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Post-Glacial Fire History of Horsetail Fen and Human-Environment Interactions in the Teanaway Area of the Eastern Cascades, Washington

Serafina Ferri
ferris@cwu.edu

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POST-GLACIAL FIRE HISTORY OF HORSETAIL FEN AND HUMAN-ENVIRONMENT INTERACTIONS IN THE TEANAWAY AREA OF THE EASTERN CASCADES, WASHINGTON

A Thesis

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In Partial Fulfillment of the Requirements for the Degree

Master of Science

Resource Management

by

Serafina Ann Ferri

February 2019
CENTRAL WASHINGTON UNIVERSITY
Graduate Studies

We hereby approve the thesis of

Serafina Ann Ferri

Candidate for the degree of Master of Science

APPROVED FOR THE GRADUATE FACULTY

___________________________
Dr. Megan Walsh, Committee Chair

___________________________
Dr. Patrick McCutcheon

___________________________
Dr. Steve Hackenberger

___________________________
Dean of Graduate Studies
ABSTRACT

POST-GLACIAL FIRE HISTORY OF HORSETAIL FEN AND ITS IMPLICATIONS FOR HUMAN-ENVIRONMENT INTERACTIONS IN THE TEANAWAY AREA OF THE EASTERN CASCADES, WASHINGTON

by

Serafina Ann Ferri

February 2019

Landscapes of the Pacific Northwest have been shaped by dramatic shifts in climate since the last glacial maximum and more recently, by human activity. However, it is unclear how past relationships between people, fire, and climate interacted on the landscape. The purpose of this research was to reconstruct the post-glacial fire history of a wetland known as Horsetail Fen, located in the Teanaway area of the eastern Cascades of Washington State. The goal was to evaluate how fire activity has varied under different climatic scenarios during the last ~16,000 years and in relation to human land-use actions. This lake was selected because it is one of only a few natural wetlands that exist in the Teanaway area below an elevation of 1220 meters (4,000 feet), and because the archaeological record contains evidence that people utilized mountain environments in the eastern Cascades like that around the site. In 2011, a nine-meter-long sediment core was extracted from Horsetail Fen using a modified Livingstone piston corer. High-resolution macroscopic charcoal analysis was used to reconstruct the fire history of the Horsetail Fen watershed. The chronology of the sediment was determined using radiocarbon (14C) dating and tephra layer identification. Results of this study show that fire frequency and severity have varied widely at Horsetail Fen during the post-glacial period. The early Holocene shows fire
activity was low and steady and increased significantly during the middle Holocene. Fire activity remained relatively high during late Holocene. The archaeological record provides evidence that people were using these landscapes throughout the Holocene. Ethnographic and oral accounts suggest people were modifying their landscapes using fire. These results can be incorporated in future management plans of forest environments in the eastern Cascades as climate continues to change.
ACKNOWLEDGEMENTS

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I would like to thank my family, my sister Luciana who I spent many hours studying with. Lu and I took some of the same classes including statistics, archaeological methods, and I was always one step behind her. When she received an A, I received an A-. She always inspired me to strive for better grades, maybe it was just sibling competition. I would like to thank my Uncle Ed who has always encouraged me, and mother Rose who has always supported my education.

Last, but most importantly, I would like to thank my 11-year-old daughter Bella, during whose entire life I have been a college student. Here’s to no more homework and late-night study sessions! I am ready to start my career and be present with you each day.
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CHAPTER I
INTRODUCTION

Problem

Since the Last Glacial Maximum, approximately 18,000 years ago, the landscapes of the Pacific Northwest (PNW) have been shaped by dramatic shifts in climate and, more recently, by human activity (Bartlein et al. 1998; Orr 1996; Prentiss et al. 2005; Walker 1998; Whitlock and Knox 2002; Whitlock 1992). Studies have shown that fire plays a major role in ecosystem dynamics in the PNW and is influenced by both climate variability and human activity (Agee 1993; Gavin and Brubaker 2015; Walsh et al. 2015). Modern relationships between people and fire are relatively well understood; however, past relationships and how they played out on the landscape in the PNW remain unclear (Burtchard 2007; Connolly 2000). Investigating these interactions is typically done using paleoecology, which by itself can only offer information regarding environmental changes but gives little insight into human-environment interactions. However, by combing paleoecological, archaeological and ethnographic information, a more complete picture of the relationship between people and their use of the landscape is possible (Delcourt 1996; Spies at al. 2014; Walsh et al. 2018).

Fires primarily occur in the PNW as the result of lightning but are also caused by human ignitions (Bartlein et al. 2008). Fire activity is both directly and indirectly influenced by weather and climate on short and long timescales (Whitlock and Bartlein 2003). On shorter timescales, weather influences fire by changing temperatures, precipitation, and relative humidity (Bartlein et al. 1998; Dalton et al. 2013). As temperatures rise and precipitation decreases, conditions conducive for fires become more prevalent resulting from dry fuels being ignited by lightning strikes. On longer timescales, changes in climate, such as variations in insolation and
atmospheric greenhouse gas concentrations, can influence fire occurrence through modifications to vegetation structure, growth rates, and fuel availability (Agee 1993; Whitlock and Larsen 2001; Marlon et al. 2006).

Along with climate variability, people have traditionally played a considerable role in modifying the environments of the PNW, specifically using fire (Agee 2003; Boyd 1986; Brown and Hebda 2000b; Turner 1991, 1999; Walsh et al. 2010b; Walsh et al. 2018). Ethnographic documents and Native American knowledge support the idea that anthropogenic ecosystems were common in the PNW (Boyd 1990; Lepofsky et al., 2005; Nickels 2002) however, human-environment interactions are better understood in some parts of the PNW than others, particularly where the archaeological/ethnographic record is better established. For example, well-documented sites found at Mount Rainier contribute to our knowledge of human-environment interactions, including settlement patterns, site types, and modified landscapes (Andrews et al. 2016; Burtchard 2007). Through the analysis of archaeobotanical remains, soils, and cultural features, indigenous people managed the landscape through intentional burning over an extensive period at Ebey’s Prairie on Whidbey Island, Washington (Weiser and Lepofsky 2009). Additionally, in areas of southwest Oregon, it is noted that Native American people, specifically women, had detailed knowledge for creating diverse ecological prairies and mountain environments as part of their subsistence practices (Boyd 1999; Tveskov 2007). However, the management of landscapes in the PNW varied tremendously based on topography, cultural differences, and differences in tool types, which is reflected in the archaeological record.

One area where extremely little is known about past human-environment interactions are the forests of the eastern Cascade Mountains of Washington. These areas were utilized by Native Americans as early as the terminal Pleistocene epoch according to the archaeological record and
detailed oral history documents (Hollenbeck and Carter 1986; Vern 1936; Walker 1998; Zweifel and Reid 1991). However, the lack of paleoenvironmental research and the absence of dates in the archaeological record limits the resolution of our understanding of how humans interacted with the environment, and more specifically used fire or fire-modified landscapes in the eastern Cascades. This research will investigate what information, if any, can be gained by comparing a newly developed fire-history record from this area with the known archaeological/ethnographic record (Crumley 1994; O’Brien 2001).

Purpose and Objectives

The purpose of this thesis is to develop a new post-glacial fire history reconstruction from the eastern Cascades Mountains and to evaluate that history using existing regional climatic records and available archaeological, ethnographic and historic records. Macroscopic charcoal analysis of a nine meter-long sediment core was used to reconstruct the post-glacial fire history of the Horsetail Fen watershed, located in the Teanaway area of the eastern Cascades. The goal of this thesis is to illustrate the value of using an interdisciplinary approach when thinking about how people either modified their environment using fire, or used fire-modified landscapes, in the central eastern Cascade Mountains of Washington. This thesis addresses the following research questions:

1) How has fire activity varied in the Horsetail Fen watershed during the past ~16,000 years?
2) What role has climate variability played in influencing the fire activity at Horsetail Fen in comparison to the regional paleoenvironmental record during the post-glacial period?
3) How does the fire history from Horsetail Fen, when combined with the record of human history in the central eastern Cascades, contribute to our understanding of past human land use of fire-modified landscapes?
Given the above purpose for the thesis, the specific objectives are:

1) To reconstruct the post-glacial fire history of the Horsetail Fen watershed using macroscopic charcoal analysis of a lake sediment core.

   In 2011, a sediment core was extracted from Horsetail Fen using a 5 cm diameter modified Livingston piston corer. Eight radiocarbon dates were used to establish an age-depth model for the core, which indicates a basal age of ~16,000 calendar years before present (cal yr BP). Macroscopic charcoal analysis was performed at 1 cm intervals and the data were analyzed using the CharAnalysis statistical program. From this the local fire history was reconstructed, which identified fire episodes and changes in fire frequency and magnitude.

2) To evaluate the Horsetail Fen fire history within the context of the known regional climatic variability, and to perform a comparison with other published fire history and vegetation records from the Pacific Northwest.

   Available climatic records were used to evaluate the influence of past climate variability on the fire history at Horsetail Fen. The fire history record was also compared to other published fire history and vegetation records from the PNW, to place the observed changes within the context of the regional history.

3) To summarize the post-glacial archaeological, ethnographic, and historical record for the central eastern Cascades, focusing on human land-use practices within fire-modified landscapes.
This was accomplished using published and unpublished documents pertaining to human land use practices using the archaeological record to identify regional archaeological sites and categorize them by space and time, when possible. Ethnographic literature was also used to illustrate the cultural history regarding land use practices in fire-modified landscapes. Historical records were used as a platform for what Europeans observed about Native American activity when they first explored and settled the Pacific Northwest.

4) To combine the Horsetail Fen fire history record, along with the regional record, with the record of human history to describe the relationship between people and their environment in the central eastern Cascades during the post-glacial period.

This was accomplished by combining the various records described above into a summary graphic that is then discussed to better illustrate human-environment interactions.

Significance

This research is significant for several reasons. First, an analysis of the Horsetail Fen record fills a geographic data gap in terms of the fire history in the PNW. Paleoenvironmental reconstructions have been conducted in other parts of the PNW including the temperate rainforests of British Columbia (B.C.) (Sanborn et al. 2006), the Fraser lowland of B.C. (Pellatt et al. 2002), Vancouver Island, Canada (Brown and Hebda 2002a; Gavin et al. 2003; Lacourse 2004), the north Cascade Range in Washington State (Cwynar 1987; Nelson 2004; Prichard et al. 2009), Mount Rainier National Park (Walsh et al. 2017), Mount Constitution Plateau of Orcas Island, Washington (Sugimura et al. 2008), southwestern Washington (Whitlock et al. 2000), and
several places in Oregon including the Willamette Valley (Walsh et al. 2008, 2010a, 2010b). Considering the extensive amount of paleo-fire history for the PNW, there is a lack of data for the more arid environments of Washington (Walsh et al. 2015), including the central eastern Cascade Mountains where up until this point, there was no long-term paleoenvironmental record available.

Second, this research bridges the gap between paleoecological and archaeological disciplines by combining the records in effort to show the relationship between people, fire, and the environment. Although there is currently no systematic approach to confirm anthropogenic burning, the argument is growing regarding the magnitude of paleo-fire management practices by indigenous peoples (Cuthrell et al. 2012). Paleoclimatic reconstruction coupled with the fire history record can help identify changes in the environment that may have influenced (or been influenced by) populations and settlement patterns. By using an interdisciplinary approach, we can gain an understanding of human-environment interactions during the post-glacial period.

Lastly, natural and anthropogenic ignitions have a major influence in today’s forests and other landscapes in the PNW. By investigating past human-environment interactions, we can better understand how to protect, restore, and mitigate for the potentially adverse effects of future climate change, which is being accelerated by human activity (Crumley 1987; Heltberg et al. 2009; O’Brien 2001). Due to fire suppression over the last hundred years, managing landscapes during fire season has been difficult. For example, the Jolly Mountain Fire located in the Okanogan-Wenatchee National Forest started during the summer of 2017. This fire was managed for full fire suppression though it burned for three months. Recognizing that paleoecological studies provide an opportunity for understanding long-term environmental history, this research
will allow forest managers in the eastern Cascades to justify current management techniques (i.e. thinning, prescribed burning) or create new strategies based on long-term environmental data.

In the following thesis, chapter two outlines the paleoecological work conducted in various areas of the PNW and discusses the archaeological record extensively for the Columbia Plateau and central eastern Cascades. Chapter three describes the physical characteristics of the landscape and human land-use for the central eastern Cascades, the Teanaway area, and the Horsetail Fen watershed. Chapter four outlines the methods used in this research to reconstruct the fire record for Horsetail Fen and human history record for the central eastern Cascades, followed by the results in chapter five. The discussion chapter summarizes the objectives and results of this research within the context of human-environmental interactions. The last chapter answers the research questions and offers suggestions for future research, which will possibly aid in the selection of management techniques applied to these landscapes in the future.
CHAPTER II
LITERATURE REVIEW

This chapter presents previous research on post-glacial climate and fire history in the PNW with a preface on understanding fire regimes and characteristics. In addition, the archaeological record and ethnographic history is summarized for Columbia Plateau archaeology, with an emphasis on the upland fire-modified landscapes on the eastern slopes of the Cascade Mountains.

