NATURAL AND ANTHROPOGENIC INFLUENCES ON THE HOLOCENE FIRE AND VEGETATION HISTORY OF THE WILLAMETTE VALLEY, NORTHWEST OREGON AND SOUTHWEST WASHINGTON

by

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Title: NATURAL AND ANTHROPOGENIC INFLUENCES ON THE HOLOCENE FIRE AND VEGETATION HISTORY OF THE WILLAMETTE VALLEY, NORTHWEST OREGON AND SOUTHWEST WASHINGTON

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The debate concerning the role of natural versus anthropogenic burning in shaping the prehistoric vegetation patterns of the Willamette Valley of Oregon and Washington remains highly contentious. To address this, pollen and high-resolution charcoal records obtained from lake sediments were analyzed to reconstruct the Holocene fire and vegetation history, in order to assess the relative influence of climate variability and anthropogenic activity on those histories. Two sites provided information on the last 11,000 years. At one site at the northern margin of the Willamette Valley, shifts in fire activity and vegetation compared closely with millennial- and centennial-time scale variations in climate, and there was no evidence that anthropogenic burning affected the natural fire-climate linkages prior to Euro-American arrival. In contrast, the fire and vegetation history at a site in the central Willamette Valley showed relatively little vegetation change in response to both millennial- and centennial-scale climate variability, but fire activity varied widely in both frequency and severity. A comparison of this paleoecological reconstruction with archaeological evidence suggests that anthropogenic burning near the site may have influenced middle- to late-Holocene fire regimes.

The fire history of the last 1200 years was compared at five sites along a north-south transect through the Willamette Valley. Forested upland sites showed stronger fire-climate linkages and little human influence, whereas lowland sites located in former prairie and savanna showed temporal patterns in fire activity that suggest a significant human impact. A decline in fire activity at several sites in the last 600 years was attributed to the effects of a cooling climate as well as the decline of Native American populations. The impacts of Euro-American settlement on the records include dramatic shifts in vegetation assemblages and large fire events associated with land clearance. The results of this research contribute to our understanding of long-term vegetation dynamics and the role of fire, both natural- and human-ignited, in shaping ecosystems, as well as provide an historical context for evaluating recent shifts in plant communities in the Willamette Valley.

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I dedicate this to my grandmothers, Sarah Katherine Walsh and Marie Elizabeth Mood.
May their kindness, strength, and love live on through me.

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CHAPTER I

INTRODUCTION

The state of the natural environment of the Americas prior to Euro-American settlement is a matter of great debate (Denevan, 1992; Cronon, 1995). Were presettlement landscapes truly natural (i.e., created and maintained by environmental processes such as climate variability and soil formation), were they a result of human landscape modification (i.e., created and maintained by anthropogenic activities such as the use of fire), or were they some combination of both (Vale, 2002)? This contentious debate extends to the Pacific Northwest and even the Willamette Valley where many scholars have proposed that the open prairie and oak savanna ecosystems widespread at the time of Euro-American settlement were the result of thousands of years of Native American burning (Boyd, 1986; Zybach, 1999; Ames, 2004), however, direct evidence to substantiate this hypothesis is rather limited (see Whitlock and Knox, 2002). Ethnographic records suggest that Native Americans used fire for many purposes, such as encouraging the growth of important food sources, as fertilizer for tobacco plants, and to drive deer for hunting (Boyd, 1986; Leopold and Boyd, 1999, Knox, 2000), but details as to the spatial and temporal extent of the burning is poorly understood. The driving question remains: were the presettlement vegetation patterns of the Willamette Valley the result of climate and other natural variations, Native American use of fire, or both?

Relatively little is known about the prehistoric vegetation patterns of the Willamette Valley. Two pollen profiles completed by Hansen (1947) from lakes that no longer exist described the general history of a few major tree taxa, but without the benefit of radiocarbon dating, they do not disclose the timing of land cover shifts. A 20,000-year-long pollen record from Battle Ground Lake (Whitlock, 1992) situated at the northern extent of the valley is the only other paleoecological work from the area and is discussed in detail in Chapter II. This vegetation reconstruction describes changes in land cover since the Last Glacial Maximum, including the existence of a parkland/tundra ecosystem at the site during the late-glacial period, followed by shifts to a closed forest at ca. 13,000 cal yr BP, open savanna at ca. 10,800 cal yr BP, and a closed forest dominated by more mesic taxa at ca. 5200 cal yr BP. However, whether or not the vegetation history at Battle Ground Lake was representative of the Willamette Valley as a whole could not be determined in the absence of other records.

Land survey records of the Federal Land Office from ca. AD 1850 provide a record of the valley's vegetation at the time of Euro-American settlement. Figure 1.1 shows the distribution of the five major vegetation types mapped by the surveyors: prairie, oak savanna, oak woodland, Douglas-fir forest, and riparian forest. Over the past 150 years these ecosystems have changed greatly in terms of general abundance, spatial distribution, and species composition. The two greatest forces of these changes have been land conversion and the removal of fire, both natural- and human-ignited, from the landscape (Sprague and Hansen, 1946; Habeck, 1961; Johannessen et al., 1971; Towle, 1982; Franklin and Dyrness, 1988).

Prairie, ranging from moist to dry, was once widespread across the floor of the Willamette Valley (Hulse et al., 2002). Upland prairie was more abundant than

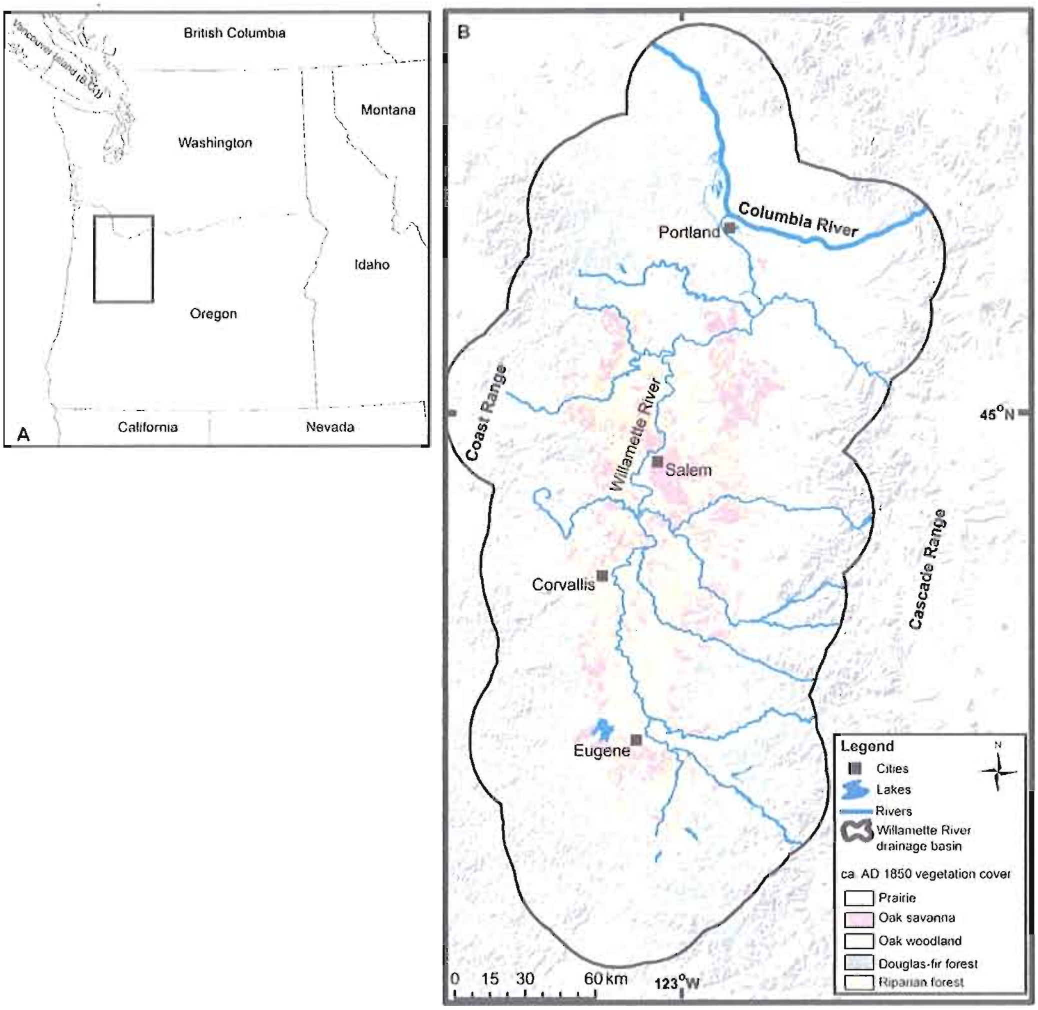


Figure 1.1. Map showing A) the location of the Willamette Valley in the Pacific Northwest and B) the ca. AD 1850 vegetation cover of the Willamette Valley known from General Land Office surveys (data source: Hulse et al. (1998)).

seasonally wet prairie; both were dominated by bunchgrasses such as *Deschampsia cespitosa* (tufted hairgrass), as well as a wide variety of other grasses, sedges, and forbs (Streatfield and Frenkel, 1997; Clark and Wilson, 2001). Christy and Alverson (1994) found that there was less than 1% of the original native wet prairie remaining in the valley. Most was converted into areas of cultivation or grazing (Towle, 1982), while the remainder has become increasingly dense with shrubs and trees and is no longer considered prairie (Johannessen et al., 1971).

Oak savanna, dominated by *Quercus garryana* (Oregon white oak) and often associated with *Quercus kelloggii* (California black oak) and *Pseudotsuga menziesii* (Douglas-fir), was also widely distributed across the Willamette Valley at the time of settlement. Characterized by the oak trees growing relatively far apart, oak savanna covered the valley's rolling hills and the foothills of the Coast and Cascade ranges (Franklin and Dyrness, 1988). Oak savanna has probably seen the greatest change since AD 1850, and today is confined to the valley edges and steep hillsides where other trees cannot establish. Most former oak savanna has grown into oak woodland or even closed forest (Fig. 1.2). Habeck (1961) and Thilenius (1968) attributed this conversion to the absence of fire on the landscape, which once kept *Quercus garryana* reproduction in oak savanna to a minimum.

Oak woodland was similar to oak savanna, but covered less total area and was more densely populated with oak trees. Today, with the absence of burning, oak woodlands support only scattered oaks under dense forests of either *Pseudotsuga*

Figure 1.2. Photos taken at the Howard Buford Recreation Area near Eugene, OR, showing a crowded former oak savanna (top) and a former oak woodland crowded with conifer trees with a field of *Camassia quamash* (camas lily) in the foreground (bottom). (Photos: M. Walsh)

menziesii or *Acer macrophyllum* (big-leaf maple), depending upon the local moisture conditions (Fig. 1.2) (Thilenius, 1968).

Douglas-fir forest dominated at higher elevations along the eastern and western slopes of the valley at the time of settlement. *Pseudotsuga menziesii* was the most common species, but *Acer macrophyllum*, *Tsuga heterophylla* (western hemlock), *Thuja plicata* (western red cedar), *Quercus garryana*, and *Cornus nuttallii* (dogwood) were also common components. Douglas-fir forest is often a successional stage between oak savanna or woodland and *Abies grandis* (grand fir) forest (Franklin and Dyrness, 1988). With the lack of burning in the forests, *Abies grandis* (a fire-intolerant species) has been able to invade and take over areas once dominated by *Pseudotsuga menziesii*, such as north-facing slopes and lower south-facing slopes, accompanied by an overall decrease in species diversity (Cole, 1977).

Riparian forest was once widely distributed across the floodplains of the Willamette River and its tributaries, often 1.5 to 3.5 km wide on either side (Towle, 1982; Sedell and Froggatt, 1984). Most common in these forests were *Fraxinus latifolia* (Oregon ash), *Populus trichocarpa* (black cottonwood), *Pseudotsuga menziesii*, *Salix* sp. (willow), and *Acer macrophyllum* in about equal abundance (Franklin and Dyrness, 1988; Frenkel and Heinitz, 1987). The understory of these forests supported many shrubs including *Spiraea* (hardhack), *Berberis aquifolium* (Oregon grape), and *Sambucus glauca* (elderberry). With changes in the hydrology of the Willamette River and the expansion of cultivation in the valley, most riparian forest is gone (Habeck, 1961; Johannessen et al., 1971; Dykaar and Wigington, 2000). That remaining today retains a composition similar to the ones that existed before AD 1850, but also houses many introduced species (Towle, 1982).

Pinus ponderosa (ponderosa pine), although not mapped as an individual vegetation unit, was another important component of the presettlement vegetation (Johannessen et al., 1971; Cole, 1977) and was widely distributed in the Willamette Valley (Hibbs et al., 2002). It occurred in oak savanna and woodland along with *Quercus garryana* and *Pseudotsuga menziesii* and was found on a range of sites from flooded valley bottoms to well-drained southerly exposed hills. Mostly it was distributed in the lower foothills of the Coast and Cascade ranges (Johannessen et al., 1971). Since the AD 1850s, however, removal of fire from the landscape has led to a decreased abundance of *Pinus ponderosa* in its former habitat and its replacement by *Thuja plicata*, *Abies grandis*, and *Pseudotsuga menziesii* (Hibbs et al., 2002).

Even less is known about the prehistoric fire regimes of the Willamette Valley. Although some accounts by early explorers and settlers to the area contain references to Native American use of fire (Wilkes, 1845; Morris, 1934; Douglas, 1959), it is impossible to tell if these actions were typical of Native American land-management practices throughout the Holocene. Additionally, no previous lake-sediment studies have been conducted and limited dendrochronological studies have targeted the valley's foothill forests, given the lack of long-lived trees on the valley floor. Sprague and Hansen (1946), looking at succession in the McDonald Forest showed that fires were more frequent in the forests flanking the valley since at least AD 1647, but were less frequent after AD 1848. Dendrochronological studies in the Coast Range by Teensma et al. (1991) and Impara (1997) show more frequent fire activity in the foothills during the presettlement time period. Weisberg (1998) calculated a mean fire interval in the western central Cascades of ca. 52 years for the period of AD 1545-1849 (presettlement), ca. 28 years for the period of AD 1849-1910 (settlement), and ca. 310 years for the period of AD 1910-present (postsettlement). Additional studies at higher elevation in the Cascade Range (Morrison and Swanson, 1990; Weisberg, 1997; Cissel et al., 1998) reinforce this pattern of frequent presettlement fire activity and the near-absence of fire in the 20th century, although the cessation of fire in the last 100 years did not occur synchronously (Weisberg and Swanson, 2003).

The need to better understand past and present fire regimes and vegetation patterns of the Willamette Valley provides the impetus for this study. The main research objectives were: 1) to use paleoecological methods to reconstruct the spatial and temporal variations in the Holocene fire and vegetation history of the Willamette Valley, and 2) to assess the relative role of environmental variability and anthropogenic activities on shaping those histories. This dissertation is part of a larger collaborative project designed by researchers at Montana State University (Cathy Whitlock) and the US Forest Service (Jane Kertis and Emily Heyerdahl). It is funded by a Joint Fire Science Program grant (04-2-1-115) and in part by funds provided by the Rocky Mountain Research Station, Forest Service, US Department of Agriculture. Additional work following the completion of this dissertation will seek to combine sediment-based fire reconstructions with tree-ring data from Willamette Valley foothill forests of the Coast and Cascade ranges collected by Heyerdahl and Kertis. The goal of this is to provide information on past vegetation and fire regimes in order to facilitate more informed, successful management decisions concerning the Willamette Valley's natural ecosystems and hazards faced by its inhabitants.

Chapter II of this dissertation describes a 14,300-year-long fire reconstruction from Battle Ground Lake, southwestern Washington, and compares it to a previous vegetation reconstruction from the site (Whitlock, 1992). Independent records of regional climate change and human activity were used to determine the influence of both natural and anthropogenic factors on those histories. Additionally, the reconstruction was compared with other paleoenvironmental reconstructions from the region to contextualize the changes seen at the site. Also described is a high-resolution, 700-year-long charcoal and pollen record from the site, which examines the impact of recent fires on the local vegetation composition and structure. This chapter is important as it details the relationships between fire, vegetation, and climate during the late-glacial and Holocene periods in low-elevation ecosystems. This chapter was prepared as a co-authored manuscript with Cathy Whitlock (who provided the pollen data, assisted with field work, study design, data analysis and interpretation, and edited the manuscript) and Patrick Bartlein (who assisted with data analysis and interpretation and edited the manuscript) and has been published in the journal *Quaternary Research.*

Chapter III describes an 11,000-year-long fire and vegetation history from Beaver Lake, Oregon, located in the central Willamette Valley. This record provides information on valley-floor fire regime and vegetation shifts experienced during the Holocene associated with changes in the drainage of the Willamette River and its tributaries, regional climatic variability, and anthropogenic activities. The Beaver Lake record was compared to the Battle Ground Lake record from Chapter II and was placed within the larger framework of Holocene paleoecological work in the region. This chapter builds on the Masters thesis of Christopher Pearl (Pearl, 1999) at the University of Oregon, and with his permission uses data and analysis presented in his document. This chapter was prepared as a co-authored manuscript with Christopher Pearl (who carried out the collection and analysis of core BL93A and assisted with writing the manuscript), Cathy Whitlock (who assisted with field work, study design, data analysis and interpretation, and edited the manuscript), and Patrick Bartlein (who assisted with data analysis and interpretation and edited the manuscript), and has been submitted for publication in the journal *Quaternary Science Reviews*.

Chapter IV describes the fire and vegetation history of three additional sites in the Willamette Valley: Lake Oswego, Warner Lake, and Porter Lake, Oregon. The Lake Oswego record spans the last ca. 1200 years, Warner Lake the last ca. 900 years, and Porter Lake the last ca. 250 years. Combined with the most recent portions of the Battle Ground Lake (Chapter II) and Beaver Lake (Chapter III) reconstructions, these records provide a detailed look at landscape change over the last 1200 years in the Willamette Valley as a result of decadal- to centennial-scale climate variability and land-use change (e.g., Native American burning and Euro-American land clearance). This chapter is important as it provides an historical context for evaluating recent shifts in plant communities and illustrates the magnitude of the impact of Euro-American land-use activities on the ecosystems in the Willamette Valley. This chapter is being prepared as a co-authored manuscript with Cathy Whitlock (who assisted with field work, study design, data analysis and interpretation, and edited the manuscript) and Patrick Bartlein (who assisted with data analysis and interpretation and edited the manuscript) for submission to the journal *The Holocene*.

Chapter V summarizes the major findings of this dissertation.

CHAPTER II

A 14,300-YEAR-LONG RECORD OF FIRE-VEGETATION-CLIMATE LINKAGES AT BATTLE GROUND LAKE, SOUTHWESTERN WASHINGTON

This chapter has been published as a co-authored manuscript in the journal *Quaternary Research* (Walsh et al., 2008).

Introduction

Background

Little is known about the presettlement fire history of the interior valleys of the Pacific Northwest, including the Puget Lowland and lower Columbia River Valley of Washington and the Willamette Valley of Oregon. Historical data and tree-ring studies spanning the last several hundred years suggest that the low- to mid-elevation ecosystems, including wet and upland prairie, *Quercus garryana* (Oregon oak) savanna and woodland, and *Pseudotsuga menziesii* (Douglas-fir)-dominated forests, are adapted to fires of varying frequency and severity, and rely on it for their perpetuation (Thilenius, 1968; Franklin and Dyrness, 1988; Agee, 1993). Summer drought, which typically extends from July through September, often leads to conditions appropriate for late-summer wildfires (Gedalof et al., 2005). However, as a result of effective fire suppression since the 1930s (Morris, 1934) and considerable human alteration of the region's ecosystems (Hulse et al., 2002), fires rarely occur. In an effort to reduce hazardous fuel build-up and restore native plant communities, fire's reintroduction into many ecosystems is underway (Pendergrass et al., 1998; Maret and Wilson, 2005), but information regarding its role in maintaining prairie, savanna, woodland, and forest ecosystems in prehistoric times is needed.

Paleoecological studies provide an opportunity for understanding the long-term environmental history of the interior valleys of the Pacific Northwest. In the lower Columbia River Valley, late Quaternary pollen records are available from Fargher Lake, WA, (Heusser and Heusser, 1980; Grigg and Whitlock, 2002) and Battle Ground Lake, WA (this site- Barnosky, 1985; Whitlock, 1992). In this paper, we supplement our understanding of the region by presenting a 14,300-year-long fire history record from Battle Ground Lake, WA. High-resolution macroscopic charcoal, sedimentological and new palynological analyses provide information on the long-term fire and vegetation history of southwestern Washington and the influence of natural controls and anthropogenic activities on those histories. The reconstruction was compared with records from other low-elevation sites across the Pacific Northwest in order to assess regional trends in fire-vegetation-climate interactions.

Site Description

Battle Ground Lake, WA, (45°08.00'N, 122°49.17'W, 154 m a.s.l.), is located approximately 30 km north of the city of Portland, OR (Fig. 2.1). The 13.5 ha lake lies in a remnant volcanic crater of late Pleistocene age in the Boring Lava field (Wood and Kienle, 1990). Maximum depth is 16 m, drainage area is 1.6 times the size of the lake, and its rim

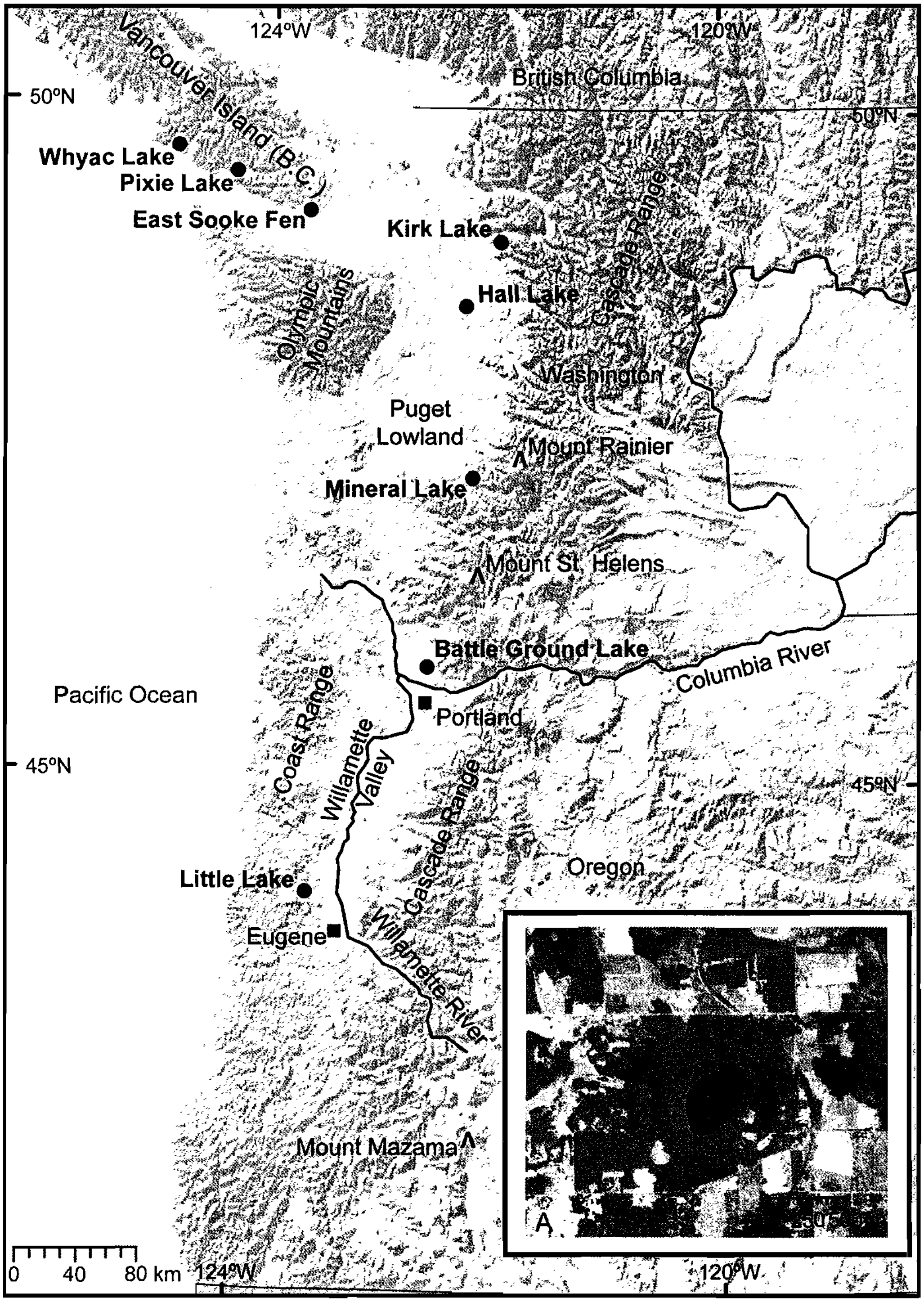


Figure 2.1. Map of the Pacific Northwest and the location of the study site, Battle Ground Lake, and other sites mentioned in the text. Inset A shows an aerial photograph of the site taken in 1990 (photo: USGS).

rises approximately 72 m above the lake surface and the surrounding valley floor. The climate of the area is influenced by the seasonal shift in the position of the polar jet stream and the northeastern Pacific subtropical high-pressure system, leading to warm, dry summers and cool, wet winters (Mitchell, 1976; Mock, 1996). For the period of 1971-2000, the city of Battle Ground weather station (located approximately 4 km SW of Battle Ground Lake) recorded an average July temperature of 17.9°C and an average January temperature of 3.8°C (Western Regional Climate Center, 2007). During that period, an average total of 1349 mm of precipitation fell annually, approximately 73% of it between November and April, mostly as rain (Western Regional Climate Center, 2007). The site is also influenced by an occasional cold wintertime easterly flow emanating from the Columbia Gorge (Sharp and Mass, 2004).

The vegetation surrounding Battle Ground Lake is a closed, second-growth forest of mostly *Pseudotsuga menziesii* and *Thuja plicata* (western red cedar), with scattered *Tsuga heterophylla* (western hemlock), *Abies grandis* (grand fir), and *Picea sitchensis* (Sitka spruce). Other common trees and shrubs found in the crater include *Alnus rubra* (red alder), *Acer macrophyllum* (big-leaf maple), *Fraxinus latifolia* (Oregon ash), *Salix* spp. (willow), *Corylus cornuta* (beaked hazel), *Cornus nuttallii* (Pacific dogwood), and *Spiraea douglasii* (hardhack), with an understory of *Polystichum* (sword fern) and other ferns. *Pteridium* (bracken fern), a heliophyte, grows in forest openings. Botanical nomenclature follows Hitchcock and Cronquist (1973). *Pseudotsuga*-dominated forests of the Pacific Northwest typically experience stand-replacing fires at >100 year-intervals, although this estimate varies considerably across the region and probably includes fires that have resulted from both human- and lightning-caused ignitions (Agee, 1993). Euro-American settlement of the Battle Ground Lake area began after the establishment of nearby Fort Vancouver (AD 1825); the population remained low throughout the 19th century, but increased rapidly in the early part of the 20th century (Allworth, 1976). The local forest near Battle Ground Lake was logged in the late 1800s and the only recorded historical fire in the crater was the Yacolt Fire of AD 1902 (Allworth, 1976).

Methods

In 2004, an 8.04 m-long sediment core (BG04A) was collected from the deepest part of the lake with a modified Livingstone piston corer (Wright et al., 1983) lowered from a floating platform (water depth=16 m). Core segments were wrapped in cellophane and foil and refrigerated in the laboratory at the University of Oregon. In 2005, a 0.67 m-long short core (BG05B) was collected using a Klein piston corer, which recovered the sediment-water interface. The short core was sampled in the field at 0.5-cm intervals. BG04A long-core segments were split longitudinally, photographed, and the lithologic characteristics were described. Magnetic susceptibility was measured at contiguous 1-cm intervals on the intact core using a Sapphire Instruments magnetic coil. Samples of 1-cm^3 volume were taken at 1-cm intervals for the upper 3 m and at 5-cm intervals for the lower 5 m of the core for loss-on-ignition analysis, which determines the water, organic, and carbonate content of the sediment (Dean, 1974).

Contiguous 1-cm^3 samples were taken for charcoal analysis at 1-cm intervals for the upper 3 m and at 0.5-cm intervals for the lower 5 m of the long core. From the short core, contiguous 1-cm^3 samples were taken at 0.5-cm intervals for charcoal analysis. Charcoal samples were soaked in a solution of 5% sodium hexametaphosphate for >24 hours and a weak bleach solution for one hour to disaggregate the sediment. Samples were washed through nested sieves of 250 and 125 µm mesh size and the residue was transferred into gridded petri dishes and counted. Only charcoal particles >125 µm in minimum diameter were tallied because previous studies indicate that large particles are not transported far from the source and thus are an indicator of local fire activity (Whitlock and Millspaugh, 1996; Whitlock and Larsen, 2001). Charcoal particles were identified and tallied as either woody or herbaceous based on their appearance and comparison to burned reference material collected at the study site (Fig. 2.2). Charcoal particles that were flat and displayed stomata within the rows of epidermal cells were counted as herbaceous charcoal, and were assumed to come from grasses or other monocots (see Jensen et al., 2007). The ratio of herbaceous/total charcoal provided information on the fuel type and severity of fire events, and allowed for a comparison of fire activity in different sections of the core (see Whitlock et al., 2006). Plant macrofossils, such as needles and twigs, were also identified whenever possible and provided material for AMS ^{14}C dating. Charcoal counts were converted to charcoal concentration (particles/cm^3) by dividing by the volume of each sample.

Charcoal accumulation rates (CHAR; particles/cm^2/yr) were obtained by interpolating the charcoal data to constant 10-yr time steps, which represented the median temporal resolution in the core; the data were not log-transformed. The CHAR data series was decomposed into a "background" and "peaks" component. The background

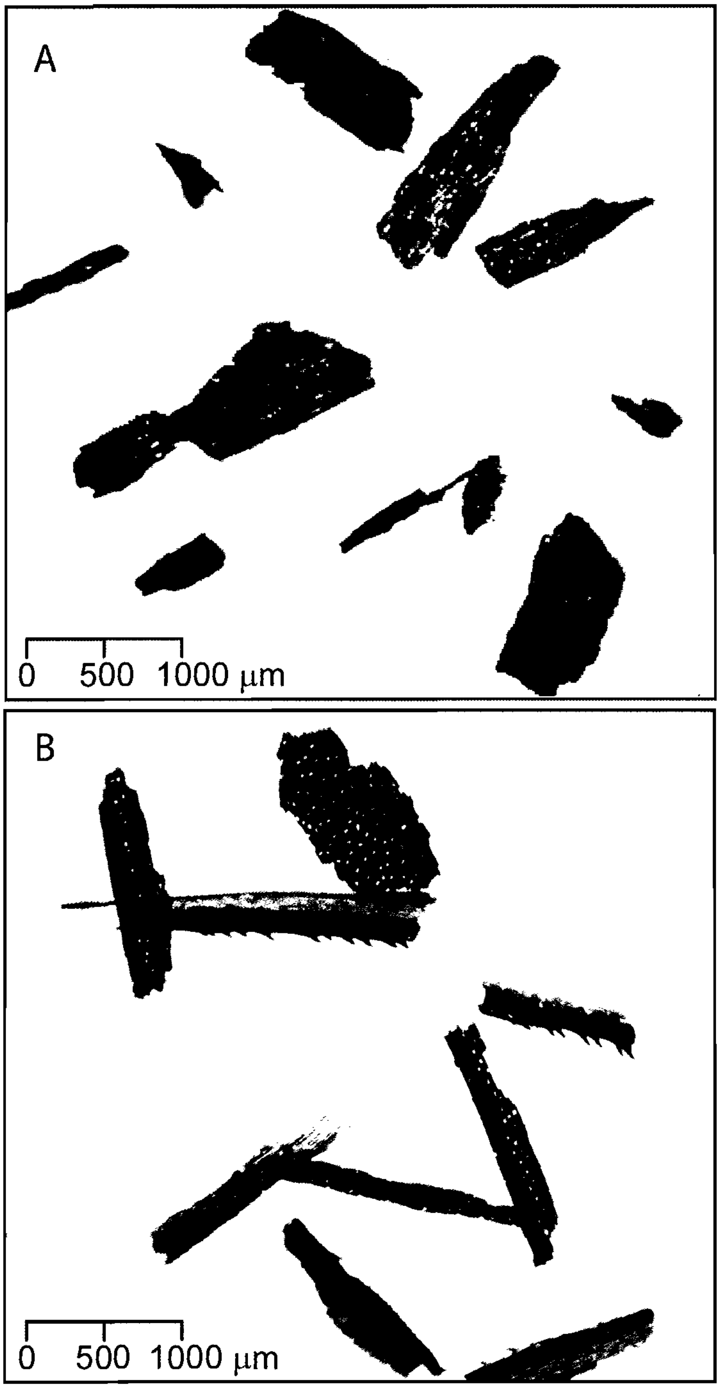


Figure 2.2. Photos of (A) woody charcoal particles and (B) herbaceous (i.e., grass) charcoal particles.

component has been discussed at length (see Millspaugh and Whitlock, 1995; Long et al., 1998; Carcaillet, 2002; Whitlock et al., 2003). Marlon et al. (2006) attributed CHAR background variation to slow changes in charcoal production associated with changing fuel types, and Higuera et al. (2007) concluded that at large temporal scales (i.e., 10 x mean fire return interval), it correlates well with area burned within the entire charcoal source area. The peaks component represents inferred "fire episodes" (i.e., one or more fires occurring in the duration of a peak) (Long et al., 1998). Charcoal analysis for core BG05A followed methods outlined in Higuera et al. (2008) and used the program CharAnalysis (Higuera et al., 2008; http://CharAnalysis.googlepages.com).

The CHAR background component was described using a robust (Lowess) smoother with a 500-yr window width, and the CHAR peaks component was taken as the residuals after background was subtracted from the interpolated time series. The threshold value separating fire-related from non-fire related variability in the peaks component was set at the 95th percentile of a Gaussian distribution modeling noise in the CHAR peaks time series. Sensitivity analysis of window widths between 300 and 1000 years showed that the signal-to-noise ratio (i.e., the measure of the separation between peaks and non-peak values) was maximized at 500 years. All CHAR peaks were screened to eliminate those that resulted from statistically insignificant variations in charcoal counts (Gavin et al., 2006). If the maximum charcoal count from a peak had a >5% chance of coming from the same Poisson-distributed population as the minimum count within the preceding 75 years, then it was identified as not significant (Higuera et al., 2008).

The CHAR time series was plotted on a log-transformed scale in order to facilitate comparison between different sections of the core. The significant peaks (i.e., fire episodes) were also plotted and used to calculate smoothed fire frequency, mean fire return interval, and fire-episode magnitude. Fire frequency (episodes/1000 yr) is the sum of the total number of fires within a 1000-yr period, smoothed with a Lowess filter. Mean fire return interval (mFRI) is the average years between fire episodes. Fire-episode magnitude (particles/cm^2) is the total charcoal influx in a peak and is related to fire size, severity, and taphonomic processes (Whitlock et al., 2006; Higuera et al., 2007).

Twelve 1-cm^3 pollen samples were taken from core BG05B at 5-cm intervals (ca. 50-100 year intervals) and processed following standard techniques (Faegri et al., 1989). *Lycopodium* was added to each sample as an exotic tracer to calculate pollen concentration and 300-500 terrestrial pollen grains and spores were counted per sample. Pollen types were assigned based on modern phytogeography, the presence of identified macrofossils, and previous macrofossil identification on an earlier core (Barnosky, 1985; Whitlock, 1992). Pollen counts were converted to percentages of the total terrestrial pollen and spores in each sample. Pollen accumulation rates (PAR; grains/cm^2/yr) were calculated by dividing pollen concentrations by the deposition time (yr/cm) of the sample.

Results

Chronology and Lithology

The age model for core BG04A was developed using seven AMS-^{14}C age determinations and the identification of four dated tephra (Table 2.1). ^{14}C dates were

Table 2.1

Age-depth relations in long core (BG04A) for Battle Ground Lake, Washington

Depth (cm below mud surface)	Lab number	Source material	Age (^{14}C yr BP)[a]	Age (cal yr BP)[b]
3		St. Helens D tephra		-30
67	AA65507	conifer needle	596±81	600 (506-679)
94	AA65739	conifer needle	911±52	830 (731-927)
144	AA65740	twig	1585±68	1470 (1336-1620)
271	AA65741	twig	3339±60	3570 (3442-3716)
333	AA65508	conifer needle	4159±42	4700 (4569-4833)
401	AA65742	conifer needle	4907±66	5650 (5577-5756)
512		Mazama O tephra		7627 (7577-7777)[c]
646.5	AA69495	bulk sediment	8671±52	9630 (9533-9778)
710		St. Helens J (upper) tephra	10490±360[d]	12260 (11243-13058)
770		St. Helens J (lower) tephra	11280±590[d]	13180 (11600-14771)

[a] ^{14}C age determinations were completed at the University of Arizona AMS Facility.

[b] Calendar ages determined using Calib 5.0.2 html (Stuiver and Reimer, 2005). Median ages rounded to the nearest decade with 2σ range are reported.

[c] Age as reported in Zdanowicz et al. (1999).

[d] Age as reported in Juvigné (1986).

converted to calendar years before present (cal yr BP) using Calib 5.0.2 html (Stuiver and Reimer, 2005). Median ages were selected and rounded to the nearest decade when appropriate. The long core contained seven tephra of known age (Juvigné, 1986; Mullineaux, 1986), but only four had reliable enough dates to include in the age model. Tephra ages based on ^{14}C age determinations were also converted to cal yr BP using Calib 5.0.2 and median ages were used. Because the deposition of tephra is likely a rapid event, the thickness of individual layers was subtracted from the true core depth to create an adjusted depth. Probability density functions for each ^{14}C age determination were plotted in Figure 2.3 to show the uncertainty of individual calendar ages, and clearly illustrate the greater uncertainty of the tephra ages as compared to the AMS-^{14}C age determinations. The resulting age model for core BG04A was best described by a 4th-order polynomial, suggesting a basal date of 14,300 cal yr BP for the core (Fig. 2.3a).

The age model for core BG05B was developed from 18 ^{210}Pb age determinations and one correlated AMS ^{14}C date from core BG04A (Table 2.2). Cores BG04A and BG05B were correlated based on charcoal peaks and tephra units present in both cores. The age model for BG05B was best described by a 4th-order polynomial for the upper 14 cm of the core, and a 2nd-order polynomial for lower 53 cm of the core (Fig. 2.3b). This shift in the sedimentation rate at ~14 cm depth was likely caused by increased slopewash following the Yacolt fire of AD 1902, which burned within the Battle Ground Lake crater. Core BG05B was composed entirely of fine detritus gyttja with the AD 1980 Mount St. Helens D tephra occurring at 2-3 cm depth.

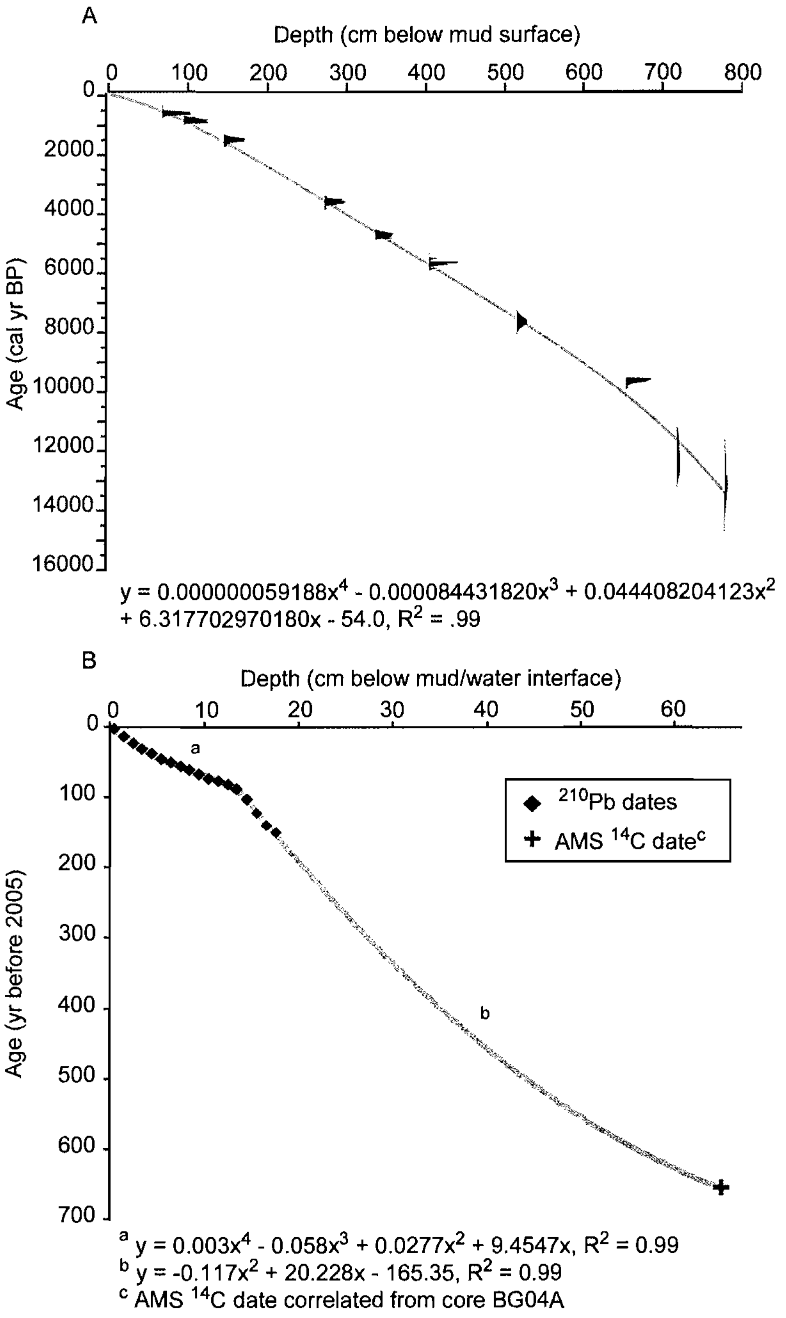


Figure 2.3. (A) Age-versus-depth model for long core BG04A (see Table 2.1 for ^{14}C and tephra dates). (B) Age-versus-depth model for short core BG05B (see Table 2.2 for ^{210}Pb dates). The radiocarbon date was correlated from the long core based on core stratigraphy (see Table 2.1 for ^{14}C date).

Table 2.2
Age-depth relations in short core (BG05B) for Battle Ground Lake, Washington

Depth (cm below mud surface)	^{210}Pb age [a] (yr before 2005)	Age (AD)
0-1	3.0	2002.0
1-2	14.1	1990.9
2-3	24.0	1981.0
3-4	31.7	1973.4
4-5	38.8	1966.2
5-6	46.3	1958.7
6-7	52.0	1953.0
7-8	56.1	1948.9
8-9	61.2	1943.8
9-10	68.3	1936.7
10-11	73.7	1931.3
11-12	77.6	1927.4
12-13	82.2	1922.8
13-14	87.9	1917.1
14-15	100.8	1904.2
15-16	122.0	1883.0
16-17	140.6	1864.5
17-18	149.4	1855.6
18-19[b]	176.3	1828.7
19-20[b]	253.0	1752.0

[a] ^{210}Pb age determinations were completed by J. Budahn at the USGS Denver Federal Center, Colorado.

[b] Age determinations for these samples were not used in the age-versus-depth model.

