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The Chemicals Between Us: A Geoarchaeological Analysis of a Shell Midden and Patterns of Deposition at the Woodstock Farm Site, Chuckanut Bay, Washington

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The Chemicals Between Us: A Geoarchaeological Analysis of a Shell Midden and Patterns of Deposition at the Woodstock Farm Site, Chuckanut Bay, Washington

By

Stacie Jo Nored Pratschner

Accepted in Partial Completion
of the Requirements for the Degree
Master of Arts

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Master's Thesis

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Stacie Jo Nored Pratschner

August 9, 2018

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A Thesis
Presented to
The Faculty of
Western Washington University

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Abstract

Human settlement of the Gulf of Georgia region by hunter-forager peoples began nearly 5000 years ago, culminating in the familiar Developed Northwest Coast Pattern exhibited in many Marpole Phase archaeological sites beginning 2400 years BP throughout the Gulf of Georgia region. The physical remnants of the intensive shellfish collection and processing that took place on the Northwest Coast are in shell midden deposits: archaeological sites that contain an abundance of discarded shell, bones, lithic tools, and charcoal. The preceding Locarno Beach Phase (3500-2400 BP), particularly in the southern Gulf of Georgia region, is less well understood by archaeologists because of the past academic focus on northern Marpole Phase sites. The Woodstock Farm site (45WH55) is a Locarno Beach Phase shell midden located in the southern Gulf of Georgia, adjacent to Chuckanut Bay in Whatcom County, Washington. Recorded in 1974, the site has been the subject of three Western Washington University archaeological field schools in 2005, 2007, and 2010, and the shell midden identified on the bluff has been the focus of study for past Anthropology graduate theses at WWU. This thesis applies a program of geoarchaeological analysis, including radiocarbon dating, grain size analysis, magnetic susceptibility, and phosphorous values, to twenty five matrix samples from the approximately 4-square meter exposed beach profile shell midden below the bluff of 45WH55. To date, there has been no geochemical or geophysical lab analysis to help interpret the depositional processes that created the complex stratigraphy that characterizes the exposed shell midden in the beach profile at 45WH55. The numerous ash lenses, layers of burnt shell, and charcoal in the shell midden indicates repeating task-specific activities that are more typical of post-Locarno Beach phases. The purpose of these tests was to describe the human activities that created the distinct and repeating layers by combining macro-level observations of the stratigraphy with micromorphological analysis of the collected midden samples. The goals were to distinguish between depositional processes present in the midden and identify archaeological features related to anthropogenic subsistence activities. The results of the laboratory tests supported the hypothesis that the shell midden is the result of in-situ anthropogenic deposition, and not contemporaneous with the Locarno Beach phase portion of 45WH55 on the upper bluff. The midden yielded later Phase dates between 508 BP and 933 BP, indicating over a thousand years of continued use of 45WH55 for intensive shellfish collection and processing. I detected evidence of hearth reuse, which aligns with the intensive, specialized subsistence activities that are expressed in later Phase archaeological sites throughout the Gulf of Georgia. This research will add to our knowledge about the history of occupation of the Woodstock Farm site.

Acknowledgements

I thank my committee members, Dr. Campbell, Dr. Koetje, and Dr. Boxberger, for your guidance, comradery, and mentorship through these years. Dr. Campbell has been a strong academic presence in my life since my undergraduate career, culminating in working together on this thesis project. My admiration and gratefulness for her expertise and friendship cannot be expressed deeply enough. Thank you also to the WWU Graduate School and the Anthropology Department for the generous funding support in the form of teaching assistantships, scholarships, and grants throughout my graduate school tenure. Thank you to Viva Barnes for her support and incredible helpfulness in everything. Thank you to Jennie D. Shaw of Salix Archaeological Services for her analysis of the charcoal samples and assistance in selecting the best candidates for radiocarbon dating; to William Callebert for his assistance in the Pacific Northwest Paleomagnetic Laboratory to complete the magnetic susceptibility tests; to Ben Paulson for his assistance in the Geology Laboratory for the grain size analysis; and to Adrienne Cobb with her assistance in creating the Adobe Illustrated stratigraphic drawing and the Oxcal chart. I am thankful as well to AMSDirect and Edge Analytical for completing the radiocarbon dating and phosphorous tests, respectively.

Concurrent with my academics has been my growth in my career in archaeology and land use planning, and I wish to thank Dimity Hammond, Gretchen Kaehler, Stephanie Kramer, Al Reid, Mary Rossi, and Lena Tso for their comradery and professional mentorship.

Most importantly is the acknowledgement of my family and friends. Thank you to my fellow graduate students, you inspire me to do my best. Thank you to my parents, Mike and Mary, for your unwavering support and excitement about my academics. Thank you to my in-laws, Greg and Jean, for being engaged and enthusiastic about this project. Greatest thanks goes to my husband Scott, for the love, patience, support, and encouragement that he gives so freely. I am forever grateful.

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Chapter 1: Introduction

The primary goal of archaeologists is to interpret past human behavior from material remains, and to then to provide explanations for this behavior (Feder et al. 1997). Archaeologists are uniquely challenged among social scientists in their attempts to classify, quantify, and describe data; they must try to infer past human behavior and beliefs from surviving material remains, often without written records and no ability to directly observe the behaviors in question (Trigger 1988). The Northwest Coast region provides these challenges of archaeological classification and quantification in two forms: a biased material record that most often only includes artifacts that can persist in acidic and wet soil conditions, like lithic tools, shell, and bone; and no written records of the Northwest Coast's Indigenous peoples prior to the beginning of sustained contact with Europeans in the 1770s (Ames and Maschner 1999; Sobel 2012).

The Gulf of Georgia Region of the Northwest Coast was settled beginning nearly 5000 years BP (Ames and Maschner 1999; Hutchings 2004; Dubeau 2012), and dramatic changes in Indigenous peoples' cultures took place beginning 3800 years ago, before the appearance of the Developed Northwest Coast Pattern (Matson and Pratt 2010; Lepofsky 2005; Lewis 2013). The Developed Northwest Coast Pattern is characterized by semi-sedentism, large-scale storage of foodstuffs and other resources, and the appearance of social stratification and rank in local societies. (Matson and Coupland 1995). The archaeological community has widely researched and reported on Marpole Phase (2400-1500 BP) archaeological sites throughout the northern Gulf of Georgia area that exhibit the above-described cultural characteristics (Lewis 2013).

The Locarno Beach Phase (3800-2400 BP) represents a time of shifting cultural norms in the Gulf of Georgia region, with subsistence changing from foraging to more intensive and specialized collection, and the beginning of large-scale procurement and storage of salmon and other anadromous fish (Borden 1950; Butler and Campbell 2004; Matson 1992). Radiocarbon dates obtained from the Woodstock Farm Site (45WH55) in the southern Gulf of Georgia region on the northern portion of Chuckanut Bay indicate that a part of the site does date to the Locarno Beach Phase (Campbell et al. 2010). The original identification of 45WH55 by J. Gaston and C. Swanson in 1974 and subsequent WWU Field Schools in 2005, 2007 and 2010 by Dr. Campbell and Dr. Koetje have provided stratigraphic data, geomorphological data, and artifact and faunal material remains (Gaston and Swanson 1974; Campbell et al 2010). To date, however, there has been no geoarchaeological chemical or physical lab analysis to help interpret the natural and cultural depositional processes that created the complex stratigraphy that characterizes the exposed shell midden in the beach profile at 45WH55. I hypothesize that the patterns of deposition in the shell midden are the physical expression of the intensive shellfish processing employed by the people who occupied 45WH55, and likely date to a later Phase than the Locarno Beach dated portion of the site located on the upper bluff. Understanding those processing activities enriches our knowledge of subsistence activities at the Woodstock Farm Site, because we can evaluate how the same location was used in two different ways in two different time periods. This will add to our knowledge of Coast Salish cultural forms across the Gulf of Georgia region (Suttles 1987).

A geoarchaeological approach is appropriate for this research project, because methods originating from earth sciences can be used to study the development of the sedimentary archaeological record (Lambert 1997; Rapp and Hill 2006). Geoarchaeology is the application of geological concepts, techniques, and knowledge to the study of processes involved in the creation of the archaeological record (Rapp and Hill 2006). Geoarchaeology is fundamental to the practice of archaeology, because understanding site formation processes informs our interpretations of the manufacture and use of artifacts (Stein 2008). Geoarchaeological chemical and physical analyses takes advantage of the eclectic nature of archaeology itself, providing data to archaeologists that is not always apparent to the naked eye (Jakes 2002). I use the phrase "eclectic nature of archaeology" to address the diversity of surviving material remains that archaeologists study, ranging from human remains, faunal remains, structural features, lithic tools, and artifacts of wood, clay, bone, metal, and textiles. Inherent within the research into the material remains of the archaeological record is the study of soils as well; the physical remains of people and their cultures are in and on the soil (Limbrey 1975). The physical and chemical studies of soil and the practice of archaeology together contribute to the study of past landscapes, geology, and populations (Limbrey 1975; Hill and Rapp 2006).

Research Questions and Objectives

The goal of this thesis is to employ geoarchaeological analyses to aid in identifying the past human subsistence activities that created the distinct and repeating layers of shells, ash, and charcoal in the midden profile. I hypothesize that the shell midden represents a later-Phase site of intensive, specialized shellfish processing created by in-situ anthropogenic deposition, with repeating human activities creating the observed stratigraphic sequence. In-situ deposition means that the stratigraphic layers are related to each other and represent archaeological features. My research is structured on the three following premises:

1) Employing Lewis Binford's middle range theory (1981), I can provide cause and effect information through actualistic archaeological research (Pobiner and Braun 2005) to link data collection (the static) to past human behaviors (the dynamic).
2) Human activities are organized in space and time, therefore any randomness or disconnect between the shell midden layers must be archaeologically demonstrated before assuming a palimpsest nature of the deposits (Vila et al. 2009).

3) Information on the depositional history of the shell midden can be garnered by studying the physical and chemical properties of sediments (Campbell 1981; Carter 2016; Muckle 1985; Stein 1992).

To explore my above-stated hypothesis, I address the following three questions in my research:

- **Can the geoarchaeological tests, in concurrence with field observations and a literature review, aid in identifying the depositional processes that have resulted in the repeating layers of ash, charcoal, and burnt shell?**
- **Is the portion of 45WH55 that is the subject of my research (the beach bank shell midden) contemporaneous with the part of 45WH55 located on the bluff above the beach?**
- **What were the natural and cultural environments that supported the development of the shell midden?**

The archaeological literature supports the theory that elevated phosphorous levels and greater magnetism in soils indicates anthropogenic input into soils, such as burning. I hypothesize that the phosphorous and magnetic susceptibility tests of the shell midden matrix, with total phosphate and the degree of magnetic susceptibility serving as proxies for human activity, will help distinguish between depositional events that created the complex stratigraphy and aid in identifying the signatures of particular actions in the profile. Specifically, the chemical and magnetic signatures in each of the mutually exclusive categories of matrix (ash, shell, charcoal, and sand) will repeat and parallel the field observations of repeating layers, and by extension repeating features that signify repeating human subsistence activities. I define a feature to be a collection of one or more archaeological artifacts and matrix (ash and charcoal lenses, burnt shell, and fire cracked rock) that represent a past human activity, such as cooking over a hearth or fire pit. I also use grain size analysis to aid in differentiating cultural versus natural deposition. Previous research at the Woodstock Farm site has identified multiple human activity areas that indicate semi-sedentary life-ways (Lewis 2013). I employ radiocarbon dating on two charcoal samples to determine if the human activities that created the shell midden on the beach were contemporaneous and connected to the human activities that created the recorded Locarno Beach-phase site on the upper terrace. I describe the pattern of erosion of the shell midden resulting from the wave cut beach processes of Chuckanut Bay, and suggest the presence of thermal features by merging existing research of shellfish processing signatures with macro-level observations of the shell midden and resulting grain size distribution, magnetic susceptibility, and total phosphate amounts.

Thesis Organization

The following chapter introduces the reader to the long occupation of the Northwest Coast region by native peoples, and I place the Locarno Beach Phase within the geographic and ethnographic context of the Gulf of Georgia sequence. Chapter 3 provides a geomorphological history of the Locarno Beach-phase Woodstock Farm site, and describes the Indigenous settlement and eventual Euro-American occupation of the site. I also describe the materials and data collected from the 2005, 2007, and 2010 Western Washington University archaeological field schools. Chapter 4 discusses the applicability of geoarchaeology to archaeological questions and gives a literature review of the geochemical and geophysical methods employed for this thesis research. Chapters 5 and 6 provide details of the laboratory methods and statistical analysis applied to the radiocarbon dating, the grain size analysis, the magnetic susceptibility tests, and the phosphorous tests in order to understand the depositional history of the shell midden. Chapter 7 discusses and makes conclusions about the significance of this study, vis á vis the identification of archaeological features related to human subsistence activities within the shell midden and reconstruction of the natural and cultural environment that set the stage for those activities. Finally, I propose potential future geoarchaeological research in the southern Gulf of Georgia region that will enrich our understanding of the history of the Coast Salish peoples.

Chapter 2: The Northwest Coast Region

The Northwest Coast geographic and culture region is defined as an area of coastline in North America, spanning the approximately 2,000 kilometers and encompassing the archipelago of Southeast Alaska, the coast of British Columbia and the coastlines of Washington, Oregon and Northern California (Ames and Maschner 1999; Goebel et al. 2008; Matson 2003; Moss 2011; Suttles 1990). In this chapter, I describe the current hypotheses of migrations from Asia to the Northwest Coast, provide an overview of the Northwest Coast environment and adaptation, and identify the importance of the Locarno Beach Phase within the Gulf of Georgia sequence.

The Journey to North America: Paleoarchaeology

The peopling of the North America began more than 15,000 years ago in the late Pleistocene during an Ice Age characterized by the enormous Laurentide and Codilleran glaciers blanketing swaths of North America (Ames and Maschner 1999; Erlandson and Moss 1999; Fedje et al.2004; Geobel, Waters and Dikova 2003, Meltzer 2013). Groups of hunter-foragers travelled from their ancestral homes in Siberia across the exposed Beringian continent and in watercraft across the Bering Sea to southeast Alaska (Ames and Maschner 1999; Tackney 2015; Meltzer 2013). These groups eventually fanned out into the ice-free portions of Alaska and down the exposed shoreline to the modern-day Pacific Northwest (Gruhn 1994). These original colonizers were skilled travelers, hunters and seafarers, pursuing marine mammals for food and hunting extinct mega-fauna across the steppe-like conditions of Beringia and into North America (Fladmark 1979; Moss 2011).

The archaeological evidence for the journey along the Northwest Coastline is corroborated by the oral histories of the Tlingit and Haida peoples of modern-day British Columbia and Alaska, whom have stated for millennia that they have been in the Northwest Coast since ancient times and that their ancestors traveled here in canoes (Moss 2011). Approximately 5000 years ago, the well-documented Northwest Coast cultural pattern emerged on and adjacent to the ribbon of islands, fjords, and beaches that stretches from Icy Bay, Alaska to Cape Mendocino, California (Ames 1994).

Northwest Coast: Environment and Adaptation

The Northwest Coast region includes the land and peoples of the narrow belt of Pacific coastland and islands from the southern border of Alaska to northern California. (Ames and Maschner 1999; Matson 2003) (Figure 1). This region boasts dynamic geology; active volcanoes, large glaciers, and enormous fault lines that span the Pacific Rim find expression in a rugged landscape supporting an immense diversity of coastal, marine, and forest resources (Moss 2011). The Indigenous cultures of the Northwest Coast region whom successfully exploited these rich natural resources challenged early Euro-American ethnographers' most closely-held assumptions regarding the development of human societies; complex social stratification, long-term settlement and large population centers developed on the Northwest Coast absent Western mono-crop agriculture (Ames 1994; Ames and Maschner 1999; Croes and Hackenburger 1988; Dubeau 2012; Fladmark 1975; Matson 1992; Moss 2012). Along the shorelines of northwestern Washington, archaeological sites containing shell midden and lithic, bone and faunal materials are part of the lasting evidence of these complex societies, and thousands of years of habitation by Indigenous peoples. Occupation of northwestern Washington dates back to the early Holocene, as evidenced by the 9600 year old radiocarbon dates obtained by Robert Meirendorf from charcoal samples in an ancient hearth on the Cascade Pass (Campbell, et. al. 2010). Radio carbon dates obtained at archaeological sites within Whatcom County indicate occupation beginning nearly 5000 years ago, as evidence by the dates of charcoal within shell middens at the Ferndale Site (45WH34) and faunal material from the Whalen Farm site in Point Roberts (45WH48) (Borden 1950; Hutchings 2004).

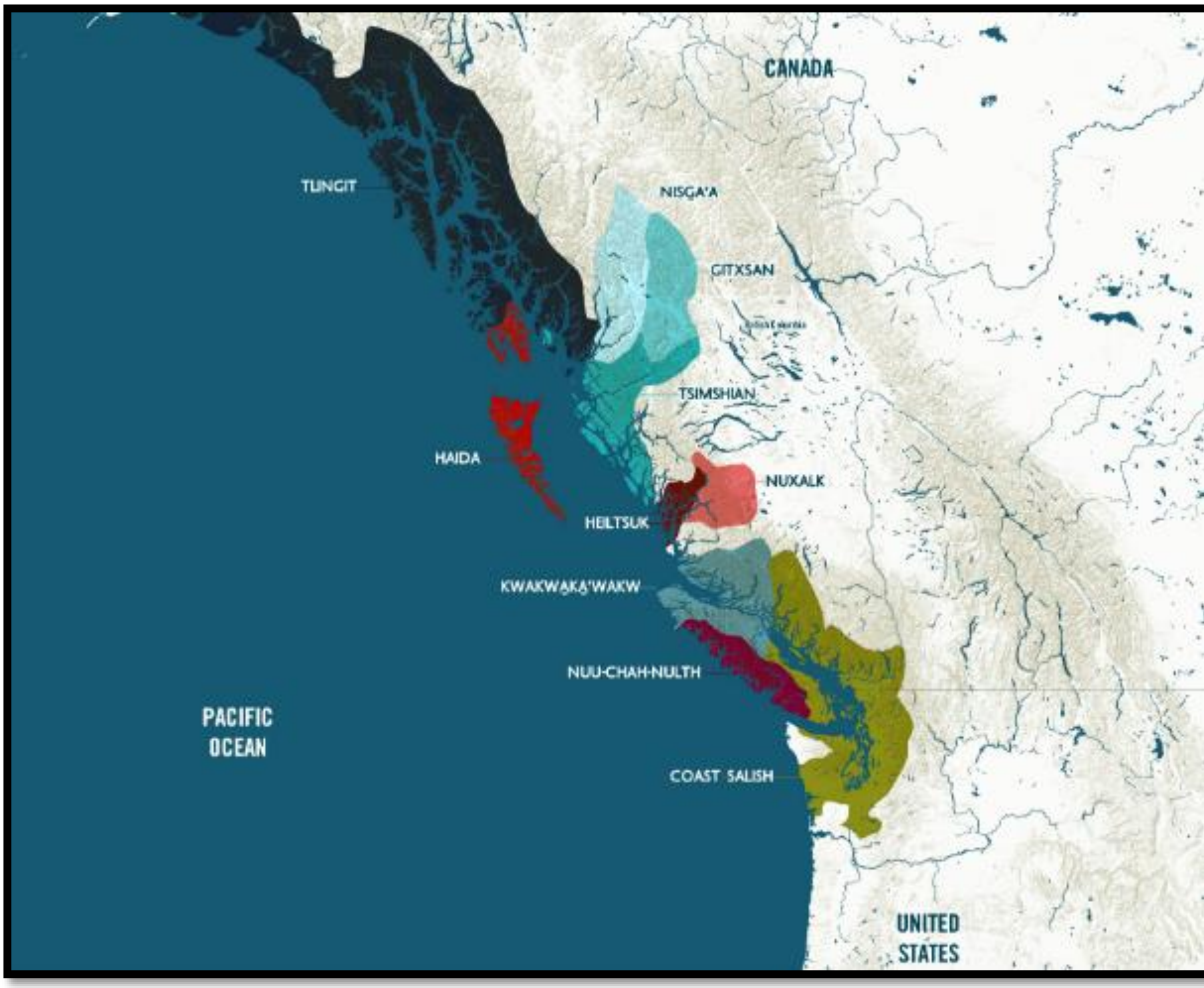


Figure 1. Map of the Northwest Coast culture region (Image courtesy of the American Museum of Natural History).

The Gulf of Georgia Sequence

The Gulf of Georgia is that portion of the Northwest Coast region that encompasses swaths of Vancouver Island, coastal British Columbia, the northeast Olympic Peninsula, and western Whatcom, Skagit, and Snohomish Counties (Clark 2013) (Figure 4). The Salish Sea, a body of water that includes the Strait of Georgia, the Strait of Juan de Fuca, and Puget Sound, is fed by riverine systems like the Fraser

River, Nooksack River, and Skagit River that support anadromous fish like salmon. (Ames and Maschner 1999; Boxberger 2000; Campbell and Butler 2010; Haggan et al. 2006; Moss and Cannon 2011).

Figure 2. Map of the Gulf of Georgia (Image courtesy of staff.wwu.edu).

The Gulf of Georgia sequence is a regional, cultural-historical classification system resulting from over 100 years of archaeology around the Salish Sea (Borden 1950; Clark 2013; Croes and Hackenberger 1988; Hammon 1986; Matson and Coupland 1995). The analytical units of Locarno Beach, Marpole (both part of the Middle Pacific period as described by Ames and Maschner 1999), and Gulf of Georgia /

Developed Northwest Coast Pattern (the Late Pacific Period) were first developed by Borden (1968) and began as a way to categorize the changes in material culture from initial settlement of the region 5000 years BP and subsequent to Euro-American contact in the 1700s based on the presence or absence of artifact types in Gulf of Georgia archaeological sites (Ames and Maschner 1999, Clark 2013) (Table 1). Archaeologists now use the Gulf of Georgia Sequence to categorize not just changes in artifact types but shifts in economies and social complexity. Croes (2015) used cladistics analysis software to measure degrees of similarity (site assemblages based on artifact types) between 50 archaeological sites around the Salish Sea, resulting in a cladogram that demonstrates the sites arranged in three "branches" (each branch representing the St. Mungo, Locarno, and Late / Gulf of Georgia Phases) in order to inform discussions of cultural trajectories (Figure 3). Croes (2015) concludes that the differences in traits that defined the individual Gulf of Georgia phases are statistically valid, and therefore provide a meaningful structure with which to understand the emergence of the Developed Northwest Coast pattern among Coast Salish peoples.

Table 1. Gulf of Georgia Sequence (Modified from Ames and Maschner 1999).

The Pacific Periods	Ames and Maschner's (1999) Gulf of Georgia Sequence
Late Pacific	*Gulf of Georgia* (1000 BP to Contact)
Middle Pacific	*Marpole* (2400 BP to 1000 BP)
	Locarno Beach (3500 to 2400 BP)
Early Pacific	*St. Mungo* (5500 BP to 3500 BP)
The Archaic Period	*Old Cordilleran / Olcott* (10,000 BP to 5500 BP)

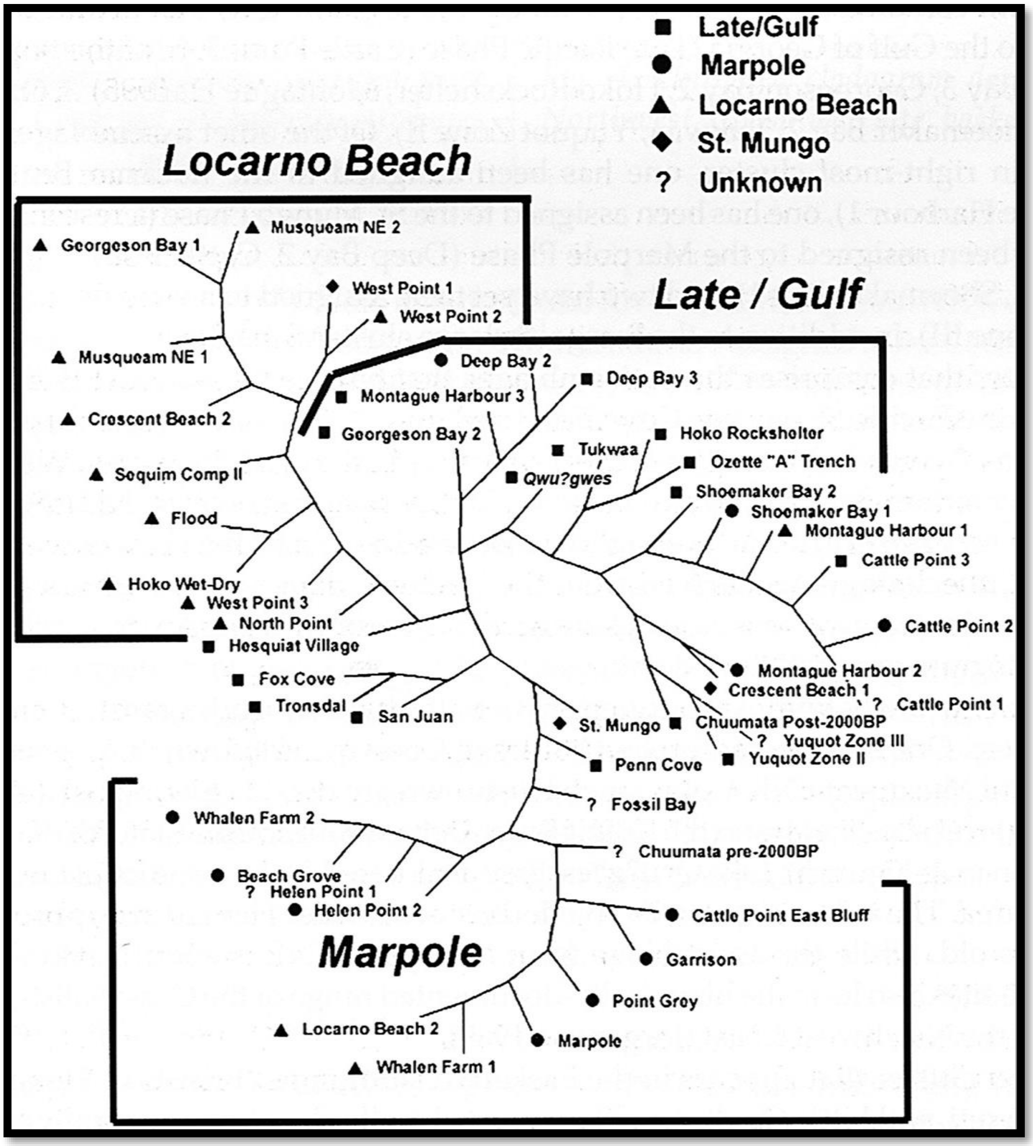


Figure 3. Gulf of Georgia Sequence cladogram comparing similarities in artifact categories (Croes 2015: Figure 15).

The Locarno Beach Phase

The Locarno Beach Phase (3500-2400 BP) of the Gulf of Georgia Sequence derives its name from the salvage excavations completed by Borden in 1948 (1950) at the Locarno Beach Site , located in southern British Columbia (Williams 2013). This phase represents a transitional time in the Gulf of Georgia region from the antecedent mobile hunter-gatherer groups to the subsequent multi-family homes and complexly ranked social hierarchies that characterize the Developed Northwest Coast Pattern (Mather 2009; Matson and Pratt 2008). The Locarno Beach phase is expressed in sites that demonstrate intensified shellfish harvesting, storage technologies, specialized and seasonal use locations, and an increase in ground stone and bone implements (Ames and Maschner 1999; Lewis 2013; Clark, 2013; Williams 2013). Thirty-three Locarno Beach-age sites have been identified in the Gulf of Georgia region; the majority of those recorded sites are located in British Columbia (Mather 2009). The southern Gulf of Georgia region has not been the subject of as much study and documentation, but the significant developments of more complex food collection and the emergence of a storage based economy in the Locarno Beach phase (Coupland 1998) renders this thesis research germane to a greater understanding of Coast Salish people's history.

Matson and Pratt (2008) recognize the Locarno Beach Phase (3500 to 2400 BP) as the pivotal time where the full scale development of the Northwest Coast Pattern was taking place. The mobile groups of hunter-foragers living in small residential sites during the St. Mungo Phase (5500 BP to 3500 BP) of the Early Pacific Period (Table 1) gave way to the semi-sedentary lifeways of the Locarno Beach phase in the Middle Pacific Period (Ames and Maschner 1999; Matson and Coupland 1995). The Locarno Beach Phase is characterized by winter season residential base camps and spring season specialized activity camps where Coast Salish peoples employed shellfish collector strategies and the procurement, processing, and storage of salmon and other anadromous fish (Butler and Campbell 2004; Lewis 2013; Moss 2011). Matson and Pratt (2008) identify the following three major issues that researcher's need to understand more fully about the Locarno Beach Phase in order better inform our knowledge of the Developed Northwest Coast Pattern: 1) its economic organization; 2) its relationship with the previous St. Mungo Phase and the subsequent Marpole phase; and 3) its social organization. The well-documented Marpole Phase (2400 to 1000 BP) is characterized by sedentary villages and the mass harvest and storage of food resources (Ames and Maschner 1999), and the later Gulf of Georgia

Phase (1000 BP to Euro-American contact) sees the development of semi-subterranean pit houses and fortifications. The long habitation of the Woodstock Farm site, as evidenced by radiocarbon dates that place portions of the site in the latter half of the Locarno Beach and Marpole Phases (Campbell et. al. 2010; Pierce 2011) offers archaeologists the opportunity to research settlement patterns and subsistence changes, and then infer societal organization.

