MAPPING ACCURACY, ACTIVITY, AND BURROW DENSITY OF WHITE-TAILED PRAIRIE DOG COMPLEXES COMPRISING POTENTIAL HABITAT FOR BLACK-FOOTED FERRETS IN THE CONTINENTAL DIVIDE/WAMSUTTER II PROJECT AREA.

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Summary: *To assess potential habitat for black-footed ferrets (*Mustela nigripes*) in the Continental Divide/Wamsutter II Project area, locations with white-tailed prairie dog (*Cynomys leucurus*) burrows were interpreted from high-resolution aerial photographs in 2001. Because there is usually some degree of error associated with aerial interpretation, we conducted ground surveys in the project area during 2003 to assess mapping accuracy by estimating rates at which prairie dog burrow locations (polygons) were not mapped (omission errors), mapped in the wrong locations (delineation errors), or mapped where there were no prairie dogs (classification errors). Ground surveys also assessed prairie dog activity levels and burrow densities. Study design and data collection, analysis, and interpretation were complicated by the 2-year interval between aerial photography and ground surveys, the large number of small polygons interpreted from aerial photography, a sylvatic plague (*Yersinia pestis*) outbreak that catastrophically reduced prairie dog populations 1999-2001, and significant spatial correlations within and among the 26 quarter sections we intensively sampled. We used a nonstandard method for estimating burrow density that was highly efficient and suggested burrow density (4.75±3.12 active burrows/707m^2) exceeded the minimum required to support ferrets, but it is as yet uncertain whether results from our method are equivalent to results from standard methods. Though prairie dog populations in the project area have had 2-4 years to recover from plague, only 9.3±10.6% of 275 correctly classified polygons were active and occupied by prairie dogs. Of 320 mapped polygons that we sampled, 93.4% had current or former prairie dog burrows, 3.8% had no evidence of prairie dogs and had been accidentally mapped because of data handling errors, and only 2.8% had no prairie dog evidence and had been mapped because of photo interpretation and classification errors. We found that 10.9±7.1% of 237 sampled polygon boundaries had not been delineated far enough outward and that prairie dog burrows at 65.3±19.7% of omission errors were contiguous with burrows in mapped polygons, indicating that polygon delineation standards were inappropriately narrow. We found unmapped prairie dog burrows at only 7.5±3.7% of 1,597 sampled locations outside polygons; 59% of these omission errors were within 100 m of mapped polygons, 78% were within 200 m, 89% were within 300m, and 91% were within 400 m. If project area managers and planners create buffer zones around mapped polygons they could emulate wider delineation standards, rectify delineation and omission errors, reduce the likelihood of development activities encountering unmapped burrows to <1%, and provide greater protection for sensitive wildlife resources.*

INTRODUCTION

In May of 2000, the Bureau of Land Management's Rawlins and Rock Springs Field Offices (BLM) published a Record of Decision authorizing the Continental Divide/Wamsutter II (CD/WII) Project (BLM 2000). The CD/WII Project permits several energy development companies to construct up to 3,000 new natural gas wells, 2,414 km of new roads, 2,414 km of new pipeline, and other associated facilities on about 429,454 ha of land in Sweetwater and Carbon Counties, Wyoming, over a 20-year period (Figure 1; BLM 2000).

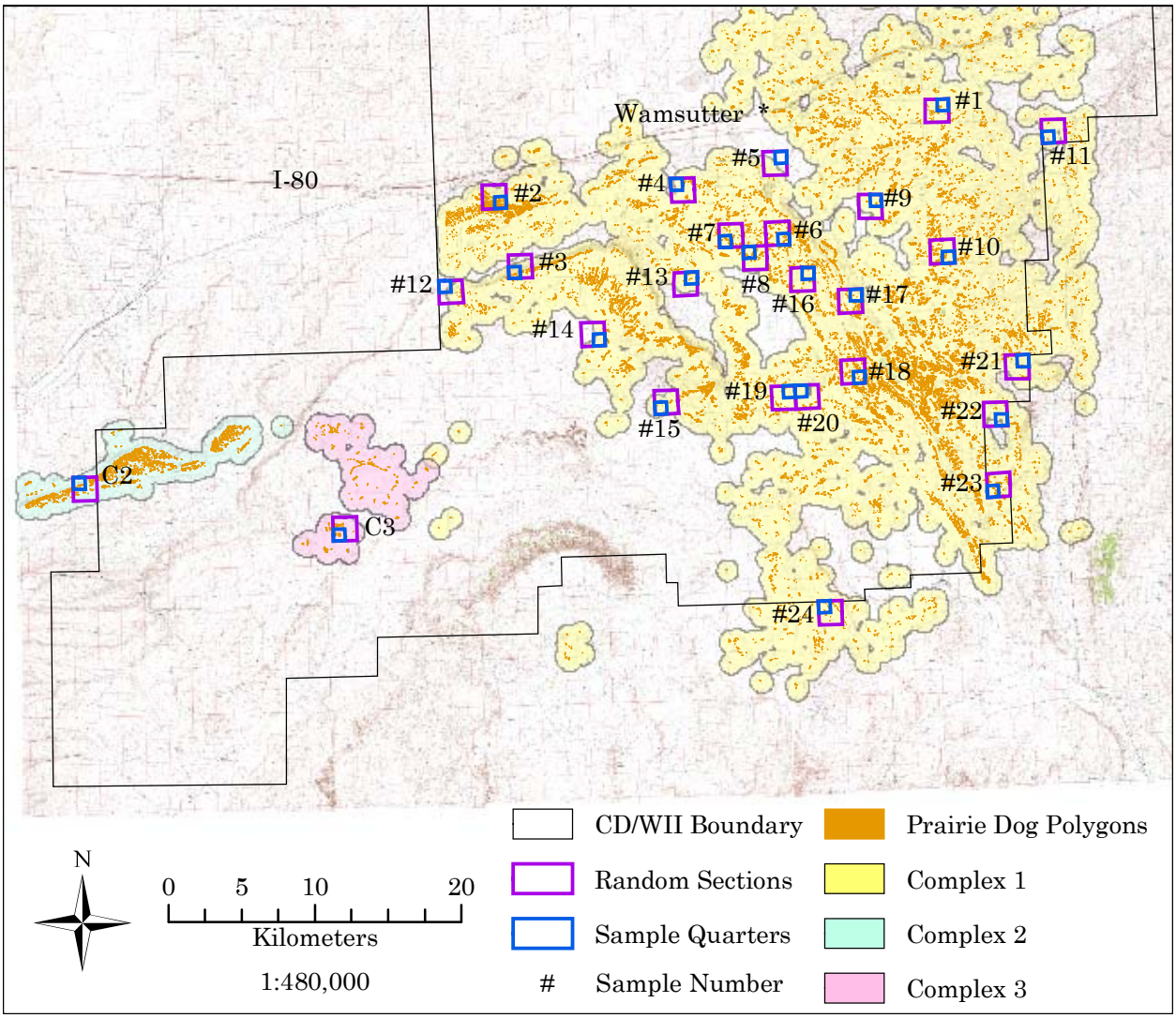

Figure 1. Locations of mapped prairie dog polygons, complexes, randomly selected sections, and quarter section sampling areas for prairie dog ground surveys in the southern half of the CD/WII project area.

Black-footed ferrets (*Mustela nigripes*; ferrets), a federally listed endangered species, were found within the CD/WII project area during the 1970's and perhaps 1980's, but whether or not there are still any ferrets in the area is unknown (BLM 2000). Ferrets are almost entirely dependent on prairie dogs (*Cynomys* spp.) for prey and shelter, and large numbers of prairie dogs are required to

maintain a ferret population (Biggins et al. 1993). Information in the project's environmental impact statement and biological assessment about the abundance of white-tailed prairie dogs (*C. leucurus*; prairie dogs) in the project area was not detailed enough to determine whether or not the project area still provides suitable habitat for ferrets (BLM 2000). The U.S. Fish and Wildlife Service (FWS) therefore required that BLM aerially map and analyze prairie dog colonies on the project area to identify where colonies are within 1.45 km of each other and cover at least 405 ha, the definition of qualifying complexes--or habitat suitable to potentially sustain some ferrets--for this project (FWS 2000).

In compliance with FWS requirements, high-resolution aerial photographs of the project area were taken during the summer of 2001 (Read 2003 and Sundberg 2003). Locations that appeared to have prairie dog burrows were interpreted and delineated from 0.3-m per pixel imagery for those portions of the project area where prairie dogs were expected to occur, and from 0.9-m per pixel imagery for the remaining portions (Sundberg 2003). Delineated burrow areas (polygons) were then entered to a geographic information system (GIS) for mapping and analyzed to determine where they had sufficient coverage and proximity to qualify as suitable ferret habitat (Read 2003). That analysis identified three qualifying complexes: Complex 1 (62,204 ha), Complex 2 (1,907 ha), and Complex 3 (1,344 ha; BLM 2002; Figure 1). BLM, the energy companies, and FWS plan on using these maps to locate new wells, roads, and pipelines outside of areas with prairie dog burrows to minimize potential project effects on ferrets, prairie dogs, and associated species, and as a baseline for possible future assessments (Read 2003).

Because some details needed to correctly map an area can be difficult or impossible to see on aerial imagery, maps made from such images can have interpretation errors. When interpretation and data entry are separate mapping steps, as with this project, there is also the possibility of data transcription or translation errors. For CD/WII it is thus possible that some prairie dog burrows were not seen on aerial images or were not mapped (omission errors). It is also possible that some areas had features that looked like burrows on aerial images and were mapped, but were not really prairie dog burrows (classification errors). And it is possible that the boundaries of burrow area polygons were mapped in the wrong locations (delineation errors) because of unseen or misidentified burrows or data entry errors. Furthermore, some characteristics of the polygons that could be important for planning or future monitoring and assessment purposes, including numbers of burrows and whether or not they're active, cannot be reliably determined from such aerial imagery. As a consequence, the project's prairie dog maps could not be reliably used for project planning or baseline purposes until rates of possible mapping errors and burrow activity were determined, and determining such rates requires ground surveys.

We were therefore contracted by BLM in September 2002 to conduct the needed ground surveys of prairie dogs in the CD/WII project area during the summer of 2003. Because our contract did not fully specify the methods to be used, and our review of the project's proceedings and data to be verified raised study design concerns, in April 2003 we presented a series of ground survey study design proposals to a technical working group of BLM, FWS, and energy company representatives (Behl and Kane 2003a). To ensure statistically reliable results, the study design that was adopted included a pilot or primary phase with intensive ground surveys of 26 quarter-sections followed by analyses of their data to see if primary sampling was sufficient to reliably estimate mapping error rates or if additional ground surveys would be needed. Significant spatial correlations within and among sampling sites restricted sample sizes and complicated the analysis and interpretation of primary sampling data (Behl and Kane 2003b), but technical working group members agreed during a 25 August 2003 telephone conference that primary sampling and data analyses were statistically reliable and that further sampling would not be necessary.

Sampling and data analyses thus completed, the purposes of this final report, in order of priority, are to: 1) describe the accuracy of CD/WII prairie dog maps, identify mapping errors,

evaluate some characteristics of those errors, identify possible error remedies, and discuss the reliability of the maps for project planning and baseline purposes; 2) describe and discuss activity status of prairie dogs in qualifying complexes; and 3) describe and discuss prairie dog burrow densities in the project area.

METHODS

Based on FWS recommendations that 10% of the sections covered by Complexes 1, 2, and 3 should be sampled, 24 sections in Complex 1, and one section each in Complexes 2 and 3 were randomly selected by BLM (Figure 1; Read 2003). Within complexes, we randomly selected a quarter section within the first BLM-selected section and then systematically selected quarters in subsequent sections in clockwise order (e.g., we randomly selected the NE ¼ of the first selected section in Complex 1 and systematically selected the SE ¼ of the second section, the SW ¼ of the third, and the NW ¼ of the fourth, etc.). If a selected section was on private property that we did not have access to, we randomly selected an adjacent section to the N, E, S, or W. If a selected quarter section was on private property that we did not have access to, we proceeded clockwise and selected the next quarter section within the section that we did have access to.

Within each selected quarter section, we used ArcView® 8.3 to identify the Universal Transverse Mercator (UTM) coordinates (North American Datum 1927) of the quarter section's SW corner from enhanced digital raster graphic files (DRGE's) of project area 7.5' quadrangles (Wyoming Geographic Information Advisory Council, wgiac.state.wy.us), and rounded the easting and northing coordinates to the next highest hundred m (e.g., we rounded 0261691 4616461 to 0261700 4616500). We took rounded coordinates as a random starting point (under the validated assumption that differences between corner and rounded coordinates were randomly distributed among selected quarter sections) and systematically selected points at 100-m intervals to the east and north until quarter section boundaries were reached (usually eight intervals and 64 total points; Appendix A). When quarter section shapes were skewed so some selected points fell on property that we did not have access to, we shifted selected points 100 m in the opposite direction.

Using BLM's GIS files and ArcView, we first stratified mapped polygons in each selected quarter section into four size classes (<223 m^2 [I], 223-2023 m^2 [II], 2,024-4,046 m^2 [III], and ≥ 4,047 m^2 [IV]) and then identified the UTM coordinates at: all polygon centers; polygon boundaries due N, E, S, and W of centers for size class IV polygons; polygon boundaries at two cardinal points, i.e. N and S or E and W, from polygon centers for size class III polygons; and polygon boundaries at one cardinal point from polygon centers for class II polygons. Cardinal directions for boundary points of the first class II and III polygons were selected at random and cardinal directions for boundary points of subsequent polygons were systematically selected in clockwise order.

Ground surveys were conducted 25 May – 2 July 2003. For each selected quarter section, we used non-differential Global Positioning System (GPS) units to locate UTM coordinates of all 100-m interval points that were not within polygon boundaries, and assessed whether or not the area within GPS error (15 m; Figure 2) of those points was correctly classified as not having prairie dog burrows conforming to the standards described in Appendix B. If any conforming burrows were found, the numbers and status (active or inactive) of burrows within 15 m were recorded, and we noted whether or not the point was contiguous with any mapped polygons or isolated from them. We also noted where we found non-conforming evidence of burrowing but no conforming burrows, and where points had been disturbed by new wells, pipelines, or roads constructed after aerial photographs were taken in 2001. We then used GPS units to locate UTM coordinates of all polygon centers within selected quarter sections, and assessed whether or not the polygon was correctly classified as containing prairie dog burrows conforming to Appendix B standards. If so, we assessed polygon status by determining if there were any active burrows within the polygon and recorded numbers and status of burrows within 15 m of polygon centers. As at 100-m interval points, we also

noted if polygons contained non-conforming evidence of burrowing when there were no conforming burrows, and if they had been disturbed by recent construction. For size class II, III, and IV polygons, we then located the UTM coordinates of each polygon's pre-selected cardinal boundary points and assessed whether or not the polygon boundary was within the 15-m GPS error of that point.

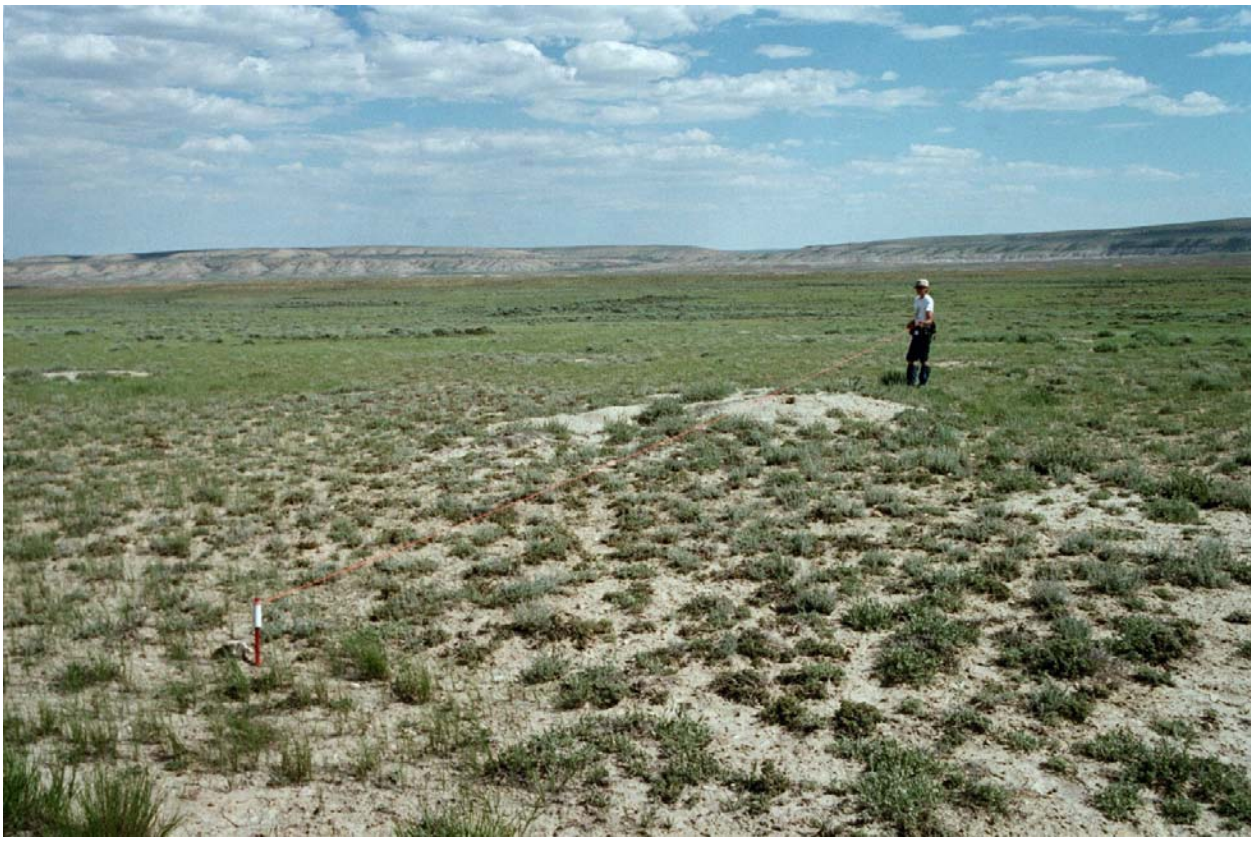

Figure 2. Field assistant using a stake and 15-m cord to mark UTM coordinates and circumscribe perimeters of 15-m radius circular plots used to sample prairie dog burrow presence and density at 100-m interval points and polygon centers during ground surveys of prairie dog mapping in the CD/WII project area.

Field classifications and UTM coordinates of 100-m interval points were input to database files, and field classifications of sampled polygons and classifications and coordinates of sampled polygon boundaries were input to shapefiles for mapping and spatial analyses with ArcView. Then, for each sampled quarter section we tallied the numbers of 100-m interval points, polygons, and polygon boundary points that were correctly and incorrectly classified, numbers of points and polygons with evidence of non-conforming burrows, numbers of incorrectly classified 100-m interval points that were contiguous and isolated, numbers of disturbed points and polygons, and numbers of active and inactive polygons, and entered the tallies to Microsoft Excel® 2000 spreadsheets. As each of these variables had only two possible responses (e.g., correct or incorrect, contiguous or isolated, active or inactive), we used binomial estimators (Steel and Torrie 1980) to determine mean proportions and variances of responses for each quarter section. For each quarter section we also input burrow numbers to spreadsheets and calculated means and variances for densities of active and inactive burrows among active and inactive polygons and among active and inactive 100-m

interval points. We then used Excel to perform log-likelihood ratio (*G*) tests to see if the frequencies of yes, no, active, and inactive responses were homogenous enough among quarter sections to use individual points and polygons as sampling units and then pool them, and single classification one-way analysis of variance tests (ANOVAs) to see if burrow densities were homogenous enough among quarter sections for pooling (Sokal and Rohlf 1981). Those tests found significant differences among quarter sections, particularly those in Complexes 2 and 3, indicating that we would have to use quarter sections as sampling units for project area estimates rather than individual points and polygons (Behl and Kane 2003b). Accordingly, we calculated means and variances of the 26 quarter section proportion and density estimates to obtain overall estimates for the project area.