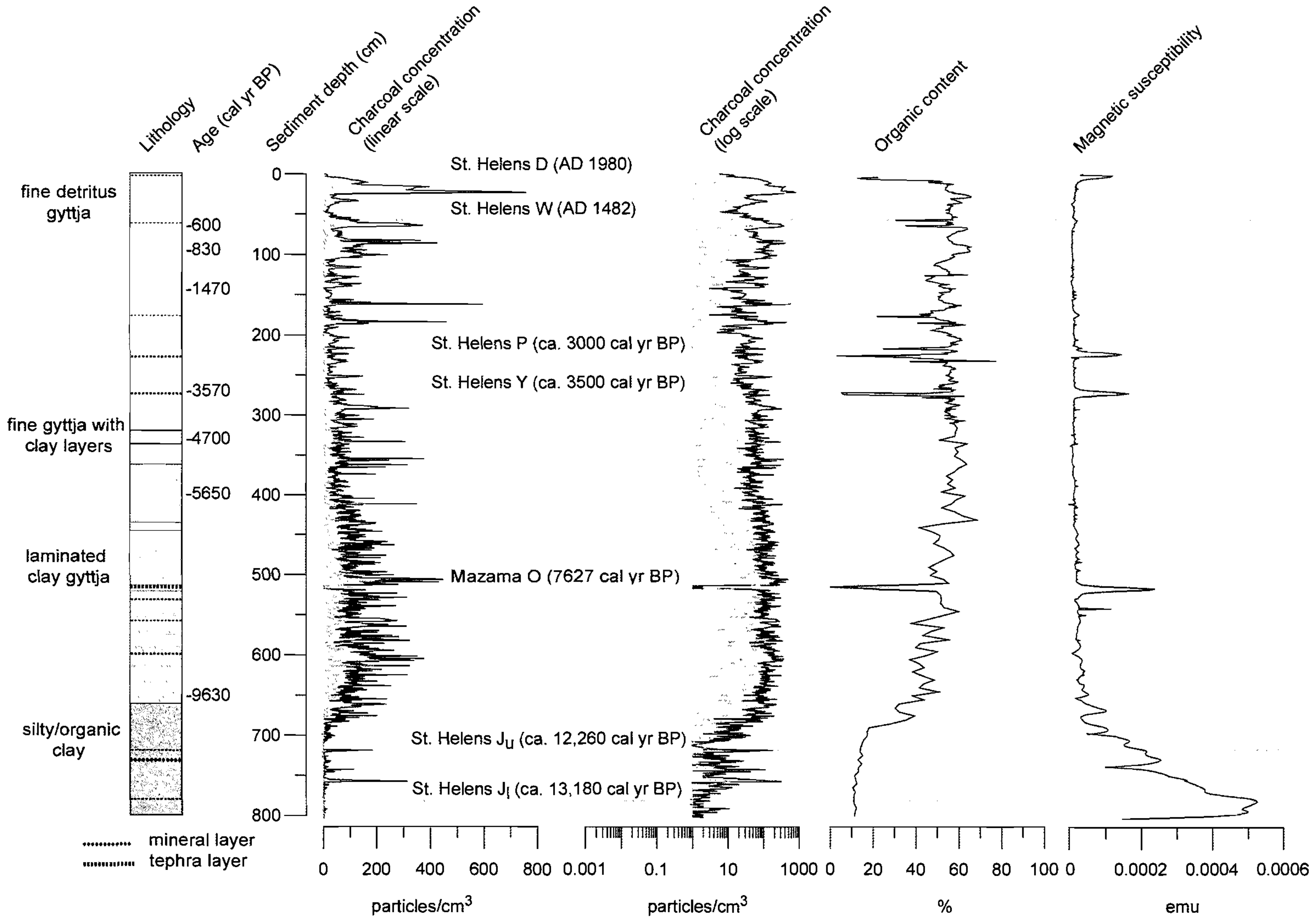
Three lithologic units were observed in core BG04A. Silty organic clay extended from the bottom to 660 cm depth and was characterized by low organic (~5%) and relatively high magnetic susceptibility values (~0.0005 emu) (Fig. 2.4). Apparently, little ground cover resulted in large amounts of inorganic clastic material washing into the lake. Above 660 cm depth, organic values were ~60% and magnetic susceptibility values were less than 0.0001 emu, indicating a more productive lake system with little clastic input, except during the deposition of tephra units. From 660-360 cm depth, the sediment was laminated fine detritus gyttja, and above 360 cm depth, it was nonlaminated fine detritus gyttja. Clay layers of ~0.5 cm width were noted between 335 and 325 cm depth. Tephra from the Mt. Mazama eruption was found at a depth of 514-519 cm depth and is the only identified tephra in the core not from Mount St. Helens.

Charcoal and Pollen Records

The charcoal record for core BG04A was compared to a previous vegetation reconstruction for Battle Ground Lake and both were described using the pollen zonation of core BG80B (Barnosky, 1985) (Fig. 2.5 and Table 2.3). The age model for core BG80B was updated by calibrating the ^{14}C dates using Calib 5.0.2 html (Stuiver and Reimer, 2005) and using a newer age determination for the Mt. Mazama eruption (Zdanowicz et al., 1999). A 4th-order polynomial was used to develop an age-depth curve for core BG80B.

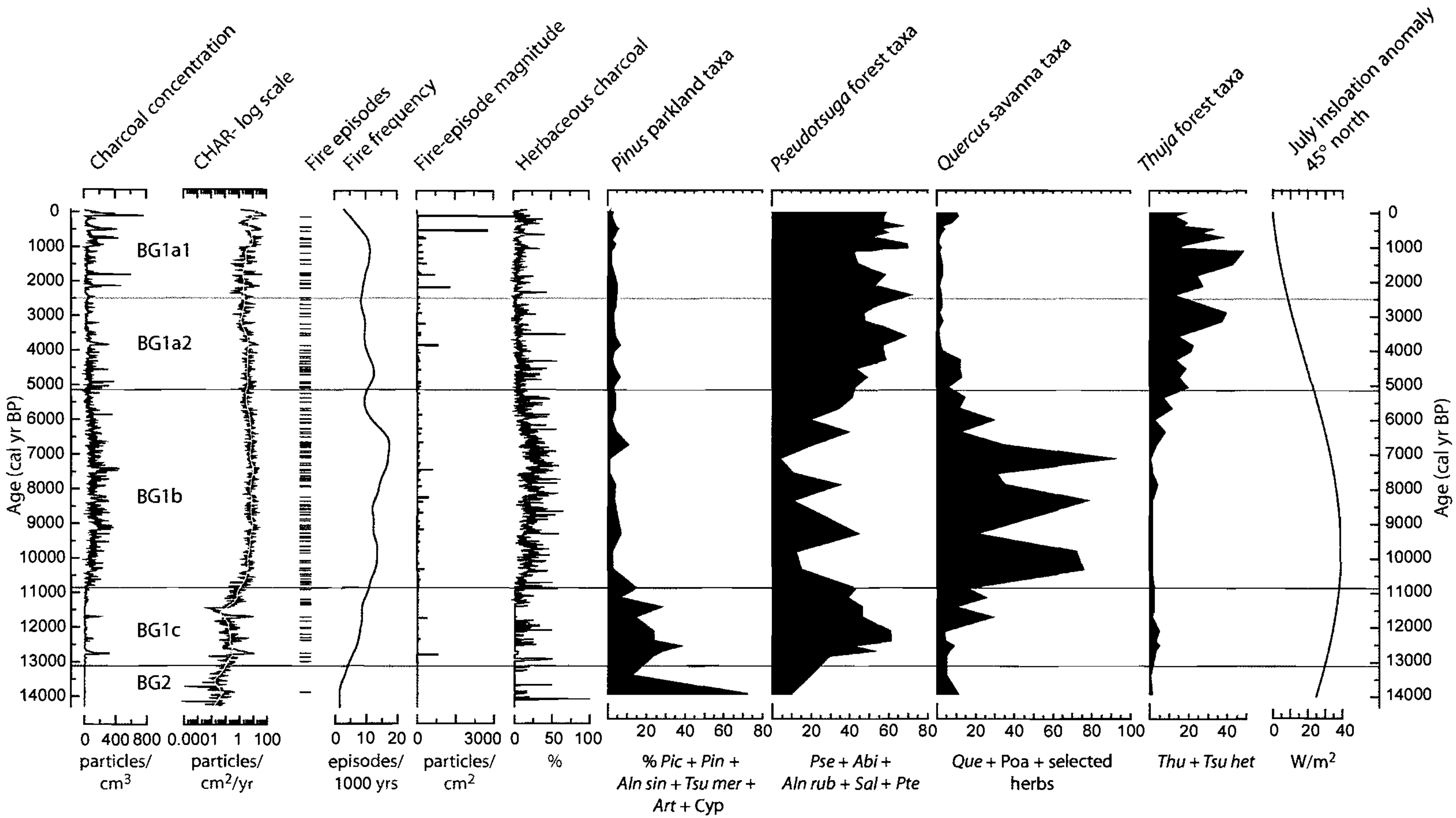
Zone BG2 (15,000-11,200 ^{14}C yr BP; 14,300-13,100 cal yr BP): Charcoal concentration was low in this zone with an average of 1.5 particles/cm^3. CHAR values ranged between 0-0.32 particles/cm^2/yr with an average of 0.04 particles/cm^2/yr. Average

Figure 2.4. Battle Ground Lake long core BG04A lithology, charcoal concentration (linear scale), charcoal concentration (log scale), organic content (%), and magnetic susceptibility (emu) plotted against sediment depth (cm below mud surface). For the charcoal concentration curves, the black line is the total macroscopic charcoal >125 µm and the gray line is the herbaceous charcoal >125 µm. The gray horizontal bars indicate identified tephra layers in the core.



M. Walsh, analyst

Figure 2.5. Battle Ground Lake long core BG04A charcoal concentration (particles/cm^3), charcoal accumulation rate (CHAR-log scale) (particles/cm^2/yr), fire episodes (black bars), fire frequency (episodes/1000 yr), fire-episode magnitude (particles/cm^2), herbaceous charcoal (%), selected summed pollen percentages from the Battle Ground Lake core BG80B, and July insolation anomaly at 45° north plotted against an age scale (cal yr BP). Pollen data are from Barnosky (1985) (Pic=*Picea*, Pin=*Pinus*, Aln sin= *Alnus sinuata*, Tsu mer= *Tsuga mertensiana*, Art=*Artemisia*, Cyp=Cyperaceae, Pse=*Pseudotsuga menziesii*, Abi=*Abies*, Aln rub=*Alnus rubra*, Sal=*Salix*, Pte=*Pteridium*, Que=*Quercus*, Poa=Poaceae, Thu=*Thuja plicata*, Tsu het=*Tsuga heterophylla*). Insolation values are from Berger and Loutre (1991).



M. Walsh, charcoal analyst

C. Whitlock, pollen analyst

Table 2.3
Average charcoal concentration, CHAR, fire frequency, fire return interval, fire-episode magnitude, herbaceous charcoal values, and fire regime description for Battle Ground Lake core BG04A.

	Average charcoal concentration (particles/cm^3)	Average CHAR (particles/cm^2/yr)	Average fire frequency (episodes/1000 yr)	Average fire return interval (yr)	Average fire-episode magnitude (particles/cm^2)	Average herbaceous charcoal (%)	Fire regime	Vegetation description[a]
BG1a: 5200- present	77.0	5.4	10	113	282	8.2	Relatively infrequent, moderate- to high-severity, understory and crown fires	*Pseudotsuga*/*Thuja*-dominated forest with openings
BG1a1: 2500- present[b]	88.6	7.2	9	124	533	7.6		
BG1a2: 5200-2500[a]	65.8	3.8	10	107	97	8.8		
BG1b: 10,800-5200	116.7	6.4	13	87	68	20.8	Frequent, low- to moderate-severity, surface and understory fires	*Quercus*-dominated savanna with herbaceous understory
BG1c: 13,100-10,800	17.5	0.7	8	149	84	5.6	Infrequent, low- to moderate-severity, surface and understory fires	*Pseudotsuga*/*Abies*-dominated forest with openings
BG2: 14,300-13,100	1.5	0.04	2	N/A	12	3.5	Little to no fire	*Pinus*/*Picea*-dominated open forest or parkland

[a] Vegetation reconstructions are from Battle Ground Lake core BG80B (Barnosky, 1985; Whitlock, 1992).
[b] The zones in gray are not based on vegetation zones (Barnosky, 1985).

fire frequency was 2 episodes/1000 yr and only one significant charcoal peak was registered in this zone (fire-episode magnitude: 12 particles/cm^2). The average herbaceous charcoal content for the zone was low (3.5%). The vegetation was an open forest or parkland of *Picea*, *Pinus contorta* (lodgepole pine), *Alnus sinuata* (Sitka alder), *Tsuga mertensiana* (mountain hemlock), *Artemisia* (sagebrush), and Poaceae.

Zone BG1c (11,200-9500 ^{14}C yr BP; 13,100-10,800 cal yr BP): Charcoal concentration and CHAR were higher in this zone than in the previous one. Average charcoal concentration was 17.5 particles/cm^3. CHAR values ranged from 0-10.3 particles/cm^2/yr with an average of 0.7 particles/cm^2/yr. Fire frequency increased from 4-11 episodes/1000 yr from the bottom to the top of this zone; mFRI was 149 yr. Fire-episode magnitude varied greatly from 0.3-785 particles/cm^2, with the largest of these episodes at ca. 12,800 cal yr BP. Another large charcoal peak with a magnitude of 359 particles/cm^2 coincided with the Mount St. Helens J (upper) tephra. Average herbaceous charcoal content in this zone was low (5.6%). The vegetation was a *Pseudotsuga*/*Abies*-dominated forest with *Alnus rubra*-type and *Pteridium* in disturbed areas.

Zone BG1b (9500-4500 ^{14}C yr BP; 10,800-5200 cal yr BP): Charcoal concentration and CHAR were much higher in this zone than the previous zones. Average charcoal concentration was 116.7 particles/cm^3. CHAR ranged from 0.2-24.3 particles/cm^2/yr with an average of 6.4 particles/cm^2/yr. Fire frequency generally increased throughout this zone to a maximum of 17 episodes/1000 yr at ca. 6700 cal yr BP. This was followed by a sharp decrease in fire frequency to its lowest point in the zone of 9 episodes/1000 yr at ca. 5400 cal yr BP. The mFRI for the zone was 87 yr. Fire-episode magnitude varied widely from 0.6 to 569 particles/cm^2 (average: 68 particles/cm^2). Large-magnitude peaks occurred immediately following the deposition of Mazama ash and had a high herbaceous charcoal content (~30%). Average herbaceous charcoal content for the zone was 20.8%, with many values as high as 40-50%. The vegetation was savanna-like with *Quercus*, *Pseudotsuga*, and Poaceae dominating, and herbaceous taxa such as *Camassia*-type (either *Camassia quamash* (camas lily) or *Zigadenus venenosus* (death camas)), *Heuchera*-type (alumroot), Asteraceae (sunflower family) subfamily Tubuliflorae, and Apiaceae (carrot family) were also present.

Zone BG1a (4500 ^{14}C yr BP – present; 5200 cal yr BP – present): This zone was divided into two subzones based on fire activity: **Subzone BG1a2 (5200-2500 cal yr BP)** had an average charcoal concentration of 65.8 particles/cm^3, average CHAR of 3.8 particles/cm^2/yr, and average fire-episode magnitude of 97 particles/cm^2. Average fire frequency was 10 episodes/1000 yr (mFRI: 107 yr) and average herbaceous charcoal content was 8.8%. **Subzone BG1a1 (2500 cal yr BP – present)** had an average charcoal concentration of 88.6 particles/cm^3 and average CHAR of 7.2 particles/cm^2/yr. Average fire frequency was 9 episodes/1000 yr (mFRI: 124 yr) and herbaceous charcoal content was 7.6%. Most notably, the average fire-episode magnitude (533 particles/cm^2) was the highest of the entire record.

Fire frequency initially increased in Zone BG1a to 13 episodes/1000 yr at ca. 4600 cal yr BP. This was followed by a general decrease until ca. 2500 cal yr BP. Fire frequency then increased again and was higher than the zone average of 11 episodes/1000 yr between ca. 1500 and 700 cal yr BP. The most recent portion of the record showed a sharp decrease in fire frequency (present-day value: 3 episodes/1000 yr). The vegetation of Zone BG1a was a closed forest dominated by *Pseudotsuga, Thuja*-type, *Tsuga heterophylla, Abies*, and *Alnus rubra*-type, with *Pteridium* and other herbaceous taxa present in disturbance-related openings.

The charcoal record for core BG05B registered three major fire episodes over the last ~700 years, at ca. AD 1350, ca. AD 1390, and the Yacolt fire of AD 1902 (Fig. 2.6). The large magnitude of the charcoal peaks and the high woody charcoal content suggests that these were high-severity crown fires. A smaller fourth peak at ca. AD 1930 probably represents re-burns associated with the AD 1902 Yacolt fire (Gray, 1990), or other fires burning outside the crater. The early 20th century was a period of high fire activity in the lower Columbia River Valley (Morris, 1934). The BG05B pollen record indicates the presence of a closed forest at Battle Ground Lake prior to ca. AD 1325, evidenced by high PAR of *Thuja*-type and *Pseudotsuga.* Early seral communities followed the fires at ca. AD 1350 and 1390, as evidenced by the increased PAR of *Pteridium*, *Alnus rubra*-type, and Poaceae at ca. AD 1425, and decreases in *Thuja*-type and *Pseudotsuga* PAR. Over the next four hundred years, *Thuja*-type and *Pseudotsuga* reestablished, although not to previous levels. Their PAR remained relatively high until the Yacolt fire of AD 1902, when *Pteridium* and then *Alnus rubra*-type increased. The decrease in *Thuja*-type and *Pseudotsuga* PAR after AD 1800 is consistent with the beginning of logging in the lower Columbia River Valley and the establishment of nearby Fort Vancouver (Allworth, 1976). Later declines in arboreal PAR indicate local logging in the late 1800s and are associated with an expansion of Poaceae. Poaceae PAR rose dramatically at ca. AD 1930 and again at

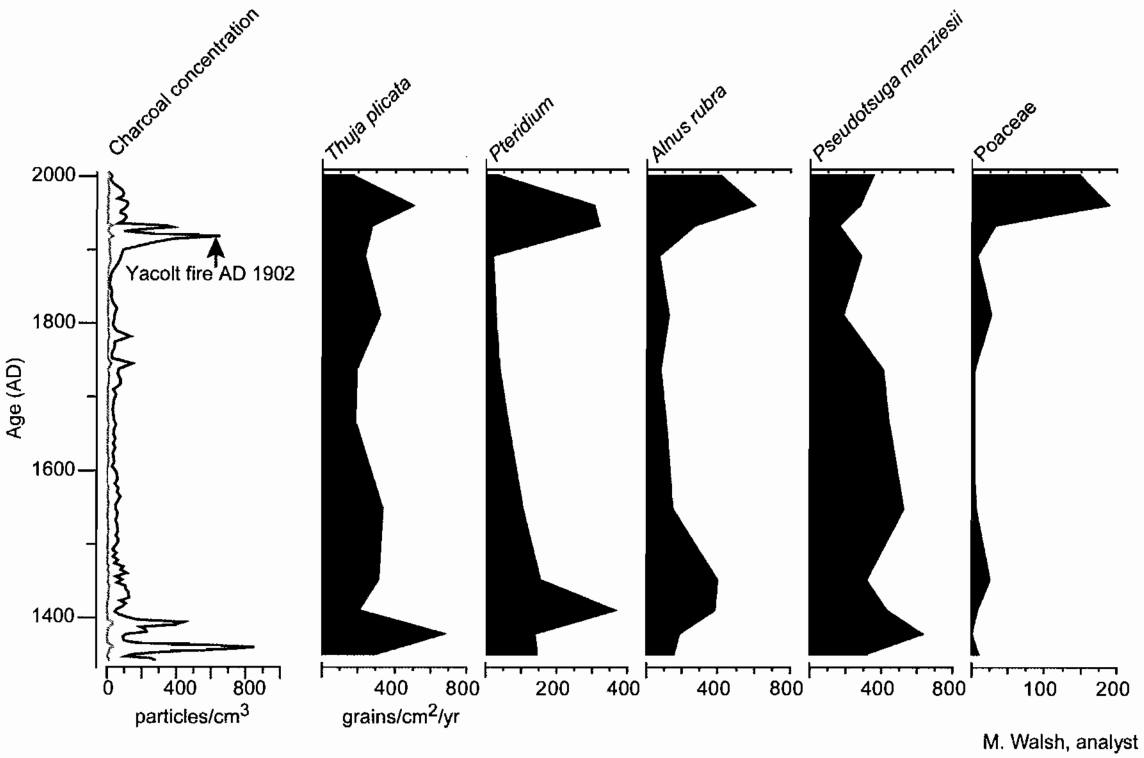


Figure 2.6. Charcoal concentration (particles/cm^3) and selected pollen accumulation rates (PARs) for the Battle Ground Lake short core BG05B plotted against age (yr AD). The black line on the charcoal concentration curve is the total number of charcoal particles >125 µm and the gray line is the number of herbaceous charcoal particles >125 µm. The gray shading shows the approximate dates of the Little Ice Age (ca. AD 1450-1850; Grove, 2001).

AD 1950, marking extensive grass seed farming in the Willamette Valley and the lower Columbia River Valley.

Discussion

Fire-Vegetation-Climate Linkages at Battle Ground Lake

In the late-glacial period (>14,300-13,100 cal yr BP), the regional climate was still likely cold and dry (Bartlein et al., 1998) and the vegetation surrounding Battle Ground Lake was an open forest or parkland dominated by *Pinus contorta* and *Picea*. The sparse vegetation and cold conditions supported little to no fire activity. As conditions warmed in the transition from the late-glacial to the early Holocene (Bartlein et al., 1998), *Pseudotsuga*, *Alnus rubra*, and *Abies* expanded at the expense of *Pinus contorta* and *Picea*, and a more closed forest developed at the site. After ca. 13,100 cal yr BP, fire episodes increased in frequency and size or severity, likely due to increased fuel biomass.

Influenced by greater summer drought in the early Holocene (i.e., ca. 11,000 cal yr BP) relative either to present or earlier (Bartlein et al., 1998), the vegetation at Battle Ground Lake shifted from a *Pseudotsuga*/*Abies*-dominated forest to a *Quercus*-dominated savanna, and fire activity increased dramatically (Fig. 2.5 and Table 2.3). Throughout the early and middle Holocene (ca. 10,800-6500 cal yr BP), frequent surface fires that burned mostly herbaceous (grass) biomass maintained the open vegetation. The ignition source for these fires may have been lightning strikes associated with increased convection during warmer summers because more subtropical moisture was likely advected into the western United States than at present (Bartlein et al., 1998; Brown and Hebda, 2002a). It may also have come from human activities. Archaeological findings suggest human habitation of the

Pacific Northwest for at least the last 11,000 years (Ames, 2003). Evidence in the lower Columbia River Valley extends as far back as ca. 8000 yr BP, but is most abundant after ca. 2500 yr BP (Pettigrew, 1990, Aikens, 1993). No archaeological evidence has been found in the Battle Ground Lake crater or the immediate vicinity, although it is likely that the area was used by prehistoric peoples. Abundant *Camassia*-type pollen in the record is attributed to the presence of *Camassia quamash* near the site in the early to middle Holocene (Whitlock, 1992). Cultural records document the burning of this important root crop in the interior valleys of the Pacific Northwest to enhance its growth (Turner and Kuhnlein, 1983; Boyd, 1986), consequently, human ignitions may be part of the fire signal at this time.

The largest or most severe fires of the early to middle Holocene occurred immediately after the eruption of Mt. Mazama. The 6 cm of tephra found in the core probably blanketed the landscape, damaging or killing the vegetation, providing additional fuel for several moderate-severity fires. Zobel and Antos (1997) reported that following the AD 1980 Mount St. Helens eruption, >2 cm of tephra was enough to kill many mosses and 15 cm killed most understory plants. The fires following the Mt. Mazama eruption, fueled by the dead or damaged shrubs and herbs, may have favored savanna taxa over forest as evidenced by increased abundance of *Quercus*, Poaceae, and other herbs at ca. 7500 cal yr BP.

The establishment of the modern forest at Battle Ground Lake, indicated by increased percentages of *Pseudotsuga*, *Thuja*-type and *Tsuga heterophylla* pollen, increased fuel loads and led to a rise in fire activity between ca. 5400 and 4600 cal yr BP.

The climate was transitional at this point, with winters becoming wetter, but with summers still sufficiently dry to support fires (Bartlein et al., 1998). The subsequent decrease in fire-episode frequency over the next 2500 years is consistent with cooler, wetter conditions in the late Holocene (Thompson et al., 1993) and the establishment of mesophytic forests in the Pacific Northwest (Heusser et al., 1985; Whitlock, 1992). This period of lower fire frequency at Battle Ground Lake occurred during a period when glaciers were advancing on Mt. Rainier, ca. 4500-2000 cal yr BP (Crandall and Miller, 1974; Kaufman et al., 2004).

The data from the past 2000 years show the influence of centennial-scale climate variability, such as the Medieval Climatic Anomaly (ca. 1100-700 cal yr BP (AD 850-1250); Mann, 2002) and the Little Ice Age (ca. 500-100 cal yr BP (AD 1450-1850); Grove, 2001) on the fire and vegetation history at Battle Ground Lake. Evidence of the Medieval Climate Anomaly in the western United States, usually in the form of increased aridity, comes from tree-ring records (Graumlich, 1993; Stine, 1994; Cook et al., 2004), lake-sediment records (Mohr et al., 2000; Brunelle and Whitlock, 2003), and changes in treeline (Leavitt, 1994). At Battle Ground Lake, fire frequency was higher than at any other time in the past 4000 years between ca. 1500 and 700 cal yr BP (Fig. 2.5), likely due to the warmer and/or effectively drier conditions associated with the Medieval Climate Anomaly. Similar to the fire regime of the early and middle Holocene, these fires were relatively small in size or severity, as compared to fire episodes directly before and after this period. Several modern studies have shown that fire activity increases as summer temperatures increase and relatively humidity decreases in the Pacific Northwest (Gedalof et al., 2005; McKenzie et al., 2004). The higher fire frequency at Battle Ground Lake during the Medieval Climate

Anomaly was likely the result of extended summer drought (i.e., a longer fire season), which would have increased the probability that late-summer lightning strikes ignited the vegetation.

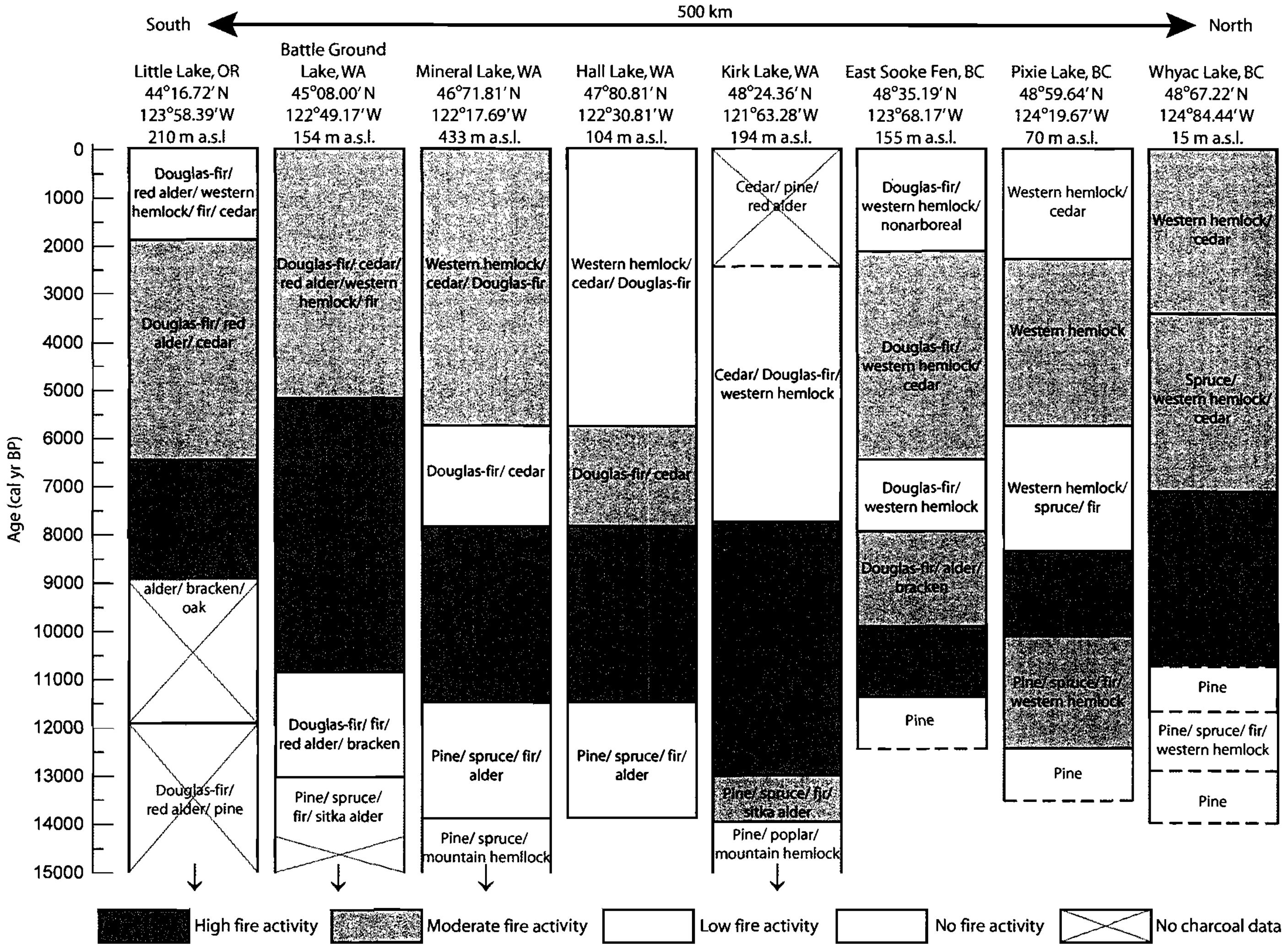
Regional evidence of cooler temperatures and greater precipitation associated with the Little Ice Age comes from tree-ring dated glacial advances (Luckman, 1995; Wiles et al., 1999), tree-ring records (Graumlich and Brubaker, 1986; Weisberg and Swanson, 2003), and lake-sediment records (Brunelle and Whitlock, 2003). Between ca. 700-100 cal yr BP only two fire episodes were registered in the Battle Ground Lake long core (Fig. 2.5) and the short core shows little fire activity during this time (Fig. 2.6). The cooler temperatures and/or effectively wetter conditions of the Little Ice Age probably shortened the fire season and suppressed most summer fire ignitions. Although fire activity at Battle Ground Lake seems to have responded to the cooler conditions, the vegetation, as inferred from the pollen data, shows no dramatic changes due to the long life span of many Pacific Northwest conifers. The pollen data do show a response to large-magnitude fire episodes, as evidenced by the increase in *Alnus rubra* and *Pteridium* following fires at ca. AD 1400 and 1900 (Fig. 2.6). Recovery from these events seems to have taken several hundred years based on the pollen changes.

In the late Holocene, settlement sites in the lower Columbia River Valley were strategically concentrated along the Columbia River and its tributaries to utilize abundant salmon and other resources (Boyd and Hajda, 1984; Pettigrew, 1990). Historical evidence suggests that at the time of Euro-American settlement in the lower Columbia River Valley, fire was used by the native inhabitants to promote the growth of many food sources, including nuts, berries, and root crops (Leopold and Boyd, 1999). Such fires were likely small and are not expressed in the Battle Ground Lake fire record. The close correspondence between the expansion of closed, mesophytic vegetation and the general decrease in fire frequency over the last ca. 5000 years argues against a sustained anthropogenic influence in the Battle Ground Lake area. Long-term cooling related to decreased summer insolation seems to have been the overriding control of fire and vegetation change in the late Holocene.

Regional Comparison of Low-Elevation Fire Histories

Regional syntheses have shown that vegetation change in the Pacific Northwest throughout the late-glacial and the Holocene has been nearly synchronous across multiple and environmentally diverse sites (Cwynar, 1987; Whitlock, 1992; Sea and Whitlock, 1995; Brown and Hebda, 2002a; Brown and Hebda, 2003). Similar shifts in fire regimes have been documented as well (Brown and Hebda, 2002b; Long and Whitlock, 2002; Hallett et al., 2003). Here we compare fire and vegetation reconstructions from several lowland sites (<500 m a.s.l.) in the region (Figs. 2.1 and 2.7). A wide array of charcoal analysis techniques were used in these studies, therefore only general comparisons of fire activity could be made. The largest difference between the techniques is in the charcoal source area; macroscopic charcoal records tend to indicate local to watershed-scale fire activity (Whitlock and Millspaugh, 1996; Gardner and Whitlock, 2001), while microscopic charcoal records provide a more regional fire signal (Patterson et al., 1987) (see Whitlock and Bartlein (2004) for more a more detailed discussion). Fire frequency estimates are

Figure 2.7. Pollen zones and inferred fire activity for eight low-elevation sites in the Pacific Northwest arranged from south (left) to north (right): Little Lake, OR (Worona and Whitlock, 1995; Long et al., 1998), Battle Ground Lake, OR (this study, Barnosky, 1985), Mineral Lake and Hall Lake, WA (Tsukada et al., 1981), Kirk Lake, WA (Cwynar, 1987), East Sooke Fen, Pixie Lake, and Whyac Lake, BC (Brown and Hebda, 2002a). Pollen zones were plotted based on the published information; all uncalibrated ages were calibrated to calendar years before present using Calib 5.0.2 html (Stuiver and Reimer, 2005), and median ages were chosen and rounded to the nearest century. The fire activity determinations for the pollen zones (box shading) are based on these author's interpretations of fire-episode frequency curves and CHAR values from Little Lake and Battle Ground Lake, charcoal fragment influx curves from Mineral Lake and Hall Lake, and CHAR curves and values from Kirk Lake, East Sooke Fen, Pixie Lake, and Whyac Lake, and are independently scaled for each site. The hatched lines indicate when the age of a vegetation zone was unknown by the author. The arrows indicate when the vegetation zone extends beyond the age scale of the figure.


South
500 km
North
Little Lake, OR
44°16.72′N
123°58.39′W
210 m a.s.l
Battle Ground Lake, WA
45°08.00′N
122°49.17′W
154 m a.s.l.
Mineral Lake, WA
46°71.81′N
122°17.69′W
433 m a.s.l.
Hall Lake, WA
47°80.81′N
122°30.81′W
104 m a.s.l.
Kirk Lake, WA
48°24.36′N
121°63.28′W
194 m a.s.l.
East Sooke Fen, BC
48°35.19′N
123°68.17′W
155 m a.s.l.
Pixie Lake, BC
48°59.64′N
124°19.67′W
70 m a.s.l.
Whyac Lake, BC
48°67.22′N
124°84.44′W
15 m a.s.l.
Age (cal yr BP)
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
11000
12000
13000
14000
15000
Douglas-fir/ red alder/ western hemlock/ fir/ cedar
Douglas-fir/ red alder/ cedar
alder/ bracken/ oak
Douglas-fir/ red alder/ pine
Douglas-fir/ cedar/ red alder/western hemlock/ fir
Douglas-fir/ fir/ red alder/ bracken
Pine/ spruce/ fir/ sitka alder
Western hemlock/ cedar/ Douglas-fir
Douglas-fir/ cedar
Pine/ spruce/ fir/ alder
Pine/ spruce/ mountain hemlock
Western hemlock/ cedar/ Douglas-fir
Douglas-fir/ cedar
Pine/ spruce/ fir/ alder
Cedar/ pine/ red alder
Cedar/ Douglas-fir/ western hemlock
Pine/ spruce/ fir/ sitka alder
Pine/ poplar/ mountain hemlock
Douglas-fir/ western hemlock/ nonarboreal
Douglas-fir/ western hemlock/ cedar
Douglas-fir/ western hemlock
Douglas-fir/ alder/ bracken
Pine
Western hemlock/ cedar
Western hemlock
Western hemlock/ spruce/ fir
Pine/ spruce/ fir/ western hemlock
Pine
Western hemlock/ cedar
Spruce/ western hemlock/ cedar
Pine
Pine/ spruce/ fir/ western hemlock
Pine
High fire activity
Moderate fire activity
Low fire activity
No fire activity
No charcoal data

only available for the macroscopic charcoal records that used high-resolution sampling schemes and identified individual fire episodes.

Similar to the fire-history reconstruction at Battle Ground Lake, low-elevation sites across the Pacific Northwest show little to no fire activity in the late-glacial period and increased fire activity into the early Holocene (Fig. 2.7). A high-resolution macroscopic charcoal study at Little Lake (44°16.72'N, 123°58.39'W, 210 m a.s.l.) in the Oregon Coast Range approximately 200 km southwest of Battle Ground Lake, shows highest fire frequency in the early Holocene, between ca. 9000 and 6850 cal yr BP (Little Lake lacks charcoal data prior to this time). At Mineral Lake, WA (46°71.81'N, 122°17.69'W, 433 m a.s.l.), in the southern Puget Trough approximately 105 km northwest of Battle Ground Lake, and at Hall Lake, WA (47°80.81'N, 122°30.81'W, 104 m a.s.l.), in the central Puget Lowland approximately 220 km north of Battle Ground Lake, pollen-slide microscopic charcoal records show fire activity was low in the late-glacial period and greatest in the early Holocene, between ca. 11,500 and 8000 cal yr BP (Tsukada et al., 1981). At Kirk Lake, WA (48°24.36'N, 121°63.28', 194 m a.s.l.), in the northern Puget Lowland approximately 280 km north of Battle Ground Lake, a pollen-slide microscopic charcoal record suggests low fire activity before ca. 13,000 cal yr BP and highest fire activity between ca. 12,500 and 9500 cal yr BP (Cwynar, 1987). Disturbance-adapted species including *Pseudotsuga*, *Alnus rubra*, and *Pteridium*, were also highest at Kirk Lake in the early Holocene.

Approximately 330 km to the northwest of Battle Ground Lake, three sites on the southern part of Vancouver Island, British Columbia, provide macroscopic charcoal records: East Sooke Fen (48°35.19'N, 123°68.17'W, 155 m a.s.l.), Pixie Lake (48°59.64'N, 124°19.67'W, 70 m a.s.l.), and Whyac Lake (48°67.22'N, 124°84.44'W, 15 m a.s.l.) (Brown and Hebda, 2002a). Fire activity was low in the late-glacial period and increased in the early Holocene, although at slightly different times and to different magnitudes. Pixie Lake recorded a higher charcoal influx (particles/cm^2/yr) in the early Holocene than the other two sites, but the increased abundance of disturbance-adapted taxa implies increased fire activity at all three sites (Brown and Hebda, 2002a).

Like Battle Ground Lake, all of the sites indicate decreased fire activity in the early and middle Holocene, but only at Little Lake and Hall Lake did this trend continue toward present (Kirk Lake lacks charcoal data after ca. 2500 cal yr BP). At Little Lake, fire episodes in the middle to late Holocene were larger or of higher severity, but less frequent than during the early Holocene. In contrast to the Battle Ground Lake record, Mineral Lake charcoal influx was higher in the middle to late Holocene, but the coarse sampling resolution makes specific fire interpretations difficult. On southern Vancouver Island, charcoal influx was variable among the sites in the middle and late Holocene. East Sooke Fen had higher charcoal influx between ca. 6400 and 5000 cal yr BP and after ca. 2000 cal yr BP. At Pixie Lake, charcoal influx was low between ca. 8500 and 6000 cal yr BP, and increased and remained high until ca. 2300 cal yr BP, when it dropped. At Whyac Lake, charcoal influx was low in the middle and late Holocene prior to ca. 2000 cal yr BP. The difference in charcoal accumulation between the sites is partially explained by their relative location along a moisture gradient (Brown and Hebda, 2002a). The rise in charcoal influx after ca. 2000 cal yr BP at East Sooke Fen and Whyac Lake, as well as at additional sites on Vancouver Island, is attributed to anthropogenic burning (Brown and Hebda, 2002b). However, given the coarse sampling resolution of the records, the increase in charcoal influx may simply reflect changes in fuel biomass associated with increased moisture leading to larger, less frequent fires, not increased fire activity. A shift at Little Lake at ca. 2000 cal yr BP to even less frequent fire episodes but overall higher CHAR values indicates decreased fire activity throughout the most recent portion of the record (Long et al., 1998).

Charcoal and pollen records from these sites reveal relationships between fire and vegetation during the late-glacial and Holocene periods. Several sites indicate that increased fire activity lagged the change to more thermophilous vegetation by several centuries in the late-glacial period. For example, the shift to more frequent, greater magnitude fire episodes at Battle Ground Lake at ca. 12,500 occurred ~400-500 years after the rise of *Pseudotsuga*. At Kirk Lake, the expansion of *Pseudotsuga* and *Tsuga heterophylla* at ca. 12,900 cal yr BP preceded the rise in fire activity by ~500 years. Likewise, fire activity increased at Hall Lake ~750 years after the appearance of *Pseudotsuga* at ca. 11,500 cal yr BP. At Pixie Lake, the expansion of *Picea* at ca. 12,600 cal yr BP was followed ~500-700 years later by an increase in fire activity. Fire activity at Whyac Lake increased ~300-500 years following a rise in *Picea* at ca. 10,800 cal yr BP. In all of these cases, the lag in the fire regime shift probably represents the time required for fuel to accumulate following the establishment of closed forests. The lag could, however, also indicate a lack of ignitions during the transition from the late-glacial to the early Holocene period, or possibly wetter conditions (see Mathewes, 1993) associated with the

North Atlantic-focused Younger Dryas climate reversal (ca. 12,900-11,500 cal yr BP; Alley, 2000). The latter explanation seems less likely because vegetation change during the Younger Dryas was not uniformly registered across the Pacific Northwest (Grigg and Whitlock, 1998; Vacco et al., 2005; Marlon et al., in press). The exception to the general occurrence of a lag in the shift in fire regime behind that of the vegetation is at East Sooke Fen, where fire activity seemingly increased simultaneously with rises in *Picea* and *Alnus* spp. at ca. 11,400 cal yr BP.

Shifts in vegetation and fire activity were more synchronous in the early Holocene. For example, as the climate warmed and dried, the shift from a closed forest to a savanna at Battle Ground Lake was accompanied by a concurrent shift in the fire regime. Additionally, fire activity dropped as *Thuja*-type increased at ca. 7000 cal yr BP at Little Lake and at ca. 5000 cal yr BP at Whyac Lake. At Pixie Lake, increased *Tsuga heterophylla* at ca. 8500 cal yr. BP occurred as fire activity decreased. At East Sooke Fen, fire activity decreased as *Pseudotsuga* increased at ca. 9800 cal yr BP. It also seems that fire history cannot be linked to the history of a particular taxon. For example, at Little Lake, Kirk Lake, Mineral Lake, Hall Lake and Pixie Lake, fire activity rose with increased *Pseudotsuga* in the early Holocene. However, at East Sooke Fen, fire activity decreased with increased *Pseudotsuga* at ca. 9800 cal yr BP. Additionally, at Whyac Lake, fire activity increased along with *Tsuga heterophylla* at ca. 10,500 cal yr BP, but it decreased at Pixie Lake when *Tsuga heterophylla* increased at ca. 8500 cal yr BP.

Conclusions

The pollen and charcoal records from Battle Ground Lake suggest that the relationships between fire, vegetation, and climate in the late-glacial and Holocene changed, depending upon the time scale of investigation. On a millennial-time scale, fire activity seemed to track climate-induced vegetation change with varying degrees of lag on the order of a few decades to several hundred years. This finding has also been noted in regional comparisons of western North and South America (Whitlock et al., 2006, 2008). When the vegetation at Battle Ground Lake shifted from a cold, *Pinus/Picea*-dominated parkland to a warmer *Pseudotsuga/Abies*-dominated forest at ca. 13,100 cal yr BP, increased fire activity lagged ~500 years behind. This probably reflects a delayed response in the build up of fuel to support fires, but it may also be related to climate variations in the late-glacial period. Vegetation and fire activity shifts were more synchronous in the early and middle Holocene when xerophytic *Quercus*-savanna replaced a more closed forest at Battle Ground Lake. Apparently fuel levels were able to support the shift to more frequent, but less severe or smaller fires at this time. The lagged fire response in the late-glacial as compared with the more synchronous fire response to vegetation change in the Holocene is evident at other low-elevations sites in the Pacific Northwest.

The Battle Ground Lake data also suggest a direct link between climate and fire activity on a centennial-time scale, in the absence of major vegetation change. For example, fire frequency was high during the Medieval Climate Anomaly, while fire episodes were nearly absent during the Little Ice Age. The only responses in the vegetation were brief and expected shifts in seral status following individual fires. Evidently, it was the influence of these shorter-scale climatic shifts on the length and severity of the fire season that controlled fire frequency, not a climate-driven change in forest composition or structure.

Finally, although humans were present in the lower Columbia River Valley during the Holocene and quite likely burned the landscape near Battle Ground Lake, the charcoal record does not show a clear anthropogenic signal. The long-term trends in fire activity can be explained through known climate variations and attendant vegetation shifts, and are observed at other sites in the Pacific Northwest. Even in the last 2500 years when human habitation in the lower Columbia River Valley was greatest, fire activity at Battle Ground Lake remained closely correlated with climate. Whether or not the fire history at Battle Ground Lake is representative of other parts of the lower Columbia River Valley and the Willamette Valley where anthropogenic burning is thought to have been important prior to Euro-American settlement, remains to be seen.

CHAPTER III

AN 11,000-YEAR-LONG RECORD OF FIRE AND VEGETATION HISTORY AT BEAVER LAKE, OREGON, CENTRAL WILLAMETTE VALLEY

This chapter has been prepared as a co-authored manuscript with C.A. Pearl, C. Whitlock and P.J. Bartlein and submitted to the journal *Quaternary Science Reviews*.

Introduction

Background

Paleoecological records from across the Pacific Northwest have increased our understanding of vegetation and climate history since the last glaciation (Hansen, 1947; Hibbert, 1979; Leopold et al., 1982; Heusser, 1983; Whitlock, 1992; Hebda, 1995; Sea and Whitlock, 1995; Worona and Whitlock, 1995; Pellatt and Mathewes, 1997; Grigg and Whitlock, 1998; Pellatt et al., 1998; Pellatt et al., 2001; Lacourse, 2005). In addition, some studies have also considered the prehistoric role of fire in such areas as southern British Columbia (including Vancouver Island) (Heinrichs et al., 2001; Brown and Hebda, 2002a; Brown and Hebda, 2002b; Brown and Hebda, 2003), northwestern Washington (Cwynar, 1987; Tsukada et al., 1981; McLachlan and Brubaker, 1995; Gavin et al., 2001; Greenwald and Brubaker, 2001; Higuera et al., 2005; Sugimura et al., 2008), southwestern Washington (Walsh et al., 2008), and western Oregon (Long et al., 1998;

Long and Whitlock, 2002; Long et al., 2007). Conspicuously missing from this network of paleofire and vegetation reconstructions are sites from the Willamette Valley of Oregon, south of the Columbia River, even though this was historically an area of widespread prairie and oak savanna, purportedly maintained by anthropogenic burning (Habeck, 1961; Johannessen et al., 1971). Unfortunately, most natural wetlands in the Willamette Valley lie in floodplain settings, and are typically young or have been disturbed by land-use activities. Hansen (1947) described two valley-floor Holocene pollen records from sites that no longer exist, but these reconstructions lacked radiometric dating, which limits their interpretability.

