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# The Hidden Landscapes of the Cambodian Early Modern Period (c. 1400-1800)

## *A Landscape-Scale Geophysical Exploration*

By

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This thesis is dedicated to all the strong women who told me I could, empowered me to be a success, and who inspire me every day.

Amy Duke

Renae Acton

Alison Carter

Julie Slevek

Marian Bailey

Doris Radecker

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# ABSTRACT

This research investigated three Early Modern (c. 1400–1800 CE) sites at Srei Santhor, Longvek and Oudong, in central Cambodia through a landscape-scale multimethod remote sensing and geophysical approach. The ephemeral nature of the Early Modern material culture – in addition to contemporary (c. 1900–current) urban and industrial expansion – has resulted in the Early Modern landscape being largely hidden in the subsurface. The Early Modern period is chronologically situated between the Angkor period (c.800–1400 CE) and the advent of modern Cambodia (c.1800–1900 CE). Evidence of this period is limited to historians' interpretations of primary documents, such as the Royal Cambodian Chronicles, with recent archaeological investigation providing new avenues for investigation. As there is partial comprehension of the specific material characteristics of the Early Modern landscape, an alternative approach was required. The methodological approach was taken to investigate the hidden landscape remains of Early Modern capital cities to consider how the result may augment the current understanding of this period of Cambodian history. This data was combined with historical information and archaeological excavation data to consider how the hidden landscape may broaden current research, which often views the Early Modern period as one of decline.

The geophysical datasets expanded our understanding of occupation at the Early Modern sites, by detecting potential additional settlement sites which were identified through a spatial analysis of the rice field configurations. In addition to this, magnetometry identified large sections of culturally modified sediment which suggest areas of occupation are hidden under the contemporary rice fields. The analysis of the rice fields and large landscape features at Longvek – in light of historical analysis of primary texts such as government codes and tax reforms – found evidence which supports current discourse around political control over the landscape, such as farming and human labour resources. The capacity to construct large-scale landscape features and have influence over rice field construction suggests a central political authority may have had control over human resources and rice production and taxation. Additional evidence was found which supports notions of continuity between the Angkor and Early Modern periods. Early Modern cultural material which appear to mimic Angkor period symbology, purpose and functionality of landscape features, suggests a level of physical adaptation was occurring. In this instance, changes which appear to be major were actually attempts at maintaining the social and political status established by the Angkorian kings. What was once understood to be a stark

change in material culture, can now be viewed as a system of adaptation based on established Angkorian principles. Examining the subsurface landscapes of Early Modern Cambodia has demonstrated how the hidden physical landscapes can add to academic debate and provide new avenues for investigating historically significant archaeological sites in Southeast Asia.

# DECLERATION

I certify that this thesis does not incorporate without acknowledgment any material previously submitted for a degree or diploma in any university; and that to the best of my knowledge and belief it does not contain any material previously published or written by another person except where due reference is made in the text.

This thesis in its entirety was edited by Elise Silson, who is not an expert in the field of archaeology or geophysics, detecting and correcting the presentation of the text to conform with standard usage and conventions as noted in the Handbook on Australian Standard for Editing Practice.

Signed.............................................

Date........18/12/2020............................

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# CHAPTER 1 - EARLY MODERN CAMBODIA

## 1.1 Introduction

This thesis uses a multimethod geophysical investigation of Early Modern hidden landscapes of Srei Santhor, Longvek and Oudong. The Early Modern period occurred between the Angkor period (c.800–1400 CE) and the advent of modern Cambodia (c.1800–1900 CE). Early interpretations refer to the period as the 'dark ages' (see, for example, David Chandler's first edition of *A History of Cambodia*, [1983]). These interpretations reinforced long-established ideas of decline related to the end of the Angkorian kingdom, and to the subsequent centuries of political instability which resulted in colonial intervention.

Historical research in this area has been limited to investigating primary documents such as the contested Royal Cambodian Chronicles ('the Chronicles', within this thesis) (for example, see Khin 1988 Mak 1981, Mikaelian 2006 and Vickery 1977a). The small amount of archaeological research conducted in this region by Polkinghorne et al. (2019b, 2018b, 2017, 2016, 2015) has been inhibited by modern urban expansion, which has made historic material unobservable on the contemporary land surface. The extant historical research and archaeological approaches have reached their limits for the investigation of such geographically large sites and a new approach is required to build on existing knowledge. To fill this void, a landscape-scale multimethod geophysical approach was undertaken to investigate the hidden landscape remains of the three Early Modern capitals (Srei Santhor, Longvek and Oudong) (Figure 1.1). This includes remote sensing techniques which were applied to the broader historic landscape, followed by large-scale magnetometer survey, and lastly targeted ground-penetrating radar. Traditional archaeological methods such as excavation were not employed for ground verification, due to logistical limitations. Geophysical data was combined with historic and archaeological research to reconstruct the physical landscape, thus facilitating the examination of adaptation and change during this period.

The maritime trade networks operating in Southeast Asia have been the primary focus of contemporary scholarship (see, for example, Andaya and Andaya 2015). Countries that were not viewed as prominent traders during this period have largely been excluded from research. The Cambodian Early Modern landscape has been a particularly neglected research area, as once-thriving capitals have been transitioned to rice farming land, which has been, in its turn, eroded by modern industrial expansion. A positive outcome of this transformation is that the rice fields are especially suitable for large-scale geophysical prospection. The open, flat topography is ideal for the multi-method approach used in this research.

Through a landscape-scale geophysical exploration, this thesis will challenge current scholarly debate concerning change and adaption during the Early Modern period, by expanding on current historical and archaeological research. This multi-method geophysical approach is the first of its kind being employed in Cambodian archaeology. No other landscape-scale investigation has been conducted in Southeast Asia, and this research paves the way for future geophysical exploration of Early Modern landscapes.

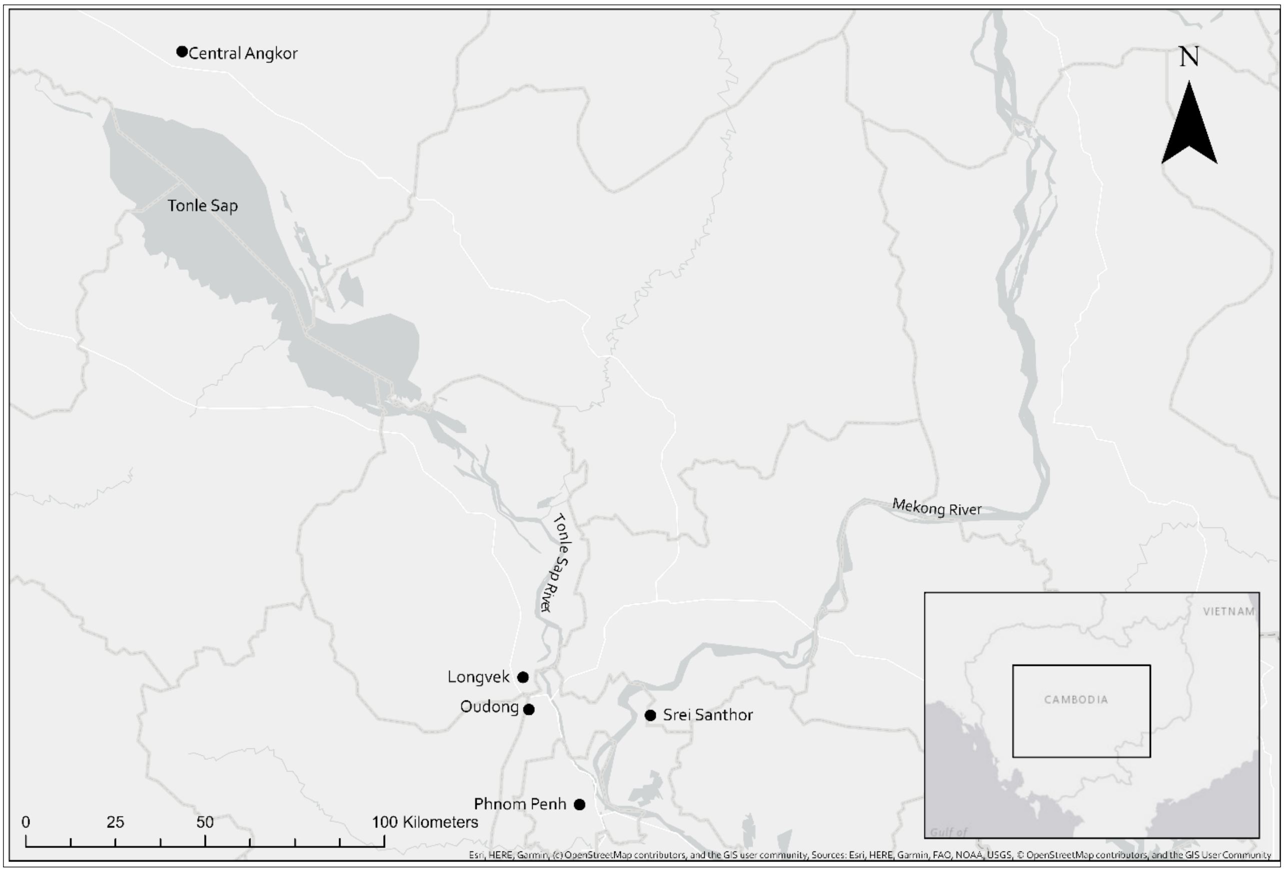


Figure 1.1: The three project areas Srei Santhor, Longvek and Oudong in relation to contemporary capital Phnom Penh and central Angkor.

## 1.2 The Early Modern Period

The term Early Modern is a twentieth century construct traditionally applied to European and American historiography. Early Modern is closely aligned with the advent of globalisation, and within a European context is defined as the period from the Renaissance (AD 1480) to the end of the French Revolution (AD 1820) (Steen 2019:1). This name is often applied without due consideration to historic context and associated negative connotations. Andaya and Andaya (2015:6) examine the application of the phrase within a Southeast Asian context, assessing whether regional specific features fit within established global characteristics. The defining characteristics of the Early Modern period—as a global concept—are the growth in long distance trade in the fourteenth century; cross-cultural encounters; expanding communication and trade patterns; polycentric international commerce; and distant economic hubs connected through the movement of people and goods (Andaya and Andaya 2015:6). Reid (1990:2) focused on trade as a central theme for the period and applied the phrase 'Age of Commerce' to describe Southeast Asia's increase in export. Reid (1990:4) notes that this turn of phrase does not fully encompass the breadth of changes to religion, state formation and strengthening, and urban expansion. Lieberman (1995) critiques Reid's (1990) position on trade in the region, believing that the Age of Commerce model is not applicable to mainland Southeast Asia, however the western and northeast archipelago certainly saw an increase in trading into the fifteenth century, supported by the steady growth and expansion of urban centres. Lieberman (2003, 2009) situated the Early Modern period in a global context by drawing broad parallels between Southeast Asia and European pre-modern periods. Pre-Colonial is applied in some historical discourse, but the phrase problematically centralises European dominance over the region in the nineteenth century, which overshadows the social, economic and political complexity of the period (Andaya and Andaya 2015:7). In examining the regional historic material, the terminology and chronology used in this study to examine Cambodian history, is defined by the polity being considered.

Terminology surrounding the Cambodian Early Modern period is related to the decline of Angkor and is referred to as either the 'Post-Classic' or 'Post-Angkor' period (Kitagawa 2007:53). Mikaelian (2013) attributes first usage of 'Post-Angkor' to Boisselier (1965) and Giteau (1966), both of whom were reinforced by Vickery (1977a), who titled his thesis into the Early Modern Chronicles *Cambodia after Angkor.* 'Post-Classic' is applied by Coe and Evans (2018), with 'Classic' indicating the Angkor period, based again on a problematic European-centric chronological naming system that emphasises the dominance of Western academic discourse in the region. 'Middle period' – as used by Pou (1977) – is less commonly used but again defines the period by its position between the Angkor and Modern periods. For this research, the term 'Early Modern' is preferred to situate this period within an international setting but also to move away from what Mikaelian (2013:293) describes as the 'dogma of decline' associated with the end of the Angkor period and also the Colonial-centric framing described by Andaya and Andaya (2015).

The decline of Angkor defines the beginning of the Early Modern period in Cambodian scholarship, with international trade an important intertwining factor. The Angkorian kingdom was dominant from the ninth to fifteenth centuries, with the central city of urban temples stretching from the banks of the Tonle Sap to the Kulen Hills in the modern province of Siem Reap, Cambodia. The extensive monumental architecture of bricks, sandstone and laterite; water management networks and sprawling low-density settlements have been the focus of research since the mid twentieth century (see, for example, Briggs 1951; Coe and Evans 2018; Cœdès 1968; Groslier 1960, 1979). The invasion of Angkor by Ayutthaya in 1431 and the move of King Cau Bañā Yāt's (also known as Ponhea Yat) capital from central Angkor to Basan, Srei Santhor, has been widely accepted as the beginning of the Early Modern period (Chandler 2008; Coe and Evans 2018; Kitagawa 2000, 2007; Polkinghorne 2018; Polkinghorne et al. 2018a; Vickery 1977a, 1979; Wolters 1966).

A dramatic description from early research depicts a mass evacuation of the city: 'First the king and surviving nobles, and then the people, fled from the "great and glorious capital" of Khmer civilization as if it were ridden with plague' (Briggs 1951:261). The elements contributing to the decline of Angkor have been examined by Briggs (1951), Coe and Evans (2018), Cœdès (1968), Fletcher et al. (Authority for the Protection and Management of Angkor and the region of Siem Reap (APSARA) Department of Monuments and Archaeology Team, 2008) and Lieberman (2003), who attribute it to a variety of factors such as the breakdown of hydraulic networks, an over-commitment to large scale infrastructure and the move to new religious cults. More recent research by Buckley et al. (2010, 2014) and Penny et al. (2019) identifies environmental pressure as a tipping point for the end of occupation in this region. What is clear is that the shift to the Early Modern period is not a single event, but rather a period of mobility and adaptation in light of changing local and regional political dynamics. Chandler (2008:78) states that "Cambodia was becoming post-Angkorian well before the abandonment of Angkor". The beginning of the Early Modern period cannot be attributed to a single date but is instead a long transitional period during the slow decline of the Angkorian kingdom.

The end of the Early Modern period is determined by the introduction of the French Protectorate in 1863, which persisted into the early twentieth century. The political decline of Cambodia leading up to the French Protectorate can be attributed to a variety of factors arising from internal and international conflict (Chandler 2008:119). Cambodian history in the eighteenth and nineteenth centuries was dominated by continuous Vietnamese and Siamese invasions and civil war. Kitagawa (2007:53) believes that the eventual decline of Cambodia was the result of internal strife, which resulted in the intervention of Siam and Vietnam. The French offered colonial intervention to terminate Thai control of the northwest provinces, mitigate Vietnamese influence and give political freedom under their protectorate (Chandler 2008:173). With the introduction of the French Protectorate, the Early Modern period makes way for the emergence of Modern Cambodia under colonial rule.

### 1.2.1 Early Modern Cambodia in Contemporary Scholarship

Rather than adopting a 'dark ages' narrative of social, economic and political decline (see, for example, Briggs 1951; Cœdès 1918; Groslier 1960), contemporary scholarship views the period as complex, and Cambodia as an invested participant in the regional political and economic activities. The economic status of Early Modern polities was dependent on trade and the exchange of goods favoured by international markets. This age of globalisation and regional commerce is characterised by the boom in trade routes between Southeast Asia and Europe (Reid 1990:2). The period saw the increase in trade along routes between Melaka, Sumatra, Brunei, Manila, Patani and Champa and European traders (Reid 1990:2). Traders of Chinese, Javanese, Indian, Burmese-Mon, Persian-Arab, Italian and Jewish heritage came from ports in Europe, the Middle East, India, Southeast Asia and China (Hall 2010:290). Pepper and spices were in high demand in the West, with China beginning a period of wealth and population expansion at the end of the fourteenth century (Reid 1990:5). States began to form around these urban centres, based on the wealth of commerce and military expertise deriving from maritime trade. Mainland states such as Siam, Burma, and Cambodia shifted towards centralised, absolutist rule (Reid 1990:3). In moving south from Angkor to establish capitals on the Mekong and Tonle Sap rivers, Cambodian elites were able to take advantage of this expansion, with raw materials such as forest goods becoming increasingly important to regional trade networks (Chandler 2008:105). Chandler (2008:95) states that:

> By the late fifteenth century, it seems, the social organization, bureaucracy, economic priorities of Angkor, based on heavy taxation, forced labour, and the primacy of the priestly caste, were no longer strong or relevant. New forms of organization, new settlement patterns, and new priorities based in part on foreign trade became feasible and attractive.

#### *1.2.1.1 Research Areas*

This thesis examines three established urban centres from Early Modern Cambodia: Basan (Srei Santhor), Longvek and Oudong (Figure 1.1) and the associated reigns of the usurper Kân (1512/3-

1525/6), King Cau Bañā Cand (Paramarājā) (1516-7-1566) and King Jayajeṭṭhā II (1619-1627) respectively.

Archaeological research on these sites includes work by Ewington (2008); Kitagawa (1999, 2000, 2007); Polkinghorne (2012-2013, 2018) and Nhim (2014-2016). However, no excavations were conducted until the *Middle Period and Related Sites Project* which began investigating selected Early Modern capitals (Polkinghorne 2018, 2012-2013; Polkinghorne et al. 2016; Polkinghorne et al. 2017; Polkinghorne et al. 2015; Polkinghorne et al. 2018b). The focus of these archaeological excavations was their landscape archaeology, including excavation at a proposed royal palace site and the examination of trade ceramics at Longvek through pedestrian foot surveys. At a broader scale, little was known about the physical landscape of the capitals beyond major surface earthworks, such as the citadel at Longvek. It has been hypothesised that a palace and trading ports existed, but there is no longer any surface material to allude to the presence of a royal capital (Polkinghorne 2018:267). The purpose of this thesis is to build on this archaeological research to better understand the historical landscape. The size of the three research areas at Srei Santhor, Longvek and Oudong makes landscape scale investigation the only practical approach.

##### 1.2.1.1.1 Srei Santhor

Srei Santhor is a parcel of land which becomes an island during wet season flooding of the Mekong and Tonle Toch Rivers. The modern town of Srei Santhor is situated on the banks of the Mekong River, in the north of the modern province of Kompong Cham. The region’s location on one of Southeast Asia’s largest river systems allowed Srei Santhor to flourish as an economic trade centre during the Angkor and Early Modern periods (Kitagawa 2000, 2007). It is generally accepted that the first capital after Angkor was established by King Cau Bañā Yāt at Basan, Srei Santhor in 1431 (Wolters 1966; Kitagawa 2000, 2007; Vickery 1977a; Chandler 2008; Coe and Evans 2018; Polkinghorne 2018). The exact location of Basan as a political centre is contentious, due to the fact that the historical sources from this period have been determined to be largely unreliable by Vickery (1977a:494).

Forest (2001:51) believes that the capital moved to the Srei Santhor region because it was a well-established religious centre for Theravāda Buddhism. Srei Santhor was occupied by rebel kings who were a constant source of tension for the legitimate kings occupying other capitals, such as Longvek (Kitagawa 2000:50). After the occupation of the area by King Cau Bañā Yāt, the Chronicles mention the area being occupied from 1494 before the capital was moved to Longvek in 1515, and again in 1594 before the capital was moved to Koh Slaket (Mak 2002:153). Historians have long debated the location of Basan, with Kitagawa (2000) utilising oral traditions to investigate Toul Basan near modern Baray Village. Close to Toul Basan is the Theravāda Buddhist site, Prasat Preah Theat Baray, which was believed to have been associated with usurper-king Kân. This identified Toul Basan is an important area in the investigation of the transition to the Early Modern period, as Kitagawa (2000) had identified Angkor and Early Modern cultural material on the surface. Nhim (2014-2016:57-58) has identified an area in the south on the Tonle Toch as Basan, citing evidence from Angkor-period Theravāda Buddhist images at the pagoda at Wat Sithor, but no surface archaeological evidence was reported to support this. Adding to this discussion, Vickery (2004) cites a village south of Phnom Penh, Ba Phnom as being the location of Basan, but this is yet to be substantiated. This argument will be expanded in 2.3.1.

##### 1.2.1.1.2 Longvek / Oudong

Dominant in the sixteenth century, Longvek was an important Early Modern capital and remains a significant site related to modern oral histories. Longvek was reputedly built by King Cau Baññā Cand (also known as Ang Chan or Chan Reachea) in 1450 on the banks of the Tonle Sap River in the modern province of Kompong Chhnang (Khin 1988:129; Vickery 1977b:21). Inscriptions found at Longvek suggest it was occupied during the pre-Angkor and Angkor periods (Briggs 1951:62). The building of the citadel itself is very briefly mentioned in the Chronicles, which record the King selecting an area to construct the citadel, royal palace, and associated mansions (Khin 1988:148). The raised walls of the citadel are visible on the ground today and in aerial photographs. They are one of the larger landscape modification projects undertaken during the Early Modern period (Polkinghorne 2018:263). There is limited surface evidence for the royal palace aside from a raised mound; likewise for the accompanying population which would have lived at Longvek. Other remaining surface features are from religious sites related to Theravāda Buddhism such as Wat Tralaeng Kaeng which is also documented in the Chronicles (Khin 1988:149-150). In addition to this temple, there are several mounds believed to be Buddhist terraces, but unlike Wat Tralaeng Kaeng there are no structures remaining, with surface evidence consisting of sculpture fragments, bricks, *sema* stones and laterite blocks. In contemporary Cambodia, Longvek is well known as the location of the Siamese invasion and consequent sacking of the capital by King Naresuan in 1593 (Khin 1988:158-60; Nhim 2014-2016:77). The story of the invasion provides details of not only the apparent demise of the city, but also the seizing of important texts and individuals, which ultimately resulted in Cambodia's decline.

Oudong, in the modern province of Kandal, is the penultimate capital for Cambodia before it was relocated to what is now modern Phnom Penh. After the destruction of Longvek, the capital was moved to Oudong during the reign of King Jayajeṭṭhā (also known as Chei Chettha) (Nhim 2014-2016:81). During a 1996 survey, Kitagawa (1999) identified a range of sites on the stretch of land between the citadel at Longvek and Oudong. She proposed two palace sites, one at Banteay Udong Lu Cei near the Tonle Sap that would have been built in the seventeenth and the final palace at Kleang Pram (Kitagawa 1999:149). Kitagawa (1999:149) completed a survey at the first proposed palace site, identifying the remains of a raised embankment/wall. With regard to other evidence, Oudong is documented in foreign accounts of Cambodia by traders and missionaries (see, for example, Népote 1973). Outside the Chronicles, these are the most comprehensive descriptions of an Early Modern structure. The perishable nature of organic building structures has resulted in no surface material remaining and, as with Longvek and Basan.

### 1.2.2 Historical Evidence

The textual sources for examining Early Modern Cambodia are a point of controversy among historians, with regard to the content and chronological accuracy of the primary documents they have examined (see, Khin 1988, Mak 1981, Mikaelian 2006 and Vickery 1977a). These documents include international sources relating to trade records, the Ayutthayan Chronicles (which date from 1350 and report on the founding of the city, translated by Cushman (2000) and eyewitness accounts to Cambodian primary material such as the Chronicles and non-government documents (Mikaelian 2013). Traditionally, these documents were published on perishable materials, such as paper or strips of palm tree leaf, and in some instances (e.g. the Chronicles), texts were re-transcribed every generation (Mikaelian 2013:261). The following sections examine the issues relating to primary sources and the debates about content and chronology, with a focus on Cambodian sources. A detailed examination of the primary sources is not the focus of this thesis, and translated primary documents are used here as a guide for the interpretation of the physical landscape.

#### *1.2.2.1 Cambodian primary sources*

The primary documents which remain from the Early Modern period number in the hundreds, written over a period of approximately 500 years. These consist largely of official government documents such as chronicles, gnomic codes and treatises, and non-government documents such as articles on magic and alchemy, epics, novels, and folk tales (Mikaelian 2013:261). Two important points need to be considered in relation to these primary documents: firstly, they are narratives whose functions are not to describe but to interpret, and secondly, these sources are primarily coming from, and relating to, royalty (Mikaelian 2013:260-261). As will be demonstrated below, the focus of historical research into these documents has been to validate their content and use them to create a linear chronology.

The Chronicles are the primary historic source for the examination of Early Modern Cambodia. These are not a single document, but rather are the product of several iterations, formalised in their current form in the nineteenth and twentieth centuries. The first and earliest known version of the Chronicles is referred to as the *Nong* text. It was transcribed in 1818 and translated into Thai later in the nineteenth century (Vickery 1977a:28). *Version II*, which is a recension of *Nong* pertaining to the reign of King Cau Bañā Cand, became a quasi-official version and the final version, the *1170 Fragment* (Vickery 1977a:28). The French colonial translation by Francis Garnier (1872, 1871) in the early twentieth century was based on the *Nong* texts, and was subsequently used by Briggs (1951), Cœdès (1918) and Leclère (1914), whose work became the dominant narrative for this period. Subsequent translations to French were conducted by scholars Mak (1981) and Khin (1988); Vickery (1977a) translating the *Nong* text and *Version II* to English.

The chronology and content of the Chronicles have been examined in detail by Mikaelian (2013), Mak (1981), Khin (1988) and Vickery (1977a). Vickery's (1977a) analysis examined variations of the *Nong* text, establishing errors in chronology and translation from Khmer to Thai and finally to French. The focus of Vickery (1979:3) study was from the end of the Angkor period in the mid fourteenth century to the early seventeenth century, coinciding with the restoration of Khmer rule after the sacking of Longvek in the late sixteenth century. Vickery (1979:135) is particularly critical of the work done on the Chronicles in the late nineteenth and early twentieth centuries, citing a multitude of issues surrounding the translation of the text from Thai to French, and a lack of critical examination of the text itself. The absence of a consistent dating system was a common complaint throughout Vickery's (1977a) analysis. Vickery (1979:150) believes that the 'first 150 years of Cambodia's post-Angkor history are thus entirely artificial' and dismisses the accuracy of the narrative surrounding the invasion of Angkor by Ayutthaya. Overall, it seems fair to say that the multiple re-writings of the Chronicles have resulted in the document becoming an altered re-creation as opposed to an accurate reproduction (Mikaelian 2013:260).

There are several core problems with relying on these texts as an accurate depiction of Cambodian history. Vickery (1977a) highlights that the Chronicles are royal documents and, as such, their content should be examined with an understanding of the date and reason of composition. In the case of the most recent incarnation, the legitimacy of the Cambodian Royal family was under consideration, which may have influenced the outcome (Mak 1977:157). While Vickery has been critical of the Chronicles themselves, Khmer researchers Khin Sok and Mak Phœun have been critical of Vickery's treatment. Khin (1986:198) is particularly scathing of Vickery's (1977a) analysis and the omission of the *Vàmn Juon* version, which was compiled under the orders of King Norodom in 1903. This version has been described by Khin (1986:214) as a faithful re-writing of the original, although he does identify several issues, including a lack of training for transcribers, the social status of the authors and their dependence on royal power, their lack of partiality, and finally, the copying of errors and the addition of details which were not in the original text. The treatment of these texts by historians adds an additional layer of complexity when considering the translation and content of the Chronicles. Mak's (1995:22-24) review is also critical of Vickery's (1977a) approach, particularly his notion that portions of the text are fictitious. Mak (1995:22) states that Vickery does not faithfully recount the text, relying on bold assumptions instead of the content of supporting documents. Mak (1995:24) poses the question:

> Why are the historic texts under consideration, which provide general information, only trustworthy since the period in which Western stories begin to appear, should they not have been used for the previous period? [own translation]

Mak (1995:24) thus challenges historians who only validate material which falls within the period beginning with Western contact in Southeast Asia. Countering Mak's (1995) analysis, Vickery's (1996:413) response is particularly critical, claiming a lack of evaluation and asserting that Mak (1995) was too reliant on foreign sources as corroborative evidence (Vickery 1996:410-411). Vickery (1996:411) reinforces this by asserting that the *Nong* version is the most reliable, while the *Vàmn Juon* used by Mak (1981) is the least reliable of all the sources, being written as a long form narrative. A particular point of contention was the reign of King Jayajeṭṭhā (1618-1626) at Oudong, with significant events documented by Mak (1981:125-154) disputed by Vickery (1996). This disagreement between versions is particularly important here, as King Jayajeṭṭhā was believed to have been the founder of Oudong and responsible for the construction of one of the palaces. The disagreement also reinforces the issue of Western historians favouring the details of foreign accounts and the Ayutthayan Chronicles over the content of the Chronicles.

To date, the Early Modern period of Cambodia has been viewed through the lens of textual sources. The Chronicles primarily focus on the events of the royal court, such as coronations, births, deaths, marriages and wars, but give little information on the built landscape. The details of this part of Cambodian history are so contentious, an alternative venue for investigation would be highly beneficial. Mikaelian (2006:24) examines of the legal codes reformed by the Khmer kings between 1601 and 1723, which adds to this narrative, but an archaeological approach including large-scale geophysical landscape investigation will provide an alternative dataset for the investigation of this period. In the examination of the physical landscape, having the most accurate date for events is not essential, especially in the application of geophysical techniques.

#### *1.2.2.2 External Historic Documents*

The variety of external primary sources is wide-ranging. Chinese accounts were recorded as the *Ming shi-lu* or *Veritable Record of the Chinese Ming Dynasty* (1368-1644), written just after the reign of King Cau Bañā Yāt based on contemporary documents (Wade 2007:5-6). According to Groslier (1958:20), western visitors arrived much later compared to other nation states. As a result, the earliest known Western eyewitness accounts were from Portuguese and Spanish sources in the sixteenth century, in particular those from a missionary Dominican priest, Gaspar da Cruz, who was at the court in Longvek in 1555-57, followed by traders in subsequent years (Groslier 1958:20-22). Detailed reviews of this material have been undertaken by Groslier (1958) and Népote (2007), with Groslier (1958) focusing on the representation of Cambodia, and more specifically Angkor, in the sixteenth century.

Historians have extensively examined this period and reported on the content within a regional narrative, including Andaya and Andaya (2015), Hall (2010), Lieberman (2003) and Reid (1988, 1990, 1993, 2000) as well as Cambodian specific historical examination by Chandler (2008) and Mak (1995); utilising primary sources relate to trading, laws, royal chronicles, and eyewitness accounts. As many of the external primary documents originate from trading sources, it is easy to see why Reid’s (1988, 1990, 1993) Age of Commerce concept has become a dominant narrative. This thesis does not seek to validate primary sources or interrogate the interpretations of historians, but rather add to established discourse in the hope of producing a more rounded understanding of Early Modern Cambodia.

#### *1.2.2.3 Choices in Transliteration and Timeline*

For the sake of consistency, a single style of transliteration and a single timeline need to be chosen. This thesis employs the longform narratives presented by Khin (1988) and Mak (1981), despite the weaknesses outlined in section 1.2.2.1. They provide the most detailed depiction of this period, and consequently offer greater detail regarding the physical landscape. As this thesis does not focus on the Chronicles, nor contribute to the debates surrounding these issues, it uses the translation and analysis of the Chronicles as a *guide* for the identification of archaeological sites and as a tool for the examination of the physical evidence. The spelling of names and dates of reigns have been taken from Mak (2002)—with the exception of direct quotes—when the source spelling is used. The spelling of place names adopts common modern English transliterations. As the chronology of the Chronicles is contentious, this thesis avoids applying exact dates wherever possible. It employs relative dating, with Chronicle dates as a guideline for the interrogation of landscape features. All dates will be reported in the common era (CE). Since the emphasis of this thesis is on the archaeological research and hidden landscapes of the Early Modern period, the focus remains spatial, in the physical landscape.

## 1.3 Investigating Hidden Landscapes

This thesis uses geophysical techniques (magnetometry and ground-penetrating radar) and remote sensing (lidar) to examine the landscape of three Early Modern sites. The multimethod approach allows for these landscapes to be examined at different scales, to investigate the broader landscape and also to focus on specific sites and identified features. The resulting data will be considered in light of spatial and landscape theories.

### 1.3.1 Research Questions and Aims

The research is guided by the following overarching question:

*How does the subsurface landscapes of Srei Santhor, Longvek and Oudong augment current understanding of Early Modern Cambodia?*

Several contributing questions also support and inform the study:

- What connections can be drawn between the physical landscape and the social and political structures of the Early Modern period?
- Are physical, social and political changes across time identifiable by comparing the three Early Modern landscapes to Angkor period landscapes (9th-15th century)?

- Can geophysics be applied to identify subsurface evidence of Early Modern period occupation and settlement patterns?

To address the current lack of archaeological evidence associated with this time period in the region, this thesis aims to:

- Conduct landscape scale geophysical investigations of three Cambodian Early Modern period sites—Srei Santhor, Longvek and Oudong—using an integrated geophysical approach.

- Investigate relationships between geophysical evidence, archaeological evidence and historical documents.

- Investigate social, cultural and political landscapes of the Early Modern period by identifying evidence of occupation and settlement

## 1.4 Thesis Outline

Chapter 2 will examine the current discourse around the recorded Early Modern landscape. This review will examine the natural, chronicled, constructed and hidden landscapes of Early Modern Srei Santhor, Longvek and Oudong. The emphases of this chapter are the types of landscape features remaining, and how they compare to similar feature types from the Angkor period and other historically contemporary counterparts. A comparison between chronicled and constructed landscapes will demonstrate that a significant portion of historic remains are now hidden in the subsurface and can be investigated using archaeological geophysical methods.

Chapter 3 will examine the methods available for examining hidden landscapes through remote sensing, magnetometry and ground penetrating radar. This chapter will examine the practicalities of each methods, their application and how they have been applied to investigating the hidden landscapes reviewed in Chapter 2. A review of how these methods have been employed in Cambodia will be conducted, centring on the site type and outcomes and identifying gaps in the current discourse surrounding the use of geophysics in Cambodia. An examination of landscape theory and spatial archaeology analysis will be conducted, focusing on how it can be applied to geophysical datasets to understand how the physical landscape can be imbued with social meaning. This chapter will justify the methods and theoretical framework being used as the best method for the landscape being investigated.

Chapter 4 presents the practical methods used for investigating the hidden landscapes of the three research locations, detailing the steps undertaken during data collection. Chapter 5 will present the results by research area and individual site. Chapter 6 is the discussion where the results are examined in light of the historical and archaeological evidence to examine physical, cultural and/or political adaptation at the three Early Modern sites. The discussion will examine each research location and site individually, examining the results in relation to current academic discourse. Finally, the concluding chapter will present final remarks and offer recommendations for future research.

## 1.5 Summary

This thesis illustrates the value and complexity of Early Modern landscapes and how a multimethod investigation can challenge or dispel the current narrative of absence. The benefit of this approach is the incorporation of surface and subsurface materials to better understand this period in Cambodian history. As a portion of the broader archaeological and historic research into the region, this study will contribute general insights into how the landscape was occupied and how it relates to important historic sites, documents and stories. This approach allows for the appraisal of previous methods and ideas surrounding Early Modern Cambodia, while interrogating new data in an integrated multimethod framework.

# CHAPTER 2 - EARLY MODERN LANDSCAPES

## 2.1 Introduction

The archaeological remains of the Early Modern period are difficult to identify due to the perishable nature of the structures, the ephemeral nature of occupation, and the expansion of modern industry. This chapter investigates the relationship between the physical landscape and social, cultural and political structures at Srei Santhor, Longvek and Oudong. This includes a discussion of how these physical landscape traditions transformed over the centuries, and how this change has previously been examined through investigation of historical resources and art history.

This examination of the transformation of Early Modern capitals from political and economic centres to agricultural land integrates several important considerations. Firstly, this chapter investigates the natural landscape in terms of the geology and climate conditions of the Early Modern period. The three research areas listed in Chapter 1 will be considered in light of the textual data. This discussion is further clarified by an examination of reported physical landscape features, taken from a review of the literature and field reports and site registers, as a significant number of these documents are unpublished. This chapter concludes with an examination of landscape features which are not visible, proving an introduction to methods that may be able to identify them. This examination is based on a comparison between Chronicle and physical landscape evidence. This review works to demonstrate the rationale behind the selection of the three sites of Srei Santhor, Longvek and Oudong that constitute the geophysical work in this thesis. As the chapter shows, these sites provide critical insight and further understanding of the social practices, movements, and conditions of life in Early Modern Cambodia.

## 2.2 The Natural Landscape

The diversity and abundance of the natural landscape of Cambodia allowed Angkor—the world's largest pre-industrial city—to flourish. The Angkorian landscape north of the Tonle Sap (Great Lake) is characterised by seasonal inundation of the lake, as the minimum and maximum shoreline variation is up to 10km (Evans 2007:16). This process of flooding deposits fertile sediment and leaves the relatively flat topography waterlogged for many months of the year. In contrast to this, the Early Modern capitals are situated on quaternary alluvium, which is unconsolidated sediment deposited by alluvial processes of the adjacent Mekong and Tonle Sap River systems (Figure 2.1).

Topographically, these territories are located on plains that are punctuated by hills, such as Phnom Preah Reach Troap, south of Longvek and Oudong, and the Cardamom Mountains, a considerable distance to the west. The geology of these mountains consists largely of granite, diorite and sedimentary rocks (Figure 2.2). Within this research area, the sites under consideration are located on alluvial plains on the Mekong River and its tributaries the Tonle Sap and the Tonle Touc Rivers. Longvek and Oudong are situated on an upland area surrounded by river back marsh, while the Srei Santhor region is characterised by higher alluvium (Figure 2.2) (Kubo 2008b:23).

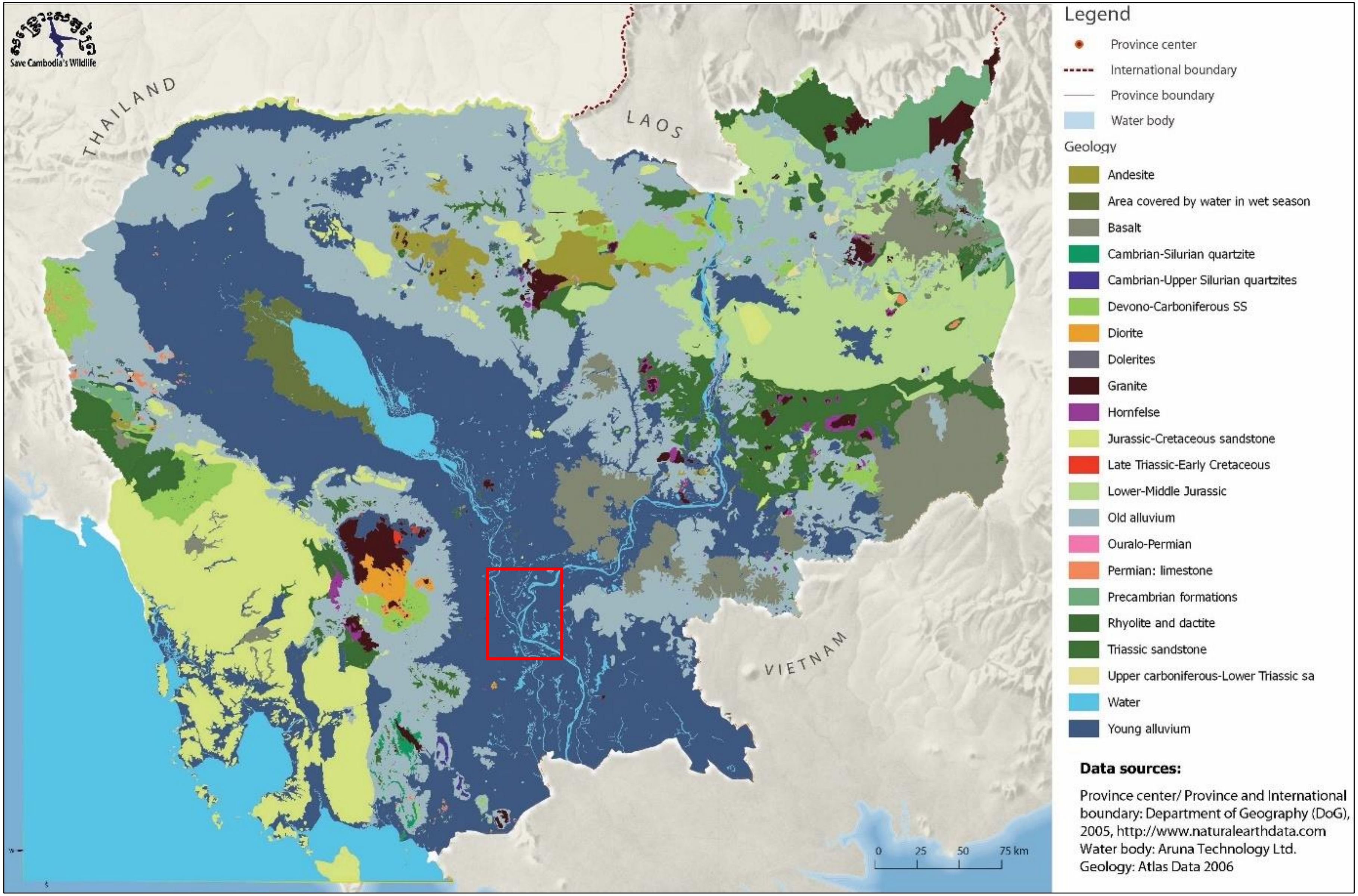


Figure 2.1: Geological map of Cambodia. Highlighted area represents Figure 2.2.

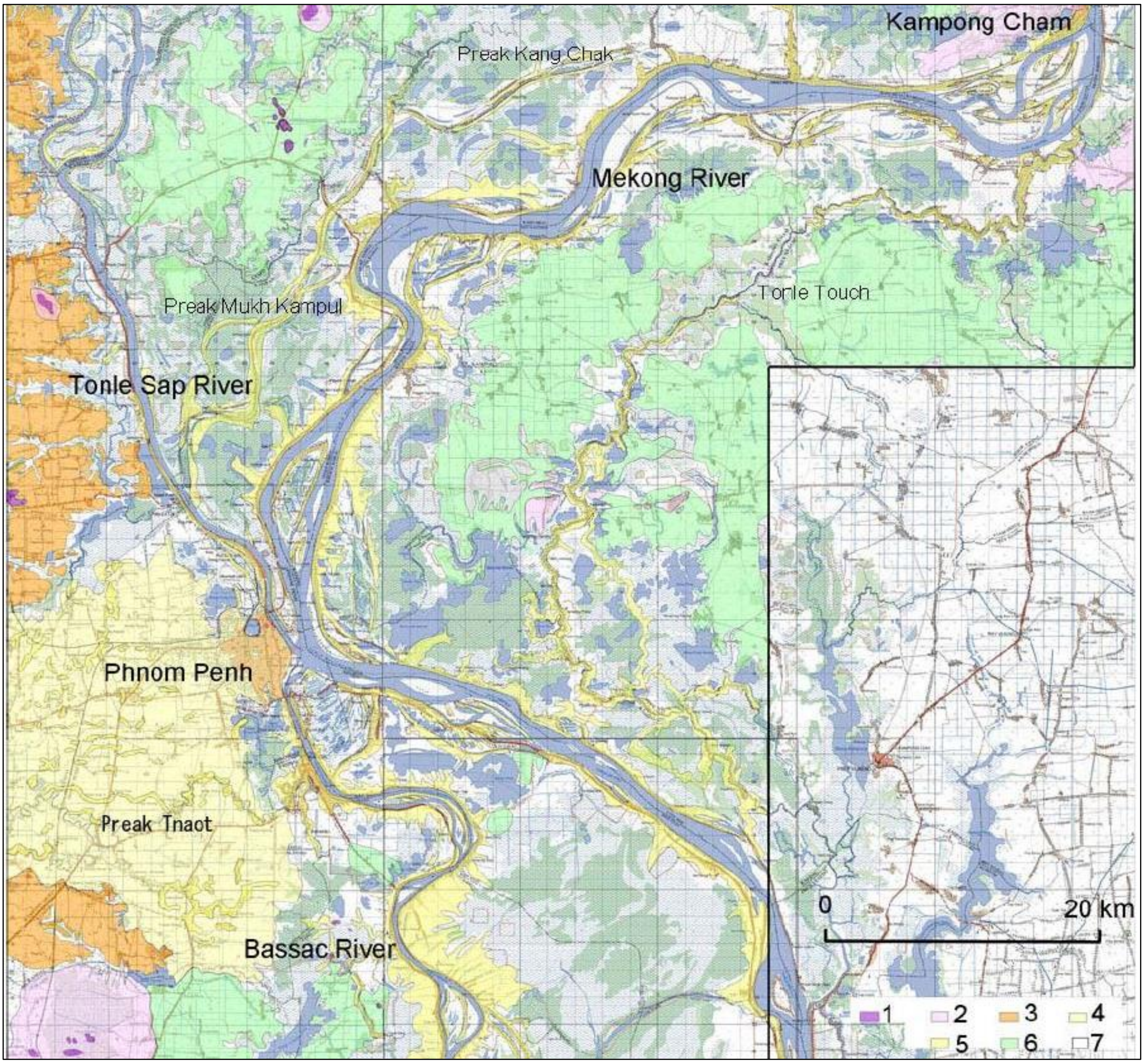


Figure 2.2: Geomorphological map from Kubo (2008b:23).1: hill, 2: pediment, 3: upland, 4: alluvial fan, 5: natural levee, 6: higher alluvial, 7: back marsh.

Cambodia is situated in a tropical monsoon climate zone which consists of a wet and dry season (Beck et al. 2018:3), with patchy rainfall occurring due to wet season rains falling from storm conditions (Delvert 1994:36). The Cambodian wet season begins in May and runs through to November, with the plains in central and lowland regions receiving 1400ml of rain per year (Heng 2015:70). Seventy-five percent of the country is on lowland plains with 25% of that subject to flooding for extended periods during the year (Delvert 1994:50). In contrast to the unpredictable falls of the monsoon, the flooding of the Mekong River and the Tonle Sap are significantly more reliable. The Mekong River begins in the Himalayas, and snakes its way down to the Mekong Delta through China, Laos, Thailand, Cambodia and Vietnam. The subsequent flooding deposits nutrientrich alluvium up the Tonle Sap River and on the surrounding floodplains (Hawken 2011a:57). From June to October, the volume of water in the Mekong River reverses the flow of the Tonle Sap River, filling the Great Lake and surrounding low lying areas. When the lake peaks in October or November, the flow reverses again (Penny 2006:310). Longvek and Oudong are on the banks of the Tonle Sap river, on a parcel of land slightly elevated above the flood zone: the modern landscape is dominated by wet season rice farming. Srei Santhor is located on low alluvial plains between the Mekong and Tonle Tonc Rivers that are seasonally inundated with water. The modern landscape is dominated by rice farming, as its topography and proximity to the Mekong and Tonle Touc Rivers results in high seasonal flooding and access to dry season irrigation (Nhim 2014-2016:72).

Current paleoenvironmental studies pertaining to Cambodia consist of either targeted studies examining Angkor, or geographically and chronologically long-range studies of Southeast Asia (for example, Cook and Jones 2012). Paleoenvironmental studies have been conducted on central Angkor assessing the decline of the hydrological networks (see, for example, Hall et al. 2018; Penny et al. 2019; Penny 2006; Penny et al. 2006). Buckley et al. (2014) investigated the relationship between climate variability and the decline of major political polities during the sixteenth and seventeenth centuries. Buckley's et al. (2014:17) results suggested periods of climatic instability in neighbouring regions during the sixteenth and seventeenth centuries and late in the eighteenth century. Climate volatility came in the form of extreme flooding and drought (Buckley et al. 2010:6748). The effects of this were seen in neighbouring Vietnam where the Tonkin empire experienced drought and famine (Buckley et al. 2014:2).

## 2.3 The Chronicled Landscape

The Chronicles and primary accounts provide a limited depiction of the three Early Modern sites under consideration. The following reviews the three sites in relation to primary documents, oral traditions and historians' interpretations. The reporting of the landscape in the Early Modern period is much different from the period that precedes it. As this chapter will demonstrate, historical representations no longer align with the physical remains and, as such, an archaeological approach is required to add a new lens of investigation into Early Modern Cambodia. A comparison between the Chronicled landscape and the physical landscape, as described below, aids in determining what landscape features may be hidden below the subsurface and require alternative methods of examination.

### 2.3.1 Srei Santhor

Speculation regarding the exact location of Basan began in the twentieth century with multiple locations suggested and contested (Figure 2.3). These are differentiated by approaches to translation of the Chronicles and Chinese accounts, which propose several locations depending on the source consulted (see, for example, Kitagawa 2000, 2007, Khin 1988, Nhim 2014-2016, Vickery 1977 and Wolters 1966). The use of Chinese sources to validate the Chronicles was applied by Wolters (1966:46), highlighting errors in the spelling of Basan, which consequently has resulted in multiple Basan locations being suggested. The common narrative of the arrival of King Cau Bañā Yāt as documented in the Chronicles recounts the journey on the river from Angkor to the subsequent establishment of a royal palace and city at Basan (Khin 1988:67). This is followed by the King moving to Phnom Penh due to seasonal flooding affecting their defensibility against Ayutthaya and diminished living conditions of his royal court (Khin 1988:67). Kitagawa (2007:57) argues that Toul Basan, near Baray Village, is the most likely location, based on the presence of tenth and eleventh century Khmer pottery and its proximity to the Theravāda Prasat Preah Theat Baray. During fieldwork in the late 1990s, Kitagawa (2000:58) identified surface ceramics and relatively dated the area as a political and economic centre from the Angkor Period until the eighteenth century. In addition to surface finds, Kitagawa (2007:58) documented the remains of large Angkorian landscape features at Prasat Preah Theat Baray.

Kitagawa (2007) proposed Prasat Preah Theat Baray, is associated with the usurper Kân, who in a popular uprising dethroned King Srey Sokonthor Bât (r. 1504–12) (Norén-Nilsson 2013:11). Now a part of an oral tradition, the story of usurper Kân documents the rise of a temple servant who, born in the year of the dragon, was envisioned by King Srey Sokonthor Bât as the usurper who would kill him (Norén-Nilsson 2013:12). The Chronicles document the rise of usurper Kân, from a commoner born in the Srei Santhor region to king in 1512 (Khin 1988:117-119). Details include the construction of a citadel and palace at Pursat, describing the complex with its numerous temples, towers and preparations for war (Khin 1988:121-123). The story of usurper Kân's reign largely focuses on war and his eventual death in 1525 (Khin 1988:176). Contrasting with this narrative are the oral traditions recorded by Kitagawa (2000), which present an alternative view of usurper Kân and his presence in the Srei Santhor region. These do not consider him to be a usurper king but rather a native king of the Srei Santhor. Stories of usurper Kân relate him to Early Modern religious sites at Prasat Preah Theat Baray, Wat Sokunream and Wat Sithor (Kitagawa 2000:60-61). At Prasat Preah Theat Baray, there is reported to be a relief of a prone Vishnu on a Naga, which is said to be a figure of usurper Kân (discussed in 2.4.1). The construction of Prasat Preah Theat Baray, has been attributed by locals to usurper Kân, with his court said to be located at Toul Basan and Toul Okña Phakdei.

In contrast, Nhim (2014-2016:57-58) used aerial photography in combination with ground survey techniques to identify an area in the south on the Tonle Toch as Basan. The evidence cited came from Angkor period Theravāda Buddhist images at the pagoda at Wat Sithor examined by Giteau (1975:58-59). Like many scholars investigating this area, Nhim (2014-2016) noted that the Srei Santhor region had a strong link to Angkor, with many sacred sites belonging to the Angkor period; these subsequently became modified to suit the principles of Theravāda Buddhist practices. Thompson (1996:283) believes Wat Sithor as an important Angkorian site and potentially the location of Early Modern royal court or palace based on the presence of tenth century inscriptions. The presence of Angkor period material reinforces Kitagawa's (2000:55) hypothesis that King Cau Bañā Yāt frequently travelled between Basan and Angkor, which would suggest Basan was established as a capital due to it being an already established centre. Based on the historical data, it would suggest that the area around Wat Sithor could also be a likely location of Basan. However, both these areas are disputed by Vickery (1977a) who believes it is located south of Phnom Penh.

The hypothesised location of Basan being in the Srei Santhor region remains disputed. Vickery (1977a:491-502) claims the location to be at Ba Phnom, south of Phnom Penh, following the claim that King Cau Bañā Yāt was a member of the Ayutthayan royal family. This hypothesis rejects Wolters' (1966) translation of the word 'Basan', asserting that Wolters has been misled by the French translations of Garnier (1871, 1872) (Vickery 1977a:42). In addition to this, Vickery (1977a:56-58) asserts broad, multifaceted disagreement over the location of Basan, based on three assertions. Firstly, the direct translation of the Chinese script of Basan means *Pa* (mountain), which therefore should translate to *Pa Phnom* in Khmer; secondly, Basan did not exist on any public maps in 1977 at the time of publication and; finally, *ba* has no meaning in Khmer, which is unusual in Cambodian naming traditions. Kitagawa (2007:56-57), however, views Vickery's (1977a) argument as unpersuasive and lacking evidence, because it misunderstood how Cambodian names were transcribed in Chinese text, and does not consider alternatives to the name such as Toul Basan (Hill of Basan). Furthermore, there may be multiple villages with the name Basan, and lastly, there are no grounds on which to prove relationship of King Cau Bañā Yāt to the Ayutthayan royal family. Based on the above debates, this thesis will consider Toul Basan, as cited by Kitagawa (2007) as a significant area for further research. This thesis examines Toul Basan, near Baray

Village as posited by Kitagawa (2000), through geophysical methods to investigate if there is evidence of a palace, or other features related to royal occupation.

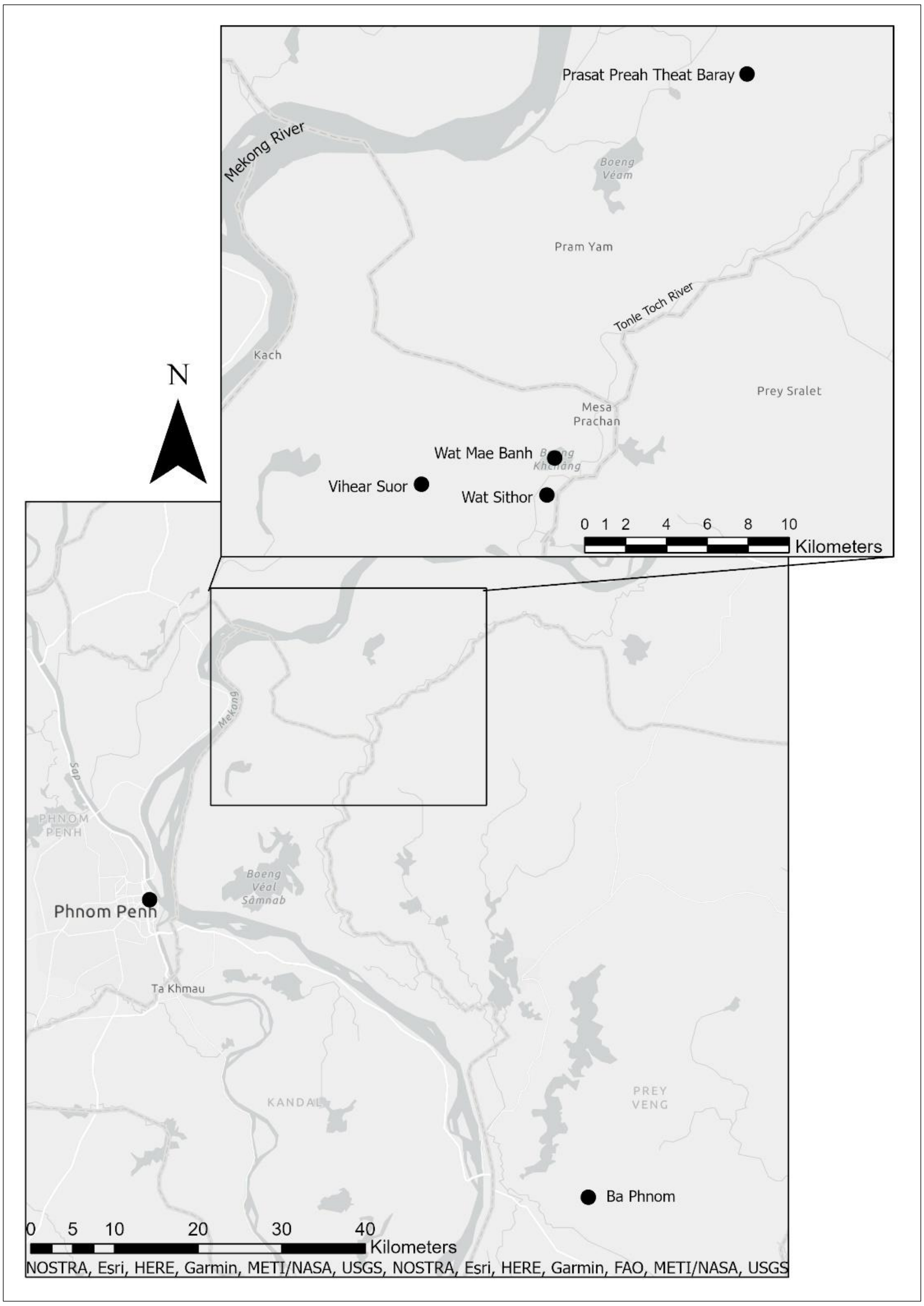


Figure 2.3: Proposed locations of Basan at Toul Basan, Wat Sithor and Ba Phnom.

### 2.3.2 Longvek / Oudong

Located on the banks of the Tonle Sap River, the sixteenth century citadel capital at Longvek was reputedly built by King Cau Bañā Cand in 1528 CE (Khin 1988:143; Vickery 1977b:129). Inscriptions found at Longvek suggest it was occupied during the Angkor periods. Briggs (1951:62) relates that an inscription dated to the reign of Harshavarman III (c.1066–1080 CE) provides a genealogy of a Khmer family, who acted as ministers and servants to the king, residing at village of Saptadevakul. Briggs (1951:62) believes this family played an important role when Longvek became a capital. The Chronicles document King Cau Bañā Cand arriving at Longvek after he defeated and killed usurper Kân (Khin 1988:143). The description of the construction projects at Longvek document King Cau Bañā Cand identifying the ideal area and ordering the construction of a palace, digging moats, raising citadel walls, laying foundation stones for the citadel and planting a defensive bamboo forest (Khin 1988:143). The raised walls of the citadel are visible on the ground and in aerial photographs and represent one of the largest remaining construction projects undertaken in Cambodia in the Early Modern period. The Chronicles provide a description that does not include how long the construction projects took, or what resources were utilised. This citadel remains one of the lasting figures of the Early Modern period's political success. In addition to the citadel, the Chronicles also reference the construction of the still-standing Buddhist temple, Wat Tralaeng Kaeng (Khin 1988:149-150), documenting the story of the king walking in the forest and discovering a block of stone on the branch of a tree (Khin 1988:191). It was from this stone and tree that the four statues of Buddha were constructed, each facing a cardinal direction. Wat Tralaeng Kaeng was constructed in 1530 CE on top of Angkor period relics, to house them (Khin 1988:192). Wat Tralaeng Kaeng was the symbolic heart of Longvek. Nhim (2014-2016:78) asserts these wooden statues were destroyed in the sixteenth century invasion of Longvek (see below), but there is no discernible evidence to support this claim.

King Cau Bañā Cand's political success was held to have been achieved through his sincere religious devotion (Thompson 2004:18). Cœdès (1995:197) believed King Cau Bañā Cand was one the greatest Early Modern kings; the Cambodian Chronicles attribute the king's political power to ending the war between the Khmer and the Siamese, which marked a generation of peace between the two polities (Khin 1988:209). The height of Cambodia's prosperity was achieved during his reign as he successfully defended Cambodia against foreign invasion and retook invaded territory (Khin 1988:210). King Cau Bañā Cand died in 1567 CE and was succeed by his eldest son Borom Reachea I (Khin 1988:212). King Cau Bañā Cand's grandson, Preahbath Satha I, was coronated after his father's death, however his reign is marked as a time of 'bad fortune' for Cambodia (Ngoun 2006:37). According to Cœdès (1995:155) during Preahbath Satha I's reign, Ayutthaya and Longvek signed a treaty, however the treaty was broken and raids on Siam restarted. According to the Chronicles, Siam attacked Longvek and the city fell in 1594 CE

(Chandler 2008:100). Ayutthaya's attack on Longvek was believed to stem from a desire to cripple the nation's ability to govern and their trade, reducing Cambodia to a tributary state of Siam (Ngoun 2006:39). This state of conflict lasted into the modern period, with additional ongoing conflict with Vietnam to the east. It is the destruction of Longvek which remains the central turning point Cambodian history.

Longvek is the setting for an oral history relating to the Legend of Preah Ko Preah Keo and committed to text in the Chronicles. Ngoun's (2006) research examined the story, considering how the narrative has shaped the Cambodia/Thai relationship, and the view Cambodians have of their Thai neighbours. The narrative is considered below, as an analysis by Ngoun (2006) alludes to metaphorical representations of landscape features. The legend of Preah Ko Preah Keo begins in the Angkor Period, but the climax of this story takes place in Longvek during the Siamese invasion. Preah Ko and Preah Keo were twin brothers, the former taking the form of an ox who possessed great divine power and held within his belly precious objects and the latter taking the form of a man (Ngoun 2006:54). Both brothers are remembered as peacemakers who brought prosperity wherever they resided. The Siamese coveted this prosperity.

The story recounts that while seeking shelter in the bamboo forest of Longvek, the Siamese army attempted to kidnap the brothers but were unable to advance. Instead, the army used cannons to shoot silver coins into the forest, then retreated. While they were gone, the locals cut down the forest in an attempt to retrieve the coins (Ngoun 2006:65). When the Siamese returned, they invaded Longvek and captured Preah Ko and Preah Keo, taking them back to Siam. Unable to escape, the brothers could not return and, as a result, Cambodia's prosperity declined (Ngoun 2006:65). Ngoun (2006:54, 58) believed Preah Ko is a metaphor for a *klang* (warehouse/store facility) which contained precious goods such as texts about religion, ceremonies, culture, arts and architecture, while Preah Keo was a metaphor for the sacred Buddha image, likely taking the form of a statue or a sacred crystal. In addition to the metaphoric landscape features, the story also describes a bamboo forest fortification and describes the citadel size as being so large, a horse could not gallop around it (Chandler 2008:101). If these metaphoric features did represent physical landscape elements, they need to be considered as elements hidden in the landscape.

Additional landscape features reported in the Chronicles include the construction of *stupa* on top of Phnom Preach Teach Troap (1533 CE) and the accompanying *boeung* or lake in the shadow of the mountain, both attributed to King Cau Bañā Cand (Khin 1988:193). The Chronicles report King

Cau Bañā Cand having a reservoir dug on the north side of Phnom Preach Treach Troap to support an iron foundry, and a second reservoir to the northeast for casters to create bronze objects and weapons (Khin 1988:151). Features were identified at Boeung Samreth during 2016 archaeological work that are consistent with the Chronicles' descriptions of a bronze foundry, although the only remains found comprise of a largely intact mould furnace (Polkinghorne et al. 2017:40-43; Polkinghorne 2012-2013:71). In addition to the foundry, the Chronicles also document the establishment of dry-season rice fields and a shed for the storage for boats and royal vehicles along the river (Khin 1988:194). It is not clear whether the rice fields of this historic period remain, or if they are identifiable as archaeological features.

The capital of Oudong was reportedly established by King Jayajeṭṭhā II in 1620 CE and remained there until the capital moved to Phnom Penh under the French protectorate (Kitagawa 2007:61; Mak 1981:130, 1995:161). The modern township of the same name is located on the Route No.5 highway, which links Phnom Penh with townships to the west. The transition from Longvek to Oudong effected a physical and political shift in Cambodian history. Physically, a new palace was believed to have been established in an area south of Wat Chedei Themei, in a location that was protected by a two sided embankment to the west and south and a reservoir to the northeast (Mak 1995:162). The Chronicles' description of the construction of the Palace at this site is very brief, reporting only that 'the king appointed the Ukana Kralahom Kaev as inspector general to build a royal palace in the region of Srah Kaev' (Mak 1981:131) [own translation]. It is not clear whether the reported Srah Kaev is the present reservoir, but the description of the site fits an area surveyed and recorded by Kitagawa (1999:147-148). Using additional historic documents, Mak (1995:162) describes the site in more detail, depicting it as being at the centre of a large paddy complex with its famous water basins (those constructed by King Cau Bañā Cand north of Phon Preah reach Troap). The construction of the palace, with it ramparts, bastions and annexes, lasted ten months and was completed in 1620 CE (Mak 1981:131, 1995:163).

The sacred landscape of Oudong has been theorised by Mikaelian (2006) who used seventeenth century Royal Ordinances to propose an abstract Cambodian Early Modern Theravāda cosmological landscape. King Jayajeṭṭhā II was acclaimed as the 'organiser of space' within a metaphoric cosmological structure where each class of person in the kingdom—intellectuals, warriors, judiciary, elites, and peasants—had a place and function within the system (Mikaelian 2006:238). The distribution of palatial structures was believed to have been a control measure for the administration of the region, with the four royal houses hierarchically classified (Mikaelian

2006:302). Social and cosmological concerns are said to influence the position of palaces within the Oudong's Early Modern landscape (Mikaelian 2006:304). Figure 2.4 is a representation of this spatial arrangement, with the different palatial units arranged on an east-west axis, with the kings palace at the centre *Citadelle du bassin de cristal* (Citadel of the Crystal Pool), which appears to be the palace site south of Wat Chedei Themei, to the west *Palais de planches* (Timber Palace), in the east *Citadelle de diamant* (Diamond Citadel), the *Citadelle du confluent* (citadel of the cross roads) in the North and Phnom Preah Reach Troap to the south (Mikaelian 2006:304).

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Figure 2.4: Configuration of the Longvek/Oudong landscape according to Theravāda cosmological ordering from Mikaelian (2006:306).

The last Early Modern palace was Banteay Oudong Lu Cei at Khleang Pram. When Kitagawa (1999:149,153) surveyed the site the only visible remains of the palace at Khleang Pram consisted of the external rammed earth wall and surface ceramics dating to the eighteenth century. Népote

(1973:11) used foreign accounts to depict the palace as a wooden structure constructed in the 1840s. It was surrounded by two separate defensive walls also constructed in the nineteenth century. The Banteay Oudong palace was built at the end of the Early Modern period and will not be considered here as it falls outside the timeframe under investigation. By the end of the Early Modern period (1850s), historians report that Oudong had a population of approximately 10,000 based on foreign accounts (Reid 1993:73). However, the legacy of the construction projects occurring at Oudong are the rice fields, which are still used by modern farmers and the *stupa* at the top of Phnom Preah Reach Troap. The walls associated with the two palace sites are the only visible surface remains at Oudong.

## 2.4 The Constructed Landscape

The constructed landscapes of Early Modern Cambodia can be divided into four broad categories: religious spaces, earthwork features, hydrological features, and evidence of industry. Each of these landscape features are examined here by type in order, to enable comparisons with other features of similar use or design found elsewhere within Cambodia and Southeast Asia. The following will examine the constructed landscape features of Early Modern Cambodia that remain standing.

### 2.4.1 Religious Space

Early Modern religious spaces largely consist of Theravāda Buddhist monasteries, temples and terraces. Prior to the arrival of Theravāda Buddhism in Cambodia, Brahmanicalal and Mahāyāna-Buddhist traditions were central to the expression of state architecture (Harris 2005:11). The expansion of these belief systems throughout Southeast Asia, saw an introduction of an architectural style that became synonymous with Angkorian design (Harris 2005:13). This included cardinally aligned temples and the incorporation of artificial water bodies which are said to represent Brahmanicalal Buddhist cosmology. Harris (2005:19) described the metaphoric style as:

> The rivers and *barays* represented the cosmic oceans; the enclosing walls, the iron-mountain chain (*cakravāla*) at the limit of the world's gold disk; and the temples, the central world mountain, Mount Meru.

Theravāda Buddhism arrived in Cambodia via the Khorat Plateau in the thirteenth century (Polkinghorne 2018:255), with Zhou Daguan describing an active religious community during his visit in 1297 CE (Zhou Daguan translated by Harris 2007:52-53). Within his account, Zhou Daguan describes 'their shaved heads and [they] dressed in yellow. They leave their right shoulder uncovered, and otherwise wrap themselves in a robe made of yellow cloth and go barefoot' (Zhou Daguan translated by Harris 2007:52). The introduction of the new cult overtook the established state religion, Brahmanism, with some scholars such as Briggs (1951:260) attributing the decline of Angkor to this change. Briggs (1951:260) described Theravāda Buddhism as a populist movement that disassembled the Brahmanicalal power structures with anti-aristocratic messaging, citing that this eventually led to the collapse of Angkor. The transition from Brahmanism to Theravāda Buddhism was a gradual process in Cambodia; the success of the cult can be attributed to its capacity to assimilate with pre-existing frameworks (Polkinghorne 2018:256). The adoption and success of Theravāda may be aligned with its ability to associate itself with existing spiritual values, sacred sites and local animist spirits (Thompson 1996:274). What is clear is the significant impact the change to Theravāda had on artistic design and material culture from the thirteenth century onwards (Polkinghorne 2018:255). The change in artistic and architectural structures is evident in the reconfiguration of Brahminic temples at sites across the region.

In the Early Modern period many of the religious spaces were the result of renovated Angkor period sites. The spaces were transformed complexes of older temples which were previously constructed of brick and stone, or new spaces built on older sites that contained only Early Modern Theravāda elements (Marchal 1918:4). There is a common theme of transformation across Early Modern sites, converting temples to a coherent and centralised Theravāda political configuration (Thompson 1996:284). Theravāda Buddhist religious spaces are some of the few places that remain intact within the Early Modern constructed landscape. Religious sites in Cambodia can consist of monasteries, temples (small and large scale) and terraced sites. Theravāda sites have a consistent layout based on cardinal orientation on the east-west axis and are characterised by a rectangular stone platform which supported a wooden structure with a tiled roof (Polkinghorne 2018:257; Thompson 1999:47). This structure was used as a prayer or assembly hall and is referred to as a *vihara* or *uposathagara*. The western end of the platform housed an image of Buddha and a pre-Theravāda p*rasat*, which was appropriated to become a *stupa*, and *sema* stones demarcated the sacred space at the eight points of the compass (Figure 2.5) (Polkinghorne 2018:257).

The previous temple complexes were reserved for the elite few, but the new Theravāda *vihara* design allowed access for all, with *sema* stones creating boundaries without inhibiting access (Marchal 1918:8; Thompson 1996:291). An examination of the transformed structures suggests that economic, logistical and spiritual factors contributed to the appropriation of established forms (Thompson 1996:178). The repetitive architectural design established in the Angkor period of aligning the long axis east-west is not only found in Cambodia, but also at Theravāda sites at Sukhothai and Ayutthaya in modern day Thailand (Thompson 1996:278). This spatial configuration is found at all the investigated sites examined here.

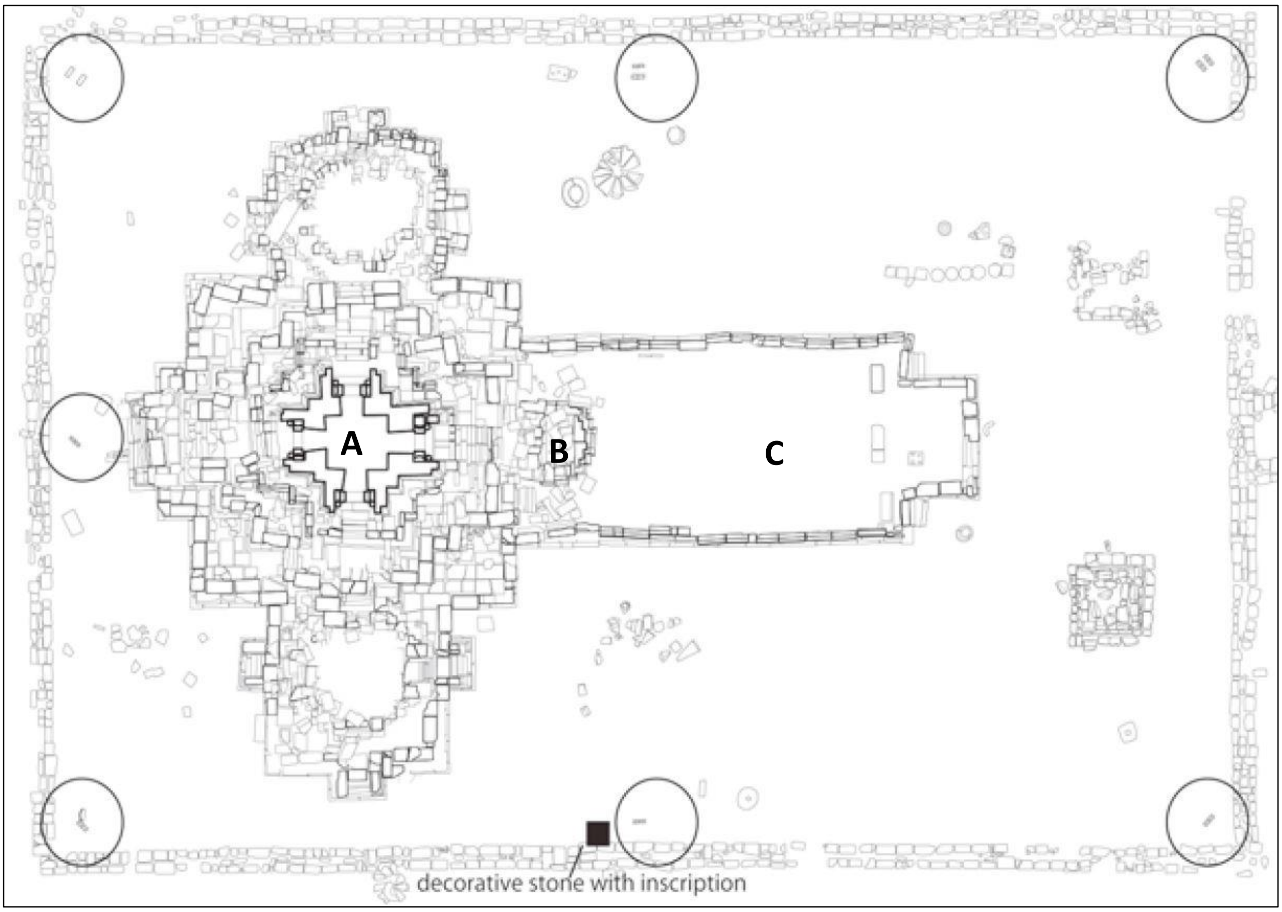


Figure 2.5: Theravāda Buddhist complex Western Prasat Top, Angkor Thom, Central Angkor. a) pre-Theravāda Prasat, b) image of buddha (not present in this example), c) platform, and d) sema stones (circled) (after Santo 2015:57).

The transformation of Brahmanicalal and Mahāyana to Theravāda Buddhist cult sites in Cambodia is not as well researched as the large religious complexes of central Angkor. The transition of temples and monasteries has been investigated by art historians, with a focus on the reappropriation of physical space (see, for example, Thompson 1996, 1998, 1999). While the transformation maintained the cardinal orientation of the previous incarnation, the bricks and sandstone under took a physical transformation and also metaphoric one to fit within the new cosmological system (Thompson 1996:274). Two examples of this are Western Prasat Top and Preah Palilay, both located within the Angkor Thom complex. Preah Palilay was investigated by French archaeologist Marchal (1925), with Western Prasat Top first recorded by Giteau (1975:113-116) and more recently investigated through conservation works by the Nara National Institute for

Cultural Properties (Sugiyama and Sato 2018; Sato 2015). Preah Palilay is characterised by a sanctuary enclosure with *gopura* and the fragmented remains of a Buddha situated toward the western end of a terrace (Marchal 1925:102). Preah Palilay is an example of a temple in transition, with two phases of construction identified: first, the typical twelfth century Khmer mountain-temple style *prasat* with a raised tower of sandstone surrounded by a laterite enclosure; and second, the thirteenth century construction of Theravāda reliefs, *gopura* and terrace (Marchal 1925:103; Thompson 1996:275). A similar two-phase process has been reported at Western Prasat Top, constructed in the tenth century, where the central tower was constructed on a laterite base overlaid by one of sandstone, both having distinct styles to the carved motifs (Marchal 1918:4). The central tower has two smaller towers to the north and east and is situated west of a terrace, with the area demarcated by *sema* stones (Figure 2.5). Recent conservation efforts have discovered that the two towers were later additions with a subsurface brick pit structure found once the towers were removed (Sugiyama and Sato 2018:2). The three-prasat configuration, first appears at Damrei Krap on the Kulen in the early ninth century and is repeated at different shapes and sizes until the mid to late tenth century (Polkinghorne 2008).

The surface and subsurface physical changes at these sites are only a portion of the transition process. The metaphoric transformation of *prasat* is also an important element in the transition to Theravāda Buddhism, as the *stupa* emerged as an important component in the broader complex construction. The *stupa* appeared in the thirteenth century as the construction of the *prasat* ended becoming a relic or antique of Brahminic traditions (Thompson 1996:280). During the Early Modern period the *stupa* became a place for sacred relics, with its physical role changed within the geometry of the Theravāda complex (Thompson 1996:280). The *prasat* was viewed as a relic of the past and, although the older sacred images they contained were maintained, the physical structure became a repository for cult objects no longer used. In turn, these sites became known as 'Preah Theat' or the 'Sacred Relic' (Marchal 1918:11; Thompson 1996:281). The image of Buddha, which is situated in the *vihara* (pavilion or assembly hall), became the central component of the complex, with the *prasat* or *stupa* decentralised behind it (Thompson 1996:281). The decentralising of the *prasat* eliminated the earlier Brahminic cosmic symbology that replicated the mountain temple complex of Mount Meru (Thompson 1996:292). Thompson (1996:282) believes the *stupa* was a device for maintaining the social memory of the Brahminic past and, in turn, the principal vehicle for transition. As such a vehicle, the investigation of Early Modern sacred relics is an important means to understand change during this period.

The terrace is another important religious element of the Theravāda complex, as it holds the image of Buddha and the *vihara*. The term terrace has a dual meaning (Marchal 1918:8), referencing the raised platform and also the site as a whole. Marchal's (1918) description is rooted in the examination of Theravāda terraces found within Angkor Thom but does not expand to sites outside the complex, or those which may have been built during the Early Modern period. The terraces found within Angkor Thom are described as raised areas, no more than a metre high, and constructed with repurposed Angkor period sandstone (Marchal 1918:8-9). This rudimentary description arises from a lack of preservation at these sites, as it is likely the *vihara* was built of perishable material and the sites are likely to have been looted. It is therefore difficult to ascertain whether the defining characteristic of a terrace is the platform itself, or the site as a whole.

Theravāda terraces outside of the Angkor Thom complex have not been widely investigated, particularly those mounded sites that no longer have surface evidence of previous use. Multiple instances of flattop mounds believed to be Theravāda terraces have been identified outside the citadel walls of Longvek. Two terraces are of interest here and will be investigated through geophysics for this thesis. The first and smaller of the mounds, Toul Slaeng, the name of which is derived from a type of tree prevalent in the area, has no evidence of surface material, encircling water or earthworks, which are only visible in the lidar data. Toul Tatob is the second and larger of the sites and is encircled by filled moat features. There is evidence of looting, with large holes toward the centre of the mound. Out of context laterite blocks are scattered across the site, along with several *sema* stones. None of the *sema* stones are situated within the traditional configuration of one at each of the eight cardinal points (Harris 2010:220). There is no surface evidence that suggests these are converted or purpose built Early Modern Theravāda Buddhist religious spaces, as both lack the traditional elements of terrace, *vihear* or *stupa*. They therefore warrant further investigation to examine the internal structure of the mounds through geophysical exploration in an attempt to understand their construction history and use.

Prasat Preah Theat Baray is a mounded Theravāda complex located near Baray Village in the Kandal Province region. It was identified as an important area to the usurper Kân (Kitagawa (2007). There have been many minor references to Prasat Preah Theat Baray throughout the literature (see, for example, Boisselier 1966:97; Bénisti 1965:101; Dagens 1968:186; Dalet 1936:27). The site was described by Lunet de Lajonquiére (1902:161-167) with a focus on the description of the lintels. The site is a raised mound on the upland floodplain, with an Angkor period *prasat* turned *stupa* at the western end and a raised terrace platform directly east. Of the *prasat*, Lunet de Lajonquiére (1902:161) described an internal structure of laterite with external sandstone decorative features and proposed that the structure had not been completed due to the consistency of missing elements (Figure 2.6). The long axis was described as being east-west, with the *prasat* having a crumbling corbelled roof and collapsed lintels (Lunet de Lajonquiére 1902:161). Although the *prasat* no longer has any vestiges of a corbelled roof, the many lintels supporting the terrace remain. The lintels at the site have been dated to the twelfth century based on the depiction of Vishnu*,* who is lying on a Naga with the top of his body straightened, in what is meant to be a representation of Vishnu giving birth to Brahma (Bénisti 1965:101). However, Dagens (1968:186) disputes this date, believing the lintels date to the eleventh century. The particular Vishnu lintel is important within the oral histories recorded by Kitagawa (2000:60), with the depiction of Vishnu laying on the Naga said to represent usurper Kân.

