

# Four Years of Remote Sensing at the Double Ditch State Historic Site, North Dakota

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## Abstract

A remote sensing program at the Double Ditch State Historic Site demonstrates the utility of combined prospecting methods for understanding complex settlements. Aerial surveys acquired high-resolution color and thermal infrared imagery. The former distinguished houses, borrow pits, and fortification ditches from middens and fill areas by changes in vegetation; the later did the same through temperature variations and showed areas with significant deposits. Topographic surveys documented surface expressions associated with ditches, houses, borrow pits, and mounds. Magnetic gradiometry revealed countless storage pits, hearths, and two previously unknown fortification systems that vastly increase the settlement's area. Ground-penetrating radar provided details about houses and mounded midden interior forms. Electrical resistance surveys helped define middens, houses, and earth-borrowing pits. The remote sensing program reduced excavation costs by allowing specific features to be targeted. Excavations confirmed anomaly identifications and established a chronology that documents late-fifteenth century origins through abandonment about AD 1785.

## 1 Introduction

Double Ditch is a large earthlodge village, located on the Missouri River in the Northern Great Plains of North America. In the historic period (beginning in the eighteenth century) the earthlodge was a dome-shaped dwelling 10-15 m in diameter, made of a timber frame that was covered with perhaps 35 cm of soil. Double Ditch is distinctive in its great size (approximately 8 ha), its large number of shallow depressions (5-50 m in diameter) representing the loci of former houses and earth borrowing pits, the size and number of large mounded middens that probably served as defensive works (some are over two meters tall), and a double fortification system of ditches that were once lined with palisades. Lewis and Clark, who helped open the American West to Euroamerican settlement through their "Voyage of Discovery," visited the ruins of this ancestral Mandan Indian village in 1804 where they learned from informants that it was abandoned about 1785. It now lies protected within the Double Ditch State Historic Site, near Bismarck, North Dakota.

The success of ground-based geophysics in previous projects in the Dakotas (summarized in Kvamme 2003) has demonstrated that archaeological features large and small can be accurately located and frequently classified to likely types. In 2001, a four-year project was initiated to study Double Ditch through combined geophysical and aerial methods. A principal focus was the development of maps and interpretations of Double Ditch's surface and subsurface features that would serve as long-term management and planning documents. Another focus was to pinpoint significant targets for a concurrent program of excavation that aimed at establishing a chronology of settlement changes and on understanding the natural and cultural processes that contributed to the final expression of the settlement. Excavations were also important for locating anomaly

sources and confirming identifications. Results of this work have been described elsewhere (e.g., Ahler 2005a; Kvamme 2006; Kvamme and Ahler 2007). The intent of this paper is to summarize principal remote sensing findings from this multidimensional project.

## 2 Aerial Imagery

Aerial investigations at Double Ditch yield an overview of the site in its present form. Imagery was obtained from a powered parachute, a slow and low-flying ultra-light aircraft. Its slow speed and low-altitude capability allows spatial resolutions of only a few centimeters (Hailey 2005). Color imagery was obtained using a Minolta Dimage A2 eight megapixel camera and a Sony DCR-TRV900 for digital video. Thermal infrared imagery was also acquired (discussed in a later section). The quality of the color imagery was such that one-inch (2.54 cm) diameter PVC pipes, used for datums and placed every 20 m across the site (for purposes of locating geophysical and topographical surveys), were visible. They became ready ground control markers for creating orthorectified photomosaics, one of which offers an overview of the site (Figure 1a). This early morning view illustrates a short grass surface immediately after the site was mowed. Low sunlight angles allow variable topography to be highlighted through shadow marks that reveal many houses and earth-borrowing depressions as well as numerous large mounds and the two prominent ditches that give the site its name. Ongoing excavations as well as historic excavations made in 1905 by Will and Spinden (1906) are visible, including three of their trenches arranged in a triangle.

