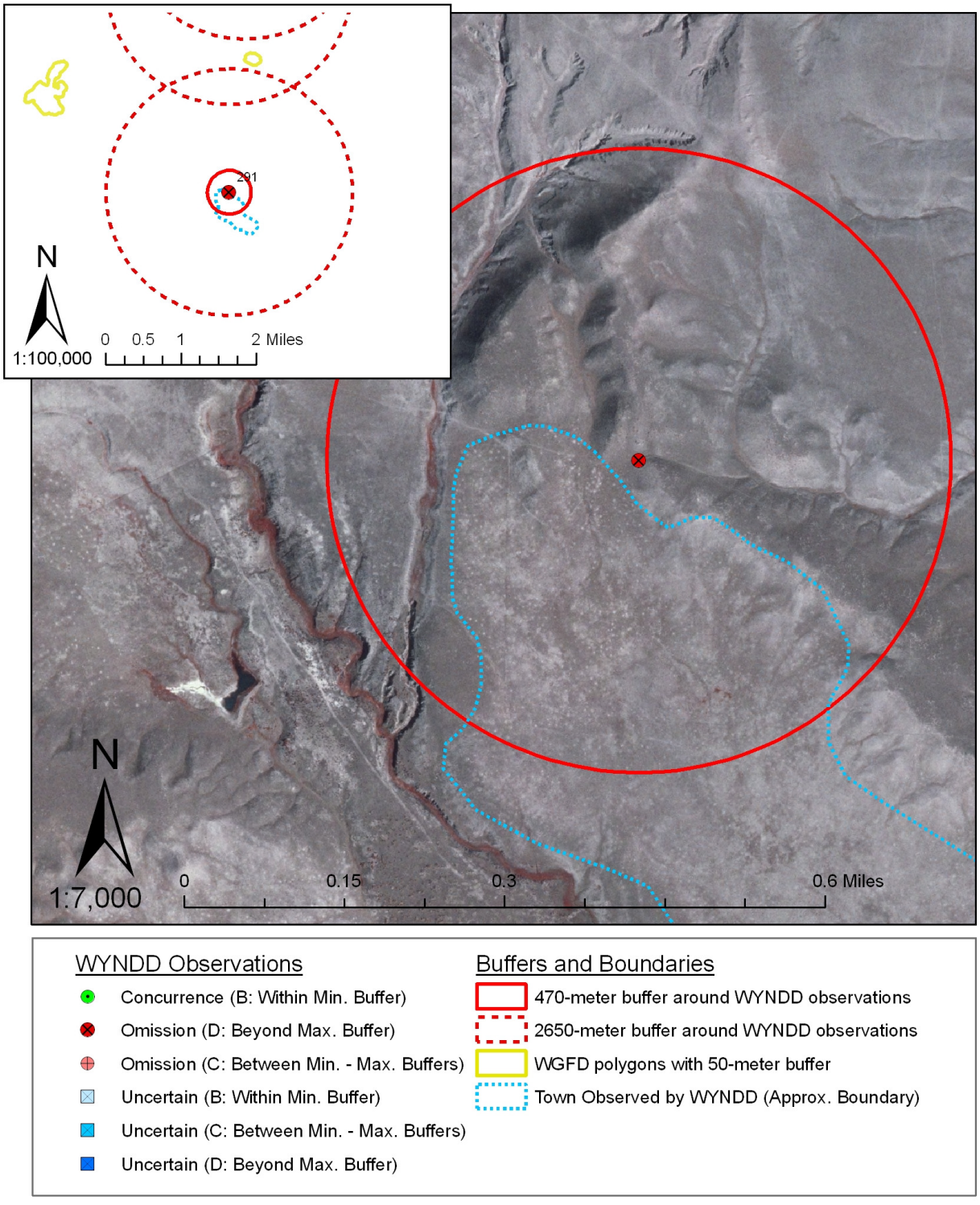


Figure A-3: Example of an observation initially labeled as an omission (because no town mapped by the WGFD was within the maximum buffer distance of WYNDD Observation Number 188), but ultimately labeled "Uncertain" after being individually evaluated. There is likely a town near this point, but it was labeled uncertain because no town was clearly visible on color infrared digital orthophotos taken in 2000.