Chapter 3: The Woodstock Farm Site

The geography and environment that 45WH55 occupies is crucial to understanding the history of occupation of the Woodstock Farm Site, because the first task of geoarchaeology is to distinguish the remains of human activity from the natural events (processes on a geologic time scale) that have formed the landscape (Rapp and Hill 2006). The following chapter explores the dynamic geomorphological processes that have created Chuckanut Bay, including the beach wave activity that has eroded the beach bank shell midden that is the subject of this thesis research. I describe the Indigenous and Euro-American use and occupation of the site, and give a synopsis of the Western Washington University field schools at the Woodstock Farm that have provided the data and materials for this study.

Figure 4. View looking south over Chuckanut Bay from the Woodstock Farm site (Image courtesy of the City of Bellingham).

Geomorphic History

The Woodstock Farm Site (45WH55) is located in Whatcom County, Washington, approximately 6 miles south of the city of Bellingham. The site is situated north of the long and narrow Chuckanut Bay, a North-South trending shallow bay in Puget Sound that is characterized by extensive mud flats during low tide. The exposed beach bank shell midden is adjacent to the colloquially named "Mud Bay", a small bay that earned its name because of the accumulation of sediment brought about by the installation of the railroad trestle in the 1920s and the construction of I-5 in the 1970s (Campbell et. al. 2010, Lewis 2013)(Figure 5). The Chuckanut Mountains rise to the east, formed by the folded layers of approximately 55 million year old conglomerate, shale, sandstone, lithified volcanic ash, and bituminous and sub-bituminous coal (Easterbrook 1970; Mustoe 1998). These 6000 meter deep folded layers, named the Chuckanut Formation, are fluvial sedimentary formations from the Eocene Era, deposited between 54 Ma (million years ago) and 34 Ma (Johnson 1984). An active strike-slip regime has resulted in the strongly N – to NW - trending folds that characterize the fragmented nature of the Chuckanut Formation (Tabor et al. 1989). The USDA (1992) maps the area as Nati Silt Loam, a well-draining soil series derived from the Eocene-era sandstone that forms at the foot of steep slopes and contains a mixture of volcanic ash and glacial till.

The topography of the Salish Sea is largely the result of the Pleistocene-era Vashon Stade of the Fraser Glaciation (18000 to 10000 BP). The Puget Lobe of the stade flowed south from British Columbia, leaving behind glacial till and scouring out extensive troughs that define the fjord-like Puget Sound region (Figure 5). Post-glacial stream erosion and deposition then combined with wave and current actions to create the many spits and sand bars that dot the Puget Lowland coastal areas (Easterbrook 1970). The Holocene era (11700 BP) then ushered in a warming climate and rising sea levels that set the stage for the emergence of Northwest Coast culture (Ames and Maschner 1999; Fladmark 1975; Moss et al. 2007). By 5000 BP, sea levels were within a few meters of modern sea levels, and by 2000 BP had stabilized to nearly modern sea levels (Lambeck et. al. 2009; Whitaker and Stein 1992).

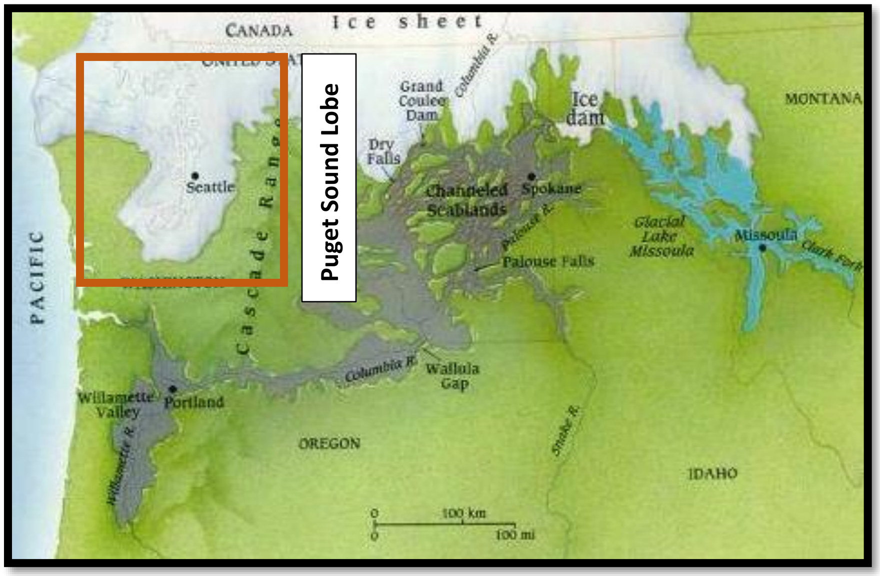


Figure 5. The Vashon Glaciation with emphasis on the Puget Lobe (15,000 BP).

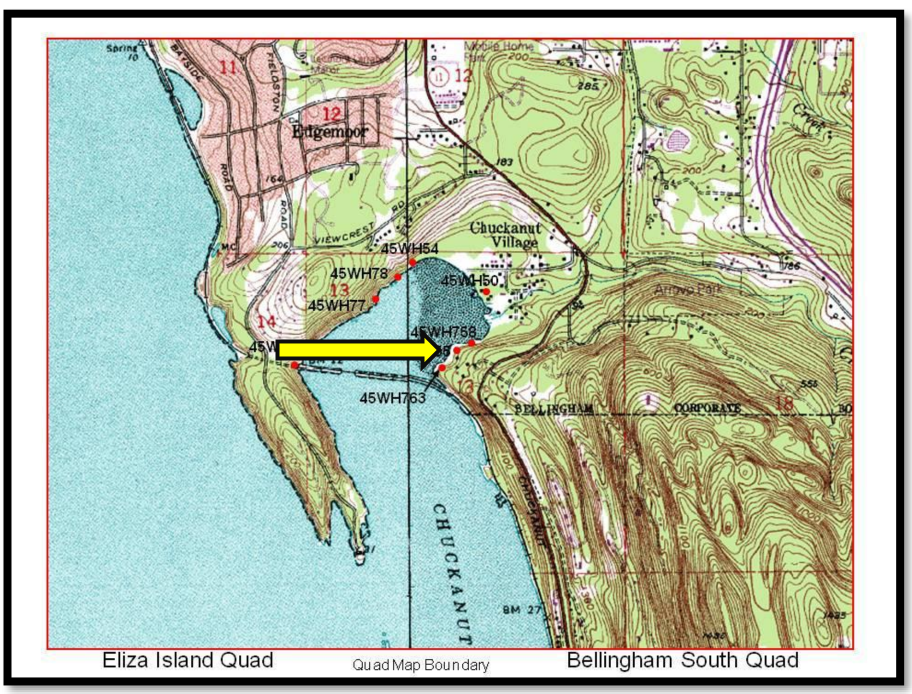


Figure 6. Northern Chuckanut Bay with location of 45WH55 (Campbell et al. 2010).

The shell midden in the exposed beach bank at 45WH55 (Figure 6) has been and continues to be subject to wave erosion, resulting in the undercutting of the base of the slope and the destruction of the midden (Figure 7). The accumulation of sediments from the installation of the railroad trestle has resulted in a shallower and muddier bay than in the past; the bay during the Locarno Beach and Marpole phases would have been deeper and sustained a rockier shoreline; this hypothesis is supported by the presence of barnacle (*Balanus sp*.) and native oyster (*Ostrea lurida*) in the two radio-carbon dated charcoal samples from the shell midden, #12 and #23A (**Appendix D**). The approximately 2-meter depth of the shell midden, dense with shellfish and the burnt remnants of cooking, demonstrates the rich resources of the past aquatic environment that attracted pre-contact Indigenous peoples to the coastline of 45WH55.

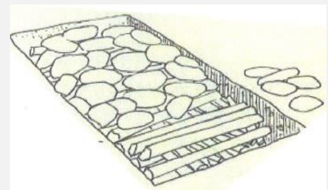
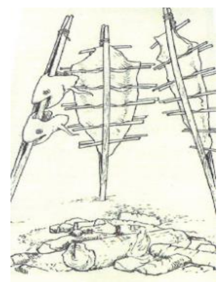
Figure 7. 45WH55 beach profile shell midden that is the subject of this thesis research. The area circled demonstrates the undercutting and erosion of the profile by wave swash.

Indigenous and Euro-American History

Wayne Suttles (1951) describes the Chuckanut Bay and the surrounding environs as home for the Straits Salish peoples, including the Lummi, Nooksack, Nuwaha, and Samish. Chuckanut Bay in particular was the northernmost boundary of the Samish exclusive use area and the southernmost boundary of the Lummi exclusive use area, and likely there was much interaction between kin groups for resource extraction and exchange (Griffin 1984; Lewis 2013; Suttles 1951). The Woodstock Farm property exhibits many of the characteristics that make for a desirable settlement, including salt water frontage with access to shellfish; proximity to fresh water; nearby forest rich in game and plant materials; and sufficient buildable area in a defensible location above the high tide line (Wallace 2017).

Ethnographic studies of Northwest Coast peoples by Franz Boas (1921) in the early twentieth century indicate that shellfish were eaten raw, roasted, dried, or steamed for consumption (Larsen 2015). Table 2 summarizes the three main types of shellfish cooking techniques and processes used by Coast Salish peoples and describes how the material remains of those processes (archaeological features) may be expressed in shell midden stratigraphy (Larson 2015; Muckle 1985; Shantry 2005). The archaeological features that result from pit baking, whole roasting, and steam baking will contain similar constituents, therefore structural feature classes will and often do overlap (Shantry 2005).

Table 2. Ethnographic examples of cooking techniques with corresponding shell midden features (Image modified from Shantry 2005: Figure 21).

Shellfish cooking technique	Process	Ethnographic Example	Shell midden feature
Pit-baking	• A shallow pit filled with stones, stones cleared and food mounted with boughs and mats, mats and dirt steamed on top of coals until steam and heat evaporated.	**Rock Oven** 	• Fire cracked rock, charcoal, and burnt shell (Royal BC Museum 2018). 
Roasting whole	• Food roasted before an open fire on single cooking sticks.	**Hearth** 	• Tan layer of ash bound with burnt and whole shell (Royal BC Museum 2018). 
Steam-baking	• A shallow pit filled with stones, stones cleared and food mounded with boughs and mats steamed on top of coals until ready to eat. • Clams: 2 forked sticks with a horizontal stick laid across for support, steamed on hot rocks and covered with mats.	**Steam Pit** 	• Discreet ash lenses (Stewart 1977). 

Shell middens were also periodically burned for purposes of disposal and sanitation; evidence of this type of burning can be found in lenses or strata where shells are gray and black and appear burnt (Larsen 2015; Muckle 1985). The previous studies of 45WH55 by Campbell et al. (2010), Lewis (2013), and Pierce (2011) demonstrate the long occupation of the site and multi-task activity areas (including cooking), with people taking advantage of the rich aquatic, terrestrial, and vegetative resources in the area.

Figure 8. Close up view of a shell midden with a tan layer of ash dumped after the cleaning out of a fire hearth (Image courtesy of the Royal BC Museum).

Site 45WH55 is part of a larger complex of pre-contact shell midden sites on the southeastern portion of Mud Bay, including 45WH758 and 45WH763 (Figure 9). Cyrus Gates, a prominent Fairhaven parks and public works leader, purchased the various parcels that constitute the site in 1907 and built a farm that included a home, six outbuildings, and a boat house. The property was purchased by the city of Bellingham in 2004 for a park, and with the assistance of Western Washington University has worked to research and protect the prehistoric resources on the property (COB website 2018).

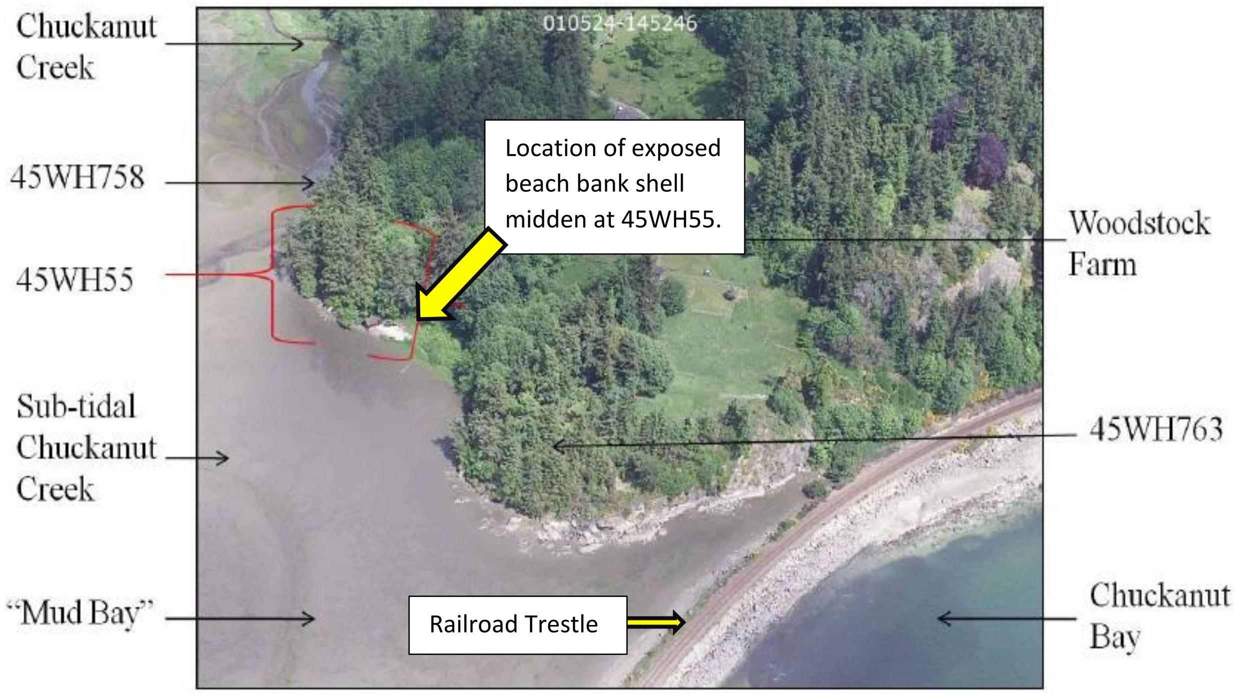


Figure 9. Aerial View of the sites at Woodstock Farm and surrounding environs (Image modified from Campbell et. al. 2010: Figure 21).

WWU Field Schools: 2005, 2007, and 2010

45WH55 at the Woodstock Farm site was first identified by C. Gaston and J. Swanson in 1974 (Gaston and Swanson 1974) and the site was the subject of WWU's archaeological field schools in 2005, 2007, and 2010 (Campbell and Koetje 2005). Updates to the original archaeological site form (**Appendix A**) were submitted to the Washington State Department of Archaeology and Historic Preservation pursuant to a State Excavation Permits Nos 05-11, 07-13, and 2010-22 (**Appendix B**). Excavations in 2005 included a number of shovel test pits (STPs) and nine 1 x 1 meter test units. Ten test units were opened during the 2007 field school, and an additional nine excavation units (EUs) were excavated in 2010. The deposits contained significant horizontal variation in the types of artifacts and features, suggesting the presence of multiple and intact activity areas (Campbell et al. 2010). Pit hearths, surface hearths, and a pit house feature were identified in the EUs. Campbell et al. did discover layers of crushed, compact shell and charcoal, but the deep and alternating layers of ash, charcoal, and shell that characterize the beach bank midden were not seen in the EUs in the upper bluff. This research completed by Campbell et al. was done to better delineate the boundaries of 45WH55 and understand the depositional nature of the site. Graduate theses by Pierce (2011) and Lewis (2013) have explored settlement and subsistence patterns of the peoples who lived on Chuckanut Bay pursuant to the data and materials collected in the three field schools.

Gaston and Swanson (1974) also identified the exposed beach bank shell midden as part of 45WH55 (Figure 9), though Campbell et al. (2010) did not identify a physical connection between those deposits and the deposits in the EUs on the bluff. Sixty four bulk samples of ash, charcoal, shell, and sand were collected on July 30 and 31 of 2010 throughout the 2-meter deep (approximately four square meter) beach bank shell midden profile. The field work is described in additional detail in Chapter 5: Methods. Selected subsamples from the sixty four shell midden matrix samples collected by Dr. Campbell from the beach bank profile are the subject of this research.

The goal of this thesis is to use geoarchaeological analyses to aid in identifying the past human subsistence activities that created the distinct and repeating layers of shells, ash, and charcoal in the midden profile. Accepting the premise that depositional and post-depositional processes can be understood by studying the physical and chemical properties of a site, I describe the natural and cultural setting that enabled Coast Salish people to live and thrive at the Woodstock Farm Site. The ability to explore my hypothesis and research questions is possible because the documentation and sample collection from the beach bank shell midden was systematically conducted, and the complexity of stratigraphy carefully recorded. This initial data collection in combination with the geochemical and geophysical tests provide a context to evaluate the repeating, anthropogenic events that resulted in the stratigraphy exhibited by the shell midden, and determine if this portion of 45WH55 is contemporaneous with the component of the site documented on the upper terrace (Campbell et al.

2010; Lewis 2013). Ultimately, this research will add to our knowledge of how the site and resources present at 45WH55 were successfully exploited by the people who lived there.

Chapter 4: Geoarchaeology and a Discussion of Methods

In this chapter, I provide a broad overview of the practice of geoarchaeology within the framework of geochemical and geophysical investigations of Northwest Coast shell midden site formation. I describe the archaeological literature that demonstrates the efficacy of correlating amounts of elemental phosphorous (P) to anthropogenic impacts to the landscape, and describe how magnetic susceptibility provides a means for investigating the development of anthropogenic soils and, as a result, site formation processes. Following this review, I discuss how the accompanying grain size analysis complements elemental (P) extraction and magnetic susceptibility measurements in determining the type of energy and environment that accompanied the human activities that resulted in the complex stratigraphy of the beach bank shell midden at 45WH55.

Geoarchaeology and Northwest Coast Shell Middens

The discipline of geoarchaeology is the application of concepts and methods of the earth sciences, especially geology, geomorphology, hydrology, sedimentology, and pedology to archaeological problems (Leach 1992). The scope of its practice includes documenting site stratigraphy, determining site formation processes, and reconstructing the interactions between humans and their landscapes (Rapp and Hill 2006). Geoarchaeology is critical to understanding the archaeological record, because the sedimentary matrix of a site provides contextual information with which to understand artifacts, understand what events have transformed the original record of human activity, and help to understand why prehistoric peoples chose the locations they did (Waters 1992; Stein and Farrand 2001; Huckleberry 2006; Rapp and Hill 2006). The features of archaeological sites are found in their stratified state, one layer, or strata, upon the other, and it is within these layers that the investigation of our human past begins (Harris 1979).

Lewis Binford (1964) emphasized that archaeological sites vary in their depositional history, and also emphasized the importance of evaluating the processes that have impacted the archaeological record. The Uniformity Principle, a theoretical system presented by the geologist Charles Lyell in the 1830's, stated that current depositional environments can be compared to with those of past environments to postulate about past conditions (Camardi 1999; Rapp and Hill 2006). The geomorphology of coastal and marine depositional settings are subject to three main geological processes: 1) changes in sea level; 2) tectonic movement's impact eustatic rise and fall; and 3) erosion driving the migration of the shoreline (Easterbrook 1970). This thesis research focuses on the structure-forming processes of a coastal shell midden.

The appearance of shell middens around the world's aquatic landscapes by the late Pleistocene and early Holocene was coterminous with the development of sophisticated fishing and seafaring technologies by human populations (Erlandson 2013). Shell middens are anthropogenic soils found in marine, lacustrine and riverine settings which exhibit stratigraphy resulting from the deposition of shells, bones, artifacts and other myriad features of human activity (Ham 1982). The bivalve shells present in middens provide valuable information about past peoples diets, the size of the population that was being fed, the types of technology used for processing the shellfish, the seasonality of the site, trade, and social organization (Muckle 1985). This type of information helps archaeologists establish regional chronologies for human occupation and discover patterns of cultural change (Rosendahl et al. 2014).   Figure 10 demonstrates how archaeological sites are dynamic entities engaged in energy exchanges with both the natural and cultural environment (Ham 1982), subject to change from events on both geological and human time scales. The shell midden in the exposed beach profile at the Woodstock Farm Site affords ample opportunity to employ Binford's middle range theory (1977) to connect static data to dynamic formation processes and thereby understand the material archaeological record of 45WH55.

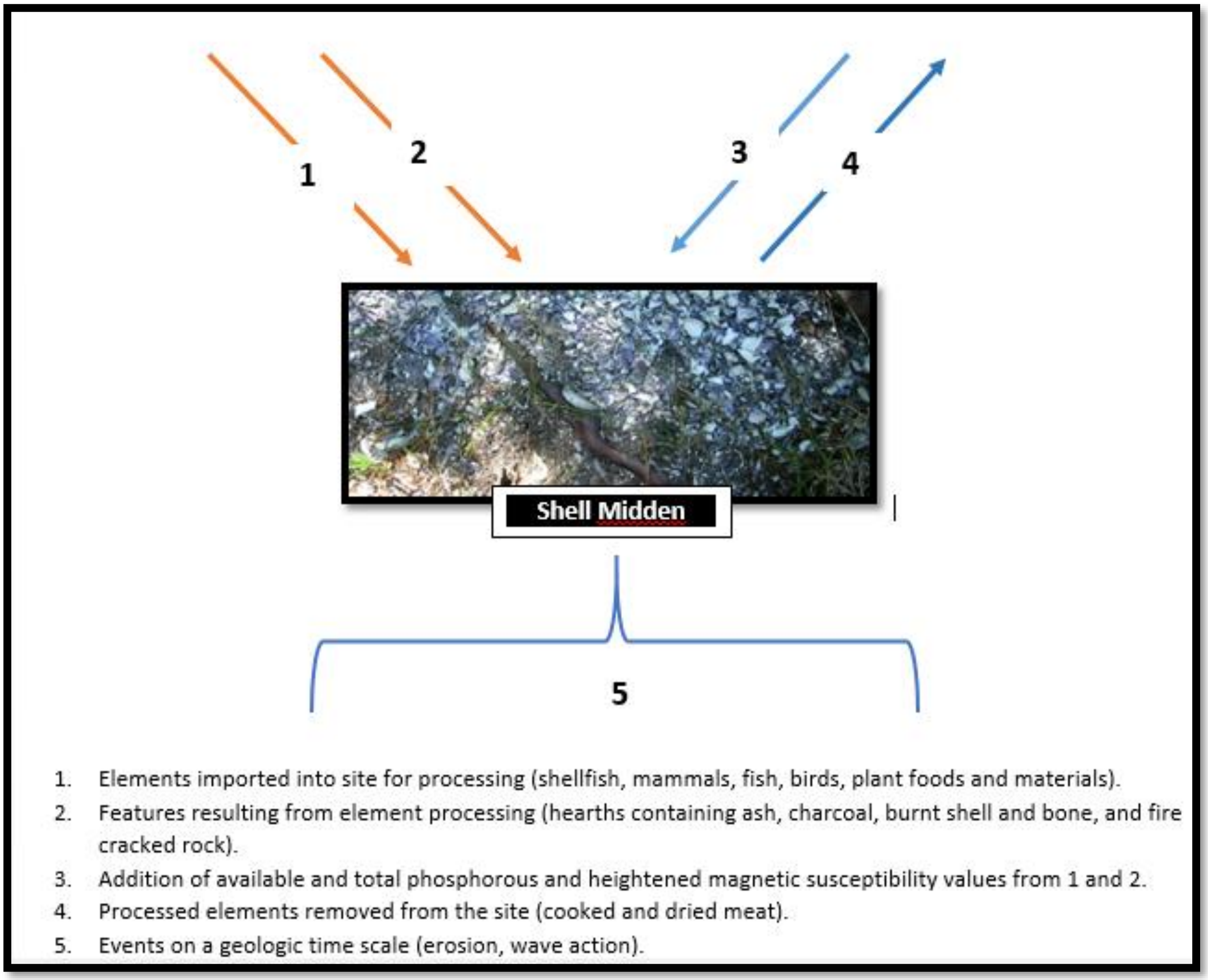


Figure 10. Elemental flow of a shell midden (modified from Ham 1982).

Northwest Coast peoples exploited shellfish for thousands of years, leaving behind a material record of shell middens in archaeological sites (Deo et. al. 2004, Stein 1992). Shell middens on the Northwest Coast primarily consist of shell, rock, bone, charcoal, plant remains, artifacts, and archaeological features like hearths and house posts (Carter 2016; Trant et. al. 2016). The investigation of coastal shell middens can be hampered by inundation from rising sea levels, slump and wave erosion, modern development that excavates and removes ancient deposits, and stratigraphic complexity (Taylor et. al. 2011).

Relatively recent work on Northwest Coast shell middens has taken more advantage of geoarchaeological methods for site prospection, laboratory analysis, and subsequent reconstruction of ancient shorelines and pre-depositional topography (Whittaker and Stein 1992). Geophysical methods like magnetic susceptibility aid archaeologists in understanding the reducing environment that resulted in burnt soils (Aitken 1974), and geochemical methods like phosphorous analysis are the most commonly used indicator for anthropogenic change in soil, because it is a stable element and is very prevalent in faunal tissue, feces, and human bones (Huisman et. al. 2009: 36). My goal was to use phosphorous amounts in combination with magnetic susceptibility measurements to elucidate connections and repetitions between the human activities that created the stratigraphy of the shell midden at 45WH55.

Discussion of Methods

Phosphorous Analysis

Archaeology is the practice of interpreting humankind's history by studying the material remnants of the past (Feder et. al.1998). Applying geochemical methods to archaeological problems aids in our understanding of the cyclic flow of individual elements between living and nonliving systems. This desire to connect the living and nonliving is at the heart of archaeological research, and can lead to researchers being able to interpret the "whys" of human behavior from the material past. Human activities modify the chemical makeup of sediments, and combining micro-level data like phosphate amounts with macro-level data such as geological landforms, spatial distributions of artifacts, and faunal remains can be used to create a more complete picture of the past (Jakes 2002; Rapp and Hill 2006).

Human activities such as farming, burials, and cooking can enrich or deplete the soil of macronutrients, including elements like potassium, nitrogen, calcium, magnesium, and phosphorous (Holliday and Gartner 2007; Rapp and Hill 2006). Sediment chemistry is used to discover post-depositional changes to archaeological sites, distinguish natural from anthropogenic deposits, and explore spatial patterning (Carter 2016; Holliday and Gartner 2007; Middleton 2004; Moss 1984; Parnell et. al. 2002; Rapp and Hill 2006; Stein 1982; Terry et. al. 2000). Relatively recent applications include using the technique for site survey, detecting activity areas, and measuring occupational intensity (Holliday and Gartner 2007; Huisman et. Al. 2009; Parnell et. al. 2002; Sanchez-Vizcaino and Canabate 1999; Stein 2008; Sterling at. al. 2008; Terry et. al. 2004). Phosphorous is a chemical element with the symbol "P" that is essential for life, and it is found in numerous compound forms (compounds containing the phosphate ion PO_4^3) as a component of DNA, RNA, and phospholipids (Orenda Technologies: 2018). Soil P is a ubiquitous and sensitive indicator of anthropogenic alteration to soils (Carter 2016; Holliday and Gartner 2007; Sterling et al. 2008). Soil naturally contains low levels of P, making variation more prominent (Grossman 2012). Phosphorous that is added to the soil bonds (or is most labile) with aluminum (Al), iron (Fe), and calcium (Ca) when soil pH is between 6 and 7 (slightly acidic), and therefore is less susceptible to leaching and oxidation processes than other common chemical elements that people add to the soil such as carbon, nitrogen, sodium, and other metals (Bethell and Mate 1989; Holliday 2004; Holliday and Gartner 2007; Smith and McGrath 2011). Therefore phosphates are comparatively stable ions that cycle through on a geological time scale, and its accumulation at the site of deposition can help archaeologists reconstruct past human activities (Carter 2016; Eidt 1977; Holliday and Gartner 2007). Holliday and Gartner (2007) caution that soil parent materials already high in phosphorous, such as apatite, can mask signatures of anthropogenic change.

The establishment of phosphorous analysis as a geoarchaeological method began in Europe in the early twentieth century, when researchers recognized the correlation between higher P levels and archaeological sites, with the resulting ability to distinguish settlement types through patterns of phosphate signatures (Bethell and Mate 1989). Rapp and Hill (2006) explain the use of phosphate analysis in the context of geochemical prospecting: levels of phosphates can be applied to use-of-space modeling when features cannot be readily identified through conventional excavation (Figure 12). This thesis accepts the premise from the archaeological literature that phosphate measurements may act as a proxy for human-induced alteration of soils and sediments, and that phosphorous is deposited by humans in proportion to the intensity of site occupation (Marwick 2005).

Forms and Measurements of Phosphorous

Holliday and Gartner (2007) acknowledge the complex and not fully understood chemistry of phosphorous, which has led to a “bewildering array of terms to refer to soil P” (2007:303). The following section describes the element as it applies to understanding and interpreting P signatures in archaeological sites.