Despite these investigations, it is still not clear when this site was transformed into a Theravāda complex. The reconfiguration of this site poses interesting questions as to how and when the site was modified but also what its original configuration may have been. With a focus on the iconographic details of the Angkor period lintels, there has been no consideration of the processes by which the site was transformed. A subsurface examination of the area surrounding the *prasat* and terrace may allude to additional structural elements that were present, providing important complementary information regarding the transformation of this space during an important transitional period in Cambodia’s history. As such, this thesis will apply geophysical methods to the investigation of the flat-top mound to examine any subsurface remains that may allude to the presence of previous structures. This site warrants investigation as it maintains elements of the Theravāda complexes identified within the Angkor area, but also shows surface evidence of Brahmanical traditions. An examination of the subsurface of this site may further indicate how the complex has been transformed since its construction in the eleventh century.

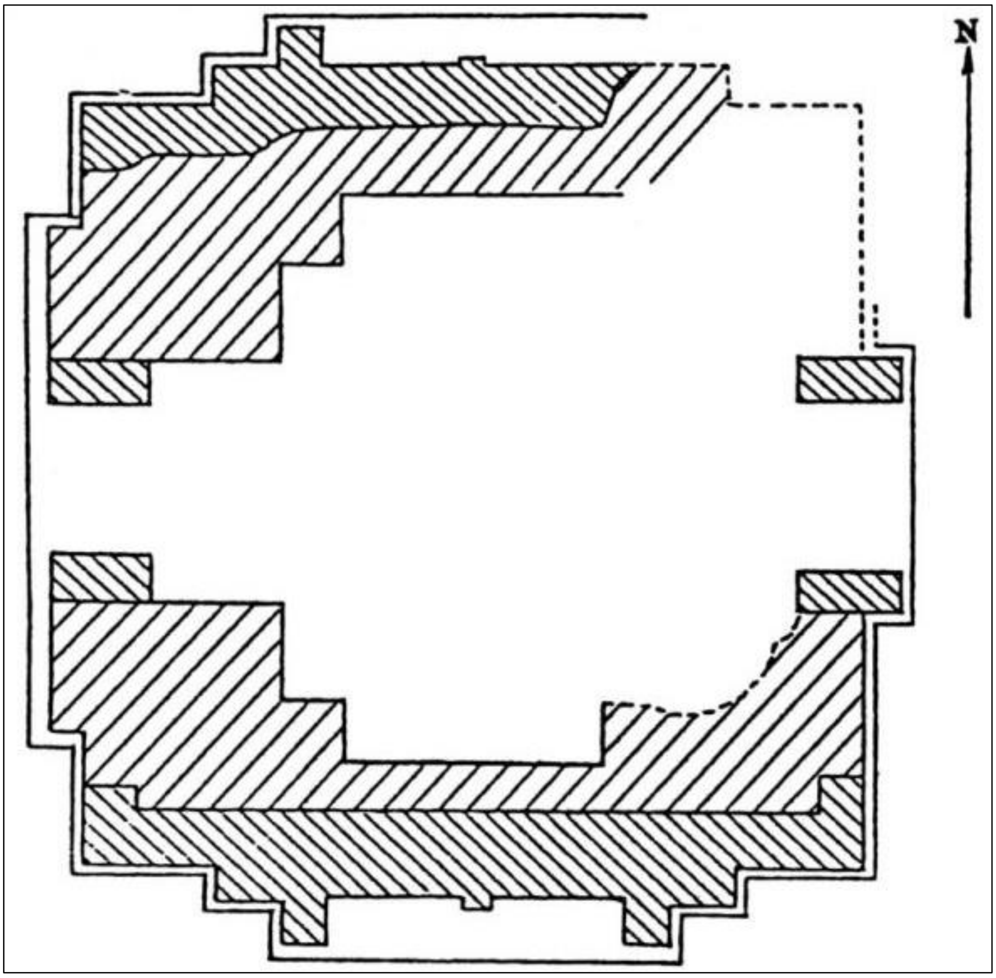


Figure 2.6: Plan view of the Prasat at Preah Theat Baray with the internal laterite and external sandstone components featured from Lunet de Lajonquiére (1902:163).

Wat Sithor in Kandal, Vihear Suor and Wat Mae Banh Province is another example of a renovated sacred space (see Figure 2.3 for location). Wat Sithor was located in an important political centre for the Early Modern period, and maintains characteristics which suggest the Angkor period complex was renovated to encompass the new and uniform architectural requirements that were well established by the fifteenth century (Thompson 1996:283). Wat Sithor was a Mahāyāna Buddhist shrine that was physically transformed to encompass the new Theravāda complex requirements by taking the existing architectural foundations and adding elements such as a *stupa* directly behind the central *vihara* (Thompson 1996:283). The recycling and transformation of existing sacred sites is in line with the changing nature of social and religious structures during this period.

Wat Tralaeng Kaeng is a Theravāda complex that is still in use at Longvek. Wat Tralaeng Kaeng was an Early Modern Theravāda complex, built on a flattop mound and the remains of an Angkor period temple. Epigraphic material, architecture, and sculpture exists from the pre-Angkor and

Angkor periods; most notably these include a series of inscriptions as documented by Cœdès (1942:119-120). In addition, the four-sided statue faces the four cardinal points with the four images of Buddha being constructed in *attharasa* style, each made of wood with their feet made of stone (Khin 1988:149-150; Vickery 1977b:22). The name, Tralaeng Kaeng—translated as “cross” or “crossing”—directly correlates to the shape of the temple, with Thompson (1998:250) describing the cruciform structure as an ‘atypical plan of the *vihāra* set on a man-made hill’. While the current statue is a nineteenth century replica, it stands between the four massive stone feet that are the only remains of the sixteenth century statue (Thompson 1998:250). Aside from these feet and the mound, it is not clear what of the Early Modern temple remains intact, hidden beneath the surface.

### 2.4.2 Constructed Topography

Constructed topography can be defined as any kind of landscape modification that alters natural topography. It is one of the most prevalent and lasting forms of landscape modification from the Early Modern period. The instances researched for this thesis mainly relate to systems of hydrological management and earthwork embankments, such as the citadel described above.

#### *2.4.2.1 Hydrology*

The hydrological systems employed are greatly dependent on the geographical and environmental conditions of the area. They are important markers of former socio-economic structures, particularly in relation to the management of water for rice production (section 2.4.3.1). As Srei Santhor, Longvek and Oudong are all located next to river systems, they all contain similar hydrological features. The hydrology devices at all three capitals consist of ponds of varying sizes, raised embankments, and channels for water control. The typology of water management in Cambodia has been well established with regards to Angkor period discourse (see, for example, Evans 2007; Lustig et al. 2018; Lustig and Pottier 2007; Pottier 2000). There are several kinds of hydrology-related constructions that were commonly built during this period. The most relevant to this thesis are: *tumnup*, embankments, *trapeang* and *prek*. These are described below.

A *tumnup*, or dyke, is a large-scale water barrage, usually constructed in a flattened “u” shape to trap water and create an artificial wet land (Nhim 2014-2016:73). This method of hydrology acts as the water source for fanning rice bund configurations, and is associated with rice farming at all three capitals. Nhim (2014-2016:75) believes the system and term originate from the Khmer but does not know when this method of irrigation may have emerged. The types of *tumnup* recorded by Nhim (2014-2016) at Longvek and Oudong have not been recorded within the greater Angkor complex. Dykes were referenced by Groslier (1979) (translated by Lustig and Pottier 2007:159), but the description of these water management devices does not fit that of the *tumnup* documented by Nhim (2014-2016). This is most likely due to the different topography between central Angkor, which requires water diversion methods, and Early Modern sites, which instead require water retention methods. *Tumnup* that trapped the receding water from the flooding of the Tonle Sap were identified on the periphery of central Angkor by Hawken (2013:352) but are believed to be contemporary features.

Other forms of raised dyke embankments for water management and control are consistently found within Angkor period and Early Modern period contexts, either as singular features or larger devices such as a *baray, trapeang,* or moats. At Srei Santhor there is evidence of an Angkor period *baray* located east of Prasat Preah Theat Baray. The *baray* in Angkor period contexts were traditionally aligned east–west, as was the general alignment with religious sites, and before the eleventh century, were placed north of the temple (Evans 2007:22). In contrast to the scale of the *baray*, a *trapeang* is a smaller rectangular rain-fed pond feature, dug into the ground. Features such as this are often associated with domestic dwellings, as the embankment is extended to accommodate housing (Evans 2007:25). The association of pond and mounds within a domestic context is considered in section 2.5.1 and as indicators of population levels within Angkor by Hanus and Evans (2016).

Another water management device found at all three sites is the *prek,* a long channel, which diverts water from a river source (Nhim 2014-2016:73). In contrast to the extensive hydrological channel network seen at Angkor (see Groslier 1979; translated by Lustig and Pottier 2007), Early Modern water management favoured the use of *prek*. The *prek* feeds agricultural systems in Srei Santhor, with Nhim (2014-2016:74) identifying fifteen still in use in the region. At Longvek, the *prek* feeds a water management network associated with rice production, which appear related to the citadel. It has been hypothesised by Nhim (2014-2016:80) that the *prek* at Longvek was related to a port at the northeast bastions and may have been an inlet for trading vessels. At Oudong, the *prek* called Peam Chumnik is believed to have been constructed in the nineteenth century during the reign of Ang Duong (Nhim 2014-2016:74). A second *prek,* running parallel to the modern National Route 5 highway, is related to a palace site proposed by Kitagawa (1999) south of Wat Chedei Themei. The *prek* identified as associated with the three Early Modern sites proposed in this study are significantly smaller and less complex versions of the water management system seen at Angkor. Nhim (2014-2016:73) notes the human resources required to construct these features would have been substantial, and a village would have been capable of building and maintaining them. Water as a commodity in the Early Modern period has not been previously considered as an indicator of social or political control in the area, but the examination of constructed hydrological systems during this period leads directly to questions about who built and administered them.

#### *2.4.2.2 Earthworks*

The walls of Longvek's citadel (Figure 2.7) are the largest extant earthwork projects constructed during the Early Modern period. It is three-sided, with the fourth side open to the Tonle Sap River. A cross section of the five metre tall south wall in Figure 2.8 demonstrates its construction methods: the digging of the ditch resulted in the accumulated earth forming the wall. The complex consists of three separate wall sections with the internal wall the most basic of these, consisting of only raised earth. The second, middle, section is the most complex, with eight rectangular defensive bastions located on the western and northern sections. A bastion is a structure that projects from the wall, large enough to hold several defenders and provide flanking fire on any attacks at close proximity (Keeley et al. 2007:67). Excavations have identified post holes on top of these bastions, which likely would have supported a wood palisade structure, further enhancing defensive capabilities (Polkinghorne et al. 2015:36). Finally, the third section appears to be connected at the northeast corner to a *prek,* although poor conservation means portions of the wall are missing on the northern edge. At the southwest corner, the wall turns into a raised road/water management embankment over the floodplain to Oudong. The two embankments at Longvek connect the south opening in the citadel wall with an area believed to have contained the palace and the still standing Wat Tralaeng Kaeng. Investigation of these features in light of Lustig and Hendrickson's (2012:193) examination of embankments' dual functions as water management devices and roads for transport would suggest these are two scaled-down versions of the Angkorian road network. The Angkor period road network stretched over 1000 kilometres, connecting the centre of the empire with those cities on the periphery (see Hendrickson 2010; Lustig and Hendrickson 2012).

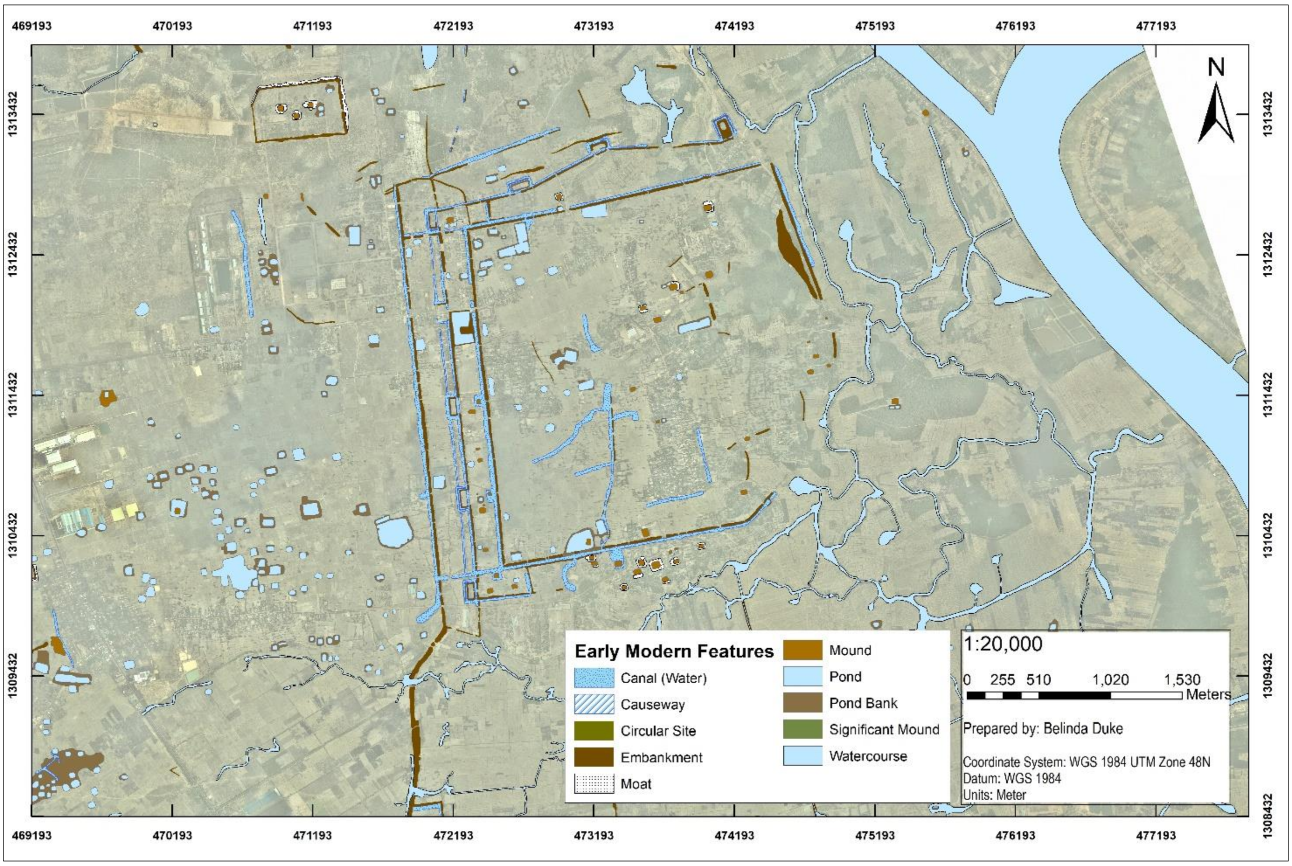


Figure 2.7: Earthworks at Longvek.

Figure 2.8: Cross section of the citadel wall from (with permission from M. Polkinghorne)

At Oudong, there are two examples of embankments that may have also been a part of a walled settlement or defensive strategy. The first is the two-sided embankment south of Wat Chedei

Themei that Kitagawa (1999) identifies as the site of the first palace at Oudong (Figure 2.9). This site has several mounds outside the complex, all of which contain surface ceramics dating from the early fifteenth to the eighteenth century (Kitagawa 1999:152). Both these embankment features have been heavily impacted by modern urban expansion, with only portions remaining in the landscape. The second is a raised wall which contains an internal wall made of brick, which Kitagawa (1999:149) identifies as Banteay Udong Lu Cei Palace. According to Kitagawa (1999) this feature was related to the palace constructed in the nineteenth century, which excludes it from the historical period that sets the research scope of this thesis.

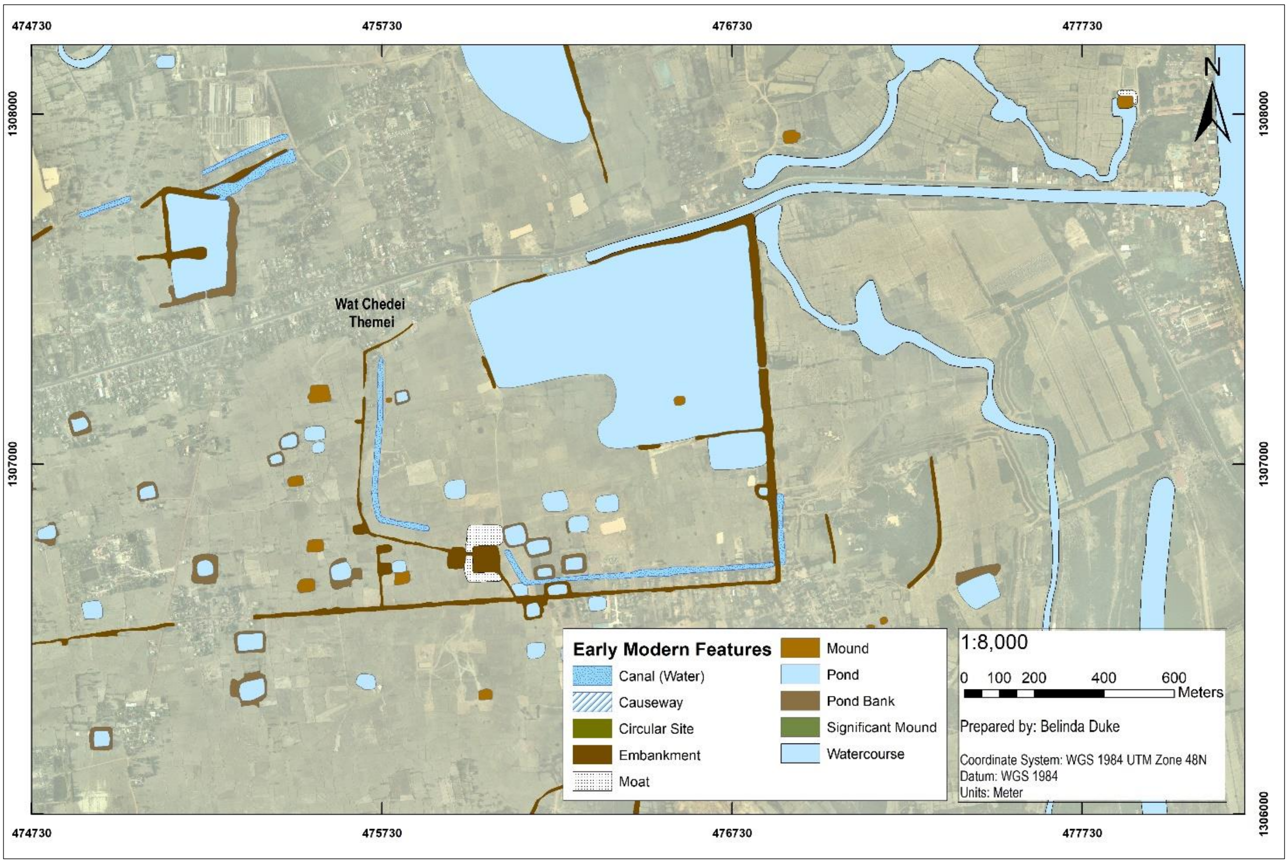


Figure 2.9: Earthworks south of Wat Chedei Themei proposed by Kitagawa (1999:69) as the palace of King Ang Dong and location of the Siam-Vietnamese War.

The use of rammed earth embankments for defensive purpose is widely documented in Southeast Asian archaeology. The Iron Age site Co Loa in northern Vietnam overshadows Longvek in terms of size and scale, however, of the examples of earthen embankments provided here, this Iron Age earthwork is most similar to that found at Longvek. Co Loa has a system of embankments which protect the ancient capital: two embankments are approximately twenty-six metres wide and nine metres high (Kim 2013:230) (Figure 2.10). These walls are associated with the period of the Warring States in the third century BC and the protection of the city Co Loa from Chinese attacks

(Kim et al. 2010:1026). Kim (2014) discusses the transformation of the landscape into a warscape defined by the presence of these fortifications, and elucidates war's legacy in the region. The walls at Co Loa required a significant workforce to complete, with Kim (2013:231) hypothesising it would have taken 1,000 to 10,000 people between 3 and 50 years to construct.

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Figure 2.10: Cross-section of the Co Loa fortifications from Kim et al. (2010:1022).

Other Iron Age sites use similar methods to those seen at Longvek. Moore and Win (2007) investigated the first millennium AD walled city of Kyaikkatha in southern Myanmar. The walls themselves were constructed from earth, laterite blocks and bricks, and ranged in size from 8 to 21 metres in width, with moats 4 to 17 metres wide (Moore and Win 2007:208-209). The complex consists of multiple walls and moats enclosing the mound and water source. Moore and Win (2007:208) observe that the patterning of the wall and the moat configuration are related more to water management than defence purposes, with the embankments' positioning allowing for drainage into lower areas. The use of embankments for hydrological purposes is further seen at prehistoric sites in the Mun River basin in North-eastern Thailand (Boyd and Chang 2010; McGrath and Boyd 2001:350). Prehistoric mound sites used a system of raised embankments, approximately 1-2 metres in both height and width to create circular earthworks around the mound (McGrath and Boyd 2001:351). Circular earthworks are also seen at the prehistoric site Lovea in Cambodia (O'Reilly and Shewan 2015, 2016). These circular embankment earthworks appear to be related to hydrology over warfare; and the same may be said for some aspects of Longvek's three wall configuration.

Comparison of the Early Modern earthworks presented here to other enclosures by construction type and purpose, demonstrates a disparity between the pre-Angkor and Angkor period examples.

The cause of this disparity requires further investigation, but there is space to hypothesise that a change in political authority and control over material and labour resources influenced the style and size of the earthen embankment defensive system. The most obvious difference between Early Modern and Angkor period structures is the use in resources to construct stone enclosures with complex defensive components, within the examples here. Considering this change within the broader Early Modern landscape may shed light on changes in social, cultural and political structures.

### 2.4.3 Industry

There is little to no documented evidence of Early Modern industry remains in the Cambodian landscape. A Chronicled bronze production site, which was mentioned in historic texts and recently surveyed and excavated, and is one of the few remains of Early Modern production known in Cambodia (Polkinghorne 2012-2013; Polkinghorne et al. 2016). Metal production was prevalent during the Angkor period, with smelting sites at centres such as Preah Khan (Hendrickson and Evans 2015). Ceramics are another Angkor period production commodity that has yet to be documented in Early Modern contexts. The investigation of ceramics in Early Modern contexts has been centred on trade ware (Polkinghorne et al. 2019a), with no ceramic manufacturing centres yet identified.

#### *2.4.3.1 Rice Production*

Rice production is an important economic and social component of modern and historic Southeast Asia, with complex pre-industrial societies emerging from the sodden floodplains of the Mekong, Irrawaddy, Chao Phraya and Red Rivers (Hawken 2011a:62). Rice production has been an important element of Cambodian prosperity, and rice fields were valued explicitly within all social and political groups. Two traditional sub species of rice, *japonica* and *indica,* are farmed across Southeast Asia (Fuller et al. 2016:86). Bunded rice fields began to emerge in the Mekong Delta from the eight century BC, profoundly transforming the hydrological landscape (Van Liere 1980:271).

Rice fields typically consist of a sophisticated system of bunds and water levees that move and trap water, with the design dependent on the water source and topography. The bunds themselves are made by gathering the topsoil into long embankments which are then compacted. The rice is planted in nursery fields before being replanted into the larger bunded fields, where the life cycle from germination to maturity is three to six months (Kuenzer and Knauer 2013:2105).

Rice is the only crop which grows under such wet conditions, with 2500 litres of water required to produce one kilogram of rice (Kuenzer and Knauer 2013:2107). Once the rice is transplanted, the farmers flood the fields, either by allowing rain to collect, or by using a system of ditches and dykes to quickly move water around and continue doing so for up to three months (Fox and Ledgerwood 1999:41). The process of farming in this manner results in a compacted sublayer that is the consequence of the constant tillage of saturated soil (Hawken 2011a:62). Referred to as a 'traffic pan' or 'pudding', the permeability of this layer creates a suspended layer of water, independent from the water table (Hawken 2011a:62). This traffic pan is a defining characteristic of rice fields, as is the size, shape and distribution of the bunded field.

The shape and size of the bunded rice field appears to be related to socio-economic management of land rather than hydrological controls. The size of the bunded rice field represents a range of external influences on farming practices. The size of the bunded area is dependent on the method of tilling the soil, with Bray (1986:56) reporting instances in Japan where the size of the rice field increased from 0.1 to between 0.3 and 0.5 hectares with the introduction of modern machinery. The size of the bunded rice field in correlation with the means of ploughing and harvesting may also be a representation of the age of the rice field. Rice farming in the lower Mekong Basin and in Cambodia is generally conducted using several different approaches. The rice fields are not dependent on the water table for a water source, utilising either rain fed or irrigated systems. Nhim (2014-2016:75) identifies *srov vossa* (rainy season rice field), *srov prang* (dry season rice field) and *srov chamkar* (shifting cultivation). Rainy season rice fields are planted depending on the availability of rain; dry season rice fields are reliant on waterways, rivers and ponds for irrigation; and shifting cultivation fields relate to a practice of slash-and-burn or swidden agricultural clearing traditionally found in the upper lands and mountains (Nhim 2014-2016:75-76). The system of using a bunded rice field with specific methods of irrigation to produce rice appears to have remained the same for centuries, with Hawken (2011a:54) describing the lineage of rice production in Cambodia as a 'living heritage'.

The archaeology of historic and prehistoric rice fields is a narrow frame of inquiry, particularly within Cambodian research. To date the focus has primarily been on Angkor as an agrarian empire, with 1000 square kilometres of farming land under its domain (Hawken 2013:347). Rice was an important, taxable commodity during the Angkor period, with the growth and power of the state the result of tax collection (Lustig 2009:187). Lustig's (2009:193) examination of Angkor period inscriptions identified a system of levies where donations to state controlled temples were often in the form of rice surplus, with instance such as at Prah Khan receiving up to 20 percent of the estimated village production output. An examination of Early Modern tax reform by Mikaelian (2006:278) revealed a hierarchical taxation system where district governors were tasked with collecting taxes for the crown. Village farmers were taxed one-tenth of their yearly crops, with local elites taxed one-fortieth. High government officials were in a position to negotiate taxation levels (Mikaelian 2006:278). Royal rice fields, which were constructed and administered by the crown, were taken in their entirety by the King who gifted land and resources to local temples centres (Mikaelian 2006:171), a practice which is evident throughout the Early Modern period and recorded in the Chronicles (see, for example, Khin 1988:151).

Research into the rice fields within the urban Angkorian landscape has been limited, although broad examinations of rice field orientation in relation to Angkorian temples were undertaken by Groslier (1979) and Van Liere (1980), with more focused examinations by Pottier (2000) and Bâty (2005). Hawken's (2011a, 2013) research was the first to examine the rice fields as a part of the urban landscape of Angkor. To undertake this research Hawken (2011a, 2013) mapped 22,000 kilometres of rice bunds in a GIS environment to understand their configuration and spatial patterning. From this analysis, Hawken (2011a, 2013) identified seven rice field systems present at Angkor, with orthogonal grid and coaxial rice field systems most prevalent (see Table 2.1). Hawken (2011a, 2013) correlated the rice field configurations to known landscapes features, such as temples. Hawken (2013:351) identified that cardinally aligned, orthogonal, square bund systems were the most closely aligned with the geographic orientation of temple systems at Angkor. This cardinal orientation is on the same axis as temple monument construction for this period, with Hawken (2013:364) stating that 'square rice fields commonly form clusters around temples, shrines, and other settlements, thus forming cultural complexes that are both spatially and temporally associated.' The cardinal systems have been aligned with the power of a central political authority, in what Hawken (2013:364) calls a 'frequently institutional landscape'.

Table 2.1: Rice field orientation types (Hawken 2011a:143-146) and figurations in Figure 2.11.

| Type | Description |
|---|---|
| Orthogonal grids of square rice fields | Square system, do not have dominant axis, system has directionality |
| Orthogonal grids of rectilinear rice fields | Small clusters around central node, two clear axes, also used in flood recession |
| Coaxial rice field system | Rice fields laid out on single dominant axis, traverse boundaries in staggered pattern |
| Radial systems | Central mound, rice fields radiate outward |
| Fan system | Radiate from central feature in fan formation |
| Khmer Rouge systems | One-hectare rice fields in clusters of four which are divided by irrigation channels |
| Aggregated rice field system | Do not have dominant axis orientation |

An examination of rice field orientation type may allow for a landscape chronology to be created from the spatial and temporal relationships between rice bunds and other landscape features. The orientation types presented by Hawken (2011a) are case specific with regards to the rice fields surrounding Angkor and their orientation in relation to it, for example, see Figure 2.11 where distinctions are drawn between types which are northeast and northwest for Angkor. In examining these patterns Hawken (2011a:238-247) identified three landscape signatures and phases of growth: radial landscapes with prehistoric development; coaxial landscapes with temporal and topographic relationships; and cardinal rice field landscapes related to Angkorian development. Prehistoric sites were characterised by a central mound with radiating rice fields limited to 200 hectares, with interlocking rice field territories linked by a communication network of radial oxcart tracks and rice bunds (Hawken 2011a:238).

Hawken's (2011a:241) coaxial landscape is associated with the archaeological shore, the fertile area which is seasonally flooded by the rising of the Tonle Sap. This is where small non-cardinal ponds, coaxial rice fields and a dense cluster of small ponds and mounds are distributed according to the contours of the area. This landscape is not typically associated with any major temple sites or related infrastructure, with some instances continuing to exist beneath the later cardinal system, indicating a complex time depth palimpsest (Hawken 2011a:241-242). The coaxial system is the most extensive and continuous rice field landscape signature operating on the fringe of the central Angkor temple complex (Hawken 2011a:242).

The cardinal rice field system is associated with the temple complexes within the central Angkor area, where direct manipulation of natural river systems was used to water the inflexible rice field network (Hawken 2011a:247). This method of expansion can be described as ‘classic Angkorian development [which] involved expansionist landscapes in the north, opportunistic reuse of existing rice field landscapes, infill landscapes, demolition landscapes and most likely abandoned landscapes’ (Hawken 2011a:247). An examination of these different rice field systems demonstrates that a process of temporal layering of rice field types was occurring. Driven by societal needs at both local and national levels, the rice field system demonstrates an interaction between the existing natural landscape and political structures that transformed areas into artificial urban landscapes.

An examination of the Angkor period rice field complex demonstrates that a relative chronology can be established by examining bund orientation and configuration. Hawken’s (2011a) research on the great Angkor temple complex north of the Tonle Sap demonstrated the potential to identify landscape activities from different periods by the examination of rice field orientation. The site in Longvek lends itself to a similar systematic analysis of the rice field configuration to shed light on the broader Early Modern landscape. In addition, this method can determine if there are prehistoric and Angkorian rice fields present, as well as possibly identify an Early Modern rice field configuration. In applying Hawken’s rice field analysis it may be possible to examine the changes in the landscape and the importance of rice production in the Early Modern period.

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Figure 2.11: The six major rice field configurations at Angkor from Hawken (2011b:Figures page 26-27).

## 2.5 The Hidden Landscape

Today, the landscape of the Early Modern period remains almost entirely hidden from view, contained within the subsurface under years of agricultural activity. This is due to the organic nature of constructed spaces at the time, in addition to the reuse of materials. To investigate what may be hidden in the subsurface, the constructed landscape needs to be considered in relation to the Chronicled landscapes, with focus on evidence for occupation, royal palaces and broader urban design. Comparison with Angkor period archaeological evidence of cultural material provides an indication of how these hidden landscapes may be configured, and what remains might exist. The following will examine occupation, palaces, urban spaces, and broader landscape evidence, in order to determine what may be hidden, and the appropriate steps to investigate it.

### 2.5.1 Occupation

The evidence of occupation spaces from the Early Modern period is sparse, with recent archaeological investigation yet to find evidence at Early Modern sites. The lack of archaeological evidence may be due to the modern population living in the same area as the historic population, taking advantage of the raised land (Evans 2016:172). In an examination of Early Modern material culture within Southeast Asia, Reid (1988:62) identified a consistency between some modern and historic structures. Based on an examination of primary documents and accounts, Reid (1988:62) describes structures constructed of perishable and easy to acquire materials, such as thatching for roofs, split bamboo for flooring and matting walls. Ethnographic observations describe modern homes raised on stilts that were not sunk in the ground but rather rested on the surface, allowing for the easy movement of the structure (Tainturier 2006:14). These types of homes are still found in modern Cambodia, with the cooking and living areas under the home or nearby. The modern structures have steep roofs, are raised one to three metres to combat seasonal monsoonal flooding, and generally have a household pond or *trapeang* nearby (Tainturier 2006:14). It is very likely this style of living has been a long-standing tradition that can be traced back to the Angkor period or earlier.

Within the archaeological record, evidence of such housing structures would be limited to postholes, if posts were dug into the ground for the stilt home. In addition, domestic areas such as kitchens, hearths and middens, would result in culturally modified sediments in the subsurface. Occupation mounds are common in prehistoric contexts such as Phum Lovea, which is the result of continuous occupation resulting in a complexly stratified sites (O'Reilly and Shewan 2016). House mounds were common, and have been investigated in relation to urban patterning as elucidated by the walls of Angkor Wat (Carter et al. 2018). Looking at Early Modern deposits from recent excavations at Longvek, archaeological deposits included a layer of cultural modified sediment, although this layer of habitation material was relatively thin (Polkinghorne et al. 2015:16). Postholes have been found through excavation, but the outlines of specific structures have not been identified (Polkinghorne et al. 2015:22). With this in mind, a multivariant approach to the examination of the subsurface best allows for a consideration of a range of possible culturally modified archaeological contexts.

European accounts of Early Modern Cambodia have been critically examined by Ewington (2013), as they are filled with inaccuracies and embellishments and often written by individuals who never visited Cambodia. An example in Figure 2.12 is a Dutch rendering of the seventeenth century Longvek. The image presents a riverside community with a royal complex in the background and Phnom Preah Reach Troap in the far distance. While some landscape elements are correct, such as the presence of Phnom Preah Reach Troap with the stupa on top, the ground level buildings along the river in the foreground are European in design, in contrast to the stilt buildings reported for this region (Ewington 2013). Stilt or pile dwellings like those in modern Cambodia are more likely to have been present. Instances like this reinforce the need for archaeological evidence of Early Modern Cambodia. If ground level structures were present at Longvek, their foundations would be evident in the subsurface.

Within Angkor Wat, Stark et al. (2015) investigated the settlement around the temple with a focus on the pattern of small occupation mounds and pond configurations. Their research was focused on chronology and stratigraphic content to better understand the use of the area in relation to the functions of Angkor Wat. While Stark et al. (2015) provide a comprehensive examination of settlement patterns, typically laid out in a uniform grid, there is no discussion of what kind of domestic structures were present. In this instance, archaeological excavation and investigation did not extend to the identification and understanding of the nature of habitation in the area. The spatial relationship between temple sites and occupation at Angkor may be applied to Longvek to aid in identifying areas of domestic dwellings. As Wat Tralaeng Kaeng was an important Angkorian and Early Modern religious structure, the areas around it warrant further investigation. The application of geophysical methods to the areas outside the temple complex allows for an investigation of associated settlement, such as absent occupation.


Figure 2.12: Depiction of seventeenth century Longvek (Vingboons Atlas, National Archief, The Hague).

A practical approach to finding evidence of occupation is to work with the theory that dwellings are located on raised areas within proximity to a water supply such as a *trapeang*, pond or *prek.* This is based on previous ethnographic examination of modern dwellings in Cambodia (Evans 2007:25; Pottier 1999:133-134; Nhim 2014-2016:73; Van Liere 1980:269). It has been noted by Evans (2007:26) that stilted homes were located along channel systems utilising the flowing water. Occupation is also associated with temples of all sizes, with evidence for this recorded on a small scale by Bâty (2005:67) who identified occupation mounds related to Prasat Trapéang Ropou, which has a mound/moat configuration (Figure 2.13). Along with an association between channels and temples, occupation is associated with small-scale pond complexes. Population density models have been constructed from these models based on semi-automated feature extraction (Hanus and Evans 2016). Hanus and Evans (2016:92), using an estimate that a pond would accommodate at least two families, identified 2219 ponds within Angkor Thom to estimate a population of 16,000 to 30,000 residents. Hence, identifying the remains of ponds and/or channels within the landscape may be a device for estimating the location and density of Early Modern populations. The application of geophysical and remote sensing methods would aid in this investigation as means to identify and correlate surface and subsurface features.

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Figure 2.13: A temple site surrounded by moat in northeast area, surrounded by occupation mounds, from Bâty (2005:67).

### 2.5.2 Royal Palaces

There are no surface remains of any of the Early Modern palaces mentioned in the Royal Cambodian Chronicles, aside from supporting infrastructures, such as the associated constructed topography and religious spaces. The Royal Cambodian Chronicles document the construction of these royal spaces, but provide no indication of the size, shape, orientation or construction materials employed. Surviving European accounts collated and presented by Népote (1973:5) discuss the building of wooden palaces, with the design becoming simpler towards the end of the nineteenth century.

The lack of surface evidence for royal palaces is not just an Early Modern issue, with Angkor period palaces constructed of wood with a tiled roof, in contrast to the more resilient religious monuments built of sandstone and laterite (Carter et al. 2018:492). The ninth and tenth century capital Hariharalaya was reported on by Coe and Evans (2018:172) who believed that the Angkor period palaces were situated north or south of the main state temple. The identification of these temples is based on the presence of associated temples, enclosures and roof tiles from the palace structures. The palace of Hariharalaya is estimated to be south-southeast of the principal state temple complex palace at Koh Ker, which is located northeast from central Angkor (Lustig et al. 2018:195). The palace, however, is also yet to be identified, as there are no physical remains of the tenth century wooden structure, with location estimations relying on the presence of related walls and enclosures and the presence of religious monuments (Evans 2010:117). Relying on the placement of other tenth century palaces, Evans (2010:118) indicates that the palace may be south-southeast of the state temple near Andong Preng, but without surface evidence or safe access to the site, this is yet to be verified.

The palace within twelfth century Angkor Thom is found in the northwest quadrant of the walled enclosure. The site is oriented on an east-west axis and surrounded by a 20 metre wide moat and laterite wall encasing a 13.8 hectare area (Coe and Evans 2018:172-173). Surface remains of the complex consist of a system of pools and earthwork foundations, with the complex easily identifiable in lidar surveys (see Polkinghorne et al. 2014). The documented account of the Royal Palace by Zhou Daguan (1296) (translated by Harris 2007:49) describes the structure as:

> … about five or six li [about 10km] in circumference. The tiles of the main building are made of lead; all the other tiles are made of yellow clay. The beams and pillars are huge and are all carved and painted with images of the Buddha. The rooms are really quite grand-looking, and the long corridors and complicated walkways, the soaring structures that rise and fall, all give a considerable sense of size.

A circumference of five or six li refers to the laterite wall which surrounded the larger complex rather than being a reference to the size of the palace itself (Harris 2007:100).

When considering what might remain of such a structure, this primary account does not provide much indication of what could be present or what might be found in the subsurface. The primary focus of investigation has been around the religious monuments associated with royal palaces, and associated investigations into their art history. The lack of inquiry does not suggest it is impossible to investigate the remains of these structures, but rather that an alternative approach should be employed to examine the subsurface remains. This thesis deploys such an approach in relation to its two proposed palace sites: the first of these being at Longvek, which the *Middle Period and Related Sites Project* (Polkinghorne et al. 2015; Polkinghorne et al. 2016; Polkinghorne et al. 2017;

Polkinghorne et al. 2018b) identified as to the west of Wat Tralaeng Kaeng on a raised area that currently houses a working brick factory. The second palace site at Oudong was proposed by Kitagawa (1999) in an area enclosed by an embankment south of Wat Chedie Themei. Both areas are now rice farming land, which has a relatively flat topography which is ideal for geophysical prospection. An examination of this land may add significant precision to speculation about the location of the palaces themselves and any related structures.

### 2.5.3 Urban landscape

The investigation of the Angkorian urban landscape has been a focus of Cambodian archaeology for the last three decades. Remote sensing techniques have shown their utility in recent research into urbanism and residential patterning at Angkor, with a comprehensive map compiled by Pottier (1999) and Evans (2007). Two types of urban settings can be identified at Angkor: the dense central Angkor and the low-density periphery. While there was no solid boundary demarcating the two areas, the dense urban centre defined by Carter et al. (2018) is distinct from the low density 'archaeological shore' identified by Hawken (2011a), and this demonstrates the variety of urban landscapes present during this period. The urban centre of Angkor is definable by the centralisation of stone temples, a comprehensive hydraulic network, and a civic-ceremonial centre (Figure 2.14) (Carter et al. 2018; Evans et al. 2013; Hawken 2013; Fletcher 2012). The mapping and investigation of these landscapes has been focused on remote sensing techniques, which enabled the identification of the characteristic orthogonal grid to which the monument structures were aligned. The results allowed for discussions around urban planning, population density and the configuration of administration centres, reinforced by the work of Hawken (2011a) who was able to define these urban elements through examining the rice field configurations. From this, Angkor has been described as the world's last low density urban complex, consisting of dispersed settlements and urban infrastructure with poorly defined boundaries between urban centres and rural extremities (Carter et al. 2018:494; Evans et al. 2007:121; Fletcher 2012:288).

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Figure 2.14: The extent of central Angkor as mapped by Evans et al. (2007:14278).

There is no evidence for an urban or residential landscape at the three Early Modern sites under consideration here. The above-mentioned features all fit within an urban landscape, and to date there has been no research conducted into what the Early Modern urban landscape consists of or how it may have been configured. It has been hypothesised by Evans (2016:172) that the evidence for Early Modern villages and urban centres lies under current, modern settlements and the lack of surface evidence is a result of a lack of occupation density at the Early Modern capitals of Longvek and Oudong. Evans (2016) compares Longvek and Oudong to Angkor and argues that a lack of evidence for urban settlements is an indicator of a lack of population movement after the city ceased being a political centre. His brief examination does not consider changes in urban planning or building practices, or the importance of maritime trade in considering how Longvek's and Oudong's landscapes should look in comparison to Angkor's. As Evans (2016) based his hypothesis on remote sensing data alone, an interrogation of the subsurface remains at the three proposed locations above may reveal a unique Early Modern urban landscape under the rice fields.

## 2.6 Conclusion

The remains of Early Modern Cambodia demonstrate a complex interaction between the physical environment and social and political structures. The Chronicles and other primary documents provide such a narrow view of the period, that it could be mistaken for being a physically and/or culturally empty landscape. However, in investigating the landscape of Early Modern Cambodia, it is evident that the period was one of intense activity resulting in the construction of perishable but complex urban landscapes. As noted, there is a disparity between the Chronicled landscape and physical remains, and it is therefore important to investigate the subsurface remains to build a more complete picture of Early Modern Cambodia. The impact of modern farming and industry at Srei Santhor, Longvek and Oudong has resulted in much of the historic period material being disturbed or removed. This thesis focusses on examination of the subsurface remains of Srei Santhor, Longvek and Oudong, in order to further illuminate the social and political changes of this period. A number of specific sites have been identified in this review that require further investigation. These investigations seek to:

- provide physical evidence surrounding the debate for the location of Basan within the Srei Santhor region.
- trace the transformation from Brahmanical to Theravāda cult traditions at Prasat Preah Theat Baray, and how it may relate to change and adaptation in the Srei Santhor region.
- apply Hawken (2011a) rice field classification approach at Longvek to investigate the construction and transformation of the landscape between the Angkor and Early Modern periods. A close examination of these rice fields provides an avenue of investigation of the socio-economic management of this land during the Early Modern period.
- investigate the potential palatial structures related to the proposed palace site at Longvek, to examine correlations between the physical layout of the structures and models of political control.
- explore the area around Wat Tralaeng Kaeng, to identify evidence of occupation and establish if there is a similarity between Angkorian and Early Modern urban design. Second to this, evaluate the potential of Angkor period material being present at this temple.
- examine two Theravāda terraces south of the citadel wall to investigate their construction history and how they relate to the broader landscape.
- evaluate the proposed palace site at Oudong south of Wat Chedei Themei, to identify potential palatial structure and how they may relate to the cosmological frameworks established by the eighteenth-century kings.

As the areas under investigation here are either buried landscapes, semi-buried architectural features or mounded features, a geophysical approach is required. By implementing a landscape scale, multimethod geophysical investigation, progress can be made towards reconstruction of elements of Early Modern Cambodia's now-hidden landscape.

# CHAPTER 3 - INVESTIGATING AND INTERPRETING HIDDEN LANDSCAPES

## 3.1 Introduction

This chapter reviews available methods of investigation of hidden archaeological landscapes, drawing on remote sensing, geophysical and theoretical approaches. It discusses application of remote sensing, magnetometry and ground-penetrating radar (GPR) in archaeological contexts, including critical review of previous work conducted in Cambodia. This critical review focuses on the types of landscapes investigated and the methods employed. Building on Chapter 2, geophysical approaches to buried landscapes, semi-buried architecture and mounded feature landscapes are considered, with particular focus on geophysical approaches and research parameters. These geophysical methods are reviewed against the literature, especially existing approaches that link archaeological theory to geophysical enquiries. Landscape and spatial archaeology will be considered to determine how social, cultural and/or political meaning can be extracted from the landscape. This chapter shows how a landscape-scale multimethod geophysical approach can be applied to investigate the hidden landscapes, providing insight into how method and theory can be integrated to answer questions surrounding change and adaptation during the Early Modern period.

## 3.2 Revealing Hidden Landscapes

Geophysical methods allow for the investigation of subsurface remains of archaeological sites. Geophysics has been applied to archaeological investigations for several decades, beginning with their application in the 1980s as the technology became more accessible (see, for example, Abbas et al. (2005:130) and Clark (1990) for historic review). These methods have been widely applied in the European context, with remote sensing methods generally applied to larger land areas and radar methods to urban spaces (see, for example, Bernardine et al. 2013; Bewley et al. 2012; Johnson and Ouimet 2014; Lasaponara et al. 2010; Prufer et al. 2015; Risbøl and Gustavsen 2018). Within Southeast Asia and Cambodia, Lidar has been the most utilised, especially within the context of investigating Angkorian settlement hidden under the dense forests (see, for example, Carter et al. 2018; Coe and Evans 2018; Evans 2016, 2007; Evans et al. 2013; Hanus and Evans 2016; Stark et al. 2015). The application of geophysics to Cambodian historic sites, however, has been much more limited and centred on the application of GPR (see, for example, Lustig et al. 2018; Moffat et al. 2019;

Sonnemann 2011; Sonnemann 2015, 2012; Sonnemann and Chhay 2014; Sonnemann et al. 2015). Magnetic methods have not been widely published, nor has there been a great deal of information regarding their viability. Ground-penetrating radar (GPR) is one of the more commonly applied methods, as it has been well proven to work in contexts where monumental architecture made of durable material is present. However, it has not been tested on sites which do not consist of such monumental remains and the work conducted has not been published or made widely available to researchers. To reveal the hidden landscapes of Early Modern Cambodia, remote sensing, magnetic and radar-based techniques will be applied.

### 3.2.1 Remote Sensing

Remote sensing is the analysis of landscapes using satellite imagery, aerial photography, geophysics, and imagery analysis, to examine the surrounding world at different resolutions, spectrums and scales (Parcak 2009:3). Data acquisition can come from a variety of sources such as spaceborne satellites, airborne planes or helicopters, and ground-based drones and geophysical devices (Figure 3.1). In an archaeological context, the application of remote sensing specifically applies to the obtaining of data via satellites or aircraft as a non-destructive investigative tool in the archaeology of human occupation and/or past landscapes (Lasaponara and Masini 2012b:4). Traditionally, remote sensing techniques have been applied to archaeological contexts as a tool for site prospection through the mapping of landscape features, however, available satellite data can give a much broader perspective (Parcak 2009:4). Remote sensing techniques encompass a range of satellite and surface acquisition methods and have accounted for a vast array of archaeological discoveries over the last twenty years. Beginning with aerial photography, the introduction of satellites and the increased spatial resolution of remotely sensed data have opened up this data set as a potent means of examining archaeological sites. The types of high resolution satellite sensors (see Lasaponara and Masini 2011:1996) and satellite synthetic aperture radar (SAR) data (see Chen et al. 2017:6) are numerous and applicable to archaeological investigation in a wide variety of ways.

The introduction of remote sensing techniques to archaeology has allowed for a variety of innovations including: mapping of archaeological sites with high resolution imagery; mapping of archaeological sites within a broader landscape enabling inter and intra site investigation and analysis; creating digital elevation models (DEM) for the interpretation and analysis of data; and examining hidden landscapes in the subsurface of archaeological sites. While this is only a selection of investigative approaches, the availability of high-resolution satellite data has greatly impacted investigative methods of archaeological sites, especially with regard to the application of high-resolution imagery for inter and intra site investigation and the application of lidar methodologies to archaeological contexts. Situating remote sensing in archaeology has been a source of research for decades (Lasaponara and Masini 2011), however, like many of the methodologies presented here, the need for more research question driven inquiry is required.

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Figure 3.1: Types of data collection devices for remote sensing from Yanazaki and Liu (2016:2).

Aerial photography is a very common method for the examination and mapping of archaeological sites. Remote sensing style techniques have been used since the advent of aerial photography, with very early researchers attaching cameras to kites to get a bird's-eye view of an excavation. Aerial photography techniques were further advanced as they were developed for military applications. Williams-Hunt (1950) early flights over Thailand on behalf of the US military allowed him to identify irregular earthworks across the Korat Plateau. Declassified Cold War American corona images are also used as a means to examine change over time (see, for example, Challis et al. 2013; Mihai et al. 2016; Rayne and Donoghue 2018). As technology progresses, there continues to be increases in the availability and resolution of aerial and satellite imagery: Google Earth images are now of high enough resolution and quality to have a positive impact on archaeology. Images from Google Earth have been applied to archaeological settings in the prospection of archaeological sites (O'Reilly and Scott 2015), in conjunction with historic maps to reinterpret historic landscapes (Green et al. 2019) and the identification of subsurface remains of constructed hydrological systems (Rost et al. 2017). The application of aerial photographs remains an important component in archaeological prospection, however, the process of site detection largely remains a process of descriptive analysis.

The application of space born satellite multispectral data in seemingly featureless anthropogenic landscapes has attained considerable success at sites throughout Europe and Central America. Multispectral satellite images are used as they allow for the different bands of colour to be separated to identify differences in the landscape (Parcak 2009:72). Strum (2016), Ard et al. (2015) and Lasaponara et al. (2016) combined multispectral data with geophysics to undertake a comprehensive examination of broader cultural European landscapes. The object-orientated approach applied by Lasaponara et al. (2016) is commonly used to extract archaeological features where supervised and unsupervised classification of the landscape are undertaken to identify cultural landscape features. The red spectral channel revealed soil marks and features through their geophysical and chemical properties, while the near-infrared (NIR), in combination with vegetation indices, distinguished crop-marks (Lasaponara and Masini 2012a:26). From this detection, it is a process of extracting features based on knowledge of the site and the cultural heritage of the area. These instances are very specific to European contexts with very specific crop types such as barley and wheat fields often under investigation to reveal hidden landscapes (Lasaponara et al. 2016:150). As this method has not been tested or employed over rice fields, which have a complex system of raised bunds, this type of remote sensing will not be employed here, despite its success in identifying hidden landscapes in other settings.

Airborne laser scanning via satellite, or lidar via plane or drone, are remote sensing technologies that use laser pulses to measure the distance of a target. The distance from sensor to target is measured by the time delay between transmission and detection of the reflected signal. Traditionally mounted on a plane or helicopter, constant advances in drone capability and device size mean that the resources required to undertake such surveys are changing. Lidar has become one of the most successful methods, due to its usefulness in peeling back forestry and vegetation to map archaeological sites. The high-resolution digital terrain models generated from lidar surveys have enabled researchers to examine largescale monuments down to micro-topographic earthworks. The advancement in drone technology, and size of sensors available, has meant lidar has become even more accessible with Risbøl and Gustavsen (2018) comparing drone-based lidar with aero-based applications. In this comparison, researchers first tested if lidar from drones presents an improvement in terms of detection success, largely based on the increased density of point clouds through smaller footprints and more points per metre (Risbøl and Gustavsen 2018:2). The second aspect is whether the documentation of archaeological features using drone lidar can increase the quality of their physical properties, by testing against features of known size (Risbøl and Gustavsen 2018:3).

The differences in sensor type, flight altitude and pulse frequency resulted in a large variation between points per metre in the creation of the DEM. The results indicated that there was a modest improvement between plane (0.7, 10 and 2 point/$m^2$ over three studies) and drone (22 points/$m^2$), based on the increase in points per metre which was largely due to the decrease in footprint of the drone (Figure 3.2) (Risbøl and Gustavsen 2018:4). The higher density of points is especially useful for smaller, less well defined landscape types (Risbøl and Gustavsen 2018:5). Overall, Risbøl and Gustavsen (2018) conclude that lidar from drones has significant advantages, and further technological improvements will continue to benefit archaeological research. What this research highlights, though, are the limitations associated with the application of airborne lidar application, particular when it pertains to smaller scale sites. The application of lidar to find micro features is of benefit here, as previous examination of lidar data reported by Evans (2016:173) of the project area suggest there is limited archaeological features compared to Angkor period sites. A review of the method applied, and the process of feature extraction may shed more light on the limitations and how it can be improved in the future.

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Figure 3.2: Variation in point per metre lidar quality: a) 0.7 point/$m^2$ , b) 2 point/$m^2$, c) 10 point/$m^2$, and d) 22 point/$m^2$. (black circles= kilns, red circles= grave mounds, yellow circles- charcoal pits) (from Risbøl and Gustavsen 2018:4).

Automated and semi-automated shape detection has been applied to archaeological sites by taking known parameters and using them to extrapolate like features. Feeland et al. (2016) applied an automated feature extraction to conical mound features related to the chiefdom structure of the Classical Tongan period on the island of Tongatapu. Two semi-automated feature extraction techniques were used. Object-based image analysis and an inverted pit-filling algorithm were applied to lidar data. Both techniques were successful in detecting mounds, with the inverted pit-filling algorithm showing slightly better results. Roughly 10,000 mounds were identified across the island, with spatial analysis of the automated features extraction showing the monumental landscape of Tongatapu to be highly structured. The vegetation density of the areas of forest cropping (coconut, banana, yam and kitchen-gardens) did not hinder the automated feature extraction, with low mound features less than 50cm identified. This contradicts Risbøl and Gustavsen (2018) conclusions which were not able to identify anthropologic structures under dense secondary growth. However, the type of features being investigated needs to be considered when making these comparisons. The automated feature extraction method was successful in the context of identifying conical shape mounds. Lidar is a beneficial tool in feature-dense investigations where ground survey is not available. In the absence of archaeological features for investigation, the application of lidar needs to be applied in more creative ways, to understand change over time within historic and prehistoric contexts. What is apparent in examining these methods is that a descriptive reporting method is most commonly used here, with automated systems having their limitations. An intense knowledge of the area investigated is required to identify and record such cultural landscape features.

Remote sensing can provide important information about cultural landscapes at a range of scales, which allows for inter- and intra-site investigations. However, there are limitations to the application in sampling and feature identification. The application of remote sensing techniques still requires an in-depth knowledge of the cultural heritage of the area being investigated, with the majority of investigative methods relying on manual feature extraction, even with automotive methods. Section 3.4 below will examine the features types presented in the study area and examine how remote sensing along with geophysical methods are best used. The use of lidar in Cambodia is examined in section 3.3.1.

### 3.2.2 Magnetometry

There are several types of magnetometer available for a magnetic survey in archaeology: fluxgate, proton free precision, electron spin resonance (Overhauser), alkali vapour (optically pumped), and cryogenic superconducting quantum interference device (SQUID) (see Table 3.1 for comparison). Magnetometers can be broadly classified as scalar or vector instruments: the scalar instruments measure total strength of a magnetic field, while the vector instruments measure a component of the magnetic field in a single direction (Aspinall et al. 2008:29). Scalar instruments are often used in the archaeological context, as they measure total field or total intensity of an area (Aspinall et al. 2008:30). Particular instruments can affect the quality of data obtained. Instrument sensitivity is an important factor. However, functional applicability is dependent on the target being surveyed, since archaeological sites are generally near-surface targets, and the need for a total field capable of depth readings may be redundant (Conyers 2018:35). The use of specific instrument types is dependent on availability, and for this reason, the fluxgate magnetometer will be the focus here.

Table 3.1: Magnetometer types and their pros and cons, from Aspinall et al. (2008:34-56).

| Magnetometer | Pros | Cons |
|---|---|---|
| Fluxgate gradiometer | Vector (vertical component), sensitivity to 0.1nT, low power and weight, relatively cheap, fast data acquisition | Heading errors, significant set-up for some types |
| Proton free precision | Total-field scalar, sensitivity 0.1-0.5nT, no heading errors, simple to use, low cost, single, differential or gradiometer mode | High power consumption, dead zones, slow data acquisition, problems in high magnetic gradients, radio frequency interference |
| Electron spin resonance (Overhauser) | Single, differential or gradiometer mode, total-field scalar, sensitivity to 0.05nT, no heading error, little power demand, no warm-up time, good gradient tolerance, fast data acquisition | Cost |
| Alkali-vapor (optically pumped) | Single, differential or gradiometer mode, total-field scalar, sensitivity to 0.1nT, small heading error, easy setup | Large power demand, dead zones, cost |
| Cryogenic superconducting quantum interference device (SQUID) | Vector (vertical and horizontal), gradiometer mode, sensitivity to 0.00001nT, low power, fast data acquisition, no dead zones | Heading errors, low temperature, very expensive, lab use only |

Figure 3.3 shows the dual sensor Bartington 601 employed for this research, which simultaneously measures the general magnetic field of the earth and the localised magnetic field (Aspinall et al. 2008:34; Conyers 2018:32). The two sensors are mounted vertically at opposite ends of the trapeze, with the data logger suited in the centre of the instrument (Conyers 2018:32). Each sensor contains a magnetically susceptible core which is wrapped in two coils of wire. An alternating electric current passes through one coil, resulting in a cycle of magnetised, unmagnetised, inversely magnetised, unmagnetised, magnetised states (for example), creating an electric current in the second coil (Aspinall et al. 2008:34). The output voltage of the second coil is proportional to the magnetic field, with the output the result of the localised magnetic field value minus the upper general magnetic field value (Aspinall et al. 2008:40). The configuration of this instrument allows for two lines of data with up to eight samples per metre collected. The configuration of the instrument allows for faster acquisition time compared to other methods such as ground-penetrating radar (GPR). This quicker acquisition speed has resulted in more landscape scale investigations being conducted (Conyers 2018:25). Where it would take months for other methods to survey hectares of land, the magnetometer can provide a large dataset in a matter of weeks.

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Figure 3.3:Duel sensor Fluxgate Gradiometer Bartington 601 (from Conyers 2018:27). Each sensor has an upper and lower portion which records the earth magnetic field and the local magnetic field respectively.

Unlike other geophysical instruments, magnetometry is a passive collection method, where the instrument collects the localised magnetic field of the ground without having contact with the surface (Conyers 2018:25). Aspinall et al. (2008:22) defines magnetometry as the process of measuring alterations and/or strength of the magnetic field of materials compared to background values. The Earth's main magnetic field has a magnetic north (positive) and magnetic south (negative) fields, and this method measures these fields in relation to the minute changes in strength, intensity and/or direction (Conyers 2018:25; Fassbinder 2015:85). Localised changes in the magnetic field can be the result of anthropogenic manipulation of the landscape. Fassbinder (2015:85) describes magnetometry as measuring the contrast in magnetic field between the archaeological feature and the neighbouring sediments. The change in magnetic field can be attributed to a variety of processes which can be either the result of natural or anthropogenic influences outlined in Table 3.2. This type of manipulation can occur as a result of the construction of homes, villages, cities or monuments, as well as domestic and industrial activities affecting the soil chemistry within a localised area, resulting in culturally modified sediment.

Table 3.2: The remanent magnetisation in archaeological sites (from Kvamme 2003; Aspinall et al. 2008; Fassbinder 2015; Conyers 2018).

| **Process** | **Description** |
| --- | --- |

| | |
|---|---|
| Thermoremanent magnetisation (TRM) | The exposing of sediment, soil or rocks to high temperatures. Features exposed initially become TRM, while cooling in the direction of the magnetisation aligned along the earth's magnetic field. |
| Detrital remanent magnetisation (DRM) | Magnetised archaeological sediments deposited in water (e.g., ditch, pit). The grains will orientate their magnetic axis parallel to the ambient magnetic field. Also known as the post-depositional remanent magnetisation. |
| Chemical remanent magnetisation (CRM) | The accumulation of particles which result in thermal fluctuations which produce a chemical remanent magnetisation. Natural processes such as burning, weathering and chemical reactions which change iron compounds to more magnetic forms. |
| Lightning-induced remanence (LIRM) | Lightning strike which produce a magnetisation in a localised area. Over 200nT value of highly intensity magnetic anomaly. |
| Accumulation of high value magnetic artefacts | Accumulation of artefacts which have been fired to a high temperature, such as pottery or bricks, or the inclusion of iron rich artefacts. |
| Anthropogenic manipulation of magnetically enriched sediment | Removal and redistribution of magnetically enriched topsoil in construction, such as for dwellings, ditches or pits, which decreases the magnetic field in one area while increasing it in another. |
| Natural high magnetic material | Variation in sediments and soils due to their composition, concentration, mineralogy, size and/or shape. The inclusion of rocks with a higher magnetic value (e.g. igneous rocks) or lower magnetic value (e.g. certain limestone). |

The remanent magnetism of a feature is recorded by the instrument, with the nanoTesla (nT) value then mapped to create a horizontal plan of a site. How a feature is represented in this data is dependent on a variety of facts such as its value, size, shape and depth. In the example in Figure 3.4, six different feature types are pictured with the magnetic value represented above as a variation in positive or negative nanoTesla value. While this example only applies to monopole features, it demonstrates how the composition of the surveyed feature is represented in the subsurface. In Conyers (2018:31), for example, he does not consider the placement of two features next to each other with one having a positive response while the other has a negative. In an instance like this, what may be a modern contaminant may be two archaeological features or vice versa. Conyers (2018) does consider the variables affecting the interpretation of magnetic features, which are dependent on earth magnetics, the feature being surveyed, and the instrument being used.

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Figure 3.4: Hypothetical natural and anthropogenic magnetic anomalies pictured with variation in nanoTesla value represented as a positive and negative above (from Conyers 2018:31).

The distance of the survey area from the equator or a magnetic pole will affect how the feature is represented in the dataset. The magnetic latitude—that is, the distance from the feature to the magnetic poles—will result in an increase in either the positive (north) or negative (south) value, dependent on global positioning (Fassbinder 2015:91). The primary issue with this offset is for the ground verification of targets identified in a magnetic survey, with the centre of the dipole often not representative of the position of the feature as in the example in Figure 3.5. Also impacting the value of the dipole is the secondary magnetic field which can be the result of a change in the ionosphere through the gravity of the sun and the moon, however, this effect is generally very minor (1-2nT) and only a problem when employing a gradiometer for collection (Conyers 2018:35). The effects are minor enough to be negated in the processing sequence, however, an understanding of the magnetic latitude of the site being surveyed will help to interpret magnetic data.

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Figure 3.5: Variation in dipole bearing based on position in relation to magnetic poles (Conyers 2018:34).

The actual feature being surveyed will have a significant impact on how it is represented within the dataset. The size, depth and orientation of the target feature all affect the mapped response generated, and the variation in these elements can make it difficult to determine the form of a subsurface feature without undertaking excavation for ground verification. The size of the recorded feature will be dependent on the physical size and magnetic value mapped, with very small features or objects with a low magnetic value almost invisible within a dataset (Conyers 2018:35). In addition, the depth of the target will affect its magnetic value, with a very deep but high magnetic object having a similar value to something shallow with a low magnetic value; the effective depth of magnetometers is ~2m (Conyers 2018:35). In addition to size and depth, the orientation of a highly magnetic object will vary in shape and intensity. Background 'noise' such as modern contamination of highly magnetic material may also confuse a dataset, with high magnetic hygiene for a survey area an important factor. The approach to survey is not only dependent on the feature target but also the instrument being employed.

Processing of magnetometer data is required before any interpretations can be made. The acquisition of data is reliant on the operator's walking pace, with variations in pace resulting in the data having a staggered appearance and often exacerbated by zig-zag acquisition, which results in the staggering also being directional (Aspinall et al. 2008:124; Conyers et al. 2008:35). Incorrectly balanced sensors may also result in a striping effect, as a result of sensors collecting unequal values. Processing programs can de-stagger data to correct acquisition errors through zero-mean traversing, which is a process whereby the mean is calculated individually for each line, then subtracted from each data point for that line (Aspinall et al. 2008:121). Once magnetometric data has been de-staggered and de-striped, outliers can be removed. Interpolation is often also applied to account for the volume of samples in one direction being considerable larger than in the other direction (Aspinall et al. 2008:133). Other processing procedures which can be applied include slope error correction, zero-mean gridding, de-spiking, high-pass filtering and periodic filtering (Aspinall et al. 2008:116-129). The application of processing procedures must be site specific. The imaging of this data is generally presented at a generic range such as -20 to 20nT, as shown in Figure 3.13 in section 3.4.1. In extremely rare instances, the display range is based on the average nanoTesla value for the dataset, with results plotted at either one, two or three standard deviations (see, for example, Linford 2004). Generic display range is common practice in geophysical publications: as this this thesis examines a variety of sites, a statistical approach using the mean and standard devidation has been selected as the most suitable statistical approach. The processed data produces magnetic anomalies, which can be interpreted as archaeological features when an in-depth understanding of the archaeological site is available. The magnetogram allows for an examination of the geometry of magnetic features, and combined with knowledge of the archaeological setting and magnetic properties of the sediment, a descriptive and comparative analysis can be undertaken (Fassbinder 2015:88).

As demonstrated in the review of investigated hidden landscapes above, magnetometry has been used successfully in Europe and the Americas (see, for example, Donati et al. 2017; Drahor 2011; Sala et al. 2013; Garcia-Garcia et al. 2016; Ullrich et al. 2011). The most promising results are from Roman and Greek sites, which have been demonstrated by Garcia-Garcia et al. (2016) and Donati et al. (2017). Both apply magnetometry as a part of a suite of methods to identify urban features hidden in the subsurface. Garcia-Garcia et al. (2016) recognised the Roman urban layout and design at the city of Navare, as it was discernible by the uniform nature of the building design. An example of this is the Greek site Halos, where Donati et al. (2017) examined changes in architectural density to determine the size of the settlement and identified clear lines of demarcation for the city's western and eastern boundaries. Similarly, Donati et al. (2017) identified uniform street patterns and levels of urban density at six other Grecian sites. The capacity of magnetometry to be used within a landscape-scale investigation makes it ideal for research of urban planning and design related to historic cities, by gathering large volumes of data over a relatively short period of time. It is the landscape-scale approach that allows for larger areas to be investigated, allowing for more nuanced questions related to the physical representation of social change within an archaeological landscape. The common theme of success in all these instances is the material in the subsurface and an intimate knowledge of Greek and Roman building formations. As yet, there are no examples of magnetometry being applied in the Southeast Asian context. This methodology still needs to be tested to determine its suitability at historic sites which do not have the characteristics of Roman, Greek or Angkorian construction.

### 3.2.3 Ground-Penetrating Radar (GPR)

GPR propagates electromagnetic energy—or radar waves—into the subsurface from an antenna housed in the instrument, measuring the time it takes for the energy to hit an object in the subsurface and be reflected back Figure 3.6 (Conyers 2013:27, 2018:19). Radar energy spreads through the subsurface in a cone-shaped geometry (Conyers 2013:47, 2018:19). The travel time changes according to the chemical or physical properties of the material that the energy is travelling though (Conyers 2013:107, 2018:19). As the radar waves move through the subsurface, they reflect off surfaces created by geology, changes in sediment composition, archaeological features, and/or other buried features (Conyers 2018:19). The physical and/or chemical composition of the target affect the relative dielectric permeability causing the rate at which the signal travels to vary (Conyers 2013:107). Some radar waves will continue into the earth and dissipate, as it takes an abrupt change in the subsurface composition for the radar wave to reflect back to the antenna (Figure 3.7) (Conyers 2013:28, 2018:19). The amplitude of the received radar wave is proportional to the change in speed as it intersects with a buried surface, with a greater change in velocity resulting in a larger reflected wave amplitude, with gradual changes not producing reflections (Conyers 2013:28, 2018:19). All GPR instruments emit up to 12,000 radar pulses per second and a single transect generating reflection profile is created for each returned wave.

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Figure 3.6: Ground-penetrating radar in use. (image source: groundpenetratingradarservice.wordpress.com).

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Figure 3.7: The change in refection wave dependent on the change in subsurface boundaries (from Conyers 2018:20).

Each radar pulse creates a single time window, which records the attenuation by how many nanoseconds it travelled as shown in Figure 3.8. The antenna is placed either directly on the ground or a few centimetres above the ground on a sled. In Figure 3.8, this distance between antenna and surface generates a small reflection, followed by the homogenous topsoil which results in very few or no reflection waves (Conyers 2013:31). As the radar is moved across the ground, a wheel measuring distance triggers the instrument to create a radar pulse, and as it reflects off an abrupt change in the subsurface, a high-amplitude reflection way is recorded (Conyers 2018:21). A reflection profile is the accumulation of time windows as seen in Figure 3.8, and presented in a layout where the two-way travel time is displayed in a format where the nanoseconds depth is plotted on the vertical axis and line distance on the horizontal (Conyers 2013:34). The two-way travel time can be converted into an approximate depth in the velocity if the radar wave is known (Conyers et al. 2013:35). Acquisition time is dependent on the size of the area, with single transects and grids commonly employed, dependent on the research question being addressed. The application of the GPR can be muffled by surface debris, such as low scrubby bushes and rough terrain.

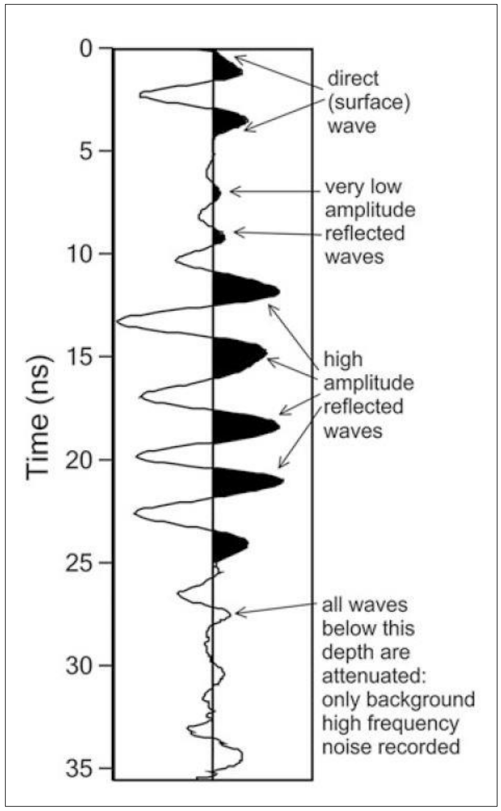


Figure 3.8: A single GPR trace with changes in amplitude and antennation over the recorded time-window (from Conyers 2018:21).

Once data has been collected, processing steps must be undertaken before any interpretation can occur. These steps are usually undertaken for clarity, and can include removing 'noise' or recording errors from the instrument system data. However, caution must be exercised, since applying a technique within the wrong context can cause artificial manipulation of the data (Conyers 2013:130). The common steps taken for the post-acquisition processing of GPR data include: the removal of horizontal banding; gaining to account for energy decay; low and high frequency band-pass removal; background removal and topographic correction. Horizontal banding is the result of 'ringing' or 'system noise' of the antenna and the result of electromagnetic transmission interference (Conyers 2013:134). Some horizontal banding may be the result of sediment boundaries: therefore, caution should be observed when applying this filter. Gain is applied to account for the loss of energy within the time-window as a result of the signal travelling deeper into the sediment (Conyers 2013:52). Low and high band-pass removal is a filter which removes the 'snow' or 'banding' created by devices such as radio transmitters or the antenna itself; for the removal of these reflections, infinite impulse response (IIR) or finite impulse response (FIR) can be applied (Conyers 2013:136). Background removal filters out reflection waves that occur at the same time across the entire profile, and much like horizontal band removal, care must be taken to not remove geological features which are consistently found across the profile (Conyers 2013:135). The final step is topographic correction to portray an accurate representation of the area being surveyed. Once processing has occurred, subsurface features will be more clearly represented such as can be observed in Figure 3.9.

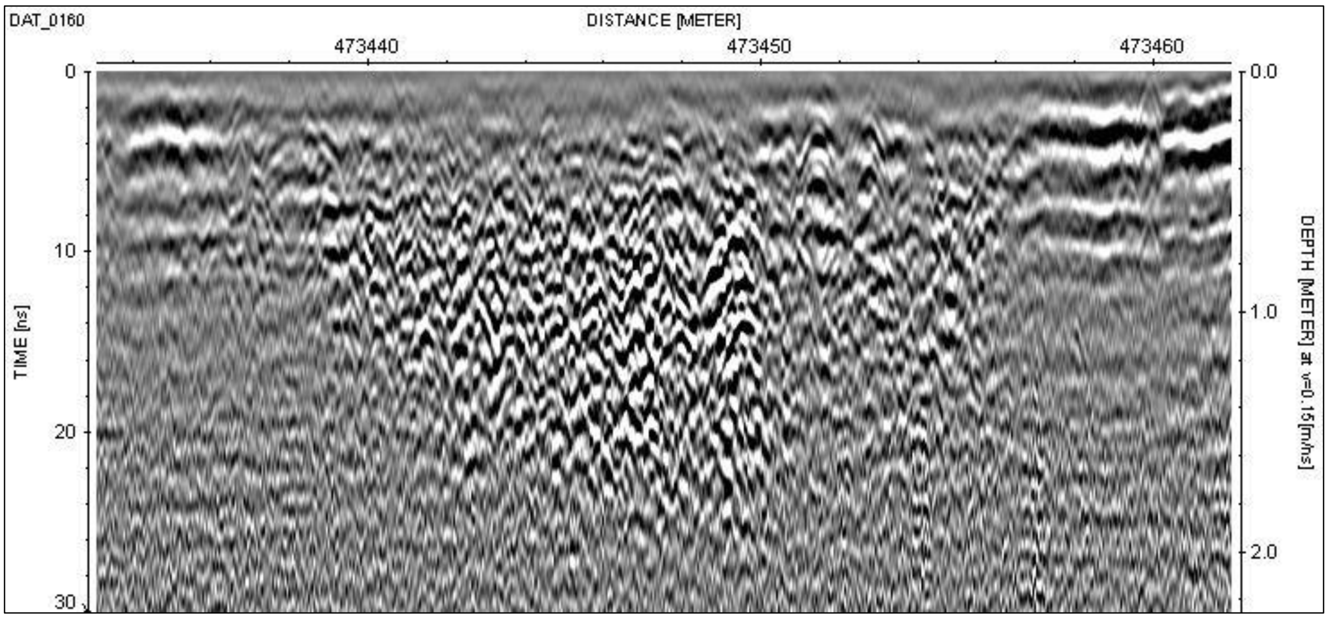


Figure 3.9: A processed GPR profile from Longvek, Cambodia.

The interpretation of GPR data requires an understanding of the archaeological site context, the subsurface properties, and how it may be represented. A hyperbola is the combination of a single object in the subsurface antennation of the radar pulse. The conical nature of the radar pulse results in the waves from the antenna reflecting back from the object at different velocities as the antenna moves closer to the object. Figure 3.10 demonstrates the creation of the hyperbola as the two-way time ($\Delta t$) depth decreases as the antenna moves over the object. For example, in Figure 3.9 the concentration of point source hyperbolas may be an indication of a collection of objects or a midden in the subsurface. Boundaries between surfaces will have a consistent reflection value, however irregular surfaces provide a layer of complexity as the reflected wave may not return to the antenna.

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Figure 3.10: The creation of a hyperbola refection due to a buried point source (from Conyers 2013:61).

In the instance of Figure 3.11, the concave nature of the features results in areas of dispersed energy being less reflective than the area of focused energy directly over the feature. While the radar is reflecting off the same layer, the undulating nature makes it appear to be a smaller feature (Conyers 2013:89). An in-depth understanding of the archaeology being investigated aids greatly in the interpretations. Identifying different feature types—and mapping them spatially—enables examination of how feature size and distribution may be representing an archaeological feature.

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Figure 3.11: Reflective surface with areas of dispersed and focused energy (from Conyers 2013:83).

The application of GPR has been successful in the investigation of urban landscapes as part of an integrated geophysics methodology (see, for example, Donati et al. 2017; Himi et al. 2016; Lueucci et al. 2013; Malfitana et al. 2015; Rogers et al. 2012; Safi et al. 2012; Sala et al. 2013; Trinks et al. 2014). While GPR on its own provides a high-resolution examination of monumental architecture and urban design, it is the integration and layering of methodologies which seems to produce the best results. For the hidden landscape of Early Modern Cambodia, a nuanced approach needs to be employed. A single approach could not encompass the layers of temporal, physical, social, cultural, and political events occurring here. To this end, a suite of theoretical approaches is being considered to aid in understanding change and adaptation in the Early Modern capitals, as examined in section 3.5.

## 3.3 Investigating Cambodian Landscapes

The investigation of Cambodian landscapes has been dominated by remote sensing techniques, with geophysical applications a more recent occurrence. Remote sensing has been used to map the extensive hydrologic network (Groslier 1979), the central temple complex (Pottier 1999), the low density urban network (Fletcher 2012) and the modern environmental conditions of the Mekong River, Tonle Sap and tributaries and associated geomorphology (see, for example, Benger 2007, 2009; Day et al. 2011; Gupta and Liew 2007; Kubo 2008a). The application of GPR has met with a diverse range of success in Cambodian contexts (see, for example, Lustig et al. 2018; Moffat et al. 2019; Sonnemann 2011; Sonnemann 2012; Sonnemann and Chhay 2014; Sonnemann et al. 2015). There are similarities between the successful use of GPR in a European context and its application to research conducted around Angkor, because of the sandstone and laterite building materials used in monument construction. For example, the dielectric permittivity of the temple foundation laterite blocks are high, making them easier to distinguish compared to their surrounding material (for example, see Sonnemann 2012:229). The following will review the work done to date in Cambodia.

### 3.3.1 Remote Sensing

Remote sensing began being applied in archaeological contexts before 1940. B.P. Groslier undertook an aerial survey throughout much of the Mekong Delta in the 1930s and, although the material was not published, it was later used to develop the 'hydraulic city' of Angkor hypothesis (Groslier 1979). Due to civil conflict that persisted from the 1970s through to the early 1990s, maps of Angkor based on Groslier's data were not revised until Pottier's (1999) PhD research. Pottier (1999) analysed aerial photographs to consider the spatial configuration of Angkor beyond the monuments, documenting evidence of community level temples and occupation mounds. Prior to this research, the focus was on mapping temple sites in isolation to the broader Angkorian landscape. Pottier's (1999) research marked a change in approach to mapping the temple complexes by including the entire landscape within a broader cultural narrative, and creating the foundations for feature identification process. This approach is still being used.

Building on the work of Groslier (1979) and Pottier (1999), Evans' (2007) PhD research collated existing map data and remote sensing datasets for the Greater Angkor area. Evans (2007) provided an extensive overview of the remote sensing work conducted in Cambodia, primarily by French researchers. Evans (2007) aim in mapping this area was to move on from Groslier's (1979) hydraulic city hypothesis, and reframe ideas around the Angkorian landscape. Evans used Landsat TM at 1:100,000, SPOT 5, IKONOS, JICA 1:5000 topographic data, FINNMAP, and Mekong River Commission

1992-3 aerial photographs to identify archaeological features. The methodological and classificatory standards established by Pottier (1999) were the basis for feature extraction. Extensive ground verification confirmed the presence of archaeological features, made easier by the linear nature of Angkorian period building techniques and their vast hydraulic network. Close examination of aerial photographs revealed extensive evidence of anthropogenic modification to the landscape, opening new avenues of investigation into the subsistence networks of Angkor, along with its growth and eventual decline (Evans et al. 2007:14282; Evans 2007:204). This work is still to date the most extensive map of the greater Angkor complex. The integrated approach taken by Evans et al. (2007) suggests that a multi-method approach is most suitable for the mapping archaeological features using remotely sensed data. This statement is still relatively applicable, as much of the research surrounding feature identification does not provide detail on how archaeological features are discerned.