To explain the significant spatial differences among quarter section samples and justify pooling Complex 2 and 3 samples with Complex 1, we first used correlation and simple linear regression analyses (Zar 1974) to explore possible relationships between quarter section estimates and suspected spatial attributes identified from GIS and field data. We then used the GLM function in SYSTAT® 10.2 to combine significant variables in a multiple linear regression model, run stepwise model selection procedures, calculate regression parameter estimates, and test for differences between complexes (Behl and Kane 2003b). All α (Type I error) for statistical tests and confidence intervals were set at 0.05.

RESULTS

Prairie Dog Burrow Density

The standard method for estimating burrow density (Biggins et al. 1993) yields estimates on a burrows-per-ha basis, but was designed for complexes where mapped prairie dog polygons are large enough to use 3 x 1000 m strip transects. We were able to estimate burrow densities, but mapped prairie dog polygons in CD/WII complexes were too small for strip transects so we used 15-m radius circular plots, and per ha burrow density estimates for CD/WII prairie dog complexes from our samples might not be directly comparable to estimates from other areas or methods. Accordingly, we calculated prairie dog burrow density estimates for CD/WII complexes on a per-15-m radius plot basis, but also report them on a per-ha basis (Table 1).

Burrow densities were moderately to highly variable and had small to moderate sample sizes, resulting in estimates with poor precision and 95% confidence intervals so wide that most differences among burrow types and locations would not be significant if tested statistically (Table 1). Even so, if burrow density estimates were reasonably accurate, then active polygons had more active than inactive burrows, and had more burrows than inactive polygons; active polygons also had slightly more burrows of both types than active 100-m points; active 100-m points had more active than inactive burrows, and more burrows in general than inactive 100-m points; and inactive polygons had more burrows than inactive 100-m points (Table 1).

Though we did not track time spent at the 390 individual 15-m radius plots, based on the amounts of time it took to sample entire quarter sections and the numbers of plots in each, we estimate that classifying, counting, and recording numbers of burrows probably averaged about 7-8 minutes per 15-m radius plot and ranged from < 5 minutes to > 10 minutes depending on numbers and activity of burrows, manpower (one or two persons assessing plots), vegetation, and other factors.

Polygon Activity Rates

Anecdotal information (Sundberg 2003) and field evidence indicated that a sylvatic plague (*Yersinia pestis*) outbreak sometime between 1999 and 2001 significantly reduced prairie dog populations in the project area. As a consequence, polygon activity rates observed during our 2003

ground surveys were low: only an estimated 9.3±10.6% of polygons among sampled quarter sections were active, with 91.7±10.6% inactive (Table 1). Neither the locations of quarter sections with active polygons or 100-m interval points (Complex 1 samples 2, 3, 8, 21, and Complex 2; Figure 1), nor our casual observations while traveling in the project area provided clear evidence that prairie dog activity rates followed any broad geographic patterns across the project area. Sampled quarter sections and thus our travel routes were located randomly, however, so there could have been geographic patterns that we weren't able to detect without samples systematically located throughout the project area.

Table 1. Densities of prairie dog burrows conforming to Appendix B standards, proportions of active and inactive polygons, 95% confidence interval limits, sample sizes, and variances estimated from ground surveys in the CD/WII project area.

Variable	*Area*	*Mean*	*Lower 95% CL*	*Upper 95% CL*	n	s^2
Active burrows in active polygons	*Per 15-m radius plot*	*4.75*	*3.44*	*6.06*	*4*	*0.67665*
	Per ha	*67.27*	*48.7*	*85.7*	*4*	*135.43*
Inactive burrows in active polygons	*Per 15-m radius plot*	*3.97*	*-1.54*	*9.48*	*4*	*12.004*
	Per ha	*56.2*	*-21.8*	*134*	*4*	*2402.5*
Inactive burrows in inactive polygons	*Per 15-m radius plot*	*3.00*	*2.32*	*3.68*	*21*	*2.2295*
	Per ha	*42.4*	*32.8*	*52.1*	*21*	*446.21*
Active burrows at active 100-m points	*Per 15-m radius plot*	*5.83*	*-3.00*	*14.7*	*4*	*30.816*
	Per ha	*82.5*	*-42.5*	*207*	*4*	*6167.4*
Inactive burrows at active 100-m points	*Per 15-m radius plot*	*1.24*	*0.167*	*2.31*	*4*	*0.45229*
	Per ha	*17.5*	*2.37*	*32.6*	*4*	*90.522*
Inactive burrows at inactive 100-m points	*Per 15-m radius plot*	*1.96*	*1.56*	*2.36*	*19*	*0.68189*
	Per ha	*27.7*	*22.1*	*33.3*	*19*	*136.47*
Active polygons	-	*0.093*	*-0.013*	*0.199*	*22*	*0.05686*
Inactive polygons	-	*0.907*	*0.801*	*1.013*	*22*	*0.05686*

Mapping Accuracy

Polygon classification errors. Before we began field sampling, we learned that mountain plover (*Charadrius montanus*) habitat had also been interpreted from the same aerial imagery as prairie dog polygons, and that some mountain plover habitat polygons had been accidentally entered to BLM's GIS files as Complex 3 prairie dog polygons (Sundberg 2003). Though BP Amoco provided us with aerial imagery correctly distinguishing prairie dog and mountain plover polygons (Sundberg 2003; Figure A-26), the GIS data we received from BLM had not yet been corrected, and it raised concerns about which set of mapping data we should verify. Rather than choose between the two data sets, we verified both of them and designated results based on BLM's GIS mapping as uncorrected, and results based on BP Amoco's (Sundberg 2003) aerial imagery as corrected (Table 2).

Table 2. Proportions of correctly and incorrectly mapped points and prairie dog burrow polygons and their 95% confidence interval limits, sample sizes, and variances estimated from ground surveys in the CD/WII project area.

Variable	*Type*	*Mean*	*Lower 95% CL*	*Upper 95% CL*	n	s^2
Correct polygons	*All (Complex 3 uncorrected)*	*0.842*	*0.746*	*0.938*	*22*	*0.04711*
	All (Complex 3 corrected)	*0.880*	*0.810*	*0.950*	*22*	*0.02508*
Incorrect polygons (classification error rate)	*All (Complex 3 uncorrected)*	*0.158*	*0.062*	*0.254*	*22*	*0.04711*
	All (Complex 3 corrected)	*0.120*	*0.050*	*0.190*	*22*	*0.02508*
	Non-conforming evidence	*0.092*	*0.030*	*0.154*	*22*	*0.01935*
Disturbed polygons	*All*	*0.020*	*-0.001*	*0.041*	*22*	*0.00219*
Correct boundaries	*All*	*0.891*	*0.819*	*0.962*	*22*	*0.02614*
Incorrect boundaries (delineation error rate)	*All*	*0.109*	*0.038*	*0.181*	*22*	*0.02614*
Correct 100-m points	*All*	*0.925*	*0.889*	*0.962*	*26*	*0.00835*
	Non-conforming evidence	*0.030*	*0.011*	*0.050*	*26*	*0.00231*
Incorrect 100-m points (omission error rate)	*All*	*0.075*	*0.038*	*0.111*	*26*	*0.00835*
	Contiguous with polygons	*0.653*	*0.455*	*0.850*	*20*	*0.17799*
	Isolated from polygons	*0.348*	*0.150*	*0.545*	*20*	*0.17799*
Disturbed 100-m points	*All*	*0.005*	*0.001*	*0.010*	*26*	*0.00014*

When using corrected results from Complex 3, we found that 88.0±7.0% of polygons in sampled quarter sections (22 quarter sections, 316 polygons) had prairie dog burrows conforming to Appendix B standards somewhere within polygon boundaries and were thus classified correctly, while 12.0±7.0% did not have conforming burrows and were designated as incorrectly classified (Table 2, Appendix A). When using uncorrected results from Complex 3, 84.2±9.6% of sampled quarter section polygons (320 polygons) had conforming prairie dog burrows and were correctly classified, while 15.8±9.6% did not have conforming burrows and were designated as incorrectly classified (Table 2, Appendix A). We found non-conforming evidence of burrows at 9.2±6.2% of sampled polygons (Table 2, Appendix A), however, indicating the percentage of interpreted and mapped polygons that had absolutely no evidence of prairie dog burrows was as low as 2.8% for corrected results and 6.6% for uncorrected results. Considering that differences between corrected and uncorrected results were caused solely by data transcription or translation rather than interpretation errors, these differences indicate that polygons were incorrectly interpreted from aerial imagery only 2.8% of the time, and that 3.8% of all polygons would not have been mapped if data handling were flawless.

Of prairie dog polygons with centers inside sampled quarter sections, an estimated 2.0±2.1% had been disturbed by well, road, or pipeline construction since aerial photographs were taken in 2001, and were omitted from mapping accuracy analyses (Table 2, Appendix A).

<u>Polygon boundary delineation errors</u>. We checked polygon boundaries at 237 points among the 22 quarter sections with polygons, and found that an estimated 89.1±7.2% of boundaries were

located within the 15-m error of our GPS units (Table 27). Of the 10.9±7.2% of polygon boundaries that ground surveys indicated were more than 15 m from mapped locations (Table 2), all were located outside of mapped polygon boundaries and none were located inside mapped boundaries (Appendix A).

Omission errors. We did not sample any 100-m interval points that fell within mapped polygon boundaries, so sampled 100-m interval points should not have had any prairie dog burrows if aerial photos and prairie dog polygons were correctly interpreted and mapped. Based on the mean of all 26 quarter section samples, about 92.5±3.7% of 100-m interval points checked during ground surveys (1597 points) didn't have any prairie dog burrows conforming to Appendix B standards within 15 m, and their locations were thus classified as correctly mapped (Table 2). Though classified as correctly mapped, we noted that at least 3.0±1.9% of these 100-m points had some evidence of burrowing but did not meet Appendix B standards (Table 2, Appendix A). Additionally, about 7.5±3.7% of sampled 100-m interval points did have prairie dog burrows conforming to Appendix B standards within 15 m, should have been interpreted and mapped within a polygon but were not, and thus estimate mapping omission error rates (Table 2, Appendix A).

Of these omission errors at 100-m interval points, field evidence suggested to us that burrows at 65.3±19.7% of them were contiguous with burrows in nearby mapped polygons, while only 34.8±19.7% of them were separate or isolated from mapped polygons (Table 2). Our GIS analyses with ArcView also found that most omission errors were near polygons: more than half of all incorrectly classified 100-m points (59%) were located within 100 m of mapped polygons, more than three quarters (78%) were within 200 m, and almost 90% (89%) were within 300 m, while fewer 100-m points with non-conforming evidence of burrowing were found near polygons (Table 3, Appendix A). Besides being more common near polygons in general, our field observations suggested that omission errors were even more frequent near active polygons. To further explore these possible relationships, we performed correlation and multiple linear regression analyses. For sampled quarter sections, these analyses found significant correlations between numbers of correctly classified polygons, total area of correctly classified polygons, polygon activity rates, and omission error rates (Table 4). We then constructed and selected a multiple linear regression model with correctly classified polygon numbers, total area, and activity rate as independent variables, and omission error rate as the dependent variable (Behl and Kane 2003b). As with simple linear regression analyses, the selected multiple linear regression model also yielded a significant relationship between omission error rates and correctly classified polygon numbers, polygon areas, and polygon activity rates ($r = 0.762$; $se_r = 0.067$; $n = 22$; $F = 8.306$; d.f. = 3, 18; $P = 0.001$).

Table 3. Numbers and percentages of 100-m interval sampling points that were incorrectly classified or had non-conforming evidence of burrowing, by distance class from nearest polygon, based on ground surveys in the CD/WII project area.

Variable	*≤ 100 m*	*≤ 200 m*	*≤ 300 m*	*≤ 400 m*	*≤ 500 m*	*≤ 600 m*	*≤ 700 m*	*≤ 800 m*	*All*
Incorrect 100-m points	*69*	*93*	*103*	*105*	*109*	*111*	*113*	*113*	*116*
%	*59%*	*78%*	*89%*	*91%*	*94%*	*96%*	*97%*	*97%*	*100%*
Non-conforming evidence	*7*	*25*	*29*	*34*	*36*	*37*	*38*	*39*	*46*
%	*15%*	*54%*	*63%*	*74%*	*78%*	*80%*	*83%*	*85%*	*100%*
Totals	*76*	*118*	*132*	*139*	*145*	*148*	*151*	*152*	*162*
%	*47%*	*73%*	*81%*	*86%*	*90%*	*91%*	*93%*	*94%*	*100%*

Table 4. Results of correlations between prairie dog mapping error rates and spatial variables within quarter sections sampled during ground surveys in the CD/WII project area.

Variable	*Parameters*	*Correctly Classified Polygon Numbers*	*Correctly Classified Polygon Acres*	*Polygon Activity Rate*
Incorrect 100-m points (omission error rate)	*Slope*	*0.005*	*0.012*	*0.299*
	r	*0.768*	*0.745*	*0.572*
	s.e. of r	*0.137*	*0.142*	*0.175*
	t	*5.623*	*5.236*	*3.275*
	n	*24*	*24*	*24*
	P	*< 0.001*	*< 0.001*	*0.003*

An estimated 0.5±0.5% of 100-m interval points outside polygon boundaries had been disturbed by well, road, or pipeline construction since aerial photographs were taken in 2001, and were omitted from mapping accuracy analyses (Table 2, Appendix A).

DISCUSSION

Prairie Dog Burrow Density

Estimating prairie dog burrow densities was the lowest priority objective for ground surveys, so we are not greatly concerned about the poor precision of density estimates. That active samples consistently had more active burrows than inactive burrows along with more burrows than inactive samples, while mapped polygons consistently had more burrows than 100-m interval points conforms with what we would have expected and supports the likelihood that density estimates were reasonably accurate on a 15-m radius plot basis even if they weren't precise. Though low prairie dog activity levels and at least two years of weathering since the reported plague outbreak could have reduced numbers of conforming burrows, our 15-m radius plots were located at polygon centers where burrows could well be most dense, and interpreted polygons for CD/WII were smaller and more focused on high burrow density areas than other prairie dog mapping projects we've seen reported (e.g. Biggins et al. 1993). We therefore believe these results apply only to burrow densities near polygon centers, and we report burrow density estimates on a per ha basis with caution because results could be misinterpreted as applying to larger areas such as whole polygons or whole complexes. If, however, burrows are distributed uniformly or randomly within polygons rather than being clustered so that 15-m radius plot estimates are representative of overall polygon burrow densities (an assumption with no field evidence to support or refute it), then active burrow densities in active polygons (67.27 burrows/ha) would considerably exceed the 25 active burrows/ha minimum thought necessary to support ferrets (Biggins et al. 1993).

We were also interested in comparing the performance of our 15-m radius plots to the standard strip transects of Biggins et al. (1993). Though classifying and counting burrows in 15-m radius plots added about 49 hours of field time to ground surveys, the plots gave us burrow counts to corroborate our polygon and 100-m point error classifications, allowed us to collect 320 density samples in the amount of time it would have taken to get about 86 samples using strip transects based on Biggins et al.'s (1993) labor estimates, and further reduced total field time needed to combine density with other sampling because we could collect density and other data at the same time and place rather than separately. Circular plots do tend to yield estimates with higher variances per unit area than long rectangular plots such as strip transects (Gysel and Lyon 1980) and our estimates had very high variances. However, our estimated variances and 95% confidence intervals would have been an average of 80% smaller or more precise (unpublished data) if

significant differences among sampled quarter sections hadn't prevented us from pooling the 320 samples and reduced sample sizes to 4-21 (Table 1). Strip transects would have had the same pooling problems and we believe the greater sample size per unit field time of 15-m radius plots reduced variances more than changing plot shape and size would have. The greatest drawbacks of the 15-m radius plots we see in comparison to strip transects was their location at polygon centers that might not be representative of overall polygon burrow density, and thus the comparability of results to other studies using strip transects--a problem that could be overcome by locating plots differently. And though 15-m radius plots might have allowed us to collect more samples per unit time, as with strip transects they only estimate burrow density and might be a poor indicator of actual population density (Severson and Plumb 1998).

Polygon Activity Rates

Though we don't know exactly when, anecdotal information (Sundberg 2003) and field observations provide good evidence that there was a plague outbreak in the CD/WII project area sometime between 1999 and 2001, so prairie dog populations in the area should have had 2-4 years to recover. Prairie dogs have little or no immunity to plague, suffer nearly 100% mortality if infected, and populations can be wiped out over large areas in a matter of weeks or months, but can also persist where population densities and thus disease transmission rates are low, or uninfected colonies are isolated from infected ones (Barnes 1993, Cully 1993). For example, plague killed 85% of prairie dogs in 4 months at a study site in southern Wyoming, but only about 51% of prairie dogs at Meeteetse (Cully 1993). Prairie dog populations that do experience and survive an outbreak usually require 4-5 years of recovery to reach the levels they were at before the outbreak (Barnes 1993). There is no way for us to know what proportion of prairie dog polygons in the project area were active when aerial photographs were taken in 2001 or before the outbreak, but that only 9.3% of polygons were active during ground surveys at least 2 years later in 2003 suggests to us that CD/WII prairie dog populations were hit unusually hard by the outbreak or have been unusually slow to recover, and it highlights the catastrophic effects of plague on prairie dogs and ferrets and their ability to maintain viable populations.

Because neither our sampling data nor other field observations indicated that the distribution of active polygons followed any particular geographic patterns across the project area, we know of no reliable way to predict where un-sampled polygons should be active. As a consequence, project area managers and planners won't be able to classify un-sampled polygons as active or inactive from mapping data and will have to conduct site visits and field assessments to make those determinations.

Because of the 2-year time lag between when aerial photographs were taken and ground surveys conducted, it was possible that prairie dogs could have colonized new areas outside mapped polygon boundaries and created false delineation or 100-m point omission errors, and our correlation and multiple linear regression analyses found that omission error rates did increase as polygon activity rates increased (Table 4). While in the field we therefore looked for evidence that prairie dogs had colonized new areas wherever we found delineation or omission errors with active burrows. In all such cases, active burrows were surrounded by old inactive burrows that were present when aerial photographs were taken, so no delineation or omission errors were created by prairie dogs colonizing new areas.

Mapping Accuracy

Polygon classification errors. There was a continuum for non-conforming evidence of prairie dog burrowing that ranged from areas that clearly had prairie dog burrows at some time in the past but inactivity and erosion had closed burrow entrances, through areas with burrows that had clearly been made by prairie dogs sometime in the past but had since been occupied by Wyoming ground

squirrels (*Spermophilus richardsonii*) and/or badgers (*Taxidea taxus*), to areas with unclear evidence that burrows might have been made by prairie dogs before being occupied by ground squirrels or badgers. Though combined for data analysis because distinctions between these evidence types would have been arbitrary and sample sizes would have been small, the 9.2% of non-conforming polygons were predominantly areas with clear evidence of past prairie dog occupancy. These non-conforming polygons tended to be near other mapped polygons with conforming burrows (Appendix A) and could be re-colonized by prairie dogs at some point in the future as the population recovers from plague, so we believe that non-conforming polygons should not be considered mapping errors and project area managers and planners should treat them as conforming polygons for planning and monitoring purposes.

Of the other 6.6 % of misclassified polygons that had no evidence of prairie dogs, 77% or 3.8% of all polygons were misclassified because Complex 3 prairie dog maps were inadvertently created from mountain plover interpretation (Figure A-26). Some omission errors also appear to have been caused by data transcription or translation errors (e.g., samples 6, 8, and 13, Figures A-6, A-8 and A-13). Given human imperfection, some data handling errors are inevitable with any large data set, and the observed number of data handling errors for CD/WII mapping might well be lower than average considering the size and complexity of the data sets. That these were merely data handling errors, however, suggests that classification errors could be reduced by further reviews of the data, and points out the importance of good data handling and checking procedures.