The terminology used to refer to phosphorous reflects the make-up of the element (e.g. organic and inorganic P) and its distribution in the biogeochemical environment (e.g. total P, available P) (Carter 2016; Holliday and Gartner 2007). People add phosphorous into the ground through activities like cooking, farming, and waste disposal; phosphorous then has the opportunity bond with other elements and it can exist as organic (contains carbon atoms) or inorganic phosphate ions (Carter 2016; Bethell and Mate 1989). Phosphorous rapidly fixes to elements in the soil (iron, aluminum, manganese, clay and calcium) under both acidic and alkaline environments, and once fixed is subject to negligible amounts of vertical and horizontal migration and no escape as a gas (Chodorowski et al. 2012; Marwick 2005). The result is that phosphates do not easily shift or leach through strata (Ullrich 2007). Substantial amounts of phosphorous are added to the soil by food, human, and animal wastes. Rapp and Hill (2006) state that a phosphorous concentration of 2000 ppm (parts per million) can indicate a burial, and Holliday and Gartner (2007) documented P levels at the San Juan Island, Washington British Camp shell midden site at orders of magnitude greater than non-midden archaeological sites. Table 3 summarizes the types of contexts and activities that enrich the amount of phosphates in the soil, with corresponding cited archaeological studies:

Table 3. Activities and contexts that raise phosphate levels in soils (Table adapted from Carter 2016).

Activity or Context	Archaeological Study
Bones, organic wastes	Middleton and Price (1996)
Burials	Rapp and Hill (2006)
Fish processing areas	Frink and Knudson (2010)
Hearths, burning, ash from fires	Middleton and Price (1996); Rapp and Hill (2006)
Kitchen / Food consumption areas	Fernandez et. al. (2002)
Shells	Holliday and Gartner (2007)

The two primary applications of phosphorous analysis in archaeology are measurements for "available P", or Pav and "total P", or Ptot. Available P describes the amount of phosphorous in the soil that is readily available for plants to use; it is a rough indicator of the amount of phosphorous in the soil because it measures weakly absorbed P (Carter 2016) but does not necessarily measure anthropogenic inputs i.e. the soil phosphorous that exists in a stable chemical compound (Holliday and Gartner 2007). Total P is the sum of inorganic and organic P in a sample. Total P, or Ptot, measures both mobile and stable components in a sample, capturing phosphates that are absorbed and immobilized as well as weakly absorbed phosphorous (Carter 2016). Measurements of Ptot may be the best indicator of human alteration of the landscape, because phosphorous that is added to the soil bonds to other elements and as a result is persistent on a geologic time scale (Bethell and Máté 1989; Skinner 1986). Holliday and Gartner (2007) caution that soil parent materials already high in phosphorous, such as apatite, can mask signatures of anthropogenic change.

Accompanying the "bewildering array" and sometimes inconsistent use of terms to identify soil phosphorous and phosphates (Holliday and Gartner 2007) are the myriad of methods that may be employed to extract it, including the use of perchloric acid digestion, sulfuric acid, hydrogen peroxide, and hydrofluoric acid (Holliday and Gartner 2007; Macphail et. al. 2000). Inductively Coupled Plasma (ICP) spectrometry is a relatively new method to measure Ptot, and it is rapid, safe, and affordable method in comparison to past tedious and sometimes dangerous chemical procedures to extract phosphates (Carter 2016; Holliday 2004). ICP is based on atomic spectrometry: samples are ionized with inductively coupled plasma, and the excited atoms in the sample emit energy at a given wavelength that corresponds to the amount of the element in the sample (Vallapragada et. al. 2011). This thesis employs ICP to measure Ptot in the subject samples in order to help differentiate between the depositional events that created the shell midden, and ultimately to determine if phosphorous amounts in combination with magnetic susceptibility measurements can elucidate connections and repetitions between the human activities that created the stratigraphy.

Comparative Studies

This section provides examples of phosphorous analysis applied to understanding a variety of archaeological sites, including Holliday's testing of different phosphorous extraction methods at the British Camp Site (Holliday 2004; Holiday and Gartner 2007); Steins study of depositional patterns at the Green River Shell Mounds (1982); Lombardo et al. identification of the anthropogenic origin of the Western Amazonian shell middens (2013); Smith and McGrath's determinations of altered surface soils due to the presence of shell middens (2011); and two case studies from the central British Columbian coast (Trant et al. 2016 and Carter 2016). Shell middens change the physical structure of soil pursuant to increased drainage, the deposition of charcoal, and the release of $CaCO_3$ from degrading shells. I also describe the results of phosphorous tests during a salvage archaeological operation on the Olympic

Peninsula (Sterling et. al. 2008). I conclude this section and the following section describing magnetic susceptibility with my expectations for the soil testing completed for this thesis.

Phosphorous Analysis outside the Northwest Coast

Lombardo et. al. (2013) used levels of phosphorous in shell midden deposits in Western Amazonia to identify early Holocene human occupation. The archaeologists conducted a program of geomorphological analysis, soil chemistry testing and faunal analysis in order to theorize about the time of human occupation of the sites and the types of human activities taking place within the site. The middens yielded phosphorous amounts in the same range as the total P amounts documented by Holliday and Gartner (2007) in the shell midden at the British Camp site, largely due to inputs of burnt residues. The authors draw conclusions about the dramatic environmental changes taking place in the middle Holocene and its impacts on the Amazonian populations.

Smith and McGrath (2011) discovered that surface soils at a shell midden site in Georgia exhibited high concentrations of P, because P is most labile (bound) with an element like Ca in soils with a pH between 6 and 7. The middens demonstrated a slightly acidic nature (6.7), and this in combination with the high Ca concentrations due to the slow release of calcium from degrading shells (Trant et. al. 2016) resulted in high phosphorous measurements. The authors conclude that even thousands of years after their abandonment, shell middens continue to have a dramatic impact on soil chemistry.

Stein (1982) used phosphorous analysis as one in a suite of geoarchaeological methods (including pH measurements, clay mineralogy, and grain size distribution) to define both the natural and cultural formation processes that were operating during the deposition of the Green River shell middens on the Ohio River. Stein presents a reconstruction of the paleoenvironment that resulted in the build-up of the middens, and draws conclusions about the subsistence strategies of the people who created the sites.

Phosphorous Analysis on the Northwest Coast

Trant et al. (2016) also concluded that the long term deposition of shellfish and other animal remains at two shell midden sites on the central coast of British Columbia greatly modified the soil pH. The addition of $CaCO_3$ from the decomposition of the shells and the charcoal from fires increased phosphorous levels. The combination of increased soil pH, higher concentrations of phosphorous, and increased site drainage altered the surrounding soil chemistry into a more nutrient-rich system.

Carter's thesis (2016) explores phosphate as an indicator of occupational intensity at a number of shell midden sites on the central coast of British Columbia, similar to the work Moss (1984) conducted at multiple sites on Admiralty Island in Alaska. Though not specific to intrasite variation like the research with this thesis, Carter discovered that phosphate levels at the sites did reflect previously inferred patterns about how frequently and for how long accumulation of the midden took place, with somewhat positive linear relationship between high fish bone densities, larger site areas, and higher P levels. The objective of the research was to apply a phosphorous testing program at a scale of analysis not typically investigated.

Phosphorous Analysis in the Gulf of Georgia

Holliday (2004) compared different phosphorous testing methods through analysis of sediments from the British Camp site, a large shell midden located on San Juan Island. The midden produced soil P values at orders of magnitude greater than values measured at non-midden sites. Holliday cautions about the use of specific P values to infer specific human activities, because variability in the type of organic discard (regardless of activity) can affect the forms and redistribution of P. Holliday's study focuses on the method as a tool for intersite analysis.

Sterling et. al. (2008) compiled geoarchaeological data from the Tse-whit-zen site on the Olympic Peninsula, and measured phosphorous in combination with radiocarbon dating and changes in the percentage of organic matter over time to determine intrasite function and reasons for eventual abandonment of the site. They discovered evidence for periods of episodic population abandonment across all three classes of data, which may have been subsequent to regional resource depression, tectonic events, or storm surges.

The next section explores the efficacy of magnetic susceptibility measurements in archaeological soil research, and my expectations that the susceptibility levels will complement analysis of phosphorous levels and aid in differentiating between depositional events expressed in the shell midden.

Magnetic Susceptibility

Low field magnetic susceptibility, referred to most commonly in the literature as simply magnetic susceptibility, is a measure of a material's ability to be magnetized (Dalan 2006; Dalan and Banerjee 1998; Dearing 1999). The susceptibility readings, collected in SI or Systeme International d'Unites, is a dimensionless measurement that indicates the degree of magnetization of a material in response to an applied magnetic field (Grossman 2012; Rapp and Hill 2006). The magnetic susceptibility of a material, symbolized by X_m, is equal to the ratio of the magnetization M within the material to the applied magnetic field strength H, or $X_m = M/H$. Magnetic enhancement of soils, like the enrichment of soil with phosphorous, is often the result of anthropogenic input: for purposes of this research, of interest are the magnetic susceptibility measurements of soil altered by human-generated fires (Dalan 2006; Dearing et. al. 1996). Burning produces an enhanced magnetic signal, and fire ash produces fine-grained magnetic iron oxides that exhibit high susceptibility values (McClean and Keen 1993).

Le Borgne (1955) was the first to note increased magnetic enhancement of burnt soil. The minerals that contribute most to the magnetic character of soil are hematite, maghemite, and magnetite (Fe_3O_4). Hematite, a mineral consisting of ferric oxide, converts to the ferromagnetic mineral magnetite in reducing environments, such as hearths (Dalan 2006; Rapp and Hill 2006). The magnetic susceptibility of a sample subject to burning therefore depends on the mineralogical transformation of the iron oxides; the higher the attained temperatures, the stronger the magnetic susceptibility of the transformed iron oxides. (Brodard et. al. 2012). Dalan's groundbreaking electromagnetic research of the Mississipian-era Cahokia Mounds in Illinois in the 1990's documented dramatic landscape alteration and creation of Cahokia as the center of the American Bottom region (Holley et. al. 1993).

Magnetic susceptibility can be measured in both the field and laboratory. The Bartington Instruments MS2 system with the accompanying Multisus program used for this thesis research measures and records the susceptibility i.e. the contribution of ultrafine magnetic grains in a sample (Dalan 2008). The following section discusses four case studies where magnetic susceptibility measurements in concurrence with other geophysical and geochemical tests (including phosphate analysis) have provided archaeologists with answers to questions about shell midden formation, site occupation, and ancient hearth use (Figure 13).

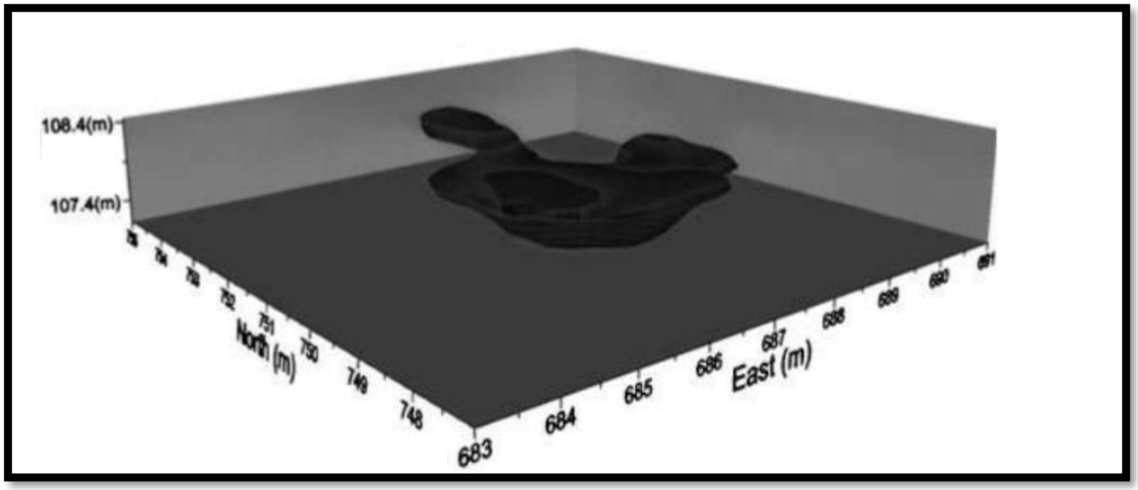


Figure 11. A three-dimensional representation of high magnetic susceptibility values for a buried structure with a fired daub, floor, and reduced subfloor (Dalan 2008).

Comparative Studies

Marwick (2005) explored changes in phosphorous levels and the magnetic susceptibility of sediments in a prehistoric rock shelter in Western Australia in concurrence with the discard rate of artifacts in Western Australia to determine the frequency of site use. Marwick concludes that increases in phosphorous and magnetic susceptibility indicate an increase of frequency of use of the site (frequency being his proxy for intensity), and as a result representative of increases in regional population density.

Grossman (2012) employs magnetic susceptibility, phosphorous analysis, and other geophysical field methods to hypothesize about the site organization of a Late Middle Woodland culture site in Indiana. Grossman identified higher magnetic susceptibility values based on feature contents (ceramics and fire cracked rock), and was able to differentiate between different activity areas using extractable phosphorous amounts.

Rosendahl et. al. (2013) measured the magnetic susceptibility of samples from three shell middens on Mornington Island in Australia. They discovered a strong relationship between depositional processes and magnetic properties at all three of the middens: samples rich in artifacts and burnt matrix had the highest susceptibility. However, Rosendahl et al. did not discover a correlation between fine-grained magnetic grains and increases in susceptibility.

Lowe et. al. (2016) combined soil magnetic studies with experimental burning to resolve the length of human occupation of rockshelter in Northern Australia. They conclude that increased susceptibility measurements are a result of elevated charcoal amounts, increased phosphorous concentrations, and use of fire.

Expectations for Research

Northwest Coast shell middens are stratigraphically complex, varying in size, distribution and form. The goal of understanding the time and rate of their accumulation has prompted the development of many innovative geoarchaeological testing strategies (Carter 2016; Stein et. al. 2003). This thesis project begins with the hypothesis that the exposed beach bank shell midden at 45WH55 is the result of in-situ deposition, with repeating human subsistence activities creating the accumulation patterns visible in the profile (Figure 12). A visual examination of the strata reveals repeating lenses of ash, clusters of fire cracked rock, charcoal, and burnt shells that align with ethnographic descriptions of shellfish processing, cooking, and discard (Boas 1921; Larsen 2015; Muckle 1985).

When used as a reconnaissance tool or to investigate activity areas (Ullrich 2018), phosphate analysis is made even more useful when accompanied with soil magnetic studies (Rapp and Hill 2006). Phosphorous is useful as an indicator of human occupation because it is an element deposited by people through their activities of living on the landscape (Table 3). Magnetic susceptibility is used as a measure of the intensity of firing of anthropogenic sediments and artifacts. Combining both data sets can assist researchers in differentiating between not just natural and cultural depositions, but can also help determine frequency of use of the site. Sediments with high Ptot and magnetic susceptibility may represent features that were frequently fired (hearths) and subject to reuse (Marwick 2005).

Applications of magnetic susceptibility methods to shell middens are limited, and it has rarely been used on the Northwest Coast for the purposes of understanding the depositional contexts. I would expect to see the samples subject to the most thermal alteration (the ash samples) exhibit both high susceptibility values and high phosphorous content. Diminishing values should correspond with layers not subject to high-temperature burning.

Chapter 5: Methods

In this chapter I describe how both geochemical and geophysical soil tests were used to characterize the depositional processes that created the stratigraphy present in the exposed bank at the Woodstock Farm Site (45WH55). I describe the methods used to test the hypothesis that the exposed beach bank at the Woodstock Farm site (45WH55) represents a place of intensive and repeating shellfish collection, processing, and discard created by anthropogenic, in-situ deposition. The objectives of the tests are to identify archaeological features related to Coast Salish subsistence activities, and determine if the repeated layers of ash, charcoal, sand, and shell in the beach bank are contemporaneous and connected to the human activities that created the Locarno Beach-phase archaeological site located on the upper terrace (Lewis 2013). The following sections describe the field methods employed to collect soil samples from the bank; the sampling methodology used to determine which soils should be subject to testing; and the geoarchaeological laboratory methods used to test the selected samples, including: 1) AMS RC dating, 2) grain size analysis, 3) phosphorous analysis, and 4) magnetic susceptibility. Chapter 6 presents the results of the statistical analysis used to determine if the data indicated in-situ deposition and categorizes the depositional units into cultural assemblages. Chapter 7 draws conclusions about the site type and dates of occupation through paleoenvironmental reconstruction. I finish the manuscript by describing opportunities for future research in the southern Gulf of Georgia region that connect environmental changes to shifts in subsistence and settlement patterns.

Field Methods

The shell midden in the exposed bank at the Woodstock Farm site was first identified in 1974 (Gaston and Swanson 1974), and the site was the subject of WWU's archaeological field schools in 2005, 2007, and 2010 pursuant to State Excavation Permits from the Washington DAHP (Campbell and Koetje

2005) (**Appendix B**). Sixty four bulk samples of ash, charcoal, shell, and sand were collected on July 30 and 31 of 2010 by Dr. Campbell throughout the approximately four square meter shell midden profile (**Appendix C**). One bag of sand, nine bags of ash, thirty-one bags of charcoal, and twenty three bags of shell were collected, and descriptions of location, matrix, and contents were completed (Table 4 and **Appendix D**). Campbell (2010) produced three stratigraphic drawings, each demonstrating the collection points of the ash, sand, charcoal, and shell samples throughout the exposed beach bank (**Appendix E**).

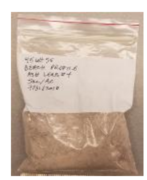
Laboratory Methods

I selected twenty-five bulk soil subsamples from the sixty-four samples collected in 2010 pursuant to stratified sampling to be the subject of my geoarchaeological testing program. Each bulk soil sample was assigned to a mutually exclusive category (sand, ash, charcoal, and shell) by Campbell (2010); I maintained these categories for my subsamples. Each of the categories reflects the type of constituent that dominates the deposit. Subsamples selected for my research program were chosen from each categories based on the following three criteria:

1. A visual examination for the presence of burnt material in a large enough size and quantity that could be evaluated for radiocarbon dating, phosphorous analysis, and the magnetic susceptibility tests.
2. Samples were chosen across the entire exposed bank in order to understand the full depositional history.
3. The single sand sample from the bottom of the profile is assumed culturally sterile and served as a control for the tests.

I selected seven ash samples, one sand sample, nine charcoal samples, and eight shell midden samples. Table 4 and **Appendix D** were produced to standardize the descriptions of the samples originally collected and documented by Campbell in 2010 and includes the bag number, the depth of the selected sample from the top of the profile, a description of the contents and matrix, the Munsell color, and a lab photograph of the twenty five subsamples selected for this thesis research. Campbell evaluated Munsell colors in 2010 for the ash samples; I completed Munsell color descriptions for the subsamples chosen for my thesis research. Figure 12 is a stratigraphic drawing demonstrating the location within the profile of each of collected samples.

Table 4. Soil subsample characteristics.

Bag Number	Distance from ground-level (cm)	Dimensions (Length X Width in cm) and Contents	Continuity and Boundaries	Munsell Color	Photograph of Sample
ASH LENS DESCRIPTIONS					
1	140 cm to 130 cm	40-50 cm X 3-10 cm Fine roots, shell fragments, and pebbles.	<u>UPPER</u>: Charcoal #11 and Shell #31 <u>LOWER</u>: Shell #32 and Shell #33	10YR/6/3: Pale brown.	
2	130 cm to 123 cm	80 cm X 2-7 cm Fine roots, shell fragments, and pebbles.	<u>UPPER:</u> Shell #32 and #33 <u>LOWER:</u> Charcoal #12 and Shell #34	10YR/5/2: Grayish brown.	
3	95 cm to 85 cm	50 cm X 3-10 cm Fine roots, shell fragments, pebbles, and charcoal.	<u>UPPER:</u> Charcoal #13 <u>LOWER:</u> Charcoal #14	10YR/5/2: Grayish brown.	
4	70 cm to 64 cm	65 cm X 2-6 cm Fine roots, shell fragments, sandy ash, and fine ash.	<u>UPPER:</u> Shell #37 <u>LOWER:</u> Ash #s 5A and 5B	10YR/7/2: Light gray.	
6A	65 cm to 48 cm	180 cm X 2-8 cm Burnt shell and no pebbles. Ash #6B is a lens within Ash #6A.	<u>UPPER:</u> Shell #47 and Ash #5B <u>LOWER:</u> Charcoal #15A and Shell #47	10YR/5/2: Grayish brown.	
7	10 cm to 1 cm (0 cm = ground level)	49 cm X 2-8 cm	<u>UPPER:</u> Shell #46	10YR/4/4: Dark	

		Concrete-like, fine ash, and tiny shell fragments.	LOWER: Shell #46	yellow brown.	
8	-8 cm to - 12 cm	27 cm X 1-4 cm	UPPER: Charcoal #25	10YR 4/3: Brown	
		Wet, sandy, some tiny shell fragments, and burnt sandstone.	LOWER: Sand Sample		
SAND SAMPLE DESCRIPTION					
SS (Sand Sample)	-10 cm to – 22 cm	NOT RECORDED	UPPER: Ash #8	10YR/5/6: Yellowish brown.	
		Unburnt shell fragments and sand.	Charcoal #27		
CHARCOAL LENS DESCRIPTIONS					
11	140 cm - 138.5 cm	4 cm X 1.5 cm	UPPER: Shell #31	10YR/2/2: Very dark brown.	
		Burnt wood and small twigs.	LOWER: Ash #1 and Shell #33		
12	123 cm – 121.5 cm	30 cm X 1.5 cm	UPPER: Ash #2	10YR/3/1: Very dark gray.	
		Large pieces of broken shell fragments.	LOWER: Shell #34		
13	95 cm – 92 cm	52 cm X 1-3 cm	UPPER: Shell #34 and FCR	10YR/2/1: Black.	
14	90 cm to 89 cm	35 cm X 1 cm	UPPER: Ash #3	10YR/4/1: Dark gray.	
		3 sections containing very fine charcoal and tiny broken shell fragments.	LOWER: Shell #35.		
17A	43 cm to 38 cm	48 cm X 1-5 cm	UPPER: Shell #38A	10YR/2/1: Black.	
		Very fine charcoal mixed with small shell fragment and burnt wood.	LOWER: Shell #40A		

		Fine charcoal mixed with larger pieces of charcoal. Lens is segmented and possibly merges with charcoal layer 18.	LOWER: Shell #40		
19	22 cm to 18 cm	46 cm X 1.5 cm	UPPER: Shell #40B	10YR/3/1: Very dark gray.	
23A	16 cm to 12 cm	Fine charcoal with large and small shell fragments.	UPPER: Shell #40C	10YR/3/1: Very dark gray.	
26	- 10 cm to – 20 cm	65 cm to 2 – 4 cm Fine charcoal mixed with small mussel shells. Lens is slightly damp.	UPPER: Shell #46 LOWER: Ash #8 and Sand Sample	10YR/5/1: Light gray.	
27	- 15 cm to – 22 cm	130 cm X 2-5 cm Huge FCRs cross into this charcoal lens. Fine charcoal (slightly damp) mixed with tiny shell fragments. Less concentrated shall fragments than the other charcoal lenses.	UPPER: Sand Sample LOWER: Not excavated	10YR/2/2: Very dark brown.	
SHELL LENS DESCRIPTIONS					
34	122 cm to 93 cm	Very little soil and ash matrix with whole and large burnt shell fragments,	UPPER: Charcoal #12 and Ash #2	10YR/8/1 and 7/1: White and light gray.	

		some charcoal, small pebbles, and fire-modified rock (FRM).	LOWER: Shell #34 and Shell #35		
35	93 cm to 70 cm	Fine sand and charcoal (more than #34) with an ash matrix.	UPPER: Charcoal #14 and Shell #34	10YR/7/1: Light gray.	
		Whole shell and large fragments. nested with ventral side up.	LOWER: Shell #36 and Shell #37		
36	70 cm – 55 cm	Fine sand and charcoal with an ash matrix. Smaller shell fragments compared to Shell #35. FMR present.	UPPER: Shell #35. LOWER: Ash #6A and Ash #17	10YR/7/1: Light gray.	
38	57 cm to 40 cm	Fine sand and charcoal with an ash matrix. Large whole shells near the top of lense, and smaller crushed shells in bottom part of lense.	UPPER: Charcoal #15 LOWER: Charcoal #17	10YR/7/2: Light gray.	
40	30 cm to 15 cm	A cemented matrix with large whole and crushed shell with FCR and small pieces of charcoal.	UPPER: Charcoal #17	10YR/6/1: Gray.	
		Large, dense, nested shells with majority ventral side up.	LOWER: Charcoal #23		

40A	40 cm to 24 cm	Smaller shell fragments with pebbles in a compacted matrix.	<u>UPPER:</u> Charcoal #17 and #17C	10YR/7/1: Light gray.	
40C	21 cm to 17 cm	Smaller shell fragments with pebbles in a compacted matrix.	<u>UPPER:</u> Charcoal #19	10YR/6/1: Gray.	
		Smaller shells than #40B, with majority stacked horizontally.	**<u>LOWER:</u>** Charcoal #23A.		
46	10 cm to -10 cm	Large whole fragments and large whole shell. Pockets of mussel, charcoal, and FCR. The shells are more loosely packed on the north end than the south end.	<u>UPPER:</u> Charcoal #23C,, #23E and #24	10YR/5/1: Gray.	
		Nested with some paired valves.	<u>LOWER:</u> Charcoal #25 and #26		

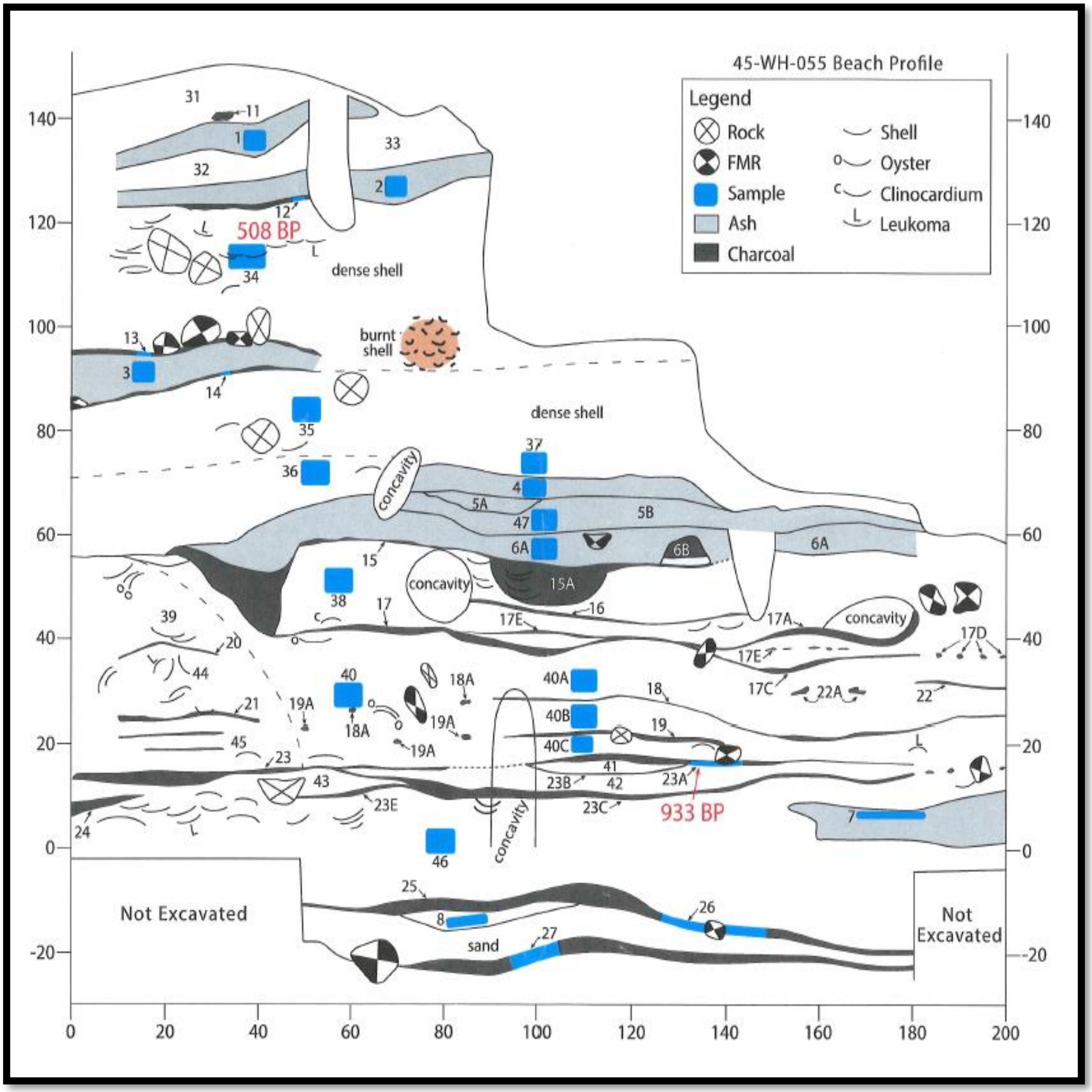


Figure 12. Stratigraphic drawing of beach bank shell midden (Image courtesy of Adrienne Cobb).

Radiocarbon Analysis

I mechanically separated charcoal from all nine of the selected bulk charcoal samples (Figure 15). I chose subsamples based on my ability to separate out the minimum amount of charcoal for AMS radiocarbon dating, and their location throughout the exposed height of the profile. The proportion of large enough portions of charcoal to matrix determined whether it was simple or difficult to extract, in addition to visually differentiating between bits of the matrix stuck together versus actual burned pieces of wood.

Figure 13. Sorting charcoal subsamples in the WWU Archaeology Lab.