Fire Characteristics and Regimes

Fire is the dominant disturbance in ecosystems of the Pacific Northwest, and in particular, forests. Fire helps maintain healthy forest structure and composition and promotes biodiversity (Agee 1993; Wright and Agee 2004). The effect fire has on ecosystems in the PNW has shown to be positive in terms of growth and regrowth, which usually favors early successional species (Agee 1993). Fire behavior is determined by many factors, including fuel, weather, and topography. Weather has a major impact on fire behavior because it determines the condition of the fuel. When fires ignite and weather conditions are dry, the fire will spread at a faster rate.

Disturbance regimes are classified by the following descriptors: frequency, predictability, extent, magnitude, synergism, and timing (Agee 1993). Fire frequency is characterized as the number of fire events in a given time period, whereas the predictability refers to the variation of fire frequency (Agee 1993). The extent of a fire refers to the area disturbed in a period, and the magnitude is described as the intensity of a fire or the severity of its effects. Synergism refers to the effects of a fire occurrence regarding other disturbance factors that change the dynamics of the landscape. Timing plays a key role in the effects of a fire, depending on seasonality, and considering the condition of fuels available (Agee 1993). One example of how to describe fire
regimes is based on return intervals (Table 1) (Heinselman 1973), although other approaches also exist (Agee 1993).

Table 1 Fire Regimes Defined by the Nature of Disturbance (Heinselman 1973)

<table>
<thead>
<tr>
<th>Fire Regime Number</th>
<th>Description of Fire Regime</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>No natural fire (or very little)</td>
</tr>
<tr>
<td>1</td>
<td>Infrequent light surface fires (more than 25-year intervals)</td>
</tr>
<tr>
<td>2</td>
<td>Frequent light surface fires (1-25 year return intervals)</td>
</tr>
<tr>
<td>3</td>
<td>Infrequent, severe surface fires (more than 25-year return intervals)</td>
</tr>
<tr>
<td>4</td>
<td>Short return interval crown fires (25-100-year return intervals)</td>
</tr>
<tr>
<td>5</td>
<td>Long return interval crown fires and severe surface fires in combination (100-300-year return intervals)</td>
</tr>
<tr>
<td>6</td>
<td>Very long return interval crown fires and severe surface fires in combination (over 300-year return intervals)</td>
</tr>
</tbody>
</table>

Post-Glacial Fire History Studies in the PNW

Paleoenvironmental data suggest that fire has been present on the landscapes of the Pacific Northwest for thousands of years (Whitlock et al. 2003; Marlon et al. 2006; Walsh et al. 2015). Depending on its characteristics, fire can have minimal to catastrophic impact on the natural environment and create major changes in ecosystem dynamics (Agee 1998). Evidence shows that climate, vegetation (including individual species), and fire all interact throughout time and across space to form the plant communities we see on the landscape today.
Post-glacial fire history is known from continuous charcoal-based lake sediment studies, and this body of knowledge has grown substantially in the PNW in the past ~30 years (Marlon et al. 2006; Walsh et al. 2015; Whitlock and Bartlein 2003; Whitlock and Gardner 2001). Some of the earliest reconstructions were conducted at Mount Rainier by Dunwiddie (1987) who set a precedent in the paleoecological community that fire regimes can be analyzed on both long- and short-term timescales. Over the years, techniques were refined and polished as paleoenvironmental reconstructions, using charcoal as a fire proxy, became more prevalent in the scientific community (Long et al. 1998; Whitlock 2001). Reconstructions in areas such as the North Cascades and places in Oregon show a relationship between fire and peaks in macroscopic charcoal in sediment cores (Long et al. 1998; Walsh et al. 2015; Whitlock and Gardner 2001). The length of the analysis is dependent on the characteristics of the location and how much sediment can be extracted through lake coring.

Since the last glacial maximum in the PNW, studies show that fire frequency and severity vary across the landscape depending on elevation, forest composition and structure (Agee 1994; Pritchard et al. 2009). Low-severity fires typically occur in oak woodland or *Pinus ponderosa* (ponderosa pine) forests, and forests with mixed conifer species (Agee 1994). High-severity fires usually occur in subalpine forests consisting of *Abies amabilis* (Pacific silver fir), *Abies lasiocarpa* (subalpine fir), and *Tsuga heterophylla* (western hemlock), as seen in a 10,500-year long record from the montane forests of the north Cascade Range (Cwynar 1987; Pritchard 2009). Several analyses of charcoal, pollen, and other proxies indicate that the PNW experienced higher fire activity in the early Holocene dating from ca. 11,000-7,800 cal yr BP, with the highest fire frequency around 8,500 cal yr BP (Marlon et. al. 2006; Whitlock et. al. 2003). Evidence suggests fire frequency declined around 8,000 cal yr BP and continued to decline
during the middle Holocene (Prichard et al. 2009). Recent studies show that fire activity at many sites in the PNW increased during the late Holocene, likely as a result of increased climate variability and/or increased human use of fire (Walsh et al. 2015; Walsh et al. 2017).

Post-Glacial Climate History of the Pacific Northwest

Paleoenvironmental reconstructions show that climate variability is the main driving force of fire activity and changes in forest composition (Walsh et al. 2015; Whitlock et al. 2001). In the last three decades, researchers have become increasingly interested in the dynamics of climate and environmental reconstructions (Agee 1994; Scharf 2009). Recent studies show that climate has varied considerably during the post-glacial period (Pritchard et al. 2009; Gavin et al. 2001). Disturbance regimes such as fire play a vital role in changing forest structure and composition as seen through paleoenvironmental records throughout this period (Cwynar 1987; Pritchard et al. 2009). Species assemblages in today’s plant communities are directly impacted by past changes in climate and on a shorter scale, fire activity (Agee 1993).

Paleoenvironmental reconstructions indicate that North America was cold and wet during the LGM (Bartlein, Hostetler, & Alder 2014; Gavin and Brubaker 2015). Following the LGM the continent was first cold and dry as the continental ice sheets retreated (Bartlein et al. 1998), and then warmer and dryer, largely due to greater insolation received than at present (Whitlock 1992). This warmer period, also known as hypsithermal or the Early Holocene Warm Period, reflected in paleoenvironmental records, showed signs of higher fire activity as vegetation dried out and created more fire-conducive conditions (Marlon et al. 2006; Walsh et al. 2008; Whitlock et al. 1984). The early Holocene depicts a time when vegetative communities were replaced by ponderosa pines in lower to mid-elevation environments in some areas of the eastern Cascades (Whitlock 2000). This change in vegetation is indicative of drier conditions. During the early
Holocene, drought-tolerant species were also widespread at higher elevations in the eastern Cascades (Barnosky 1985).

Following the Early Holocene Warm Period, research depicts the middle to late Holocene as a cooler and wetter environment in the Pacific Northwest (Osborn et al. 2007; Whitlock 1992), in which fires would have occurred shortly after a wet period or during a drought in an overall wet period (Whitlock and Bartlein 2003). The middle to late Holocene is characterized as neoglacial due to increasing precipitation and declining temperatures. This is largely due to decreasing insolation values as compared to the early Holocene (Bartlein et al. 1998).

Recent studies show an increase in fire activity during the Medieval Climate Anomaly (MCA; 700-1100 cal yr BP) (Marlon et al. 2012; Walsh et al. 2015). Records suggest the increase in fire frequency was correlated with the climatic conditions, which were generally warm and dry (Gates 1993; Stine 1994; Brunelle and Whitlock 2003). Drought conditions created vegetation that is conducive for fire, which allowed for parts of the landscape to burn (Marlon 2006; Whitlock et al. 2003). After the MCA, the PNW experienced a cooling trend. The Little Ice Age (LIA) occurred between ca. 550-150 cal yr BP, and generally cool, wet conditions prevailed (Brunelle and Whitlock 2003).

**Pacific Northwest Archaeology**

Indigenous peoples of the Pacific Northwest have been a topic of archaeological inquiry since the early 1900s (Chatters 1995; Daugherty 1956; Flannery 1966; Lewarch and Benson 1999; Walker 1998; Zweifel and Reid 1991). Evidence for early occupation in the PNW extends back to approximately ca. 14,000 cal yr BP (Zweifel and Reid; Waters & Stafford 2011). This span of time is based on the scientific community’s confidence in radiocarbon dating for several
sites in the PNW and greater region, including the speared mastodon found at the Manis site in northwestern Washington dating to ca. 13,800 cal yr BP (Waters and Stafford 2011) and the human coprolites found at the Paisley Cave site in south central Oregon dating to ca. 14,200 cal yr BP (Gilbert et al. 2008; Jenkins et al. 2012). The greater Pacific Northwest’s rich archaeological record is characterized by dozens of Native American groups who flourished throughout the area for over 10,000 years. The Columbia Plateau, located in the rain shadow of the Cascade Mountain Range (Fig. 2.1), holds convincing evidence for early occupation and has been the focus of archaeological investigations since the 1960s (Benson and Lewarch 1989; Butler 1962; Nelson 1969; Swanson 1962).

![Figure 2.1 Southern Plateau Archaeological Sites and Regions (Ames 1998).](image-url)
The Columbia Plateau culture area extends south from the Okanogan Highlands in northern Washington into central Oregon, bordered by the western edges of the Bitterroot Range to the east and the Cascade Mountains to the west (Ames 1998). Columbia Plateau archaeology indicates that people were on the Plateau as early as ca. 13,000 cal yr BP based on artifacts including a Clovis point found in the Wenatchee area of Washington State (Gramly 1993; O’Brien 2016). The Clovis point found in this area sits on top of Mount Saint Helens tephra layer J dating to ca. 13,800-12,800 cal yr BP (Pyne-O’Donnell et al. 2016). The BPA Springs site near the Wanapum Dam contains stemmed Windust point and flakes, in sediments determined to be from the late Pleistocene period (Huckleberry et al 2003). The Winchester Wasteway site in Ephrata, Washington, contained a Clovis fluted point, and sparse lithic scatter, also considered to be from the late Pleistocene period (Huckleberry et al. 2003). In addition to artifacts, human remains are also known from the archaeological record. Human skeletal remains found at the Marmes Rockshelter site (45-FR-50) located at the confluence of the Snake and Palouse Rivers in southeastern Washington were revealed to be older than ca. 13,000-12,300 cal yr BP (Fryxell et al. 1968; Sheppard et al. 1987). In 1996, a skeleton (Kennewick Man) was discovered on the south bank of the Columbia River outside of Kennewick Washington with a calibrated date of ca. 8,430-9,200 cal yr BP (Chatters 2000).

Archaeologists built chronologies of cultural development across space and time of Plateau peoples based on the increasing artifacts found in the record (Walker 1998). Prehistory of the Columbia Plateau was divided into three periods (e.g., I, II, III) illustrated by changes in artifact type and style as seen in the archaeological record. Each period is further divided into sub-periods (e.g., Ia) resulting from variations in artifact tool assemblages and style, as well as land use patterns (Ames 1998; Walker 1998). Period Ia (ca. 11,500-11,000 cal yr BP) is
represented by the Richey-Roberts Clovis Cache located in east Wenatchee, Washington, which is in the northern part of the Southern Columbia Plateau region. Period Ib (ca. 11,000-5,000/4,400 cal yr BP) signifies the Post-Clovis culture characterized by a large hunter/gatherer subsistence economy. Up until approximately ca. 6,000 cal yr BP people of the Southern Plateau explored a more mobile lifestyle exploiting a variety of resources (Hackenberger 2009). Native American settlement patterns were mobile with seasonal camps along river corridors, and in both lowland and montane environments (Benson and Lewarch 1989; Chatters et al. 2012).

Period II (ca. 5,000/4,400-1900 cal yr BP) is marked by two significant changes shown in the archaeological record including the disappearance of certain artifact types and a change in settlement patterns. Period II is characterized by the beginning of subterranean pit houses that appear in the archaeological record (Ames 1998; Walker 1998). Period II is defined differently according to Plateau location. The southeast Plateau incorporates subphase Late Cascade and part of the Tucannon phase. Sites contain pit houses with charcoal-based radiocarbon dates of ca. 3130-2930 cal yr BP (Walker 1998). Most dwellings in the southeast Plateau contain large clusters of hopper mortars, stone pestles, anvils. Some archaeologists have used these contents to argue that plant foods were a major part of subsistence during this period, using these tools to grind down roots (Walker 1998). Period II is marked by major cultural changes seen in the record in the south-central part of the Plateau. Cascade technology had almost disappeared completely, and it is thought that people used more efficient means to exploit resources, such as root crops and salmon. Faunal remains are also more diverse in this area (Lyman 1976).

Lastly, Period III is marked by the widespread evidence of pit houses between ca. 1900-1720 cal yr BP. The archaeological record provides evidence of an increased reliance on fishing, storage facilities for salmon, and a change in land use patterns where natives exploited higher
elevation environments during certain times of the year (Chatters 1989, 1995). Period III is correlated with the last half of the Tucannon Phase. Subperiod IIIa dates from ca. 1900-500 cal yr BP and is marked by increasing use of rivers (Walker 1998). Sites correlated to this period are found across major environmental zones of the southeast Plateau (Leonhardy and Rice 1970). Subperiod IIIb, ca. 1720 cal yr BP to present shows evidence of winter villages in all areas of the Plateau region (Walker 1998). Most sites contained pit houses along salmon-bearing streams, upland camps increased substantially, and artifact assemblages contained hunting-related artifacts and plant gathering and processing tools (Galm et al., 1981).