In this paper, we describe the paleoecological history of Beaver Lake, OR, based on high-resolution macroscopic charcoal, pollen, and sedimentological data. Our objective was to assess the relative influence of natural (i.e., geomorphic development, hydrologic shifts, and millennial- and centennial-scale climate variability) and anthropogenic activities (i.e., Native American burning and Euro-American settlement) on the vegetation and fire history of the site over the past 11,000 years. The Beaver Lake reconstruction is also placed within the framework of the Holocene paleoecological history of the Pacific Northwest.

Study Area

The Willamette Valley forms the southern portion of a structural depression between the Coast and Cascade ranges from southern British Columbia to central western Oregon (Fig. 3.1) (Gannett and Caldwell, 1998). Beaver Lake (44°55.03’N,

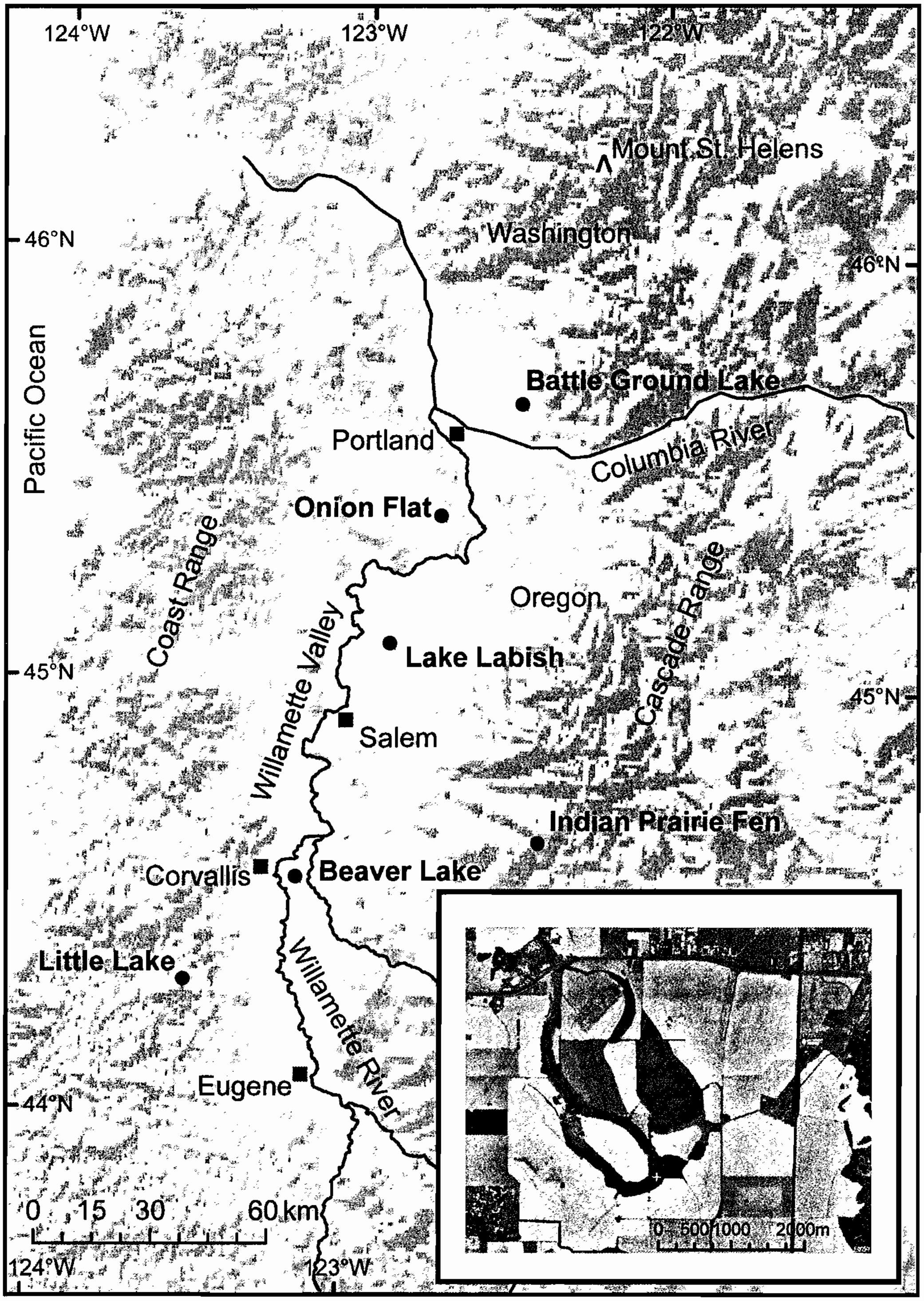


Figure 3.1. Map of the Willamette Valley and location of the study site Beaver Lake and other sites mentioned in the text. Inset shows an aerial photograph of the site taken in 2000 with the approximate coring location (white cross) (photo: USGS).

123°17.78'W, 69 m a.s.l.) is located in the central Willamette Valley, ~7 km east of Corvallis, OR (16 km east of the Coast Range and 35 km west of the Cascade Range foothills). It occupies an oxbow/abandoned meander bend that is ~1 km in length and has an average width of 50 m. The site experiences warm dry summers and cool wet winters typical of the Willamette Valley, as a result of the seasonal shift in the position of the polar jet stream and the northeastern Pacific subtropical high-pressure system (Mitchell, 1976; Mock, 1996). The climate of the site is known from the city of Corvallis weather station located ~7.5 km WNW of the site, which for the period of 1971-2000 recorded an average July temperature of 19.2°C, an average January temperature of 4.6°C, and an average annual total precipitation of 1109 mm (~78% of it between November and April) (Western Regional Climate Center, 2007). Water depth in Beaver Lake varies seasonally and is typically less than 1.5 m by late summer.

General Land Office (GLO) survey notes from AD 1853 indicate that the study area supported a large *Salix* (willow)-dominated riparian forest, surrounded by prairie on the upland surface east of the lake and to a lesser extent *Quercus garryana* (Oregon white oak) savanna at the time of settlement (Christy et al., 1997). The presettlement *Salix* forest was significantly reduced following Euro-American settlement and converted to intensive agriculture by the time of the first aerial photograph in AD 1935. Agricultural production of mostly ryegrass (*Lolium* spp.) and wheat (*Triticum* spp.) continues near the site today (Fig. 3.1, inset). The current vegetation surrounding Beaver Lake is a narrow riparian forest composed of *Salix* spp., *Populus trichocarpa* (black cottonwood), *Fraxinus latifolia* (Oregon ash), and *Quercus garryana*, with an understory of *Spiraea* *douglasii* (hardhack), *Oemleria cerasiformis* (Indian plum), *Rhus diversiloba* (poison oak), and *Symphoricarpos albus* (snowberry). Beaver Lake is presently a shallow eutrophic system, with the littoral zone dominated by wetland vegetation, including *Phalaris arundinacea* (reed canarygrass), *Ludwigia palustris* (water purslane), *Nuphar polysepalum* (yellow pond-lily), and *Lemna* sp. (duckweed). Larger strips of riparian hardwood forest of *Acer macrophyllum* (bigleaf maple) and *Populus trichocarpa* grow along the Willamette River (ca. 5 km to the west) and the Calapooya River (ca. 2 km to the east). Botanical nomenclature follows Hitchcock and Cronquist (1973).

Methods

Two sediment cores were recovered from Beaver Lake using a 5-cm diameter modified Livingstone piston corer (Wright et al., 1983): a 7.87 m-long sediment core (BL93A) in 1993, and an 8.07 m-long sediment core (BL05B) in 2005, which recovered the sediment/water interface. Core segments were extruded on site, wrapped in plastic wrap and foil, transported to the University of Oregon and refrigerated.

BL93A and BL05B core segments were split longitudinally and photographed, and the lithologic characteristics were described. Magnetic susceptibility was measured in electromagnetic units (emu) to determine the inorganic content of core BL05B (Thompson and Oldfield, 1986). Measurements were taken at contiguous 1-cm intervals using a Sapphire Instruments magnetic coil. Loss-on-ignition analysis on core BL05B was undertaken to determine the bulk density and organic and carbonate content of the sediment (Dean, 1974). Samples of 1-cm^3 volume were taken at 5-cm intervals, dried at

80°C for 24 hours and combusted at 550°C for 1 h to determine the percent organic content and at 900°C for 2 h to determine the percent carbonate content.

Pollen samples of 1-cm^3 were taken from core BL93A at 4-cm intervals above Mazama ash and at 8 to 30-cm intervals below. Pollen samples of 1-cm^3 were also taken at 5-cm intervals (ca. 20-80 year intervals) from the top 65 cm of core BL05B. Pollen analysis followed standard techniques (Faegri et al., 1989). *Lycopodium* was added to each sample as an exotic tracer to calculate pollen concentration and 300-500 terrestrial pollen grains and spores were counted per sample. Pollen was tallied at magnifications of 400 and 1000x and identified based on modern phytogeography. *Pinus monticola*-type pollen included the haploxylon pines (*P. monticola* [western white pine], *P. lambertiana* [sugar pine], and potentially *P. albicaulis* [whitebark pine]). *P. contorta*-type pollen included diploxylon pines (*P. contorta* [lodgepole pine] and *P. ponderosa* [ponderosa pine]). *Pseudotsuga/Larix*-type pollen was considered to be from *Pseudotsuga menziesii* (Douglas-fir), since *Larix* (larch) grows on the east slope of the Cascade Range (Franklin and Dyrness, 1988). Pollen counts were converted to percentages using different sums. The terrestrial sum included all upland forest, oak savanna, and disturbance taxa, and some wet prairie (i.e., Apiaceae and Liliaceae) taxa, and was used to calculate the percentages of those taxa. The terrestrial sum plus Poaceae and Cyperaceae was used to calculate percentages for the disturbance taxa. The terrestrial sum plus the riparian sum was used to calculate percentages for Poaceae and Cyperaceae. The terrestrial sum plus the aquatic sum was used to calculate percentages for the aquatic taxa. Arboreal to nonarboreal (AP/NAP) pollen ratio was calculated by dividing the arboreal sum by the total arboreal plus nonarboreal sum.

Contiguous 1-cm^3 samples were taken from core BL05B for charcoal analysis at 0.5-cm intervals between 0.0-2.5 m depth and from 4.5 m depth to the bottom of the core. The remainder of the core was sampled at 1-cm intervals. Charcoal samples were soaked in a 5% solution of sodium hexametaphosphate for >24 hours and a weak bleach solution for one hour to disaggregate the sediment. Samples were washed through nested sieves of 250 and 125 μm mesh size and the residue was transferred into gridded petri dishes and counted. Previous studies indicate that large particles are not transported far from the source and thus are an indicator of local fire activity (Whitlock and Millspaugh, 1996; Whitlock and Larsen, 2001); therefore, only charcoal particles >125 μm in minimum diameter were considered. Charcoal particles were identified and tallied as either woody, herbaceous, or lattice type based on their appearance and comparison to burned reference material (Fig. 3.2). Herbaceous charcoal, which comes from grasses or other monocots, was flat and contained stomata within the epidermal walls (Jensen et al., 2007; Walsh et al., 2008). Lattice charcoal, which likely comes from leaves and non-woody material, was abundant in some samples. Comparison of the abundance of charcoal from different sources helped characterize fire activity in different sections of the core by providing information on fire severity. A previous study has shown that as fire severity increases, the proportion of herbaceous charcoal to the total charcoal decreases (Walsh et al., 2008). Plant macrofossils, mostly wood fragments, provided material for ^{14}C AMS dating.

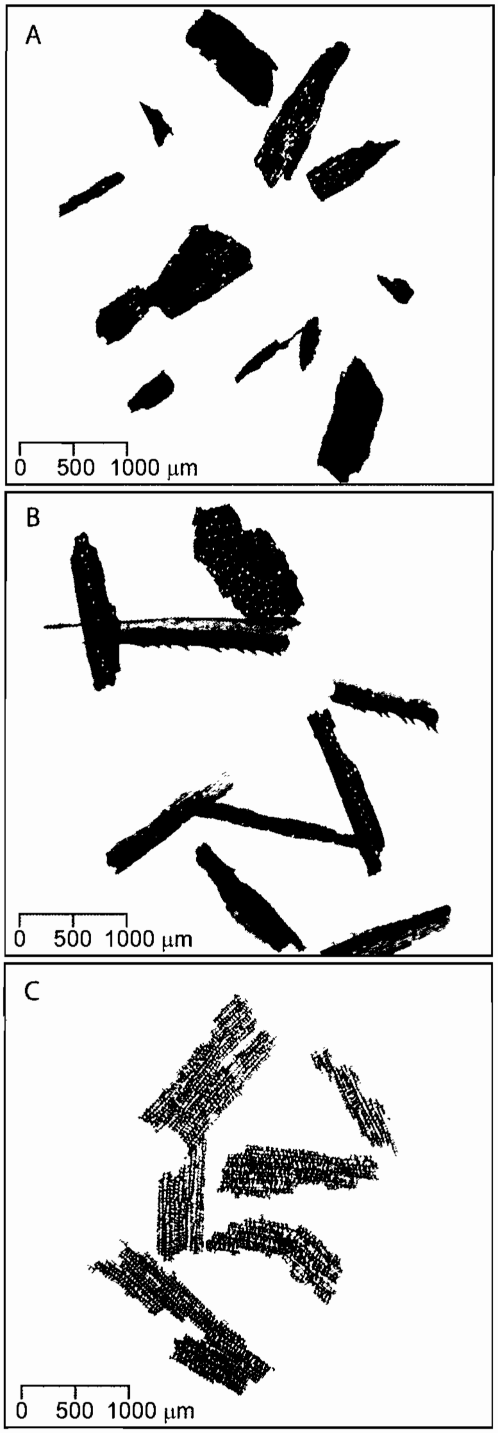


Figure 3.2. Photos of (A) woody charcoal, (B) herbaceous (i.e., grass) charcoal, and (C) lattice (source unknown) charcoal particles.

Charcoal counts were divided the by the volume of the sample to calculate charcoal concentration (particles/cm^3). Analysis of the charcoal data followed methods outlined in Higuera et al. (2008) and used the statistical program CharAnalysis (Higuera, 2008; http://charanalysis.googlepages.com/). Concentration values were interpolated to constant 5-yr time steps, which represents the median temporal resolution of the record, to obtain the charcoal accumulation rate (CHAR) time series. The non-log-transformed CHAR time series was decomposed into a peaks (C_{peak}) and background ($C_{background}$) component in order to determine individual fire episodes. C_{peak} represents the inferred fire episodes (i.e., one or more fire occurring during the duration of a charcoal peak) (Long et al., 1998; Whitlock and Bartlein, 2004) and $C_{background}$ has been attributed to many factors, including long-term changes in fuel biomass (Marlon et al., 2006) and area burned (Higuera et al., 2007). A robust Lowess smoother with a 400-yr window width was used to model $C_{background}$, and C_{peak} was the residuals after $C_{background}$ was subtracted from the CHAR time series. A locally determined threshold value to separate fire-related (i.e., signal) from non-fire related variability (i.e., noise) in the C_{peak} component was set at the 95th percentile of a Gaussian distribution model of the noise in the C_{peak} time series. Sensitivity analysis of window widths between 100 to 1000 years showed that the signal-to-noise ratio was maximized when a window width of 400 years was used. C_{peak} was screened and peaks were eliminated if the maximum charcoal count from a peak had a >5% chance of coming from the same Poisson-distributed population as the minimum count within the preceding 75 years (Gavin et al., 2006; Higuera et al., 2008).

The CHAR time series was plotted on a log-transformed scale in order to facilitate comparison between different sections of the core. Smoothed fire-episode frequency, mean fire-return interval, and fire-episode magnitude were also calculated and plotted. Fire-episode frequency (episodes/1000 yr) is the sum of the total number of fires within a 1000-yr period, smoothed with a Lowess filter. Mean fire-return interval (mFRI) is the average years between fire episodes within a zone. Fire-episode magnitude (particles/cm^2) is the total charcoal influx in a peak and is related to fire size, severity, and taphonomic processes (Whitlock et al., 2006; Higuera et al., 2007).

Results

Chronology

Eight ^{14}C age determinations on bulk sediment, one AMS ^{14}C age determination, and the accepted age of Mazama ash (Zdanowicz et al., 1999) were used to develop the age-depth model for core BL93A (Table 3.1, Fig. 3.3a). Eleven ^{210}Pb age determinations, seven AMS ^{14}C age determinations on wood fragments, one AMS ^{14}C age determination on bulk sediment, and the accepted age of Mazama ash were used to develop the age-depth model for core BL05B (Table 3.1, Fig. 3.3b). All ^{14}C age determinations were converted to calendar years before present (cal yr BP; present= 1950 AD) using Calib 5.0.2 html (Stuiver and Reimer, 2005). The probability density function (PDF) curves were plotted (Figs. 3.3a and 3.3b) to show the range of possible calendar ages for each ^{14}C age determination. Calendar ages were selected based on the following criteria: 1) the median age was chosen if it did not fall in a trough on the PDF curve and did not

Table 3.1. Age-depth relations for Beaver Lake, OR

Depth (cm below mud surface)	Lab number	Source material	Dates (^{210}Pb, ^{14}C,volcanic tephra)	Calibrated age (cal yr BP)
Core BL93A				
63.0-70.0	Beta-85262	lake sediment	1370 +/- 80[a]	1100[b]
101.0-111.0	Beta-81660	lake sediment	1130 +/- 60[a]	1220[b]
218.0-228.0	Beta-72836	lake sediment	2570 +/- 60[a]	2520[b]
239.0-249.0	Beta-109116	lake sediment	2920 +/- 60[a]	2900[b]
291.0-301.0	Beta-81661	lake sediment	2940 +/- 60[a]	3310[b]
390.0-400.0	Beta-81662	lake sediment	5710 +/- 90[a]	6420[b]
420.0-430.0	Beta-109117	lake sediment	6070 +/- 120[a]	6940[b]
479.0-481.0	...	Mazama tephra	...	7627 +/- 150[c]
670.0-680.0	Beta-109118	lake sediment	9290 +/- 50[a]	10440[b]
709.0-719.0	Beta-72837	lake sediment	9860 +/- 360[a]	10800[b]
Age-depth model: $y = -39.03x^3 + 428.13x^2 + 445.13x$				
Core BL05B				
1.0-2.0	...	lake sediment	3.0[d]	-52.0
5.0-6.0	...	lake sediment	28.6[d]	-26.4
9.0-10.0	...	lake sediment	36.9[d]	-18.1
13.0-14.0	...	lake sediment	41.6[d]	-13.4
17.5-18.5	...	lake sediment	46.4[d]	-8.6
21.0-22.0	...	lake sediment	54.8[d]	-0.2
25.0-26.0	...	lake sediment	68.0[d]	13.0
29.0-30.0	...	lake sediment	79.0[d]	24.0
33.0-34.0	...	lake sediment	94.3[d]	39.3
37.0-38.0	...	lake sediment	117.6[d]	62.6
41.0-42.0	...	lake sediment	148.7[d]	93.7
45.5-46.5	...	lake sediment	272.6[d,e]	217.6
84.5	AA71936	twig	1102 +/- 35[f]	980[b]
144.0	AA71937	twig	1842 +/- 42[f]	1750[b]
220.0	AA71938	wood	3512 +/- 44[f]	3780[b]
316.5	AA71939	wood	5050 +/- 43[f]	5830[b]
400.0	...	Mazama tephra	...	7627 +/- 150[c]
451.0	AA71940	twig	8413 +/- 51[f]	9330[b]
555.0	AA71941	twig	8860 +/- 53[f]	9920[b]
642.5	AA72365	twig	8776 +/- 60[f]	10100[b]
849.0	AA72364	lake sediment	9623 +/- 96[f]	11100[b]

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[a] ^{14}C age determinations were completed at Beta Analytic, Inc.

[b] Calibrated ages determined using Calib 5.0.2 html (Stuiver and Reimer, 2005).

[c] Age as reported in Zdanowicz et al. (1999).

[d] ^{210}Pb age determinations completed by J. Budahn at the USGS Denver Federal Center, Colorado.

[e] Denotes samples not used in the age-depth model.

[f] ^{14}C age determinations completed at the University of Arizona AMS facility.

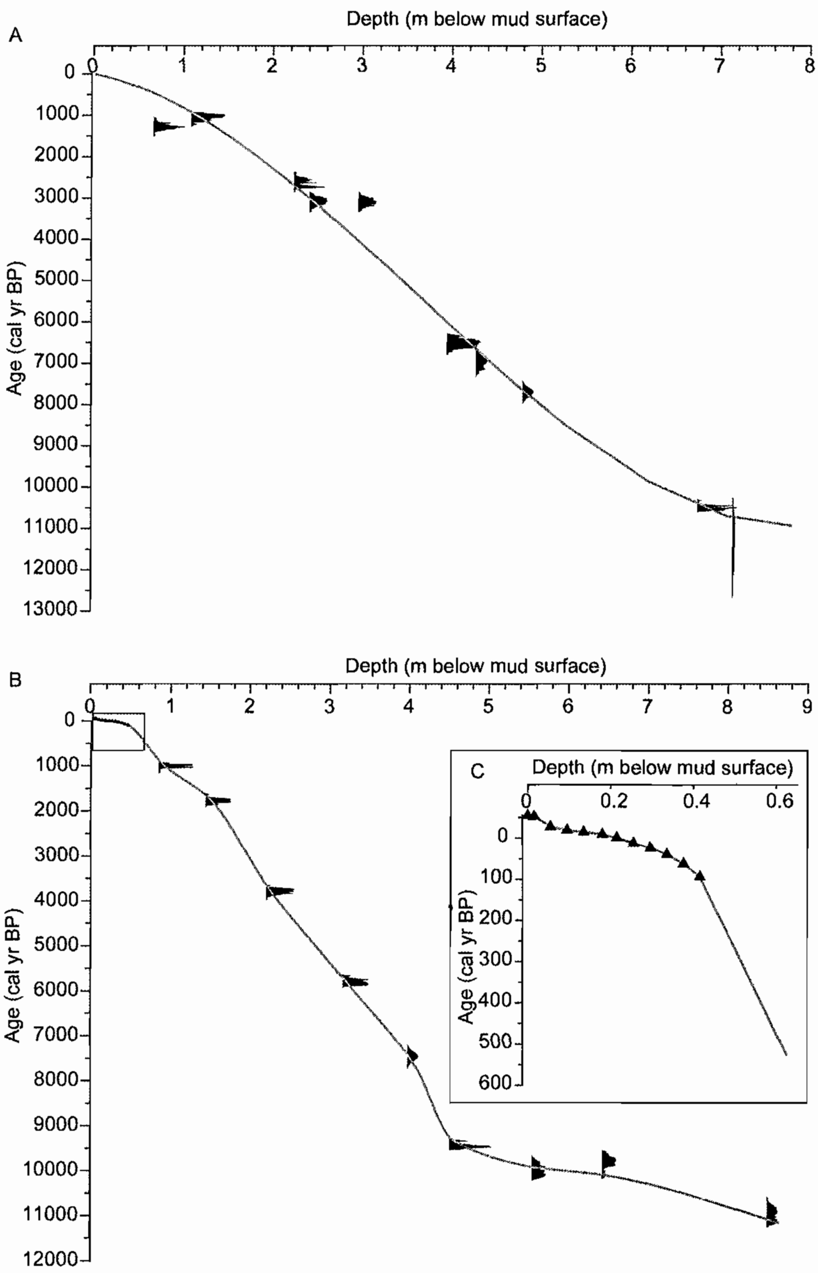


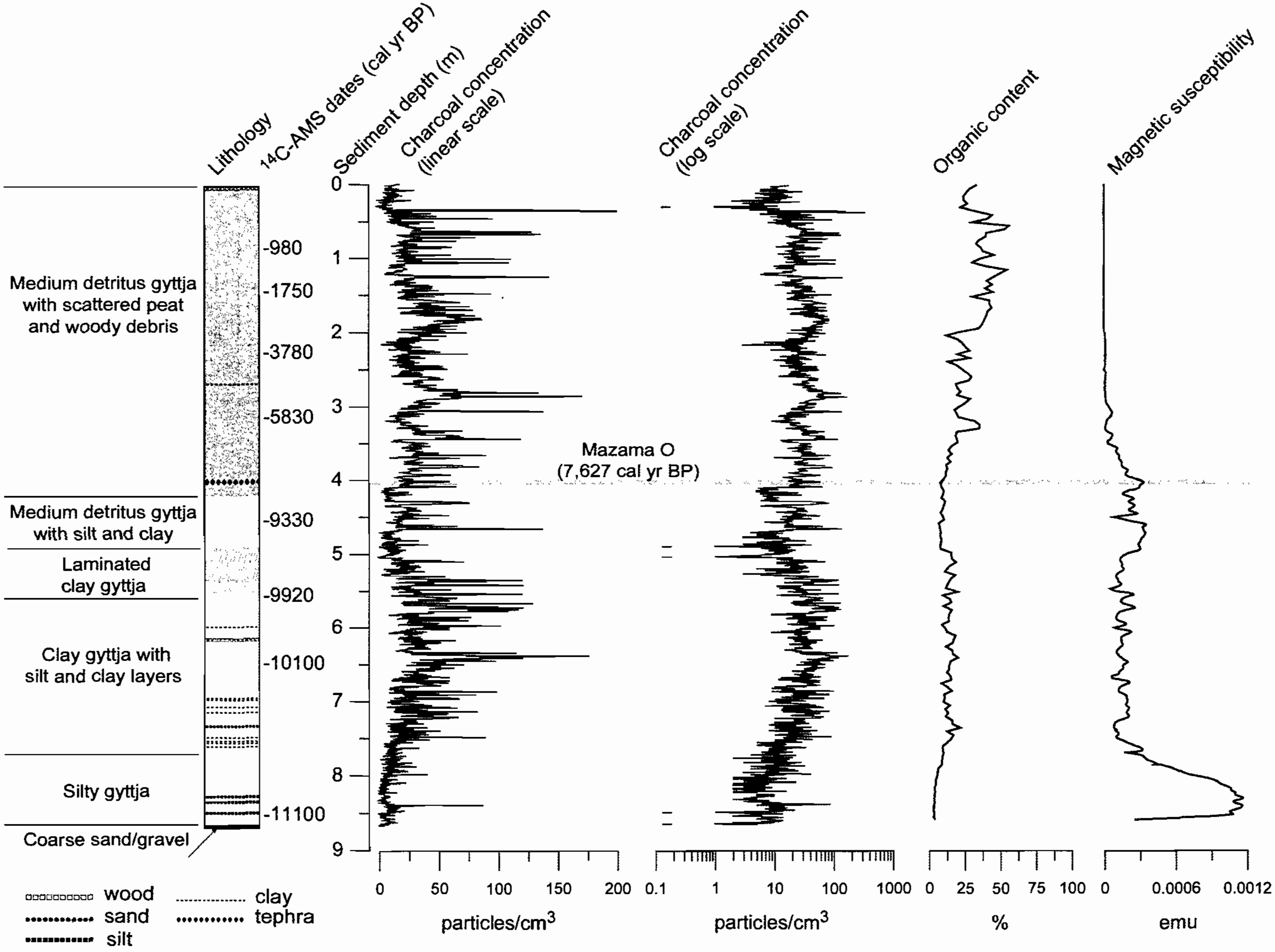
Figure 3.3. Depth-versus-age relations for (A) core BL93A and (B) core BL05B based on the age model information given in Table 3.1. (C) shows the depth-versus-age relations for the top 0.65 m of core BL05B based on ^{210}Pb dating, which is the area indicated by the rectangle on curve B.

cause a reversal in the core chronology; 2) if the median age fell in a trough on the PDF curve, then the value of the nearest, largest peak was chosen; and 3) if choosing the median age caused a reversal in the core chronology, then the value of the nearest, largest peak that did not lead to a reversal in the core chronology was chosen. All age determinations fell within the 2 σ range of possible ages. The resulting age model for core BL93A was best described by a 3rd-order polynomial ($y = -39.03x^3 + 428.13x^2 + 445.13x$), suggesting a basal date of approximately 10,920 cal yr BP (Fig. 3.3a). A constrained cubic smoothing spline was used to fit the age model of core BL05B, suggesting a basal date of 11,190 cal yr BP (Fig. 3.3b). Cores BL93A and BG04B were correlated based the chronology of the two records.

Lithology

The lithology of cores BL93A and BL05B was nearly identical and only the longer of the two cores (BL05B) is described here (Fig. 3.4). The base of core BL05B consisted of coarse sand and gravel. Between 8.65 and 7.55 m depth, the sediments were fine silty gyttja with inorganic silt layers interspersed. Magnetic susceptibility values were highest in this part of the core (~0.0011 emu), and the organic content was lowest (~3%). These results are consistent with a fluvial environment receiving large amounts of inorganic input. Between 7.55 and 5.55 m depth, the sediments were clay gyttja (~12.5% organic content) interspersed with inorganic clay, silt, and sand layers. Magnetic susceptibility values dropped to ~0.0003 emu, although peaks in magnetic susceptibility were associated with several silt and clay layers. The sediments indicate a

Figure 3.4. Lithology, ^{14}C-AMS dates, charcoal concentration (linear scale), charcoal concentration (log scale), organic content, and magnetic susceptibility for core BL05B plotted against depth (m). The vertical ticks on the charcoal concentration (log scale) curve represent zero values.


Lithology
14C-AMS dates (cal yr BP)
Sediment depth (m)
Charcoal concentration (linear scale)
Charcoal concentration (log scale)
Organic content
Magnetic susceptibility
Medium detritus gyttja with scattered peat and woody debris
Medium detritus gyttja with silt and clay
Laminated clay gyttja
Clay gyttja with silt and clay layers
Silty gyttja
Coarse sand/gravel
-980
-1750
-3780
-5830
-9330
-9920
-10100
-11100
0
1
2
3
4
5
6
7
8
9
Mazama O (7,627 cal yr BP)
0
50
100
150
200
particles/cm3
0.1
1
10
100
1000
particles/cm3
0
25
50
75
100
%
0
0.0006
0.0012
emu
wood
sand
silt
clay
tephra

period of lacustrine deposition interrupted by periods of flooding, typical of an oxbow lake. Sediments were laminated clay gyttja between 5.55 and 4.85 m depth, and medium detritus gyttja with some silt and clay between 4.85 and 4.20 m depth. A tephra in the core at 4.00 m depth was assumed to have come from the eruption of Mt. Mazama, (Sea and Whitlock, 1995; Walsh et al., 2008). From a depth of 4.20 m to the top of the core, sediments were medium detritus gyttja containing layers of peat and woody debris. High organic content (~40%) and low magnetic susceptibility indicate a productive lake with little fluvial input. Organic content decreased to ~31.5% in the top 0.25 m of the core, most likely due to the removal of the surrounding *Salix*-dominated riparian forest and the conversion of the watershed to agriculture (discussed below).

Core BL93A Pollen Record

The BL93A record was divided into six pollen zones based on visual changes in the abundance of major taxa (Fig. 3.5).

Zone BL93A-1 (7.78 m-4.57 m; ca. 10 920 to 7250 cal yr BP): Percentages of upland forest taxa were generally low in this zone with the exception of *Pinus contorta*-type, *Pinus* undifferentiated, *Picea*, *Thuja*-type, and *Polystichum*-type, which were high at the start of the record, and then decreased and remained low until the top of the zone. Oak savanna taxa (i.e., *Pseudotsuga*-type, *Quercus*, *Corylus*, and *Acer macrophyllum*) were present in relatively high percentages. Disturbance taxa, predominantly *Alnus rubra*-type, dominated most this zone and declined toward the top. *Pteridium* was initially high at the start of the record, decreased for most of the zone, and then increased toward the top of the

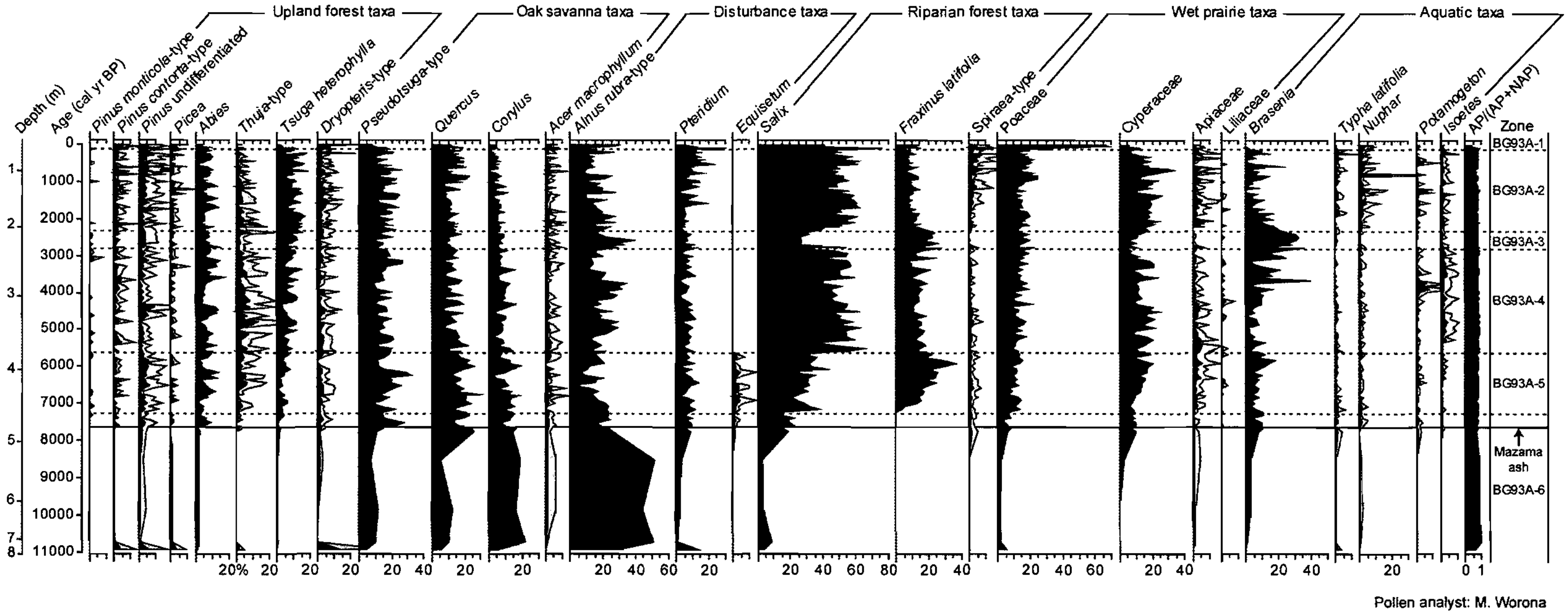


Figure 3.5. Percentages of selected pollen taxa and spores, and AP/NAP ratios for core BL93A plotted against age (cal yr BP). Gray curves represent a 3X exaggeration of solid black curve. Dashed lines indicate zone boundaries.

zone. Riparian forest taxa (i.e., *Salix* and *Spiraea*-type) and wet prairie taxa (i.e., Poaceae [grasses], Cyperaceae, and Apiaceae) were characterized by very low percentages. The pollen data suggest the presence of xeric woodland near the site, with *Alnus rubra* and some *Pteridium* in disturbed areas. The high AP/NAP ratio indicates a relatively closed forest canopy.

Zone BL93A-2 (4.57-3.73 m; ca. 7250 to 5600 cal yr BP): Percentages of many upland forest taxa (i.e., *Pinus* undifferentiated, Abies, *Thuja*-type, *Tsuga heterophylla*, and *Dryopoteris*-type) increased in this zone. Oak savanna taxa percentages remained relatively high and variable. Percentages of *Alnus rubra*-type decreased greatly from the previous zone, but remained relatively high. *Pteridium* percentages increased from the previous zone and *Equisetum* (horsetail) percentages were highest in this zone. Riparian forest taxa percentages of *Salix* increased dramatically and *Fraxinus* first appeared and increased in the zone. Wet prairie taxa percentages (i.e., Poaceae, Cyperaceae, and Apiaceae) increased steadily above BL93A-1 levels, and Liliaceae pollen first appeared in this zone. Several aquatic taxa, including *Brasenia* (water shield), *Typha latifolia* (broadleaf cattail), and *Nuphar*, were also abundant. The pollen percentages in this zone suggest that upland forest increased in abundance, probably on hillsides near the site, although this pollen may represent changes in forests of the Coast Range. The high percentages of *Fraxinus* and *Salix*, both of which produce pollen that is not widely dispersed (Faegri et al., 1989), imply the development of riparian forest near Beaver Lake. Elevated percentages of Poaceae, Cyperaceae, Apiaceae, and Liliaceae pollen also suggest increased availability of moisture in the immediate area and likely indicate the development of seasonally wet prairie near the site. Prairie expansion, perhaps at the expense of oak savanna, is further supported by a decrease in the AP/NAP ratio, suggesting less forest cover. Lower percentages of some disturbance taxa (i.e., *Alnus rubra*-type), yet higher percentages of others (i.e., *Pteridium* and *Equisetum*) implies that the type of disturbance at the site may have changed, but disturbance in general remained common.

Zone BL93A-3 (3.73-2.32 m; ca. 5600 to 2850 cal yr BP): Percentages of upland forest taxa and oak savanna taxa were generally unchanged in this zone, although *Thuja*-type pollen reach its highest percentages and *Corylus* percentages gradually decreased. Disturbance taxa percentages changed little from the previous zone, but with the absence of *Equisetum*, *Alnus rubra*-type percentages increased slightly from the previous zone and were highly variable. Among the riparian forest taxa, *Salix* percentages increased at the expense of *Fraxinus* and *Spiraea*-type, and dominated the pollen assemblage. Wet prairie taxa percentages of Cyperaceae, Apiaceae, and Liliaceae changed little in this zone, while Poaceae percentages generally increased toward the top. High percentages of *Salix* and *Fraxinus* indicate the persistence of riparian forest close to Beaver Lake. Little overall change in oak savanna taxa and wet prairie taxa indicate the continued presence of these ecosystems near the site as well. Fairly consistent percentages of *Alnus rubra*-type and *Pteridium* suggest disturbance near the site.

Zone BL93A-4 (2.32-2.00 m; ca. 2850 to 2300 cal yr BP): This zone was characterized by sharp declines in *Salix*, *Spiraea*-type, Cyperaceae, and Apiaceae percentages. *Brasenia* increased dramatically from the previous zone, along with increased *Alnus rubra*-type and *Fraxinus*. At the top of the zone, however, the aforementioned taxa had returned to their previous levels. This zone recorded a period of low water or short-term drying at Beaver Lake. Changes in littoral hydrophytes can be considered indicators of water-level variations (Barnosky, 1981; Singer et al., 1996). High percentages of *Brasenia* suggest more littoral zone and decreased water depths in the lake basin. Decreased *Salix* and *Spiraea*-type also suggest drier conditions than before. Increased *Alnus rubra*-type may indicate greater disturbance at the site or expanded *Alnus rubra*-dominated riparian forest.

Zone BL93A-5 (2.00-0.18 m; ca. 2300 to 100 cal yr BP): This zone is generally similar to Zone BL93A-3. Upland forest taxa percentages changed little in this zone or compared to the previous one. *Tsuga heterophylla* percentages were highest of the record and *Thuja*-type percentages decreased from the bottom to the top of the zone. *Tsuga heterophylla* can be transported relatively long distances on prevailing winds (Minckley and Whitlock, 2000), and is likely a regional signal from the slopes of the Coast and Cascade ranges. Oak savanna percentages of *Pseudotsuga*-type, *Quercus*, and *Acer macrophyllum* remained relatively high, while *Corylus* decreased toward the top of the zone. Percentages of the disturbance taxa *Alnus rubra*-type decreased in this zone, while *Pteridium* percentages increased to its highest values of the record at the top of the zone. Riparian forest taxa percentages of *Salix* and *Spiraea*-type increased, while *Fraxinus* decreased. Wet prairie percentages of Poaceae increased slightly toward the top of the zone, and Cyperaceae and Apiaceae percentages were higher than the previous zone. Several aquatic taxa were more abundant in this zone, including *Typha* and *Nuphar*. The pollen percentages in this zone suggest a heterogeneous mix of vegetation types around

Beaver Lake, similar to the mosaic of *Salix*-dominated riparian forest, prairie, and oak savanna first described by the AD 1853 GLO survey notes.

Zone BL93A-6 (0.18-0.00 m; 100 to 0 cal yr BP): The uppermost zone from core BL93A illustrate changes associated with mid-19th century Euro-American settlement and land-use activities and are discussed in further detail in the next section.

Core BL05B Pollen Record

The pollen from the top 60 cm of core BL05B illustrate in greater detail the vegetation at Beaver Lake over the last ~550 yr (Fig. 3.6). Little change was observed prior to ca. 170 cal yr BP and pollen percentages were generally similar to Zone BL93A-5. Following settlement at ca. AD 1830, *Salix*-dominated riparian forest in the Beaver Lake meander bend, as well as *Quercus*-dominated savanna around the lake, was greatly reduced. *Salix* percentages increased initially following settlement, but then sharply decreased, as did *Spiraea*-type percentages. *Fraxinus* percentages initially decreased but then slightly increased after ca. AD 1950. *Quercus* percentages decreased after ca. AD 1900 and remained low. *Alnus rubra*-type declined after ca. AD 1775, but became more abundant by ca. AD 1950. *Pteridium* abundance increased after ca. AD 1850 and has varied since then. The development of intensely cultivated grassland was evidenced by the sharp increase in Poaceae pollen at ca. AD 1930. Poaceae pollen reached its greatest Holocene abundance at ca. AD 1960 and remains high today.

Further indication of Euro-American impact on the vegetation near Beaver Lake is evident in the initial decrease of *Pseudotsuga*-type pollen percentages after ca. AD 1850 as

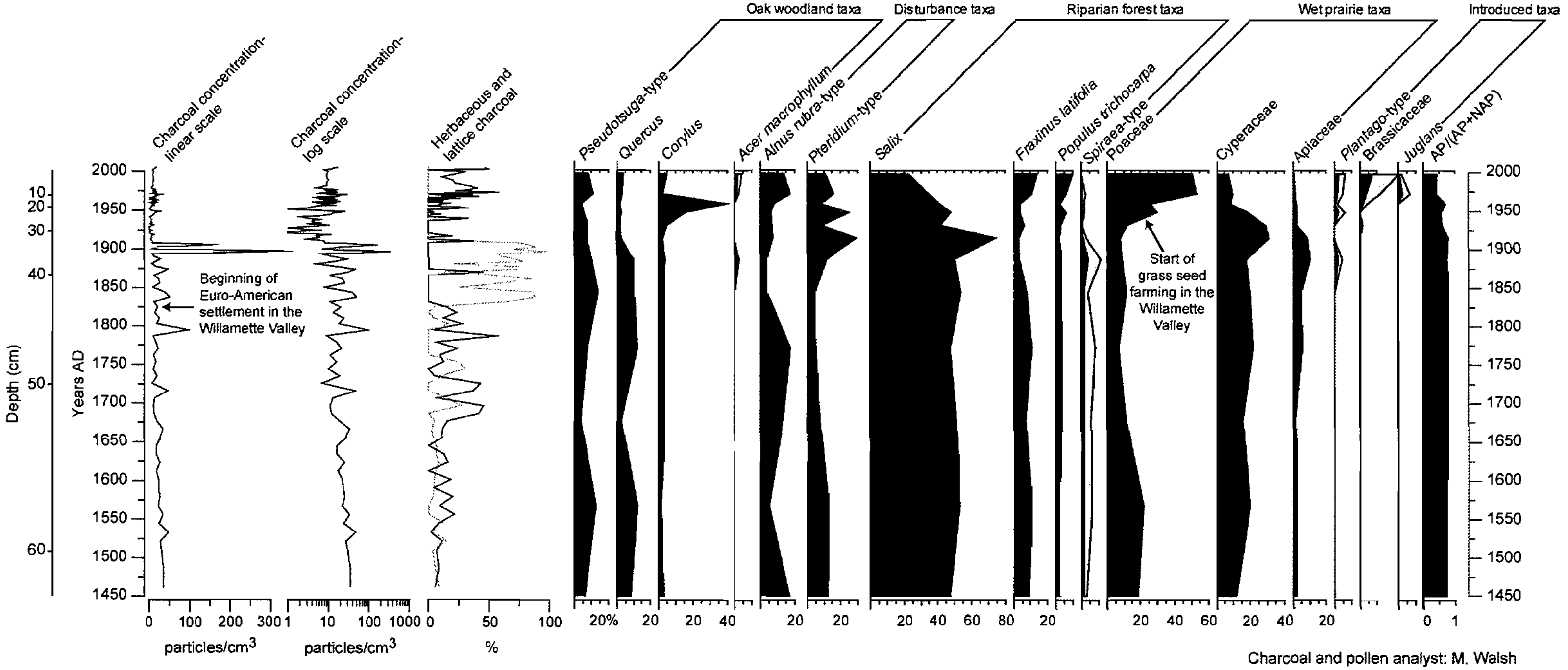


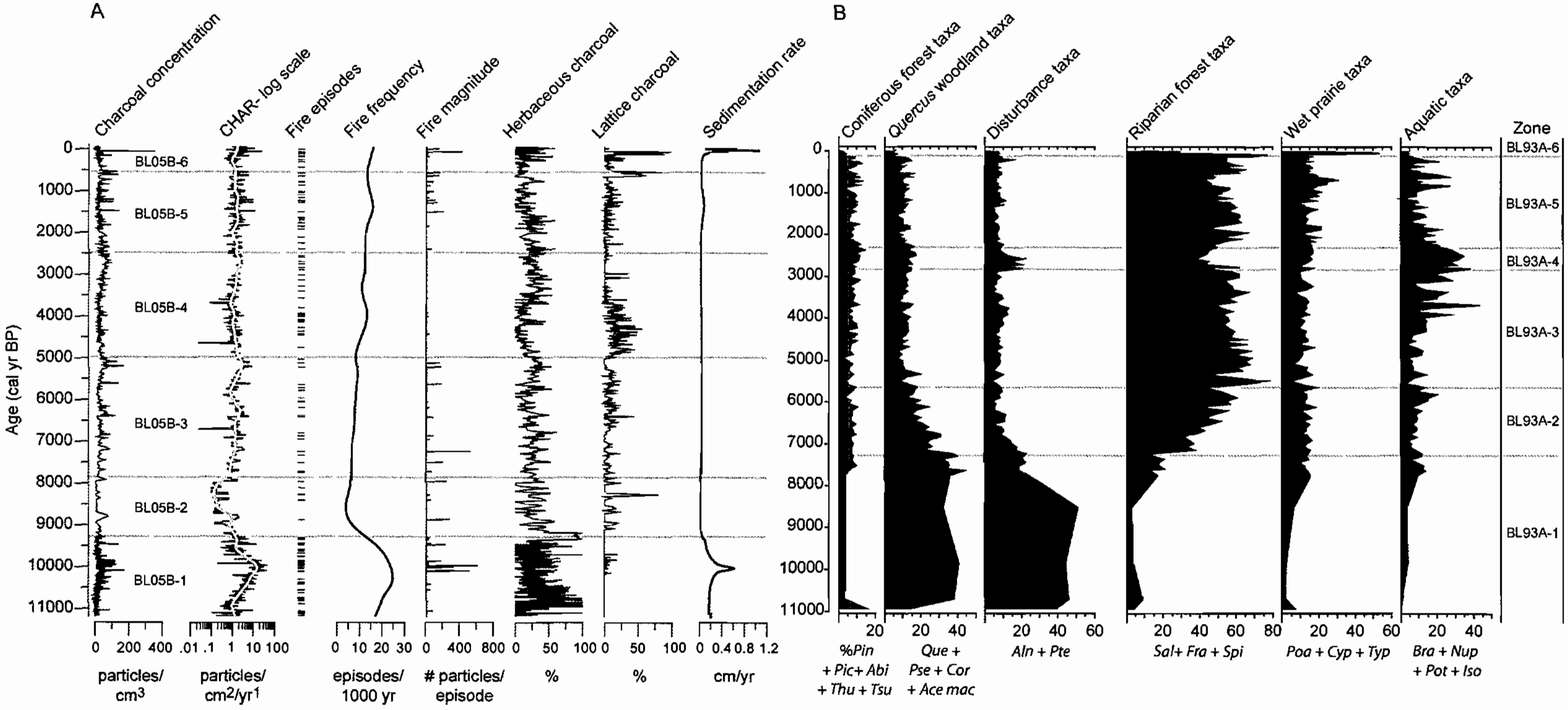
Figure 3.6. Charcoal concentration (linear scale), charcoal concentration (log scale), herbaceous (black line) and lattice (gray line) charcoal, selected pollen taxa percentages, and AP/NAP ratios from the top 65 cm of core BL05B plotted against depth (cm) and age (yr AD). Gray curves represent a 3X exaggeration of solid black curves.

a result of logging, and a slight increase after ca. AD 1950 with the elimination of fire and spread of *Pseudotsuga* into oak savanna (Johannessen et al., 1971). A large peak in *Corylus* pollen at ca. AD 1950 is attributed to large-scale hazelnut farming near the site, given that Linn County is one of seven counties that account for 97.5% of the commercial hazelnut production in Oregon (O'Connor, 2006). Pollen from additional ornamental/cultigen taxa appeared in the uppermost sediments of the core after ca. AD 1950, including Brassicaceae (mustard family) and *Juglans* (walnut) pollen. *Plantago*-type (plantain) pollen also appeared at ca. AD 1850 and generally increased in abundance toward the top of the record. This is probably the non-native *Plantago lanceolata* (English plantain), commonly found in remnant Pacific Northwest prairies (Dunwiddie et al., 2006).