The next step in remote sensing in Cambodia was the application of QuickBird multispectral data. Evans and Traviglia (2012) employed QuickBird and ASTAR to investigate the paleo-environment and anthropogenic modification of the pre-Angkorian fluvial systems. The heavy forest coverage which had inhibited some previously employed methods, was mitigated by examining the slight differences in the biomass through spectral processing operations, vegetation indices, vegetation suppression and principal component analysis (Evans and Traviglia 2012:215-222). The integration of spectral processing allowed Evans and Traviglia (2012) to identify paleo-environments and their relationship to the greater Angkor complex. The use of remotely sensed data has greatly transformed how the greater Angkor complex has been investigated; however, it is the application of lidar which provides all new high-resolution data.

The thick tree cover which has protected the Angkor period landscape remains from invasive clearing and levelling has been a considerable hindrance to the application of remote sensing in the region. The introduction of lidar provided new insight into the scale and expanse of the greater Angkor complex. Evans et al.'s (2013) paper on reconstructing the landscape under the dense forest around central Angkor using lidar was the first application of this method in Cambodia. Earthwork construction, engineering and modification were clearly identified and mapped using lidar, giving an alternative and comprehensive dataset to examine the hydraulic network (Evans et al. 2013). Previously unseen occupation areas around the temples themselves were identified and new sites excavated (Evans and Fletcher 2015; Stark et al. 2015). Stark et al. (2015) identified hundreds of occupation mounds around Angkor Wat as living quarters for those who serviced the temple. Lidar has also been applied at city sites outside of central Angkor, such as Preah Khan where Hendrickson and Evans (2015) were able to identify hydraulic management, industrial activities, and secular occupation and examine how these features fit within broader political and economic systems. At Longvek, Evans (2016) used lidar to make comparisons to Angkor Thom, drawing conclusions on population movement of the Angkor population after the decline of the empire as discussed in section 2.5.1 (Figure 3.11). In all these contexts, lidar has provided a new avenue of enquiry for the examination of large and complex landscape features. Common themes within this work have been the relationship between landscape features and political and economic systems, occupation and ideas of diaspora. The incorporation of geophysical methods would greatly expand this approach to incorporate subsurface material not attainable in lidar data.

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Figure 3.12:Comparison of Angkor Thom (top) to Longvek (bottom) from Evans (2016:173).

### 3.3.2 Geophysics

Geophysics has been applied to Cambodian historic sites in a very targeted way. The research undertaken by Sonnemann (2011) throughout greater Angkor accomplished a "proof of concept" study for the application of GPR within a Cambodian context. The research focused on targeted surveys designed to investigate subsurface features largely associated with monumental construction. A broad collection of sites was examined by Sonnemann (2011), but in most instances, this research did not progress sufficiently to contribute to any current debates, such as the relationship between landscape features and political and economic systems mentioned above. Part of this research was a targeted, small scale investigation of a pottery kiln site in the village of Bangkong, 20 kilometres east of major Angkor temple sites such as Angkor Wat and Angkor Thom (Sonnemann and Chhay 2014). Five sites were investigated to determine the extent of the kilns disturbed by farming, and to generate 3D profiles of the undisturbed kilns. The extent of the site was fully mapped to protect them from further disturbance and assist heritage management. This targeted approach was also conducted at Hariharālaya, located 14km southwest of the modern centre Siem Reap. Hariharālaya was a political centre from the eighth to ninth centuries and a major urban centre. The GPR survey aimed to increase understanding of the water management network (Sonnemann 2015). Lines of GPR data were collected by surveying long transects on existing roads and paths to assess the visible archaeological features and augment this data by mapping the subsurface. By embedding the single GPR transects with satellite data into a GIS environment, the visible surface patterns were complemented by the 2D radargrams. The survey provided additional data to appraise the early Angkorian hydraulic network, but was not able to map the paleo environment.

In contrast to this targeted approach, Sonnemann (2012) conducted a 4.4 hectare GPR survey within the Angkor Wat enclosure. This survey identified the bases of six laterite towers, in alignment with the still-standing western entrance gate. Linear features were also found that are believed to have been the original alignment of the southern road, which connects the southern gate to the main temple. Sonnemann et al. (2015) followed up the GPR results with targeted excavations to investigate the buried towers within the Angkor Wat enclosure. While both the targeted and large scale GPR surveys conducted at Angkor were highly successful, in both instances the integration of other geophysical techniques would have greatly enhanced the results obtained. For example, the work conducted within the Angkor Wat closure would have benefited from magnetometer prospection before the GPR survey. By narrowing down the GPR survey area, a focus on data quality over quantity could have been considered. For instance, Sonnemann (2012:230) states that 'no column foundations were clearly identified during the GPR survey, either because they had been completely removed, or possibly as a result of the survey line spacing of 50cm.' The integration of GPR with magnetometry may have provided the fine-grained data needed to investigate such features.

More recently, a GPR survey was undertaken at the city of Koh Ker to investigate the decline of the water management network, with Lustig et al. (2018) examining the breakdown of the hydraulic system and Moffat et al. (2019) investigating the failure of the reservoir. Both investigations identified flaws in the design of the hydraulic systems, with Lustig et al. (2018) using a combination of remote sensing methods and GPR, while Moffat et al. (2019) used only GPR. Both methods employed a 500MHz antenna as a part of a targeted investigation over multiple grids. In both these instances, the researchers were able to make nuanced interpretations as to why the hydraulic systems failed at Koh Ker, and in turn to discuss the broader implications for Koh Ker as a capital of the Angkor empire.

Outside of the Angkor complex, a small GPR survey was undertaken on the Early Modern period site Krang Kor, north of Longvek (Sugiyama and Sato 2015:46). The investigation was undertaken as a mode of prospection to inform excavations being undertaken at the site. A 400mHz antenna was employed at a 0.5 metre line spacing within grid at four locations (Sugiyama and Sato 2015:46). The survey identified a range of subsurface features that were later excavated, with the most significant anomaly revealing a burial at 0.7m depth (Sugiyama and Sato 2015:51). The GPR survey appears to have identified the disturbance created by the grave cut and grave goods, which consisted of an assortment of pottery and small artefacts (Sugiyama and Sato 2015:10). The conclusions that could be drawn from the GPR results were limited, as there is no comparable data from Early Modern period sites. However, Sugiyama and Sato (2015:51) saw the results as encouraging for the application of the method in this region.

Several themes can be taken from the remote sensing and geophysical investigations already conducted in Cambodia. First, there is a push to move away from investigating sites in isolation, and instead, to consider how they fit within the broader cultural landscape. Second, the application of geophysics has been a targeted, site-specific approach, with limited integration with other methods. With these two points in mind, it is important to consider how to move the methods forward to develop a finer-grain understanding of the cultural landscape. The real challenge, however, will be the implementation of these methods in contexts which do not fit the traditional site type, in order to form a new and unique dataset specific to hidden landscapes. GPR appears to be a commonly applied tool, but when compared to the research being undertaken within Europe, it is apparent this technique – along with magnetometry – has been largely neglected. As yet, there has been no discussion around why this may be. The application of GPR to monumental structures appears to be a common theme, as is the application of lidar to forested sites. The question needs to be raised as to why other methods, such as magnetometry, which is widely used in a variety of historic and prehistoric contexts in Europe, have not been applied in Southeast Asia.

## 3.4 Approaches to Investigating Early Modern Hidden Landscapes

The following will examine the use of geophysical methods in three key hidden Early Modern landscape types: (i) buried, (ii) semi-buried architecture and (iii) mounded features. These landscape types were selected based on the sites proposed for investigation in Chapter 2, summarised in section 2.6. These proposed sites consist of completely buried landscape features, such as evidence for occupation at Longvek; the semi-buried architecture such as Prasat Preah Theat Baray; and finally, the mounded sites associated with potential palaces and religious complexes. This review will inform the methodological approach best suited to investigate the outlined landscape features.

### 3.4.1 Buried Landscapes

Buried landscapes are defined here as cultural features completely contained to the subsurface. The methods used to investigate these archaeologically are often applied in a landscape-scale approach which seeks to survey the largest land area possible. With the advancement of geophysical and geographical positioning equipment, this method is becoming more prevalent. The investigation of the hidden landscapes associated with the prehistoric site of Stonehenge is one of the most comprehensive and integrated landscape scale geophysical investigations (Bewley et al. 2012; Darvill et al. 2013; De Smedt et al. 2014; Gaffney et al. 2018; Gaffney et al. 2012; Saey et al. 2015). Combining lidar with earth resistance, electrical imaging, magnetometer, ground-penetrating radar and electromagnetics, ten square kilometres of the Wiltshire countryside was surveyed (Gaffney et al. 2018:256). This survey was an important step in understanding the complex prehistoric landscape, with numerous new features identified. The magnetic survey was the most revealing. A 16-channel magnetometer at 0.25 metre, mounted on a vehicle-towed cart, was used to detect ferrous metals, in addition to structures with a varied magnetic value such as culturally modified sediments associated with pits, ditches, postholes, hearths and embankments (Darvill et al. 2013:66). Modern contaminants hindered the magnetic survey. The area around Stonehenge is currently used for farming, and fencing and below-ground piping had a significant impact on the results. Furthermore, the area had been used as a music festival site, as well as for manoeuvres by the armed forces, as well as being quite close to a newly constructed major highway (Darvill et al. 2013:66).

The success of the geophysical survey at Stonehenge was in the identification of new landscape features, and in the expansion of the dataset of known features. The survey at the Stonehenge Cursus, which is a three kilometre long elongated earthwork, identified First World War features through multi-receiver electromagnetic induction and ground-penetrating radar (Saey et al. (2015). However, it was the magnetometer survey which was able to map the full extent of the earthwork boundary (Darvill et al. 2013:69). In addition, high nanoTesla-value circular features were identified as barrows, which are associated with twenty-five mounds present on the surface at King Barrow Ridge Cemeteries. This leads to the conclusion that these structures date from the mid-third millennium BC (Darvill et al. 2013:78; Gaffney et al. 2018:257). The success of this survey can be attributed to the scale of the investigation and composition of the features investigated. The scale allowed for the entire landscape to be considered, which is critical when considering massive kilometre-long landscape features. The contrast between cultural modification sediments and the surrounding farmland made it possible to distinguish buried landscape features.

Landscape-scale geophysics has also been applied to sites in Greece to examine the urban planning of ancient cities. Donati et al. (2017) examined six ancient Greek cities using GPR, electromagnetic induction (EMI), magnetics and resistivity. At the site Mantinea, 53% coverage of 10.36 hectares over 3.5 working days was achieved (Donati et al. 2017:3). Such high coverage over a short work period can be attributed to the application of multi-sensor equipment, which has been mounted to carts with high-precision geographic information systems. The magnetometer applied was an eight-sensor array with a 0.5 metre line space attached to a cart; the GPR was configured with an eight-channel, 250MHz antenna mounted to a quadbike (Donati et al. 2017:2). The open, flat and accessible farming land being surveyed allowed for faster acquisition. Figure 3.13 shows the magnetic and EMI data overlaid on an aerial photograph. The results show the gridded roads appear to have a high positive nanoTesla value, with potential structures indicated by a negative value (Donati et al. 2017:4). Proposed buildings were located along roadways, with sizable zones that have limited to no variation, suggesting no trace of architectural features. However, this empty space was not considered here in light of the broader ideas of urban planning (Donati et al. 2017).

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Figure 3.13: Ancient city of Mantinea, Greece. Magnetics and EMI magnetic susceptibility results from Donati et al. (2017:5).

The examination of urban design does not need to be a landscape-scale investigation, with more targeted surveys identifying complex urban systems. Vanvalkenburgh et al. (2015) combined gradiometer and GPR surveys in the Zana Valley, Peru. Vanvalkenburgh et al.'s (2015) research methods were designed to identify and investigate government building foundations, and in turn consider the influence of centralised government on urban design in domestic and religious spheres. Their research focused on examining areas devoid of anomalies to identify plazas, communal public spaces and religious sites. The geophysical survey identified the void space of the town plaza and the foundations of the town's church and civic buildings. By comparing the geophysical survey data to historical documents, subtle variations between the two were found. It has been postulated by

Vanvalkenburgh et al. (2015:126) that these variations demonstrate the influence of local government on state-sanctioned building and urban design. Also examining empty space using geophysics is Ullrich et al. (2011) who used magnetics and ERT to investigate three German settlement histories through their analysis of domestic and industrial areas. Through this, Ullrich et al. (2011) associated circular positive anomalies with domestic habitation, and high-resolution pits with metal working and smelting. The clustering of anomalies was an important device for Ullrich et al. (2011) to determine the difference between domestic and industrial areas. Thompson et al. (2016) investigated the sixteenth century colonial landscape of Santa Elena, country, focusing on the spaces between built environments rather than geophysical anomalies per se. Building on this method would be an interesting analysis of how communities used liminal spaces. In these three instances, the spaces absent of anomalies are being considered to further interpret buried landscapes. These are a few instances investigating why a space that is being avoided may be as useful as why a space is being heavily used. More emphasis needs to be placed on these empty spaces and the nature of the absence in geophysical data. Nelson (2014) examined in section 3.5.2 is an exceptional example of considering empty space in geophysical data. Overall, the application of magnetometry and GPR at any scale is a useful tool for examining buried landscapes. It is also important to not only consider the areas with anomalies, but also the void areas.

### 3.4.2 Semi-Buried Architecture

Thanks to the Romans, Greeks, Mayans and Egyptians and their penchant for building large and status-affirming monuments, a significant degree of monumental architecture has been investigated using remote sensing and geophysical methods. Investigating the physical foundations which make up such architecture is one of the most extensively researched areas in geophysics, particularly in European contexts. This is because the nature of the material being investigated makes it especially susceptible to the radar waves of GPR and magnetic investigations of magnetometry. Investigating the monumental architecture of civilisations which often consist of semi-buried architecture and have historical records to support the identification of sites and contents generates the most successful geophysical prospection results.

Geophysics has been proven time and time again to be an excellent tool for investigating structures made of brick and stone. Anchuela et al. (2016) used a multi-method approach that integrates magnetic and GPR data in order to investigate a Roman villa in the Iberian Peninsula. On the surface, the Roman villa consisted of *in situ* walls. From known starting points, Anchuela et al. (2016:107) provided a systematic analysis of the steps taken in the investigation of this site. These included (i) historical investigation of the site, (ii) pre-testing techniques on similar known materials and modelling anomalies for comparison, (iii) geophysical survey, including magnetometry, ERT and GPR, analysis of results and (iv) interpretation. From this data set, the magnetic survey undertaken by Anchuela et al. (2016:115) enabled them to reliably record the nanoTesla value for features such as monumental structures (>50nT range), bricks and metal deposits (10-15nT) and pit houses (>50nT). With this information, a detailed map of the area was generated, and further verified with the application of GPR. By integrating these methods, Anchuela et al. (2016:115) were able to generate the most robust interpretations in relation to the origins of the geophysical anomalies. With a focus on refining methods for prospection in this region, this approach does not consider, however, how these results affect current archaeological research in the Iberian Peninsula.

In contrast to the above prospection approach, Barone et al. (2011) investigated Regio III in Pompeii, Italy, to examine how the changes in wealth distribution were reflected in the outward movement of large monuments and households. Barone et al. (2011) used GPR in multi-directional grids to investigate the deep deposits of volcanic ash in the outer suburbs. Reflection profiles mapped a series of undulation reflections generated by ash layers. Amplitude slice maps presented large linear features, which Barone et al. (2011) attributed to monumental sized wall features which are believed to have been a sign of wealth. Other, smaller linear features were also identified. The significance of these features is their large-scale monumental size which Barone et al. (2011) suggest were over 5 metres tall and representative of the elite moving out of the city centres. The gentrification of the periphery of the city resulted in family groups of entrepreneurs becoming wealthier, rather than the elite moving out of the city. This geophysical survey was able to identify regional trends through the collection of GPR reflection grids at different orientations allowing for a refined landscape reconstruction and ultimately new conclusions on social stratification.

Mohamed-Ali et al. (2012) used magnetic gradient and electrical resistivity tomography surveys in combination to investigate the capital city of the Kush Kingdom in Sudan. The most prominent features of this city are the remains of government buildings, temples, palaces and a stone-walled enclosure. The purpose of this investigation was to investigate monumental architecture to understand the extent of the palace and temple sites and of the city stone walls. In addition, Mohamed-Ali et al. (2012) were also testing the magnetic susceptibility of mud bricks and roadways for the purposes of refining future investigations. The site is situated on what was once an island in the river Nile. As a result, the sediment consists mainly of flood-plain alluvium. Mohamed-Ali et al. (2012) attributed the success of their survey to the sandy sediment composition having a low relative dielectric permeability, which contrasted well against the highly reflective archaeological features. The magnetic gradient mapping identified small archaeological features, the remains of sandstone and brick buildings and the main enclosure wall, all of which had a low negative nanoTesla value (see Figure 3.14). The buildings identified by magnetic survey were complemented by the ERT data, clarifying the extent and depth of buildings. These results were verified, in part, by archaeological investigations. The low negative nanoTesla value and highly reflective properties of the stone-walled enclosure contrasting against the natural sand allowed for highly defined prospection results. This research appears to have been undertaken in ideal conditions, which resulted in extremely clear and well defined semi-buried architectural features.

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Figure 3.14: Magnetic survey at the capital city of the Kush Kingdon, Sudan. a) magnetic survey, b) proposed building layout and c) ground verification (Mohamed-Ali et al. 2012:62).

Safi et al. (2012) used GPR at the Late Classic Mya site of El Baul, Cotzumalhuapa, Guatemala to examine the wider urban structures associated with monuments and causeways. As with the examination of the built landscapes reviewed above, Safi et al. (2012) set out to investigate if a central polity organised the urban structures in relation to the monuments and causeways or if the urban design was organic in nature. Thirty-three GPR grids were systematically surveyed. Time slices revealed evidence of geometric shapes aligned with the known monuments and causeways. Safi et al.

(2012) suggest this evidence aligned with the hypothesis that the area was part of an integrated complex of civic, domestic and monumental zones. The GPR surveys were confirmed by targeted excavations that investigated the high-amplitude reflections identified by the GPR, and revealed a network of well-organised settlement at El Baul (Safi et al. 2012). The use of stones in construction resulted in highly reflective targets for GPR prospection as evident in Figure 3.15.

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Figure 3.15: Excavation plan superpositioned over GPR data at Gavarrete Causway. High-amplitude reflections correlating with subsurface rocks (Safi et al. 2012:422).

As can be seen from the examples given here, the investigation of semi-buried architecture has been successful within geophysical research. This can be attributed to the durable nature of construction materials such as sandstone and bricks, and their ability to survive semi-buried. The variability in magnetic properties between natural sediment and archaeological features—and high relative dielectric permeability of this material—create ideal conditions for geophysical methods to effectively identify and map subsurface remains. These well-researched sites, largely from historic Roman and Greek locations, also have the benefit of surface remains and historical sources which can direct survey design and aid in interpretation. These positive outcomes can also be attributed to the building style with consistent structural design principles used by established civilisations such as the Romans or Mayans, ensuring a predictability in architecture and making detection of associated semi-buried remains a relatively easy task. The investigation of semi-buried architecture has also been undertaken in Cambodia and will be further examined in section 3.3.2.

### 3.4.3 Mounded Features

The use of geophysical methods to investigate mounded landscape features has been applied in a variety of prehistoric and historic contexts, as not all mounds serve the same purpose. The mounds considered here are burial, monumental and occupation. Burial mounds are commonly investigated using geophysics, due to its non-destructive nature (see, for example, Conyers et al. 2018; Forte and Pipan 2008; Mojica et al. 2014; Verdonck et al. 2009). At a site in northern Italy, Forte and Pipan (2008) investigated *tumuli* burial mounds using seismic tomography and GPR in a radial collection method. Their survey used a 250MHz antenna with a radial collection method which had 12 overlapping midpoints, allowing for a 3D reconstruction of the internal mound features. The GPR survey successfully mapped large subsurface features which consisted of abrupt stratigraphic changes as the result of mound construction as shown in Figure 3.16 (Forte and Pipan 2008:2621). The clearest of these features in the GPR profile is the looter's hole, which created a stratigraphic break in the profile between the topsoil, the dipping horizon and the layer of silty sediment over the burial chamber (Forte and Pipan 2008:2621). Despite being able to identify these stratigraphic changes, Forte and Pipan (2008:2622) were not able to achieve clear radar resolution beyond the 0.2 metre of topsoil due to the 250MHz antennation limits. The lack of antennation at depth has been attributed to the mound's clay composition, and the use of boulders in the construction, which caused scattering in the profile (Forte and Pipan 2008:2622). Despite these issues, the internal structure of the burial mound was mapped and corroborated through ground verification, confirming that large stratigraphic horizons can be successfully surveyed using GPR.

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Figure 3.16: GPR transect (a) and corresponding excavation (b) showing (v) looting attempt, (h) dipping horizon, (s) layer of silty brown soil, and (t) funeral chamber not represented in the GPR profile (Forte and Pipan 2008:2621).

The use of mounds as monuments and effigies has been seen in many historic and prehistoric communities and investigated using geophysical methods (see, for example, Bigman and Lanzarone 2014; Dalan and Bevan 2002; Seinfeld et al. 2016; Whittaker and Storey 2008). In contrast to the burial mound example above, the investigation of effigies and monuments are often less complicated, due to construction processes. Flat-topped mounds related to monument construction are the focus here, with an example from Bigman and Lanzarone (2014), who examined a north American mound complex to identify internal structures, determine construction events, and speculate human labour costs. Bigman and Lanzarone (2014:217) undertook a GPR survey at the summit of the flat-top mound using a 500MHz antenna at a 0.5 metre line spacing with a total depth of approximately 5 metres. Based on previous excavations at the mound, Bigman and Lanzarone (2014:217) knew the dielectric contrast between sediment units would provide clear radar reflection profiles. The stratigraphic horizons were represented in the GPR profiles by layers of high-amplitude reflection signatures and incoherent low amplitude responses, with excavation trenches represented by section breaks filled with homogenous low amplitude sediment (Bigman and Lanzarone 2014:117). Through mapping the stratigraphic evolution of this mound, Bigman and Lanzarone (2014:221) were able to draw correlations between mound construction and changes in labour investment, site access, function, and meaning, concluding that the mound served both as a monument and domestic structure. Four mound summits were detected during the GPR survey, which were correlated to changes in the functionality and labour capital available as additions became less elaborate over time (Bigman and

Lanzarone 2014:222). The examination of monument mounds using geophysics can provide a unique suite of results which extend beyond the prospection of archaeological features. As this example demonstrates, geophysical data can be used to draw parallels between the physical landscape, labour control, cultural meaning and social attachment.

Occupation mounds are one of the landscape features that are less commonly studied using geophysical techniques. The densely accumulated archaeological material makes it exceedingly difficult to identify archaeological features and stratigraphic horizons. Figure 3.17 shows the effects of dense anthropogenic shell deposits at a hunter-gatherer occupation mound. The level of shell density results in an incoherent collection of high-amplitude radar reflections, making it difficult to determine any individual features beyond the midden as a whole. In the case of this mound, Thompson and Pluckhahn (2010:46) viewed the midden as a part of the architectural feature that is the result of seasonal use of the mound. Contrasting this, Duke et al. (2016) interpreted stratigraphic breaks in densely accumulated material as large-scale archaeological features, corroborated by a nearby excavation trench. This survey was conducted at Ban Non Wat, in north-east Thailand, to further examine a large water management feature that was identifiable during excavations. Occupation mounds such as Ban Non Wat are common in Southeast Asia, with densely stratified sites such of Phum Lovea found in Cambodia (O'Reilly and Shewan 2015, 2016). The complex stratigraphy is the result of continued occupation which results in the accumulation of culturally modified sediments over time (O'Reilly and Shewan 2015). The complex stratification found at Ban Non Wat was a hindrance at identifying smaller archaeological features; however, the complex stratification in this instance aided the detection of the feature. This was especially useful as the radar response, similar to the example in Figure 3.17, consisted of incoherent high-amplitude features. The general conclusions derived here suggest the application of GPR to mounded sites is best suited to contexts with minimal stratigraphic layering. Large features are easily identifiable, but depending on the size and composition of the mound, the resolution and antennation depth can be compromised. The most useful application of GPR for the examination of mound stratigraphy is to aid in determining construction phases and basic internal composition.

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Figure 3.17: GPR profile from a hunter-gather mound at Crystal River, Florida, showing the high-amplitude radar responses caused by a subsurface shell midden within an occupation mound (Thompson and Pluckhahn 2010:46).

## 3.5 Interpreting Geophysical Results: An Archaeological Framework

Geophysical methods have been used in archaeological contexts since the late 1980s, the advent of which arose in response to increased access to the necessary instruments. Since this time, archaeological prospection has taken geophysics from a series of proof-of-concept research approaches to an important central component of archaeological research. However, successful and consistent utilisation of results continues to be functionally disconnected from archaeological interpretations or archaeological theory. Geophysical approaches need to be treated like any other method, as part of a process of answering archaeological questions. The application of social theory to geophysical methods allows for the examination of archaeological sites as more than a geophysical response, providing alternative avenues for interpretation and investigation. Much like the interpretation of archaeological strata or a ceramic collection, the digital artefacts produced from geophysical data need to undergo the same rigorous analysis and interpretation. The application of social theory to these datasets may help fill this gap in archaeological geophysics. Geophysical datasets are moments of social action, where each feature is a representation of human activity. In short, geophysical methods have been over-described and under-theorised.

### 3.5.1 Answering Archaeological Questions with Geophysical Methods

The problem identified in the course of this research is the lack of archaeological interpretation of geophysical results. Table 3.3 is an overview of the bibliographic material examined during the research phase of this thesis. Sixty papers were included, excluding review articles, methodology papers and PhDs, to examine which methods were being applied to landscape-scale and targeted geophysical surveys. Of the sixty, only twenty-one took the results further and interpreted them as part of an archaeological framework; only two applied a theoretical framework. Landscape-oriented investigations appear to be the most common, with conclusions around spatial analysis of results and how they relate to social change (see, for example, Garcia-Garcia et al. 2016; Himi et al. 2016). Mound sites can provide data that elucidates ritual and burial rites, drawing correlations between mound construction and social investment (see, for example, Bigman and Lanzarone 2014; Seinfeld et al. 2016). The issue of using geophysics to answer archaeological questions has been considered previously by Conyers (2012), Kvamme (2003), Thompson (2010) and Thompson et al. (2011), who all take a methods-centric approach to the issue, attempting to frame archaeological research questions so that they have geophysics at the centre.

Although geophysicists have attempted to address this problem, they have tended to take a very 'methods-centric' approach. One example is the book *Anthropological Research Framing for Archaeological Geophysics* by Thompson (2010:6), which asserts that archaeologists are not asking the right kinds of questions for geophysics to answer and gives examples such as 'Do features indicated at Site X by AGP [archaeological geophysics] vary spatially? If so, how?'. Placing the method in the research question does not rectify the issue of framing archaeology to suit geophysics. What Thompson (2010) has not considered is that geophysics is just the *method* and should not be the starting point in the framing of research questions. Geophysics is only one method, which will likely be part of a wider suite, to answer an archaeological research question. In saying this, the aim is not to diminish the discipline, but rather to highlight the need to examine how geophysics can contribute to and further archaeological theory, integrating the method within a broader paradigm. Thompson (2010:31) compares the framing of geophysics within an anthropological research paradigm to using a medical ultrasound to assess a person's behaviour: the method can diagnose a condition, but not the social behaviour which caused it. However, this analogy fails to recognise the need for a nuanced understanding of the patient (or in this case the archaeological site) in order to fully understand the results provided.

Table 3.3: Selected papers on archaeological geophysics for landscape investigations. Excludes review articles, methodological articles and PhDs.

| Reference | Location | Target | Magnetic | Radar | Electric | Remote sensing | Methodological | Prospection Only | Furthers results | Applies theory |
|---|---|---|---|---|---|---|---|---|---|---|
| Abbas et al. (2005) | Egypt | Temples | X | X | | | | X | | |
| Agapiou et al. (2016) | Italy | Neolithic settlement | | | | X | X | X | | |
| Alexakis et al. (2009) | Greece | Neolithic settlement | | | | X | X | X | | |
| Anchuela et al. (2016) | Spain | Roman Villa | X | X | X | | | X | | |
| Ard et al. (2015) | France | Neolithic causeway | X | | | | | X | | |
| Barone et al. (2011) | Italy | Roman settlement | | X | | | | X | | |
| Batayneh et al. (2007) | Jordan | buried structures | X | | X | | | X | | |
| Bernardine et al. (2013) | Italy | Roman forts | | | | X | | X | | |
| Bewley et al. (2012) | UK | Prehistoric features | | | | X | | X | | |
| Bigman (2014) | USA | Settlement boundaries | X | | | | X | X | | |
| Bigman and Lanzarone (2014) | USA | Mound exploration | | X | | | | | X | X |
| Burks (2014) | USA | Earthworks | X | X | | | | X | | |
| Caldara et al. (2014) | Italy | Medieval settlement | X | | | X | | X | | |
| Carter et al. (2018) | Cambodia | Residential patterning | | | | X | | | X | |
| Chianese et al. (2004) | Italy | Buried settlement | X | X | | | | X | | |
| Conyers et al. (2013) | Portugal | Coastal palaeogeography | | X | | | | X | | |
| Darvill et al. (2013) | UK | Prehistoric landscape | X | | | | | | X | |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| De Smedt et al. (2014) | UK | Prehistoric landscape | | | X | | | X | | |
| di Maio et al. (2016) | Greece | Settlement/site stratigraphy | X | X | X | X | | X | | |
| Donati and Sarris (2016) | Greece | Settlement foundations | | | | X | | X | | |
| Donati et al. (2017) | Greece | Urban landscape | X | X | X | X | | X | | |
| Drahor et al. (2008) | Turkey | Roman camp | X | | X | | | | X | |
| Duke et al. (2016) | Thailand | Water management | | X | | | | | X | |
| Evans (2016) | Cambodia | Historic site | | | | X | | | X | |
| Evans et al. (2007) | Cambodia | Historic site | | | | X | | | X | |
| Evans and Traviglia (2012) | Cambodia | Pre-settlement water ways | | | | X | | X | | |
| Evans et al. (2013) | Cambodia | Historic site | | | | X | | X | | |
| Forte and Pipan (2008) | Italy | Burial Mound | | X | | | X | X | | |
| Garcia-Garcia et al. (2016) | Spain | Roman settlement | X | | | | | | X | |
| Hawken (2013) | Cambodia | Rice field orientation | | | | X | | | X | |
| Himi et al. (2016) | Syria | Buried architecture | | X | X | | | | X | |
| Kadioglu et al. (2013) | Turkey | Hellenistic street system | | X | | | | X | | |
| Keenan and Ellwood (2014) | USA | Mound effigies | X | | X | | | X | | |
| Linford et al. (2010) | UK | Roman settlement | | X | | | X | X | | |
| Linsay et al. (2010) | Armenia | Buried architecture | X | | | | | | X | |
| Lueucci et al. (2013) | Turkey | Buried architecture | | X | | | | | X | |
| Malfitana et al. (2015) | Albania | Roman urban remains | | X | | | | X | | |
| Moffat et al. (2019) | Cambodia | Reservoir failure | | X | | | | | X | |
| Mohamed-Ali et al. (2012) | Sudan | Buried architecture | X | | X | | | X | | |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Mojica et al. (2014) | Panama | Funerary complex | X | | | | | X | | |
| Nelson (2014) | USA | Settlement distribution | X | | | X | | | X | X |
| Rego and Cegielski (2014) | Spain | Roman hill forts | X | | | | | | X | |
| Safi et al. (2012) | Guatemala | Buried architecture | | X | | | | | X | |
| Sala et al. (2013) | Catalonia | Urban landscape | X | X | | | | | X | |
| Schneidhofer et al. (2016) | Norway | Palaeoenvironment reconstruction | | X | | | X | X | | |
| Seinfeld et al. (2016) | USA | Mound effigy | | X | | X | | | X | |
| Simon and Moffat (2015) | Greece | Mound prospection | X | | X | | X | X | | |
| Sonnemann (2012) | Cambodia | Buried architecture | | X | | | | X | | |
| Sonnemann (2015) | Cambodia | Buried water management | | X | | X | | X | | |
| Sonnemann and Chhay (2014) | Cambodia | Historic kilns | | X | | | | X | | |
| Sonnemann et al. (2015) | Cambodia | Buried architecture | | X | | | | X | | |
| Stark et al. (2015) | Cambodia | Residential patterning | | | | X | | | X | |
| Strum (2016) | USA | Land use patterns | | X | | X | | | | |
| Thompson et al. (2016) | USA | Military forts | X | X | X | | | X | | |
| Trinks et al. (2014) | Sweden | Viking settlement | X | X | | | | X | | |
| Ullrich et al. (2011) | Germany | Settlement history | X | | X | | | X | | |
| van Leusen et al. (2014) | Italy | Site detection | X | | | | X | X | | |
| Vanvalkenburgh et al. (2015) | Peru | Urban landscape | X | X | | | | | X | |
| Viberg et al. (2016) | Sweden | Semi-buried landscape | | X | | X | | | X | |
| Yuratikan et al. (2014) | Thailand | Buried landscape | | X | | | | X | | |

Thompson (2010:45) notes that archaeologists benefit from utilising tolerance for the subjectivity, ambiguity, and relativity that is inherent within geophysical results, and for archaeologists to have a better understanding of the different methods. Conyers (2012:204-207) provides a checklist for successful collaboration, however, the most important point is the need for informed participation, where the geophysicist has enough contextual information for a successful survey, and the archaeologist has basic knowledge of the method being employed so that they can understand and interpret outcomes. They also need to approach the research question with the understanding that geophysics is a method of analysis, and results should be approached like any other dataset. By approaching the data in this way, social theory can then be applied.

In a post-processual approach to methods in archaeological research, the mistake appears to be related to choosing the method before determining the research question. There is a need to situate research questions within the archaeology and in the case of geophysics, understand the limitations of the method and what kind of research questions it can be applied to. The same can be said for the application of social theory to geophysical results: they need to be a part of the tool kit to address the research question. As with many archaeological research questions needing multiple methods to address them, multiple epistemological stances may be required.

Landscapes are the physical representation of social practice, belief systems, identity, memory, and meaning. The examination of these landscapes can provide insight to how these aspects of the socio-cultural and political frameworks have changed over time (Bender 2006:305). An examination of a landscape is a two-pronged issue. It firstly relates to how the research interprets the physical landscape as landform and topography, and, second, how the researcher attempts to understand landscape as a cultural phenomenon. In the examination of hidden landscapes thus far, the features are elements of landform and topography. However, in asking questions about socio-cultural and political change, meaning needs to be identified and interpreted from such physical remains. The following review of theories is specific to this research in the examination of hidden landscapes, and is not an exhaustive set of methods that can be applied. Multiple theories are considered here to reflect the fluidity of the methods used, and the complexity of the sites being investigated. While this thesis cannot address all the issues surrounding the application of theory to geophysical results, it aims to move away from over describing geophysics, and interrogate results within a theoretical framework.

### 3.5.2 Landscapes and Spatial Archaeology

The definition of landscape in an archaeological context has many incarnations dependent on the researcher and the approach taken. Two common avenues of investigation are a focus on the physical, ecological and economic landscape, or on an interpretive theoretical approach and the social meaning behind place (Ashmore 2008:256). Taking an interpretive approach, Bender (2006:303) states that 'landscape is "the world out there" as understood, experienced, and engaged with through human consciousness and active involvement. Thus, it is a subjective notion, and being subjective and open to many understandings it is volatile.' An analytical approach does not focus on the subjective experience of engaging and experiencing landscape, or how the landscape may be a manifestation of the social, but rather focuses on the investigation of space through geographical information systems (GIS) (see, for example, Antrop and Van Eetvelde 2017). An example of this within landscape and spatial discourse is Taylor's (2020) examination of the interaction between space and time using a GIS framework. Within this research, Taylor (2020:424) creates a spatiotemporal model to examine a landscape over time, that, while fulfilling the objective of demonstrating change, only highlights that space and landscape need to be considered within a theoretical framework. The model examines cultural landscapes within a GIS framework, where conceptual modelling of space within a time-space occurs through a computational approach (Taylor 2020:410). The distinction here between analytical and theoretical approaches is how landscape can be viewed as space or place. Space is a bondable, physical setting, whereas place is created through social processes which require human agents placing value on the space they inhabit (Preucel and Meskell 2008:215).

Landscape is the interaction of place and time and how we apply meaning to this is biased by the approach, analytical or theoretical, and our limited observation capacities. Branton (2009:53) reinforces this by stating that archaeologists must explicitly define their analysis in terms of its physical limitations, temporal setting, social, and cultural context. Archaeological methods rely on a framework of time and space that place physical artefacts within stratigraphic profiles or into chronologies (Blake 2008:231). Bender (2002:104) states that 'landscape is time materializing.' Landscape is not nature, geology or topography, but an embodiment of human interaction and experience of a space, with meaning embedded by movement, memory, or creation (Bender 2002:103). Ingold's (1993:153) work attempted to move landscapes away from the physical representation of space as neutral backdrops to map activity, recognising that the views and perceptions of the dweller of the space will differ from the views and perceived meaning given by the archaeologist. In examining the landscape, meaning is generated from the information archaeologists gather from it, in an attempt to understand the embedded meaning, essentially using the *-emic* to try to extrapolate the *-etic*. With the inclusion of time and the archaeologist's inherent need to assign chronology, meaning is extracted through the examination of times within space, with space turning into place through the intervention of the human dwellers (Ingold 1993:155). The temporality of a landscape is an important indicator of change and how it represents an interaction between, place, time, meaning, and identity (Ingold 1993:152). In examining the landscape, archaeologists are analysing the material components of place to understand identity, society and power (Branton 2009:51). This interpretive approach requires a framework to be situated, such as spatial archaeology.

Spatial archaeology examines a very broad range of topics which pertain to the analysis of space at any particular scale or context (Clarke 1977b:1). Its development into a core archaeological technique is documented by Gillings et al. (2020), but the interest here is spatial archaeology and the volume of work edited by Clarke (1977a). Clarke (1977b:9) defines spatial archaeology as:

> the retrieval of information from archaeological spatial relationships and the study of the spatial consequences of former hominid activity patterns within and between features and structures and their articulation within sites, site systems and their environments: the study of the flow and integration of activities within and between structures, sites and resource spaces from the micro to the semi-micro and macros scales of aggregation.

This definition incorporates a variety of surface evidence of human occupation and activity, which can be viewed as nodes within a broader landscape. Physical elements of the site and its systems may be represented as settlements and the pathways that connect them within the landscape. The environment is the natural element but also the 'resource space', defined as area or land as a resource in itself i.e. the farming land around a settlement (Clarke 1977b:9). While Binford (1981:7) uses the term 'economic zonation' and Ingold (1993:162) applies the term 'taskscape', the terms all consider the intuitive value of the space as an economic commodity, which ordinarily may be represented within the archaeological record as a village or household (Clarke 1977b). Data points within this economic zone can be viewed as levels of a site system; a non-random output of human choice consisting of the site, the built structure and the resource space (Clarke 1977b:10). Clarke attempted to be holistic in their examination of space, but does not explicitly consider that which is absent. For example, the application of geophysics to semi-buried architectural landscapes, where the hidden material can redefine the meaning of a space by having all its parts represented, such as the example from Vanvalkenburgh et al. (2015). When recording archaeological sites, a bias is created by only considering what is visible to the researcher.

The examination of archaeological sites within the spatial archaeology framework considers sites as data points on a map, whereas this data can be statistically summarised, examined as a qualitative or quantitative value, may be statically random, and related to elements that are not recorded (Clarke 1977b:10). Within the spatial archaeology framework Clarke (1977b:11) proposed three arbitrary levels of resolution in which interactions occurs: micro, semi-micro and macro scales. The micro scale consists of personal and social space defined by the individual and cultural factors dominated by economic systems, for example, a house. The semi-micro scale is influenced by social and cultural factors, for example, a village; while the macro scale captures the interaction between sites defined by geographic and economic factors (Clarke 1977b:11-13). These scales have been used to examine space in a range of contexts (see, for example, Fleisher and Wynne-Jones 2012; Kantner 2008; Smith 2011). What is absent from this early work is a consideration of what is absent or hidden in the subsurface and how this omission may affect our interpretation of space. This thesis seeks to consider the absent in considering how subsurface hidden material may augment current discourse surround Early Modern Cambodian research.

Since Clarke's (1977b) original essay, and due to his untimely death, the development of spatial archaeology has become more focused on GIS applications and the investigation of sites in an artificial environment. Space and archaeology are linked to time, mobility, stories, daily practice, and in absence and presence (Gillings et al. 2020:2-3). Gillings et al. (2020:1) further Clarke's work by stating that 'Being human embodies space and spatial relationships within a material world and just as this applied to people living in the past, so it applies to those of us concerned with trying to understand those past lives through their remaining material residues.' Further, Gillings et al. (2020:7) wish to remove space from its passive background as scaffolding for people, ideas and culture, and explore the notion of landscape as a spatial metaphor. Removing landscape from being descriptive spatial dimensions between sites means that the focus shifts to spatial analysis as a mode of narrative through theory based on rigorous methodology (Gillings et al. 2020:8). In combining the two, it allows for archaeological theory to inform and transform raw data into meaningful conclusions about how people perceived and used the landscape around them.

The integration of spatial frameworks with geophysical methods allows for the examination of archaeological landscapes at different scales, placing the subsurface evidence in a wider cultural landscape and drawing correlations between space, time and cultural change. With the availability of GIS systems, the concept of space has been expanded, with a capacity to investigate the macro level sites in more rigorous analytical ways. The examples provided here demonstrate the importance of understanding how archaeological sites fit within a broader network or nodes, but also needing to recognise that there are inherent biases in the datasets by not acknowledging what is missing. Contrasting this, the missing element may be the meaning behind the landscape, and a more theoretical approach to how people are represented by how they shaped their surroundings needs to be undertaken. To this end, the integration of spatial archaeology and landscape theory may provide an avenue for broadening our understanding of archaeological landscapes.

The most comprehensive examination of geophysical data used for the examination of social landscapes is by Nelson (2014), whose work integrates magnetometry survey and spatial analysis to understand the physical remains, while also considering empty space as intimate landscapes. Through a landscape scale magnetometry survey, clusters of Mississippi period homes were identified in the south eastern United States dating from AD1000-1540 (Figure 3.18). These were grouped into four ‘neighbourhoods’ which were separated by magnetically empty spaces (Figure 3.19) (Nelson 2014:50). These anomalies were determined to be homes because of their magnetic signature, size and orientation based on previous archaeological work in the region. Through an examination of the interaction between the individual homes and between neighbourhoods, Nelson (2014:54) identified that the arrangement was conforming to common Mississippian domestic arrangements for that period. Using Clarke (1977b) framework, a variation between the micro, semi-micro and macro scales were identified. While Nelson (2014) does not explicitly use this framework for discussion, the variation in scale is clear, as is the spatial investigation undertaken.

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Figure 3.18: Magnetic features interpreted as housing with houses in configuration with central courtyard from neighbourhood two (left) and linear alignment of houses from neighbourhood three (right) (from Nelson 2014:52).

A significant finding from the spatial analysis was the value of empty space at a household and community level, with housing orientated around small household courtyards and neighbourhoods clustered around a central plaza (Nelson 2014:54). Importantly, Nelson (2014) discussed the mobility of individuals operating within this landscape and the performative characteristics of operating within public spaces. Nelson's (2014) research emphasises the need to understand the landscape outside the spatial parameters but also to consider the agents moving within them. What is unique to this research is the consideration of empty space and how it adds to the overall narrative of the landscape. The conclusions drawn by Nelson (2014) are not commonly considered in geophysical interpretations, with this research being a unique example of what can be achieved through more nuanced theoretical thinking. However, Nelson's (2014) work does not explicitly consider the implications of landscape theory as a theoretical framework for these interpretations. Correlations are drawn between the performative nature of moving within a landscape and the complexity imbedded in the action of being seen within the landscape, but these conclusions lack supporting evidence. The issue of integration of archaeological theory and geophysical results remains an issue and raises the question of whether geophysical techniques provide enough information to make broader assertions about social, cultural and/or political connection to the landscape.

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Figure 3.19: Four neighbourhoods identified back on clustering of magnetic anomalies (from Nelson 2014:52).

## 3.6 Conclusion

This chapter has examined in detail the three methods being employed in this thesis: remote sensing, magnetometry and ground penetrating radar, and it has established that they are suitable tools for the investigation of the Early Modern sites. Remote sensing investigations have been widely applied in Cambodian historic investigations, particularly for the examination of urbanism and its relationship to economic and political structures. Geophysics has not been widely used in Cambodia to date, but it appears to compliment and clarify results gained through remote sensing. Through an examination of geophysical methods being utilised in Cambodia and internationally, a trend of target site prospection methodology was identified. Reconsidering the target approach of previous geophysical research, this research has incorporated a broad landscape-scale investigation of buried, semi-buried and mounded landscape features at the three Early Modern sites. This thesis is the first multi-method landscape-scale geophysical investigation to be undertaken in Cambodia. This review justifies the methods being considered here and guides the acquisition parameters presented in Chapter 4. The application of archaeological theory was examined to aid in furthering the geophysical data collected for this research—beyond prospection—to answer the main research question proposed.

# CHAPTER 4 - METHODS

## 4.1 Introduction

It was established in Chapter 2 that an investigation of subsurface Early Modern materials in Cambodia was required. Due to the perishable nature of building materials, this approach uses a suite of methods which can investigate the broader landscape, conduct targeted subsurface examination, and integrate them within a digital environment. Through a review of geophysical techniques in Chapter 3, it was established that the application of remote sensing and geophysical techniques would best suit the nature of the landscapes under investigation. This approach begins with a broad landscape examination employing remote sensing techniques, followed by landscape scale magnetometer survey and ground verification by ground-penetrating radar (GPR). These methods are then integrated to reconstruct the Early Modern landscape within geographical information systems (GIS). Areas of interest for investigation were identified through consultation with project directors and through examination of excavation results (Polkinghorne et al. 2018b; Polkinghorne et al. 2015; Polkinghorne et al. 2016).

Data collection was conducted over three seasons from 2018-2019 (Table 4.1 ). December to February were chosen to take advantage of the dry season, for easy site access. These periods are at the end of the rice production seasons for each area, ensuring the rice fields would be dry and accessible.

Table 4.1: Data collection schedule

| Season | Date | Method | Location | Area Survey (hectares) | |
|---|---|---|---|---|---|
| 1 | February 2018 | Magnetometry | Brick Factory North | Mag | 2.04 |
| 2 | December- February 2018-19 | Magnetometry and Ground Penetrating Radar | Brick Factory North, Wat Tralaeng Kaeng South, Wat Chedei Themei South | Mag | 10.45 |
| | | | | GPR | 0.5 |
| 3 | May 2019 | Ground Penetrating Radar | Toul Basan, Prasat Preah Theat Baray | GPR | 0.42 |
| Total | | | | Mag | 12.49 |
| | | | | GPR | 0.92 |

## 4.2 Positioning Controls

All positions were projected to WGS1984 UTM Zone 48N. In field positioning was recorded using several methods: total station, static global positioning system (GPS) and Real Time Kinematic Global Positioning System (RTK-GPS). The Leica TPS1200+ total station was employed for field season one in tandem with the CHC x9+ Static GPS. The static GPS was employed to correct ground points by placing the instrument over base points, collecting satellite data for a minimum of one hour. Positions were post-processed using Australian Positioning (AUSPOS) services to centimetre accuracy. Positions taken with the Leica total stations were then corrected based on these post-processed points. For season two and three, a Leica TS09 RTK-GPS was used in a base and rover configuration. The base operated as a static GPS positioned over base points, collecting satellite data for a minimum of one hour per point. These base positions were then post-processed through AUSPOS and used for total station setup throughout. Positions taken with the Rover have sub-centimetre accuracy to the base position. Collected points were then corrected in relation to corrected base points. All positions were projected in ArcGIS 10.6.1.

## 4.3 Remote Sensing

Lidar was conducted by Dr Damien Evans in 2015 using the parameters established in Evans et al. (2013), with feature identification parameters as established by Pottier (1999) and Evans et al. (2007) applied. This data is partially published in Evans (2016).

### 4.3.1 Rice Field Analysis

The one metre hill-shade digital elevation models from the lidar survey used to map the rice fields inside and outside the citadel at Longvek were analysed using the methodology of Hawken (2011a:140). The area was bounded by a small creek to the south, the Tonle Sap River to the east, modern industrial area to the west and the northern wall of the citadel. Analysis was conducted in ArcGIS 10.6.1. Rice bund positioning was taken from the lidar, and high-resolution aerial photos by manual visual inspection and drawing polylines along each bund. These polylines were then converted into a feature class for analysis. A bearing was calculated for each line. The bearing were then sorted by class using azimuth ranges from Hawken (2011a:140) (Figure 4.1). Analysis was conducted by comparing the rice field distribution of Longvek to the parameters from Hawken (2013:351) established for Angkor (Figure 4.2).

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Figure 4.1: Eight part geometric classification for rice bund analysis from Hawken (2011b:140).

To understand the positioning of the features in relation to each other, a classification by azimuth following Hawken (2011a:140) was conducted. For a standardised comparison with the results between all remote sensing and geophysical results, the classification criteria remain unchanged. The features mapped by CALI were converted to polylines, and bearings were established and classified by azimuth. This analysis incorporated features for the entire survey area which includes Longvek and Oudong and excludes natural features such as rivers, floodplains and waterways.

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Figure 4.2: Rice field system types from Hawken (2013:351). 1. orthogonal square, 2. orthogonal rectilinear, 3. coaxial system, 4. fan, 5. radial, 6. Khmer Rouge.

## 4.4 Magnetometry

Subsurface remains were identified and mapped using landscape-scale magnetometry. This method is applied due to its relatively quick acquisition time and ability to encompass a larger area than other methods (Aspinall et al. 2008). A Bartington 601 Fluxgate Gradiometer was employed. Two instruments were used for data collection. For session one, a single sensor instrument was employed with 1 metre line spacing. For session two, a dual sensor instrument was used at 0.5 metre line spacing.

Maintaining magnetic hygiene was paramount for this survey, due to the sensitivity of the instrument and the small level of variation being recorded in the subsurface. A magnetically hygienic operator was required to be completely devoid of all metal on person and clothing. Regular checks were made to ensure hygiene was maintained. The magnetometer was turned on and set to scan to "warm up" the instrument in a similar working environment to the survey, before calibration. Calibration was conducted multiple times a day over a magnetically sterile 2 metre by 2 metre area with an absolute value of less than 2nT. Calibration was conducted at the beginning of the day and after any long breaks. Once calibrated, parameters were established. These were: zig-zag traverse, 0.5 metre line spacing, eight samples per metre, range 100nT, threshold 100nT and reject 50Hz. Pace, grid size and start orientation differed depending on the area being surveyed and surveyor. The height of the instrument from the base of the sensor to the ground was 15 centimetres. Depending on the height of the operator, height was maintained by adjusting the sensor height once the harness was attached.

Acquisition grid size varied dependent on location and surface obstacles. Ten by ten or twenty by twenty-metre grids were employed throughout. Surface material such as trees, shrubs and rice bunds were avoided where possible when establishing grids. When obstacles were within the grid, the line was stopped, resulting in no data collected in that section. Where rice bunds could not be avoided, the surveyor walked over them, attempting to maintain a steady pace. Positions for each corner of each grid were taken with either the RTK GPS or the total station and stitched together after post-processing.

Data were processed using the freeware software Snuffler. Once imported and gridded, where applicable, the data were post-processed using methods outlined in Table 4.2 below. The data were first de-staggered to eliminate any variation in walking speed between traverses. Following this, the data were de-striped to average out any variation between the sensors caused during calibration and de-spiked to remove any outlying points which may have been the result of modern contaminates such as metal. Finally, the data were interpolated to account for the variation between the x-axis, which had 0.5 metre spacing, and the y-axis, which had 0.125 metre spacing. To ensure consistency, the plotting of grids was done by calculating standard deviation from the mean of each area's dataset. One, two and three standard deviations were applied to clip the projected data range for analysis (Table 4.2). Maps at all three standard deviation variations were projected in ArcGIS 10.6.1 using recorded positions.

Table 4.2: Methods applied in Snuffler for data processing.

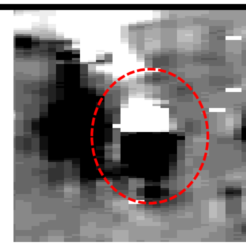
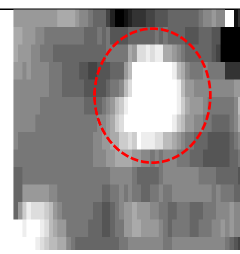
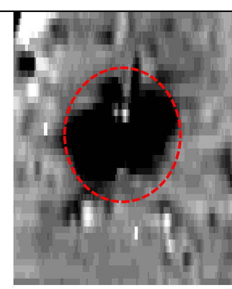
| **Process** | **Purpose** |
|---|---|
| De-stagger | Remove data collection error resulting from pace changes during profile acquisition. |
| De-stripe | Remove error resulting from an imbalance between sensors as a result of calibration error |
| De-Spike | Remove high spikes of data |
| Interpolate | Fill in gaps in the data resulting from the collection parameters, where eight samples per metre were taken in vertical profile but only three samples per metre in the vertical profile |

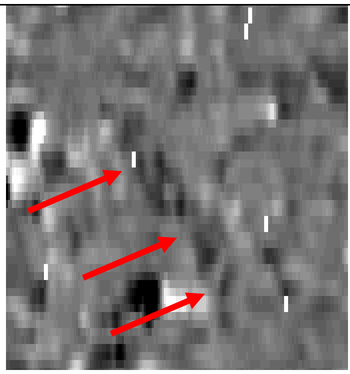
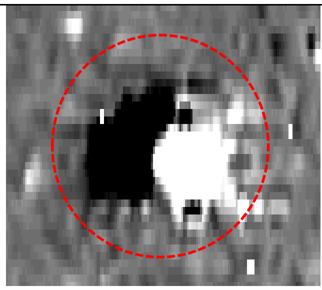
Table 4.3: Standard deviation by site.

| **Area** | **Average (nT)** | **Standard Deviation (nT)** | **1σ +ve (nT)** | **1σ –ve (nT)** | **2σ +ve (nT)** | **2σ –ve (nT)** | **3σ +ve (nT)** | **3σ –ve (nT)** |
|---|---|---|---|---|---|---|---|---|
| Brick Factory | 0.584 | 5.18 | 5.8 | -4.6 | 10.9 | -9.8 | 15.9 | -14.7 |
| WTK | 0.841 | 6.63 | 7.4 | -5.8 | 14.1 | -12.8 | 20.5 | -18.8 |
| Oudong | 0.364 | 4.78 | 5.14 | -4.4 | 9.9 | -9 | 14.7 | -13.9 |

Analysis was then conducted using a feature selection scheme based on the nature of magnetic response (Table 4.4). Features were eliminated based on visible surface features. These include surface metal, rice bunds (excluding a two-metre buffer around each bund), modern paths and roads, and any surface material recorded in site photography. Features were then extracted based on the anomaly configuration, excavation reports and literature where available. As this is the first application of this kind of method in Cambodian contexts there are no opportunities for comparison to other sites.

Table 4.4: Magnetic anomaly feature identification for magnetometry

| **Feature Code** | **Description** | **Example** |
|---|---|---|
| 1 | Dipole |  |
| 2 | Positive response |  |
| 3 | Negative response |  |

| | | |
|---|---|---|
| 3 | Linear feature of same value response or bounding an area of same value response |  |
| 4 | Surface metal contamination |  |

## 4.5 Ground Penetrating Radar

A Mala X3M 500mHz antenna unit was applied at several locations across Longvek, Toul Basan and Prasat Preah Theat Baray. Survey was undertaken in either a grid configuration or transects, with acquisition parameters changing between the two, see Table 4.5. The design of the survey for ground verification was based on infield examination of the magnetometer results, identifying magnetic anomalies potentially correlating with areas of occupation. GPR grids were established with a buffer of several metres around each area under consideration. Each grid varied in size and orientation and the location was recorded using the RTK-GPS and photographed for post processing analysis. The instrument parameter settings, in Table 4.5, a were applied for this ground verification and anywhere additional grids were established. The GPR was used to investigate mounded terrace sites at Longvek and Srei Santhor and single transects were applied across the width and breadth of the site where possible. Single transects were used to collect this data, largely due to the inaccessible nature of the terraces. In some instances, the RTK-GPS was directly interfaced with the GPR unit to collect spatial points with the line data. In the absence of line positioning, RTK-GPS points were taken along the transects, with the spatial information included in the line data during processing. Photographs were also taken of the grids and transects for post-processing analysis to ensure surface contaminants were not affecting the data. To fully encompass the mound topography, transects were orientated on the north-south and east-west axes where ground surface allowed.

Table 4.5: Ground penetrating radar acquisition parameters.

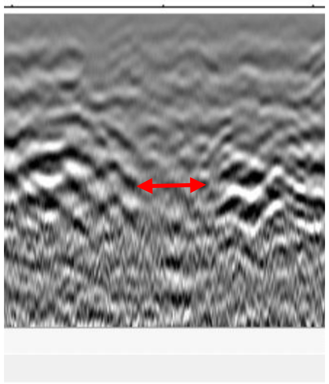
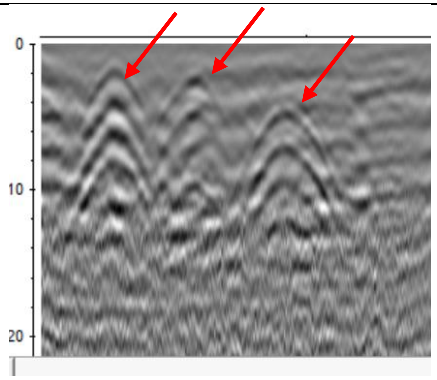
| | Survey | Antenna | Point interval | Time window | Sampling frequency | Signal search | Auto stacks | # of stacks | Collection method |
|---|---|---|---|---|---|---|---|---|---|
| a | Grid | 500 mHz shallow | 0.02m | 60 | 10,000 | Manual | Off | 2 | 0.5m spacing, zigzag clockwise orientation |
| b | Transect | 500mHz deep | 0.02m | 83 | 12,000 | Manual | Off | 2 | Single transects |

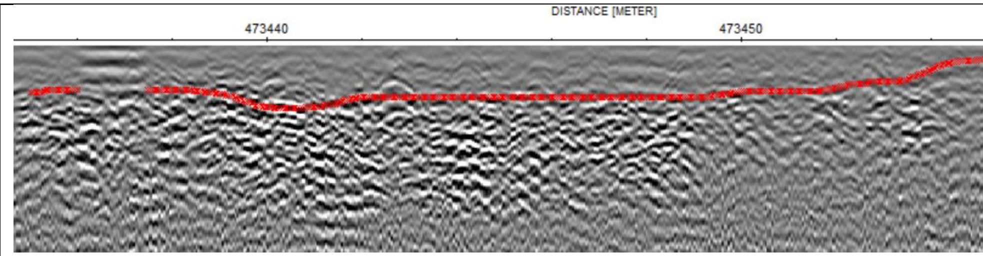
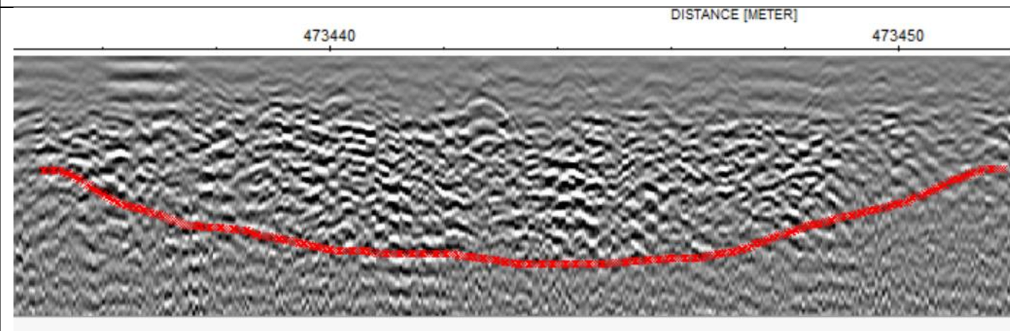
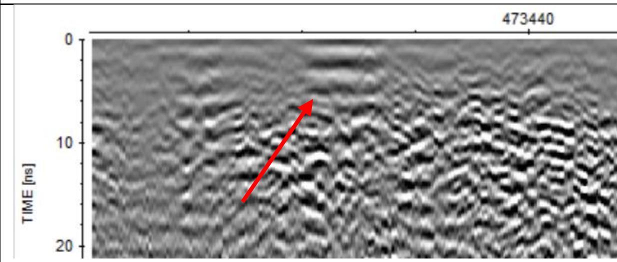
All GPR lines and grids underwent the same post-processing procedure. Each line was loaded and converted to a Reflex format using ReflexW with recorded start and stop points. Once loaded, each line was processed using the methods ordered in Table 4.6. Velocity fitting applied following Jocob and Urban (2016) was undertaken to establish depth in metres. Once the profiles were loaded and processed, topographic correction was applied when available. This step was almost exclusively applied to the lines of the transect data, as the grids were on flat ground. A visual inspection of the data was conducted to identify reoccurring features types for feature extraction and picked using a unique code outlined in Table 4.7. Each profile was examined with feature types given a specific pick code. These pick codes were then exported with their xyz co-ordinates and feature amplitude. These were then imported into ArcGIS and mapped. From these points, subsurface ground features could be identified and mapped.

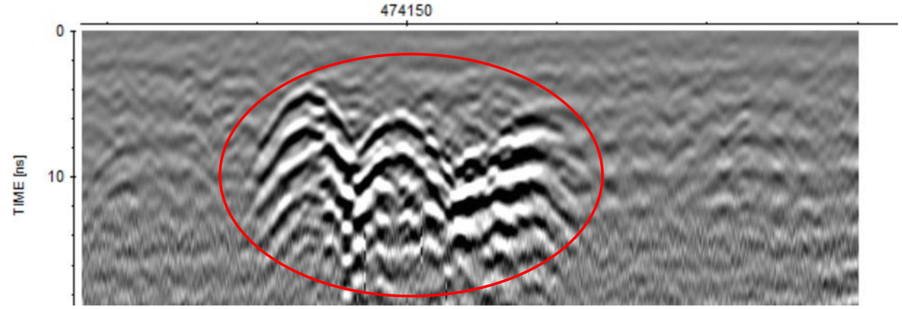
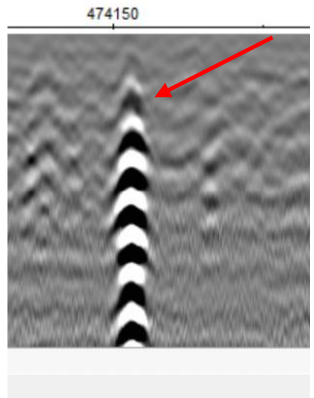
Table 4.6: Methods applied in RelexW for data processing (from Conyers 2013:134-135).

| **Step** | **Process** | **Purpose** |
|---|---|---|
| 1 | Move start time | Remove data above the actual start time of the instruments. |
| 2 | Remove horizontal banding (de-wow) | Remove horizontal banding or “ringing’ caused by system noises, external radio frequencies and/or other low frequency noise. |
| 3 | Gain-energy decay | Recover lower amplitude data resulting from the decrease in energy propagation lower in the profile |
| 4 | Bandpass Butterworth | Remove anomalously high and low frequency noise acquired during data acquisition. |
| 5 | Background removal | Remove horizonal banding reflections which are the result of system noises. |
| 6 | Time cut | Cut profile at depth where energy waves no longer penetrate |
| 7 | Velocity fitting | Establish depth from surface |
| 8 | Topographic correction | Correct the profile for change in topography. |

Table 4.7: Radar reflection feature identification for GPR

| Pick Code | Description | Example |
|---|---|---|
| 1 | Small strata break (less than 0.2m) | As below but smaller |
| 2 | Medium strata break (0.2 to 1m) | As below but smaller |
| 3 | Large strata break (more than 1m) |  |
| 4 | hyperbola (amplitude 1.5 and above) |  |
| 5 | hyperbola (amplitude 1.4 and below) | As above but weaker |

| | | |
|---|---|---|
| 6 | Surface #1 transition from homogenous strata with little disturbance to area of multiple discrete high-amplitude features |  |
| 7 | Surface #2 transition from as above to lower level undisturbed strata. |  |
| 8 | Surface material creating horizontal ringing |  |

| | | |
|---|---|---|
| 9 | Multiple high-amplitude hyperbola and high-amplitude features suggesting anthropogenic material |  |
| 10 | Hyperbola with extensive vertical ringing |  |

## 4.6 Conclusion: Feature Identification

Once the three datasets were integrated in ArcGIS 6.2.1, feature identification was conducted using a visual examination of feature shape, size and distribution. The magnetic response for Early Modern features are very subtle, 1-2nT variance, with the one standard deviation from the mean was determined to best represent Early Modern landscape. This is due to the very high value, 10-100nT value as represented in the three standard deviation maps, of modern contaminates which consist of largely metal objects having a very high magnetic nanoTesla value, in most instances these features exceeded the instruments 100nT cut off. For the purpose of this study, features identified in one and two standard deviation maps were examined, along with high nanoTesla value linear features found in the three standard deviation maps. These features were identified through visual inspection, and marked as a location point in ArcGIS. The collated points were examined in isolation to look for patterns, linear features, or features which could represent historic material. These points were drawn as linear features and then from these patterns, uniform polygon shapes were drawn in an attempt to replicate potential structures.

Once the GPR data was examined for the different feature types in Table 4.7, the spatial coordinates were exported from ReflexW and imported to ArcGIS. Patterns between feature types which occurred across multiple GPR lines were identified. These features were mapped as polygons. The magnetic, GPR and lidar features were then integrated. The feature identification process based on Pottier (1999) framework and further refined by Evans (2007), was applied here. Identified features were mapped in a GIS framework and integrated with lidar and excavation results. The lidar, magnetometry and GPR possible features are combined to generate a proposed landscape reconstruction of the area. From this map, interpretations can be made.

# CHAPTER 5 - RESULTS

## 5.1 Introduction

This chapter examines the results from the remote sensing and geophysical investigations at Srei Santhor, Longvek and Oudong. While the methods were presented by technique (see Chapter 4), the results will be presented by location, to allow for data integration. The three sites under consideration here are being investigated as significant Early Modern capitals. As will be demonstrated, the two sites at Srei Santhor are unique landscape features. Toul Basan and Prasat Preah Theat Brary were both investigated using ground-penetrating radar (GPR) and show varying degrees of anthropogenic manipulation. The survey of Longvek incorporates lidar, magnetometry and GPR to look at the landscape at different resolutions to identify larger landscape features and narrow the investigation to three specific sites to investigate potential landscape features related to a proposed palace site, potential occupation sites related to Theravāda complex Wat Tralaeng Kaeng and, finally, an examination of two Theravāda terraces. Finally, a second proposed palace site at Oudong south of Wat Chedei Thmei is examined using magnetometry, to identify either the palace or associated settlement in the area. Very high-resolution images can be found at: https://osf.io/4jwtx/?view_only=f33775d08d574eacb35bc33d4de04481

## 5.2 Srei Santhor

The area of Srei Santhor is significant in the narrative of the Chronicles, as Toul Basan was believed to have been the first capital after the decline of Angkor. As discussed in Section 2.3.1, the location of Toul Basan has been contentious. The mound examined here was proposed by Kitagawa (2000) as the Palace site of King Cau Baññā Yāt. In addition to this site, the eleventh century Brahmanical site (converted in the thirteenth century to a Theravāda Buddhist site) of Prasat Preah Theat Baray was also examined as it has been related to the Early Modern usurper Kân, and chronologically contemporary to Toul Basan. The aerial photograph in Figure 5.1 shows how these two sites are related to the modern Baray Village and Angkor period water management *baray* and *tumnup*. Ground-penetrating radar was applied to both sites. At Toul Basan the objective was to investigate evidence of an Early Modern palace and at Prasat Preah Theat Baray to identify evidence of Brahmic structural elements located in the subsurface. The unprocessed data from this research is available at Duke (2020c).

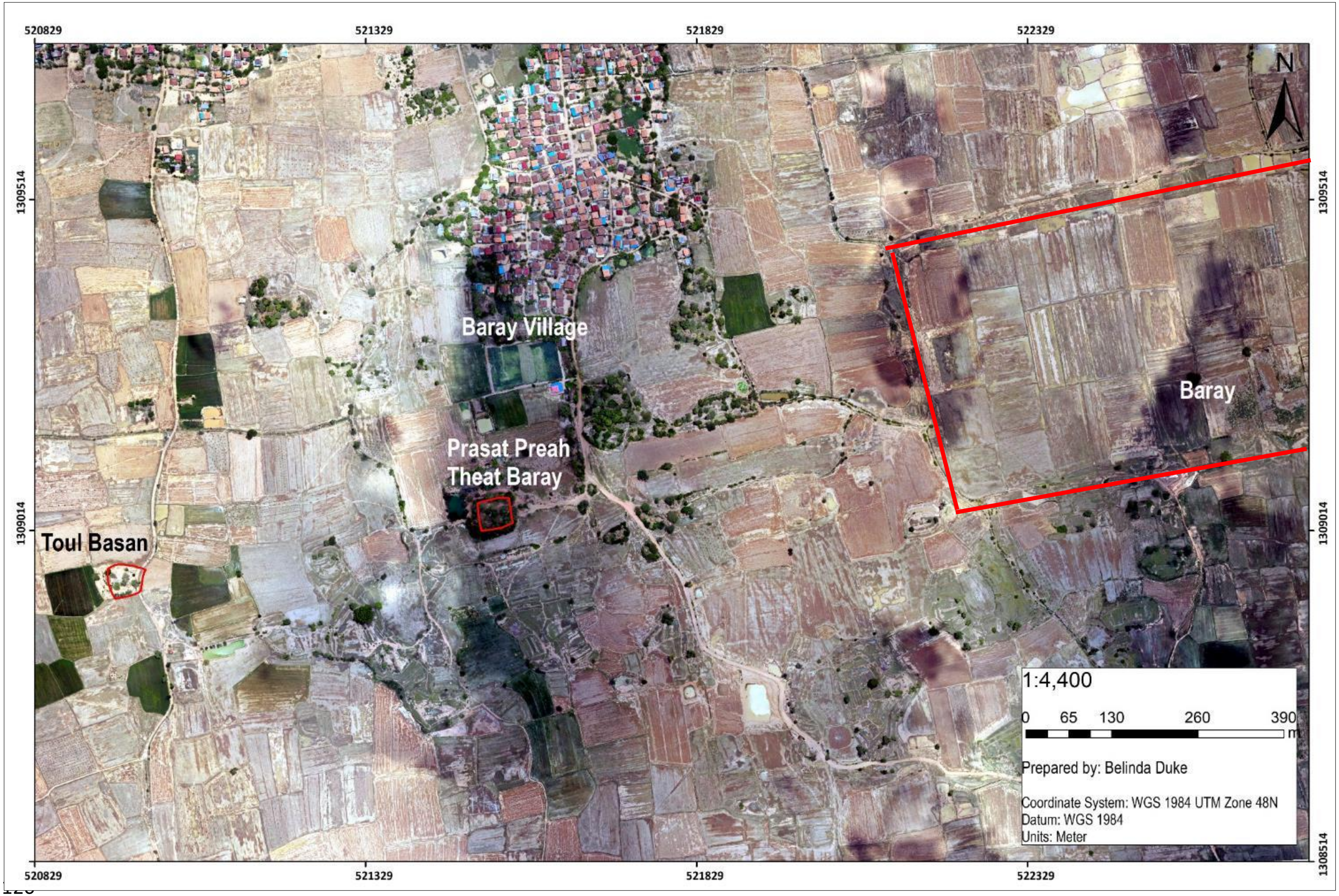



Figure 5.1:Survey areas Toul Basan and Prasat Preah Threat Baray in Srei Santhor (Base map courtesy Professor Tsuyoshi Haraguchi from Osaka City University).

### 5.2.1 Toul Basan

Toul Basan is a small mound raised from the rice fields which surround it. It is thought to be anthropogenic, based on ethnographic investigations by Kitagawa (2000). A GPR grid at 0.5m line spacing and several transects were conducted to investigate the internal structure of the mound (Figure 5.4). Ground surface coverage was largely open dirt, with trees on the edges of the site and the mound appears to have been manipulated recently (Figure 5.5). In the centre of the site, a large pit as present, but it is not clear what caused this disturbance. A two-metre square trench was excavated at the same time as the survey, with the placement of the grid directly west. Figure 5.2 shows excavation trench SST1903 at Toul Basan. The presence of eleventh to twelfth century ceramics suggest it was used during the Angkor period. The stratigraphic sequence was well defined, with subtle boundaries between sediment changes as seen in Figure 5.3. Four transects were also conducted across the site. GPR and excavation were the only investigative methods employed at this location. Surface debris largely consisted of modern garbage, such as tin cans, scrap metal and modern roof tiles.

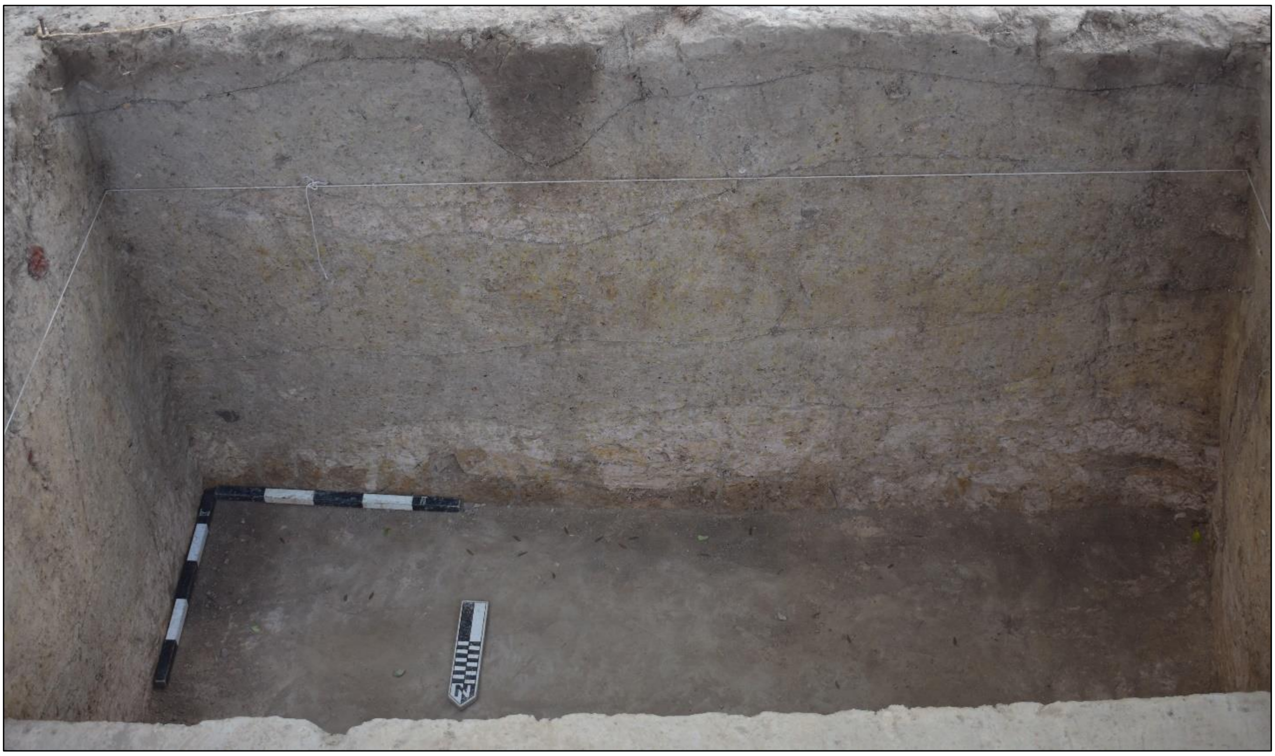


Figure 5.2: Excavation trench 1903, southern section at Toul Basan. (photo with permission of M. Polkinghorne).

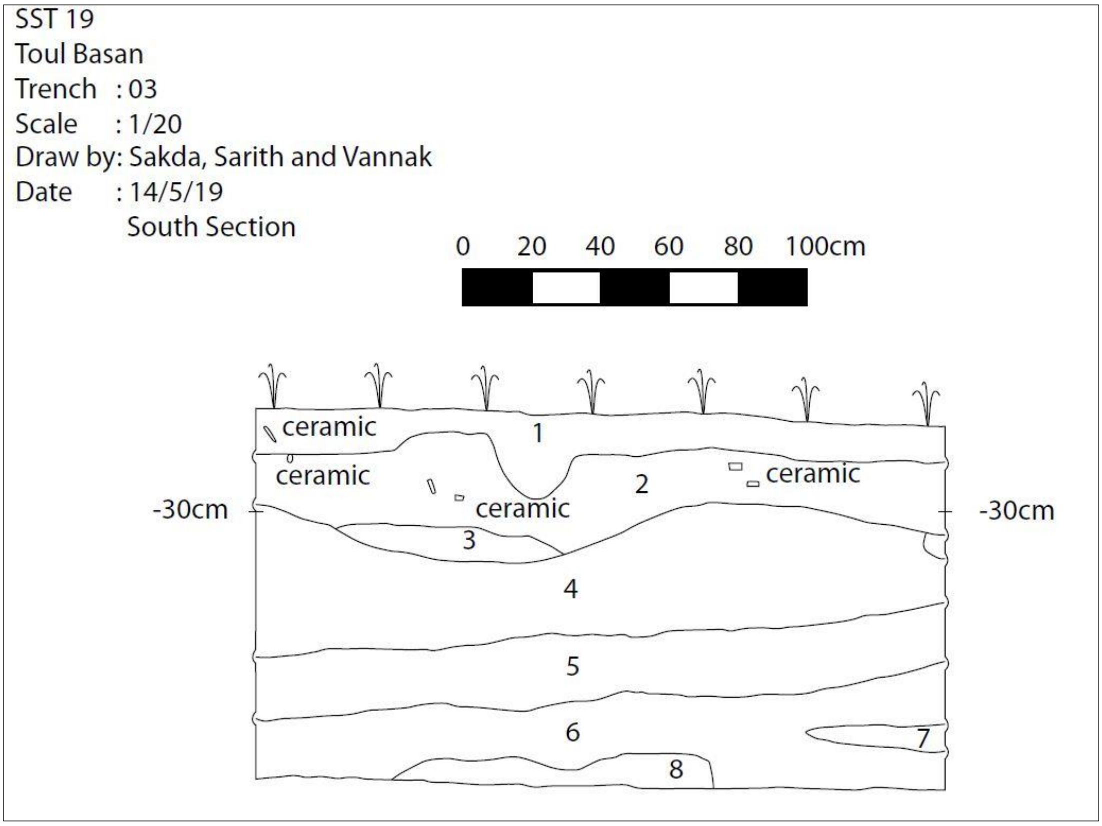



Figure 5.3: Toul Basan, trench 1903, east section. Layer 1 : Sandy clay loam, soft (7.5YR7/1 light grey); Layer 2: Sandy clay loam, mixed with small pebbles, slightly compacted (7.5YR7/1 light grey); layer 3: Sandy clay loam, compact soil mixed with laterite (10YR7/2 light grey); Layer 4: Sandy clay loam, compact soil mixed with laterite and yellow clay (7.5YR6/3 light brown); Layer 5: Clay loam with sandy, compact soil with laterite and yellow clay and black soil (10YR6/4 light yellowish brown); Layer 6: Grey soil ,clay loam with some sand, compact soil with laterite and yellow soil and charcoal (10YR6/1 grey); Layer 7: Very hard compact soil and a little of sandy loam and clay loam with grey soil (5YR6/2 pinkish grey); Layer 8 : Sandy (Soil Munsell colours measured when dry)

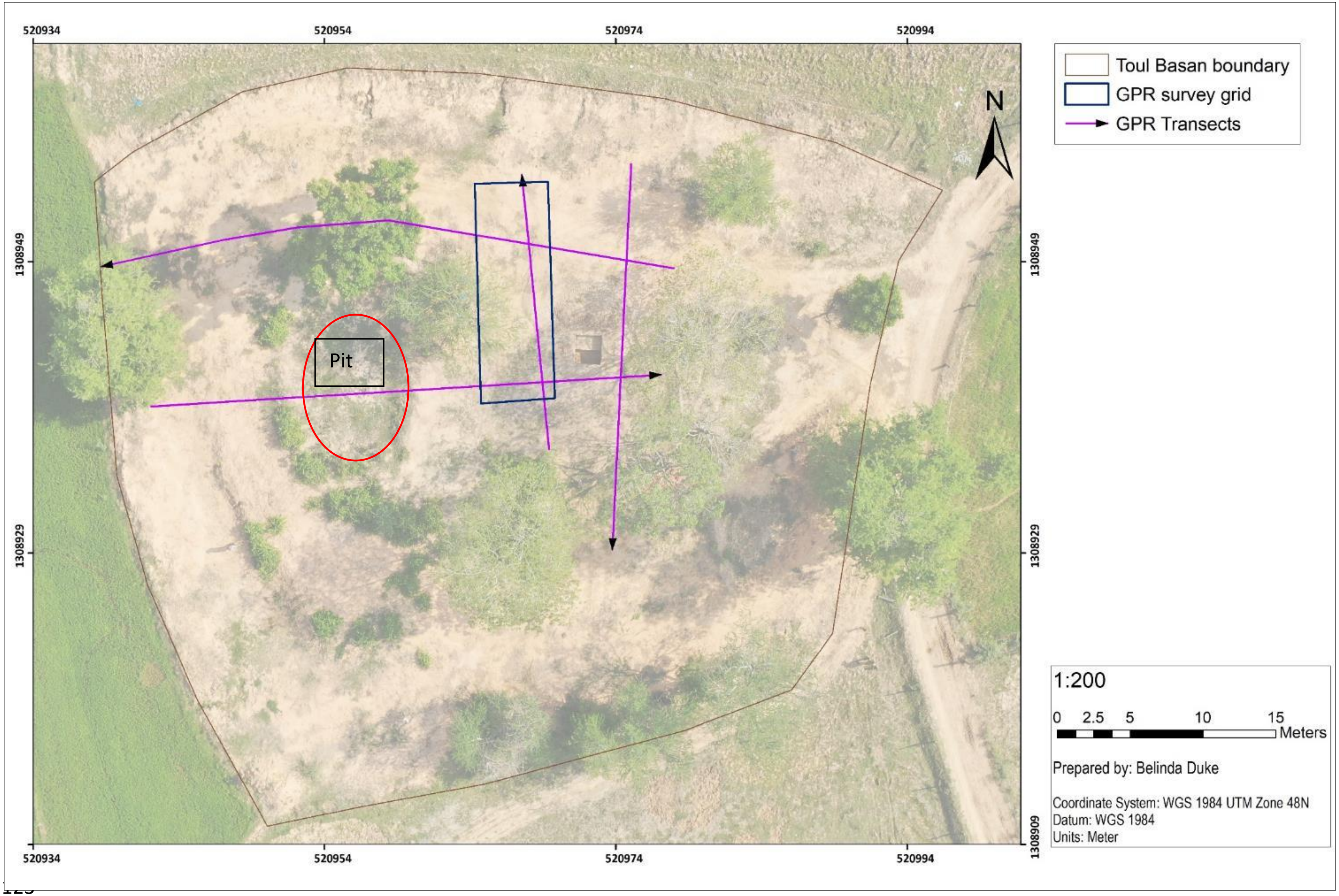



Figure 5.4: GPR transects and survey grid at Toul Basan.