As noted above, archaeologists have developed several chronologies of cultural groups over the past six decades. The chronologies that are most frequently cited are found in Galm et al. (1981) and Walker (1998), both of which are widely used in defining the different archaeological phases of Columbia Plateau, which is also generally representative of the eastern Cascades. Changes in cultural development for indigenous peoples are based on chronological tool assemblage distributions throughout the region (Chatters et al. 2012). The archaeological record reflects changes in artifacts, styles, and distributions and supports the idea that people moved around on the landscape initially, before settling down into a semi-sedentary pattern and then later a sedentary settlement pattern (Chatters et al. 2012; Galm et al. 1981; Walker 1998). Below is a summarized timeline of the cultural and historical phases of Columbia Plateau peoples (Hackenberger 2009). A more general summary of archaeological phases is also presented by Ames et al. (1998).
Cultural and Historical Phases of Columbia Plateau Peoples

Clovis (ca. 14,000-12,500 cal yr BP): East of the crest of the Cascades, the Clovis Phase is described as small groups of people who were highly mobile. People moved throughout the landscape as hunter/gatherers to exploit a variety of resources for subsistence (Walker 1998). Clovis sites are documented as small areas that reveal low artifact densities, associated with landforms such as upland plateaus (Hackenberger 2009).

Windust Phase (ca. 12,500-9,500 cal yr BP): The Windust Phase is characterized as small groups of foragers and collectors. People of this phase were thought to have exploited plant and animal resources at specific times of the year due to a warming climate (Chatters 1986). There are few cultural deposits from this phase and most areas demonstrate low artifact densities (Hackenberger 2009).

Cascade/Vantage Phase (ca. 9,500-7,000 cal yr BP): Archaeological data reveal peoples from the Vantage/Cascade Phase adapted to a more riverine environment (Chatters 1986). This phase implies people relied on fish for subsistence and it was an important part of the daily diet. Projectile points were large lanceolates found along rivers and streams during this phase (Hackenberger 2009; Galm et al. 1985).

Tucannon/Frenchman Springs Phase (ca. 7,000-2,500 cal yr BP): Introduction of semi-subterranean houses was found during the Frenchman Springs Phase (Chatters 1986). Evidence of root collecting, and plant processing is present during this period, and several styles of projectile points smaller in nature than the previous phase suggest that lifeways changed substantially between the Cascade/Vantage and Frenchmen Phases. Archaeologists argued that the Plateau Culture developed towards the end of this phase (Hackenberger 2009).
Harder/Cayuse Phase (ca. 2,500-500 cal yr BP): The Cayuse Phase depicts a time where people of the Columbia Plateau spent their winters in large villages consisting of pit houses (Chatters, 1986). Lifeways changed as people became more sedentary. Evidence in the archaeological record illustrates that people established hunting stations in higher elevation environments, particularly as seasons became more diverse as climate changed during the MCA and the LIA. This phase portrays coastal and interior groups as having closer ties. Artifacts from coastal communities appeared in the record at interior sites (Chatters and Prentiss 2005).

Contact Period (ca. 500 BP- present): Introduction of the horse and eastern European (American) technology led to cultural change for Native Americans on the Plateau. Settlement patterns changed as people expanded throughout the land (Hackenberger 2009). Native Americans lost land due to logging, transportation routes, and the development of the built environment. This was a time where disease plagued Native Americans (Chatters 1986). Thousands of Native Americans on the Plateau died resulting from European expansion westward, and the rest were primarily relegated to tribal reservations (Boyd 1996).

*People and the Environment*

The Columbia Plateau is diverse in both physiography and vegetation and encompasses all biotic zones from shrub steppe to alpine forests (Chatters 1998; Franklyn and Dyrness 1973; Lyman et al. 1992). As noted above, archaeological evidence suggests that people interacted with these environments throughout most of the Holocene (Delcourt et al. 1998; Lepofsky et al. 2000). Archaeological investigation confirms that people used lowland and upland areas for the
last ca. 11,000 years and all types of terrain were utilized regardless of accessibility (Butler 1962; Chatters et al. 2012; Knudson 1980).

Several sources argue that Plateau people have utilized upland environments in the eastern Cascades since the late Pleistocene (Ames et al. 1998; Burtchard 1998; Zweifel and Reid 1991). First, many sites were recorded in higher elevation environments. Second, the large distribution of sites can be used to imply there were travel routes, resource utilization, and high-use areas in upland environments. Lastly, archaeologists suggest that a variety of site types, and a wide array of resources were available, many of which were not in lower elevation landscapes (Zweifel and Reid 1991). The archaeological record is used as evidence for the explanation that people were temporarily living in or at least traveling to montane environments for the utilization of resources. In addition to the archaeological record, ethnographic history provides evidence that indigenous people used mountainous regions as well as lowland areas to extract resources (Burtchard 2007; Boyd 1999; Zweifel and Reid 1991).

*Indigenous Burning and the Management of Resources using Archaeology and Ethnography*

The idea that people of the past interacted with their environment is not difficult to understand. People need to interact with their environment for survival; the interaction is innate and integral as human beings. The concept that Native Americans managed resources for thousands of years is widely accepted; however, determining the way in which people manipulated their environment, such as though the use of fire, can be problematic when it comes to recognizing evidence for that in the archaeological record. There are not many cases providing strong evidence that people managed resources by use of fire, although the concept is believable. There are some examples, however, where research was conducted in areas containing a rich archaeological record in attempt to provide evidence that people used fire manipulate the
landscape. Two research projects in the 1990s used a multidisciplinary approach to provide evidence for anthropogenic burning. Both studies used paleoecology to reconstruct the charcoal and pollen record to combine with the known archaeological record (see Delcourt and Delcourt 1997; Delcourt et al. 1998).

Several published reports state people used fire for the cultivation of plants and forest succession in areas all over the North America, including the Cliff Palace Pond Rockshelter located on the Cumberland Plateau within the boundaries of the Daniel Boone National Forest, Kentucky (Delcourt et al. 1998). In 1996, a study was conducted to look at the relationship of pre-contact human activities and the changing dynamics of forest landscapes. The hypothesis was that fossilized carbon plant remains from sediment cores can offer insights into how Native Americans selected and propagated plant-food resources by use of fire. Archaeological data including 95 absolute dates suggests this area shows temporal patterns of human occupation extending back to ca. 13,500 years. The extraction of sediments from two rock shelters included thirty-six ethnobotanical assemblages representing a relative abundance of plant remains from species that Native Americans were known to have cultivated.

Paleoecological data included the analysis of charcoal and pollen from a sediment core extracted from the Cliff Palace pond, although all Holocene radiocarbon dates were discarded due to contamination of carbonized woody material. However, a timeline was constructed based using pollen time lines interpolated from well-dated surrounding areas to see how fire-tolerant and -intolerant species increased and decreased over time. Archaeological remains and the increase in local fires during the past 3000 years supports the hypothesis that there was a clear relationship between humans and their environment surrounding the Cliff Palace Pond.
Rockshelter, and the interrelationships between people and fire, as part of forest succession and plant cultivation (Delcourt et al. 1998).

Another study in the southern Appalachian landscapes of North Carolina suggests Native Americans use of fire was prevalent prior to European contact (Delcourt and Delcourt 1997). Studies support the hypothesis that Native American use of fire affected forest composition in the eastern deciduous forest region of the southern Appalachians. A comparison was made between charcoal and pollen records of a peat deposit in Horse Cove Bog located in the highlands of North Carolina and the known archaeological record. Paleoecological results indicate that Native Americans played a significant role in determining vegetation in the southern Appalachians during the last 4000 years through selective fire use (Delcourt and Delcourt 1997). This was determined by non-native species that appeared in the pollen record during Native American occupation of these areas. Plants such as goosefoot, plantain, maize and many others were thought to be indicative of human activities.

During the last 4,000 years, people were concentrated in two areas of the landscape: 1) alluvial bottoms near rivers, major camps and villages were established and remanences of garden plots were seen in the archaeological record, and 2) ridgetops where people hunted and gathered resources such as nuts and acorns that were in higher elevation landscapes (Delcourt and Delcourt 1997). Delcourt speculated that the mosaic of vegetation was established by fire management used by Native Americans throughout the course of their time in the southern Appalachian Mountains of North Carolina. Although Kentucky and North Carolina are far from Washington, archaeologists, anthropologists, and ecologists mention in several reports that similar practices have occurred in the Pacific Northwest region including places in Washington,

In the last few decades an effort has been made by paleoecologists and archaeologists to share information with the overarching goal of better understanding past changes in human-environmental history (Crumley 1987; Delcourt et al. 1996; O’Brien 2001; Walsh et al. 2017, 2018). However, ethnography provides stronger evidence of human-environment interactions with the use of fire. It is known that indigenous cultures throughout the PNW utilized a variety of resources and is thought by many to have managed landscapes by use of fire throughout the Holocene (Barrett 1980, 1981a; Delcourt et al. 1998; Johnson and Gottesfeld 1994; Norton 1979; Vale 2002). Ethnographic accounts of human activity show people altered and extracted resources using fire to manipulate their environments (Burtchard 2007; Byers 1967; Flannery 1966; Hollenbeck and Carter 1986).

The archaeological record combined with ethnographic history supports the assumption that people not only changed their cultural traditions in tool use and styles, processing, subsistence, and land use (Chatters et al. 2012), but also in human adaptation and their ability to modify their environments (Delcourt et al. 1998; Williams 1994). Ethnographic history including journal entries by explorers such as Lewis and Clark in the early 1900s support several hypotheses that people were using and managing higher elevation landscapes to propagate specific resources found only in those areas (Barrett 1980; Boyd 1986; Burtchard 2007; Mack and McClure 2002). There is little doubt that indigenous groups employed the use of fire for managing resources in low and high elevation environments, although there are many theories about the extent of this burning (Lightfoot and Cuthrell 2015; Norton 1979; Spies et al. 2014).
Evidence for indigenous burning for the maintenance and propagation of resources in the PNW is growing. There is evidence of anthropogenic prairies in western Washington, and explorers of the region including Lewis and Clark, George Vancouver (1792), Charles Wilkes (1841), and several others, reported indigenous burning on the landscape or remarked upon the prairies being ‘unnatural in origin’ (Norton 1979). Native Americans used fire to manage oak and woodland communities in the Fort Lewis area of Washington (Regan and Agee 2004). Evidence shows anthropogenic maintenance of bear grass in the savannas located in the southeastern Olympic Peninsula, Washington. What was once a mosaic of prairies, woodlands, and savannas maintained through burning has given way to overgrown forests containing Douglas-fir and lodgepole pine (Peter and Shebitz 2006).

People have traditionally played a considerable role in altering the environments of the PNW through use of fire (Vale 2002). Looking more closely at the east side of the Cascade Mountains, the Columbia Plateau’s environment could support the likelihood of indigenous burning based on the similar conditions of prairies and meadows in mid- to upland environments, as well as low elevation areas for hunting practices. Well documented oral histories reveal native peoples were burning on the landscape to manage resources in these areas, such as burning to increase the harvests of huckleberries, nuts, seeds, and camas (Hollenbeck and Carter 1986; Shuster 1982). Several ethnographic accounts were reviewed which document that camas fields were one of the most important foods produced. Fields were managed, cleared by fire, and cultivated before being systematically planted and transplanted (Connolly 2000). Native Americans used fire for two common purposes: to create open areas on the landscape for hunting and gathering, and to maintain open prairies that allow for resource growth by the constant addition of nutrients to the soil. Plateau tribes in the eastern Cascades most certainly used
extensive burning for landscape maintenance (Agee 1993; Ames 2005a; Boyd 1999; Burtchard 2007).

Low-elevation burning was used to drive game into areas that were open and conducive to hunting. Burning the understory also promoted resources such as camas, bracken fern, salmonberries, blackberries and other resources used by Native Americans for sustenance (Ames 2005; Boyd 1999; Gahr 2013; Robbins and Wolf 1994). Fire was also used to manage huckleberry patches in higher elevations (Burtchard 2007; Mack and McClure 2002) and may have been used to heighten the production of grasses and assist in hunting strategies. This idea fits well with semi-sedentary cultures and hunter/gatherer subsistence societies where people moved around on the landscape to manage and extract a variety of resources through modifying landscapes (Boyd and Hajda 2007; Brown and Hebda 2002; Connolly 2000; Turner 1991, 1999; Zweifel and Reid 1991).

Native American use of fire is well known throughout the PNW. Archaeologists, anthropologists, historians, and ethnographers have studied Native American culture for many decades and have concluded that the landscapes of the PNW have probably experienced anthropogenic burning for millennia (Burtchard 2007; Whitlock and Knox 2002; Lepofsky et al. 2005). Ethnographic studies have documented the use of fire in areas such as the Willamette Valley, Oregon (Boyd 1999). Documentation of resources provides evidence that the areas of the eastern Cascades is ecologically productive, and probably contained a variety of resources that could have been propagated, managed, and extracted by indigenous cultures for thousands of years.
The information gathered under the umbrella of ethnography was obtained using Native American informants who shared information that was passed down through generations and archaeologists, ethnologists, and geographers who had direct experience with indigenous people including, engaging with them, and observing their ways of life (Ray 1936). Scientists, traders and explorers crossed paths with natives since the time of European contact when people migrated to the New World and documented their interactions and native territories during travel (Fig. 2.2).