A different view of Double Ditch under long vegetation

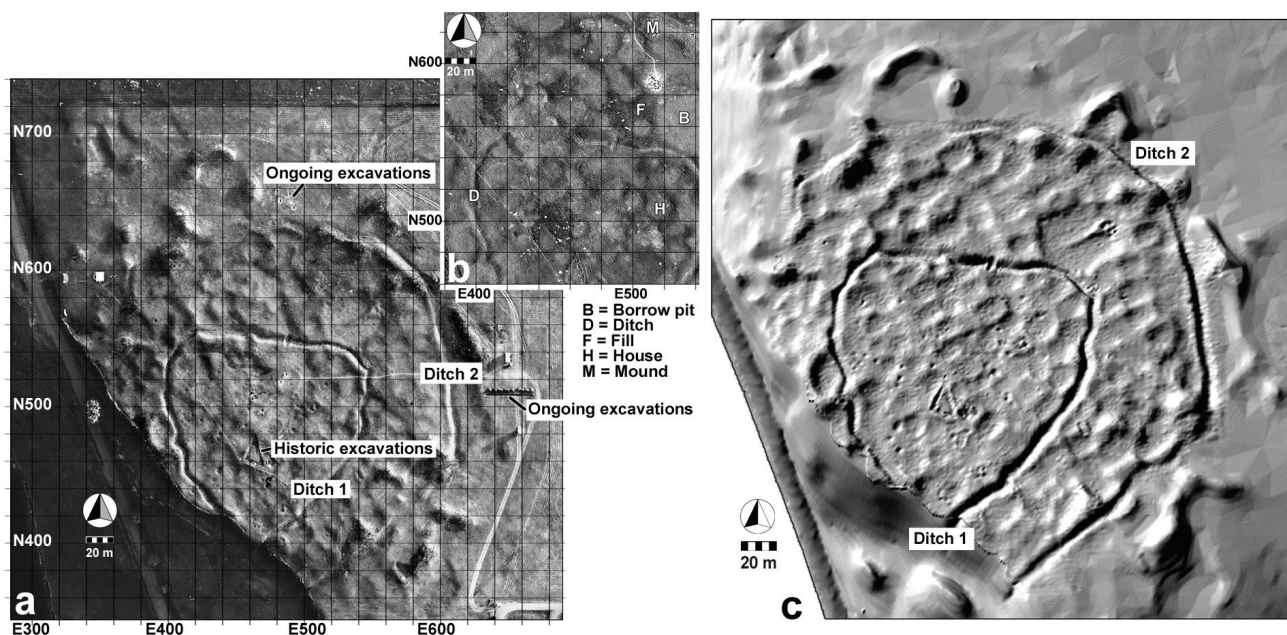


Figure 1. Aerial imagery of the Double Ditch State Historic Site. a) Early morning shadowed imagery under short vegetation illustrating topographic variations. b) Long vegetation view illustrating at least three distinctive vegetation types that correlate with site features. c) Double Ditch DEM collected with robotic total station.

is illustrated in Figure 1b where variable plant growth and “vegetation marking” delineates many shallow features. Color saturation and contrast manipulation enhances patterns of vegetation growth allowing fortifications, houses, and earth borrowing depressions to be distinguished from tall mounds and occupation areas. Although a black and white image does not do justice, these variations are nevertheless visible in Figure 1b (see Hailey 2005 for a color image of nearly the same view). These findings represent one line of evidence about Double Ditch’s structure and offer comprehensive views of the site’s principal feature types and surface topography.

### 3 Microtopography

A high-resolution Digital Elevation Model (DEM) of Double Ditch became necessary to record the site’s significant spatial structure more concretely than topographic changes only inferable from shadowed aerial imagery (Figure 1a). Such a model documents Double Ditch’s state today and forms a digital record for preservation and change studies. The geophysical surveys also benefit from a DEM because many responses correlate with topography. A Trimble 5600 robotic theodolite was employed for this task, controlled by radio from a remote control pad connected to a wheeled reflector rod. The last is simply rolled over the landscape while the theodolite, linked by radio, “tracks” it and continuously acquires data at a rate of about one measurement per second (these operations and field protocols are fully described in Kvamme et al. 2006). The outcome is a detailed and highly accurate DEM, with half-meter spatial resolution that characterizes many of the site’s features (Figure 1c). It shows not only fortification ditches, houses, and earth borrowing depressions, but also smaller holes that represent

collapsed cache pits or looters’ holes, early twentieth century excavations, and other features. This DEM forms a significant data source for understanding structural aspects of Double Ditch.