Salix Archaeological Services in Seattle, WA identified woody taxa for the selection of testable fragments for radiometric analysis (Shaw 2017) (**Appendix F**). Fragments from bags 12 and 23A were determined to be of a sufficient weight and content for radiocarbon dating, and fulfilled the goal of identifying charcoal from both the upper layer and lower portions of the shell midden so that I could determine a range of dates of site occupation.

DirectAMS Radiocarbon Dating Services in Bothell, WA (**Appendix G**) analyzed the charcoal fragments from Bags 12 and 23A. I discuss the resulting radiocarbon dates and the dates of site occupation demonstrated by the shell midden in Chapter 6 – Results.

Grain Size Analysis

I employed grain size analysis to determine the size of the different particles that constitute the archaeological subsamples. The purpose of this analysis was to determine if a different energy and environment deposited the materials in the exposed beach bank (Lopez 2017) than the natural depositional processes that resulted in the sand subsample assigned as culturally sterile by Campbell in 2010 (Table 4).

Grain size analysis was conducted on twenty four of the subsamples selected for this program of study. Sample #11 is a single large chunk of charcoal, and contained no matrix to analyze; therefore I did not test this sample for grain size. I used the Rotap Sieve Shaker in the Western Washington University Geology Lab to conduct the grain size analysis. The total volume of the each sample was dependent on the amount of soil available for testing; sub samples ranged from as small as 5 grams up to 50 grams. **Appendix H** demonstrates the volume of each subsample tested, the sieve sizes, the mass of soil retained in each sieve, and the calculated percentage of coarse sand, medium sand, fine sand, and silt / clay in each sample. Table 4 averages the percentage of grain sizes in the ash, charcoal and shell subsample categories. The total grain size percentages for the single sand sample are presented as well.

Table 5. Average percentage of grain sizes in ash, charcoal, and shell submsamples and total percentage of the sand sample.

ASH SUBSAMPLES (#'s 1, 2, 3, 4, 6A, 7, and 8)	
GRAIN SIZE	**AVERAGE PERCENTAGE**
Coarse Sand	31.4%
Medium Sand	30.92%

Fine Sand	26.06%
Silt / Clay	8.23%
CHARCOAL SUBSAMPLES (#'s 11, 12, 13, 14, 17A, 23A, 26, 27)	
GRAIN SIZE	**AVERAGE PERCENTAGE**
Coarse Sand	34.96%
Medium Sand	34.47%
Fine Sand	27.67%
Silt / Clay	4.52%
SHELL SUBSAMPLES (#'s 34, 35, 36, 38, 40, 40A, 40C, 46)	
GRAIN SIZE	**AVERAGE PERCENTAGE**
Coarse Sand	70.06%
Medium Sand	19.44%
Fine Sand	8.12%
Silt / Clay	10.36%
SAND SUBSAMPLE (# SS: CONTROL SUBSAMPLE)	
GRAIN SIZE	**PERCENTAGE**

Medium Sand	9.88%
Fine Sand	90.02%

Magnetic Susceptibility

I conducted magnetic susceptibility testing in order to detect the amount of magnetism resulting from the burning of the selected samples. High values of magnetic susceptibility correlate with periods of intense human activity (Aidona et al. 2001).

Magnetic susceptibility testing was conducted on twenty four of the samples selected for this program of study using the Bartington MS-2 dual frequency susceptibility meter in the Paleomagnetism Lab at WWU (**Appendix I**). Figure 14 shows the equipment and software I used in the Western Washington University Paleomagnetism Laboratory. Sample 11 is a single large chunk of charcoal, and there was no ability to test this sample without destroying it; therefore I did not test this sample for magnetic susceptibility. The 6-gram plastic sampling containers were first washed, and then filled with approximately 4 grams of matrix materials from each of the 25 samples. The spatula used to obtain the material for testing was wiped down with chemical-free paper between each sample, to avoid contamination. Total mass was obtained for each sample (charcoal samples generally had less mass than the ash, shell, and sand samples). The susceptibility readings, or Bartington Unit or SI Units, are a dimensionless measurement that indicates the degree of magnetization of a material in response to an applied magnetic field. The resulting unit is a ratio of magnetization (magnetic moment per unit volume) to the applied magnetizing field intensity. The resulting magnetic susceptibility for each tested subsample is listed in Table 5**.**

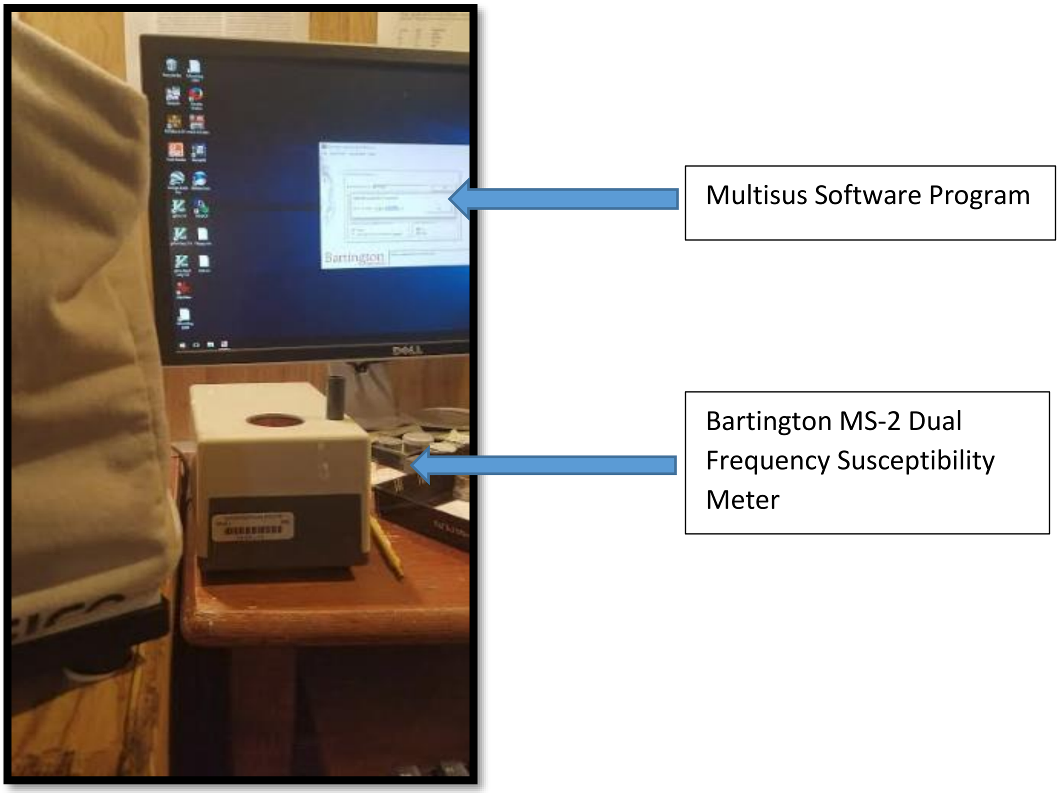


Figure 14. Magnetic Susceptiblity equipment in the Paleomagnetism Lab at WWU.

Table 6. Magnetic Susceptiblity (X_m) of subsamples.

Bag Number	Mass	Magnetic Susceptibility (Bartington Units and SI = X_m)
SAND SAMPLE RESULT		
SS	3.92	42.5
ASH SAMPLE RESULTS		
1	2.39	71.4
2	2.28	49.5
3	2.37	67.7
4	1.65	52.5
6A	2.31	62.1
7	2.26	30.2
8	2.48	75.1
CHARCOAL SAMPLE RESULTS		
12	2.64	5.5
13	1.28	33.3

14	2.82	4.8
17A	1.12	21.9
19	2.00	12.2
23A	1.88	138.8[1]
26	2.73	21.0
27	3.48	11.5
SHELL SAMPLE RESULTS		
34	1.73	-0.1[2]
35	2.23	23.8
36	1.74	16.0
38	2.83	10.9
40	2.11	4.7
40A	2.33	8.8
40C	2.77	7.3
46	1.88	4.7

[1] This result is the average between two different readings taken on two different days.

[2] A negative reading indicates a diamagnetic character (materials repelled by a magnetic field).

Phosphorous (Ptot)

I completed phosphorous testing in order to identify the changes in amounts of total phosphorous (Ptot) in parts per million (ppm) among the selected subsamples. Phosphorous is a commonly-used indicator for anthropogenic change in soils, and phosphorous levels correlate with human activities (Holliday 2004; Huisman et al. 2009).

Figure 15. Soil subsamples for total phosphorous (Ptot) analysis.

Phosphorous testing was conducted on twenty three of the samples selected for this program of study by Edge Analytical in Burlington, WA using inductively coupled plasma (ICP) spectrometry (**Appendix J**). Sample 11 is a single large chunk of charcoal, and there was no ability to test this sample without destroying it. Sample 12 did not contain enough material sufficient for the testing. I did not test subsamples 11 or 12 for Ptot. The 25-gram plastic sampling containers were first washed, and then filled with matrix materials from the 23 subsamples. The spatula used to obtain the material for testing was wiped down with chemical-free paper between each sample, to avoid contamination. The resulting total elemental phosphorous (in mg/Kg, or ppm) of each sample is listed in Table 6**.**

Table 7. Total phosphorous (Ptot) test results.

Bag Number	Total Phosphorous or Ptot (ppm)
SAND SAMPLE RESULT	
SS	125
ASH SAMPLE RESULTS	
1	1980
2	5298
3	5825
4	5026
6A	5879
7	1543
8	2121
CHARCOAL SAMPLE RESULTS	
13	3539
14	1617
17A	1719
19	1358
23A	602
26	372
27	378
SHELL SAMPLE RESULTS	
34	1641
35	1580
36	3233

38	3587
40	290
40A	597
40C	576
46	359

Chapter 6: Results

The methods described in the previous chapter were successfully applied to the subsample assemblage. This chapter presents the results of these analyses beginning with the radiocarbon dates, followed by sections on grain size analysis, magnetic susceptibility, and the phosphorous tests. Statistical tests are used to illustrate the relationship between phosphate levels and magnetic susceptibility measurements, and by accepting these two measurements as proxies for human activity, to determine if the measurements can aid in identifying human subsistence features within the shell midden.

Radiocarbon Dates

I obtained two radiocarbon dates from the subject shell midden in order to understand the chronology of 45WH55 and help better explain the cultural and environmental conditions under which the site formed. Obtaining additional radiocarbon dates was hampered by the paucity of large enough charcoal pieces to date (Shaw 2017).

Salix Archaeology identified four fragments of charcoal in subsample #12A that when combined weighed enough to be radiocarbon dated. Two of the fragments were unidentifiable, but two of the fragments were *Alnus* sp. (alder), documented by Northwest Coast ethnobotanists as the preferred fuel for smoking fish (Shaw 2017; Turner and Bell 1971). Two charcoal fragments from subsample #23A were selected, one being *Lonicera* sp. (twinberry, honeysuckle) and one was *Acer* sp. (maple). *Lonicera* bark and leaves were used for medicinal purposes on the Northwest Coast, and maple was considered a valuable fuelwood by many Tribes (Gunther 1945; Shaw 2017). The sample from charcoal lens #12A (near the top of the profile) was dated to 508 BP and the sample from charcoal lens #23A (near the bottom of the profile) was dated to 933 BP by AMSDirect Radiocarbon Dating Service. The results in Table 7 are in units of percent modern carbon (pMC) and the uncalibrated radiocarbon age before present (BP). Campbell et al. (2010) obtained radiocarbon dates from shell samples in the 45WH55 deposits on the upper bluff, placing the site in the latter half of the Locarno Beach Phase and possibly the early Marpole Phase. Pierce (2011) obtained a radiocarbon date from an excavation unit on the bluff The radiocarbon dates obtained from the beach bank shell midden demonstrate that it is not connected temporally to the potion of 45WH55 located on the bluff (**Appendix G**). Chapter 7 discusses the implications of these results for understanding occupation of the Woodstock Farm Site.

Table 8. Radiocarbon dates of charcoal subsamples #12 and #23A (AMSDirect Radiocarbon Dating Services 2018).

DirectAMS code	Submitter ID	Sample type	Fraction of modern		Radiocarbon age	
			pMC	1σ error	BP	1σ error
D-AMS 026682	Bag 12	charcoal, wood	93.87	0.27	508	23
D-AMS 026683	Bag 23A	charcoal, wood	89.04	0.28	933	25

Grain Size Analysis

This study employed grain size analysis to better understand the depositional history and environmental context for the human activities at 45WH55 (Goldberg and Byrd 1999; Stein 1982). The grain size distribution of a site is an expression of the nature of the sediment deposition; it measures a continuum of grain size classes to determine the type of energy and environment that created the midden matrix. **Appendix H** provides percentages of coarse sand, medium sand, fine sand, and silt / clay in each of the 23 tested sub-samples. Table 9 demonstrates the average percentages for the subsamples in each of the categories: ash, charcoal, shell, and sand. Table 10 demonstrates the grain size percentages across the entire subsample set, excluding the culturally sterile sand subsample # SS (control sample). Figures 16 demonstrates the percentage of each grain size in the subsamples from the bottom of the profile to the top, and Figure 17 demonstrates the average grain sizes across the subsample set. Subsample # SS was presumed to be entirely the result of the natural deposition of sediments on the beach from wave action.

Table 9. Average of grain sizes in each subsample category.

	Coarse Sand	Medium Sand	Fine Sand	Silt / Clay
Ash	31.4%	30.92%	26.06%	8.23%
Charcoal	34.96%	34.47%	27.67%	4.52%
Shell	70.06%	19.44%	8.12%	10.36%
Sand	n/a	9.88%	90.02%	n/a

Table 10. Average grain size percentages across the entire subsample set (with the exception of the control sand subsample, # SS).

Grain Size	Percentage across Entire Subsample Set
Coarse Sand	34.11%
Medium Sand	21.21%
Fine Sand	15.46%
Silt / Clay	5.78%

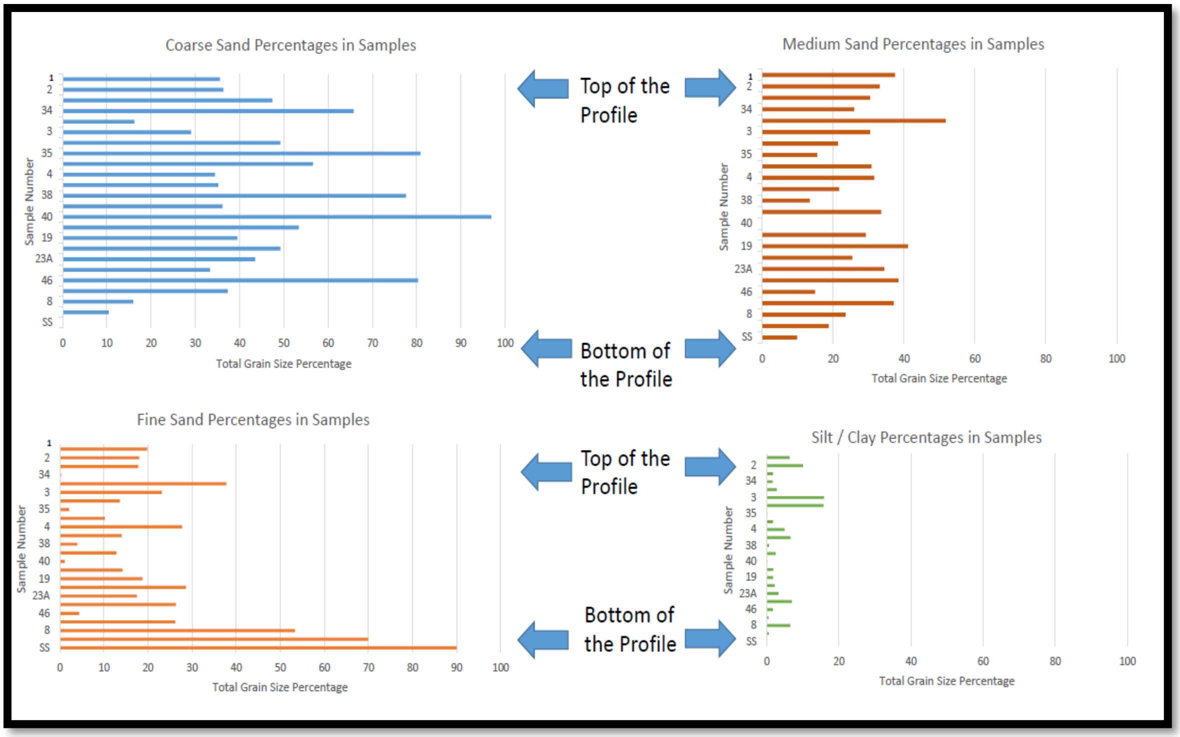


Figure 16. Grain size distributions from the bottom to the top of the shell midden profile.

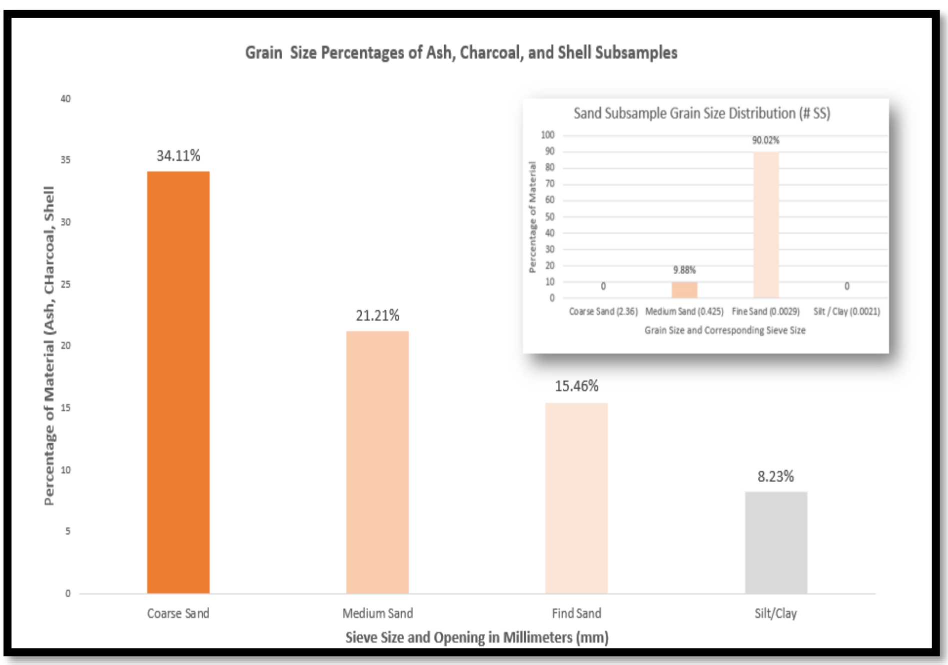


Figure 17. Average grain size percentages of ash, charcoal, and shell subsamples compared with the sand sample.

Coarse and medium sand dominate the subsample set, with μ = 55.31%. This is in contrast to the culturally sterile sand sample (Sample #SS) collected at the bottom of the profile, which is composed almost entirely of fine sand (90.02%). These differences indicate a different depositional environment resulted in the shell midden stratigraphy than in the beach sand. The coarse-sized material in the matrix was largely composed of burnt shell, pebbles, charcoal, and fire cracked rock. Fine grained sand comprises a larger percentage of the older (lower) portion of the profile.

Magnetic Susceptibility Results

Magnetic susceptibility has been predominately used in archaeological investigations to identify sediment features and burnt material (Dalan and Banerjee 1998). The resulting Bartington Units, or SI, result from the Bartington MS2 instrument creating a magnetic field (H), detecting the magnetism in the sample (M), and then calculating the ratio (X_m) between the two. The resulting mass magnetic susceptibility is mathematically expressed as $\boldsymbol{X_m = M/H}$.

Figure 18 illustrates magnetic susceptibility of each sample, grouped based on the subsample category (ash, charcoal, shell, and the culturally sterile sand sample).

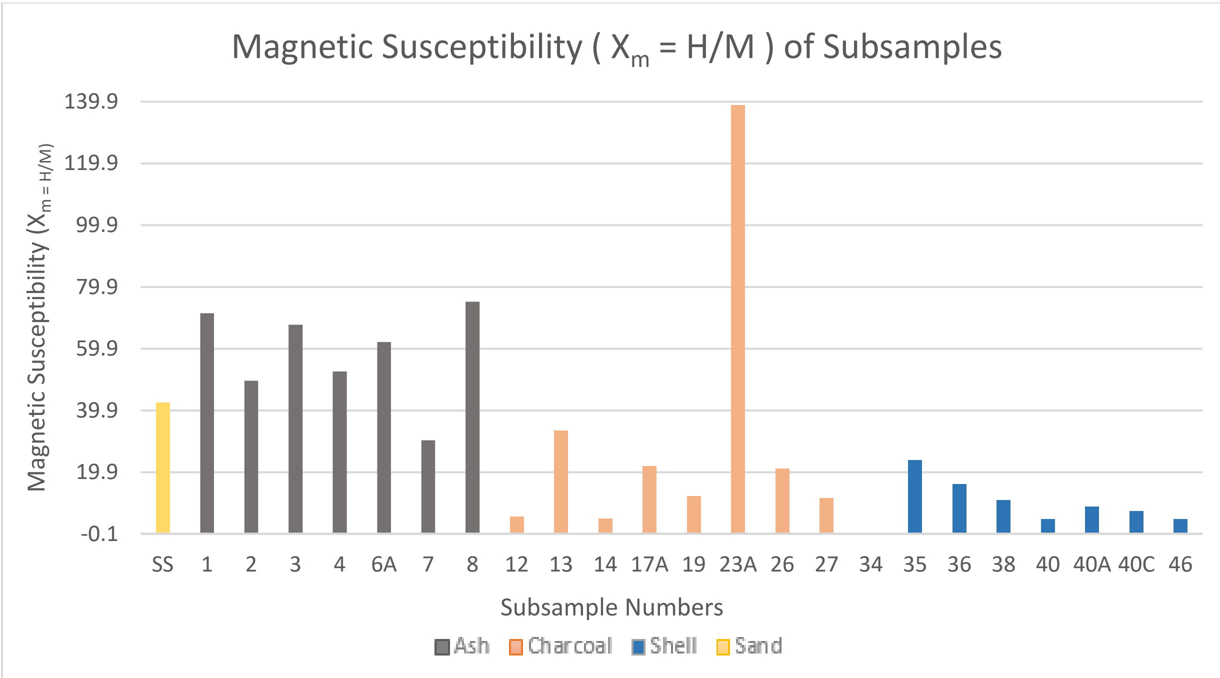


Figure 18. Magnetic Susceptibility (X_m = H/M) of subsamples.

The highest SI units were recorded in the ash lens samples with decreasing susceptibility present in the charcoal and shell samples, respectively. Charcoal sample 23A was measured twice on two different days, to try and determine if the very high reading was due to operator or equipment error. I conducted a visual analysis of the sample and could not determine the reason for 23A being an outlier.

Interestingly, the culturally sterile sand sample from the bottom of the beach profile demonstrated a higher susceptibility rating than the charcoal or ash samples (with the exception of 23A, the outlier). The beach sand adjacent to Chuckanut Bay is largely derived from the surrounding Chuckanut sandstone formations, and of the three common rock types (sedimentary, metamorphic, and igneous) sedimentary rocks normally have the lowest susceptibility values when for example compared to mafic and ultramafic rocks (Skrede 2012). However, Chuckanut sandstone and the local soil series Nati Silt Loam both contain magmatic material in the form of volcanic ash, which may account for the relatively high reading (Fitzsimmons et al. 2013).

Phosphorous Results

Phosphorous is a persistent and significant indicator of anthropogenic alteration of soils (Holliday and Gartner 2007). Middleton and Price (1996) confirmed that activities like burning result in elevated phosphate levels in the soil. Inductively Coupled Plasma (ICP) spectrometry measures the total phosphorous (or Ptot) in milligrams per kilogram, or parts per million (ppm).

The following graph illustrates the amount of Ptot in ppm of each sample, grouped based on the subsample category:

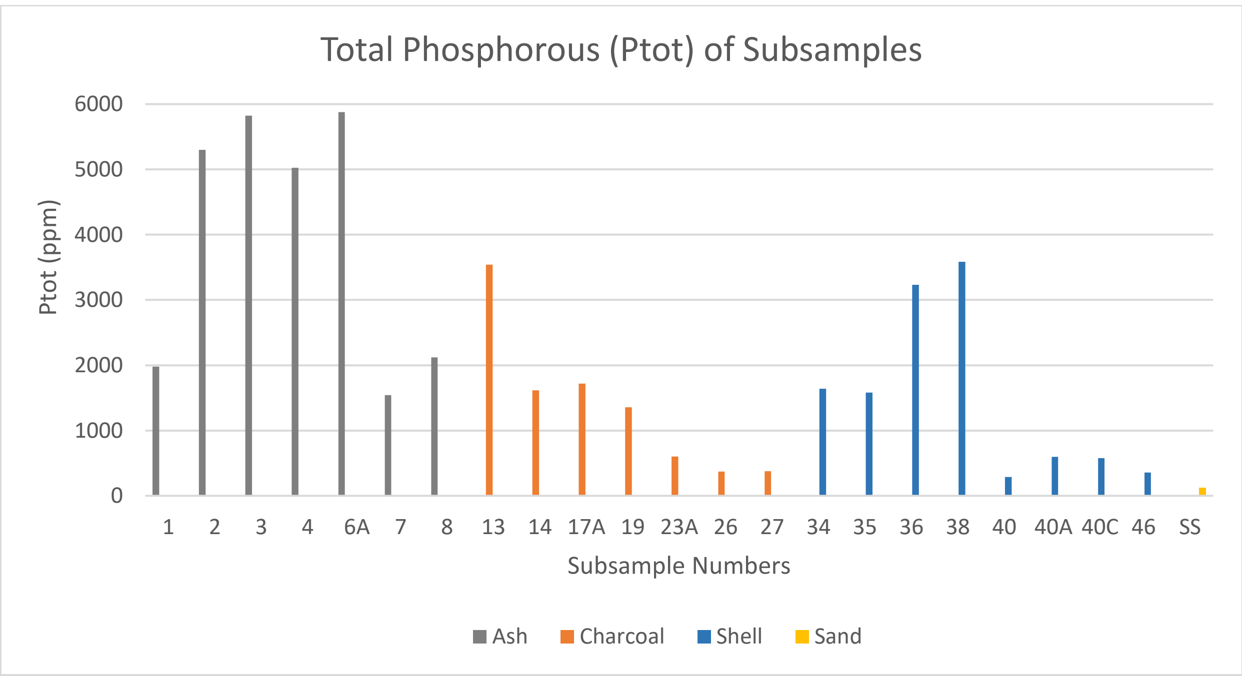


Figure 19. Total phosphorous values (Ptot) in parts per million (ppm).

Figure 19 demonstrates that the highest measurements of Ptot were concentrated in the ash samples ($\bar{x}$ = 3953.14), while the shell samples on had slightly greater amounts of Ptot ($\bar{x}$ = 1482.88) than the charcoal samples ($\bar{x}$ = 1369.29). The culturally sterile sand sample contained the least amount of Ptot (125 ppm).

In order to explore the hypothesis that the magnetic susceptibility and phosphorous values could help identify subsistence features within the profile, I assigned the magnetic susceptibility measurements and the Ptot totals to interval scales, categorized as Low, Medium, Medium-High, and High. The magnetic susceptibility intervals are in 15 X_m (a low reading being less than 15, and the highest readings being above 50), and the phosphorous intervals to 1500 ppm (a low reading being less than 1500, and a high reading being greater than 4500). I also assigned a color to each of the subsample categories, in order to create a visual of whether high SI and Ptot readings correspond to the samples that I assumes to be heated the most (the ash lenses):

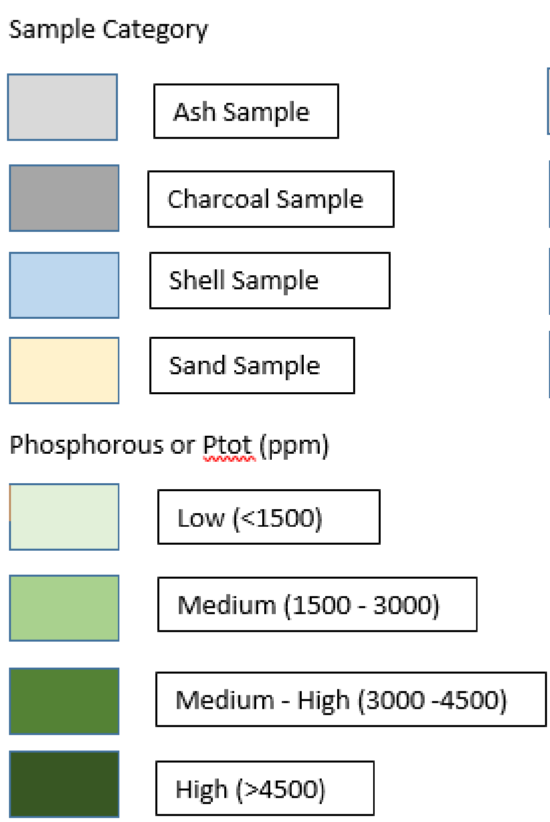


Figure 20 sorts the samples by their category type, with the corresponding level of magnetic susceptibility and Ptot on either side. The highest magnetic susceptibility and phosphorous readings appear to cluster around the ash lenses, and correspond with field observations of potential hearth and fire pit features.