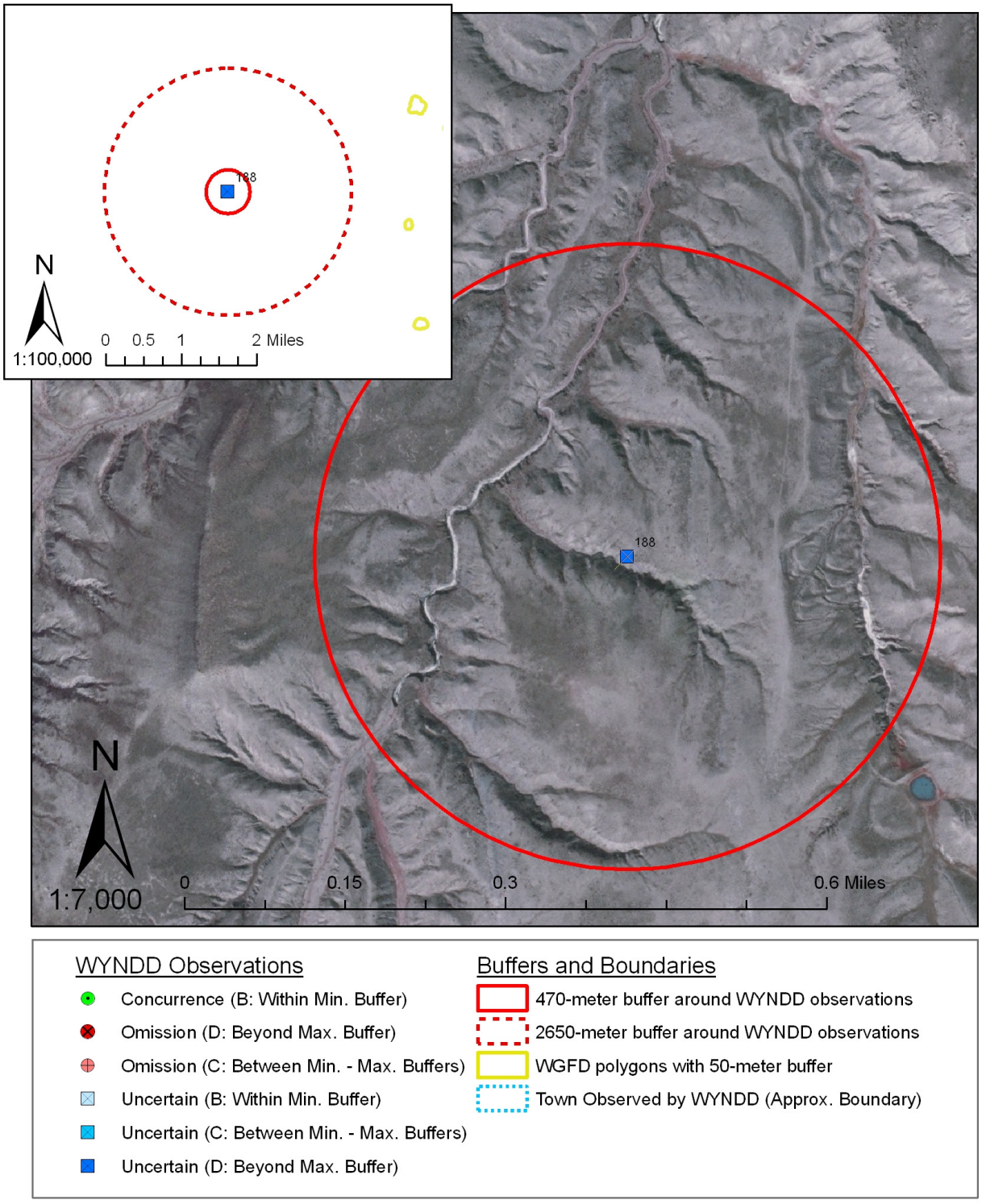


Figure A-4: Example of an observation initially labeled as a possible omission because no town mapped by the WGFD was within the minimum buffer distance of WYNDD Observation Number 240. Individual evaluation of this point confirmed that it was an omission, since there is clearly a town visible on color infrared digital orthophotos taken in 2000.