### 4 Magnetic Gradiometry

Magnetometry has proven to consistently and accurately reveal subsurface archaeological features in the Northern Great Plains (e.g., see Weymouth 1979; Kvamme 2003). The survey at Double Ditch was carried out with a Geoscan Research FM-36 fluxgate gradiometer from 2001-2003 (at four samples/m) and the more advanced FM-256 in 2004 (at eight samples/m, with each the average of two readings for noise reduction). Survey transects were separated by a half-meter to enable detection of small features. With thousands of anomalies in the 11 ha of survey, only principal findings are discussed here. These include two large areas within corresponding surface depressions, 30 and 50 m in diameter, completely devoid of anomalies and interpreted as soil borrowing areas (borrowed soil was used for lodge coverings or mound building) (Figure 2). The survey also indicates large middens and mounds as strong magnetic anomalies as well as berms of mounded soil adjacent to ditches and house perimeters. Numerous “point” anomalies about a meter in diameter principally represent subterranean storage pits (used for caching maize), while those located near the centers of houses are frequently hearths (houses are indicated by surface depressions and other geophysical evidence). In general, anomalies associated with cache pits resemble hearth-generated anomalies in common grayscale imagery—both are circular and a meter or so in diameter—but Markussen (2005) demonstrates that *maximum* measurements acquired over the former (an average of 4.66 nT)



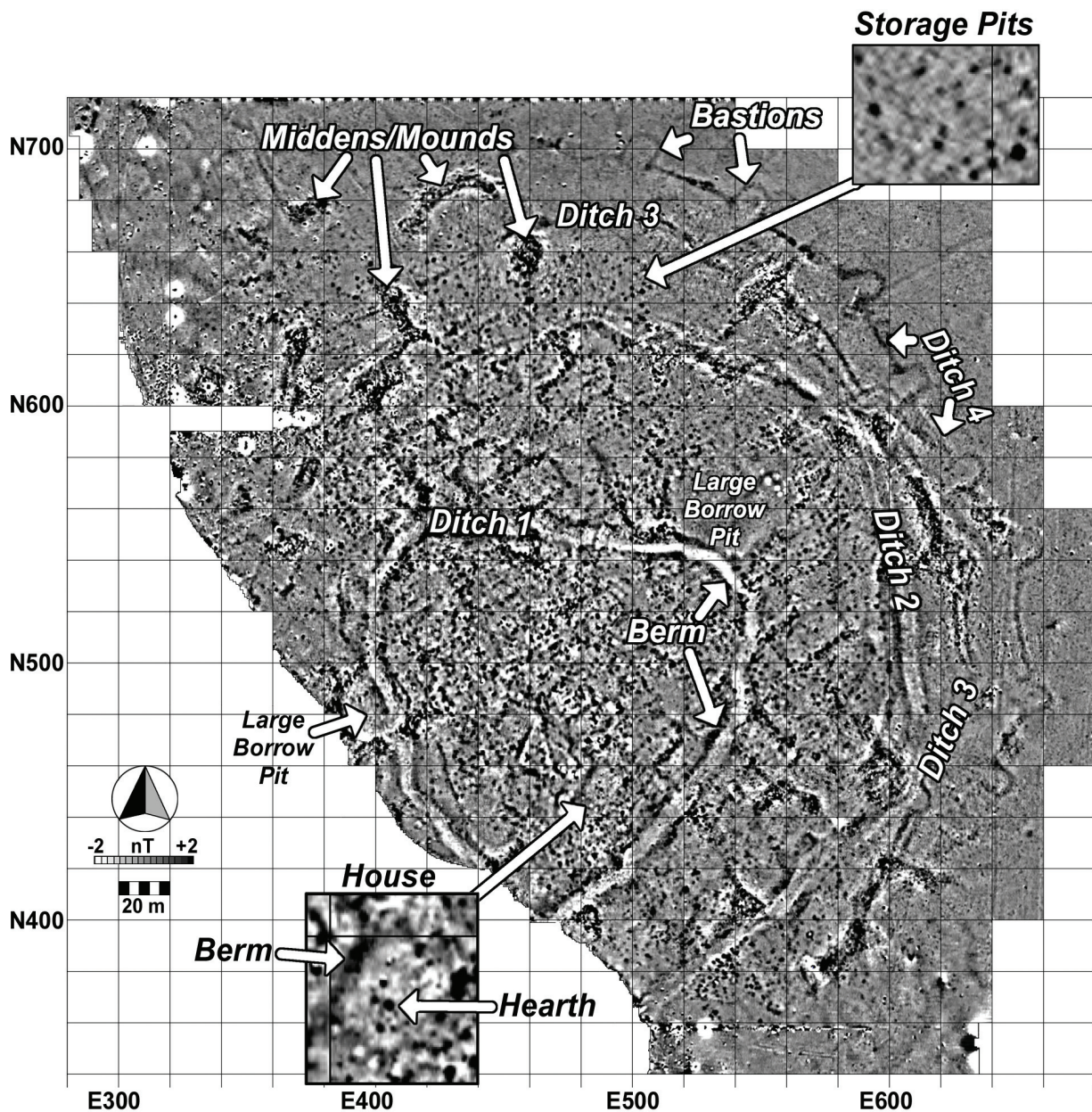


Figure 2. Magnetic gradiometry results at Double Ditch.

are statistically smaller than maximum values yielded by the latter (an average of 9.22 nT), with a two-sample *t*-test yielding  $t=6.2$  ( $n_1=42$ ,  $n_2=8$ ,  $p<.001$ ).