Figure 5.5: Toul Basan raised mound from the surrounding rice fields. Looking northwest.

#### *5.2.1.1 Ground-penetrating radar*

**GPR Grid 103** had a total area of 5x15 metres and was collected with a half-metre line spacing with meandering collection acquisition, with the 0,0 at the northeast corner and the survey orientated south. The survey grid was placed approximately one metre west of the excavation trench. The proximity of the survey grid to the excavation trench is evident in the GPR profile, in the form of a faint section break in Figure 5.7. The conical shape of the propagated radar energy resulted in the nearby trench being present in the data. Also present in Figure 5.7 is a high-amplitude radar reflection feature which was observed in several profiles, but there is no obvious spatial association to suggest a relationship. Similarly, stratigraphic breaks were identified across many of the profiles, but their lack of continuity across multiple GPR profiles did not suggest connection.

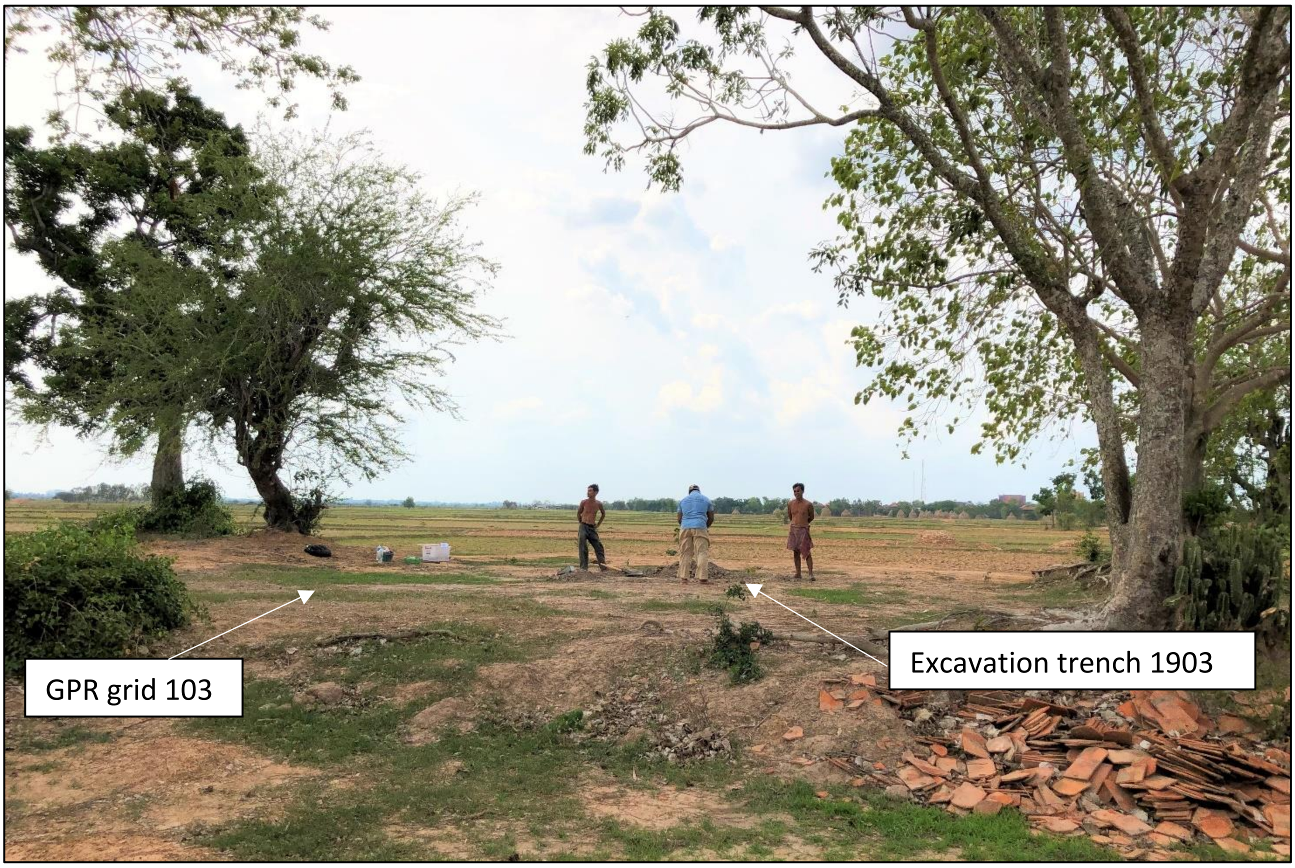



Figure 5.6: Toul Basan, GPR Grid 103 left, excavation trench right, looking to the north.

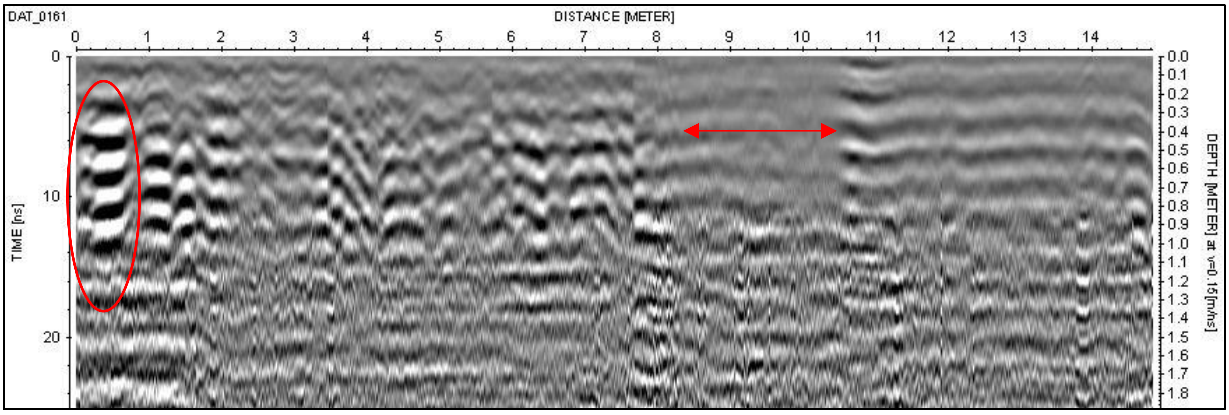



Figure 5.7: GPR line 161 at 0m of Grid 103 at Toul Basan. This line was taken adjacent to the excavation square. The reflection of the square resulting in a line break reflection highlighted by red arrow. Also present is possible buried material causing high-amplitude radar responses (circled).

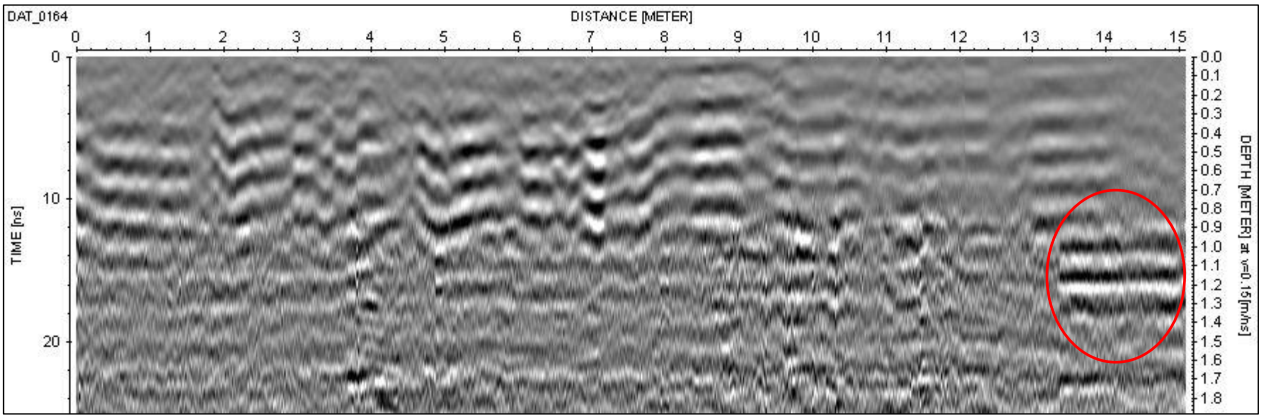



Figure 5.8: GPR line 164 at 2m of Grid 103 at Toul Basan. GPR feature one depth below surface, highlighted in red are present. However, these are likely the result of instrument reflection error.

The results of the four GPR transects reveal an inconsistency of features that is similar to those found in Grid 103. The steep sides of the mound and surrounding flooded rice fields made it difficult to conduct a full transect across the entire mound. There was little evidence of archaeological material being present on the surface, although ceramics have been found at other mounds in the area. Figure 5.9 is the longest transect running east to west beginning at the eastern edge of the mound. The eastern edge contains homogeneous sediment with multiple section breaks less than one metre. The area highlighted in red in Figure 5.9 contains a wider variety of high-amplitude radar reflections, all of which look like the result of subsurface material such as modern contamination from metal. Nothing in this profile suggests *in situ* archaeological material.

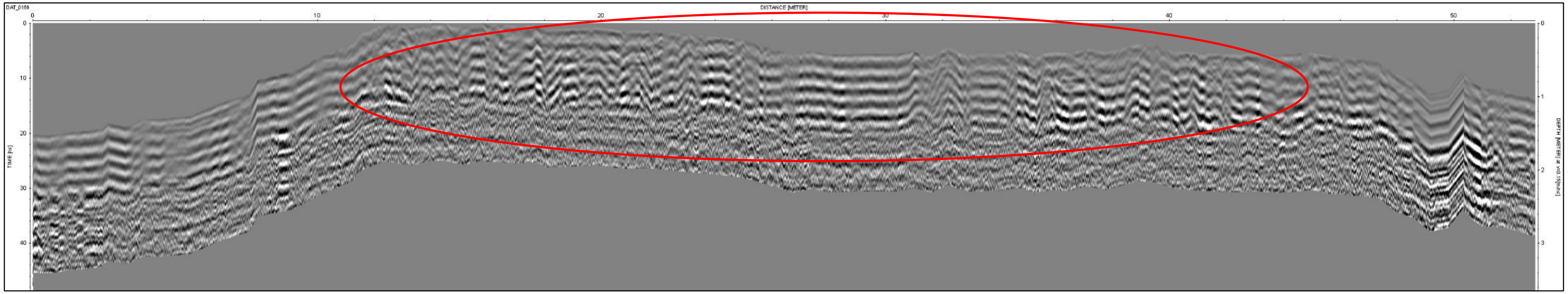



Figure 5.9: Toul Basan transect one running east (left) to west (right) at Toul Basan. The area of archaeological material highlighted. The modern fill is more homogenous than the historic.

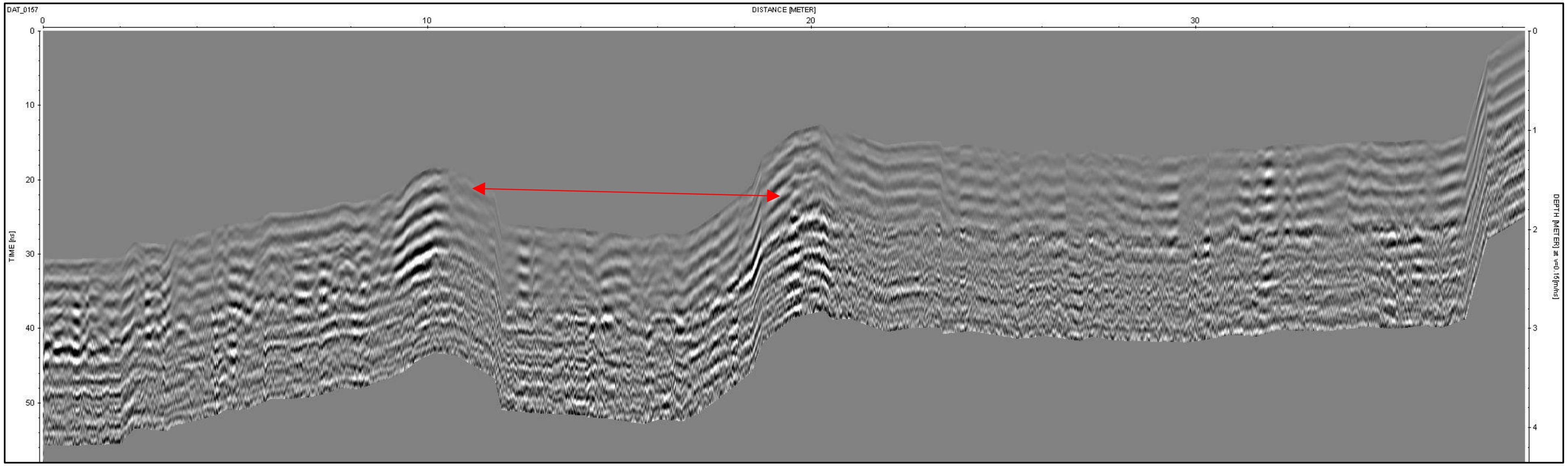



Figure 5.10: Toul Basan transect two running west (right) to east (left) at Toul Basan. This transect more homogenous than transect one, with surface bit highlighted.

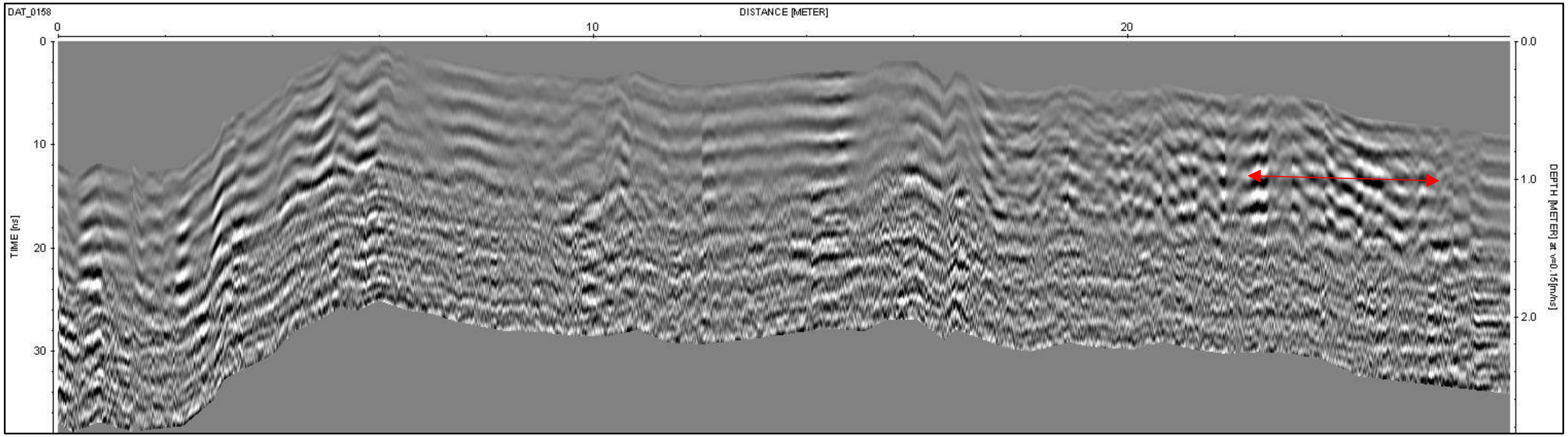



Figure 5.11: Toul Basan transect three running south (right) to north (left) at Toul Basan. Area largely homogenous except for area highlighted.

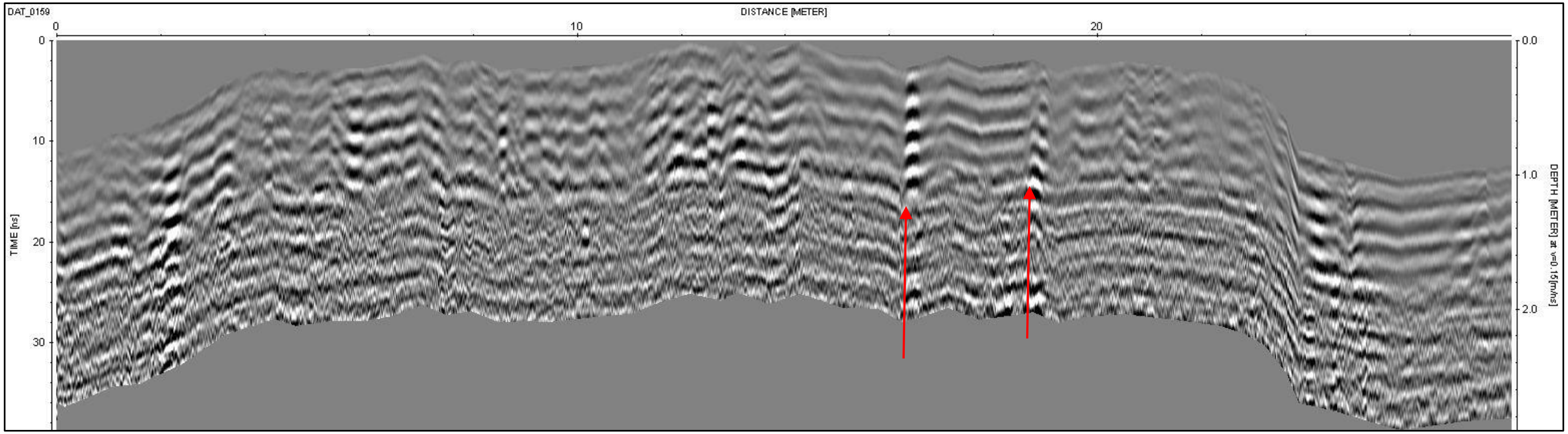



Figure 5.12: Toul Basan transect four running north to east at Toul Basan. Note areas of vertical ringing caused by an object in the near subsurface.

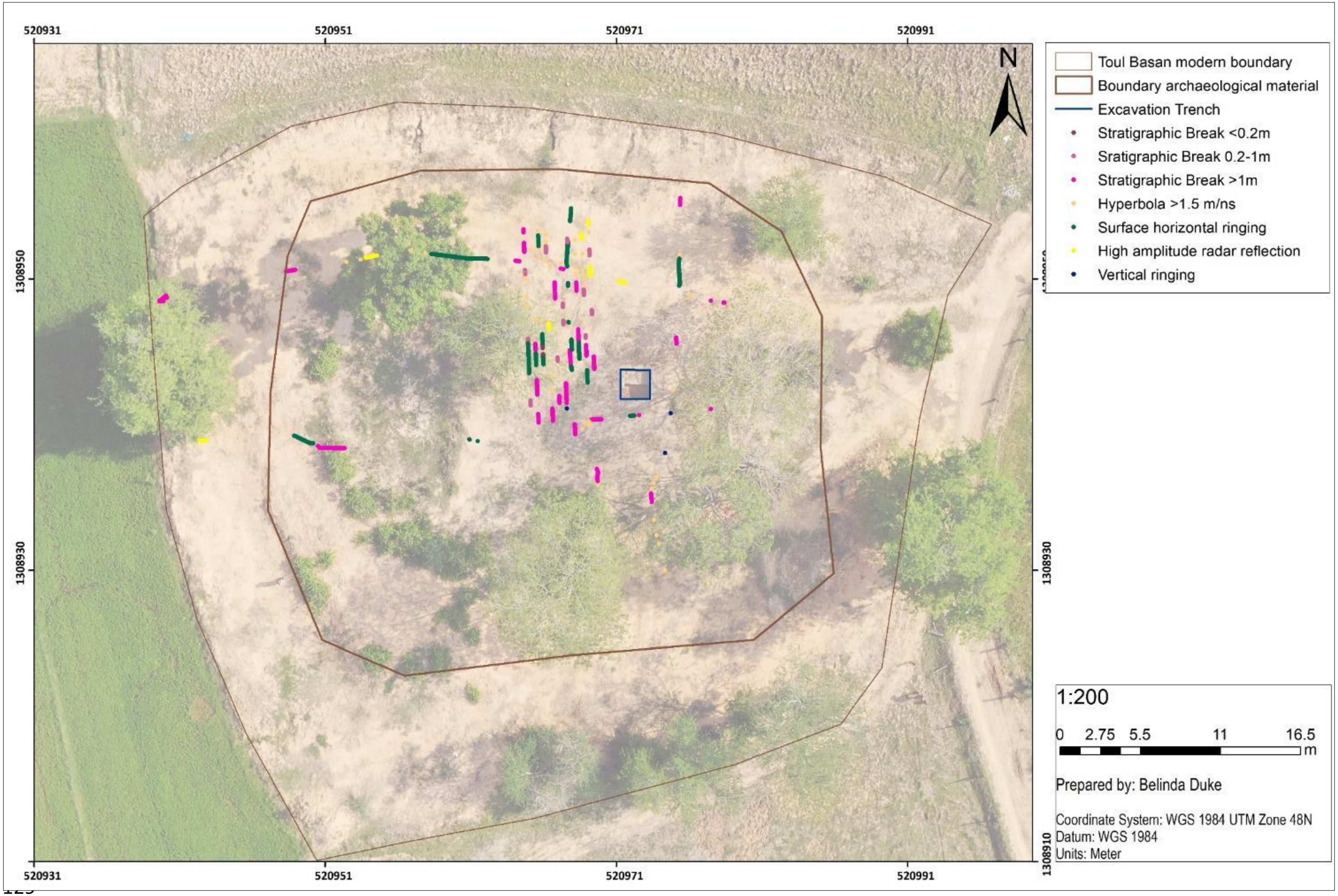



Figure 5.13: Toul Basan GPR survey with proposed area of archaeological material highlighted.

#### 5.2.1.2 Identified Features

There do not appear to be any geophysical features that are not related to modern or contemporary period surface or near-surface contamination. The features identified suggest the area has been heavily disturbed, including via the removal and addition of sediment. The irregular shape of the mound may suggest that sediment has been removed from the edges. The four transects show little stratigraphic variation across the mound. The most homogeneous radar responses were from the extremities and would suggest an expansion event may have occurred. An approximation of the area of archaeological material is shown in Figure 5.13. Comparing the geophysical data to the archaeological data reinforces the consistency of sediment deposition across the mound. The excavation did not find any evidence of structures being present at this site. The prevalence of stratigraphic breaks, along with the pit in the centre of the mound, may suggest the area has been disturbed, as there is no consistency across GPR profiles to suggest continuous features. The homogeneous nature of the sediment on the outer edges would suggest it was accumulated during a single period. There does not appear to be any archaeological activity represented in this GPR dataset.

### 5.2.2 Prasat Preah Theat Baray

Prasat Preah Theat Baray is a raised artificial mound with a rectangular complex of a raised terrace and prasat orientated east to west. The *prasat* (Figure 5.15), which currently houses the images of Buddha, is located at the western end, with a raised platform central to the mound (Figure 5.16). The platform is raised a metre above the mound and is surrounded by eight decorative door lintels which hold back the sediment within the platform. The mound has secondary deposited sandstone and laterite blocks and surface bricked areas.

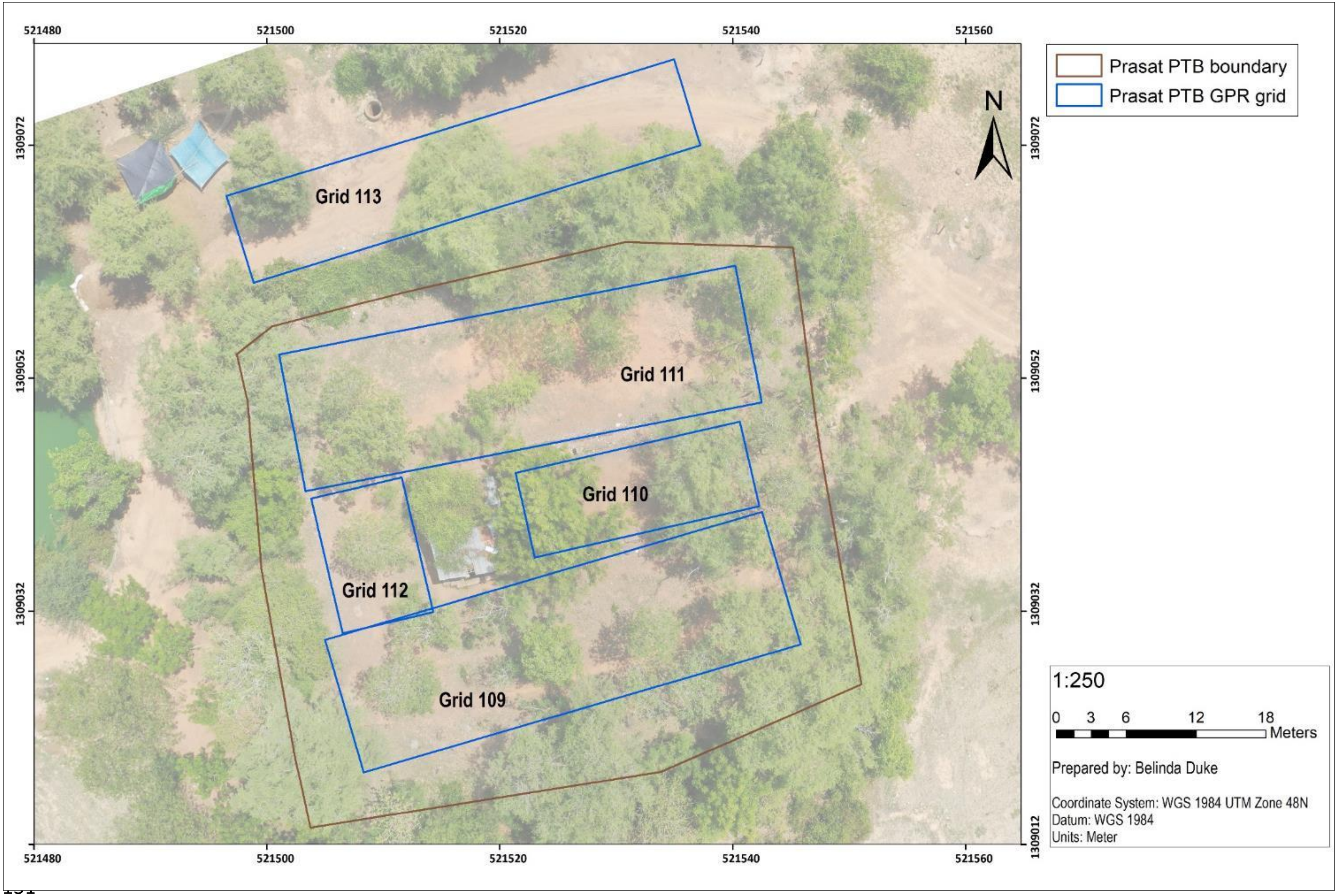



Figure 5.14: Prasat Preah Theat Baray (PTB) ground-penetrating radar survey areas.

### *5.2.2.1 Ground-penetrating Radar*

**GPR Grid 109** had a survey area of 12x38 metres, with a half-metre spacing with meandering acquisition, 0,0 in the northwest corner and survey direction orientated east. The grid is located on the southern side of the Prasat and platform, running the length of the mound. The surface and near surface debris are represented in the data in the form of high-amplitude hyperbolas. Figure 5.17 shows the high-amplitude responses which are prevalent across seven profiles. This response is likely caused by highly reflective disturbed material in the subsurface, such as modern metal contamination. Figure 5.18 shows a similar response, but in this instance the feature appears to be more uniform.

Figure 5.15: A Buddha sitting within the *prasat* at Prasat Preah Theat Baray. The structure consists of laterite blocks and sandstone detailing.

Figure 5.16: Steps leading up to the platform with the moon stone in the foreground and the *prasat* in background.

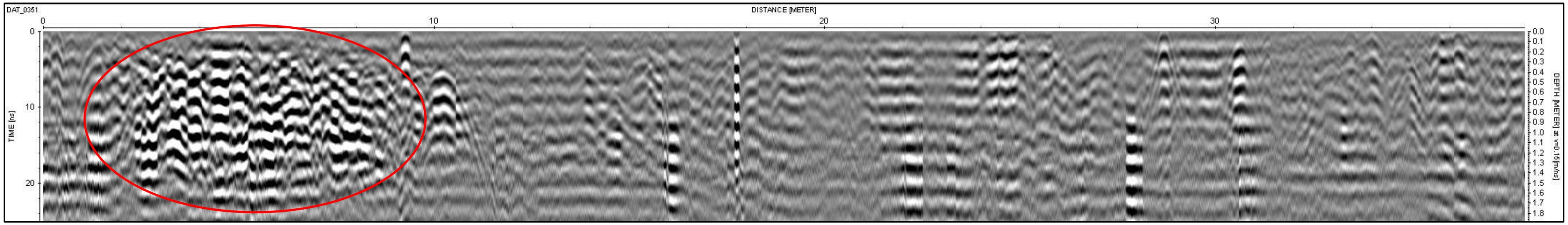



Figure 5.17: GPR line 351 at 3m of Grid 109 at Prasat Preah Theat Baray. Area of high-amplitude radar reflection highlighted which is present in profiles 350-356.

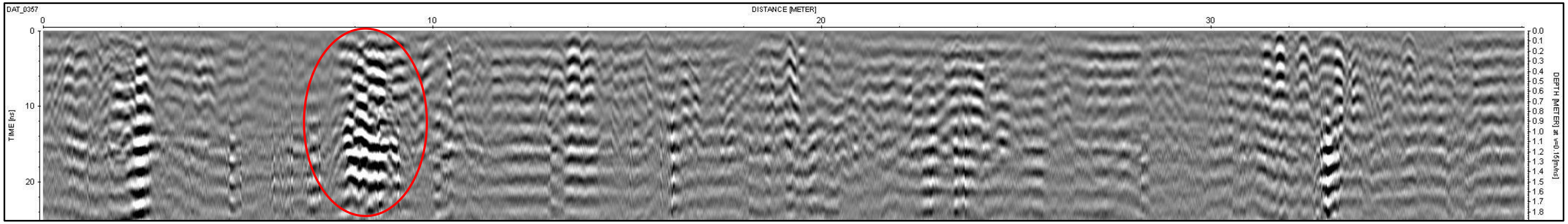



Figure 5.18: GPR line 357 at 6m of Grid 109 Prasat Preah Theat Baray. Area of high-amplitude radar reflection highlighted which appears to be undisturbed and *in situ.*

**GPR Grid 110** had a total area of 6.5x17 metres, with half-metre line spacing and meandering acquisition. Point 0,0 was located at the northwest corner and the survey direction was orientated east. This grid was placed on top of the raised platform, running its full length. The results show that high-amplitude features are present across the area, although attenuation here is the only area where propagation depth exceeds one metre. This is likely due to the nature of the platform being constructed on top of the mound. The features seen in Figure 5.17 are found consistently across the profiles, as are the section breaks in Figure 5.18.

Figure 5.19: GRP Grid 110 on top of the platform at Prasat Preah Theat Baray. Note the sandstone blocks used as reinforcement for the mound, to the left of image.

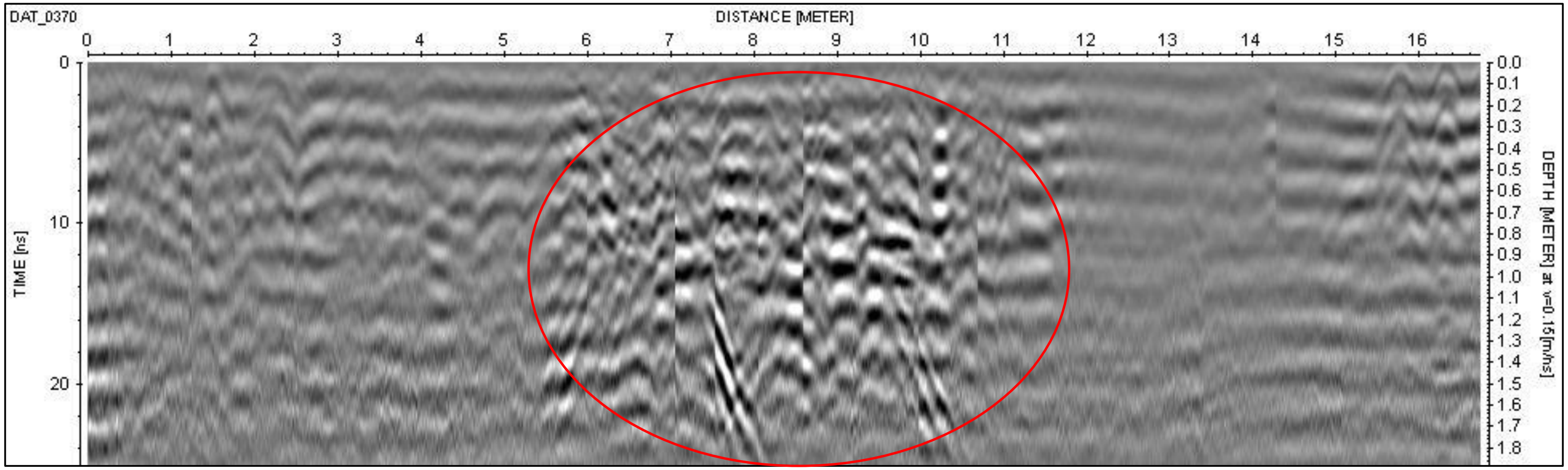



Figure 5.20: GPR line 370 a 0m of Grid 110 at Prasat Preah Theat Baray. Note disturbed area centre.

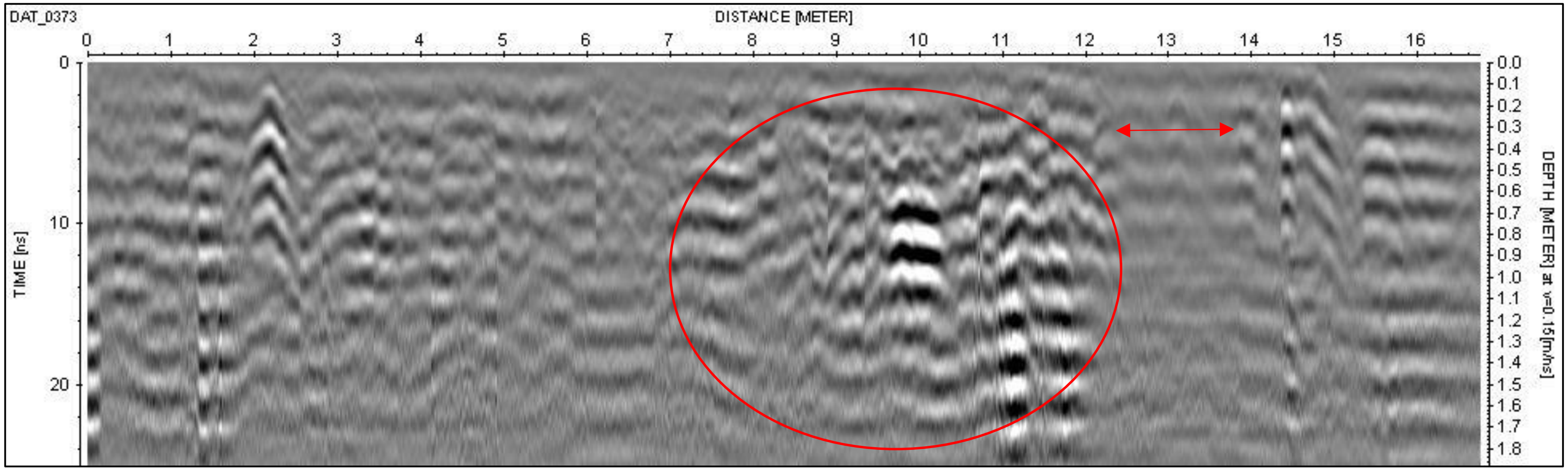



Figure 5.21: GPR line 373 at 1.5m of Grid 110 at Prasat Preah Theat Baray with area of archaeological features centre and section break right which is consistently found across all profiles.

**GPR Grid 111** was an area of 12x40 metres with a half-metre line spacing and meandering acquisition. Point 0,0 was at the northwest corner, and the survey direction was oriented east. This grid encompasses the northern side of the *prasat* and platform on top of the mound. The area was cleared of any surface rubbish before the survey began. Some laterite blocks were present in the grid and avoided where possible. Figure 5.23 profile shows the extent of near subsurface disturbance occurring in the form of point source hyperbola. None of these near surface features correlate with the location of surface materials. Figure 5.24 shows two areas of high-amplitude radar response, with one being more reflective than the other. This suggests material with a contrasting relative dielectric permeability in the subsurface, such as bricks, laterite or sandstone. The difference in the amplitude response between the two areas may be due to a change in material present.

Figure 5.22: Survey area of GPR Grid 111 looking Southeast with the terrace platform of the prasat in the background.

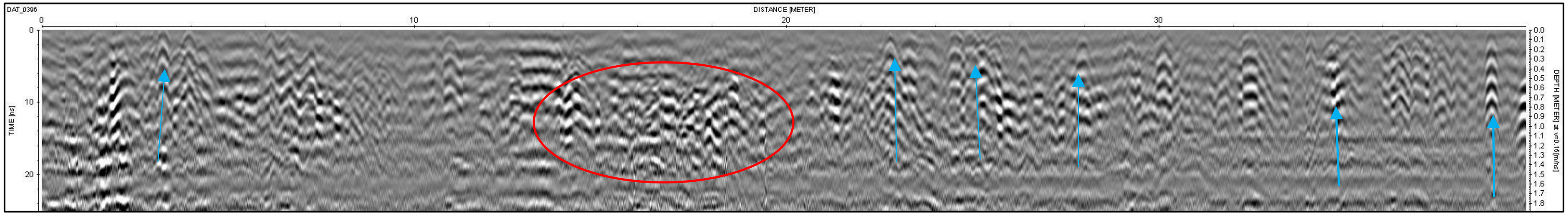



Figure 5.23: GPR line 396 at 5.5.m at Grid 111 of Prasat Preah Theat Baray. The profiles shows consistent point source hyperbolas across the profile (in blue) with some consistent areas of high-amplitude radar reflection (in red).

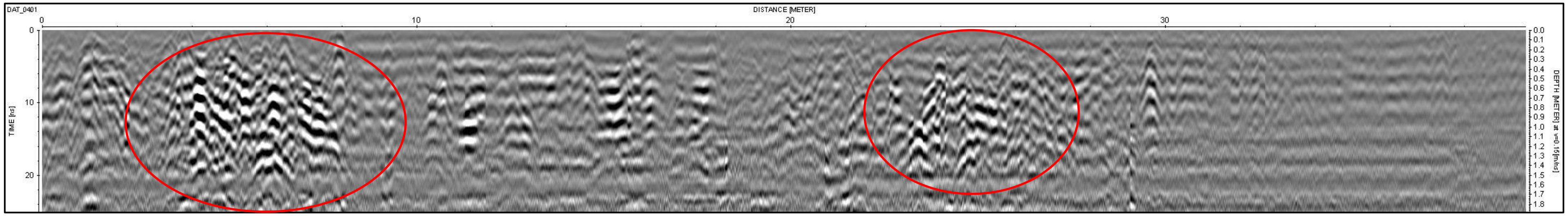



Figure 5.24: GPR line 401 at 7m of Grid 111 at Prasat Preah Theat Baray. The profile shows two discrete areas of high-amplitude radar reflection (highlighted in red). The area on the left with higher amplitude than the one on the right.

**GPR Grid 112** was an area of 8x12 metres. It had a half-metre line spacing and a meandering acquisition, with 0,0 in the northeast corner and the survey orientated east. This grid is located directly west of the *prasat* (Figure 5.25). The grid contained modern surface rubbish and bricks that had fallen from the *prasat*; these were removed from the grid where possible. This area contained the least amount of near surface hyperbolas of all the survey grids at Prasat Preah Theat Baray. Figure 5.26 shows some higher amplitude responses, but these are not consistent across profiles. Figure 5.27 shows higher amplitude surface ringing that was present across consecutive profiles, although there is nothing present on the surface to have caused this.

Figure 5.25: GPR survey Grid 112 as shown from the southeast with *prasat* in the background.

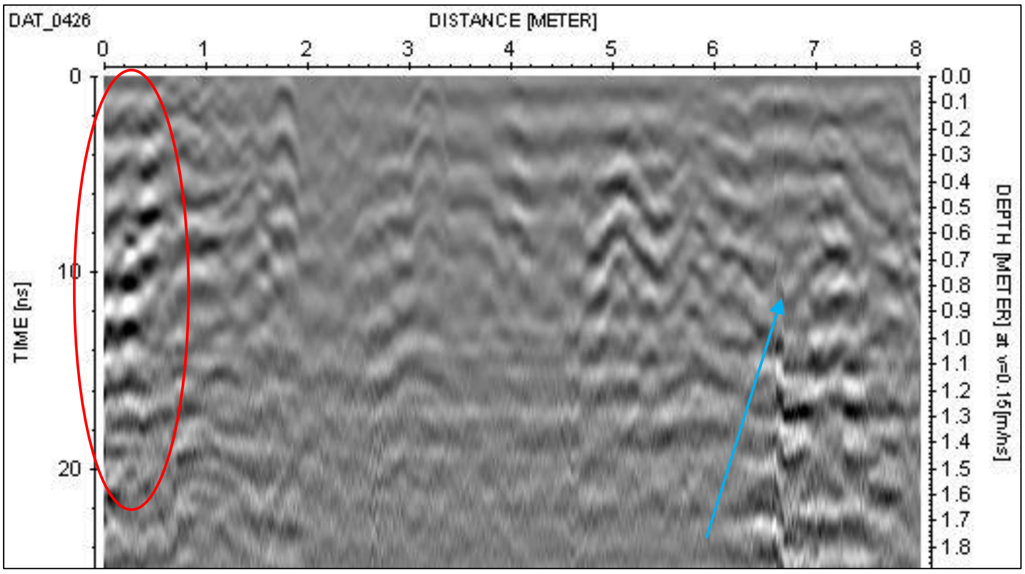



Figure 5.26: GPR line 426 at 11m of Grid 112 at Prasat Preah Theat Baray. Area of high-amplitude reflection on the left (red) with area of what appears to be disturbed sediment to the right (blue).

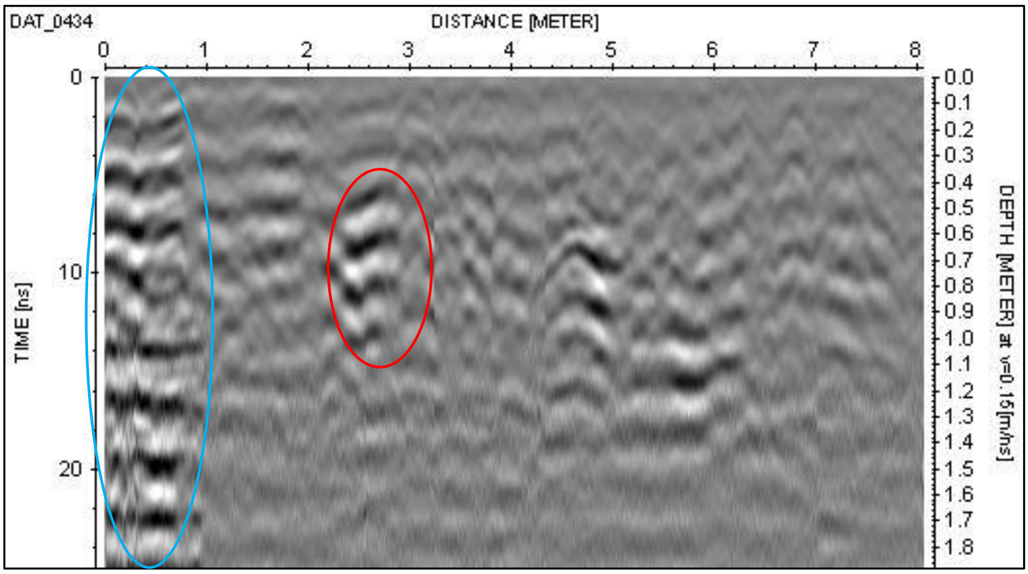



Figure 5.27: GPR line 434 at 11m of Grid 112 at Prasat Preah Theat Baray. Note high-amplitude radar reflections in red and surface ringing to the left in blue.

**GPR Grid 113** covered an area of 40x8 metres. It had a half-metre line spacing with meandering acquisition. Point 0,0 was located in the southeast corner and the grid was oriented west. This grid is located north of the mound on what is now an access road to the rice fields and duck farm to the northwest (Figure 5.28). This grid contained no surface archaeological material. Figure 5.29 and Figure 5.30 both demonstrate the homogeneous nature of the area, which could largely be due to compaction, as the road ran through the grid. The most clearly identifiable feature was the surface ringing best represented in Figure 5.30.

Figure 5.28: GPR Grid 113. Prasat mound left and duck farm in the background. Note track running through centre of grid.

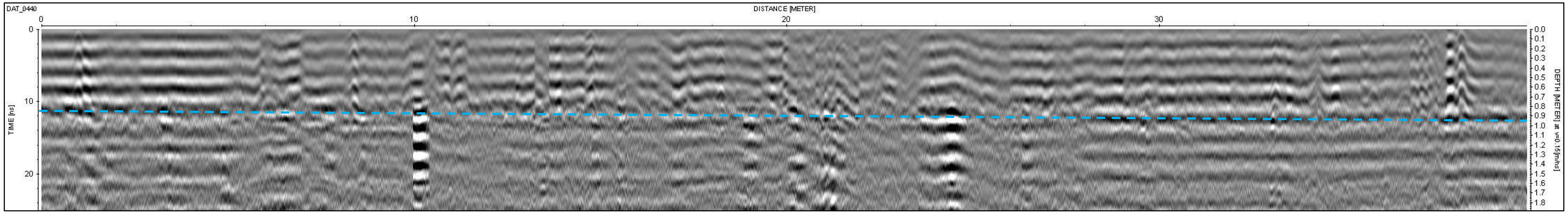



Figure 5.29: GPR line 440 at 1.5m of Grid 113 which runs north  parallel to Prasat Preah Theat Baray. Profile largely homogenous with consistent surface ringing likely caused by compaction of the road. The issue of the radar waves not penetrating beyond a meter is most evident here and highlighted in blue.

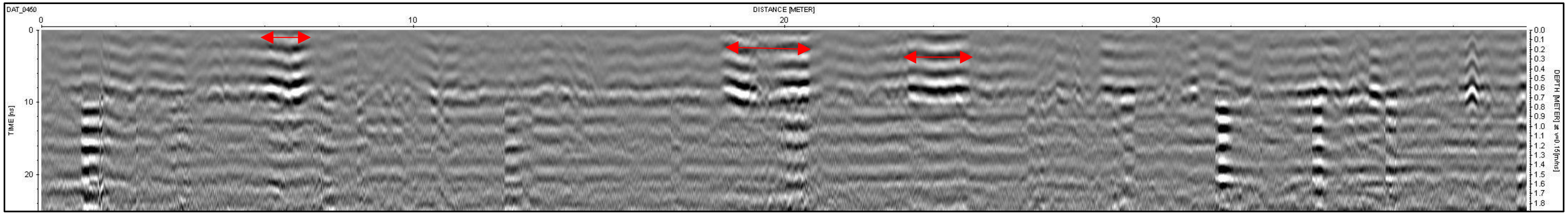



Figure 5.30: GPR line 450 at 6.5m of Grid 113 which runs north  parallel to Prasat Preah Theat Baray. As profile above, no archaeological material present. Area is largely homogenous. Effects of horizonal ringing represented in red.

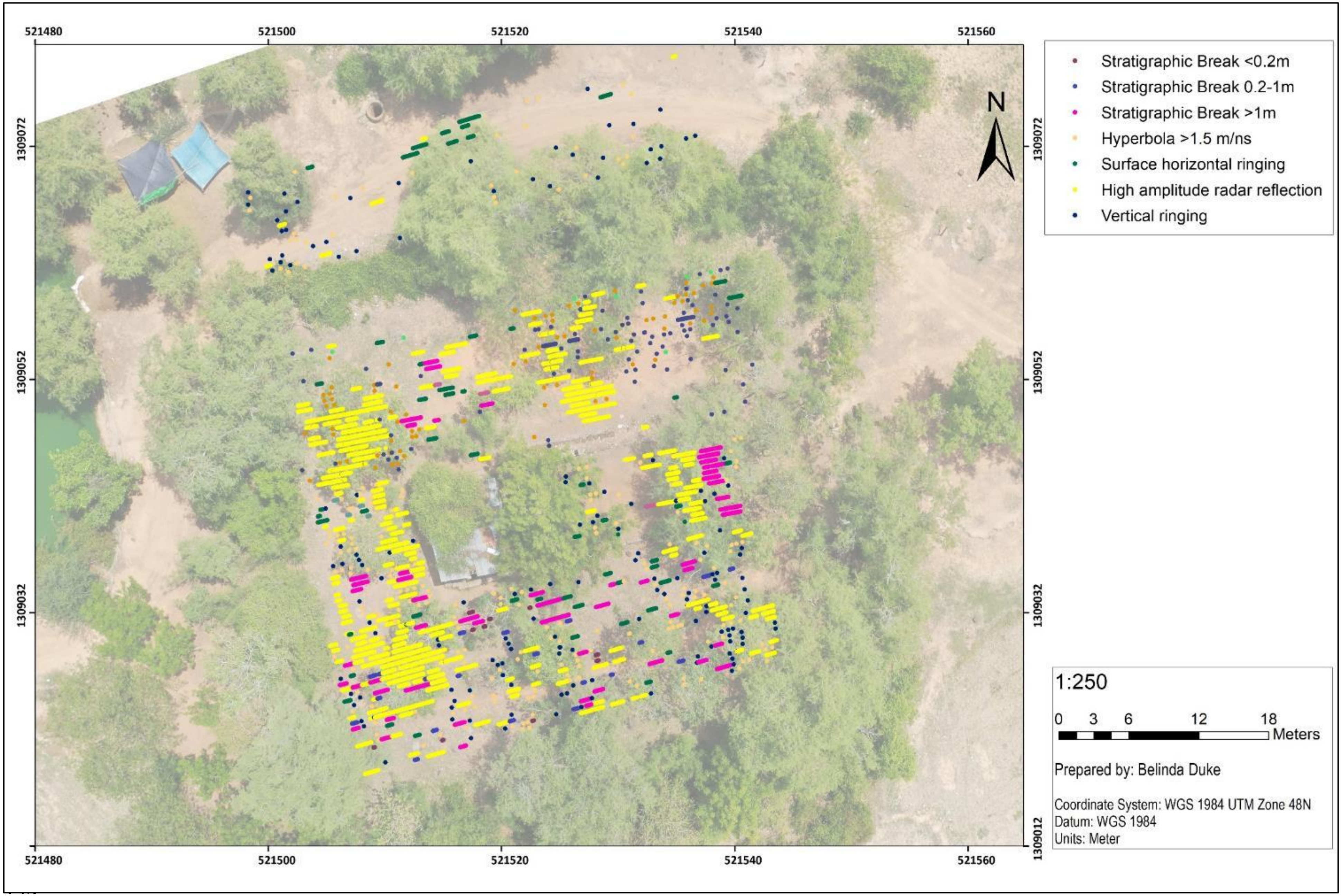



Figure 5.31: Prasat Preah Theat Baray ground-penetrating radar subsurface features.

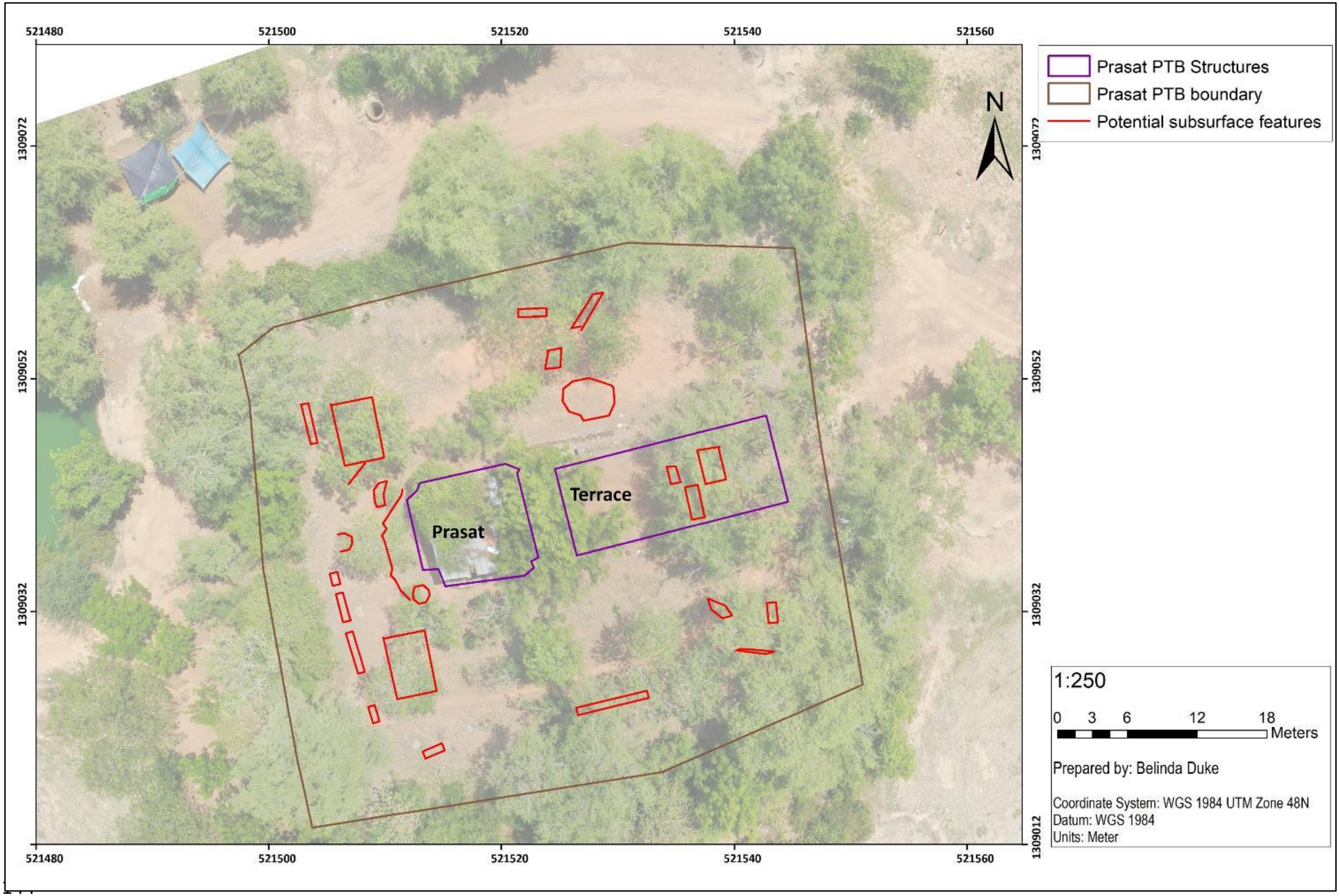



Figure 5.32:Proposed GPR features from Prasat Preah Theat Baray.

#### *5.2.2.2 Identified Features*

GPR Grids 109-112 show several areas of high-amplitude radar reflection. This suggests there are multiple discrete subsurface features consisting of possible archaeological material. The two areas to the western end of the *prasat* have the highest amplitude responses, which are likely caused by buried material possessing a significant variation in relative dielectric permeability, such as bricks or laterite. The third area with the lower amplitude response in the north-eastern quadrant may also contain similar buried archaeological remains, but this is not as clear. The high-amplitude response found in GPR Grid 110 was consistent across all profiles, which corresponds with an area of strata breaks. On the eastern, western and norther edges of the mound there appears to be a broad band of high-amplitude radar reflections at approximately a half-metre depth. The placement of these features may suggest a buried wall consisting of a material such at laterite. A high-amplitude radar response feature was also found west of the *prasat* at a depth of 0.2 metres, which would suggest a very near surface feature that may be a part of the *prasat* structure. Overall, there appears to be at minimum of two subsurface structures in the west of Prasat Preah Theat Baray, with a potential third in the northeast quadrant. Additional features suggest this area was once walled with laterite.

## 5.3 Longvek/Oudong

The investigation area for Longvek ran from the northern wall on the citadel south to the flood zone area, east to the river and west to the industrial zone (Figure 5.33). The base maps for results at Longvek and Oudong were collected and processed by the Cambodian Archaeological Lidar Initiative (CALI). The lidar survey conducted in 2015 used a Leica ALS60 laser system and a 40-megapixel Leica RCD105 medium-format camera within an external pod mounted to a helicopter and was processed using Terrascan software. Lidar point densities averaged 4–5 points per square metre and raw photo images at 8-centimetre resolution. This data was postprocessed CALI and their interpretations are included here. The modern landscape of Longvek is dominated by independent rice farming, a Cambodian military complex and industrial clothing factories. What remains of the historic landscape has been mapped by the by CALI research team through lidar and ground verification and the Japan International Cooperation Agency (JICA) archaeological research team through foot surveys and site visits. This interpreted dataset has been examined here to understand the types of historic features present for integration with geophysical data. Magnetometry was applied across three sites to identify magnetic variations in the subsurface, with GPR used as ground verification and to investigate mounded terraces. The raw magnetometry data can be found at Duke (2020a) and raw GRP data can be found at (Duke 2020b).

### 5.3.1 Lidar Survey: Feature Overview

The lidar feature identification as interpreted by CALI has provided opportunity to examine a large volume of landscape features, with 1807 total features identified from the lidar (Figure 5.34). One-hundred and eighteen landscape features identified were visited for ground verification. As only a tenth of the features have been ground-verified, the whole dataset will be used here. As Table 5.1 shows, ponds are the most prevalent landscape feature identified in this survey, with 771 recorded. Mounds are also a common feature, with 123 identified. Embankments consist of either largescale such as the citadel walls or small scale related to water control dikes. The *tumnup* were not been identified as a historic feature by CALI and are therefore not represented here.

Table 5.1: CALI features identified via lidar survey.

| **Feature Type** | **Total Identified** |
|---|---|
| Canal (water) | 50 |
| Embankment | 277 |
| Moat | 28 |
| Mound | 123 |
| Pond | 771 |
| Pond Bank | 465 |
| Temple | 3 |
| Unknown | 55 |
| Watercourse | 35 |

The dataset was then converted into polylines and examined by bearing according to Hawken (2011a) (Figure 5.34). The key outcomes of this process are that:

- Figure 5.34 shows that the Citadel has a class eight orientation.
- Figure 5.35 shows that class one is the most dominant class at 24%, followed by class eight at 21%.

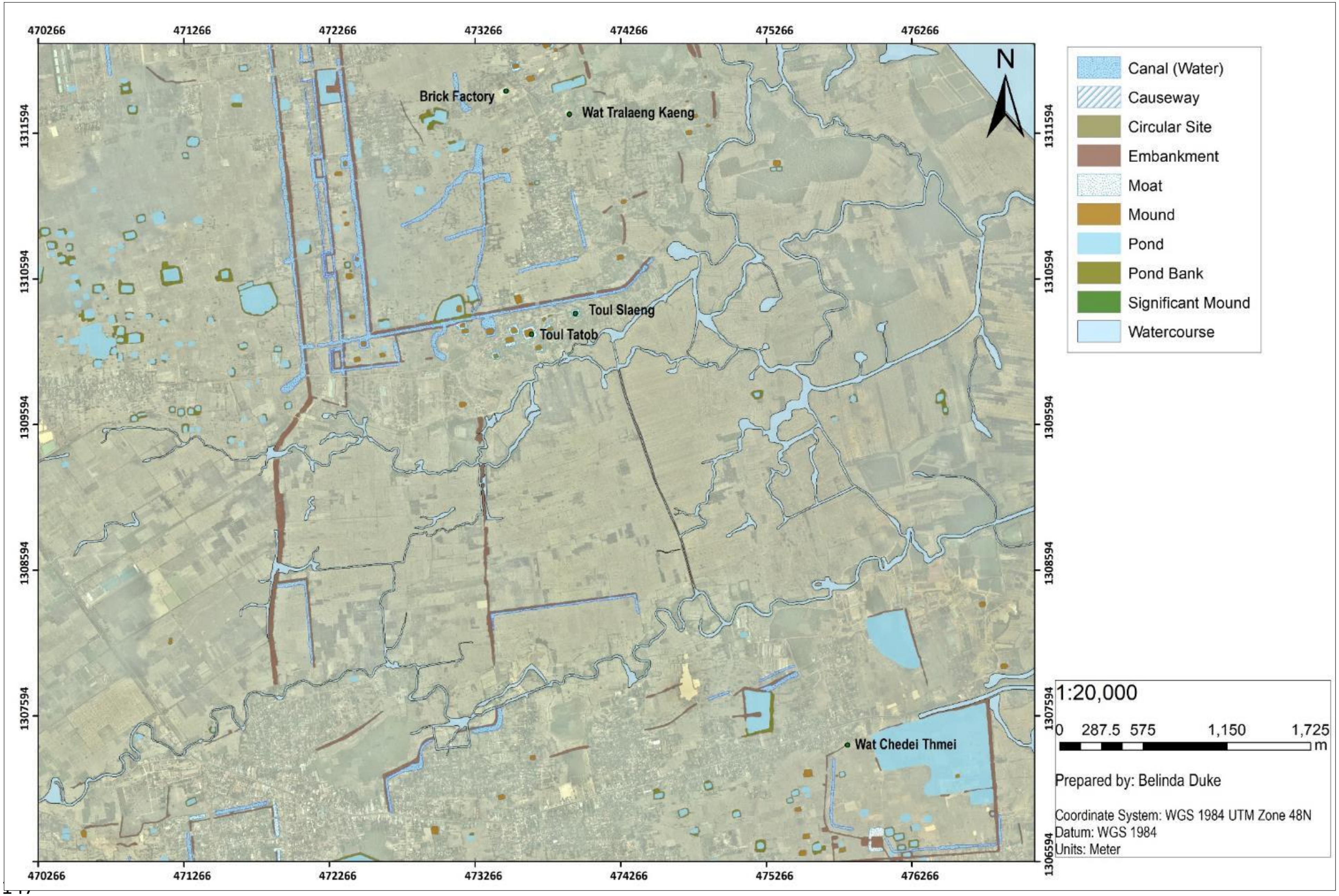



Figure 5.33: Location of sites investigated in the Longvek and Oudong area.

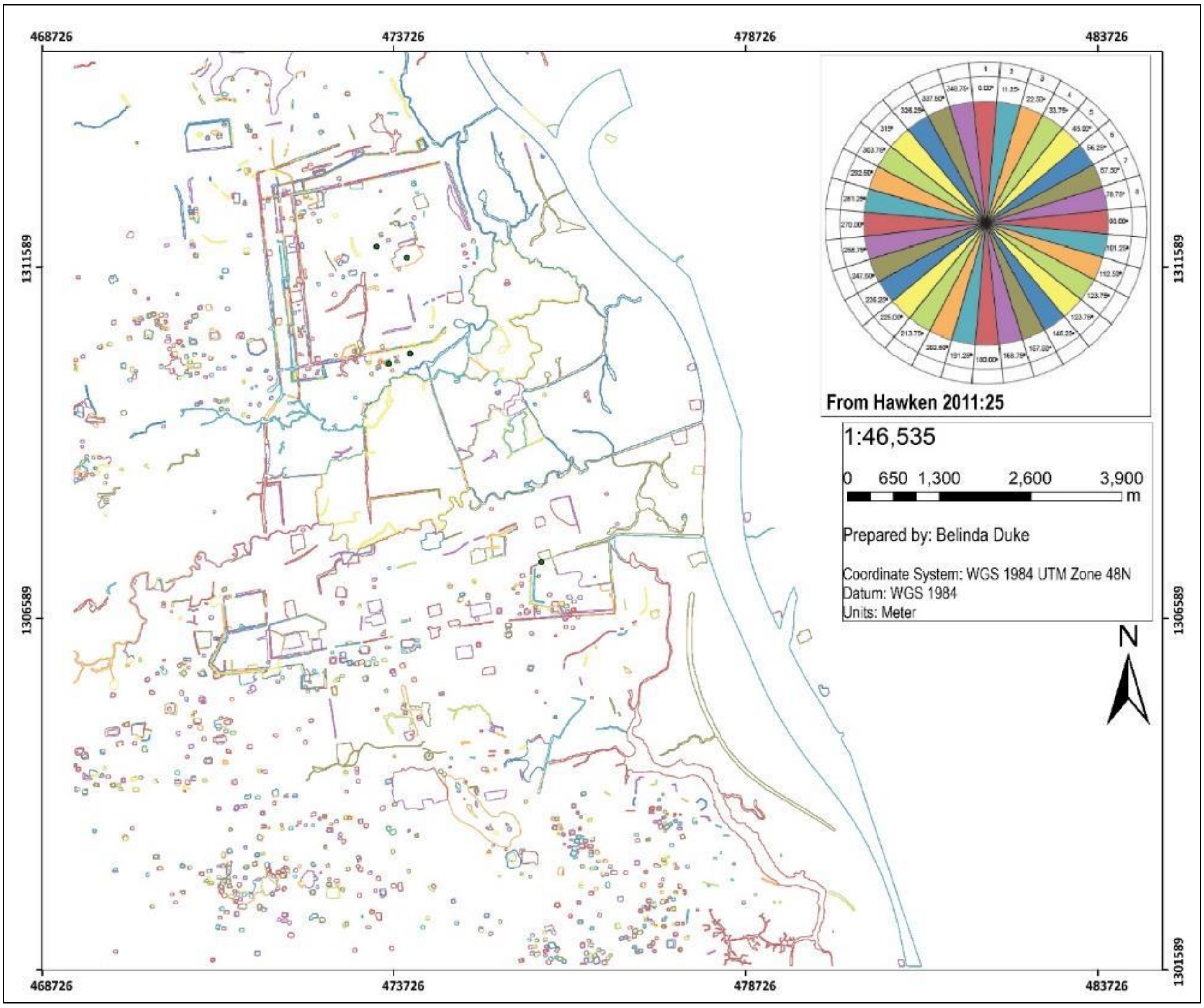



Figure 5.34: Feature extraction from lidar survey conducted and ground verified by CALI. Results then transformed from feature class to polyline to be classified by bearing following Hawken (2011a:140). Archaeological features only included here.

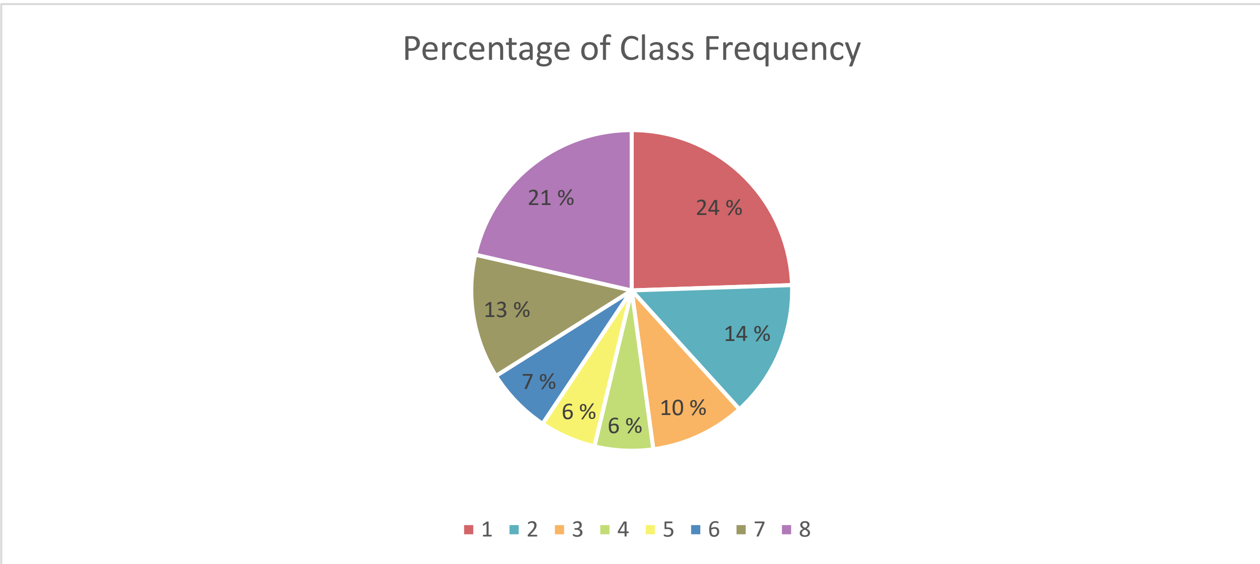



Figure 5.35: Percentage of class frequency of landscape features identified in lidar survey.

### 5.3.2 Rice Field Analysis

This rice field analysis was based on the work of Hawken (2011a), who identified a variety of rice field types in relation to the fields in central Angkor (see Section 2.4.1 and Table 2.1) based on a classification system (see Section 4.3.1 and Figure 4.1). Using the lidar data, over 18,000 rice bunds were mapped to undertake Hawken's analysis. The study area is shown in Figure 5.36, and was bounded by a small river in the south, the Tonle Sap river to the east, the citadel wall and military area to the north and an industrial area to the west. The bearing was then established for each bund before it was classified using the method developed by (Hawken 2011a:140). Based on the frequency distribution by class shown in Figure 5.37, frequency distribution by bearing in Figure 5.38 and the percentage of class distribution as shown in Figure 5.39, the following observations can be made:

- Class One (0.00-5.63, 84.39-95.63, 174.39-185.63, 264.39-275.63, 354.39-360) accounts for 23% of distribution across the sample area. When examined against the CALI lidar analysis, cardinal rice fields are associated with water sources such as pond and river systems. Fields consist of square and rectangular orthogonal systems.
- Class Two (5.64-16.88, 95.64-106.88, 185.64-196.88, 275.64-286.88) accounts for 5% of the class distribution. There does not appear to be any pattern of distribution across the sample area. Instances where this class type is clustered appear to be associated with the river south of the citadel and terraced areas north of the citadel.
- Class Three (16.89-28.13, 106.86-118.13, 196.89-208.13, 286.89-298.13) accounts for 3% of class distribution. The orientation of these rice fields is sporadic and does not appear to follow any pattern. The sample is too small to understand the placement of these bunds.
- Class Four (28.14-39.38, 118.14-129.38, 208.14-219.38, 298.14-309.38) accounts for 2% of class distribution. The primary placement of these bunds is in association with *tumnup* use, although the sample is too small to understand the placement and distribution of these features.
- Class Five (39.39-50.63, 129.39-140.63, 219.39-230.63, 309.39-320.63) accounts for 2% of class distribution. The sample size is too small to understand the placement and distribution of these bunds.
- Class Six (50.64-61.88, 140.64-151.88, 230.64-241.88, 320.64-331.88) accounts for 7% of class distribution. This class consists of long linear bunds close to the river.

- Class Seven (61.89-73.13, 151.89-163.13, 241.89-253.13, 331.89-343.13) accounts for 22% of class distribution. This bund formation is mostly modern in nature, with uniform grids prevalent.
- Class Eight (73.14-84.38, 163.14-174.38, 253.14-264.38, 343.14-354.38) is the most prevalent class, with 36% of distribution. This class is also represented across all rice bund configuration types. Class eight rice bunds are on the same orientation as the citadel itself.

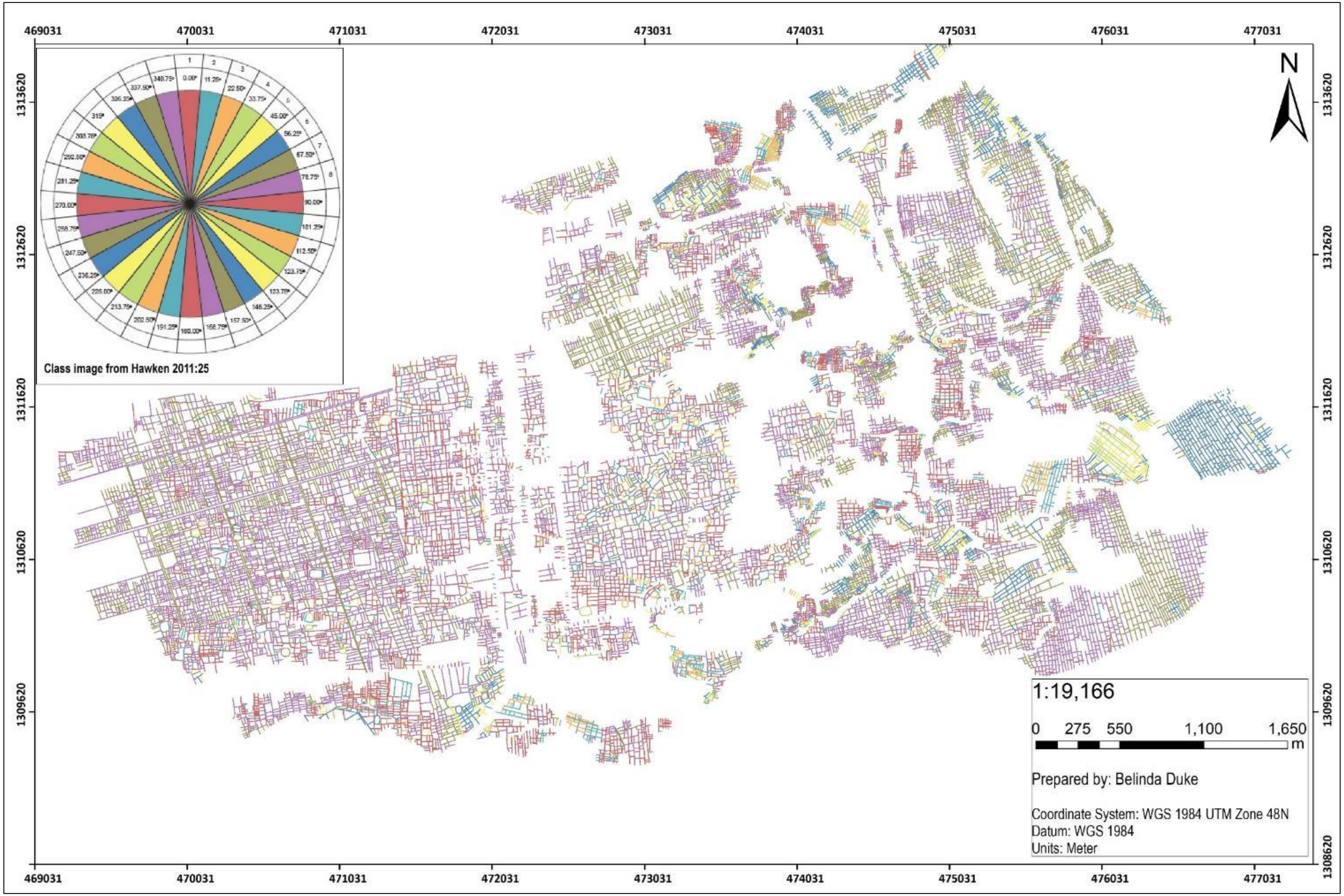



Figure 5.36: Sample area of rice bund mapping. Classification following Hawken (2011a:140).

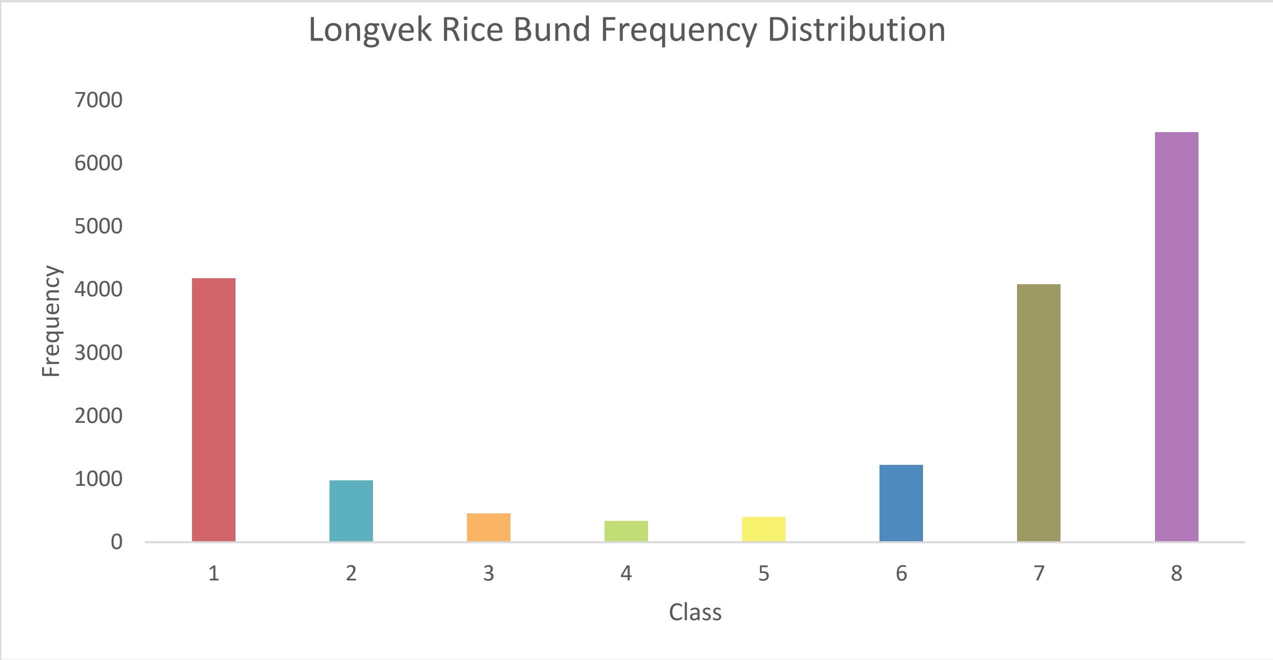



Figure 5.37: Frequency distribution of rice bunds at Longvek by class. Class eight is the most dominant bund followed by class one and class seven.