Core BL05B Charcoal Record

The BL05B record was divided into six charcoal zones based on a visual inspection of CHAR and fire-episode frequency curves (Fig. 3.7). See Table 3.2 for zone averages.

Zone BL05B-1 (8.67-4.50 m; 11,190 to 9300 cal yr BP): Charcoal concentration and CHAR were high in this zone. The highest CHAR value (47.8 particles/cm^2/yr) of the record occurred at ca. 10,000 cal yr BP. Fire-episode frequency was also high and increased from 17 episodes/1000 yr at the beginning of the record to 25 episodes/1000 yr at ca. 10,000 cal yr BP, and then decreased to 13 episodes/1000 yr by the end of the zone. Fire-episode magnitude was high, but varied widely from 0.4-607 particles/cm^2. Herbaceous charcoal content was also high, especially before ca. 10 500 and after 9500 cal yr BP. Lattice charcoal content was low.



Charcoal analyst: M. Walsh

Pollen analyst: M. Worona

Figure 3.7. (A) Core BL05B charcoal concentration, charcoal accumulation rate (log scale), fire episodes, fire frequency, fire magnitude, herbaceous charcoal, lattice charcoal, and sedimentation rate plotted against age (cal yr BP). (B) Core BL93A selected summed pollen percentages plotted against an age scale (cal yr BP). Pollen abbreviations are as follows: Pic=*Picea*, Abi=*Abies*, Thu=*Thuja plicata*, Tsu het=*Tsuga heterophylla*, Que=*Quercus*, Pse=*Pseudotsuga menziesii*, Cor=*Corylus*, Ace mac=*Acer macrophyllum*, Aln=*Alnus rubra*, Pte=*Pteridium*, Sal=*Salix*, Fra=*Fraxinus latifolia*, Spi=*Spiraea*, Poa=Poaceae, Cyp=Cyperaceae, Typ=*Typha latifolia*, Bra=*Brasenia*, Nup=*Nuphar*, Pot=*Potamogeton*, Iso=*Isoetes*.

Table 3.2. Average charcoal concentration values, CHAR values, fire frequency, fire- episode magnitude, mean fire return interval, herbaceous charcoal, lattice charcoal, and fire regimes for Beaver Lake core BL05B

Zone (age, cal yr BP)	Ave. charcoal concentration (particles/cm^3)	Ave. CHAR (particles/ cm^2/yr)	Ave. fire frequency (episodes/1000 yr)	Ave. fire-episode magnitude (particles/cm^2)	Mean fire return interval (yr)	Ave. herbaceous charcoal (%)	Ave. lattice charcoal (%)	Fire regime
BL05B-6: 550- -55	19.9	2.2	15	71	54	12	14	Frequent, small to medium size or low- to moderate-severity fires
BL05B-5: 2500-550	33.1	1.9	14	50	87	20	6	Frequent, small to medium size or low- to moderate-severity fires
BL05B-4: 5000-2500	35.9	1.4	12	8	100	19	12	Relatively frequent, very small size or low-severity ground fires
BL05B-3: 7800-5000	38.0	1.7	8	86	159	25	6	Relatively infrequent, medium size or moderate-severity fires
BL05B-2: 9300-7800	21.7	0.6	6	117	230	36	5	Infrequent, small to medium size or small- to moderate-severity fires
BL05B-1: 11,190-9300	25.4	5.5	21	63	52	29	0.3	Very frequent, small to large size or low- to high-severity fires

Zone BL05B-2 (4.50-4.05 m; 9300 to 7800 cal yr BP): CHAR was low in this zone, but charcoal concentration remained relatively high. Fire-episode frequency was also low and dropped to its lowest level of the record of 4 fire episodes/1000 yr at ca. 8600 cal yr BP. The mFRI was highest of the record. Because the sedimentation rate in this zone was slow (0.03 cm/yr), it is difficult to compare fire-episode frequency with other intervals. Fire-episode magnitude varied widely from 0.4-269 particles/cm^2. Herbaceous charcoal content was higher in this zone than before, and lattice charcoal content increased slightly.

Zone BL05B-3 (4.05-2.76 m; 7800 to 5000 cal yr BP): CHAR rose from the previous zone, but remained relatively low. Charcoal concentration was relatively high. Fire-episode frequency was slightly higher in this zone than before, and gradually increased from 6-9 episodes/1000 yr. The mFRI dropped from the previous zone. Fire-episode magnitude had the greatest variability in this zone, ranging from 0.3-517 particles/cm^2. Herbaceous charcoal content decreased in this zone as compared to the previous interval, while lattice charcoal content remained almost unchanged.

Zone BL05B-4 (2.76-1.75 m; 5000 to 2500 cal yr BP): Charcoal concentration and CHAR were similar to the previous interval. Fire-episode frequency increased from 9-13 episodes/1000 yr from the bottom to the top of the zone, with even higher values than the zone average between ca. 4200 and 3700 cal yr BP. The mFRI was lower than the previous zone. Overall, fire-episode magnitude was low and ranged from 0.01-34 particles/cm^2. Grass charcoal content decreased from the previous zone and lattice charcoal content doubled.

Zone BL05B-5 (1.75-0.65 m; 2500 to 550 cal yr BP): Charcoal concentration and CHAR were similar to the previous two zones. Fire-episode frequency increased overall, but changed little; however, a period of higher than average fire-episode frequency occurred from ca. 1700 to 1000 cal yr BP. The mFRI was lower than the previous zone. Fire-episode magnitude and variability (0.02-201 particles/cm^2) increased dramatically from the previous zone. Herbaceous charcoal content remained constant, while lattice charcoal content decreased.

Zone BL05B-6 (0.65-0.0 m; 550 to -55 cal yr BP): Charcoal concentration dropped in this zone as compared to the previous one and was lowest of the record. CHAR was similar to the previous zone, but displayed greater variability after ca. 160 cal yr BP. Fire-episode frequency increased slightly from 14-16 episodes/1000 yr from the bottom to the top of the zone. The mFRI and fire-episode magnitude, which ranged from 2-418 particles/cm^2, were similar to Zone BL05B-1. Herbaceous charcoal content was lowest of the record and lattice charcoal content was highest.

Discussion

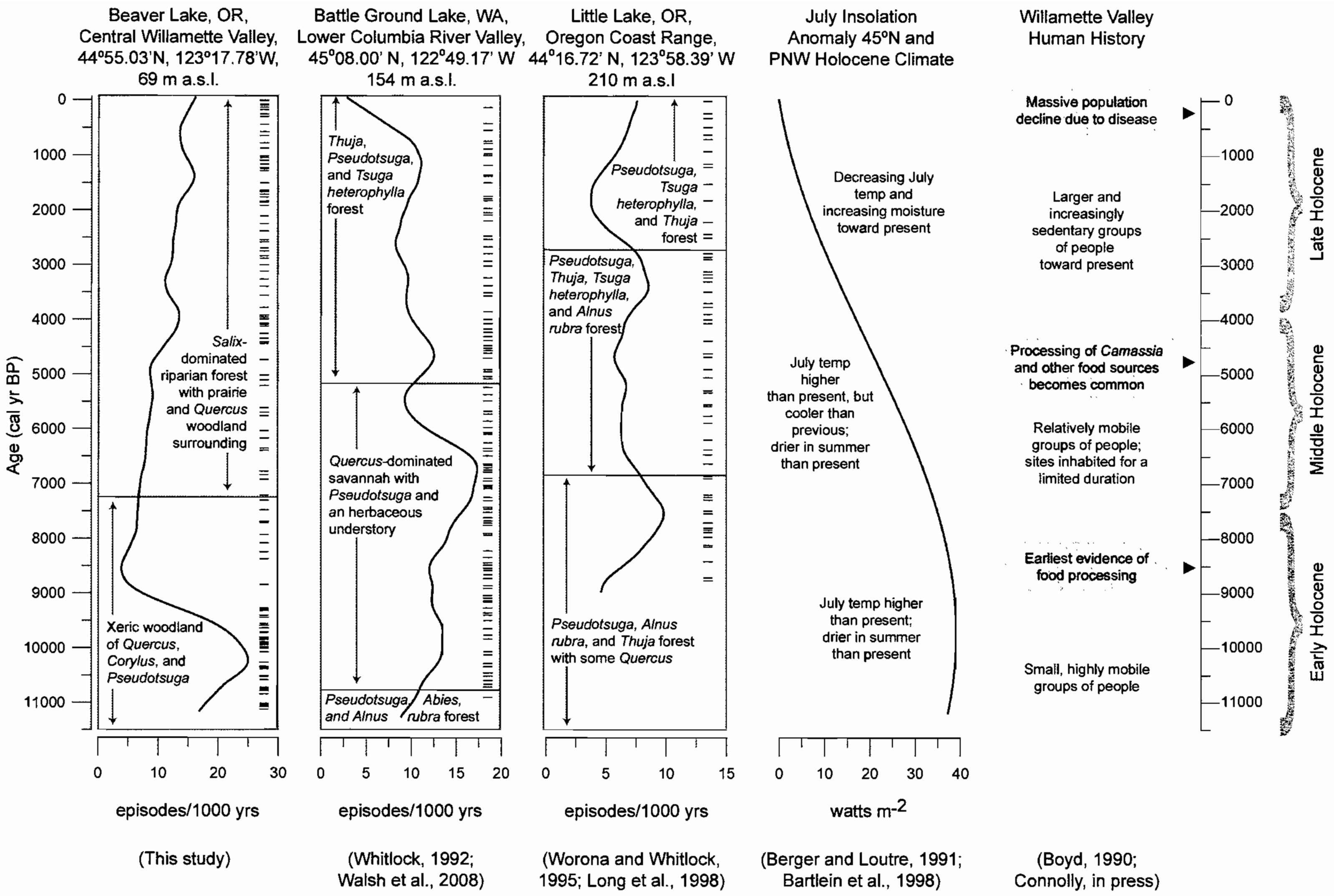
Beaver Lake Fire and Vegetation History

Regional climate variability and local geomorphic/hydrologic development in the Willamette Valley have influenced Beaver Lake and its fire and vegetation history over the last ca. 11,000 years. Between ca. 15,000 and 12,800 cal yr BP, as many as 40 outburst floods from glacial Lake Missoula flowed down the Columbia River (Waitt, 1985; Allen et al., 1986), inundated the Willamette Valley and deposited an enormous amount of sediment across the valley floor (Allison, 1978). This basin fill has been eroded and redeposited throughout the late Pleistocene and Holocene by the Willamette River and its tributaries (Gannett and Caldwell, 1998). The formation of the Beaver Lake meander bend occurred soon after the cessation of these floods, evidenced by the age of the lowest sediments and the lake's position on the Winkle geomorphic unit, the oldest erosional/alluvial terrace associated with the present drainage system (Balster and Parsons, 1968). The location of Beaver Lake raises the possibility that the site could have been subjected to flooding, however, the continuity and character of the sediments (i.e., the presence of laminations) indicates that such flooding did not substantially modify the sediment record.

Although the Beaver Lake record does not technically extend into the late-glacial period, the earliest pollen samples from zone BL93A-1 seem to have captured the end of the *Pinus contorta* (lodgepole pine)-dominated landscape described by Hansen (1947). Similar *Pinus*-dominated landscapes existed further north in the lower Columbia River Valley and the Puget Trough (Whitlock, 1992). The long-term climate history of the Pacific Northwest changed gradually during the Holocene as the Earth's orbital parameters changed (i.e., timing of perihelion, tilt of the Earth's axis) (Berger and Loutre, 1991; Kutzbach et al., 1993). Paleoclimatic model simulations show that during the early Holocene (ca. 11,000-7500 cal yr BP) when summer insolation was amplified and effective moisture was reduced, the Pacific Northwest experienced warmer summers and drier conditions than present (Thompson et al., 1993; Bartlein et al., 1998). Xerophytic (drought-tolerant) taxa, including *Quercus* and *Pseudotsuga* (Minore, 1979), and disturbance-tolerant taxa, such as *Corylus*, *Alnus rubra*, *Quercus*, and *Pseudotsuga* (Agee, 1993), were more abundant near Beaver Lake in the early Holocene. Fire-episode frequency was highest during this period, but the relatively low magnitude of most episodes and high proportion of herbaceous charcoal imply frequent surface fires. Large-magnitude fire episodes dominated by woody charcoal occurred at ca. 10,000 cal yr BP and indicate some crown fire events. Although it is impossible to rule out the possibility that floods transported charcoal during this period, there was no correspondence between inorganic (i.e., sand, silt, clay) layers and charcoal peaks to suggest that the fires were not local. More frequent lightning ignitions in the early Holocene as compared to earlier, the result of generally warm and dry conditions that increased convection due to stronger radiational heating at the surface (Bartlein et al., 1998), likely caused the high fire activity.

Studies from additional sites in the Willamette Valley and other areas of the Pacific Northwest reveal early-Holocene trends similar to those observed at Beaver Lake. At Lake Labish and Onion Flat, *Quercus* expansion occurred prior to the deposition of Mazama ash (ca. 7627 cal yr BP; Zdanowicz et al., 1999) (Hansen, 1947). An expansion of *Quercus*, *Alnus rubra*, and *Pteridium* was also noted at Little Lake in the central Oregon Coast Range in the early Holocene (Worona and Whitlock, 1995), at a time when fire frequency was also high (Long et al., 1998) (Fig. 3.8). *Quercus* and *Corylus* pollen maxima were recorded at Indian Prairie Fen in the central Cascade Range in the early to middle Holocene (ca. 10,000-7000 cal yr BP), when these taxa apparently extended their elevational range as much as ca. 500 m above the Willamette Valley floor (Sea and

Figure 3.8. Reconstructed fire-episode frequency, fire episodes (peaks), and vegetation plotted on an age scale (cal yr BP) for northwest Oregon sites. Sites are arranged from low to high elevation (left to right). Also shown are July insolation anomaly for 45°N latitude and Pacific Northwest Holocene climate history and a generalized human history for the Willamette Valley, Oregon.


Beaver Lake, OR, Central Willamette Valley, 44°55.03'N, 123°17.78'W, 69 m a.s.l.
Battle Ground Lake, WA, Lower Columbia River Valley, 45°08.00' N, 122°49.17' W 154 m a.s.l.
Little Lake, OR, Oregon Coast Range, 44°16.72' N, 123°58.39' W 210 m a.s.l
July Insolation Anomaly 45°N and PNW Holocene Climate
Willamette Valley Human History
Age (cal yr BP)
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
11000
Salix-dominated riparian forest with prairie and Quercus woodland surrounding
Xeric woodland of Quercus, Corylus, and Pseudotsuga
Thuja, Pseudotsuga, and Tsuga heterophylla forest
Quercus-dominated savannah with Pseudotsuga and an herbaceous understory
Pseudotsuga and Alnus
Abies, rubra forest
Pseudotsuga, Tsuga heterophylla, and Thuja forest
Pseudotsuga, Thuja, Tsuga heterophylla, and Alnus rubra forest
Pseudotsuga, Alnus rubra, and Thuja forest with some Quercus
Decreasing July temp and increasing moisture toward present
July temp higher than present, but cooler than previous; drier in summer than present
July temp higher than present; drier in summer than present
Massive population decline due to disease
Larger and increasingly sedentary groups of people toward present
Processing of Camassia and other food sources becomes common
Relatively mobile groups of people; sites inhabited for a limited duration
Earliest evidence of food processing
Small, highly mobile groups of people
Late Holocene
Middle Holocene
Early Holocene
0 10 20 30
0 5 10 15 20
0 5 10 15
0 10 20 30 40
episodes/1000 yrs
episodes/1000 yrs
episodes/1000 yrs
watts m-2
(This study)
(Whitlock, 1992; Walsh et al., 2008)
(Worona and Whitlock, 1995; Long et al., 1998)
(Berger and Loutre, 1991; Bartlein et al., 1998)
(Boyd, 1990; Connolly, in press)

Whitlock, 1995). *Quercus* and herb-dominated savanna also extended north to Battle Ground Lake in the lower Columbia River Valley (Whitlock, 1992), and prairies in the central Puget Trough expanded as well (Hibbert, 1979). The fire history from Battle Ground Lake indicates relatively frequent, low- to moderate-severity fires burning mostly herbaceous material helped maintain the open landscape (Fig. 3.8) (Walsh et al., 2008). The early-Holocene savanna at Battle Ground Lake featured less *Corylus* and more Poaceae and other herbs (Barnosky, 1985) than at Beaver Lake, suggesting a more open landscape in the lower Columbia River Valley as compared to the central Willamette Valley.

Fire activity decreased after 9500 cal yr BP at Beaver Lake, although a drastic drop in sedimentation rate in the core at this time may overemphasize the decline (Fig. 3.7). Less frequent silt and clay layers after ca. 9000 cal yr BP also suggest reduced flooding and greater hydrologic isolation of the oxbow lake. The drop in *Alnus rubra* pollen after ca. 8500 cal yr BP is consistent with decreased flooding and fires at this time. *Quercus* increased to its highest level, suggesting that it may have colonized the former fluvially-disturbed habitats previously dominated by *Alnus rubra.*

Cooler and effectively wetter conditions as a result of decreasing summer insolation (Bartlein et al, 1998) and changes in the Willamette River system in the middle Holocene (ca. 7500-4000 cal yr BP) (Parsons et al., 1970) likely led to the establishment of mesophytic and hydrophytic vegetation near Beaver Lake. Increased *Salix* and *Spiraea* by ca. 7500 cal yr BP and the appearance of *Fraxinus latifolia* at ca. 7250 cal yr BP mark the development of riparian forest at the site. The rise in Poaceae, Cyperaceae, Apiaceae, and Liliaceae at ca. 7500 cal yr BP is associated with the appearance of wet prairie habitats. A slight decrease in the AP/NAP ratio, suggests less forest cover at the site. Oak savanna, which probably included *Quercus*, *Pseudotsuga*, *Corylus*, and *Acer macrophyllum* (Thilenius, 1968), decreased from its early-Holocene maximum, but the pollen data suggest it persisted through the middle and late Holocene (ca. 4000 cal yr BP-present), probably on drier hillsides and other upland areas.

A period of *Equisetum* abundance occurred at Beaver Lake between ca. 7500 and 5600 cal yr BP, coincident with a decrease in magnetic susceptibility values to almost zero, and an increase in organic content of the sediment. *Equisetum* species are proficient colonizers of newly exposed substrates and this period probably marks the establishment of Beaver Lake as a closed, productive system perched above the active floodplain. Beyond a short period of inferred low water depth from ca. 2850-2300 cal yr BP, during which *Brasenia*, *Alnus rubra*, and *Fraxinus* expanded at the expense of *Salix* and *Spiraea*, Beaver Lake was relatively uninfluenced by further major hydrologic changes in the middle and late Holocene (Fig. 3.7). The lack of silt and clay layers in the record and the low magnetic susceptibility values after this time suggest that the site was infrequently flooded in the middle and late Holocene, although the site was likely seasonally inundated with water due to abundant winter precipitation.

Pollen records throughout the Pacific Northwest indicate an expansion of mesophytic vegetation in the middle Holocene (Cwynar, 1987; Whitlock, 1992; Worona and Whitlock, 1995; Brown and Hebda, 2002a). At Little Lake, *Thuja* pollen increased at the expense of *Quercus* and *Pseudotsuga* at ca. 6400 cal yr BP (Worona and Whitlock, 1995). At Indian Prairie Fen, *Abies* expanded at the expense of *Quercus* and *Corylus* at ca. 7600 cal yr BP (Sea and Whitlock, 1995). *Quercus*-dominated savanna at Battle Ground Lake decreased in the middle Holocene and was replaced by *Pseudotsuga*/*Thuja*-dominated forest by ca. 5200 cal yr BP (Whitlock, 1992).

Further increases in effective moisture and decreased seasonal differences in insolation in the late Holocene (Bartlein et al, 1998) led to the establishment of modern coniferous forests in the Cascade and Coast ranges. At most sites, this transition is marked by a decline in *Pseudotsuga* and *Alnus* and an expansion of *Tsuga* spp. and *Thuja* (Tsukada et al., 1981; Sea and Whitlock, 1995; Long and Whitlock, 2002; Brown and Hebda, 2003). At Battle Ground Lake, savanna was greatly reduced as indicated by the decrease in *Quercus* and numerous herbaceous taxa (Whitlock, 1992). In contrast, the vegetation record from Beaver Lake showed little change through the middle and late Holocene. The increased presence of conifer pollen likely reflects the expansion of mesophytic forest in the Coast and Cascade ranges and foothill regions of the Willamette Valley (Worona and Whitlock, 1995). *Salix*/*Fraxinus* riparian forest, herb-dominated wet prairie, and *Quercus*-dominated savanna persist near the site over the last ca. 8000 years with little change (Fig. 3.7). Beyond a general shift from more xerophytic to more mesophytic vegetation at ca. 7500 cal yr BP and an early-Holocene fire activity maximum between ca. 11,200 and 9300 cal yr BP, this reconstruction has little similarity with other low-elevation (<500 m a.s.l.) records in the Coast and Cascade ranges, the lower Columbia River Valley, Vancouver Island, or the Puget Lowland (Walsh et al., 2008).

Anthropogenic Versus Climatic Influences on the Beaver Lake Record

Relatively little is known about the Holocene human history of the Willamette Valley, but the discovery of Clovis projectile points suggests habitation since ca. 13,000 years ago (Aikens, 1993; Waters and Stafford, 2007). Early-Holocene evidence is sparse (Cheatham, 1984, 1988), either because repeated flooding of the Willamette River and its tributaries removed or buried many archaeological sites (Aikens, 1993), or because the highly mobile lifeways of the inhabitants left few cultural remains (Connolly, in press). High magnetic susceptibility values and numerous sand, silt, and clay layers present in the Beaver Lake record prior to ca. 9000 cal yr BP suggest that the lake was located on a floodplain and intermittently inundated by floodwater in the early Holocene. This would have made the area surrounding the site inhospitable for permanent settlement and unlikely that human ignitions were important.

Fire-episode frequency increased over the last 8000 years at Beaver Lake. The initial increase occurred at the time when the pollen record registered the appearance of wet prairie taxa near the site. Fires apparently occurred in prairie vegetation, which dried seasonally, as indicated by the relatively high proportion of herbaceous charcoal (~30%). One would expect that the fire-episode frequency would stabilize or even drop as the regional climate cooled and became wetter toward present (Bartlein et al., 1998), but that did not occur at Beaver Lake (Fig. 3.8). In contrast, at Little Lake, fire-episode frequency decreased from ca. 7500 cal yr BP to the present, with a slight increase in activity between ca. 4000-3000 cal yr BP and after ca. 2000 cal yr BP (Long et al., 1998). At

Battle Ground Lake, fire-episode frequency was high at ca. 6800 cal yr BP but generally decreased toward present (Fig. 3.8) (Walsh et al., 2008).

The fact that Beaver Lake remained fairly open with frequent fires during middle- and late- Holocene cooling suggests that anthropogenic burning may have been more important at Beaver Lake than at other sites. Middle Holocene archaeological sites in the Willamette Valley are more abundant than earlier and dominated by pit ovens containing the charred remains of *Camassia quamash* (camas lily) bulbs, hazelnut shells, and oak acorn meats (O'Neill, 1987; O'Neill et al., 2004; Connolly., in press). With an intensification of food processing, Kalapuyan groups may have seasonally occupied or managed the area around Beaver Lake to harvest local resources such as acorns and hazelnuts (both *Quercus* and *Corylus* pollen remained relatively abundant in the record through the middle to late Holocene). Although no *Camassia*-type pollen was found at Beaver Lake (unlike at Battle Ground Lake in the early to middle Holocene; Whitlock, 1992), modern plant associations of relic stands place it within lowland riparian forest and wet prairie ecosystems (Christy, 2004).

A dramatic shift from a period of highly variable fire-episode magnitude to a one of small-magnitude fires near Beaver Lake occurred at ca. 5000 cal yr BP and persisted until ca. 1500 cal yr BP. A greater proportion of lattice charcoal in the record also occurred at this time, indicating that the fire regime was inherently different than before. The timing of this shift coincides with increases in human populations in the Willamette Valley (Cheatham, 1988; Connolly et al., 1997; O'Neill et al., 2004) and the establishment of cooler, effectively wetter conditions typical of present day. This change in climate greatly altered the seasonal availability of food resources and necessitated food storage, which in turn led to a semi-sedentary lifestyle where seasonal camps were frequently re-used or inhabited for extended amounts of time (Prentice and Chatters, 2003; O'Neill et al., 2004). Population pressure and resource competition between neighboring groups may have decreased the amount of land available to each community, thus necessitating the use of fire as a management tool. The small magnitude of the fire episodes during this period suggests that climatic conditions were too wet for large fires to spread, or that small surface fires were used to enhance the growth of desired food sources.

Between ca. 1500-500 cal yr BP, fire episodes became much greater in magnitude than before (Fig. 3.7) and could be the result of drier conditions associated with the Medieval Climate Anomaly. Five fire episodes with an average magnitude of 45.3 particles/cm^2 were recorded during the time of the Medieval Climate Anomaly (ca. 1100-700 cal yr BP, AD 850-1250; Mann, 2002), and a shift to less herbaceous charcoal (~16%) suggests fires were more severe than before. Two later fire episodes (at ca. 630 and 540 cal yr BP) are notable, not only because they were last relatively large/intense fire episodes, but also because they were composed almost exclusively of lattice charcoal (60% and 85%, respectively). Only two other fire episodes at ca. 6400 and 4450 cal yr BP had a similar composition to these fire episodes.

At ca. 500 cal yr BP, during another period of lower fire frequency, the fire regime at Beaver Lake shifted again, this time to very small/low-severity fire episodes and the lowest charcoal concentration of the entire record. This decline in burning may have been the result of cooler wetter conditions during the Little Ice Age (ca. 500-100 cal yr BP, AD 1450-1850; Grove, 2001); only five fire episodes with an average magnitude of 10 particles/cm^2 were registered during this time. However, this shift could also indicate human abandonment of the area due to lack of resources, or a reduction in population size due to introduced disease. Boyd (1990) estimated that as early as ca. AD 1770 (ca. 190 cal yr BP) disease had reached the Northwest Coast and had begun to reduce Native American populations. Others suggest that this may have occurred even earlier (Dobyns, 1983; Campbell, 1990), although there is no evidence to support this hypothesis. After ca. AD 1875, fires at Beaver Lake are attributed to Euro-American settlement and land clearance (Figs. 3.6 and 3.7). A shift to a high proportion of lattice charcoal occurred simultaneously with these activities and indicates that these fires were anomalous to those of the previous 400 years. The largest/most severe postsettlement fire episode occurred at ca. AD 1890 (ca. 60 cal yr BP) and was composed predominantly of lattice charcoal (~76%). No significant fire episodes were recorded at Beaver Lake over the last 45 years, and today, approximately half of the charcoal entering the lake is herbaceous and likely comes from annual burning of nearby grass seed fields.

Conclusions

Beaver Lake provides the first Holocene fire and vegetation history from the Willamette Valley. In the early Holocene, warmer drier summers than at present and frequent flooding were responsible for relatively xeric woodland of *Quercus*, *Corylus*, and *Pseudotsuga*, with abundant *Alnus rubra* in disturbed areas. Riparian forest and wet prairie habitat developed in the middle Holocene, likely a result of less frequent flooding and a shift to effectively cooler wetter conditions than before. The vegetation at Beaver Lake remained relatively unchanged over the last 8000 cal yr; riparian forest and wet prairie grew around the lake and on the active floodplains, oak savanna existed on surrounding uplands, and conifer forest covered the foothills of the Coast and Cascade ranges. The exceptions to this were a brief period of inferred local drying/lowered lake level from ca. 2850 to 2300 cal yr BP, and the period Euro-American land clearance and agriculture after ca. 160 cal yr BP.

Highest fire activity at Beaver Lake occurred between ca. 11,200-9300 cal yr BP in association with warm dry conditions and the presence of xeric woodland near the site. Fires were frequent surface burns, although a few crown fires were also registered. A drastic decrease to the lowest fire frequency of the entire record occurred after 9300 cal yr BP, possibly the result of cooler wetter climatic conditions. Increased fire frequency throughout the middle and late Holocene, a period in which climatic conditions became wetter and cooler, points to the likely importance of anthropogenic burning. The middle and late Holocene fire history from Beaver Lake differs from other fire-history records at low-elevation sites in the Pacific Northwest, suggesting that the maintenance of wet prairie and oak savanna in the Willamette Valley, especially over the last 5000 years, may have been aided by human activity.

CHAPTER IV

1200 YEARS OF FIRE AND VEGETATION HISTORY IN THE WILLAMETTE VALLEY, OREGON AND WASHINGTON

This chapter has been prepared as a co-authored manuscript with C. Whitlock and P.J. Bartlein for submission to the journal *The Holocene*.

Introduction

Background

The current vegetation of the Willamette Valley is vastly different from that seen by 19th-century Euro-American explorers and settlers. Survey notes from the General Land Office (GLO) provide detailed documentation that presettlement vegetation (ca. AD 1850) was a complex mosaic of *Quercus* (oak) savanna and woodland, prairie (ranging from moist to dry), coniferous upland forest, and extensive riparian forests (Habeck, 1961; Towle, 1982; Christy et al., 1997). Today, only small remnants of these ecosystems remain, precariously perched between rapidly expanding urban and agricultural areas (Hulse et al., 2002). Numerous studies have shown that over the past ca. 150 years, shrubs and trees have established in former wet and upland prairie, and conifers have come to dominate former oak savanna and woodland (Thilenius, 1968; Johannessen et al., 1971; Cole, 1977; Frenkel and Heinitz, 1987; Hibbs et al., 2002). The removal of fire, both naturally- and human-ignited, from these ecosystems is partially, if not entirely, responsible for the magnitude of change seen, but the question remains as to how much of the presettlement fire regime was the result of human modification of the landscape?

Few records of any kind are available to detail the presettlement fire history of the Willamette Valley. Limited historical records, mainly journal entries by early explorers (ca. AD 1800), make reference to areas of scorched vegetation and attribute these fires to Native Americans (e.g., Wilkes, 1845; Douglas, 1959). Ethnographic studies document the use of fire by the native inhabitants as a means of encouraging the growth of food plants, hunting and warfare tactics, as well as other uses (Boyd, 1999), but the spatial and temporal details of the burning remains unknown (Whitlock and Knox, 2002). Dendrochronological studies that provide a record of past fires on the valley floor are sparse due to the lack of long-lived trees. In a synthesis of ten tree-ring-based fire-history studies from western Washington and Oregon, including studies in valley foothill forests (Impara, 1997; Weisburg, 1997), Weisburg and Swanson (2003) identified four general periods of fire activity: ca. AD 1400s to 1650, widespread burning; ca. AD 1650 to 1800, reduced burning; ca. AD 1800 to 1925, increased fire activity; and ca. AD 1925 to present, limited burning. A recent study specifically targeting low-elevation Willamette Valley fringe forests, however, suggests that pre- to postsettlement burning patterns were more spatially variable than Weisburg and Swanson (2003) propose (J. Kertis, personal communication, 2008).

In this paper, we use high-resolution macroscopic charcoal and pollen analyses to reconstruct the fire and vegetation history of the Willamette Valley for the last 1200 years. Presented in this paper are three new paleoecological reconstructions from Lake Oswego, Porter Lake, and Warner Lake, Oregon, and portions of reconstructions from Battle Ground Lake, Washington (Chapter II), and Beaver Lake, Oregon (Chapter III). The five study sites sit along a north-south transect through the valley (Fig. 4.1). The purpose of this study was to 1) better understand the fire and vegetation history of the Willamette Valley over the last 1200 years, and 2) assess the relative role of climate variability and anthropogenic activities on those histories.

The Willamette Valley

The Willamette Valley is a broad structural depression that lies between the Coast and Cascade ranges of northwestern Oregon and southwestern Washington (Fig. 4.1) (Orr and Orr, 1999). Bounded by the Lewis River to the north, it stretches ~210 km south to Cottage Grove, OR, and is typically 40 to 65 km wide with an average elevation of ~90 m above sea level (a.s.l.). The Willamette Valley gently slopes to the north and is drained by the Willamette River, which flows into the Columbia River at Portland. Small hills mark the landscape (e.g., the Portland, Salem, Eola, and Coburg hills), which otherwise consists of broad alluvial surfaces (Balter and Parsons, 1968).

The climate of the Willamette Valley, as well as the rest of the Pacific Northwest, is characterized by cool wet winters and warm dry summers. Annual precipitation is influenced by the position of the polar jet stream and the contraction and expansion of the northeastern Pacific subtropical high pressure system (Mitchell, 1976; Mock, 1996). In winter, the Pacific subtropical high contracts and the polar jet stream shifts southward to

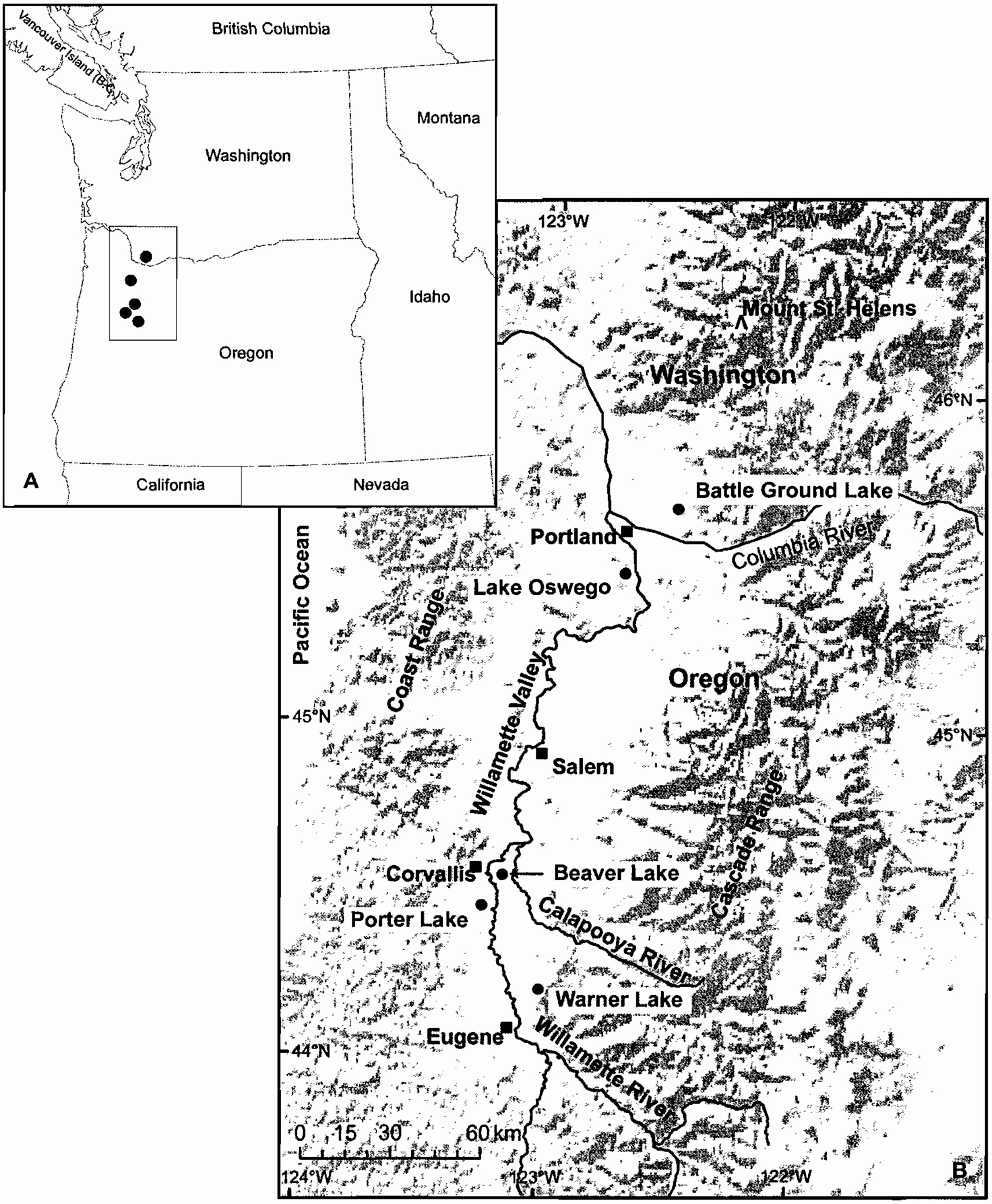


Figure 4.1. (A) Map of the Pacific Northwest showing the location of the study area (gray box) and the study sites (black dots), and (B) map of the Willamette Valley showing the location of the five study sites.

the latitude of the Pacific Northwest, enhancing precipitation in the region. In summer, the jet stream shifts northward as the subtropical high expands (due to increasing seasonal insolation) and suppresses precipitation. The Willamette Valley sits in the rain shadow of the Coast Range and receives an average of 110 cm of precipitation annually, approximately 89% of that between the months of October and May (Western Regional Climate Center, 2007). Precipitation between June and September is infrequent, and a mild summer drought is typical. Temperatures are fairly mild in the Willamette Valley, with an average July temperature of ~19°C and an average January temperature of ~4.5°C (Western Regional Climate Center, 2007), although averages vary slightly from north to south.

The climate of the Pacific Northwest has varied during the last 1200 years, although the exact cause of these variations is not clear. Two relatively well-documented, centennial-scale climate change events are the Medieval Climate Anomaly (ca. 1100-700 cal yr BP [ca. AD 850-1250]; Mann, 2002) and the Little Ice Age (ca. 500-100 cal yr BP [ca. AD 1450-1850]; Grove 2001). Evidence of the Medieval Climate Anomaly in the western United States comes from tree-ring records (Graumlich, 1993; Stine, 1994; Cook et al., 2004), lake-sediment records (Mohr et al., 2000; Brunelle and Whitlock, 2003), and changes in treeline (Leavitt, 1994). Cook et al. (2004), using annually-resolved tree ring records to extend the Palmer Drought Severity Index to ca. 1200 years ago, calculate the annual percent of the western United States affected by drought from AD 800 to the present. In doing so they provide evidence of substantial periods of elevated aridity in the western United States during the Medieval Climate Anomaly; the four driest periods were centered on AD 936, 1034, 1150, and 1253.

Evidence of cooler temperatures and greater precipitation in the region associated with the Little Ice Age comes from multi-proxy temperature reconstructions (Jones et al., 2001), tree-ring dated glacial advances (Luckman, 1995; Wiles et al., 1999) and tree-ring records (Graumlich and Brubaker, 1986; Graumlich, 1987). Cross-dated subfossil wood from glacial forefields and times of moraine stabilization show several "Little Ice Age" glacial advances in western Prince William Sound, AK, during the last 1000 years (Wiles et al., 1999); the first between ca. AD 1200-1300, the second between ca. AD 1600-1700, and the third between AD 1874-1895. Tree-ring data from Graumlich and Brubaker (1986) in Longmire, WA (46°47'N, 121°44'W, 842 m a.s.l.) show that cool episodes occurred between AD 1600-1650, 1700-1760, and 1860-1900, and that the mean reconstructed temperature (AD 1590-1913) was almost 1°C lower than the mean temperature of the observed record (AD 1914-1979). Their record shows a distinct rise in temperatures (ca. AD 1840) and a decrease in snow accumulation (ca. AD 1900), marking the end of the Little Ice Age in the Pacific Northwest.

GLO land survey records divide the presettlement vegetation of the Willamette Valley into five general types: riparian forest, prairie, oak savanna, oak woodland, and upland (coniferous) closed forest (Habeck, 1961; Johannessen et al., 1971). Kilometer-wide riparian forests once covered the active floodplains of the Willamette River and its tributaries (Towle, 1982; Sedell and Froggatt, 1984). The most common trees were *Populus trichocarpa* (black cottonwood), *Fraxinus latifolia* (Oregon ash), *Salix* spp.

(willow), *Alnus rubra* (red alder), *Pseudotsuga menziesii* (Douglas-fir), and *Acer macrophyllum* (big-leaf maple), with an understory of shrubs, including *Spiraea douglasii* (hardhack), *Berberis aquifolium* (Oregon grape) and *Sambucus glauca* (elderberry) (Franklin and Dyrness, 1988; Frenkel and Heinitz, 1988). Seasonally wet and upland prairie were also widespread on the valley floor and were dominated by *Deschampsia cespitosa* (tufted hairgrass), but also supported numerous other herbaceous plants (Habeck, 1961; Streatfield and Frenkel, 1997). Oak savanna, dominated by *Quercus garryana* (Oregon white oak) with the occasional *Quercus kelloggii* (California black oak) and *Pseudotsuga menziesii* (Douglas-fir), covered the rolling hills of the valley and lower Coast and Cascade range foothills (Franklin and Dyrness, 1988). Oak woodland was also found in the valley and was more densely populated with *Quercus* trees than savanna (Habeck, 1961). Closed upland forests dominated at higher elevations along the eastern and western slopes of the valley, with *Pseudotsuga menziesii* as the dominant species, and *Acer macrophyllum*, *Tsuga heterophylla* (western hemlock), *Thuja plicata* (western red cedar), *Quercus garryana*, and *Cornus nuttallii* (dogwood) also present (Habeck, 1961). Additionally, *Pinus ponderosa* (ponderosa pine) grew on a range of sites from flooded valley bottoms to oak savanna and woodland, and in the lower foothills of the Coast and Cascade ranges (Johannessen et al., 1971; Hibbs et al., 2002). Botanical nomenclature follows Hitchcock and Cronquist (1973).

Archaeological evidence from the Willamette Valley and the lower Columbia River Valley (the portion of the valley immediately to the south and north of the Columbia River) suggests that human populations grew larger and more sedentary during the Late Holocene (ca. 3000 cal yr BP- Euro-American contact) (Beckham et al., 1981; Pettigrew, 1990; Ames, 1994; Connolly, in press). Many settlement sites in the Willamette Valley appear to have been continuously occupied for the last 2000-3000 years, with activities focused on the seasonal processing of vegetable foods (O'Neill et al., 2004). In the early 19th century, Kalapuyan-speaking tribes inhabited most of the Willamette Valley in elongated territories extending from the Willamette River to the Coast or Cascade Range and incorporated river channel, floodplain, and mountains (Zenk, 1990). These groups subsisted by fishing, hunting, and gathering the natural resources found in the valleys and surrounding montane areas, such as the bulb of *Camassia* spp. (camas lily) and other root crops, nuts, and berries (Zenk, 1990). Native inhabitants followed the seasonal availability of different food sources and used fire as a means of encouraging the growth of many plants (Boyd, 1999; Leopold and Boyd, 1999). In contrast to the Kalapuyans, Chinookan-speaking tribes at the time of Euro-American contact were gathered in large numbers along both sides of the lower Columbia River and its tributaries (Aikens, 1993). Fish was a main staple for them and settlements were more permanent (Boyd and Hajda, 1987; Pettigrew, 1990).