Of large significance, the gradiometry yielded the amazing discovery of two previously unknown fortification ditches with associated bastions unseen on the surface (Figure 2). Subsequent excavations showed them to be truncated—only their bottom portions remained intact—but they were still nearly 1.5 m deep in two excavations and completely filled with magnetically enriched topsoil and rubbish that created strong anomalies. Radiocarbon dates and artifact styles from these ditches extend the occupation to the late fifteenth century, considerably older than was previously thought (Ahler 2005b). These discoveries force new perspectives about the age, size, and importance of Double Ditch because it no longer can be considered a typical Northern Plains village. The outer ditch encloses an area of about 7.7 ha and may have included 160 households

(perhaps 2,000 residents) based on house density data from Mandan sites in the region (Wood 1967). Four ditches not only suggest the site is misnamed, but point to a more complex site history with at least four episodes of building and contraction.

## 5 Ground-penetrating Radar

Nearly a dozen GPR surveys were performed at Double Ditch, in blocks ranging in size from 100 m<sup>2</sup>–2,400 m<sup>2</sup>. A Geophysical Survey Systems Inc. SIR-2000 was utilized, generally with a 400 MHz antenna. Half-meter transect separations were uniformly employed with 20–50 traces/m and time windows up to 60 nS. One survey illustrates typical anomalies through the central portion of a rectangular-shaped house (Figure 3a). Its perimeter is clearly indicated by linear anomalies, as is a centrally located anomaly