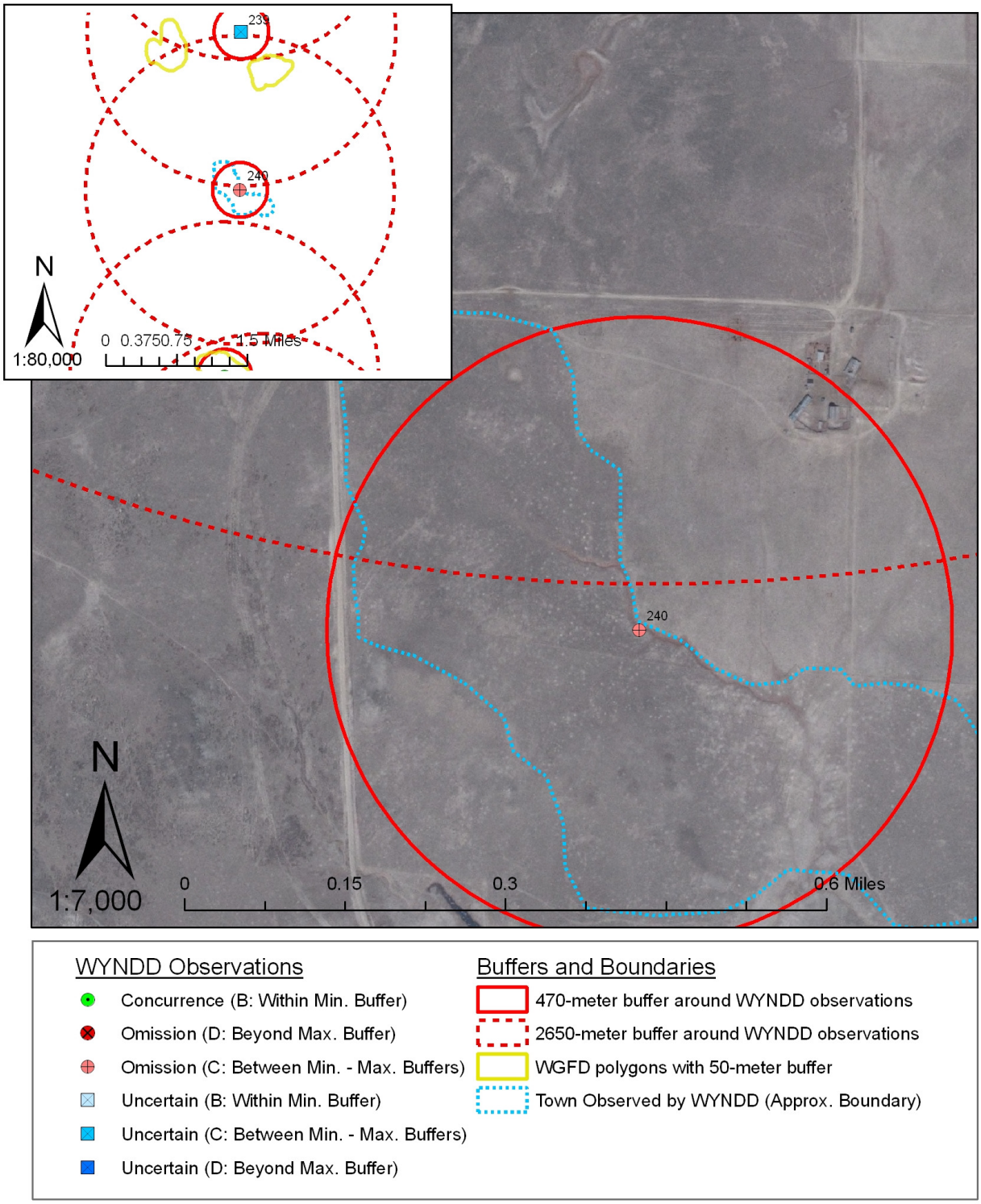


Figure A-5: Example of an observation initially labeled as a possible omission because no town mapped by the WGFD was within the minimum buffer distance of WYNDD Observation Number 213. After individual evaluation of this point, we labeled it "Uncertain," because there was only vague indication of a town on color infrared digital orthophotos taken in 2000. Later photographs, taken in 2006, clearly show a town at this location.