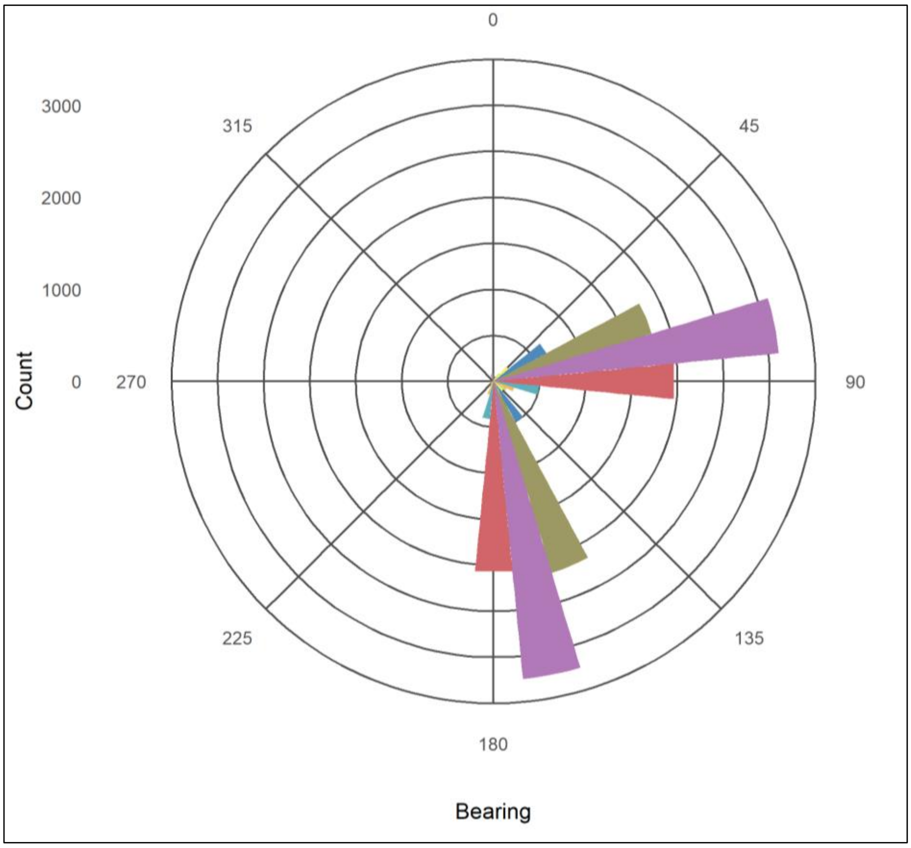



Figure 5.38: Rice bund frequency distribution by bearing classification by Hawken (2011).

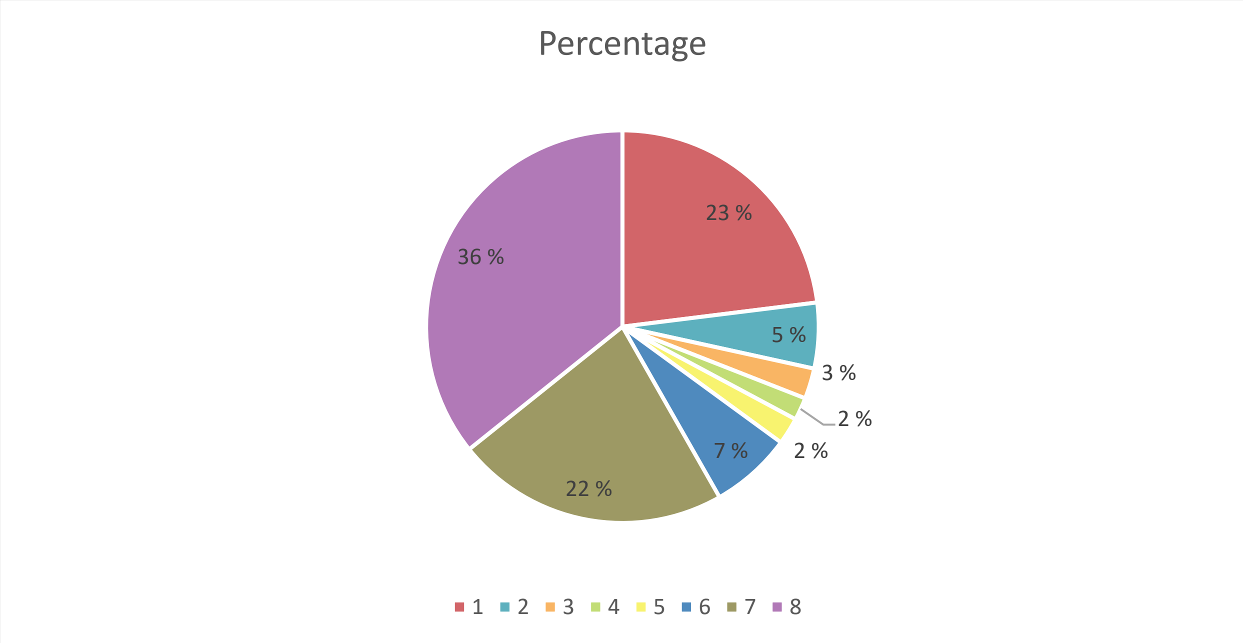



Figure 5.39: Percentage of distribution of Longvek rice bund orientation by class.

### 5.3.3 Brick Factory North

The area north of the Longvek brick factory is a mix of used and unused rice fields, and cattle grazing areas. The proximity to the working brick factory resulted in surface contaminants, such as bricks and metal, that had to be removed from the survey area. Magnetometer and GPR were used in this area in Figure 5.40.

#### *5.3.3.1 Magnetometer*

Using the single sensor instrument resulted in a high number of data points not recorded due to an unknown instrument error. This is presented as unplotted null data points in Figure 5.41, Figure 5.42 and Figure 5.43. The season two survey area was very irregular, with trees and low shrubbery bordering many of the fields. As a result, a patchwork of overlapping grids was used to achieve the best possible coverage of the area. The placement of survey grids was also dependent on land use, with rice farming occurring during the December 2018 collection period, which prevented access to rice fields.

The mean nanoTesla value was found for all magnetic grids, as was the standard deviation. The standard deviation set the display parameters for the magnetic data. The data was plotted over three standard deviations from the mean to find which best represents an Early Modern dataset as discussed in Section 3.2.2. Data to three standard deviations are shown in Figure 5.41, which illustrates the areas with the highest peaks of magnetic responses. These features were mapped by the criteria established in Chapter 5, excluding modern surface contamination and a one-metre buffer placed around the rice bunds. Linear features bounding spaces of consistent magnetic responses appear throughout and in some cases were distributed in a spatially regular pattern. The high-amplitude features have a very similar response to modern contamination, suggesting near surface metal or a very high temperature firing event. Such an event could be attributed to modern or historic period material. As the survey area is used for farming, these features appear more dispersed across an area due to ploughing activity. The three standard deviation dipoles and positive and negative monopoles are being suggested here to best represent modern surface contamination due to the high value of the plotted data. These anomalies are believed to be modern and are therefore not considered in the analysis. Linear features mapped in Figure 5.41, however, will be included in further analyses. Two standard deviation magnetic responses, shown in Figure 5.42, will also be considered. Dipoles, negative and positive monopoles, high-value and linear features will be considered in the landscape reconstruction.

At the Brick Factory North survey, one standard deviation magnetic responses appear to best represent the Early Modern landscape based on the organic historic building materials and the ephemeral occupation condition. Figure 5.43 shows the features with the smallest magnetic variation. Figure 5.44 shows all the data points under consideration. The potential landscape features mapped in Figure 5.45 have been chosen based on the data points mapped in Figure 5.44. Potential features are identified by looking for linear clusters of magnetic points in uniform shapes which may correspond to the range of occupation structures discussed in section 2.5.1. There is a considerable number of potential magnetic features present. Before suggesting specific features from this data, it must be examined in combination with the remote sensing data (see above) and GPR data which follows.

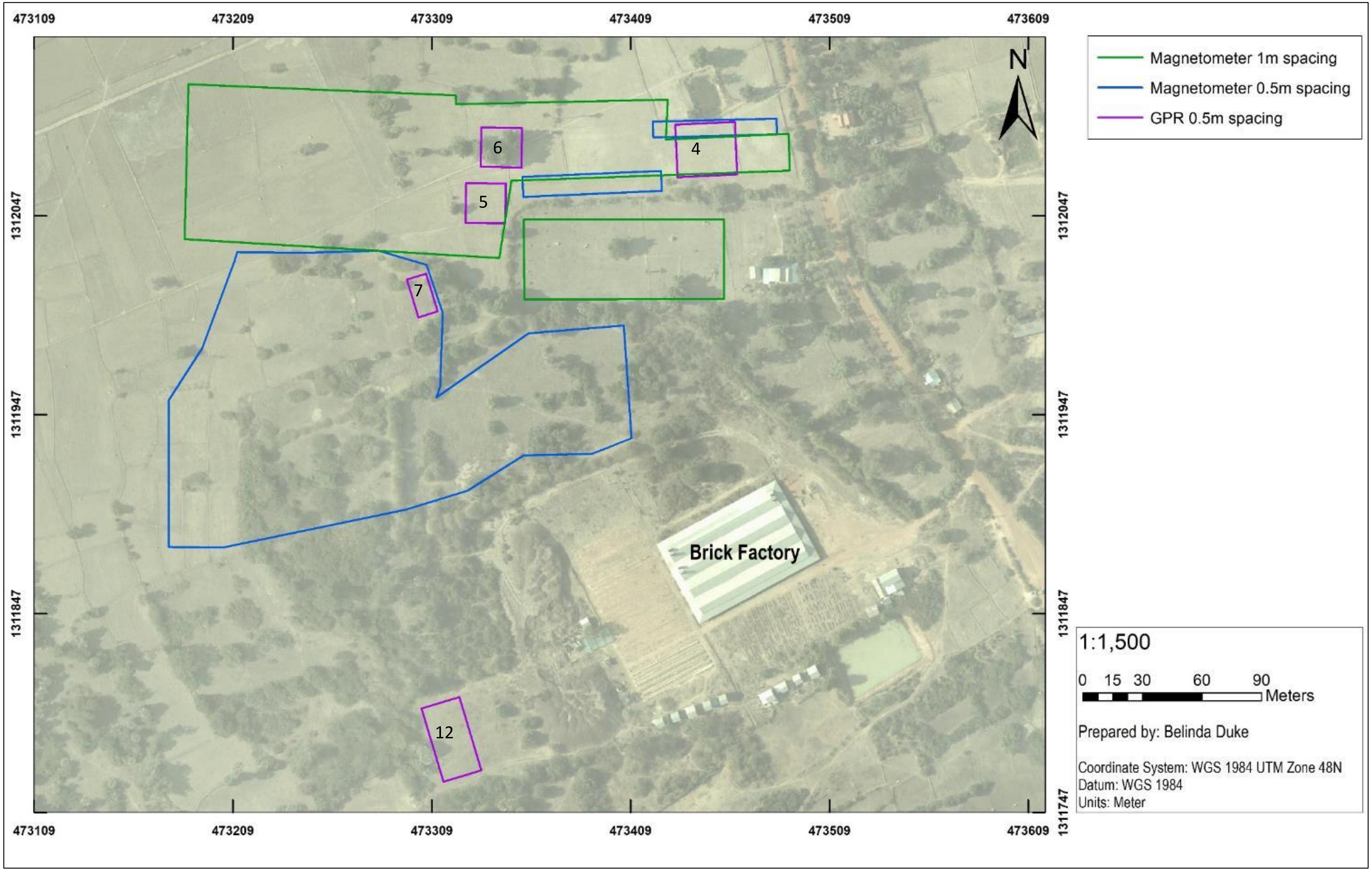



Figure 5.40: Geophysical survey conducted at Brick Factory North using a single and dual sensor magnetometer and 500mHz GPR antenna, grids numbered.


Figure 5.41: Brick factory north magnetometer survey conducted in February and December 2018. Gridding either in 20x20m or 10x10m squares magnetometer results presented with the nT range three standard deviations (-14.7-15.9 nT) from the mean.


Figure 5.42: Brick factory north magnetometer survey conducted in February and December 2018. Gridding either in 20x20m or 10x10m squares magnetometer results two standard deviation (-9.8- 10.9 nT) from the mean.


Figure 5.43: Brick factory north magnetometer survey conducted in February and December 2018. Gridding either in 20x20m or 10x10m squares magnetometer results One standard deviation (-4.6 – 5.8nT) from the mean.

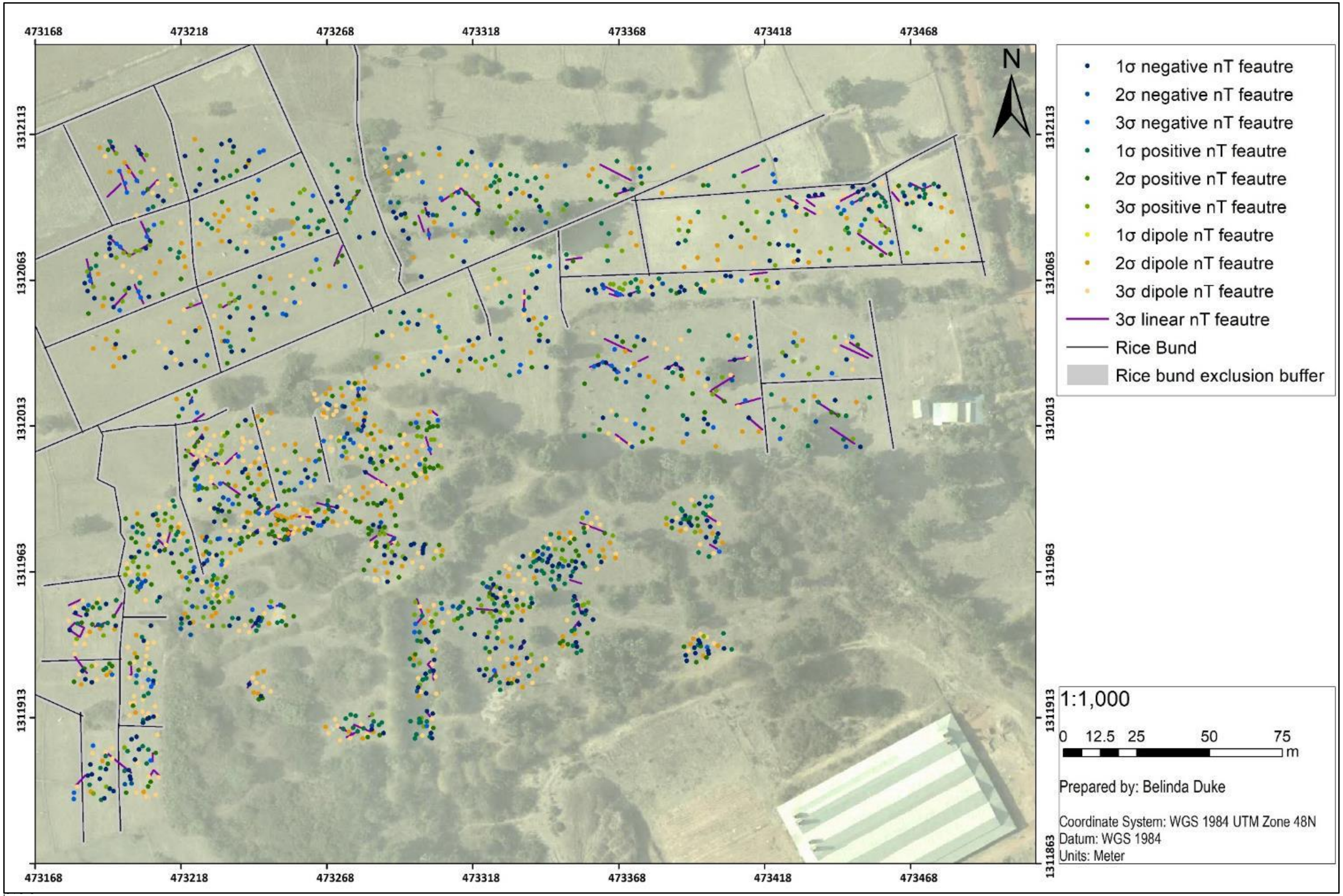



Figure 5.44: Brick factory north distribution of all identified magnetometer features at three, two and one standard deviation combines all the identified features from the three data mapping ranges. Boundary between two areas when examining the volume of points. The top half had a one-meter line spacing while the bottom has a half meter line spacing.

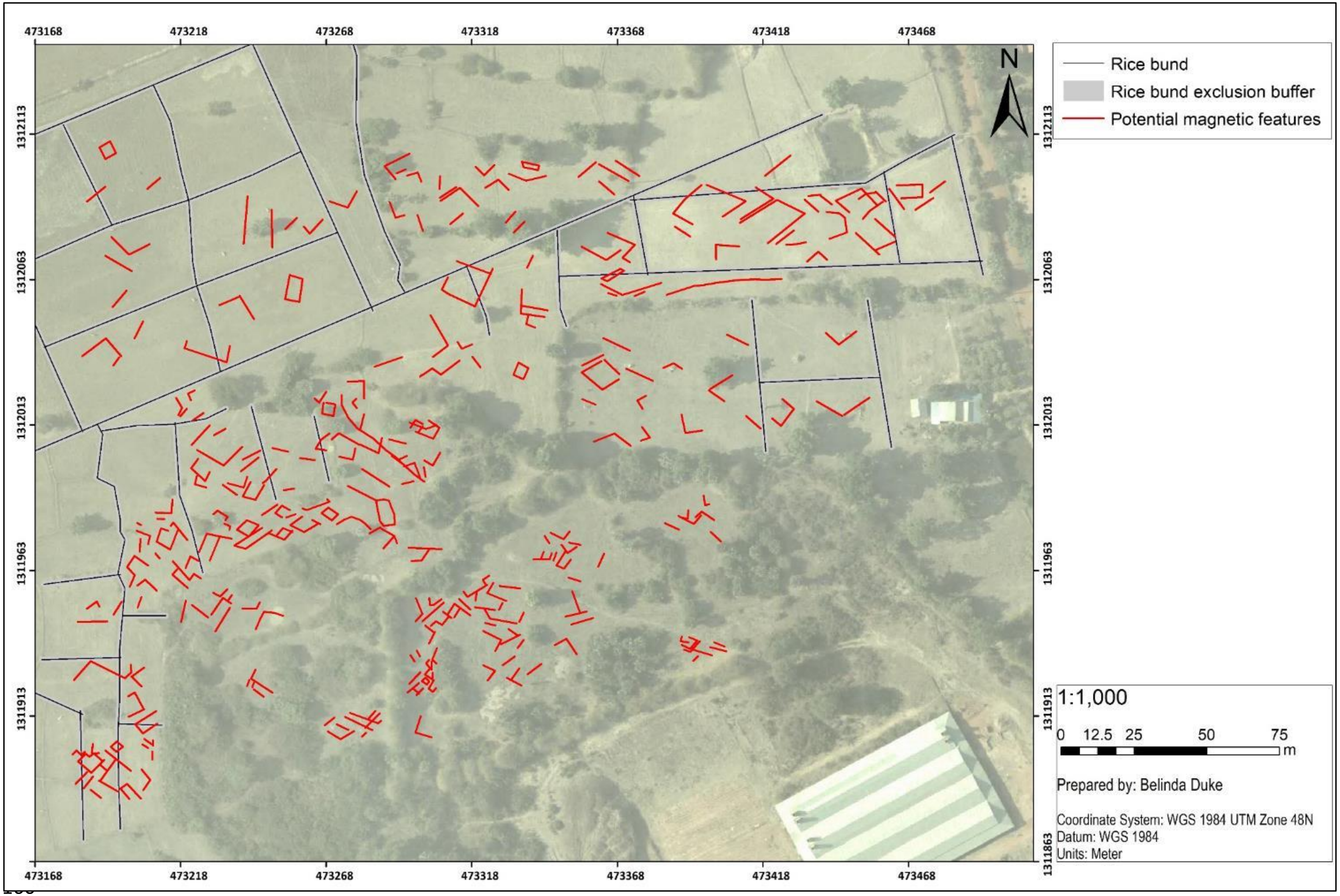



Figure 5.45: Features mapped from an examination of the feature picking of the magnetometer data at Brick factory north.

High value nanoTesla features (over approximately 20nT) present at the brick factory north site, suggests that these are either high-temperature burning events, pits which have been filled with high nanoTesla value material (such as metal or material subject to high temperatures) or surfaces which have been subject to repetitive use which has resulted in the accumulation of material with a high nanoTesla value. The shape and size of these features is dependent on the composition of the feature. If it were an iron rich artefact in the ground, the plotted response size would depend on the size and depth of the object.

#### *5.3.3.2 Ground Penetrating Radar*

***GPR Grid 04*** had a total area of 30 x 30 metres, with a half-metre line spacing in meandering acquisition. Point 0,0 was in the northeast corner and the survey direction was orientated south. The surface was highly disturbed by heavy vehicles and from the removal of a tree nearby (Figure 5.46). The last lines in the grid were most heavily disturbed, resulting in no data being collected from 27-30 metres. There is a clear layer of archaeological material that is distinguished by a dense number of hyperbolas in the GPR profiles, with an upper and lower boundary present. In Figure 5.47 this division is clear in the upper horizon, which transitions from homogeneous topsoil strata to an area of archaeological disturbance (indicated in yellow) and the lower horizon, which transitions from an area of archaeological disturbance to undisturbed strata (indicated in red). The depth of each of these horizons was separately recorded, and the two were then interpolated to create a contour representation of the subsurface. Figure 5.48 shows the interpolated surface of the upper horizon with features defined. Figure 5.49 shows a much more undulating surface with multiple pit features. These pits are filled with high-amplitude radar reflections indicating archaeological material (see Figure 5.50). The lower horizon suggests the presence of landscape modification, but the full size of this feature is not clear. The inclusion of consistent high-amplitude radar reflections across all profiles within the fill of this feature may suggest an event of purposeful infilling. The upper boundary represents a later land use event that is potentially related to current farming practices.

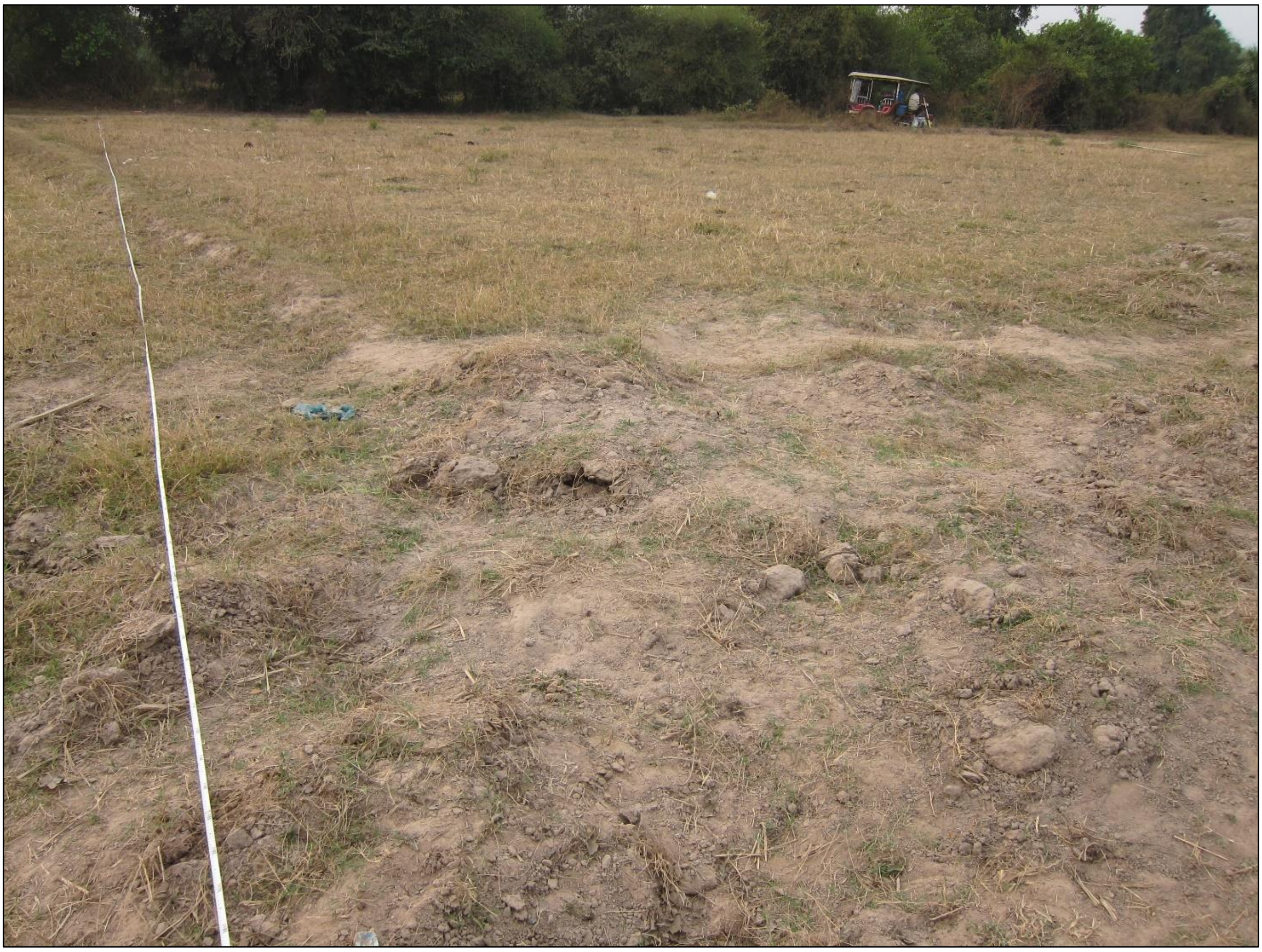


Figure 5.46: GPR grid 04 north west corner. Note disturbed surface which is consistent across the western edge of the grid.

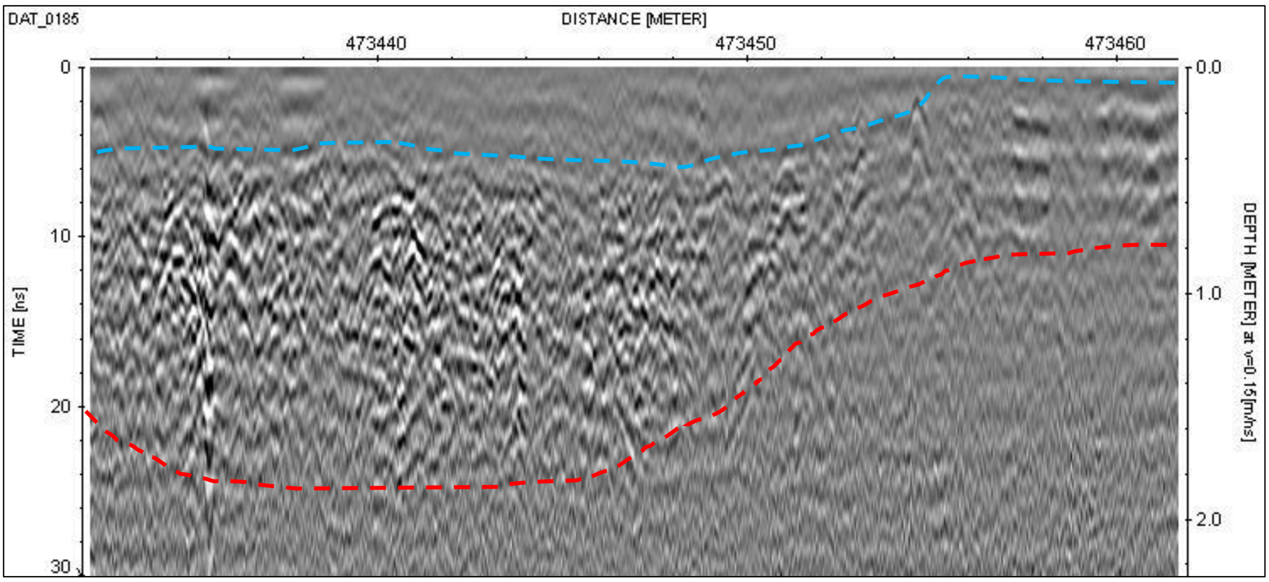



Figure 5.47: GPR Line 26 at 12.5m of Grid04 at brick factory north showing a layer of high-amplitude radar reflections with an upper boundary, in blue , transitioning to homogenous sediment and a lower boundary, in red, transitioning to undisturbed strata at the lower boundary.

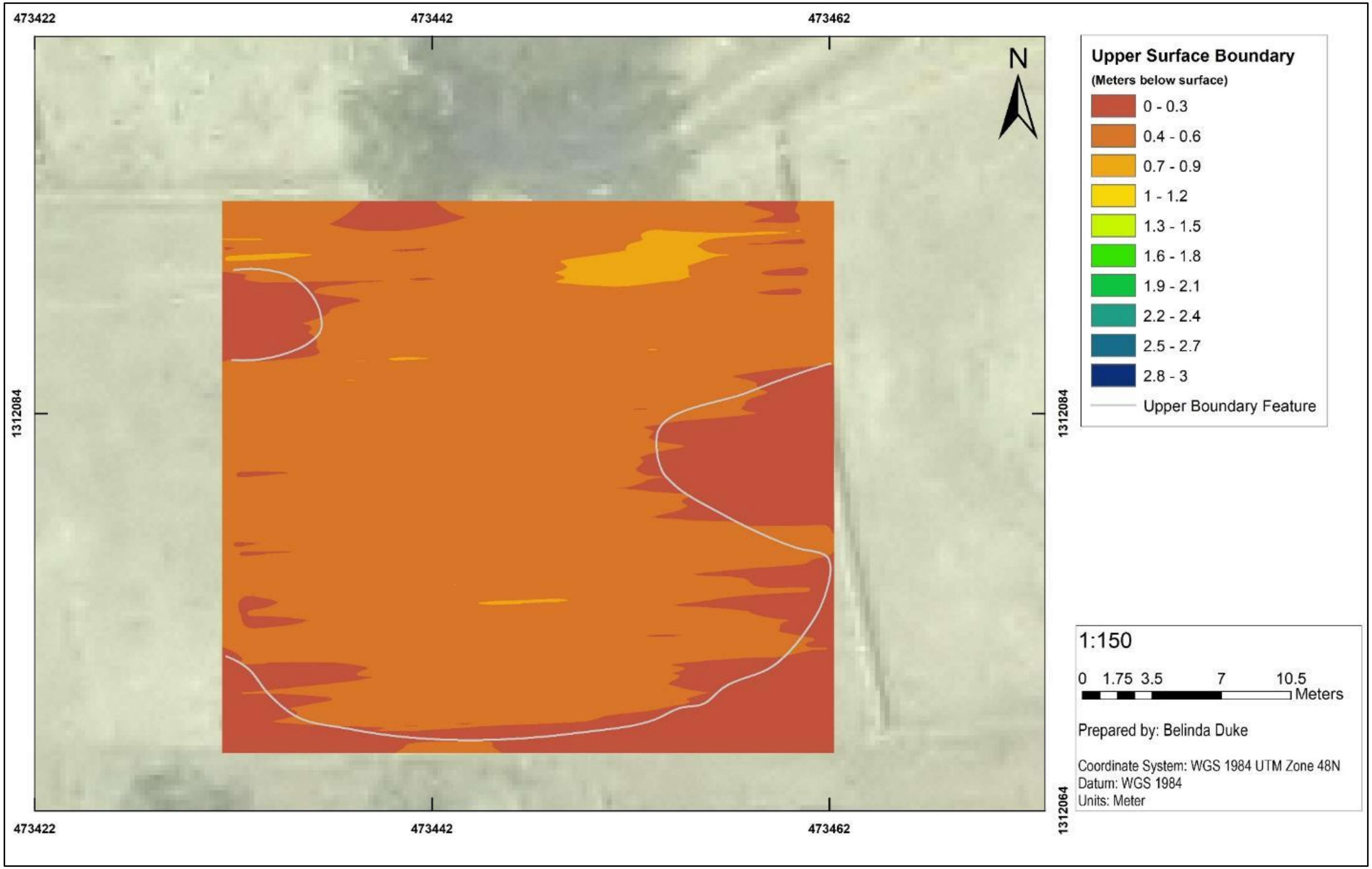



Figure 5.48: Brick factory north GPR Grid 04 subsurface topography mapped from depth of upper surface boundary which is the surface transition from upper homogenous strata with little disturbance to middle area of intensified discrete high-amplitude features. Areas not in depression were compacted strata which the radar pulsed did not penetrate. Compaction may be due to surface disturbance caused by heavy vehicles and soil disturbance.

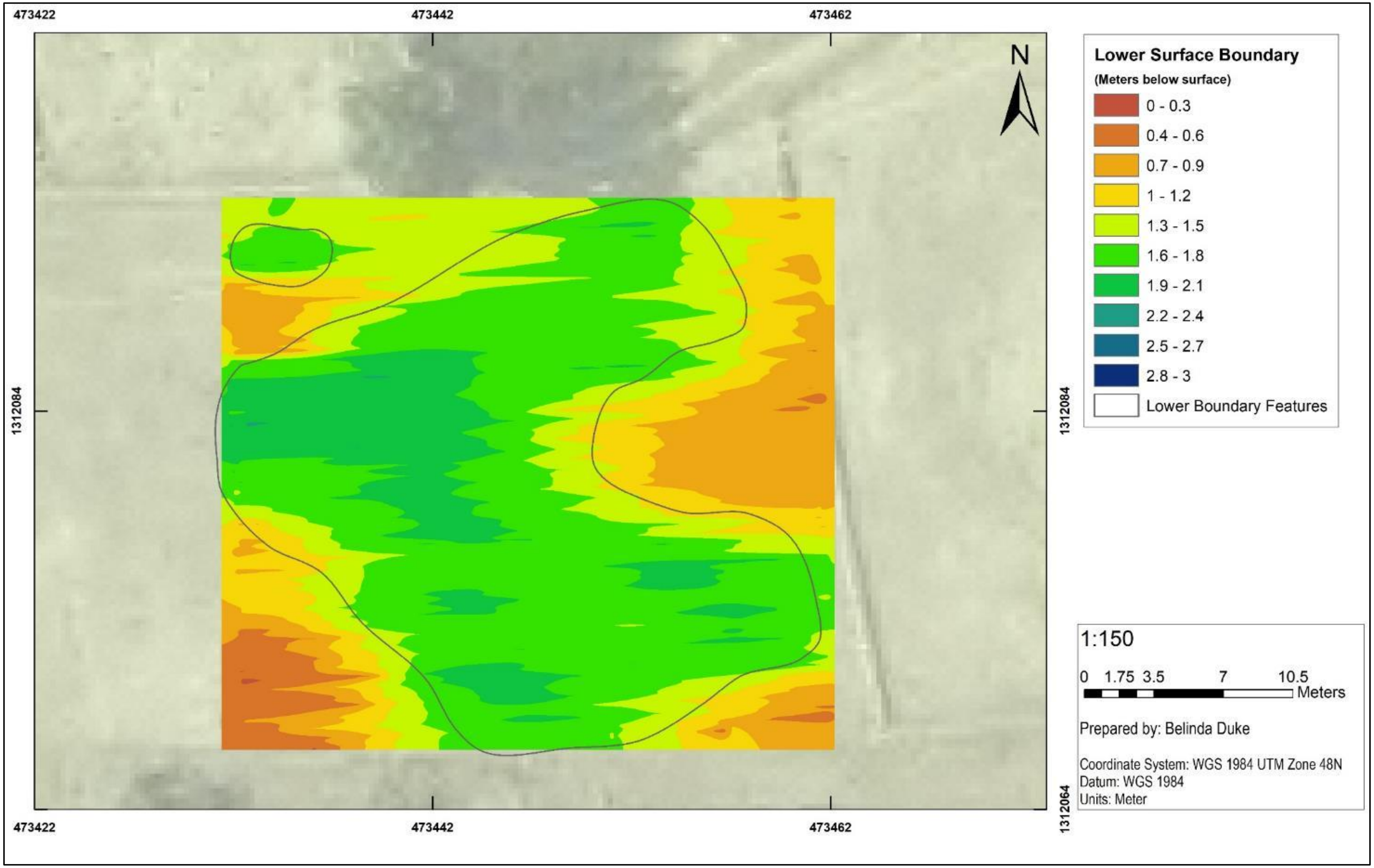



Figure 5.49: Brick factory north GPR Grid 04 subsurface topography mapped from depth of lower surface boundary which is the surface transition from middle area of intensified discrete high-amplitude features to lower level undisturbed strata. Two large pits and two medium sized pits identified. Possibly a large single feature, however surface disturbance which caused compacted strata from heavy vehicles may be impacting this.

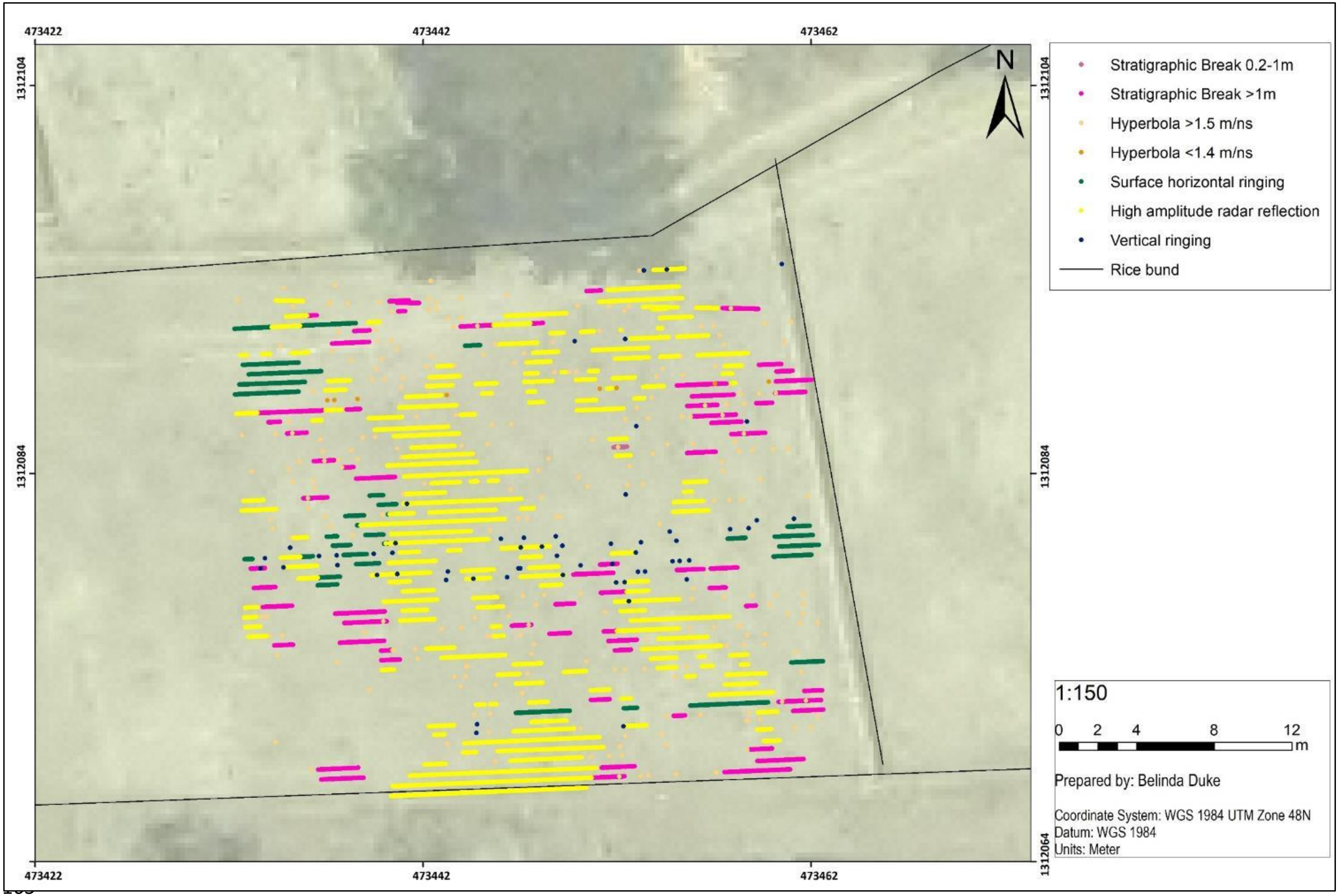



Figure 5.50: Brick factory north GPR Grid 04 subsurface features by feature type. Multiple high-amplitude hyperbola and high-amplitude features which suggest archaeological material most prevalent in areas of the lower horizon pit depressions. Many hyperbolas with extensive vertical ringing.

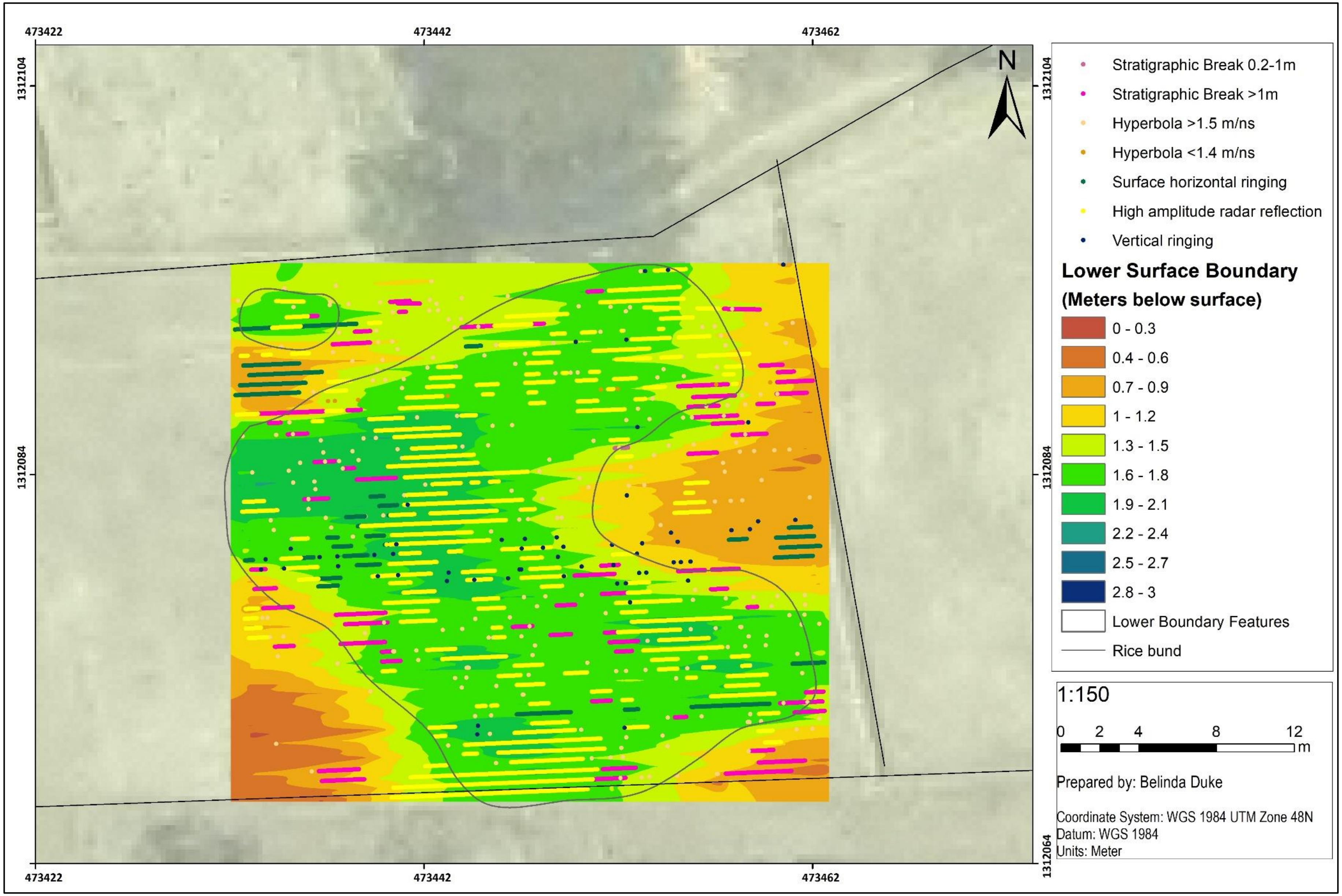



Figure 5.51: Brick factory north GPR Grid 04 with features overlayed lower surface boundary. Note the majority of the high-amplitude radar response are contained within the lower areas of the feature.

***GPR Grid 05*** covered an area of 20x20 metres, with a half-metre line spacing in meandering acquisition. Point 0,0 was in the southeast corner and the survey orientated west. Subsurface topography was less well defined in this grid. While the surface not as disturbed as that in Grid 04, the area has been used for recent rice farming and cattle grazing was evident by the presence of surface material in Figure 5.52. The radar profiles are largely consistent with homogeneous strata, with some instances of hyperbolas and high-amplitude responses. The GPR survey was established here to investigate a high negative value monopole magnetic feature. However, the feature seen in the magnetometry was not found in the GPR profiles. Figure 5.53 is typical of this area, demonstrating the distribution of material. There does not appear to be any consistency in the geographic distribution of features to indicate *in situ* archaeological material. Figure 5.54 is the last GPR reflection profile taken from the eastern edge of the grid. Of interest here is the definable lower horizon between archaeological material and the undisturbed sediment below. The presence of a pit feature represented by high-amplitude radar reflections is also evident in the profile and was found in the southern most three lines (1.5 metres) of the grid.

Figure 5.52 Brick factory north GPR Grid 05 southeast corner looking northwest.

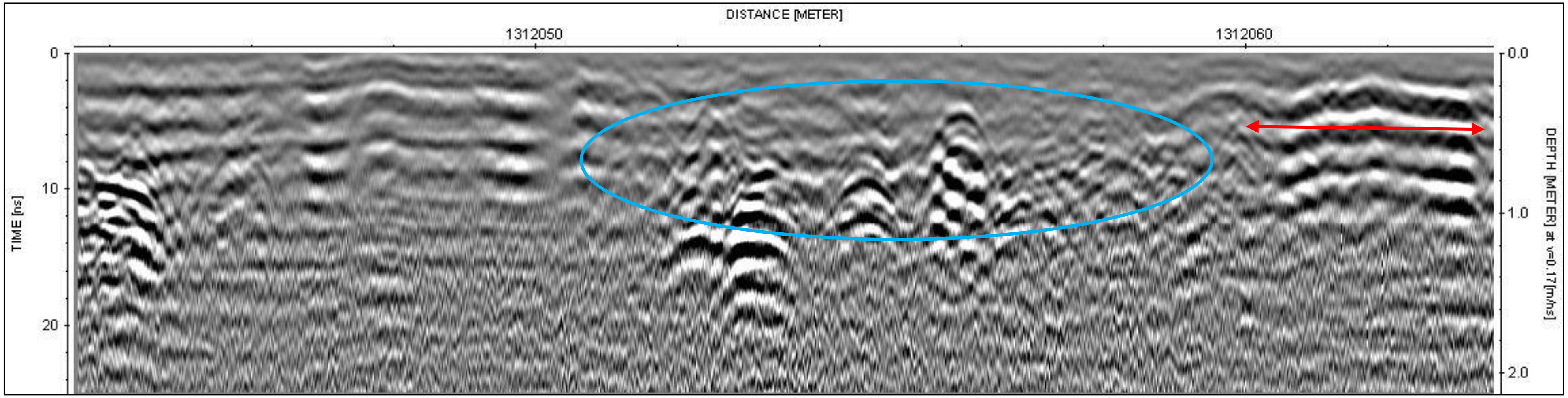



Figure 5.53: Brick factory north GPR line 231 at 9.5m of Grid 05. Note disturbed area with limited high-amplitude radar response in blue and homogenous areas highlighted in red.

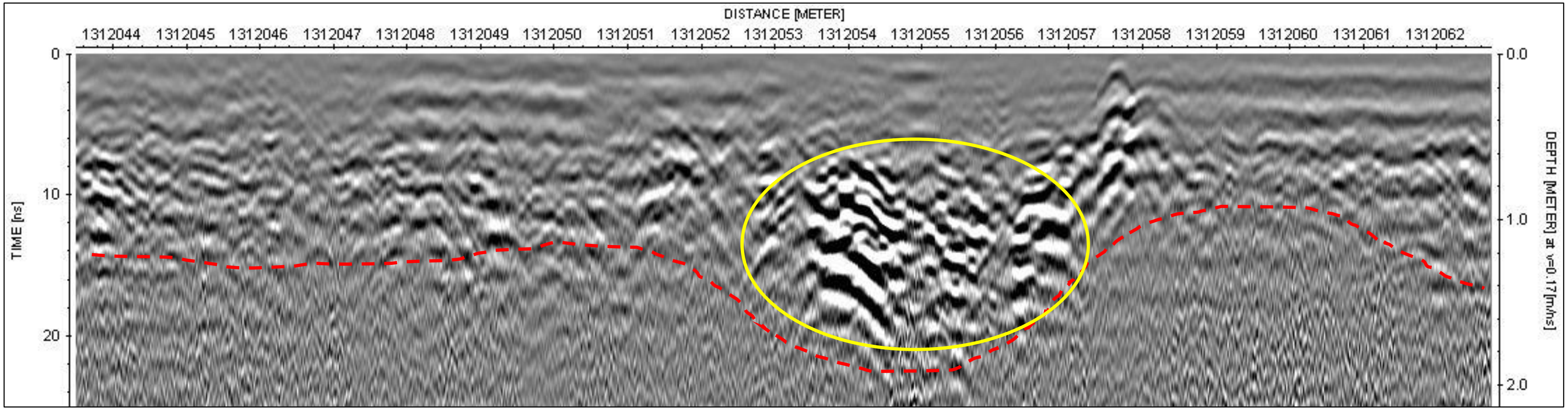



Figure 5.54: Brick factory north GPR line 254 at 20m of Grid 05 red dashed line highlighting the change in topography with ditch which is filled with high-amplitude radar responsive material highlighted in yellow.

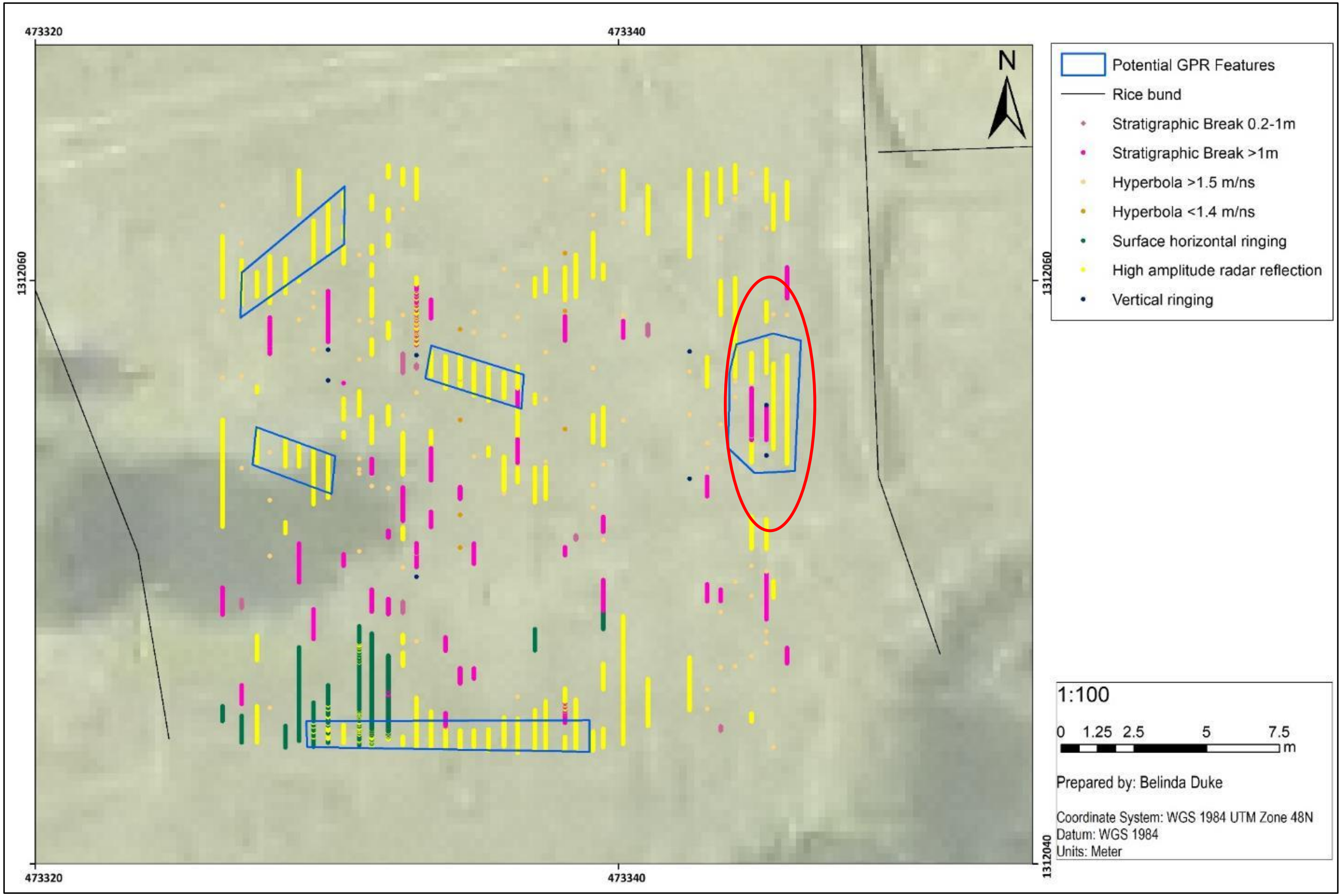



Figure 5.55: Brick factory north GPR Grid 05 sub-surface GPR features. Area highlighted in red corresponds with pit features highlighted in Figure 5.54.

***GPR Grid 06*** had an area of 20x20 metres, with a half-metre line spacing in meandering acquisition and 0,0 located in the southeast corner. Survey direction was orientated west. The grid contained several trees and as a result several of the lines were stopped and restarted the other side of the obstruction. In addition to the trees there was a raised path/rice bund running north to south through the grid, as well as one running east to west in the north-eastern corner (Figure 5.56). These surface features were considered during processing. The high quantity of hyperbolas (>1.5 m/ns) as seen in Figure 5.57, are consistent with research documenting the response of tree roots in the subsurface by Li et al. (2016). The path contains consistent high-amplitude radar reflections that are likely due to construction of the raised path and the continual deposition of modern contaminants. Figure 5.58 shows the interpolation of GPR positioning points for the boundary marking the transition from archaeological material to undisturbed strata. There are several pits of interest which contain high-amplitude radar reflections. These pits appear to be archaeological in nature.

Figure 5.56: Brick factory north GPR Grid 06 looking southwest. Note trees and rice bunds throughout.

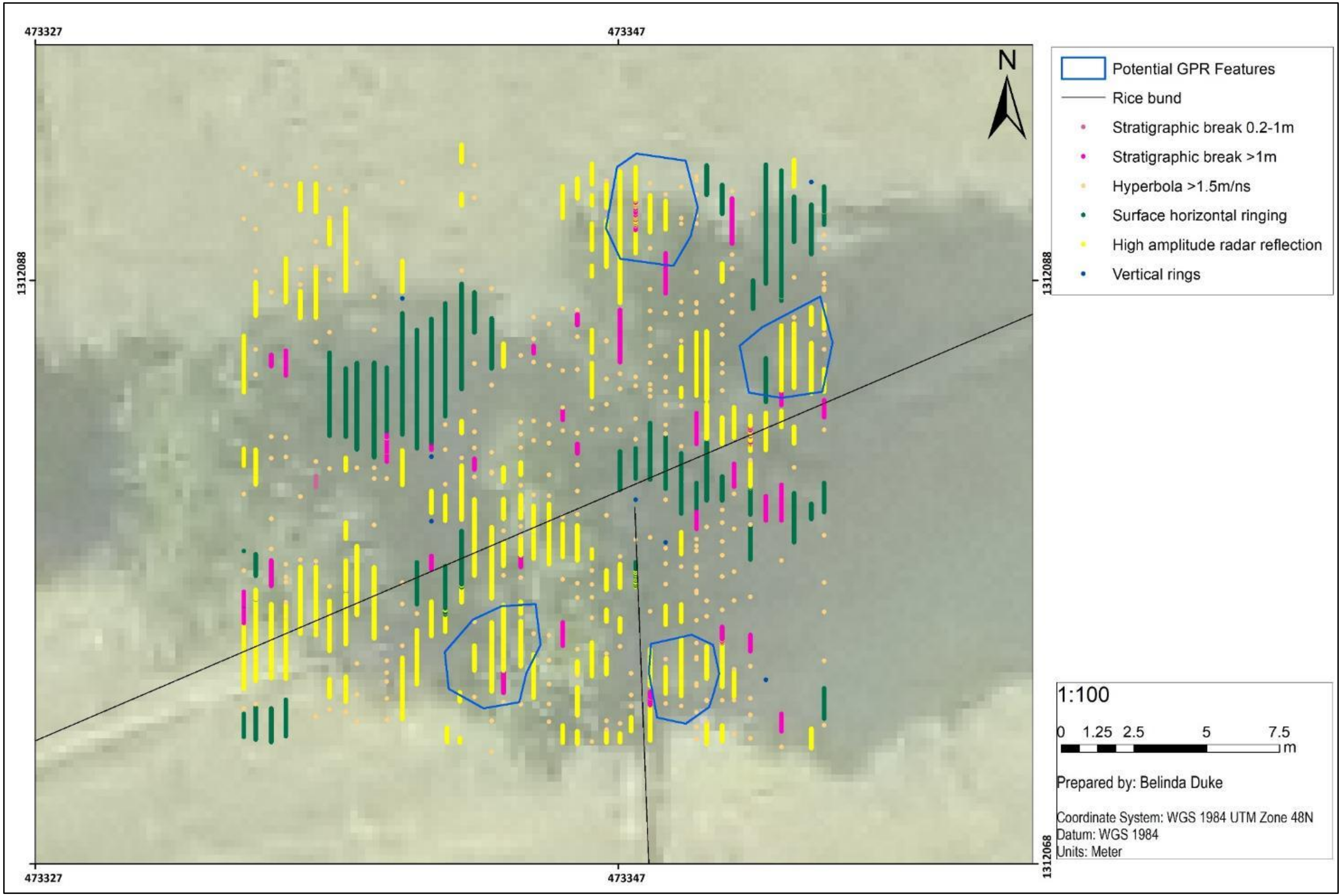



Figure 5.57: Brick factory north GPR Grid 06 with sub-surface GPR features.

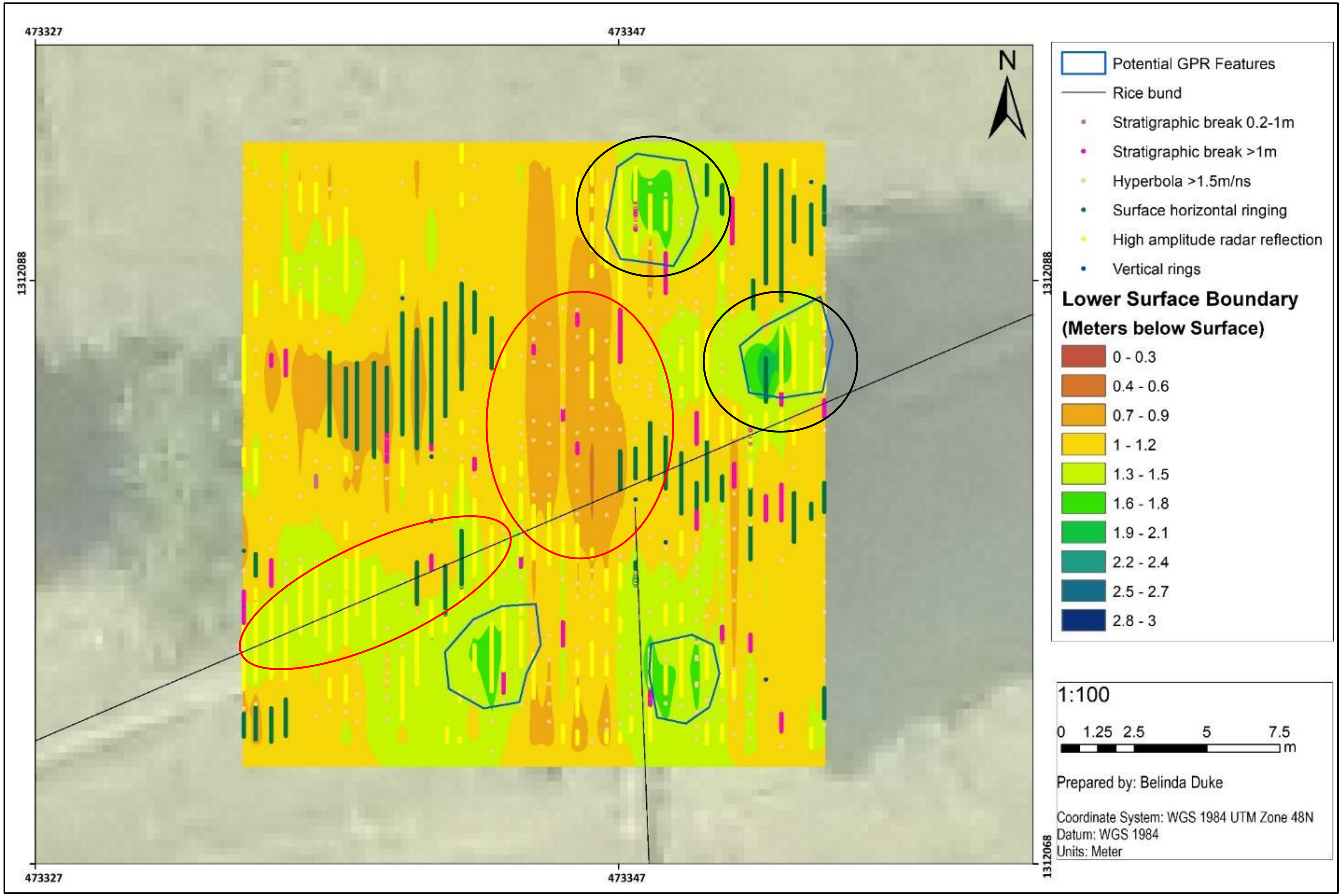



Figure 5.58: Brick factory north GPR Grid 06 interpolation of the lower boundary between archaeological material and undisturbed strata below. Highlighted in red is the area missing data due to trees and pit features in black.

**GPR Grid 07** is an area of 10x20 metres. It had a half-metre line spacing in meandering acquisition and 0,0 was located in the southwest corner (Figure 5.59). The survey direction was orientated west. This grid had a consistent layer of archaeological material present across the entire grid with many hyperbolas in the very near surface (Figure 5.60). The increase in near surface features may be attributed to contamination from the nearby brick factory. The area is flat with a surface feature that seems to align with magnetometer results but does not correlate with any GPR subsurface features. The radar responses here may be modern, although there are consistent high-amplitude features across the profiles shown in Figure 5.61 and Figure 5.62 and mapped in Figure 5.63. These linear features differ to those recorded using the magnetometer and do not appear to be modern. Features of this nature have also been documented in Angkorian context and may represent a pre-Early Modern feature. While the GPR and magnetometer results to not correspond, they do complement each other when mapped in a landscape reconstruction.

Figure 5.59: Brick factory north GPR Grid 07 southwest corner looking northwest.

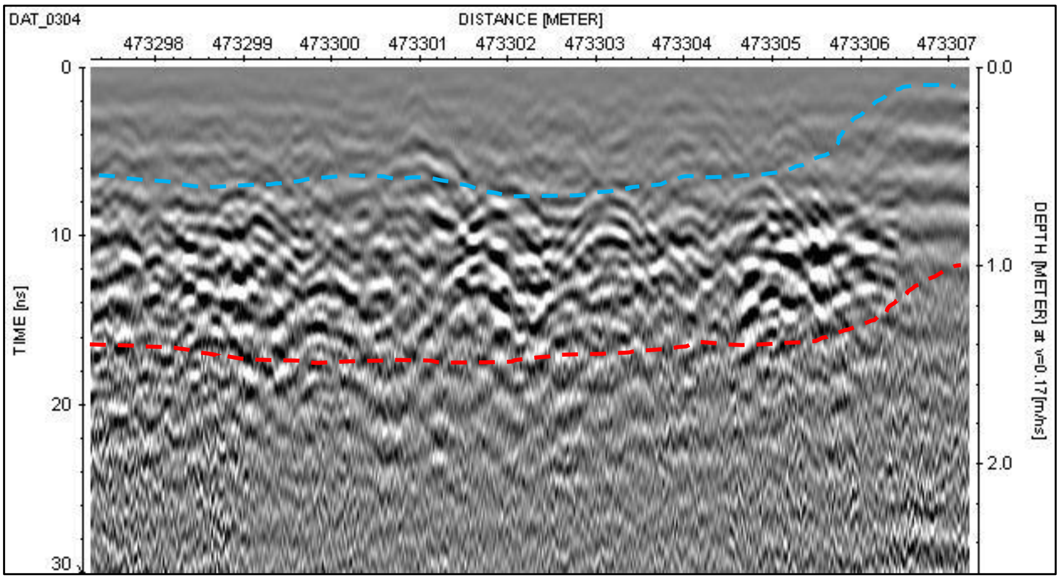



Figure 5.60: Brick factory north GPR line 304 at 1.5m of grid 07. Transition from homogenous strata with little disturbance to area of multiple high-amplitude features (blue) and transition from high-amplitude features to lower level undisturbed strata (red). This defined layer is consistent across Grid 07.

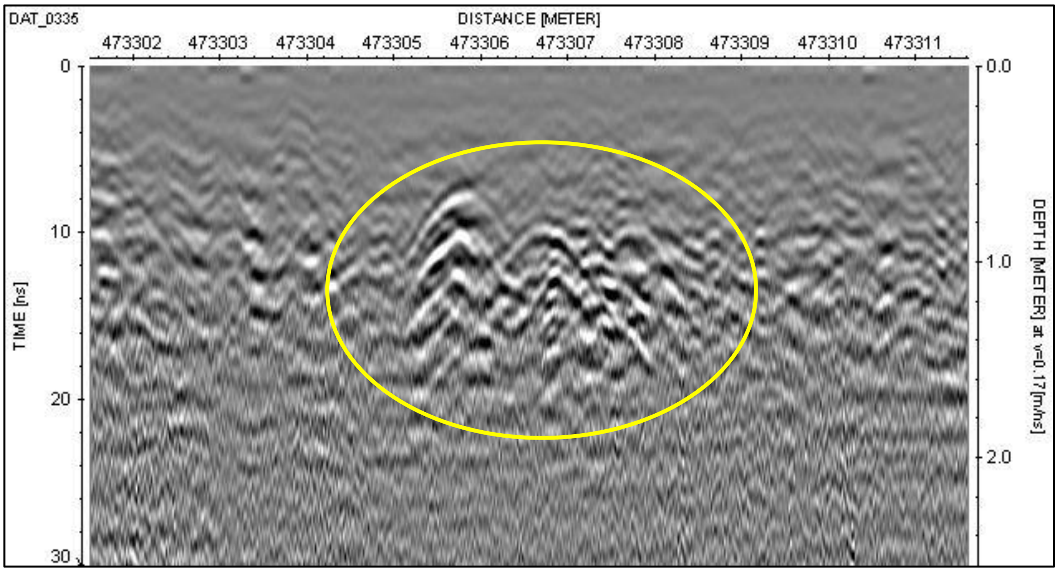



Figure 5.61: Brick factory north GPR line 335 at 17.5m of Grid 07, high-amplitude hyperbola (highlighted in yellow) likely the result of archaeological material. Deep enough in the profile to be unrelated to surface contamination.

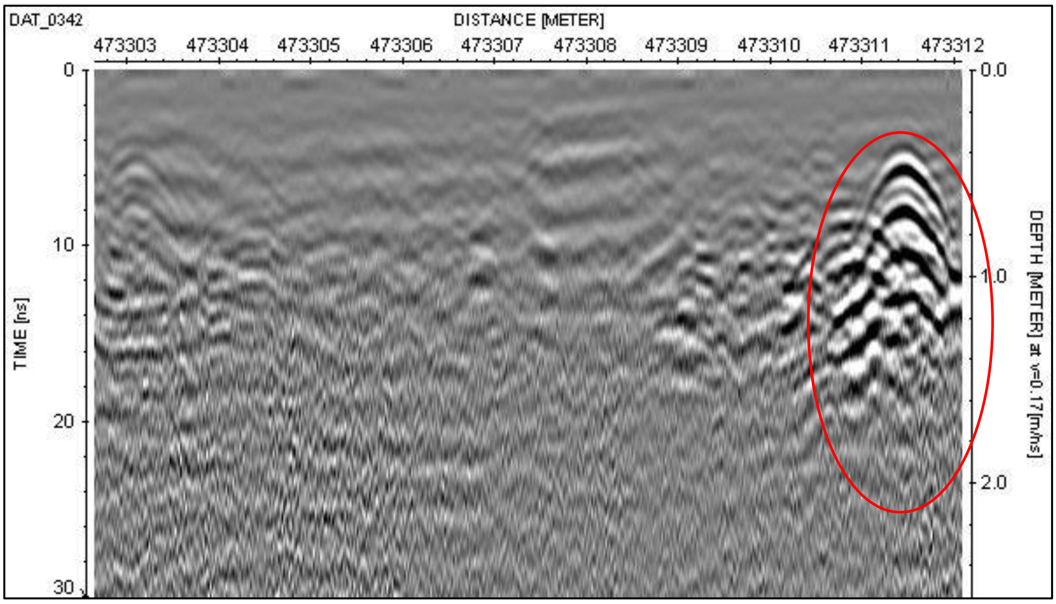



Figure 5.62: Brick factory north GPR line 342 at 20m of Grid 07. Last line in the profile with high-amplitude features and surface horizontal ringing.

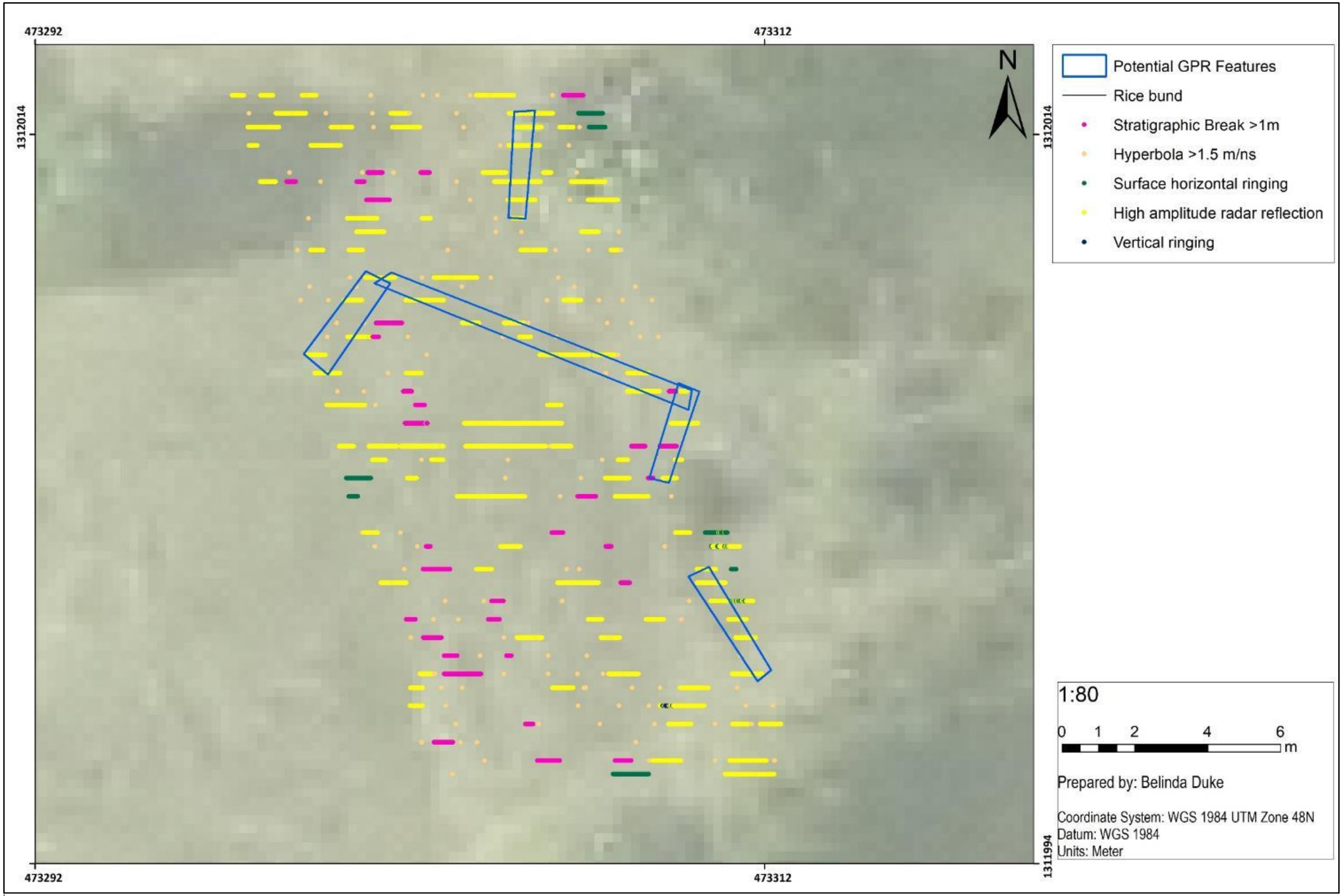



Figure 5.63: Brick factory north GPR Grid 07 with proposed subsurface features.

**GPR Grid 12** covered 20x40 metres. It had a half-metre line spacing with meandering acquisition and the 0,0 was in the southeast corner. Survey direction was orientated west. GPR Grid 12 (Figure 5.64) was established over excavation grids conducted in 2015/16 as a part of *the Middle Period and Related Sites Project*. While this area does not have any magnetometer data, the placement of the grid over excavation trenches allowed for ground verification of GPR results. The area which was excavated is no longer clear on the surface and without positioning information at hand at the time of survey, the grid was established hoping for the best cross over. Excavation trench LVK1501 was 1.5x2 metres, orientated north. The main feature of note was a large pit filled with a loamy sand (7.5YR 4/3 Brown) that contained several cutting events (Figure 5.65). Charcoal, ceramics (earthenware, Chinese trade, porcelain and stoneware) and daub were found in this trench. The trench sections in Figure 5.66 confirm that the layer of archaeological material is no more than a metre thick. When compared to the GPR profile shown in Figure 5.67 that intersects this section, a corresponding layer of archaeological material can be seen.

Figure 5.64: GPR Grid 12 south of the brick factory. Southeast corner looking north. The 2015/16 excavation trenches no longer visible on the surface.

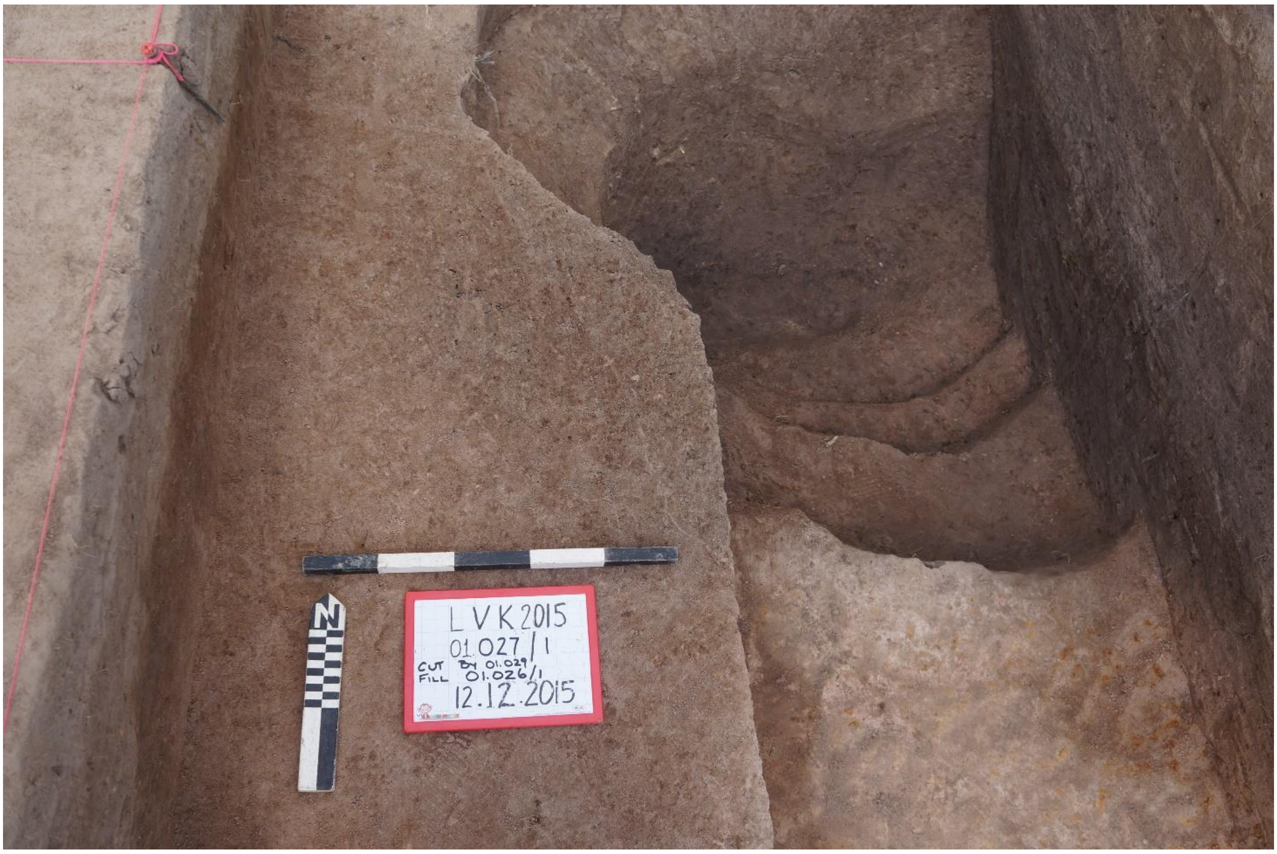


Figure 5.65: Trench 1501 south of the brick factory. Large pit feature excavated (all seen in profile in Figure 5.68). (Used with permission from S. Mackey.)

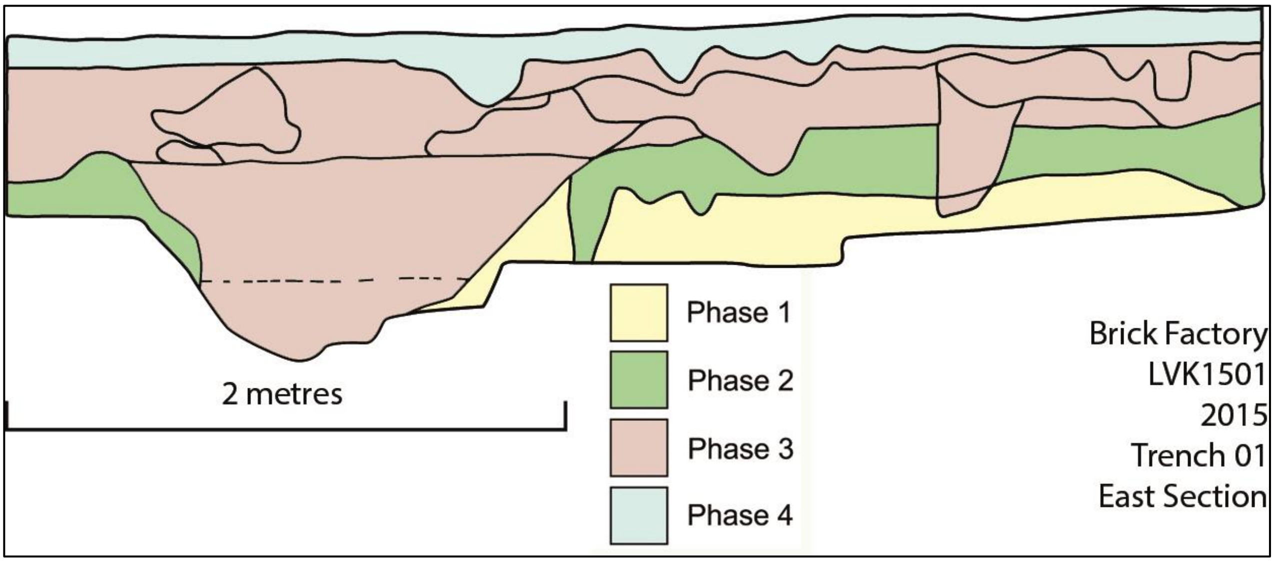



Figure 5.66: Section profiles from trench 1501 south of the Brick factory. Phase 1- increased mottling with lateritic staining, minimal ceramic, Phase 2- friable loamy sand (7.5YR 5/3 Brown) intensification of archaeological material such as ceramics and features, Phase 3- (10YR 3/3 Dark Brown) ceramics contained to pit feature believed to be fifteenth to sixteenth century. Phase 4- friable loamy san (7.SYR 4/3 Brown) topsoil and underlaying 0.20m of soil, mixed with secondary redeposits. (Soil Munsell colours measured when dry)

The archaeological assemblage excavated from this area contained minimal material, with ceramics found throughout. The ceramic inclusions may cause the point source hyperbola. A pit feature was also found in the GPR profiles as shown in Figure 5.68 that corresponds with the interpolated lower surface boundary mapped in Figure 5.70. The radar response within the pit feature would suggest it contains material with a high relative dielectric permeability. Comparing the two features, the material found in the excavated pit, such as fired daub and ceramic, could also be represented in the radar data in the second pit. The greatest variability is the depth. The excavated material was located approximately 1.5 metres below the surface, while the GPR survey indicated that the base of the pit is approximately 2.5 metres below the surface.