In our view, the remaining 2.8% of mapped polygons with no field evidence of prairie dogs represents an interpretation and classification error rate that is unusually low and should be acceptably small enough for most project area planning and monitoring purposes.

<u>Polygon boundary delineation errors</u>. We checked polygon boundaries at individual points with 15-m buffers rather than trying to assess boundary lines or segments in order to minimize the possibility of finding false boundary delineation errors caused by habitat changes between 2001 and 2003, GPS error, or boundary interpretation and delineation differences between observers (Behl and Kane 2003a). We are confident that we applied the same polygon boundary delineation standards in the field as were used to interpret the aerial photography, and that our 10.9% delineation error estimate does not include false errors caused by temporal changes, GPS error, or observer differences. Nevertheless, we would be skeptical about the locations of mapped polygon boundaries if we were planning a development project in the area because we believe the delineation standards used were inappropriately narrow, as evidenced by the fact that all boundary errors were cases where delineated boundaries did not extend far enough outward and 65% of omission errors were contiguous with mapped polygons. Had delineation standards been appropriate, there should have been at least some boundary errors where delineated boundaries extended too far out, fewer delineation errors, or less proximity of omission errors to mapped polygons. It occurs to us that project area managers and planners might share our concern that boundary delineation standards were inappropriately narrow, or believe that delineation error rates are too high, and thus find that current polygon boundary mapping is unacceptable for planning purposes. Fortunately, it would be very easy to emulate wider standards and rectify delineation errors without re-mapping the project area by simply using a GIS to create appropriate buffers around polygon boundaries and produce mapping that would be acceptable for planning purposes.

<u>Omission errors</u>. In contrast to the non-conforming burrows found within mapped polygons, non-conforming evidence of burrowing at 100-m interval points was found only 3.0% of the time, was less clear, and was found farther from mapped polygons (Table 3). These factors reduce the likelihood that 100-m point non-conforming burrows were made by prairie dogs or would be re-colonized by them in the foreseeable future, and suggest to us that non-conforming 100-m points should not be combined with omission errors or be a further concern in planning and monitoring.

We believe that omission errors should be the greatest concern for project area managers and planners because development activities that encounter unmapped prairie dog polygons in the field would have to be altered at potentially considerable time, labor, and other costs, or could adversely impact prairie dogs, ferrets, and associated species. The 7.5% omission error rate we estimated from ground surveys is already lower than other projects we are aware of, and within a range that most land managers and planners would find acceptable. If, however, it were readily possible to reduce the omission error rate or identify the locations of unmapped prairie dog burrows, then project area managers and planners could reduce the likelihood of unexpectedly encountering unmapped burrows along with the associated costs and risks. Fortunately, ground survey results have identified the locations of most omission errors: they are more likely to be found where polygon density, area, and activity are high (Table 4); 59% of them are within 100 m of mapped polygons, 78% are within 200m of mapped polygons, 89% are within 300 m, 91% are within 400 m (Table 3); and 65% are actually contiguous with mapped polygons. If project area managers and planners created 100-m buffers around mapped polygons they would rectify most omission and boundary delineation errors, and encounter unmapped burrows only about 3.1% of the time; 200-m buffers would obviate noticeably more errors and produce encounters with unmapped burrows only 1.7% of the time; 300-m buffers would effectively reduce omission and delineation error rates and the chances of encountering unmapped burrows to 0.8%; and 400-m buffers would further reduce them to 0.7%. Such buffers would also provide greater protection from development activities for sensitive wildlife species and habitats associated with prairie dogs, and reduce the chances of prairie dogs colonizing development areas as their population recovers from plague.

Each of these buffer widths would substantially reduce the costs and risks of development encountering unmapped polygons, such costs and risks decreasing and their attending benefits increasing as buffer width increases. Increasing buffer width also increases development restrictions and costs, however, so the overall benefits and costs must be weighed to determine optimal buffer widths. We recognize that other factors about which we have no information should be factored into that determination, including the protection of other natural resources (e.g., mountain plovers) and site-specific development plans. But based primarily on ground survey results rather than any particular biological or ecological criteria, we suspect that 100-m buffers would provide sufficient benefits in many cases, 200- and 300-m buffers would have increasing benefit-cost ratios, and that 400-m buffers might have additional benefits that outweigh their additional costs in some but not most cases. If our suspicions are true, we would probably recommend 300-m buffers in general unless their costs are unexpectedly much higher than for 200-m buffers, or applying a variety of different sized buffers as appropriate on a site-specific basis, using the widest practicable buffers for a given site or area. If such measures are taken, we believe that the accuracy of prairie dog mapping in the CD/WII project area would be more than acceptable for planning and monitoring purposes, and would prove to be a highly valuable resource protection and development planning tool.

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APPENDIX A

Appendix A maps of quarter section samples and results were made by using ArcView to layer DRGE's for 7.5' quadrangles, BP Amoco aerial data (Sundberg 2003), BLM prairie dog polygon files, and sampling data (METHODS). File creation dates for BP Amoco data both precede and postdate BLM polygon files, so polygon differences between the two are not necessarily errors.

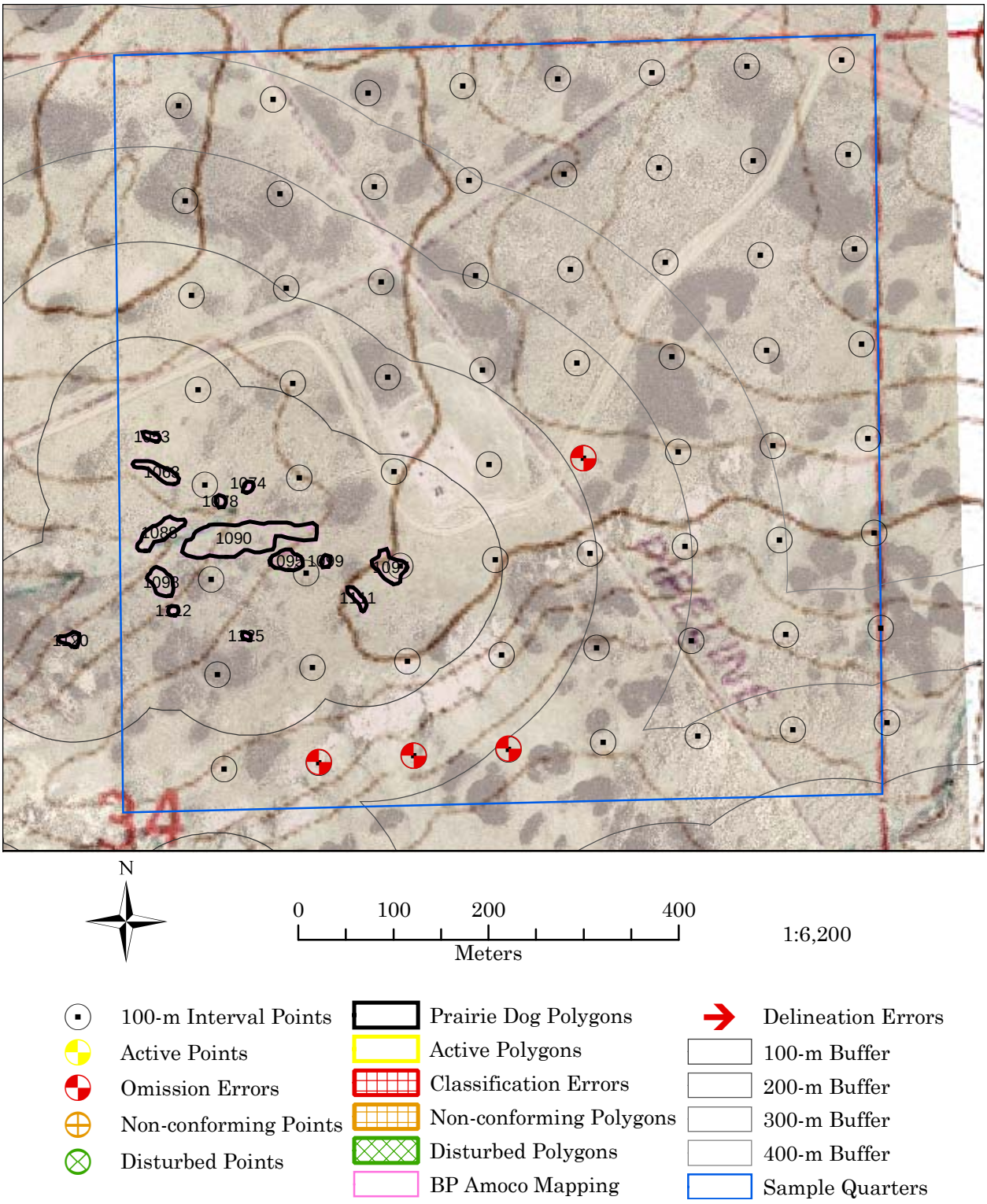

Figure A-1. Locations of quarter section sample boundaries, sampled 100-m interval points with 15-m radius circles, prairie dog burrow polygons, observed mapping errors, and buffers in prairie dog Complex 1, Sample 1, NE¼, Section 34, Township 20 N, Range 93 W.

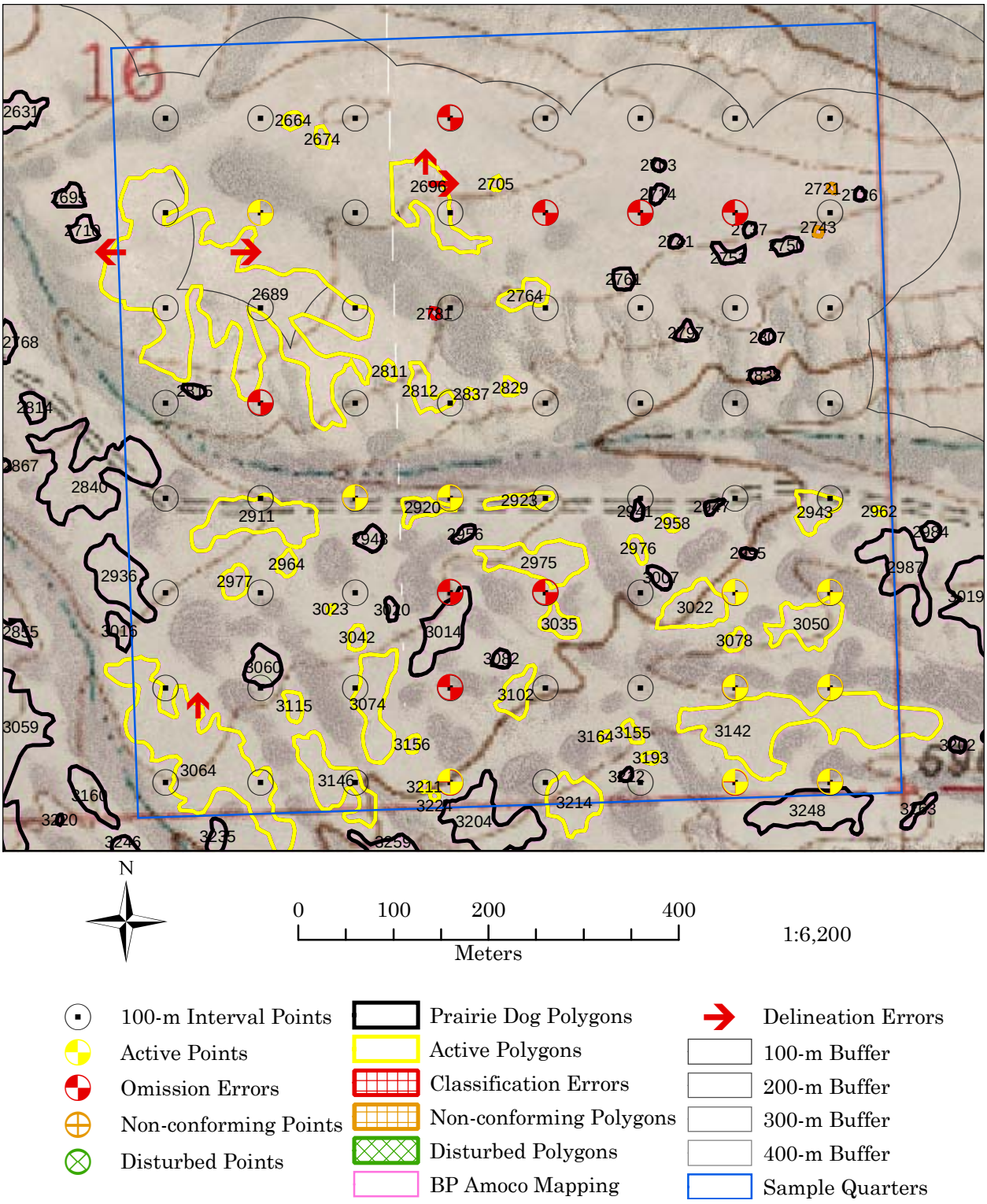

Figure A-2. Locations of quarter section sample boundaries, sampled 100-m interval points with 15-m radius circles, prairie dog burrow polygons, observed mapping errors, and buffers in prairie dog Complex 1, Sample 2, SE¼, Section 16, Township 19 N, Range 96 W.

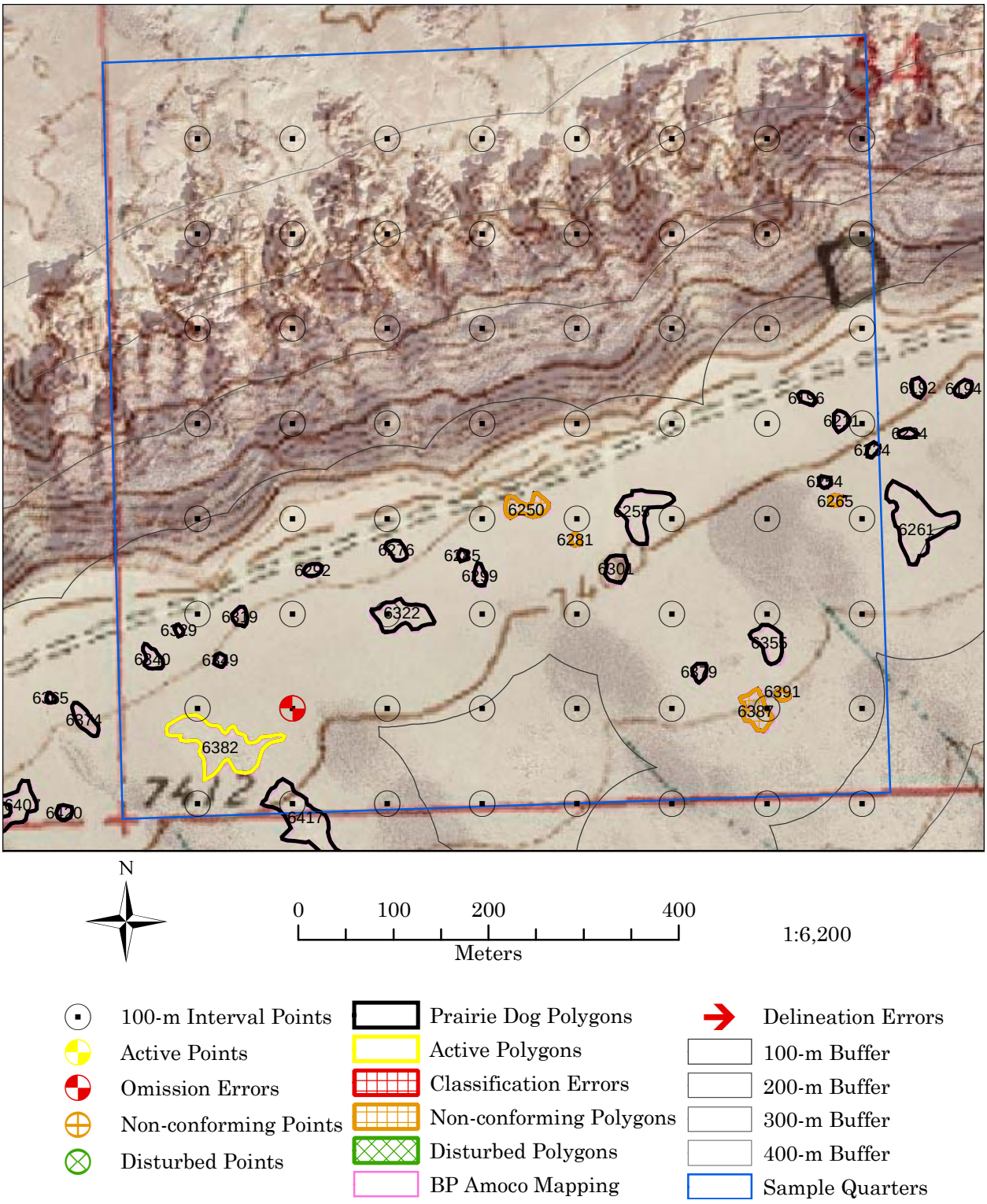

Figure A-3. Locations of quarter section sample boundaries, sampled 100-m interval points with 15-m radius circles, prairie dog burrow polygons, observed mapping errors, and buffers in prairie dog Complex 1, Sample 3, SW¼, Section 34, Township 19 N, Range 96 W.

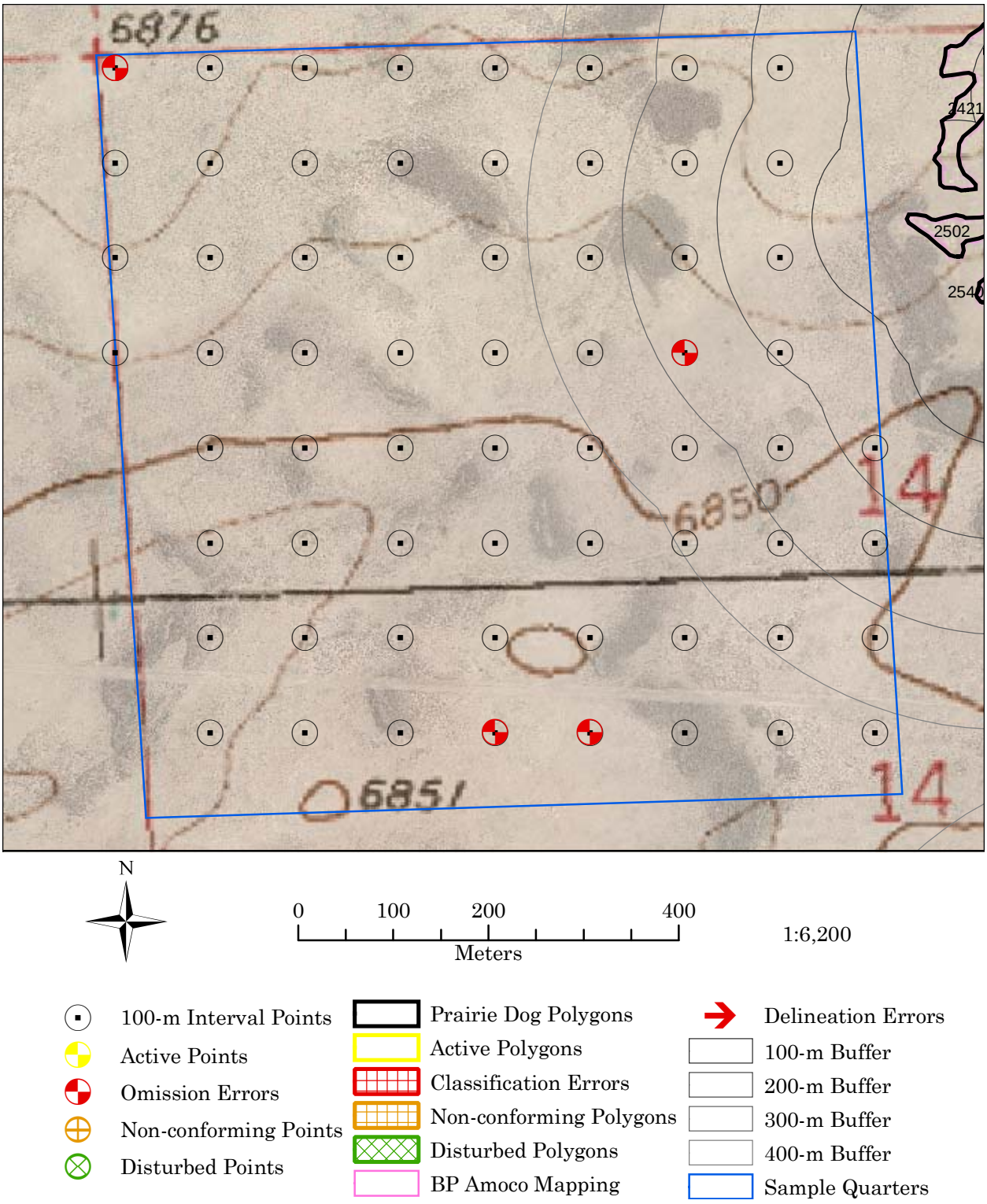

Figure A-4. Locations of quarter section sample boundaries, sampled 100-m interval points with 15-m radius circles, prairie dog burrow polygons, observed mapping errors, and buffers in prairie dog Complex 1, Sample 4, NW¼, Section 14, Township 19 N, Range 95 W.

