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LiDAR Predictive Modeling of Kalapuya Mound Sites in the Calapooia Watershed, Oregon

by

Tia Rachelle Cody

A thesis submitted in partial fulfillment of the
requirements for the degree of

Master of Science
in
Anthropology

Thesis Committee:
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Doug Wilson
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Portland State University
2019

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Abstract

Archaeologists grapple with the problematic nature of archaeological discovery. Certain types of sites are difficult to see even in the best environmental conditions (e.g., low-density lithic scatters) and performing traditional archaeological survey is challenging in some environments, such as the dense temperate rain forests of the Pacific Northwest. Archaeologists need another method of survey to assess large areas and overcome environmental and archaeological barriers to site discovery in regions like the Pacific Northwest. LiDAR (light detection and ranging) technology, a method for digitally clearing away swaths of vegetation and surveying the landscape, is one possible solution to some of these archaeological problems.

The Calapooia Watershed in the southern Willamette Valley in Oregon is an ideal area to focus LiDAR's unique archaeological capabilities, as the region is heavily wooded and known to contain hundreds of low-lying earthwork features or mounds. Modern Indigenous Communities, such as the Confederated Tribes of Grand Ronde, consider the Willamette Valley mound sites highly sensitive locations, as ethnographic accounts and limited archaeological work indicate that some are burial sites. However, these mounds have received little archaeological study. Land ownership (94 percent privately owned), dense vegetation that obscures mounds, and the sheer expanse of the landscape (234,000 acres) have impeded professional archaeological research.

The focus of this thesis is the development and the testing of a LiDAR and remote sensing predictive model to see if this type of model can detect where potential mound sites are located in the Calapooia Watershed, Oregon. I created a LiDAR and remote sensing predictive model using ArcMap 10.5.1, LiDAR, and publicly available aerial imagery; I manipulated data using standard hydrological tools in ArcMap. The resulting model was successful in locating extant *previously identified mound sites*. I then conducted field work and determined that my model was also successful in identifying seven new, previously unrecorded mound sites in the watershed. I also identified several possible patterns in mound location and characteristics through exploratory model analysis and fieldwork; this exploratory analysis highlights areas for future mound research.

This project has clearly established a method and a model appropriate for archaeological mound prospection in the Willamette Valley. This project also shows the efficacy of LiDAR predictive models and feature extraction methods for archaeological work, which can be modified for use in other regions of the Pacific Northwest and beyond. Furthermore, by identifying these mounds I have laid the groundwork for future studies that may continue to shed light on why and how people created these mounds, which will add valuable information to a poorly understood site type and cultural practice.

Dedication

To my family for supporting me during this process, through all its up’s and downs’.

Thank you for being the safe harbor in which I can dock my crazy ship.

Acknowledgements

I would first like to thank my advisor Dr. Shelby Anderson for all of her advice and support throughout this project. Without her guidance, I would still be stuck at the first sentence of this thesis, without an idea. I would also like to thank all of my committee members: Dr. Virginia Butler, Dr. Doug Wilson, David Banis, and Briece Edwards for their classes and help in designing and carrying out this thesis. I cannot thank them enough.

Briece Edwards and David Harrelson of the Grand Ronde Tribe invited me to investigate the Willamette Valley mounds. Many thanks to Briece, David, and the Grand Ronde Tribe for the incredible honor of trusting me with this special project. It has been an immense pleasure to work on a project that has so much meaning to the members of the Grand Ronde Tribe as well as archaeologists throughout the state. My gratitude to all of you cannot ever be fully expressed.

A very, very big thank you to the landowners who allowed me to access their land to test whether my model created during this project actually worked. Mr. Mack Slate, Mr. Jerry and Mrs. Cherry Skiles, and Mrs. Pat Keen your permission allowed this thesis to continue and your conversation and knowledge were incredible and invaluable. Your help is much appreciated. I would like to thank Ann Bennett Rogers, Dan Snyder, Dave Ellis, Danny Gilmore, and Naomi Brandenfels; all of your help in acquiring land access was invaluable and helped put the finishing touches on this thesis. The Korean War Veterans Association and the Oregon Heritage Commission supported my graduate studies and this research project.

I would also like to thank all of the wonderful archaeologists in the Pacific Northwest and beyond who have offered me advice, field work help, and general support throughout this project. Patrick Burns helped me on the GIS side of this project, giving me the idea that got me started on my model. Pat Reed acted as a sounding board, helped me in the field, and loaned me a mountain of books to help with this thesis. Katherine Tipton also assisted me in the field and has always offered her support through all the various stages of my project.

Thank you to all of the Portland State University Anthropology graduate students for all of your support and love throughout my time here. Without you all I surely would have gone insane a long time ago. A special thank you to my dear friend Chelsea Rose. Thank you for being my rock and my dearest of friends throughout grad school, also thank you for all of the soul soothing Thai and buttercream frosting. Thank you to Robert Soberano who helped to keep me sane in the final stages of this project and for your never-ending encouragement and support.

Finally, a massive thank you to my family. Thank you for never batting an eye when I said I wanted to be an archaeologist and then when I said I wanted to be an archaeologist with a master's degree. I honestly couldn't have done it without you.

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Chapter 1: Introduction

Archaeologists grapple with the problematic nature of archaeological discovery. Human activities and associated archaeological sites are not uniformly distributed or easily discernable across a landscape. Sites are dispersed, clustered, low or high in visibility, fragmented or relatively complete. All of these factors affect the likelihood that archaeologists will find a site during pedestrian archaeological survey. Furthermore, archaeological survey recovery rates are highly variable depending on the shape of the survey (linear, elliptical, rectangular, etc.), the transect interval, the time spent in each transect, access to survey areas, local environment, and the nature of the archaeology itself (Sundstrom 1993). In addition to the general visibility of archaeological sites, the amount of land that needs to be covered by archaeological survey, the attention and ability of archaeological crewmembers, as well as time and money constraints can all limit the accuracy of site identification through pedestrian survey (Wandsnider and Camilli 1992:169-170). The types of material that artifacts or sites are constructed out of, and the preservation environment, further affect the visibility of archaeological sites and the likelihood that archaeologists will find sites or artifacts (Wandsnider and Camilli 1992). Certain types of sites are difficult to see even in the best environmental conditions (e.g., low-density lithic scatters) and some environments are challenging to perform archaeological survey in, such as jungles or dense temperate rain forests like those of the Pacific Northwest. These challenging environments can obstruct an archaeologists' ability to identify even the largest of sites, such as monumental structures or earthwork features, let alone small lithic scatters.

Archaeologists need another method of archaeological survey to address these challenges; we need a survey method that can be used to assess large areas and overcome some of the environmental barriers that archaeologists find in regions like the Pacific Northwest. LiDAR (light detection and ranging) technology, a method for digitally clearing away swaths of vegetation and surveying the landscape, is one possible solution to some of these archaeological problems (Crow et al. 2007; Devereux et al. 2015). LiDAR technology has the potential to change our approach to pedestrian survey in the Pacific Northwest, where dense forest growth, uneven terrain, and access are major obstacles in designing and carrying out surveys. LiDAR modeling is effective over large areas and can be combined with other remote sensing data to create archaeological predictive models that identify likely site locations and guide pedestrian survey design.

The use of LiDAR modeling to aid in the identification of archaeological sites has been growing in popularity and use since 2002, when its potential as an archaeological tool was first explored (Challis et al. 2011; Holden et al. 2002). Use of LiDAR data to identify earthworks and other engineered landscapes has become common practice around the world, aiding in the discovery of ancient agricultural fields, deteriorated medieval structures, as well as Mayan ruins (e.g., Challis et al. 2011; Chase et al. 2011; Hesse 2010; Lasaponara and Coluzzi et al. 2011; McCoy et al. 2011; Weishampel 2012). North American applications, however, are limited and are mostly restricted to states east of the Mississippi River (Gallagher and Josephs 2008; Harmon et al. 2006; Johnson and Ouimet 2014; Pluckhahn and Thompson 2012; Riley 2009; Riley 2012; Rochelo et al. 2015). Archaeological LiDAR applications are even more limited in the Pacific

Northwest, although see Barrick (2015) for application in the identification of historic gold mines. Archaeologists have not yet applied LiDAR to the identification of pre-contact archaeological sites in this region.

The southern Willamette Valley in Oregon is an ideal area to focus LiDAR's unique archaeological capabilities, as the region is heavily wooded and known to contain hundreds of low-lying earthwork features or mounds. Modern Indigenous Communities, such as the Confederated Tribes of the Grand Ronde, preserve knowledge of these low-lying mounds, which were constructed by their Kalapuyan ancestors during the pre-contact era Euro-American naturalists and archaeologists have been aware of the Willamette Valley mounds for almost 200 years (Powers 1886; Wright 1922). However, these mounds have received little archaeological study. Land ownership, dense vegetation that obscures mounds, and the sheer expanse of the landscape has impeded professional archaeological research. Out of the potentially hundreds of mounds in the Calapooia Watershed alone (Laughlin 1941; Briece Edwards personal communication 2016) only 24 mounds are formally recorded with the Oregon State Historic Preservation Office (SHPO) (Table 1). The Grand Ronde Tribe considers the Willamette Valley mound sites highly sensitive locations, due in part to the presence of burials at many mounds; furthermore, Bergman's (2016) research suggests that mounds and other places on the landscape are imbued with ideological power (2016). Ethnographic accounts and limited archaeological work also indicate that some mounds are burial sites (Mackey 1974; Laughlin 1941; Laughlin 1943; Roulette et al. 1996). Therefore, identifying and protecting mound sites is a priority, but pedestrian survey of the Calapooia watershed is impractical given that it covers roughly 234,000 acres and is 94 percent privately owned (Runyon et al. 2004:1; Calapooia Watershed Council 2016).

Research Overview

The focus of this thesis is the development and the testing of a LiDAR and remote sensing predictive model to identify mound sites in the Calapooia Watershed in the Willamette Valley, Oregon (Figure 1). The primary question that guides this research is: can LiDAR and other remote sensing data detect where potential mound sites are located in the Calapooia Watershed? The creation of a successful model will be an important contribution to Tribal historic preservation efforts, and will also facilitate future archaeological research into the daily practices that created the mound sites.

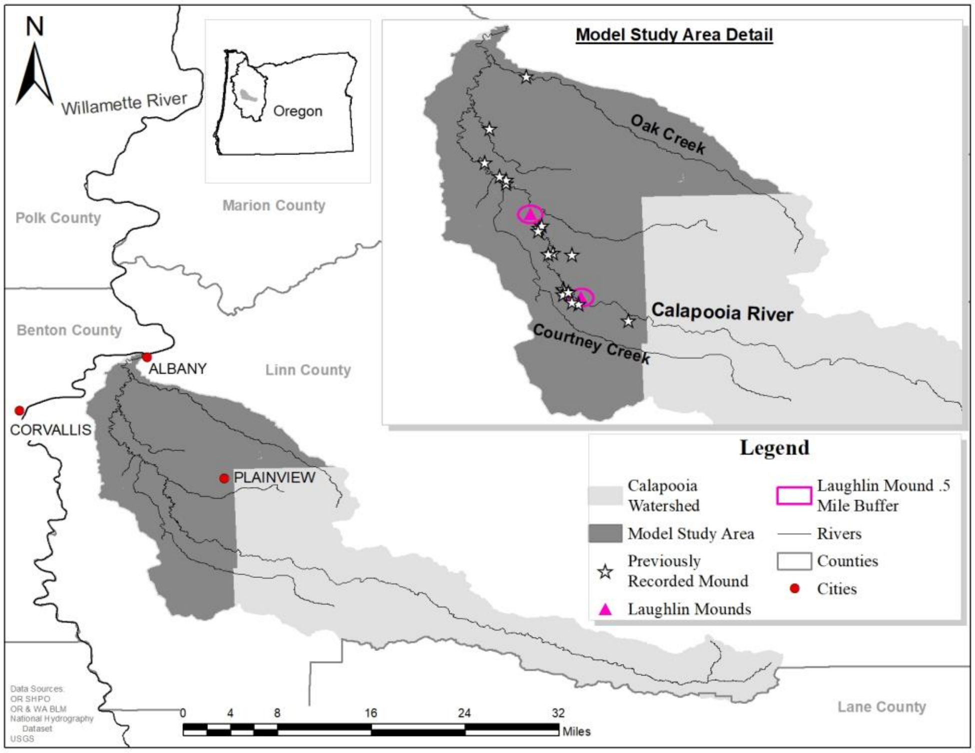


Figure 1. Calapooia Watershed, cities, counties, other major river systems, and previously recorded mound sites. Note that the locations of most previously recorded mound sites are approximate.

To address my research question, I created a predictive model in a geographic information system (GIS) and then assessed the efficacy of the model through further computer analysis and field work. I acquired LiDAR data from the Oregon Department of Geology and Mineral Industries (DOGAMI) LiDAR data viewer (Oregon.gov 2018) and analyzed data within Environmental Systems Research Institute's (ESRI) GIS ArcMap 10.5.1. I entered LiDAR data into ArcMap and manipulated data using various standard raster analysis tools provided by ArcMap. I reviewed previously recorded mound site data in the Oregon SHPO website to understand the general characteristics of the mound sites, such as shape and dimensions, and used this information to inform my methodological approach and to initially assess whether my model was operating properly. After I identified potential mound sites in ArcMap, I selected a subset of model-identified mounds and ground-truthed their presence with pedestrian survey on accessible land in the Calapooia Watershed. By analyzing the presence or absence of these mounds in the field I was able to assess the efficacy of my GIS model.

This project establishes a novel method and model appropriate for identifying mound features in the Willamette Valley; my approach can also be modified for use in other regions of the Pacific Northwest and beyond. Furthermore, the initial results of my modeling and fieldwork contribute new information to the discussion of why and how people created these mounds, and also lay the groundwork for additional research into these poorly understood sites and associated cultural practices. The development of a predictive LiDAR model has broad implications for regional historic preservation. This project provides evidence that LiDAR predictive models can and should be widely used tools in archaeological discovery.

Thesis Structure

This thesis is organized into five chapters. In Chapter 2, I discuss what was previously known about the mound sites in the Calapooia Watershed and the cultural background of the Kalapuyan peoples who constructed these mounds. I then discuss the history and efficacy of aerial remote sensing, including LiDAR, in archaeology. Last, I describe the environmental and geological context for the mounds that also factor into my model. In Chapter 3, I explain my research design in more detail, including the assumptions that guided the methods I used in mound identification. The latter half of this chapter is a detailed discussion of the GIS methods utilized to identify potential new mound sites. In Chapter 4, I present the results of my LiDAR predictive model and the model assessment fieldwork. Finally, in Chapter 5, I discuss the success of the LiDAR model, and also consider the implications of my work for future study of mound formation processes. I conclude with a discussion of future research directions and the implications of the usage of this model.

Chapter 2: Background

In this Chapter I discuss what is currently known about the Kalapuyan mounds in both the Calapooia Watershed and the Willamette Valley as a whole. From here I discuss what is known ethnographically known about the Kalapuyan peoples who made the mounds as well as the limited amount of ethnographic work discussing their burial practices. I then discuss the history of the archaeological usage of remote sensing and LiDAR. I conclude with a discussion on the geological and environmental context of the mounds.

Prior Research on Willamette Valley Mounds

Mound sites are an archaeological enigma in the landscape of the Willamette Valley. There is little agreement in the archaeological community about the age and nature of Willamette Valley mound sites and systematic investigation of mound sites is limited. Archaeological investigation of mound sites in the Calapooia Watershed is minimal and consists of only seven excavations, most of which occurred in the 1940s (Laughlin 1941). From this and other research on mounds around the region (see discussion below) we know that the mounds are roughly ovoid earthworks; Oregon SHPO records indicate that recorded mounds in the Calapooia Watershed range from 22 meters to 120 meters long, 15 meters to 85 meters wide, and less than 3 meters in height (although note that the Oregon SHPO records rarely include mound height information) (Figure 2).

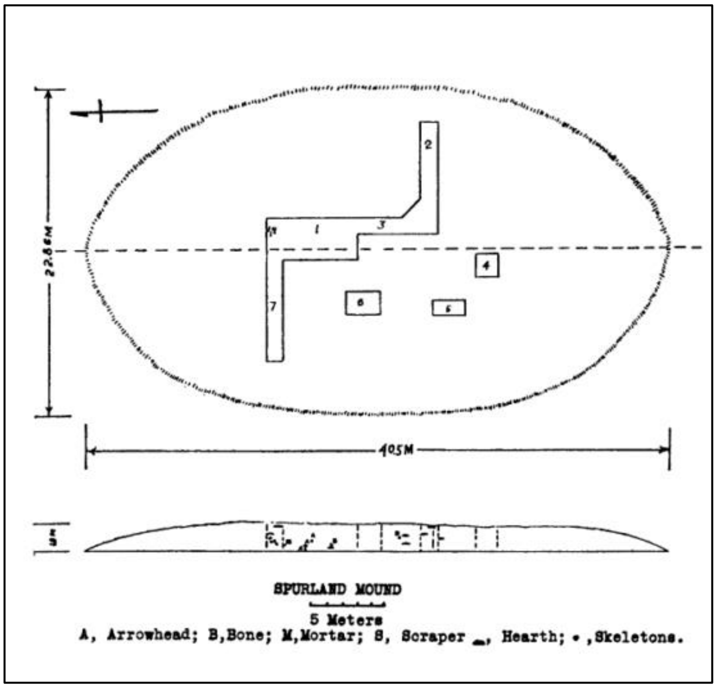


Figure 2. Spurland Mound Excavation Schematic (Laughlin 1941:148).

The size and appearance of mound sites in the Willamette Valley and the Calapooia Watershed in particular have long attracted the interest of Euro-American naturalists and pre-professional archaeologists, with some of the earliest mentions dating back to 1886 (Powers 1886). In the early discussions of these mounds, the focus was typically placed on the amount of artifacts discovered in them including bone charms, needles, knives, pestles, and projectile points (Powers 1886:166). However, despite a large early interest in the mounds, hardly any information as to their construction, use, or abandonment was discerned by early investigators. Theories and speculation as to the origins of the mounds were abundant, with some even suggesting that the mounds were an off-shoot of mound building activities seen in Japan and Siberia (Wright 1922). Powers (1886:166) says that he "opened a large number of them...", yet the only recorded information about these mounds are the “relics in [his] collection”. According to Mackey, over the last 90 years amateur archaeologists excavated approximately 80 mounds in the Calapooia Watershed and along the Muddy Creek (Mackey 1974:48, 51-56). However, no detailed accounts, records, or artifacts from these investigations are available. Collins (1951) also mentions that an early survey of mound sites in the watershed was conducted in 1928 by A. Belvins, Porter Slate, and Stewart Brock with contributions from E.H. Margason (compiled by W.P. Anthony). This early survey led to the creation of a rough sketch of the location of 88 mounds (Figure 3). These early investigations were highly destructive and yielded little to no data.