Magnetic Susceptiblity	Samples from top to bottom of Profile	Phosphorous
	#1	
	#2	
	#3	
	#4	
	#6A	
	#7	
	#8	
	#12	Not Tested
	#13	
	#14	
	#17A	
	#19	
	#23A	
	#26	
	#27	
Diamagnetic	#34	
	#35	
	#36	
	#38	
	#40	
	#40A	
	#40C	
	#46	
	SS	

Figure 20. Visual representation of Ptot and X_m values of the subsample categories.

The following Pearson's correlation coefficient can determine the extent of the linear relationship between the magnetic susceptibility and Ptot values:

$$r = \frac{n(\Sigma xy) - (\Sigma x)(\Sigma y)}{\sqrt{[n\Sigma x^2 - (\Sigma x)^2][n\Sigma y^2 - (\Sigma y)^2]}}$$

N (both capitalized *N* and lower case *n* may be used) is equal to the number of pairs (the subsamples); x and y are the magnetic susceptibility and Ptot measurements, respectively (see Tables 6 and 7 in Chapter 5 for the P(tot) and Xm values); and ∑ is the sum of those scores. R is correlation coefficient, with a value between 1 and -1. 1 indicates a strong positive relationship, -1 indicates reflects a negative relationship, and 0 means the two variables are not related. Sample 12 is not included in the following result, because I was not able to test that sample for one of the variables (Ptot).

The resulting r = 0.3, indicating a moderate positive linear relationship between the chemical and magnetic variables. Removing the outlier magnetic susceptibility measurements (X_m = 138.8) from sample #23A (Table 6) strengthens the relationship to r = 0.6. Figure 21 is a scatter plot chart of each tested subsample (minus the outlier) and shows the trendline between the two variables:

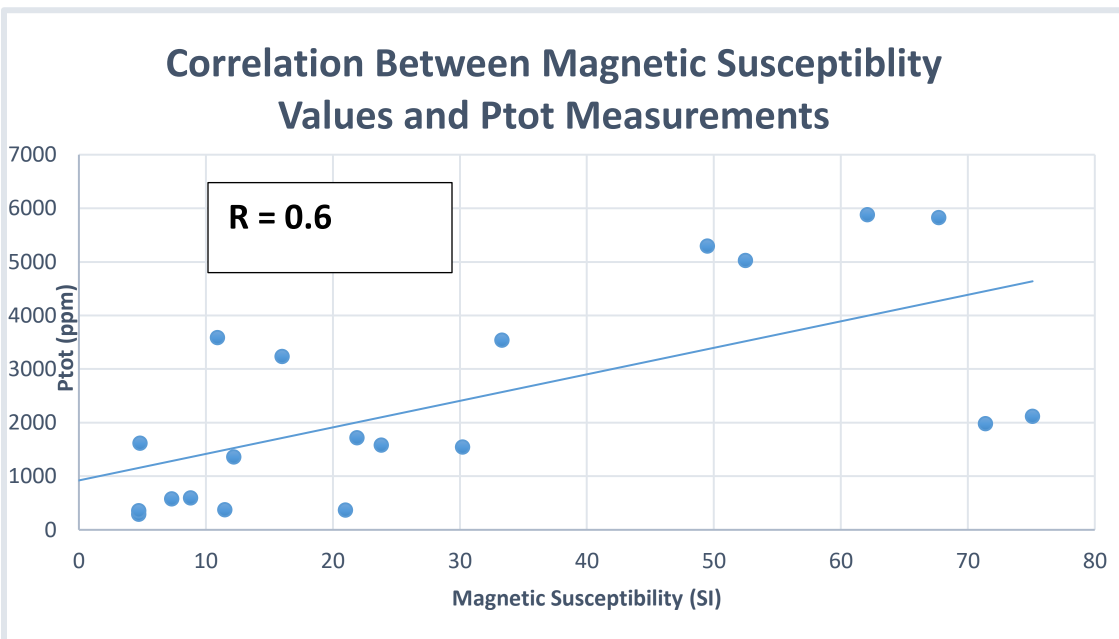


Figure 21. Correlation between magnetic susceptibility and Ptot measurements.

Testing the Hypothesis

This research began with the hypothesis (H_1) that the complex stratigraphy present in the exposed beach bank shell midden at 45WH55 was the result of anthropogenic, in-situ deposition, with repeating human activities such as localized burning for shellfish processing resulting in the distinct and repeating layers of tan ashy lenses, pockets of burnt shell, and charcoal. The null hypothesis (H_o) is that the shell midden is not entirely the result of repeating human activities, and the layers are the result of discrete events disconnected from one another. This thesis has accepted the premises in the archaeological literature that both elevated phosphorous values and magnetic susceptibility measurements can serve as proxies for human activity; in other words, the actions of living (cooking, processing, waste) enrich both the magnetic susceptibility and phosphorous content of soil. A moderately positive linear relationship exists between the two variables within my subsample set (Figure 21). I further propose that the variation in Xm and Ptot between the ash and charcoal subsamples reflects different depositional events; in other words, the ash samples will be more chemically and magnetically similar to each other and significantly different than the chemical and magnetic values of the charcoal samples. Therefore, the geoarchaeological test results can be evaluated when the hypotheses are stated as follows:

Magnetic Susceptiblity (X_m)

(X_m)H_0: *The true mean difference (μ_d) of magnetic susceptibility (X_m) in the ash, charcoal, and shell subsamples will be equal to zero.*

(X_m)H_1: *The true mean difference (μ_d) of magnetic susceptibility (X_m) in the ash, charcoal, and shell subsamples will not be equal to zero.*

Total Phosphorous (Ptot)

(Ptot)H_0: *The true mean difference (μ_d) of total phosphorous (Ptot) in the ash, charcoal, and shell subsamples will be equal to zero.*

(Ptot)H_1: *The true mean difference (μ_d) of total phosphorous (Ptot) in the ash, charcoal, and shell subsamples will not be equal to zero.*

I had an equal number of charcoal and shell samples (eight of each) that were tested for magnetic susceptibility, and seven ash samples tested for X_m (Table 6). I had an equal number of ash and charcoal samples (seven of each) that were tested for total phosphorous, and eight shell samples tested for Ptot (Table 7). To test whether we can reject or accept the null hypotheses stated above, I used the paired comparison two sample t-test (α = .05) to compare the equal samples, and the unpaired t-test to compare the unequal samples:

$$t = \frac{\bar{d}}{S_d / \sqrt{n}}$$

Paired Comparison T-test

$$t = \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{s^2 \left(\frac{1}{n_1} + \frac{1}{n_2} \right)}}$$

Unpaired Comparison T-test

The following table demonstrates the results of the t-test calculation for the magnetic susceptibility among subsamples. We can reject the null hypotheses, ***(X_m)H_0,*** if $t > 2.306$ (unpaired) and $t > 2.262$ (paired) (Madrigal 1998):

Table 11. Paired and Unpaired two-tailed t-test results for the magnetic susceptibility of the ash, charcoal, and shell samples.

Ash and Charcoal (X_m) = Unpaired	***Variable 1***	***Variable 2***
Mean	58.35714286	9.51
Variance	242.8861905	56.09337143
Observations	7	8
Hypothesized Mean Difference	0	
df	8	
t Stat	7.563462191	
P(T<=t) two-tail	6.525E-05	
t Critical two-tail	2.306004135	
Ash and Shell (X_m) = Unpaired	***Variable 1***	***Variable 2***
Mean	58.35714286	9.51
Variance	242.8861905	56.09337143
Observations	7	8
Hypothesized Mean Difference	0	
df	8	
t Stat	7.563462191	
P(T<=t) two-tail	6.525E-05	
t Critical two-tail	2.306004135	
Charcoal and Shell (X_m): Paired	***Variable 1***	***Variable 2***
Mean	31.12625	9.51
Variance	1983.049798	56.09337143
Observations	8	8
Pearson Correlation	0.096598421	
Hypothesized Mean Difference	0	

df	7
t Stat	1.375858905
P(T<=t) two-tail	0.211270881
t Critical two-tail	2.364624252

The following table demonstrates the results of the t-test calculation for the total phosphorous among subsamples. We can reject the null hypotheses, ***(Ptot)H₀***, if t > 2.228 (unpaired) and t >2.446 (paired) (Madrigal 1998):

Table 12. Paired and unpaired two-tailed t-test results for the total phosphorous of the ash, charcoal, and shell samples.

Ash and Charcoal (Ptot): Paired	***Variable 1***	***Variable 2***
Mean	3953.142857	1369.285714
Variance	3871877.81	1242900.571
Observations	7	7
Hypothesized Mean Difference	0	
df	6	
t Stat	2.968751106	
P(T<=t) two-tail	0.024997915	
t Critical two-tail	2.446911851	
Ash and Shell (Ptot) = Unpaired	***Variable 1***	***Variable 2***
Mean	3953.142857	1482.875
Variance	3871877.81	1688279.839
Observations	7	8
Hypothesized Mean Difference	0	
df	10	
t Stat	2.825867461	
P(T<=t) two-tail	0.017978872	
t Critical two-tail	2.228138852	
Charcoal and Shell (Ptot): Unpaired	***Variable 1***	***Variable 2***
Mean	1369.285714	1482.875
Variance	1242900.571	1688279.839
Observations	7	8
Hypothesized Mean Difference	0	
df	13	
t Stat	-0.182217602	
P(T<=t) two-tail	0.858222708	
t Critical two-tail	2.160368656	

T > 2.306 for the X_m ash and charcoal and ash and shell, therefore the true mean difference of magnetic susceptibility is greater than zero. T< 2.262 for the charcoal and shell, so there does not appear to be a significant difference in the magnetic susceptibility for these two sample categories.

T > 2.446 for the P(tot) ash and charcoal and ash and shell, therefore the true mean difference of total phosphorous is greater than zero. T<2.228 for the charcoal and shell, so there does not appear to be a significant difference in total phosphorous for these two sample categories.

Chapter 7: Conclusions and Future Research

Shell midden archaeological sites on the Northwest Coast are the material remnants of thousands of years of successful exploitation of shellfish resources by indigenous peoples. The dynamic anthropogenic and natural formation processes that result in the complex stratigraphy exhibited by many shell middens can be analyzed by applying geoarchaeological analysis to the midden matrix. Archaeologists can study soil chemistry, magnetism, grain size, and other physical measurements to gain contextual information with which to understand the artifacts suspended in the matrix. The goal of this thesis, structured by Binford's middle range theory, was to complete geophysical and geochemical analyses to aid in identifying the past human subsistence activities that created the distinct and repeating layers of shells, ash, and charcoal in the midden profile. To accomplish this goal, the soil tests were employed to confirm that the visual similarity of the repeated layers were related to similar chemical and magnetic values, and thus likely the result of the same processes. The results of this study demonstrate the utility of geophysical and geochemical tests to support macro-level observations, and will assist future researchers in identifying specific activity areas within this shell midden. The following sections summarize the findings of each of the tests, and I complete this manuscript with recommendations for future geoarchaeological research at 45WH55.

Summary of Findings

Twenty-five of the 64 shell midden matrix samples (approximately 39%) originally collected by Campbell (2010) were included in my subsample set (**Appendix D**). Samples were chosen on the basis of enough material to undergo testing, and were selected to give a broad data-set across the exposed midden wall. All 64 sample descriptions were standardized from the original field notes, while the 25 subsamples were additionally evaluated for Munsell color (Table 3). We completed a stratigraphic drawing indicating the location of both the samples and subsamples within the shell midden (Figure 12).

Radiocarbon analysis was successfully completed on two subsamples from near the top and bottom of the profile (**Appendix G**). Grain size analysis was conducted on twenty-four of the subsamples; twenty-three of the samples were subject to total phosphorous (Ptot) testing using ICP-spectrometry; and twenty-four of the samples were subject to magnetic susceptibility measurements (**Appendices H, I**, and **J**).

Salix Archaeology identified charcoal samples suitable in weight for radiocarbon dating (**Appendix F**). Two of the samples were comprised of burnt maple and alder, both important fuelwoods for Northwest Coast peoples. One piece of charcoal from subsample #23A was *Lonicera* (black twinberry or honeysuckle), used for medicinal purposes on the Northwest Coast. The radiocarbon dates derived from samples #12 and #23A (508 BP and 933 BP) date from the Late Pacific Period Gulf of Georgia phase, (Tables 1 and 7) indicating that the activities that created the shell midden are not contemporaneous with the Locarno Beach phase activities that created the midden on the upper bluff, but may have occurred at the same time as the later Marpole activities documented by Pierce and others (Campbell et. al. 2010; Lewis 2013; Pierce 2011) (Figures 22 and 23). These Gulf of Georgia phase dates support our understanding of the Woodstock Farm Site as a location of long habitation by Indigenous peoples, whom successfully exploited the abundant terrestrial and aquatic resources during the Locarno Beach, Marpole, and San Juan Phases of the Gulf of Georgia sequence.

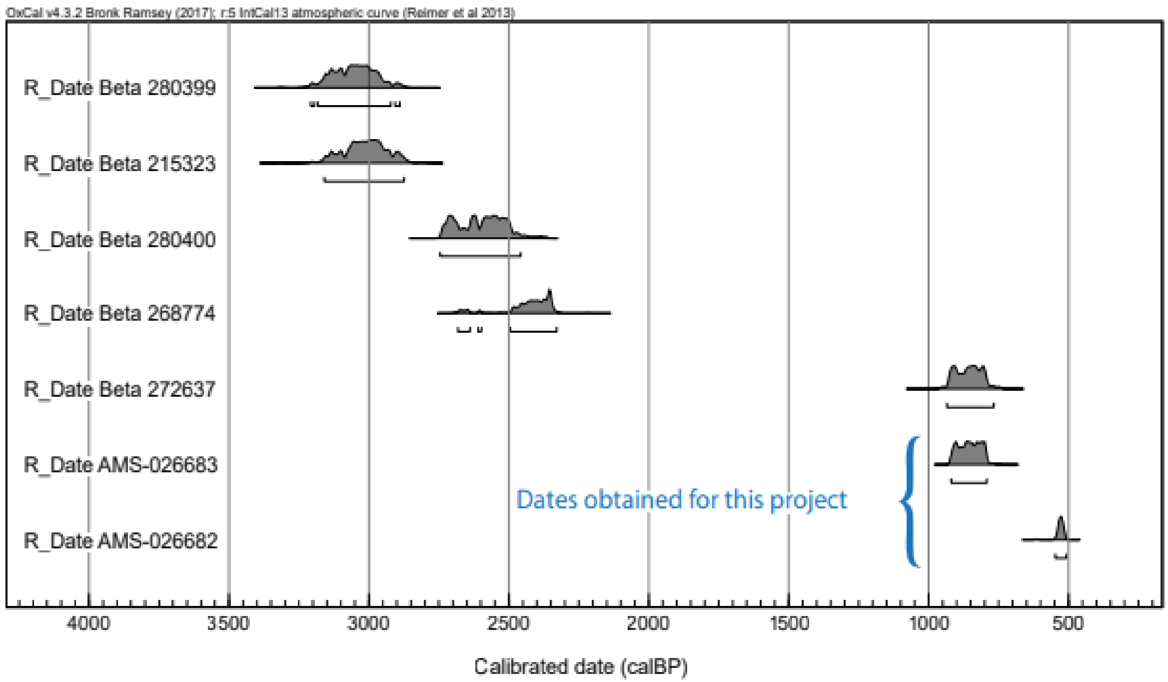


Figure 22. Oxcal chart demonstrating radiocarbon dates collected at 45WH55 (Image courtesy of Adrienne Cobb).

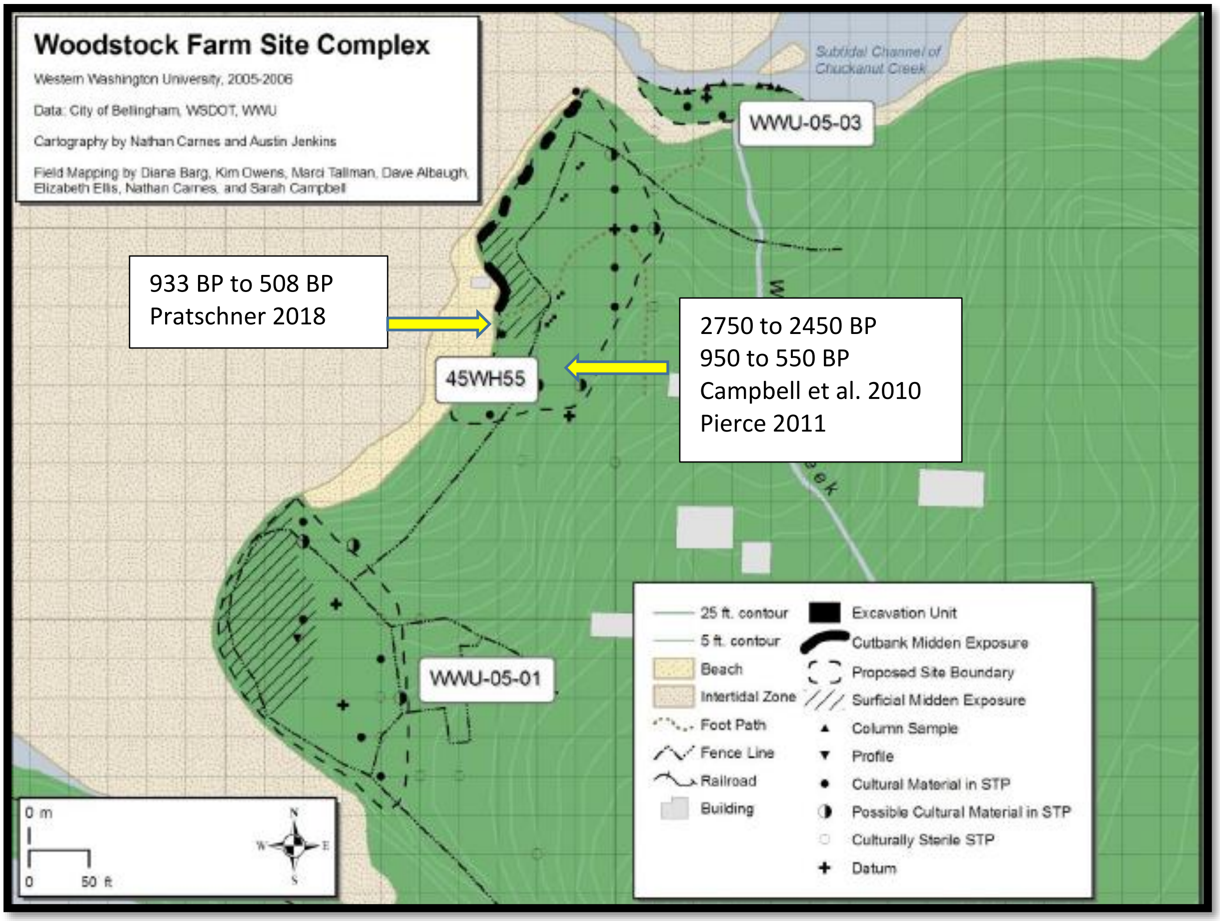


Figure 23. Map of the Woodstock Farm site with radiocarbon dates from this thesis research, Campbell et al. 2010 and Pierce 2011 (Modified from Campbell et al. 2010: Figure 2).

The grain size analysis demonstrated the consistent distribution of grain sizes across the three mutually exclusive categories within the subsample set (ash, charcoal, shell), with coarse and medium-sized sand making up approximately $\mu = 62\%$ of the total subsample matrix material, and fine sand and clay making up the remaining $\mu = 38\%$ (Table 4 and Figures 16 and 17). All of the subsamples with the exception of the culturally sterile sand sample (SS) contain evidence of anthropogenic origin, including burnt shells, charcoal, and fire cracked rock. Compared to the lack of artifacts and over 90% fine sand grain size present in the culturally sterile sand sample (SS), we can infer that a different depositional environment (anthropogenic deposition) resulted in the observed midden stratigraphy than in the beach sand. Grain size analysis of the remaining samples not chosen for this study in combination with additional beach sand samples for control may reveal further details about the shell midden' s depositional history.

Phosphate values, serving as a proxy for human activity, can independently evaluate patterns in other data. Eidt (1984) established that the average inorganic phosphate content of sedimentary rock is approximately 200 parts per million (ppm), while Hill and Rapp (2006) state that phosphorous content of 2000 ppm can indicate a burial. This research relies on the accumulation of phosphate as an indicator of people's continual use of the landscape. The ash subsamples exhibited the highest average measurements ($\bar{x}$ = 3953.14 ppm), followed by the shell ($\bar{x}$ = 1482.88 ppm) than the charcoal samples ($\bar{x}$ = 1369.29 ppm) (Figure 19). The Ptot of the sand subsample had a Ptot value of 125 ppm. The Ptot measurements met our expectations that the samples heated to the highest temperatures (the ash layers) would exhibit the most phosphorous enrichment. There was a moderately positive correlation between the Ptot measurements and the magnetic susceptibility measurements (Figure 21). There was a significantly statistical difference (Tables 11 and 12) between the magnetic susceptibility and total phosphorous of the ash and charcoal, and the ash and shell, but no statistical difference for either measurements between the charcoal and shell samples. The relatively high X_m value of the sand subsample indicates that anthropogenic processes may not be the leading factor in magnetic enhancement of the deposits. The sand adjacent to Chuckanut Bay is largely derived from the surrounding sandstone and the resulting Nati Silt Loam soil series, both of which contain admixtures of volcanic ash. Magnetic iron oxides are major components in many soils containing magmatic minerals (Pizarro et al. 2017), therefore the magnetic susceptibility of the sand sample may reflect the volcanism that is expressed in a number of rock and soil types throughout the northwest Washington region. Alternatively, the sand sample may contain eroded matrix materials from the midden which renders its X_m value no statistically different from the X_m in the ash, shell**,** and charcoal samples (Table 10).

Paleoenvironmental Reconstruction and Stratigraphic Analysis

Campbell et al. (2010) and Lewis (2013) both discuss how the portion of Chuckanut Bay adjacent to 45WH55 would have been deeper and supported a rockier substrate prior to the installation of the railroad trestle in the 1920s. Sea levels stabilized after the early Holocene, and the vegetative and climate regime in the Gulf of Georgia supported the development of the Developed Northwest Coast Pattern (Lepofsky et. al. 2005). Prior to the site's recording in 1974 by Gaston and Swanson, the beach bank shell midden would have extended further into Mud Bay, accumulating material in a convex pattern as shells were processed, cooked, and faunal remains and used tools were discarded. Pursuant to the radiocarbon dates obtained from near the top and bottom of the approximately 2-meter thick profile, I conclude that the accumulation of the midden took place at the very end of the Marpole Phase and into the Gulf of Georgia Phase (Table 1) over an approximately 500 year time period. Stein et al. (2011) in their study of shell accumulation rates across a number of later-Phase sites on the San Juan Islands, characterized rapid accumulation rates as >.5 cm / year. The 2 meter or 200 centimeter deep beach bank shell midden divided by 500 years calculates to an average accumulation rate of 2.5 centimeters per year. This rapid accumulation is consistent with Stein, et al.'s (2011) hypothesis that later Phase sites, especially those dated 650 cal BP and later, accumulate shell more rapidly than earlier Phase sites due to an increase in site permanence. Destructive wave action on the coastline has eroded the midden, creating a wave cut notch at the base and a concave profile section (Figures 7 and 24). A combination of rising sea levels and wave swash will continue to erode the shell midden in the future.

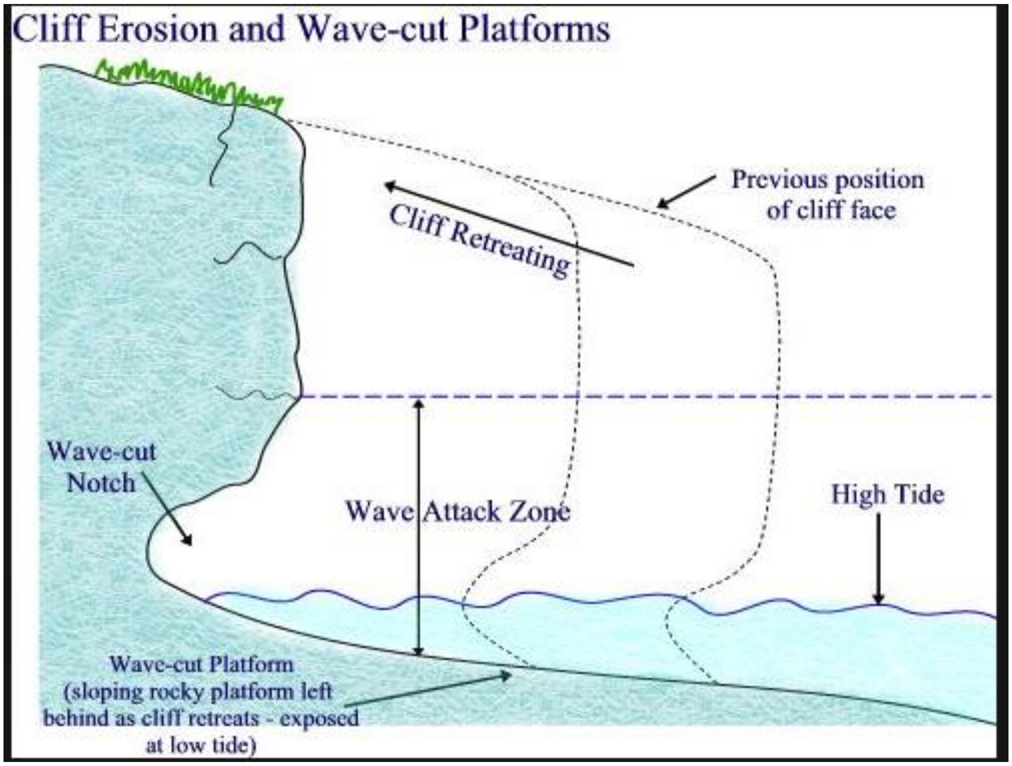


Figure 24. Coastal erosion due to wave swash (Image courtesy of https://annemarieaitken.wordpress.com/2014/09/13/coastal-landforms-and-processes/).

Campbell (1981) and Stein (1992) state that cultural traits of features within a shell midden include contents, size, shape, and the nature of boundaries. In the context of this research, I define an archaeological feature within the shell midden as a collection of artifacts and matrix that represents a human subsistence activity associated with intensive shellfish collection, processing, consumption, and eventual discard. Campbell et al. (2010) suggested in their excavation of the portion of 45WH55 on the upper bluff that the lenses of charcoal, ash, burnt shell, and whole *Protothaca* (Pacific littleneck clam) represent hearth features and the remains of cooking activities (Pierce 2011). The stacked nature of the shellfish deposits may suggests vertical discard (Campbell et al. 2010; Pierce 2011), with post-depositional processes impacting whether the shells are oriented concave-side down or up (Muckle 1985). Aligning the field observations and sample collection with this thesis' geoarchaeological analysis provides an opportunity to assign the depositional units into meaningful cultural assemblages. Table 13 describes the stratigraphy of the shell midden from the beach (bottom of the deposits) to the ground level (top of the deposits) and combines the field observations, the geoarchaeological tests results indicating a positive linear relationship between magnetic susceptibility and total phosphorous, and statistical differences between the ash and charcoal, and Coast Salish ethnography to identify features and conclude what kinds of human subsistence activities that may have resulted in the distinct layers.

Table 13. Suggested archaeological features within the beach bank shell midden at 45WH55.

Distance from Ground Level	Description	Proposed Depositional Process
-30 to -20 cm	Not excavated; sterile sand sample collected.	Beach sand from wave swash.
-20 to -10 cm	Sand layer bound by diffuse and thin charcoal layers, an ash layer and fire cracked rock.	Fire pits that have been subsequently altered.
-10 cm to 40 cm	A large lens of ash with alternating thin layers of charcoal, burnt shell, and fire cracked rock.	Burning for disposal and sanitation.
40 cm to 70 cm	Large convex lenses of charcoal with thick layers of ash and dense shell.	Re-use of fire pits.
70 cm to 85 cm	Dense shell, some burnt.	Cooked shell disposal.
85 cm to 100 cm	Ash layer bound by charcoal layers and fire cracked rock.	Re-use of fire pits.
100 cm to 120 cm	Burnt shell and rocks.	Cooked shell disposal.
120 cm to 140 cm	Ash lenses with between pockets of whole shell. Two small pockets of charcoal.	Re-use of fire pits.

Conclusions and Future Research

This research represents a geoarchaeological approach in understanding the lifeways of the community whom successfully exploited the abundant natural resources at 45WH55 for over one thousand years. The compilation of the field data in combination with the laboratory tests support the hypothesis of a shell midden site that is the result of anthropogenic, in-situ deposition by Coast Salish peoples engaged in intensive shellfish processing during the Gulf of Georgia phase. An in-depth analysis of the bivalve and faunal assemblages within the 64 total midden samples could elucidate further subsistence patterns and answer questions of seasonality exhibited by the other pre-contact shell middens on the Woodstock Farm property. On a larger scale, applying a similar geoarchaeological program of study to the soil samples from the other recorded sites at Woodstock Farm will further inform depositional and site formation patterns across the site.