![Native Territorial Distribution of Northern the Plateau Documented circa 1850 (Ray 1936).](image-url)
CHAPTER III

RESEARCH AREA

This study site for this research exists in the Okanogan and Wenatchee National Forest (Fig. 3.1) in the eastern portion of the Cascade Mountains in Washington State. The Cascade Range extends 700 miles from British Columbia through Washington, Oregon, and down into northern California with peaks reaching approximately 4300 m (14,000 ft) in elevation (Fig. 3.2). Lying in the rain shadow of the Cascade Mountains, the eastern portion of the state is divided into six primary physiographic zones. This area consists of ponderosa pine, Douglas-fir, and grand fir, ranging in elevation from 600-1100 m, with subalpine fir and western hemlock on its upper borders at approximately 1200-1500 m.

Figure 3.1 Okanogan-Wenatchee National Forest (USDA Forest Service 2018)
Eastern Cascades

Geology

The eastern Cascade Mountains were formed by volcanic activity beginning about 40 million years ago (Orr and Orr 2002). The present-day northwest is divided into several physiographic zones and geologic provinces resulting from these tectonic processes. Volcanic activity plays a substantial role in sedimentation, erosion, climate, land formations, and rainfall, all of which are significant in the signature of the present-day Cascade Mountain Range (McBirney 1978; Orr and Orr 2002). The geologic sequence of the Cascade Mountains is complex. The oldest rocks reside in the northern part of the Cascade Range of

Figure 3.2 Cascade Mountains, Orr and Orr, 2002
British Columbia and Washington State and date back to the Mesozoic era (Sharrod & Smith 2000). However, the younger rocks of the Cascade Mountain formation began approximately 40 million years ago (mya) by plate convergence between the Juan de Fuca and North American plates (Orr & Orr 2002).

*Hydrology*

The eastern Cascades are characterized by two major river drainages the Columbia and Yakima Rivers. The Columbia River is the largest river in the Pacific Northwest and one of the largest in the U.S. The Columbia River begins in the Rocky Mountains of British Columbia and travels approximately 2000 km (1,243 mi) through British Columbia, Washington, and Oregon before draining into the Pacific Ocean (Fig. 3.3).

![Figure 3.3 Columbia Basin, WSA Digital Library Collection 2017](image)
The Columbia River is one of the most industrialized river basins in the world, with over 250 dams and over 100 hydropower projects (Hamlet et al. 2002). One of the main tributaries of the Columbia is the Yakima River. The Yakima River’s headwaters are in the Cascade Range at an elevation of 746 km (2,449 feet), and is the longest river in Washington State, running approximately 344 km (214 miles) from headwaters to mouth where it reaches the Columbia River. The Yakima has three main tributaries including the Cle Elum River, Naches River, and the Teanaway River.

**Ecoregions**

The eastern Cascade ecoregion is described as hot dry summers and cold snowy winters (Raymond et al. 2014). The eastern Cascades tend to vary significantly in temperature throughout the annual cycle. Between the years 1981-2010 the annual temperature had an average high of 16°C (60°F) and an average low of 1.7°C (35°F). Temperatures typically reach 32°C (90°F) during the summer months of July and August. Most of the precipitation falls between October and April with an average of 225 mm (8.89 in) of precipitation and an average snowfall of 558 mm (22 in) annually (U.S. Climate Data 2018).

**Flora**

According to the Environmental Protection Agency (EPA) this area is considered a level III ecoregion, determined by similarities in ecosystems. This area encompasses a level III Columbia Plateau ecoregion and Cascade ecoregion (EPA 2017). The eastern Cascades contain greater temperature extremes and less precipitation than areas west of the Cascade Range. As part of the Okanogan and Wenatchee National Forest, the higher elevation environments in this area are composed of lush forests rich with subalpine fir, western hemlock, and grand fir. The mid elevations are a mix of Douglas-fir and ponderosa pine, while lower elevations encompass
sparsely forested areas, woodlands, and desert shrub steppe near the foothills of the Cascades, commonly referred to as the Columbia Basin (Franklin and Dyrness 1973; Walker 1998). Forest zones in the eastern Cascades are separated by weather conditions and altitude. Eastern Washington’s forests are dominated by five forest types (Table 2) including *Pinus ponderosa*, *Pseudotsuga menziesii*, *Abies grandis*, *Tsuga heterophylla*, *Abies lasiocarpa* or *Tsuga mertensiana* (Franklin and Dyrness 1973).

Table 2 Eastern Washington Cascade Forest Zones (Franklyn and Dyrness 1973)

<table>
<thead>
<tr>
<th>Eastern slopes of Washington Cascades Forest Zones</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Pinus ponderosa</em></td>
</tr>
<tr>
<td><em>Pseudotsuga menziesii</em></td>
</tr>
<tr>
<td><em>Abies grandis</em></td>
</tr>
<tr>
<td><em>Abies lasiocarpa</em></td>
</tr>
<tr>
<td><em>Tsuga mertensiana</em></td>
</tr>
</tbody>
</table>

Ponderosa stands are found in the warmest and driest areas of eastern Washington and Oregon (Spies et al. 2006). Bordering eastern Washington’s shrub steppe community, ponderosa pines are found along the edges of the Columbia Basin, southeast, central and northeast Cascades, Okanogan, and the Blue Mountains. The ponderosa pine zone is intermixed with and transitions to the Douglas-fir zone. The typical elevational range for Douglas-fir is 600-1300 m and is the most extensive forested zone in eastern Washington (Spies et al. 2006; Franklin and Dyrness 1988). Douglas-fir stands are known to encompass a variety of species such as *P. ponderosa*, *P. contorta*, and *Larix occidentalis*. *Abies amabilis* (1100-1500 m) is bounded on its lower edges by Douglas-fir and western hemlock on its upper limits. Grand fir is a drought sensitive species where temperature and precipitation are moderate (Franklin and Dyrness 1988).
Bordering the edges of the grand fir zone lies a band of western hemlock at 800-1200 m, followed by subalpine fir with a minimum elevation of 1500 m and a maximum of 1700 m in other areas (Franklin and Dyrness 1988). Neighboring subalpine fir on its upper limits lies a thin band of mountain hemlock in some areas of eastern Washington and Oregon.

*Land Use of the Eastern Cascades*

During the early 19th century, several European explorers set out west in hopes of profiting in the fur trade market, coal mining and logging. Small settlements started popping up throughout what used to be called the Oregon Region or Territory, now recognized as Washington State (Spaulding 1956). However, settlement of the central and eastern Cascades did not come without consequences. White men and Native Americans fought over territory and there were sporadic outbreaks throughout the 1800s as the frontier expanded (Uebelacker 1980). Several interpretations by people who wrote about Native American and European communications marked it as a time of ‘territorial aggression’ (Glauret and Kunz 1976; Jermann and Mason 1976; Lyman 1919; Uebelacker 1980). Native Americans fought aggressively to defend their land and resources from the expansion of the frontier. This ultimately led to the Treaty of 1855 between the U.S. government and the Confederated Tribes and Bands of the Yakama Nation (Pritzker 2000).

**The Teanaway Area**

The Teanaway area is a high elevation drainage situated near the headwaters of the Yakima Basin in the Wenatchee National Forest. The region neighbors the edges of the Columbia Basin and southern Washington Cascade provinces (Fig. 3.4). The area encompasses approximately 50,000 acres of forests and contains nearly 400 miles of free-flowing streams and has a history of grazing and timber harvesting (Department of Natural Resources 2017).
Geology

The Teanaway area is characterized by abrupt topographic relief resulting from geomorphic processes of uplift and erosion driven by glacialiations (Franklin and Dyrness 1973). The geologic background of the Teanaway is described by two major geologic processes. The first process is a series of lava flows called the Columbia River basalts or the Columbia River Basalt Group (CRBG) (Beeson and Tolan 1990). These formations are described by normal folding and faulting resulting in the anticlinal ridges and synclinal valleys which make up the mountainous regions of Yakima we see today, called the Yakima Fold Belt (Bush and Cheney 1996). The second major geologic process is uplifting. Through uplift of the Cascade Mountains, the Teanaway is comprised of sharp jagged mountain tops sparse with foliage resulting from...
glaciation. The effects of uplift have caused strata to become tilted resulting in mass wasting (Bush and Cheney 1996).

The Teanaway area is mainly characterized as sandstone that overlies basalt, with the basalt characterized as fine grained and glassy in nature (Beeson and Tolan 1990; Clayton 1973). However, there is much more than basalt in the Teanaway; pyroclastic material ranging in composition including other volcanic rock such as rhyolite is present, as well as sedimentary rock (Tabor 1982). As a result of the many overlying formations, and massive landslides over millions of years, the age of the Teanaway is not easily determined. Geologist state the closest age is probably around 47 mya, putting the Teanaway in the Eocene epoch according to the matrix of nearby rocks in surrounding areas (Tabor et al. 1982). Several dikes in the formation prove to be younger in age from the Miocene epoch, characterized as glassy, and were difficult to separate from the Teanaway flows as they are similar in nature (Tabor et al. 1982). The Teanaway is scattered with extrusive rhyolite outcrops and appear to be intermixed with clay and sandstone material demonstrating signs of weathering and oxidation over time (Clayton 1973).

Hydrology

The hydrology of the Teanaway is created by a web of rivers and streams that is part of the Yakima River Basin and eventually flows into the Columbia River (Fig. 3.5). The drainage is bounded by the Wenatchee Mountains to the north, Teanaway Ridge to the east and Cle Elum Ridge to the south and west. Located in the upper Yakima River Basin, the Teanaway area includes approximately 320 km of rivers and streams covering draining an area of 30,417 ha (U.S. Forest Service 2009). The geography of the Teanaway area is characterized by the three forks and high relief uplands interwoven between drainages. The watershed consists of a
dendritic drainage pattern, generally oriented northwest to southeast (U.S. Forest Service 2009). The Teanaway River watershed drains an area of 5.35 m² (207 mi²) and is fed by three smaller streams including the Middle, West and North Fork tributaries, with the North Fork River being the widest running north to south (Department of Ecology 2016). Five springs are also present within the Teanaway watershed: Jungle Creek, Beverly Spring, Esmeralda Spring, Iron Creek and Upland Road Spring (U.S. Forest Service 2009). In addition to the rivers and streams, several wetlands such as Horsetail Fen lie within the Teanaway drainage. These wetlands are typically replenished by snowmelt and precipitation with few outflows. The wetlands, bogs, and
fens are dispersed throughout the drainage and are usually located on slopes (Department of Ecology 2016).

**Climate and Flora**

Climate in this area does not vary much from climate in the surrounding areas of the eastern Cascades. This area lies in the rain shadow of the Cascade Mountains and experiences cold, wet winters and hot, dry summers. Below are two climographs (Fig. 3.6 and 3.7), Ellensburg and Cle Elum, as the specific study site is situated between these two areas.

![Cle Elum Climograph](image1.png)

**Figures 3.6** Climograph of Cle Elum (1981-2010). Western Regional Climate Center, 2017.

![Ellensburg Climograph](image2.png)

**Figures 3.7** Climograph of Ellensburg (1981-2010). Western Regional Climate Center, 2017.
Vegetation in the Teanaway is in the level III Cascade ecoregion containing the Yakima and Columbia Plateau ecoregion, the eastern Cascade slopes and foothills, and the grand fir mixed forest ecoregion. The grand fir ecoregion lies between 671-1829 m (2,200-6,500 ft.). This area is characterized by steep canyons, plateaus, and gradient streams that flow from the mountain tops to the lower shrub steppe (EPA 2017). This area is not much different from the eastern region in its entirety. The higher elevations are mixed with subalpine fir, mountain hemlock and grand fir, while the mid elevations are a blend of western hemlock, Douglas-fir, and ponderosa pine toward the lower elevations.

Land Use

Pre-EuroAmerican

The archaeology of the Teanaway is like the archaeology in the surrounding region. Documents provide information showing archaeological sites blanket the landscape throughout the Teanaway area, including the Grissom Site (45KT301) located in central Washington (Finley 2016; Shea 2012), and several other sites documented between the years 1960-1990. Most documents were obtained from the Wissard database providing information of pre-contact settlement patterns with the majority considered to be seasonal camps according to the artifacts listed on the cultural site forms. Most sites scattered throughout the Teanaway are near forest road 9730, Red Top Mountain, and tributaries of the Teanaway River, and nearby springs including Indian and Jack Creek (KT1250, KT1251, 45KT1285, KT1242, WF00357, WF00689). Nineteen archaeological sites were documented in the Teanaway area. Most sites were recorded by archaeological surveyor David Powell and are part of the region 6 inventory list for the Forest Service in the Cle Elum ranger district (Powell 1989). Sites include lithic scatter and debitage, flakes, and chalcedony pieces with flake scars. Most of the archaeological site forms include
coordinates, maps, pictures of the area, pictures of the artifacts, and a written description of the area including topography, vegetation, and nearby water sources (Powell 1989).