The angle and sediment composition of trench LVK1625 has made it difficult to identify it in the GPR profiles. This trench was stopped at approximately 1.3 metres below the surface as they believed they had reached a sterile natural surface but the GPR data suggests there was evidence of culturally modified sediment material below this level up to approximately 3 metres. This disparity between the sterile excavation level and the GPR lower boundary may suggest there is an issue with the depth calculated in ReflexW or that there was more archaeological material below the excavated depth. The lower surface interpolated and mapped in Figure 5.70 may be the horizon between the natural substrate, with purposefully deposited material represented as the layer of culturally modified sediment. The variation between the two sediment layers may be geological and the material present is the result of laterite which was noted as stains in the excavation section in Figure 5.66.

Within the GPR profiles the upper and lower surface boundaries that contain the archaeological material were interpreted and their positioning interpolated into a sub-surface topographic reconstruction. Figure 5.69 is the subsurface topographic reconstruction of the upper boundary between the largely homogeneous topsoil and the archaeological material below. This figure shows that this surface is undulating, and contains several larger features varying up to 30 centimetres in depth. Figure 5.70 is the subsurface topographic reconstruction of the lower boundary separating archaeological material from the homogeneous sediment below. This topography shows an undulating surface with greater variance than the upper boundary. These features are mapped and considered within the reconstruction. Figure 5.71 is the distribution of different GPR responses mapped from all the profiles. The area has a very high number of high-amplitude radar responses, contrasting with defined quiet areas that are devoid of GPR features. The area also has a high volume of high-amplitude hyperbolas, which are consistent with proximity to the brick factory causing near subsurface contamination.

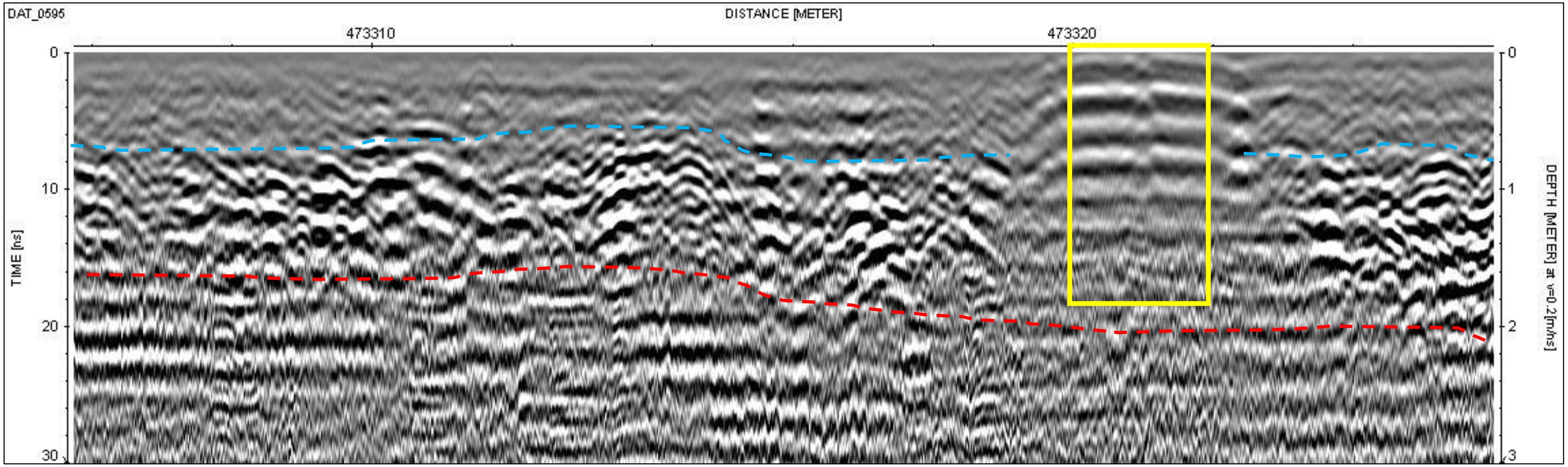



Figure 5.67: South of the brick factory GPR line 595 at 34m of Grid 12. Highlighted excavation trench 1501 in yellow represented as a stratum break, upper surface horizon in blue and lower surface horizon in yellow. Archaeological deposit here 1.5-2m deep. Comparable to excavation section drawing in Figure 5.66 view south.

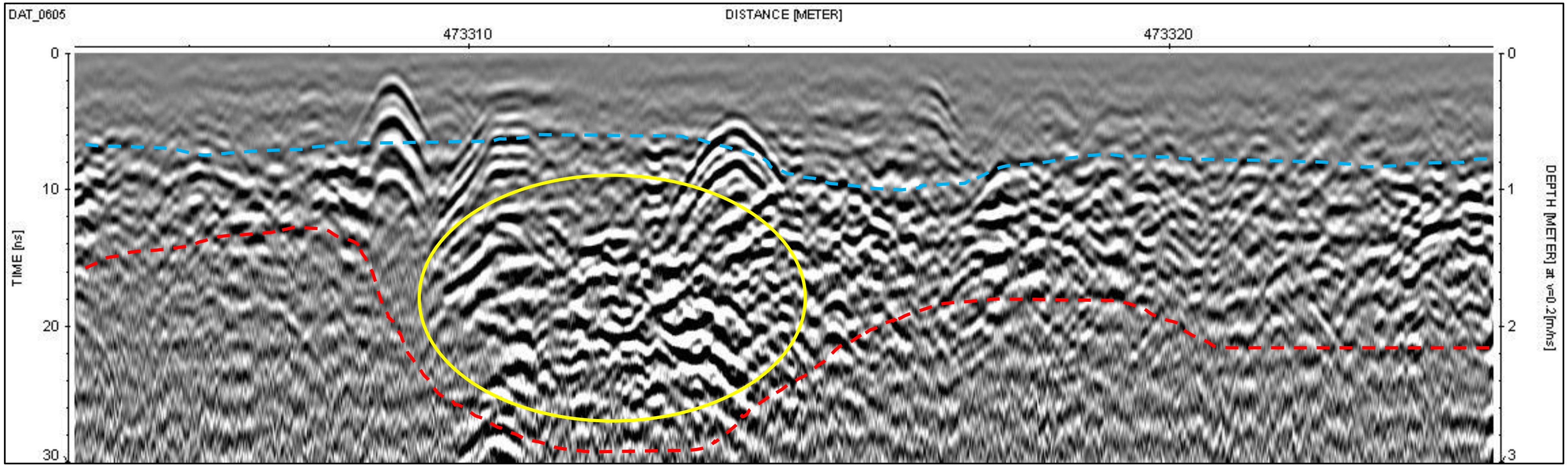



Figure 5.68: South of the brick factory GPR line 605 at 39m of Grid 12. The last line in the survey grid, highlighted in blue the upper sediment horizon and lower in red. Note in yellow a pit filled with high-amplitude radar responses. Pit may be comparable to that found during excavation in Figure 5.65.

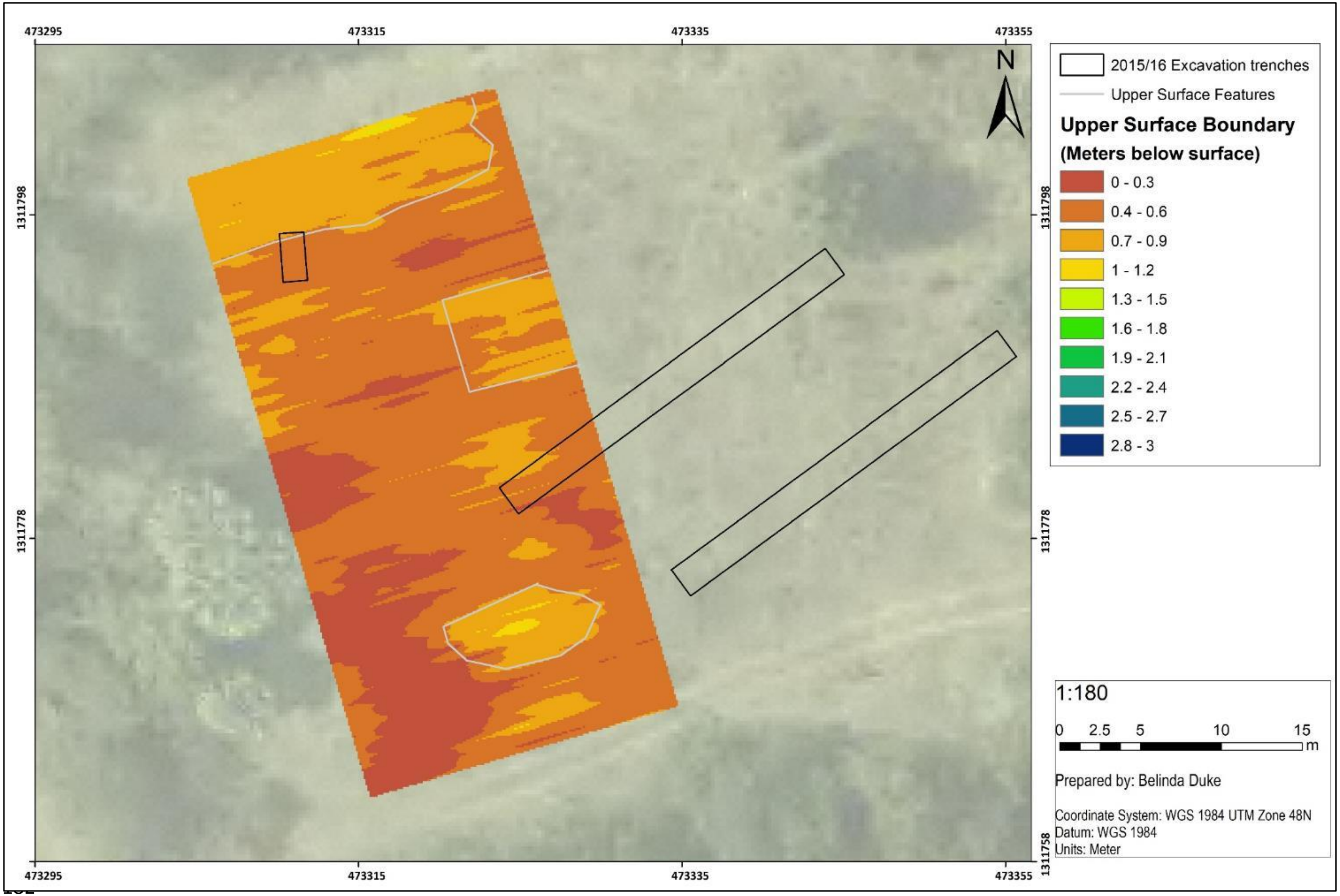



Figure 5.69: GPR Grid 12 south of the brick factory sub-surface topographic reconstruction of the upper surface boundary identified within the profiles.

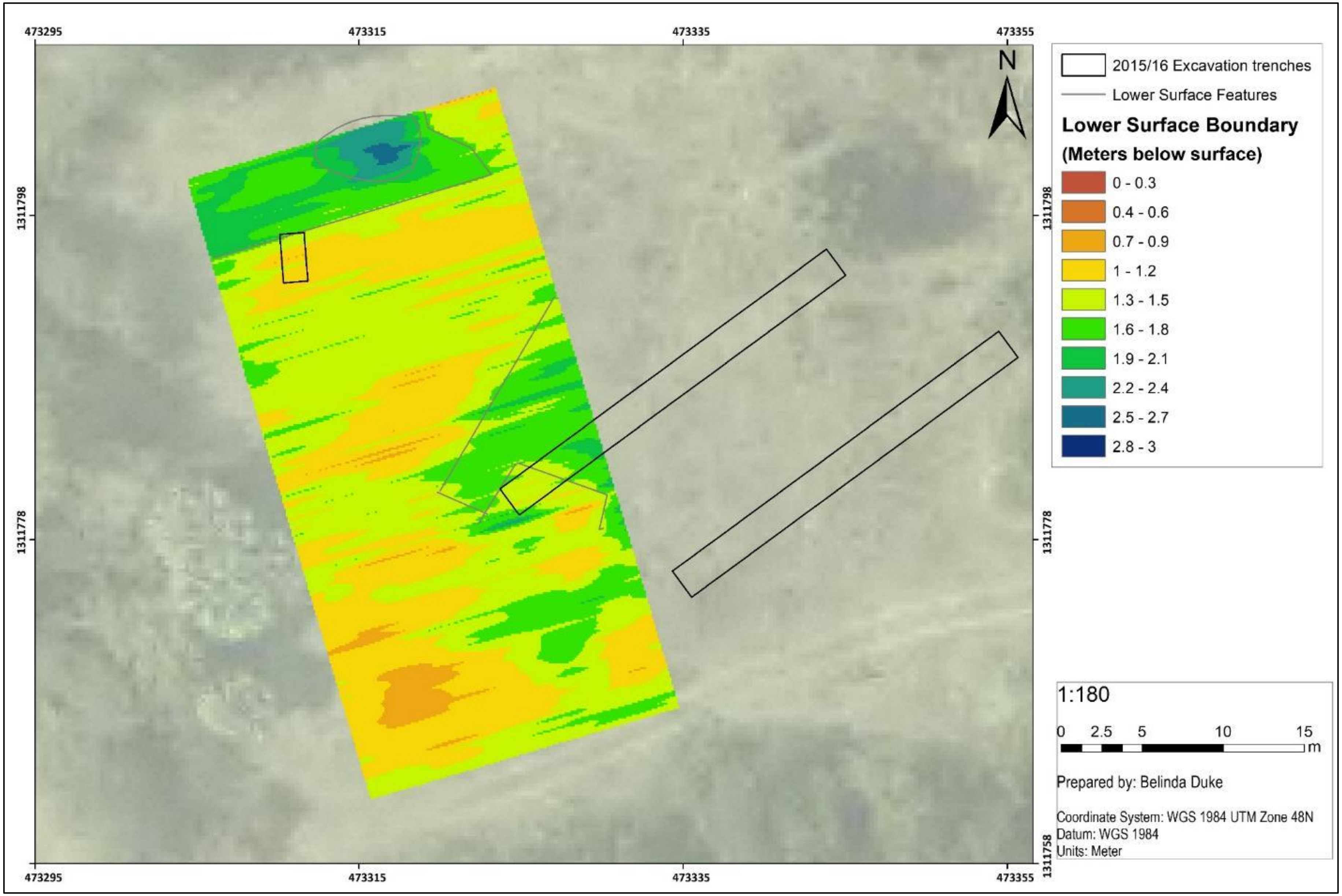



Figure 5.70: GPR Grid 12 south of the brick factory sub-surface topographic reconstruction of the lower surface boundary.


Figure 5.71: GPR Grid 12 sub-surface features. Note high volume of high-amplitude radar reflections present here.

##### 5.3.3.3 *Brick Factory - Proposed Landscape Reconstruction*

Based on the magnetometer features shown in Figure 5.45 and GPR features in Figure 5.72, Figure 5.73 is a proposed reconstruction of the landscape. This reconstruction is based on the configuration of magnetic features and high-amplitude radar responses. The feature identified in GPR Grid 04 that is interpreted as a pond is an exception to this, as it was reconstructed from the GPR profiles based on depth. GPR Grid 04 when considered in conjunction with the magnetometer data, shows that there are no magnetic responses that correlate with the GPR features, it is suggested that the depth of the pond feature is below the prospection depth of the magnetometer and that the related magnetic features postdate the construction and filling of the feature. Much like the distribution of magnetic features, the possible structures are more prevalent within the treelined surveyed area closer to the brick factory. The two structures most likely associated with the proposed palace were found in GPR Grid 12 and were determined by the amount of high-amplitude radar anomalies found around them. The density of magnetic features found throughout would suggest the entire area surveyed with the magnetometer was culturally modified.

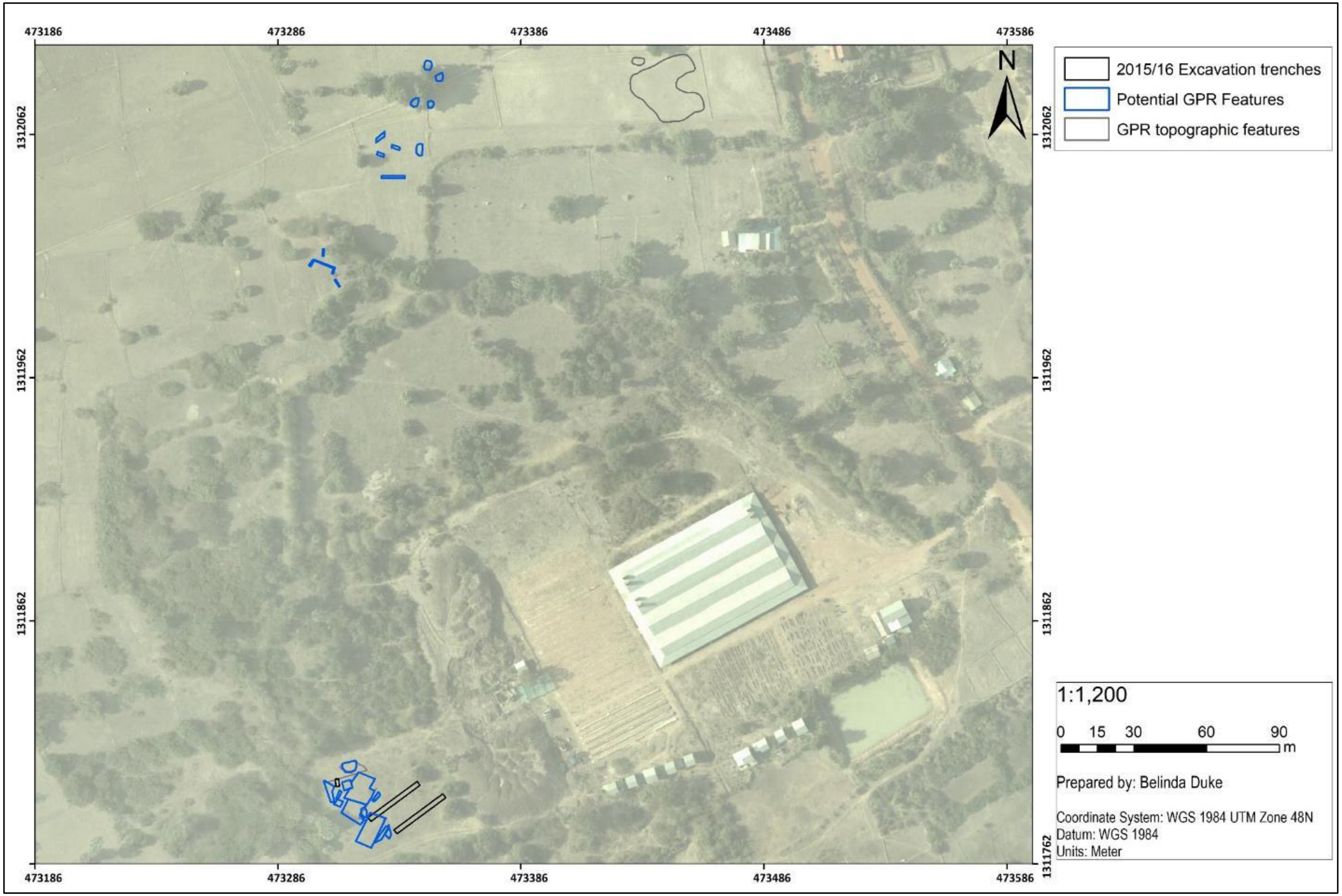



Figure 5.72: Brick factory north proposed GPR subsurface features.

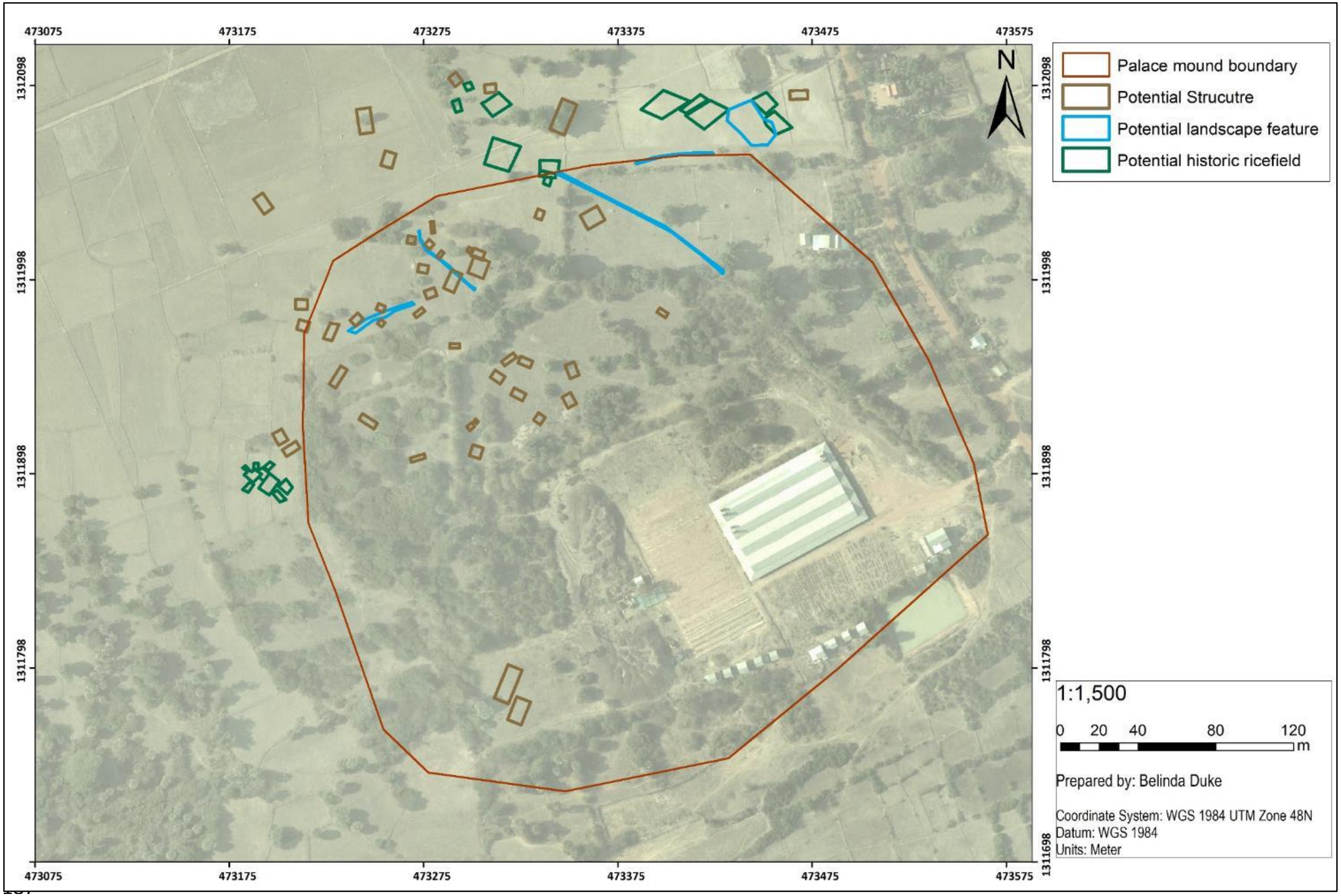



Figure 5.73: Brick factory north reconstruction of the landscape based on Magnetometer and GPR surveys.

### 5.3.4 Wat Tralaeng Kaeng South

Wat Tralaeng Kaeng appears to be an eleventh century Angkorian religious complex which underwent modification in the Early Modern period, and is still used as a Theravāda Buddhist monastery. The area directly south and southeast was chosen for survey due to the high quantity of surface ceramics that were collected during 2018 archaeological investigations. Figure 5.74 shows the area surveyed using magnetometry and GPR.

#### *5.3.4.1 Magnetometer*

The magnetometer survey was conducted from December 2018 to January 2019. A Bartington Grad 601 dual sensor magnetometer was used throughout. The area was largely open flat rice fields, although some were inaccessible at the time of survey due to rice harvesting. The easternmost area of the survey was conducted on terraced rice fields, which resulted in the mapped patchwork effect when the data were placed in a GIS framework. The mean nanoTesla value and standard deviation were found for all magnetic grids. The standard deviation set the display parameters for the magnetic data. Once plotted and processed, features were identified over anomalies identified at three (Figure 5.75), two (Figure 5.76) and one (Figure 5.77) standard deviations from the mean and nanoTesla values. To determine possible archaeological features from this landscape, dipole and monopole features at three standard deviations were not considered. Linear and high nanoTesla value anomalies were included in the feature map to examine how they related to other features. Through this process of elimination Figure 5.78 was produced and from this, features were identified and mapped in Figure 5.79.

The high value features identified at three standard deviations from the mean were not discarded, as they very likely represent modern activities. The magnetometer survey revealed several high nanoTesla value subsurface features. During this survey local informants were able to tell us that and area southeast of Wat Tralaeng Kaeng had been used as a bomb shelter dugout for a period, although they were not clear on the time frame or exact location. The magnetometer survey confirms that the area has been disturbed, with three features requiring further investigation. The linear nature, shape and high nanoTesla value of these features warranted examination with the GPR.

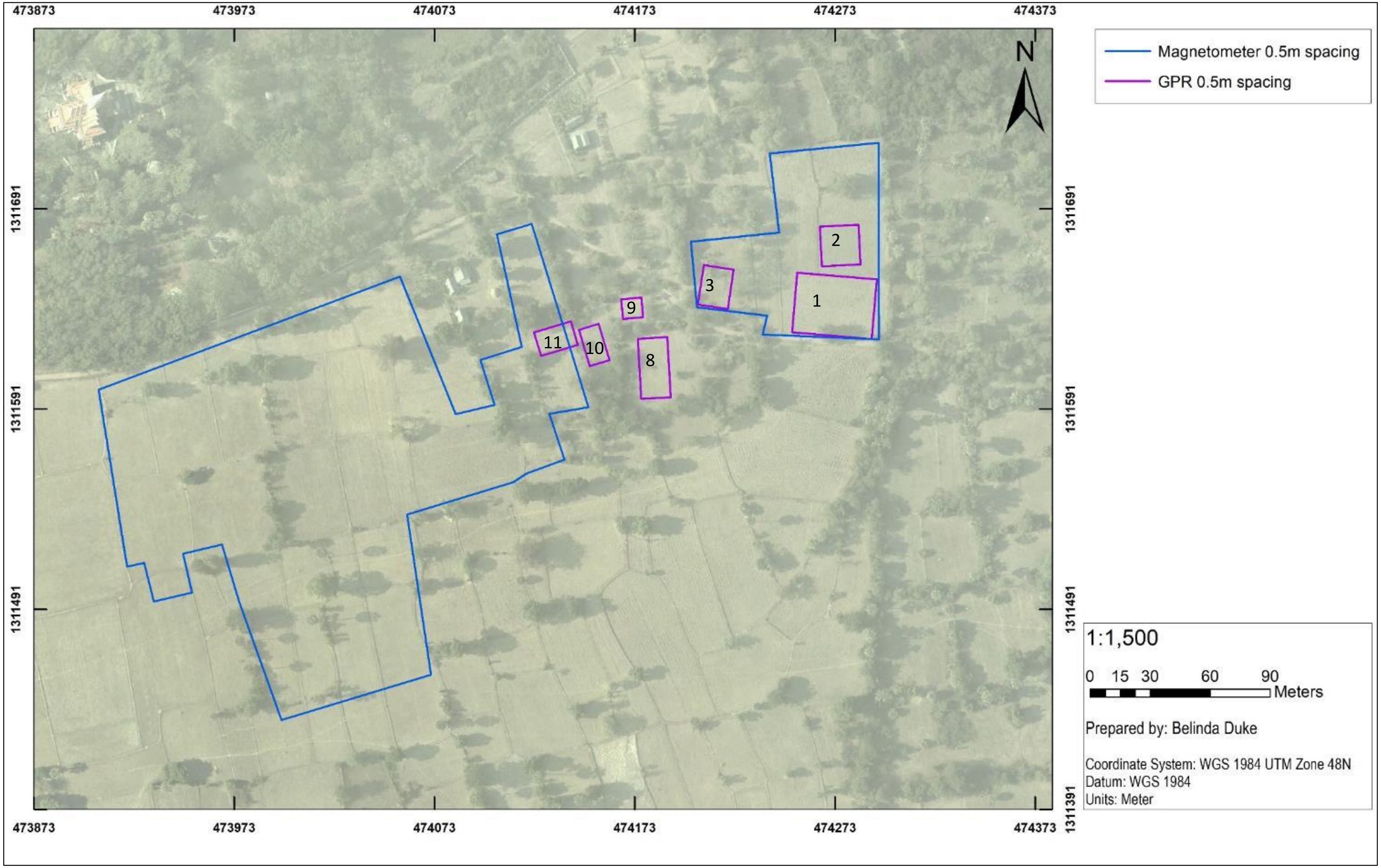



Figure 5.74: Wat Tralaeng Kaeng South geophysical survey area, dual sensor Bartington 601 and 500mHz antenna, with GPR grids numbered.


Figure 5.75: Wat Tralaeng Kaeng South geophysical survey. Gridding either in 20x20m or 10x10m squares magnetometer results presented with the nT range three standard deviations (-18.79 – 20.47 nT) from the mean.


Figure 5.76: Wat Tralaeng Kaeng South geophysical survey. Gridding either in 20x20m or 10x10m squares magnetometer results presented with the nT range two standard deviations (-12.8 – 14.1nT) from the mean.


Figure 5.77: Wat Tralaeng Kaeng South geophysical survey. Gridding either in 20x20m or 10x10m squares magnetometer results presented with the nT range one standard deviations (-5.8 – 7.5nT) from the mean.


Figure 5.78: Wat Tralaeng Kaeng South geophysical survey, with all magnetometer survey features presented.


Figure 5.79: Wat Tralaeng Kaeng South potential features from magnetometer survey.

### *5.3.4.2 Ground Penetrating Radar (GPR)*

**GPR Grid 01** covered an area of 30x40 metres. Like all other grids, it used a half-metre line spacing with meandering acquisition. Point 0,0 was located in the southwest corner and survey was oriented north. This grid was established to investigate high value magnetic features identified during the magnetometer survey. The survey area was open ground over a rice field that has not been used for several seasons, and was in use for grazing cattle at the time of the survey (Figure 5.80). The GPR response is largely homogeneous, as seen in Figure 5.81 and Figure 5.82. Figure 5.83 plots these radar responses, demonstrating the distinct lack of archaeological features, especially when compared to other grids. The use of the land, the high prevalence of section breaks, and low volume of features would suggest that the radar responses are indicating changes that are modern in nature. The high value magnetic response does not appear in the GPR profile and is interpreted as the result of modern activity, however without verification through excavation this cannot be confirmed.

Figure 5.80: GPR Grid 01 Wat Tralaeng Kaeng South.

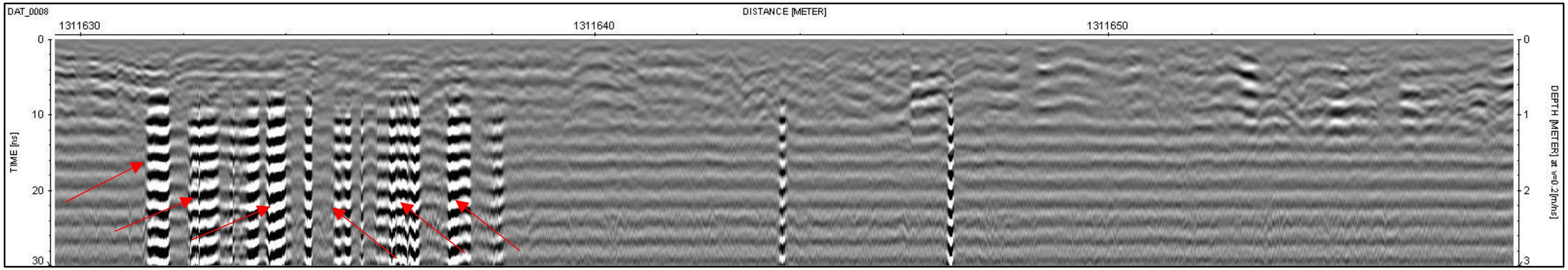



Figure 5.81: GPR line 11 at 8m of Grid 01, Wat Tralaeng Kaeng south, limited subsurface material identified in this in this grid. Note vertical ringing, highlighted in red, likely caused by material with a high relative dielectric permeability.

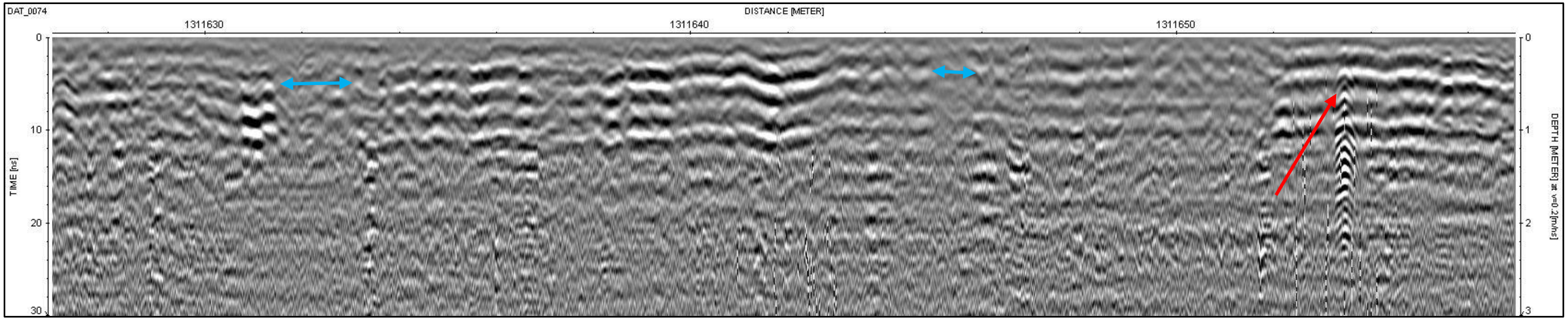



Figure 5.82: GPR line 74 at 34.5m of Grid 01, Wat Tralaeng Kaeng South. Section breaks found across area and are likely the result of farming activity (in blue). Vertical ringing highlighted in red likely the result of metal in the subsurface.

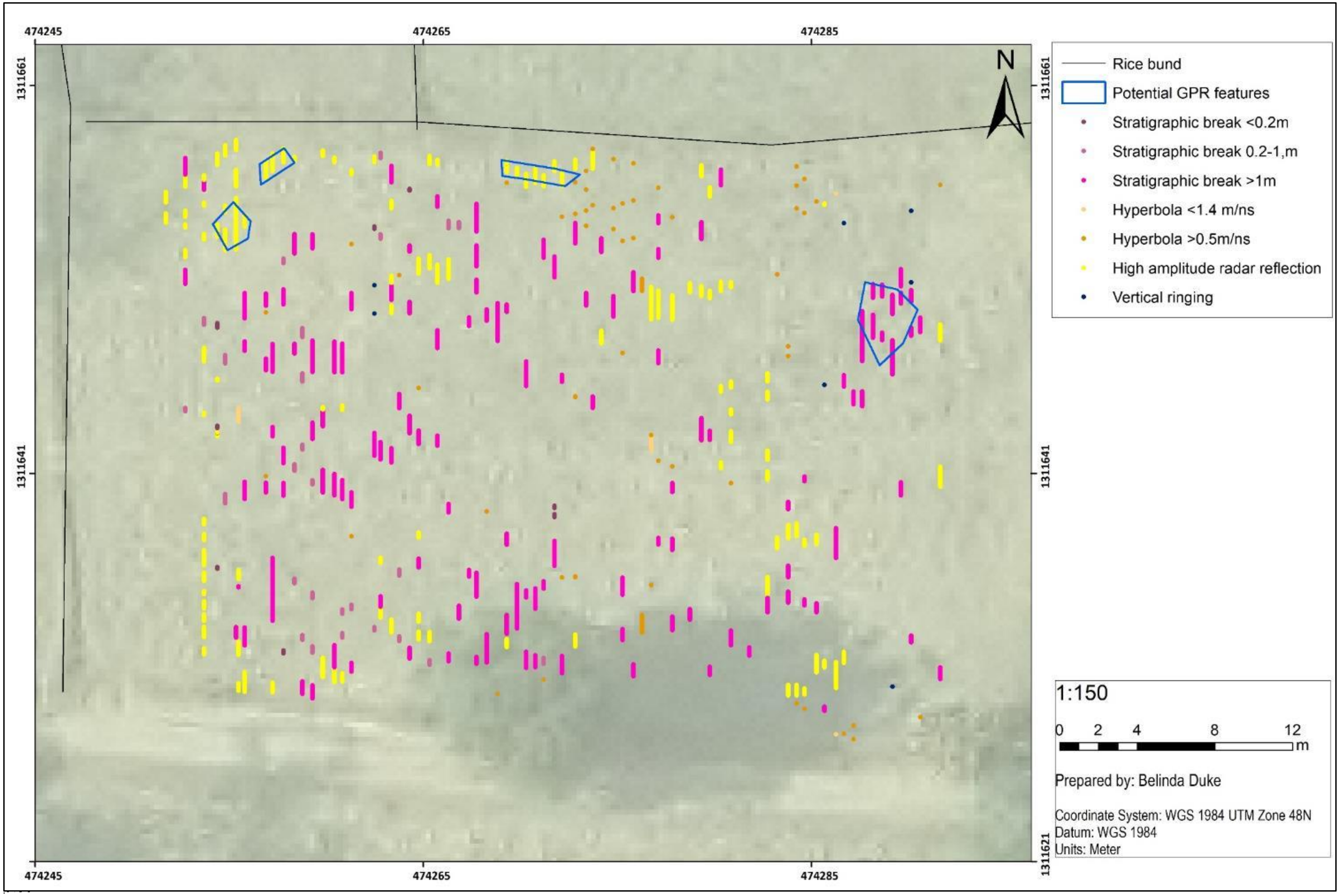



Figure 5.83: GPR Grid 01 Wat Tralaeng Kaeng South. Radar response reflects homogenous nature of the sediment with high prevalence of section breaks. Features identified are likely modern.

**GPR Grid 02** with had an area of 20x20 metres, and used a half-metre line spacing with meandering acquisition, and 0,0 in the southwest corner; the survey was orientated north (Figure 5.84). Like GPR Grid 01, there is little radar response found here, although the mapped features are located beneath the plough line which is clearly visible in Figure 5.85. Figure 5.86 shows the large number of section breaks that are wider than one metre in this grid. It is difficult to determine if they are historic in nature or the result of modern farming activity because the farming activities in the area—such as the creation and maintenance of the terraced rice fields—has heavily disturbed the subsurface.

Figure 5.84: GPR Grid 02 Wat Tralaeng Kaeng South. Looking west.

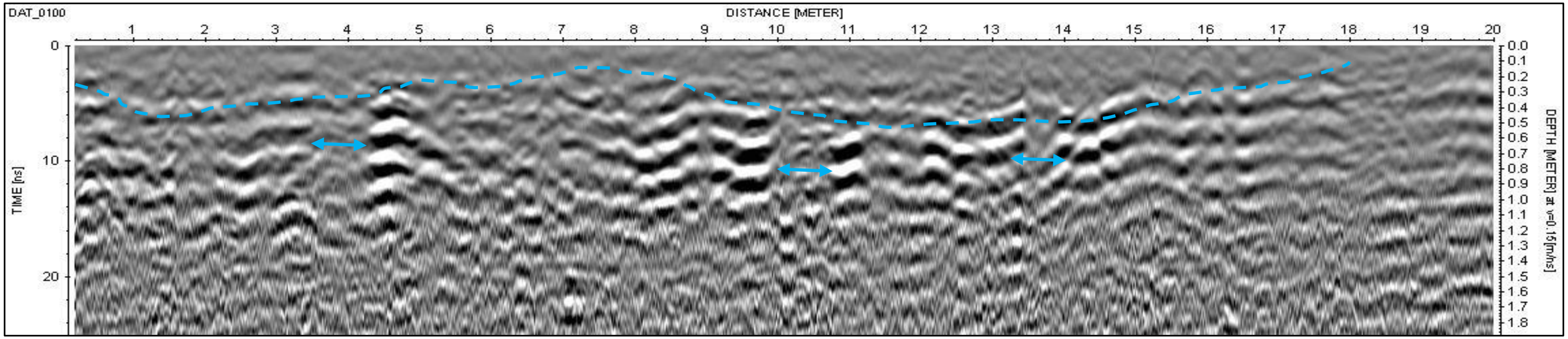



Figure 5.85: GPR line 100 at 7m of Grid 02 Wat Tralaeng Kaeng south, profile of a GPR showing line breaks (blue arrows) like Grid 01. Section breaks are below the plough line (highlighted with blue dashed line).

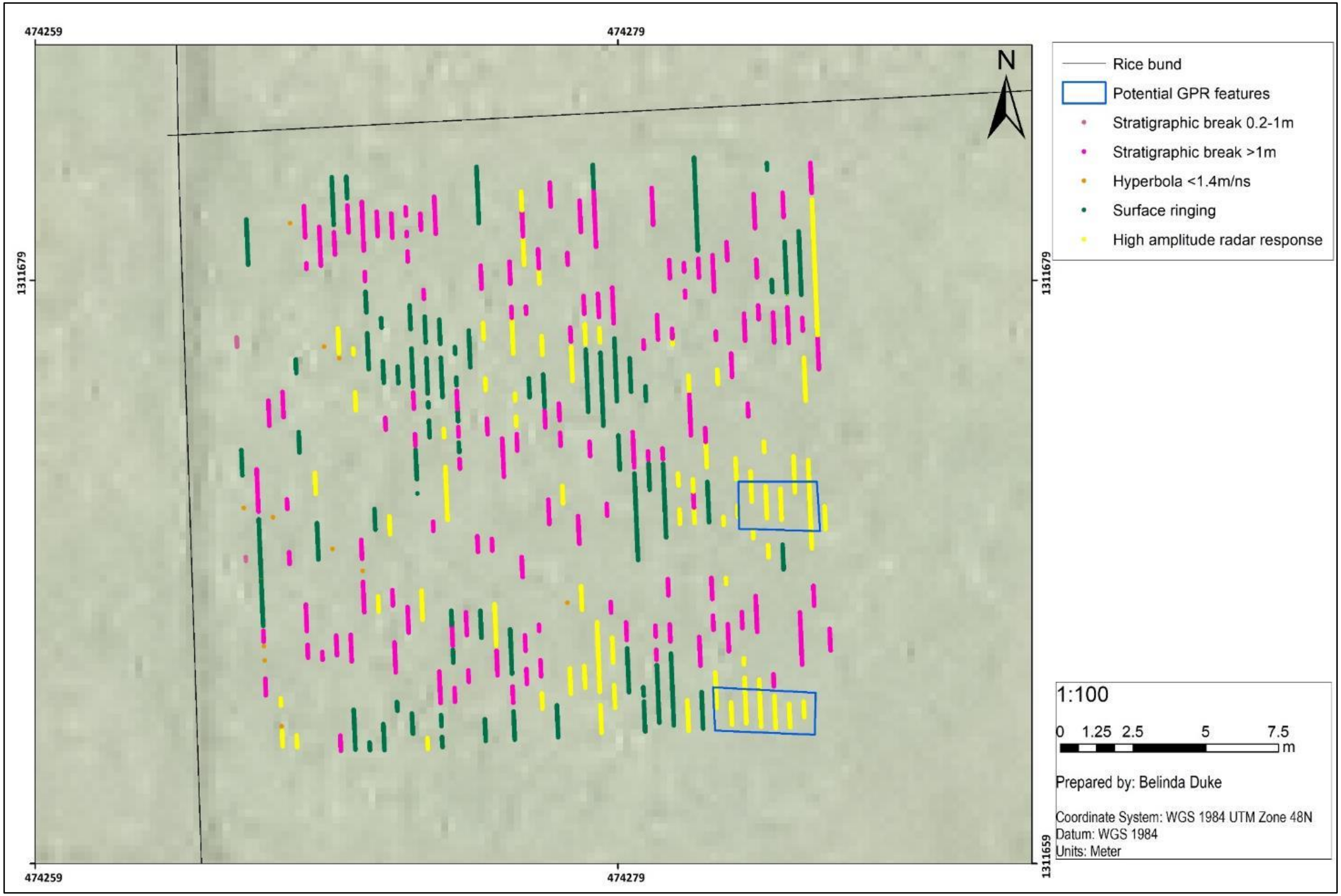



Figure 5.86: GPR Grid 02 Wat Tralaeng Kaeng south. Area contains a high volume of section breaks, like Grid 01. Likely due to ongoing farming activities.

**GPR Grid 03** covered an area of 20x15 metres, used a half-metre line spacing with meandering acquisition and 0,0 located in the southwest corner; survey was orientated north. The area had been cleared before the survey and Figure 5.87 shows that the topsoil had been removed. The most prominent features identified in the geophysical survey are the surface horizontal ringing (Feature A Figure 5.88) and high-amplitude radar reflections (Feature B Figure 5.88). The GPR profile in Figure 5.88 is indicative of the features found in the area. There is a distinct lack of subsurface material resulting from the clearance and removal of historic material. An interesting feature is the area between Feature A and B which has a uniform radar response. Three potential features can be identified here, all of which appear to have undergone a process of construction and rapid infilling. The high value of the magnetometer response and GPR response suggest this feature is modern in nature.

Figure 5.87: GPR Grid 03 Wat Tralaeng Kaeng south. Open ground surface with some ceramics visible. Topsoil removed month before the survey.

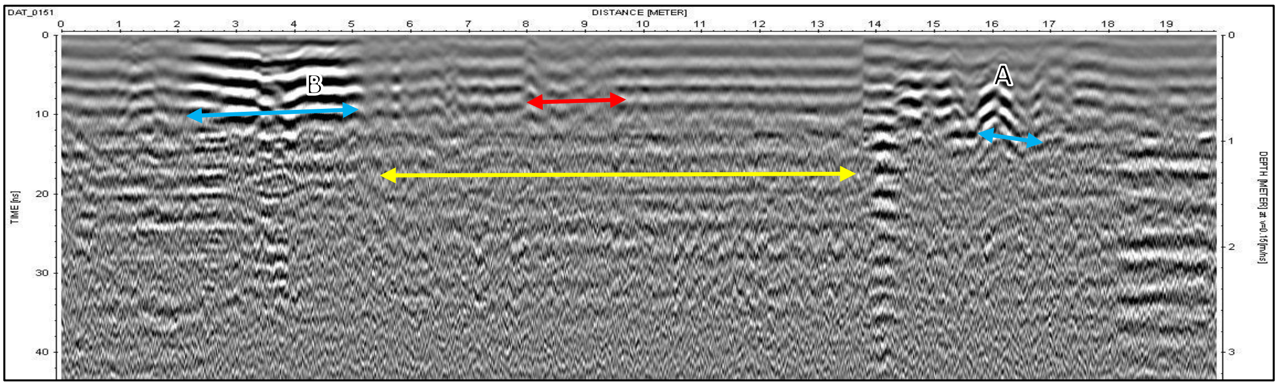



Figure 5.88: GPR line 151 at 11m of Grid 03 Wat Tralaeng Kaeng south, feature A and B are consistent across a series of profiles, and when mapped in Figure 5.89 form a unified shape across the area which corresponds with the magnetometry results. Also present but not represented in the magnetometry is a section break at the centre of the profile (red) and the area of largely homogenous activity (yellow).

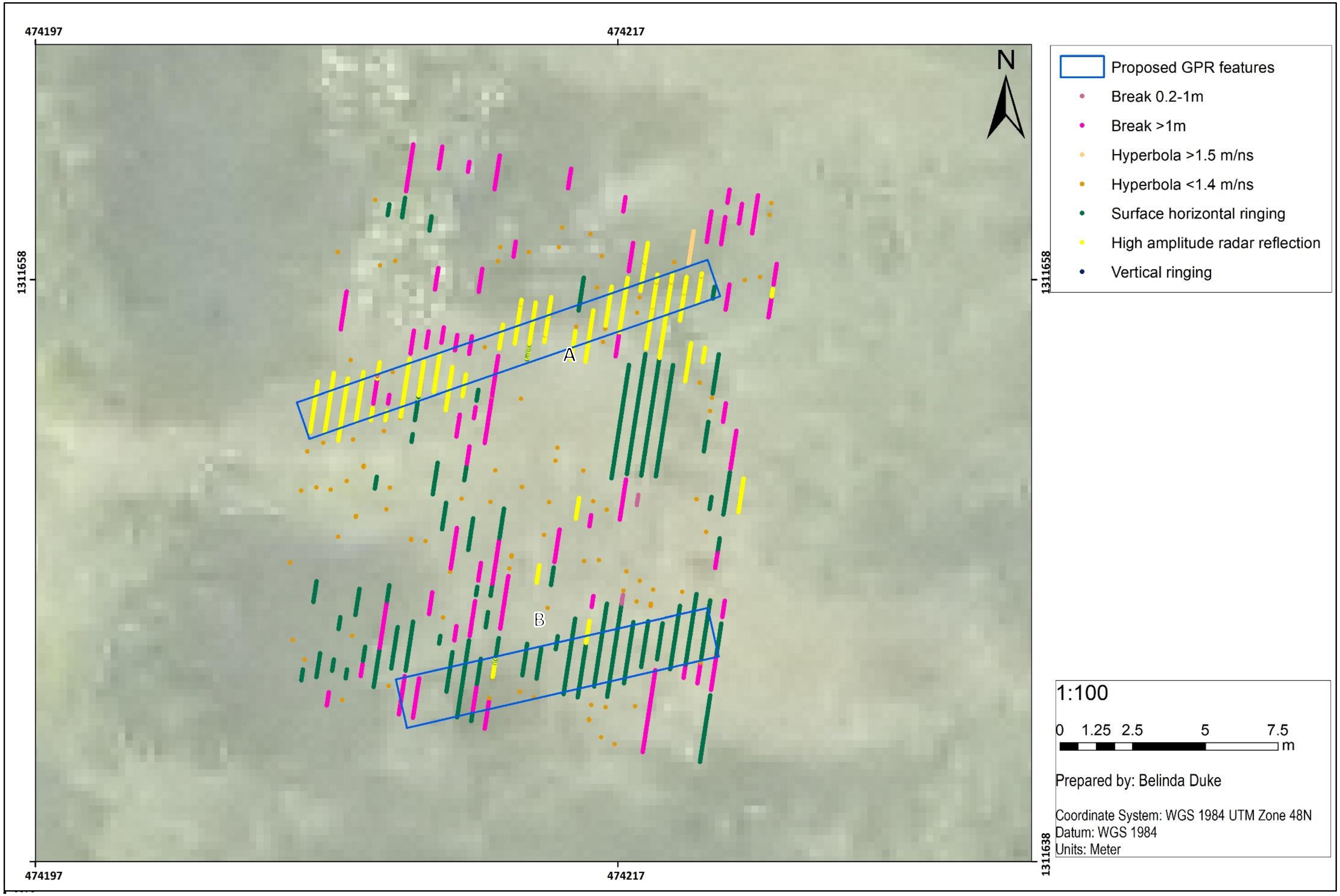



Figure 5.89: GPR Grid 03 Wat Tralaeng Kaeng south, features A and B corresponding with features in Figure 5.88. These distinct features were also found in the magnetometer results.

**Grid 08** covered an area of 15x30 metres, and used a half-metre line spacing with meandering acquisition and 0,0 located in the southeast corner; survey orientation west. Figure 5.90 shows the tree lined area as relatively flat, with small shrubs and trees present. The area also contained animal disturbance in the form of burrows. The GPR transects went around these obstacles where possible or the line was stopped and restarted. The area has a high number of point source hyperbolas compared to nearby grids 01, 02 and 03. The high-amplitude of these hyperbolas would suggest they are metal and a modern contaminant. Figure 5.91 and Figure 5.92 show typical features identified in the GPR profile and Figure 5.93 shows these mapped. The high-amplitude radar responses cluster to the north of the grid. The shape of these have been defined in Figure 5.93.

Figure 5.90: GRP Grid 08 Wat Tralaeng Kaeng south. Uneven surface with small shrubs and trees within the grid. Also present, large holes in the ground.

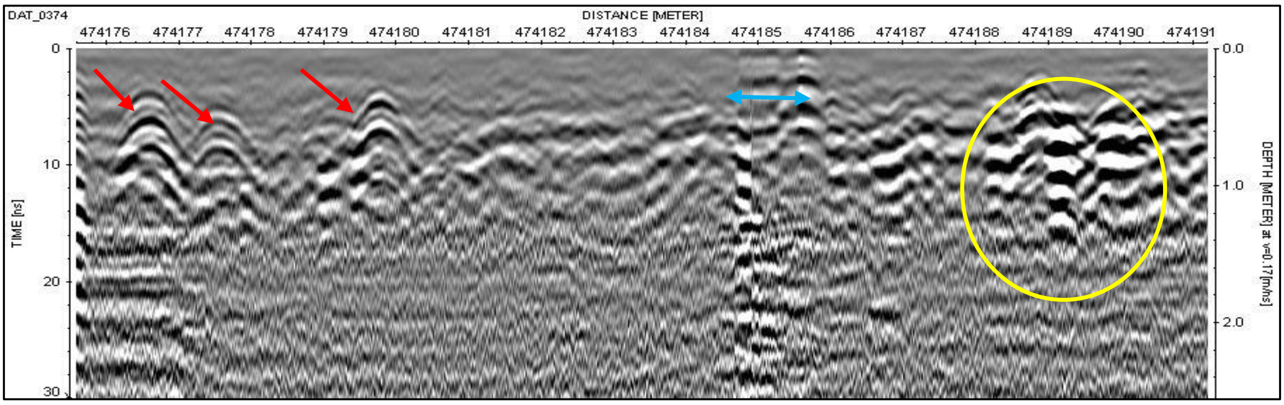



Figure 5.91: GPR line 374 at 13.5m of Grid 08 Wat Tralaeng Kaeng south. Area contains a high volume of hyperbola (red) and surface ringing (blue). High-amplitude radar reflections (yellow) also present.

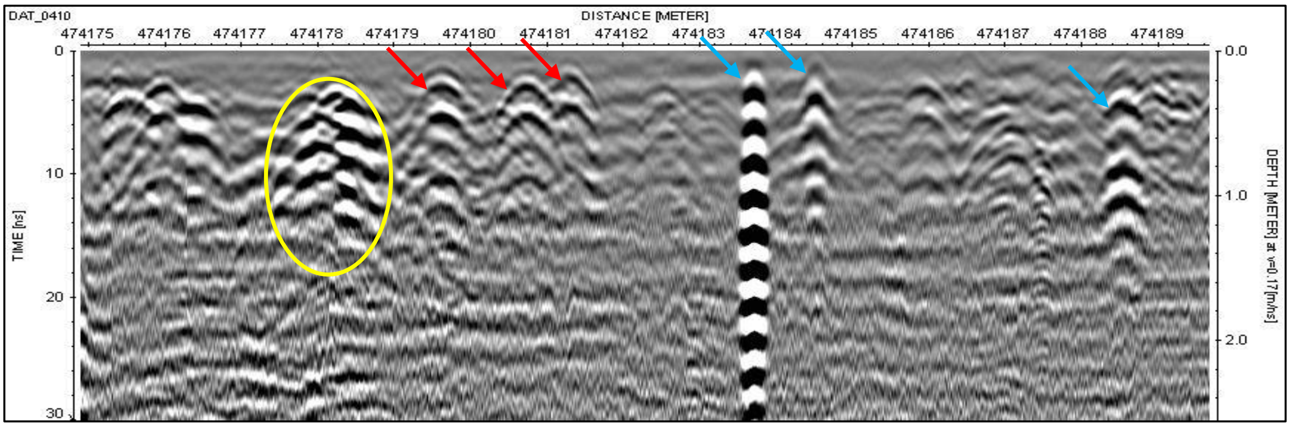



Figure 5.92: GPR line 410 at 30m of Grid 08 Wat Tralaeng Kaeng south. Continuation of the hyperbola (red) but also in this profile is high-amplitude vertical ringing (blue) and thing but in yellow.

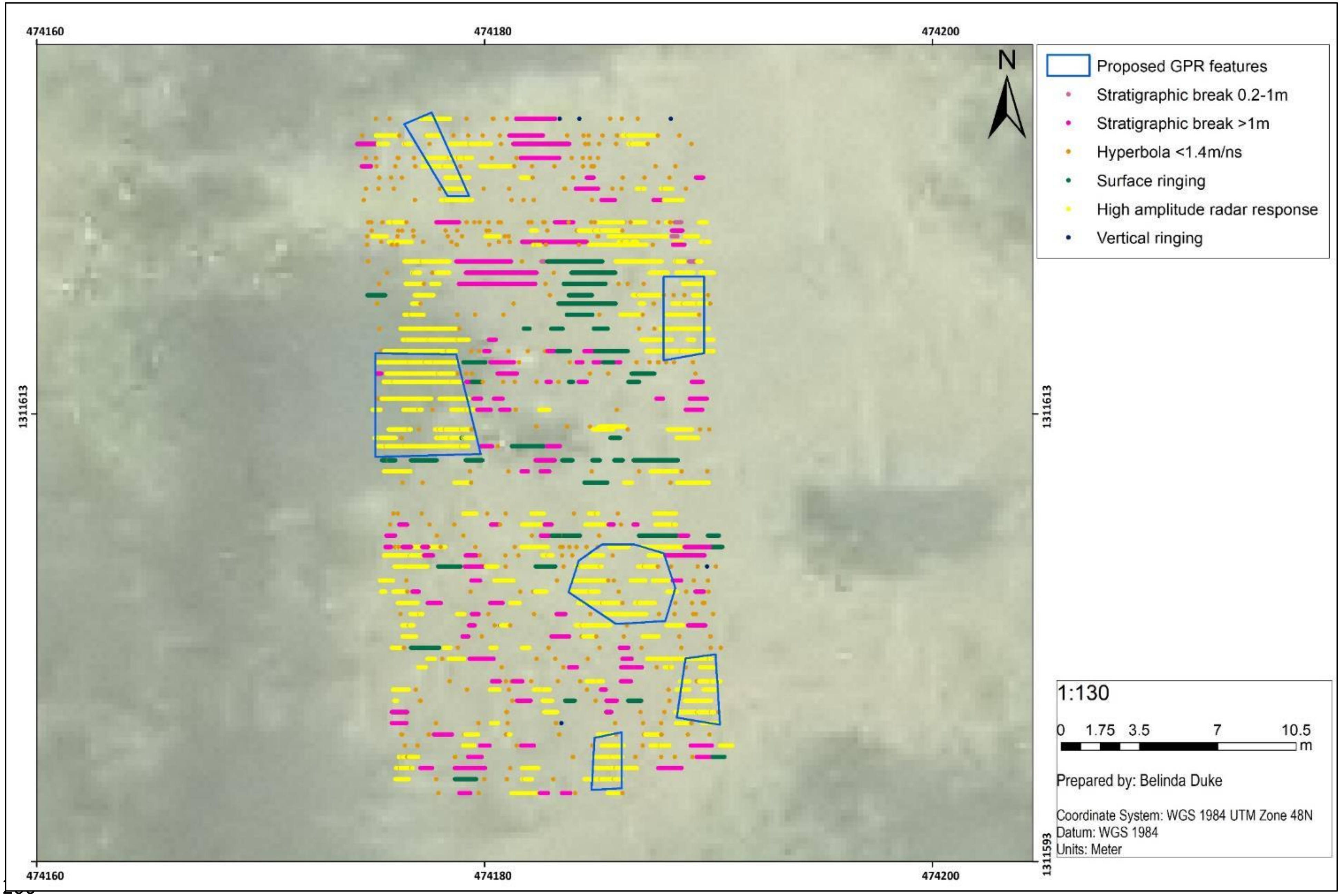



Figure 5.93: GPR Grid 08 Wat Tralaeng Kaeng south. GPR subsurface points mapped with potential features highlighted in red.

**GPR Grid 09** covered an area of 20x10 metres, used a half-metre spacing with meandering acquisition, the 0,0 located in the southeast corner; survey orientation west. Surface cover was open and the area does not appear to have been used for farming (Figure 5.94), possibly because of the homogeneous sediment found here. Figure 5.95 shows the homogeneous fill with a high-amplitude feature that has resulted in significant horizontal ringing. Figure 5.96 shows high-amplitude hyperbolas at depth. Figure 5.97 maps the GPR subsurface features and highlights the potential archaeological features present. A large pit containing high-amplitude radar responses in the north of the grid is like those found at GPR Grid 12 at the brick factory.

Figure 5.94: GPR Grid 09 Wat Tralaeng Kaeng South. Area enclosed by trees, but flat and open within the survey grid.

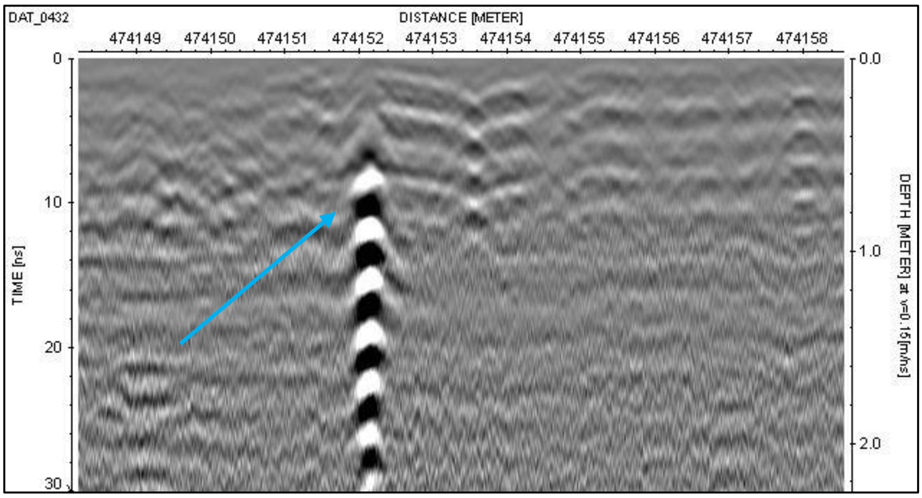



Figure 5.95: GPR line 432 at 10m of Grid 09 Wat Tralaeng Kaeng south. High-amplitude vertical ringing (blue)

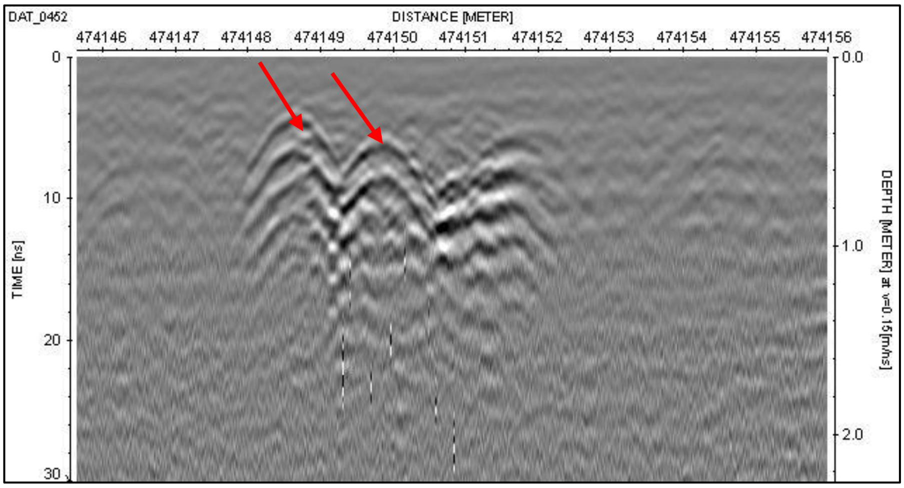



Figure 5.96: GPR line 452 at 19.4m of Grid 09 Wat Tralaeng Kaeng South. High-amplitude hyperbola (red).


Figure 5.97: GPR Grid 09 Wat Tralaeng Kaeng south. GPR subsurface features with possible archaeological feature.

**GPR Grid 10** covered an area of 10x10 metres, and used a half-metre line spacing with meandering acquisition and 0,0 located in the southwestern corner; survey orientation north. This grid was in a treelined area of flat ground without any obstructions (Figure 5.98). High-amplitude features causing vertical ringing are present at this grid, as seen in Figure 5.99 and Figure 5.100. Prominent in this grid are strata breaks over one metre, and high-amplitude radar reflections that are mapped in Figure 5.101. These features are likely archaeological in nature.

Figure 5.98: GPR Grid 10 Wat Tralaeng Kaeng south. Area surrounded by tree, surface within grid flat with no obstructions.

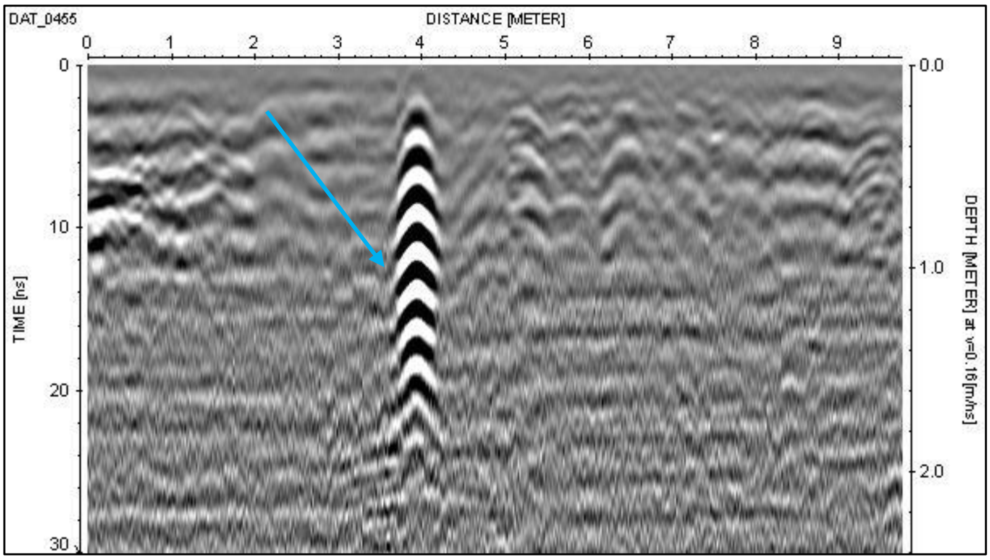



Figure 5.99: GPR line 455 at 0m of Grid 10 Wat Tralaeng Kaeng south. High-amplitude vertical ringing (blue), similar to other survey grids for this area.

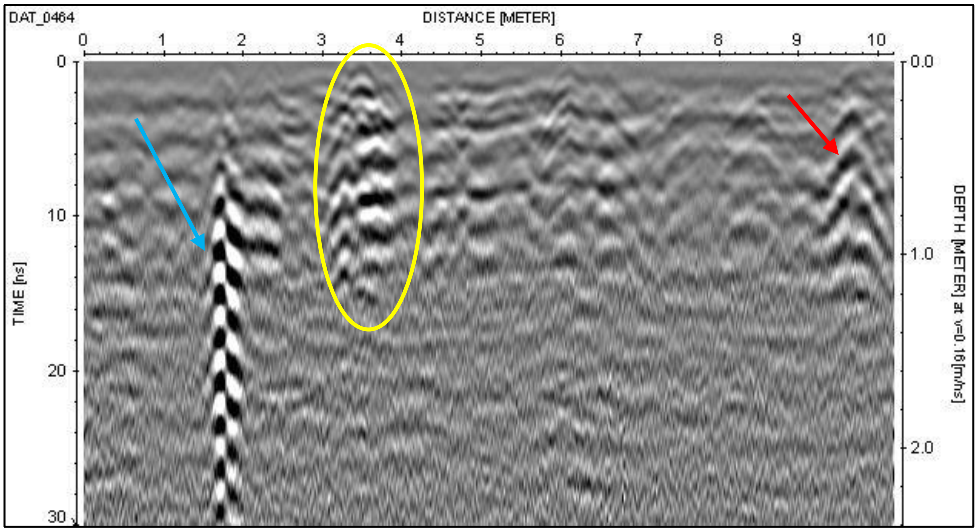



Figure 5.100: GPR line 464 at 4.4m of Grid 10 Wat Tralaeng Kaeng south. High-amplitude vertical ringing (blue), high-amplitude radar respone (yellow) high-amplitude hyperbola (red).

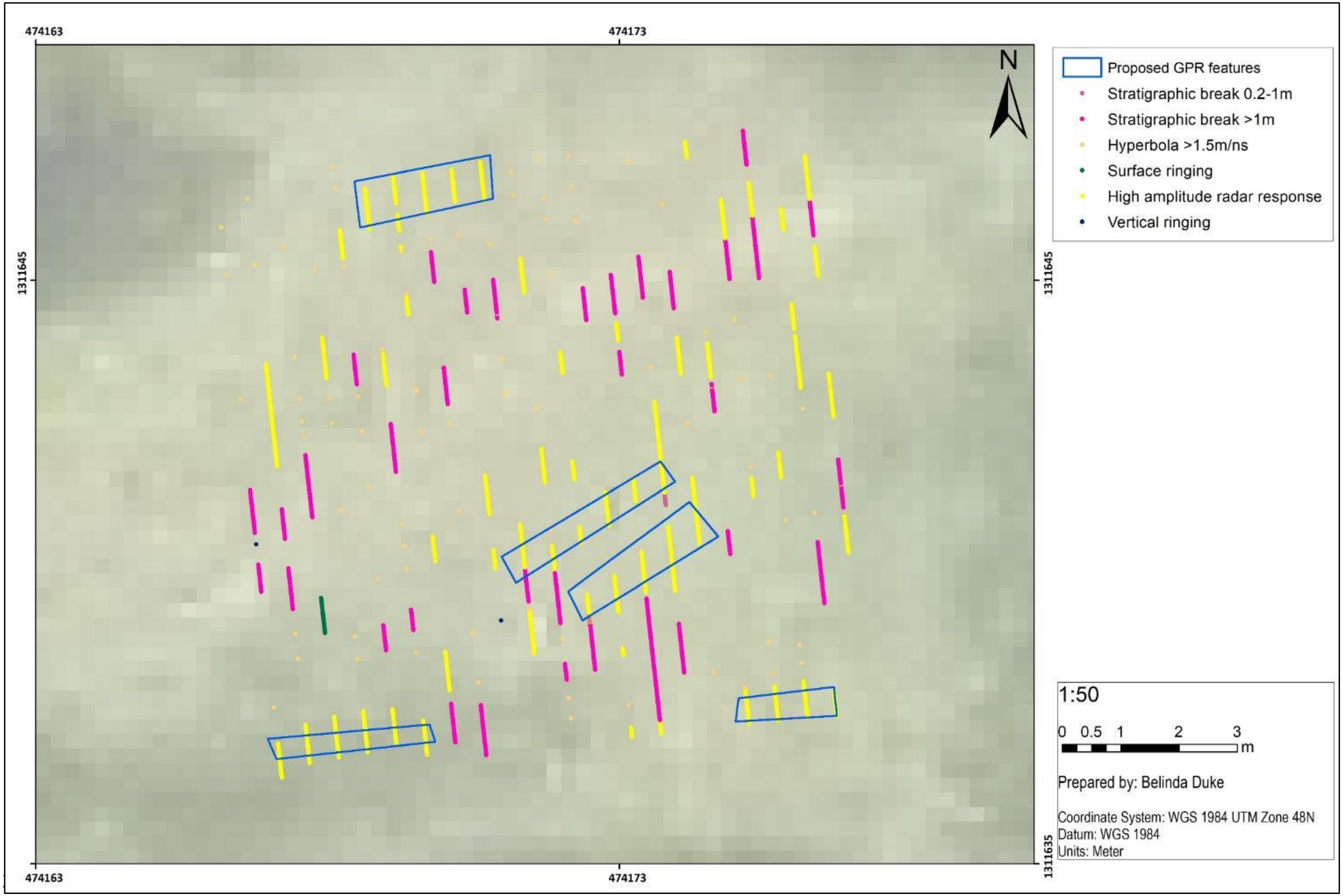



Figure 5.101: GPR Grid 10 Wat Tralaeng Kaeng south. Subsurface GPR features mapped with potenial archaeological features highlighted.

**GPR Grid 11** covered an area of 19x13 metres, and used a half-metre line spacing with meandering acquisition, the 0,0 located in the northeast corner; survey orientation south. This grid is in a rice field that had been used recently for farming (Figure 5.102). The grid does not include any rice bunds and is on flat ground without any obstructions. High-amplitude radar responses and surface ringing are consistent across this grid. The high-amplitude feature identified in Figure 5.103 and Figure 5.104 is consistently found across most of the GPR profiles and mapped in Figure 5.105. It appears to be archaeological in nature. There is nothing on the ground surface to indicate what is causing the surface ringing seen across most of the profiles.

Figure 5.102: GPR Grid 11 Wat Tralaeng Kaeng south. Area is within a rice field, however it does not include any bunds within the grid.

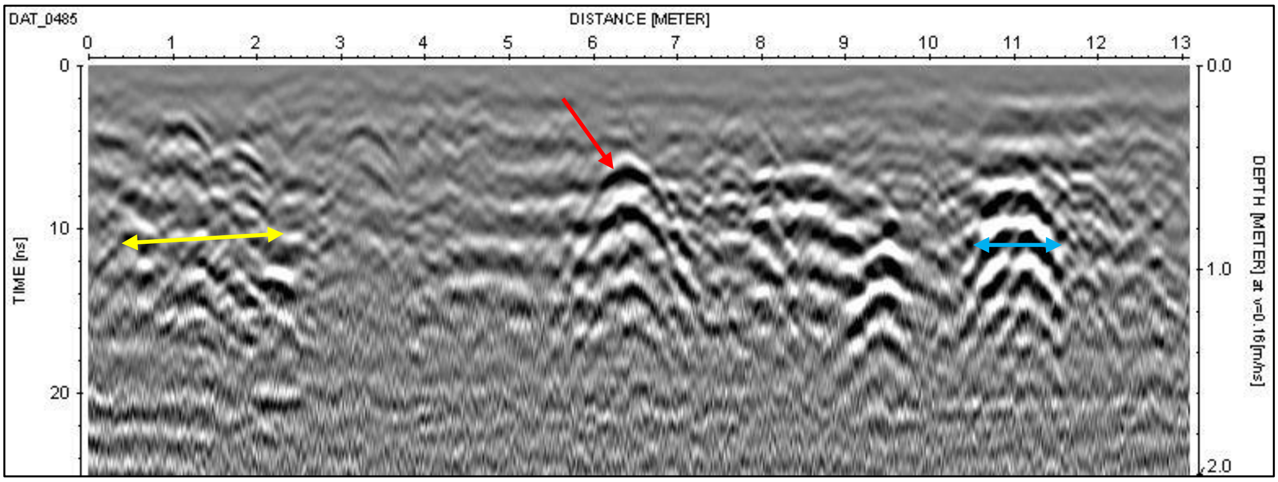



Figure 5.103: GPR line 485 at 4.5m of Grid 11 Wat Tralaeng Kaeng South. In-situ high-amplitude response (blue). Also present high-amplitude hyperbola (red) and area of disturbance (yellow), also seen in profile of Figure 5.104, occuring over almost all profiles which corresponds with a large features mapped in Figure 5.105.

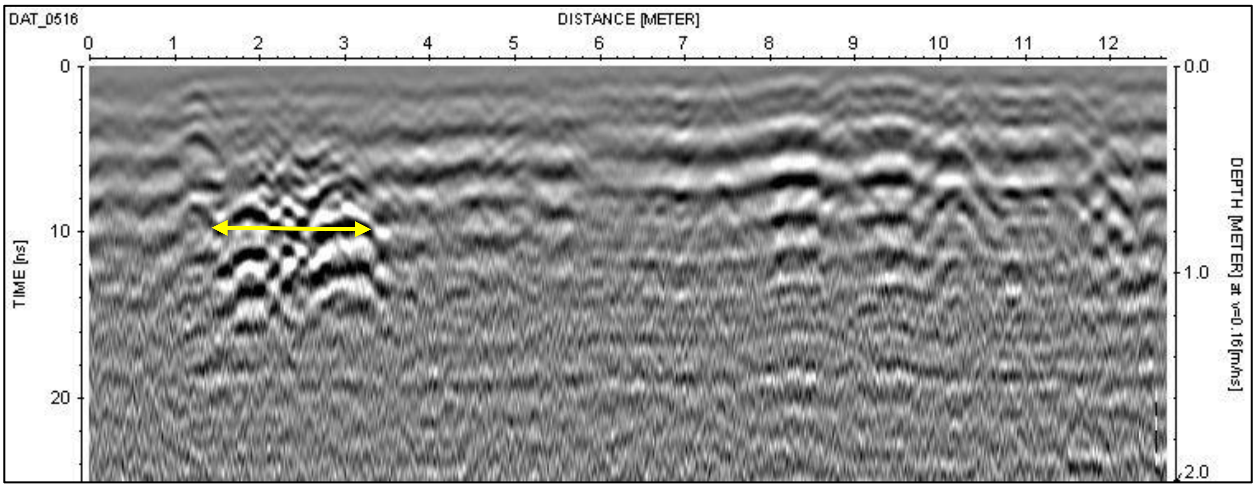



Figure 5.104: GPR line 516 at 19m of Grid 11 Wat Tralaeng Kaeng south. Area of disturbance (yellow) across multiple profiles and mapped in Figure 5.105.