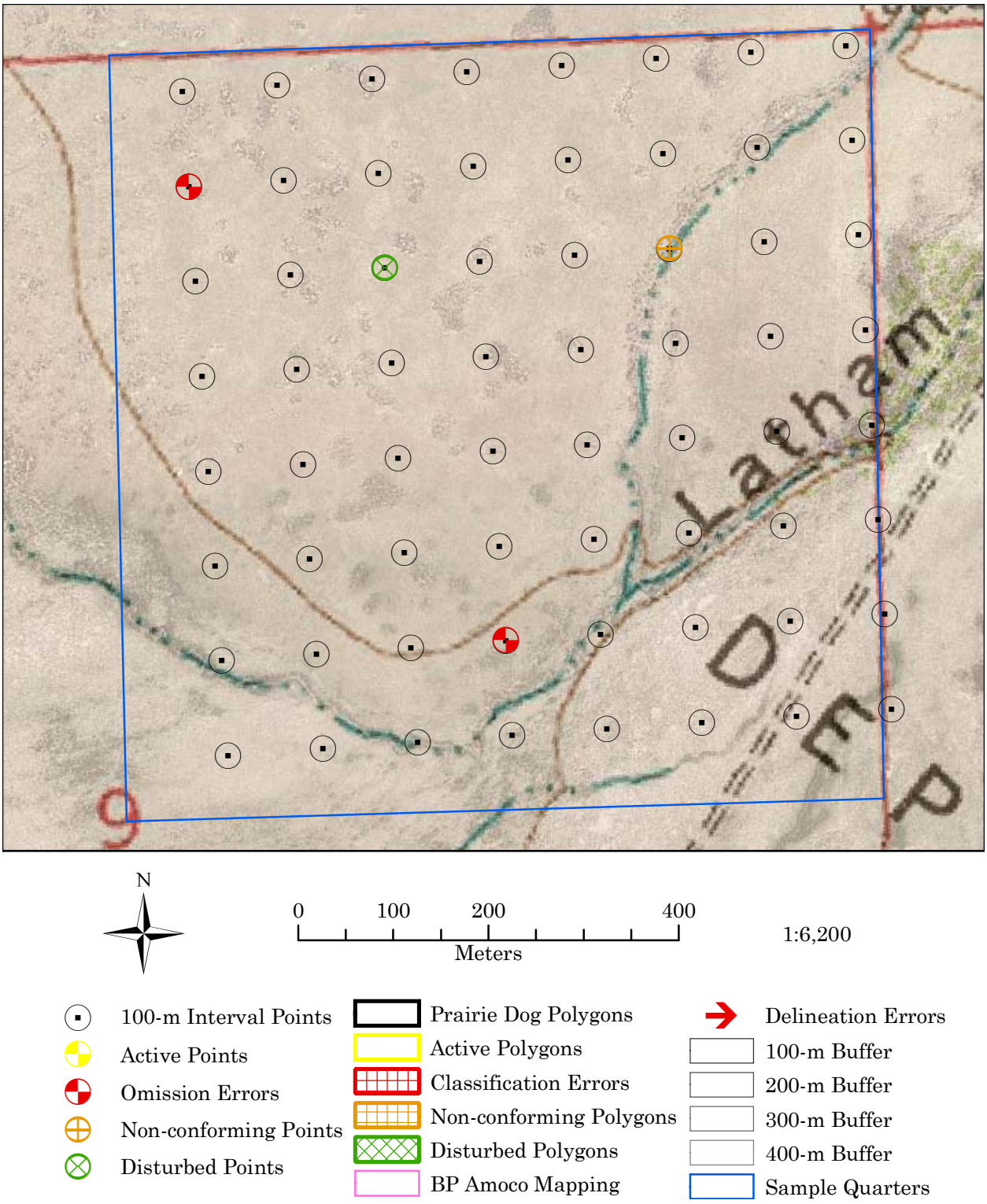

Figure A-5. Locations of quarter section sample boundaries, sampled 100-m interval points with 15-m radius circles, prairie dog burrow polygons, observed mapping errors, and buffers in prairie dog Complex 1, Sample 5 NE¼, Section 9, Township 19 N, Range 94 W.

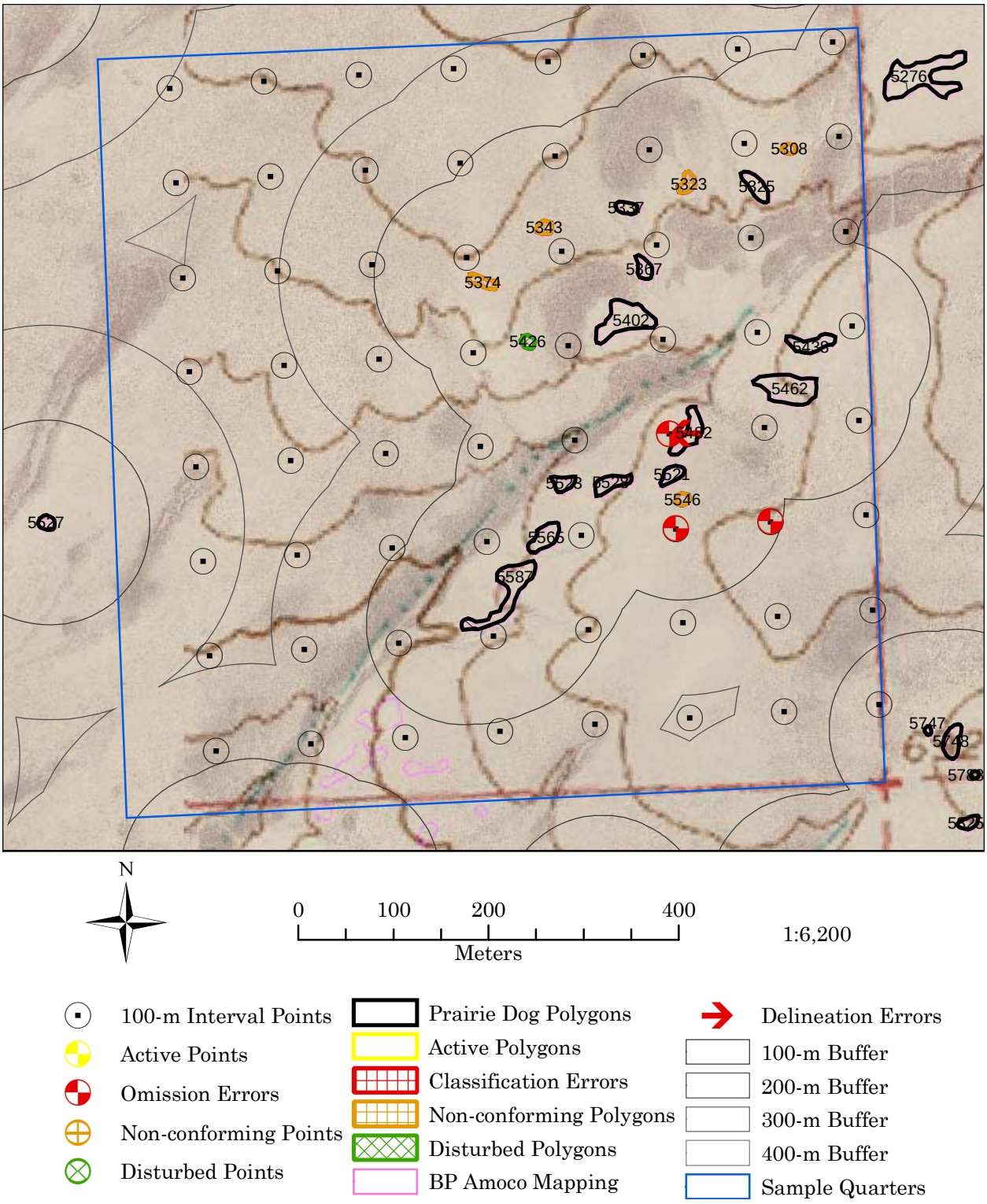

Figure A-6. Locations of quarter section sample boundaries, sampled 100-m interval points with 15-m radius circles, prairie dog burrow polygons, observed mapping errors, and buffers in prairie dog Complex 1, Sample 6, SE¼, Section 28, Township 19 N, Range 94 W.

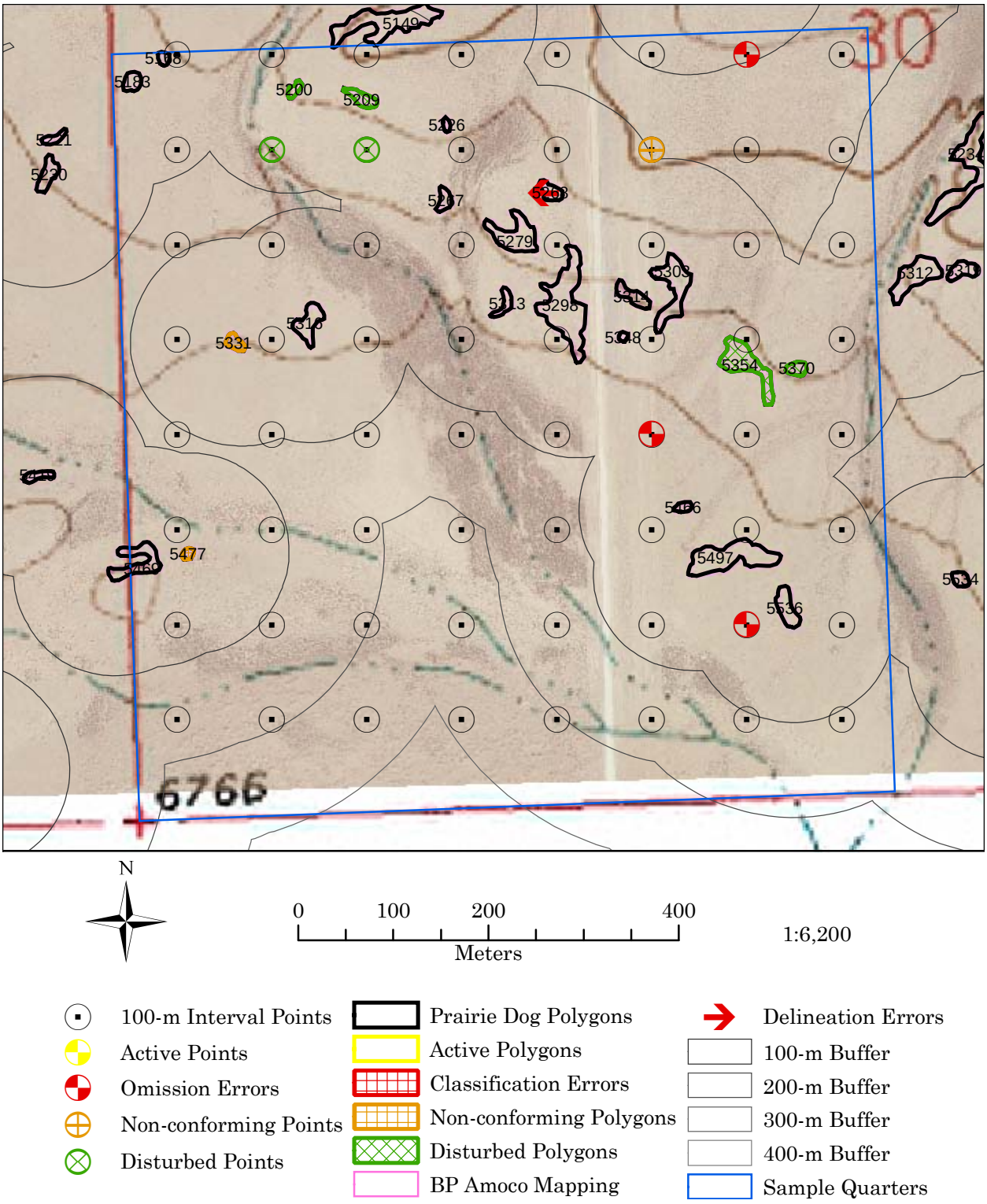

Figure A-7. Locations of quarter section sample boundaries, sampled 100-m interval points with 15-m radius circles, prairie dog burrow polygons, observed mapping errors, and buffers in prairie dog Complex 1, Sample 7, SW¼, Section 30, Township 19 N, Range 94 W.

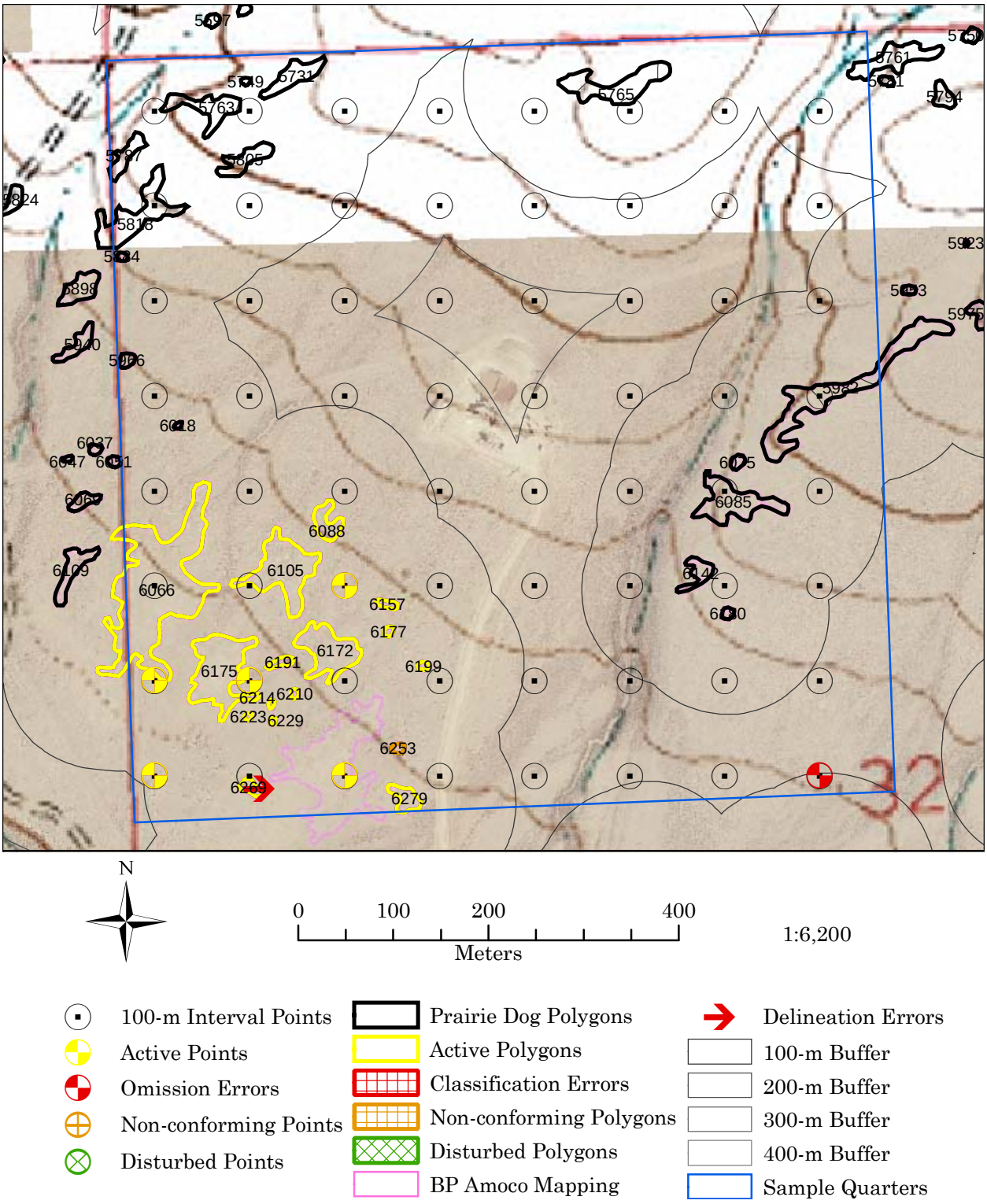

Figure A-8. Locations of quarter section sample boundaries, sampled 100-m interval points with 15-m radius circles, prairie dog burrow polygons, observed mapping errors, and buffers in prairie dog Complex 1, Sample 8, NW¼, Section 32, Township 19 N, Range 94 W.

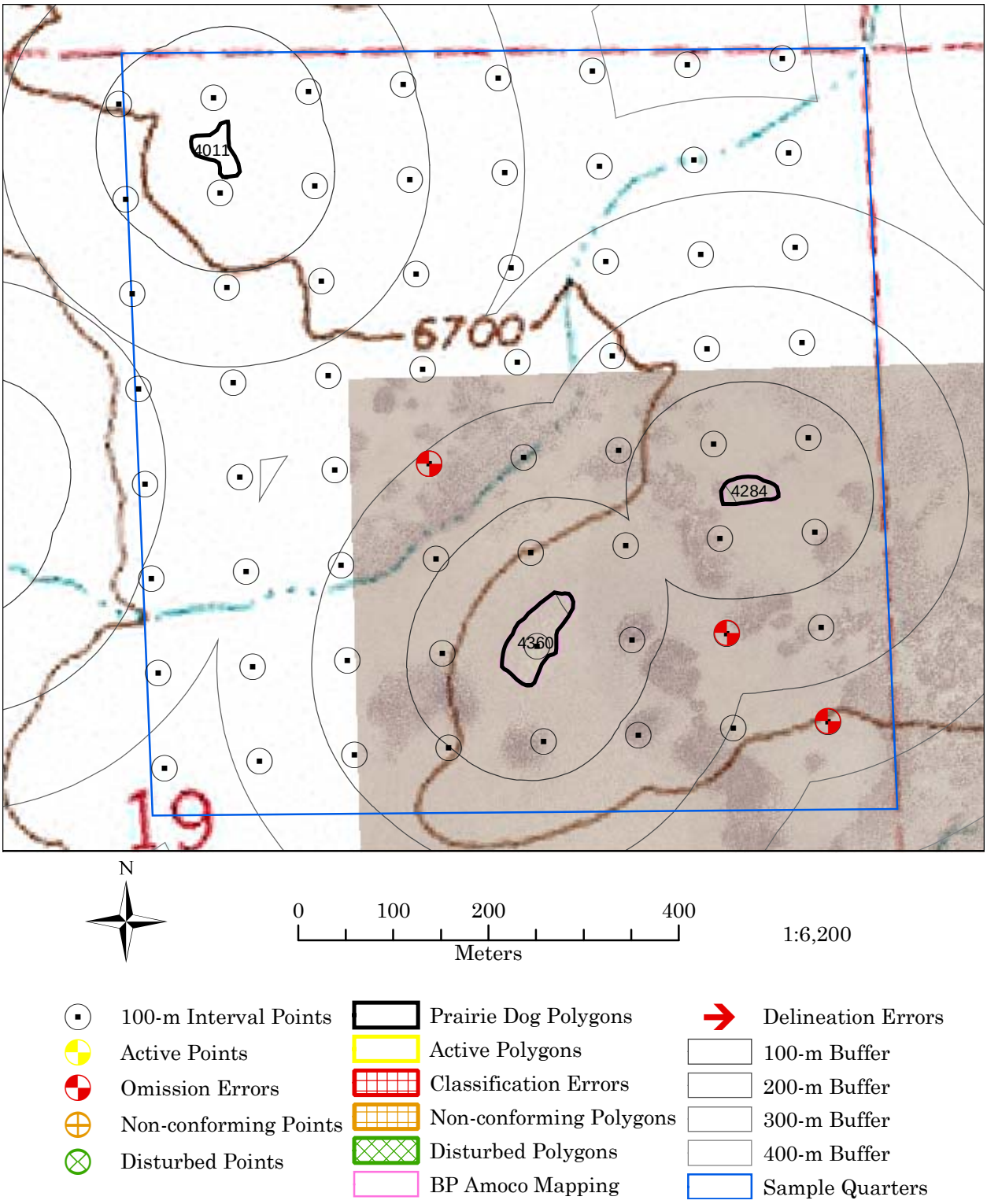

Figure A-9. Locations of quarter section sample boundaries, sampled 100-m interval points with 15-m radius circles, prairie dog burrow polygons, observed mapping errors, and buffers in prairie dog Complex 1, Sample 9, NE¼, Section 19, Township 19 N, Range 93 W.