European contact led to a rapid decline in native populations caused by the outbreak of several epidemics beginning as early as AD 1770 (Boyd, 1985, 1990). Down from a pre-contact population estimate of 16,000, Kalapuyans numbered only 600 in AD 1841 (Wilkes 1926; Boyd, 1990). Between AD 1830-1841, total loss of tribal population in the Willamette Valley and lower Columbia River Valley was ~92% (Boyd, 1990). In the 1850s and 1860s, the remaining small populations were moved to the Grande Ronde and Siletz reservations in Oregon and the Nisqually and Puyallup reservations in Washington, and land in the Willamette Valley was converted to agricultural fields and homesteads (Beckham, 1990; Marino, 1990). Fires continued to occur as a result of Euro-American land-use activities including land clearance, but by AD 1933, fire suppression efforts had become very successful (Morris, 1934). Today, most fires occur as a result of accidental human ignition or field burning, but lightning-started fires are important in the upland areas surrounding the valley floor (Hardy et al., 2001; Bartlein et al., 2008).

Study Sites

Battle Ground Lake, WA (45°08.00'N, 122°49.17'W, 154 m a.s.l.), is located approximately 30 km north of the city of Portland and sits in a remnant volcanic crater of late Pleistocene age (See Table 4.1 for site information, Fig. 4.2a) (Wood and Kienle, 1990). The vegetation surrounding the site is closed, second-growth forest of *Pseudotsuga menziesii* and *Thuja plicata*, with scattered *Tsuga heterophylla*, *Abies grandis*, *Picea sitchensis* (Sitka spruce), *Alnus rubra*, *Acer macrophyllu*m, *Fraxinus latifolia*, *Salix* spp., *Corylus cornuta*, *Cornus nuttallii*, *Spiraea douglasii*, and *Polystichum* (sword fern).

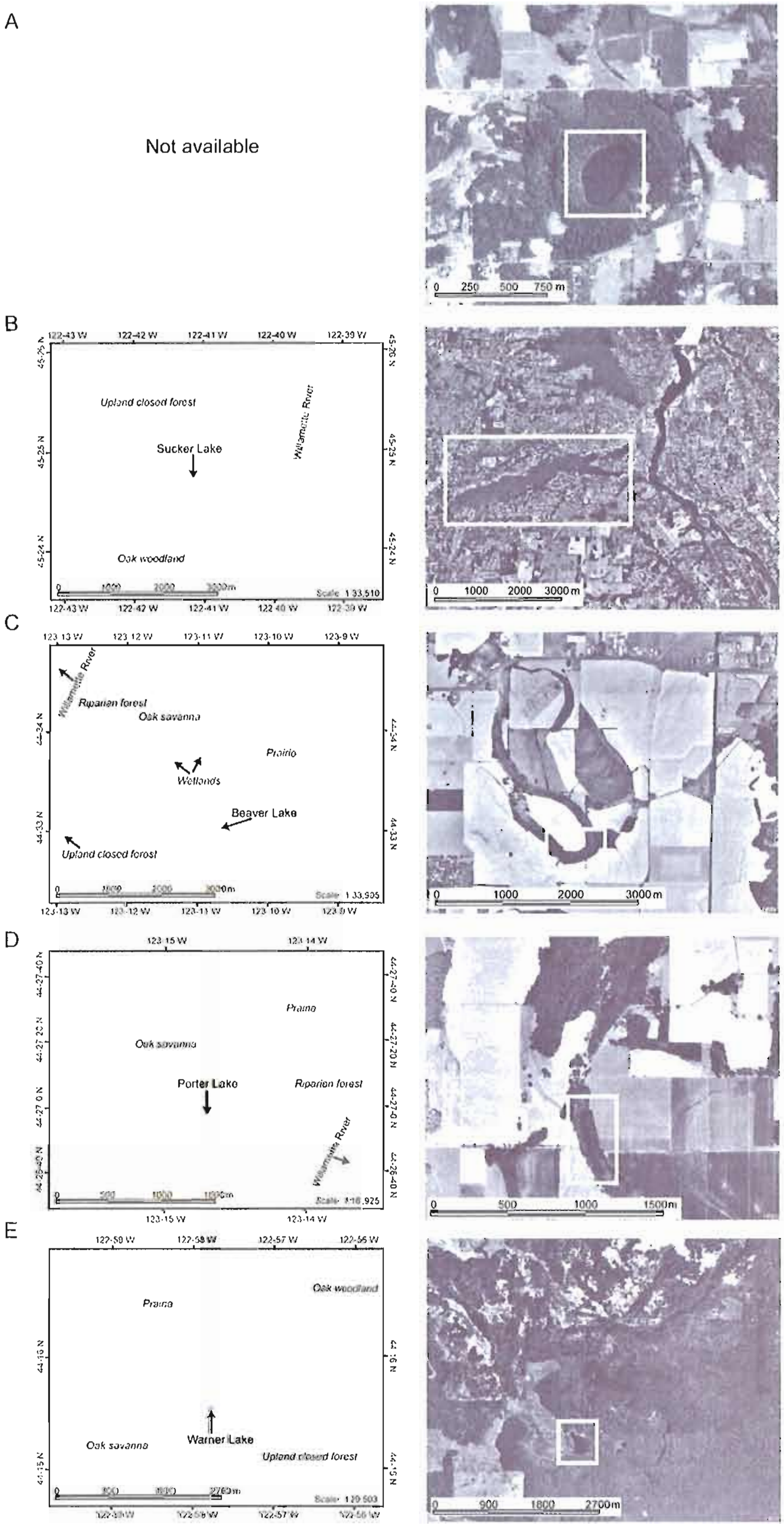
Lake Oswego, OR (45° 24' 40" N, 122° 39' 58" W, 30 m a.s.l.), is a former channel of the Tualatin River and is located approximately 13 km south of the city of Portland (Johnson et al., 1985). Originally named Sucker Lake, it was enlarged after construction of a small dam across the outlet and completion of the Tualatin Canal in AD

Table 4.1.
Physical and climatic data for study sites

	Battle Ground Lake	Lake Oswego	Beaver Lake	Porter Lake	Warner Lake
Latitude	45°48’17" N	45°24’40" N	44°33’01" N	44°26’52" N	44°14’46" N
Longitude	122°29'38" W	122° 39' 58" W	123°10’40" W	123°14’34" W	122°57’27" W
Elevation (m)	157	30	69	73	590
Area (ha)	14	160	2.2	1.4	15.5
Drainage basin area (ha)	21.6	1600	N/A	N/A	150
Maximum water depth (m)	16	17	3	3	18
Climate station	Interpolated[a]	City of West Linn	Interpolated[a]	City of Corvallis	Interpolated[a]
Location relative to site	N/A	7.5 km SW	N/A	13.8 km SSW	N/A
Period of record	1961-1990	1961-1990	1961-1990	1971-2000	1961-1990
Ave Jan temp (°C)	3.4	2.5	4.4	4.6	2.3
Ave July temp (°C)	17.6	19.1	18.6	19.2	16.9
Ave annual precip (mm)	1543	1223	1135	1109	1426
% precip Nov-April	75	75	78	78	76

[a] Elevationally adjusted interpolations based on CRU CL 2.0 (New et al., 2002).

Figure. 4.2. AD 1851 reconstructed vegetation cover maps and AD 2000 USGS aerial photos of (A) Battle Ground Lake, (B) Lake Oswego, (C) Beaver Lake, (D) Porter Lake, and (E) Warner Lake. Vegetation cover maps were made using the Willamette Explorer map tool (available at http://vaduz.library.oregonstate.edu:8080).


A
Not available
0 250 500 750 m
B
122-43 W
122-42 W
122-41 W
122-40 W
122-39 W
45-25 N
45-24 N
45-26 N
Upland closed forest
Willamette River
Sucker Lake
Oak woodland
0 1000 2000 3000m
Scale 1:33,510
0 1000 2000 3000 m
C
123-13 W
123-12 W
123-11 W
123-10 W
123-9 W
44-34 N
44-33 N
Willamette River
Riparian forest
Oak savanna
Prairie
Wetlands
Beaver Lake
Upland closed forest
0 1000 2000 3000m
Scale 1:33,905
0 1000 2000 3000 m
D
123-15 W
123-14 W
44-27-40 N
44-27-20 N
44-27-0 N
44-26-40 N
Prairie
Oak savanna
Porter Lake
Riparian forest
Willamette River
0 500 1000 1500m
Scale 1:16,925
0 500 1000 1500m
E
122-59 W
122-58 W
122-57 W
122-56 W
44-16 N
44-15 N
Oak woodland
Prairie
Warner Lake
Oak savanna
Upland closed forest
0 900 1800 2700m
Scale 1:29,503
0 900 1800 2700m

1863, which connected the Tualatin River with the east end of the lake (City of Lake Oswego, 2007). The dam raised the water level by several meters and increased its length from approximately 4.4 to 5.6 km (City of Lake Oswego, 2007). GLO maps indicate that Sucker Lake was surrounded by upland closed forest and oak woodland at the time of Euro-American settlement (Fig. 4.2b). The current forest includes many native taxa, such as *Pseudotsuga menziesii*, *Thuja plicata*, *Quercus garryana*, *Alnus rubra*, and *Fraxinus latifolia*, as well as numerous introduced and ornamental species. Today, a mixture of forest and development (including private homes and the town of Lake Oswego) surrounds the site.

Beaver Lake, OR (44°55.03’N, 123°17.78’W, 69 m a.s.l.), is a small oxbow lake located in the central Willamette Valley between the Willamette and Calapooya rivers, approximately 7 km ESE of the city of Corvallis. GLO survey notes indicate that the lake and the rest of the meander bend supported a riparian shrubland surrounded by prairie and oak savanna at the time of settlement (Fig. 4.2c). The current vegetation is a narrow riparian forest composed of *Populus trichocarpa*, *Salix* spp., *Fraxinus latifolia*, and *Quercus garryana*, *Oemleria cerasiformis* (Indian plum), *Rhus diversiloba* (poison oak), *Spiraea douglasii*, and *Symphoricarpos albus* (snowberry), surrounded by extensive agricultural fields.

Porter Lake, OR (44°26’52”N, 123°14’34”W, 73 m a.s.l.), is a small oxbow lake located just to the west of the Willamette River, approximately 14 km SSW of the city of Corvallis. GLO maps indicate that oak savanna surrounded a small riparian shrubland at the time of settlement, with prairie and larger tracts of riparian forest nearby (Fig. 4.2d).

Similar to Beaver Lake, the current vegetation is a narrow riparian forest composed predominantly of *Populus trichocarpa*, *Salix* spp., *Fraxinus latifolia*, *Quercus garryana*, *Spiraea douglasii*, *Symphoricarpos albus*, and numerous invasive species including *Rubus discolor* (Himalayan blackberry). Agricultural fields, predominantly grass seed farms, surround Porter Lake.

Warner Lake, OR (44°14’46”N, 122°57’27”W, 590 m a.s.l.), is a landslide-dammed lake located in the Coburg foothills of the Cascade Range, approximately 25 km NNW of the city of Eugene. GLO maps indicate the site was entirely surrounded by closed upland forest at the time of settlement, but oak woodland, oak savanna, and prairie existed nearby (Fig. 4.2e). Today the landscape is a mixture of second- and third-growth forest, with some recent clear cuts. Major forest components include *Pseudotsuga menziesii*, *Pinus ponderosa*, *Thuja plicata*, *Tsuga heterophylla*, *Alnus rubra*, *Acer macrophyllum*, *Calocedrus decurrens* (incense-cedar), and *Arbutus menziesii* (Pacific madrone), with an understory of *Sambucus racemosa* (elderberry), *Berberis aquifolium*, *Polystichum* spp., and *Equisetum* spp. (horsetail).

Methods

Field and laboratory methods are described here for the Lake Oswego, Porter Lake, and Warner Lake cores. Methods for Battle Ground Lake and Beaver Lake can be found in Chapters II and III, respectively, except where noted.

In 2004 and 2005, sediment cores were collected from the deepest part of each lake. Long cores were recovered from Lake Oswego (LO05B) and Warner Lake

(WL04A) using a 5-cm diameter modified Livingstone piston corer (Wright et al., 1983). Core segments were extruded on site, wrapped in plastic wrap and foil, and transported to the laboratory at the University of Oregon and refrigerated. Short cores were collected from Lake Oswego (LO05C) and Porter Lake (PL05C) using a Klein piston corer that recovered the sediment-water interface. The cores were extruded in the field at 1-cm intervals and samples were stored in plastic bags.

In the laboratory, long core segments were split longitudinally and photographed, and the lithologic characteristics were described. Magnetic susceptibility, which determines the allochthonous inorganic content of the core (Thompson and Oldfield, 1986; Gedye et al., 2000), was measured on the long cores at contiguous 1-cm intervals using a Sapphire Instruments magnetic coil. Loss-on-ignition analysis, which determines the bulk density, organic, and carbonate content of the sediment (Dean, 1974), was completed at 5-cm intervals on all cores. Samples of 1-cm^3 volume were dried at 80°C for 24 hours, weighed, and combusted at 550°C for 1 h and 900°C for 2 h. Weight measurements after each combustion determined the percent organic and percent carbonate content of each sample.

Contiguous 1-cm^3 samples were taken for charcoal analysis at 1-cm intervals from the Lake Oswego long core (LO05B) and the Porter Lake short core (PL05C), and at 0.5-cm intervals from the Lake Oswego short core (LO05C) and the Warner Lake long core (WL04A). Charcoal samples were soaked in a 5% solution of sodium hexametaphosphate for >24 hours and a weak bleach solution for one hour to disaggregate the sediment. Samples were washed through nested sieves of 250 and 125 μm mesh size, and the residue was transferred into gridded petri dishes and counted. Charcoal particles were identified and tallied as either woody, herbaceous, or lattice type, based on their appearance and comparison to reference material (see Chapters II and III for photos). Herbaceous charcoal, which comes from grasses or other monocots, was flat and contained stomata within the epidermal walls (Jensen et al., 2007; Walsh et al., 2008). Lattice charcoal, which likely comes from leaves and non-woody material, was only present in the Beaver Lake core. Previous studies indicate that large particles are not transported far from the source and thus are an indicator of local fire activity (Whitlock and Millspaugh, 1996; Whitlock and Larsen, 2001); therefore only charcoal particles >125 μm in minimum diameter were considered. Charcoal counts were divided the by the volume of the sample to calculate charcoal concentration (particles/cm^3). Charcoal influx (particles/cm^2/yr) was determined by dividing charcoal concentration by the deposition time (yr/cm) of the samples.

The Battle Ground Lake, Lake Oswego, Beaver Lake, and Warner Lake charcoal records were analyzed statistically using the program CharAnalysis (Higuera, 2008; http://charanalysis.googlepages.com/), which decomposed the records into a peaks (C_{peak}) and background ($C_{background}$) component in order to determine individual fire episodes (Higuera et al., 2008). Concentration values were interpolated to constant time steps, which represented the median temporal resolution of each record, to obtain the charcoal accumulation rate (CHAR) time series. The median temporal resolution for Battle Ground Lake was 6 years, Lake Oswego and Beaver Lake was 5 years, and Warner Lake was 2 years. The non-log-transformed CHAR time series were fit with a robust Lowess smoother that modeled $C_{background}$ and C_{peak} , which were the residuals after $C_{background}$ was subtracted from the CHAR time series. A locally determined threshold value to separate fire-related (i.e., signal) from non-fire related variability (i.e., noise) in the C_{peak} component was set at the 95th percentile of a Gaussian distribution model of the noise in the C_{peak} time series. Sensitivity analysis of window widths between 100 to 1000 years showed that the signal-to-noise ratio was maximized at a window width of 500 years for Battle Ground Lake and Lake Oswego, 400 years for Beaver Lake, and 300 years for Warner Lake. C_{peak} was screened and peaks were eliminated if the maximum charcoal count from a peak had a >5% chance of coming from the same Poisson-distributed population as the minimum count within the preceding 75 years (Gavin et al., 2006; Higuera et al., 2008).

Pollen samples of 1-cm^3 were taken at 5-10-cm intervals on all cores except the Lake Oswego long core (samples were taken at 5-30-cm intervals) and analysis followed standard techniques (Faegri et al., 1989). *Lycopodium* was added to each sample as an exotic tracer to calculate pollen concentration and 300-500 terrestrial pollen grains and spores were counted per sample. Pollen was identified and tallied at magnifications of 400 and 1000x, and pollen types were assigned based on modern phytogeography. Pollen counts for terrestrial taxa were converted to percentages using different sums. The terrestrial sum for Lake Oswego excluded *Alnus rubra*-type, *Pteridium*, and Poaceae when percentages were calculated for the remaining terrestrial taxa. The terrestrial sum for Porter Lake excluded *Salix*, *Fraxinus latifolia*, and Poaceae. The terrestrial sum at Warner Lake excluded *Alnus rubra*-type and Cupressaceae. The terrestrial sum for Battle

Ground Lake excluded *Pseudotsuga*-type and *Thuja*-type. Aquatic taxa percentages were calculated using the modified terrestrial and aquatic taxa sum. Arboreal/non-arboreal pollen ratio was calculated by dividing the arboreal sum by the total arboreal plus non-arboreal sum.

Results

Chronology

Age-depth models were developed based on ^{210}PB and AMS ^{14}C age determinations (see Table 4.2 for the age-depth relations for the Lake Oswego, Porter Lake, and Warner Lake cores; age-depth relations for the Battle Ground Lake and Beaver Lake cores are listed in Chapters II and III, respectively). All ^{14}C age dates were converted to calendar years before present (cal yr BP; present= 1950 AD) using Calib 5.0.2 html (Stuiver and Reimer, 2005). The Battle Ground Lake short core (BG05B) and a portion of the long core (BG04A) were correlated based on tephra and charcoal stratigraphy and combined to create a continuous record for the last 1200 years (hereafter referred to as core BG05C; see Chapter II for a description of the cores). A constrained cubic smoothing spline based on 20 ^{210}Pb dates and two AMS ^{14}C dates was used to fit the age model of the core (Fig. 4.3a). For Lake Oswego, the chronology of core LO05C was based on eleven ^{210}Pb and one AMS ^{14}C age determination and the chronology of core LO05B was based on two AMS ^{14}C age determinations. Using stratigraphic markers present in both cores, LO05B and LO05C were correlated and combined to create one continuous record from the site (hereafter referred to as core LO05A). A constrained

Table 4.2
Age-depth relations for Lake Oswego, Porter Lake, and Warner Lake, OR

Depth (cm below mud surface)	Lab number	Source material	Dates (^{210}Pb, ^{14}C yr BP)	Calibrated age (cal yr BP)[a]
Lake Oswego, OR: Core LO05C				
0.0-3.0	...	lake sediment	2.3[b]	-53.2
3.5-5.5	...	lake sediment	7.0[b]	-48.5
6.5-8.5	...	lake sediment	11.4[b]	-44.2
9.0-10.5	...	lake sediment	14.3[b]	-41.3
11.5-12.5	...	lake sediment	16.3[b]	-39.2
14.0-15.0	...	lake sediment	19.6[b]	-35.9
16.5-17.5	...	lake sediment	27.3[b]	-28.2
19.0-20.0	...	lake sediment	37.0[b]	-18.5
21.5-22.5	...	lake sediment	43.2[b]	-12.3
24.0-25.0	...	lake sediment	55.9[b]	0.4
26.5-27.5	...	lake sediment	90.34[b]	34.8
29.0-30.0	...	lake sediment	155.8[b,c]	100.3
89.0	AA72363	lake sediment	693 +/- 55[d]	670
Lake Oswego, OR: Core LO05B				
157.0	AA72362	lake sediment	1243 +/- 56[d]	1180
261.0	AA69497	lake sediment	3042 +/- 32[d]	3260
Porter Lake, OR: Core PL05C				
83.0	UCI33408	wood	200 +/- 25[e]	180
Warner Lake, OR: Core WL04A				
1.0-2.0	...	lake sediment	3.7[b]	-50.3
4.0-5.0	...	lake sediment	15.8[b]	-38.2
8.0-9.0	...	lake sediment	29.8[b]	-24.2
13.0-14.0	...	lake sediment	41.3[b]	-12.8
16.0-17.0	...	lake sediment	49.7[b]	-4.3
20.0-21.0	...	lake sediment	61.1[b]	7.1
24.0-25.0	...	lake sediment	76.6[b]	22.6
28.0-29.0	...	lake sediment	87.6[b]	33.6
34.0-35.0	...	lake sediment	96.6[b]	42.6
37.0-38.0	...	lake sediment	109.6[b]	55.6
40.0-41.0	...	lake sediment	121.7[b]	67.7
43.0-44.0	...	lake sediment	147.3[b]	93.3
69.0	AA69046	twig	277 +/- 33[d]	310
168.0	AA63176	twig	813 +/- 37[d]	720

[a] Calibrated ages determined using Calib 5.0.2 html (Stuiver and Reimer, 2005).
[b] ^{210}Pb age determinations completed by J. Budahn at the USGS Denver Federal Center, Colorado.
[c] Denotes samples not used in the age-depth model.
[d] ^{14}C age determinations completed at the University of Arizona AMS facility.
[e] ^{14}C age dertermination completed at the University of California Irvine AMS facility.

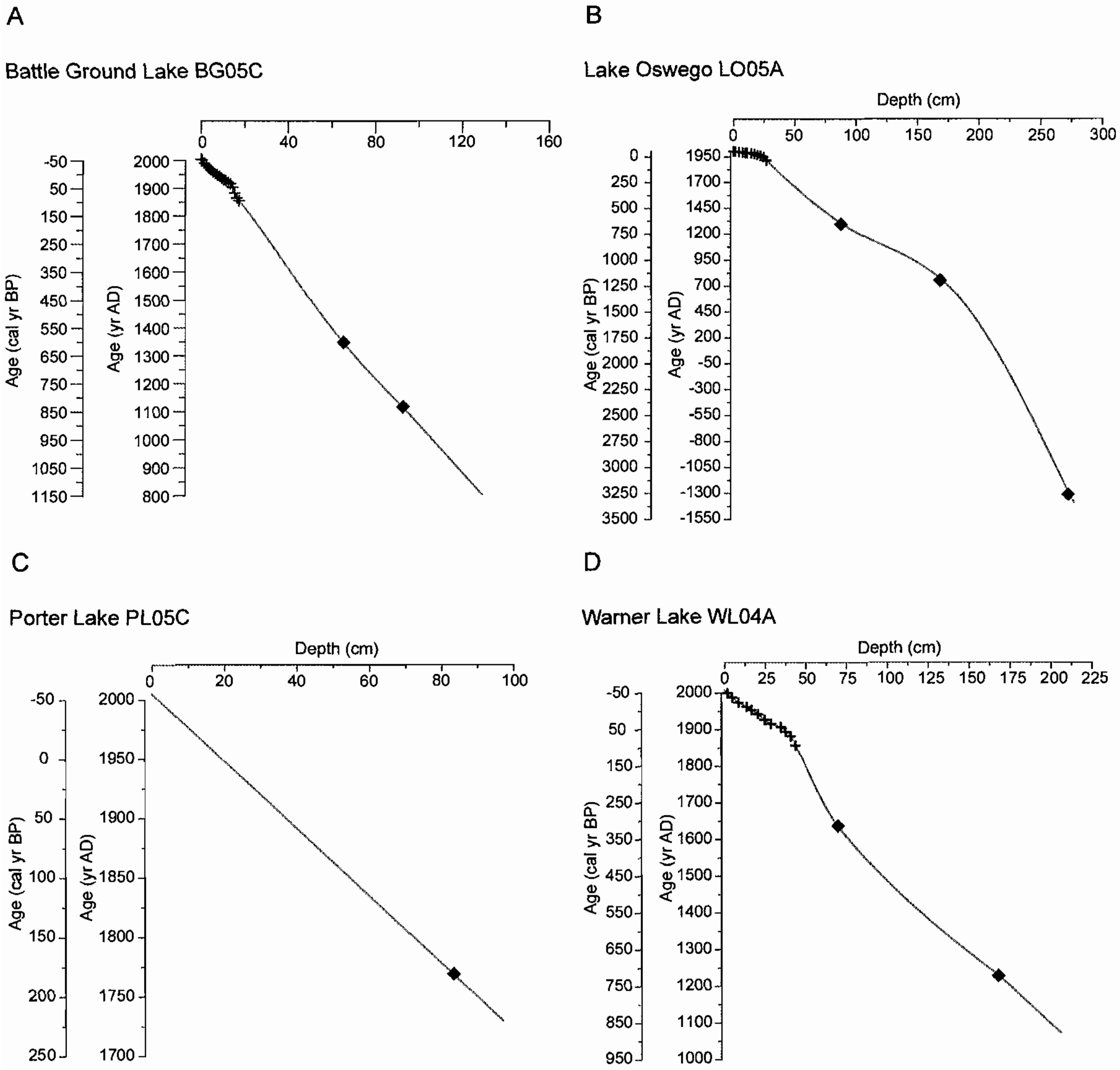


Figure 4.3. Age-versus-depth relations for (A) Battle Ground Lake (BG05C), (B) Lake Oswego (LO05A), (C) Porter Lake (PL05C), and (D) Warner Lake (WL04A) based on the age model information given in Table 4.2. The + symbol indicates ^{210}Pb age determinations and the ◆ symbol indicates AMS ^{14}C age determinations.

cubic smoothing spline was used to fit the age model of core LO05A, suggesting a basal date of 3340 cal yr BP (Fig. 4.3b). Only the last 1200 years of the record is presented here. For Porter Lake, the chronology of core PL05C was based on one AMS ^{14}C age determination and a date of -55 cal yr BP for the top of the core. Linear interpolation was used to develop the age model, suggesting a basal date of 220 cal yr BP (Fig. 4.3c). For Warner Lake, the chronology of core WL04A was based on twelve ^{210}Pb and two AMS ^{14}C age determinations. A constrained cubic smoothing spline was used to develop the age model, suggesting a basal date of 875 cal yr BP (Fig. 4.3d).

Lithology

The lithology, charcoal concentration, organic content, and magnetic susceptibility values for the Lake Oswego (LO05A), Porter Lake (PL05C), and Warner Lake (WL04A) vary considerable within and between cores (Fig. 4.4). Core LO05A consisted almost entirely of brownish/gray clay gyttja (Fig 4.4a). Magnetic susceptibility values were extremely low for the core (4.5 x10^{-5} emu) and changed little overall. Organic content was also relatively low (16%), but rose slightly at the top of the core to ~21%. Black bands occurred in the sediment above 35 cm depth (ca. 120 cal yr BP), presumably the result of pollution, first from iron smelters located on the shores of the lake (ca. AD 1865-1900) and later from recreational motor boat use (ca. AD 1940-present) (City of Lake Oswego, 2007).

The lithology of core PL05C consisted of clay gyttja from the base of the core to a depth of 29 cm, and fine-detritus gyttja above that (Fig. 4.4b). The organic content of the

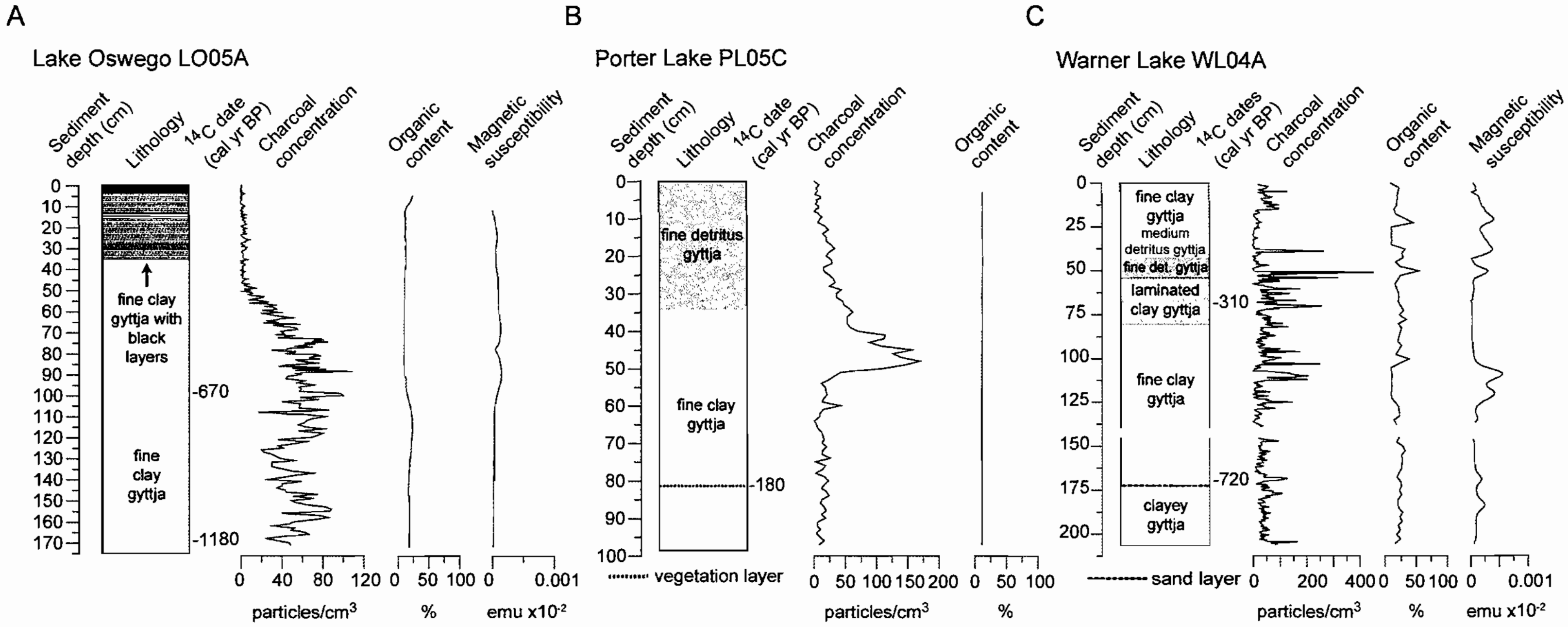


Figure 4.4. Lithology, AMS ^{14}C dates, charcoal concentration (particles/cm^3/yr), organic content (%), and magnetic susceptibility (electromagnetic units) for (A) Lake Oswego, (B) Porter Lake, and (C) Warner Lake plotted against sediment depth (cm). Magnetic susceptibility data are not available from Porter Lake.

core remained almost constant at 12%. A vegetation layer was found at a depth of 83 cm and provided material for a ^{14}C date.

The lithology of WL04A consisted of clay gyttja from the base of the core to a depth of 170 cm, with an average organic content of 24% (Fig. 4.4c). Between 170 and 80 cm depth the sediment was clay gyttja with clay layers interspersed, and the average organic content was 21%. A sand layer occurred at a depth of 172 cm and sediments were not recovered from 145 to 138.5 cm depth. Between 80 and 55 cm depth, the sediment was laminated clay gyttja with an average organic content of 25%, and was fine-detritus gyttja between 55 and 35 cm depth with an average organic content of 30%. An unconsolidated section of medium-detritus gyttja occurred between 35 and 25 cm depth in the core and had a lower average organic content (11%). The sediment was fine clay gyttja above 25 cm depth with an average organic content of 22%, although the organic content value for the top loss-on-ignition sample dropped to 11%. Magnetic susceptibility values remained relatively low throughout most of the core, especially below 55 cm depth (average of 1.27×10^{-4} emu). Magnetic susceptibility peaks in this section of the core, however, correlated well with large charcoal concentration peaks (e.g., at 177 and 167 cm depths, and higher in the core at 124.5 cm depth and between 111.5 and 107.5 cm depth). This correlation indicates that fires in the watershed triggered allochthonous input into the lake following these events. Above 55-cm depth, magnetic susceptibility values were generally higher (average of 2.2×10^{-4} emu), indicating greater slopewash of clastic material into the lake. Again, several magnetic susceptibility peaks correlated well with large charcoal concentration peaks (e.g., at 50.5

and 38.5 cm depths). However, the sustained period of relatively high magnetic susceptibility values between 35 and 25 cm depth occurred when charcoal concentration values were low. The anomalous lithology, low organic values, and high magnetic susceptibility values in this part of the core likely indicate the start of logging in the watershed (ca. AD 1880).

Charcoal and Pollen Records

Battle Ground Lake, WA

The Battle Ground Lake charcoal and pollen record was divided into pre- and postsettlement zones (Fig. 4.5). **Zone BG05B-1 (ca. AD 1340 – 1850):** High charcoal concentration values were recorded near the beginning of the zone, at ca. AD 1350 and 1390. Almost no fire activity occurred throughout the rest of zone, indicated by generally low concentration values and low variability in the charcoal influx values. However, influx variability did increase somewhat between ca. AD 1700-1850. The average herbaceous charcoal content for the zone was relatively low (11%). The pollen record shows the successional response of the forest taxa to disturbance. Following the high charcoal values at ca. AD 1350 and 1390, *Pteridium* increased, followed by *Alnus rubra*, which was eventually replaced by *Pseudotsuga* and *Thuja* over the next two hundred years. The small decrease in the AP/NAP ratio further suggests a loss of forest cover following these events. Overall, the pollen assemblage in this zone suggests a closed forest with some disturbance-related openings and a small riparian community near the edge of the lake.

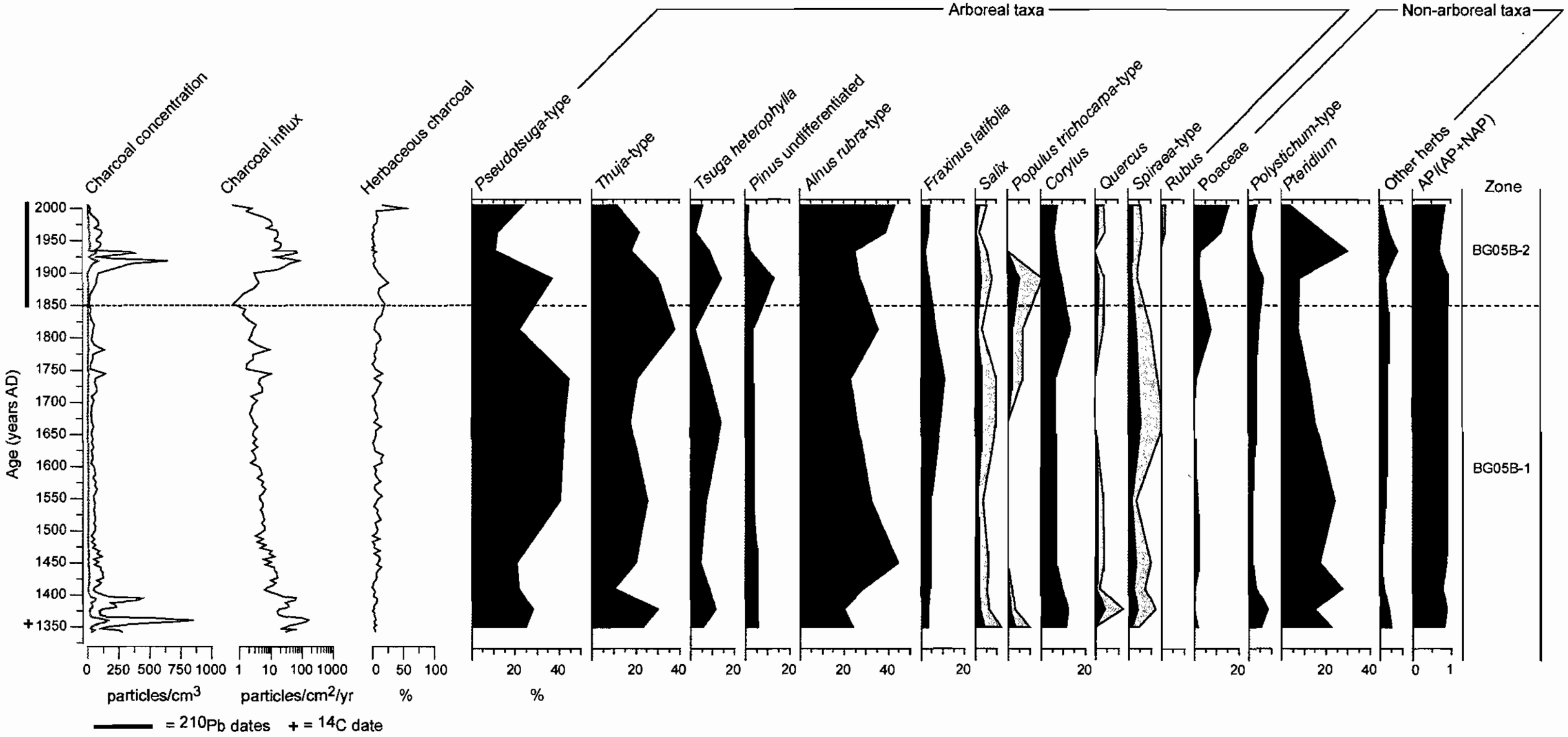


Figure 4.5. Battle Ground Lake (BG05B) charcoal concentration (particles/cm^3/yr; black line = total charcoal, gray line = herbaceous charcoal), total charcoal influx (particles/cm^2), herbaceous charcoal (%), selected pollen percentages (gray curves represent a 3X exaggeration of solid curve), and AP/NAP ratio plotted against age (AD). The vertical black bar to the left of the age axis represents the age range of the ^{210}Pb dates and the + symbol represents the age of the AMS ^{14}C date.

Zone BG05B-2 (ca. AD 1850 - 2005): This zone shows the impact of Euro-American settlement and land clearance near the site. The charcoal concentration curve recorded the most recent fire within the Battle Ground crater, the Yacolt fire of AD 1902. This fire had a low herbaceous charcoal content (~5%). The subsequent high charcoal concentration value at ca. AD 1930 may be from a re-burn associated with the Yacolt fire (Gray, 1990), although none occurred inside the crater. Charcoal influx values remained high through the rest of the zone and charcoal may have come from fires outside the crater or possibly from campfires (the site has been a popular recreation destination during the 20th century and is now part of the Washington State park system) (Allworth, 1976). The pollen record shows the effects of both logging and fire on the vegetation in the Battle Ground Lake crater over the last 200 years. The drop in *Thuja* sometime after ca. AD 1800 probably indicates the start of nearby logging associated with the establishment of Fort Vancouver in AD 1825 (Allworth, 1976). The simultaneous drop in *Pseudotsuga*, *Tsuga heterophylla*, *Pinus*, *Populus trichocarpa*, as well as an additional drop in *Thuja*, in the late 1800s indicates local logging inside the crater. The forest succession recorded in Zone BG05A-1 occurred again following these events (i.e., an initial rise in *Pteridium* followed by a subsequent rise in *Alnus rubra*). Further evidence of Euro-American impact near the site is evident in the rise in Poaceae in the last 50 years, which is the result of grass seed farming in the Willamette Valley and lower Columbia River Valley, and a rise in non-native *Rubus* in the Pacific Northwest.

Lake Oswego, OR

The Lake Oswego charcoal and pollen record was divided into three zones (Fig. 4.6). **Zone LO05A-1 (ca. AD 800 – 1200):** This zone records a high level of fire activity indicated by high charcoal concentration and influx values. The average herbaceous charcoal content was generally low (7.5%). The pollen record indicates that the local forest was dominated by taxa such as *Pseudotsuga*, *Thuja*, *Tsuga heterophylla*, and some *Pinus*. Disturbance taxa, including *Alnus rubra* and *Pteridium*, were common as well. Other riparian and woodland taxa, such as *Fraxinus latifolia*, *Salix*, *Populus trichocarpa*, *Corylus*, and *Quercus*, were present, but relatively low in abundance. The pollen assemblage and the high AP/NAP ratio suggest a closed forest surrounded the site, with some disturbance-related openings and probably a narrow riparian shrubland.

Zone LO05A-2 (ca. AD 1200 – 1700): This zone records major changes in both the fire regime and vegetation. Higher charcoal concentration values occurred between ca. AD 1200-1450 and coincided with a major vegetation shift. At this time, many herbaceous taxa including Poaceae, *Polystichum*, *Pteridium*, and *Rumex* increased at the expense of the coniferous taxa, especially *Pseudotsuga*. The large drop in the AP/NAP ratio at ca. AD 1250 points to the loss of canopy cover near the site. After ca. AD 1450, charcoal concentration decreased drastically to almost zero by ca. AD 1700. As the charcoal input into the lake decreased, the abundance of most herbaceous taxa (i.e., *Pteridium*, *Polystichum*, *Rumex*, and *Plantago*) decreased. Forest slowly returned to the site over this 350-year period, evidenced by the increased AP/NAP ratio, but it was dominated by *Alnus rubra* and *Fraxinus latifolia* instead of *Pseudotsuga* and *Thuja* as in

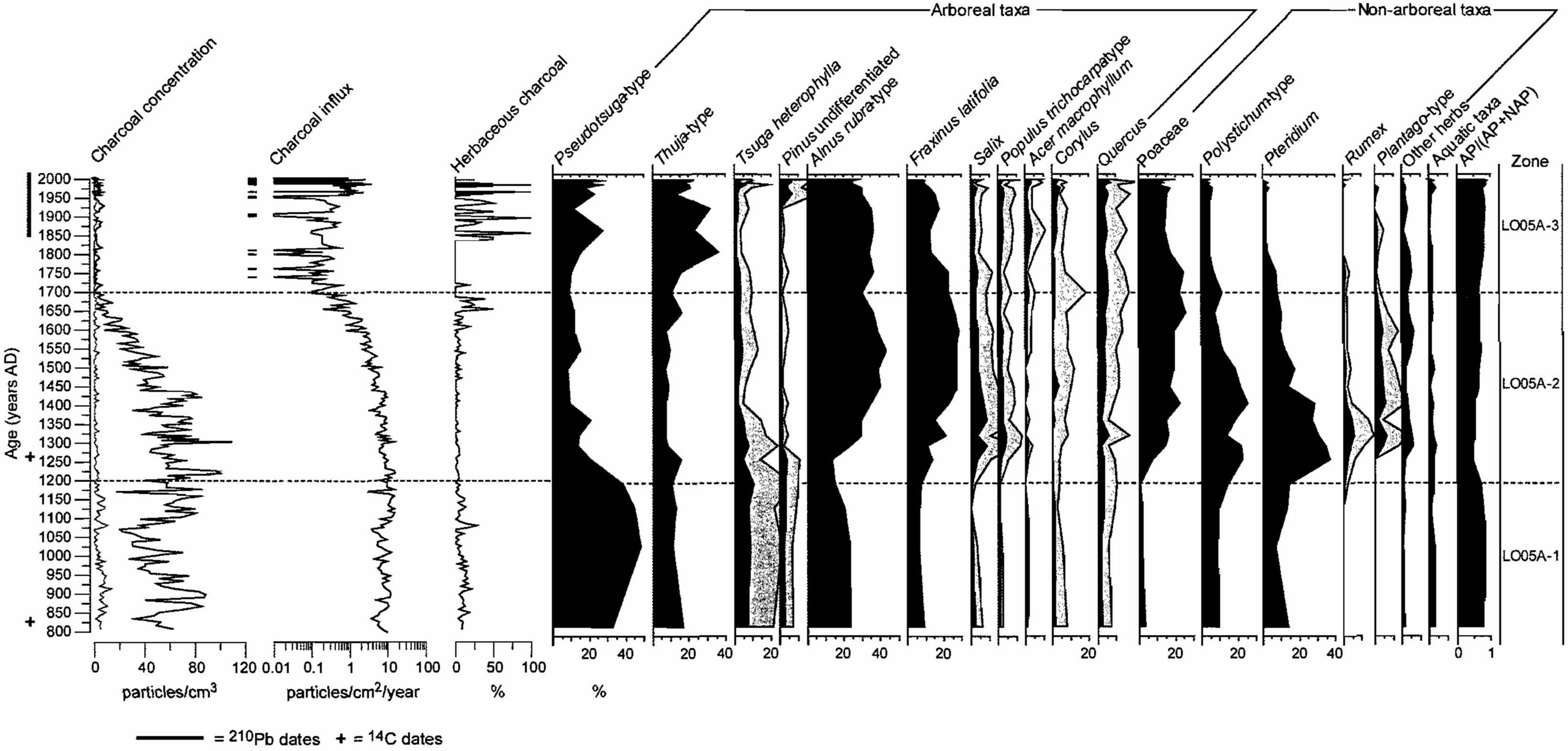


Figure 4.6. Lake Oswego (LO05A) charcoal concentration (particles/cm^3/yr; black line = total charcoal, gray line = herbaceous charcoal), total charcoal influx (particles/cm^2; ticks below the curve represent zero values), herbaceous charcoal (%), selected pollen percentages (gray curves represent a 3X exaggeration of solid curve), and AP/NAP ratio plotted against age (AD). The vertical black bar to the left of the age axis represents the age range of the ^{210}Pb dates and the + symbol represents the age of the AMS ^{14}C dates.

Zone LO05A-1. Percentages of *Alnus rubra*-type, *Fraxinus latifolia* and Poaceae remained high through the zone. The average herbaceous charcoal content was low for this zone (3.6%), which implies that mostly woody material was burned.