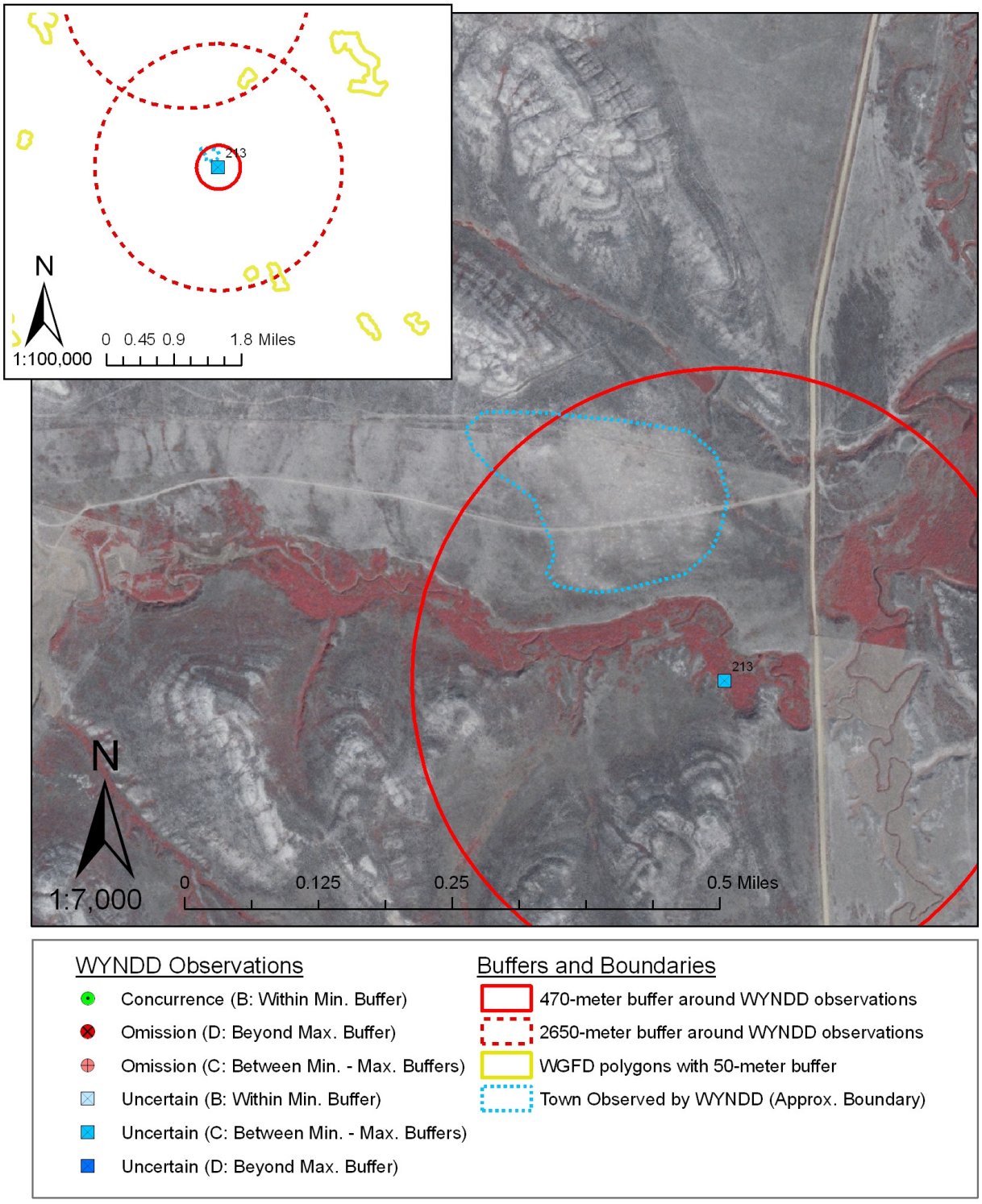


Figure A-6: Example of an observation initially labeled as a concurrent with the WGFD map of praire dog towns (because a town mapped by the WGFD fell within the minimum buffer distance of WYNDD Observation Number 262). However, after individual evaluation of this point we labeled it "Uncertain" because it was not clear that the WYNDD observation and WGFD polygon referred to the same town based on color infrared digital orthophotos taken in 2000. Moreover, there was much evident prairie dog activity that was not encompassed by the nearest WGFD polygon.