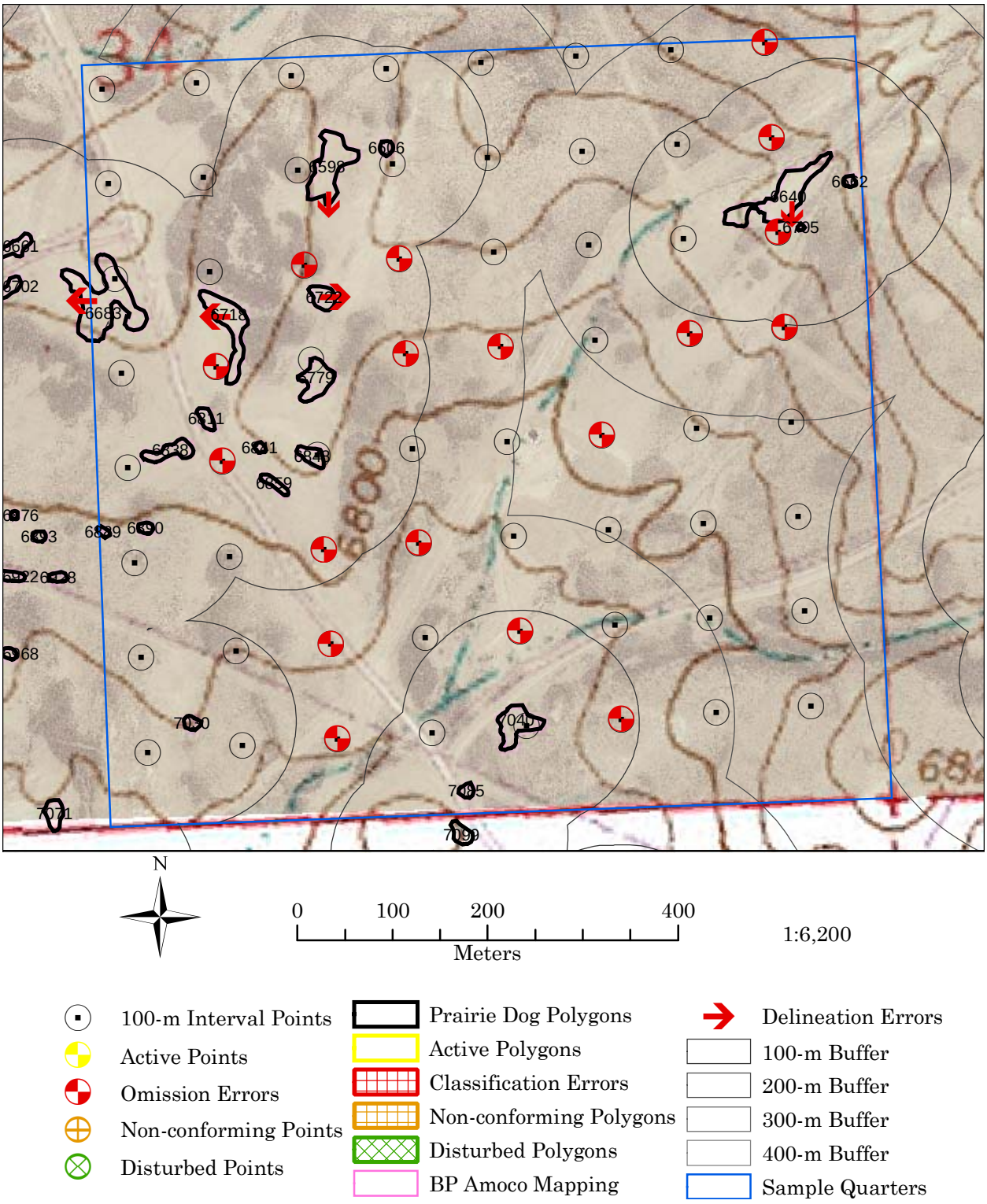

Figure A-10. Locations of quarter section sample boundaries, sampled 100-m interval points with 15-m radius circles, prairie dog burrow polygons, observed mapping errors, and buffers in prairie dog Complex 1, Sample 10, SE¼, Section 34, Township 19 N, Range 93 W.

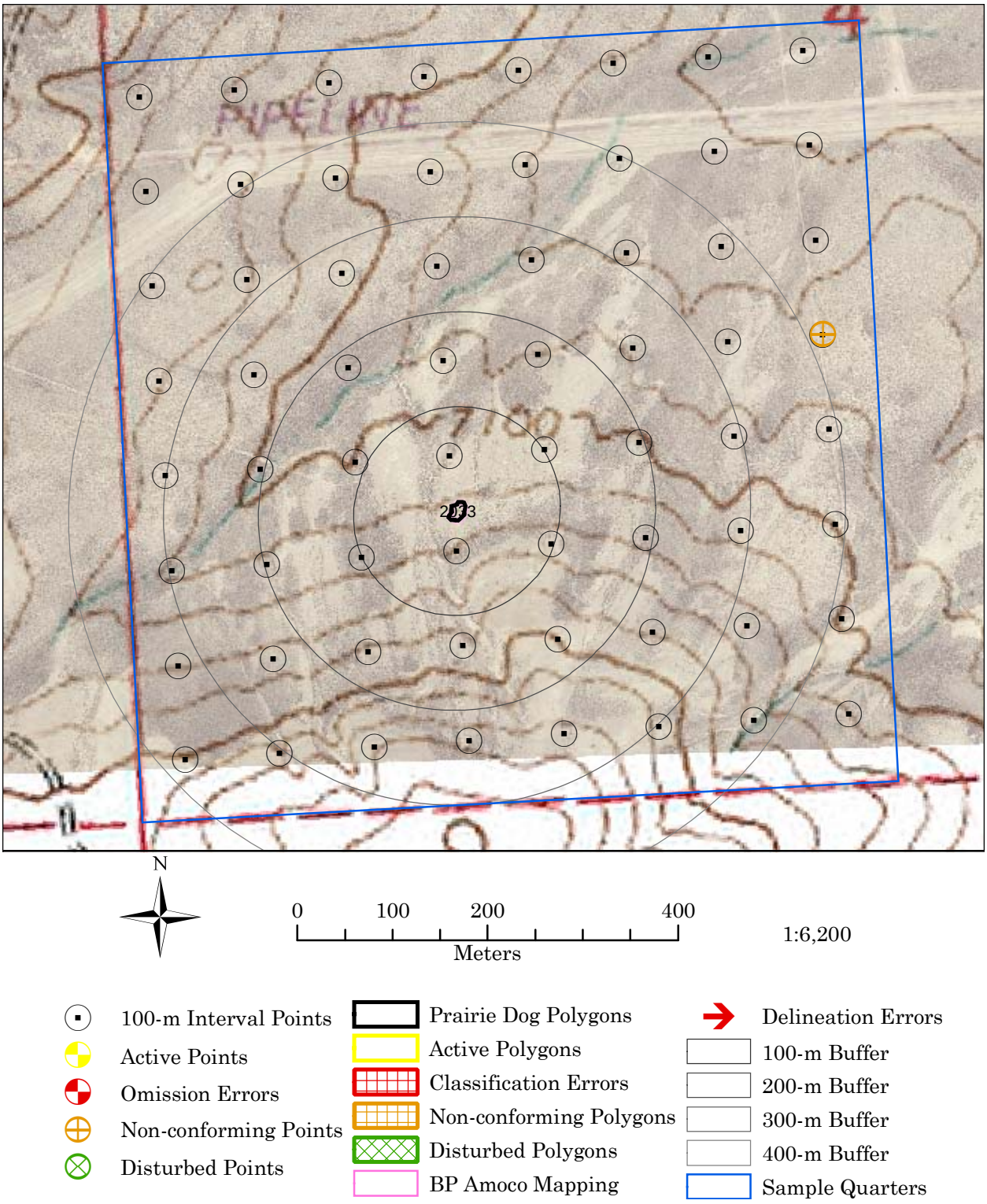

Figure A-11. Locations of quarter section sample boundaries, sampled 100-m interval points with 15-m radius circles, prairie dog burrow polygons, observed mapping errors, and buffers in prairie dog Complex 1, Sample 11, SW¼, Section 4, Township 19 N, Range 92 W.

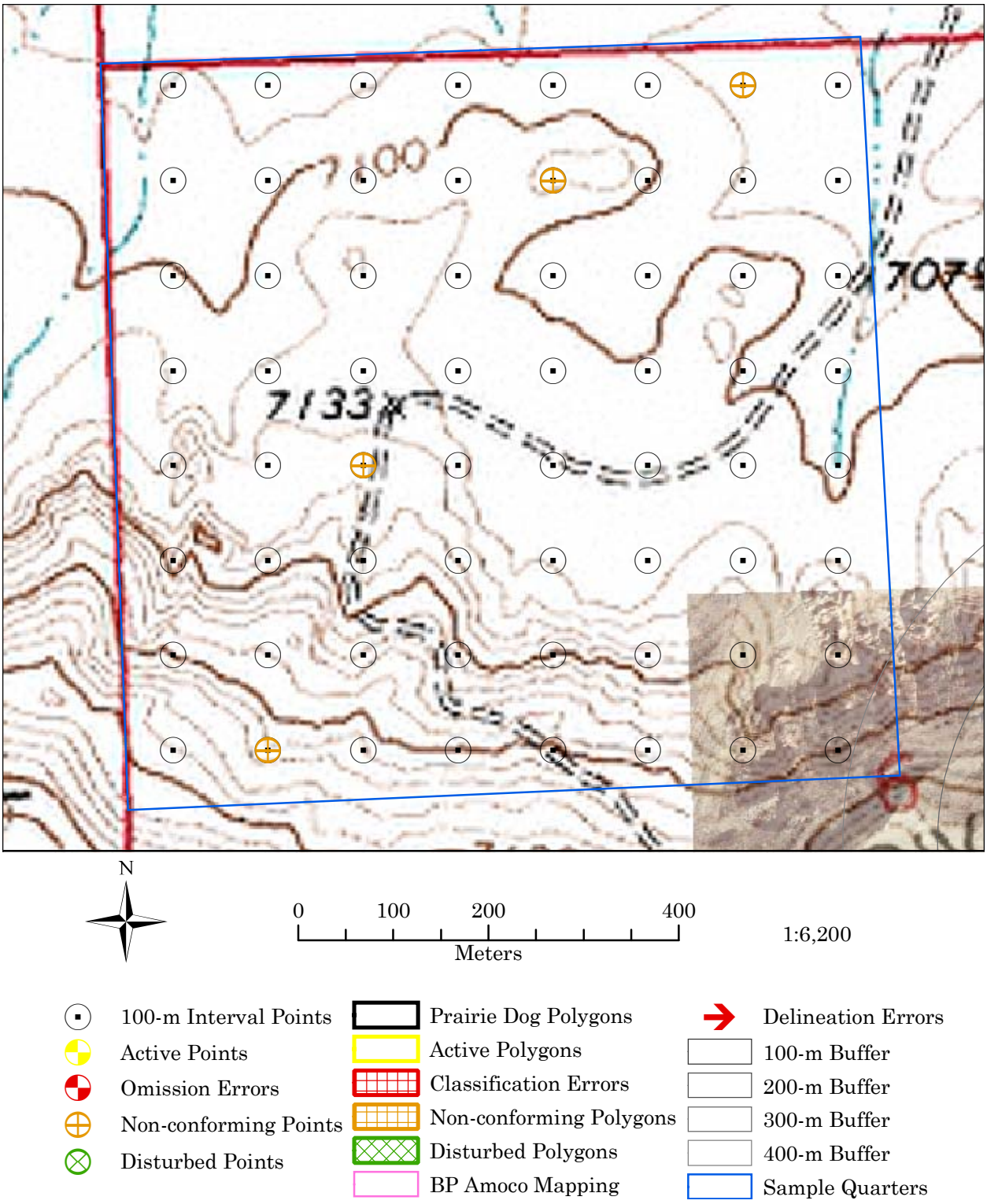

Figure A-12. Locations of quarter section sample boundaries, sampled 100-m interval points with 15-m radius circles, prairie dog burrow polygons, observed mapping errors, and buffers in prairie dog Complex 1, Sample 12, NW¼, Section 6, Township 18 N, Range 96 W.

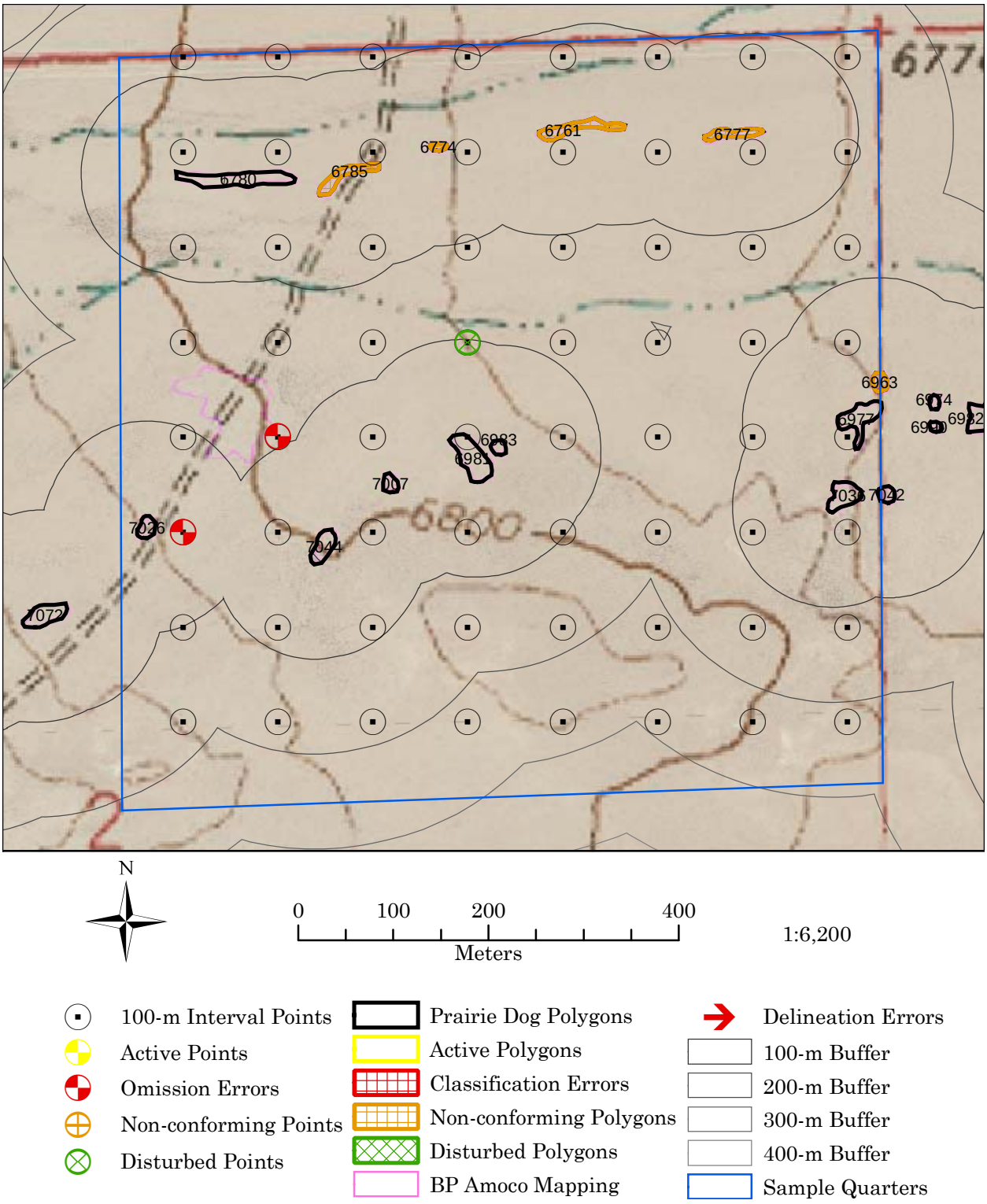

Figure A-13. Locations of quarter section sample boundaries, sampled 100-m interval points with 15-m radius circles, prairie dog burrow polygons, observed mapping errors, and buffers in prairie dog Complex 1, Sample 13, NE¼, Section 2, Township 18 N, Range 95 W.