Figure 3. A. Belvins, Porter Slate, and Stewart Brock 1928 Map (Collins 1951)

Archaeological mound exploration by early professional archaeologists took place from the 1930s to the 1950s. This was the “first scientific archaeological field work in midden deposits of the Willamette Valley” (Collins 1951:58). This period was marked by semi-systematic excavation and collection with work focusing on site and artifact descriptions. In 1930, Strong, Schenck, and Steward excavated several mounds on “the lower Calapooya river in the vicinity of Tangent or Albany, Oregon” (Strong et al. 1930:147). Their description of these excavations is limited and simply mentions that some of the mounds might be natural rises. But they also describe recovering “poor burials” and artifacts (Strong et al. 1930:147). Cressman, Berreman, and Stafford performed work at the mounds at Virgin Ranch and Smithfield along the Long Tom River near Franklin, Oregon in 1933 (Collins 1951:58; Cheatham 1988:11-12) (Figure 4). The Virgin Ranch site produced *in situ* charred camas (*Camassia quamash)* roots and the Smithfield site produced a number of “fire pits or camas pit-ovens”, which occurred throughout the mound (Collins 1951:58). They also discovered an infant burial.

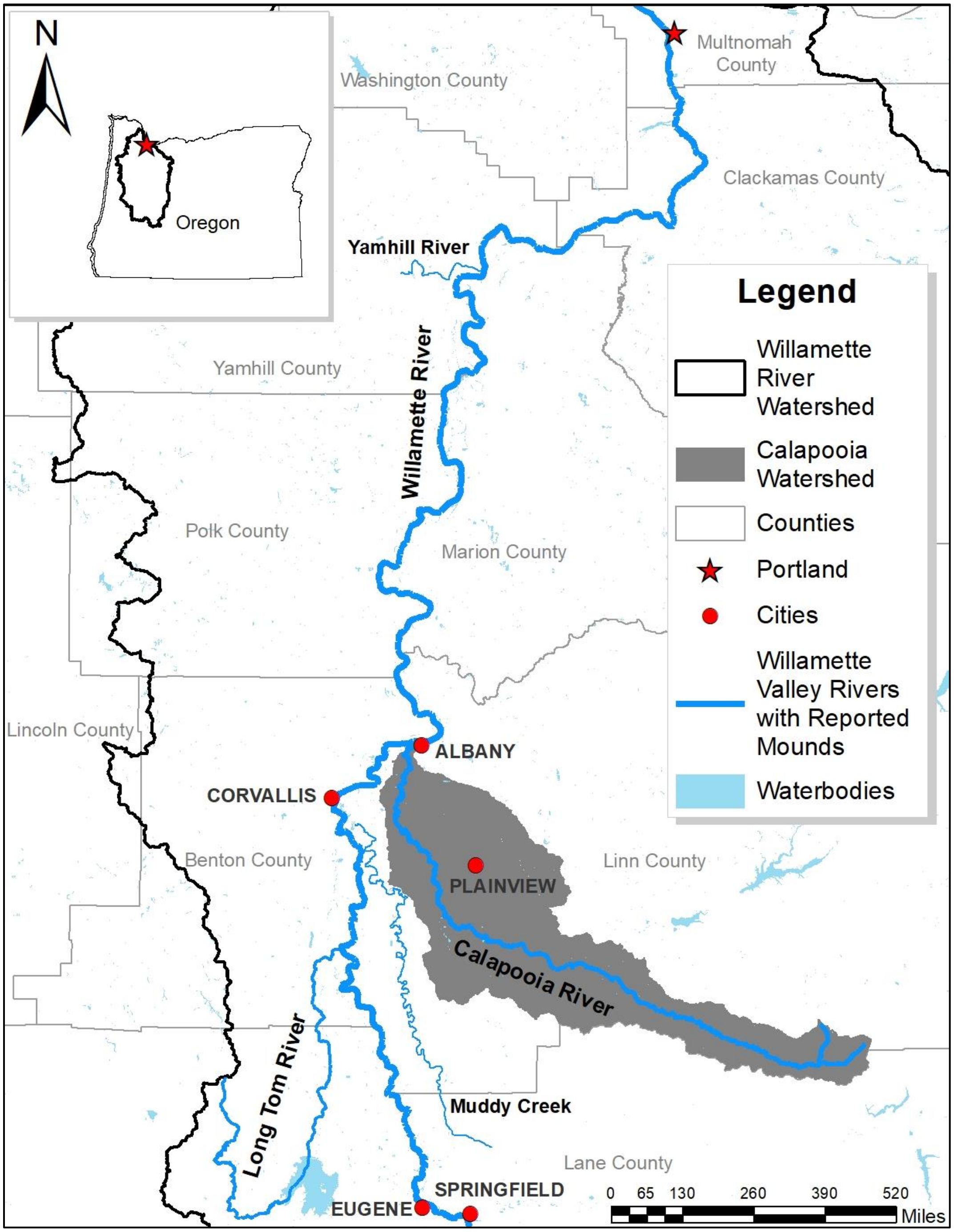


Figure 4. Rivers in the Willamette Valley where mound sites are known from prior research.

In the early 1940s, Laughlin excavated the Spurland, Halsey, Miller, and Shedd mounds in Linn County (Laughlin 1941) and the Fuller and Fanning mounds in Yamhill County (Laughlin 1943) (Figure 4 and 5). Laughlin recovered Native American remains and associated artifacts including a whale bone club, lithic tools, fire cracked rock (FCR), a shell necklace, groundstone, and camas root digging tools among other objects (Collins 1951:70). Laughlin's work is the first instance of professional scientific excavations, recordation, and collection of Willamette Valley mounds, although his analysis is primarily descriptive.

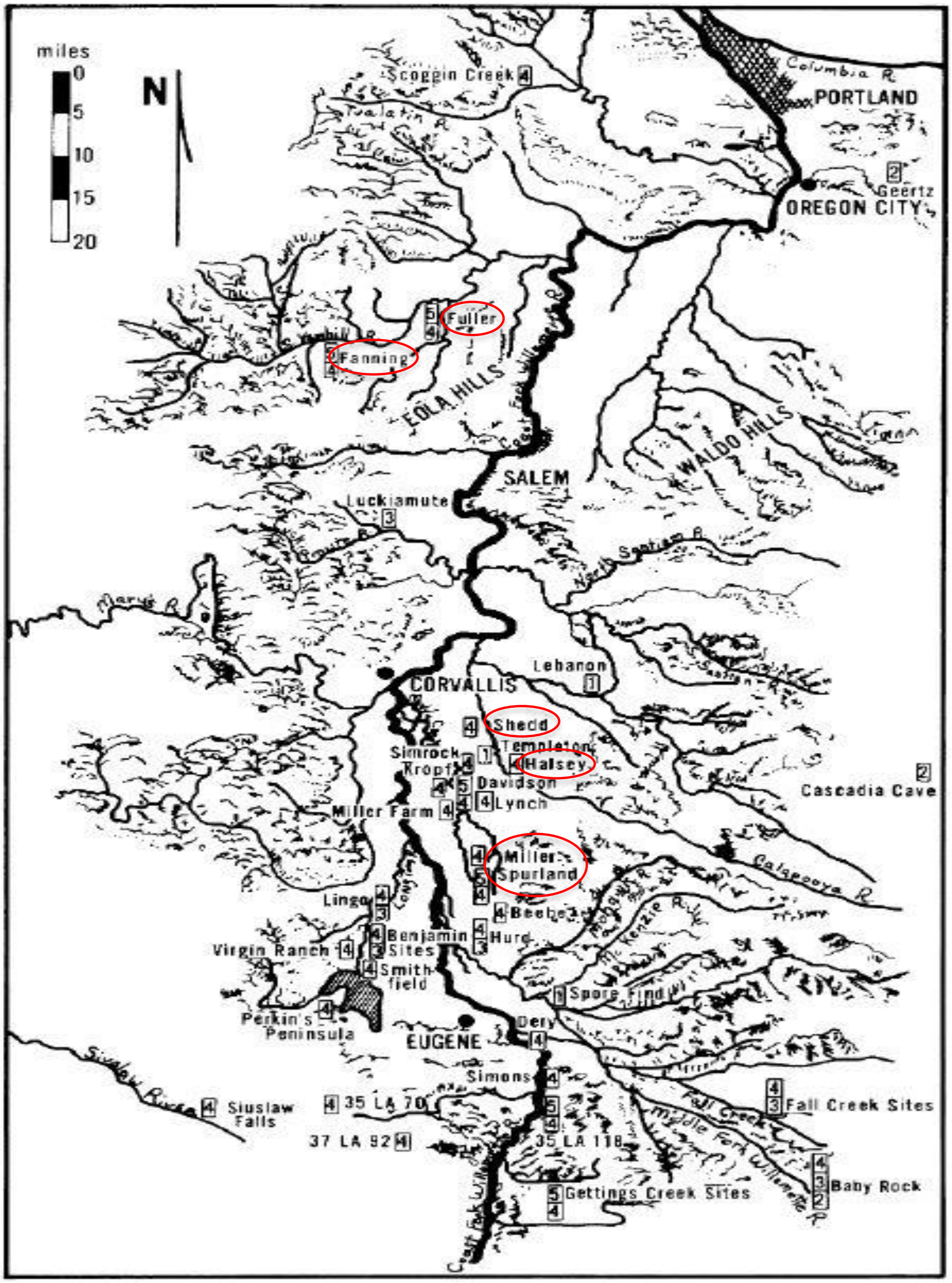


Figure 5. Map depicting Willamette Valley sites, including the Laughlin Mounds (names circled in red) (White 1979).

The archaeological mound investigations from 1950 to 1975 are marked by the work of professional archaeologists and graduate students focusing almost entirely on the mounds along the Long Tom River. Collins' work was cultural historical in approach; he focused on describing and synthesizing the Fuller and Fanning Mounds in his 1951 thesis "The Cultural Position of the Kalapuya in the Pacific Northwest". Collins also performed a cross cultural analysis of the Kalapuyan peoples to other Native cultures in the surrounding area (e.g. California and the Plateau peoples). Later work is more problem-oriented and informed by processual theory, with research directed at the question of why and how the mounds were constructed. Cordell's (1967) thesis "The Lingo Site, A Calapuya Midden" was one of the first systematic, scientific excavations of a mound site in the Willamette Valley. Cordell's initial goal of identifying post holes to prove or disprove the theory that mound sites were habitation sites, was derailed by changes in landowner permission (Cordell 1967). Instead most of her research ended up focusing on artifact analysis. Miller's 1970 thesis "Long Tom River Archaeology, Willamette Valley, Oregon" marks the last master's thesis focusing on the Willamette Valley mound sites. His work focused on the excavation of the Benjamin Site Mounds, 35LA41 and 35LA42. Miller also performed artifact analysis and a site type analysis. During this same period, several cultural resource management (CRM) investigations were undertaken in the Calapooia Watershed in response to construction projects (Table 1); these efforts recorded 14 mound sites.

The modern era of archaeological mound investigation began in 1975 and continues to the present day. This period is defined primarily by CRM investigations in relation to construction projects. The Fern Ridge Archaeological Project examined five mound sites along the Long Tom River, which included 35LA565 (Kirk Park 1), 35LA568 (Kirk Park 2), 35LA567 (Kirk Park 3), 35LA566 (Kirk Park 4), and 35LA282 (Perkins Peninsula Site-Park Area). These excavations uncovered lithic tools, groundstone, pipe fragments, bone tools, ochre, FCR, charcoal, and charred camas bulbs (Cheatham 1984; Cheatham 1988). One of the more interesting characteristics of these mounds is that none of them contained human remains, which were found in almost every other excavated mound in the Willamette Valley. More recently, Archaeological Investigations Northwest, Inc. (AINW) excavated a mound site known as the Calapooia Midden Site (35LIN468). This investigation recovered human remains, faunal remains, hearth features, charred camas remains, and a variety of artifacts including flaked and ground stone tools. Five other mound sites were recorded as part of CRM efforts between 1975 and the present (Table 1).

A total of 20 mound sites are recorded with the SHPO office in the Calapooia Watershed (Table 1). Four additional mounds were recorded in or near the watershed by Laughlin (1941). In addition, 134 possible mounds in the Calapooia Watershed are noted in the SHPO database, but lack location data or any detailed information about mound size, contents, etc.

Table 1. Previously recorded mound sites in the Calapooia Watershed.

Site Number (Report Number)	Site Name	County	Site Type	Year Recorded
35LIN00020	N/A	Linn	Heavily pot hunted mound, with lithics, FCR, and human remains; darkened soils mentioned	1979
35LIN00041	N/A	Linn	A mound-midden site; located within a plowed field; several projectile points and glass scrapers (were collected); darkened soils mentioned	1970
35LIN00042	N/A	Linn	A mound-midden site; potential for lithic material; surface collection noted	1970
35LIN00045	N/A	Linn	A mound-midden; noted as being excavated by amateurs; extensive lithic, decorative, and food processing artifacts found; burials were found in Feature 2, 3 bags of artifacts removed including points; Feature 2 is a camas oven; soil sample taken	1970
35LIN00046 (24023)	N/A	Linn	Noted in 1970 to be a mound with points having been collected by landowner; Revisit in 2010 couldn't find mound but stated it was possibly still present; small lithic scatter found	1970, 2010
35LIN00048	N/A	Linn	A midden site; partially in plowed field partially naturally vegetated; small bag collected including a point; darkened soils mentioned	1970
35LIN00050	N/A	Linn	A midden-mound site; heavily vegetated; 11 bags of artifacts collected including points and C14 sample; one test pit; human remains found on surface; darker soils mentioned	1970
35LIN00051	N/A	Linn	A midden-mound site; one surface bag collected with one point being noted; darker soils mentioned	1970
35LIN00053	N/A	Linn	A midden-mound site; noted as being rather large; one surface collection bag, no lithics; exhibited evidence of potting	1970
35LIN00054	N/A	Linn	A midden-mound site; one bag of flakes and a pestle fragment were collected; darker soils mentioned	1970
35LIN00055	N/A	Linn	A midden-mound site; flakes and bones were noted on the surface as well as bioturbation; one bag of flakes collected; darker soils mentioned	1970
35LIN00057	N/A	Linn	A midden-mound site; flakes noted to be around mound; noted to have possibly been a burial that had been plowed; one surface collection bag; previous collections by "F. Fisher (Halsey) – Button" in 1851; darker soils mentioned	1970

Table 1, continued

35LIN00059	N/A	Linn	A midden-mound site; flakes noted to be around the mound allowing for identification; surface collection; darker soils mentioned	1970
35LIN00061 (27361)	Foster Dam	Linn	A mound-like area; located very close to the water; several lithic artifacts collected	1973
35LIN00095	N/A	Linn	Mound site known to the land owner's family for generations; large amounts of lithic artifacts, FCR, and faunal remains; has been pothunted; surface collection of artifacts; has been partially plowed	1979
35LIN00291 (7143)	N/A	Linn	Potentially a historic burial mound; prehistoric artifacts and FCR found in rodent backfill; historic artifacts present	No Date Given
35LIN00468 (12444, 13032, 15342, 15608, 24287, 26383)	Calapooia Midden	Linn	Mound located on an old levee; lots of lithics, points, and FCR found on the surface; human remains recovered; dense charcoal; evidence of pot hunting and cattle grazing	1991
35LIN00711 (21363)	N/A	Linn	Large mound with lithic debitage and FCR; evidence of looting and collector piles (Figure 6)	2007
35LIN00805 (26383)	Mound Site	Linn	Mound adjacent to a lithic and FCR scatter; potentially a burial although it wasn't examined	2013
35LIN00806 (26383)		Linn	Potential midden with a historic structure built on top(?); hundreds of lithics, FCR, and pestles; some historic artifacts found	2013
Unknown	Spurland Mound	Unknown	Large trenched mound with six human skeletal remains, animal bone, extensive lithic artifacts, FCR, a copper necklace, preserved rawhide and leather, bone artifacts, and shell	1940-1941
Unknown	Miller Mound	Unknown	Mound without systematic excavation; three human skeletons were removed by a collector; one skeleton removed by Willamette University; trenches found lithic material and FCR	1936, 1940-1941
Unknown	Halsey Mound	Unknown	Large trenched mound; hearths, charcoal, FCR, and lots of lithic and bone material found; scattered human remains; mentions remains of two Native Americans who were allowed to live on the mound by the white landowner	1940-1941
Unknown	Shedd Mound	Unknown	Two plowed mounds of very poor condition; minimal lithic debris; skeleton, mortar and pestle, and well-made lithic tools were removed and kept by the land owner	1940-1941

Figure 6. 35LIN711. The mound is centered and is right in front of the tree line (35LIN711 site form pg.5).

Mound Age and Archaeological Theories on Past Use

Eight mound sites have been dated, and the majority of dated sites are located along the Long Tom River rather than the Calapooia. The mounds have not been consistently dated or reported; when not reported, we assume that pre-1980 dates are not calibrated. Although the number of dated mound sites is limited, the dates suggest that the use and creation of the Kalapuyan mounds persisted for around 4,000 years, with some sites suggesting multiple phases of use throughout time (Table 2).

Table 2. Dated Willamette Valley mound sites.

Site Name/No.	Mound Age	Type of Date	Watershed	Reference
35LIN00050	840 ± 110 B.P.	Radiocarbon dated (conventional); Direct	Calapooia	White 1975:115
35LIN00468	15 dates ranging from 2880 ± 80 cal B.P. to 130 ± 50 cal B.P.	Radiocarbon dated; Direct	Calapooia	Roulette et al. 1996:8-73 – 8-74
Miller Mound	1600 A.D.	Dendrochronology; Indirect	Muddy Creek	
Spurland Mound	350 years ago (Late pre-contact/early historic [Kalapuyan Phase])	Dendrochronology; Indirect	Muddy Creek	Collins 1951:103; White 1979:564
Virgin Ranch Sites	250 years old	Dendrochronology; Indirect	Long Tom	
The Lingo Site	4270 ± 110 cal B.P. and 2045 ± 120 cal B.P.	Radiocarbon dated; Direct	Long Tom	Cordell 1975:275
The Benjamin Sites (35LA00041)	2320 and 1640 B.P.	Radiocarbon dated; Direct	Long Tom	Miller 1975:346
Kirk Park Mounds	14 dates ranging from less than 100 years old to 3310 ± 150 years B.P. (Cheatham 1984).	Radiocarbon dated; Direct	Long Tom	Cheatham 1984

There is little to no consensus as to the use of the mound sites. A single ethnographic account (Laughlin 1941) mentions a Kalapuyan Tribal member and his son living at Halsey Mound, suggesting that the mounds may have been habitation sites in some cases. This theory is pervasive (White 1975; Collins 1951; Cordell 1967) but ethnographic accounts (Mackey 1974; Collins 1951:40; Zenk 1990:548; White 1979:557) all indicate that the primary winter housing structures of the Kalapuya were permanent plank houses, which would have used posts as supports. No excavated mound site to date has ever exhibited post holes or the remains of posts (e.g. Cordell 1967). Materials recovered from mound excavations indicate that they were burial sites, and/or were associated with camas processing and/or other food processing activities (Kaehler 2002; Roulette et al. 1996:8-58, 8-144; White 1975; Wilson 1993; Wilson 1997; Wilson personal communication 2017). Some researchers believe that the mound sites were used year-round near campsites or habitation sites and are the remains of intensive processing activities (White 1975; Miller 1975:345-346; Roulette 2006). No researcher has yet to discuss the particular reasons behind the presence of human remains in the Kalapuyan Mounds (although see Bergman 2016 for discussion of possible ideological meanings for places on the Willamette Valley landscape from an ethnographic perspective).