Zone LO05A-3 (ca. AD 1700 - 2005): This zone records almost no fire activity near the site. Charcoal concentration remained near zero, and although charcoal influx varied greatly, it was still low. For the first time in the record, charcoal influx values of zero were recorded starting at ca. AD 1740. The average herbaceous charcoal content of the zone was higher than the previous two zones (10.6%), indicating that a greater proportion of herbaceous charcoal was burned. The lack of fire activity near the site after ca. AD 1700 evidently led to a major shift in the vegetation. Coniferous taxa, such as *Pseudotsuga* and *Thuja*, increased in abundance again at this time, while herbaceous taxa, such as Poaceae, *Polystichum*, *Pteridium*, *Rumex*, and *Plantago*, all generally decreased from the beginning to the end of the zone. *Alnus rubra* continued to be a major forest component. Decreased percentages of *Pseudotsuga*-type and *Thuja*-type after ca. AD 1840 are the result of logging near the lake. The pollen assemblage at ca. AD 1851 is consistent with the GLO map of this area (Fig. 4.4b), which indicates a mixture of closed upland forest and oak woodland.

Beaver Lake, OR

The Beaver Lake charcoal and pollen record was divided into pre- and postsettlement zones (Fig. 4.7). **Zone BL05B-1 (ca. AD 1460 – 1830):** This zone records little fire activity near the site. Charcoal concentration and influx values remained low in

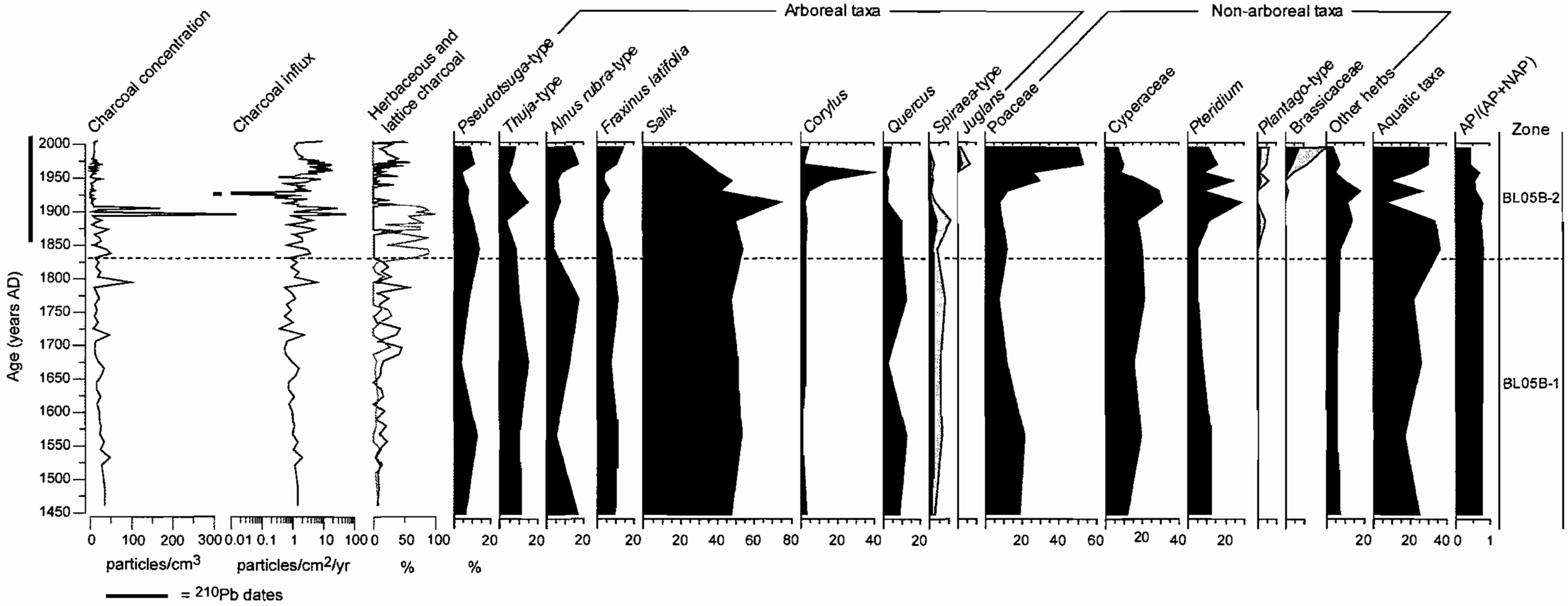


Figure 4.7. Beaver Lake (BL05B) charcoal concentration (particles/cm^3/yr), total charcoal influx (particles/cm^2; ticks to the left of the curve represent zero values), herbaceous charcoal (%; black line) and lattice charcoal (%; gray line), selected pollen percentages (gray curves represent a 3X exaggeration of solid curve), and AP/NAP ratio plotted against age (AD). The vertical black bar to the left of the age axis represents the age range of the ^{210}Pb dates.

this zone and the vegetation remained relatively constant. *Salix*, *Alnus rubra*, and *Fraxinus latifolia* dominated the local riparian shrubland and *Pseudotsuga* and *Thuja* probably grew in nearby upland closed forests, while *Corylus*, *Quercus*, *Spiraea*, Poaceae, Cyperaceae, and *Pteridium* grew in surrounding savanna and prairie.

Zone BL05B-2 (ca. AD 1830 – 2005): This zone records the impact of Euro-American settlement and land clearance near the site. Starting as early as ca. AD 1830, the fire regime at Beaver Lake changed drastically. Charcoal influx became much more variable and higher charcoal concentration values were recorded. Fire activity at the beginning of this zone was probably the result of local land clearance and produced a high proportion of a different type of charcoal (i.e., lattice charcoal, which was not identified as either woody or herbaceous) than the fire activity of the previous 350 years. The vegetation also changed dramatically near Beaver Lake following settlement. *Salix* and Cyperaceae increased in abundance initially at ca. AD 1900, but then sharply decreased over the next 100 years. *Pseudotsuga*, *Thuja*, *Alnus rubra*, *Fraxinus latifolia*, *Quercus*, and *Spiraea* all decreased in abundance after settlement, although some taxa have rebounded in recent years (e.g., *Pseudotsuga*, *Alnus rubra*, and *Fraxinus latifolia*). Higher *Pteridium* percentages after ca. AD 1850 probably indicate a more open landscape near the site, which is further supported by the drop in the AP/NAP ratio. The sharp increase in Poaceae pollen at ca. AD 1930 recorded the conversion of the region to an intensely cultivated grass landscape. Herbaceous charcoal content also increased greatly at this time. From AD 1960 – 2005, the average was 23%, with some values as high as 58%, and a large percentage of the charcoal reaching the lake today is from the burning of nearby grass fields. A large peak in *Corylus* pollen at ca. AD 1950 indicates the intensification of hazelnut farming near the site (O'Connor, 2006). Several other postsettlement ornamental/cultigen taxa were recorded after ca. AD 1850, including Brassicaceae (mustard family), *Juglans* (walnut), and *Plantago*-type (plantain, probably the non-native *Plantago lanceolata* [English plantain]).

Porter Lake, OR

The Porter Lake charcoal and pollen record was divided into pre- and postsettlement zones (Fig. 4.8). **Zone PL05C-1 (ca. AD 1730 – 1830):** This zone records little fire activity near the site, indicated by low charcoal concentration values. The average herbaceous content of this zone was relatively high (55%), suggesting that mostly herbaceous material was burned. The vegetation remained fairly stable during this zone and validates the ca. 1851 GLO map of the area surrounding Porter Lake (Fig. 4.3c), which suggests that riparian shrubland and oak savanna surrounded the site at the time of settlement. Relatively high percentages of *Alnus rubra*-type, *Fraxinus latifolia*, *Salix*, and *Populus trichocarpa*-type indicate that these taxa dominated the local riparian shrubland, as well as the larger tracts of nearby riparian forest. Relatively high percentages of *Quercus* and *Corylus* indicate that extensive oak savanna surrounded the site. Poaceae and *Pteridium* were probably common in the understory of the savanna but may have also come from nearby prairie. *Pseudotsuga*-type, *Thuja*-type, and *Pinus* percentages likely reflect nearby upland closed forest not shown on the GLO map.

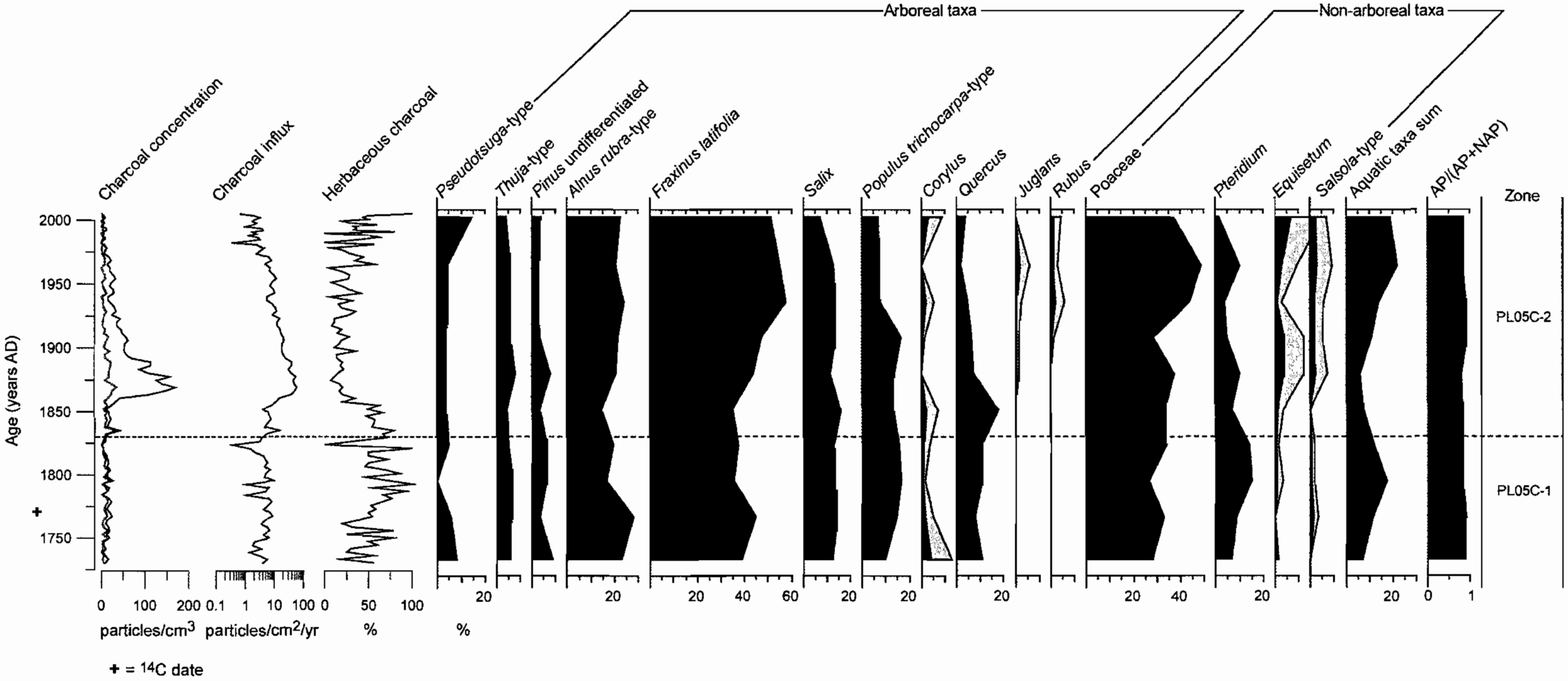


Figure 4.8. Porter Lake (PL05C) charcoal concentration (particles/cm^3/yr; black line = total charcoal, gray line = herbaceous charcoal), total charcoal influx (particles/cm^2), herbaceous charcoal (%), selected pollen percentages (gray curves represent a 3X exaggeration of solid curve), and AP/NAP ratio plotted against age (AD). The + symbol to the left of the age axis represents the age of the AMS ^{14}C date.

Zone PL05C-2 (ca. AD 1830 – 2005): This zone records the impact of Euro-American land clearance for agriculture near the site. After ca. AD 1830, charcoal concentration and the influx values greatly increased in the Porter Lake record. High charcoal concentration values between ca. AD 1860-1920 probably indicate several decades of burning related to local land clearance (Morris, 1934). The average herbaceous charcoal content of this period was 18%, suggesting that a greater proportion of woody material burned as compared to Zone PL05C-1. After ca. AD 1920, charcoal concentration and influx decreased toward present. Today, very little charcoal accumulates in the lake, and the majority of it is herbaceous charcoal (average of 39% since AD 1960), most likely from the burning of nearby grass fields. This is consistent with the rise in Poaceae pollen after ca. AD 1915. Also notable is the increase in *Fraxinus latifolia* after ca. AD 1850, as other riparian trees, such as *Salix* and *Populus trichocarpa*, decreased. Decreased percentages of *Quercus* and *Corylus* after ca. AD 1950 indicate the loss of nearby savanna, although *Corylus* has increased in recent decades (again, probably due to hazelnut farming near the site). *Alnus rubra* and *Equisetum* both increased in abundance after ca. AD 1850 and indicate increased disturbance near the site. Other invasive and exotic species found in the record after AD 1850 included *Juglans* and *Rubus*, and increased percentages of nonnative *Salsola*-type (Russian thistle).

Warner Lake, OR

The Warner Lake charcoal and pollen record was divided into four zones (Fig. 4.9). **Zone WL04A-1 (ca. AD 1075 – 1350):** This zone records relatively little fire

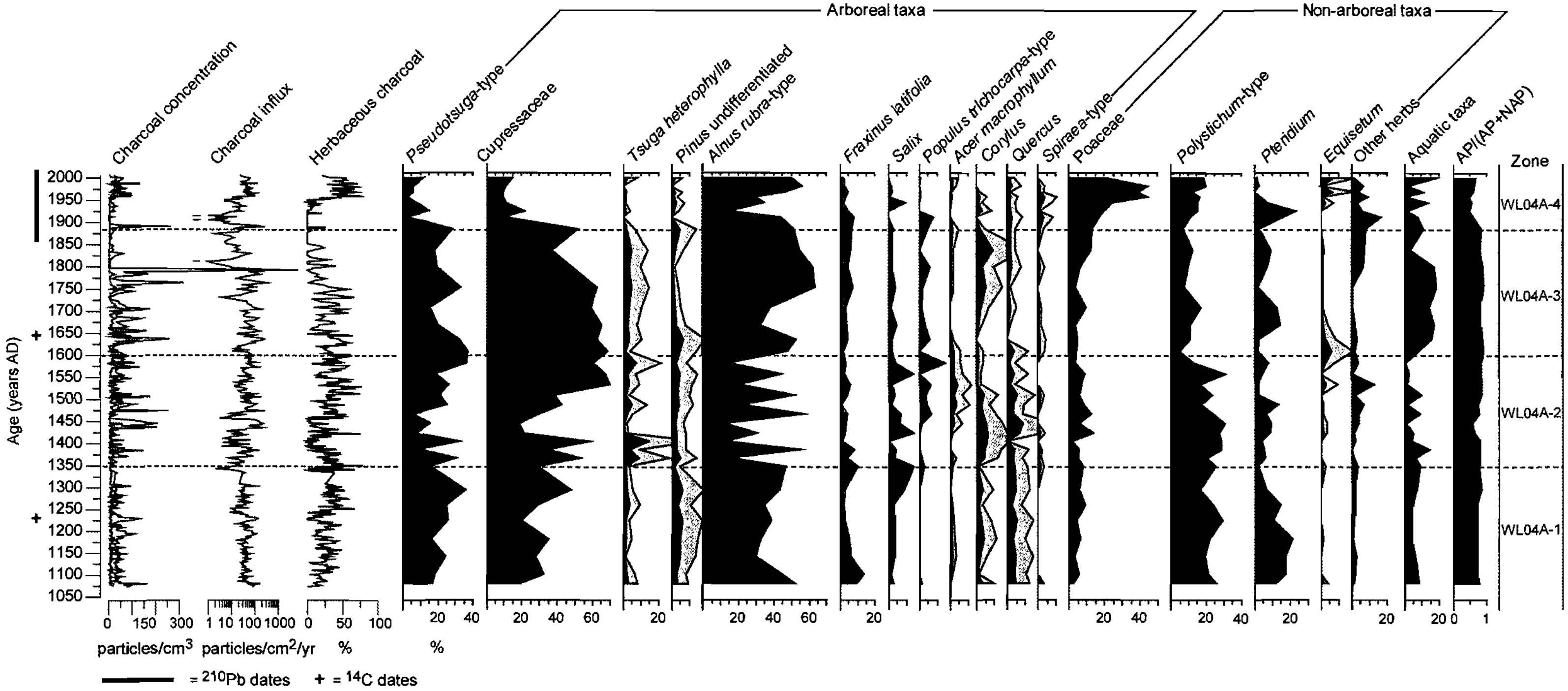


Figure 4.9. Warner Lake (WL04A) charcoal concentration (particles/cm^3/yr; black line = total charcoal, gray line = herbaceous charcoal), total charcoal influx (particles/cm^2; ticks to the left of the curve represent zero values), herbaceous charcoal (%), selected pollen percentages (gray curves represent a 3X exaggeration of solid curve), and AP/NAP ratio plotted against age (AD). The vertical black bar to the left of the age axis represents the age range of the ^{210}Pb dates and the + symbol represents the age of the AMS ^{14}C dates.

activity near the site. Charcoal concentration values and charcoal influx variability were generally low compared to later in the record, but the average herbaceous charcoal content was relatively high (26%). The pollen assemblage of this zone suggests that *Pseudotsuga*, Cupressaceae, and *Alnus rubra* were the major components of the local forest, with Poaceae, *Polystichum*, and *Pteridium* dominating the understory. *Tsuga heterophylla*, *Pinus*, and *Acer macrophyllum* were also present in the forest in lower abundance, and *Fraxinus latifolia* and *Salix* grew near the edge of the lake. *Corylus* and *Quercus* likely grew in nearby oak woodland and savanna. *Alnus rubra* and herbs such as Poaceae, *Polystichum*, and *Pteridium* were probably common in the fire-created openings in the forest.

Zone WL04A-2 (ca. AD 1350 – 1600): This zone is characterized by greater fire activity than the previous zone. Higher charcoal concentration values were recorded and charcoal influx variability increased. The average herbaceous charcoal content also increased from the previous zone to 29%. Highly variable percentages of *Alnus rubra*-type, generally decreased percentages of *Pseudotsuga*-type, Cupressaceae, and *Tsuga heterophylla*, increased percentages of herbaceous taxa such as Poaceae and *Polystichum*-type, and a generally lower AP/NAP ratio in this zone, suggest a loss of forest cover and a more open environment near the site (i.e., more prairie and oak savanna). Riparian taxa percentages also increased in this zone, including *Salix* and *Populus trichocarpa*-type, as well as *Acer macrophyllum*, *Corylus*, *Quercus*, and *Spiraea*-type.

Zone WL04A-3 (ca. AD 1600 – 1880): This zone records a large shift in fire activity. Charcoal concentration values generally increased until ca. AD 1800 and charcoal influx variability was even greater than the previous zone. After ca. AD 1800, however, charcoal concentration values dropped to near zero and influx variability increased even further, recording zero values for the first time in the record. The average herbaceous charcoal content for this zone decreased to 24%. The pollen assemblage of this zone is similar to Zone WL04A-1 and suggests that the local forest was dominated by *Pseudotsuga*, Cupressaceae, and *Alnus rubra*, with *Tsuga heterophylla* and *Pinus*. Decreased percentages of *Corylus*, *Quercus*, and many other herbs, as well as an increase in the AP/NAP ratio, indicates that oak woodland/savanna and prairie decreased near the site at the beginning of this zone. However, increased *Corylus* percentages after ca. AD 1700 suggest its importance as a member of the local forest understory. The pollen assemblage of this zone is consistent with the ca. AD 1851 GLO map, which indicates that the site was surrounded by an upland closed conifer-dominated forest, but oak woodland/savanna and prairie existed nearby.

Zone WL04A-4 (ca. AD 1880 – 2004): This zone is characterized by steep declines in percentages of most arboreal taxa, including *Pseudotsuga*-type, Cupressaceae, *Tsuga heterophylla*, *Pinus*, *Alnus rubra*-type, *Fraxinus latifolia*, *Populus trichocarpa*-type, *Acer macrophyllum*, and *Corylus*, most likely associated with logging in the Warner Lake watershed. Sharp increases first in *Pteridium*, *Polystichum*-type, and other herbs, as well as a drastic drop in the AP/NAP ratio, indicate the loss of forest near the site. The generally high abundance of *Alnus rubra*, *Polystichum*, and *Equisetum* after ca. AD 1900 suggests that disturbance remained frequent near the site, probably as a result of continued logging in the watershed. High charcoal concentration values occurred at ca.

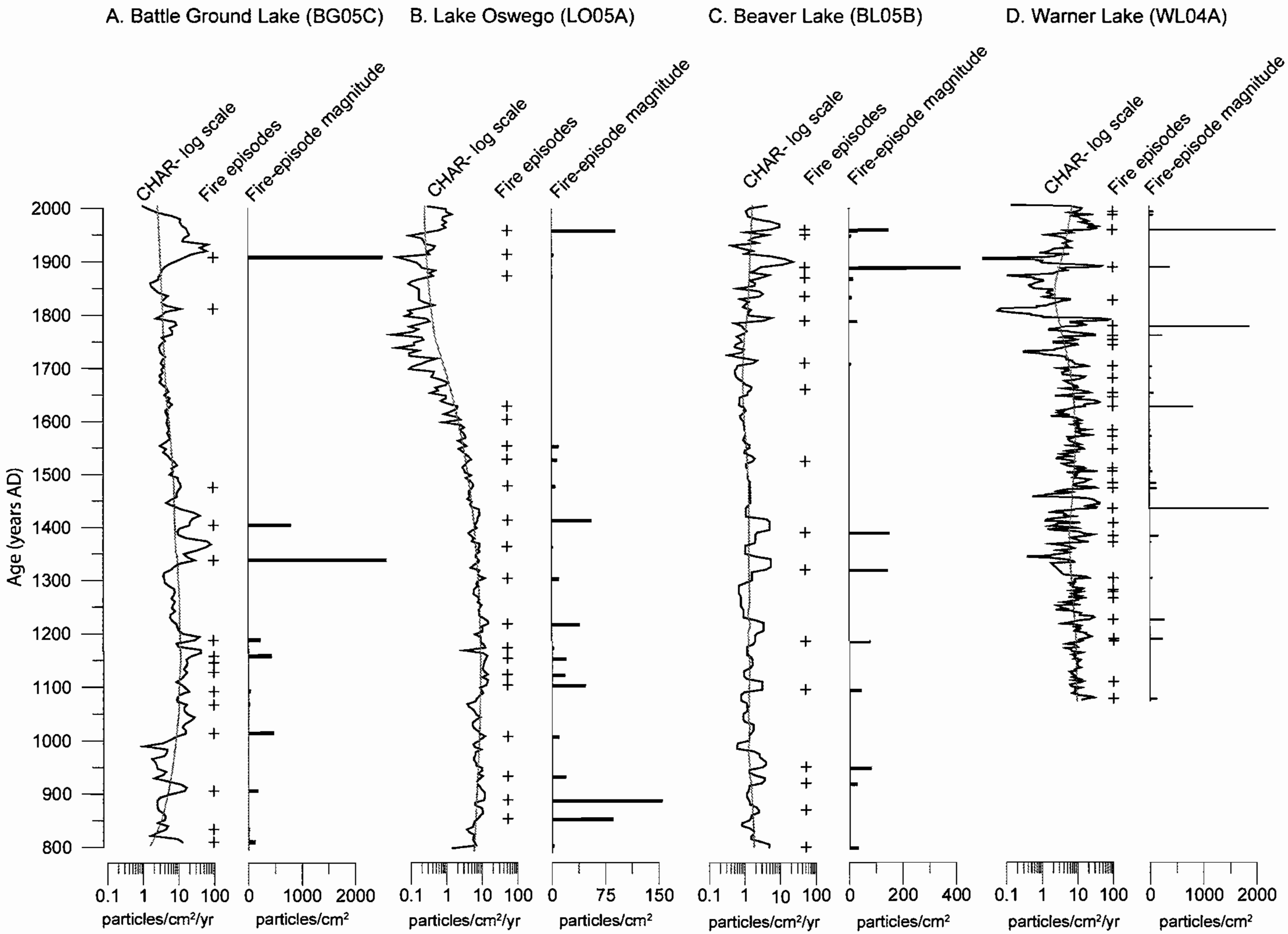
AD 1890 in association with logging and slash pile burning (Agee, 1989). The average herbaceous charcoal content was only 3% between ca. AD 1880-1950, which suggests that mostly woody material was burning. Charcoal concentration and influx remained low between ca. AD 1900-1950, but then increased and remain relatively high at present. This increase was coincident with a rise in herbaceous charcoal (average of 45% after AD 1950) and Poaceae pollen, suggesting that the likely source of the charcoal is from grass fires on the valley floor and foothills.

Fire Episode Reconstruction

Decomposition of the charcoal records from Battle Ground Lake (BG05C), Lake Oswego (LO05A), Beaver Lake (BL05B), and Warner Lake (WL04A) indicate fire-episode occurrence and magnitude over the last 1200 years (Fig. 4.10). Years of fire episodes discussed below are the beginning of a charcoal peak in the record. Analysis of the charcoal record from Battle Ground Lake indicates that 15 fire episodes occurred over the last 1200 years. In general, fires were more frequent between ca. AD 800-1200 (10 fire episodes), but were small-to-moderate in magnitude. After that, fires decreased in frequency, but increased in magnitude. Between ca. AD 1300-2005, only five fire episodes occurred, three of which were the largest magnitude fires of the record (ca. AD 1340, 1400, and 1910). No fire episodes occurred between ca. AD 1500-1800.

The charcoal reconstruction from Lake Oswego indicates that 20 fire episodes occurred during the last 1200 years. Fires were more frequent before ca. AD 1630, with 17 of the 20 fire episodes of the record occurring during this time. In general, larger

Figure 4.10. Charcoal accumulation rate (CHAR-log scale) (particles/cm^2/yr), fire episodes (+ symbols), and fire-episode magnitude for (A) Battle Ground Lake (BG05C), (B) Lake Oswego (LO05A), (C) Beaver Lake (BL05B), and (D) Warner Lake (WL04A) plotted against age (yr AD).


A. Battle Ground Lake (BG05C)
B. Lake Oswego (LO05A)
C. Beaver Lake (BL05B)
D. Warner Lake (WL04A)
CHAR- log scale
Fire episodes
Fire-episode magnitude
Age (years AD)
2000
1900
1800
1700
1600
1500
1400
1300
1200
1100
1000
900
800
0.1
1
10
100
0
1000
2000
75
150
200
400
particles/cm²/yr
particles/cm²

magnitude fire episodes occurred prior to ca. AD 1425 and smaller ones between ca. AD 1425-1630. No fire episodes occurred between ca. AD 1630-1870. Three fire episodes occurred after this time, at ca. AD 1875, 1915, and 1960. The ca. AD 1875 and 1915 fires were small-magnitude events, but the ca. AD 1915 fire episode was larger.

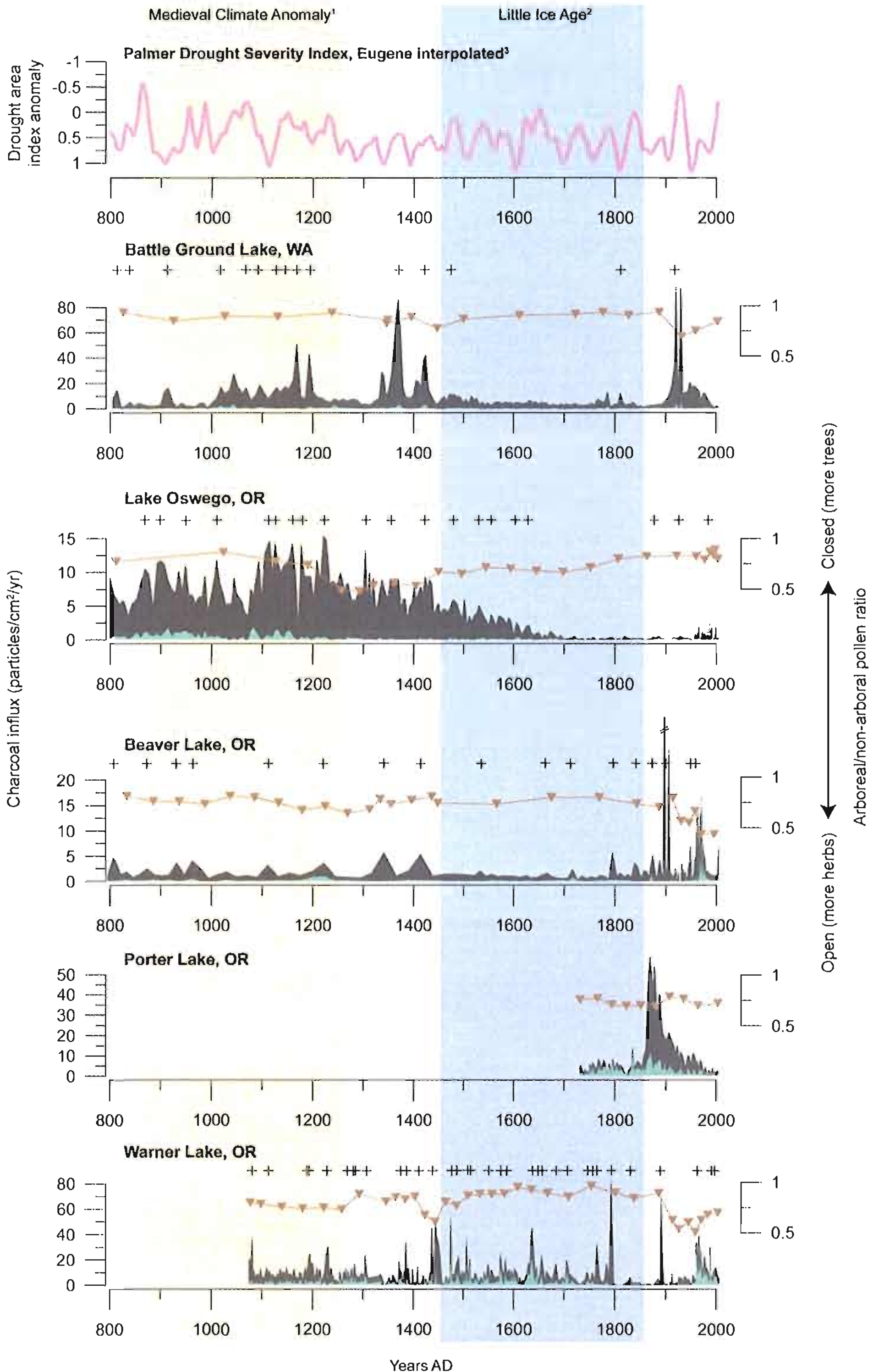
The fire-history reconstruction from Beaver Lake indicates that 17 fire episodes occurred over the last 1200 years. Eight fires occurred between ca. AD 800-1400 and were relatively moderate in magnitude, with the greatest magnitude fire episodes at ca. AD 1320 and 1390. Six fire episodes occurred between ca. AD 1400-1870 and were small magnitude events. The largest-magnitude fire episode of the record occurred at ca. AD 1890, followed by two smaller events at ca. AD 1950 and 1960.

The Warner Lake fire-history reconstruction indicates that 34 fires occurred over the last 950 years. Eleven fire episodes occurred prior to ca. AD 1400 and were generally small magnitude. Eighteen fire episodes occurred between ca. AD 1400-1800 and ranged widely from small- to large-magnitude. Two especially large fires were recorded at ca. AD 1436 and 1780. Five fire episodes have occurred since ca. AD 1800 and again, vary widely from small- to large-magnitude, with the two largest at ca. AD 1890 and 1960.

Discussion

Charcoal influx values, fire episodes, and AP/NAP ratios from the five study sites were compared in order to assess the pre- to postsettlement landscape of the Willamette Valley (Fig. 4.11). Charcoal composition (Figs. 4.5-4.9) and fire-episode magnitude (Fig. 4.10) were evaluated in tandem as indicators of fire size/severity. AP/NAP ratios

Figure 4.11. Charcoal influx (total= black curve; herbaceous= green curve), fire episodes (+ symbols), and AP/NAP ratios (brown lines with ▼ symbols) for the five study sites arranged from north (top) to south (bottom) plotted against age (yr AD). The placement of the fire episode symbols has been adjusted to illustrate the mid-point of the charcoal peaks. A portion of the Battle Ground Lake AP/NAP ratio curve was correlated based on age from core BG80B (Whitlock, 1992; see Chapter II) and a portion of the Beaver Lake AP/NAP ratio curve was correlated based on age from core BL93A (Pearl, 1999; see Chapter III). Palmer Drought Severity Index (Cook et al., 2004) interpolated to Eugene, OR, is also shown (purple line). This was calculated with a Lowess curve using the loess () function in R with a span equal to 0.025. Negative values indicate drier conditions and positive values indicate wetter conditions. The vertical orange shading represents the approximate years of the Medieval Climate Anomaly (ca. AD 850-1250; Mann, 2002) and the vertical blue shading represents the approximate years of the Little Ice Age (ca. AD 1450-1850; Grove, 2001).



¹Mann (2002)
²Grove (2001)
³Cook et al. (2004)

were used as an indicator of openness in the upland vegetation as a result of disturbance (Fig. 4.11). The results were interpreted within the framework of known climatic events and cultural records of human habitation and activity. The Palmer Drought Severity Index (Cook et al., 2004) was used to characterize the climate of the region over the last 1200 years and highlight moisture availability during the Medieval Climate Anomaly and the Little Ice Age (Fig. 4.11). The comparison of the location of the study sites in proximity to know cultural sites helped address potential human influences on the fire and vegetation reconstructions (Fig. 4.12). Additional consideration was given to the interplay between climatic variability, landscape change, and resource availability.

The Presettlement Landscape of the Willamette Valley (ca. AD 800 - 1830)

Reconstructions from the five study sites reveal presettlement similarities in fire activity across the Willamette Valley. Prior to ca. AD 1450, Battle Ground Lake, Lake Oswego, and Beaver Lake recorded relatively high fire activity (Fig. 4.11). Fires were relatively frequent at all of these sites during this period; however, the effects of fire episodes on the vegetation varied. At Battle Ground Lake, generally small, low- to moderate-severity fire episodes prior to ca. AD 1200 seem to have had little impact on the surrounding forest, but two larger, higher-severity fires at ca. AD 1340-1400 briefly opened the landscape for the next approximately 100 years. At Lake Oswego, relatively frequent, moderate-severity fires between ca. AD 1100-1400 led to a shift from a relatively closed forest dominated by *Pseudotsuga*, *Thuja*, and *Alnus rubra* to an open

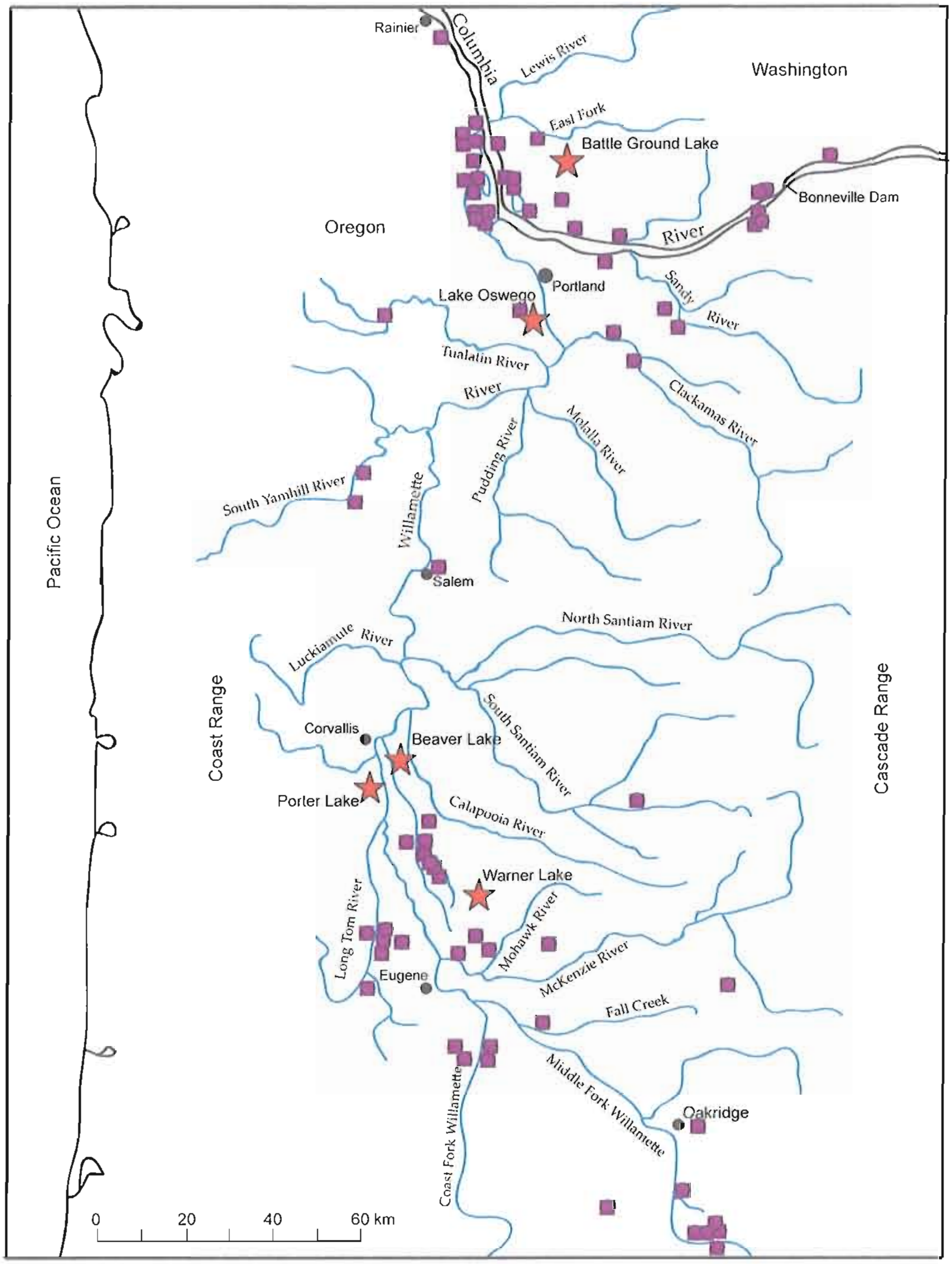


Figure 4.12. Map of Willamette Valley late Holocene and historic archaeological sites (purple squares) in relationship to lake-sediment study sites (orange stars). Adapted from Pettigrew (1990); other sources: Burnett (1995); O'Neill et al. (2004).

landscape dominated by herbaceous taxa, such as Poaceae, *Polystichum*, and *Pteridium*. Similarly at Beaver Lake, relatively frequent, low- to moderate-severity fires before ca. AD 1400 maintained openness near the site, although the impact was less than at Lake Oswego.

The Battle Ground Lake, Lake Oswego, and Beaver Lake fire histories are also alike in that they record a general drop in fire activity after ca. AD 1450, but again, the effects that this had on the vegetation varied. Few fires occurred at Battle Ground Lake after ca. AD 1450 and the vegetation at the site remained generally unchanged. At Lake Oswego, fires continued to occur until ca. AD 1630, but greatly decreased in severity over that time. The vegetation at the site responded to the lower fire activity by steadily increasing forest cover. Lower-severity fire episodes than before also continued to occur at Beaver Lake after ca. AD 1450, but the vegetation remained generally unchanged.

The fire activity trends illustrated in the Willamette Valley reconstructions are generally similar to tree-ring-based fire-history records from the Pacific Northwest. Weisberg and Swanson (2003) suggest that burning was relatively widespread before ca. AD 1650. This is consistent with the records from Battle Ground Lake, Lake Oswego, and Beaver Lake; however, their findings suggest that this period of high fire activity lasted until later than indicated by the Battle Ground record (which lasted until ca. AD 1475), but is consistent with the sharp decline in fire activity at Lake Oswego at ca. AD 1650. The remainder of the presettlement fire reconstructions from Battle Ground Lake, Lake Oswego, Beaver Lake, and the short presettlement record from Porter Lake is also consistent with their findings of reduced burning between ca. AD 1650-1800.

Centennial-scale climate change may help explain the fire histories of the Willamette Valley. The relatively high fire activity at Battle Ground Lake, Lake Oswego, and Beaver Lake between ca. AD 850-1250 (Fig. 4.11) may be the result of increased aridity during the Medieval Climate Anomaly (Cook et al., 2004). Only at Battle Ground Lake and Lake Oswego was the number of fire episodes during the Medieval Climate Anomaly greater than the number of fire episodes during the Little Ice age, but at all three sites, fire-episode size/severity was much greater/higher. The subsequent reduction in fire activity at Battle Ground Lake, Lake Oswego, and Beaver Lake after ca. AD 1450 could be the result of regionally cooler temperatures and greater precipitation (Graumlich and Brubaker, 1986; Cook et al., 2004) during the Little Ice Age (AD 1450-1850; Grove, 2001). At all three sites, fire episodes were infrequent and/or low severity during this time. For example, only two fire episodes occurred at Battle Ground Lake during the Little Ice Age and both were extremely small/low-severity. Fire episodes at Lake Oswego greatly decreased in size/severity after ca. AD 1450 and did not occur between ca. AD 1630-1870. And although fires continued to occur at Beaver Lake during the Little Ice Age, they were all small/low-severity events.

Climate change, however, does not explain the record from Warner Lake, which indicates that fire episodes were generally less frequent between ca. AD 1075-1400, but then increased in frequency and size/severity until ca. AD 1800. It is possible that the higher elevation of Warner Lake (590 m a.s.l.) led to more frequent lightning ignitions than on the valley floor. The National Interagency Fire Center suggests that lightning-fire ignition rates for the Willamette National Forest were 43 lightning fires/400,000 ha/yr for the period of 1970-2002, or 0.0001075 lightning fires/ha/yr (reported in Kay, 2007), and Day (2005) reported seven lightning-fire ignitions at Jim's Creek, a 276 ha former savanna in the Willamette National Forest (approximate elevation 850 m) since 1970. This suggests that lightning strikes are not uncommon in the lower Cascade foothills. However, if lightning was the primary ignition source for fires at Warner Lake, then fire-episode frequency should have decreased during the Little Ice Age when effective moisture was greater.

Anthropogenic burning may help explain the elevated fire activity at Warner Lake as compared to the other Willamette Valley sites. Cultural records suggest relatively large populations inhabited the valley prior to Euro-American contact and that settlement patterns were heterogeneous and determined by resource availability (Boyd and Hajda, 1987; O'Neill et al., 2004). There is no archaeological evidence from the Warner Lake watershed (Fig. 4.12), but it seems likely that this forest-savanna-prairie ecotone was visited at least seasonally by Native Americans. The elongated territories of the Kalapuyans extended into the Coburg foothills of the Coast Range (Zenk, 1990), and Warner Lake may have offered important summer resources since lakes and perennial streams are somewhat rare in this area. Higher fire frequency between ca. AD 1350-1800 (Fig. 4.11) may have been an attempt to increase openness near the site since burning would have encouraged the growth of important food resources. The shift in the fire regime at Warner Lake at ca. AD 1800 coincides well with the timing of Native American population decline in the valley suggested by Boyd (1990), and may explain the greatly decreased fire activity after ca. AD 1790. Additional archaeological and fire-history records from the foothills of the Oregon Coast Range are needed to substantiate this hypothesis.

Native American use of fire may also help explain why fire histories are different between valley-floor sites. At Battle Ground Lake, the *Pseudotsuga/Thuja* forest of the late Holocene (see Chapter II) was probably relatively unimportant in terms of resource availability and likely explains why no archaeological evidence of Native American activity has been found in the Battle Ground Lake crater (Fig. 4.12). *Camassia* grew at the site in early Holocene, and in the late Holocene, it probably grew in nearby prairies and oak savannas (Boyd and Hajda, 1987). These surrounding environments may have been burned regularly (Leopold and Boyd, 1999), but such fires were not reflected in the Battle Ground Lake charcoal record. In addition, the lake did not contain fish until it was stocked in ca. AD 1900 (Allworth, 1976). The relative lack of resources at Battle Ground Lake and the fact that the fire-history reconstruction correlates well with known climatic shifts during the last 1200 years suggests little presettlement human influence at the site.

In contrast, sites farther south in the Willamette Valley may have experienced a greater human influence. Archaeological evidence from Lake Oswego suggests human occupation at the site between ca. 6000-300 years ago (Fig. 4.12) (Burnett, 1995), and historical records indicate that the Clackamas (considered to be part of the Chinook tribal group) probably lived in fairly permanent dwellings near the site prior to Euro-American settlement (Ruby and Brown, 1986; Pettigrew, 1990). Kalapuyan tribes also may have seasonally migrated to the lake to take advantage of the abundance of root crops, fish, and waterfowl (Kohnen, 2008). Frequent anthropogenic burning, enabled by the warmer and drier climate of the Medieval Climate Anomaly, probably explains the high fire activity at Lake Oswego before ca. AD 1450. Burning continued near Lake Oswego into the Little Ice Age, when cooler and wetter conditions than today would have suppressed naturally-ignited fires, although fire-episode size/severity did decrease during this time. The drop in fire activity starting at ca. AD 1450 and the lack of fire episodes between ca. AD 1630-1870 may indicate human abandonment of the Lake Oswego area due to drastic declines in Native American populations associated with Euro-American contact (Boyd, 1990), but it could also be the result of the climatic conditions of the Little Ice Age. However, given the fact that fire activity had all but ceased by ca. AD 1700, which is the same time that humans are suspected to have abandoned the area (Burnett, 1995), a human-related explanation seems more likely. Either way, the fire history from Lake Oswego indicates that the upland closed forest and oak woodland that surrounded the site at the time of Euro-American settlement had not burned in more than 200 years.