Post-EuroAmerican settlement

By the middle of the 1800s, trapping parties entered the Yakima and Naches River basins to trap beaver. However, by 1846 fur trade markets were declining, and the development of mining and logging was in progress (Uebelacker 1980). These areas include coal mining in the Cle Elum and Roslyn areas beginning in the 1880s, the gold mining district of the Swauk area in 1873, logging throughout the mountains and foothills of the central eastern Cascades, and the Thorp Mill, powered by a waterwheel which operated from 1883-1946 (Glauert and Kunz 1976). Several other areas were settled at this time including the Naches River Basin, Tieton River drainage, Ellensburg, Ronald, Liberty, Yakima, and Union Gap. Union Gap used to be the largest settlement in the area, until the new city called north Yakima was started by the Pacific Railroad Company in 1885 (Kirk and Alexander 1990). Although logging was a major draw to the eastern Cascades, mining was the dominant industry (Uebelacker 1980). Remnants of cabins, old mining shafts, and the character of mining towns can still be seen throughout the region in the PNW, and in some places is well preserved and listed on the National Register of Historic Places (Glauert and Kunz 1976).

There are few historical documents that show direct land use of the research area. The closest documentation is logging/mining camps and old sheep camps found near the Teanaway River and nearby tributaries and springs. Those include remnants of old camps including partial structures used in the late 1800s to early 1900s (Uebelacker 1980). Horsetail Fen is unnamed on the map and was informally named for this project. Logging and or mining camps may have been closer to Horsetail Fen than currently recognized.
Several of the cultural site forms listed above include remnants of historic camps used by people settling the west. Historic materials include sections of railway from the 1920s Cascade Lumber Company Railroad, sheep camps near forest service road 9730, and historic camps found near meadows in the area. Logging camps were found near Teanaway Ridge, Indian Creek, and several other places with historic materials including tables that were set up for sharpening saws. Most of the sites however, had been somewhat destroyed during trail maintenance in the 1950s. No ages have been assigned to the historic sites, but they are thought to be early to mid-1900s. Most historic sites were listed as undetermined or left blank under the National Register of Historic Places eligibility portion of the form.

Study Site

Horsetail Fen (HTL; informal name) is small fen located in Teanaway area of central eastern Cascades (47°19′46″ N, 120°46′57″ W, 1,183 m a.s.l.), and is situated east of the Teanaway Ridge, north of Red Top Mountain, and south of the Mount Stuart Range (Figure 3.8). Horsetail Fen is triangular and approximately 241 m in length from north to south and 230 m wide running east to west (Figure 3.9). The area is located on a relatively flat surface of the hillside, surrounded by generally steep topographic relief.
Figure 3.8 USGS Topographic Map of Horsetail Fen, 2014
Geology and Hydrology

Horsetail Fen was likely formed by glaciers that retreated at the end of the last ice age (ca. 16,000 cal yr BP). This site sits on a relatively flat bench of the Teanaway ridge hillside and is fed by an excess of water from the water table that rises to the surface. However, this fen is mainly fed by precipitation and snow melt. The site has no true inflows, and its only outflow is a small stream on the south side of the fen that flows into Indian Creek and then the North Fork of the Teanaway. This water level of the fen drops during the summer, creating a marshy environment.

Climate

Climate in Horsetail Fen receives a little more precipitation than Ellensburg or Cle Elum and is slightly cooler as it sits at a higher elevation (Figure 3.10). Average temperature in August is 62° F of 28° F in January. Horsetail Fen gets most of its precipitation between November and
February with an annual average of 38 inches (Western Regional Climate Data, 2019). This area experiences hot and dry summers like the rest of the eastern Cascades.

![Horsetail Fen Climograph](http://www.prism.oregonstate.edu/(2018)).

**Flora**

Horsetail Fen lies within the Grand Fir Vegetation Zone, and grand fir is the dominant tree species in the watershed, although Douglas-fir is also abundant (Franklin and Dyrness 1973) (Fig. 3.11). Other conifers present in smaller numbers include ponderosa pine, lodgepole pine, Engelmann spruce (*Picea engelmannii*), western white pine (*Pinus monticola*), and western red cedar (*Thuga plicata*), while the deciduous trees include mountain alder (*Alnus incana*), red elderberry (*Sambucus racemosa*), and several species of willow (*Salix* spp.). The forest understory is dominated by shrubs including huckleberry (*Vaccinium* spp.), wild rose (*Rosa* spp.), spirea (*Spiraea*), kinnickinnick (*Arctostaphylos uva-ursi*), Cascade grape (*Berberis nervosa*), and false azalea (*Menziesia ferruginea*), while the common herbs found at the site include lupine (*Lupinus*), arnica (*Arnica*), queens-cup (*Clintonia uniflora*), and tall silvercrown
(Cacaliopsis nardosmia). Horsetail Fen itself is covered by numerous varieties of sedges and horsetails (Fig. 3.12).

Figure 3.11 Horsetail Fen, Serafina Ferri 2013

Figure 3.12 Horsetail Fen, Serafina Ferri 2013
Land Use

*Pre-EuroAmerican*

There are four known archaeological sites at Horsetail Fen (Table 3). Site 45KT1228 sits just to the northeast of Horsetail Fen in a dry meadow at the head of the Jack Creek tributary, approximately 550 m from Horsetail Fen (Powell 1994a). The site contains an isolate flake red opaque cryptocrystalline (CCS). Site 45KT1242 lies just southeast of the fen, about 200 m, and contains an isolate of a single cryptocrystalline (CCS) flake. The flake is opaque grey in nature and measures 2.4 x 1.9 x 0.9 cm (Powell 1994b). Site 45KT1284 sits about 200 m east of the Horsetail Fen and contains undisturbed lithics according to archaeological surveyor who recorded the site (Powell 1994c). The cultural site report for 45KT1284 stated that cultural material at this site consisted of several flakes of agate. It was noted that the dense vegetation at this site created poor visibility, so it is possible this site is much larger than the given dimensions (Zweifel and Varner 1989). The last archaeological site (45KT1285) is 20 m south of Horsetail Fen and 100 m south of the Indian Creek tributary (Powell 1994d). The cultural material contains numerous flakes of agate, basalt, and chert. It was noted that there were several quarries in the area and could have been the source for cultural material. No fire cracked rock, ground stone or formed tools were found at this site.

Cultural material found at all four sites were not dated, however these sites were considered as prehistoric due to similarities with other sites in the region (Zweifel and Varner 1989). The cultural resource site report indicated that this site would have been ideal for an upland seasonal camp, which makes sense given the lower seral plant communities of such a wetland in the woods. Cultural material from all four sites was discovered near the meadow and
pond. According to field reports, this site was considered seasonal camp due to ethnographic accounts of upland use by Native Americans (Zweifel and Varner 1989).

Table 3 Archaeological Sites at Horsetail Fen

<table>
<thead>
<tr>
<th>Site Number</th>
<th>Cultural Material Description</th>
<th>Distance from HTL (meters)</th>
</tr>
</thead>
<tbody>
<tr>
<td>45KT1228</td>
<td>Isolate red opaque cryptocrystalline (CCS) flake</td>
<td>550 m</td>
</tr>
<tr>
<td>45KT1242</td>
<td>Isolate of a single cryptocrystalline (CCS) flake</td>
<td>200 m</td>
</tr>
<tr>
<td>45KT1284</td>
<td>Lithic scatter, agate flakes</td>
<td>200 m</td>
</tr>
<tr>
<td>45KT1285</td>
<td>Lithic flakes, consisting of agate, basalt and chert</td>
<td>20 m</td>
</tr>
</tbody>
</table>
CHAPTER IV
METHODS

Site Selection and Field Methods

This site was selected because it is one of few natural wetlands in the Teanaway Range, and because the larger area has experienced several recent wildfires. In 2011, sediment cores were extracted from Horsetail Fen using a 5 cm diameter modified Livingstone piston corer (Wright et al. 1984). Central Washington University (CWU) Geography field school students led by Dr. Megan Walsh extracted sediment cores from a floating platform anchored in the deepest part of the wetland, approximately ~9 meters in depth. Extruded core segments were ~1 meter in length and ten drives were recovered. Each drive length was described in the field and wrapped in plastic wrap and aluminum foil and encased in a split PVC pipe for protection and transferred to the Paleoecology Laboratory at CWU, where they were kept under refrigeration.

Laboratory Methods

*Magnetic susceptibility*

Magnetic susceptibility is used to measure the quantity of magnetic matter including volcanic tephra within the core (Thompson and Oldfield 1986). Measurements were taken in 1 cm intervals for the Horsetail Fen core using a Sapphire Instrument 5 cm ring sensor at the Paleoecology Laboratory at the University of Oregon, located in Eugene Oregon. Values were graphed to show magnetic susceptibility throughout the core. High magnetic susceptibility shows periods of higher iron content being deposited into the fen, usually following volcanic eruptions and mass movements. Sections with lower magnetic susceptibility are typical with more organic material.
Lithology and Chronology

The Horsetail Fen core was split longitudinally, and each meter was analyzed to document stratigraphic changes throughout the core (Fig. 4.1). A Munsell soil color chart was used to describe the changes in the sediment based on color and lithology. Tephra layers were identified to help establish a chronology of the core.

![Figure 4.1 Extracted core from Horsetail Fen, CWU Paleoecology Lab, 2013](image)

Eight samples of 2 cm$^3$ were dried at 90°C and sent to AMSDirect laboratory in Seattle, Washington, where $^{14}$C dating was completed. An age-depth model was created for the core based on the calibrated ages of the eight radiocarbon dates, combined with the known age of Mount Mazama tephra (Zdanowicz et al. 1999). AMS $^{14}$C dates were converted to calendar years using CALIB 7.1 (Stuiver et al., 2017). Median ages were chosen unless they fell within a trough on the probability distribution function, and in that case, the age of the nearest peak was used. All ages were rounded to the nearest decade. A constrained cubic smoothing spline was used to create the age-depth model and ages in cal yr BP were assigned to each depth in the core.
Loss-on-Ignition

Loss-on-ignition helps determine both the productivity of the Horsetail Fen system and the productivity (in terms of biomass) of the surrounding forest (Dean 1974). One cubic centimeter (cc) was taken every 5 cm by packing sediment into a syringe and placing it in porcelain crucibles. The crucibles were weighed while empty and then filled with 1 cc of sediment and weighed again. Each sample was dried overnight at 90°C in a drying oven. Once cooled, the sample was weighed and then placed in a muffle furnace at 550°C for 2 hours to burn off the organic content. The sample was then placed in a desiccation tank to cool. The sample was weighed again to determine the percentage loss of organic material. The percentage content of each sample was determined by the following formula: \(((\text{dry weight before 550°C ignition} - \text{dry weight after 550°C ignition})/\text{dry weight before 550°C ignition}) \times 100\) (Heiri et al., 2001). The following day the crucibles were weighed and burned in the muffle furnace for a second time at 900°C for 2 hours to determine the percentage loss of carbonate matter. After cooling in the desiccation tank the crucibles were weighed for a final time using the calculation: \((\text{dry weight before ignition and dry weight after ignition})/\text{dry weight before ignition} \times 1.36\) \times 100 (Heiri et al. 2001).

Charcoal

Macroscopic charcoal analysis was used to reconstruct the fire history of the Horsetail Fen watershed. Contiguous 1 cc samples were taken at 1 cm intervals and packed in a modified syringe. Each sample was washed into a plastic vial and soaked in a 5% sodium hexametaphosphate solution for at least 24 hours (Whitlock and Anderson 2003). Samples were then soaked in a bleach solution for 4-6 hours to disaggregate the sediment (Walsh et al. 2008). Each sample was sieved through a set of nested mesh screens (250 μm and 125 μm) to isolate the
charcoal particles. Only particles >125 μm in diameter are counted because they are representative of local fire activity (Whitlock and Bartlein 2003). The sample residues were then washed into gridded petri dishes to be counted (Long et al. 1998). Each sample was examined using a stereoscope at 40X magnification to obtain the total charcoal counts, and each particle was identified as either woody or herbaceous charcoal (Fig. 4.2 and 4.3) based on their appearance (Walsh et al. 2008, 2010a, 2010b, 2014, 2018).

Charcoal concentration (particles/cm³) was determined by dividing the number of charcoal particles in each sample by the total volume of the sample. The charcoal data, along with ages of each sample depth, were put into a spreadsheet to be analyzed using the CharAnalysis statistical program (Higuera et al. 2010), which separates the charcoal data into a peak and background component. The CharAnalysis program identified individual fires within the record and calculated the fire frequency and peak episode magnitude, and the data were plotted (Higuera et al. 2010).
Archaeological, Ethnographic/Historic Methods

The goal of the archaeological component of this research was to summarize the post-glacial archaeological, ethnographic, and historical record for the central eastern Cascades, focusing on human land-use practices within fire-modified landscapes. This was accomplished using published documents pertaining to human history to identify regional archaeological sites and categorize them based on time and space, when possible. Much of the archaeological evidence derived from the ‘Handbook of North American Indians’ edited by Deward Walker in 1998. Other pertinent information stemmed from archaeologists whose work was mainly in eastern Washington, and those who provided a timeline of culture development based on radiocarbon dates, or artifacts found in the record that distinguishes one cultural phase from another (Benson and Lewarch 1989; Chatters 1995, 2012; Galm et al. 1981; Hackenberger 2009; Zweifel and Reid 1991).