The previous research suggests that an increase in resource extraction and processing, particularly camas, led to the development of mound sites in the Calapooia Watershed and the Willamette Valley more broadly. Alternatively, mounds may have been multipurpose sites that encompassed some or all of the above activities. Unfortunately, there are no available oral histories describing how mounds were created and used by people in the past.

Mounds in the Ethnographic Literature

Although the origin of mound sites not well understood, it is well established that the Kalapuya mounds were created by the Kalapuyan people who inhabited the region and are now one of the Confederated Tribes of the Grand Ronde as well as the Confederated Tribes of Siletz Indians. There are roughly 35 different spellings of the Kalapuya, which are all used interchangeably when referring to the Kalapuyan peoples (Teverbaugh 2000:16). There were up to 20 different bands of Kalapuyan people

(Beckham 1977:38, 43). The most commonly known and recognized Kalapuyan bands of people include the Tualatin at the far north of the Willamette Valley, the Yamhill, Pudding River (Ahantchuyuk), Champoeg, Luckiamute, Mary's River (Chepenefa), Santiam, Tsankupi, Tsan-chifin, Mohawk (Chafan), Muddy Creek (Chemapho), Long Tom (Chelamela), Winnefelly, and finally the Youncalla (Yonkalla) at the far southern end of the Willamette Valley (Zenk 1990:548; Teverbaugh 2000:33-34) (Figure 7). The Santiam, Tsankupi, Tsan-chifin, and the Mohawk all traditionally lived in the Calapooia River region. The Mary's River people were located near the confluence of the Calapooia and the Willamette Rivers.

Figure 7. Map of Kalapuyan Tribes (the red line denotes the bands that make up the Kalapuyan Tribe) (Teverbaugh 2000:34).

Few ethnographic accounts of the Kalapuya before the reservation system exist, and most were focused on "memory" or salvage ethnology, e.g., collecting information before the last Native speakers died (Collins 1951:16; Teverbaugh 2000:18-19; Jacobs 1945:5). Therefore, these ethnographic accounts depict social structures that were significantly altered from what they were prior to removal (Aikens et al. 2011:287; Teverbaugh 2000:17). The Kalapuyan populations were also decimated by small pox in 1805 - 1806 and malaria in 1830, which swept through the area and killed roughly 90 percent of the Native People in the Willamette Valley (Aikens et al. 2011:287; Boag 1988:38-39; Teverbaugh 2000:51). Because of this, much of the Kalapuyan ways of life prior to the reservation period were lost or co-opted into new ways of living within the reservation system or with Euro-American settlers. The following ethnographic description of the Kalapuya is based on the limited information left or recorded; it is not comprehensive.

The Kalapuyan people were a primarily inland group that subsisted on the various floral and faunal resources in the Willamette Valley including salmon (*Oncorhynchus* spp.), deer (*Odocoileus* spp.), and camas (Beckham 1977:48; Boag 1988:21; Mackey 1974:43; Elder 2010:10-11; Teverbaugh 2000). The Kalapuyan peoples regularly control-burned the surrounding landscape primarily to cultivate camas (Beckham 1977:49; Bowen 1978: 60; Christy and Alverson 2011; Teverbaugh 2000:30; Walsh et al. 2010; Zenk 1990:547)

The Kalapuyans were more nomadic than their Chinookan neighbors to the north. In the winter months larger, multiple family groups occupied permanent plank houses.

However, in the summer, the groups split into smaller, transient groups which moved throughout the region tending resources (Beckham 1977:45; Mackey 1974:42; Teverbaugh 2000; White 1979:557; Zenk 1990:548). Although the remains of housing structures have not been found in association with mound sites, Laughlin (1941) mentions that at Halsey Mound, located on the Calapooia River as it begins to head eastward near the modern-day town of Halsey, a Euro-American landowner remarked that they had let a Native American and his son continue to live on a mound on "their" land. This supports some researcher's beliefs that the mound sites could be year-round habitation sites (White 1975), although there is little archaeological data to support this idea.

The presence of human remains in some mound sites suggests that these sites could be burial mounds. Unfortunately, the burial practices of the Kalapuyan peoples are minimally documented and even less understood. Collins (1951:51) notes that burial practices are documented/reported for only a few bands (Tualatin, Santiam, and Mary's River) (see Jacobs, et al.1945). In his ethnographic description of the Santiam, Jacobs mentions that when a person died tribal members would dig a hole, bury the individual, and then leave for home, or the tribe would cremate the body (Jacobs 1945:74). Another description states that the body was first wrapped in blankets and then buried with important items in a five-foot deep by six feet long by three feet wide grave; the dead's home was later burned (Gatschet et al. 1945:196-197). The only other account of Kalapuyan burial practices comes from an unnamed source who wrote to the editor of the American Antiquarian and Oriental Journal in 1882 (American Antiquarian 1882:330-

331). In this account the author mentions that they personally witnessed a burial ceremony and recalled that:

> *On the Willamette, they buried their dead in the earth. When the grave was dug, they placed slabs on the bottom and sides, and when they had lowered the wrapped body down, placed another over, resting on the side ones, and filled in the earth. ... After thus depositing the body and filling the graves, they built a fire on the same, and all the friends sat about it and chanted a mournful dirge for a long time, ... Often after, the mother came and deposited food in the earth at the head of the grave. At a man's grave was stuck up a paddle, at a woman's a camas stick…*

Given that there are no other accounts of Kalapuyan burial practices and that there are no mentions of the mounds at all, the ethnographic literature offers limited information regarding the development, use, and/or cultural processes that led to the creation of the mounds. The Grand Ronde, and potentially other Tribes, consider these mounds to be particularly culturally sensitive sites because of the presence of burials.

In summary, there is little agreement about why and how mound sites were formed by past people in the Willamette Valley. We know little about site distribution and contents, as little research has taken place. This lack of information is a significant barrier to preservation of these culturally sensitive sites. I use novel LiDAR and other remote sensing techniques to identify previously unknown mound sites in the Calapooia Watershed, which will aid in the active preservation of these important archaeological sites for Native, and other interested, communities.

Remote Sensing in Archaeology

LiDAR and other remote sensing data can be used to identify mound sites, as remote sensing data provides archaeologists with a new digital vantage point over the landscape. The uses of remote sensing datasets have proven their efficacy over time in archaeological prospection, beginning with early use of aerial photographs to identify archaeological sites in the late 1800s (Ceraudo 2013:11; Bewley 2003:274). Archaeologists have used remote sensing techniques with increasing frequency since the 1960s, with one of the first applications being the archaeological analysis of NASA satellite imagery that became available in the 1960s (Giardino 2011). This work led to the discovery of previously unknown ancient canal systems in Arizona (Giardino 2011). Since then, archaeologists have used satellite imagery all over the world to identify sites and guide on-the-ground survey; mound sites are one of the most prevalent site types identified through analysis of satellite imagery (e.g. Challis et al. 2011; Rajani and Rajawat 2011; Grøn et al. 2011; Lasaponara et al. 2011; Meredith-Williams et al. 2014). Methods for identifying low-lying features in remote sensing data include analysis of satellite imagery to identify paleochannels in India (Rajani and Rajawat 2011) and the manipulation of satelitte imagery using statistical tools as a Principal Component Analysis to identify sites in Peru (Lasaponara and Masini et al. 2011).

LiDAR technology was developed more recently than aerial or satellite imagery. It was first used to accurately measure the elevation of terrain in the 1970s (Price 2012:25). LiDAR is created by a plane flying over any given landscape and sending a multitude of light pulses down to the Earth. Those light pulses then bounce back off of the terrain and are collected by the plane, creating a point cloud. This point cloud is then post processed to create a digital elevation model (DEM) that represents the elevation and terrain of the landscape without vegetation. Archaeological applications of LiDAR are more recent, with the first mention of its potential applicability in archaeology in 2002 (Holden et al. 2002). Since the early 2000s, archaeologists have increasingly realized the potential of LiDAR and are using LiDAR as a method of archaeological prospection (Challis et al. 2011; Holden et al. 2002). The process of adoption has been slow because the expense of using traditional methods to collect LiDAR imagery (via low flying aircraft), which has impacted the availability of LiDAR data, particularly primarily in the United States (U.S.). Only 23 states, mostly in the eastern U.S., have complete LiDAR imagery (NOAA 2018). However, LiDAR flights are becoming more affordable and readability available; additionally, the collection of LiDAR from unmanned aerial vehicles (UAVs) is contributing to the affordability and expansion of LiDAR availability and its use in archaeology.

LiDAR and other remote sensing data have proven particularly effective at identifying mounds and other earthworks. For example, archaeologists have analyzed aerial imagery to determine differences between mounds, such as shell mounds, and the surrounding landscape (Meredith-Williams 2014). Others have studied multi-spectral and hyper-spectral imagery (the difference between the two is the number of light bands acquired by the sensor) to identify anomalies in the spectral imagery attributed to both standing and plowed mounds in Denmark (Grøn et al. 2001:2026), and to assess the vegetation signatures and species variability on shell mounds in Louisiana (Giardino

2011:2007). Archaeologists manipulate LiDAR data, using local relief modeling to locate grave fields in Sweden (Doneus 2013) and house mounds in Belize (Shane Montgomery personal communication 2017). Researchers in Tonga used LiDAR and hydrological methods to successfully identify both known and unknown low-lying mound sites in the Kingdom of Tonga (Freeland et al. 2016). After comparing their model to previously recorded sites, Freeland et al. (2016:70) found that their model had an 85 percent positive identification rate. Researchers like Challis et al. (2011:287) note that slope calculations from a LiDAR derived elevation-based model are effective in analyzing archaeological earthwork features and in highlighting their uniqueness on the landscape by showing localized increases in slope.

In the U.S., archaeologists have primarily applied LiDAR to the problem of identifying archaeological sites in densely vegetated environments (Gallagher and Josephs 2008; Johnson and Ouimet 2014). Additionally, some studies assessed whether LiDAR could detect the presence or absence of archaeological features on the landscape (Harmon et al. 2006; McCoy et al. 2011; Price 2012; Randall 2014; Riley and Tiffany 2014). In other cases, the focus is on understanding how LiDAR can be used in conjunction with other geospatial techniques to create more accurate archaeological site maps (e.g. Pluckhahn and Thompson 2012). In a few cases, U.S. archaeologists have used LiDAR to relocate previously identified mounds and to assess the viability of using LiDAR in the identification of mounds. Randal (2014) used LiDAR to highlight previously known freshwater shell mounds in Florida but did not perform any analysis beyond pairing LiDAR with topographic maps. Similarly, Davis et al. (2018) used

LiDAR to identify new and previously recorded shell rings and mound sites in South Carolina. For the most part, archaeologists applying LiDAR in the U.S. are using it to locate previously known features, and have sometimes identified new features in a previously studied archaeological landscape. Only one study has used LiDAR solely to locate unidentified archaeological sites in the U.S. (Davis et al. 2018).

Most archaeological researchers are visually examining LiDAR and identifying potential features of archaeological interest to investigate further through field work or other remote sensing analysis. Only recently are archaeologists taking advantage of the analytical power of GIS by conducting more in-depth GIS analysis to identify potential features of interest. Few archaeologists, particularly in the U.S., have used automatic feature extraction [AFE] methods available in GIS. AFE is the automatic detection of specific features using identified parameters or algorithms. AFE has exciting potential uses in the archaeological applications of GIS and LiDAR analysis as it effectively uses the computer, rather than the researcher, to survey the digital landscape for features within a set of parameters established by the modeler. This increases archaeological efficiency in LiDAR analysis as archaeologists no longer have to scroll through LiDAR data to identify mounds; instead the computer identifies the likely mound locations. However, uses of AFE in identifying mound features in the United States is limited. Some of the only examples are Riley’s 2009 master’s thesis and a subsequent publication (2012) on the automatic feature extraction model she created to identify mound sites in Iowa. Riley’s [2012] AFE tool is published by the Iowa SHPO and can be used by archaeologists to identify unknown archaeological sites in Iowa. Davis et al.’s (2018) work is the most recent example of using AFE to identify mound locations in South Carolina.

Archaeological LiDAR usage is still in its infancy, with its full analytical capabilities yet to be entirely understood or utilized by archaeologists. This thesis is an exciting expansion of archaeological LiDAR methods and usage to an important historic preservation issue. Furthermore, my work is a novel exploration of the use of AFE in feature identification that has important historic preservation implications both locally and beyond.

Calapooia Watershed: Geological and Environmental Background

The geologic and natural environment that define the Calapooia Watershed are critical in understanding the nature and location of the mound sites, and thus to the creation of a predictive model. The Willamette Valley sits atop a 10 million-year-old layer of Pliocene volcanic flow rock. When the valley formed these flows blocked off the northern Willamette River outlet, forcing all of the river’s sediments back into the large trough that would later create the valley. This allowed for massive flooding in the valley during glacial advance and retreat in the region from roughly one million to 13,000 years ago (Beaulieu et al. 1974a:7-8; Boag 1988:12-14; O’Connor et al. 2001:24, 36).

The Willamette Valley is characterized by relatively flat terrain; Linn County only gains a total of 160 feet in elevation in the floodplain regions (Beaulieu et al. 1974a:7). The soils in the immediate vicinity of the Calapooia River are predominately a clay loam/silty clay loam that is relatively mixed with clay and silty clay. The surrounding soils are a loam or silty loam (Beaulieu et al. 1974b). As climate began to warm after the last glacial maximum 20,000 years ago, the vegetation and climate that is now associated with the Willamette Valley began to appear, stabilizing roughly 2,000 years ago (Boag 1988:16). The Valley is characterized by a temperate climate, with the region around the Calapooia River receiving roughly 40 to 60 inches (101.6 to 152.4 cm) of rain every year from late fall to late spring (Beaulieu et al. 1974a:5; Boag 1988:16).

Unlike some of the other rivers in Linn County, including the North and South Santiam Rivers, the Calapooia River is a relatively stable river system with only a minor amount of stream modification and meandering (Beaulieu et al. 1974a; O'Connor et al. 2001:18). The stability of the Calapooia River in comparison to the other river systems in Linn County (with the exception of Muddy Creek), has most likely allowed those mound sites that are present in the direct floodplain of the Calapooia River to remain over time. The relative stability of the Calapooia River makes it a more stable environment for human settlement and activity; with minimal meandering and a reduction in the effects of large flooding events, less land is eroded (Brown 1997:38). In contrast unstable, dynamic, braided channels offer limited environmental stability and will infrequently preserve archaeological materials as they are usually quickly washed away (Brown 1997:37-38).

Another potential reason for the preservation of mound sites in the Calapooia Watershed is that intense flooding is less severe and causes less damage in environments that are less modified and more wooded; it is likely that the Calapooia Watershed was more wooded before Euro-American settlement and farming activities in the region (Brown 1997:39). The Willamette Valley and the Calapooia Watershed are both prone to periods of intense and even catastrophic flooding that inundate the floodplains of these river systems (Beaulieu et al. 1974a:47; White 1975:38). Heavy rainstorms, snow melt, or the combination of the two are the main causes of intense flooding in the region, which primarily occurs between October and April, with the majority of intense flood events occurring in December and January (Beaulieu et al. 1974a:47) (Figure 8). The narrowness of the Calapooia River valley and the encompassed tributary watersheds, causes ponding in the immediate floodplain (Beaulieu et al. 1974a:53; O'Connor et al. 2001; White 1975:38). Ponding creates a rich organic, black soil, as well as rich environments for marshy plants to grow (including wapato [*Sagittaria latifolia*] and camas) and an excellent environment for migratory marsh birds that were hunted by the Kalapuyan People (Beaulieu et al. 1974a:53; White 1975:38).

Figure 8. Intense flooding of the Calapooia River in December 1964 (Beaulieu et al. 1974a:49).

Laughlin (1941:149) mentioned that the soils in the mounds he excavated were a silty, dark loam that was distinct from the surrounding soil color. It is possible that the distinctive soil of the mounds is created by ponding. However, some of Laughlin's Kalapuyan mounds were found in both immediate floodplains and riparian zones, which suggests that the marked difference in soil color is due to the contents and nature of the mounds themselves. Culturally created or modified soils are often dark in color due to increased organic content (Hester et al. 2009:136).

Previous analysis of Willamette Valley archaeological sites (White 1975) indicates that most of the mound sites either lie directly in the floodplain of the Calapooia River and/or surrounding tributaries, or are in the riparian zone. In his analysis, White (1975) states that flooding and ponding in the floodplain created an ideal environment for camas; and people came to these areas to be close to camas, which played a major part in the Kalapuyan People's diet. Mound sites are also present in riparian zones "because of a combination of concentrated occupation and a lack of periodic inundation" (White 1975:39). The riparian zone is distinguished from the floodplain by a sharp enough slope that archaeological sites are protected from the erosional effects of floods. The floodplain and riparian zones were geologically and environmentally ideal for resource extraction and usage, which drew people here and resulted in mounds and other archaeological site types.

The Willamette Valley is home to a diverse and abundant vegetation, and was historically home to seven distinct vegetation zones. These zones include water environments, marshland, riparian forest, prairie, savanna, woodland forests in the foothills, and upland forests in the Cascades (Christy and Alverson 2011). Understanding these historical vegetation zones is useful in understanding and predicting the location of mound sites. Mounds are most frequently found in the historical riparian zone forest and prairie areas of the Valley. However, today most of the prairie and savanna lands are used as agricultural and pasture land, which suggests that those mound sites that were once located in the prairie and savanna regions of the valley may now potentially be gone or at least greatly diminished.

The environmental and geological characteristics that define the Willamette Valley, and the Calapooia Watershed more specifically, are important foundational factors in the creation of my model. They provide a broad framework that create the initial parameters for the LiDAR predictive model and the analysis to follow, which are described in the next Chapter.

Chapter 3: Research Design and Methods

The primary question guiding the development of the LiDAR model is "can LiDAR and other remote sensing data detect where potential mound sites are located in the Calapooia Watershed?" Although this is a simple question, it serves as the foundation for any future research and inquiry regarding the Kalapuya Mounds. The mounds cannot be further understood, preserved, or protected without first understanding where they are located. If I can identify potential mound sites using a remote sensing model, future researchers will be able to explore the long-standing hypotheses about what behaviors and daily practices led to the creation of these mounds. To address my research question there are three stages of my project: 1) model development; 2) field survey to ground truth the model, and 3) analysis of lab and field data to assess the efficacy of the model.