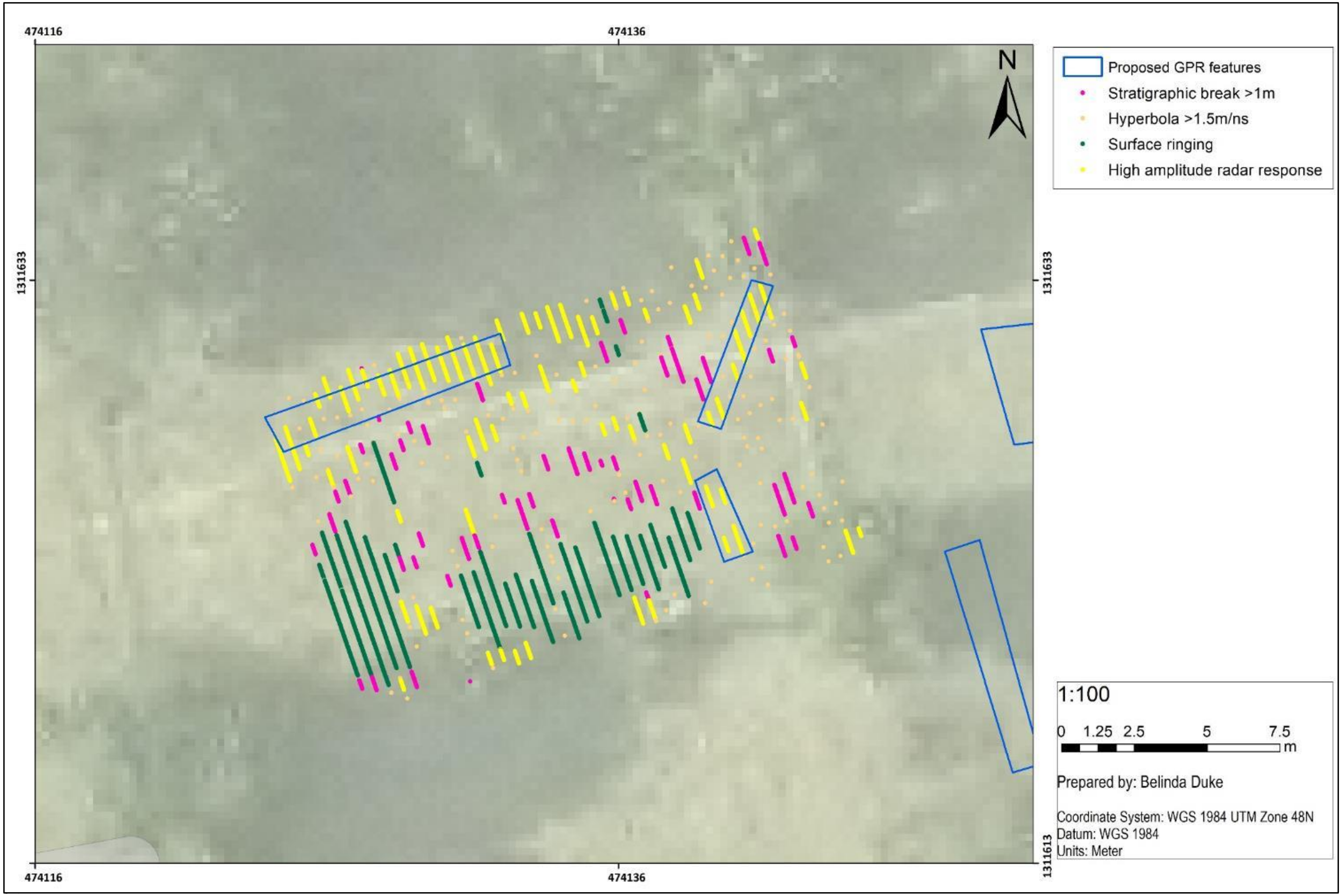



Figure 5.105: GPR Grid 11 Wat Tralaeng Kaeng south. Subsurface GPR features mapped with potential archaelogcial feautres highlighted in red. Horizontal surface ringing is present across almost all the grids, however, there is no discernable uniformity of distribution.

#### *5.3.4.3 Wat Traeleng Kaeng South - Proposed Landscape Reconstruction*

In combining the potential features identified through magnetometry in Figure 5.79 with the results from the GPR survey in Figure 5.106, a proposed landscape reconstruction has been produced and presented in Figure 5.107. Within this reconstruction there are four feature types proposed: proposed occupation, proposed structure, historic rice fields and contemporary features. This classification is based on what is known to have existed in this area from historical documentation. The historic rice fields consist of linear features in a different configuration to modern ones. These features are defined by areas of low to no magnetic variance (the proposed rice bund) and area of higher magnetic variance (the proposed rice field). This configuration is the opposite of the magnetic response found in modern fields, which are constructed using culturally modified sediment. In historic fields the bunds would likely have been constructed using unmodified sediment, assuming the land had not been lived on before construction. The higher magnetic response of the field would be due to the farming process over time altering the magnetic response of the sediment through fertilising and burning practices. Proposed historic features are defined by linear high magnetic responses. Often these features are a boundary to areas of little to no magnetic response. Historic features are defined here by the areas containing little to no cultural material, as a building will result in a magnetic response-free zone. The GPR data suggests there are potential high-amplitude features in the subsurface in the elevated tree line area. The high value of these features would suggest they are Angkorian in nature and not Early Modern.

The final feature type is related to contemporary (c. 1900 to present) features and disturbance. In the GPR profiles, the hyperbolas are mostly contained to the 20-30 centimetres of topsoil. Little to no hyperbolas relate to dipoles or monopoles. This may be due to the point source being of a non-ferrous material, such as aluminium, or at a depth the magnetometer cannot record. Linear responses with high magnetic value or high-amplitude value have been classified as contemporary features, particularly those without any uniform configuration. As these have been classified as contemporary, they will not be considered in the landscape reconstruction.


Figure 5.106: Potential GPR features identified at Wat Tralaeng Kaeng South.

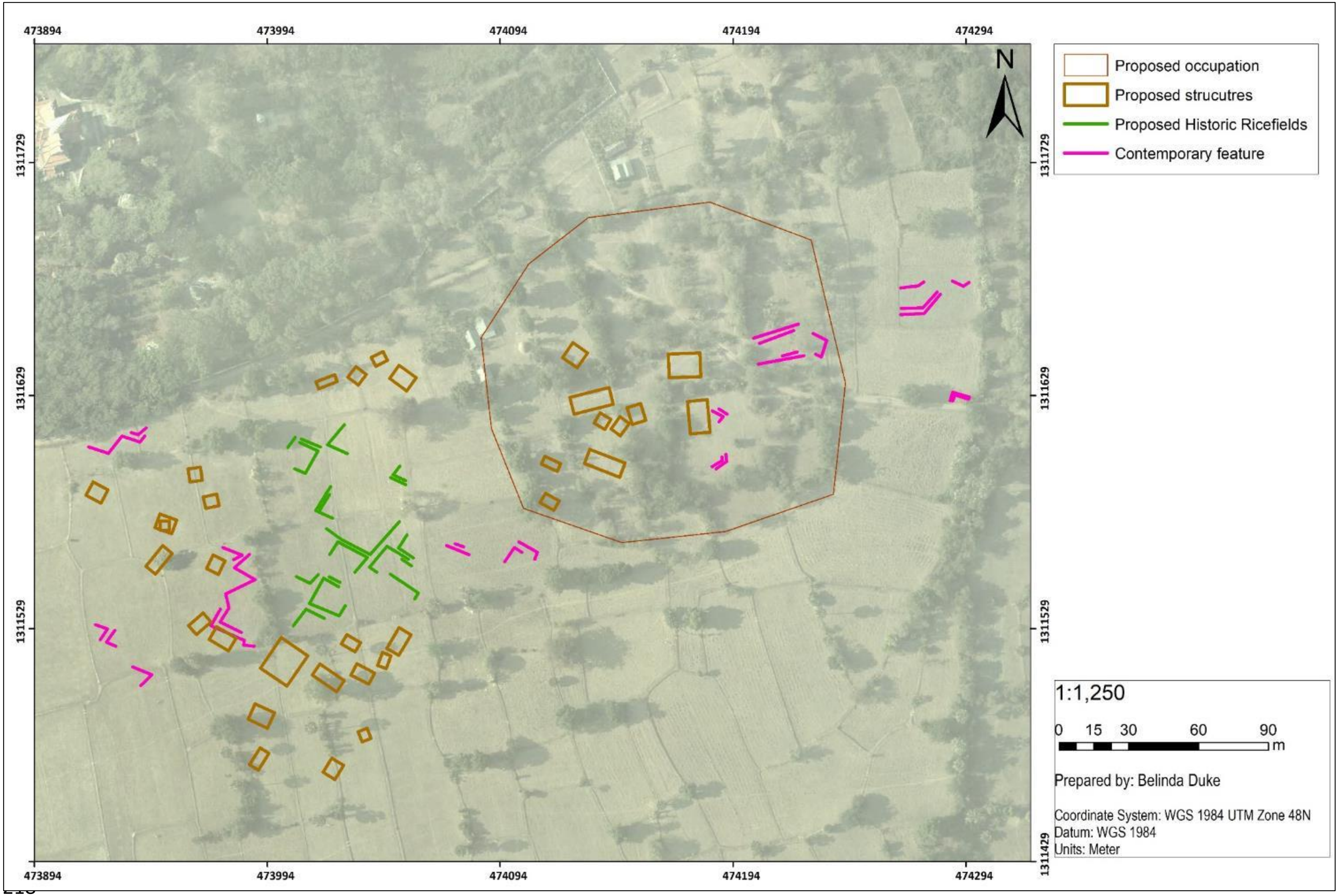



Figure 5.107: Wat Tralaeng Kaeng South proposed reconstructed landscape.

### 5.3.5 Citadel Wall South

Several mounded sites were found via the lidar survey and were identified as Theravāda terraces. Of these, Toul Tatob and Toul Slang south of the citadel wall were chosen for investigation through GPR (Figure 5.109). Toul Tatob, which still had remains of a Theravāda shrine, was investigated to examine the internal structure of the mound and to comment on construction of the silted moat; and Toul Slaeng was surveyed to identify any features which would confirm the mound was used as a terrace, again through an examination of the internal structure and silted moats.

#### *5.3.5.1 Toul Tatob*

Toul Tatob is the largest of the mounds and the lidar data show evidence of the site having had a moat. The site itself has surface materials consisting of laterite blocks (Figure 5.108) and *sema* or boundary stones (Figure 5.110). A platform likely stood at the centre of the mound with a statue; this area has been looted in the last century resulting an irregular pit (Figure 5.111).

Figure 5.108: Toul Tatob, laterite bricks of what would have been part of a platform, now out of context around a second looters pit.

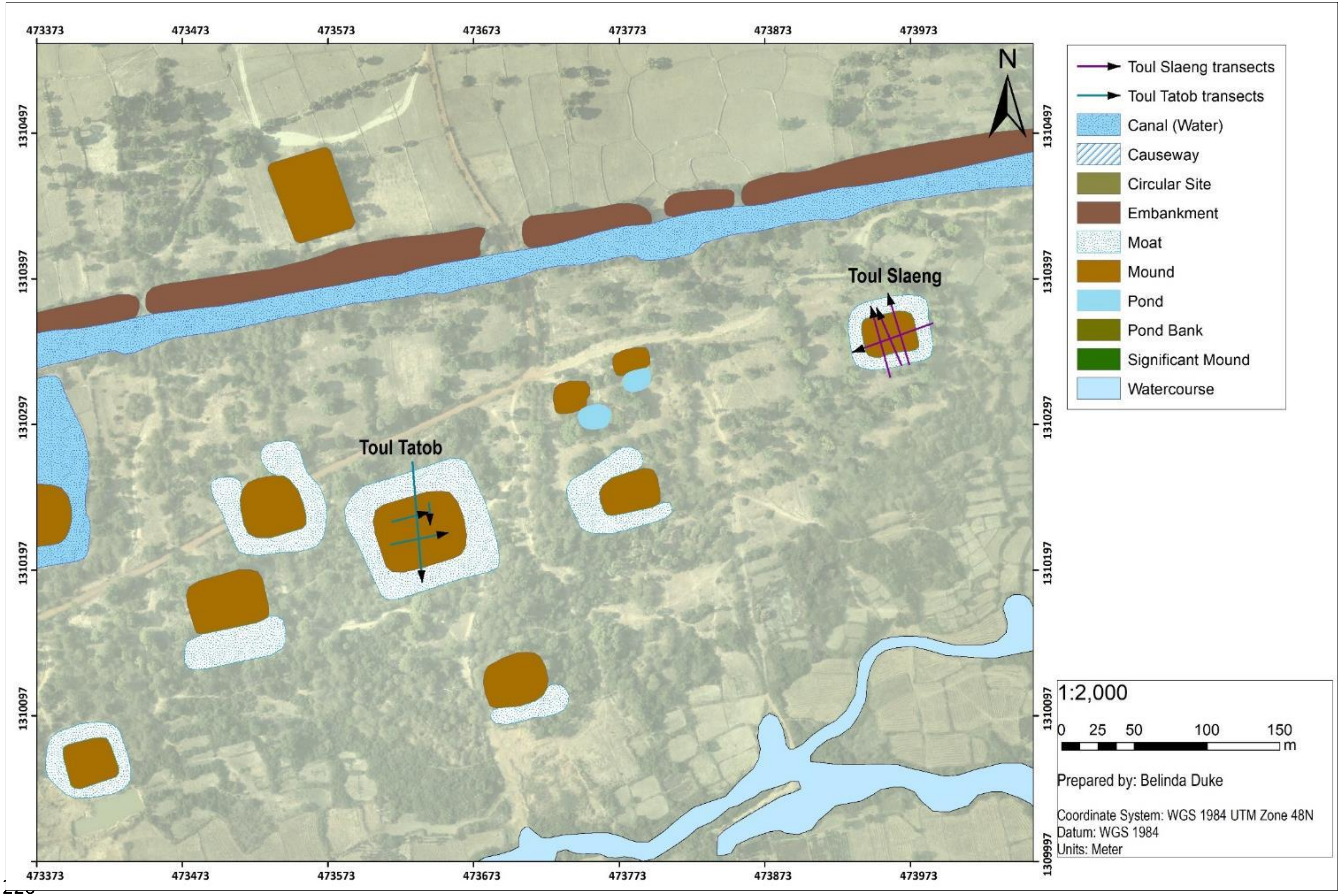



Figure 5.109: Terraces Toul Tatob and Toul Slaeng in relation to lidar analysis conducted by CALI.

Figure 5.110: Toul Tatob, example of *sema* stones at the site.

Figure 5.111: Toul Tatob, looters pit centre to the mound.

Transect 01 is the longest of the four, beginning off the mound. It includes the moat and the entire width of the mound. The moat is very clearly represented in this profile. While the moat appears in the lidar data, it is currently almost completely filled with silt, as shown in Figure 5.113. Transect 01 in Figure 5.113 shows discrete layers of sediment accumulation in the moat, with the top 0.05m of sediment being very homogeneous. This difference may suggest there were distinct flooding events that deposited sediment that contrasted to the topsoil which accumulated slowly over time. On the mound, a surface represented by a reflective sediment boundary was found in three areas. This surface was found in transects at approximately half meter depth. The consistency of this surface may be indicative of an accumulation event occurring at Toul Tatob, where the mound was purposefully raised. The looted area at the centre of the mound is represented in the GPR transect data as an area of high-amplitude radar reflection, which is likely the result of redeposited laterite stone. Transects 02 (Figure 5.114), 03 (Figure 5.115) and 04 (Figure 5.116) all have the same kind of radar responses as seen in transect 01. A high volume of near surface hyperbolas can be attributed to contemporary material in the near subsurface, such as bricks, which has been secondarily deposited, as confirmed in the excavation profile discussed below. Transect 03 in Figure 5.115 appears to have the only *in situ* archaeological material. However, without ground verification there is no conclusion as to what this may be.

Figure 5.112: The now-filled moat at Toul Tatob highlighted in red.

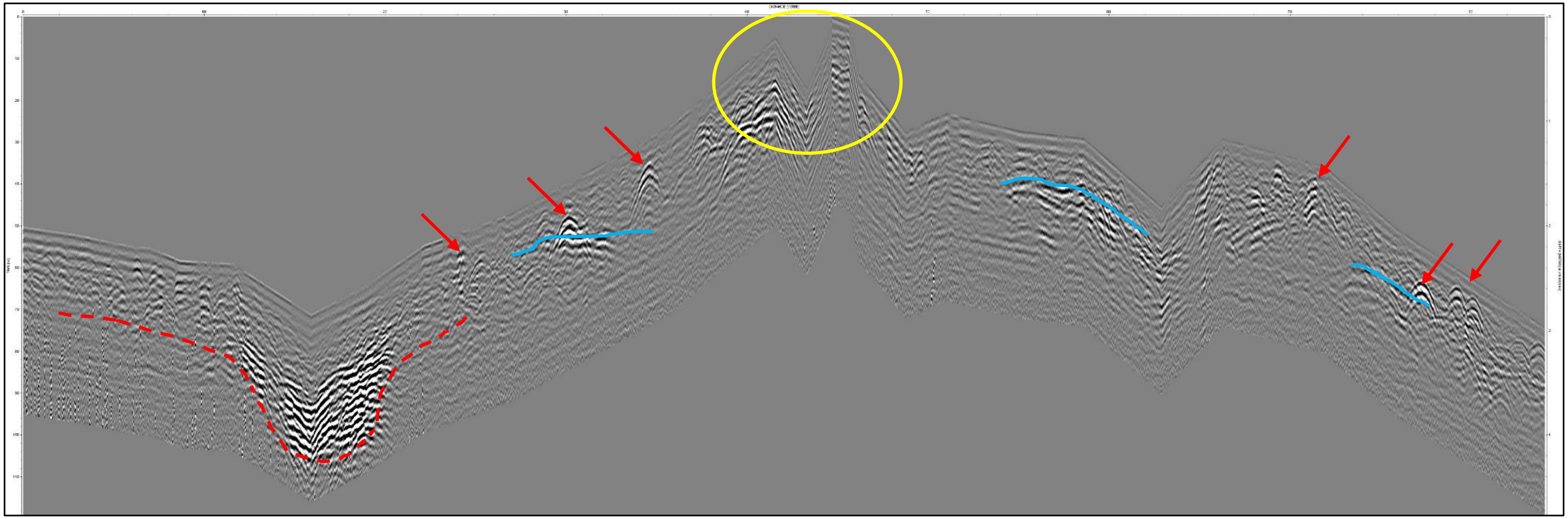


Figure 5.113: GPR Transect 01 Toul Tatob. Note vertical exaggeration. Sediment of the now filled moats (red), disturbed area of the looters pit (yellow), surface found in multiple locations across mound (blue) and hyperbolas (red).

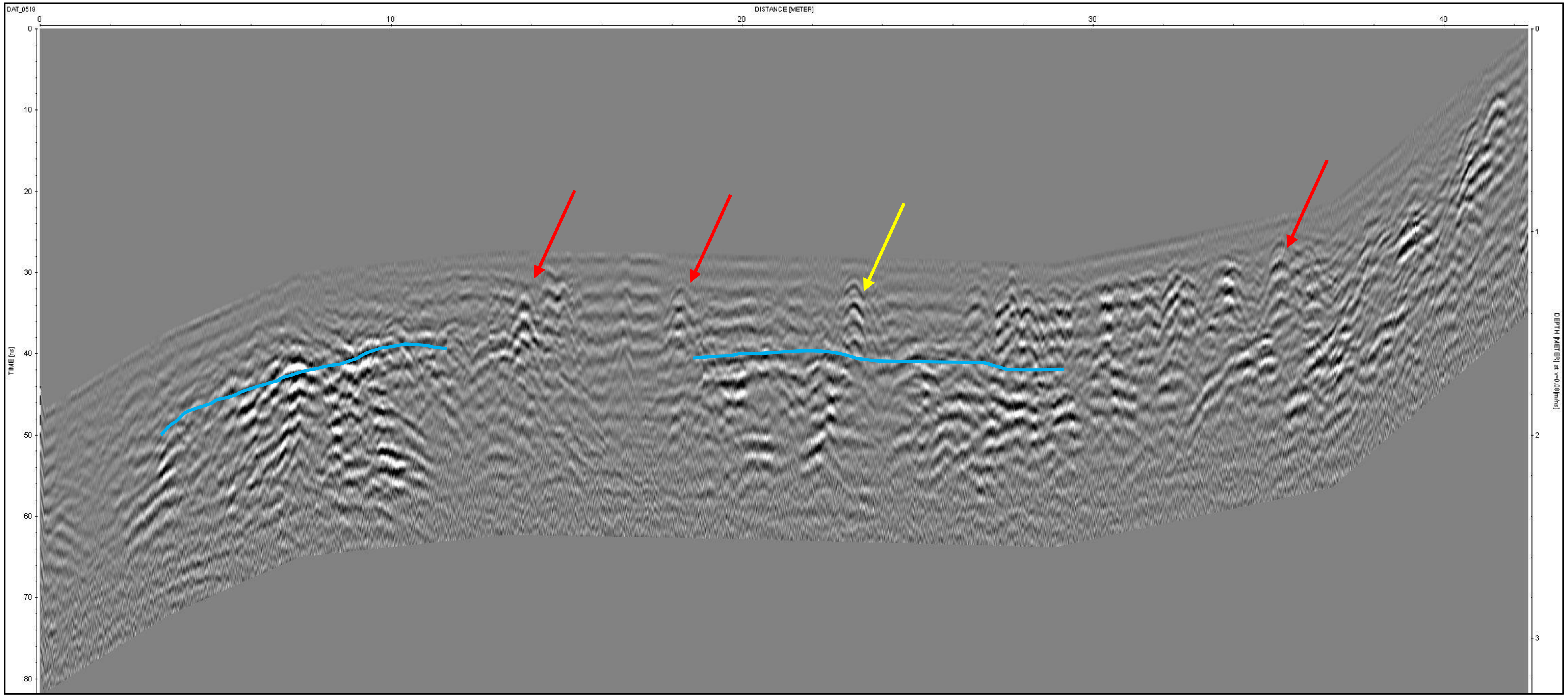



Figure 5.114: GPR Transect 02 Toul Tatob. Note vertical exaggeration. Buried surface (blue), hyperbola (red). The hyperbola indicated by the yellow arrow is likely the brick found in section in Figure 5.117.

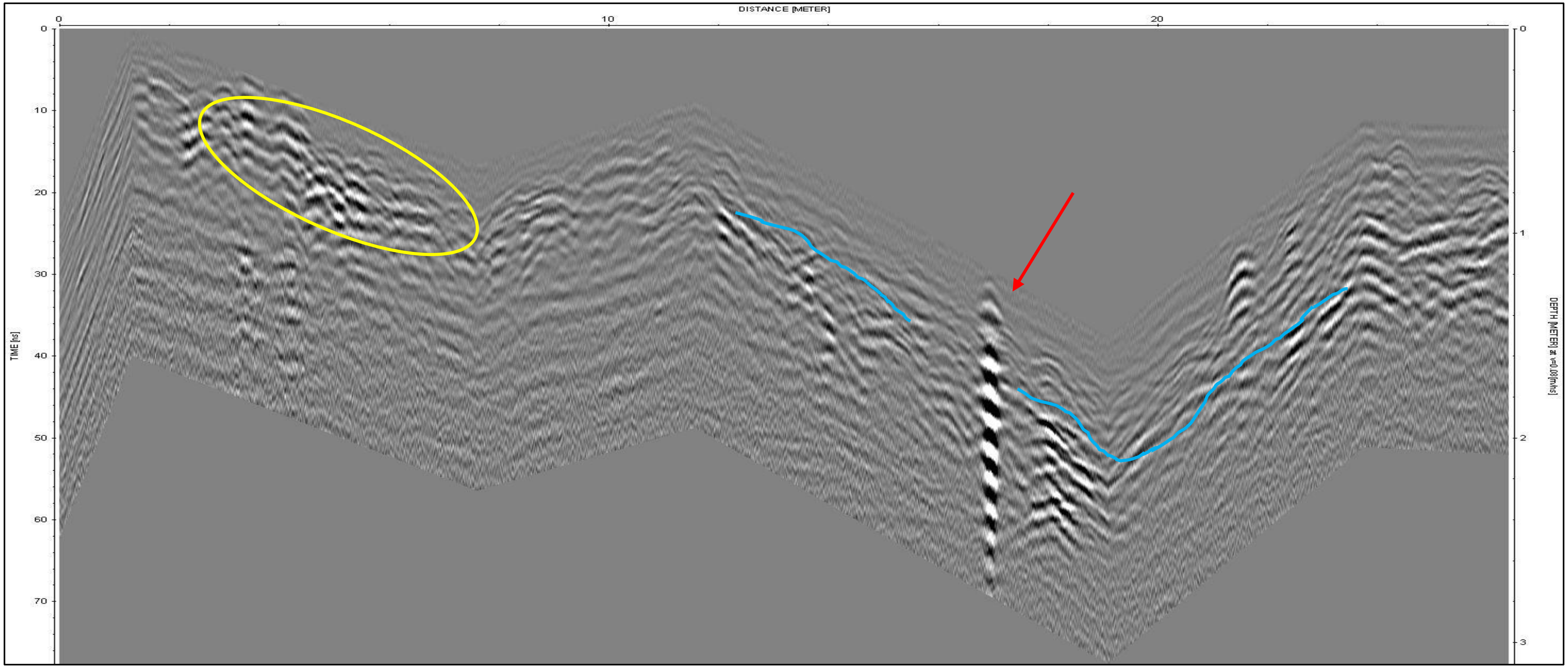



Figure 5.115: GPR Transect 03 Toul Tatob. Note exaggerated vertical axis. In situ feature (yellow), high-amplitude vertical ringing (red) and sub surface layer (blue).

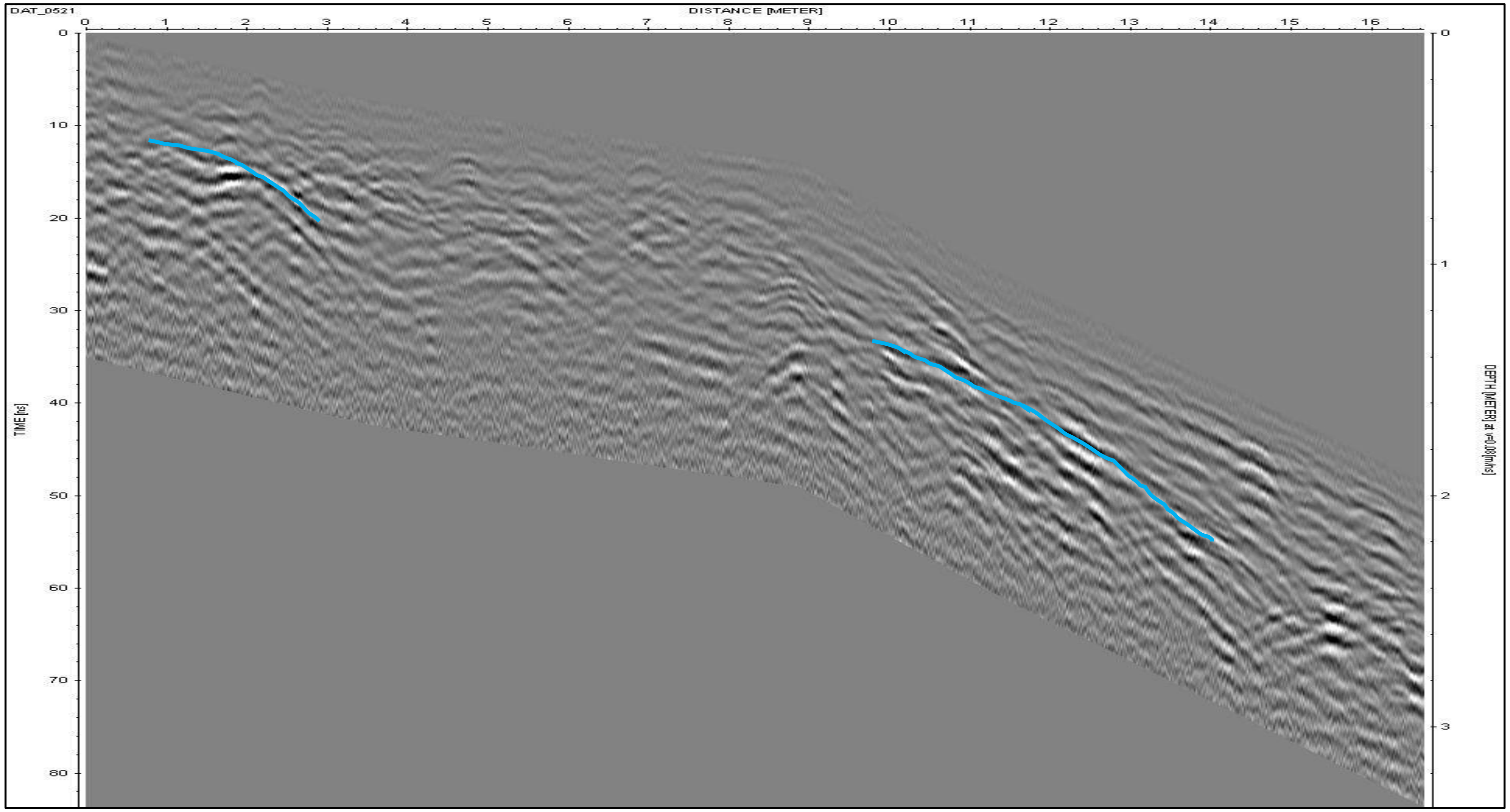



Figure 5.116: GPR Transect 04 Toul Tatob, note vertical exaggeration. Subsurface surface (blue).

From the GPR survey conducted at Toul Tatob, an excavation trench was placed at the centre of the mound, positioned over transect 02 south of the laterite stones, to investigate the surface identified in Figure 5.114. The near-surface bricks found during excavation (seen in section in Figure 5.117) would account for the hyperbola found in transect 02 in Figure 5.114. The surface mapped in transect 02 would likely be the result of a sharp contrast between two strata. The profile in Figure 5.117 would suggest the strata is very homogeneous sandy loam, with few archaeological materials at depth. The excavation did not reach sterile natural sediment below the mound and the surface seen in the GPR profile may have be the layer highlighted in yellow in Figure 5.117.

Figure 5.117: Excavation trench LVK1938, southern section at Toul Tatob. Note brick inclusion in red with is likely the hyperbola represented in Figure 5.113. There is no clear layer of strata which would account for the surface found in the profile of Transect Two. Yellow highlighting change in strata which caused buried surface refection in Figure 5.117.

### 5.3.5.2 Toul Slaeng

Toul Slaeng is the smaller of the two mounds surveyed. Its long axis is on an east-west orientation. The mound was identified from the Lidar (Figure 5.118). Four GPR transects were conducted over the mound where space was available. Transect 01 in Figure 5.119 was orientated north and runs through the centre of the mound over the short edge. In the profile, surface contamination is evident in the form of hyperbolas (something which is consistent over all four profiles). Transect 01 contains the strata break at the centre of the mound. Also evident in transect 01 is the subsurface feature which consists of a surface with high-amplitude hyperbolas above and below it, located off both edges of the mound. The GPR is reflecting off a possible clay surface due to its highly reflective properties. The shape of these features would not suggest they are a moat. The surfaces recorded at Toul Slaeng are similar to those found at Toul Tatob in Figure 5.113.

Figure 5.118: Toul Slaeng tree-covered mound. The moats identified in the lidar are not visible through on the ground visual inspection.

Transect 02 in Figure 5.120 runs east to west along the longest line of the mound and does not have the off mound subsurface features as seen in other transects. It does, however, show that the centre of the mound has concentrations of hyperbolas and high-amplitude radar responses. These two feature types appear to be sitting on top of a surface which consists of a very reflective material that may be the original ground surface of the mound. This may account for why the buried surface seen in other transects is not present here, as the line surveyed was not long enough to include it.

Transect 03 in Figure 5.121 very clearly shows the off-mound buried surfaces present on either side. Like transect 01, this surface is highly reflective but does not continue onto the mound. Within the mound itself there are two areas high-amplitude radar responses that appear to be *in situ* archaeological features. The nature of the response may indicate it is a brick work of some kind, potentially related to similar feature above. As with with other survey lines, Transect 03 has a high volume of near surface hyperbola features.

Transect 04 in Figure 5.122 again has the buried surface located off the mound. This buried surface at the northern edge of the transect is also associated with high-amplitude hyperbolas and radar responses below. This may suggest there is still *in situ* material remaining in the subsurface. At the centre of the mound are other examples of burried surfaces and *in situ* material. Across the entire profile there is a high number of hyperbolas.

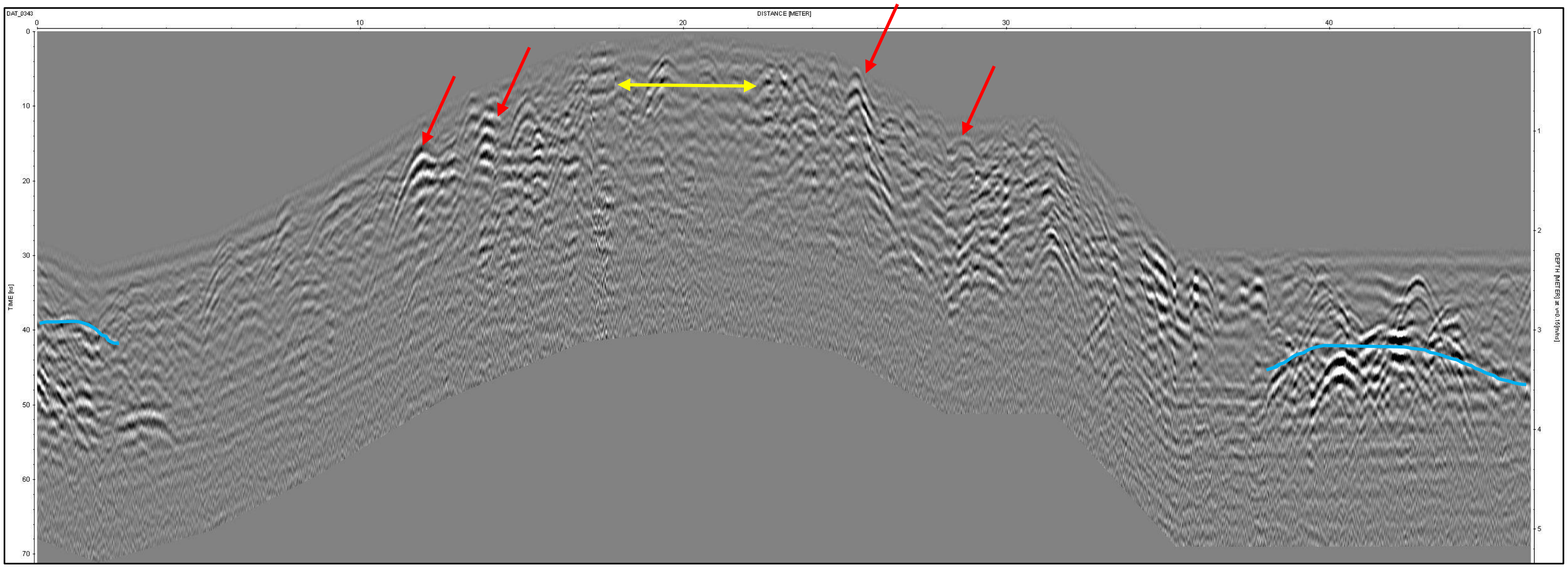


Figure 5.119: GPR Transect 01 Toul Slaeng. Note vertical exaggeration. Subsurface surface (Blue), centre of the mound has a higher number of hyperbolas (red) and a strata break at the centre (yellow).

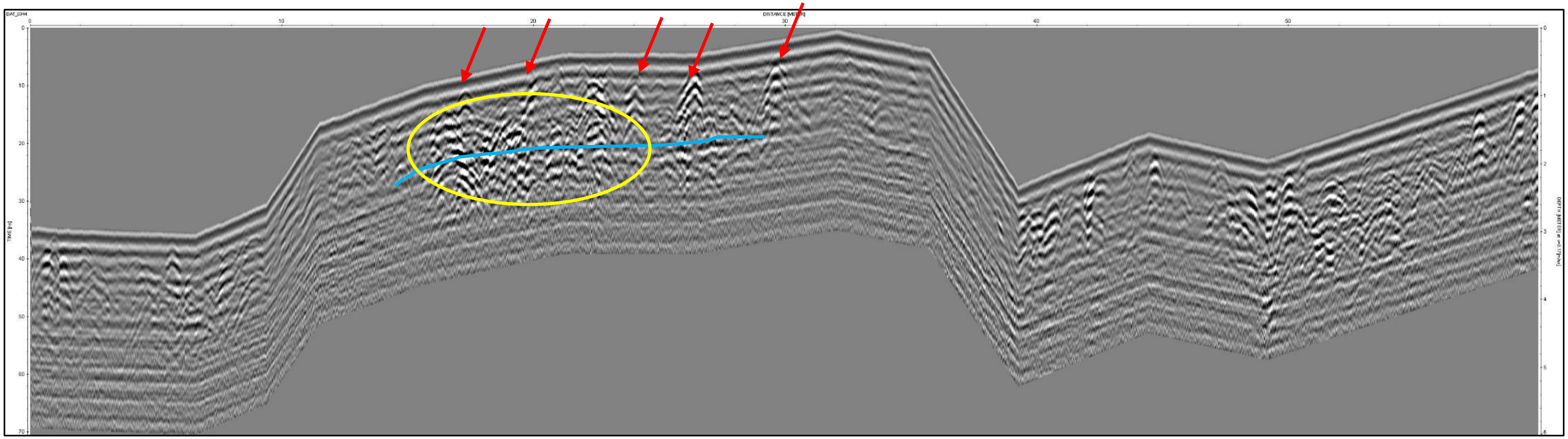


Figure 5.120: GPR Transect 02 Toul Slaeng, note vertical exaggeration. Area of high-amplitude responses (yellow) centre of the mound in combination of hyperbolas (red) and a subsurface surface (blue). Subsurface hyperbolas also present on the periphery.

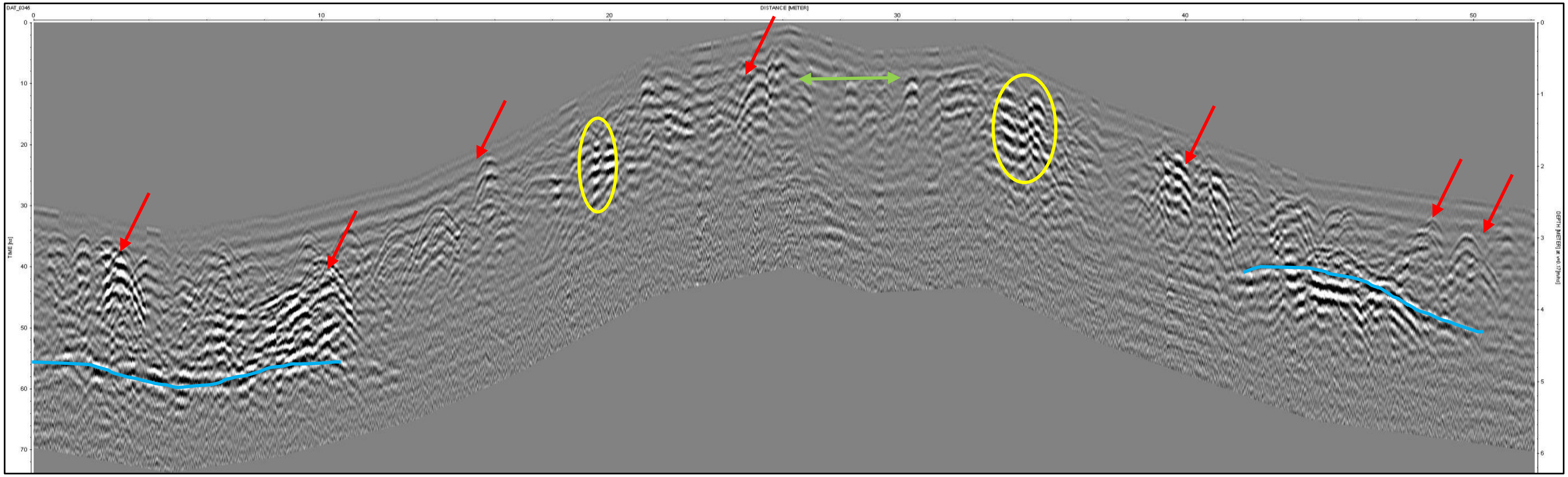



Figure 5.121: GPR Transect 03 Toul Slaeng. Note vertical exaggeration. Subsurface surface off the mound (blue), possible in situ high-amplitude feature (yellow), strata break (green) and hyperbolas (red).

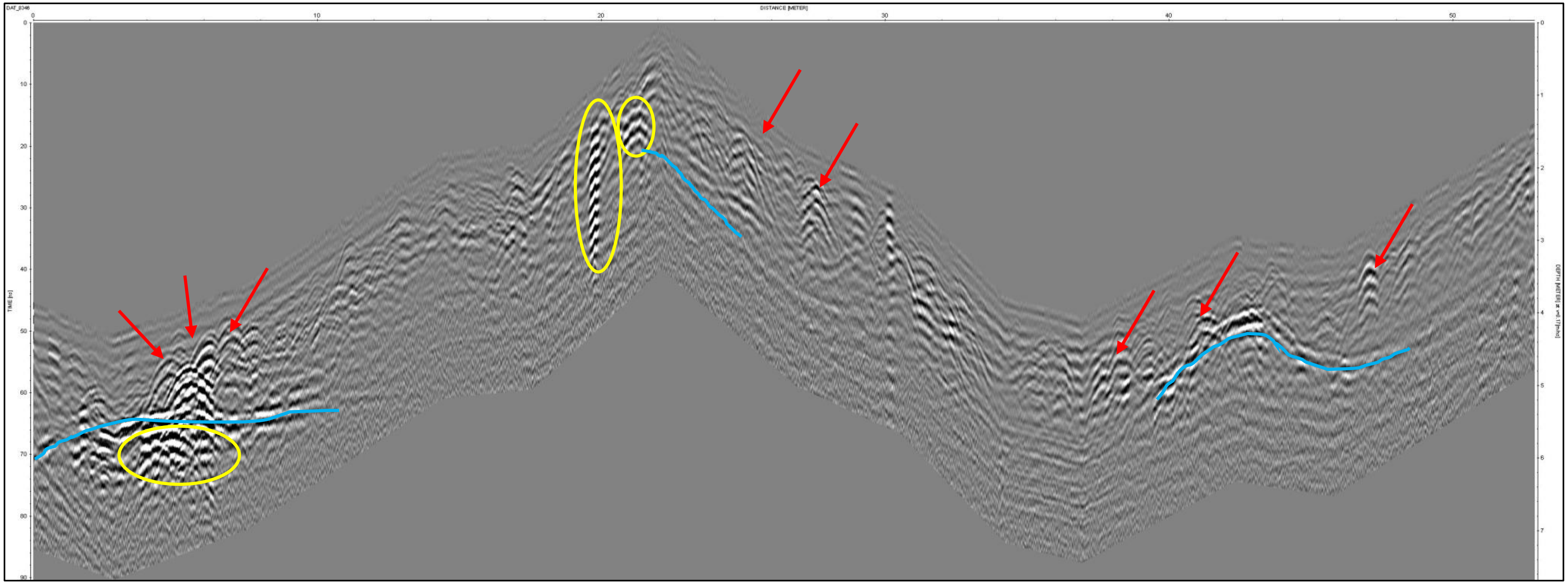



Figure 5.122: GPR Transect 04 Toul Slaeng. Note vertical exaggeration. Subsurface surface (blue), possibility in situ features (yellow), high-amplitude hyperbolas (red) and high-amplitude radar response under (yellow) buried under the surface.

### 5.3.6 Wat Chedei Thmei South

The areas south of Wat Chedei Thmei were investigated to identify evidence possibly relating to the palace complex proposed by Kitagawa (1999). The area is enclosed by an embankment identified in the lidar survey and by Kitagawa (1999) survey. In addition to surface features, late sixteenth to early nineteenth century ceramics were found. The area under investigation is inside and just south of the embankment. The area has been terraced with a permanently flooded area on the lowest terraces directly south of the Wat. During the survey the lower terraces were being excavated to be made into a pond (Figure 5.123).

#### *5.3.6.1 Magnetometry*

The magnetometer survey was conducted in January 2019. A Bartington Grad 601 dual sensor magnetometer was used throughout. One-hundred and fifty-nine 20x20 metre magnetometer grids were surveyed at Oudong, covering 6.3 hectares of land (Figure 5.124). The mean nanoTesla value and the standard deviation was found for all magnetic grids. The standard deviation set the display parameters for the magnetic data. Once plotted and processed, features were identified over three (Figure 5.125), two (Figure 5.126) and one (Figure 5.127) standard deviations from the mean, identifying dipoles, monopoles of negative and positive values, linear features and areas of high magnetic value. To determine subsurface landscape features dipoles, positive and negative monopoles and high value magnetic response from three standard deviations were excluded, along with a one-metre buffer around the current rice bunds. The two and one standard deviation feature types are mapped in Figure 5.128. The density of magnetic anomalies suggests the entire area surveyed contains culturally modified sediment which is the result of human activity in the area. Removing the highest magnetic responses eliminates some of the modern ferrous contaminants. There are more magnetic features on areas of higher elevation, particularly in the north and northeast grids and the western grids outside the wall. The lower elevation grids have more linear features and areas with little to no magnetic anomalies. A lack of physical artefacts would suggest the magnetic responses are due to culturally modified sediment as the result of occupation. Alternatively, the archaeological material may have been gathered within the topsoil to create the current rice bunds and would account for this high magnetic response as mentioned above.

Figure 5.123: Wat Chedai Thmei South removal of rice fields to expand pond.

Through a visual inspection of the map in Figure 5.128, magnetic features were determined and mapped in Figure 5.129. These features are a combination of feature types which occur in a linear configuration. In some instances features have been identified by groupings of similar (or possibly identical) magnetic responses which may indicate a pile dwelling. Areas on a lower elevation consist of larger features and potentially an earlier rice field configuration. More linear features and areas lacking any magnetic response were located outside the wall and indicate sediment had been removed. The size of the area may suggest a mound was removed.

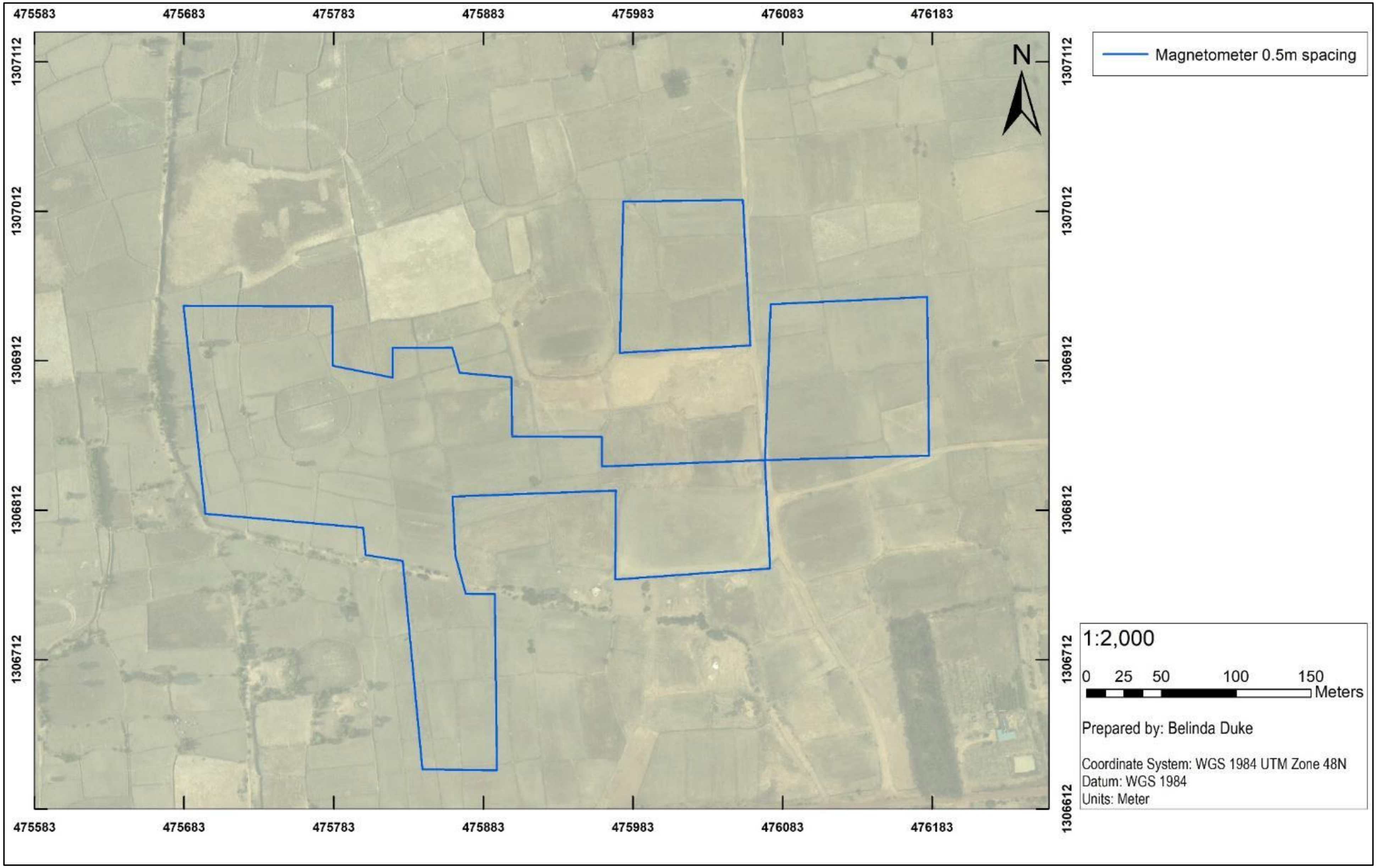



Figure 5.124: Geophysics survey area, Wat Chedei Thmei South.


Figure 5.125: Wat Chedei Thmei South Gridding in 20x20m squares magnetometer results presented with the nT range three standard deviations (-14 – 14.7 nT) from the mean.


Figure 5.126: Gridding in 20x20m squares magnetometer results presented with the nT range two standard deviations (-9.03 – 9.93nT) from the mean.


Figure 5.127: Gridding in 20x20m squares magnetometer results presented with the nT range one standard deviations (-4.42 – 5.14nT) from the mean.


Figure 5.128: Wat Chedai Thmei South distribution of all identified magnetometer features at three, two and one standard deviation combines all the identified features from the three data mapping ranges.

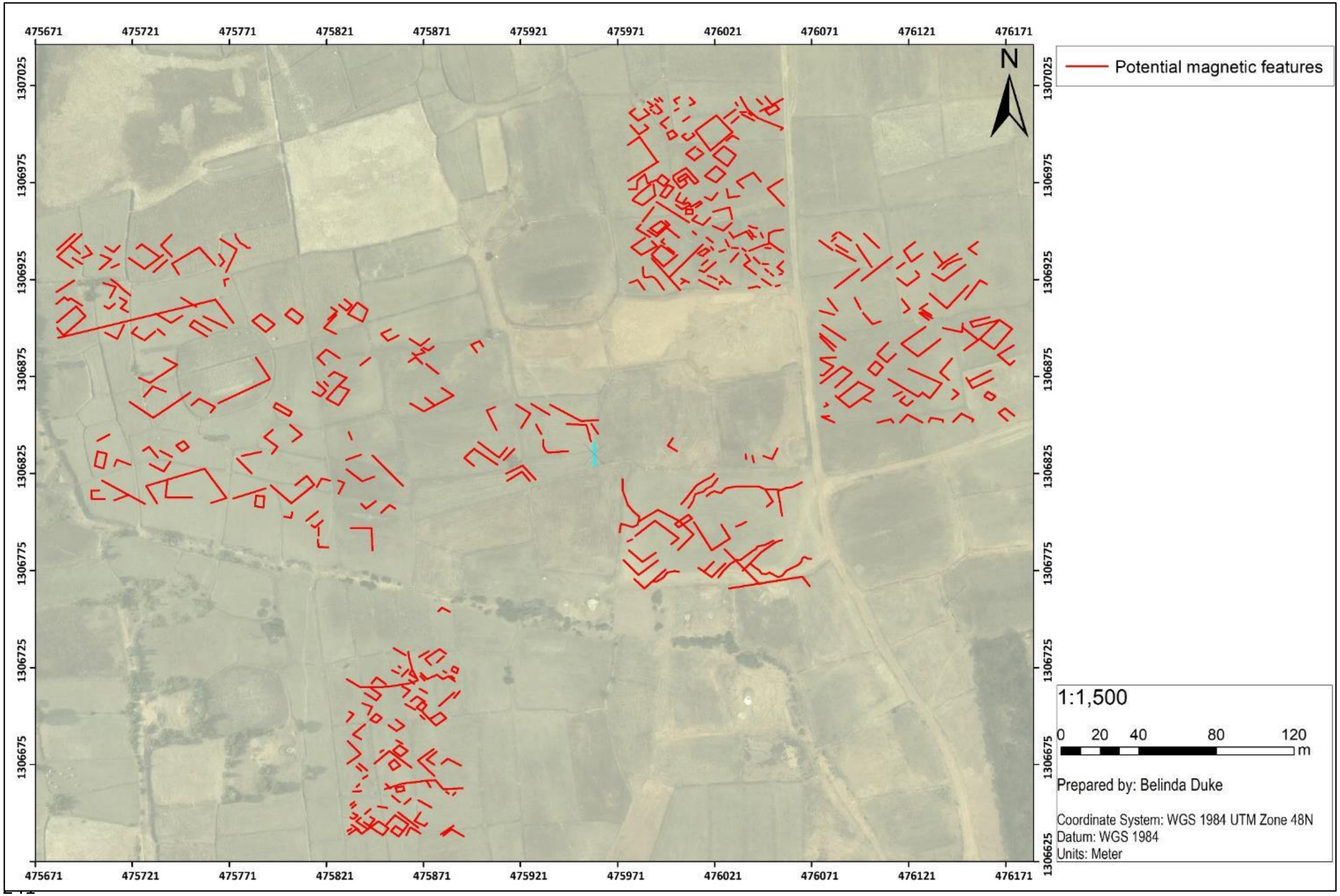



Figure 5.129: Wat Chedai Thmei South features mapped from a visual examination of magnetic points taken from picked points.




Figure 5.130: Wat Chedei Themei South proposed subsurface features.

#### 5.3.6.2 *Identified Features*

The high number of magnetic anomalies found at this site suggests the entire area contains culturally modified sediment. The most discernible pattern is that created by the modern rice bunds. While there is no evidence of obvious subsurface structures which could represent a palace, there is evidence for modern features outside the embankment wall, along with an area with very few magnetic anomalies, which may be the result of a mound being removed. Inside the embankment walls a variety of potential structures have been identified. While a palace has not been found, the remains of a village or palatial structures are potentially present.

## 5.4 Concluding Summary

Based on the result presented above, the following key points were established:

- The GPR results from Toul Basan suggest there is no evidence for a structure, nor is there evidence of anthropogenic manipulation. The mound has been altered recently, first to add to the mound to make it larger, with the margins shaped to suit the topography of the rice fields around it.
- The GPR survey at Prasat Preah Theat Baray suggests there are two highly likely subsurface structures, one northwest and the second southwest of the *prasat*, with a possible third north of the terrace. Other features present suggest the subsurface remains of a wall which is more discernible in the northern, southern and western edges of the mound.
- The examination of the broader landscape of Longvek/Oudong relies on the lidar data collected by CALI. The most relevant feature type recorded through these data were ponds. Examining these data in light of the classification system used by Hawken (2011a), the citadel has a class eight orientation.
- The lidar examination of the rice fields identified a dominant bund orientation (class eight) which is believed to be Early Modern. In addition to this, Angkor period bunds (class one) were identified along the waterway south of the citadel and around ponds west of the citadel. *Tumnup* east of the citadel do not have any single standard orientation, as the radiating bunds are dependent on the dyke wall. However, further investigation is required to qualify this conclusion.
- The magnetometer survey north of the brick factory identified that the entire area under consideration contained culturally modified sediment. No clear patterns were found in

these data but through the process of eliminating potential modern anomalies, a range of potential structures were identified.

- The GPR survey north of the brick factory identified several subsurface features which are believed to have been Early Modern. This included a potential pond which appears to be filled with anthropogenic material; and two structures which are in the vicinity of the potential palace site.
- The magnetic survey at Wat Tralaeng Kaeng South identified an alternative rice field configuration in the subsurface, along with a number of potential structures. Potential contemporary material found.
- The GPR survey at Wat Tralaeng Kaeng South suggests there is Angkor period material in the subsurface on an elevated area defined by trees.
- The GRP survey at Toul Tatob suggests the terrace was constructed in two phases. The looting at the site as represented in the GPR profile has secondary deposited high-amplitude radar responses. The fill of the moats appears to have occurred in several flood events, with the topsoil accumulating slowly.
- The GPR survey at Toul Slaeng found a variety of features within the mound and on the margins. Highly reflective surfaces were found in the moats associated with high-amplitude radar reflections. At the centre of the mound, there is a large section-break suggesting a hole was dug and refilled. This section break is surrounded by high-amplitude features. The mound also has surfaces consistent with those found at Toul Tatob, which may suggest this mound was also constructed in stages.
- The magnetic survey Wat Chedei Thmei South suggests the entire area contains culturally modified sediment. Magnetic anomalies may correlate with the remains of a village or palatial structures inside the embankment walls but failed to identify a palace. Outside the embankment, a modern subsurface feature were identified, and a mound may have been removed.

# CHAPTER 6 - REVEALING THE HIDDEN LANDSCAPES OF EARLY MODERN CAMBODIA

## 6.1 Introduction

The three Early Modern landscapes examined provide a diverse snapshot of a dynamic period of Cambodian history. In reconstructing the hidden landscape, the visible surface remains, and historical evidence examined in Chapter 2 have been integrated with the geophysical results presented in Chapter 5. The collation of these data allows for an approximate reconstruction of the Early Modern landscape. Srei Santhor will be examined as a transitional landscape, considering the superposition of Early Modern features over Angkor period material, which results in an entwined mix of surface and subsurface features. The interaction of everyday Early Modern material intermingling with the royal spaces will be examined at Longvek, considering how the physical and subsurface remains correspond with the Chronicles and oral histories. Finally, Oudong will be examined in light of political change in relation to the reign of King Jayajeṭṭhā II (c. 1619–1627 CE), who relocated the capital after the Ayutthayan invasion and undertook tax and law reform (Mak 1981, 1995). This reconstruction can then be broadly examined in relation to Angkor period material, to identify links that demonstrate change and/or adaptation across time. From this comparison the main research question and sub-research questions can be addressed:

*How does the subsurface landscapes of Srei Santhor, Longvek and Oudong augment current understanding of Early Modern Cambodia?*

- What connections can be drawn between the physical landscape and the social and political structures of the Early Modern period?
- Are physical, cultural and political changes across time identifiable by comparing the three Early Modern landscapes to Angkor period landscapes (9th-15th century)?
- Can geophysics be applied to identify subsurface evidence of Early Modern period occupation and settlement patterns?

To conclude, a review of geophysical methods will be undertaken.

## 6.2 Srei Santhor

References to Srei Santhor and its position as an important centre during the Early Modern period are frequent throughout the Chronicles, but the interpretations are fragmentary (see section 2.3.1). Srei Santhor is generally depicted in the Chronicles as the area of political refuge for transient kings, including King Cau Bañā Yāt as he left Angkor (Khin 1988:65), or a place for usurper kings, told through oral traditions which depict the rise and dominance of individuals such as usurper Kân (Kitagawa 2000). Identifying the palaces of kings and usurper kings has been complicated by the lack of surface remains, with several possible areas identified. Toul Basan, located near Baray Village in the Kompong Cham province, was investigated to test Kitagawa's (2000:57) hypothesis that Toul Basan may be the Basan of the Chronicles. This site is close to the eleventh century Theravāda Prasat Preah Theat Baray, which has elements of both Brahmanical and Theravāda Buddhist traditions. Toul Basan is also within proximity of Angkor period landscape features such as the *baray*. An examination of Toul Basan and Prasat Preah Theat Baray was conducted using ground-penetrating radar to test Kitagawa's hypothesis, and also examine how the *prasat* underwent physical transformation from a Brahmanical to a Theravāda complex.

### 6.2.1 Toul Basan

Identifying the location of Toul Basan with historical texts has been hindered by translation issues, with the diversity of transliterations of Basan from the Chronicles and Chinese accounts resulting in no clear idea of the capital's location (see, Kitagawa 2000; Vickery 1977a; Wolters 1966). To hamper this search further, the lack of surface evidence has made the verification of suggested sites almost impossible without archaeological or geophysical intervention. The lack of surface material can be attributed to the brief period of occupation by Cambodian kings. Leclère (1914:219-20) reports a new capital only being occupied for a matter of months before the king relocated to Phnom Penh, although Leclère's interpretations have been criticised for mixing local fables with the Chronicles, a complaint also articulated by Vickery (1977a:18). Vickery's (1977b:91) translation of the Chronicles reports that "H.M. [His Majesty] went up to reside in the new palace in Basan village, Srei Santhor province. He lived there for 9 years…" The contradictory evidence from the Chronicles, combined with the organic nature of building material and the monsoon climate of the region, resulted in limited surface remains.

The mound suggested by Kitagawa (2000) as being the Basan of the Chronicles is located near Baray Village, and is approximately 20x20 metres wide and 2 metres high, elevated from the surrounding landscape by rice fields. The GPR survey discussed in section 5.2.1.1 and shown in Figure 5.4 consisted of four transects and a small 15x5 metre grid. The survey size was constrained by three main factors. Firstly, a small 2x2 metre excavation trench that had been opened before the survey, limiting the available space for grid and transect placement. Secondly, a large pit at the centre of the mound also limited grid placement. And, finally, the mound appears to have been altered recently, resulting in a sharp drop into the rice field at the edges. Within these restrictions, the purpose of the survey was to investigate the internal composition of the mound in an attempt to identify any evidence of an Early Modern structure or archaeological activity. The four GPR transects provide an overview of the mound structure by imaging the boundaries of homogeneous material; it is possible from this to identify the area of archaeological material as shown in Figure 5.13. The area of archaeological material is considerably smaller than the overall mound size. Comparing the GPR profiles with the excavation sections confirms the homogeneous nature of material present and the absence of a clear boundary between any of the stratigraphic units as discussed in section 5.2.1.2. The homogeneous sediment, however, means there is little opportunity to comment on the overall construction of the mound using GPR.

The excavation results suggest the mound was used in the eleventh or twelfth centuries based on limited ceramic finds (Polkinghorne et al. 2019b). Considering the GPR results alongside the excavation data, it suggests that there was an initial building event followed by periods of sporadic use. The transects did identify small areas of high-amplitude hyperbolas which were likely the results of subsurface debris. Within the grid, potential areas of activity were also identified, but they were very localised and dismissed as contemporary contamination, as they were not seen across multiple GPR profiles. The mound appears to have undergone manipulation in recent years, such as the removal of sediment at the edges and from the pit at the centre, and the accumulation of sediment in other areas. This manipulation makes it difficult to determine the size and shape of the mound as constructed in the eleventh and twelfth centuries, as well as whether it was used during the Early Modern period.

The overall size of Toul Basan would suggest it is too small to have contained any palace resembling the structures reported in the Chronicles. When compared to other mound investigations, such as Forte and Pipan’s (2008) examination of a burial mound, Toul Basan does not share any characteristics of these anthropogenically constructed features. The burial mound was well stratified with strong radar reflections caused by change in sediment deposition as the mound was constructed. Burial mounds are accumulated through secondary deposition, with archaeological inclusions, such as the burial chamber. In contrast to this example, the Toul Basan mound is very homogenous, with very little stratification, which suggests it was not the result of deliberate deposition. In addition to this, Toul Basan is missing elements such as the layering of secondary material and archaeological inclusions. The survey of Toul Basan did not identify the natural substrate, and the mound lacks any clear layers which may have related to mound construction. Toul Basan also does not have the characteristics of an occupation mound, where the complex stratigraphic layering results in incoherent high-amplitude radar reflections as documented by Duke et al. (2016) and Thompson and Pluckhahn (2010). The lack of stratigraphic layering may be due to the radar's inability to penetrate beyond one metre depth, and the lack of variation between the strata. The GPR results suggest that Toul Basan was neither an occupation mound nor a burial mound, and the presence of Angkor period material may suggest that the small mound was inconsistently used.

With the available evidence at hand, it is possible to conclude this is not the site of King Cau Baññā Yāt's palace or the Toul Basan reported in the Chronicles. The GPR survey did not identify any subsurface features which would suggest the presence of a royal palace. When compared to the description provided by Leclère (1914:219), the area overlooks rice fields, not a river, although the area certainly fits the criticism of King Cau Bañā Yāt, who stated that the area was too wet to occupy, due to immense seasonal flooding; this is supported by the environmental processes reported by Nhim (2014-2016:72). If the area was used as a capital during the Early Modern period, it was certainly only for a short time. Excavations in the area confirm the Early Modern material is constrained to the very near subsurface, with stratified Angkor period material below it (Polkinghorne et al. 2019b). How Toul Basan got such a politically significant name is largely unknown and may be a reflection of the translation errors identified by Kitagawa (2000:54), Vickery (1977a:57) and Wolters (1966:48). The site's relationship to local oral traditions as reported by Kitagawa (2000) may be an indication of the use of Basan by the usurper Kân, who may have renamed this mound in an attempt to draw connections between himself and the kings of Angkor. However, this hypothesis is purely speculative. As this is not the Basan of the Chronicles, the next likely site for consideration is southwest located near Wat Sithor.

### 6.2.2 Prasat Preah Theat Baray

As discussed in section 2.3.1, local oral tradition suggests that Prasat Preah Theat Baray is an important site related to the usurper Kân, with reports of his depiction in a carved sandstone lintel

(Kitagawa 2000:60). The contemporary custodians connect the eleventh century image of *Vishnu* laying upon a *Naga* to the fifteenth century usurper Kân, and a relationship between the usurper king and the *prasat* may be indicative of his political influence in the area and spiritual influence over the transformation of the site. It is not clear when the Prasat Preah Theat Baray was transformed from Brahmanical to Theravāda Buddhist traditions. The current configuration of the complex is in the standard Theravāda Buddhist tradition, with the *prasat* west of a platform orientated on a west-east axis. The platform is supported by a border of sandstone door lintels and other decorative features which was previously hypothesised to have been repurposed from standing *prasat* and potentially two other missing towers, but the surface evidence did not indicate the presence of these additional structures. The eight lintels suggest that at least one more structure in addition to the *prasat* was present. Lunet de Lajonquiére (1902:161) believed this site was incomplete and in 1902 noted that the *prasat* had a corbelled arched roof which is no longer present. The purpose of the present survey was to map the subsurface to identify possible remains of historic structures, reconstruct the Brahmanical complex using geophysical techniques and consider the impact of the transition to Theravāda traditions. To examine the subsurface of this complex almost total coverage of the mound with the GPR grids was achieved.

The GPR was successful in the investigation of subsurface features at Prasat Preah Theat Baray, with numerous features of interest identified as shown in section 5.2.2.1. Concentrated areas of hyperbolas and high-amplitude radar reflections as demonstrated in Figure 5.24 were the most common features identified in the survey. Individual hyperbolas were largely contained to the very near subsurface (<0.2m) and are likely the result of contemporary contamination, such as metal, as there was no consistency of distribution. The features with most potential are shown by high-amplitude radar responses at approximately half-metre depth at three locations as shown in Figure 5.31. The high-amplitude responses would suggest they are the result of a highly reflective material, such as masonry, buried brickwork, laterite or sandstone in the form of *in situ* foundations or debris from potential additional buildings. This radar response type is consistent with those recorded by Sonnemann (2011:309), who identified similar condensed high-amplitude radar reflections to be masonry related to Angkor period temples. The subsurface features are not an easily definable shape, but the GPR evidence does suggest some *in situ* archaeological material may be present. The two areas are approximately 8x10 metres and smaller than the *prasat*. The configuration could reflect a three towered Brahmanical temple complex similar to that reported at Western Prasat Top by Sugiyama and Sato (2018). A third area with a high-amplitude radar response measuring 6x8 metres, was identified in the northeast area of the site. As shown in Figure 5.24, this radar response in similar to the features found west of the *prasat*, but there is a lower concentration of high-amplitude hyperbolas and high-amplitude radar responses. The variation between the two areas may suggest the material is in the subsurface do not have the same reflective properties as laterite or sandstone, and could be attributed to ceramics or roof tiles. The third area is also in line with the north-western subsurface feature and could potentially represent a third area of foundations.

Examining the configuration of subsurface anomalies in Figure 5.32 some correlations can be drawn between this site and other known eleventh century temples. The lack of a fourth subsurface anomaly in the south-eastern area of the site rules out the five-tower configuration which has been documented at monuments such as Angkor Wat, and which is normally restricted to temple-pyramid structures (see Coe and Evans 2018:144). If the fourth subsurface structure was present but had been completely removed, a break in the strata where the foundations would have been removed should have been evident in the GPR profiles. Buddhist terraces like this traditionally supported a light structure which Thompson (1996:275) describes as an open pavilion made of wood with a tiled roof. As the pavilion is no longer present, the third subsurface anomaly may be its remains. The broken roof tiles and decomposing wood would not have such a high-amplitude response as brick or laterite, and this would account for the variation between the amplitude and density of features.

The survey conducted on top of the platform had a deeper penetration depth than any of the other surveys, which is likely due to the different grain size of the sediment used to create the mound. Two significant features were identified on top of the platform. The first is a high-amplitude radar response seen in multiple lines across the width of the survey, and the second is a stratigraphic break of a similar width running parallel. If these features were related to the *prasat*, they would be in the western end of the platform where the image of Buddha is traditionally mounted (Thompson 1996). In some instances, ritual deposits were found under the Theravāda imagery, as documented by Polkinghorne et al. (2013), but at Prasat Preah Theat Baray there is no evidence for a pedestal for an image of Buddha or a ritual deposit. There appear to be no structural reasons for these features to be present within the platform.

In addition to these larger features found adjacent to the *prasat* and within the platform, the terrace has several smaller subsurface high-amplitude radar responses. These features may be what is left of the corbelled arch roof, laterite wall or *sema* boundary stones. When combined with the existing surface material and two potential subsurface tower foundations, this suggests a three-towered complex on a flat-topped mounded terrace, with a low laterite wall and *sema* stones marking out the sacred space. The building materials used here are the same as those used on Angkor period sites previously investigated using GPR. The GPR data presented here are comparable to those collected at Angkor Wat by Sonnemann et al. (2015), where buried tower foundations were identified. Angkor period building material is easily identifiable within GPR profiles as it is highly reflective. This is also found in relation to other instances of semi-buried architecture, where buried sandstone remains from structures and temples have been easily identified using GPR (see, for example, Anchuela et al. 2016; Himi et al. 2016; Kadioglu et al. 2013; Seren et al. 2008).

This is the first geophysical survey investigating the transformation of religious cult sites in Cambodia. The combination of the geophysical results and the artistic analysis of existing door lintels (Polkinghorne pers. comm May 2019), confirms this was an eleventh century Brahmanical temple complex. While there are not enough decorated lintels present to have adorned three towers, it is possible that other carved elements have been removed from the site over the last century. The size and configuration of Prasat Preah Theat Baray is more in line with other transformed sites such as Western Prasat Top. However, the key difference between Western Prasat Top and Prasat Preah Theat Baray is the placement of the adjacent towers. The asymmetry was not uncommon during the Angkor period, with many temples lacking alignment, such as Preah Ko in the late ninth century city of Hariharālaya (see, Coe and Evans 2018:122). This variation in alignment may suggest a staged construction for Prasat Preah Theat Baray, with Lunet de Lajonquiére (1902:162) commenting that the current standing *prasat* seemed unfinished. If the *prasat* was incomplete, perhaps the additional subsurface anomalies were towers that were never built beyond their foundations, as opposed to a structure that was removed. The single tower configuration is more in line with Preah Palilay, which is also enclosed by a laterite wall, similar to Prasat Preah Theat Baray. The main difference between the two, is that the Preah Palilay tower sits on top of a pyramidal mound, while Prasat Preah Theat Baray is flat topped. Subsurface anomalies directly west of the *prasat,* as shown in Figure 5.26, suggest that the current ground level is not the original, with the *prasat* elevated on a stone platform.

The GPR evidence may also be indicative of an incomplete restructure of the Theravāda complex, which is supported by the evidence at Western Prasat Top, where the two additional towers were constructed after the central Prasat. However, Western Prasat Top had significantly more reconfiguration undertaken compared to Prasat Preah Theat Baray (Sugiyama and Sato 2018). Similarities lie in the three-tower configurations and layout of the area, the use of boundary markers and the presence of *sema* stones. At Western Prasat Top, once the two towers were removed, two brick lined pits were found beneath, measuring approximately 2x2m and 1.5m deep (Sugiyama and Sato 2018). The radar response at Prasat Preah Theat Baray does not suggest the same brick-lined pits are present, as there were no section breaks suggesting a pit or a reflective surface such as a brick lined pit would create. The size of the subsurface anomalies are also significantly larger than those found at Western Prasat Top, but if the structure had collapsed in on itself, it may be represented in the current dataset (based on the size of the anomalies, this seems unlikely).

Comparison between sites that have undergone renovations from Brahmanical to Theravāda traditions suggest the physical transformation of religious sanctuaries was a complex undertaking. The comparison between Preah Palilay, Western Prasat Top and Prasat Preah Theat Baray demonstrates an *ad hoc* renovation process. The physical changes vary from site to site, contrasting the documented consistency at sites in the Srei Santhor region examined by Thompson (1996) and suggesting that temple transformation processes were not fully refined until the Early Modern period. The physical transformation occurring – along with paradigmatic changes – is site specific and individualistic, as evident in the variability between Prasat Preah Theat Baray, Western Prasat Top and Preah Palilay. When comparing the surface and subsurface remains of Prasat Preah Theat Baray to local oral tradition, it would appear that the eleventh century site was already transformed before the arrival of the usurper Kân. This does not diminish the importance of oral traditions in the region, but rather suggests the social significance of the *prasat* and the narratives associated with King Kân.

### 6.2.3 Transitional Landscape at Srei Santhor

The broader landscape of Srei Santhor encompasses more than the two sites examined here. While the investigation was a targeted approach with specific research hypotheses to test, it also adds to current discourse on the region by narrowing the search field for Basan and adding to discussions surrounding the transition to Theravāda Buddhism. Scholars have considered the introduction of Theravāda Buddhism as the national religion in the late thirteenth century as an event which marked the beginning of Angkor's decline, but it can also be viewed as the beginning of a long period of change and adaptation that carried the civilisation into the era of Early Modern globalisation. The major changes documented here, particularly the discontinued used of sandstone and laterite in temple construction, while attributed to be Early Modern period, are in fact Angkor period changes. The transformation occurring in the Baray Village area appears to have occurred during the late Angkor period, with the landscape features being further utilised during the Early Modern.

Rather than rupture, the decline of Angkor and the transition to the Early Modern period might be more appropriately appraised as period of continuity, demonstrated by the similarities between the archaeological landscapes of the Angkorian and Early Modern periods (Pou 1977). The difference between the three sites examined by Thompson (1998), Wat Sithor, Vihear Suor and Wat Mae Banh, and the three temple complexes investigated here is one of continuity. Thompson (1996:284) argued that the Cambodian court had a well-established religious culture resulting in continuity of worship at established religious sites during the Early Modern period. However, Early Modern structures at Angkor, like the Buddhist Terraces studied by Marchal (1918) are examples of an original style and form being retrofitted to suit the new Theravāda structures. The transition from an ad hoc to a coherent site design demonstrates the concreting of Theravāda traditions and the end of Angkor traditions. The lack of unity in the transition from a Brahmanical to a Theravāda complex reinforces that these sites were transformed in the Angkor period and not representative of Early Modern traditions. A more in-depth investigation of transformed complexes and Early Modern Theravāda sites is required to fully understand the differences and continuity of traditions.

The landscape of Srei Santhor contains transitional elements between Brahmanical and Theravāda cults, physical transformations from Angkor to Early Modern and cultural change in the form of transformed sacred sites. The landscape of Srei Santhor demonstrates socio-cultural and political change in the region as revealed though the examination of land use, temple reconstruction and the presence of standardised Early Modern elements. The use of the broader landscape to understand this change has had not been previously considered within Early Modern research. However, building on the work from Nhim (2014-2016), a finer-grain examination of the area through an archaeological and geophysical lens could provide further insights into the nature of change in the area. Examining the area around the still used Wat Sithor, for instance, to find the palace of King Cau Baññā Yât, or an examination of the Mekong River to identify the remains of trade ports or shipping could greatly expand our understanding of this landscape.

## 6.3 Longvek/Oudong

The Longvek landscape was the most intensely investigated of the three sites. The combination of lidar, excavation and geophysical data allowed for a multi-scale examination of the landscape. As Longvek is the setting for some of the largest remaining Early Modern features, such as the citadel, and significant events, such as the Ayutthayan invasion, a multimethod geophysical investigation was needed to create a more comprehensive picture of this culturally modified landscape. As previously established in section 2.3.2, Longvek was an Angkorian centre before it was made a capital in 1528 by King Cau Baññā Cand (Khin 1988). Inscriptions found date to the reign of Harshavarman III (1066-1080) and report on an important elite family living at Longvek, outlining their genealogy and their service as ministers to the king (Briggs 1951:62). Angkor period landscape features still remain, superimposed by the addition of Early Modern styles. A significant portion of the cultural remains are hidden in the subsurface. The broader landscape of Longvek was previously examined through targeted foot surveys, site recording and, more recently, lidar. The targeted survey approach provided the baseline information of the Angkor and Early Modern period sites in the region, providing context through surface finds and architectural features. Angkor period inscriptions and artefacts, such as statues and ceramics, were found scattered throughout this landscape, intertwined with Early Modern material. In this area there appears to be a mix of Angkor period (c. 900–1400 CE), Early Modern (c. 1400–1800 CE), modern (c. 1800–1900 CE) and contemporary (c. 1900– present) material.

### 6.3.1 The Broader Landscape

The application of lidar has resulted in the mapping of a 131.6 square kilometre area, detecting landscape features such as small mounds and ponds which had not previously been identified. As the previous lidar studies in Cambodia focused on Angkor period sites, the features identified and mapped conformed to the typology developed by Pottier (1999) and Evans (2007). The survey was compared to the walled capital Angkor Thom, drawing conclusions around population density and migration in relation to the decline of Angkor (Evans 2016). The comparison between the two cities is limited. Current discourse around central Angkor is focused on maximum population density for a city that was occupied for several centuries (Evans et al. 2013). Occupation at Longvek by contrast was brief. It was dominant as a capital only in the sixteenth century and the function and economic structures of Longvek vary to such an extent that a comparison between the two capitals is not possible. With over a century between the occupation of Angkor Thom and that of Longvek, it should be no great surprise that variations are evident. Angkor Thom was densely populated, while Longvek was a trading centre that was probably populated by transient traders and local elite. While the two capitals have broad similarities, the differences are indicative of the shift to trade as the dominant economic mechanism.

The citadel of Longvek is one of the largest remaining landscape features of the Early Modern period. Historians proposed up to 10,000 people living at Longvek at its height in the sixteenth century (Reid 1993:76). The lidar survey identified a range of landscape features following the criteria established by Pottier (1999). The most prevalent feature identified in the lidar survey were ponds and small mounds (see section 5.3.1). Ponds and mounds have been previously associated with occupation. The prevalence of ponds has been investigated previously in relation to Angkor population density models, proposing up to two families associated with each communal pond and estimating up to 16,000 people living within Angkor Thom (Hanus and Evans 2016:91). Seven hundred and seventy-one possible ponds were recorded within the lidar survey area, which includes Longvek and Oudong. Applying Hanus and Evans (2016) premise of two families per pond, with five people to a family, the Longvek/Oudong dataset (Table 6.1) suggests that 7710 individuals potentially lived in the area. As Hanus and Evans (2016) highlight, this approach does not take into account a chronology for the construction of the ponds and whether each of these landscape features was being consistently used at the same time. The relative landscape chronology of Longvek (discussed below in section 6.3.2) suggests these ponds were related to an Angkor period settlement based on the rice field orientation of a series of ponds west of the citadel, suggesting that a considerable population had been present in the region as early as the eleventh century based on local inscriptions (see Cœdès 1942:119-120). In applying this premise to an Early Modern landscape context, it does not factor in a transient population of international traders or whether families may have been living along other sources of water, such as rivers or channels. Adding in these factors would suggest that a population as large as 10,000 could have been residing at Longvek and Oudong, and challenges previous understandings of this landscape.

Table 6.1: Population estimates of Longvek/Oudong based on Hanus and Evans (2016) approach.

| **Ponds identified in lidar** | **Two families per pond** | **Five people per family per pond** |
|---|---|---|
| 771 | 1542 | 7710 |

The application of population estimates has its limitations, as the lidar survey represents only a sample of the broader landscape. At the very least, it opens discussion about population density in the region. Evans (2016) conclusions centre on arguments related to migration from Angkor following its decline, suggesting that there was not a large enough population at Longvek to represent a mass movement of people. This conclusion is accurate based on the evidence at hand, although the notion of diaspora neglects to consider that centres such as Longvek were already established urban centres. The geophysical investigation conducted here complements the work conducted by Evans (2016), furthering the current discourse surrounding population density. The review of the Longvek landscape suggests an already established population during the Angkor period. As research into Angkor's decline is further developed, issues of population migration may become clearer. Based on the evidence at Longvek, this was not a diasporic population, but rather a community established during the Angkor period that was well situated to capitalise from the increase in international trade in Cambodia.

The population at Longvek was large enough to undertake the construction of features such as the citadel, *tumnup, prek,* ponds and mounds. The citadel is an important landscape feature due to its size and defensive capacities and would have taken a considerable work force for its construction. When compared to the massive earthworks of the prehistoric site Co Loa, which Kim (2013:231) estimated took 1000 to 10,000 people 3-50 years to construct, the multi-walled citadel at Longvek would have also required a significant workforce over many years to construct. The capacity to command a workforce of this size suggests a continuation of political control over indentured labour systems established in the Angkor period. Future research into this structure could consider the volume of the citadel walls and make more appropriate estimates of the labour force required. Without absolute dates on the walls themselves it will not be clear how long it took to construct or extrapolate the labour force required. An alternative view yet to be considered is that the citadel was constructed in the Angkor period and the timeline changed to suit the narrative of the Chronicles.