Secondary data including ethnographic literature was used to investigate the cultural history regarding land use practices in fire-modified landscapes (Burtchard 2007; Delcourt et al. 1998; Gottesfeld 1994; Lightfoot and Cuthrell 2015). The ethnographic record was used to build on the argument that people used fire in various locations and physiographic zones to modify their landscapes throughout the Pacific Northwest region (Connolly 2000; Norton 1979; Peter and Shebitz 2006). Most of the ethnographic history comprised of information regarding Native American land use patterns, subsistence strategies included hunting and gathering, and the management of resources by use of fire. Historical records were used as a platform for what Europeans observed about Native American activity when they explored the Pacific Northwest, specifically the Columbia Plateau (Norton 1979).
CHAPTER V

RESULTS

Age-depth model

The total length of the core for Horsetail Fen (HTL11B) was 8.24 meters, which included including several tephra layers. An age-depth model was created for Horsetail Fen using eight AMS $^{14}$C dates and the Mount Mazama O tephra (Table 4; Fig. 5.1). Radiocarbon dates were converted to calendar years before present using CALIB 7.1 (Stuiver et al. 2017) and the tephra layers were removed. The results for the Horsetail Fen age model suggests a basal date of 15,930 cal yr BP. Results indicate a slow and constant sedimentation rate from the base of the core (824 cm) to the Mazama tephra layer (661 cm). Sedimentation rate then increased from Mazama to approximately 220 cm, and then slightly decreased and remained constant to the top of the core.

Table 4 Ages for Horsetail Fen Core HTL11B

<table>
<thead>
<tr>
<th>Depth (cm below mud surface)</th>
<th>Lab Number</th>
<th>Source Material</th>
<th>Age ($^{14}$C yr BP)</th>
<th>Age (cal yr BP)</th>
</tr>
</thead>
<tbody>
<tr>
<td>119</td>
<td>D-AMS-015374</td>
<td>Bulk Sediment</td>
<td>2129 ± 26</td>
<td>2100 (2004-2296)</td>
</tr>
<tr>
<td>219</td>
<td>D-AMS-015375</td>
<td>Bulk Sediment</td>
<td>3298 ± 28</td>
<td>3520 (3454-3563)</td>
</tr>
<tr>
<td>319</td>
<td>D-AMS-015376</td>
<td>Bulk Sediment</td>
<td>4059 ± 31</td>
<td>4540 (4428-4789)</td>
</tr>
<tr>
<td>408</td>
<td>D-AMS-015377</td>
<td>Bulk Sediment</td>
<td>4830 ± 28</td>
<td>5580 (5478-5640)</td>
</tr>
<tr>
<td>489</td>
<td>D-AMS-015378</td>
<td>Bulk Sediment</td>
<td>5533 ± 30</td>
<td>6330 (6287-6397)</td>
</tr>
<tr>
<td>535</td>
<td>D-AMS-015373</td>
<td>Bulk Sediment</td>
<td>5737 ± 30</td>
<td>6530 (6451-6633)</td>
</tr>
<tr>
<td>661</td>
<td></td>
<td>Mount Mazama Tephra*</td>
<td>7627 (7577-7777)</td>
<td></td>
</tr>
<tr>
<td>740</td>
<td>D-AMS-015379</td>
<td>Bulk Sediment</td>
<td>10280 ± 38</td>
<td>12050 (11827-12373)</td>
</tr>
<tr>
<td>814</td>
<td>D-AMS-015380</td>
<td>Bulk Sediment</td>
<td>12945 ± 48</td>
<td>15470 (15266-15695)</td>
</tr>
</tbody>
</table>

$^{14}$C age calculations were conducted at DirectAMS, Seattle, WA. Calendar ages with the 2 sigma age ranges determined using Calib (Stuiver et al., 2017) *Known age of Mount Mazama eruption
Lithology

The Horsetail Fen core was composed almost entirely of coarse peat, apart from a clay layer at the bottom of the core and several tephra layers. Organic material was high throughout most of the core averaging between 75-80% (Fig. 5.2). Magnetic susceptibility (MS) was at its highest towards the bottom of the core. There was a peak in MS at a depth of 775 cm due to a volcanic eruption, most likely the Glacier Peak eruption, which occurred sometime between ca. 13,710–13,410 cal yr BP (Kuehn 2009). The second spike in MS was a result of the Mount
Mazama O eruption, found between the depths of 670-660 cm. The core was also interspersed with a clay peat mixture right below the Mount Mazama tephra O layer. Organic values increased significantly between 775-735 cm showing organic content between 18-90% before decreasing to 30% at 725 cm. Organic material then fluctuated between 35-100% between 725-450 cm. Values decreased between 440-420 cm to almost 0% and briefly increased to 75% between 425-430 cm. Organic values were steady between 410 cm to the top of the core ranging between 70-90%. The carbonate material was near zero throughout the entire core.

Figure 5.2 Lithology, charcoal concentration (particles >125 µm/cm³ units) (total concentration =black curve, herbaceous = green curve, loss-on-ignition (% organics = brown curve; % carbonates = light green curve), and magnetic susceptibility (electromagnetic units = orange curve) plotted against depth in the core (cm).
Charcoal Concentration

Charcoal concentration values were low at the bottom of the core between the depths of 824-750 cm (ca. 15,930-12,550 cal yr BP), averaging 1.9 particles/cm³ with 20% herbaceous charcoal identified (Fig. 5.2). Values for total charcoal and herbaceous charcoal started to rise substantially between 750-662 cm (ca. 12,550-7630 cal yr BP) before decreasing immediately after the Mount Mazama eruption. Average charcoal concentrations were 12.9 particles/cm³ with 37% herbaceous charcoal. Between 662-489 cm (ca. 7630-6310 cal yr BP), concentration values were consistent. Average charcoal concentration for this depth was 5.1 particles/cm³ with 32% herbaceous charcoal. Total charcoal concentrations declined slightly from 489-175 cm (ca. 6310-2960 cal yr BP) with an average charcoal concentration of 4.2 particles/cm³ and 20% herbaceous charcoal. Charcoal concentrations generally rose between 175-50 cm (ca. 2960- 890 cal yr BP) with an average of 5.7 particles/cm³ and 32% herbaceous charcoal. Total charcoal concentrations were generally constant from a depth of 50 cm to the top of the core (ca. 890 cal yr BP- present), with an average charcoal concentration of 4.3 particles/cm³ and 13% herbaceous charcoal.

CharAnalysis

Using a background smoothing window of 500 years, the global signal-to-noise index for the HTF11B core was maximized at 5.375. This is well above the threshold of 3.0 determined by Kelly et al. (2011), which indicates whether CharAnalysis is suitable to use for identifying fire episodes and reconstructing fire frequency. This high value indicates that the CharAnalysis program was easily able to identify fire episodes in the Horsetail Fen record (Fig 5.3), although it is important to note that identified fire episodes could potentially be made up of multiple fires if they occurred close together in time (Long et al. 1998). The only periods where it struggled to
identify individual fire episodes were during a portion of the Late Glacial period, between ca. 12,700-12,300 cal yr BP, and during a very brief period at ca. 8500 cal yr BP.

Table 5 CharAnalysis Statistics for Horsetail Fen

<table>
<thead>
<tr>
<th>Age</th>
<th>Ave. CHAR Values</th>
<th>Ave. % of Herb. Char.</th>
<th>Fire Episodes</th>
<th>Ave. Peak Magnitude</th>
</tr>
</thead>
<tbody>
<tr>
<td>LG 15,930-12,000</td>
<td>.045 particles/cm²/yr</td>
<td>20%</td>
<td>13</td>
<td>6.33 part./episode</td>
</tr>
<tr>
<td>EH 12,000-8,000</td>
<td>.205 particles/cm²/yr</td>
<td>12%</td>
<td>12</td>
<td>23.63 part./episode</td>
</tr>
<tr>
<td>MH 8,000-4,000</td>
<td>.532 particles/cm²/yr</td>
<td>26%</td>
<td>35</td>
<td>24.66 part./episode</td>
</tr>
<tr>
<td>LH 4,000-present</td>
<td>.31 particles/cm²/yr</td>
<td>24%</td>
<td>27</td>
<td>18.11 part./episode</td>
</tr>
</tbody>
</table>

Late Glacial (LG; 15,890 – 12,000 cal yr BP)

Charcoal values were generally low during the Late Glacial period. Charcoal concentration (total) averaged 2.07 particles/cm³ while average herbaceous concentration was 0.88 particles/cm³ (20%). Average charcoal accumulation rate (CHAR) was .045 particles/cm²/yr (Table 5.2, Fig. 5.3). Average fire frequency was 3.4 episodes/1,000 yr, while average peak magnitude was 6.33 particles/episode. Thirteen fire episodes occurred during the Late Glacial period. Fire frequency increased to 5 episodes/1,000 yr at ca. 14,600 cal yr BP, decreased throughout most of the period and then rose to 4.5 episodes/1,000 yr between ca. 12,500-12,000 cal yr BP. Peak magnitude was at its highest at ca. 15,600 cal yr BP with ~25 particles/episode, but overall was extremely low. The signal-to-noise index stayed above 3.0 for most of the Late Glacial period but decreased briefly to zero between ca. 12,800-12,200 cal yr BP, likely because CHAR values in this part of the record were near zero.
Early Holocene (EH; 12,000 – 8,000 cal yr BP)

Charcoal values were generally higher in the early Holocene as compared to the Late Glacial period, although one fewer fire episode occurred (Fig. 5.3). Average total charcoal concentration was 12.5 particles/cm³, while average herbaceous charcoal concentration was 5.40 particles/cm³ (12%). Average CHAR values were .205 particles/cm²/yr. Average fire frequency was 3.02 fire episodes/1,000 yr, while average peak magnitude was 23.63 particles/episode (Table 5.1). There were a total 12 fire episodes during this period. Fire frequency was at its highest during the early Holocene between ca. 12,000-11,700 cal yr BP at 5.5 fire episodes/1,000
yr. Fire frequency declined between ca. 11,700-10,700 cal yr BP to ~2 fires/1,000 yr, with peak magnitude at 50 particles/cm². Fire frequency slowly started to increase at the end of the period between ca. 10,500-9000 cal yr BP to ~4 fires/1000 yr. Peak magnitude was at its highest during this time with 180 particles/episode. Fire frequency experienced a brief drop at ca. 9000 cal yr BP to ~3 fire episodes/1,000 yr, and then increased back up to 4 episodes/1,000 yr at ca. 8000 cal yr BP, but peak magnitudes were near zero at this time. The signal-to-noise index remained above 3.0 throughout most of the early Holocene but took a slight dip below at ca. 8,500 cal yr BP, and no fire episodes were identified at this time.

**Middle Holocene (MH; 8,000 – 4,000 cal yr BP)**

Fire activity increased substantially during the middle Holocene as compared to earlier in the record (Fig. 5.3). Average total charcoal concentration was 5.22 particles/cm³ with average herbaceous concentrations at 1.84 particles/cm³ (35%). Average CHAR values were 0.53 particles/cm²/yr. Average fire frequency was 8.5 episodes/1,000 yr with 35 individual fires and an average peak magnitude of 24.66 particles/episode during the middle Holocene (Table 5.1). Fire frequency was at its lowest at ca. 8000 cal yr BP with 4 fire episodes/1,000 yr. Peak magnitude was around 150 particles/cm². Fire frequency increased significantly from ca. 7,800-6,600 cal yr BP, and fire frequency peaked for the entire record at ~12 fire episodes/1000 yr; however, peak magnitudes were generally lower at this time (~25 particles/cm² or lower). Fire frequency decreased to ~8 fire episodes/1,000 yr at ca. 6,300 cal yr BP before rising again to ~9 episodes/1,000 yr at ca. 5,500 cal yr BP. Peak magnitude was at its highest during the middle Holocene at 225 particles/episode at ca. 6,500 cal yr BP. Fire frequency declined for the remainder of the middle Holocene to ~6 fire episodes/1,000 yr at ca. 4000 cal yr BP. Peak magnitude fluctuated between 0-50 particles/episode during this time. The signal-to-noise index
was above a 3.0 throughout the middle Holocene indicating that CharAnalysis was able to easily identify fire episodes.

**Late Holocene (LH; 4,000 cal yr BP – present)**

Fire activity decreased slightly during the late Holocene in comparison to the middle Holocene, however it was still substantially higher than what was experienced during the Late Glacial and early Holocene (Fig. 5.3). Average total charcoal concentration during the late Holocene was 4.81 particles/cm³ while average herbaceous concentration was 1.35 particles/cm³ (24%). Average CHAR during the late Holocene was .31 particles/cm²/yr, and average fire frequency was 6.77 episodes/1,000 yr. 27 individual fire episodes occurred and average peak magnitude was 18.11 particles/cm². Fire frequency started at ~6 episodes/1,000 yr at ca. 4000 cal yr BP with a peak magnitude of 125 particles/cm². Fire frequency then increased slightly and remained constant at ~7 episodes/1,000 yr between ca. 3,800-1,800 cal yr BP. Fire frequency then increased to its highest point in the late Holocene reaching ~8 episodes/1000 yr at ca. 1,000 cal yr BP. Fire frequency then declined sharply to ~3 episodes/1,000 yr from by the end of the record. Peak episode magnitudes were variable during the late Holocene, but were generally smaller after ca. 1800 cal yr BP. The signal-to-noise index remained above 3.0 throughout most of the late Holocene, and then decreased to just below 3 approximately 200 years before present.
CHAPTER VI
DISCUSSION

Fire-Climate-Vegetation-Human Interactions at Horsetail Fen

This thesis outlines the relationship between people, fire, climate and vegetation throughout the post-glacial period within the Horsetail Fen watershed, located in the Teanaway area of the eastern Cascades. The goal was to combine the Horsetail Fen fire history record, along with the regional record, with the record of human history to describe the relationship between people and their environment in the central eastern Cascades during the post-glacial period. This chapter is divided chronologically into Late Glacial, early Holocene, middle Holocene, and late Holocene sections, discussing within each the influence of climate variability and vegetation change on the fire history record, followed by potential interactions between people, fire, and the landscape.