Model Development

The first step in the creation of the model was an exploration of various methods that may be effective for identifying mounds through iterative modeling. The program I used for my analysis was ESRI’s ArcMap 10.5.1. I began this process by focusing first on the potential use of slope derived from the LiDAR data and vegetation data to identify mound sites. Then I employed hydrological methodology and zonal statistics to highlight and extract potential mounds from the LiDAR dataset (DOGAMI 2009; this is the only LiDAR currently available for the project area). I used several additional spatial datasets to build the mound identification model (Table 3), which added to the robusticity of the LiDAR dataset and aided in analysis.

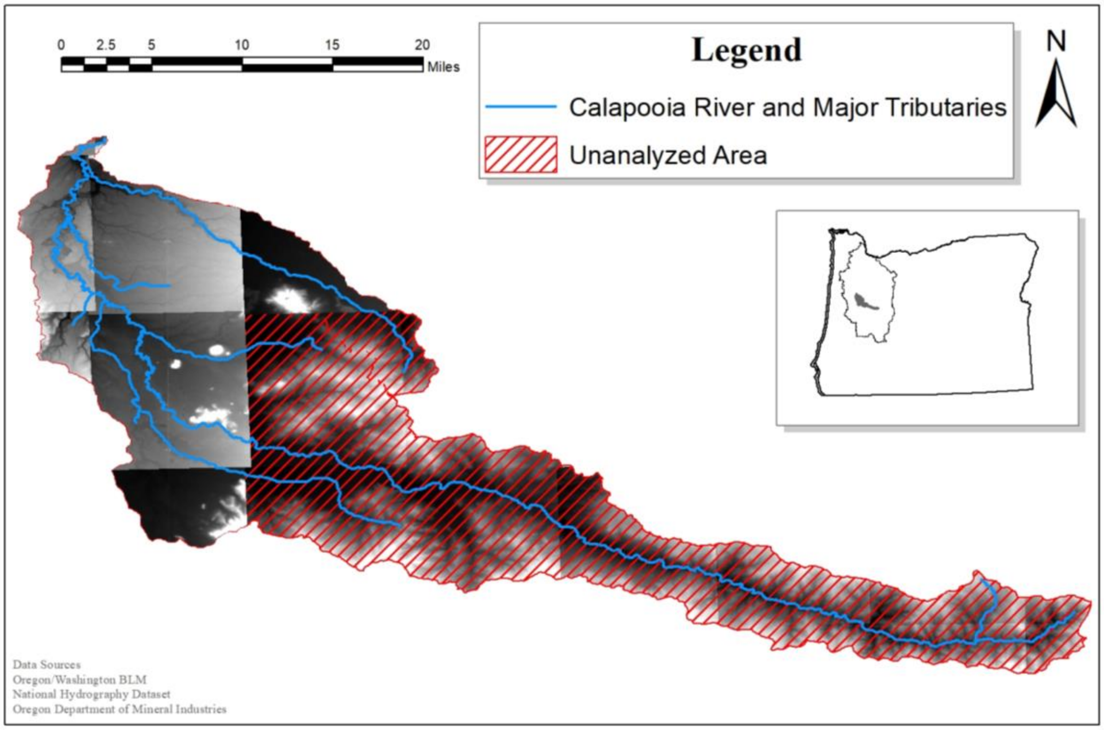
I made the following assumptions, which are given in any LiDAR or remote sensing model:

- Mound sites will be uniquely visible and relatively uniform in their dimensions.
- Mounds will be of a height and width that can be identified within the LiDAR data and aerial photography.
- Mounds will be relatively low lying and either circular or ovoid in shape.
- Mounds will express a slope change that is distinguishable and unique in comparison to the surrounding landscape.

Table 3. Datasets used to construct the LiDAR model.

Type of Dataset	**Dataset**	**Data Source**
Remotely Sensed Imagery	One-meter spatial resolution LiDAR Digital Elevation Model (DEM)	Oregon Department of Mineral Industries (DOGAMI) www.oregongeology.org/lida (2009) (Portions supplied by the Grand Ronde Tribe)
Remotely Sensed Imagery	Aerial Imagery	ESRI ArcMap Basemap sourced from: ESRI, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community (2018)
Standard	Oregon Cities and Towns Data	Acquired from the Oregon Spatial Data Library
Standard	Oregon Hydrography Data, including Calapooia Watershed boundary	National Hydrography Dataset from the United States Geological Survey
Standard	Oregon Public Transit Roadways Data	Acquired from the Oregon Spatial Data Library
Archaeological	Previously Identified Mound Sites	SHPO site form location info

The DOGAMI LiDAR data came in sets that measured approximately 9 miles by 9 miles (the amount that the LiDAR dataset covers on the actual ground surface of the earth). I downloaded 19 LiDAR datasets and clipped them to the Calapooia Watershed boundary. I then excluded the eastern portion of the Calapooia Watershed as it is dominated by the Cascade Mountain Range where there are no known mound sites and no terrain suitable for mound site construction. The final area used for analysis was comprised of 9 LiDAR datasets (Figure 9). The LiDAR data had a linear spatial unit of a U.S. foot; I converted the linear spatial unit to a meter. This converted the LiDAR DEM into meters so as to match mound elevation heights.



Data Sources
Oregon/Washington BLM
National Hydrography Dataset
Oregon Department of Mineral Industries

Figure 9. Calapooia Watershed LiDAR datasets analyzed for this project.

I used the data I had on known mounds to build and inform the initial model; the previously identified mound site locations are used to teach the model what a mound looks like (Freeland et al. 2016:66-67; Hanus and Evans 2015:91). I told the model where to look for known mounds and to use the characteristics of those mounds to identify other mounds. Once the model was initially run, I used the dimensions the model derived for these previously identified mound sites to further filter the model as I carried out subsequent geospatial analysis described in the following sections. To teach the model I acquired *previously identified mound site* information from the Oregon SHPO database by examining the location information from recorded mound site forms. I digitized and uploaded the sites (N=5) that had Universal Transverse Mercator (UTM) easting and northing data into ArcMap. Locations for the remaining 15 sites that did not have UTM locations were digitized by examining their location on the Oregon SHPO's online database map and then converting those locations into UTM coordinates using an online program (Nathansen 2017). As a result, some of the *previously identified mound site* locations are an approximation of their actual location.

During the initial stages of modeling, I found that a slope layer was a useful tool for visually identifying sites as Chase et al. (2011) mentioned in their visual analysis (see discussion of this method in Chapter 2). A slope layer is derived from a LiDAR DEM, and calculates the steepness compared to each surrounding cell within the DEM raster dataset (a dataset in which each cell contains information). The initial goal of using the slope layer was to identify a range of slope values that were associated with *previously identified mound sites* and then query the slope layer (querying allows for selection of a subset of features or attributes within data) for these values in a given area. However, the slope layer is difficult to query due to the number of unique values in the dataset. This method of mound identification required several complicated steps, including reclassifying (grouping like values into subcategories or "classes") the slope dataset into three unique classes and then converting the reclassified values into a vector dataset (comprised of measurable points, lines, and polygons). From here, the dimensions of each newly created polygon could be calculated and then queried using known mound dimensions. The resulting model was only 40 percent successful in identifying known mounds. This process has the potential to be refined, for instance, by adjusting the mound area query and finer resolution slope attributes. However, this particular slope layer method was complex and inefficient. I abandoned this approach as it was not viable.

I also experimented with the use of remotely sensed satellite imagery to identify vegetation differences and therefore mounds, using National Agricultural Imagery Program (NAIP) imagery. Vegetation grows differentially on archaeological sites, especially those that contain foreign organic material such as human or animal remains (Giardino 2011:2008; Grɵn 2011:2025). This differential vegetation growth can be detected in remotely sensed satellite imagery. I found, however, that this method did not provide consistent enough mound identification results to be useful in the model, as only a fraction of *previously identified mound sites* were identified, while others were virtually invisible. The efficacy of satellite and infrared imagery (a subset of satellite imagery) may be improved through the analysis of an aggregation of satellite imagery over the years, which could allow for the identification of differential vegetation growth on mound sites across time. However, I determined that this method was inefficient and unreliable for initial mound identification and might only prove useful as a supplementary dataset for future mound analysis.

Next, I attempted a method that involved inverting the LiDAR dataset and then applying hydrological GIS methods to the inverted dataset. Then, I utilized zonal statistics on the LiDAR DEM and the LiDAR derived slope layer. All of this was conducted in the program ArcMap 10.5.1. This method was the most successful and efficient method of mound identification, for both new and previously recorded mounds. This approach was inspired by similar successful methods used by Freeland et al. (2016), who developed an iMound algorithm that inverted the landscape and then identified mounds using a hydrological pit-filling algorithm developed by researchers Wang and Liu (2006). Their method had an 85 percent positive identification rate when examining mound sites in the Kingdom of Tonga. At Greater Angkor in Cambodia, archaeological researchers also successfully identified household ponds by manipulating the 'Fill' tool in ArcMap. Rather than use the tool's intended function of filling pits/ponds, they manipulated the tool so that it would *identify* and *mark* ponds (Hanus and Evans 2015:91).

In my model there are two stages to this method. The first is the mound identification process and the second is the mound extraction process. For this method I used the one-meter spatial resolution LiDAR DEM acquired from DOGAMI. The first stage involves filtering the LiDAR DEM. Although a one-meter spatial resolution dataset is fine-grained enough to identify mounds, it has so much detail it also identifies a fair amount of extraneous non-mound data points, or "noise". To address this excess of data, I used the ArcMap 'Filter' tool, which smooths the data and/or enables the enhancement of features that might have been missed originally (Arcgis.com 2016a). I used the 'Low

Pass Filter' as it smooths the dataset by "reducing local variation and noise," both of which are issues when analyzing one-meter spatial resolution LiDAR data, as mentioned above (Arcgis.com 2016a). The local variation and noise in the LiDAR data is caused by the fact that a one-meter spatial resolution dataset is created from a very large number of points (since a LiDAR DEM is initially derived from a point cloud) some of which are anomalous. The sheer amount of detail within a one-meter LiDAR DEM exceeds the needs of this project, so the extraneous LiDAR must be smoothed away so as to highlight broader differences (in this case the mounds). I applied the 'Low Pass Filter' to the dataset several times, between four or five times initially, thusly removing some extraneous elevation points.

The second step in the process of mound identification was to invert my LiDAR DEM. The inversion effectively causes the Kalapuyan mound sites to act as sinks, which can retain digital water, as mentioned by Freeland et al. (2016). Sinks are defined as areas for which the direction of waterflow from that area cannot be identified, or as areas of "internal drainage" (Arcgis.com 2016b). Since these sinks effectively trap digital water they can allow for their identification in ArcMap. To identify the mound "sinks" using the inverted LiDAR DEM, it was necessary to apply the 'Flow Direction' tool to the dataset. The 'Flow Direction' tool assesses the direction that water would flow from each cell in the DEM raster dataset to its "steepest downslope neighbor" (Arcgis.com 2016c).

The third step toward mound identification was to apply the 'Sink' tool, which identified the sinks created by the application of the 'Flow Direction' tool to the dataset. The 'Sink' tool extracted the areas of "internal drainage," all of which are potential mound sites as defined by this methodology (Arcgis.com 2016b). As shown in Figure 10, this process identifies over 20,000 “potential mound sites” in one LiDAR grid (covering roughly 81 square miles) far more than would be expected to exist, which shows that there is still a large amount of extraneous data to sort through; however, even during this initial stage, the methodology was successful in identifying *previously identified mounds*. It should be noted however, that the “Sink” tool does not necessarily identify the entirety of the mound on the ground, it often identifies the top most portion of the mound as can be shown in Figure 10. This has implications for the model further into the process.

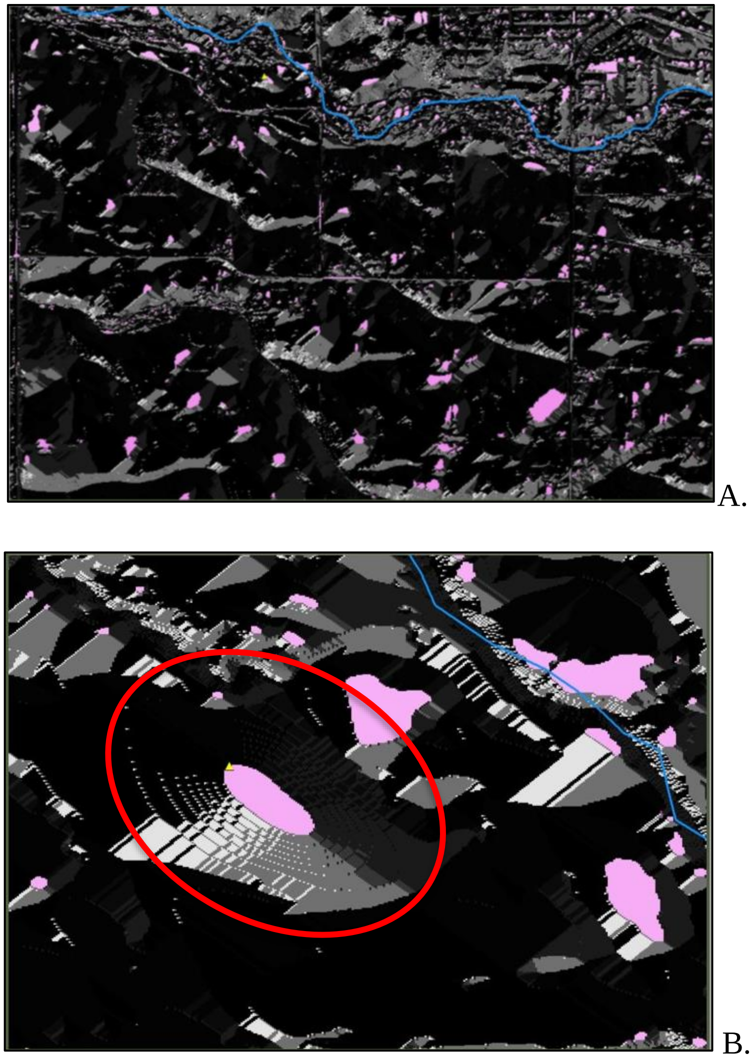


Figure 10. A. The results of the 'Flow Direction' and 'Sink' Tools (pink indicates a possible mound site); B. The identification of a *previously identified mound site* using the ‘Flow Direction’ and ‘Sink’ Tools (red circle denotes mound).

Although the first stage of my model development, described above, was successful in identifying previously known mound sites, it produced far too many potential mound sites to be useful. Therefore, a second stage was necessary to further reduce the number of potential mound sites. The second stage of my model involved the extraction of mound sites from the ‘Flow Direction’ and ‘Sink’ tool outputs. First, I converted the results of the ‘Flow Direction’ and ‘Sink’ tools from a raster dataset to a vector dataset. By converting the potential mound sites into a vector data model, I was able to create a polygon for each potential mound site. For this second stage I first experimented with identifying mounds by using a perimeter/area ratio or a shape index. A perimeter ratio or a shape index is used to represent "the degree to which a shape is compact", and the more compact a shape is the higher that shapes accessibility to all of its parts, e.g., how much area is actually exposed to the edges of the shape (Wenwen et al. 2013:1227-1228; Helzer and Jelinski 1999). Therefore, shapes that are more ovoid or circular (more compact, e.g., mounds) and will have smaller perimeter to area ratio/will be more compact, those shapes/model-identified mound sites that have more variable perimeters (e.g., more blob like) or are highly elongated will have higher perimeter to area ratios/will be less compact (Helzer and Jelinski 1999:1449). A perfectly circular shape will have the lowest perimeter to area ratio (Helzer and Jelinski 1999:1450). To perform a perimeter to area ratio on the mound sites I first calculated the area as well as the perimeter of each of the polygons created. I then divided the perimeter calculations of each polygon by the area calculation of each polygon. Upon creating the perimeter to area ratios of each polygon I noted that there was no consistent indicator of compactness for any of the *previously identified mound sites* versus any other identified polygon in the model. Therefore, I determined that the perimeter to area ratio was not an adequate method of extracting mound sites.

The next method I tried, and the one that was the most successful was to extract the model-identified potential mound sites by area, which then served as a starting point for further statistical analysis. To do this, I examined the area values for each previously identified mound that was identified in the first stage; then, I queried those values. The area values of the previously identified mounds ranged from 22 square meters to 825 square meters. This query reduced the number of potential mound sites in one LiDAR grid by roughly 55 percent as it eliminated those areas that I considered too big or too small to be mound sites (Figure 11).

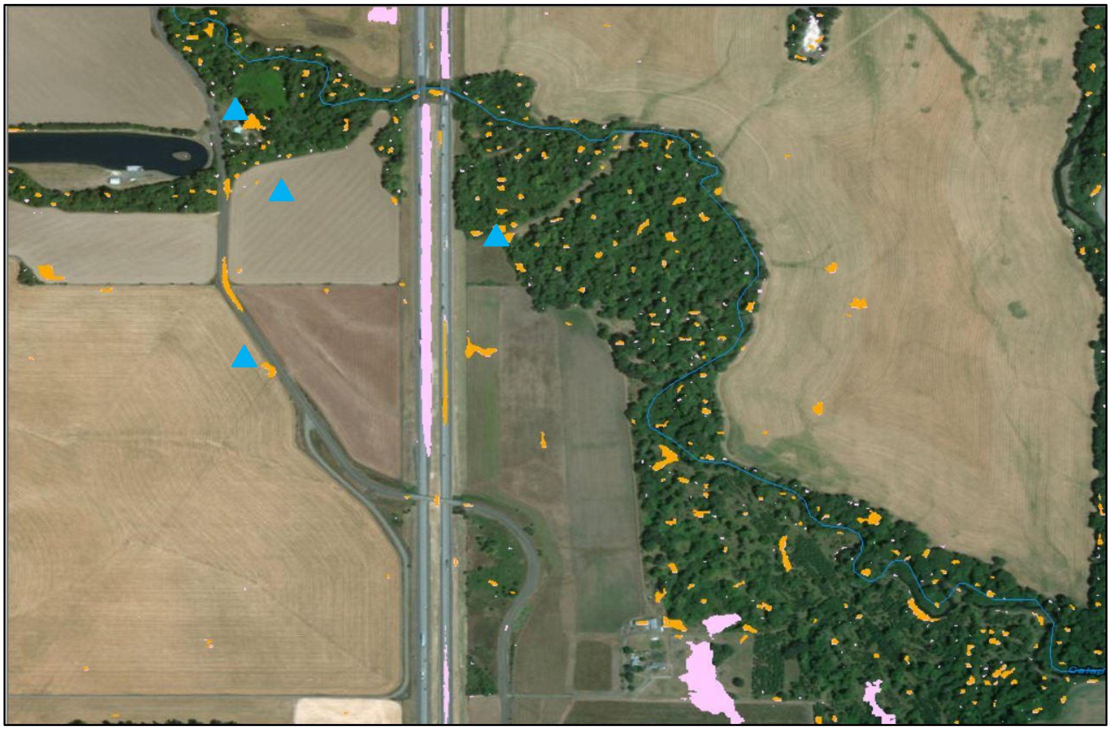


Figure 11. Area extraction (orange) polygons versus sink identification (pink) shown for comparison. Blue triangles indicate the location of a previously identified mound.