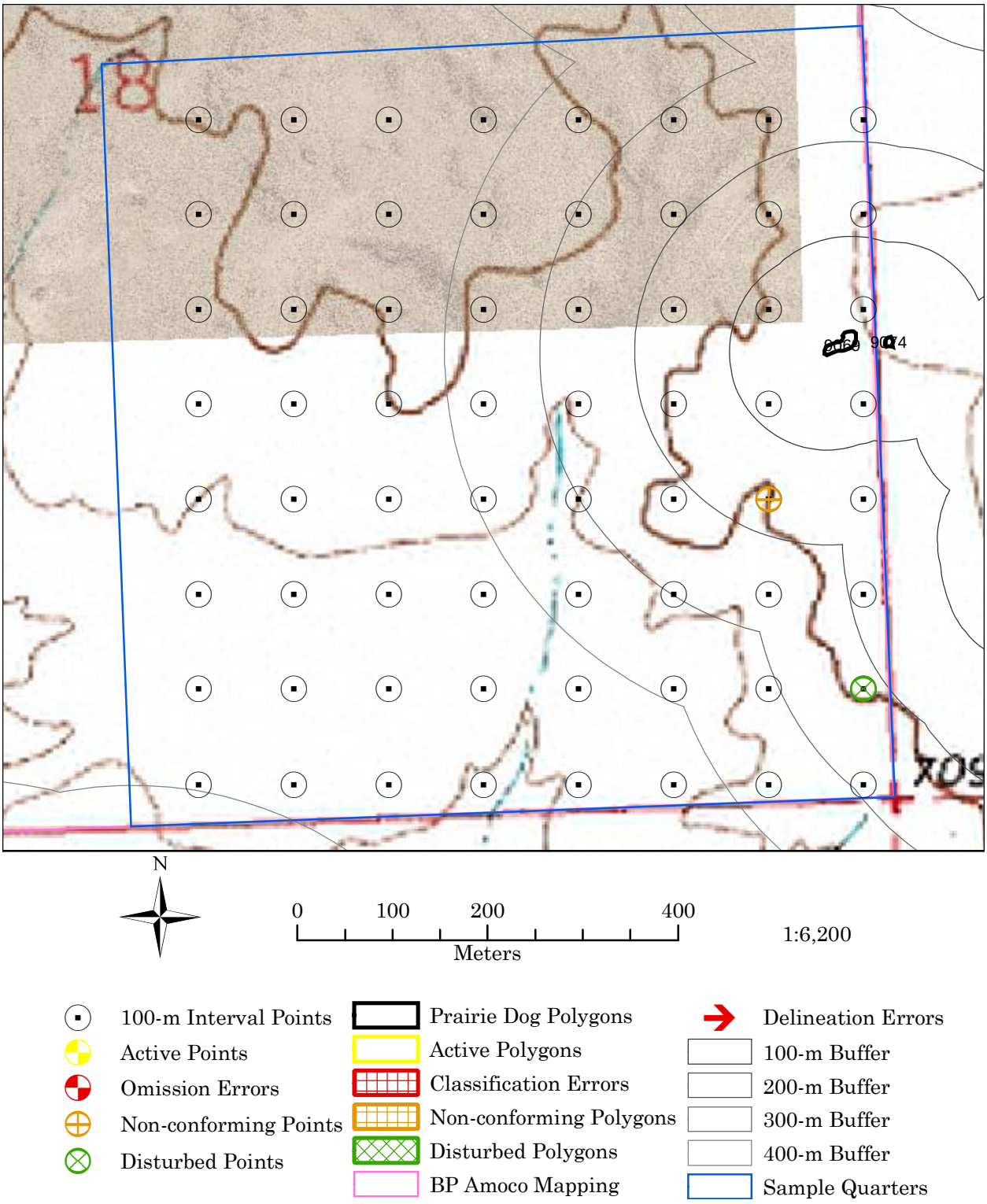

Figure A-14. Locations of quarter section sample boundaries, sampled 100-m interval points with 15-m radius circles, prairie dog burrow polygons, observed mapping errors, and buffers in prairie dog Complex 1, Sample 14, SE¼, Section 18, Township 18 N, Range 95 W.

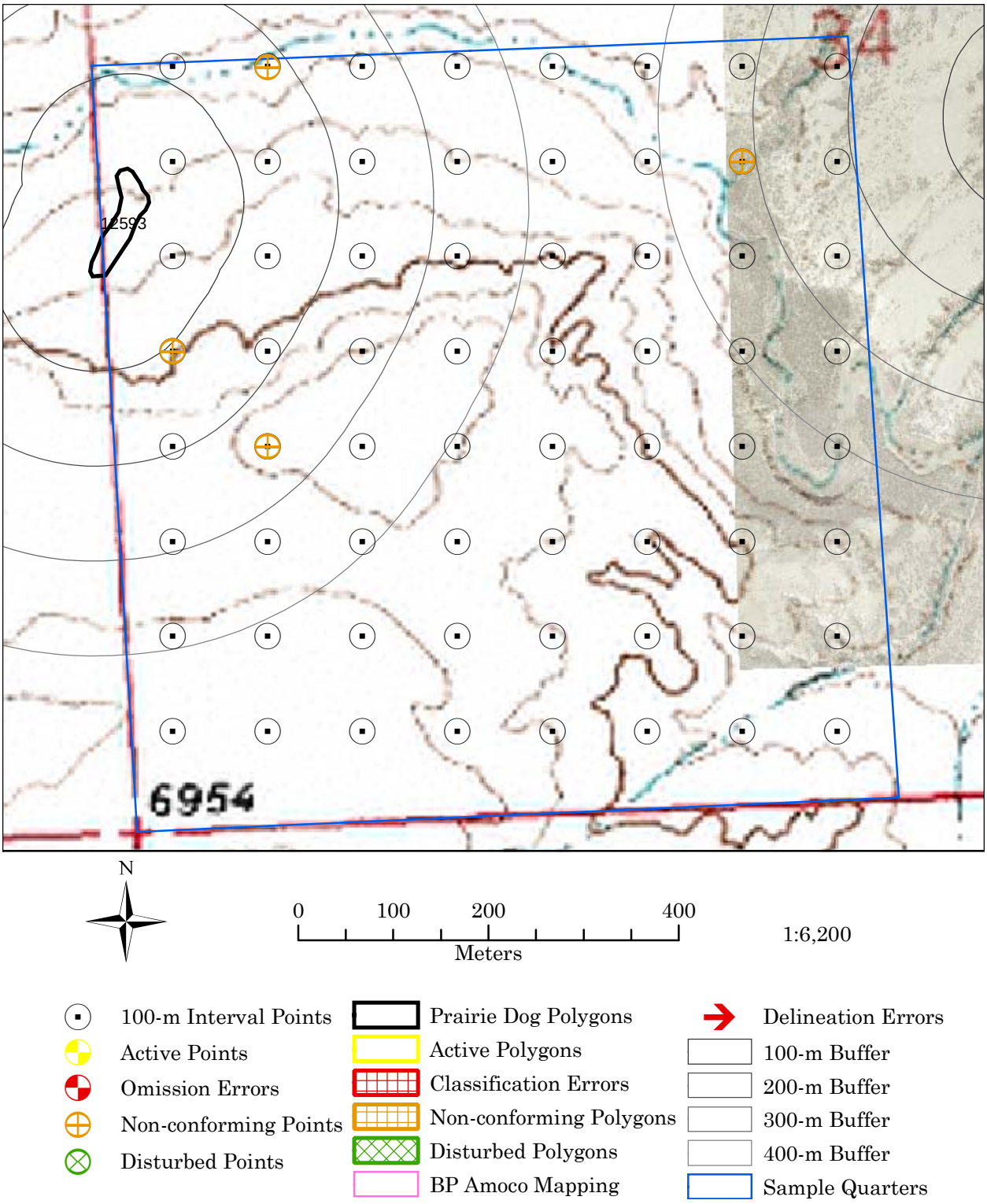

Figure A-15. Locations of quarter section sample boundaries, sampled 100-m interval points with 15-m radius circles, prairie dog burrow polygons, observed mapping errors, and buffers in prairie dog Complex 1, Sample 15, SW¼, Section 34, Township 18 N, Range 95 W.

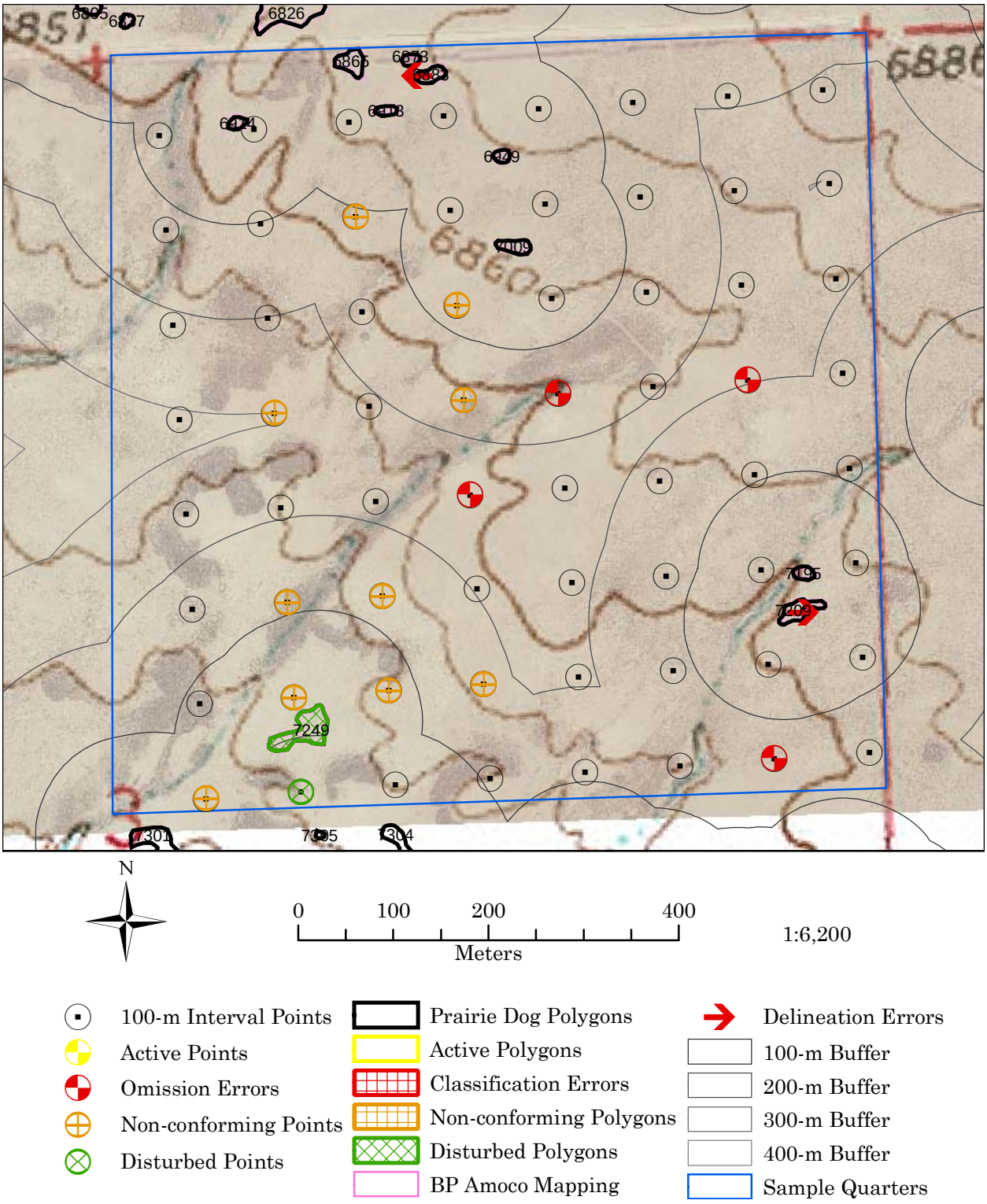

Figure A-16. Locations of quarter section sample boundaries, sampled 100-m interval points with 15-m radius circles, prairie dog burrow polygons, observed mapping errors, and buffers in prairie dog Complex 1, Sample 16, NE¼, Section 3, Township 18 N, Range 94 W.

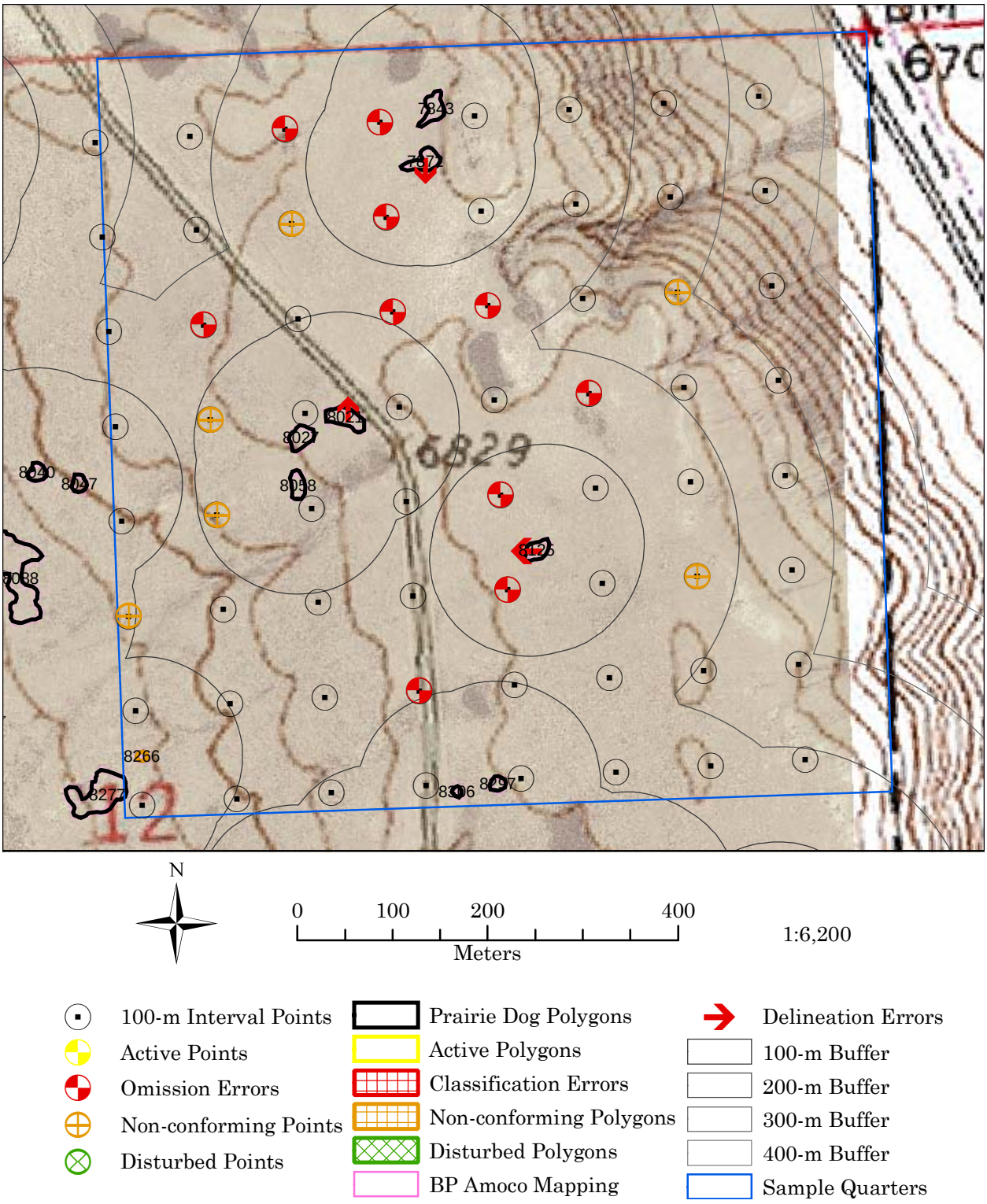

Figure A-17. Locations of quarter section sample boundaries, sampled 100-m interval points with 15-m radius circles, prairie dog burrow polygons, observed mapping errors, and buffers in prairie dog Complex 1, Sample 17, NE¼, Section 12, Township 18 N, Range 94 W.

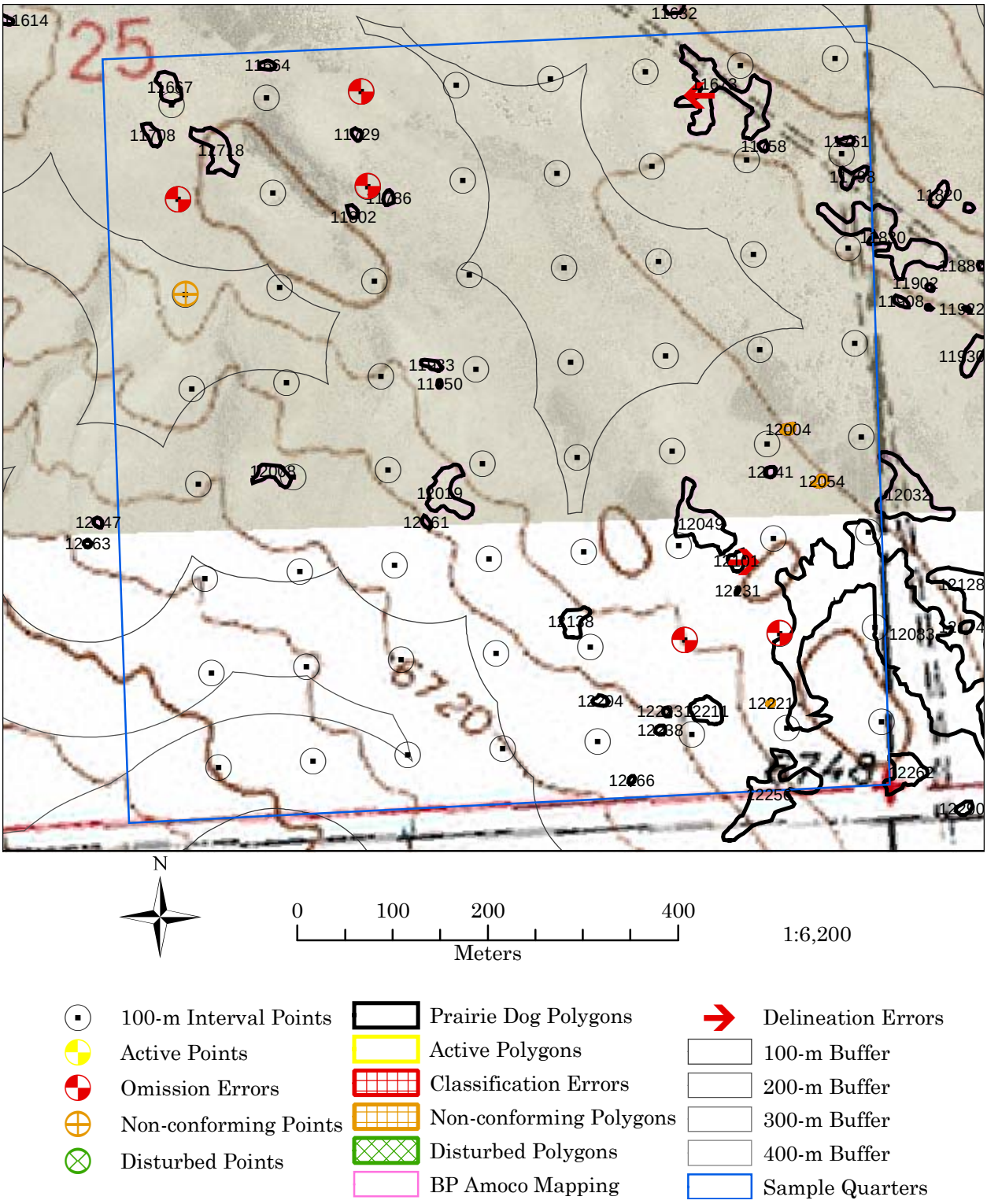

Figure A-18. Locations of quarter section sample boundaries, sampled 100-m interval points with 15-m radius circles, prairie dog burrow polygons, observed mapping errors, and buffers in prairie dog Complex 1, Sample 18, SE¼, Section 25, Township 18 N, Range 94 W.