Late Glacial (15,890 – 12,000 cal yr BP)

With a basal date of ca. 15,930 cal yr BP, Horsetail Fen is one of the oldest paleoenvironmental study sites in the Pacific Northwest. Other sites in the Pacific Northwest of a similar (or older) age include Sunrise Lake in Mount Rainier National Park, Washington (Walsh et al. 2017), Blair Lake in the central Oregon Cascades (Cox 2016), Battleground Lake in southwest Washington (Whitlock 1992), and Carp Lake in south-central Washington (Whitlock and Bartlein 2000). The last glacial maximum occurred in the Pacific Northwest sometime between 20,000-18,000 years ago (Clark et al. 2009); however, cold conditions still prevailed for several millennia longer because of the persistence of the ice sheet (Bartlein et al. 1998). This likely explains the low fire activity at Horsetail Fen during the Late Glacial period (Fig. 6.1).
During that time, the vegetation of the eastern Cascades was likely a tundra environment mixed with shrub steppe; however, in some areas white bark pine, western white pine, fir, and spruce likely grew (Whitlock 1992). This vegetation assemblage, coupled with the generally dry climatic conditions (Whitlock, Shafer & Marlon 2003), allowed parts of eastern Washington Cascades to burn, including the Horsetail Fen watershed. It is likely, however, that these fires were small and of low-severity, given the low peak episode magnitude values. It is also likely that the episodes identified by CharAnalysis include more than one individual fire, given the low temporal resolution in this part of the record. Climate fluctuated throughout the Late Glacial period, particularly in response to the retreating Cordilleran ice sheet and increasing insolation (Whitlock and Bartlein 2003). This likely explains the slight increase in fire frequency observed at Horsetail Fen toward the end of the period, ca. 12,500-12,000 cal yr BP.

It is thought that people inhabited the PNW soon after the retreat of the Cordilleran and Laurentide glaciers, and that flooding of major drainages has destroyed most of the archaeological record during the Late Glacial period in this area (Knudson 1980; Sheppard 1987). Depending on what is taken at face value for early occupation, archaeologists have suggested Paleoindian and Archaic lifeways started in the Pacific Northwest as early as ca. 14,000 cal yr BP (Chatters et al. 2012; Waters and Stafford 2007). Although there is not a lot of evidence showing human occupation, there are a couple archaeological sites that provide evidence that people inhabited the region at this time (Mierendorf et al. 2013). The Manis Mastodon located in the region dating to ca. 13,800 cal yr BP, and the Ayers Pond sites in the Puget Lowlands associated with butchered bones from mastodon and bison, both provide strong evidence that people were surviving in the region during the late Pleistocene (Kenady et al. 2011; Waters et al. 2011).
There are 22 known Clovis sites that cover a wide geographic range in North America, one of which is in east Wenatchee (Waters and Stafford 2007). These sites are named Clovis by paleolithic toolkits found in the record indicative of Clovis culture (Waters and Stafford 2007). Eleven of the 22 sites have 43 radiocarbon dates attached to them. These dates range depending on geographic area, but the Clovis period segment according to INTCAL04 calibration reveal a maximum date of ca. 13,250-12,800 cal yr BP putting the beginning of Clovis occupation during the Late Glacial period (Waters and Stafford 2007). The Marmes Rockshelter located at the mouth of the Palouse River in the southeast Washington also show the presence of early human occupation (ca. 13,000-12,300 cal yr BP) (Sheppard et al 1987). The Wilson Butte Cave located in Idaho on the Snake River plain also provides evidence of human occupation in the PNW between ca. 13,000-12,000 cal yr BP (Sheppard 1987). Fire activity was low during the Late Glacial period due to low biomass, and it is unlikely that people at this time had major impacts on the landscape during this time.

If we take all the archaeological evidence and look at it within the context of fire, one could suggest that even the earliest of inhabitants used fire. Clovis people may have used fire for hunting practices. However, because Clovis sites are documented as small areas that reveal low artifact densities, we could assume that they did not stay in one area for too long and moved throughout the landscape as needed, not needing fire to propagate resources. Or perhaps Clovis used fire as needed, burned landscapes, and returned to those areas as resources became available. However, that is probably unlikely since fire activity was low during the Clovis period.
Figure 6.1 Total (black curve) and herbaceous (purple curve) charcoal influx (CHAR; particles/cm²/yr), fire frequency (episodes/1000 yr), archaeological phases (Galm et al. 1981), PNW regional biomass burning curve (Walsh et al. 2015) and July insolation anomaly at 45°N (Berger and Loutre 1991) plotted against age (cal yr BP) for the HTL11B record.
Early Holocene (12,000 – 8,000 cal yr BP)

Climate became warmer and drier than the Late Glacial Period in the PNW during the early Holocene as a result of increased insolation (Fig. 6.1; Bartlein et al. 1998; Walker and Pellatt 2008; Whitlock 1992). Fire activity seemingly increased during the early Holocene at Horsetail Fen, as indicated by the higher charcoal influx values (Fig. 6.1). However, fire frequency remained relatively low, but was at its highest during the onset of the early Holocene (ca. 12,000-11,000 cal yr BP). Fire frequency then decreased and remained mostly steady for the remainder of the period. The regional biomass burning curve for the PNW shows that fire activity throughout the region was low at the beginning of the early Holocene (ca. 12,000 cal yr BP) and then started to rise as insolation and burnable biomass increased (Walsh et al. 2015). However, fire frequency at Horsetail Fen showed a decrease at this time. This could be because burnable biomass was still low at the site at this time, or it could be that CharAnalysis underestimated the number of episodes due to the low resolution of the record in the early Holocene. Conversely, greater charcoal accumulation into the record occurred during this period, which likely indicates greater fire activity.

Higher pollen percentages of sage, grass, sedge and amaranth in the Columbia Basin, in areas north and east of Horsetail Fen including the Okanogan Highlands and Channeled Scablands, support the idea that the early Holocene was warm and dry, particularly between ca. 10,500 to 8,000 cal yr BP (Walker and Pellatt 2008; Whitlock 1992). However, it is likely that few trees grew in the Horsetail Fen watershed at this time, and burnable biomass was likely low. Pollen records show vegetation consisted of *Artemisia* and haploxylon-type pines such as western white pine in the Okanogan Valley located in the north eastern Cascades approximately 10,000 years ago (Mack et al. 1979). This may explain why Horsetail Fen shows a higher
percentage of herbaceous charcoal during ca. 11,500-9,500 cal yr BP, indicating fires were low in severity, burning shrubs and grasses.

Evidence from the archaeological record suggests human occupation was growing at the onset of the early Holocene (Waters and Stafford 2007). Radiocarbon dates from Marmes Rockshelter record indicate a contiguous 10,000-year sequence of stratified remains. This sequence was used as a comparison to other archaeological sites in the region (Sheppard et al. 1987). According to the known archaeological phases, the tail end of the Clovis period, the Windust and part of the Cascade Vantage phase all take place during the early Holocene. Low artifact densities are present during the Windust Phase; however, it is thought that people exploited plant and animal resources due to a warming climate (Chatters 1986; Connolly 2000; Hackenberger 2009). The fire record for Horsetail Fen (Fig. 6.1) shows that fire frequency and magnitude fluctuated throughout the Windust Phase. Fire frequency was high during the first half of the Windust Phase and then decreased and remained steady through the first part of the Cascade Phase. It is not until the last half of the Cascade/Vantage Phase, around ca. 8,000 cal yr BP, that we see a marked increase in fire activity. This could be a result of more anthropogenic burning on the landscape for resource extraction. The Lind Coulee site is an example of early anthropogenic burning (Daughtery 1956). Lind Coulee archaeological site (45GR97) contained the oldest man at ca. 11,750 cal yr BP (Lyman 2015), in addition to containing cultural debris such as projectile points, knives, scrapers and lithic debitage resulting from tool production (Daugherty 1956). Daugherty stated there were faunal remains and evidence of fire at the site (Ames 1998, 2005; Knudson 1980).

The archaeological record of the early Holocene reflects human occupation in areas of the eastern Cascades. However, a cultural transition is seen in the record between the Paleoindian
to Archaic traditions which is marked by the Western Stemmed Tradition (WST) and the Old Cordilleran Tradition (OCT). These traditions are markedly different in subsistence practices, stone tools, bone and processing technologies, clothing, land use and settlement patterns (Chatters et al. 2012). There is evidence of human activity in the open areas of the Columbia Basin during the OCT (Lyman 1985). The archaeological record shows evidence of human activity in upland mountain ranges and river drainages, as well the dry lowlands of the Columbia Plateau. Evidence demonstrates that the entire Columbia Basin was in fact inhabited during the early Holocene (Chatters et al. 2012; Lyman 1985).

Clearly all the evidence in the archaeological record does not directly tie into fire in the way we would like it to because we do not have enough recorded sites dated. However, it does show that people used fire for procuring foods such as ungulates, production of stone tools, using fire to cook bison, birds and other small animals, and using fire for camas production. I think it is safe to assume indigenous peoples used fire in a multitude of ways including burning the landscape for management purposes including propagating floral species (Lightfoot & Cuthrell 2015).

**Middle Holocene (8,000-4,000 cal yr BP)**

Climate during this period shifted from warm and dry to wetter and eventually cooler due primarily to a continued decrease in insolation (Fig. 6.1; Bartlein et al. 1998; Berger and Loutre 1991). However, even with the lower temperatures fire activity in the Horsetail Fen watershed was at its highest during the middle Holocene. *Pinus* parkland environments still dominated the landscape throughout the eastern Cascades during the first part of the middle Holocene (Whitlock 1992; Whitlock et al. 2000). However, a shift in vegetation in the central and northern eastern Cascades from a sparse *Pinus* parkland to a closed canopy mixed conifer forest occurred
at ca. 7000 cal yr BP, signifying this shift in climate. After this time, the forests of the eastern Cascades included Douglas-fir, larch, fir, hemlock and spruce, indicating that climatic conditions were cooler and wetter (Haydon 2018; Walker and Pellatt 2008; Whitlock et al. 2000). Fire episodes, frequency, and magnitude increased considerably at Horsetail Fen between ca. 8,000-6,700 cal yr BP (Fig. 6.1), right around the time Mount Mazama erupted. Fire frequency declined between ca. 6,700-6,000 cal yr BP while simultaneously showing the largest spike in magnitude seen in the entire core between ca. 6,500-6,300 cal yr BP, indicating there were several large or high-severity fires in Horsetail Fen watershed. The exponential increase in fire magnitude from wood charcoal also indicated that these fires were probably large landscape fires, burning trees not just the understory. Fire activity in other areas of the PNW remained relatively steady throughout the middle Holocene according to the regional biomass record (Fig. 6.1) (Walsh et al. 2015). It is interesting that fire activity at Horsetail Fen differed in frequency during this period, however, both records show a substantial decrease in fire activity at ca. 5,700 cal yr BP. High fire activity was likely the result of a shift in vegetation, which would have provided an abundance of fuel that allowed more frequent and larger and/or more severe fires to burn, but it could also be that greater climate variability or human use of fire contributed to the observed trends (Haydon 2018; Walsh et al. 2015).

The cultural phases during the Late Holocene are the Tucannon/Frenchman phase between ca. 4,000 to the beginning of the Harder/Cayuse phase (ca. 2,500 cal ty BP). Archaeologists note that Columbia Plateau culture began towards the end of the Tucannon/Frenchman phase (Hackenberger 2009). Evidence of root plant processing and semi subterranean appears in the record. It is likely that people used fire to help facilitate those processes. The record shows evidence that people were living a sedentary lifestyle beginning
around ca. 2,500 cal yr BP (Galm et al. 1981). Winter villages appear in the record along with hunting stations at higher elevations (Chatters 1986). People using fire as a hunting strategy is well known throughout ethnographic and oral histories. It is likely that people used fire on the Plateau during hunting practices.

As previously noted, it is well known that Native Americans used fire in a variety of ways; managing landscapes using fire as a horticultural tool, hunting strategies, and enhancing the biodiversity of landscapes (Lightfoot and Cuthrell 2015). There is also evidence of burning certain times of the year for procuring and drying seeds (Connolly 2000). The large rise in the fire activity starting at ca. 8,000 cal yr BP could be the result of higher percentage of the landscape being used, population increasing, or cultural development.