The second step was to perform a slope extraction. To do this I uploaded a slope layer (produced from the LiDAR DEM using the ArcMap ‘Slope’ Tool) and then, using the ‘Zonal Statistics’ Tool, I extracted a range of statistics for the slope of each potential mound site. The ‘Zonal Statistics’ tool calculates a range of statistics for a raster dataset (in this case, the slope dataset), based on the parameters set by another dataset (potential mound sites vector data model) (Arcgis.com 2016d). For the slope extraction, I chose to use the mean statistic because this gave me the average slope of each previously identified mound. The mean slopes from *previously identified mound sites* ranged from roughly 1.5° to 9.57°. I then queried all the mean slopes for each potential mound site vector that fell within the above range; this query reduced the number of potential mounds sites by roughly another 14 percent (Figure 12).

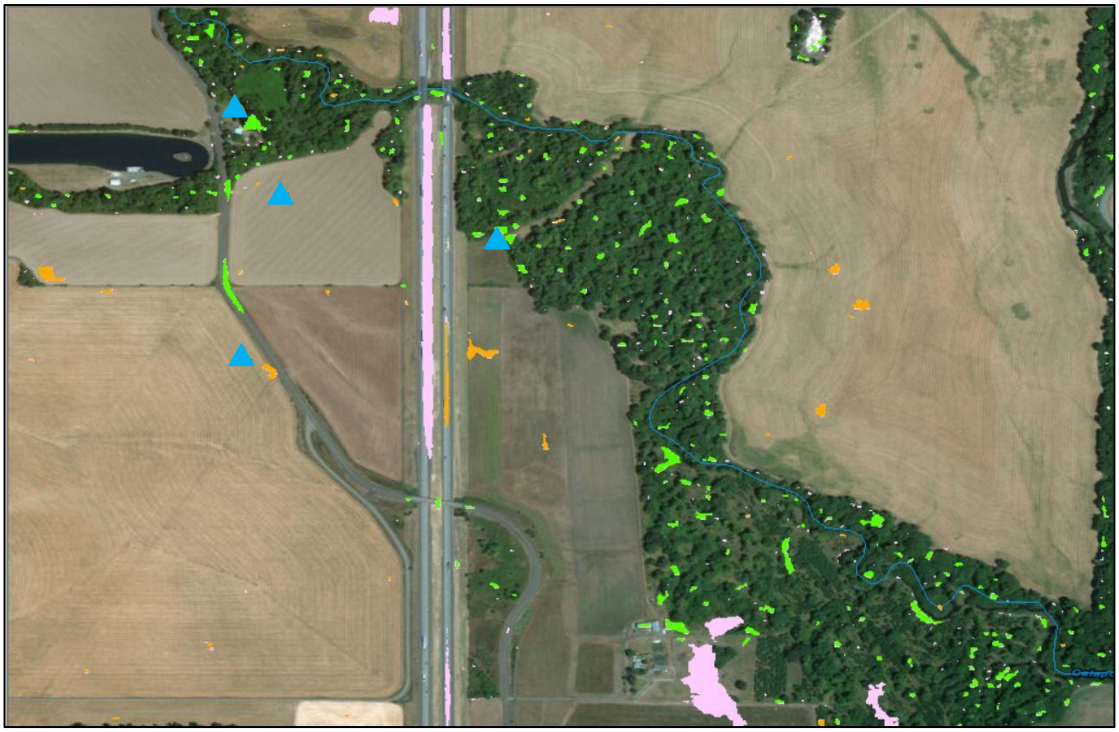


Figure 12. Slope extraction (green) polygons versus area extraction (orange) and sink identification (pink) shown for comparison. Blue triangles indicate the location of a previously identified mound.

The final step was to perform an elevation extraction. To do this I used the 'Zonal Statistics' tool in the same manner as described for the slope extraction except on the LiDAR DEM. For this extraction, however, I chose to use the statistical range of elevation values for each *previously identified mound site* vector, as this would provide me with the heights of each mound within the defined mound polygon/zone. The height values in this output do not necessarily indicate the true height of the mound, as it only identifies the height within the defined zone, which in some cases does not cover the entire possible mound, only the top-most portion of the mound as defined by the "Sink" tool. The heights of each previously identified mound within each mound polygon/zone fell within a range of 0.155 meters to .720 meters. I queried all the elevation ranges that fell within the above parameters for each potential mound site vector; this query reduced the number of potential mound sites by roughly another 4 percent (Figure 13). The result of 0.155 meters for the height of a mound seemed relatively unusual, however it was retained in the analysis as it was thought to represent those potential mound sites that might have been affected by plowing or erosional forces.

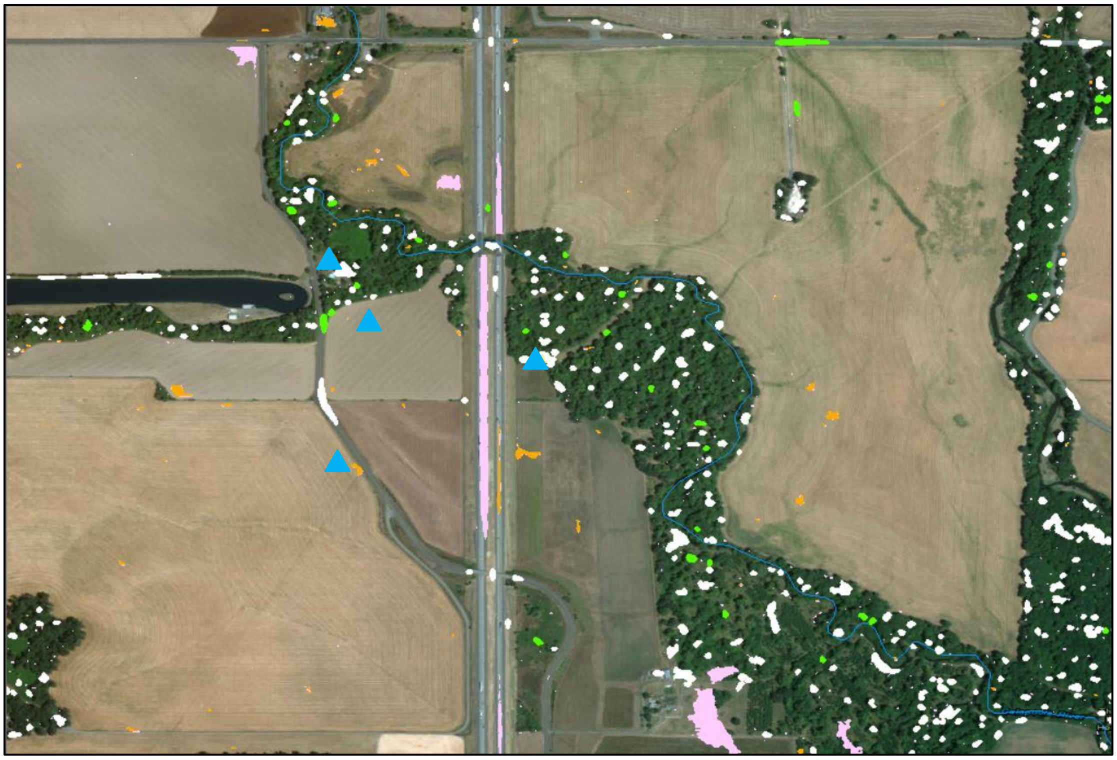


Figure 13. Elevation extraction (white) polygons versus slope (green) and area (orange) extraction, as well as sink identification (pink) shown for comparison. Blue triangles indicate the location of a previously identified mound.

After completing the above extractions, there were still extraneous potential mound site locations in the dataset primarily in roads, cities, and towns. For example, several model-identified mound sites, when examined in aerial photography, were in fact portions of roads or houses in one of the many towns in the watershed. To address this issue, I first uploaded an Oregon towns and cities dataset into ArcMap. Once uploaded, I digitized in the town of Shedd, Oregon based off of aerial imagery as the original dataset did not have this location and it was clear that the model was identifying erroneous potential mound sites within the town boundaries. In addition, I adjusted the western boundaries of both the cities of Albany and Tangent, Oregon as the city boundaries extended into “open space” that I considered to have potential for a mound site. To accomplish this, I used the “Edit Vertices” tool in the editing tool bar to shift the boundaries of the towns to a place I deemed a suitable distance from the “open spaces”. After these minor alterations, I queried the model-identified mound sites that ‘intersected’ with the boundaries of towns and cities. I chose the ‘intersect’ query option because it includes all those areas that overlap the boundary of a city or town at any point in its geometry, which allowed me to account for those misidentified potential sites that might not be located completely within the boundary of a city or town. After querying for those potential mound sites that intersected the cities and towns, I removed those polygons that were highlighted by the program.

After the city and town query, I uploaded the Oregon Public Transit Roadways lines dataset and clipped the roadways dataset to the Calapooia Watershed boundary so as to focus my roads query to my study area. From here, I separated out the I-5 highway, minor highways/arterials, and then all other roads. I subdivided the roadways dataset because road dimensions vary depending on the road type. After the roadway subdivision, I placed a 17-meter buffer around the lines for I-5, a 15-meter buffer around the lines for minor highways/arterials, and then a 14-meter buffer around the lines for all other roads (see Table 4 for the math used to create each buffer). All buffers were rounded up to the next highest integer. After each buffer was created, I merged all of these separate buffers into one layer and then performed another ‘intersect’ query. I then removed all those potential mound sites that were identified as intersecting a roadway.

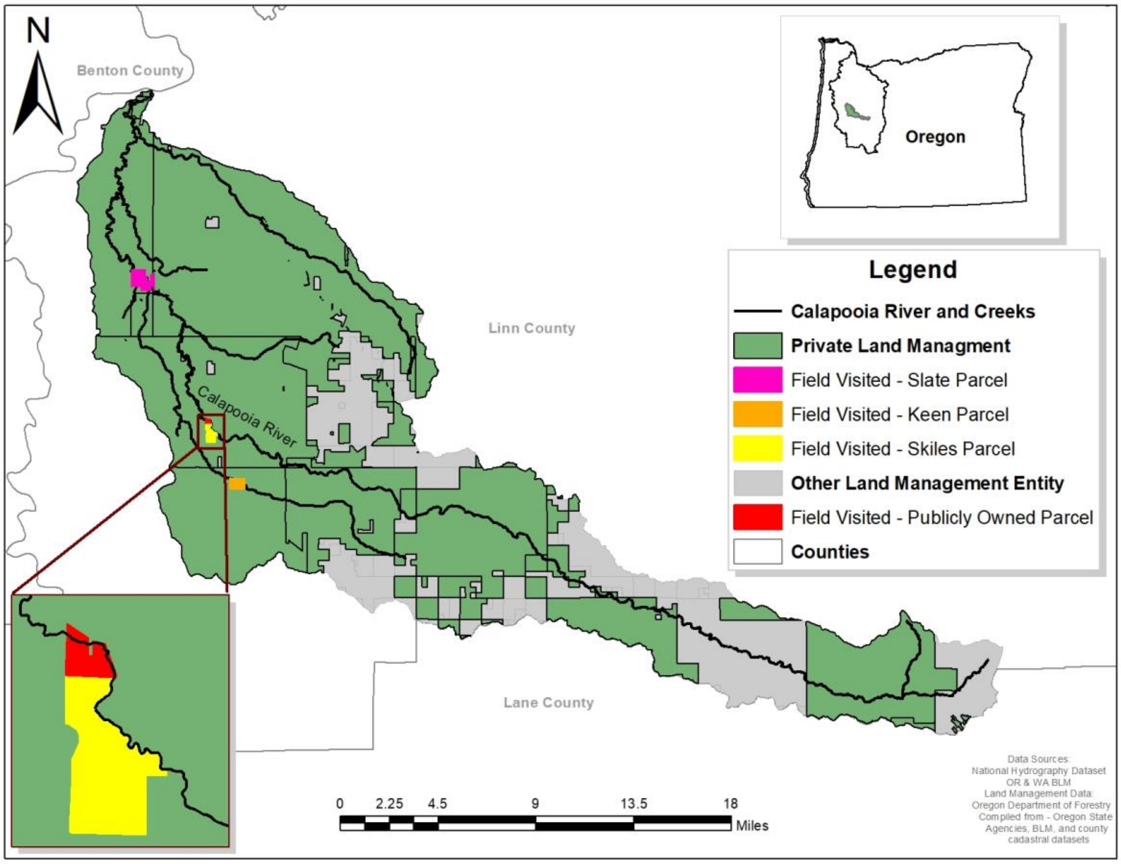
Table 4. Roadway dimensions used in the "roadway buffer" application. *

Road Type	**Lane Width**	**Total Roadway Width (each direction)**	**Inside Shoulder Width**	**Outside Shoulder Width**	**Road Right-of-Way Buffer**	**Total Buffer Width Before Rounding Up**
Highway	3.7 meters	7.4 meters	1.2 meters	3.0 meters	5.0 meters (2.5 meters either side)	16.6 meters
Minor Highway /Arterial	3.4 meters	6.8 meters	1.2 meters	1.2 meters	5.0 meters (2.5 meters either side)	14.2 meters
All Other Roads	3.1 meters	6.2 meters	1.2 meters	1.2 meters	5.0 meters (2.5 meters either side)	13.6 meters

* All roadway widths were acquired from Federal Highway Administration (FHWA 2014)

Field Survey Methods

After building and running the model in GIS, my goal was to visit multiple potential mound sites identified by my model in order to assess its efficacy. Probable mounds were those mounds whose structure in the “Sink” identification dataset matched or was similar to a *previously identified mound* site shown in Figure 10 or the area appeared mounded in aerial imagery. Ideally, survey areas would be randomly chosen using a simple random or stratified random sampling strategy. However, easily accessible publicly-owned land in the watershed is limited, and most of the federally-owned land is in the Cascades, which was excluded from my study (Figure 14). The limited amount of public land made the use of a simple random or stratified random sampling strategy practically impossible. I identified 56 probable mounds that appeared similar to a known mound (Figure 10) in the model or aerial imagery, and then judgmentally selected survey areas based on the presence of probable mounds and my ability to access the property.



Data Sources:
National Hydrography Dataset
OR & WA BLM
Land Management Data:
Oregon Department of Forestry
Compiled from - Oregon State
Agencies, BLM, and county
cadastral datasets

Figure 14. Land management zones and field visited parcels in the Calapooia Watershed.

There was a single public land parcel that had a probable mound and was also accessible to me. Permission to access private land was challenging. I contacted landowners that had probable mounds on their property, and who also were known to be more favorable to archaeological investigation (USDA-NRCS personal communication 2018). I contacted a total of 17 landowners in the Calapooia Watershed via a written letter (Appendix) mailed on April 9th, 2018; I identified landowners names and addresses through the Linn Counties Tax Lot database (Linn County Maps 2013). I requested permission to access their property and to perform a field survey of potential mound sites.

Seven of these landowners did not grant access, seven landowners did not respond, and three landowners granted permission (Jerry and Cherry Skiles, Mrs. Pat Keen, and Mr. Mack Slate). I visited the three properties where permission for access and fieldwork was granted.

I undertook reconnaissance, rather than systematic, survey on the public and private land parcels to which I had access. Systematic survey was not possible due to time and budgetary constraints, and also because field conditions were challenging; localized flooding restricted land access. Properties could not be systematically surveyed and we could not visit all of the probable mound locations on each property due to field conditions. Our reconnaissance survey consisted of walking directly to probable mound locations. We also visited several landowner identified sites that were not identified as probable mounds.

In the field my crew and I determined which of the model-identified potential mounds sites were mounded or not by visually assessing if a model-identified potential mound site was higher than the local elevation. If there was dense vegetation, we tried to work our way as far into the vegetation as possible to get a sense of whether or not the ground was sloping generally upward. Once we had determined if the model-identified potential mound point was in fact mounded, we determined whether or not the model-identified potential mound point was cultural or natural. Cultural sites were those that had some sort of cultural material found in association, either historic or pre-contact in nature. Natural sites were mounds without identifiable cultural material. Finally, my crew and I determined which of the cultural model-identified mound sites were Kalapuyan. To do this we visually examined the mound for darker soils, FCR, lithic material, and possibly human remains; prior research has established that all of these materials are indicative of mound sites. If the above cultural materials were found in association with a cultural mound, the mound was determined to be Indigenous/Kalapuyan in nature. If other cultural materials were present in or on a mounded area, such as Euro-American historic artifacts or refuse, the mound was determined cultural, but not an Indigenous/Kalapuyan mound.

Photographs and field notes were taken for all mounds. For mounds located on public land a GPS point was recorded using the Google Maps App for an IOS Apple Phone. On private land, a GPS point and/or polygon of each mound was recorded using a hand-held Trimble GEO7x unit. In addition, a GPS point and/or polygon data were recorded for non-mound, model identified locations. The length, width, and height of the field verified mound sites were determined in the lab using ArcMap 10.5.1 by analyzing the model as well as the data acquired in the field. Length and width were measured using the “Measure” tool in ArcMap by measuring the polygon drawn around the mound in the field or if the model identified the entire extent of the mound, the measurements were taken off of that. The heights of each field verified mound site were acquired by subtracting an average of the lowest points of the mound as determined by the LiDAR

DEM from an average of the highest points of the mound as determined by the LiDAR DEM.

Methods for the Assessment of Model Success

I used two metrics to assess the success, or efficacy, of my model. The first metric for model success was a comparison in GIS of the number of *previously identified mound sites* in the SHPO database to a model identified mound point. A previously identified mound was considered positively identified by the model if its actual location was within 20 meters or less of a model-identified mound point. A range of 20 meters was chosen as it was considered a conservative estimate of the degree of location error inherent in the previously identified mound data (see the Model Development subsection of this Chapter for details on location data).

The second metric for model success that I used was a comparison of the number of model-identified mound sites to the number that were field verified as cultural mounds. This metric for success will not be robust as originally desired given the minimal amount of land access acquired; only four properties were visited).

Chapter 4: Results

In this chapter I discuss the results of the model and the field survey.

Initial Model Results

After the identification and extraction methods were applied, including the removal of roads and cities, my model identified 4,053 potential mound sites for one LiDAR grid (Table 5). Although this is a high number of potential mound sites, one prominent factor should be kept in mind. Further filtering of the LiDAR DEM may reduce the amount of false positives identified, however the amount of filtering is variable as I don't want to "erase" any possible mounds because of over filtering. The number of potential mound sites will likely continue to drop with further filtering. I discuss this in more detail in the Discussion and Conclusion section of this thesis.

Table 5. Results of mound identification and extraction.

Method	Features Identified	Percent Decrease in Identified Features
Flow Direction & Sinks	15,346	---
Area Extraction	6,953	54.7%
Slope Extraction	4,836	68.5%
Elevation Extraction	4,356	71.6%
Road & City Extraction	4,053	73.6%

In several notable instances, the model identified modern "mounds", such as pitching mounds in baseball fields and septic systems (Ronald and Karen Litwiller personal communication 2018). Although these are not archaeological mounds, they serve as evidence that the model, in fact, identifies culturally mounded features.