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Appendix A: 45WH55 Site Form (Modified from Dr.'s Gaston and Swanson original form)

WASHINGTON ARCHAEOLOGICAL SITE INVENTORY FORM

Date 2-12-86 Compiler ______ County Whatcom
Site # 45 WH 55 (for WARC use only)

Location Information Restrictions: Yes_ No _ Unknown_

SITE DESIGNATION

Site Name ______

Field or other designations ______ Computer # ______

SITE LOCATION

UTM:* Zone 10 Easting 536808 Northing 5394208

Legal Description:* T37N R2E Sec 13 ¼,¼,¼____ ¼,¼ SE ¼ SW

Latitude ___° ___' ___" Longitude ___° ___' ___" Elevation (ft/m) ______

USGS MAP:* Quad Name Bellingham South Series 7.5 Date 1954

Other Maps: Type ______

Scale ______ Source ______ Date ______

Drainage: Major ______ Minor ______ River Mile ______

Aspect ______ Slope ______

Location Description (general to specific)* South on Chuckanut Drive just past Chuckanut Creek

Approach (to relocate)* On E. shore of Chuckanut Bay between RR tracks and Chuckanut Creek in small cove. Bank rises quite sharply up to Lee's property. Shell concentrated between boat house and tiny spring fed creeks

* Mandatory information for official site designation

WASHINGTON ARCHAEOLOGICAL SITE INVENTORY FORM

(PAGE 2) Site # ______________
(For WARC use only)

SITE DESCRIPTION

Narrative Description * Quite dense shell midden in cut bank on beach, which seems to continue at least to 6 m. elevation. Fresh water found in Whatcom Creek which emptys into Bay just NE of site. Some springs too.

Site Type * MS

Dimensions: Method of horizontal measurement ______

Length 50 m Direction ______ Width 25 m Direction ______

Depth ______ m Method of vertical measurement ______

Vegetation: On Site ______

Local ______ Regional ______

Landforms: On Site ______ Local ______

Water Resources: Type ______ Distance ______ Permanence ______

CULTURAL MATERIALS & FEATURES

Narrative Description * Collected: 2 choppers, possible incomplete net sinker, adze, fragments (chip stone?), possible agate core.

observed: fire-broken rock, dense shell.

Method of Collection(s) ______ / ______ / ______

SITE AGE

Component * ______ Dates * ______ Dating Method * ______

Phase * ______ Basis for Phase designation * ______

WASHINGTON ARCHAEOLOGICAL SITE INVENTORY FORM

(PAGE 3) Site # ________ (For WARC use only)

SITE RECORDERS

Observed by ________ Address ________

Recorded by * J. Gaston + G. Swanson Affiliation * WWU

Date Recorded * 4-29-74

Revisited by ________ Affiliation ________

Date Revisited ________

SITE HISTORY

Previous Work (references)

SITE OWNERSHIP

Owner/Address * Mr. Raymond Lee

____

Tenant ________

FORM RECORDS

Other forms (specify):

WASHINGTON ARCHAEOLOGICAL SITE INVENTORY FORM

(PAGE 4)

Site # ________________
(for WARC use only)

USGS MAP

Quad Name* ________________

Series* ________________

Date* ________________

COPY AND ATTACH*
USGS MAP PORTIONS

Section____

Plot site location at left

SKETCH MAP

Legend

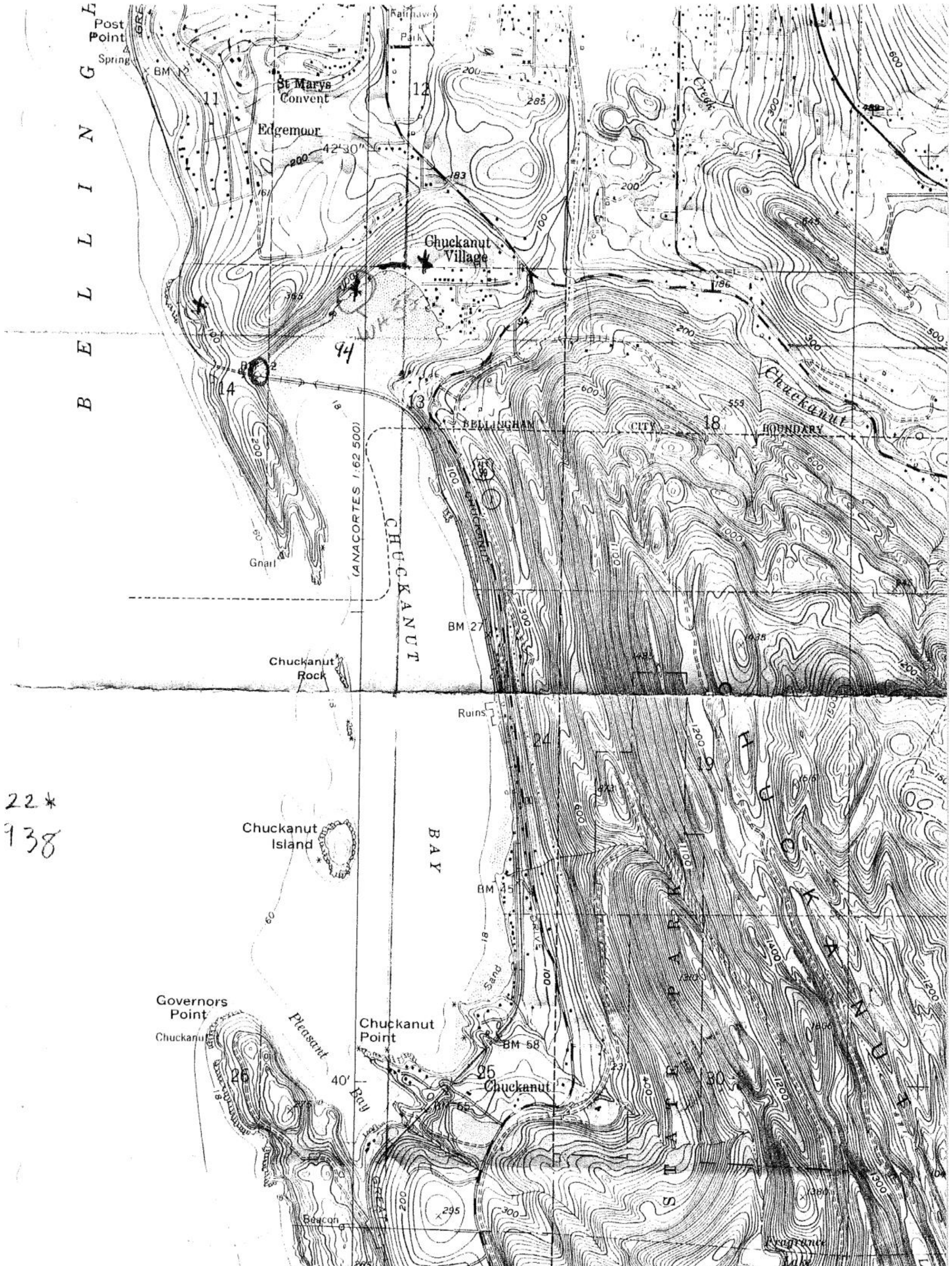
Known boundary _._.

Possible boundary

Other symbols
(other than USGS)

SCALE:

North Arrow
(mag.)


Post Point
Spring
BM
Fairhaven Park
St Marys Convent
Edgemoor
Chuckanut Village
Creek
BELLINGHAM
CITY
BOUNDARY
Chuckanut
Gnarl
(ANACORTES 1:62 500)
CHUCKANUT
BAY
BM 27
Chuckanut Rock
Ruins
Chuckanut Island
BM 45
Sand
Governors Point
Chuckanut
Pleasant Bay
Chuckanut Point
BM 58
Chuckanut
BM 65
Beacon
Whiskey Rock
Sandstone
BM 72
Fragrance Lake
Lost Lake
94

22*
138

Duplicate

Whatcom 45-WH-55

Bellingham South Quad USGS 15' series

Midden

Lummi? Nooksack?

S on Chuckanut Drive just past Chuckanut Crk. SE quarter of the SW quarter. Site in bank above beach at Teddy Bear Cove just S of mouth of Chuckanut Crk. 13 37N 2E

Mr. Raymond Lee Woodstock Farm Chuckanut

Mr. Raymond Lee

Mr. Al Richardson

None

Quite dense shell midden in cut bank on beach, which seems to continue at least to 6m elevation. Fr. water found in Whatcom Crk. which emptys into Bay just NE of site. Some springs too.

On E shore of Chuckanut Bay between RR tracks and Chuckanut Crk in sm cove. Bank rises quite sharply up to Lee's property. Shell concentrated between boat house and tiny spring fed creeks.

50x25m approx., judging by cut bank

At least a solid 2m in bank, perhaps 4m up bank farther, numerous, crushed and whole shell layers, and ash, FBR charcoal, stained earth.

Bank is eroding and a jeep road has cut thru it. Also several trees growing in bank disturbing stratig. Otherwise good.

A pit dug last yr by daughter Marjory (geology student WWSC) apparently nothing recouvered.

2 choppers, possible incomplete net sinker, adze frag. (chip stone?), possible agate core.

FBR, dense shell

At least a test cut or two. Only lg. midden site in S end of county. May be especially important if Nooksack affil. Ethnograph. report area was one of their only salt water accesses.

see field notes p. 21 (with 45-WH-48 f.n.).

J. Gaston and C. Swanson April 29, 1974

Western Washington State College
Archaeological Field Forms
Site Survey Form

County Whatcom Site No. 45-WH-55

1. Map reference Bellingham South Quad USGS 15' series
2. Type of site Midden
3. Cultural affiliation
4. Location S on Chuckanut Drive just past Chuckanut Crk. SE quarter of the SW quarter. Sec 13 T 37N R 2E
5. Owner and address Mr. Raymond Lee
6. Previous owners
7. Tenant Mr. Raymond Lee
8. Informants Mr. Al Richardson
9. Previous designations for site None
10. Site description Quite dense shell midden in cut bank on beach, which seems to continue at least to 6m elevation. Fr. water found in Whatcom Crk. which emptys into Bay just NE of site. Some springs too.
11. Position of site and surroundings On E shore of Chuckanut Bay between RR tracks and Chuckanut Crk in sm cove. Bank rises quite sharply up to Lee's property. Shell concentrated between boat house and tiny spring fed creeks.
12. Area of occupation 50x25m approx., judging by cut bank
13. Depth and character of fill At least a solid 2m in bank, perhaps 4m up bank farther, numerous, crushed and whole shell layers, and ash, FBR charcoal, stained earth.
14. Present condition Bank is eroding and a jeep road has cut thru it. Also several trees growing in bank disturbing stratig. Otherwise good.
15. Previous excavations A pit dug last yr by daughter Marjory (geology student WWSC) apparently nothing recouvered.
16. Material collected 2 choppers, possible incomplete net sinker, adze frag. (chip stone?), possible agate core.
17. Material observed FBR, dense shell
18. Material reported and owner
19. Recommendations for further work At least a test cut or two
20. Photograph nos.
21. Maps of site

Recorded by J. Gaston and C. Swanson Date April 29, 1974

County

Site No.

Appendix B: Archaeological Excavation Permits for 45WH55

STATE OF WASHINGTON

Office of Archaeology and Historic Preservation

1063 S. Capitol Way, Suite 106 • Olympia, Washington 98501
(Mailing Address) PO Box 48343 • Olympia, Washington 98504-8343
(360) 586-3065 Fax Number (360) 586-3067

ARCHAEOLOGICAL EXCAVATION PERMIT
NO: 05-11

Archaeological site:	45WH55
Individual responsible for carrying out the terms and conditions of the permit:	Sarah Campbell & Todd Koetje Western Washington University
Individual responsible for field investigations:	Same
Nature of work:	Test Excavations
Repository in which collected records and data shall be deposited:	Western Washington University
Date fieldwork to begin:	June 27, 2005
Date fieldwork shall end:	August 20, 2005
Period of analysis:	Concurrent through December 31, 2006
Date final report due:	Preliminary Field Report due October 30, 2005 Final report due June 30, 2007

Special Conditions:

- Follow all protocols stated in permit application dated May 18, 2005
- If human remains are encountered, stop work in that unit and notify parties stated in permit application
- Provide copy of the field and final reports to consulting parties & reference permit number in report
- Submit updated site form to DAHP by October 30, 2005
- Submit a Determination of Eligibility Form to DAHP by June 30, 2007
- Allow for on-site visits from Tribal Representatives
- Adhere to any conditions required by the City of Bellingham

Issued this 27th day of June.

Allyson Brooks, Ph.D.
State Historic Preservation Officer

STATE OF WASHINGTON

Department of Archaeology and Historic Preservation

1063 S. Capitol Way, Suite 106 • Olympia, Washington 98501
(Mailing Address) PO Box 48343 • Olympia, Washington 98504-8343
(360) 586-3065 Fax Number (360) 586-3067

ARCHAEOLOGICAL EXCAVATION PERMIT
NO: 07-13

Archaeological site:	45WH55, 45WH758, 45WH763
Individual responsible for carrying out the terms and conditions of the permit:	Professor Sarah Campbell Western Washington University
Individual responsible for field investigations:	Same
Nature of work:	Test Excavations
Repository in which collected records and data shall be deposited:	Western Washington University
Date fieldwork to begin:	Upon Receipt
Date fieldwork shall end:	August 30, 2007
Period of analysis:	Concurrent through December 31, 2009
Date final report due:	Preliminary Field Report due December 31, 2007 Final report due June 30, 2009

Special Conditions:

- Follow all protocols stated in permit application dated 6/05/07
- If human remains are encountered, stop work in that unit and notify parties stated in permit application
- Provide copy of the field and final reports to consulting parties & reference permit number in report
- Submit updated site forms to DAHP by October 30, 2007
- Submit a Determination of Eligibility Form to DAHP by December 31, 2007
- Allow for on-site visits from Tribal Representatives
- Adhere to any conditions required by the City of Bellingham

Issued this 12th day of July 2007.

Stephenie Kramer
Assistant State Archaeologist

STATE OF WASHINGTON

DEPARTMENT OF ARCHAEOLOGY & HISTORIC PRESERVATION

1063 S. Capitol Way, Suite 106 • Olympia, Washington 98501
Mailing address: PO Box 48343 • Olympia, Washington 98504-8343

ARCHAEOLOGICAL EXCAVATION PERMIT
NO: 2010-22

Archaeological sites:	45WH55
Individual Responsible for carrying out the terms and conditions of the permit:	Professors Sarah Campbell & Todd Koetje Western Washington University
Individual responsible for field investigations:	Same
Nature of work:	Data recovery excavations
Repository in which collected records and data will be deposited:	Western Washington University; upon completion of DAHPs Curation Questionnaire and inclusion on DAHPs repository list by June 30, 2015
Date fieldwork to begin:	Upon receipt
Date fieldwork shall end:	October 31, 2010
Period of analysis:	Concurrent through March 15, 2012
Date final report due:	March 15, 2012 Per WAC 25-48-041, if the report is late, a Notice of Violation will be issued & a $5000 penalty assessed

Special Conditions:

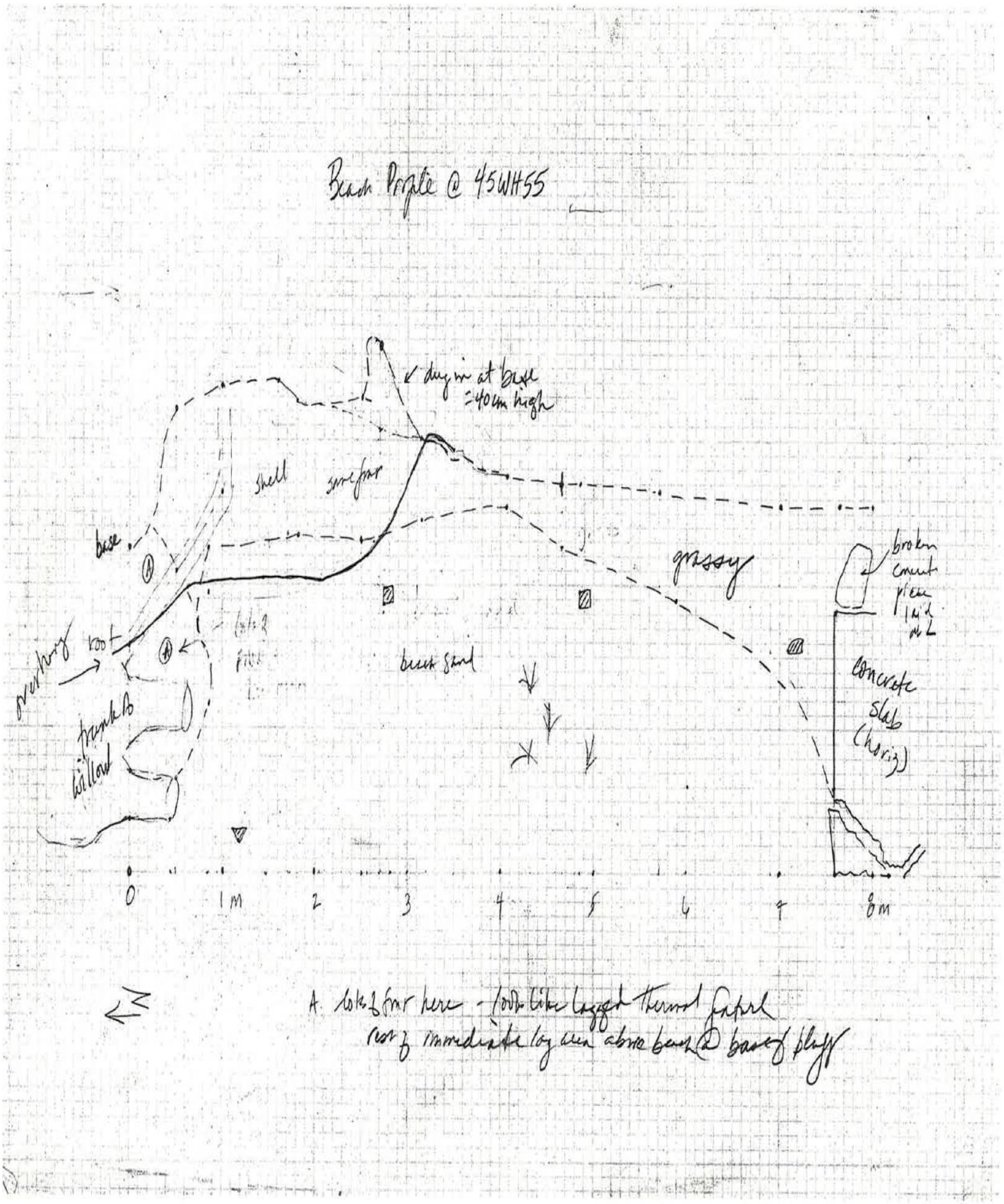
- Follow protocols stated in permit application of 6/2/10
- Append copies of Beta Analytic data sheets to report
- Provide copy of the final report to consulting parties
- Submit updated site form to DAHP with final report
- Report must follow DAHP's Survey and Inventory Standards
- Report must be submitted in paper and pdf formats
- Append artifact catalog to report & reference permit number in report
- If human remains are encountered, stop work, secure the area, notify the county coroner, sheriff, DAHP, & affected Tribes per RCW 27.44.055

Issued this 19th day of July 2010.

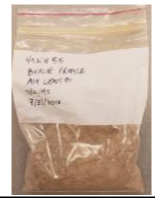
Stephenie Kramer
Assistant State Archaeologist

DEPARTMENT OF ARCHAEOLOGY & HISTORIC PRESERVATION
Protect the Past, Shape the Future

Appendix C: Measured Profile Drawing of Beach Bank Shell Midden at 45WH55
(Campbell 2010)



Appendix D: Standardized Descriptions of all Matrix Samples

Bag Number	Distance from ground-level (cm)	Dimensions (Length X Width in cm) and Contents	Continuity and Boundaries	Munsell Color	Photograph of Sample
ASH LENS DESCRIPTIONS					
1	140 cm to 130 cm	40-50 cm X 3-10 cm Fine roots, shell fragments, and pebbles.	UPPER: Charcoal #11 and Shell #31 LOWER: Shell #32 and Shell #33	10YR/6/3: Pale brown.	
2	130 cm to 123 cm	80 cm X 2-7 cm Fine roots, shell fragments, and pebbles.	UPPER: Shell #32 and #33 LOWER: Charcoal #12 and Shell #34	10YR/5/2: Grayish brown.	
3	95 cm to 85 cm	50 cm X 3-10 cm Fine roots, shell fragments, pebbles, and charcoal.	UPPER: Charcoal #13 LOWER: Charcoal #14	10YR/5/2: Grayish brown.	
4	70 cm to 64 cm	65 cm X 2-6 cm Fine roots, shell fragments, sandy ash, and fine ash.	UPPER: Shell #37 LOWER: Ash #s 5A and 5B	10YR/7/2: Light gray.	
5A	67 cm to 63 cm	22 cm X 1-4 cm Fine roots, shell fragments, and shell with ash.	UPPER: Ash #4 LOWER: Shell #47 and Shell #5B	10YR/5/1: Gray.	SAMPLE NOT SELECTED
5B	65 cm to 61 cm	57 cm X 1-4 cm Fine roots, burnt shell, no pebbles, and ash.	UPPER: Ash #4 and Shell #35 LOWER: Ash # 6A	10YR/6/2: Light brownish gray.	SAMPLE NOT SELECTED
6A	65 cm to 48 cm	180 cm X 2-8 cm Burnt shell and no pebbles. Ash #6B is a	UPPER: Shell #47 and Ash #5B LOWER: Charcoal	10YR/5/2: Grayish brown.	

		lens within Ash #6A.	#15A and Shell #47		
6B	58 cm to 50 cm	180 cm X 2-8 cm	UPPER: Ash #5B and Ash #6A	10YR/8/1: White. 10YR/5/2: Grayish brown.	SAMPLE NOT SELECTED
		Fine ash, pebbles and tiny broken shell fragments. Ash #6B is a lens within Ash #6A.	LOWER: Charcoal #15A		
7	10 cm to 1 cm (0 cm = ground level)	49 cm X 2-8 cm	UPPER: Shell #46	10YR/4/4: Dark yellow brown.	
		Concrete-like, fine ash, and tiny shell fragments.	LOWER: Shell #46		
8	-8 cm to - 12 cm	27 cm X 1-4 cm	UPPER: Charcoal #25	10YR 4/3: Brown	
		Wet, sandy, some tiny shell fragments, and burnt sandstone.	LOWER: Sand Sample		
SAND SAMPLE DESCRIPTION					
SS (Sand Sample)	-10 cm to – 22 cm	NOT RECORDED	UPPER: Ash #8	10YR/5/6: Yellowish brown.	
		Unburnt shell fragments and sand.	Charcoal #27		
CHARCOAL LENS DESCRIPTIONS					
11	140 cm - 138.5 cm	4 cm X 1.5 cm	UPPER: Shell #31	10YR/2/2: Very dark brown.	
		Burnt wood and small twigs.	LOWER: Ash #1 and Shell #33		
12	123 cm – 121.5 cm	30 cm X 1.5 cm	UPPER: Ash #2	10YR/3/1: Very dark gray.	
		Large pieces of broken shell fragments.	LOWER: Shell #34		
13	95 cm – 92 cm	52 cm X 1-3 cm	UPPER: Shell #34 and FCR	10YR/2/1: Black.	

		Fire cracked rock (FCR) and tiny shells.	LOWER: Ash #3		
14	90 cm to 89 cm	35 cm X 1 cm	UPPER: Ash #3	10YR/4/1: Dark gray.	
		3 sections containing very fine charcoal and tiny broken shell fragments.	LOWER: Shell #35		
15	58 cm to 56 cm	100 cm X 1.5 cm - 2 cm	UPPER: Ash #6A	SAMPLE NOT SELECTED	
		Two sections separated by ash sample 6B: wet and tiny pieces of shell.	LOWER: Shell #38		
15A	56 cm to 52 cm	25 cm X 5 cm	UPPER: Ash #6A	SAMPLE NOT SELECTED	
		Large whole and broken shell fragments.	LOWER: Shell #38		
16	45 cm to 42 cm	57 cm X 1-3 cm	UPPER: Shell #38A	SAMPLE NOT SELECTED	
		Large whole and broken shell fragments.	LOWER: Shell #38A		
17	42 cm to 35 cm	105 cm X 2 cm	UPPER: Shell #38 and #38B	SAMPLE NOT SELECTED	
		Very fine charcoal mixed with tiny shell fragments.	LOWER: Shell #40 and 40A		
17A	43 cm to 38 cm	48 cm X 1-5 cm	UPPER: Shell #38A	10YR/2/1: Black.	
		Very fine charcoal mixed with small shell fragment and burnt wood.	LOWER: Shell #40A		
17B	36 to 35 cm	26 cm X 1 cm	UPPER: Shell #38B	SAMPLE NOT SELECTED	

		Very fine charcoal mixed with tiny shell fragments. The lens is broken into small sections to merge with charcoal layer 17.	<u>LOWER:</u> Shell #38B	
17C	33 cm to 30 cm	56 cm X 1 cm	<u>UPPER:</u> Shell #38B	SAMPLE NOT SELECTED
		Very fine charcoal mixed with tiny shell fragments. Lens is segmented but appears to connect to charcoal layer 17D.	<u>LOWER:</u> Shell #40A	
17D	38 cm to 37 cm	17 cm X 1 cm	<u>UPPER:</u> Shell #38A	SAMPLE NOT SELECTED
		Fine charcoal mixed with tiny shell fragments and darker soil. Lens is segmented but appears to connect to charcoal layer 17C.	<u>LOWER:</u> Shell #40D	
17E	42 cm to 38 cm	16 cm X 1.5 cm-2 cm	<u>UPPER:</u> Shell #38B	SAMPLE NOT SELECTED
		Fine charcoal mixed with tiny shell fragments. The lens is continuous and the southern end merges with charcoal layer 17.	<u>LOWER:</u> Shell #38B	

18	25 cm to 20 cm	105 cm X 1 cm – 2 cm	UPPER: Shell #40A	SAMPLE NOT SELECTED	
		Fine charcoal mixed with tiny shell fragments, but no shell. The lens is continuous with a possible margin with charcoal layer 18A.	LOWER: Shell #40B		
18A	25 cm to 24 cm	50 cm X 1 cm	UPPER: Shell #40	SAMPLE NOT SELECTED	
		Fine charcoal mixed with larger pieces of charcoal. Lens is segmented and possibly merges with charcoal layer 18.	LOWER: Shell #40		
19	22 cm to 18 cm	46 cm X 1.5 cm	UPPER: Shell #40B	10YR/3/1: Very dark gray.	
		Fine charcoal with small shell fragments. Lens is continuous between shell layers	LOWER: Shell #40B		
19A	25 cm to 18 cm	35 cm X 1 cm	UPPER: Shell #40	SAMPLE NOT SELECTED	
		Fine charcoal with tiny shell fragments. Lens is segmented and between shell layers.	LOWER: Shell #40		
20	38 cm to 32 cm	20 cm X 1 cm	UPPER: Shell #39	SAMPLE NOT SELECTED	
		Tiny pieces of shell fragments and larger charcoal pieces. A continuous lens between	LOWER: Shell # 44		

		shell layers with large shells.			
21	24 cm to 22 cm	32 cm X 1 cm Fine charcoal mixed with pieces of charcoal. Small shell fragments. Lens is continuous between shell layers.	<u>UPPER:</u> Shell # 39 <u>LOWER:</u> Shell # 45	SAMPLE NOT SELECTED	
22	32 cm to 30 cm	17 cm X 1.5 cm Fine charcoal mixed with tiny shell fragments. Lens is continuous between shell layers.	<u>UPPER:</u> Shell # 40D <u>LOWER:</u> Shell # 40A	SAMPLE NOT SELECTED	
22A	31 cm to 30 cm	18 cm X 1 cm Fine charcoal mixed with tiny shell fragments. Lens is broken into two sections and may be an extension of charcoal layer 22. Lens is between shell layers.	<u>UPPER:</u> Shell # 40D <u>LOWER:</u> Shell # 40A	SAMPLE NOT SELECTED	
23	15 cm to 12 cm	62 cm X 1 – 4 cm Fine charcoal (wet) mixed with tiny shell fragments. Lens is continuous between shell layers.	<u>UPPER:</u> Shell # 45 <u>LOWER:</u> Shell # 43	SAMPLE NOT SELECTED	
23A	16 cm to 12 cm	Fine charcoal with large and small shell fragments.	<u>UPPER:</u> Shell #40C <u>LOWER:</u> Shell #42	10YR/3/1: Very dark gray.	