Understanding that people used fire for survival really is that simple. One can look at the archeological record and assume that people who hunted more for subsistence used fire to cook game. People who were more reliant on aquatic species procuring salmon and fish would have used fire in preparing meals. When we look at all the evidence in the archaeological record, such as tool assemblages and types, and understand basic human nature, it is not hard to assume or make the argument that indigenous peoples in the Cascades, Columbia Plateau, the PNW, or anywhere else used fire in a multitude of ways (Boyd 1986). One could say that as indigenous cultures evolved so did the use and need for fire. Hunter/gatherers who ate food as they extracted it used fire less than maybe say a forager/collector who did not use resources right away. Instead, collectors may have used fire more frequently because they were semi-sedentary and used fire to manipulate the landscape for horticulture including cultivation or burning to create biodiversity across landscapes.
Either way, one can only speculate based on tangible evidence in the archaeological record. What we can say though, is that not only has lifestyle changed according to mobile versus sedentary but also in resource extraction and intensification (Lightfoot and Cuthrell 2015). Evidence suggests that people’s use of resources grew over time. Studies note that in almost all cases, the need for fire on the landscape in the PNW was related to food resource and propagation (Boyd 1999; Walsh et al. 2018). Resource intensification by use of fire was heavily relied upon as populations grew in the inland northwest (Barrett 1980; Boyd 1986, 1999; Gottesfeld 1994). As populations grew, people would have needed more resources from the same amount of land, and likely moved around the landscape as needed. Mobility was somewhat dependent on subsistence quests. In a way, seasons defined human-environment interactions according to resource location. For example, plant foods were available in altitudinal areas where dry plant roots flourished, in April and May. Camas was mostly available June through September, and mountain huckleberry thrived in August-September (Boyd 1999).

*Late Holocene (4,000 cal yr BP–present)*

Regional climatic records indicate that the late Holocene was cold and wet, particularly between ca. 4,000-2,500 cal yr BP (Walker and Pellatt 2008). However, fire frequency rose at Horsetail Fen at ca. 3,500 cal yr BP and remained steady until ca. 1500 cal yr BP, and then fire frequency increased to its maximum at ca. 900 cal yr BP, before decreasing for the remainder of the period. Similarly, the PNW biomass burning curve shows a steady increase in fire activity during the past ~5500 years (Fig. 6.1) (Walsh et al. 2015). The increased fire activity during what was regionally a cold/wet period could be a result of greater climate variability, or from other factors such as increased anthropogenic burning. Additionally, the Horsetail Fen and the PNW records show a simultaneous peak in fire activity concurrent with the Medieval Climate
Anomaly (or Warm Period) between ca. 1100-700 cal yr BP (Mann et al. 2009), and a drop in fire activity during the Little Ice Age, starting at ca. 550 cal yr BP (Mann et al. 2009). As illustrated in Marlon et al. (2012), this is one of the strongest fire trends in the PNW during the Holocene, and suggests that at least to some extent, climate variability was influencing fire activity at Horsetail Fen during the late Holocene.

Studies suggest that higher climate variability caused an increase in fire activity during the middle and late Holocene and was could have been influenced by the El-Nino Southern Oscillation (Heyerdahl 2008; Walsh et al. 2015, 2017). Analysis shows interactions between fire and climate were synchronous and influenced by the El-Nino Southern Oscillation (ENSO) and the Pacific Decadal Oscillation (PDO). Heyerdahl et al. (2008) examined existing fire scar dates from 15 sites within the interior northwest (British Columbia, Washington, Oregon). Both warm trending phases influenced fire patterns indicative of climatic fluctuations. However, during the analysis period between 1651-1900, years of both widespread fires and no-fire occurrences appeared across the landscapes of the interior Northwest (Heyerdahl et al. 2008). They concluded that variations in climate seemed to heavily influence fire regimes in the inland northwest. Years that were warm and dry were synchronous with the years that had the highest numbers of fires, and years where fires occurred, large areas may have burned due to the amount and type of fuel available (Heyerdahl et al. 2008).

Another study was conducted in the Teanaway area of the PNW shows that fire activity was low and steady during the late Holocene, before decreasing significantly around the time of EuroAmerican contact. A 433 year-long fire history was obtained in the Teanaway River Drainage by reconstructing a mixed-conifer forest using dendrochronological techniques. Ninety-two sites consisting of 257 cross-sections and 1,569 individual fire scars were surveyed
all including ponderosa pines, Douglas-fir, grand fir, and western hemlock within 30,000 ha (Wright 1996). The study concluded that fire frequency varied, fires were of low to moderate severity, and had a mean fire interval range of 7.7-48.4 years (Wright 1996). Eighty percent of all fires occurred late in the growing season and almost all consisted of ponderosa pine stands (Wright and Agee 1994). High intensity crown fires or understory fires in the study area detailed by the lack of fire-scar evidence according to Wright and Agee. The study also concluded that larger fires were probably indicative of periods that received below average precipitation.

Large fires also seem to have occurred below the confluence of where the three main forks meet the Teanaway River. This was probably a result of strong winds and climatic conditions in the Teanaway River drainage and the fact that the study area abutted Swauk Prairie, an area where the Kittitas Band of the Yakama Indians occupied historically (Glauert and Kunz 1972). Written accounts do not specify that the area was deliberately burned by indigenous ignitions however, references are made about the prevalence of smoke and burned areas by settlers who traveled through and settled in or near the area (Wright 1996). Research revealed that the study area experienced a dramatic decline in fire activity in the early 1900s, probably coinciding with new landscape management techniques, such as fire suppression initiated by the U.S. Forest Service in 1910, in addition to the advent of timber harvesting in the area (Wright and Agee 1994; Wright 1996). The overall conclusions remained that weather conditions were probably an important factor in the spread of fire within the mixed conifer forests of the Teanaway, and Swauk Prairie could have also been a starting point for fires due to inhabitants of the area (Glauert and Kunz 1972).

The archaeology of the eastern Cascade region during Late Holocene is divided into two major phases; Tucannon/Frenchmen Springs Phase (ca. 7,000-2,500 cal yr BP) and the
Harder/Cayuse Phase (2,500-500 cal yr BP) (Fig. 6.1). Both are further divided into subgroups based on cultural material found in the record (Ames 1988, 1998; Chatters 2012). Material evidence suggests lifeways substantially changed between Cascade/Vantage and Tucannon/Frenchman phase (Chatters 1986). Projectile points became smaller, evidence of root collecting, and plant processing were present, and the notion that ‘Plateau Culture’ was developed during this phase is widely accepted across the archaeological community (Hackenberger 2009). Archaeological sites near Horsetail Fen that provide evidence of early Plateau culture include the Grissom Site (45KT301), located in northeast Kittitas in central Washington (Finley 2016; Shea 2012), the Sunset Creek Site (45-KT-28), and several other sites listed on the Wissard data base showing archaeological sites blanket the landscape throughout the region during the late Holocene (Ames et al. 1998).

The Harder/Cayuse phase (2,500-500 BP) illustrates a time where winter pit houses were seen in the record, solidifying the idea that life was sedentary at this point (Chatters 1986). People still traveled to higher elevations to extract/gather resources as needed, but for the most part, people lived in villages comprised of pit houses. People still moved throughout the landscape as needed and possibly used fire to manipulate the landscape.

Fire activity declined during the post-contact period (the past ~500 years). Management of landscapes changed during this period when EuroAmericans migrated west (Wallin et al. 1996). There is no clear evidence of fire suppression in the record, however, indigenous lifeways were changed dramatically due to EuroAmerican contact. Populations decreased amongst native communities as a result of disease (Boyd 1986). Native Americans were also removed from areas and put on reservations, changing the way in which they could manage landscapes, including burning for resources (Eagle and Johnson 1986). The regional fire record and Horsetail
Fen declined the last 500 years and could be a result of less use of fire by humans, due to decreasing populations.
CHAPTER VII
CONCLUSION

The purpose of this research was to reconstruct the post-glacial fire history of the Horsetail Fen watershed using macroscopic charcoal analysis of a lake sediment core. The goal of this research was to better understand how climate, fire, vegetation, and people interacted with one another during the past ~16,000 years in the Teanaway area of the eastern Washington Cascades. There were three research questions that initiated this research. Below is a summary of the research questions and conclusions:

(1) How has fire activity varied in the Horsetail Fen watershed during the past ~16,000 years?

The fire history reconstruction from Horsetail Fen indicates that fire activity varied widely during the past ~16,000 years. Fire activity was lowest during the Late Glacial period and fires were least frequent at this time. Fire frequency started to rise at the beginning of the early Holocene, and episodes varied in peak magnitude indicating that fires were a mix of small and large/low and high severity. A rise in herbaceous charcoal is also seen in the record during this time. This is likely correlated with the type of vegetation surrounding Horsetail Fen at the time, which likely lacked substantial amounts of trees.

Fire frequency and peak magnitudes were highest during the middle Holocene. The highest increase in fire frequency occurred between ca. 8000-7000 cal yr BP. This is likely due to warmer conditions and more biomass available for burning as vegetation shifted at this time from a Pinus parkland/sagebrush steppe to a mixed conifer forest. Fire frequency dropped somewhat in the late Holocene but then remained fairly constant before peaking at ca. 900 cal yr
BP, and then declining toward present. Charcoal accumulation continued until present, indicating that fires still burned on the landscape, but were perhaps were smaller or less severe.

(2) What role has climate variability played in influencing the fire activity at Horsetail Fen in comparison to the regional paleoenvironmental record during the post-glacial period?

Climatic variations seem to be the determining factor on fire patterns at Horsetail Fen during the post-glacial period. Fire activity was relatively low at Horsetail Fen during the Late Glacial period. Climate was cold and dry which did not allow for a substantial amount of biomass growth for fuel. Fire frequency started to rise after 12,500 cal yr BP for the rest of the Late Glacial period, indicating climate was on a warming trend. The increase in climate is likely due to an increase in solar radiation following the retreat of the glaciers (Bartlein et al. 2014).

Climate was warmer during the middle Holocene than today’s climate. Records show that drought occurred in areas east and north of Horsetail Fen which could explain why vegetation records show a *Pinus* parkland landscape occurred early (ca. 9,000 cal yr BP) in some areas of the eastern Cascades (Whitlock 2000). Fire activity was at its highest during the middle Holocene and could have been a result of changes in insolation resulting in colder and wetter seasons and allowing for more diverse vegetation on the landscape (Bartlein et al. 2014). Solar insolation for the region was declining around ca. 7,000 cal yr BP (Whitlock and Bartlein 2003), which explains why the regional record shows wetter and cooler conditions but does not explain why fire activity was at its highest at Horsetail Fen. This could be that local climate at the site experienced a drier period during this time. Or higher fire activity at the site may not be primarily driven by climate but more so anthropogenic factors.

Climatic conditions continued to cool during the late Holocene, as indicated by changes in vegetation. Some areas of the eastern Cascades experienced higher percentages of *Abies* and
*Picea* (Whitlock 2000). Fire activity remained constant at Horsetail Fen during this wetter and colder period. It seems that climate was the main driving force in fire activity at Horsetail Fen, however, the increase of fires during periods of wetter and colder climates could indicate a of human use of fire on the landscape.

(3) How does the fire history from Horsetail Fen, when combined with the record of human history in the central eastern Cascades, contribute to our understanding of past human land use of fire-modified landscapes?

We live in a part of the country that is rich in archaeological diversity. Sifting through six decades of research has been challenging while attempting to put the fire history into context with the archaeology of the region in order to make sense of human-environmental interactions as it pertains to fire. There is an enormous amount of archaeological data for the Pacific Northwest and more specifically, the Columbia Plateau (Benson and Lewarch 1989; Galm et al., 1981; Walker 1998)

Based on the archaeological record and 60+ years of studies, anthropogenic burning on the landscape for subsistence is widely accepted amongst the scientific community (Boyd 1999; Connolly 2000). There was a total of 19 archaeological sites located in the Teanaway drainage, four of which are located at or in very close proximity of Horsetail Fen (Powell 1989, 1994). As noted in chapter III, these sites would have been ideal for seasonal camping. Native Americans would have had a plethora of resources in addition to a local water source. It is likely based on the characteristics of the landscape that people could have burned this area to create low seral environments ideal for plant growth. Although the human-landscape aspect will always be an assumption, the fire history combined with the human history show people were interacting and
modifying the landscapes in areas east of the Cascades, especially in areas with ideal resources for subsistence, such as Horsetail Fen.

Future Research

Even though the information gathered from Horsetail Fen will contribute to a larger body of literature in paleoecology, more information is needed and can be obtained using pollen analysis on the record. Pollen analysis is a proxy for vegetation history and contributes to our understanding of past climatic variations. By having a detailed chronology of the local vegetational history we can better understand what species might have grown at Horsetail Fen during the post-glacial period, and what local climate was doing. In addition to the fire record and vegetation history, the archaeological record holds significant information about indigenous cultures and how people might have contributed to the changing landscapes we have seen through environmental reconstructions. Further research can be conducted to add to our growing body of knowledge about the diversity of these cultures and who utilized lowland and upland environments for thousands of years. The practice of burning landscapes for resource extraction and subsistence has long been explored and observed by anthropologists and will continue to do so in the future. A detailed understanding of past human-environment interactions pertaining to fire modified landscapes can have extraordinary impacts on how we manage today’s and future landscapes.
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