Given that such a high number of potential mound sites were identified by the model, and in some cases, mounds identified by the model were modern cultural features, it was imperative to field test my model so as to determine which identified points are in fact mounds. Data collected during fieldwork can also be used to refine further iterations of my model to improve model output.

Field Survey Results

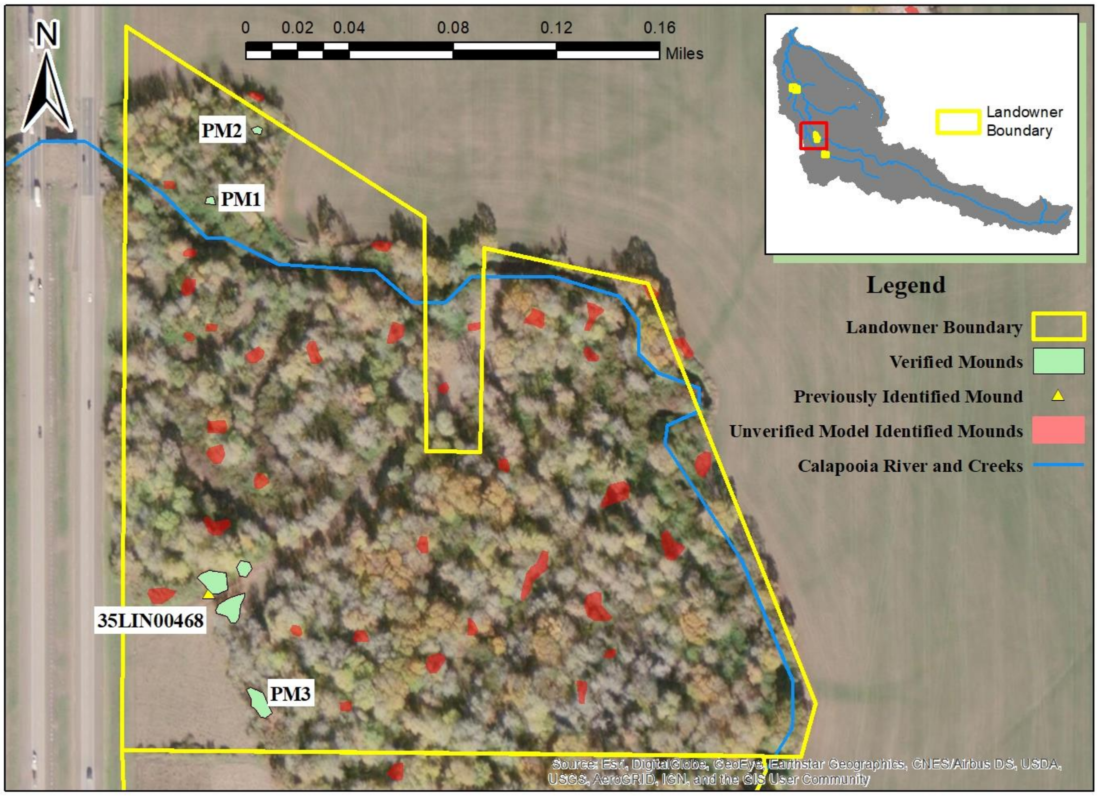
I visited one public land parcel and three privately owned parcels to further assess the accuracy of my model and to collect data on positively identified mounds. Of 25 potential mounds (PMs) visited, seven were field verified as Kalapuyan mounds (Table 6).

Table 6. Summary of field findings.

Potential Mound (PM)	**Is It Mounded**	**Is It Cultural**	**Kalapuyan Mound**
PM1	Yes	Unknown	Unknown
PM2	Yes	Yes	Yes
PM3	Yes	Yes	Yes
PM4	Yes	Yes	Yes
PM5	No	No	No
PM6	No	No	No
PM7	Yes	Yes	Yes
PM8	No	No	No
PM9	No	No	No
PM10	No	No	No
PM12	Yes	Unknown	Unknown
PM13	No	Yes	No
PM14	No	No	No
PM17	No	Yes	No
PM18	Yes	Yes	No
PM19	Yes	Yes	Yes
PM20	No	No	No
PM21	No	No	No
PM22	No	No	No
PM23	Yes	Yes	Yes
PM24	Yes	No	No
PM25	Yes	Yes	Yes

<u>Public Land Parcel:</u>

My crew and I were able to visit three model-model identified potential mounds sites (PM1, PM2, and PM3 [Table 6]) out of the 33 identified on a small parcel of publicly owned land in the project area (9 percent visited) (Figure 15).



Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Figure 15. Public land parcel boundary and mounds visited in the field.

I visited two mound sites on March 23rd, 2018, accompanied by one crew member (Patrick Reed). Given the size of the parcel, as well as the wet and water-logged conditions, Reed and I walked directly to the probable mound locations and performed a visual survey. We found that PM2 was partially destroyed; the remaining portion of PM2 was approximately 4 meters long by 2.5 meters wide by 1.4 meters high. Dense vegetation on site made accurate measurement of mound dimensions impossible. There was FCR, darker soils, and lithic materials (all indicative of mound sites [Table 2]) exposed on disturbed ground surface at the site (Figure 16). Part of the mound is currently being used as a berm made by the neighboring landowner to contain the Calapooia River, which explains the relatively small size of the remaining mound (Figure 17); apparently much was destroyed by berm construction/maintenance activities.

We could not reach PM1 on foot at the time of the field visit due to roughly two feet of standing water surrounding the site. It is unclear if the mound possessed cultural material but we were able to verify that it is a mound. The mound rose at least .5 meters above the standing water and was only minimally covered in vegetation.

On May 7th 2018, I revisited this same parcel of land with two field crew members (Patrick Reed and Shelby Anderson). We verified a third new mound site (PM3) and visited a previously recorded mound site (35LIN468) at the southern edge of this parcel. Table 7 summarizes the data collected at the field verified mounds.

Figure 16. Field verified mound site PM2 and associated artifacts. A) Pat Reed in front of a field verified mound (view to the east); B) A chert flake found adjacent to the mound site; C) Charcoal found adjacent to the mound site.

Figure 17. PM2: A. View to the south-southwest of the mound from the berm; B. View to the southeast of the berm from the mound.

Table 7. Summary of field verified and model identified mound data.

Potential Mound (PM)	Mound Size	Cultural Material Present	Darker Soils Present
PM2	4m L x 2.5m W x 1.4m H	FCR, lithic material (chert flakes)	Yes
PM3	~21.4m L x ~10m W x 30-50cm H	FCR, lithic material (flakes and core)	Yes
PM4	~20.9M L x ~16.2m W x 50cm H	FCR, lithic material (flakes), camas growing	Yes
PM7	~15.7m L x ~6.8m W	Lithic material (flakes, basalt core)	Unknown
PM19	42.1m L x 36.7m W x 2.4-3m H	Lithic material (chert shatter), FCR, faunal bone – Landowner has mentioned lots of cultural material and human remains	Yes
PM23	23.8m L x 22.3m W x 80cm H	Lithic material (projectile point, biface tip, flakes), FCR, faunal bone	Yes
PM25	31.8m L x 21.8M W x 30cm H	None visible – Landowner has mentioned lithics and human remains	Unknown

Skiles Property:

On May 7th, 2018, two field crew members (Patrick Reed and Dr. Shelby Anderson) and I visited the Skiles parcel of private property to assess both *previously identified mound sites* and the potential mound sites located on that land (Figure 18). On the Skiles property eight model-identified potential mound sites out of 85 were visited (9 percent visited).

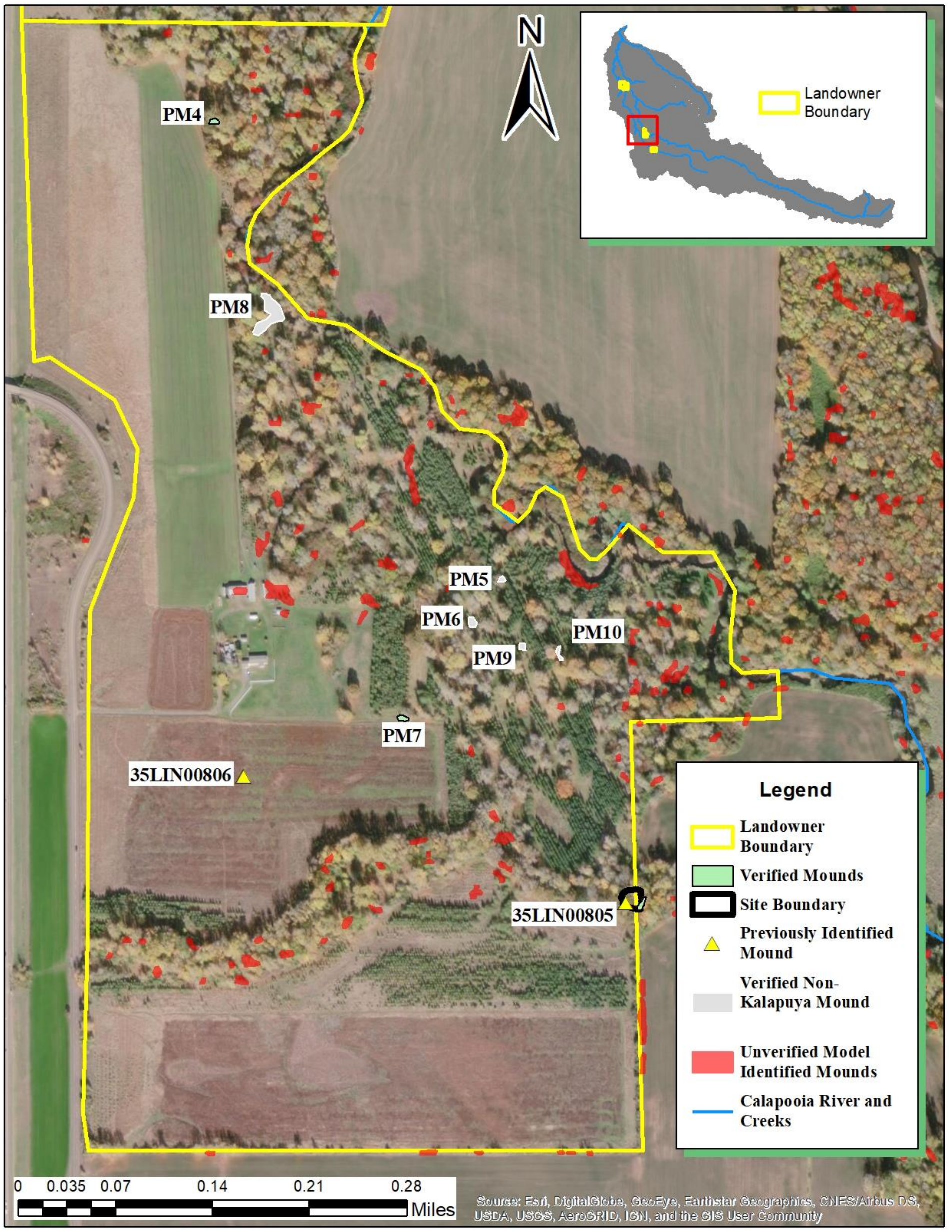


Figure 18. Skiles parcel and mounds visited in the field.

We visited seven model-identified potential mound sites. We verified two new mound sites (PM4, PM7), noting darker soils, lithic material (including an obsidian projectile point [Figure 19], a basalt core, flakes, etc.), and an abundance of FCR in the vicinity of the mound sites (Table 7). Camas was growing next to several of the mounds.

Figure 19. Obsidian projectile point identified at PM4, a field verified mound site.

Of the remaining five model-identified potential mound sites that were visited, two were non-cultural mounds (PM5 and PM6). One was a heavily sedimented pile of wood likely piled by the landowners (PM6) (Table 6). The pile was small and extremely low lying, so its identification as a potential mound site might be the result of too much remaining "noise" in the model. The three other potential mound sites ended up being false positives as they were either just very small natural rises or blackberry bushes. We also attempted to relocate two previously recorded sites (35LIN805 and 35LIN806) recorded on the property. We were able to relocate 35LIN805 and take photos and collect GPS information. According to Mr. J. Skiles the site was excavated by previous owners in the 1940s to obtain organic-rich soil for farming activities (Jerry Skiles personal communication 2018). We could not relocate 35LIN806; Mr. J. Skiles told us that the site was deflated due to plowing activities but showed the crew a pestle found in the area of the former mound (Jerry Skiles personal communication 2018 [Figure 20]).

Figure 20. Pestle found at deflated mound site 35LIN806.

Keen Property:

On August 8th, 2018, crew member (Katherine Tipton) and I visited the Keen property. We visited five out of five model-identified potential mound sites (PM12 – PM14, PM17, PM18) (100 percent visited) (Table 6

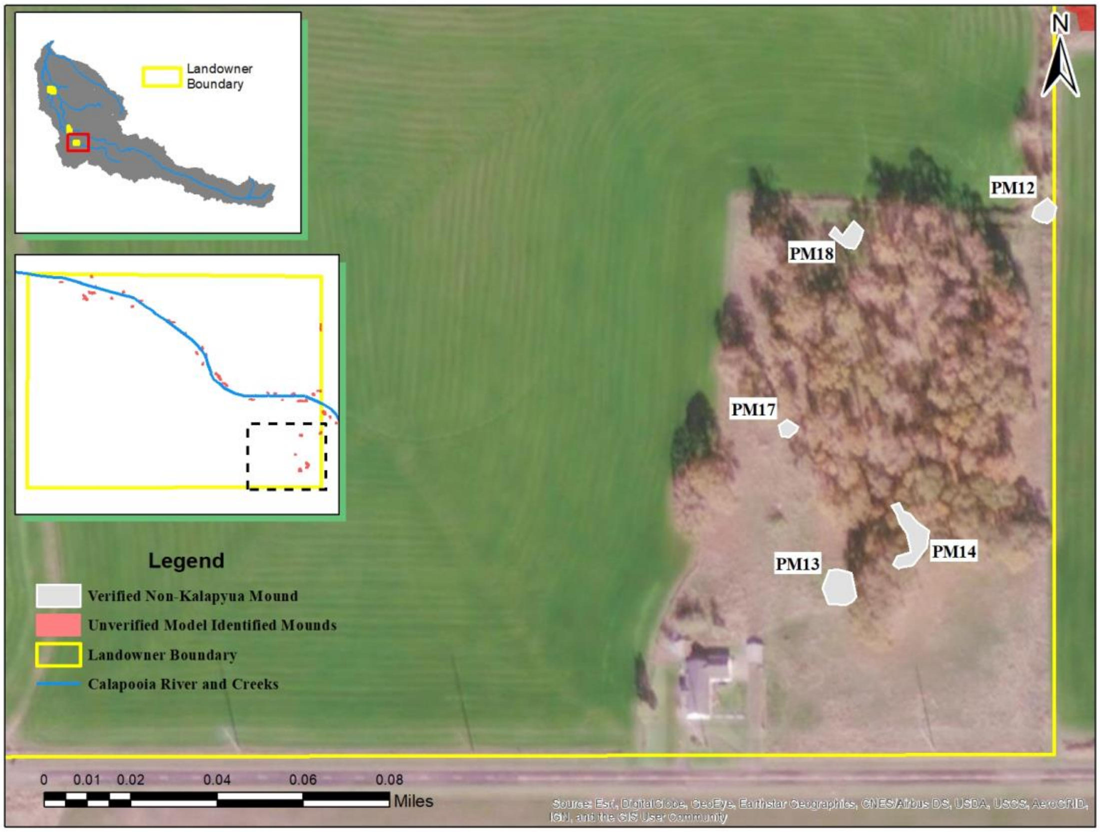
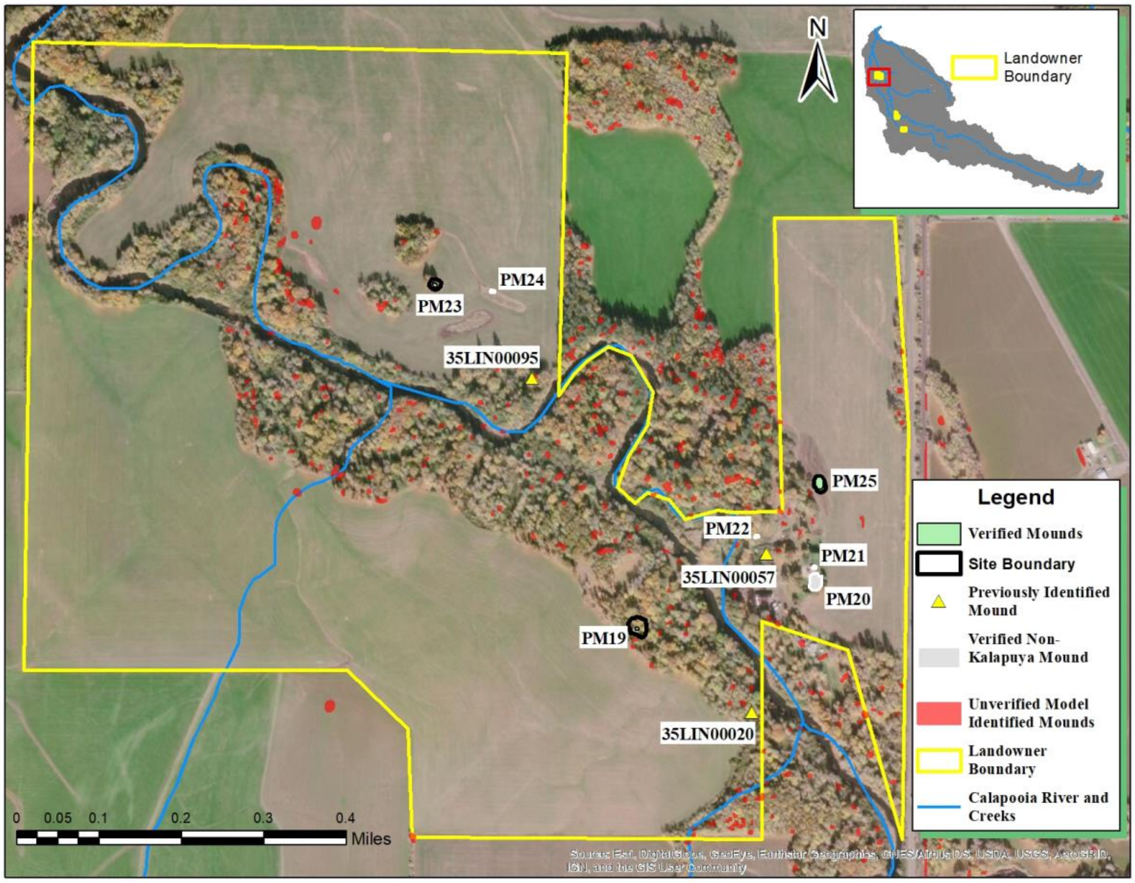


Figure 21. Keen parcel and mounds visited in the field.