23B	16 cm to 12 cm	28 cm X 1.5 – 2 cm Very fine charcoal (slightly wet). Dust-like shell fragments, and pieces of sparse shell.	<u>UPPER:</u> Shell #41 <u>LOWER:</u> Shell #42	SAMPLE NOT SELECTED
23C	15 cm to to 8 cm	129 cm X 1-2 cm Fine charcoal (slightly damp). Tiny shell fragments and clay-like in the middle section.	<u>UPPER:</u> Shell #42 <u>LOWER:</u> Shell #46	SAMPLE NOT SELECTED
23D	15 cm to 13.5 cm	17 cm X 1.5 cm Very fine charcoal mixed with tiny shell fragments and dark soil. Lens is segmented between shell layers.	<u>UPPER:</u> Shell #46 <u>LOWER:</u> Shell #40B	SAMPLE NOT SELECTED
23E	13 cm to 10 cm	28 cm X 2 cm Fine charcoal with large and small shell fragments. Lens is continuous between shell layers.	<u>UPPER:</u> Shell #43 <u>LOWER:</u> Shell #46	SAMPLE NOT SELECTED
24	10 cm to 6 cm	20 cm X 1.5 cm Fine charcoal with bigger pieces of charcoal. Intermittent tiny shell fragments.	<u>UPPER:</u> Shell #46 <u>LOWER:</u> Shell #46	SAMPLE NOT SELECTED
25	- 8 cm to - 12 cm	70 cm X 3-4 cm Fine charcoal (wet) with tiny mussel shell fragments.	<u>UPPER:</u> Shell #46 <u>LOWER:</u> Ash #8 and Sand Sample	SAMPLE NOT SELECTED

		Lens is continuous between ash/sand and shell layers.			
26	- 10 cm to – 20 cm	65 cm to 2 – 4 cm	UPPER: Shell #46	10YR/5/1: Light gray.	
		Fine charcoal mixed with small mussel shells. Lens is slightly damp.	LOWER: Ash #8 and Sand Sample		
27	- 15 cm to – 22 cm	130 cm X 2-5 cm	UPPER: Sand Sample	10YR/2/2: Very dark brown.	
		Huge FCRs cross into this charcoal lens. Fine charcoal (slightly damp) mixed with tiny shell fragments. Less concentrated shall fragments than the other charcoal lenses.	LOWER: Not excavated		
		SHELL LENS DESCRIPTIONS			
Bag Number	**Distance from ground level (cm)**	**Matrix and Shell Orientation**	**Continuity and Boundaries**	**Photography of Sample**	
31	145 cm to 130 cm	Sandy matrix with whole and broken shell.	UPPER: Ground level.	SAMPLE NOT SELECTED	
		Shells are nested with ventral side up.	LOWER: Charcoal #11 and Ash #1.		
32	138 cm to 125 cm	Sandy matrix with whole and broken shell.	UPPER: Ash #1	SAMPLE NOT SELECTED	
		Shells are nested with ventral side up.	LOWER: Ash #2		
33	142 cm to 132 cm	Sandy matrix with whole and broken shell.	UPPER: Ash #1 and Shell #31	SAMPLE NOT SELECTED	
		Shells are nested with ventral side up.	LOWER: Ash #2		

34	122 cm to 93 cm	Very little soil and ash matrix with whole and large burnt shell fragments, some charcoal, small pebbles, and fire-modified rock (FRM).	UPPER: Charcoal #12 and Ash #2	10YR/8/1 and 7/1: White and light gray.	
		Shells are nested with ventral side up.	LOWER: Shell #34 and Shell #35		
35	93 cm to 70 cm	Fine sand and charcoal (more than #34) with an ash matrix.	UPPER: Charcoal #14 and Shell #34	10YR/7/1: Light gray.	
		Whole shell and large fragments. nested with ventral side up.	LOWER: Shell #36 and Shell #37		
36	70 cm – 55 cm	Fine sand and charcoal with an ash matrix. Smaller shell fragments compared to Shell #35. FMR present.	UPPER: Shell #35.	10YR/7/1: Light gray.	
		Horizontal and vertical stacking of shells at different angles.	LOWER: Ash #6A and Ash #17		
37	70 cm – 55 cm	Fine sand and charcoal (more than #34) with an ash matrix.	UPPER: Shell #34	SAMPLE NOT SELECTED	
		Whole shell and large fragments. nested with ventral side up.	LOWER: Ash #4		
38	57 cm to 40 cm	Fine sand and charcoal with an ash matrix. Large whole shells near the top of lense,	UPPER: Charcoal #15	10YR/7/2: Light gray.	

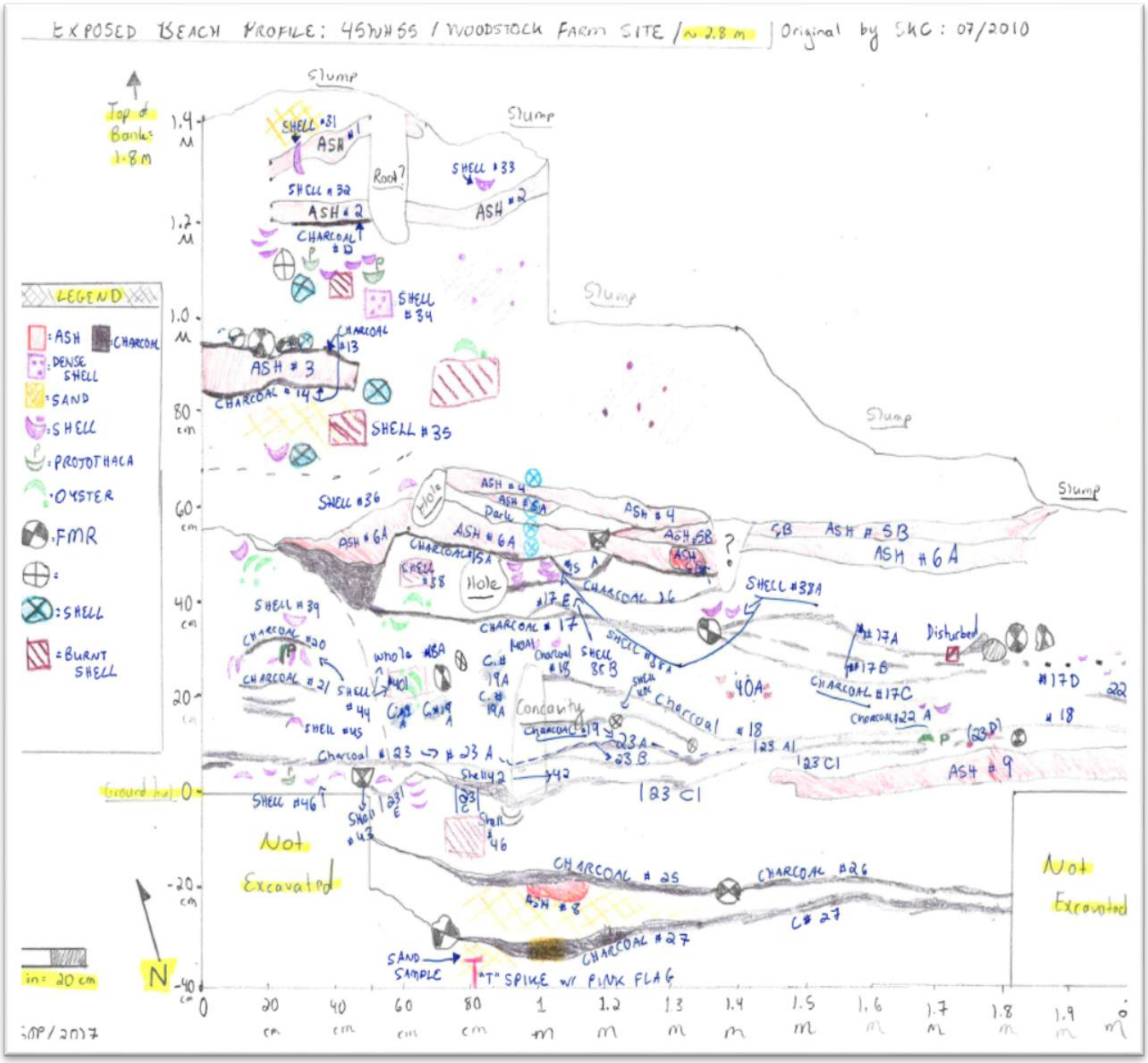
		and smaller crushed shells in bottom part of lense.			
		Shells nested with ventral side up.	LOWER: Charcoal #17		
38A	57 cm to 43 cm	Fine sand and charcoal with an ash matrix. Large whole shells with charcoal pockets.	UPPER: Ground level and Ash #6A	SAMPLE NOT SELECTED	
		Shells are nested and ventral side up.	LOWER: Shell #38A		
38B	46 cm to 37 cm	Fine sand and charcoal with an ash matrix. Smaller and friable shell fragments with native oyster.	UPPER: Ash #16	SAMPLE NOT SELECTED	
		Small and mostly horizontal stacking.	LOWER: Ash #17E		
39	50 cm to 42 cm	Fine sand and charcoal with an ash matrix. Large whole and crushed shell with FCR and small pieces of charcoal.	UPPER: Shell #36	SAMPLE NOT SELECTED	
		Large, dense, nested shells with majority ventral side up.	LOWER: Charcoal #20		
40	30 cm to 15 cm	A cemented matrix with large whole and crushed shell with FCR and small pieces of charcoal.	UPPER: Charcoal #17	10YR/6/1: Gray.	

		Large, dense, nested shells with majority ventral side up.	LOWER: Charcoal #23		
40A	40 cm to 24 cm	Smaller shell fragments with pebbles in a compacted matrix.	UPPER: Charcoal #17 and #17C	10YR/7/1: Light gray.	
		Smaller shells than #39, with majority stacked horizontally.	LOWER: Charcoal #18		
40B	28 cm to 22 cm	Smaller shell fragments with pebbles in a compacted matrix.	UPPER: Charcoal #18	SAMPLE NOT SELECTED	
		Smaller shells than #40A, with majority stacked horizontally.	LOWER: Charcoal #19		
40C	21 cm to 17 cm	Smaller shell fragments with pebbles in a compacted matrix.	UPPER: Charcoal #19	10YR/6/1: Gray.	
		Smaller shells than #40B, with majority stacked horizontally.	LOWER: Charcoal #23A		
40D	33 cm to 28 cm	Compacted and cemented similar to #40 (but softer).	UPPER: Charcoal #17D	SAMPLE NOT SELECTED	
		Smaller shells than #40, with majority stacked horizontally.	LOWER: Charcoal #22		
41	15 cm to 12 cm	Smaller shell fragments with pebbles in a compacted matrix.	UPPER: Charcoal #23A	SAMPLE NOT SELECTED	

		Smaller shells than #40B, with majority stacked horizontally.	LOWER: Charcoal #23B	
42	15 cm to 8 cm	Smaller shell fragments than #41 in a compact, ashy, and fine sand matrix.	UPPER: Charcoal #23, #23A, and #23D	SAMPLE NOT SELECTED
		Smaller shells than #41, with no clear orientation.	LOWER: Charcoal #23C	
43	14 cm to 10 cm	Medium-sized fragmented shell in very little matrix (but sandy).	UPPER: Charcoal #23	SAMPLE NOT SELECTED
		Medium shell fragments with a horizontal orientation.	LOWER: Charcoal #23E, #24, Shell #46	
44	38 cm to 24 cm	Fine sand and charcoal with an ash matrix. Large whole and crushed shell with some mussel, and small pieces of charcoal.	UPPER: Charcoal #44 and Shell #39	SAMPLE NOT SELECTED
		Large, dense, nested shells with majority ventral side up.	LOWER: Charcoal #21 and Shell #45	
45	20 cm to 13 cm	Fine sand and charcoal with a compact ash matrix. Large whole and crushed shell with some mussel, and small pieces of charcoal.	UPPER: Charcoal #21 and Shell #44	SAMPLE NOT SELECTED
		Less whole shell, and nested and horizontal shell similar to #39.	LOWER: Charcoal #23	

46	10 cm to -10 cm	Large whole fragments and large whole shell. Pockets of mussel, charcoal, and FCR. The shells are more loosely packed on the north end than the south end.	UPPER: Charcoal #23C,, #23E and #24	10YR/5/1: Gray.	
		Nested with some paired valves.	LOWER: Charcoal #25 and #26		
47	65 cm to 70 cm	Small shell fragments and pebbles with small pieces of charcoal in a compact matrix.	UPPER: Ash 5A and 5B	SAMPLE NOT SELECTED	
		Shell fragments lie horizontally.	LOWER: Ash 6A		

Appendix E: Original Beach Bank Shell Midden Sketch (Modified from Campbel 2010 by Pratschner 2017)



Appendix F: Salix Archaeological Services Report

SALIX
archaeological services
PO Box 31911, Seattle, WA 98103 • (206) 356-6563

April 21, 2017

Stacie Pratschner
Anthropology Department
Western Washington University
Arntzen Hall 315
Bellingham, Washington 98225

Submitted via email to: noreds@wwu.edu

RE: Woodstock Farm Site (45WH55) Charcoal Selection for Radiometric Analysis; SALIX 16-10

I recently analyzed charred wood (charcoal) fragments from archaeological site 45WH55, the Woodstock Farm Site, located on the shoreline approximately six miles south of Bellingham, Washington. The site is a Locarno Beach-phase shell midden and was excavated by Western Washington University field schools. My purpose was to identify woody taxa from nine samples and select the most appropriate charcoal fragments for radiometric analysis. Per your request, the priorities were to identify one fragment from an upper layer and one fragment from a lower layer that could then be submitted for AMS dating. Appropriate fragments in this case are specimens identified as: 1) short-lived trees or shrubs, typically angiosperms (also called "hardwoods"), 2) twigs, or 3) bark. Dating a fragment from a short-lived hardwood, twig, or piece of bark reduces the likelihood that radiometric ages will be subject to the "old wood effect."

The "old wood effect" refers to the artificial inflation of radiocarbon ages when wood from the inner rings, or heartwood, of a long-lived tree species is dated and equated to the archaeological event of interest (e.g., the felling or burning of the tree). Coniferous species have negative reputations for skewing radiocarbon ages, especially in northwestern North America, where some conifers can live for over 1,000 years, such as Douglas fir (*Pseudotsuga menziesii*), Sitka spruce (*Picea sitchensis*), and western redcedar (*Thuja plicata*). In the Northwest, it is best to avoid coniferous taxa for these reasons, while most deciduous trees are relatively short-lived and appropriate for radiocarbon dating. Alternatively, a twig or piece of bark represents recent or new growth and dates resulting from these materials should not be subject to the old wood effect. The best way to assure that old wood will not bias radiometric ages is to provide taxonomic identifications of wood or charcoal fragments prior to submittal.

Sample Provenience

Nine samples were submitted to SALIX for analysis, as indicated in Table 1.

Table 1. Provenience information for samples from the Woodstock Farm Site (45WH55)

Bag No.	Material	Depth from top of profile (cm)	Depth indicated on sample bags (cm)
11	charcoal	40	4
12	charcoal	60	30
13	charcoal	90	52
14	charcoal	100	52
17A	charcoal	140	33-38
19	charcoal	160	46
23A	charcoal	170	22-25
26	charcoal	190	12-16
27	charcoal	210	130

Methods

As indicated previously, analysis proceeded with the goal of identifying one fragment suitable for AMS from a lower layer and one fragment from an upper layer, in order to bound the site's occupation period. To this end, I analyzed charcoal from Bag 11 first, then moved to Bag 12, if no suitable piece was found in the first bag. Similarly, for the lower layers, I analyzed Bag 27, then proceeded to Bag 26, and so on.

As is standard with charcoal analysis, I sieved fragments into size fractions (in this case: >4 mm, 2-4 mm, <2 mm) and assessed only those fragments greater than 2 mm in size. Occasionally, charcoal fragments between 1 mm and 2 mm are sufficiently preserved to be identifiable, but their small size may mean certain anatomical features are not represented on a given fragment. Fragments less than 1 mm must be examined using a Scanning Electron Microscope (SEM) and were not considered in the present study.

Charcoal fragments were fractured along three planes with a single-edge razor blade and mounted in a sand-filled box for easy manipulation under the microscope. Fragments were identified using an Olympus BX43 microscope with reflected light and up to 500x magnification. Care was taken to thoroughly wash and sterilize all points of contact between identified samples and the analyst, in order to minimize cross-contamination.

Identifications were aided by the use of standard anatomical keys, namely the hardwood (dicotyledon) and softwood (conifer) keys published by Panshin and De Zeeuw (1980) and Friedman (1978), the softwood key by Kukachka (1960), and the conifer bark key by Chang (1954). I also relied on my own comparative collection to aid in identifications.

Wood anatomists typically provide genus-level identifications for wood and charcoal samples, since individual species are difficult, if not impossible, to differentiate under the microscope. I followed this standard practice for the 45WH55 sample. In some cases, it is safe to assume a species from a genus-level identification, if the analyst is confident that that species is the only member of the genus to be indigenous to or present in the given area. For instance, *Pseudotsuga menziesii* (Douglas fir) is the only *Pseudotsuga* native to the Pacific Northwest.

Results

In order to avoid the old wood effect, my goal was to identify an angiosperm (or hardwood) specimen, a twig, or a bark fragment. The results are summarized in Appendix 1, including size fractions, weights, charcoal counts, and taxonomic identifications.

BAG 11. Five fragments were analyzed from Bag 11; all five fragments are unidentified bark (phloem). These fragments are extremely degraded, as indicated by dense fungal hyphae, vegetative spores, and general cellular collapse. Brief examination of eight more fragments demonstrated that these characteristics are pervasive in the charcoal from Bag 11 and further taxonomic identification is not warranted.

Since these fragments are not assignable to genus, I cannot rule out the potential that they are *Pseudotsuga menziesii* (Douglas fir) bark. Douglas fir phloem can accumulate in 1 to 2 foot thick sections and bark may be one hundred to several hundred years old (Panshin and De Zeeuw 1980:50). If these specimens are Douglas fir bark, a resulting AMS date could be artificially old by 100-200 years, but not as old as the xylem (wood) of the same species. If you choose to risk this possibility in order to date this layer, I recommend submitting fragment #11.02, which is of sufficiently good condition and weight to withstand the AMS process.

BAG 12. Four fragments were analyzed from Bag 12. Two fragments are *Alnus* sp. (alder), one fragment is unidentified plant material, and one fragment is an unidentified angiosperm. In western Washington, the native *Alnus* species are *Alnus rubra* (red alder) and *Alnus sinuata* (Sitka alder). Both species of alder are relatively short-lived deciduous trees or shrubs. *Alnus rubra* lives typically 100 years or less, and often no more than 50 years (Favorite and Immel 2006; Pojar and McKinnon 1994). *Alnus sinuata* attains 25 to 50 year lifespans (Darris 2011). While these fragments cannot be identified to species, deciduous genera in the Pacific Northwest are much shorter-lived than coniferous genera and, therefore, are less likely to be subject to the old wood effect. Alder has been widely documented by ethnobotanists working in the Northwest Coast and Alaska as a preferred fuel for smoking fish, among other uses (Russell 1990:21-21; Turner and Bell 1971:79). Erna Gunther (1945:27) states: "Uniformly in this area alder wood is preferred for smoking salmon. It is also used for firewood in the open because it does not spark."

Individually, the two *Alnus* fragments (12.02 and 12.03) do not weigh enough to meet the minimum requirements at DirectAMS (http://www.directams.com/charcoal/). Together, however, the four identified fragments (no. 12.01, 12.02, 12.03, and 12.04) meet the 10 mg (0.01 g) minimum weight requirements. If you choose to date this layer, I recommend that you combine these fragments and submit them as one sample for AMS.

BAG 27. Fifteen fragments were identified from Bag 27. Eleven fragments were identified as *Pseudotsuga menziesii*, three are unidentified conifers, and one is unidentified wood. In the Pacific Northwest, the only species of false hemlock is *Pseudotsuga menziesii*, or Douglas fir, further differentiated as a coastal subspecies (ssp. *menziesii*) and an interior subspecies (ssp. *glauca*). Coastal Douglas fir is commonly found between sea level and 5,000 feet. Ethnographic literature tells us that the wood and bark have long been sought as firewood: "everywhere the bark was considered to be a top quality fuel because it burned with a hot smokeless flame" (Turner and Bell 1971:71). Since1,000 year old Douglas fir specimens have been documented (Arno and Hammerly 1999:67-74), I do not recommend the fragments from Bag 27 for AMS dating.

BAG 26. Twelve fragments were analyzed from Bag 26, representing 100% of fragments greater than 2 mm. The specimens identified to genus include two *Salix* sp. (willow) fragments, one *Alnus* sp. fragment, and one *Pseudotsuga menziesii* fragment. In addition to the alder and Douglas fir trees already discussed, numerous species of willow are native to the Northwest Coast, including Scouler's willow, Hooker's willow, Pacific willow, and Sitka willow. All are classified as shrubs or small trees, rarely exceeding 12 m in height (Pojar & MacKinnon 1994:88-89), and usually are considered old at 30 years.

Individually, the identified angiosperms (*Salix* and *Alnus*; catalog nos. 26.03, 26.08, and 26.10) are not heavy enough to withstand the AMS process. Even when combined, these fragments do not exceed the 0.01 g required minimum amount of material. For reasons mentioned previously, I do not recommend the *Pseudotsuga menziesii* fragment for dating. Fragment 26.01 (unidentified Pinaceae [pine family] bark), however, is a possible AMS candidate, should you choose to date this layer. Douglas fir is a member of Pinaceae, so the same caveats regarding several-hundred year old bark apply to fragment 26.01.

BAG 23A. Two fragments were analyzed from Bag 23A, one is cf. *Lonicera* sp. (twinberry, honeysuckle) and one is *Acer* sp. (maple). The *Lonicera* fragment was identified using an anatomical key for Northwest Coast woods (Friedman 1978), but is qualified by a "cf." due to the absence of this genus from my comparative collection.

In western Washington, both *Lonicera involucrata* (black twinberry) and *Lonicera ciliosa* (western trumpet honeysuckle) are found as short-lived shrubs and vines. Ethnographic evidence cites use of *Lonicera* bark and leaves for medicinal purposes (Gunther 1945). On the Northwest Coast, *Acer* may take the form of a large tree (*Acer macrophyllum* - Bigleaf maple), or smaller shrubs/trees like *Acer circinatum* (vine maple) and *Acer glabrum* (Douglas maple). Bigleaf maple may live up to 200 years, while the vine maple is considerably shorter lived, around 20 years (Arno and Hammerly 1999). Since charcoal identification is usually conducted to genus level and the selected fragment is extremely small, a species-level identification is not possible. Maples were considered valuable fuelwoods by many Northwest tribes (Gunther 1945:39-40).

Because of the potential for fragment 23A.02 to derive from a longer lived *Acer macrophyllum* tree, I recommend fragment 23A.01, *Lonicera* sp., for AMS submittal.

Conclusion

The samples from 45WH55, like archaeological charcoal samples from throughout the Pacific Northwest, contain primarily charred conifer fragments and those fragments that are identified as angiosperms often do not meet the minimum weight requirements for AMS. As a reminder, charcoal must weigh at least 0.01 g (10 mg), and preferably 0.02 g, for AMS dating to be successful. This analysis presents choices that must be made based on tolerable error and expected age gradients across site layers. Table 2 presents a summary of options for AMS submittal.

Table 2. Summary of AMS recommendations for 45WH55

Bag No.	*Catalog No.*	*Weight (g)*	*ID*	*Comments*
11	11.02	0.02	Unidentified bark	This fragment has potential to be Douglas fir bark, which may be 100+ years old
12	12.01	<0.01	Unid. plant material	Must combine all four fragments to provide sufficient weight (0.01 g) for AMS date
	12.02	<0.01	*Alnus* sp.	
	12.03	<0.01	*Alnus* sp.	
	12.04	<0.01	Unid. angiosperm	
23A	23A.01	0.06	cf. *Lonicera* sp.	Good AMS candidate
26	26.01	0.06	Unidentified Pinaceae bark	This fragment has potential to be Douglas fir bark, which may be 100+ years old
27	-	-	-	No short-lived fragments; no recommended AMS specimens

Upper Layers

Fragment 11.02, from the uppermost sample, is unidentified bark. As previously stated, bark is typically an ideal AMS candidate, but the risk that this fragment is several hundred year old Douglas fir bark is quite possible. Moving to the next lower sample, Bag 12, resulted in identification of short-lived *Alnus* fragments, but they must be combined with the other fragments in the 2-4 mm size fraction (12.01, 12.02, 12.03 and 12.04) to meet minimum AMS weight requirements (0.01g). The wild card – fragment 12.01: "unidentified plant material" – may be an angiosperm like the other identified fragments, or it may be a long-lived conifer.

Lower Layers

No short-lived genera are represented in the Bag 27 charcoal fragments. Bag 26 does contain fragments of unidentified bark and fragment 26.01 (unidentified Pinaceae bark – pine family) exceeds the minimum weight requirements for AMS. Fragment 26.01, therefore, is a possible AMS candidate qualified by the Douglas fir bark potential described above. Bag 23A presents a very clear choice for AMS: fragment 23A.01 is cf. *Lonicera* sp., a short-lived shrub, and meets AMS weight requirements.

Thank you for the opportunity to contribute to the Woodstock Farm site project! If you require any further information, please do not hesitate to contact me.

Best regards,

Jennie D. Shaw
Paleoethnobotanist, Owner

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SALIX
archaeological services

Project	Woodstock Farm Site (45WH55)	**APPENDIX 1. Taxonomic Identification of Archaeological Charcoal**
Location	Bellingham, WA	
PI	Stacie Pratschner, Sarah Campbell	
Organization	Western Washington University	
Salix Project No.	16-10	
Analyst	Jennie Shaw	

Catalog No.	Date ID	Material	Wt (g)	Size	Condition	ID	Comments
11	**BAG**	**charcoal**	**0.40**	**4-8 mm**	-	-	**COUNT=2**
11	**BAG**	**charcoal**	**0.15**	**2-4 mm**	-	-	**COUNT=28**
11	**BAG**	**charcoal**	**0.22**	**<2 mm**	-	-	**N/A**
11.01	4/13/2017	charcoal	0.02	4-8 mm	very poor	unidentified bark	extreme fungal hyphae
11.02*	4/13/2017	charcoal	0.02	4-8 mm	fair	unidentified bark	extreme fungal hyphae
11.03	4/17/2017	charcoal	0.01	2-4 mm	good	unidentified bark	extreme fungal hyphae
11.04	4/17/2017	charcoal	0.01	2-4 mm	fair	unidentified bark	extreme fungal hyphae
11.05	4/17/2017	charcoal	0.01	2-4 mm	poor	unidentified bark	extreme fungal hyphae
12	**BAG**	**charcoal**	**0.00**	**4-8 mm**	-	-	**COUNT=0**
12	**BAG**	**charcoal**	**0.01**	**2-4 mm**	-	-	**COUNT=4**
12	**BAG**	**charcoal**	**0.01**	**<2 mm**	-	-	**N/A**
12.01*	4/18/2017	charcoal	<0.01	2-4 mm	fair	unidentified plant material	slightly vitrified
12.02*	4/18/2017	charcoal	<0.01	2-4 mm	poor	*Alnus* sp.	fungal hyphae
12.03*	4/18/2017	charcoal	<0.01	2-4 mm	poor	*Alnus* sp.	Alnus frags <0.01 comb.
12.04*	4/18/2017	charcoal	<0.01	2-4 mm	poor	unidentified angiosperm	
27	**BAG**	**charcoal**	**0.18**	**4-8 mm**	-	-	**COUNT=7**
27	**BAG**	**charcoal**	**0.11**	**2-4 mm**	-	-	**COUNT=12**
27	**BAG**	**charcoal**	**0.07**	**<2 mm**	-	-	**N/A**
27.01	4/18/2017	charcoal	0.03	4-8 mm	fair	*Pseudotsuga menziesii*	
27.02	4/18/2017	charcoal	0.03	4-8 mm	fair	unidentified conifer	
27.03	4/18/2017	charcoal	0.02	4-8 mm	good	*Pseudotsuga menziesii*	
27.04	4/18/2017	charcoal	0.02	4-8 mm	good	*Pseudotsuga menziesii*	
27.05	4/18/2017	charcoal	0.02	4-8 mm	poor	unidentified conifer	
27.06	4/18/2017	charcoal	0.02	4-8 mm	poor	unidentified wood	

Appendix 1: Page 1

Project	Woodstock Farm Site (45WH55)	**APPENDIX 1. Taxonomic Identification of Archaeological Charcoal**
Location	Bellingham, WA	
PI	Stacie Pratschner, Sarah Campbell	
Organization	Western Washington University	
Salix Project No.	16-10	
Analyst	Jennie Shaw	

Catalog No.	Date ID	Material	Wt (g)	Size	Condition	ID	Comments
27.07	4/18/2017	charcoal	<0.01	4-8 mm	poor	*Pseudotsuga menziesii*	
27.08	4/18/2017	charcoal	0.02	2-4 mm	fair	*Pseudotsuga menziesii*	
27.09	4/18/2017	charcoal	0.02	2-4 mm	fair	*Pseudotsuga menziesii*	
27.10	4/18/2017	charcoal	0.02	2-4 mm	fair	*Pseudotsuga menziesii*	
27.11	4/18/2017	charcoal	0.01	2-4 mm	fair	*Pseudotsuga menziesii*	
27.12	4/18/2017	charcoal	<0.01	2-4 mm	fair	*Pseudotsuga menziesii*	
27.13	4/19/2017	charcoal	0.01	2-4 mm	fair	*Pseudotsuga menziesii*	
27.14	4/19/2017	charcoal	<0.01	2-4 mm	fair	*Pseudotsuga menziesii*	
27.15	4/19/2017	charcoal	<0.01	2-4 mm	fair	Unid. conifer	
27.16	4/19/2017	charcoal	<0.01	2-4 mm	N/A	Not analyzed due to insufficient weight	
27.17	4/19/2017	charcoal	<0.01	2-4 mm	N/A	Not analyzed due to insufficient weight	
27.18	4/19/2017	charcoal	<0.01	2-4 mm	N/A	Not analyzed due to insufficient weight	
27.19	4/19/2017	charcoal	<0.01	2-4 mm	N/A	Not analyzed due to insufficient weight	
26	**BAG**	**charcoal**	**0.06**	**4-8 mm**	-	-	**COUNT=1**
26	**BAG**	**charcoal**	**0.05**	**2-4 mm**	-	-	**COUNT=11**
26	**BAG**	**charcoal**	**0.02**	**<2 mm**	-	-	**not counted**
26.01*	4/19/2017	charcoal	0.06	4-8 mm	fair	unidentified Pinaceae bark	pine family
26.02	4/19/2017	charcoal	<0.01	2-4 mm	fair	unidentified conifer	
26.03	4/19/2017	charcoal	<0.01	2-4 mm	fair	*Salix* sp.	Salix fragments do not = 0.01 g
26.04	4/19/2017	charcoal	<0.01	2-4 mm	fair	unidentified conifer	
26.05	4/19/2017	charcoal	<0.01	2-4 mm	fair	*Pseudotsuga menziesii*	
26.06	4/19/2017	charcoal	<0.01	2-4 mm	fair	unidentified conifer	

Project	Woodstock Farm Site (45WH55)
Location	Bellingham, WA
PI	Stacie Pratschner, Sarah Campbell
Organization	Western Washington University
Salix Project No.	16-10
Analyst	Jennie Shaw

APPENDIX 1. Taxonomic Identification of Archaeological Charcoal

Catalog No.	Date ID	Material	Wt (g)	Size	Condition	ID	Comments
26.07	4/19/2017	charcoal	<0.01	2-4 mm	fair	unidentified bark	
26.08	4/19/2017	charcoal	<0.01	2-4 mm	fair	*Alnus* sp.	
26.09	4/19/2017	charcoal	<0.01	2-4 mm	fair	unidentified bark	
26.10	4/19/2017	charcoal	<0.01	2-4 mm	fair	*Salix* sp.	
26.11	4/19/2017	charcoal	<0.01	2-4 mm	poor	unidentified bark	with rootlets
26.12	4/19/2017	charcoal	<0.01	2-4 mm	poor	unidentified conifer	
23A	**BAG**	**charcoal**	**0.10**	**4-8 mm**	**-**	**-**	**COUNT=2**
23A	**BAG**	**charcoal**	**0.27**	**2-4 mm**	**-**	**-**	**COUNT=37**
23A	**BAG**	**charcoal**	**0.29**	**<2 mm**	**-**	**-**	**N/A**
23.01*	4/19/2017	charcoal	0.06	4-8 mm	fair	cf. *Lonicera* sp.	
23.02	4/19/2017	charcoal	0.03	4-8 mm	fair	*Acer* sp.	