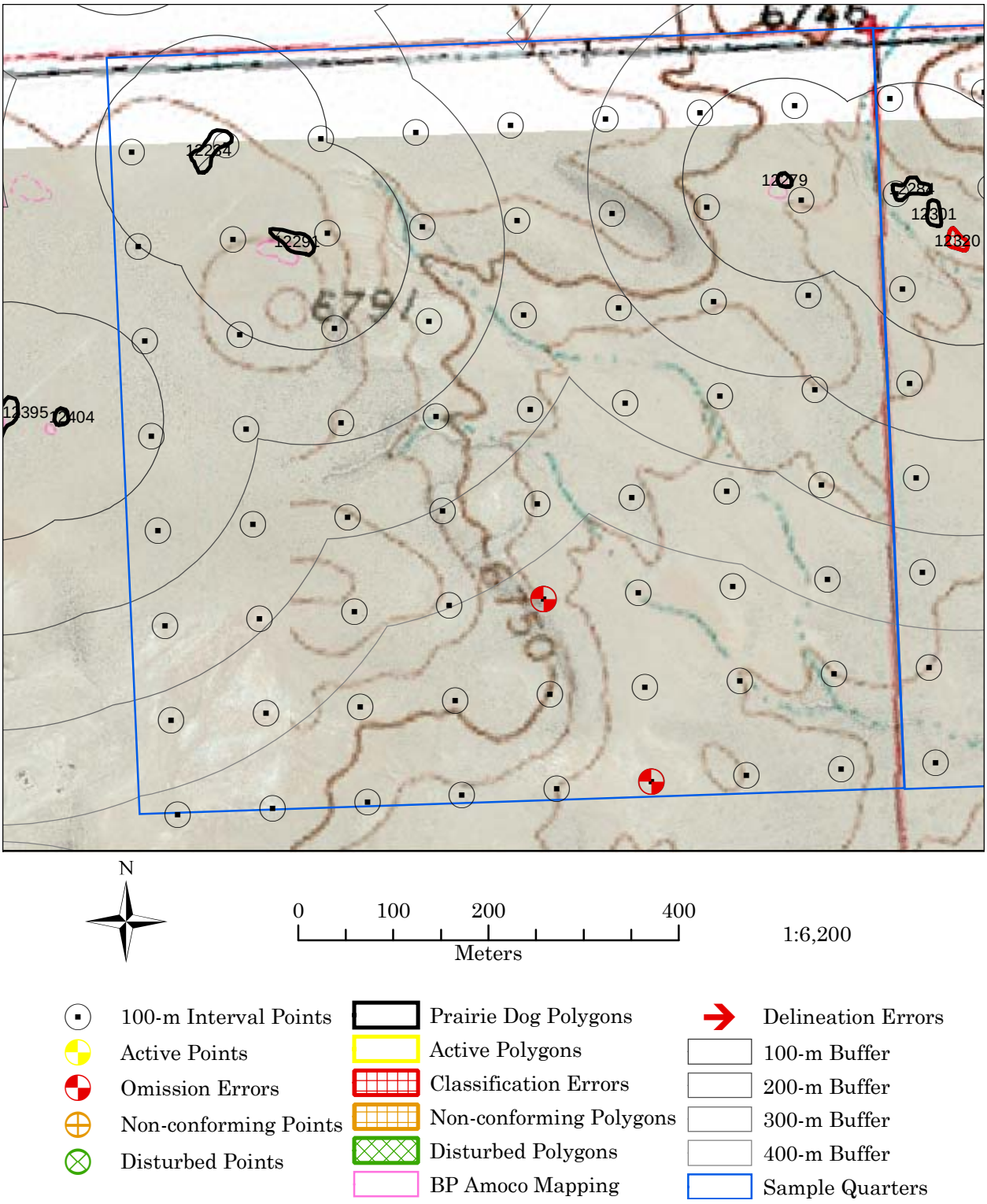

Figure A-19. Locations of quarter section sample boundaries, sampled 100-m interval points with 15-m radius circles, prairie dog burrow polygons, observed mapping errors, and buffers in prairie dog Complex 1, Sample 19, NE¼, Section 33, Township 18 N, Range 94 W.

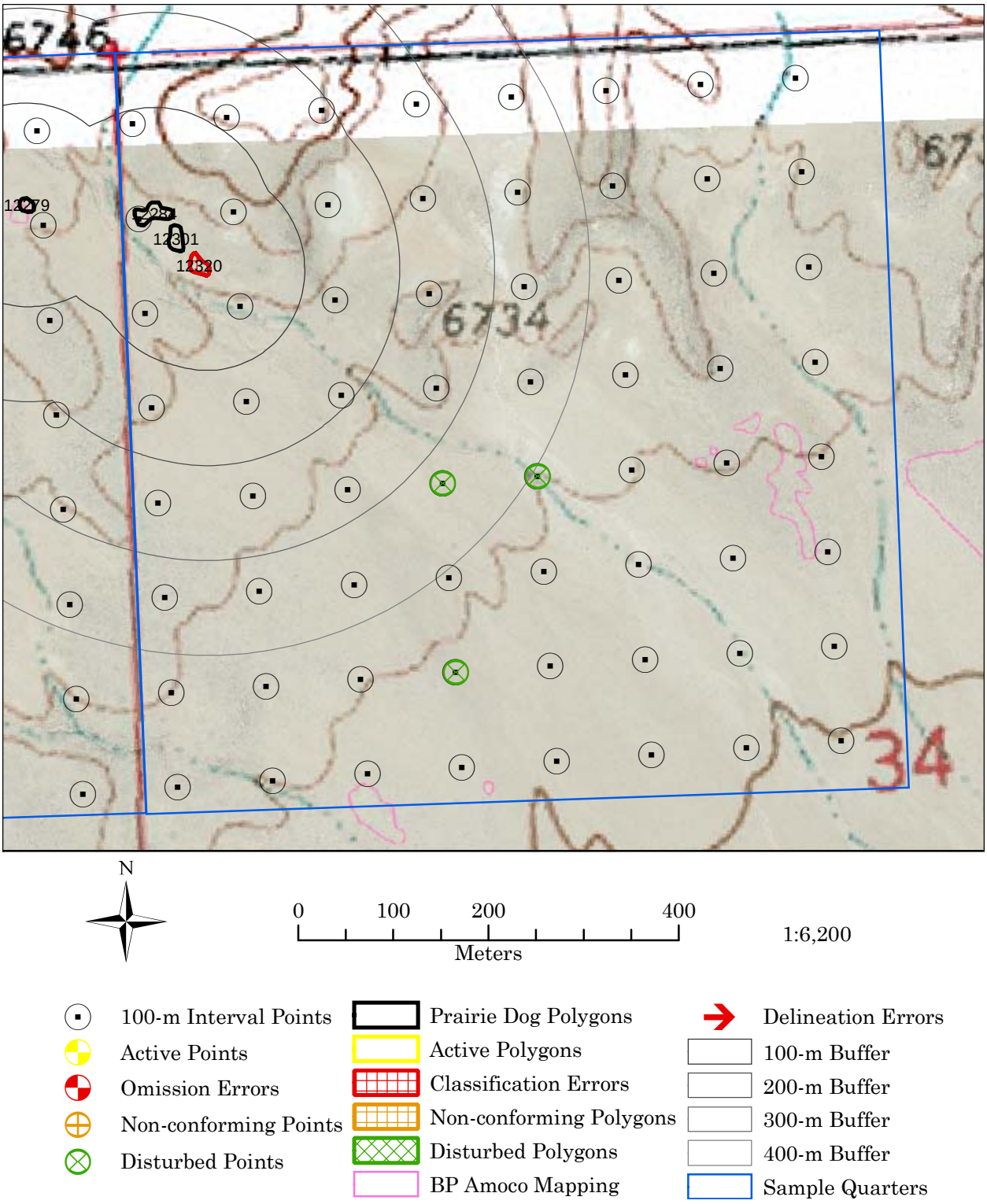

Figure A-20. Locations of quarter section sample boundaries, sampled 100-m interval points with 15-m radius circles, prairie dog burrow polygons, observed mapping errors, and buffers in prairie dog Complex 1, Sample 20, NW¼, Section 34, Township 18 N, Range 94 W.

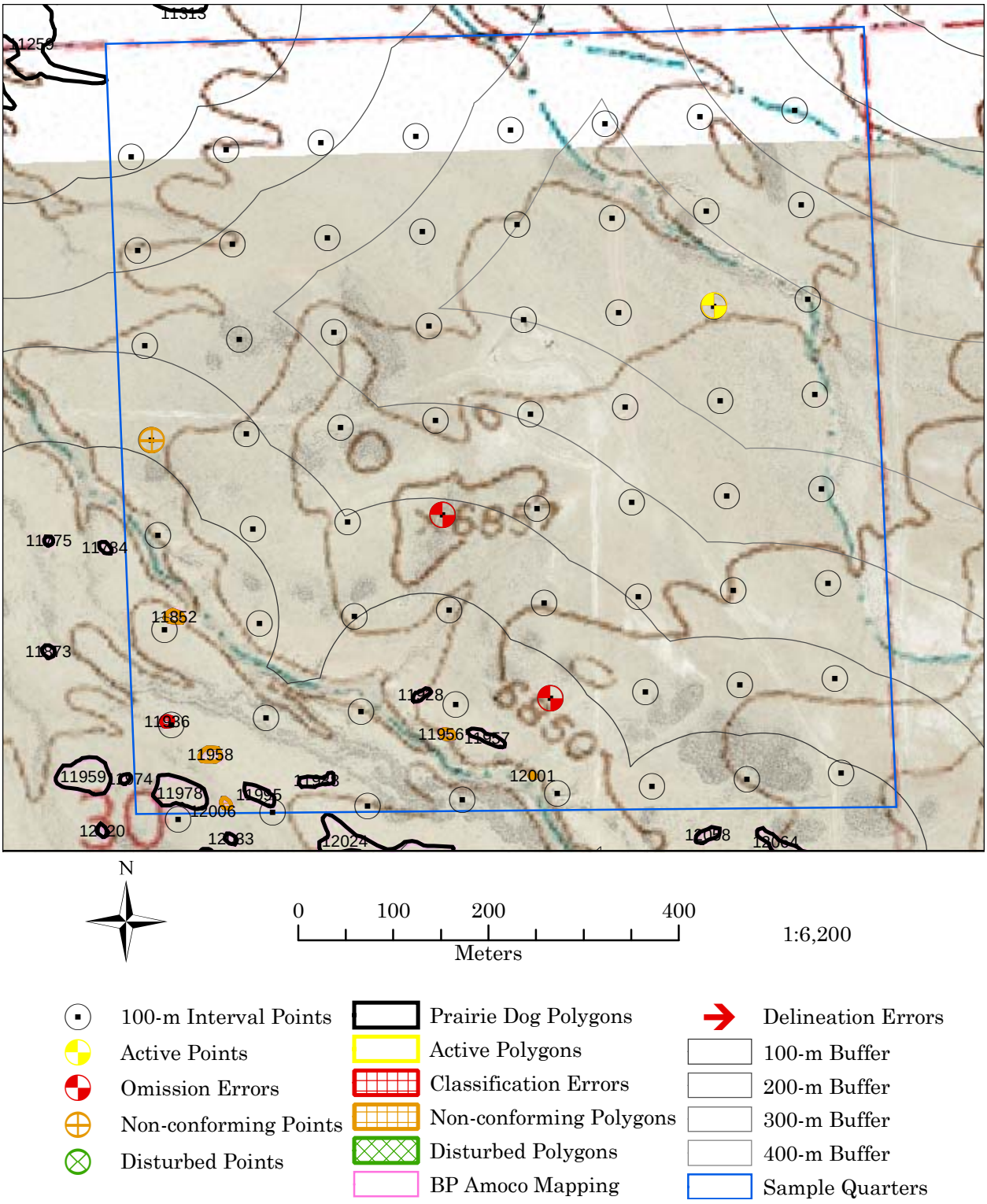

Figure A-21. Locations of quarter section sample boundaries, sampled 100-m interval points with 15-m radius circles, prairie dog burrow polygons, observed mapping errors, and buffers in prairie dog Complex 1, Sample 21, NE¼, Section 30, Township 18 N, Range 92 W.

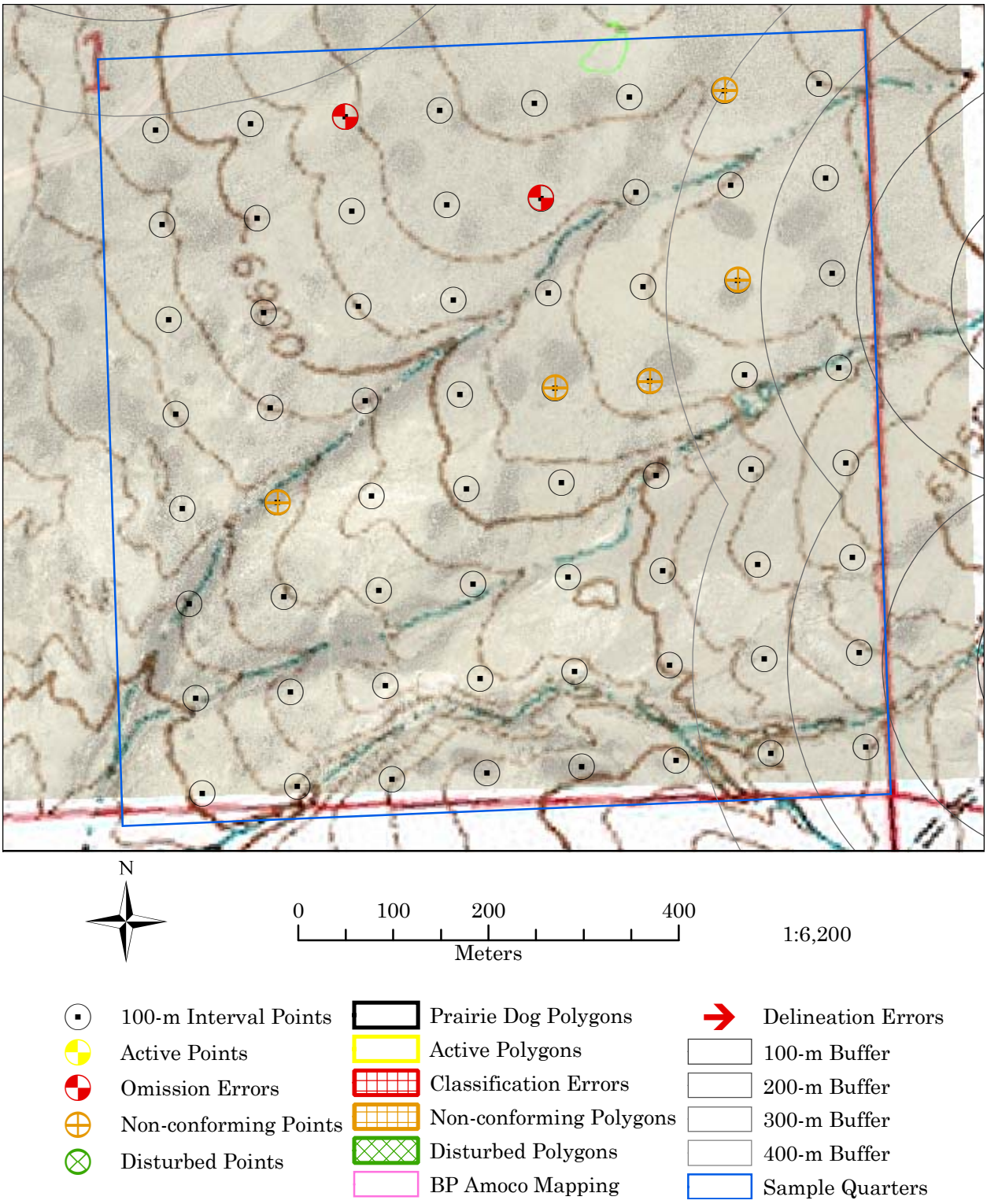

Figure A-22. Locations of quarter section sample boundaries, sampled 100-m interval points with 15-m radius circles, prairie dog burrow polygons, observed mapping errors, and buffers in prairie dog Complex 1, Sample 22, SE¼, Section 1, Township 17 N, Range 93 W.

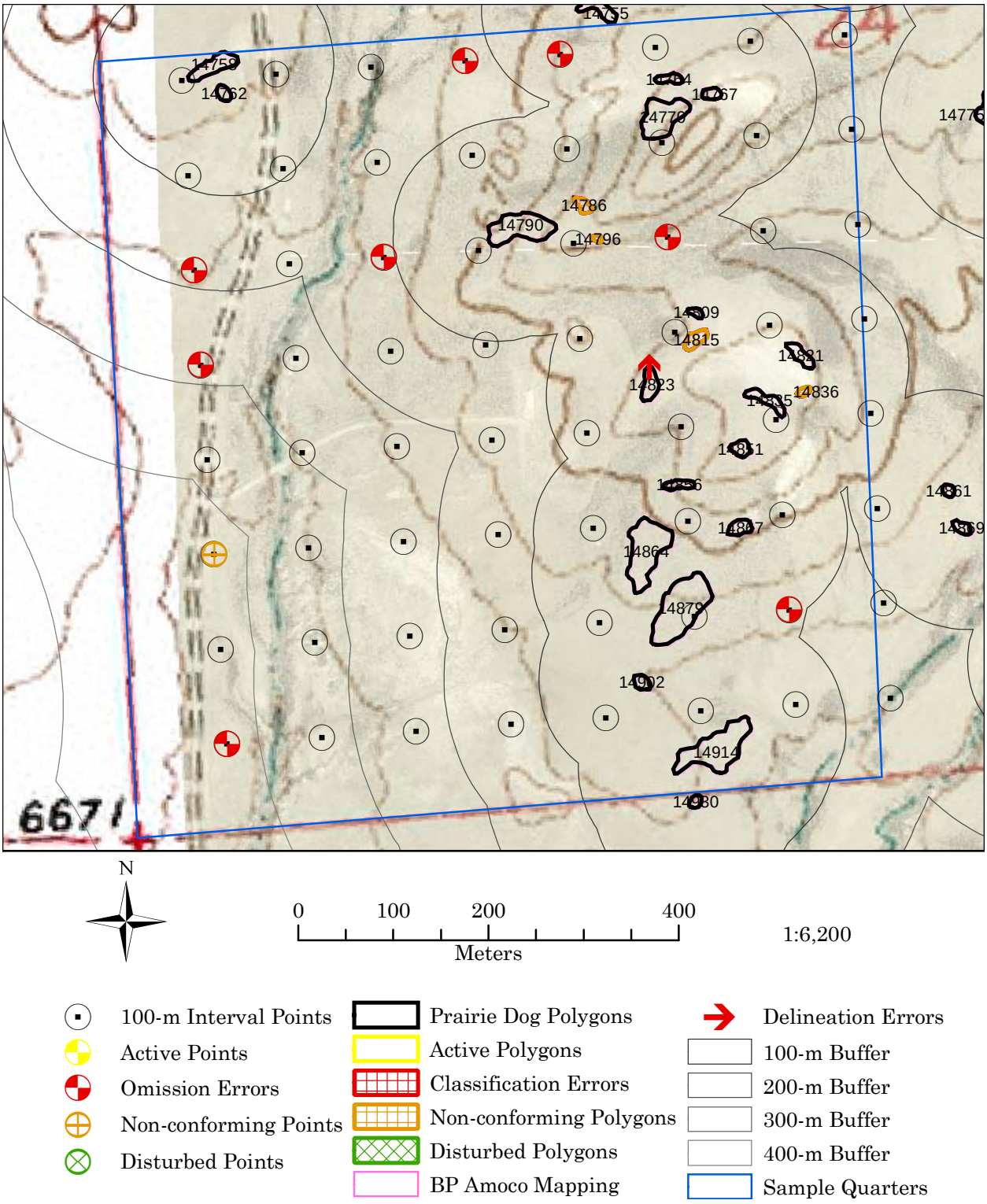

Figure A-23. Locations of quarter section sample boundaries, sampled 100-m interval points with 15-m radius circles, prairie dog burrow polygons, observed mapping errors, and buffers in prairie dog Complex 1, Sample 23, SW¼, Section 24, Township 17 N, Range 93 W.