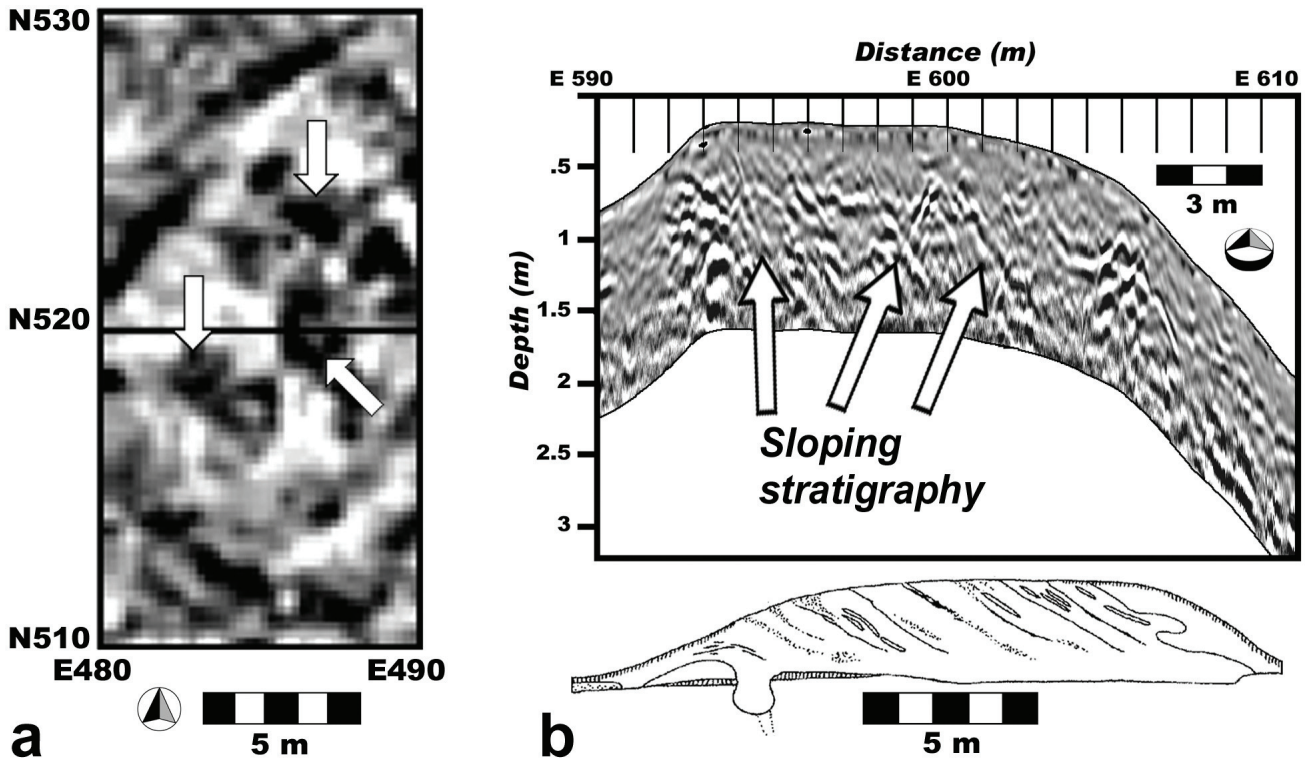


Figure 3. Ground-penetrating radar results at Double Ditch. a) Time-slice through a shallow house showing linear anomalies representing its perimeter, central hearth (diagonal arrow), storage pits (vertical arrows), and ubiquitous rodent work to about 44 cm below surface. b) GPR profile with extreme vertical exaggeration through mound showing sloping stratigraphy (top) with 1905 excavation profile of same mound (meters away) indicating sloping stratigraphy (bottom).

representing a hearth (verified by coring, diagonal arrow) and anomalies revealing storage pits (verified by excavation, vertical arrows). The remaining anomalies probably represent a combination of cache pits, auxiliary hearths, or rodent damage, which is considerable in the site.

GPR profile data were also informative. A transect over one of the largest mounded middens suggests diagonally sloping stratigraphy, a circumstance initially reported by Will and Spinden (1906) in their trench excavation through the very same mound (Figure 3b). The stratigraphy represents multiple dumping episodes where basket loads of soil and rubbish were deposited onto the mound's eastern slope, which allowed it to eventually grow into one of the site's largest mounds.

## 6 Electrical Resistance

An electrical resistance survey of about 10 ha was carried out with a Geoscan Research RM-15 twin-probe array and MPX-15 multiplexer. The latter accelerated survey coverage because four twin-probe arrays were established side-by-side in a single frame, allowing four readings per insertion. Prospecting depth was set at a half-meter to capture shallow house features and upper reaches of storage pits and ditches. Four measurements per square meter were uniformly acquired. Significant variations in topography (Figure 1c) influenced ground moisture and electrical properties of the soil, with low points retaining moisture and high points drying out more quickly. The data primarily reveal contrasts

between low resistance surface depressions (houses, borrows, ditches) and high resistance mounds, berms, and other prominences (Figure 4a). This allowed clear definition of mounds, middens, and even areas of moderate soil mounding, often better and more discretely than the magnetic gradiometry survey. Other electrical resistance anomalies reflect subsurface conditions—bastions and segments of the hidden fortification ditches are revealed as well as larger storage pits (Figure 4a).

## 7 Electromagnetic Induction

Limited electromagnetic (EM) induction instruments were carried out in two areas totaling about 0.4 ha using a Geonics Ltd. EM-38B. This instrument records two important dimensions of the subsurface: soil conductivity and magnetic susceptibility. Although the former is sensitive through a depth of about 1.5 m, the latter has a limited prospecting depth of about 50 cm (Dalan 2006). In a survey in the village core, the conductivity data paralleled electrical resistance findings, as expected from theory, but the magnetic susceptibility results revealed important evidence of soil mounding and depletion processes within the site owing to variations in thicknesses of magnetically enriched settlement soils (Kvamme and Ahler 2007).