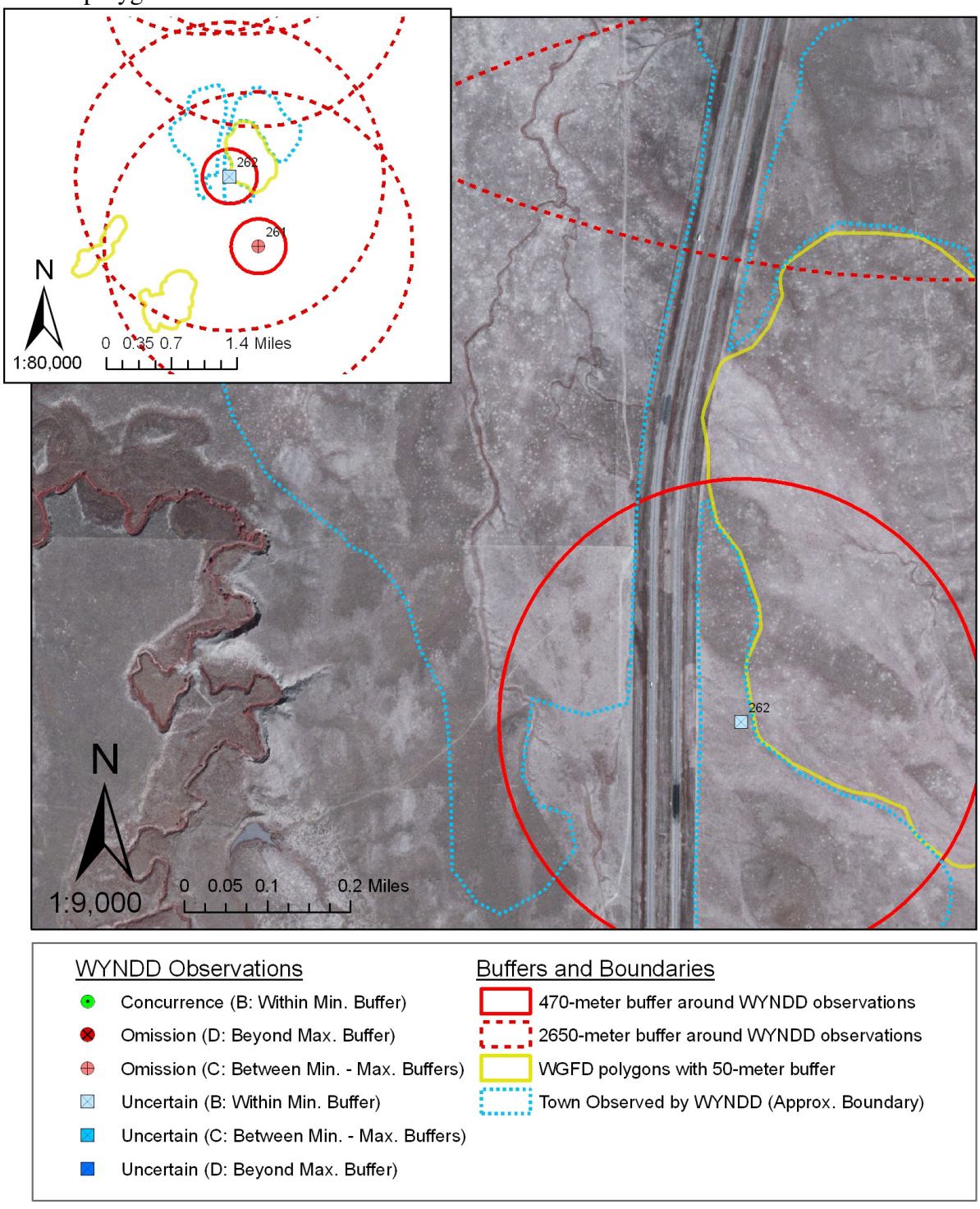


Figure A-7: Example of an observation that was labeled as concurrent with the WGFD map of prairie dog towns based on both initial classification (the town mapped by the WGFD fell within the minimum buffer distance of WYNDD Observation Number 69) and after individual evaluation using color infrared digital orthophotos taken in 2000.