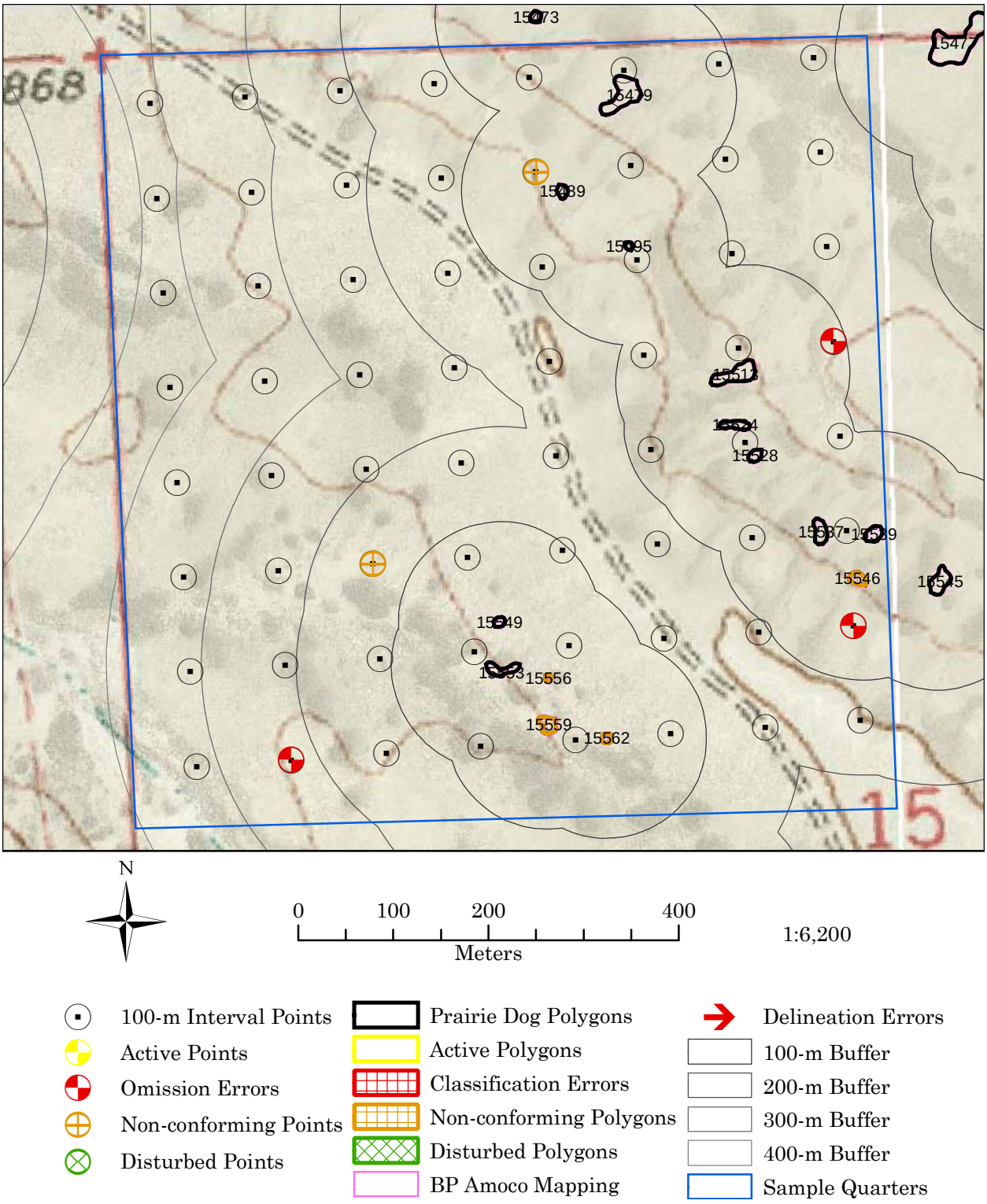

Figure A-24. Locations of quarter section sample boundaries, sampled 100-m interval points with 15-m radius circles, prairie dog burrow polygons, observed mapping errors, and buffers in prairie dog Complex 1, Sample 24, NW¼, Section 15, Township 16 N, Range 94 W.

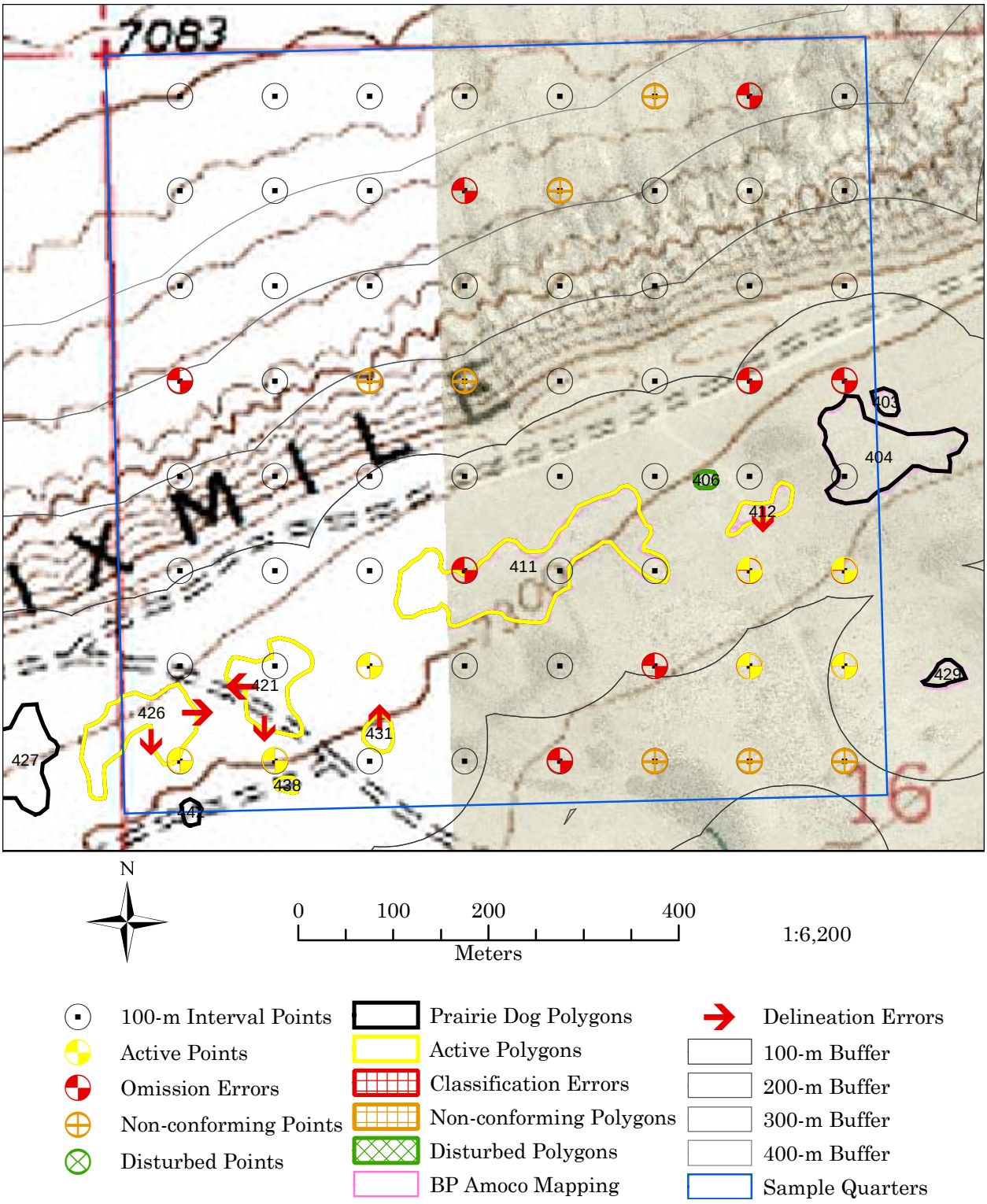

Figure A-25. Locations of quarter section sample boundaries, sampled 100-m interval points with 15-m radius circles, prairie dog burrow polygons, observed mapping errors, and buffers in prairie dog Complex 2, NW¼, Section 16, Township 17 N, Range 99 W.

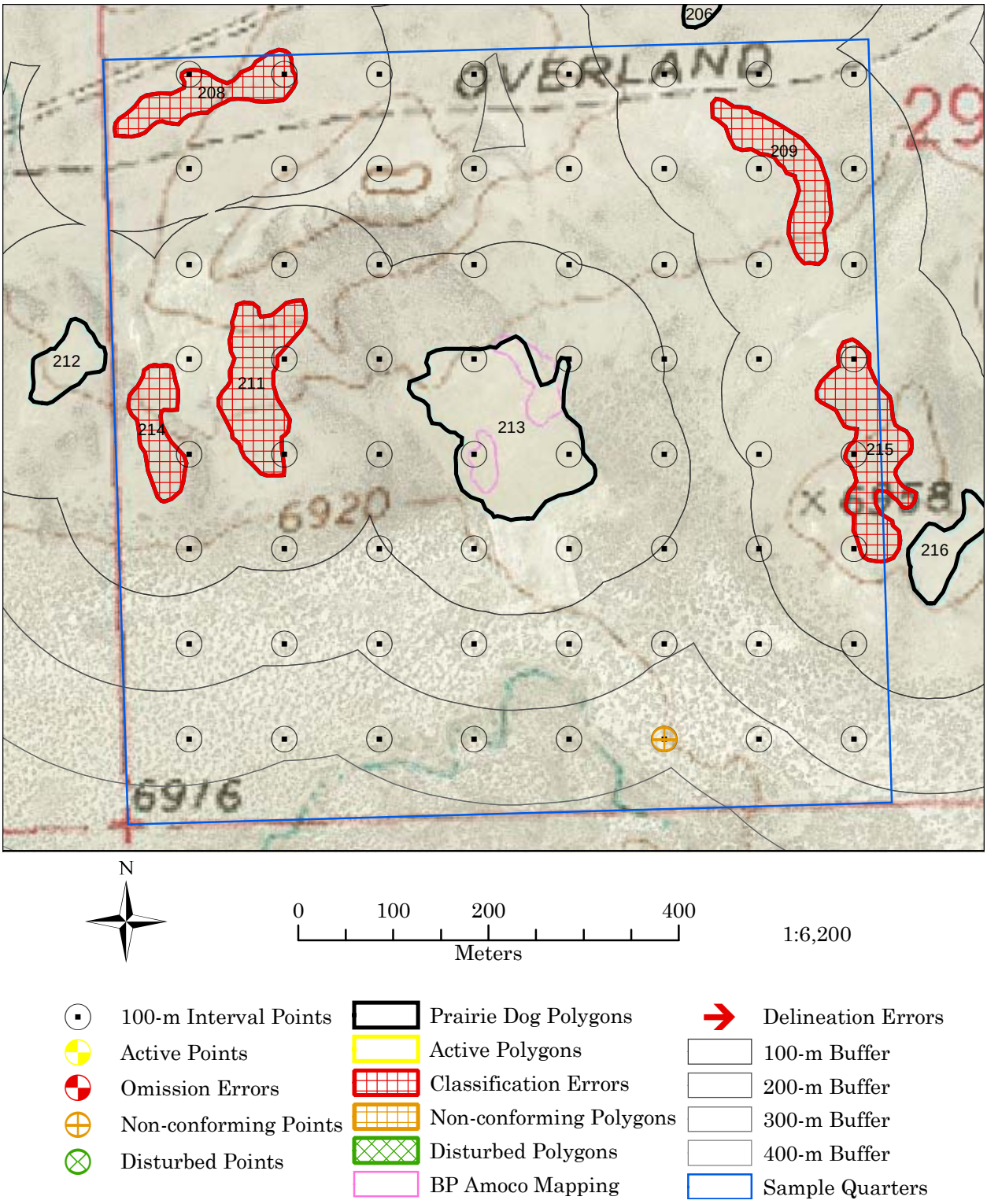

Figure A-26. Locations of quarter section sample boundaries, sampled 100-m interval points with 15-m radius circles, prairie dog burrow polygons, observed mapping errors, and buffers in prairie dog Complex 3, SW¼, Section 29, Township 17 N, Range 97 W.

APPENDIX B

Burrow Classification Standards

The standard method for evaluating prairie dog burrows (Biggins et al. 1993) recommends counting only burrows ≥ 7 cm across and so deep the end can't be seen on quick inspection (Figures B-1 and B-2) including badger-reamed holes (Figures B-3 and B-4). If we had conducted ground surveys the same year as aerial photos were taken, we would have used Biggins et al.'s (1993) standards for counting holes. Aerial photos were taken in 2001, however, and plague apparently wiped out >90% of prairie dogs 1999-2001, so most locations didn't have any prairie dogs to maintain burrows, and weathering deteriorated the inactive burrows during the 2-year interval between aerial photography and ground surveys. Had we employed Biggins et al.'s standards during ground surveys in 2003, we would have found no burrows ≥ 7 cm at many polygons and 100-m interval points, but would have been able to count them if surveys had been done in 2001 before burrows deteriorated, thus underestimating the numbers of correct polygons and incorrect 100-m points interpreted from photography. Additionally, there was often clear field evidence that burrows were originally made by prairie dogs but had since been occupied by Wyoming ground squirrels (Figure B-5) and then sometimes dug out by badgers, leaving us to question whether or not ground squirrels had occupied prairie dog burrows before or after air photos were taken, and whether badgers had dug out ground squirrels or prairie dogs. The evidence wasn't always clear, and with > 90% of polygons inactive this situation was common and created the potential for tremendous bias in results depending on how burrows were classified.

Unaware of any published standards for aging inactive burrows, we therefore felt the need to modify Biggins et al.'s (1993) burrow criteria and establish our own standards to reduce potential biases in data and results. First, we distinguished prairie dog, ground squirrel, and badger holes primarily on size: holes < 7 cm in diameter were classified as ground squirrel, holes ≥ 7 cm in diameter were classified as prairie dog, and holes ≥ 14 cm across were badger. Because prairie dog and badger hole sizes and shapes overlapped considerably (e.g., Figures B-1 and B-3), when necessary and possible we distinguished between them based on soil mound shapes and other evidence in the area. Then we relaxed Biggins et al.'s (1993) recommendation that counted burrows be ≥ 7 cm across, and counted narrower partially to mostly filled-in openings as prairie dog burrows conforming to our standards (conforming burrows) if we could distinguish enough of an arc to determine that its former diameter had been ≥ 7 cm, and we could see at least some tunnel ceiling past the opening (Figure B-6). Completely filled-in openings, depressions, or mounds (Figures B-7 and B-8) were not classified or counted as burrows but were considered as evidence of prairie dog burrowing that did not conform with burrow classification and counting standards (non-conforming evidence of burrowing). Prairie dog burrows were classified as active or inactive per the standards described in Biggins et al. (1993).

If a mapped polygon or 100-m interval point had ≥ 1 conforming prairie dog burrows--even if ground squirrel burrows were also present--it was recorded as a correctly classified prairie dog polygon or incorrectly classified point as appropriate, and all conforming prairie dog burrows and badger holes within 15 m of the polygon center or 100-m point were counted and recorded as burrows. Similarly, if a mapped polygon or 100-m point had ≥ 1 active prairie dog burrow, then the entire polygon was classified as active. If a polygon or 100-m point had non-conforming evidence of prairie dog burrowing, badger holes, and/or ground squirrel burrows, but no conforming prairie dog burrows, it was recorded as an incorrect polygon or correct point and no badger holes were counted as burrows, but we noted that non-conforming evidence was present. If a polygon or 100-m point only had holes that could have been made by either prairie dogs or badgers and we could not find any distinguishing evidence (i.e., a 50:50 call), we classified, counted, and recorded every other one.

Figure B-1. Active prairie dog burrow, per standards used for classifying prairie dog burrows during ground surveys of prairie dog mapping in the CD/WII project area, with 7.5-cm diameter lens cap.

Figure B-2. Inactive conforming prairie dog burrow on left and non-conforming evidence of burrowing on right, per standards used for classifying prairie dog burrows during ground surveys of prairie dog mapping in the CD/WII project area, with 7.5-cm diameter lens cap.

Figure B-3. Freshly dug badger hole, per standards used for classifying prairie dog burrows during ground surveys of prairie dog mapping in the CD/WII project area, with 7.5-cm diameter lens cap.

Figure B-4. Old badger hole, per standards used for classifying prairie dog burrows during ground surveys of prairie dog mapping in the CD/WII project area, with 7.5-cm diameter lens cap.

Figure B-5. Ground squirrel burrow (in non-conforming prairie dog mound), per standards used for classifying prairie dog burrows during ground surveys of prairie dog mapping in the CD/WII project area, with 7.5-cm diameter lens cap.

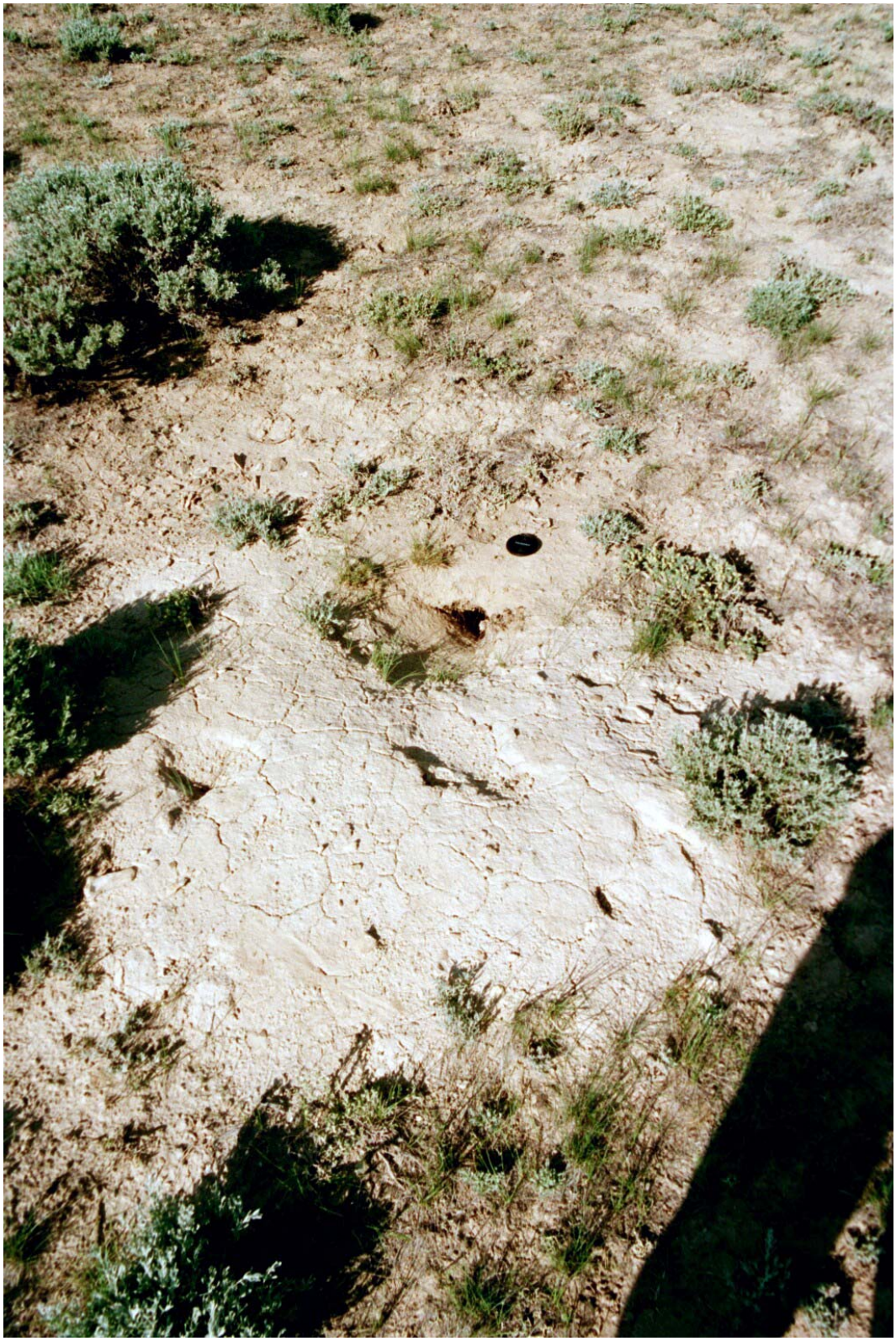

Figure B-6. Inactive conforming prairie dog burrow, per standards used for classifying prairie dog burrows during ground surveys of prairie dog mapping in the CD/WII project area, with 7.5-cm diameter lens cap.

Figure B-7. Non-conforming evidence of prairie dog burrowing, per standards used for classifying prairie dog burrows during ground surveys of prairie dog mapping in the CD/WII project area, with 7.5-cm diameter lens cap.

Figure B-8. Non-conforming evidence of prairie dog burrowing, per standards used for classifying prairie dog burrows during ground surveys of prairie dog mapping in the CD/WII project area, with 7.5-cm diameter lens cap.