None of these model-identified points were Kalapuyan mounds. PM14 was neither a mound nor cultural and is a false positive. PM12 was mounded, however it could not be determined to be cultural or not due to heavy blackberry growth. PM13 was a historic concrete foundation with associated concrete pilings and a trash pile. PM17 was a historic trash pile. PM18 was a slight mound created by historic burning activities.

<u>Slate Property:</u>

Tipton and I visited a second privately-owned parcel on August 8th, 2018 and field verified three model-identified mound sites and three previously recorded mounds (35LIN20, 35LIN57, 35LIN95). On the Slate property eight out of 178 model-identified potential mound sites were visited (4.5 percent visited).



Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Figure 22. Slate parcel and mounds visited in the field.

Mr. Slate and his son-in-law accompanied Tipton and I to each potential mound location. PM19 was large and resembled 35LIN805 (a *previously identified mound site* on the Skiles Property) in size and shape (Figure 23 and 24). We noted dark silty loam/silty clay loam soils much like Laughlin (1941:149) described during his mound excavations. There was a large amount of FCR on the surface of the PM19 mound (Figure 25). We did not identify any other cultural material but Mr. Slate mentioned that he had found lithics at the mound in the past (Mack Slate personal communication 2018). Mr. Slate also informed us that Linn-Benton Community College visited this mound twice and put in two excavation units, one of which contained the complete lower half of a human individual. The Linn-Benton community College excavations were unpermitted (unbeknownst to the landowner) and they never finished their excavations; the disposition of the collections is unknown although they did collect the human remains.

Figure 23. Slate property mound (PM19). Author standing midway up the mound. View to the Southeast.

Figure 24. PM19 located on the Slate property. Author standing at the top of the mound. View to the Southeast.


Figure 25. FCR at PM19 on the Slate property.

PM23 and PM25 were both in agricultural fields. Mr. Slate has protected PM23 by plowing around it and maintaining a circle of three mature trees around the mound (Figure 26). The Slate family has known about PM23 for 90+ years, since Mr. Slate was a child, and the site has yielded lithics throughout the years (Mack Slate personal communication 2018). The mound was comprised of darker soils than the surrounding area. We noted an abundance of chert, obsidian, and basalt flakes at the site, as well as FCR, the tip of an obsidian biface, and an almost complete obsidian projectile point (Figure 27).

Figure 26. PM23 mound currently protected by Mr. Slate. View to the East.

Figure 27. Obsidian projectile point found at PM23 on the Slate property.

PM25 has been plowed for roughly 90 years and is now only a slight undulation in the terrain (Mack Slate personal communication 2018). We did not identify any cultural material on the surface when visiting the site. Mr. Slate informed us that the mound has yielded cultural material for decades now and at one point in time plowing activity disturbed a portion of a human occipital bone from a depth of approximately 8 – 10 inches (Mack Slate personal communication 2018). Since then no other human remains have been identified at the site.

We visited four other model-identified potential mound sites on the Slate property (PM20 – PM22, PM24) and the recorded location of three *previously identified mound sites*. None of the four model-identified potential mound sites were cultural mounds. Some of the areas identified were buildings on the property or equipment piles. Of the three *previously identified mound sites*, we could not find 35LIN57, due to the poor location information and the fact that it appears to have been rather close to the Slate residence and is most likely destroyed. We were unable to determine if 35LIN20 or 35LIN95 were still extant due to poor location information, the difficulty of accessing these locations (they are heavily overgrown), and time constraints. I chose to focus on documenting the landowner-reported sites that were also identified by the model.

In the next chapter, I further discuss the results of modelling and field work, as well as the efficacy of the model.

Model Efficacy Assessment

To assess the efficacy of my model I conducted additional analysis in GIS and then included the outcome of fieldwork in my interpretation of those results. Out of the

20 *previously identified mound* sites incorporated into my model, four mounds were directly identified by the model (20 percent of the previously identified mounds), four mounds were 20 meters away from a model-identified potential mound site (20 percent), and 12 previously identified mounds were not identified by the model as a potential mound site (80 percent). When examining direct identification, the model is only 20 percent successful. However, the majority of previously recorded mound sites were recorded in the 1970s or early 1980s (N = 15), when locational data for archaeological sites was far less accurate than it is today with use of modern GPS technology. I approximated the location of these sites, with a possible location error of up to 20 meters (as described in the Chapter 3). When considering that four *previously identified mound sites* were within 20 meters of a model-identified mound site, the accuracy of my model increases to 40 percent. One of the 12 *previously identified mounds sites* that was not a model-identified mound site was recorded in the middle of the farm and housing complex on the Slate property (35LIN57); field work verified that this site was destroyed, likely because of farm activities. Another *previously identified mound site* was noted as destroyed/deflated (35LIN806) upon its initial recording and therefore it is not surprising that the model did not identify it. If these two non-extant mounds are disregarded, the accuracy of my model increases to 44 percent. Of the remaining 10 *previously identified mound sites* that were not identified by the model, all of them except (35LIN61, which was outside the model study area) are in active agricultural fields. It is possible that these sites were plowed out of existence since the time of initial recording; the model could not identify these mounds as they likely no longer exist. If these 10 probable non-extant

previously identified mound sites removed from the accuracy rating, my model identifies extant *previously identified mound sites* within 20 meters of a model-identified potential mound site with 100 percent accuracy.

Chapter 5: Discussion and Conclusion

This chapter includes a discussion of the results of modeling and fieldwork, and a consideration of the broader implications of my findings for future modeling efforts and for research on the Willamette Valley mounds.

Can Modeling Identify Mounds in the Calapooia Watershed?

My primary goal for this project was to determine if a LiDAR model could identify where the mounds were located in the Calapooia Watershed. Knowing where the mounds are creates a foundation for any future mound investigation as well as future and current preservation efforts by the Confederated Tribes of Grande Ronde, other Indigenous communities, and archaeologists. The results of my fieldwork and analysis indicate that modeling can identify cultural mounds in the Calapooia watershed. My model was 44 percent successful in identifying cultural mounds; if some *previously identified mound sites* no longer exist due to farming and development activities, then my model was 100 percent successful in identifying extant, *previously identified mound sites*. I also succeeded in locating seven new mound sites through both lab and field work. However, additional work is needed to address some of the problems I encountered over the course of my project and improve the efficacy of the model and its applicability to historic preservation issues in the Willamette Valley.

Although the model successfully located previously identified mounds as well as new mounds, at least in the areas where field assessment occurred, there are a fair number of false positives that remain, given that the model identified 4,053 probable mounds in one LiDAR grid alone (9 mile by 9-mile area). This is likely due to the model falsely identifying localities of intense low-lying vegetation as potential mound sites; the riverine areas of the Calapooia watershed are typified by dense vegetation (see further discussion in the next section). LiDAR is an excellent tool for digitally clearing away vegetation, although there can be some issues with extremely dense low-lying vegetation, such as blackberries. This dense low-lying vegetation can return a majority of the LiDAR pulses before the pulses actually hit the ground surface, which can effectively create a false ground surface (Bater and Coops 2009; Gould et al. 2013; Hodgson et al. 2005).

The model also sometimes identifies anthropogenic features that are not Kalapuya mound sites, such as historic foundations, trash piles, etc. This must be kept in mind when visually analyzing the model as well as when field crews are field testing the model. Even with this limitation in mind, the model's ability to quickly identify probable mound locations will facilitate planning and carrying out future fieldwork in a more informed and directed manner. And, there is the unanticipated potential of identifying historical sites that can be obscured and artificially mounded by vegetation overgrowth.

An additional consideration is that I utilized existing information about mounds to initially create and filter. If further fieldwork yields different dimensions and other spatial characteristics for mounds, the model should be adjusted; this is a standard part of the iterative modeling process (*sensu* Freeland et al. 2016:66-67; Hanus and Evans 2015:91).

What Patterns and Potential Human Behaviors are Associated with the Mounds?

In exploratory analysis of the model output, a clear pattern arose in terms of site location. Many of the model-identified possible mound locations were located in the vicinity of the waterways in the Calapooia Watershed. The average distance of the mounds from the Calapooia River and other major tributaries is 240 meters (this narrows to 70 meters as one moves east in the watershed), while the average distance of the mounds from smaller rivers and tributaries is 100 meters. Roughly 39 percent of all model-identified points fall within these distances from modern waterways. A majority of other model-identified potential mound sites fall along minor tributaries. All of the field-verified mounds are located in a riverine environment, including along old oxbows of the Calapooia River being a dominant geographical feature (Figure 28). This patterning was also noted in prior fieldwork, as Miller (1970) also noticed that all previously recorded mounds were along waterways. However, he also noted that survey was biased to identify resources in waterways and called for future field work to be conducted in non-waterway adjacent areas. Additionally, river corridors are typically heavily wooded, as can be seen in aerial imagery of the area (see Figures 15, 18, 21, and 22 for examples), and thus provide protection from agricultural activity. This is due to the fact that agricultural activities, such as plowing, could destroy a low-lying mound over time. Few potential mound sites were identified in active agricultural fields, although there are some. While these initial results suggest that locations along waterways is culturally meaningful (see discussion below) additional further field research that includes investigation of areas both inside and outside of river corridors is needed to further evaluate this apparent pattern in mound distribution before coming to any conclusions about mound formation and use based on location.

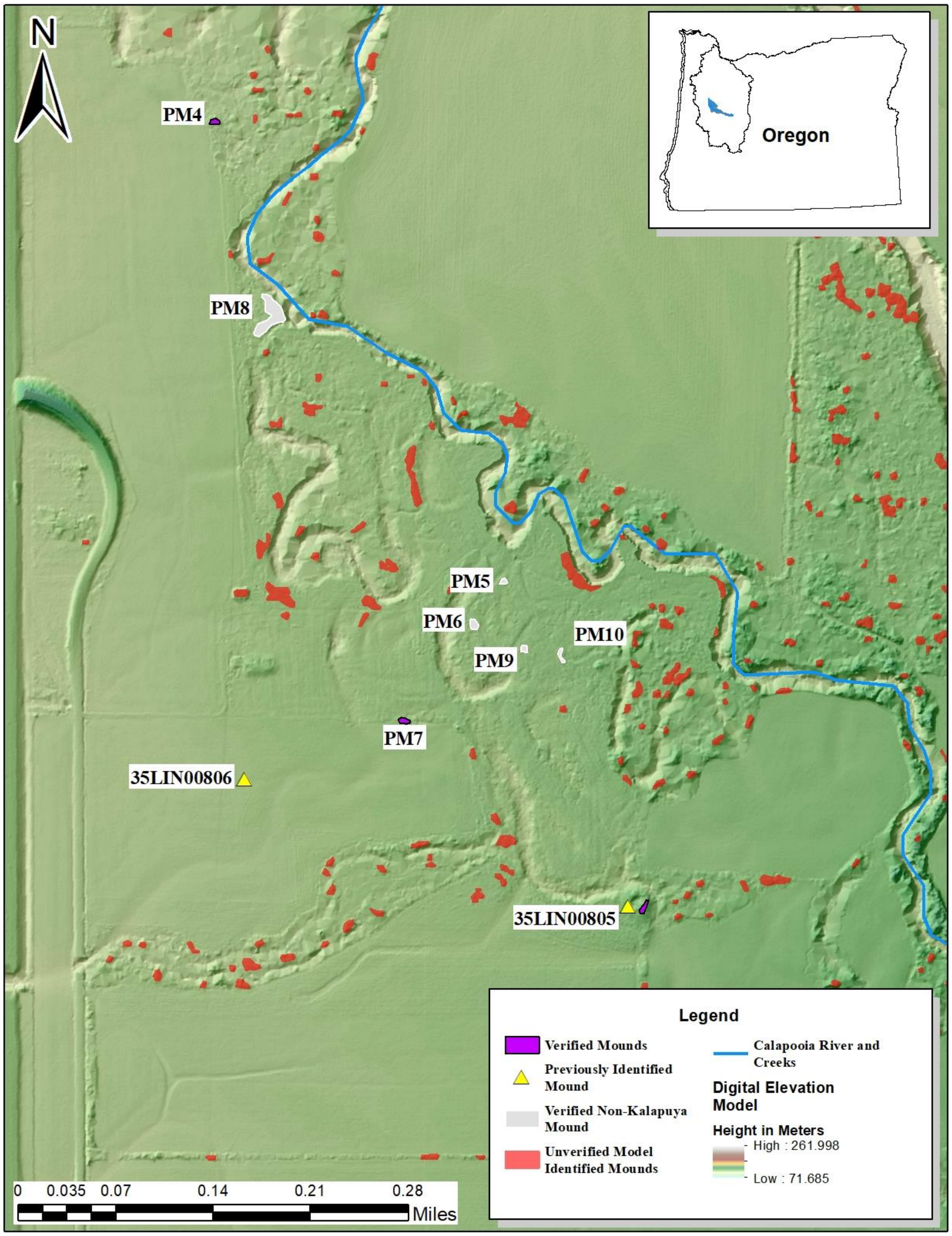


Figure 28. Model-identified and field verified mound sites in relation to the Calapooia River as old river meanders and oxbows.

With the caveats about potential patterning discussed above in mind, a consideration of what my modeling effort and fieldwork has contributed to our limited knowledge of mound formation processes is informative. All of the *previously identified mound sites* were along both the Calapooia River and the Long Tom River. The model-identified possible mound locations' proximity to the major waterways also aligns with White's (1975; 1979) analysis that most of the mound sites appear to be located in the riparian and floodplain zones of major waterways and tributaries. These areas next to the waterways, as mentioned in Chapter 2, are characterized by ponding cause by flooding events, which result in rich, dark silty loam soils that are found in the mounds and which are also prime environments for important Native American resources especially camas (Beaulieu et al. 1974a:53; White 1975:38). These areas allowed easy access to resources for the Kalapuyan Peoples. The areas were naturally protected from destructive forces (e.g. erosion, flooding) and were most likely both naturally and anthropogenically maintained (White 1979). The proximity to waterways and easily accessible camas patches sheds some light on the placement of the mounds, as waterways provided both transportation, resource materials, and created an environment suitable for easy food extraction.

The placement of the mounds near the Calapooia River and its major tributaries could be for a number of reasons: 1) these areas are prime locations for camas beds, 2) the rivers provide an abundance of rock resources which are needed to process camas, 3) the diversity and accessibility of riverine areas, which facilitates an abundance of human processing activities, 4) spiritual or ideological meanings associated with the river, and 5) as territorial markers.

My field work, while limited, indicates that there is some patterning in mound contents given that most mounds (51.5 percent) contain quantities of FCR. The amount of FCR as well as the presence of fire pits (Cordell 1967; Miller 1970; Cheatham 1984), and roasting ovens (Collins 1951; Roulette 2006), at excavated mound sites suggests that the mounds were related to the processing of camas, which was a staple resource for the Kalapuyan Peoples (Mackey 1974; Thoms 1989:213). Wilson (1997:2) mentions that a large amount of labor would have had to go into the collecting of rocks to account for the sheer numbers of FCR. The necessity of a large amount of rocks for food processing and other activities was no small feat and that Native Peoples would have had to situate themselves close to resource areas that could supply an adequate amount of rocks for their needs (Wilson 1997; Thoms 1989:249). Rivers can be excellent sources of rock material as well as providing transportation means for that rock material. Therefore, again, it is not surprising to find mound sites along rivers where it was easy to acquire and transport this important resource. The sheer number of FCR identified at the mound sites is indicative of the site’s importance to Native American activities (such as camas processing, which will be discussed in the following paragraphs) as well as the efficiency with which the thermal rocks were used (Wilson 1997:3). Wilson (1997:3) suggests the more efficiently a thermal rock is used, the more blocky and spall fragments one will find in an assemblage. This could possibly account for the number of FCR that was identified and for its relatively small size; it was used extensively, exhausted, and then discarded.

Thoms (1989:249) also mentions that rocks are “non-renewable” resources and thus once the resource was exhausted at any given area, people had to move on. This could possibly explain the number of mound sites reported by Laughlin (1941) and others; Native Peoples used up useful rock resources at any given location, so they then abandoned it to move to a new one with more “non-renewable” resources.

Thoms (1989) makes an important connection between the presence and abundance of FCR to the processing of camas (Wilson 1997), and also outlines a process for the formation of mound sites that could be further explored through further field investigation of mounds (Figure 29). Thoms mentions that “camas processing leaves a distinct signature in the form of hummocky surfaces (e.g. pits and mounds), and a landscape cluttered with by products, namely fire-cracked rock and charcoal” (Thoms 1989:248). It is possible, that Kalapuyan mound sites were created as a result of camas processing waste removal, or are the result of multiple use camas roasting ovens that were abandoned as non-camas resources ran low. The use and then disposal of camas due to processing initially may seem like simple behavior, however the way that humans used and eventually discarded the resources supplied and extracted from the environment can leave noticeable signatures on the landscape in the form of the Kalapuya mounds, which Thoms (1989) poses as a potential mound creation model (Figure 29). Thoms goes on to make the argument that as populations increased, camas was utilized more heavily as more people were competing for the higher ranked resources (e.g. salmon and deer), which would lead to a greater amount of camas processing features, and a greater abundance of FCR (Thoms 1989:183). It is interesting to note that the likely increase of population and thusly the increase in camas utilization posed by Thoms (1989:320) dates to from around 4,000 years ago until the contact era, and all of the dated mound sites fall within this time frame. Although this is an intriguing connection, it must be kept in mind that the dates acquired from the excavated *previously recorded mound sites* are limited; further dating is needed to further explore these potential connections.