*possible choices for AMS submittal

Appendix G: DirectAMS Radiocarbon Dating Services Results

DirectAMS
RADIOCARBON DATING SERVICE
measure more. learn more.

Report: **1908-026682-026683** 5 February 2018

Customer: 1908
Stacie J. Pratschner
Western Washington University
Anthropology Department
Arntzen Hall #315
Bellingham, WA 98225
USA

Samples submitted for radiocarbon dating have been processed and measured by AMS. The following results were obtained:

DirectAMS code	Submitter ID	Sample type	Fraction of modern		Radiocarbon age	
			pMC	1σ error	BP	1σ error
D-AMS 026682	Bag 12	charcoal, wood	93.87	0.27	508	23
D-AMS 026683	Bag 23A	charcoal, wood	89.04	0.28	933	25

Results are presented in units of percent modern carbon (pMC) and the uncalibrated radiocarbon age before present (BP). All results have been corrected for isotopic fractionation with an unreported $\delta^{13}C$ value measured on the prepared carbon by the accelerator. The pMC reported requires no further correction for fractionation.

Appendix H: Grain Size Analysis

ASH SUB-SAMPLES				
BAG 1: 50 ml sub-sample size				
Sieve Size (Tyler)	**Opening in Millimeters (mm)**	**Gravel Size**	**Mass of Sample Retained in Milliliters (ml)**	**Percentage**
8	2.36	Pebbles/Gravels/Coarse Sand	17.78	35.56%
40	0.425	Medium Sand	18.75	37.50%
200	.0029	Fine Sand	9.89	19.78%
270	.0021	Silt / Clay	3.20	6.40%
BAG 2: 50 ml sub-sample size				
Sieve Size (Tyler)	**Opening in Millimeters (mm)**	**Gravel Size**	**Mass of Sample Retained in Milliliters (ml)**	**Percentage**
8	2.36	Pebbles/Gravels/Coarse Sand	18.17	36.34%
40	0.425	Medium Sand	16.58	33.16%
200	.0029	Fine Sand	9.01	18.02%
270	.0021	Silt / Clay	5.05	10.10%
BAG 3: 50 ml sub-sample size				
Sieve Size (Tyler)	**Opening in Millimeters (mm)**	**Gravel Size**	**Mass of Sample Retained in Milliliters (ml)**	**Percentage**
8	2.36	Pebbles/Gravels/Coarse Sand	14.52	29.04%
40	0.425	Medium Sand	15.23	30.46%
200	.0029	Fine Sand	11.58	23.16%
270	.0021	Silt / Clay	7.96	15.92%
BAG 4: 50 ml sub-sample size				

Sieve Size (Tyler)	Opening in Millimeters (mm)	Gravel Size	Mass of Sample Retained in Milliliters (ml)	Percentage
8	2.36	Pebbles/Gravels/Coarse Sand	17.22	34.44%
40	0.425	Medium Sand	15.83	31.66%
200	.0029	Fine Sand	13.87	27.74%
270	.0021	Silt / Clay	2.50	5.00%
BAG 6A: 50 ml sub-sample size				
Sieve Size (Tyler)	**Opening in Millimeters (mm)**	**Gravel Size**	**Mass of Sample Retained in Milliliters (ml)**	**Percentage**
8	2.36	Pebbles/Gravels/Coarse Sand	17.58	35.16%
40	0.425	Medium Sand	10.85	21.7%
200	.0029	Fine Sand	7.02	14.04%
270	.0021	Silt / Clay	3.32	6.64%
BAG 7: 50 ml sub-sample size				
Sieve Size (Tyler)	**Opening in Millimeters (mm)**	**Gravel Size**	**Mass of Sample Retained in Milliliters (ml)**	**Percentage**
8	2.36	Pebbles/Gravels/Coarse Sand	16.66	33.32%
40	0.425	Medium Sand	19.21	38.42%
200	.0029	Fine Sand	13.16	26.32%
270	.0021	Silt / Clay	3.50	7.00%
BAG 8: 50 ml sub-sample size				
Sieve Size (Tyler)	**Opening in Millimeters (mm)**	**Gravel Size**	**Mass of Sample Retained in Milliliters (ml)**	**Percentage**
8	2.36	Pebbles/Gravels/Coarse Sand	7.99	15.98%
40	0.425	Medium Sand	11.76	23.52%
200	.0029	Fine Sand	26.68	53.36%

270	.0021	Silt / Clay	3.27	6.54%
SAND SUB-SAMPLE				
BAG SS: 50 ml sub-sample size				
Sieve Size (Tyler)	**Opening in Millimeters (mm)**	**Gravel Size**	**Mass of Sample Retained in Milliliters (ml)**	**Percentage**
8	2.36	Pebbles/Gravels/Coarse Sand	n/a	n/a
40	0.425	Medium Sand	4.94	9.88%
200	.0029	Fine Sand	45.01	90.02%
270	.0021	Silt / Clay	n/a	n/a
CHARCOAL SUB-SAMPLES				
BAG 11: Not tested, single piece of burnt wood.				
BAG 12: 5 ml sub-sample size				
Sieve Size (Tyler)	**Opening in Millimeters (mm)**	**Gravel Size**	**Mass of Sample Retained in Milliliters (ml)**	**Percentage**
8	2.36	Pebbles/Gravels/Coarse Sand	2.37	47.4%
40	0.425	Medium Sand	1.52	30.4%
200	.0029	Fine Sand	0.89	17.8%
270	.0021	Silt / Clay	0.09	1.8%
BAG 13: 5 ml sub-sample size				
Sieve Size (Tyler)	**Opening in Millimeters (mm)**	**Gravel Size**	**Mass of Sample Retained in Milliliters (ml)**	**Percentage**
8	2.36	Pebbles/Gravels/Coarse Sand	.81 (charcoal and shell)	16.2%
40	0.425	Medium Sand	2.59	51.8%
200	.0029	Fine Sand	1.89	37.8%
270	.0021	Silt / Clay	0.14	2.8%
BAG 14: 5 ml sub-sample size				

Sieve Size (Tyler)	Opening in Millimeters (mm)	Gravel Size	Mass of Sample Retained in Milliliters (ml)	Percentage
8	2.36	Pebbles/Gravels/Coarse Sand	2.46 (charcoal and shell)	49.2%
40	0.425	Medium Sand	1.42	28.4%
200	.0029	Fine Sand	1.03	20.6%
270	.0021	Silt / Clay	1.14	22.8%
BAG 17A: 25 ml sub-sample size				
Sieve Size (Tyler)	**Opening in Millimeters (mm)**	**Gravel Size**	**Mass of Sample Retained in Milliliters (ml)**	**Percentage**
8	2.36	Pebbles/Gravels/Coarse Sand	9.03 (charcoal and shell)	36.12%
40	0.425	Medium Sand	8.40	33.6%
200	.0029	Fine Sand	6.43	12.86%
270	.0021	Silt / Clay	1.25	2.5%
BAG 19: 25 ml sub-sample size				
Sieve Size (Tyler)	**Opening in Millimeters (mm)**	**Gravel Size**	**Mass of Sample Retained in Milliliters (ml)**	**Percentage**
8	2.36	Pebbles/Gravels/Coarse Sand	9.87 (charcoal and shell)	39.48%
40	0.425	Medium Sand	10.29	41.2%
200	.0029	Fine Sand	4.68	18.72%
270	.0021	Silt / Clay	.90	1.8%
BAG 23A: 25 ml sub-sample size				
Sieve Size (Tyler)	**Opening in Millimeters (mm)**	**Gravel Size**	**Mass of Sample Retained in Milliliters (ml)**	**Percentage**
8	2.36	Pebbles/Gravels/Coarse Sand	10.88(charcoal and shell)	43.52%
40	0.425	Medium Sand	8.60	34.4%
200	.0029	Fine Sand	4.37	17.48%

270	.0021	Silt / Clay	.83	3.32%
BAG 26: 25 ml sub-sample size				
Sieve Size (Tyler)	**Opening in Millimeters (mm)**	**Gravel Size**	**Mass of Sample Retained in Milliliters (ml)**	**Percentage**
8	2.36	Pebbles/Gravels/Coarse Sand	9.33(charcoal and shell)	37.32%
40	0.425	Medium Sand	9.28	37.12%
200	.0029	Fine Sand	6.54	26.16%
270	.0021	Silt / Clay	.13	.52%
BAG 27: 25 ml sub-sample size				
Sieve Size (Tyler)	**Opening in Millimeters (mm)**	**Gravel Size**	**Mass of Sample Retained in Milliliters (ml)**	**Percentage**
8	2.36	Pebbles/Gravels/Coarse Sand	2.61(charcoal and shell)	10.44%
40	0.425	Medium Sand	4.71	18.84%
200	.0029	Fine Sand	17.49	69.96%
270	.0021	Silt / Clay	.15	0.6%
SHELL SUB-SAMPLES				
BAG 34: 50 ml sub-sample size				
Sieve Size (Tyler)	**Opening in Millimeters (mm)**	**Gravel Size**	**Mass of Sample Retained in Milliliters (ml)**	**Percentage**
8	2.36	Pebbles/Gravels/Coarse Sand	32.87	65.74%
40	0.425	Medium Sand	13.01	26.02%
200	.0029	Fine Sand	0.15	0.3%
270	.0021	Silt / Clay	0.83	1.66%
BAG 35: 50 ml sub-sample size				
Sieve Size (Tyler)	**Opening in Millimeters (mm)**	**Gravel Size**	**Mass of Sample Retained in Milliliters (ml)**	**Percentage**

8	2.36	Pebbles/Gravels/Coarse Sand	40.43	80.86%
40	0.425	Medium Sand	7.77	15.54%
200	.0029	Fine Sand	1.03	2.06%
270	.0021	Silt / Clay	.10	0.2%
BAG 36: 50 ml sub-sample size				
Sieve Size (Tyler)	**Opening in Millimeters (mm)**	**Gravel Size**	**Mass of Sample Retained in Milliliters (ml)**	**Percentage**
8	2.36	Pebbles/Gravels/Coarse Sand	28.29	56.58%
40	0.425	Medium Sand	15.41	30.82%
200	.0029	Fine Sand	5.11	10.22%
270	.0021	Silt / Clay	.90	1.8%
BAG 38: 50 ml sub-sample size				
Sieve Size (Tyler)	**Opening in Millimeters (mm)**	**Gravel Size**	**Mass of Sample Retained in Milliliters (ml)**	**Percentage**
8	2.36	Pebbles/Gravels/Coarse Sand	38.79	77.58%
40	0.425	Medium Sand	6.72	13.44%
200	.0029	Fine Sand	1.99	3.98%
270	.0021	Silt / Clay	.34	0.68%
BAG 40: 50 ml sub-sample size				
Sieve Size (Tyler)	**Opening in Millimeters (mm)**	**Gravel Size**	**Mass of Sample Retained in Milliliters (ml)**	**Percentage**
8	2.36	Pebbles/Gravels/Coarse Sand	48.42	96.84%
40	0.425	Medium Sand	n/a	n/a
200	.0029	Fine Sand	.58	1.16%
270	.0021	Silt / Clay	.11	0.22%
BAG 40A: 50 ml sub-sample size				

Sieve Size (Tyler)	Opening in Millimeters (mm)	Gravel Size	Mass of Sample Retained in Milliliters (ml)	Percentage
8	2.36	Pebbles/Gravels/Coarse Sand	26.68	53.36%
40	0.425	Medium Sand	14.63	29.26%
200	.0029	Fine Sand	7.11	14.22%
270	.0021	Silt / Clay	.92	1.84%
BAG 40C: 50 ml sub-sample size				
Sieve Size (Tyler)	**Opening in Millimeters (mm)**	**Gravel Size**	**Mass of Sample Retained in Milliliters (ml)**	**Percentage**
8	2.36	Pebbles/Gravels/Coarse Sand	24.60	49.2%
40	0.425	Medium Sand	12.74	25.48%
200	.0029	Fine Sand	14.32	28.64%
270	.0021	Silt / Clay	1.13	2.26%
BAG 46: 50 ml sub-sample size				
Sieve Size (Tyler)	**Opening in Millimeters (mm)**	**Gravel Size**	**Mass of Sample Retained in Milliliters (ml)**	**Percentage**
8	2.36	Pebbles/Gravels/Coarse Sand	40.15	80.3%
40	0.425	Medium Sand	7.46	14.92%
200	.0029	Fine Sand	2.18	4.36%
270	.0021	Silt / Clay	.85	1.7%

Appendix I: Magnetic Susceptibility Results

```
"Bartington Instruments Multisus File"
"-----------------------------------------------------------------"
"20-01-2018 15:19","C:\Users\Tesla\Desktop\45WH55.sus","Multisus 32/2.31"
"-----------------------------------------------------------------"
"45WH55"
"-----------------------------------------------------------------"
"Sensor","MS2B"
"Range",.1
"Units","SI"
"Frequency","LF"
"Drift Limit",5
"Weight Correction",1
"Container weight",.000001
"Container Correction",0
"Container sus SI",0
"Container sus CGS",0
"-----------------------------------------------------------------"
"Sample","Weight","LF Sus","HF Sus","Freq.Dep.%"
"54","0.00","664904.6","",""
"3905","0.00","5567470.5","",""
"SS","3.92","42.5","",""
"1","2.39","71.4","",""
"46","1.88","4.7","",""
"2","2.28","49.5","",""
"8","2.48","75.1","",""
"3","2.37","67.7","",""
"26","2.73","21.0","",""
"12","2.64","5.5","",""
"17A","1.12","21.9","",""
"19","2.00","12.2","",""
"23A","1.88","134.6","",""
"40C","2.77","7.3","",""
"27","3.48","11.5","",""
"40A","2.33","8.8","",""
"13","1.28","33.3","",""
"38","2.83","10.9","",""
"40","2.11","4.7","",""
"35","2.23","23.8","",""
"7","2.26","30.2","",""
"6A","2.31","62.1","",""
"4","1.65","52.5","",""
```

Appendix J: Edge Analytical Total Phosphorous Data Report

EDGE ANALYTICAL

Burlington, WA Corporate Laboratory (a)
1620 S Walnut St - Burlington, WA 98233 - 800.755.9295 - 360.757.1400

Bellingham, WA Microbiology (b)
805 Orchard Dr Ste 4 - Bellingham, WA 98225 - 360.715.1212

Portland, OR Microbiology/Chemistry (c)
9150 SW Pioneer Ct Ste W - Wilsonville, OR 97070 - 503.682.7802

Corvallis, OR Microbiology/Chemistry (d)
540 SW Third Street - Corvallis, OR 97333 - 541.753.4946

Bend, OR Microbiology (e)
20332 Empire Blvd Ste 4 - Bend, OR 97701 - 541.639.8425

Data Report

Client Name: Stacie J. Pratschner
256 Shantel Street
Mount Vernon, WA 98274

Reference Number: 18-18949
Project: 45WH55 Soil Tests

Report Date: 6/13/18

Date Received: 5/29/18
Approved by: bj
Authorized by:

Lawrence J Henderson, PhD
Director of Laboratories, Vice President

Sample Description: 1 Chuckunut Bay, WA — Sample Date: 7/15/10 12:00 pm
Lab Number: 38817 — Sample Comment: — Collected By: Sarah K. Campbell

CAS ID#	Parameter	Result	PQL	MDL	Units	DF	Method	Lab	Analyzed	Analyst	Batch	Comment
7723-14-0	TOTAL PHOSPHORUS	1980	41		mg/Kg	10.0	6010B/3051	a	6/7/18	ANP	60100_180607A	

Sample Description: 2 Chuckunut Bay, WA — Sample Date: 7/15/10 12:00 pm
Lab Number: 38818 — Sample Comment: — Collected By: Sarah K. Campbell

CAS ID#	Parameter	Result	PQL	MDL	Units	DF	Method	Lab	Analyzed	Analyst	Batch	Comment
7723-14-0	TOTAL PHOSPHORUS	5298	50		mg/Kg	10.0	6010B/3051	a	6/7/18	ANP	60100_180607A	

Sample Description: 3 Chuckunut Bay, WA — Sample Date: 7/15/10 12:00 pm
Lab Number: 38819 — Sample Comment: — Collected By: Sarah K. Campbell

CAS ID#	Parameter	Result	PQL	MDL	Units	DF	Method	Lab	Analyzed	Analyst	Batch	Comment
7723-14-0	TOTAL PHOSPHORUS	5825	38		mg/Kg	10.0	6010B/3051	a	6/7/18	ANP	60100_180607A	

Sample Description: 4 Chuckunut Bay, WA — Sample Date: 7/15/10 12:00 pm
Lab Number: 38820 — Sample Comment: — Collected By: Sarah K. Campbell

CAS ID#	Parameter	Result	PQL	MDL	Units	DF	Method	Lab	Analyzed	Analyst	Batch	Comment
7723-14-0	TOTAL PHOSPHORUS	5026	47		mg/Kg	10.0	6010B/3051	a	6/7/18	ANP	60100_180607A	

Sample Description: 6A Chuckunut Bay, WA — Sample Date: 7/15/10 12:00 pm
Lab Number: 38821 — Sample Comment: — Collected By: Sarah K. Campbell

CAS ID#	Parameter	Result	PQL	MDL	Units	DF	Method	Lab	Analyzed	Analyst	Batch	Comment
7723-14-0	TOTAL PHOSPHORUS	5879	40		mg/Kg	10.0	6010B/3051	a	6/7/18	ANP	60100_180607A	

Sample Description: 7 Chuckunut Bay, WA — Sample Date: 7/15/10 12:00 pm
Lab Number: 38822 — Sample Comment: — Collected By: Sarah K. Campbell

CAS ID#	Parameter	Result	PQL	MDL	Units	DF	Method	Lab	Analyzed	Analyst	Batch	Comment

Notes:

ND = Not detected above the listed practical quantitation limit (PQL) or not above the Method Detection Limit (MDL), if requested.
PQL = Practical Quantitation Limit is the lowest level that can be achieved within specified limits of precision and accuracy during routine laboratory operating conditions.
D.F. - Dilution Factor

If you have any questions concerning this report contact us at the above phone number.

Form: cRslt_2.rpt

EDGE ANALYTICAL

Reference Number: 18-18949
Report Date: 6/13/18

Data Report

CAS ID#	Parameter	Result	PQL	MDL	Units	DF	Method	Lab	Analyzed	Analyst	Batch	Comment
7723-14-0	TOTAL PHOSPHORUS	1543	45		mg/Kg	10.0	6010B/3051	a	6/7/18	ANP	60100_180607A	

Sample Description: 8 Chuckunut Bay, WA — Sample Date: 7/15/10 12:00 pm
Lab Number: 38823 — Sample Comment: — Collected By: Sarah K. Campbell

CAS ID#	Parameter	Result	PQL	MDL	Units	DF	Method	Lab	Analyzed	Analyst	Batch	Comment
7723-14-0	TOTAL PHOSPHORUS	2121	38		mg/Kg	10.0	6010B/3051	a	6/7/18	ANP	60100_180607A	

Sample Description: SS Chuckunut Bay, WA — Sample Date: 7/15/10 12:00 pm
Lab Number: 38824 — Sample Comment: — Collected By: Sarah K. Campbell

CAS ID#	Parameter	Result	PQL	MDL	Units	DF	Method	Lab	Analyzed	Analyst	Batch	Comment
7723-14-0	TOTAL PHOSPHORUS	125	0.40		mg/Kg	10.0	6010B/3051	a	6/12/18	ANP	60100_180612A	

Sample Description: 13 Chuckunut Bay, WA — Sample Date: 7/15/10 12:00 pm
Lab Number: 38825 — Sample Comment: — Collected By: Sarah K. Campbell

CAS ID#	Parameter	Result	PQL	MDL	Units	DF	Method	Lab	Analyzed	Analyst	Batch	Comment
7723-14-0	TOTAL PHOSPHORUS	3539	50		mg/Kg	10.0	6010B/3051	a	6/7/18	ANP	60100_180607A	

Sample Description: 14 Chuckunut Bay, WA — Sample Date: 7/15/10 12:00 pm
Lab Number: 38826 — Sample Comment: — Collected By: Sarah K. Campbell

CAS ID#	Parameter	Result	PQL	MDL	Units	DF	Method	Lab	Analyzed	Analyst	Batch	Comment
7723-14-0	TOTAL PHOSPHORUS	1617	39		mg/Kg	10.0	6010B/3051	a	6/7/18	ANP	60100_180607A	

Sample Description: 17A Chuckunut Bay, WA — Sample Date: 7/15/10 12:00 pm
Lab Number: 38827 — Sample Comment: — Collected By: Sarah K. Campbell

CAS ID#	Parameter	Result	PQL	MDL	Units	DF	Method	Lab	Analyzed	Analyst	Batch	Comment
7723-14-0	TOTAL PHOSPHORUS	1719	48		mg/Kg	10.0	6010B/3051	a	6/7/18	ANP	60100_180607A	

Sample Description: 19 Chuckunut Bay, WA — Sample Date: 7/15/10 12:00 pm
Lab Number: 38828 — Sample Comment: — Collected By: Sarah K. Campbell

CAS ID#	Parameter	Result	PQL	MDL	Units	DF	Method	Lab	Analyzed	Analyst	Batch	Comment
7723-14-0	TOTAL PHOSPHORUS	1358	43		mg/Kg	10.0	6010B/3051	a	6/7/18	ANP	60100_180607A	

Sample Description: 23 Chuckunut Bay, WA — Sample Date: 7/15/10 12:00 pm
Lab Number: 38829 — Sample Comment: — Collected By: Sarah K. Campbell

CAS ID#	Parameter	Result	PQL	MDL	Units	DF	Method	Lab	Analyzed	Analyst	Batch	Comment
7723-14-0	TOTAL PHOSPHORUS	602	46		mg/Kg	10.0	6010B/3051	a	6/7/18	ANP	60100_180607A	

Sample Description: 26 Chuckunut Bay, WA — Sample Date: 7/15/10 12:00 pm
Lab Number: 38830 — Sample Comment: — Collected By: Sarah K. Campbell

CAS ID#	Parameter	Result	PQL	MDL	Units	DF	Method	Lab	Analyzed	Analyst	Batch	Comment
7723-14-0	TOTAL PHOSPHORUS	372	28		mg/Kg	10.0	6010B/3051	a	6/7/18	ANP	60100_180607A	

Notes:
ND = Not detected above the listed practical quantitation limit (PQL) or not above the Method Detection Limit (MDL), if requested.
PQL = Practical Quantitation Limit is the lowest level that can be achieved within specified limits of precision and accuracy during routine laboratory operating conditions.
D.F. - Dilution Factor

Form: cflait_2.rpt

EDGE ANALYTICAL

Reference Number: **18-18949**
Report Date: 6/13/18

Data Report

Sample Description: 27 Chuckunut Bay, WA | Sample Date: 7/15/10 12:00 pm
Lab Number: 38831 | Sample Comment: | Collected By: Sarah K. Campbell

CAS ID#	Parameter	Result	PQL	MDL	Units	DF	Method	Lab	Analyzed	Analyst	Batch	Comment
7723-14-0	TOTAL PHOSPHORUS	378	43		mg/Kg	10.0	6010B/3051	a	6/7/10	ANP	60100_100607A	

Sample Description: 34 Chuckunut Bay, WA | Sample Date: 7/15/10 12:00 pm
Lab Number: 38832 | Sample Comment: | Collected By: Sarah K. Campbell

CAS ID#	Parameter	Result	PQL	MDL	Units	DF	Method	Lab	Analyzed	Analyst	Batch	Comment
7723-14-0	TOTAL PHOSPHORUS	1641	51		mg/Kg	10.0	6010B/3051	a	6/7/10	ANP	60100_100607A	

Sample Description: 35 Chuckunut Bay, WA | Sample Date: 7/15/10 12:00 pm
Lab Number: 38833 | Sample Comment: | Collected By: Sarah K. Campbell

CAS ID#	Parameter	Result	PQL	MDL	Units	DF	Method	Lab	Analyzed	Analyst	Batch	Comment
7723-14-0	TOTAL PHOSPHORUS	1580	49		mg/Kg	10.0	6010B/3051	a	6/7/10	ANP	60100_100607A	

Sample Description: 36 Chuckunut Bay, WA | Sample Date: 7/15/10 12:00 pm
Lab Number: 38834 | Sample Comment: | Collected By: Sarah K. Campbell

CAS ID#	Parameter	Result	PQL	MDL	Units	DF	Method	Lab	Analyzed	Analyst	Batch	Comment
7723-14-0	TOTAL PHOSPHORUS	3233	21		mg/Kg	10.0	6010B/3051	a	6/7/10	ANP	60100_100607A	

Sample Description: 38 Chuckunut Bay, WA | Sample Date: 7/15/10 12:00 pm
Lab Number: 38835 | Sample Comment: | Collected By: Sarah K. Campbell

CAS ID#	Parameter	Result	PQL	MDL	Units	DF	Method	Lab	Analyzed	Analyst	Batch	Comment
7723-14-0	TOTAL PHOSPHORUS	3587	50		mg/Kg	10.0	6010B/3051	a	6/7/10	ANP	60100_100607A	

Sample Description: 40 Chuckunut Bay, WA | Sample Date: 7/15/10 12:00 pm
Lab Number: 38836 | Sample Comment: | Collected By: Sarah K. Campbell

CAS ID#	Parameter	Result	PQL	MDL	Units	DF	Method	Lab	Analyzed	Analyst	Batch	Comment
7723-14-0	TOTAL PHOSPHORUS	290	51		mg/Kg	10.0	6010B/3051	a	6/7/10	ANP	60100_100607A	

Sample Description: 40A Chuckunut Bay, WA | Sample Date: 7/15/10 12:00 pm
Lab Number: 38837 | Sample Comment: | Collected By: Sarah K. Campbell

CAS ID#	Parameter	Result	PQL	MDL	Units	DF	Method	Lab	Analyzed	Analyst	Batch	Comment
7723-14-0	TOTAL PHOSPHORUS	597	49		mg/Kg	10.0	6010B/3051	a	6/7/10	ANP	60100_100607A	

Sample Description: 40C Chuckunut Bay, WA | Sample Date: 7/15/10 12:00 pm
Lab Number: 38838 | Sample Comment: | Collected By: Sarah K. Campbell

CAS ID#	Parameter	Result	PQL	MDL	Units	DF	Method	Lab	Analyzed	Analyst	Batch	Comment
7723-14-0	TOTAL PHOSPHORUS	576	17		mg/Kg	10.0	6010B/3051	a	6/7/10	ANP	60100_100607A	

Notes:

ND = Not detected above the listed practical quantitation limit (PQL) or not above the Method Detection Limit (MDL), if requested.
PQL = Practical Quantitation Limit is the lowest level that can be achieved within specified limits of precision and accuracy during routine laboratory operating conditions.
D.F. - Dilution Factor

Form: cRslt_2.rpt

EDGE ANALYTICAL

Reference Number: 18-18949
Report Date: 6/13/18

Data Report

Sample Description: 46 Chuckunut Bay, WA
Lab Number: 38839 Sample Comment:
Sample Date: 7/15/10 12:00 pm
Collected By: Sarah K. Campbell

CAS ID#	Parameter	Result	PQL	MDL	Units	DF	Method	Lab	Analyzed	Analyst	Batch	Comment
7723-14-0	**TOTAL PHOSPHORUS**	359	50		mg/Kg	10.0	6010B/3051	a	6/7/18	ANP	60100_180607A	

Notes:

ND = Not detected above the listed practical quantitation limit (PQL) or not above the Method Detection Limit (MDL), if requested.
PQL = Practical Quantitation Limit is the lowest level that can be achieved within specified limits of precision and accuracy during routine laboratory operating conditions.
D.F. - Dilution Factor

Form: cRslt_2.rpt