Considering the resourced used for the construction such a significant defensive structure, it does beg to question why a fourth wall was not within the citadel design. The current small portion of wall evident in the lidar bears no indication that it was constructed as part of the citadel, if it is a water management device or a modern construction. The missing portion of the embankment would suggest that the designer did not foresee the need to defend the citadel from incursion from the river. The land between the citadel and the river is flooded rice fields during the wet season, only accessible by small boat and during the dry season, accessible by foot. Considering the *prek* to the north could be a controlled entry point from the river, it is easy to see why this portion of the citadel would not be constructed. Future research could focus on the meandering bedding of the river as it changed course over the centuries to fully understand the nature of this portion of land. Once this information is established and compared to historic document, a better understanding of the citadel construction and its relationship to the river and hydraulic systems could be achieved.

The hydraulic systems found at Longvek are significantly different to those found in central Angkor. The hydraulic city theory—as proposed by Groslier (1979)—presents a network of channels for the purpose of providing water for an agrarian kingdom based on surplus rice production. At Longvek the hydraulic landscape features are either *prek*, channels that are cut to divert river water into the landscape, or *tumnup*, embankments that retain water for rice production. The placement of the *prek* along the river could suggest these were related to trade and possible ports. The Longvek ports were proposed by Nhim (2014-2016:80) to be located at the northeast bastion of the citadel and therefore using the northern most *prek*. While water management systems and technologies between Angkor and Early Modern periods have significant differences, the value of the rice fields and rice production should not be overlooked, and is discussed further below.

The Early Modern landscape recorded by lidar has its limitations within the context of this research. The methodology used to investigate open rice fields at Longvek was the same used to investigate the forest-covered cities of central Angkor (Evans et al. 2013; Evans and Fletcher 2015; Evans 2016). This method was very successful in defining large landscape features such as temples, embankments, channels, ponds and mounds. The lidar survey undertaken at central Angkor by Evans et al. (2013) had an average of three points per square metre, ideal for larger features. Risbøl and Gustavsen (2018) undertook multiple surveys at the same site to test variations in methods and capacity for an increased point per metre average and are important here to understand how future lidar studies at Longvek could be adapted to find smaller landscape features. The parameters that Evans et al. (2013) applied to this Early Modern landscape (as reported in Evans (2016), could have been adapted to account for differences in landscape coverage at Longvek, which consists of cleared rice fields. In Risbøl and Gustavsen's (2018:8) study, they found that the application of drone lidar allowed for 22 points per square metre, resulting in a much more detailed digital elevation model that could identify significantly more landscape features. Future research may take an alternative approach at Longvek to determine whether a more detailed digital elevation model could be created, and less prominent landscape features identified. Since being established by Pottier (1999) in the first comprehensive largescale mapping of Angkor, the parameters for identifying Angkor period landscapes have not changed, nor been reconsidered for an Early Modern context. In future lidar studies of Early Modern sites, a new set of collection parameters and feature identification criteria may be beneficial.

### 6.3.2 The Rice Fields

The analysis of the rice fields of Longvek, through the application of Hawken's (2013, 2011a) investigative framework as described in section 2.4.3.1, has allowed for the investigation of bund orientation and field configurations. Hawken's framework allowed for the development of a relative chronology based on configuration variations and the identification of patterns of landscape adaptation and potentially revealed new archaeological sites. As the rice fields are continuously used as contemporary material culture, their relative chronology can only be attributed to when they may have been constructed and what changes they may have undergone. By comparing the Early Modern and Angkorian period agricultural landscapes, change to the physical, cultural and/or political structures can be considered. Through the careful mapping and analysis of the rice fields within the citadel and surrounding area, the following configurations have been identified.

#### *6.3.2.1 Rice Field Configurations and Chronology*

Cardinally (class one) oriented rice fields are related to water sources, such as the river south of the citadel and ponds to the southwest of the citadel. This formation is prevalent at Angkor and related to the central temple network and is Hawken (2011a) class one. The Longvek field sizes averaged 40x40 metre bunded systems. Their distribution does not follow a consistent pattern, and is dissimilar to the central Angkor temple network where this field type was most prevalent (Hawken 2011a:218). The cardinal fields at Angkor were directly related to state-level farming activities in the region, with urban density decreasing at the periphery of central Angkor. At Longvek, the situation would appear to be the opposite, with the prevalence of cardinal fields being limited to what potentially may be Angkor period village sites. As these clusters of class one rice fields are found in small pockets, it may be indicative of an Angkor period settlement living in the region. The Chronicles do not allude to an existing settlement at Longvek, although inscriptions examined by Cœdès (1942:119-120) detail an elite family residing here at in the eleventh century. An existing population of Angkor elite landowners in the area would make the settlement more enticing, as physical and political structures may have already been in place.

A significant landscape element to consider here are the *tumnup*, their origin and how they relate to broader rice production. The radiating rice fields found east between the citadel and the river are creating by an embankment or dyke, producing an artificial wetland which irrigates very long and narrow rice fields. These radiating rice fields are different from the type described by Hawken (2011a) that radiate from a central landmark, such as a temple. These fields do not conform to any single class, as their bearing is dependent on the shape of the *tumnup*. This type of field configuration has not been reported at Angkor, as the *tumnup* are believed to be a contemporary modern structure. The very narrow and small fields would indicate they were constructed before the advent of contemporary machinery, similar to what Bray (1986:56) documented for pre-industrial rice production in Japan. Absolute dating of these structures is required to place these landscape features within a timeline, a verification process required for all the geophysical results presented in this research. Their function as an irrigation tool and an artificial wetland would have greatly benefited the subsistence capacity of Early Modern communities. Observations made during data collection near wetlands similar to those created by the *tumnup,* saw these landscape features frequently used by local collaborators, who collected water plants, frogs, crabs, fish and small invertebrates on a daily basis, but to fully understand the use of these features an ethnographic investigation of contemporary subsistence strategies would be required.

If these *tumnup* at Longvek are determined to be historic structures it adds a level of complexity to the management of water, land and human resources in this region. The *tumnup* are large enough to require an organised workforce for their construction, and historic texts document elite landowners being afforded the legal privilege of assembling human resources for the crown

(Mikaelian 2006:262). This may suggest these were either administrated at a local or state level. A better understanding of these landscape features could clarify the importance of rice farming in relation to international trade during the Early Modern period. Future research needs to consider the rise of rice farming elites in the sixteenth century before the fall of Longvek and how this may have contributed to the prosperity of the capital. In addition to this, further research could examine the output capacity of the region to assess the value of rice within the Early Modern economy.

The Early Modern configuration is best represented by rice field orientation class eight, as demonstrated in section 5.3.2 (Hawken 2011a). This classification has been assigned because the fields are oriented to the citadel walls as opposed to contemporary infrastructure and is the dominant class for the region. Fields are narrow and irregular compared to contemporary field types. This class is most prevalent west of the citadel and associated with a series of ponds identified in the lidar survey. The ponds are on a different orientation to the class eight rice fields, suggesting they may be superimposed over the Angkor period settlement suggested above. The layering of Early Modern rice fields over an Angkorian settlements may suggest that the population estimates based on these ponds (see above 6.3.1) do not relate to the Early Modern period. The variation in feature orientation aids in developing a relative chronology for the broader landscape, as there is evidence of these rice fields being adapted to suit contemporary irrigation systems.

The chaotic rice fields represented by Hawken's classes two, three, four and five (Hawken 2011a) do not appear to conform to a distinct pattern, instead following the natural topography similar to the systems found on the archaeological shore of Angkor. Hawken (2011a) describes those at Angkor as being coaxial fields, which have temporal and topographic relationships, but at Longvek the sample size is small, dispersed and not conclusive. This rice field type may be an indication of small-scale community level farming, as it is often related to terracing radiating from a central point. It is this field type which makes site identification possible. These chaotic rice fields may be associated with prehistoric, historic or contemporary farmers making minor changes to individual rice bunds. The contemporary rice fields are defined by a grid system bounded by irrigation channels, are often orientated along roads and large enough to accommodate contemporary machinery (approximately a quarter hectare). At Longvek this configuration is best represented by Hawken's (2011a) classes six and seven. The larger grid system to the west outside the citadel appears to have been superimposed over the existing rice field configuration. This contemporary field configuration differs from those reported by Hawken (2011a), who reported on the very large gridded system introduced in the 1970s.

#### *6.3.2.2 Apparent Social and Political Control?*

A relative chronology of field development can be created for the rice fields around the citadel of Longvek. West of the citadel, it is possible to see the layering of Angkor, Early Modern and contemporary systems. This layering would suggest that the construction of rice fields increased during the Early Modern period. Their uniformity may suggest they were constructed for royal use, however without further interrogation of the historical documentation in relation to the remotes sensing results, this conclusion remains speculative. Broadly, the rice fields do not have the same structured distribution as seen at Angkor, but there appears to be correlations between the administration of agricultural land through the consistent reproduction of a rice field type. It would suggest that the class eight orientation of the citadel and surrounding rice fields of Longvek are evidence of state level control of landscape modifications during the sixteenth and seventieth century. Seventeenth century legal codes and royal orders describe the king as the 'organiser of space', having control over the management of royal rice fields (Mikaelian 2006:262-264). Agricultural tax reforms outlining a tiered system based on social status saw officials linked to the crown, such as governors, negotiating their tax, with elites paying one-fortieth and the general population one-tenth of their field yields (Mikaelian 2006:278). The variation in field types may be related to different levels of social status.

There are significant physical variations between the Early Modern and Angkor examples. Unlike at Angkor, where the dominant orientation is aligned to temples, at Longvek this is dependent on the water source. Outside the citadel wall, rice field orientation is associated with ponds, channels, dykes and rivers. The shared orientation of the rice fields inside and outside the citadel reinforces the hypothesis that elements of planning were involved in their layout and construction. The placement of rice fields within the citadel may suggests they were the royal fields described by Mikaelian (2006:262). If these fields were present within the citadel while it was a capital, it reinforces the ongoing value of rice as a commodity. During the Angkorian period, the agrarian empire closely managed urban farming and water management systems, as they were a central part of maintaining wealth. The rice field configuration at Longvek suggest there was a continuation of control over agricultural resources. This is further reinforced by seventeenth century Early Modern laws prohibiting land being left untended and protecting farmers against theft and destruction (Mikaelian 2006:462, 466). The continued control over agricultural commodities would suggest the value of rice production did not diminish between the Angkor and Early Modern periods and it remained an important taxable item despite the arrival of international trade.

#### *6.3.2.3 New Archaeological Sites?*

In addition to providing a comparative analysis of Angkor and Early Modern landscapes, rice field analysis also provides opportunities to identify previously undocumented sites at Longvek. Additional archaeological sites have been identified using Hawken's (2011a) premise of rice fields radiating from a central point, such as a village level temple. There are several instances where this is the case at Longvek. Six potential sites have been identified, shown in Figure 6.1. Of these, one—site G in Figure 6.1— was foot surveyed by the *Middle Period and Related Sites Project* and surface ceramics found. The site is approximately 200 metres in diameter, which is a standard village mound size form and comparable to other prehistoric mounds, such as Lovea in central Angkor (O'Reilly and Shewan 2016), and those on the Khorat Plateu (Boyd and Chang 2010). The difference here is the lack of height, as the mound near the southern citadel wall is slightly raised above the surrounding rice fields compared to the prehistoric mounds which, in some instances, can be several metres high. The size and shape of this landscape feature may suggest it is prehistoric in nature, although the surface ceramics suggest it is more likely to be Early Modern. Without ground verification via excavation, the nature of this mound will remain unknow.

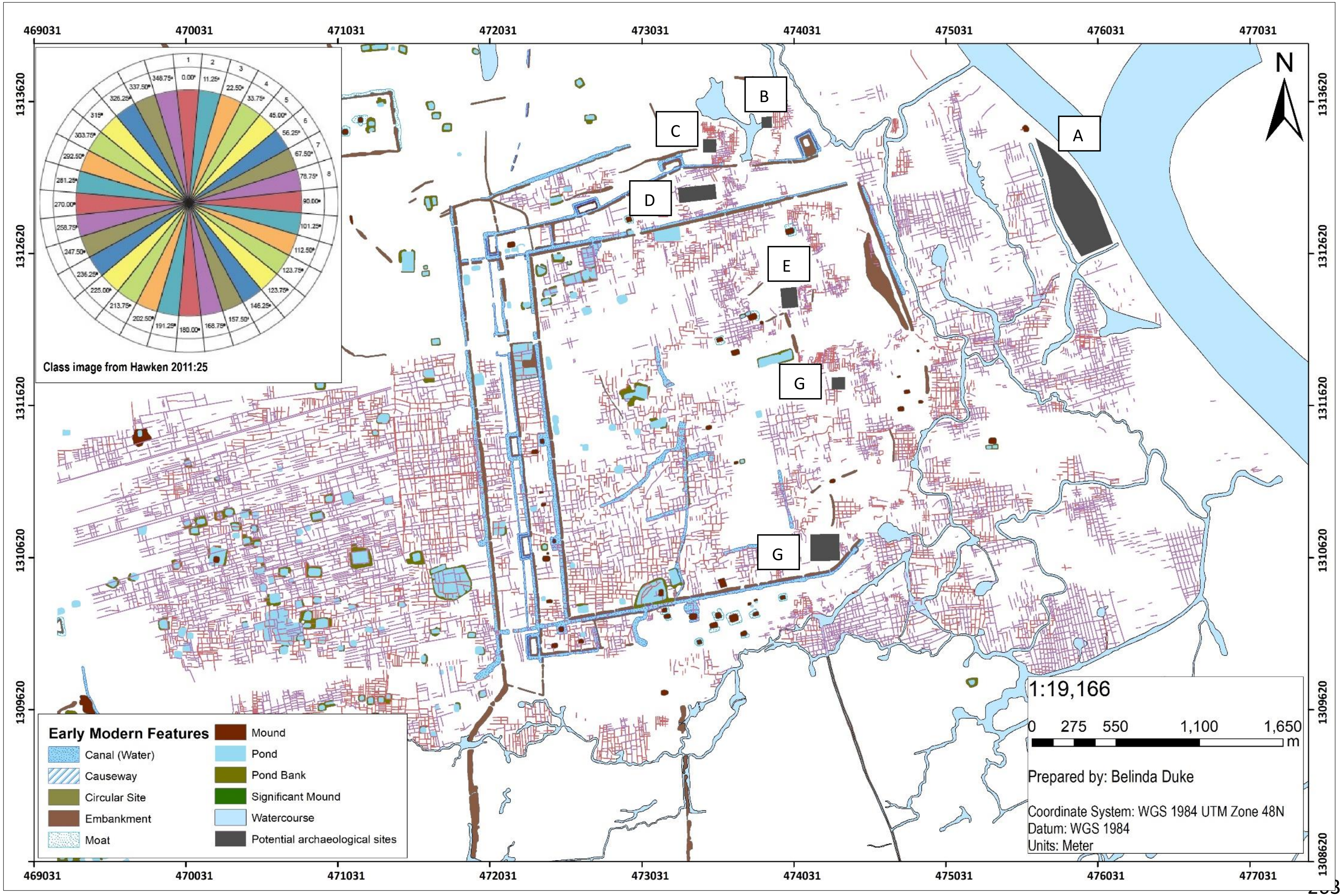



Figure 6.1:Potential new archaeological sites at Longvek based on rice field analysis.

Other identified sites do not have the characteristics of an occupation mound, but rather utilise the natural elevated topography. Also around 200 metres in diameter, these potential sites are identifiable by the steep and narrow terraced fields that radiate from them. If these are areas of occupation, it greatly increases the areas previously thought to have been inhabited, particularly when combined with the geophysical results below. Of these features, two potential sites north of the citadel wall and a few hundred metres from the bastion are of interest, site B, C and D in Figure 6.1. Nhim (2014-2016) proposed that a trading port was in this location, based on an examination of remote sensing data, as a port could make use of the bastion and *prek*. If this area is considered in light of the Dutch rendering of the area in Figure 2.9, the position of the potential port in the landscape in relation to the *prek* in the image could suggest there is some accuracy to this painting. The basic elements of this painting are a small river to the south and a fortified settlement in the mid-ground which appears to be the *prek*. If the settlement in the Dutch painting was present, it may be located where modern rice fields (class seven) are found along the river. These sites should be further investigated in relation to trade at Longvek, along with the other mounded sites. Knowing where people were living in this landscape may provide further insights into land and resource management. The lack of uniformity amongst the distribution of these potential sites may suggest that centralised (i.e. royal) control over space did not extend to villages.

### 6.3.3 Brick Factory North

The royal palace at Longvek is believed to be under a working brick factory constructed in 2015. The brick factory is on top of a mounded area and consists of three kilns, accompanied by brick making and drying areas, and a large mound of sediment imported to the site. This location for a palace was proposed because of its slightly mounded elevation, its proximity to Wat Tralaeng Kaeng and the fact that it vaguely matched the description given in the Chronicles, which reports King Cau Bañā Cand finding the area and ordering the construction of a palace and associated structures (Khin 1988:143). Due to a lack of access or open space for survey, however, the area within the brick factory could not be investigated. The survey was conducted in the immediate area around the brick factory to investigate features that may be associated, such as royal palatial structures. Landscape features have been identified through a combination of magnetometry and ground-penetrating radar data.

#### *6.3.3.1 Magnetometry*

Neither the Chronicles nor any other historic texts provide a description of any Early Modern palace or related palatial structure. As such, contemporary ethnographic examples presented in Tainturier (2006) are considered here, as they show stilted dwellings sitting on bases made of concrete or stone, or dug into the ground. Angkor period examples of wooden structures offer some insight into the tradition of wood architecture, but archaeological examples of this are rare, see 2.5.2. The investigation of wooden structures is reliant on examining the associated material culture, as the structures themselves are not identifiable through geophysics.

Housing structures have previously been identified by the magnetic variation from ritually burnt structures as investigated by Nelson (2014), although in this context the ephemeral nature of land use and building materials has resulted in the magnetic response being very subtle, with no clearly identifiable features represented. Features were identified through a process of elimination and visual inspection of patterns based on subtle variations in the magnetic response between the potential feature and surrounding sediment. North of the brick factory, as discussed in section 5.3.3.1 there is an increase in magnetometer responses within the tree-lined mound area proposed as the broader palace site. This variation may be due to the different sensors used or the line spacing, as a single sensor at one metre spacing was used outside the tree boundary but a dual sensor at half-metre spacing inside and outside the tree boundary. The variation of the sensor does not appear to have influenced the comparison, although the change in linespacing from one metre to half a metre may have. The half-metre line spacing allows for greater resolution of data, as more data points can be collected in a single area. In comparing the two sets of data with the variance in linespacing in mind, the survey grids over the rice fields have fewer magnetic features recorded. This is likely the result of either the farming process mixing and distributing magnetic data (with rice bund construction accumulating magnetic rich sediment), or the fact that the mound was the primary area for occupation in this area. All areas, however, have evidence of culturally modified sediment. While the magnetic features mapped at Longvek do not provide a clear urban planning layout, what appears to be present in this context is anthropogenic activity around structures. As there is no comparable reference material for Southeast Asian magnetic responses, the process to identify possible structures in the landscape involved a visual inspection of datapoints to establish whether a pattern emerged. With no reference material of what a palace or related structure consisted of, an assumption was made that they were likely four-sided, uniform structures. Non-linear features were also mapped and, depending on their size and shape, were examined in relation to larger landscape features.

Trenches excavated at the brick factory showed an anthropogenic lens of sediment related to Early Modern occupation (Polkinghorne et al. 2015) that could also be recognised in the GPR data. Occupation and house mounds have been reported in many Cambodian historic and prehistoric contexts (see, for example, Carter et al. 2018; O'Reilly and Shewan 2016; Stark et al. 2015), but the geophysical investigation of occupation mounds has been extremely limited (see, Duke et al. 2016). The combination of excavation data and the prominence of magnetic features on the mound reinforce that the sediment has been culturally modified through occupation. The organic and perishable nature of the building material and the ease of removing and moving settlements, as described by Reid (1988:62), starkly contrasts with geophysical investigations of European sites, where streets and structures are easily identifiable due to the magnetic properties of building materials such as fired clay or bricks. This is particularly evident when compared to magnetic surveys such as Donati et al. (2017), where the streets were shown to have a high positive magnetic value. At Longvek the remains of a uniform urban landscape are not evident, as shown in Figure 5.44

The most prominent features were the contemporary rice fields. This was evident from early in the survey, and exclusion buffers were therefore created during processing. The very high magnetic value (>10nT) of the anomaly compared to the surrounding area is believed to have been the result of archaeological inclusions. The construction of the bunds – which involves the gathering of topsoil to create the bund, as examined in section 2.4.3.1 – likely resulted in the secondary deposition of cultural modified sediment and artefacts such as pot sherds. Linear anomalies bounded by high nanoTesla value features were identified outside the palace mound boundary. Contemporary rice bunds—which are highly magnetic linear features approximately a metre wide—were excluded from the analysis. Subsurface features with the same characteristics could suggest they are disused rice bunds. In this case, these features were not interpreted as being related to structures, as their long and narrow nature does not conform with any structural design examined here. Furthermore, these proposed rice fields are on a different orientation to the contemporary and may possibly have been the result of the previous rice fields being removed by the construction of the citadel and the current configuration established after Longvek was no longer a capital.

Based on the excavation results at the brick factory, it is clear this mound is the result of occupation and the application of magnetometry was successful in identifying culturally modified sediment in the surrounding area. The presence of culturally modified sediments suggests the areas around the mound were also occupied. While this survey cannot be certain of these features without excavation, it does confirm that this area was used, and to an extent, helps confirm Evans (2016:172) conclusion that the Early Modern evidence lies under the contemporary landscape at Longvek. This suggests the land has undergone a series of modification processes throughout history, but the lack of a temporal scale for the geophysical data makes it difficult to date these changes.

#### *6.3.3.2 Ground-Penetrating Radar*

Ground-penetrating radar (GPR) data adds to this investigation by providing a method of ground verification and by providing a vertical scale for magnetic data that can only be represented horizontally. There were very few instances of the magnetic and GPR data identifying the same feature, with the GPR identifying anomalies at a depth beyond the magnetometer's capacity. In GPR Grid 04 a large subsurface feature was identified half a metre below the ground surface. It is being interpreted here as a pond, as its depth and dimensions (20x30 metres) conform to the shape and situation of ponds that remain in the landscape around Longvek. The GPR data shows a clear, flattened 'u'-shaped lower horizon boundary that can be seen across all profiles of Grid 04. While the depth of the lower boundary is variable across all profiles, this feature has a consistent fill of high-amplitude radar responses, which appear to be the result of filling the feature with anthropogenic material, similar to the processes of midden accumulation described by Thompson and Pluckhahn (2010). The upper horizon acts as a horizontal reflective layer and appears to be the result of rice production. The farming and ploughing process creates an artificial 'traffic pan' in the subsurface which separates the water from the water table below (Hawken 2011a:62). This appears to be represented in the GPR profile as horizonal reflections at approximately half to one metre in depth. Above this horizon is the sediment of the rice field. With the magnetometer data superimposed on top of these data, it is possible to see a sequence of events here.

High-amplitude radar reflections were found consistently across all the GPR grids. Near surface hyperbolas were attributed to contemporary contamination and generally did not align with any magnetic anomalies. All identified GPR anomalies were mapped in GIS and considered alongside the magnetic data. Pit features, as defined by their depth and contents, were also consistently found across the survey grids. Figure 5.54 is an example of this, where the bottom horizon is deeper than the surrounding and the fill consists of a condensed collection of hyperbolas. In some instances a pit was found across multiple lines of date, such as in GPR Grids 05, 06 and 12. In GPR Grid 05, a feature was identified across five lines of data and was approximately 2.5 metre long and approximately 1.5 metre deep. In this example it is not clear if this is a pit or part of a channel, as the grid did not cover its full extent. However, considered alongside the magnetics data, a long narrow magnetic anomaly crossing the width of the nearby field could possibly be a continuation of this feature as it aligns with a contemporary ditch.

Highly reflective material was found in multiple instances in GPR Grids 07 and 12. In GPR Grid 07, forming a linear feature across multiple profiles. In Cambodian contexts, these feature types have been interpreted as buried masonry, such as laterite or sandstone (see, for example, Sonnemann et al. 2015). In Figure 5.59 these features appear to form a shape that could be interpreted as subsurface foundations. These features differ from a pit, as they are more uniform and narrower (less than half a metre wide). There was no surface evidence to suggest this was a contemporary feature. If this is an Angkor period feature it is supported by other local evidence for the presence of a pre-Early Modern population, such as eleventh century inscriptions found at Wat Tralaeng Kaeng by Cœdès (1942:119-120).

GPR Grid 12 had the highest quantity of high-amplitude radar reflection caused by archaeological anomalies. Archaeological excavations conducted in the vicinity of the brick factory to find the palace identified a layer of archaeological material which correlates to the radar responses. This lens of material is bounded by an upper and lower horizon and is consistent with examples at other occupation sites, such as the prehistoric occupation mounds investigated by Duke et al. (2016). This layer is about a metre thick and consists of unstratified, dense radar reflections. This lens is also found in GPR Grid 07 and is the same thickness. This confirms the brick factory mound and proposed palace site consists of accumulated archaeological material. Grids not on the mound, such as GPR Grids 05 and 06, did not have this defined lens. Of interest at GPR Grid 12 was the area that was devoid of high-amplitude responses. The size and shape of the areas with high-amplitude responses may suggest the presence of a structure, where the presence of the building prevented the accumulation of anthropogenic sediment. Other areas devoid of magnetic responses were also prevalent, although these are more difficult to interpret and at present have no clear identification. All features discussed above were interpreted along with the magnetic dataset to reconstruct the landscape.

#### 6.3.3.3 Potential Landscape Features

The landscape reconstruction, in Figure 5.73, was created by combining the results from the magnetometer and GPR surveys. This reconstruction did not identify many landscape elements, as many of the linear features identified in the magnetometer survey were not spatially relatable to other magnetic of GPR features. Overall, the potential structures identified did not conform to any orientation or spatial pattern. This is a contrast to the residential patterning identified at Angkor Thom documented by Hanus and Evans (2016) which is found on a linear grid system. The placement of the potential structures at brick factory north is very much ad hoc, with no clear pattern in size or placement and it is not possible to place any of them into a chronology. The presence of such a large-scale feature, such as the pond found in GPR Grid04, suggests other larger landscape features are hidden throughout the subsurface of the citadel outside the survey area. While there is a distinct boundary created by the palace mound, the magnetic responses outside this boundary suggest that the exterior, too, is a culturally modified space.

### 6.3.4 Wat Tralaeng Kaeng South

Wat Tralaeng Kaeng remains an important Theravāda Buddhist site related to the Angkorian, Early Modern and contemporary periods. The area south of the site was investigated to determine if a uniform grid system of occupation was present similar to other sites such as Angkor Wat, where it was documented by Carter et al. (2018) and Stark et al. (2015). Magnetometry and GPR were used here to investigate the subsurface, with the GPR survey used to investigate features identified by the magnetometer. When the magnetometer stopped working, GPR was undertaken in isolation. Magnetometry and GPR anomalies were then examined in GIS to reconstruct a possible Early Modern landscape.

#### 6.3.4.1 Magnetometry

An alternative rice field configuration was identified in the magnetometry survey south of Wat Tralaeng Kaeng. The magnetic signature of this field configuration is inverse to those found at the brick factory, see Figure 5.79. The magnetic value of the identified potential field was significantly higher than the area believed to be the rice bund. The variation between the two areas may be an indication of the chronology of the field construction. The high magnetic value of the contemporary bunds has been hypothesised to be caused by the accumulation of cultural modified sediment. If the bund was created before the area had been settled, then the bunds may have been created through the accumulation of unmodified sediments. The higher magnetic response within the rice field is related to farming practices, resulting in a chemical change in the sediment and causing chemical remanent magnetisation (as documented by Fassbinder 2015:87). These bunds may have been created before the Angkor period and before the temple was constructed, then removed when the temple was built. The removal of these fields would suggest a wide scale palimpsest event when the area was settled during either the Angkor or Early Modern periods. As there is Angkor period material at Wat Tralaeng Kaeng (and also found in the GPR survey), it would suggest this modification occurred when the area was settled, possibility in the eleventh century based on local inscriptions (Cœdès 1942:119).

The evidence of occupation or associated structures, much like the area north of the brick factory, is limited. While the entire survey area shows evidence of culturally modified sediment being present, there is no definable pattern in the magnetic response to suggest a uniform urban grid pattern as seen around the temple complex of Angkor Wat as recorded by Carter et al. (2018). Once again, the ephemeral nature of landscape occupation makes it exceedingly difficult to distinguish possible landscape features. The features identified in Figure 5.107 suggest there was no control over the placement of buildings in the vicinity of Wat Tralaeng Kaeng and the only uniformity present is in the current rice field configuration, which may have been constructed after the area ceased being a capital. This once again questions the degree of social or political control over urban planning in the area and the notion that the king was an the organiser of cosmological and physical space as documented in historic texts by Mikaelian (2006:238).

The terraced area of rice fields, to the southeast of the temple, was surveyed. Very high magnetic variation was found here and imaged in Figure 5.77. The magnetic features were consistently >50nT and formed three large uniform square shapes. Based on the very high magnetic value of these features they were ruled to be contemporary. Two areas, located on the terraced fields, showed the most variance, with one having an extremely high magnetic response of approximately 100nT that appears to be the result of magnetic sediment brough to the area. The second area has almost no magnetic response, averaging approximately 1nT with highly magnetic inclusions. The lack of magnetic response is hypothesised to be the result of the topsoil being removed, as demonstrated in Figure 5.87. The presence of these features in the magnetometry survey complicated interpretation and demonstrates the layering of magnetic material. What makes this area so complex is the superimposed contemporary modern features with potentially Angkorian and Early Modern elements. In examining the landscape via geophysical techniques, it is important to consider all the landscape uses and how these may impact geophysical data. This instance highlights the lack of a temporal scale when using geophysics and the need to have a sound understanding of the site to be able to distinguish between features and determine how they fit within a timeline.

#### *6.3.4.2 Ground-Penetrating Radar*

The GPR survey was conducted at seven locations. Four were placed to further investigate magnetic features, with the other three established in the absence of a magnetic survey. GPR Grids 01 and 02 were established to investigate magnetic features believed to be contemporary, but the surveys were mostly inconclusive. The lack of GPR features in Grid 01, which corresponded to the largest magnetic feature, reinforces the conclusion that highly magnetic sediment was brought to the area. The features found appear to relate to the farming process, with stratigraphic breaks occurring in a uniform pattern that may have been caused by ploughing. In some instances, the upper horizon was similar to that seen in GPR Grid04 and appears to represent the rice field traffic pan. Aside from the rice field structures, the GPR data suggest this area has exclusively been used for rice farming for some time. The magnetic survey suggests a terraced area on the outskirts of a raised mound area, similar to the mound related to the proposed palace site at the brick factory, shown in Figure 5.73.

GPR Grid 03 appears to be on the mound, but the topsoil which likely contained Early Modern material had been removed, as confirmed by the magnetometer survey. While GPR Grid 03 does not appear to contain Early Modern features, it has several features that align with the magnetic survey and which likely are related to contemporary activities, Figure 5.89. Feature A appears to be a high-amplitude hyperbola that is consistently found across half the grid. It is likely this is cabling or a metal pipe in a trench approximately 1.5 metres wide, as there are no contemporary houses close by for this kind of infrastructure to be related to below ground electrics or plumbing. A second feature in the magnetic data, which consists of a 2 metre-wide trench represented by a stratigraphic break, runs parallel to this feature. It is likely this is a large contemporary trench which was subsequently filled, and, as contemporary material, was excluded from this research.

GPR Grid 08, 10 and 11 are on the proposed mound and had a high concentration of high-amplitude radar response features across almost all GPR profiles. High-amplitude vertical rings and hyperbolas were found across this area and are likely the result of contemporary contamination. The high-amplitude radar responses are consistent with the examples seen in Sonnemann (2011), where similar features were attributed to subsurface Angkor period masonry. There is no consistent patterning to such subsurface materials, however, as seen with the buried towers reported by Sonnemann et al. (2015). The highly reflective nature of the material may be related to buried rooftiles or a similar reflective material. Grids 10 and 11 both have a prevalence of high-amplitude, linear radar response features that are more in line with Angkor period GPR results. Grid 11 has associated magnetic data that do not show the linear feature found in the GPR results, but as the high-amplitude radar response is found within the top metre of strata, it may indicate that the feature is not magnetic in nature and therefore not high temperature fired bricks or roof tiles related to Angkor period material. The highly reflective material with no magnetic response may be related to stone or laterite, as seen in GPR Grid 03. This feature is approximately 2 metres wide but does not have a clear break in the strata to suggest it is a trench. It is not clear if the high-amplitude radar response features found on the mound are related to contemporary or Angkor period features, but these features are not Early Modern.

#### *6.3.4.3 Potential Landscape Features*

The area south of Wat Tralaeng Kaeng is a complex mix of potentially Angkor, Early Modern and contemporary material which is intertwined in the geophysical data. The GPR data suggest that Angkor period material represented in Grids 08-11, although the potential rice fields found in the magnetic survey may have been configured in the eleventh century. The spacing between the features would suggest they are rice bunds, but the area they define is much smaller than either contemporary or Angkor period rice fields, which are generally larger than 40x40 metres. Their orientation is similar to the proposed Early Modern structures identified, which might suggest that they are related. Much like the area around the brick factory, the placement of potential structures is *ad hoc* and does not conform to any pattern. The features here are consistent with those found at the Brick Factory, which may suggest these are Early Modern in nature, although they are not comparable to any urban design recorded in relation to Angkor period contexts. The presence of potential contemporary material, however, complicates the interpretation of Early Modern features. It is interesting that high-amplitude features are associated with Wat Tralaeng Kaeng and future research into the construction of the temple and related Angkor period remains would be beneficial. The combination of geophysical and historic evidence suggests the temple was constructed before the citadel was established in the sixteenth century and this may have influenced King Cau Baña Cand's decision to settle here. It does question the validity of that particular detail of the Chronicles, which very much views the settlement and construction of Wat Tralaeng Kaeng as an Early Modern event.

### 6.3.5 South of the Wall

The Theravāda Buddhist terraces directly south of the citadel wall are now overgrown and covered by thick bamboo. The construction of these terraces likely predates the construction of the citadel, as Theravāda Buddhism emerged in the thirteenth century (Polkinghorne 2018). The moats surrounding the terraces are characteristic of the demarcation of temple sites in the Angkor period (see, for example, Evans 2007:22). The two terraces investigated here are known to locals and were identified in the lidar survey. The smaller of the two, Toul Slaeng, is no longer used, although Tuol Tatob has evidence that the local community still use the area as a sacred site. While their use is minimal, they remain significant scared spaces within the contemporary cultural landscape.

#### *6.3.5.1 Toul Tatob*

Toul Tatob, the larger of the two terraces, is still used by local worshipers. The looting which occurred in the last century has caused significant damage to what would have been a platform but also to the subsurface strata as evident in Figure 5.111 and the GPR profile in Figure 5.113. The removal of the platform originally supporting the image of Buddha may be an indication that a ritual deposit was removed. The internal structure of the terrace appears to be largely homogeneous as confirmed by excavations conducted in 2018 (Polkinghorne et al. 2018b). The excavation was undertaken to investigate a reflective surface identified in the GPR survey, as shown in Figure 5.117. This surface was confirmed to be a change in the sediment deposition, with the inclusion of black charcoal remains. This reflective layer is similar to those found by Forte and Pipan (2008) in the investigation of burial mounds. Reflective layers like the one found at Toul Tatob are interpreted to be related to mound construction. In this instance the surface may be the result of a break in construction, with later additions added. This surface is consistent across the four transects. The charcoal inclusions might suggest a burning event occurred before the slow accumulation of sediment. The half-metre or so of topsoil contains a high quantity of hyperbolas, suggesting the accumulation of sediment may be either modern and/or contemporary.

The longest of the transects intersecting the mound on a north/south axis also intersection the northern moat. The cut of the moat is very clear within the GPR profile, with a significantly higher radar reflection response for the fill contrasting against the surrounding strata. The layering of this fill is very distinct, as shown in Figure 5.113, although there is a stark contrast between the moat fill and the top half metre of fill. This layering of fill may suggest an initial event that filled the moat, after which runoff from the terrace was heavily contaminated by archaeological material, resulting in highly reflective layers. Future excavation of the moat may provide a chronology of this event and an examination of the strata may indicate if the initial fill in the moat is related to the reflective layer mentioned above. Without further investigation, it is difficult to determine what these subsurface features might be. The GPR survey confirms that this terrace was likely constructed in stages.

#### *6.3.5.2 Toul Slaeng*

Toul Slaeng has less evidence of contemporary disruption compared to Toul Tatob, but also has no surface remains to indicate it was a terrace. This terrace is about one to one and a half metres above the natural ground surface and there is no visible moat present. The internal structure of Toul Slaeng has the same reflective surfaces as those found at Toul Tatob. As Toul Slaeng is not as high as Toul Tatob, it is likely this reflective surface is the ground level that the mound was constructed on. Figure 5.119 shows this most clearly, suggesting there may have been a slight mound already present in the natural topography. Figure 5.120 is a north-south transect across the western end of the mound. Central to the mound is a large 4 metre wide stratigraphic break. Traditionally the image of Buddha is found in this area of a Theravāda terrace. The stratigraphic break may be related to the missing component and may indicate a ritual deposit has been removed. The presence of hyperbolas within the break suggest this took place in the last century.

Highly reflective surfaces were identified off the mound, in an area that would likely have been a moat. The presence of high-amplitude radar reflections under the surface may suggest cultural material is present. This anomaly was also found in the moats in Figure 5.121 and Figure 5.122. In Figure 5.122, the type of radar response suggests the presence of masonry of laterite or stone. This cultural material may be the remains of a laterite platform on which the image of Buddha would have been placed, or even the remains of the statue itself. There is a considerable number of hyperbolas found in the moat. Unlike Toul Tatob there is no definable moat cut that is visible in the profile. The reflective surface may represent this cut, but as there is cultural material below it seems unlikely. The internal structure of Toul Slaeng shares many of the same anomaly types as Toul Tatob. The main difference is the reflective surfaces which appear to be the natural ground level. Lacking any surface evidence of the classic *vihara* or *stupa*, there are few defining features present. Much like the terraces recorded by Marchal (1918) within the walls of Angkor Thom, the only real defining feature is the elevated mound. As Toul Slaeng is significantly smaller than Toul Tatob, it might be worth considering that the construction of the terrace was not completed.

### 6.3.6 Wat Chedei Themei South

The contemporary city of Oudong encompasses several historic sites which have since been transformed by urban, commercial and farming activities (see Figure 2.9). The Early Modern remains are difficult to define amongst the growing infrastructure, but some sites are still discernible in the landscape. Phnom Preach Teach Troap remains a prominent and still-sacred landscape feature, with its mountain top *stupas* housing the remains of previous kings. This important landmark is found throughout the Chronicles, with reference to the construction of the *stupa*. King Jayajeṭṭhā II established a capital at Oudong and built a palace here in 1620, setting out to reform government codes after the Ayutthayan invasion destabilised many political systems (Mikaelian 2006). The focus here was the palace site proposed by Kitagawa (1999), which is hypothesised to be within an embankment south of Wat Chedei Themei. A magnetic survey was conducted to identify the location of the palace and associated palatial structures. While the survey was being undertaken, areas of the land were not accessible as a result of earth moving activities to create new, and expand existing, ponds.

#### *6.3.6.1 Magnetometry*

Broadly, the magnetometry survey confirms that sediment has been modified as a result of cultural activity that is best represented by data potted at one standard deviation, Figure 5.127. Ongoing earth works limited the space available to conduct a continuous magnetic survey—in addition to the terracing of the rice fields—and resulted in a patchwork of survey grids. The terraced topography influenced the distribution of magnetic features, with more anomalies identified on the higher elevated areas. Once again there is no clear pattern to the magnetic features found in this dataset. By plotting each individual magnetic response, it was possible to identify the low nanoTesla value features that are believed to best represent Early Modern material. There are several large magnetic features defined by the bounding of space that have consistent magnetic responses (1-2nT). The largest is a rectangular space, approximately 30x80 metres, west of the survey area, with its short edge in line with the embankment. In the east of the survey area there are two additional large features measuring about 20x30 metres which surround smaller internal features. The majority of the potential structures identified are about 10 to 20 metres long and clustered with other anomalies. Only one of the potential structures is aligned to cardinal points, and none are found in any consistent gridded pattern. Potential structures were found inside and outside the embankment.

South of the embankment there were very high-amplitude features which may indicate a mixing of historic and contemporary subsurface remains, as shown in Figure 5.130. A subsurface grid system based on the variation of magnetic responses was identified in the southernmost area of the survey, but it is difficult to determine if this is the result of a previous rice field configuration or the result of modern features. The modern features consist of lower magnetic responses bounded by areas of very high magnetic response (>50nT). This is consistent with the magnetic pattern of contemporary features identified south of the Wat Tralaeng Kaeng, as seen in Figure 5.77. North of these contemporary features, near the embankment, is an area with very minimal magnetic response. The area does not seem to have been cleared recently, as it is used for rice production. It is unclear what may have been present when the feature was cleared. The boundary follows the rice bund, which means the original shape is hard to define. It is difficult to speculate what may have been removed but with the prevalence of mounds outside the embankment, it may be possible to suggest the removed landscape feature was a mound. Without ground verification it is not possible to determine what this feature represents, nor whether it is historic or contemporary.

#### *6.3.6.2 Potential Landscape Features*

The size and shape of the potential features identified are large enough to consider them to be palatial structures. The likelihood that any of these features can be confirmed to be King Jayajeṭṭhā II's palace is very low. Historic texts do not give descriptions of the dimensions, design or position of the royal palace, but allude to the spatial relationship of the buildings based on the king's needs and the cosmic order of Theravāda ideology. Mikaelian (2006:304) has stated that the important palatial structures at Oudong were arranged on an east-west axis so the king could watch the sun rise, with associated palatial structures for the king's family placed in the landscape at different locations on the cardinal to the palace. When examining potential landscape features in light of these details, it appears that none of the features identified in the magnetic survey conform to these descriptions. One potential feature is on an east-west axis, just north of the embankment wall. The magnetic survey alone is not conclusive enough to suggest the palace of King Jayajeṭṭhā II has been identified. However, it does suggest this area has a significant amount of culturally modified subsurface sediment, and is likely the palace site as proposed by Kitagawa (1999).

### 6.3.7 Continuity and Adaptation at Longvek and Oudong

The construction and use of the Early Modern landscape of Longvek and Oudong can provide insights into a range of social and political interactions with the physical landscape. As the Chronicles give little description of the physical landscape, re-creating a proposed Early Modern landscape through lidar and geophysics has added new information to the narrative. Although there are limitations to how far this landscape reconstruction can be taken and what conclusions can be drawn, this alternative dataset can provide new insights into land use and occupation. In addition to this, an examination of the degree of political control that may have been present over the landscape can be discerned from the geophysical results. By combining all datasets, a relative chronology can be constructed to further understand how the landscape has changed over time and how it may represent processes of continuity and adaptation throughout the Early Modern period.

#### *6.3.7.1 Spatial Political Control*

The construction of a large landscape features, such as a citadel, *prek*, *tumnup*, embankment or channel required control over human resources through a centralised authority. The capacity to undertake this work suggests a continuum of political control by the ruling royal families after the decline of Angkor. As a hundred years intervened between the decline of Angkor and the establishment of Longvek as a capital, drawing parallels between the two are challenging. Engaging in correlation of Longvek and Angkor Thom—as if they are a part of a continuum of political authority—negates a century of political and social adaptation. Taking Ewington's (2008) research into consideration, the landscape of Longvek shows evidence of adaptation, mobility and continuity. Examining the citadel of Longvek in light of the Angkor period traditions suggests that political authorities were changing their approach to large-scale architecture, with more basic designs allowed to maintain the size and defensive capabilities of the structure. The inclusion of bastions suggests defensive approaches had shifted over time. As a device which imbues meaning to a landscape, a bastion signals the political control and wealth of the crown after the Angkor period. The differences between the citadel at Longvek and the defensive walls of Angkor Thom demonstrate how alterations have been made to maintain a continuity of political power.

The Early Modern kings still maintained influence over the use of space. While this has not been corroborated in the geophysical dataset in relation to urban design, the correlation between the Early Modern rice fields and citadel orientations may also suggest there was a continued centralised control over rice production. The ongoing taxation of rice farming was an important source of revenue for Early Modern kings, especially when compared to Angkor-period tax systems, where the growing of rice was controlled, along with taxation for the crown (Lustig 2009:187). Government codes prohibiting farming land from being left untended, also reinforce the importance of rice farming (Mikaelian 2006:278). The value of rice farming reinforces the need for a central authority over rice fields and production outputs. A more in-depth comparison of the

Angkorian and Early Modern tax systems is required, particularly to understand the capacity of rice farming in the region and what wealth this may have generated for the crown.

Wat Tralaeng Kaeng is an important landscape feature that has be adapted over the centuries to suit changing political and religious structures. The area around the temple appears to have undergone several large-scale reconfigurations, which would have required a central authority. Magnetometry evidence for previous rice field alignment would suggest the area was used for farming before the temple was erected. The large-scale clearing of the land for the construction of the temple and associated pond was undertaken in accordance with Brahmanical traditions. As inscriptions indicate an elite family associated with the monarch lived in the area, the construction of the temple would have cemented this as a regional Angkorian site. The presence of potential Angkor period building foundations in the GPR survey may suggest that additional associated buildings were present on the raised occupation mound. Their materials may indicate they were related to other temple foundations, and potentially a *prasat.* As the size and shape of this mound is similar to the proposed palace site located at the brick factory, this may also be a palace site, placed on the foundation of a previously sacred Brahmanical temple.

The lack of a uniform urban layout to the palatial or occupation structures as revealed in the geophysics does not mean that there was a lack of control over space, but rather, the ephemeral nature of the occupation and construction materials means that no clear geophysical response is present. When comparing the magnetic data of Longvek and Oudong to the urban design of Angkor Thom or Angkor Wat it is easy to assume that the lack of uniformity between the two is the result of a lack of political control. For a fair comparison, an examination between village site distribution in the Angkor and Early Modern periods would be more indicative of the kind of change occurring, but the focus of urban dwellings has centred on those related to very large-scale temple structures (see, for example, Carter et al. 2018; Stark et al. 2015). The palace site at Angkor Thom was also largely constructed of wood and provides little comparison, as it, too, deteriorated over time. The uniform house mounds at Angkor Wat are very much related to state religious centres constructed under a cosmological design. The continued use of wood in the construction of palaces suggests a continuity in construction methods over the centuries. The longevity of wooden construction traditions is incredible but due to it perishability it has been under investigated using archaeological methods.

Changes in building styles which have been attributed to the Early Modern period largely occurred during the Angkor period, such as the end of sandstone monuments. The continuity of traditions in the Early Modern landscape suggests that change in architectural styles between the Angkor and Early Modern periods was minimal. The continuation is most evident in the use of non-perishable materials and without tangle evidence, many conclusions remain speculative. The variations in physical landscape features allowed for a continuation of social and political structures centring around the crown. The Early Modern landscape of Longvek and Oudong suggests a continuation of political control over the landscape and economic priorities such as human resources and the taxation of rice, which were occurring alongside foreign trade. This evidence challenges previously held ideas by historians such as Chandler (2008), who did not have the physical evidence available to contest historic texts.

#### *6.3.7.2 A Landscape Chronology*

Based on an examination of the lidar data, rice field configurations, site distribution, historic documents and geophysical data, a very broad relative chronology can be created, but without ground verification it is largely a hypothesis. Angkor period material is found throughout the Longvek landscape. The area south of the citadel along the river appears to have been an Angkorian settlement, defined by the rice field configurations, presence of ponds and the Theravāda terraces. The proximity of the southernmost occupation mound to the terraces may suggest this is also from the Angkor period. The size is on par with the proposed palace site, which may be an indication of the mound's use. Potentially the occupation mound is for the elite family mentioned in local inscriptions. The *tumnup* which are also south of the citadel are difficult to place in the timeline and are argued here to be from the Angkor period. This assertion is based on their presence at sites at Srei Santhor which are Angkorian and their presence on the periphery of central Angkor. The area which Wat Tralaeng Kaeng occupies appears to be Angkorian based on eleventh century inscriptions and the geophysical data which identified potential Angkorian settlement on a raised occupation mound within the vicinity. Established farming land was cleared for the construction of the temple and associated structures. Occupation occurred on the periphery of the temple, with associated terraced rice fields still present. The arrival of King Cau Bañā Cand at Longvek saw the beginning of major construction projects. The citadel, likely constructed in phases, was established, along with the royal palace and related structures. The geophysical data suggest a significant population lived within the vicinity of the palace and Wat Tralang Kaeng. Water management devices became more prevalent, with the *prek* and embankments established. Rice farming was extended to accommodate the needs of the royal palace and an increased trading population, as evident by the increase in the rice fields constructed, many of which expanded on Angkorian fields. The rice field distribution also suggests an increase in occupation spaces. This physical data can then be combined with the historic texts to develop the following relative and provisional chronology.

- Eleventh to twelfth century:
    - an Angkorian elite family was farming this land;
    - Wat Tralaeng Kaeng was constructed as a Brahmanical sacred site, with the flat top mound constructed.
- Thirteenth to the fifteenth century:
    - Tralaeng Kaeng transformed into a Theravāda site;
    - Terraces were constructed south near the river;
    - Area visited by royalty and usurper kings as a crossroads to Ayutthaya;
    - Potential new international trade occurring.
- Sixteenth century:
    - King Cau Baññā Cand settled the area, constructing the citadel and a palace;
    - Expansion of rice farming outside the citadel;
    - Construction of water management devices such as the *Prek,* which were constructed in two locations along the river to divert water into to the citadel and facilitate trade;
    - Construction of ports associated with *prek*;
    - Expansion of international trade, wealth and prosperity;
    - Peak population size living within and around the citadel;
    - Ayutthayan invasion, city overcome, and the capital moved to Oudong.
- Seventeenth century:
    - Oudong palace constructed;
    - Rice farming established within the citadel, expanding on current fields;
    - King Jayajeṭṭhā II initiates political reforms in light of the political destabilisation due to invasion.

Without any excavation or absolute dating, it is not clear how accurate this relative chronology can be. It does not consider the changes in kings, international wars, civil wars or the mobility of the

Khmer kings. It does, however, demonstrate that Longvek was an adaptive landscape, changing to suit the needs of its inhabitants. To confirm these landscape changes, a widespread absolute dating campaign will be required. The contemporary landscape is indicative of this, as the needs of industry slowly encroach onto the landscape. The oral traditions which inform this landscape help maintain its social significant as a site of war and decline. However, Longvek is very much a landscape of adaptation and continuity, as Cambodia’s ruling kings attempted to maintain the status established by their Angkorian predecessors.

## 6.4 Conclusion

### 6.4.1 Defining the Early Modern Landscape

The definition of an Early Modern landscape based on the suite of methods applied here is further based on the physical representation of features, and how they reflect themes of transition, adaptation and decline. Historic documents characterise the Early Modern period as a period of rupture and decline (Briggs 1951; Cœdès 1918; Groslier 1960), which then transitioned to one of mobility and continuity (Ewington 2008). Based on the investigation of the hidden landscape of the three Early Modern sites via geophysical techniques, the notions of mobility and continuity can be expanded to include adaptation. This thesis is contributing to a paradigm in transition, by adding alternative avenues for investigation through landscape scale geophysical investigation. From the results presented in Chapter 5 and discussed above, the following will answer the sub-research questions posed in Chapter 1.

*What connections can be drawn between the physical landscape and the social and political structures of the Early Modern period?*

The combination of large-scale landscape features, such as the citadel and water management devices, and the construction and control of the rice fields, best represent social and political structures in the Early Modern period. Features such as the citadel are mechanisms of political power and control and could be viewed as a continuation of the tradition of indentured labour as seen in the Angkor period. The distribution and use of rice fields and rice for taxation suggests a continuity of political structure between the Angkor and Early Modern periods. This does not negate the importance of international trade but highlights the continuity of established systems at new capitals.

*What level of change is identifiable by comparing the three Early Modern capitals to Greater Angkor (ninth to fifteenth century)?*

Table 6.2 is a comparison between Angkorian and Early Modern landscape features based on the review of literature, archaeological evidence and the results presented in this thesis. The common theme across many of these landscape features is the repurposing of Angkor period material, as evident through the Theravāda appropriation of Brahmanical sites and the continued use of Angkorian water management systems. The significant change is often cited as being the end of the large-scale temple structures constructed on sandstone and laterite. This is a significant marker in the Cambodian timeline, but this change occurred long before the beginning of the Early Modern period. The most significant change would be the approach taken to water management. With the decline of the hydraulic city, Early Modern kings settled in landscape that did not require such an elaborate irrigation system, as their proximity to very large river networks allowed for seasonal flooding and irrigation.

An example of change in an attempt to stay the same is the construction of defensive structures around the palaces. If the physical walls of Angkor Thom, Longvek and Oudong are considered together, the construction styles, materials and economic expenditure would suggest a decline over time. However, if the political or social implications of such features are considered, the social status and power required to maintain a walled palace remain the same. In examining these changes over time, it is very clear that the beginning period of the Early Modern period needs to be reframed, as the Ayutthaya invasion of Angkor no longer fits within this narrative.

Table 6.2: Comparison between Early Modern and Angkor period structures based on evidence from this thesis and Carter et al. (2018); Evans et al. (2007); Evans (2007); Evans and Traviglia (2012); Evans et al. (2013); Evans and Fletcher (2015); Hawken (2011a, 2013); Hendrickson and Evans (2015); Kitagawa (1999, 2000); Moffat et al. (2019); Nhim (2014-2016); Polkinghorne et al. (2015); Polkinghorne et al. (2016); Polkinghorne (2018); Polkinghorne et al. (2018b); Polkinghorne et al. (2019b); Sonnemann and Chhay (2014); Stark et al. (2015); (1996).

| **Type** | **Type/ size** | **Material** | **Description** | **Type/Size** | **Material** | **Description** |
|---|---|---|---|---|---|---|
| | **Angkor Period** | | | **Early Modern Period** | | |
| Religious spaces | State/very large scale | Laterite, sandstone | The configuration of temples is not dependent on size. Central rectilinear platform/elevated area surrounded by a moat. Causeway crossing across moat at larger structures, smaller structures with three-sided moat. Chronological progression of building materials from earliest of brick transitioning to laterite and sandstone. Building material dependent on size. Temples chronology defined by inscriptions and iconography. | State/very large scale | Repurposed Angkor period materials | The construction of very large-scale state level religious spaces ended in the Angkor period and not found in Early Modern contexts. |
| | Local | Brick, wood | | Local | Wooden, flat-topped mounds | Theravāda Buddhist sites follow very few construction parameters as they are largely reconfigured Brahmanical structures. Once Early Modern traditions are well established, continuity found amongst sacred sites. |
| Constructed Topography | Above ground water storage (*baray)* | Banks built up above landscape | Very large scale. Rectangular, length-width ratio of 2:1, generally aligned east-west. Associated with religious structures such as temples. | *Baray* | Repurposed Angkor period materials | No constructed in the Early Modern period but existing features continued to be used. |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | | fed by canals and connected to hydraulic network. | | | |
| | Large Pond<br><br>*(Trapeang)* | Dug into the ground | Disused became silted and now a part of rice farming networks. Some continue to be used and evidence of Angkor occupation can be found. Embankments around *Trapeang* are often extended and used as platforms for housing. The house/pond configuration can be traced back to Angkor period. rain fed, unrelated to hydraulic network. | *Trapeang* | Repurposed Angkor period materials | Very large-scale feature is not present at three sites considered here. |
| | Channel | Dug into the ground | Channel system developed as a part of the wider hydraulic system. Channels dug to divert water supplies. | *prek* | Dug into the ground | *Prek* are prevalent at three Early Modern locations. Channels are dug to divert water from river systems for the purpose of irrigation and trading. |
| | Small Pond | Dug into the ground | Household ponds small in scale and may have serviced 2-3 families per pond. Thousands located across the landscape. | Household ponds | Dug into the ground | Household ponds prevalent throughout and important Early Modern, Modern and Contemporary landscape. |

| | | | | | | |
|---|---|---|---|---|---|---|
| | Roads | Raised earthen embankments 1-2m | Roads constructed to be raised off the landscape. Construction of the road leaves negative impression or channel running alongside. Roads connected major ruling centres. Roads also act as a conduit for water drainage. | Roads | Raised earthen embankments 1-2m | Continuation of Angkor traditions with few Early Modern auditions at Longvek. |
| | Embankments (defensive) | Raised rammed earth walls | Fortification walls surrounding major centres. Raised earthen with fortification features such as gates. | Embankments (defensive) | Raised rammed earth walls | Fortification walls surrounding major centres, such as the citadel at Longvek. |
| | Embankments (dykes) | Raised embankment | Raised walls for water management. Apart of the broader Angkorian hydraulic network. | Embankments (*tumnup)* | Raised rammed earth walls | Raided walls for the creation of a water reservoir/artificial wetland. Used for irrigation of rice fields and potentially local foraging. |
| Occupation | House mound | Raised earth | Materials related to domestic habitation non-durable in nature and not preserved in the archaeological record. House mounds consistently associated with *Trapeang.* Stilt houses on the embankments of roads and channels. Consistent reliance on wet-season high ground, easy access to dry-season water. Village | Occupation mound | Raised earth | Early of occupation either under contemporary villages, or occupation mounds large enough to contain a small village. Village mounds definable by their association with surrounding rice fields. |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | | temple sites evidence of surrounding settlement on the central moats and series of mounds bordering. | | | |
| Commerce | Farming | Bunds are made of earth compacted by hand and maintained as needed | Bunded rice fields are a consistent feature across Cambodia. Angkor field pattern are unique and distinguishable to contemporary field configurations. Fields interconnected. Complex system designed and adapted to distribute from water sources. Rice field patterns consist of pre-modern ear configurations. Management and distribution of water achieved by gravity, small bund breaches and a network or very small channels. | farming | Bunds are made of earth compacted by hand and maintained as needed | Bunded rice fields are a consistent feature across Cambodia. Fields interconnected. Complex system designed and adapted to distribute from water sources. Rice field patterns consist of pre-modern ear configurations. Management and distribution of water achieved by gravity, small bund breaches and a network or very small channels. |

### 6.4.2 Review of the Geophysical Approach

The geophysical methods being applied here are not novel, but the combination of magnetometry and GPR and the scale of acquisition has never been applied in Cambodian or Southeast Asian archaeology before this study. The application of geophysical methods in Cambodian archaeology has been restricted to the application of GPR at Angkor period sites, making this research the first to apply magnetometry to historic sites in Cambodia. This multimethod approach had many instances of success in identifying subsurface evidence of Early Modern landscapes. A review of the methods applied considers the pros and cons of each method and how applicable they are for future application to Cambodian archaeological sites. The following will address the research question:

*Can geophysics be applied to identify subsurface evidence of an Early Modern period hidden landscape?*

#### *6.4.2.1 Magnetometry*

Application of magnetometry was successful in demonstrating that all areas surveyed contain culturally modified subsurface material resulting from anthropogenic landscape modification. The Early Modern signature was best represented by minor changes in the magnetic response of sediments, represented by one standard deviation from the mean magnetic value and within 1-2nT variation. The criteria for defining Early Modern features related to these subtle changes in magnetic variation, but also the defining of magnetically variant space. Often, these areas of variation were the result of an intensification of magnetic features bounded by an area with very little magnetic variation. This contrasts with European examples where cultural artefacts are very obvious, with features such as buildings having a high magnetic response and a uniform shape. An example is by Donati et al. (2017), whose large scale investigation of urban planning demonstrated the stark contrast between constructed spaces.

Defining archaeological features through magnetometry in Cambodia was a difficult task and required an intense knowledge of the contemporary use and archaeological history of each area, in addition to establishing appropriate post-acquisition processing procedures. It is difficult to define a landscape by what is not present, but in this instance a void space provided more information than a set of complex magnetic responses. Whether finding nothing or finding something, the application of magnetic methods has identified a cultural landscape not previously defined by traditional methods.

Several challenges were encountered applying magnetometry to these sites. The lack of a vertical depth scale was a trade-off for fast acquisition coverage, with several resultant limitations to the interpretations. The lack of vertical scale has made it challenging to determine:

- the shape and size of features. A magnetic response for an archaeological feature is dependent on a variety of factors, including the magnetic value of the sediment or object, the depth of its burial, its association with features around it and also how the depth/width ratio influences the size of the magnetic response.
- whether the response is related to an object or sediment.
- whether features are related.
- the depth of an object or feature.
- whether an object is contemporary contamination.

The processing sequence of elimination allowed for the identification of high-value magnetic responses that are likely to be associated with contemporary contamination. The inability to determine which features are contextually related is the greatest downfall of this method, particularly with small features. The impact of contemporary metal was also a problem, as the magnetic response of metal was not contained to the size of the object but the magnetic properties of the material and resulted in the magnetic field of the object dominating the area, essentially hiding other archaeological material that might be close by. Magnetometry best lends itself to identifying very large landscape features over large spaces.

A methodological challenge here has been the untangling the layering of events at each site. The magnetometer does not simply record Early Modern material, it records all variances in the magnetic field. This has been problematic at all three sites where events that came before and after the Early Modern period needed to be taken into consideration. The impact of contemporary events had the greatest influence on the magnetometry data. Some of these impacts were found within the subsurface and resulted in the manipulation of the magnetic properties of the sediment. In considering all the historic events which have occurred on this land, the Early Modern material is deeply entangled in a complex series of events which have had significant impact on the landscape and the community living there.

Overall, the magnetic survey of Early Modern capitals of Cambodia was successful in identifying subsurface cultural modification. As a method to be used on its own, it would not have been as successful for defining cultural landscapes. If larger areas were investigated, it may prove useful in determining the limits of cultural sediment, giving an indication on the amount of space being inhabited, but magnetometry on its own has not been successful in identifying the urban planning systems of the Early Modern capitals. This can be attributed to the factors outlined above. The greatest issues have been the transitory nature of land use, the materials used at the time and ongoing farming activity that has disturbed the subsurface. Magnetometry should not be dismissed as an investigative tool, but it should be used in tandem with other geophysical methods.

#### *6.4.2.2 Ground-Penetrating Radar*

The application of GPR to investigate Early Modern sites was very successful. Unlike the issues encountered with magnetometry, the GPR survey was able to untangle some of the contextual issues experienced and define a vertical sequence. The GPR's greatest success was its capacity to identify subsurface features that neither the remote sensing nor magnetometry surveys could identify. The best example of this is the subsurface pond north of the brick factory, which had been filled with cultural material. This cultural feature was deep enough not to influence the magnetometer and had no surface depression, making it impossible to identify with the lidar. This instance reinforces the need to use an integrated suite of methods in the investigation of Early Modern sites and highlights how well geophysical approaches complement remote sensing results.

There were specific instances where limits to the GPR's capabilities were encountered. The ground composition of Srei Santhor caused interference that resulted in the GPR radar being unable to penetrate below a metre in depth across the entire area. The only exception to this was GPR Grid 110 on top of the platform at Prasat Preah Threat Baray because of the layering of sediment on top of an artificial mound. The penetration issue experienced across the rest of Srei Santhor may be due to monsoonal flooding cycles, which see high volumes of water and alluvial sediment deposited across the area. This may result in the subsurface clay matrix being forced down to the water table. However, within the archaeological excavations no sediment change was noted across any of the trenches. The antenna choice also limited the examination of larger mounds such as Prasat Preah Theat Baray and Toul Tatob. The 500mHz antenna maximum permeability depth was no more than two metres. The loss of antennation beyond this depth resulted in features at depth not being identified. In future investigation of these large mounds, a 250mHz antenna may be a better option.

The greatest success in applying GPR was at transition sites with Angkor period remains, such as Prasat Preah Theat Baray. The highly reflective remains of laterite, sandstone and brick make identification significantly easier when using geophysical prospection. This has been proven by many GPR prospection projects on Angkorian sites investigating the monumental architecture, large scale water management devices and smaller industry-related features (see, for example, Moffat et al. 2019; Sonnemann 2011; Sonnemann 2012, 2013, 2015; Sonnemann and Chhay 2014; Sonnemann et al. 2015). This targeted approach limits the kinds of questions that can be asked. For example, in Moffat et al. (2019) the objective was to investigate a water management device identified by archaeological excavation. This method was very successful in answering questions relating to the failure of that particular landscape feature. As this thesis aimed to answer broader research questions relating to the broader Early Modern landscape, an alternative approach was required. The two approaches are complementary and future work expanding on the results could incorporate a more targeted geophysical approach, particularly when combined with archaeological excavation.

Overall, the GPR survey was a very successful tool in the examination of Early Modern capitals. It identified subsurface material that no other method was able to pinpoint, and allowed for a finer examination of the hidden landscape. The volume of data collected was not as extensive as that from the magnetometer survey, but the trade-off for data volume is having a stratigraphic sequence of sorts to help better understand site formation processes. GPR has provided insight into a complex layered landscape that has been impacted by many events over the centuries. Without the application of GPR, an understanding of site formation would have been impossible to achieve.

### 6.4.3 Outcomes and Future Directions

Overall, the geophysical survey was a success in the investigation of the hidden landscape of Early Modern Cambodia. Alternative datasets were collected which broaden the current understanding of this under researched period in Cambodian history. A wide range of landscape features were identified through the multimethod approach. The magnetic survey was successful in identifying previous land use, such as alternative farming, and was very successful in identifying culturally modified sediment relating to occupation. The addition of the GPR survey allowed for a relative timescale to be applied to the geophysical results. This method was particularly useful in identifying Angkor period material, allowing for an examination of how the landscape changed over time. The GPR results from Prasat Preah Theat Baray were the most convincing, shedding new light on the complexities of transitioning cults in the thirteenth century.

Contemporary contamination was the primary hindrance for geophysical prospection in this area. The areas investigated are influenced by farming and industry, and the waste they generate badly pollutes the topsoil, from an archaeological perspective. The worst of these sites was the brick factory, which produced and discarded high-fired bricks throughout the site. All the survey grids, with the exception of Prasat Preah Theat Baray and Toul Basan, were conducted within rice fields. The contamination of these fields is effected by ploughing, and by waste consisting of items such as tin cans and household rubbish. In the magnetic data these contaminants generally have a very high magnetic response, >50nT, and were easily identifiable in the dataset. In the GPR contemporary contaminants were generally represented by hyperbolas very near the surface and could therefore also be excluded from the interpretation.

In addition to untangling the many events which occurred on this land, the impact of continual farming activities in this landscape needs to be considered. Contemporary farming has resulted in the destruction of many surface remains and continues to do so. This research has identified several elements related to rice production that affect geophysical prospection. The first is the construction of the rice bunds, which are the result of collecting the topsoil, mounding and compacting it to create the bund. It is this process that results in the rice bunds having such a high magnetic response, as the topsoil contained much of the archaeological material which is now out of context in a rice bund. This is evident from the many surface artefacts, such as pot sherds, that are visible in the rice bunds themselves.

Second, ploughing has a significant impact on archaeological features, as the remaining topsoil is overturned and redeposited. As a result, archaeological features are removed and often deposited along the plough lines. For material below the plough line which may still be in context, the lack of vertical context means it is near impossible to distinguish between undisturbed and disturbed archaeological contexts using geophysics.

Third, the continual ploughing and flooding of rice fields creates a “traffic pan”, an artificial layer that creates a boundary between the rice field and the water table below. While this did not impact the magnetometer survey, it did impact the GPR survey, and this artificial layer could easily have been misidentified as a cultural layer.

Fourth, the flooding of rice fields in these areas also means that fine alluvial sediment is being continually redeposited over the archaeological surface. In some instances where the land has not had such intense farming activity this results in a protective cap over the archaeological material, which is best represented in GPR Grid 12 at the brick factory site. Finally, in areas where there has been consistent farming over a long time period, it has resulted in sterile material being mixed with archaeological sediment, diminishing the magnetic response and making features difficult to identify in GPR profiles.

In future geophysical surveys, some changes to the approach need to be considered. The success of the magnetometry survey in identifying culturally modified sediment relating to occupation makes it ideal for defining urban areas. Future surveys would benefit from concentrating on a single survey area instead of multiple areas as in this research. By investigating the largest possible area, it may be possible to identity the boundaries of urban spaces. In addition to this, decreasing the line spacing to a quarter of a metre would be beneficial. As the magnetic variance related to Early Modern sites is very minimal, an increase in line density may allow for greater definition of small-scale features. This approach was undertaken by Gaffney et al. (2018) at Stonehenge in the investigation of prehistoric landscapes. The quarter-metre line spacing used in their magnetic survey provided much finer and more detailed output for the identification of features.

A rigorous sediment testing program would also be beneficial. Ground verification of magnetometer responses, either through coring or excavation, would help create a better understanding of what kinds of magnetic features may be present and would contribute to future identification of similar responses at other sites. Systematic sediment sampling through coring would enable sediment profiling and sampling for laboratory magnetic susceptibility tests. One of the limitations of this survey was the lack of comparable evidence. Undertaking ground verification and experimental surveys at recently moved contemporary homes would also be highly beneficial. Being able to draw a correlation between magnetic response and household areas, such as kitchens, would making future interpretations more rigorous.

# CHAPTER 7 - CONCLUSION

## 7.1 Introduction

This thesis has taken a complex period of Cambodian history and provided a new avenue for investigation through landscape-scale geophysical prospection. Academic discourse in the early twentieth century centred on the now dispelled notions of decline which viewed the end of Angkor as a terminus event (see, for example, Briggs 1951), with more recent investigations identifying elements of continuity between the two periods (Ewington 2008). Historic research of primary documents, such as the Chronicles, provided insight into the royal lineage and events, but research was largely centred on debates regarding the validity of the primary texts examined by Khin (1988), Mak (1981) and Vickery (1977a). Physical evidence and oral traditions related to prominent sites was investigated by Kitagawa (2000, 1999) to further examine the contents of the Chronicles. While recent historical investigations of Early Modern tax and law reform by Mikaelian (2013) provide insight into social and political structures in the seventeenth century; Polkinghorne et al. (2019b); Polkinghorne et al. (2016); Polkinghorne et al. (2017); Polkinghorne et al. (2015); Polkinghorne et al. (2018b) project, *Middle Period and Related Sites Project,* undertook the first archaeological investigation of the Early Modern capitals and, as a result, widened the scope of research by examining the physical material cultural remains in light of historic sources. The purpose of this thesis was to expand on previous research through an examination of the surface and subsurface landscape features.

This thesis has added to the current understanding of change and adaptation at the three Early modern sites: Srei Santhor, Longvek and Oudong in central Cambodia. To achieve this, the current literature was interrogated in Chapter 2, comparing landscape features recorded in historical texts to the physical landscape, considering what elements may be hidden under the modern rice fields. Aspects of Early Modern occupation, urban design and palatial spaces were considered to be missing components which warranted further examination. A multimethod landscape-scale geophysical prospection approach, as examined in Chapter 3, was chosen as it allowed for large areas of the Early Modern surface and subsurface to be inspected. The investigation design – outlined in Chapter 4– was to find potential landscape features that are no longer visible on the ground surface, through both landscape-scale and targeted geophysical approaches. The incorporation of remote sensing, magnetometry and ground penetrating radar at the three Early

Modern sites allowed for an examination of the research areas at different scales, from the broader landscape down to variations in culturally modified sediment, with the results presented in Chapter 5. The results of this research demonstrate there are elements of the Early Modern landscape hidden in the subsurface. This research furthers current archaeological research by discovering new alternative settlement locations, allowing for discussion regarding population density in the region. Remote sensing results, supported by primary textual data, suggested a degree of political control over the landscape which had not been previously considered. This approach was not able to detect elements of urban planning or confirm the presence of palatial structures, it did however, confirm that areas related to the Early Modern royal palaces were inhabited which resulted in a culturally modified subsurface environment. The thesis findings were compared to Angkor period counterparts to consider how landscape features have changed and/or adapted over time and what implications this has for our current understanding of Early Modern Cambodia.

## 7.2 Main Thesis Findings: Adaptation in Early Modern Cambodia

Previous studies related to Early Modern Cambodia have focused on reconstructing the chronology of events through analysis of primary texts with a focus on validating textural sources. This complementary approach—with the aim of investigating change and adaptation through a close examination of Early Modern landscape features—was undertaken by implementing a landscape-scale geophysical investigation, which was integrated with archaeological and historic research. The discussion of finding presented in Chapter 6 and the sub-questions addressed in sections 6.4 and 6.4.2. The primary research question considered has been:

*How does the subsurface landscapes of Srei Santhor, Longvek and Oudong augment current understanding of Early Modern Cambodia?*

Through an examination of the geophysical results in light of archaeological and historic evidence, the broad findings are:

- an expanded understanding of the presence of occupation and settlement at the Early Modern sites;
- spatial evidence, through an examination of largescale landscape features and rice field orientations, furthers current discourse around political control over the landscape, such as

farming a rice surplus and human labour resources for the construction of large-scale landscape features;
- supporting evidence for continuity between the Angkor and Early Modern periods, with evidence of adaptation of physical landscape elements in an attempt to preserve or reuse Angkor period social and political structures.

These findings only relate to the three Early Modern landscapes, and are restricted to the contexts investigated at Srei Santhor, Longvek and Oudong. The lack of temporal scale in using geophysical and remotely sensed data means these findings are not specific to a single period of time, but rather conclusions gathered from a landscape which appears to have been occupied at least from the eleventh to the twenty-first century. With these limitations in mind, the broad findings interrogated in Chapter 6 are summarised below to answer the primary research question.

### 7.2.1 An Occupied Early Modern Landscape

Previously, it was believed the areas of Early Modern occupation were hidden under current villages, and that there was minimal evidence of an urban population locations throughout the landscapes of Longvek and Oudong. The lidar analysis of rice field orientation and geophysical prospection suggests there are more occupation-spaces hidden under the current rice fields and that the area within the citadel may have been more heavily populated than previously thought. This, combined with the population estimates based on the presence of ponds in the landscape, could support population of 10,000, as proposed by Reid (1993:76). There is significant complexities when attempting population estimates, particular the lack of a temporal scale for investigating landscape features of this kind. Further investigation of the broader Longvek landscape, outside the lidar study zone, may provide greater information of the occupation density of the region. The outcomes of this research have been to identify new potential archaeological sites and alternative research questions to be examined. The potential new occupation sites identified in the rice field analysis reinforces that there is a change in occupation in relation to the configuration of the Early Modern capital Longvek. Additional geophysical investigations and excavation at these proposed new sites may confirm these are occupation sites, who may have lived there and how these villages fit within the Early Modern landscape. Investigating areas along the Tonle Sap River—as identified in the rice field analysis—may also provide information on potential trading ports reported in historic primary texts. This investigation would greatly expand on current discussions around the populations living at Longvek, who they may have been and how they fit within the broader discourse of trade.

### 7.2.2 Perceived Political Control

Current discourse around political control was largely based on historic primary documents which focus on tax reform in the seventeenth century (Mikaelian 2013). Previous conclusions suggested the bureaucracy-based systems of heavy taxation and forced labour ended with the Angkor period, as new financial priorities based on trade became feasible and lucrative (Chandler 2008:95). Considering this notion through an examination of the larger landscape features and rice field configuration, it is reasonable to suggest a central control over farming and human resources was still present. This interpreted control does not appear extend beyond the context of large-scale infrastructure and framing land, with no identified urban planning identified in relation to palace or sacred sites. This is a contrast to the Angkor period urban planning identified at sites such as Angkor Wat and Angkor Thom (Carter et al. 2018; Stark et al. 2015)

The rice field analysis was very successful in identifying patterns in the landscape and expanding on current discourse around land use. The application of the rice field analysis to the broader Longvek, beyond the lidar study area, may provide further insight into how the land around the capital was utilised and consider what broader population may have been present. In addition, the rice fields south of Longvek at Oudong warrant investigation with lidar, particularly to understand the extent of crown control over rice fields and production and examine how these patterns may relate to political control. Future research could consider if the urban design of Early Modern Longvek and Oudong similar to the village complexes in the periphery of central Angkor.

### 7.2.3 Continuity and Adaptation Over Time

This thesis has provided an alternative perspective for investing Early Modern Cambodia by considering landscape features hidden from view. Evidence of continuity has been found in two forms of this research: the existence of Angkor period settlement and material, and the configuration of Early Modern landscape features which reflect Angkorian traditions. The integration of Angkorian and Early Modern landscape features demonstrates a level of continuity and adaptation over time. The prevalence of landscape features—such as fortifications—suggests a conscious effort to recreate existing Angkorian features within the constraints of an Early Modern political and economic systems. As Longvek was an established Angkorian centre, it is likely the landscape was appropriated by Early Modern kings, adapting existing features to suit the new royal agendas. The appropriation of sites is common, particularly with the transition from Brahmanical to Theravāda Buddhism. Examining the physical parameters of the transformation from Brahmanical to Theravāda traditions sees a slow transition from *ad hoc* processes beginning in the Angkor period, to uniform construction practices in the Early Modern period.

The transition from Angkor to the Early Modern period is not a linear set of changes, but rather a series of characteristics adapted from established Angkorian principles, evidence of which is seen in constructed and transformed landscape features. These reuse of Angkorian characteristics may represent a continuation of political organisation and governance of social and sacred spaces. Evidence of continuity and adaptation at Early Modern sites are important markers of social and political activity. The decline of Angkor is a significant marker of change in Cambodian history, and was previously viewed as a catastrophic event which the Khmer culture could not recover from. This view was based on Early Modern textual material and had not considered the cultural material hidden from view. The application of archaeological methods—specifically geophysical methods—has provided evidence which indicate processes of change after Angkor. With the addition of this geophysical dataset, there is evidence of continuity and variability, with Early Modern political entities attempting to maintain the traditions established during the Angkor period. For example, fortification features are a common landscape features during the Angkor and Early Modern periods. The symbology of the gated walls around Angkor Thom and the citadel at Longvek and embankments at Oudong did not change, only the physical parameters. This example demonstrates how change is necessary, to maintain social and political continuity. Future research should consider the Srei Santhor and Longvek using a landscape-scale approach to further investigate the Angkor period occupation and how it was adapted to Early Modern needs.

## 7.3 Conclusion

The findings of this thesis demonstrate that new layer of spatial data adds a level of complexity to Early Modern research. The geophysical dataset presented here is the largest collected in Cambodian archaeological research. The integration of this dataset with archaeological and historical information has expanded our understanding of how the physical landscape can be imbued with social and political influence. This research has provided new avenues for investigating occupation spaces and demonstrated how a multimethod geophysical approach can be used to answer complex archaeological questions. In reconstructing portions of the Early Modern landscape, it has provided new insight into the continuation of Cambodian political physical structures as it entered the modern era. Examining the subsurface landscapes of Early Modern Cambodia has demonstrated how the hidden physical landscapes can add to academic debate, and provide new avenues for investigating historically significant archaeological sites in Southeast Asia.

# GLOSSARY

*Baray*- Khmer word for an artificial body of water created through raised walls. Fed by cannels and a part of the broader hydraulic network at Angkor. Cardinally aligned rectangular structure with length to width ration of 2:1.

*Brahmanical*- religious cult dominant during majority of the Angkor period. Was temporarily and partially overshadowed by Mahāyāna traditions and later replaced by Theravāda Buddhism.

*Bund*- related to rice farming, small barriers to catch water.

*Gopura*- monumental entrance tower.

*Lidar*- abbreviation and common spelling for, light detection and ranging.

*Mahāyāna*- religious cult briefly dominant during the reign of Jayavarman VII.

*Prasat*- Khmer word meaning temple related to Brahmanical monument systems.

*Prek*- Khmer word meaning a channel dug to divert water from rivers.

*Preah Theat*- Khmer words meaning ‘sacred relic’

*Processual*- an archaeological approach that focuses on the dynamic relationship of social, economic and environmental facets of culture to understand change.

*Sema*- Khmer word for boundary stone, which is used to define space of sacred sites.

*Terrace*- raised flat top earthen mound. Related to Theravāda Buddhist sacred sites in this context.

*Theravāda*- dominant religious cult in Cambodia from the late thirteenth century to modern times.

*Tonle*- Khmer word for large river.

*Toul*- Khmer work for mound.

*Trapeang*- Khmer word for a water management device dug into the ground. Length to width ration of 2:1. Rainfed water storage unrelated to the Angkor hydraulic network.

*Tumnup*- Khmer word for dyke.

*Vihara*- assembly hall found at Buddhist monasteries.

*Wat*- Khmer word for a Buddhist monastery or temple.

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