O'Neill et al. (2004) suggest that seasonally inundated, fluvial areas (i.e., river and stream edges and floodplains) were the focus of land and resource use in the central and lower Willamette Valley due to the abundance of *Camassia* and other wetland staples and the relative ease of harvesting these plants from the soft soil as compared to more dense upland soils. Bowden (1995) argues that the late-Holocene inhabitants of the lower Willamette Valley relied heavily on the harvesting of *Camassia* as a food source, and its distribution and abundance determined the location of settlements and duration of occupation throughout the year. Relatively abundant archaeological evidence (i.e., mounds containing artifact assemblages and human burial remains; see Bowden, 1995) near Beaver Lake suggests hunting and gathering activities took place near the site (Fig. 4.12). Because fire was used for such activities (Boyd, 1999), human-set fires are likely part of the charcoal record. Increased fire activity at Beaver Lake throughout the middle and late Holocene until ca. AD 1450 (see Chapter III) indicates that this area may have been intensely used as a resource base for several thousand years. The reduction in fire activity after ca. AD 1450 may have been caused by cooler conditions associated with the Little Ice Age; however, it could also be the result of human abandonment of the area.

The Postsettlement Landscape of the Willamette Valley (ca. AD 1830 - Present)

The fire and vegetation reconstructions from the five study sites reveal the nature and magnitude of landscape change experienced in the Willamette Valley since Euro-American settlement. Battle Ground and Warner lakes recorded concurrent logging and burning activities in the local watersheds (ca. AD 1890-1910), which were expressed by the large drops in AP/NAP ratios associated with high-severity fire episodes. Beaver and Porter lakes also recorded major postsettlement fire episodes (ca. AD 1880-1890) as a result of burning associated with land clearance for agriculture. The anomalous increase in AP/NAP ratios at Porter Lake at ca. AD 1900 probably reflects a reduction in the extent of prairie, as this land was most highly prized for settlement and agriculture (Bowen, 1978). The fire records from Battle Ground, Beaver, Porter, and Warner lakes are somewhat consistent with the findings of Weisberg and Swanson (2003) (who identified a second period of widespread fire from ca. AD 1800–1925), but indicate that fires associated with Euro-American settlement were greatest at the turn of the 20th century.

The exception to this trend is Lake Oswego, where only a small Euro-American settlement signal was recorded. The persistently high AP/NAP ratios, which unlike the Battle Ground Lake, Beaver Lake, and Warner Lake records, do not show the effects of logging in the watershed, are probably a result of the changes that occurred when the Tualatin River was diverted into the lake (AD 1863). This would have greatly increased the source area from which pollen was accumulating and may have masked the local vegetation signal. The fire-history reconstruction does record a small/low-severity fire episode at ca. AD 1875, which likely came from burning associated with an iron blast furnace that operated with limited success near the lake between ca. AD 1865-1884 and was powered by charcoal produced from local timber (Minor and Kuo, 2008).

Few fires occurred in the Willamette Valley after ca. AD 1930, which likely indicates the effectiveness of fire suppression efforts (Morris, 1934). Two fire episodes that occurred at Beaver Lake and three at Warner Lake after ca. AD 1950 were probably grass fires, given the high proportion of herbaceous charcoal. One fire episode also occurred at Lake Oswego and although it did not have a high proportion of grass charcoal, the timing (ca. AD 1960) suggests that it was related to agricultural activities.

Conclusions

The presettlement vegetation and fire regimes of the Willamette Valley were influenced by a combination of natural and anthropogenic factors. Some sites show a stronger influence from climate, whereas others were more impacted by human activity. Resource availability, which probably to a great extent determined human habitation patterns in the valley, likely explains why some sites were maintained by Native American fires and others were not. For example, Battle Ground Lake near the northern end of the valley had few important resources and remained forested up to Euro-American time. This consideration, as well as evidence that changes in the charcoal record corresponded well with known climatic shifts, suggests that human ignitions contributed little if at all to the presettlement fire regime. On the other hand, the location of Beaver Lake in a seasonally inundated area of the valley that provided abundant food resources was more likely to have been subjected to anthropogenic fires. Human-set fires near Lake Oswego also seem to be the best explanation for the observed changes in the fire and vegetation history. However, fires may have been modulated by changes in regional climate during the Medieval Climate Anomaly and the Little Ice Age. Finally, all four valley-floor fire reconstructions, including the short presettlement record from Porter Lake, imply that fires in Willamette Valley, whether the result of climate or human activities, were small/low-severity and infrequent in the 200-300 years prior to Euro-American settlement. The presettlement record from Warner Lake, however, indicates that fires in the foothills of the Cascade Range were much larger/more severe and more frequent than on the valley floor, at least until ca. AD 1800. This may be the result of anthropogenic burning near the site and its cessation as a result of Native American population decline resulting from introduced disease (Boyd, 1990)

The postsettlement portions of the reconstructions indicate that the impacts of Euro-American settlement in the Willamette Valley were relatively synchronous between the five study sites. With the exception of Lake Oswego, high-severity fire(s) occurred between ca. AD 1880-1910. In addition, the most dramatic shifts in vegetation occurred in association with Euro-American land clearance for agriculture and logging. As a final point, the postsettlement records from the five study sites indicate that few fires in the Willamette Valley have occurred since ca. AD 1930, and fires today are predominantly grass fires.

CHAPTER V

SUMMARY

In this dissertation I examined the fire and vegetation history of the Willamette Valley using high-resolution macroscopic charcoal and pollen analysis. Paleoecological records were evaluated from five study sites located in different ecological settings, including closed upland forest, former oak savanna and prairie, and riparian forest. The goal of this research was to provide information on the environmental history of the region and to determine the relative role of natural and anthropogenic factors in shaping past and present landscapes. Two time scales of investigation were used, one spanning the Holocene, and the other focused on the last 1200 years. The results from this study inform our understanding of fire-vegetation-climate-human relationships on multiple spatial and temporal scales, and suggest that both climate and humans influenced the fire regimes and vegetation patterns of the Willamette Valley.

The paleoecological record from Battle Ground Lake suggests that fire regimes varied greatly during the Holocene and that fire-vegetation-climate relationships differed depending upon the timescale of the investigation. On a millennial-scale, climate-induced vegetation shifts influenced fire activity through shifts in fire frequency, fire-episode magnitude, and fire size/severity throughout the late-glacial and Holocene. In the late-glacial period (ca. 14,300-13,100 cal yr BP) when conditions were cold and dry, *Pinus contorta/Picea*-dominated open forest or parkland experienced little fire activity and fire-episode magnitudes were low. In the transition from the late-glacial to the early

Holocene (ca. 13,100-10,800 cal yr BP), the vegetation shifted to a closed forest of mostly *Pseudotsuga* and *Abies*, and shortly after, fire frequency and fire-episode magnitude increased, suggesting a fire regime of relatively infrequent surface and understory fires. In the early Holocene (ca. 10,800-5200 cal yr BP) when greater summer insolation led to increased drought, *Quercus*-dominated savanna supported frequent surface fires, evidenced by an increased fire frequency, decreased fire-episode magnitude, and a greater proportion of herbaceous charcoal than before. Finally, during the late Holocene (ca. 5200 cal yr BP- present) when climatic conditions were becoming cooler and wetter, vegetation shifted to a closed forest dominated by *Pseudotsuga*, *Thuja*, and *Tsuga heterophylla*. Fire frequency dropped accordingly, but fire-episode magnitude generally increased, suggesting infrequent crown fires. The Battle Ground Lake reconstruction also provides evidence that shifts in fire regime lagged vegetation changes from a few decades to several hundred years, depending upon local fuel conditions and the presence of an ignition source.

A more direct relationship between fire and climate variability was observed at Battle Ground Lake on a centennial-scale. This was evidenced by higher fire frequency and a shift to smaller surface fires during the Medieval Climate Anomaly and a drop in fire frequency during the Little Ice Age. These regime shifts apparently occurred in the absence of major vegetation changes, probably a consequence of the long life span of conifers in the Pacific Northwest. Additionally, the Battle Ground Lake record provides no direct evidence that anthropogenic burning had any influence on the paleoecological history of the site prior to Euro-American settlement.

The Beaver Lake reconstruction also provides evidence of major shifts in vegetation and fire regimes in the Willamette Valley during the Holocene, although the driver of those changes is less clear than at Battle Ground Lake. In the early Holocene (ca. 11,000-7250 cal yr BP), the site supported a relatively xeric woodland of *Quercus*, *Corylus*, and *Pseudotsuga*; *Alnus rubra* grew disturbed areas. Fire frequency was highest between ca. 11,190-9300 cal yr BP, probably the result of warm dry climatic conditions. It decreased dramatically afterwards, possibly the result of cooler wetter conditions. At ca. 7250 cal yr BP, the vegetation at Beaver Lake shifted to more mesophytic taxa, including *Salix* and *Fraxinus* and members of the Poaceae family, indicating the establishment of riparian forest and wet prairie near the site. Also, the continued presence of *Quercus* and *Corylus* suggests that oak savanna grew on nearby on upland areas. These ecosystems persisted until Euro-American land clearance (ca. AD 1850), when most of the surrounding landscape was converted to agriculture.

Over the last ca. 8000 years, fire frequency at Beaver Lake increased. The relatively high levels of herbaceous charcoal throughout this interval suggest that these were predominantly surface fires occurring in nearby prairie. This increase took place in the absence of any additional major vegetation shifts and also occurred as the regional climate became cooler and wetter. Subsequent shifts in fire-episode magnitude and charcoal composition coincided with known cultural shifts (i.e., when populations became more sedentary due to the necessity of food storage), as indicated by the existence of middle and late Holocene archaeological sites near Beaver Lake. Native American activities probably contributed to the high levels of fire occurrence and helped maintain the wet prairie and oak savanna near the site, especially over the last 5000 years. However, the impact of shorter-scale climate variability (e.g., the Medieval Climate Anomaly and the Little Ice Age) is also evident in the fire-history record through changes in fire size/severity.

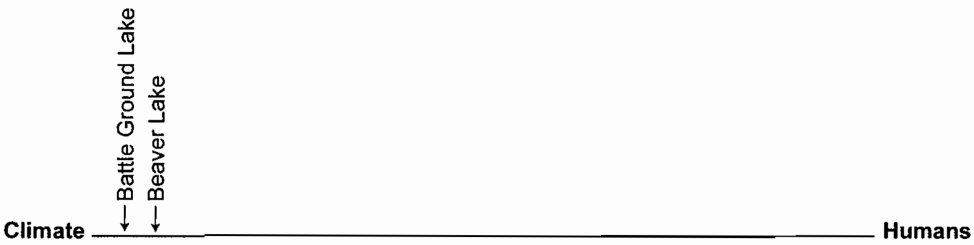
A comparison of paleoecological records from western Washington and Oregon provides context for the Battle Ground Lake and Beaver Lake reconstructions. Whereas major shifts in vegetation and fire regimes at Battle Ground Lake were similar in both timing and direction to several other sites, changes observed at Beaver Lake were relatively unique. This may be due the difference in the ecological settings of the study sites; Battle Ground Lake is located in an isolated remnant volcanic crater at the northern edge of the valley and Beaver Lake is located in an abandoned meander bend in the central valley. Human activity, which according to archaeological records, was focused on the valley floor in former oak savanna and prairie and may thus account for the increased fire frequency at Beaver Lake throughout the middle and late Holocene. This trend of increasing fire activity during the Holocene is opposite to that observed at Battle Ground Lake. It is possible that human-ignited fires contributed to the Battle Ground Lake record, especially in the early Holocene when more open xerophytic vegetation would have been favorable for Native American resource harvesting, but direct evidence does not exist to confirm this. The Battle Ground Lake and Beaver Lake reconstructions jointly suggest that the extent to which natural and anthropogenic factors influenced the fire and vegetation histories varied greatly between the two sites. More Holocene records are needed to assess valley-wide patterns.

The combined results from Battle Ground Lake, Lake Oswego, Beaver Lake, Porter Lake, and Warner Lake reveal that over last 1200 years, presettlement vegetation and fire regimes in the Willamette Valley were influenced by a combination of natural and anthropogenic factors. Battle Ground Lake, which remained forested over the last several thousand years, was more strongly influenced by climate. Seasonally inundated valley sites (i.e., Lake Oswego, Beaver Lake) were more influenced by human activity, but human-set fires were also modulated by climate variability. For example, at Lake Oswego and Beaver Lake, fire-episode frequency was higher and fire size/severity was greater during the Medieval Climate Anomaly as compared to the Little Ice Age. Additionally, the records from Battle Ground Lake, Lake Oswego, Beaver Lake, and Porter Lake imply that fires were infrequent in the 200-300 years prior to Euro-American settlement. In contrast, the presettlement record from Warner Lake indicates that fires were more frequent in the foothills of the Coast Range, at least until ca. AD 1800. The decline in fire activity at all of the sites sometime in the last 600 years indicates a cooling climate and declining Native American populations.

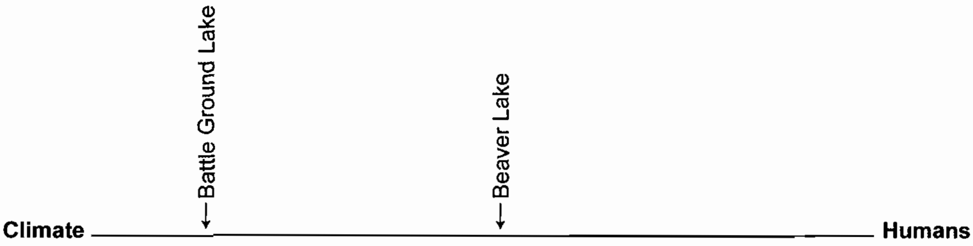
The postsettlement portions of the reconstructions illustrate the impact of Euro-American settlement in the Willamette Valley. The most dramatic shift in vegetation at Battle Ground Lake, Beaver Lake, Porter Lake, and Warner Lake occurred as a result of Euro-American land clearance for agriculture and logging, and all four sites recorded major fires between ca. AD 1890-1910 in association with these activities. Lake Oswego, however, experienced a drastic decline in fire activity earlier than the other sites, starting at ca. AD 1500, and displayed a smaller Euro-American signal in the fire and vegetation records. The postsettlement reconstructions from all of the sites indicate few fires in the Willamette Valley after ca. AD 1930, and fires today are predominantly grass fires.

The Willamette Valley sites can be arranged along a continuum between those mostly influenced by natural factors and those influenced by human activity (Fig. 5.1). Consequently, the answer to the question "were the presettlement vegetation patterns of the Willamette Valley the result of climate and other natural variations, Native American burning, or both?," is both, but the relative proportions of those influences vary depending upon the spatial and temporal scale of the investigation. For example, on a Holocene timescale, Battle Ground Lake seems to have been strongly influenced by variations in vegetation and climate (Fig. 5.1a). The same is true during the early Holocene at Beaver Lake, but not in the middle and late Holocene, when the site seems to have been more influenced by human activity (Fig. 5.1a and 5.1b).

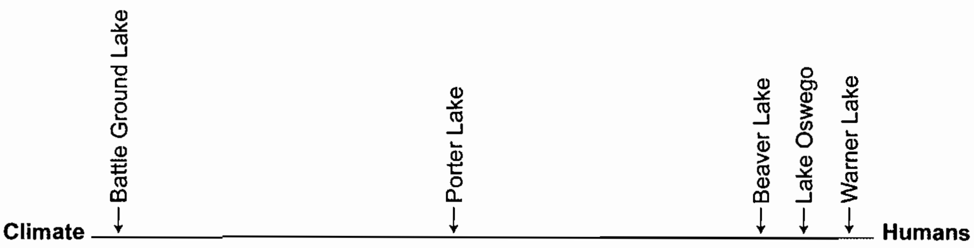
On a centennial timescale, the records suggest a high degree of variability between climatic and human influences, especially during the last 1200 years (Fig, 5.1c). For example, at Battle Ground Lake, fire regime shifts seems to correlate well with known climatic shifts (i.e., the Medieval Climate Anomaly and the Little Ice Age). At Lake Oswego and Beaver Lake, human activity, including the deliberate use of fire as a land management tool, was superimposed on regional climatic shifts. At Warner Lake, no clear climatic influence on the record was detected; therefore, it is assumed that human activity strongly influenced the environmental history of the site. The



A. Early Holocene (ca. 11,000-7500 cal yr BP)



B. Middle Holocene (ca. 7500-4000 cal yr BP)



C. Late Holocene (ca. 4000-120 cal yr BP)

D. Post Euro-American settlement (ca. 120 cal yr BP- present)

Figure 5.1. Conceptual model showing the relative influence of climate and humans on the fire and vegetation histories of the five Willamette Valley study sites in the (A) early Holocene, (B) middle Holocene, (C) late Holocene, and (D) post Euro-American settlement.

postsettlement portions of the records reveal an almost exclusive human (i.e., Euro-American) influence on the fire and vegetation histories (Fig, 5.1d).

The reconstructions from Battle Ground Lake, Lake Oswego, Beaver Lake, Porter Lake, and Warner Lake bring forth several testable hypotheses that might help guide future research examining the natural and anthropogenic influences on the fire and vegetation history of the Willamette Valley.

Hypothesis 1) *Climate more strongly influenced fire and vegetation history than did human activity in the closed forests of the Willamette Valley.* This hypothesis suggests that climate variability, not Native American use of fire, shaped prehistoric fire regimes in forested areas. This is plausible given that closed forests provided few important food resources, which means that human-set fires would have been of little benefit in this environment. Support for this hypothesis comes from the Battle Ground Lake record, which shows that the late-glacial and Holocene fire regimes could be explained through known climatic and attendant vegetation shifts. At first glance, the fire and vegetation record from Warner Lake (which was also surrounded by a closed forest over the last several hundred years) seems to provide evidence against this hypothesis (i.e., changes in fire activity and vegetation at Warner Lake during the last 1200 years were not correlated with known climatic shifts). However, if we consider the existence of ecologically important ecotones near the site, then it becomes clearer why human-set fires would have been more frequent at Warner Lake as compared to Battle Ground Lake. Additional reconstructions from sites in the northern Willamette Valley and the foothills of the Cascade Range would help reveal the extent to which climate variability controlled prehistoric fire regimes in the closed forests of the valley.

Hypothesis 2) *Human activity more strongly influenced fire and vegetation history than did climate in seasonally inundated areas (i.e., river edges and floodplains) and ecologically important ecotones (i.e., prairie-oak savanna, oak savanna-oak woodland, oak woodland-closed forest) of the Willamette Valley.* This hypothesis suggests that Native Americans used fire more often in areas that provided necessary food resources than in other less productive areas. Evidence to support this comes from the middle and late Holocene record from Beaver Lake and the 1200-year-long record from Lake Oswego, which show that human-set fires helped maintain vegetation, and even caused vegetation shifts, favorable for resource availability. However, these fires were modulated by centennial-scale climate variability. To an even greater extent, this hypothesis is supported by the record from Warner Lake, which shows little to no climatic influence on the fire and vegetation history at the site during the last 900 years (i.e., fires burned during warm dry periods as well as during times of increased effective moisture). None of the records from the five study sites suggest a lack of human influence on oak savanna/woodland and prairie fire regimes, except during the 200-300 years prior to Euro-American settlement of the valley. This is evidenced by the low level of fire activity at Lake Oswego and Porter Lake between ca. AD 1600-1875. Additional study sites from ecologically similar areas would illustrate whether anthropogenic burning was a local phenomenon, or whether this activity was typical of all seasonally inundated and ecologically important areas in the valley.

Hypothesis 3) *Human-set fires strongly influenced the fire and vegetation history of areas in the Willamette Valley where there is an archaeological record of human habitation during the middle to late Holocene.* This hypothesis is based on the idea that as human resource use became more focused on harvesting, processing, and storing food in the middle to late Holocene, Native American use of fire as a land management tool subsequently increased or became more spatially focused. Therefore, in areas where there is greater cultural evidence of food processing (i.e., archaeological sites that include rock-lined pits containing *Camassia* (camas) bulbs, *Quercus* (acorn) meats, and *Corylus* (hazelnut) shells), Native Americans used fire more intensely to encourage the growth of these food resources. The records from Lake Oswego and Beaver Lake support this hypothesis (archaeological sites containing this type of evidence exist nearby), which suggests at least a partial human explanation of the fire regimes. Conversely, the fire and vegetation history from Battle Ground Lake supports this hypothesis as well (there is no known archaeological evidence from the Battle Ground Lake crater) and the fire-history reconstruction suggests a climate-driven system. Additional study sites located close to known archaeological sites would help determine if anthropogenic burning was commonly used as a land management tool.

Hypothesis 4) *Human-set fires strongly influenced the fire and vegetation history of areas in the Willamette Valley even where there is no archaeological evidence of human habitation during the Holocene.* This hypothesis is built around the idea that the lack of archaeological evidence does not necessarily mean that anthropogenic burning did not affect certain portions of the valley (i.e., the absence of evidence is not necessarily evidence of absence). Several explanations exist as to why archaeological evidence may be lacking from some areas: 1) activities were such that no cultural evidence was left on the landscape; 2) geomorphic events (i.e., floods and landslides) and Euro-American agricultural activities removed or buried cultural evidence; and 3) insufficient searches for cultural evidence have been conducted (especially on private land). The last reason likely explains why no archaeological evidence has been found near Warner Lake; however, the anomalously high fire activity, as compared to the valley-floor records, suggests there is a high probability that archaeological evidence of human land use exists near the site.

Hypothesis 5) *The prehistoric fire and vegetation histories of similar ecosystems (i.e., prairie, oak savanna, deciduous woodland) in geographic areas outside the Willamette Valley were strongly influenced by human use of fire.* This hypothesis suggests that for the same reasons Native Americans used fire in the Willamette Valley (i.e., to encourage the growth of food resources, hunting, clearing trails, etc.), other indigenous cultures also modified prehistoric vegetation patterns through the use of fire. Areas such as the prairie and oak savanna ecosystems in the Puget Lowland and Vancouver Island (British Columbia), the prairie-forest border of the upper Midwest, the tall grass prairies of the Great Plains, and the hardwood forests of the northeastern and southeastern United States are all believed to have been managed to some extent by anthropogenic burning prior to Euro-American settlement. Much paleoecological work has been done in an effort to support this hypothesis (see Delcourt and Delcourt, 1997; Loope and Anderton, 1998; Brown and Hebda, 2002b; Foster et al., 2002; Lepofsky et al., 2003; Fowler and Konopik, 2007), but the relative extent to which climate and humans controlled prehistoric fire regimes remains unclear in many cases.

Additional studies that incorporate multiple lines of evidence (i.e., lake-sediment and dendrochronological records, archaeological evidence, ethnographic studies) are needed and will help elucidate the extent to which natural and anthropogenic influences shaped the prehistoric fire regimes and vegetation patterns of the Willamette Valley.

APPENDIX A

BATTLE GROUND LAKE BG04A CHARCOAL DATA

Depth (cm)	Age (cal yr BP)	Charcoal particles >250 µm	Charcoal particles >125 µm	Charcoal concentration (particles/cm^3)	Herbaceous charcoal (%)
0.0	-54.00	1	5	6	16.7
1.0	-47.64	3	10	13	7.7
2.0	-41.19	2	13	15	0.0
3.0	-34.65	6	21	27	7.4
4.0	-28.02	11	39	50	12.0
5.0	-21.31	18	57	75	8.0
6.0	-14.51	24	67	91	2.2
7.0	-7.63	21	85	106	0.9
8.0	-0.66	31	103	134	3.0
9.0	6.40	27	119	146	2.7
10.0	13.53	19	142	161	3.7
11.0	20.76	28	109	137	0.7
12.0	28.06	25	90	115	1.7
13.0	35.45	36	105	141	5.0
14.0	42.92	61	164	225	3.1
15.0	50.48	99	297	396	7.3
16.0	58.11	154	193	347	12.1
17.0	65.83	97	242	339	8.6
18.0	73.62	115	219	334	5.1
19.0	81.50	103	214	317	0.9
20.0	89.45	118	233	351	2.3
21.0	97.49	256	434	690	2.6
22.0	105.60	389	369	758	2.9
23.0	113.79	114	151	265	7.9
24.0	122.06	49	62	111	5.4
25.0	130.40	14	19	33	9.1
26.0	138.82	18	29	47	12.8
27.0	147.32	13	28	41	4.9
28.0	155.89	7	23	30	10.0
29.0	164.54	11	22	33	15.2
30.0	173.27	16	32	48	2.1
31.0	182.06	22	40	62	1.6

32.0	190.94	49	71	120	9.2
33.0	199.88	59	69	128	5.5
34.0	208.90	33	34	67	37.3
35.0	217.99	13	34	47	12.8
36.0	227.15	17	37	54	9.3
37.0	236.38	5	30	35	14.3
38.0	245.69	8	19	27	18.5
39.0	255.06	6	19	25	28.0
40.0	264.51	5	11	16	0.0
41.0	274.02	4	18	22	9.1
42.0	283.61	9	10	19	15.8
43.0	293.26	7	11	18	11.1
44.0	302.98	4	8	12	25.0
45.0	312.77	7	10	17	11.8
46.0	322.63	3	4	7	28.6
47.0	332.55	4	6	10	30.0
48.0	342.54	3	33	36	19.4
49.0	352.60	18	15	33	15.2
50.0	362.72	3	25	28	14.3
51.0	372.91	20	25	45	17.8
52.0	383.16	4	20	24	8.3
53.0	393.48	7	23	30	3.3
54.0	403.86	19	84	103	8.7
55.0	414.30	5	42	47	4.3
56.0	424.81	16	71	87	2.3
57.0	435.38	56	78	134	3.0
58.0	446.01	33	71	104	5.8
59.0	456.71	47	78	125	3.2
60.0	467.46	63	66	129	4.7
61.0	478.28	121	196	317	1.6
62.0	489.15	115	192	307	1.0
63.0	500.09	192	181	373	13.7
64.0	511.09	106	229	335	9.3
65.0	522.14	100	100	200	10.0
66.0	533.26	16	62	78	5.1
67.0	544.43	20	36	56	12.5
68.0	555.66	8	24	32	6.3
69.0	566.95	4	32	36	2.8
70.0	578.30	6	30	36	8.3
71.0	589.70	12	54	66	4.5

72.0	601.16	13	56	69	8.7
73.0	612.68	8	47	55	10.9
74.0	624.25	11	57	68	13.2
75.0	635.88	8	46	54	20.4
76.0	647.56	15	53	68	39.7
77.0	659.29	19	26	45	20.0
78.0	671.08	7	49	56	16.1
79.0	682.93	11	63	74	12.2
80.0	694.82	13	65	78	7.7
81.0	706.77	39	71	110	6.4
82.0	718.78	143	223	366	5.2
83.0	730.83	28	43	71	1.4
84.0	742.94	23	57	80	0.0
85.0	755.09	96	331	427	1.4
86.0	767.30	50	133	183	3.3
87.0	779.56	28	103	131	4.6
88.0	791.87	68	76	144	2.1
89.0	804.22	64	46	110	3.6
90.0	816.63	42	95	137	0.7
91.0	829.09	51	58	109	5.5
92.0	841.59	30	42	72	6.9
93.0	854.15	39	74	113	8.0
94.0	866.75	62	102	164	8.5
95.0	879.40	38	52	90	4.4
96.0	892.09	19	45	64	3.1
97.0	904.84	57	86	143	7.0
98.0	917.62	33	78	111	7.2
99.0	930.46	38	112	150	0.7
100.0	943.34	89	153	242	13.6
101.0	956.27	14	114	128	8.6
102.0	969.24	34	74	108	10.2
103.0	982.25	43	105	148	15.5
104.0	995.31	22	48	70	14.3
105.0	1008.41	9	35	44	18.2
106.0	1021.56	4	5	9	0.0
107.0	1034.75	9	32	41	19.5
108.0	1047.98	13	23	36	19.4
109.0	1061.26	3	12	15	33.3
110.0	1074.57	4	16	20	0.0
111.0	1087.93	3	18	21	4.8

112.0	1101.33	3	37	40	12.5
113.0	1114.77	1	16	17	11.8
114.0	1128.25	14	30	44	6.8
115.0	1141.78	39	103	142	4.2
116.0	1155.34	29	95	124	3.2
117.0	1168.94	4	24	28	10.7
118.0	1182.58	7	14	21	14.3
119.0	1196.26	7	14	21	0.0
120.0	1209.98	5	17	22	0.0
121.0	1223.73	10	21	31	9.7
122.0	1237.53	21	17	38	5.3
123.0	1251.36	7	15	22	4.5
124.0	1265.23	16	30	46	6.5
125.0	1279.14	7	15	22	13.6
126.0	1293.08	9	5	14	14.3
127.0	1307.06	70	63	133	6.0
128.0	1321.07	35	34	69	2.9
129.0	1335.12	24	80	104	2.9
130.0	1349.21	13	16	29	6.9
131.0	1363.33	28	27	55	9.1
132.0	1377.48	3	14	17	0.0
133.0	1391.67	2	7	9	0.0
134.0	1405.90	7	18	25	4.0
135.0	1420.15	26	50	76	1.3
136.0	1434.45	31	112	143	9.8
137.0	1448.77	19	40	59	6.8
138.0	1463.13	25	77	102	1.0
139.0	1477.51	37	70	107	1.9
140.0	1491.94	11	43	54	1.9
141.0	1506.39	0	3	3	0.0
142.0	1520.87	2	7	9	11.1
143.0	1535.39	3	5	8	0.0
144.0	1549.94	11	15	26	7.7
145.0	1564.51	3	9	12	8.3
146.0	1579.12	4	16	20	0.0
147.0	1593.76	10	18	28	14.3
148.0	1608.42	11	21	32	12.5
149.0	1623.12	7	25	32	0.0
150.0	1637.85	2	27	29	3.4
151.0	1652.60	7	22	29	0.0

152.0	1667.38	4	22	26	0.0
153.0	1682.20	1	11	12	8.3
154.0	1697.03	1	19	20	5.0
155.0	1711.90	12	34	46	4.3
156.0	1726.79	28	86	114	3.5
157.0	1741.72	10	19	29	0.0
158.0	1756.66	3	23	26	3.8
159.0	1771.64	32	146	178	0.6
160.0	1786.64	4	27	31	0.0
161.0	1801.67	256	340	596	2.9
162.0	1816.72	20	40	60	1.7
163.0	1831.80	8	14	22	4.5
164.0	1846.90	2	3	5	0.0
165.0	1862.03	3	9	12	25.0
166.0	1877.18	4	18	22	13.6
167.0	1892.35	9	16	25	4.0
168.0	1907.56	5	10	15	0.0
169.0	1922.78	6	17	23	13.0
170.0	1938.03	4	9	13	7.7
171.0	1953.30	9	55	64	6.3
172.0	1968.59	6	13	19	0.0
173.0	1983.91	4	13	17	5.9
174.0	1999.25	0	3	3	0.0
175.0	2014.61	3	32	35	2.9
176.0	2029.99	13	59	72	11.1
177.0	2045.40	3	9	12	16.7
178.0	2060.82	7	16	23	8.7
179.0	2076.27	16	52	68	14.7
180.0	2091.74	3	27	30	3.3
181.0	2107.23	25	106	131	1.5
182.0	2122.74	21	51	72	2.8
183.0	2138.27	153	308	461	1.3
184.0	2153.82	25	102	127	2.4
185.0	2169.39	46	125	171	1.8
186.0	2184.97	18	40	58	10.3
187.0	2200.58	2	11	13	0.0
188.0	2216.21	0	7	7	0.0
189.0	2231.85	5	20	25	4.0
190.0	2247.52	16	33	49	2.0
191.0	2263.20	9	16	25	0.0

192.0	2278.90	2	4	6	0.0
193.0	2294.62	2	13	15	6.7
194.0	2310.35	3	12	15	13.3
195.0	2326.10	2	5	7	42.9
196.0	2341.87	0	5	5	20.0
197.0	2357.66	6	17	23	8.7
198.0	2373.46	7	18	25	4.0
199.0	2389.28	11	26	37	2.7
200.0	2405.11	8	20	28	10.7
201.0	2420.97	16	30	46	0.0
202.0	2436.83	29	27	56	3.6
203.0	2452.72	40	58	98	0.0
204.0	2468.61	11	34	45	6.7
205.0	2484.53	10	30	40	2.5
206.0	2500.45	15	24	39	0.0
207.0	2516.39	17	39	56	1.8
208.0	2532.35	16	30	46	2.2
209.0	2548.32	8	27	35	2.9
210.0	2564.31	9	14	23	0.0
211.0	2580.30	5	19	24	0.0
212.0	2596.32	3	23	26	0.0
213.0	2612.34	5	36	41	2.4
214.0	2628.38	5	12	17	0.0
215.0	2644.43	13	38	51	2.0
216.0	2660.49	26	90	116	0.9
217.0	2676.57	5	13	18	0.0
218.0	2692.66	5	11	16	18.8
219.0	2708.76	7	24	31	3.2
220.0	2724.87	3	23	26	7.7
221.0	2741.00	1	12	13	0.0
222.0	2757.13	19	35	54	1.9
223.0	2773.28	53	42	95	4.2
224.0	2789.44	6	18	24	12.5
225.0	2805.61	14	22	36	0.0
226.0	2821.79	1	18	19	5.3
227.0	2837.98	6	29	35	8.6
228.0	2854.18	11	20	31	19.4
229.0	2870.39	12	37	49	2.0
230.0	2886.62	33	53	86	3.5
231.0	2902.85	17	41	58	17.2

232.0	2919.09	26	56	82	1.2
235.0	2967.87	14	0	14	28.6
236.0	2984.15	1	17	18	0.0
237.0	3000.43	4	20	24	12.5
238.0	3016.73	9	31	40	2.5
239.0	3033.03	3	16	19	5.3
240.0	3049.35	6	13	19	0.0
241.0	3065.67	3	21	24	4.2
242.0	3082.00	5	14	19	0.0
243.0	3098.33	6	14	20	10.0
244.0	3114.68	5	27	32	9.4
245.0	3131.03	11	20	31	0.0
246.0	3147.39	4	12	16	6.3
247.0	3163.75	2	14	16	6.3
248.0	3180.13	6	12	18	5.6
249.0	3196.51	10	44	54	1.9
250.0	3212.89	51	96	147	1.4
251.0	3229.29	39	70	109	4.6
252.0	3245.69	4	10	14	7.1
253.0	3262.09	7	16	23	13.0
254.0	3278.51	4	12	16	18.8
255.0	3294.92	11	9	20	0.0
256.0	3311.35	3	15	18	11.1
257.0	3327.78	10	18	28	3.6
258.0	3344.21	1	11	12	8.3
259.0	3360.65	17	32	49	6.1
260.0	3377.10	15	29	44	2.3
261.0	3393.55	10	8	18	5.6
262.0	3410.01	14	32	46	15.2
263.0	3426.47	5	17	22	18.2
264.0	3442.93	13	25	38	0.0
265.0	3459.40	12	16	28	7.1
266.0	3475.88	30	67	97	2.1
267.0	3492.35	43	80	123	0.8
268.0	3508.84	13	41	54	14.8
269.0	3525.32	10	32	42	4.8
270.0	3541.82	14	62	76	68.4
271.0	3558.31	30	122	152	0.7
272.0	3574.81	10	53	63	6.3
273.0	3591.31	4	28	32	6.3

274.0	3607.82	5	28	33	9.1
275.0	3624.33	5	52	57	5.3
276.0	3640.84	18	36	54	3.7
277.0	3657.35	12	65	77	5.2
278.0	3673.87	14	68	82	4.9
279.0	3690.39	4	27	31	0.0
280.0	3706.92	4	46	50	6.0
281.0	3723.44	4	59	63	4.8
282.0	3739.97	8	29	37	10.8
283.0	3756.50	14	72	86	5.8
284.0	3773.04	13	67	80	3.8
285.0	3789.57	19	122	141	7.1
286.0	3806.11	24	181	205	2.9
287.0	3822.65	32	146	178	8.4
288.0	3839.19	64	257	321	4.4
289.0	3855.74	22	79	101	4.0
290.0	3872.28	7	63	70	10.0
291.0	3888.83	12	62	74	16.2
292.0	3905.38	12	57	69	1.4
293.0	3921.93	27	38	65	3.1
294.0	3938.48	14	35	49	8.2
295.0	3955.03	17	55	72	5.6
296.0	3971.59	23	30	53	13.2
297.0	3988.14	40	94	134	6.7
298.0	4004.70	14	45	59	8.5
299.0	4021.25	20	58	78	15.4
300.0	4037.81	18	36	54	22.2
301.0	4054.37	10	72	82	3.7
302.0	4070.93	54	135	189	1.1
303.0	4087.49	9	24	33	9.1
304.0	4104.05	3	36	39	10.3
305.0	4120.61	7	34	41	9.8
306.0	4137.17	9	50	59	0.0
307.0	4153.74	13	42	55	9.1
308.0	4170.30	37	89	126	11.9
309.0	4186.86	31	45	76	3.9
310.0	4203.42	25	63	88	6.8
311.0	4219.98	36	92	128	3.9
312.0	4236.55	24	65	89	7.9
313.0	4253.11	9	22	31	19.4

314.0	4269.67	10	26	36	2.8
315.0	4286.23	17	31	48	8.3
316.0	4302.79	12	41	53	13.2
316.5	4311.07	14	31	45	6.7
317.0	4319.35	47	126	173	57.2
317.5	4327.63	12	48	60	8.3
318.0	4335.91	15	33	48	4.2
318.5	4344.19	13	27	40	25.0
319.0	4352.47	5	26	31	12.9
319.5	4360.75	23	49	72	6.9
320.0	4369.03	13	41	54	11.1
320.5	4377.31	17	56	73	15.1
321.0	4385.59	16	90	106	9.4
321.5	4393.87	15	64	79	10.1
322.0	4402.15	20	57	77	5.2
322.5	4410.43	11	27	38	13.2
323.0	4418.71	21	36	57	3.5
323.5	4426.99	9	36	45	20.0
324.0	4435.27	17	52	69	2.9
324.5	4443.55	6	33	39	0.0
325.0	4451.82	4	72	76	6.6
325.5	4460.10	12	57	69	8.7
326.0	4468.38	17	48	65	21.5
326.5	4476.66	38	113	151	1.3
327.0	4484.93	12	37	49	18.4
327.5	4493.21	14	28	42	9.5
328.0	4501.49	16	34	50	4.0
328.5	4509.76	23	46	69	5.8
329.0	4518.04	19	50	69	2.9
329.5	4526.32	40	63	103	43.7
330.0	4534.59	20	54	74	8.1
330.5	4542.87	11	41	52	9.6
331.0	4551.14	28	55	83	22.9
331.5	4559.42	148	157	305	36.7
332.0	4567.69	25	42	67	19.4
332.5	4575.97	12	34	46	8.7
333.0	4584.24	19	36	55	21.8
333.5	4592.52	7	23	30	6.7
334.0	4600.79	15	47	62	8.1
334.5	4609.06	18	60	78	5.1

335.0	4617.34	26	71	97	8.2
335.5	4625.61	15	68	83	8.4
336.0	4633.88	28	43	71	4.2
336.5	4642.15	17	29	46	2.2
337.0	4650.42	18	53	71	15.5
337.5	4658.70	16	60	76	9.2
338.0	4666.97	10	53	63	9.5
338.5	4675.24	19	20	39	7.7
339.0	4683.51	10	31	41	34.1
339.5	4691.78	3	15	18	0.0
340.0	4700.05	11	51	62	11.3
340.5	4708.32	28	69	97	34.0
341.0	4716.59	5	22	27	7.4
341.5	4724.86	28	43	71	5.6
342.0	4733.13	14	34	48	27.1
342.5	4741.39	14	27	41	14.6
343.0	4749.66	13	42	55	21.8
343.5	4757.93	14	32	46	21.7
344.0	4766.20	25	26	51	2.0
344.5	4774.46	48	56	104	28.8
345.0	4782.73	11	44	55	3.6
345.5	4791.00	5	61	66	10.6
346.0	4799.26	14	34	48	8.3
346.5	4807.53	17	28	45	4.4
347.0	4815.79	12	22	34	11.8
347.5	4824.06	8	22	30	0.0
348.0	4832.32	24	58	82	9.8
348.5	4840.59	29	40	69	8.7
349.0	4848.85	9	24	33	36.4
349.5	4857.11	19	36	55	1.8
350.0	4865.38	21	39	60	11.7
350.5	4873.64	22	52	74	12.2
351.0	4881.90	10	58	68	13.2
351.5	4890.16	14	76	90	10.0
352.0	4898.42	30	78	108	2.8
352.5	4906.69	13	42	55	14.5
353.0	4914.95	165	212	377	2.9
353.5	4923.21	8	60	68	2.9
354.0	4931.47	14	91	105	1.9
354.5	4939.73	14	92	106	0.9

355.0	4947.99	53	192	245	1.6
355.5	4956.24	42	106	148	2.0
356.0	4964.50	12	48	60	6.7
356.5	4972.76	27	60	87	5.7
357.0	4981.02	13	60	73	16.4
357.5	4989.28	6	41	47	10.6
358.0	4997.53	6	41	47	6.4
358.5	5005.79	11	83	94	10.6
359.0	5014.05	5	39	44	6.8
359.5	5022.30	18	49	67	9.0
360.0	5030.56	41	78	119	15.1
360.5	5038.81	69	245	314	4.1
361.0	5047.07	15	60	75	9.3
361.5	5055.32	14	68	82	4.9
362.0	5063.57	17	46	63	1.6
362.5	5071.83	24	36	60	3.3
363.0	5080.08	6	20	26	3.8
363.5	5088.33	117	115	232	4.7
364.0	5096.59	14	47	61	3.3
364.5	5104.84	42	44	86	3.5
365.0	5113.09	8	12	20	10.0
365.5	5121.34	5	16	21	14.3
366.0	5129.59	6	21	27	7.4
366.5	5137.84	12	31	43	7.0
367.0	5146.09	16	20	36	8.3
367.5	5154.34	6	17	23	0.0
368.0	5162.59	6	28	34	2.9
368.5	5170.84	11	29	40	10.0
369.0	5179.09	9	45	54	16.7
369.5	5187.34	5	13	18	5.6
370.0	5195.59	8	39	47	2.1
370.5	5203.83	16	43	59	3.4
371.0	5212.08	23	44	67	13.4
371.5	5220.33	4	36	40	7.5
372.0	5228.58	12	63	75	8.0
372.5	5236.82	38	159	197	5.6
373.0	5245.07	13	72	85	2.4
373.5	5253.31	10	35	45	11.1
374.0	5261.56	10	28	38	2.6
374.5	5269.80	7	42	49	8.2

375.0	5278.05	10	30	40	5.0
375.5	5286.29	11	29	40	2.5
376.0	5294.54	5	22	27	3.7
376.5	5302.78	3	41	44	11.4
377.0	5311.02	10	31	41	12.2
377.5	5319.27	8	34	42	11.9
378.0	5327.51	6	34	40	7.5
378.5	5335.75	7	52	59	32.2
379.0	5344.00	3	40	43	7.0
379.5	5352.24	10	34	44	9.1
380.0	5360.48	14	47	61	16.4
380.5	5368.72	10	22	32	3.1
381.0	5376.96	28	58	86	44.2
381.5	5385.20	24	51	75	44.0
382.0	5393.44	1	28	29	0.0
382.5	5401.68	23	71	94	46.8
383.0	5409.92	0	33	33	39.4
383.5	5418.16	2	21	23	21.7
384.0	5426.40	11	29	40	7.5
384.5	5434.64	2	34	36	5.6
385.0	5442.88	5	34	39	2.6
385.5	5451.12	3	25	28	7.1
386.0	5459.36	17	47	64	20.3
386.5	5467.60	11	49	60	0.0
387.0	5475.84	4	28	32	12.5
387.5	5484.07	11	63	74	10.8
388.0	5492.31	10	58	68	7.4
388.5	5500.55	22	79	101	5.0
389.0	5508.79	10	25	35	8.6
389.5	5517.02	4	11	15	26.7
390.0	5525.26	5	22	27	37.0
390.5	5533.50	6	36	42	16.7
391.0	5541.73	0	48	48	20.8
391.5	5549.97	19	35	54	18.5
392.0	5558.21	12	51	63	14.3
392.5	5566.44	7	60	67	4.5
393.0	5574.68	17	34	51	13.7
393.5	5582.91	8	68	76	36.8
394.0	5591.15	3	30	33	12.1
394.5	5599.39	3	26	29	3.4

395.0	5607.62	4	33	37	5.4
395.5	5615.86	1	27	28	7.1
396.0	5624.09	3	41	44	4.5
396.5	5632.33	4	36	40	25.0
397.0	5640.56	8	37	45	2.2
397.5	5648.80	12	40	52	13.5
398.0	5657.03	1	37	38	7.9
398.5	5665.27	7	23	30	0.0
399.0	5673.50	6	41	47	8.5
399.5	5681.74	10	78	88	11.4
400.0	5689.97	25	83	108	5.6
400.5	5698.20	15	51	66	3.0
401.0	5706.44	22	55	77	22.1
401.5	5714.67	17	72	89	6.7
402.0	5722.91	35	79	114	6.1
402.5	5731.14	18	52	70	4.3
403.0	5739.38	41	151	192	2.1
403.5	5747.61	14	49	63	17.5
404.0	5755.85	7	22	29	6.9
404.5	5764.08	4	23	27	7.4
405.0	5772.31	11	34	45	13.3
405.5	5780.55	7	28	35	8.6
406.0	5788.78	13	57	70	4.3
406.5	5797.02	19	82	101	12.9
407.0	5805.25	13	37	50	4.0
407.5	5813.49	9	48	57	19.3
408.0	5821.72	18	89	107	17.8
408.5	5829.96	25	73	98	9.2
409.0	5838.19	15	50	65	24.6
409.5	5846.43	18	94	112	17.0
410.0	5854.66	83	268	351	46.2
410.5	5862.90	21	110	131	10.7
411.0	5871.13	45	103	148	23.6
411.5	5879.37	11	41	52	0.0
412.0	5887.61	11	42	53	17.0
412.5	5895.84	12	71	83	12.0
413.0	5904.08	8	78	86	15.1
413.5	5912.31	3	22	25	12.0
414.0	5920.55	25	88	113	43.4
414.5	5928.79	22	64	86	33.7