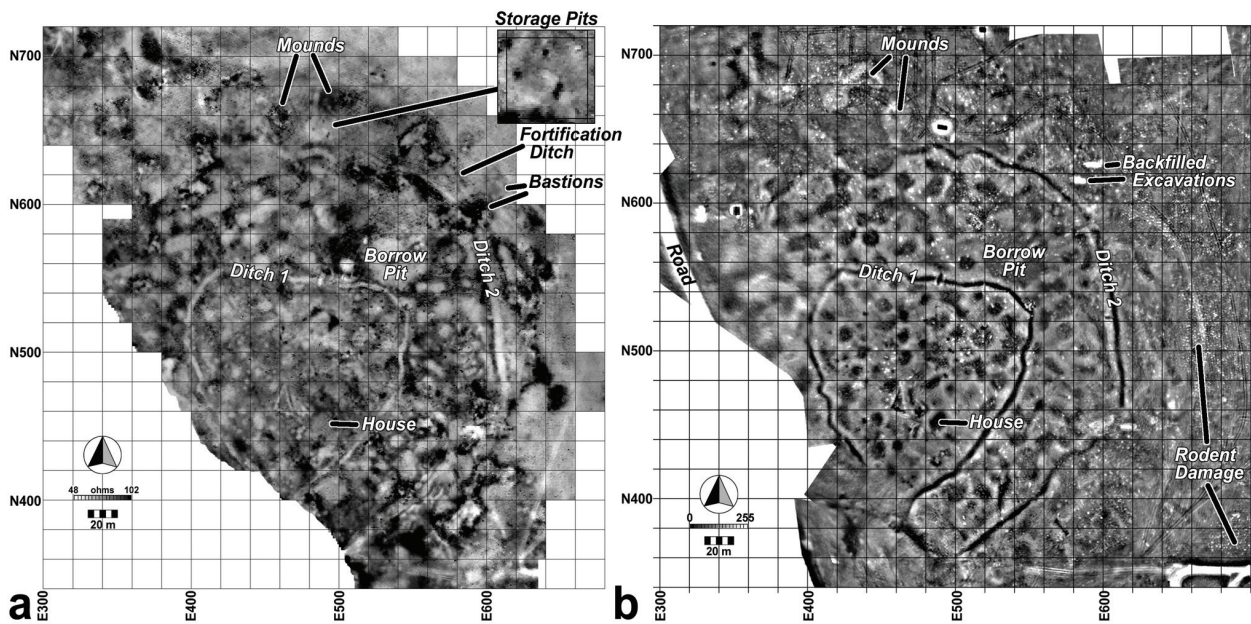


Figure 4. Geophysical results from Double Ditch: a) the electrical resistance survey, and b) thermal infrared composite from an evening flight under long vegetation.

## 8 Aerial Thermography

Thermal infrared imagery was acquired with a Raytheon Palm-IR250 (with sensitivity to about  $0.1^{\circ}\text{C}$ ) from the powered parachute at altitudes between 300–500 m above the site, which yielded spatial resolutions as high as 10 cm. Ground control markers (meter-wide crosses of thermally reflective metal) allowed imagery to be rectified and registered to the project's coordinate system by GIS methods. Results reveal warm roads, bare mounds of rodent-generated spoil dirt, and backfilled excavations from previous years that have not yet re-vegetated (Figure 4b). Of more significance are thermal differences between cool surface depressions (houses, borrow pits, ditches) and warm mounds and areas of village fill. These data emphasize the different nature of the ground within the village core (inside Ditch 2) where a complex surface of excavated and filled areas is portrayed, and the region outside of Ditch 2 where the surface appears featureless except for a few mounds. Evidence from excavations points to surface and near-surface obliterating processes caused by soil borrowing—including stripping of broad areas—that operated primarily outside of Ditch 2 (Kvamme and Ahler 2007). Unfortunately, the thermal data do not reveal deep features—no indications of buried Fortification Ditches 3 and 4 or of large storage pits are visible.

## 9 Conclusions

Geophysical, aerial, and topographic surveys at Double Ditch revealed countless anomalies of archaeological significance and give better understanding of the overall layout and structure of this important settlement. Although all methods contributed to an understanding of Double Ditch, magnetometry was the most productive and reliable, a common circumstance in other Northern Plains sites (Weymouth 1979; Kvamme 2003). Houses, borrow pits, ditches,

bastions, middens, cache pits, hearths, historic excavations, and numerous other features were revealed. They permitted excavations to be precisely located over targets of interest. The discovery of the previously unknown, outer two ditches forces new perspectives about the importance of this site in prehistory. Double Ditch is a village of much greater size, age, and complexity than previously thought. The nearly eight hectare area enclosed by its outer fortifications makes it one of the largest villages in the Northern Great Plains, which perhaps once included as many as 2000 inhabitants. Its interior structure, which now includes three additional lines of defensive ditches, palisades, and mounds, points to at least three episodes of contraction during the settlement's history. These changes probably came about through a combination of warfare and smallpox epidemics. Remote sensing surveys combined with targeted excavations have allowed the piecing together of a complex site history with an amount of detail not before seen in Northern Plains sites of this size (see Ahler 2005a; Kvamme and Ahler 2007).

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