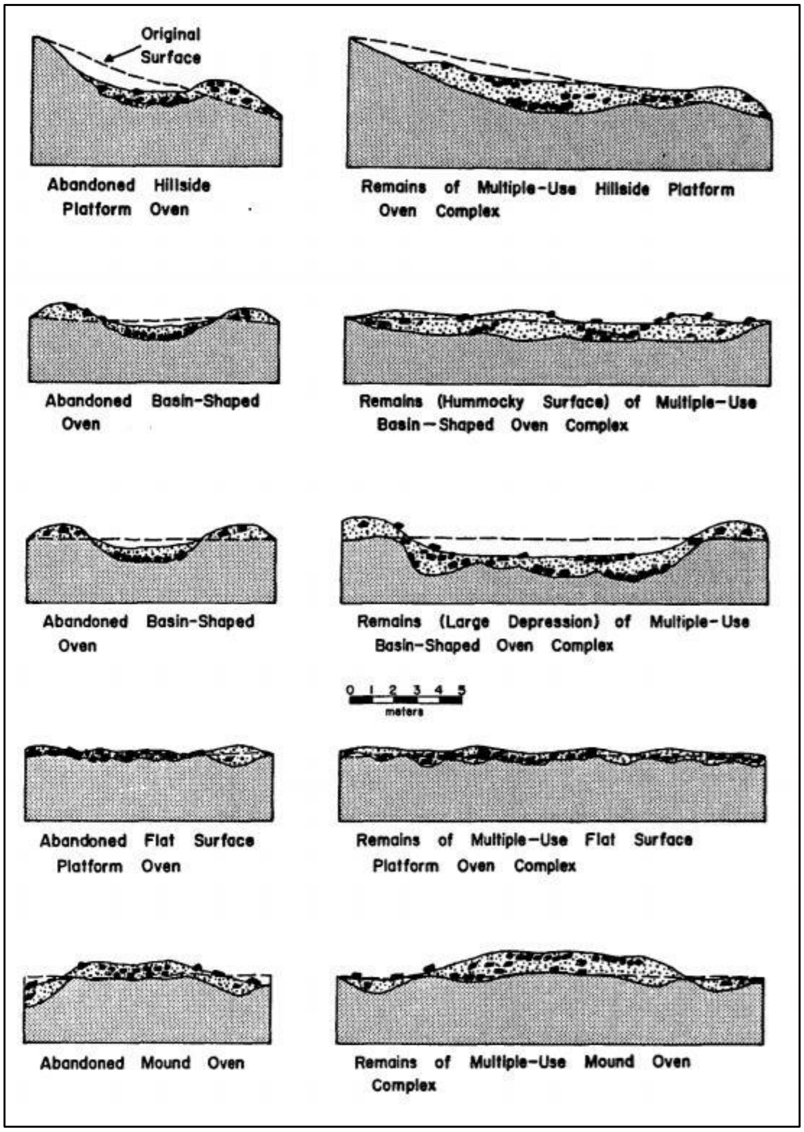


Figure 29. Life cycle of single and multiple-use camas ovens from the Callispel Valley (Thoms 1989:399).

The above discussion regarding camas processing and fire cracked rock does not explain the presence of human remains in 38.7 percent of the known mounds in the Calapooia Watershed, which certainly played a role in the creation of the mounds. A possible theory for the presence of human remains along with the remains of resource processing is the idea of the “ritual feeding of the dead”. In the case of the shell mound burials of coastal California, Luby and Gruber (1999) argue that since shell was used as a primary food source for the living, the burial of their dead among shell allowed for the provisioning of their dead ancestors in the afterlife. They argue “the concepts of ‘food’ and ‘ancestor’ join together at shell mounds, so much so that ritual attention to the ancestors was likely regarded as essential to ensuring a continuing supply of food” (Luby and Gruber 1999:96). What Luby and Gruber (1999) suggest is that food procurement was directly tied to the generosity of the ancestors. To assure that food would continue to be available, peoples engaged in the mutually beneficial behavior or feeding the ancestors with food waste so that the ancestors might feed them in return. It is possible that the Kalapuyan Peoples buried their dead in these mounds to serve as a visual reminder of the responsibility to their ancestors as well as a tending of both physical and spiritual resources (Luby and Gruber 1999:104).

Another potential cultural factor that could have contributed to the formation of the mounds is the idea of mounds as territorial markers in an environment. Researchers have frequently noted that territoriality and socio-political identity are integrally tied with the construction of highly visible monuments such as mounds, because mounds convey the idea “of [a] classified area, boundary, enforced control and conflict at local and regional scales" which is communicated and thusly perceived by outside groups (Gartner 1999:672; Sack 1986:1). The placement of mounds along conveyance areas (such as waterways), although it most certainly served a cost-effective resource procurement strategy, could have also served as a territoriality display (Cornelison 2013:212; Luby and Gruber 1999:99; Gartner 1999:681; Connolly et al. 1997). Conveyance systems are complex meeting grounds of natural boundaries, social boundaries, and persistent social memory all of which create the perfect environment for mound construction. With increased population and the fact that the Kalapuyan Peoples lived in a cultural environment in which the exchange of slaves between the Kalapuyan's and neighboring peoples was frequent (Mackey 1974:23-24, 29; Zenk 1990:550), the need for physical, environmental markers may have been necessary. The addition of human remains to mounds as territorial markers could have further tied the Kalapuayn People to their physical territorial markers. The presence of ancestral remains could indicate ownership just as much as the physicality of the mounds themselves (Bergman 2016), as suggested in a Californian context by Luby and Gruber (1999).

The circumstances that led to the creation of the Kalapuyan Mounds are still unknown. Although my research provides new information about patterns in mound distribution and character, many questions remain about these earthworks. The processes that led to the creation of the mounds are most a likely complex interweaving of practical, cultural, political, and spiritual factors that all served equally in the construction of these mounds. The predictive model I developed will be an important tool for protecting mound sites and focusing future research efforts directed at better understanding the specific cultural nature of these important sites.

Future Work

The LiDAR predictive model I created for this project is successful in its identification of previously recorded mounds and new mound sites. This offers compelling prospects for future archaeological work, although additional work is required to increase the efficacy of the model. Further fieldwork should be conducted to collect data needed to refine the model, which can then subsequently be modified and further filtered to yield better output that will inform continued research on the mounds.

Further fieldwork should be conducted in areas of dense, low-lying vegetation given the problems outlined above with densely vegetated areas. Dense low-lying vegetation can potentially affect the ability of LiDAR to map the surface accurately, which in turn can greatly affect archaeologists understanding of how archaeology and that landscape intertwine and influence each other. Fieldwork should also be directed at the collection of additional information (dimensions, contents, location) on Kalapuyan mounds. Additional information gained about the mounds themselves and also the efficacy of the model in certain environments will further inform the modeling process, facilitate model refinement, and likely result in fewer false positives in the future. Prior to additional fieldwork, model area parameters should be adjusted in future model iterations to reflect the new mound measurements acquired from my field work and from any subsequent fieldwork. By narrowing the area parameters, the model can become more focused on actual mound sites and return fewer false positives, such as septic tanks and baseball mounds. The model could be used to further direct future fieldwork by creating a buffer around the rivers (selecting a certain distance out from the rivers and waterways) and then running the model in these buffered areas. By limiting the amount of area that the model has to assess, the model will produce less spurious points, will be more focused, and the problem of identifying homes, buildings, and roadways will most likely be eliminated or at least greatly reduced. At the same time, fieldwork should also include systematic survey of non-riverine areas to address the existing survey bias, to determine if agricultural activities have in fact been a factor in mound destruction, and to clarify whether or not the apparent association of mounds with riverways is real.

In tandem with ongoing field assessment of the model, archaeologists should begin creating better relationships with the landowners in the Calapooia Watershed. Although many landowners stated that they did not want archaeological investigations to take place on their property, there were several who were excited to share what they knew about the mounds. Mr. Slate, and Mr. and Mrs. Skiles, were very knowledgeable about the mound sites on their properties, and provided invaluable information as to the status of the mounds over the years. These landowners are currently being ignored as archaeological resources by regional archaeologists, and it would be extremely beneficial in the continuing studies of these mound sites to include knowledgeable landowners. Future discussions with these knowledgeable landowners and cultural resource stakeholders could potentially lead to new ways of managing and protecting these significant cultural sites that both suit the needs of landowners, Indigenous community members, archaeologists, and interested members of the public.

My work also suggests future directions for collaborative research on mound formation. For example, Thoms' (1989) model of mound formation through camas processing could be investigated through further excavation. Further modeling directed survey and analysis of mound distribution could investigate the possibility of mounds as territorial markers, and/or as ideological or spiritual locations on a landscape imbued with meaning. Radiocarbon dating additional mounds, perhaps through a program of limited coring, would do much to advance our knowledge about the antiquity of the mounds and their possible uses. Collaborative Tribal-archaeological research would be the most productive avenue towards advancing understanding of the mounds, which likely are the product of multiple complex cultural activities. These collaborations could lead to a more human centered approach to mound modeling methods, including the use of territorial boundary markers based on ethnographic sources as buffer feature, or agent-based modeling, which could focus on the reasons people might have chosen certain places to build mounds over others (Cegielski and Rogers 2016).

Conclusions

The use of LiDAR in archaeology has increased dramatically in recent years as archaeologists discover its capacity to aid archaeological discovery in environments that are prohibitive to survey and landscape level site analysis. My study further establishes the efficacy of LiDAR in the archaeological realm. Even though further refinement of the model is necessary, my research shows that Willamette Valley mounds can be located using a LiDAR predictive model. Furthermore, the automatic extraction of mound sites offers a unique chance to truly utilize all that LiDAR and ArcGIS have to offer to archaeologists.

This project has done the important first steps that are necessary to conduct more in depth and broad archaeological analysis on these mounds. Before this model, archaeologists relied on survey to identify these mounds, frequently with poor results. Given that these mound sites are relatively low-lying, can easily be mistaken for undulations in the terrain, are located in areas of dense vegetation, and frequently access to them is frequently barred by land access issues; it is no surprise that field crews were frequently missing these important archaeological features. With the creation of this model, archaeologists can now digitally survey the terrain before performing a field survey and highlight areas of interest for field crews to visit to assess whether or not the identified point is a mound.

Although, the LiDAR model was a success it should by no means serve as a replacement for field archaeology, as both my model and field results show. The model does not take the place of trained field archaeologists in discerning between what is a cultural mound and what is simply a naturally mounded area. Rather, the results discussed above indicate that LiDAR is a viable and valuable tool in assisting archaeologists in archaeological prospection for culturally sensitive sites. It serves as a guide that can focus archaeological fieldwork in the watershed and allow for greater efficiency in field surveys.

This project has clearly established a novel method and a model appropriate for archaeological prospection, particularly mound prospection, for the Willamette Valley.

This project also shows the efficacy of LiDAR predictive models and feature extraction for archaeological work, which can be modified for use in other regions of the Pacific Northwest and beyond. Furthermore, by identifying these mounds I have laid the groundwork for future studies that may shed light on why and how people created these mounds, which will add valuable information to a poorly understood site type and cultural practice.

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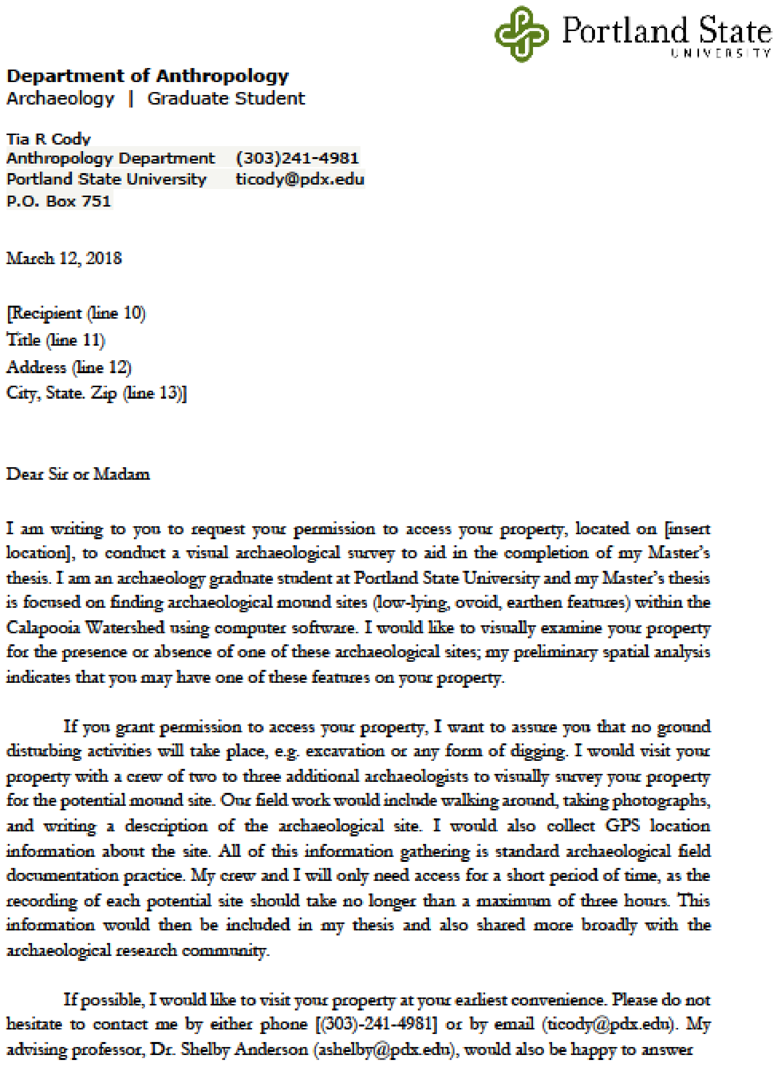
Appendix: Landowner Letter



Portland State University

Department of Anthropology
Archaeology | Graduate Student

Tia R Cody
Anthropology Department (303)241-4981
Portland State University ticody@pdx.edu
P.O. Box 751

March 12, 2018

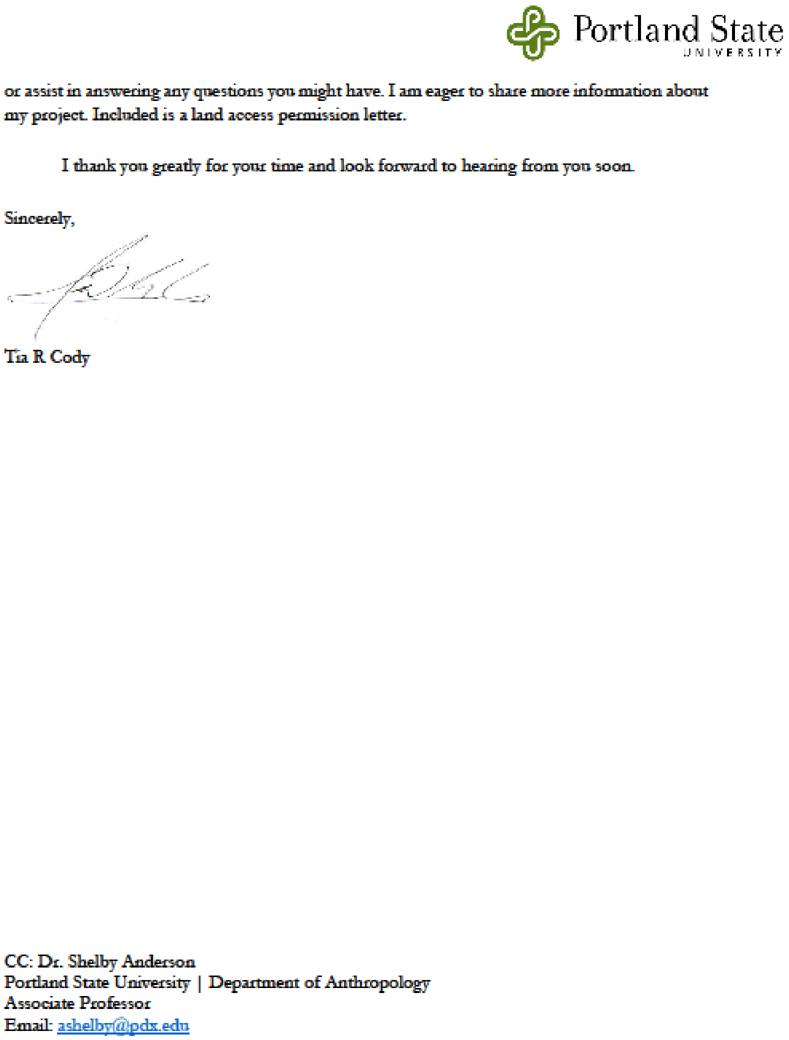
[Recipient (line 10)
Title (line 11)
Address (line 12)
City, State. Zip (line 13)]

Dear Sir or Madam

I am writing to you to request your permission to access your property, located on [insert location], to conduct a visual archaeological survey to aid in the completion of my Master's thesis. I am an archaeology graduate student at Portland State University and my Master's thesis is focused on finding archaeological mound sites (low-lying, ovoid, earthen features) within the Calapooia Watershed using computer software. I would like to visually examine your property for the presence or absence of one of these archaeological sites; my preliminary spatial analysis indicates that you may have one of these features on your property.

If you grant permission to access your property, I want to assure you that no ground disturbing activities will take place, e.g. excavation or any form of digging. I would visit your property with a crew of two to three additional archaeologists to visually survey your property for the potential mound site. Our field work would include walking around, taking photographs, and writing a description of the archaeological site. I would also collect GPS location information about the site. All of this information gathering is standard archaeological field documentation practice. My crew and I will only need access for a short period of time, as the recording of each potential site should take no longer than a maximum of three hours. This information would then be included in my thesis and also shared more broadly with the archaeological research community.

If possible, I would like to visit your property at your earliest convenience. Please do not hesitate to contact me by either phone [(303)-241-4981] or by email (ticody@pdx.edu). My advising professor, Dr. Shelby Anderson (ashelby@pdx.edu), would also be happy to answer



Portland State
UNIVERSITY

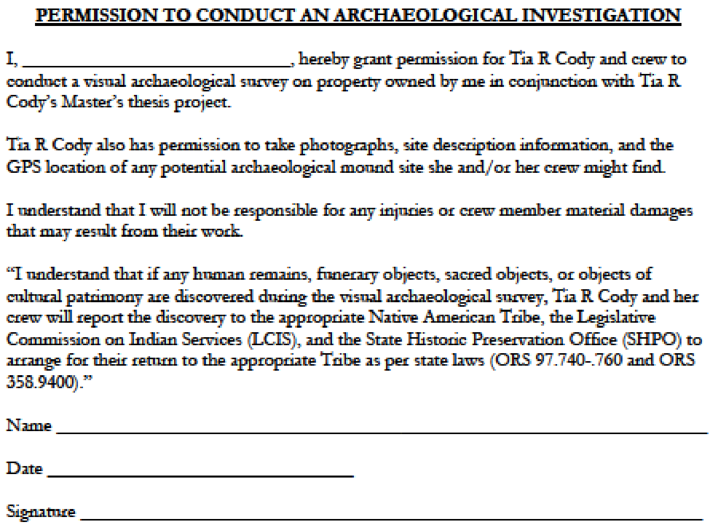
or assist in answering any questions you might have. I am eager to share more information about my project. Included is a land access permission letter.

I thank you greatly for your time and look forward to hearing from you soon.

Sincerely,

Tia R Cody

CC: Dr. Shelby Anderson
Portland State University | Department of Anthropology
Associate Professor
Email: ashelby@pdx.edu



PERMISSION TO CONDUCT AN ARCHAEOLOGICAL INVESTIGATION

I, ____________________________, hereby grant permission for Tia R Cody and crew to conduct a visual archaeological survey on property owned by me in conjunction with Tia R Cody's Master's thesis project.

Tia R Cody also has permission to take photographs, site description information, and the GPS location of any potential archaeological mound site she and/or her crew might find.

I understand that I will not be responsible for any injuries or crew member material damages that may result from their work.

"I understand that if any human remains, funerary objects, sacred objects, or objects of cultural patrimony are discovered during the visual archaeological survey, Tia R Cody and her crew will report the discovery to the appropriate Native American Tribe, the Legislative Commission on Indian Services (LCIS), and the State Historic Preservation Office (SHPO) to arrange for their return to the appropriate Tribe as per state laws (ORS 97.740-.760 and ORS 358.9400)."

Name ____

Date ______________________________

Signature ____