415.0	5937.02	8	39	47	25.5
415.5	5945.26	6	14	20	30.0
416.0	5953.50	12	53	65	29.2
416.5	5961.74	18	61	79	17.7
417.0	5969.97	13	74	87	21.8
417.5	5978.21	10	86	96	11.5
418.0	5986.45	20	115	135	16.3
418.5	5994.69	25	112	137	14.6
419.0	6002.93	9	75	84	17.9
419.5	6011.17	22	101	123	8.9
420.0	6019.41	5	63	68	4.4
420.5	6027.65	15	45	60	10.0
421.0	6035.89	30	88	118	2.5
421.5	6044.13	9	85	94	8.5
422.0	6052.37	16	37	53	9.4
422.5	6060.61	16	66	82	11.0
423.0	6068.85	9	92	101	4.0
423.5	6077.10	33	108	141	16.3
424.0	6085.34	18	90	108	8.3
424.5	6093.58	23	81	104	18.3
425.0	6101.83	21	121	142	9.2
425.5	6110.07	18	112	130	19.2
426.0	6118.31	21	52	73	11.0
426.5	6126.56	19	46	65	16.9
427.0	6134.80	24	98	122	21.3
427.5	6143.05	14	31	45	8.9
428.0	6151.30	30	52	82	7.3
428.5	6159.54	18	47	65	23.1
429.0	6167.79	43	78	121	42.1
429.5	6176.04	36	86	122	20.5
430.0	6184.29	19	46	65	9.2
430.5	6192.54	5	39	44	15.9
431.0	6200.79	32	126	158	12.7
431.5	6209.04	15	87	102	19.6
432.0	6217.29	24	81	105	7.6
432.5	6225.54	39	62	101	20.8
433.0	6233.79	49	118	167	21.0
433.5	6242.05	50	146	196	12.2
434.0	6250.30	48	128	194	8.2
434.5	6258.55	39	120	167	19.8

435.0	6266.81	27	99	147	9.5
435.5	6275.06	14	43	113	6.2
436.0	6283.32	25	116	68	55.9
436.5	6291.58	16	50	132	11.4
437.0	6299.84	6	40	56	5.4
437.5	6308.09	14	54	54	29.6
438.0	6316.35	15	38	69	8.7
438.5	6324.61	13	38	51	15.7
439.0	6332.88	26	74	100	15.0
439.5	6341.14	11	56	67	20.9
440.0	6349.40	20	73	93	19.4
440.5	6357.66	9	58	67	31.3
441.0	6365.93	28	133	161	9.3
441.5	6374.19	17	75	92	13.0
442.0	6382.46	19	75	94	11.7
442.5	6390.73	27	158	185	25.4
443.0	6399.00	46	131	177	24.9
443.5	6407.26	33	93	126	13.5
444.0	6415.53	57	164	221	7.2
444.5	6423.81	8	97	105	17.1
445.0	6432.08	7	50	57	10.5
445.5	6440.35	12	74	86	19.8
446.0	6448.62	16	120	136	8.8
446.5	6456.90	10	43	53	15.1
447.0	6465.18	18	51	69	14.5
447.5	6473.45	27	75	102	28.4
448.0	6481.73	7	84	91	23.1
448.5	6490.01	25	134	159	17.6
449.0	6498.29	11	82	93	21.5
449.5	6506.57	38	111	149	30.2
450.0	6514.86	41	61	102	30.4
450.5	6523.14	13	76	89	29.2
451.0	6531.43	29	131	160	12.5
451.5	6539.71	14	77	91	29.7
452.0	6548.00	37	99	136	22.1
452.5	6556.29	31	93	124	36.3
453.0	6564.58	16	49	65	29.2
453.5	6572.87	10	66	76	28.9
454.0	6581.16	16	108	124	18.5
454.5	6589.46	19	90	109	31.2

455.0	6597.75	16	98	114	23.7
455.5	6606.05	15	85	100	17.0
456.0	6614.35	23	146	169	22.5
456.5	6622.65	30	187	217	21.7
457.0	6630.95	57	184	241	14.5
457.5	6639.25	18	134	152	39.5
458.0	6647.55	30	134	164	22.0
458.5	6655.86	34	186	220	21.4
459.0	6664.16	15	52	67	13.4
459.5	6672.47	12	54	66	36.4
460.0	6680.78	21	88	109	16.5
460.5	6689.09	45	222	267	40.8
461.0	6697.40	20	73	93	15.1
461.5	6705.72	15	71	86	27.9
462.0	6714.03	19	88	107	26.2
462.5	6722.35	32	152	184	18.5
463.0	6730.67	12	88	100	17.0
463.5	6738.99	5	66	71	8.5
464.0	6747.31	13	44	57	22.8
464.5	6755.64	25	147	172	14.0
465.0	6763.96	39	153	192	32.8
465.5	6772.29	27	124	151	21.2
466.0	6780.62	2	32	34	5.9
466.5	6788.95	6	37	43	9.3
467.0	6797.28	17	59	76	23.7
467.5	6805.61	56	126	182	45.6
468.0	6813.95	23	68	91	30.8
468.5	6822.29	17	43	60	11.7
469.0	6830.63	16	47	63	23.8
469.5	6838.97	11	50	61	21.3
470.0	6847.31	27	54	81	35.8
470.5	6855.66	48	90	138	37.0
471.0	6864.01	16	69	85	31.8
471.5	6872.36	20	82	102	27.5
472.0	6880.71	16	108	124	27.4
472.5	6889.06	15	104	119	22.7
473.0	6897.41	12	54	66	25.8
473.5	6905.77	21	106	127	19.7
474.0	6914.13	42	194	236	55.1
474.5	6922.49	14	68	82	24.4

475.0	6930.86	22	111	133	33.1
475.5	6939.22	12	61	73	34.2
476.0	6947.59	17	89	106	46.2
476.5	6955.96	9	49	58	10.3
477.0	6964.33	52	163	215	44.2
477.5	6972.70	14	56	70	38.6
478.0	6981.08	20	61	81	43.2
478.5	6989.46	7	51	58	36.2
479.0	6997.84	15	52	67	19.4
479.5	7006.22	11	44	55	14.5
480.0	7014.61	27	63	90	30.0
480.5	7023.00	30	56	86	29.1
481.0	7031.39	31	104	135	34.8
481.5	7039.78	8	55	63	42.9
482.0	7048.17	68	126	194	43.8
482.5	7056.57	21	79	100	20.0
483.0	7064.97	21	100	121	34.7
483.5	7073.37	75	141	216	25.5
484.0	7081.78	18	108	126	11.1
484.5	7090.19	11	82	93	14.0
485.0	7098.59	30	111	141	18.4
485.5	7107.01	39	157	196	34.2
486.0	7115.42	7	72	79	30.4
486.5	7123.84	14	77	91	33.0
487.0	7132.26	14	53	67	19.4
487.5	7140.68	16	62	78	14.1
488.0	7149.11	41	89	130	24.6
488.5	7157.54	22	59	81	30.9
489.0	7165.97	7	67	74	20.3
489.5	7174.40	20	58	78	23.1
490.0	7182.84	23	100	123	39.8
490.5	7191.27	15	80	95	24.2
491.0	7199.72	26	87	113	36.3
491.5	7208.16	10	61	71	21.1
492.0	7216.61	18	67	85	21.2
492.5	7225.06	23	78	101	26.7
493.0	7233.51	14	70	84	41.7
493.5	7241.97	19	102	121	33.1
494.0	7250.43	65	114	179	26.8
494.5	7258.89	67	164	231	48.1

495.0	7267.35	59	166	225	46.7
495.5	7275.82	14	53	67	25.4
496.0	7284.29	42	90	132	40.9
496.5	7292.77	13	70	83	39.8
497.0	7301.24	20	165	185	31.9
497.5	7309.73	18	103	121	34.7
498.0	7318.21	27	111	138	33.3
498.5	7326.70	64	200	264	59.1
499.0	7335.19	9	86	95	44.2
499.5	7343.68	22	87	109	50.5
500.0	7352.18	16	59	75	46.7
500.5	7360.67	21	89	110	30.0
501.0	7369.18	9	136	145	23.4
501.5	7377.68	26	96	122	20.5
502.0	7386.19	17	69	86	16.3
502.5	7394.71	23	130	153	26.1
503.0	7403.22	70	347	417	32.9
503.5	7411.74	79	294	373	15.0
504.0	7420.27	89	357	446	28.3
504.5	7428.79	80	265	345	42.3
505.0	7437.32	32	183	215	45.6
505.5	7445.86	30	179	209	19.1
506.0	7454.39	25	172	197	26.4
506.5	7462.94	15	190	205	28.8
507.0	7471.48	50	379	429	51.5
507.5	7480.03	34	197	231	23.8
508.0	7488.58	20	127	147	23.8
508.5	7497.14	33	158	191	35.1
509.0	7505.69	38	175	213	31.0
509.5	7514.26	20	133	153	22.2
510.0	7522.82	37	241	278	40.6
510.5	7531.39	71	206	277	22.0
511.0	7539.97	81	115	196	41.8
511.5	7548.55	6	47	53	5.7
512.0	7557.13	8	74	82	26.8
512.5	7565.72	32	126	158	15.2
513.0	7574.31	9	87	96	22.9
513.5	7582.90	8	81	89	25.8
514.0	7591.50	15	64	79	3.8
514.5	7600.10	13	77	90	7.8

515.0	7608.71	15	94	109	22.0
515.5	7617.32	7	116	123	9.8
516.0	7625.93	10	83	93	18.3
516.5	7634.55	85	189	274	32.8
517.0	7643.17	14	89	103	13.6
517.5	7651.80	15	52	67	9.0
518.0	7660.43	5	79	84	15.5
518.5	7669.06	23	145	168	25.0
519.0	7677.70	16	77	93	9.7
519.5	7686.35	11	115	126	14.3
520.0	7694.99	23	186	209	36.4
520.5	7703.65	13	107	120	25.0
521.0	7712.30	13	78	91	12.1
521.5	7720.96	70	242	312	61.2
522.0	7729.63	31	208	239	31.0
522.5	7738.30	14	140	154	13.6
523.0	7746.97	15	74	89	10.1
523.5	7755.65	8	75	83	14.5
524.0	7764.34	18	125	143	22.4
524.5	7773.03	45	164	209	21.1
525.0	7781.72	12	116	128	18.8
525.5	7790.42	11	85	96	31.3
526.0	7799.12	9	105	114	21.9
526.5	7807.83	26	96	122	14.8
527.0	7816.54	3	58	61	29.5
527.5	7825.25	13	52	65	18.5
528.0	7833.98	19	143	162	56.8
528.5	7842.70	4	102	106	25.5
529.0	7851.43	16	62	78	21.8
529.5	7860.17	8	51	59	18.6
530.0	7868.91	11	69	80	17.5
530.5	7877.65	21	97	118	23.7
531.0	7886.41	26	114	140	12.9
531.5	7895.16	20	93	113	12.4
532.0	7903.92	12	82	94	12.8
532.5	7912.69	34	237	271	6.3
533.0	7921.46	26	211	237	11.0
533.5	7930.24	26	171	197	28.9
534.0	7939.02	13	72	85	23.5
534.5	7947.80	8	110	118	20.3

535.0	7956.60	20	132	152	39.5
535.5	7965.39	11	60	71	16.9
536.0	7974.19	21	107	128	18.0
536.5	7983.00	29	129	158	29.1
537.0	7991.82	15	57	72	12.5
537.5	8000.63	21	68	89	34.8
538.0	8009.46	7	49	56	30.4
538.5	8018.29	23	115	138	20.3
539.0	8027.12	13	43	56	32.1
539.5	8035.96	7	52	59	20.3
540.0	8044.81	21	50	71	19.7
540.5	8053.66	17	58	75	18.7
541.0	8062.52	30	85	115	22.6
541.5	8071.38	26	103	129	24.0
542.0	8080.25	8	101	109	22.9
542.5	8089.12	13	70	83	39.8
543.0	8098.00	21	112	133	29.3
543.5	8106.89	15	109	124	32.3
544.0	8115.78	22	80	102	46.1
544.5	8124.68	40	50	90	42.2
545.0	8133.58	9	90	99	52.5
545.5	8142.49	6	65	71	50.7
546.0	8151.41	7	60	67	29.9
546.5	8160.33	4	36	40	27.5
547.0	8169.25	19	115	134	35.8
547.5	8178.19	12	79	91	23.1
548.0	8187.13	15	97	112	25.0
548.5	8196.07	17	199	216	45.8
549.0	8205.02	51	171	222	14.4
549.5	8213.98	29	218	247	23.1
550.0	8222.95	27	206	233	15.9
550.5	8231.92	31	211	242	13.6
551.0	8240.89	60	211	271	24.7
551.5	8249.88	23	245	268	30.2
552.0	8258.87	8	81	89	20.2
552.5	8267.86	30	103	133	30.8
553.0	8276.86	10	70	80	37.5
553.5	8285.87	10	104	114	25.4
554.0	8294.89	34	100	134	11.2
554.5	8303.91	27	121	148	21.6

555.0	8312.94	21	141	162	35.2
555.5	8321.97	57	185	242	22.3
556.0	8331.01	40	180	220	13.2
556.5	8340.06	19	146	165	12.1
557.0	8349.12	18	227	245	5.3
557.5	8358.18	14	296	310	11.9
558.0	8367.25	25	144	169	5.3
558.5	8376.32	15	124	139	9.4
559.0	8385.40	15	100	115	30.4
559.5	8394.49	10	112	122	29.5
560.0	8403.59	3	86	89	38.2
560.5	8412.69	11	46	57	17.5
561.0	8421.80	5	79	84	21.4
561.5	8430.92	5	39	44	13.6
562.0	8440.04	8	94	102	12.7
562.5	8449.17	9	71	80	6.3
563.0	8458.31	5	67	72	8.3
563.5	8467.46	14	195	209	22.0
564.0	8476.61	13	121	134	14.9
564.5	8485.77	12	72	84	13.1
565.0	8494.94	13	120	133	14.3
565.5	8504.11	15	187	202	12.9
566.0	8513.29	13	67	80	16.3
566.5	8522.48	14	122	136	23.5
567.0	8531.68	6	120	126	27.8
567.5	8540.89	6	134	140	36.4
568.0	8550.10	6	56	62	35.5
568.5	8559.32	2	75	77	15.6
569.0	8568.54	36	220	256	9.4
569.5	8577.78	20	103	123	43.9
570.0	8587.02	6	57	63	14.3
570.5	8596.27	22	133	155	41.9
571.0	8605.53	49	233	282	28.4
571.5	8614.79	10	121	131	37.4
572.0	8624.07	0	60	60	21.7
572.5	8633.35	5	71	76	11.8
573.0	8642.64	12	78	90	26.7
573.5	8651.93	35	187	222	65.3
574.0	8661.24	25	197	222	36.9
574.5	8670.55	13	108	121	14.9

575.0	8679.87	43	255	298	20.5
575.5	8689.20	44	278	322	16.5
576.0	8698.54	7	69	76	28.9
576.5	8707.88	15	86	101	16.8
577.0	8717.24	5	61	66	15.2
577.5	8726.60	5	34	39	20.5
578.0	8735.97	12	64	76	28.9
578.5	8745.35	10	118	128	21.9
579.0	8754.74	39	189	228	54.4
579.5	8764.13	9	117	126	32.5
580.0	8773.53	4	109	113	34.5
580.5	8782.95	14	143	157	19.7
581.0	8792.37	9	71	80	30.0
581.5	8801.80	6	83	89	43.8
582.0	8811.23	6	39	45	11.1
582.5	8820.68	2	108	110	23.6
583.0	8830.14	15	156	171	28.1
583.5	8839.60	6	99	105	21.0
584.0	8849.07	9	82	91	23.1
584.5	8858.55	12	157	169	19.5
585.0	8868.04	10	96	106	20.8
585.5	8877.54	19	185	204	16.7
586.0	8887.05	14	192	206	44.7
586.5	8896.57	5	123	128	21.1
587.0	8906.09	23	178	201	27.4
587.5	8915.63	13	221	234	27.4
588.0	8925.17	36	228	264	9.5
588.5	8934.73	19	188	207	30.9
589.0	8944.29	33	155	188	6.9
589.5	8953.86	13	137	150	16.0
590.0	8963.44	4	96	100	18.0
590.5	8973.03	15	117	132	29.5
591.0	8982.63	29	144	173	25.4
591.5	8992.24	16	122	138	18.8
592.0	9001.86	17	141	158	17.7
592.5	9011.49	18	179	197	26.4
593.0	9021.12	15	166	181	10.5
593.5	9030.77	15	127	142	14.1
594.0	9040.43	15	137	152	12.5
594.5	9050.09	15	217	232	16.8

595.0	9059.77	66	285	351	16.0
595.5	9069.45	16	222	238	13.0
596.0	9079.15	19	162	181	18.8
596.5	9088.85	12	159	171	21.6
597.0	9098.57	26	151	177	22.6
597.5	9108.29	13	180	193	20.2
598.0	9118.03	18	357	375	23.7
598.5	9127.77	20	153	173	11.6
599.0	9137.53	20	222	242	11.6
599.5	9147.29	54	270	324	7.4
600.0	9157.07	31	249	280	18.6
600.5	9166.85	20	320	340	27.4
601.0	9176.65	12	145	157	19.1
601.5	9186.45	19	189	208	21.2
602.0	9196.27	13	93	106	33.0
602.5	9206.09	4	81	85	31.8
603.0	9215.93	14	100	114	22.8
603.5	9225.78	8	61	69	13.0
604.0	9235.63	7	108	115	31.3
604.5	9245.50	9	132	141	18.4
605.0	9255.38	5	128	133	33.8
605.5	9265.27	12	87	99	22.2
606.0	9275.17	25	140	165	10.9
606.5	9285.08	6	93	99	26.3
607.0	9295.00	7	315	322	59.0
607.5	9304.93	24	120	144	12.5
608.0	9314.87	8	99	107	12.1
608.5	9324.82	6	80	86	14.0
609.0	9334.79	6	126	132	10.6
609.5	9344.76	15	108	123	10.6
610.0	9354.75	13	123	136	4.4
610.5	9364.75	13	111	124	4.8
611.0	9374.75	12	132	144	13.9
611.5	9384.77	26	192	218	7.8
612.0	9394.80	13	125	138	5.1
612.5	9404.84	16	137	153	21.6
613.0	9414.90	6	80	86	15.1
613.5	9424.96	14	170	184	10.3
614.0	9435.04	8	66	74	12.2
614.5	9445.12	20	86	106	6.6

615.0	9455.22	13	91	104	16.3
615.5	9465.33	15	113	128	11.7
616.0	9475.45	15	109	124	10.5
616.5	9485.58	15	108	123	5.7
617.0	9495.73	8	72	80	6.3
617.5	9505.88	9	103	112	11.6
618.0	9516.05	22	146	168	32.7
618.5	9526.23	90	224	314	15.9
619.0	9536.42	21	111	132	21.2
619.5	9546.63	12	77	89	14.6
620.0	9556.84	5	90	95	2.1
620.5	9567.07	15	140	155	18.1
621.0	9577.31	2	107	109	29.4
621.5	9587.56	3	119	122	8.2
622.0	9597.82	10	71	81	7.4
622.5	9608.09	8	136	144	9.7
623.0	9618.38	16	135	151	37.7
623.5	9628.68	5	121	126	23.8
624.0	9638.99	6	113	119	26.1
624.5	9649.32	6	85	91	12.1
625.0	9659.65	7	99	106	17.9
625.5	9670.00	25	132	157	28.7
626.0	9680.36	38	164	202	29.2
626.5	9690.74	7	98	105	18.1
627.0	9701.12	19	104	123	21.1
627.5	9711.52	5	110	115	22.6
628.0	9721.93	12	66	78	32.1
628.5	9732.36	13	113	126	22.2
629.0	9742.80	14	90	104	46.2
629.5	9753.25	28	66	94	28.7
630.0	9763.71	14	126	140	27.9
630.5	9774.18	23	129	152	9.2
631.0	9784.67	22	88	110	17.3
631.5	9795.17	60	194	254	10.2
632.0	9805.69	18	38	56	17.9
632.5	9816.22	13	98	111	25.2
633.0	9826.76	16	54	70	27.1
633.5	9837.31	4	49	53	32.1
634.0	9847.88	15	60	75	18.7
634.5	9858.46	28	105	133	24.1

635.0	9869.05	34	114	148	32.4
635.5	9879.66	8	68	76	28.9
636.0	9890.28	31	121	152	30.9
636.5	9900.91	6	55	61	11.5
637.0	9911.56	38	125	163	46.6
637.5	9922.22	4	57	61	24.6
638.0	9932.90	4	66	70	25.7
638.5	9943.59	33	94	127	14.2
639.0	9954.29	16	77	93	29.0
639.5	9965.00	3	44	47	4.3
640.0	9975.73	7	111	118	20.3
640.5	9986.48	13	86	99	32.3
641.0	9997.24	12	55	67	16.4
641.5	10008.01	5	70	75	21.3
642.0	10018.79	5	56	61	16.4
642.5	10029.59	11	47	58	19.0
643.0	10040.41	6	22	28	3.6
643.5	10051.23	15	88	103	20.4
644.0	10062.08	14	61	75	5.3
644.5	10072.93	11	61	72	23.6
645.0	10083.80	5	73	78	42.3
645.5	10094.69	20	113	133	36.8
646.0	10105.59	3	58	61	37.7
646.5	10116.50	14	89	103	31.1
647.0	10127.43	6	57	63	14.3
647.5	10138.38	12	79	91	23.1
648.0	10149.33	63	176	239	15.5
648.5	10160.31	18	75	93	18.3
649.0	10171.29	9	40	49	8.2
649.5	10182.30	18	128	146	17.8
650.0	10193.31	3	18	21	23.8
650.5	10204.34	9	62	71	12.7
651.0	10215.39	13	93	106	26.4
651.5	10226.45	7	70	77	14.3
652.0	10237.53	6	68	74	31.1
652.5	10248.62	6	89	95	22.1
653.0	10259.73	10	76	86	15.1
653.5	10270.85	13	104	117	5.1
654.0	10281.99	29	193	222	12.2
654.5	10293.14	20	208	228	12.3

655.0	10304.31	35	179	214	20.1
655.5	10315.50	11	139	150	22.0
656.0	10326.70	8	96	104	17.3
656.5	10337.91	21	108	129	28.7
657.0	10349.14	13	113	126	17.5
657.5	10360.39	25	117	142	43.7
658.0	10371.65	28	92	120	39.2
658.5	10382.93	19	78	97	42.3
659.0	10394.22	5	58	63	15.9
659.5	10405.53	2	44	46	30.4
660.0	10416.85	7	31	38	18.4
660.5	10428.20	7	35	42	9.5
661.0	10439.55	7	18	25	16.0
661.5	10450.93	9	57	66	10.6
662.0	10462.31	7	26	33	15.2
662.5	10473.72	11	40	51	7.8
663.0	10485.14	23	91	114	14.0
663.5	10496.58	9	61	70	24.3
664.0	10508.03	3	56	59	20.3
664.5	10519.51	9	53	62	21.0
665.0	10530.99	6	58	64	18.8
665.5	10542.50	20	147	167	10.8
666.0	10554.02	6	48	54	1.9
666.5	10565.55	7	26	33	12.1
667.0	10577.11	31	25	56	5.4
667.5	10588.68	9	44	53	7.5
668.0	10600.26	2	25	27	7.4
668.5	10611.87	17	73	90	8.9
669.0	10623.49	14	188	202	10.9
669.5	10635.13	6	45	51	3.9
670.0	10646.78	5	43	48	12.5
670.5	10658.45	6	40	46	10.9
671.0	10670.14	4	43	47	12.8
671.5	10681.85	21	113	134	3.7
672.0	10693.57	8	62	70	4.3
672.5	10705.31	0	7	7	0.0
673.0	10717.07	0	4	4	50.0
673.5	10728.85	7	11	18	0.0
674.0	10740.64	15	69	84	8.3
674.5	10752.45	7	26	33	6.1

675.0	10764.28	6	27	33	12.1
675.5	10776.12	4	50	54	13.0
676.0	10787.99	17	79	96	6.3
676.5	10799.87	10	40	50	12.0
677.0	10811.77	4	15	19	36.8
677.5	10823.68	1	3	4	0.0
678.0	10835.62	0	4	4	0.0
678.5	10847.57	1	10	11	0.0
679.0	10859.54	1	5	6	33.3
679.5	10871.53	1	4	5	0.0
680.0	10883.53	4	22	26	19.2
680.5	10895.56	2	12	14	57.1
681.0	10907.60	0	12	12	8.3
681.5	10919.66	6	44	50	4.0
682.0	10931.74	3	47	50	8.0
682.5	10943.84	0	7	7	0.0
683.0	10955.96	0	6	6	0.0
683.5	10968.09	0	13	13	0.0
684.0	10980.25	4	19	23	0.0
684.5	10992.42	5	14	19	0.0
685.0	11004.61	3	20	23	8.7
685.5	11016.82	0	9	9	0.0
686.0	11029.05	1	19	20	5.0
686.5	11041.30	3	17	20	0.0
687.0	11053.56	2	17	19	0.0
687.5	11065.85	0	15	15	13.3
688.0	11078.15	0	6	6	0.0
688.5	11090.48	0	6	6	16.7
689.0	11102.82	0	4	4	25.0
689.5	11115.18	0	7	7	0.0
690.0	11127.56	17	10	27	3.7
690.5	11139.96	2	12	14	0.0
691.0	11152.38	5	15	20	10.0
691.5	11164.82	0	2	2	0.0
692.0	11177.28	1	10	11	0.0
692.5	11189.76	6	25	31	3.2
693.0	11202.26	3	36	39	0.0
693.5	11214.78	4	37	41	7.3
694.0	11227.32	2	17	19	15.8
694.5	11239.87	0	5	5	0.0

695.0	11252.45	0	7	7	14.3
695.5	11265.05	6	26	32	3.1
696.0	11277.67	3	18	21	14.3
696.5	11290.31	3	20	23	17.4
697.0	11302.96	0	7	7	14.3
697.5	11315.64	0	4	4	0.0
698.0	11328.34	0	4	4	0.0
698.5	11341.06	2	10	12	0.0
699.0	11353.80	1	3	4	0.0
699.5	11366.56	1	2	3	0.0
700.0	11379.34	3	8	11	0.0
700.5	11392.14	2	4	6	16.7
701.0	11404.96	1	3	4	0.0
701.5	11417.80	0	1	1	0.0
702.0	11430.66	1	3	4	0.0
702.5	11443.55	0	3	3	0.0
703.0	11456.45	0	0	0	0.0
703.5	11469.38	0	0	0	0.0
704.0	11482.32	0	0	0	0.0
704.5	11495.29	0	0	0	0.0
705.0	11508.28	0	0	0	0.0
705.5	11521.29	0	1	1	0.0
706.0	11534.32	0	1	1	0.0
706.5	11547.37	0	1	1	0.0
707.0	11560.44	0	0	0	0.0
707.5	11573.54	0	0	0	0.0
708.0	11586.65	0	0	0	0.0
708.5	11599.79	0	0	0	0.0
709.0	11612.95	0	0	0	0.0
709.5	11626.13	0	0	0	0.0
710.0	11639.33	0	3	3	0.0
710.5	11652.56	1	4	5	0.0
711.0	11665.80	0	2	2	0.0
711.5	11679.07	14	82	96	0.0
712.0	11692.36	37	147	184	1.6
712.5	11705.68	34	115	149	0.0
713.0	11719.01	3	9	12	0.0
713.5	11732.37	6	25	31	0.0
714.0	11745.75	0	0	0	0.0
714.5	11759.15	0	2	2	0.0

715.0	11772.57	2	2	4	0.0
715.5	11786.02	1	2	3	0.0
716.0	11799.48	0	3	3	0.0
716.5	11812.98	2	2	4	25.0
717.0	11826.49	0	1	1	0.0
717.5	11840.03	0	0	0	0.0
718.0	11853.58	0	11	11	9.1
718.5	11867.17	0	1	1	0.0
719.0	11880.77	0	5	5	20.0
719.5	11894.40	0	1	1	0.0
720.0	11908.05	0	5	5	0.0
720.5	11921.72	0	9	9	0.0
721.0	11935.42	0	2	2	0.0
721.5	11949.14	0	3	3	33.3
722.0	11962.88	0	3	3	0.0
722.5	11976.65	2	7	9	33.3
723.0	11990.44	0	6	6	0.0
723.5	12004.25	2	8	10	0.0
724.0	12018.09	4	23	27	22.2
724.5	12031.95	3	22	25	16.0
725.0	12045.84	0	5	5	20.0
725.5	12059.74	0	1	1	0.0
726.0	12073.67	4	13	17	5.9
726.5	12087.63	0	4	4	50.0
727.0	12101.61	0	4	4	0.0
727.5	12115.61	1	2	3	0.0
728.0	12129.64	0	6	6	16.7
728.5	12143.69	0	1	1	0.0
729.0	12157.77	0	2	2	0.0
729.5	12171.87	0	1	1	0.0
730.0	12185.99	0	0	0	0.0
730.5	12200.14	0	9	9	0.0
731.0	12214.31	3	16	19	10.5
731.5	12228.51	0	18	18	11.1
732.0	12242.73	2	8	10	10.0
732.5	12256.98	0	4	4	0.0
733.0	12271.25	2	6	8	0.0
733.5	12285.55	0	5	5	0.0
734.0	12299.87	0	5	5	0.0
734.5	12314.22	1	38	39	0.0

735.0	12328.59	10	104	114	7.0
735.5	12342.98	1	3	4	0.0
736.0	12357.41	0	4	4	25.0
736.5	12371.85	0	1	1	0.0
737.0	12386.32	0	8	8	0.0
737.5	12400.82	4	40	44	2.3
738.0	12415.34	0	11	11	9.1
738.5	12429.89	3	5	8	0.0
739.0	12444.46	0	4	4	25.0
739.5	12459.06	0	2	2	0.0
740.0	12473.69	1	4	5	0.0
740.5	12488.34	0	9	9	11.1
741.0	12503.01	1	6	7	28.6
741.5	12517.72	0	4	4	0.0
742.0	12532.44	0	2	2	0.0
742.5	12547.20	0	4	4	0.0
743.0	12561.98	0	2	2	0.0
743.5	12576.78	0	2	2	0.0
744.0	12591.62	0	2	2	0.0
744.5	12606.47	1	3	4	0.0
745.0	12621.36	0	2	2	0.0
745.5	12636.27	0	12	12	0.0
746.0	12651.21	0	17	17	0.0
746.5	12666.17	0	21	21	0.0
747.0	12681.16	0	21	21	0.0
747.5	12696.18	3	60	63	4.8
748.0	12711.23	3	60	63	4.8
748.5	12726.30	20	93	113	4.4
749.0	12741.39	20	93	113	4.4
749.5	12756.52	22	290	312	3.8
750.0	12771.67	22	290	312	3.8
750.5	12786.85	0	7	7	0.0
751.0	12802.06	0	7	7	0.0
751.5	12817.29	0	1	1	0.0
752.0	12832.55	0	1	1	0.0
752.5	12847.84	0	0	0	0.0
753.0	12863.15	0	0	0	0.0
753.5	12878.50	2	18	20	0.0
754.0	12893.87	2	18	20	0.0
754.5	12909.27	0	4	4	50.0

755.0	12924.69	0	4	4	50.0
755.5	12940.15	0	3	3	33.3
756.0	12955.63	0	3	3	33.3
756.5	12971.14	0	0	0	0.0
757.0	12986.68	0	0	0	0.0
757.5	13002.24	1	12	13	0.0
758.0	13017.84	1	12	13	0.0
758.5	13033.46	3	6	9	0.0
759.0	13049.11	3	6	9	0.0
759.5	13064.79	1	3	4	0.0
760.0	13080.50	0	3	3	0.0
760.5	13096.23	0	1	1	0.0
761.0	13112.00	0	1	1	0.0
761.5	13127.79	0	2	2	0.0
762.0	13143.61	0	5	5	20.0
762.5	13159.46	1	1	2	0.0
763.0	13175.34	0	0	0	0.0
763.5	13191.25	1	2	3	0.0
764.0	13207.19	0	3	3	0.0
764.5	13223.15	0	3	3	0.0
765.0	13239.15	1	5	6	16.7
765.5	13255.17	0	2	2	0.0
766.0	13271.23	0	2	2	0.0
766.5	13287.31	0	1	1	0.0
767.0	13303.42	0	3	3	0.0
767.5	13319.57	0	0	0	0.0
768.0	13335.74	0	0	0	0.0
768.5	13351.94	0	1	1	0.0
769.0	13368.17	0	2	2	0.0
769.5	13384.43	0	0	0	0.0
770.0	13400.73	1	2	3	0.0
770.5	13417.05	1	1	2	0.0
771.0	13433.40	0	0	0	0.0
771.5	13449.78	0	0	0	0.0
772.0	13466.19	0	0	0	0.0
772.5	13482.63	0	1	1	0.0
773.0	13499.11	0	0	0	0.0
773.5	13515.61	0	0	0	0.0
774.0	13532.14	0	0	0	0.0
774.5	13548.70	0	3	3	0.0

775.0	13565.30	0	0	0	0.0
775.5	13581.92	0	1	1	0.0
776.0	13598.58	0	0	0	0.0
776.5	13615.27	0	1	1	0.0
777.0	13631.98	0	0	0	0.0
777.5	13648.73	0	1	1	0.0
778.0	13665.51	0	2	2	50.0
778.5	13682.32	0	0	0	0.0
779.0	13699.16	1	0	1	0.0
779.5	13716.04	0	0	0	0.0
780.0	13732.94	0	0	0	0.0
780.5	13749.88	0	0	0	0.0
781.0	13766.85	0	2	2	0.0
781.5	13783.84	0	2	2	0.0
782.0	13800.88	1	0	1	0.0
782.5	13817.94	0	0	0	0.0
783.0	13835.03	0	2	2	0.0
783.5	13852.16	0	6	6	16.7
784.0	13869.32	1	10	11	9.1
784.5	13886.51	1	2	3	0.0
785.0	13903.73	0	6	6	16.7
785.5	13920.99	0	0	0	0.0
786.0	13938.27	2	2	4	0.0
786.5	13955.59	0	0	0	0.0
787.0	13972.94	0	1	1	0.0
787.5	13990.33	0	2	2	0.0
788.0	14007.74	0	1	1	0.0
788.5	14025.19	2	3	5	20.0
789.0	14042.68	0	1	1	0.0
789.5	14060.19	0	0	0	0.0
790.0	14077.74	0	1	1	100.0
790.5	14095.32	0	0	0	0.0
791.0	14112.93	0	0	0	0.0
791.5	14130.58	0	2	2	0.0
792.0	14148.26	0	0	0	0.0
792.5	14165.98	0	1	1	0.0
793.0	14183.72	0	1	1	0.0
793.5	14201.50	0	2	2	0.0
794.0	14219.32	0	1	1	0.0
794.5	14237.16	0	0	0	0.0

795.0	14255.05	0	2	2	0.0
795.5	14272.96	0	0	0	0.0
796.0	14290.91	0	0	0	0.0

APPENDIX B

BATTLE GROUND LAKE BG04A MAGNETIC SUSCEPTIBILITY DATA

Depth (cm)	Magnetic susceptibility (emu)
0	0.00003556
1	0.00003116
2	0.00011842
3	0.00011456
4	0.00009566
5	0.00007347
6	0.00004974
7	0.00003853
8	0.00002984
9	0.00002735
10	0.00002147
11	0.00002234
12	0.00001816
13	0.00001744
14	0.00001809
15	0.00001536
16	0.00001845
17	0.00001618
18	0.00002274
19	0.00001597
20	0.00001791
21	0.00001743
22	0.00001487
23	0.00001519
24	0.00001344
25	0.00001422
26	0.00001518
27	0.00001453
28	0.00001261
29	0.00001571
30	0.00001196
31	0.00001397
32	0.00001584

33	0.00001358
34	0.00001168
35	0.00001109
36	0.0000084
37	0.00000525
38	0.00000621
39	0.00000808
40	0.00001206
41	0.00001062
42	0.00001283
43	0.00001177
44	0.00001142
45	0.0000118
46	0.0000135
47	0.00001274
48	0.00001175
49	0.00001088
50	0.00000993
51	0.00001085
52	0.00000881
53	0.00000869
54	0.00001039
55	0.0000123
56	0.00001548
57	0.00001606
58	0.00002067
59	0.00001784
60	0.00001846
61	0.00001436
62	0.00001319
63	0.00001361
64	0.00001355
65	0.00001302
66	0.00001158
67	0.00000927
68	0.00000781
69	0.00000685
70	0.00000666
71	0.00001143
72	0.00000631

73	0.00000651
74	0.00000655
75	0.00000776
76	0.00000677
77	0.00000674
78	0.00000665
79	0.00000705
80	0.00000685
81	0.00000708
82	0.00000751
83	0.00000621
84	0.00000861
85	0.00000732
86	0.00000796
87	0.00000639
88	0.0000064
89	0.00000679
90	0.00000622
91	0.00000579
92	0.0000074
93	0.00000652
94	0.00000639
95	0.00000714
96	0.00000706
97	0.00000699
98	0.00000789
99	0.00000652
100	0.00000784
101	0.00000747
102	0.00000746
103	0.00000773
104	0.00000794
105	0.00000933
106	0.00000744
107	0.0000112
108	0.00000758
109	0.00000798
110	0.00000787
111	0.00000823
112	0.00000852

113	0.000007
114	0.00000725
115	0.00001028
116	0.00000474
117	0.00000804
118	0.0000111
119	0.00000773
120	0.00000746
121	0.00000972
122	0.00000829
123	0.00000965
124	0.00000937
125	0.00000953
126	0.00000534
127	0.00000389
128	0.00001099
129	0.00000853
130	0.00000895
131	0.00000797
132	0.00000638
133	0.00000418
137	0.00000538
138	0.00000664
139	0.00000792
140	0.0000094
141	0.00000862
142	0.0000084
143	0.00000965
144	0.00001047
145	0.00000859
146	0.00001551
147	0.00000767
148	0.00001131
149	0.00000898
150	0.00001789
151	0.00000997
152	0.00000918
153	0.00000989
154	0.00001654
155	0.00001584

156	0.00000712
157	0.00000805
158	0.00000762
159	0.00000861
160	0.0000077
161	0.0000084
162	0.00000884
163	0.00001253
164	0.00000931
165	0.00000877
166	0.00000924
167	0.00000961
168	0.00001018
169	0.00001014
170	0.00001247
171	0.00001382
172	0.00001711
173	0.00001939
174	0.00002412
175	0.00002662
176	0.00002359
177	0.00001968
178	0.00001629
179	0.00001263
180	0.0000116
181	0.00001205
182	0.00001529
185	0.00001394
186	0.00001232
187	0.00001732
188	0.0000114
189	0.00001353
190	0.00001115
191	0.00001269
192	0.00001053
193	0.00001174
194	0.00001133
195	0.00001156
196	0.00001218
197	0.00001119

198	0.00000986
199	0.00001159
200	0.00001325
201	0.00001227
202	0.00001349
203	0.00001287
204	0.00001456
205	0.00001227
206	0.00002027
207	0.00001338
208	0.00001187
209	0.00001401
210	0.0000119
211	0.00001371
212	0.0000092
213	0.00000924
214	0.00001921
215	0.00002192
216	0.00003098
217	0.0000228
218	0.00001814
219	0.00002383
220	0.00003612
221	0.00006485
222	0.00010618
223	0.00012884
224	0.00014062
225	0.00013213
226	0.00010212
227	0.00004721
228	0.00000865
229	0.00002308
230	0.00001485
231	0.00001231
232	0.00001268
233	0.0000097
237	0.00001031
238	0.00000992
239	0.00000986
240	0.00000981

241	0.00001664
242	0.00001369
243	0.00001081
244	0.00001052
245	0.0000108
246	0.00001306
247	0.00001168
248	0.00001118
249	0.0000104
250	0.00001092
251	0.00001206
252	0.00001284
253	0.00001268
254	0.00001097
255	0.00001205
256	0.00001115
257	0.00001115
258	0.00001134
259	0.00001394
260	0.0000145
261	0.00001216
262	0.0000128
263	0.0000123
264	0.00001287
265	0.00001421
266	0.00001594
267	0.00002418
268	0.00002621
269	0.00004139
270	0.00007744
271	0.00011895
272	0.00014142
273	0.00015862
274	0.00014299
275	0.00010834
276	0.00006089
276	0.00007365
277	0.00003496
278	0.00002112
279	0.00001513

280	0.00001178
281	0.00001163
282	0.00001227
283	0.0000103
286	0.00001296
287	0.00001003
288	0.00000962
289	0.00001119
290	0.00001391
291	0.00001031
292	0.00000974
293	0.00002196
294	0.00000996
295	0.00001065
296	0.00001061
297	0.00001065
298	0.00001124
299	0.00001006
300	0.00001069
301	0.00001056
302	0.00001031
303	0.00001594
304	0.00001064
305	0.00001269
306	0.00001147
307	0.00001322
308	0.00001056
309	0.00000862
310	0.00000834
311	0.00000915
312	0.00000939
313	0.00000961
314	0.0000103
315	0.00001157
316	0.00001044
317	0.00000978
318	0.00001075
319	0.00001182
320	0.00001141
321	0.00001105

322	0.00001059
321	0.00001113
323	0.00001112
324	0.00001481
325	0.00000602
326	0.00001188
327	0.00001235
328	0.00001174
329	0.00001344
330	0.00001652
331	0.00001347
332	0.00001334
333	0.00001196
334	0.00001431
335	0.000012
336	0.00001981
337	0.00000868
338	0.00000376
337	0.00000637
339	0.0000053
340	0.00000646
341	0.00000709
342	0.00000723
343	0.00000805
344	0.00000796
345	0.0000079
346	0.00000767
347	0.00000799
348	0.0000087
349	0.00000919
350	0.0000085
351	0.00000867
352	0.00000814
353	0.00000796
354	0.00000733
355	0.00000659
356	0.0000064
357	0.00000636
358	0.00000662
359	0.00000668

360	0.00000733
361	0.00000755
362	0.00000862
363	0.00000881
364	0.00001221
365	0.00001005
366	0.00000939
367	0.00001009
368	0.00000855
369	0.00000837
370	0.00000855
371	0.0000083
372	0.00000834
373	0.00000865
374	0.00000881
375	0.00000911
376	0.00000877
377	0.0000098
378	0.00001113
379	0.00001153
380	0.00001284
381	0.00001312
382	0.0000178
383	0.0000131
384	0.00001416
385	0.0000134
386	0.00001384
387	0.00001363
388	0.00001412
389	0.00002189
390	0.00001353
391	0.00001306
392	0.00001359
393	0.0000137
394	0.00001328
395	0.00001273
396	0.00001376
397	0.00001156
398	0.00001102
399	0.00001109

400	0.00000997
401	0.0000103
402	0.0000108
403	0.00001078
404	0.00001055
405	0.00001489
406	0.00000897
407	0.0000119
408	0.00001416
409	0.00001485
410	0.00001535
411	0.00001553
412	0.00000076
413	0.0000134
414	0.00001829
415	0.00001434
416	0.00002087
417	0.00001247
418	0.00001426
419	0.00001241
420	0.00001266
421	0.000014
422	0.00001257
423	0.00001325
424	0.00001528
425	0.00001992
426	0.00001171
427	0.0000115
428	0.00001419
429	0.00001224
430	0.00001854
431	0.00001193
432	0.00001395
433	0.00001556
434	0.00001262
435	0.00001257
436	0.00001251
437	0.0000105
442	0.00001431
443	0.00001643

444	0.00001741
445	0.00001866
446	0.00002001
447	0.00002036
448	0.00002116
449	0.00002298
450	0.00002276
451	0.00002145
452	0.00002097
453	0.00001916
454	0.00001766
455	0.00001687
456	0.00001742
457	0.00001916
458	0.00002082
459	0.00002308
460	0.00002402
461	0.00002583
462	0.00002542
463	0.00002612
464	0.00002323
465	0.00002058
466	0.00001903
467	0.00001468
468	0.0000181
469	0.00001806
470	0.00001875
471	0.00002245
472	0.00002483
473	0.00001995
474	0.00001994
475	0.00001875
476	0.00001786
477	0.00001888
478	0.00001848
479	0.00002249
480	0.00002133
481	0.00002652
482	0.00002074
483	0.00001988

484	0.00001709
485	0.00003088
486	0.0000159
487	0.00001338
488	0.00001296
489	0.00001351
490	0.0000136
491	0.00001428
492	0.00001481
493	0.00001595
494	0.00002224
495	0.00002734
496	0.00001833
497	0.00001902
498	0.00001808
499	0.00001833
500	0.00001838
501	0.00001848
502	0.00001802
503	0.00001761
504	0.00001735
505	0.00001736
506	0.00001974
507	0.00001742
508	0.00001711
509	0.0000181
510	0.00002021
511	0.0000245
512	0.00002717
513	0.0000369
514	0.00005733
515	0.00008674
516	0.00014381
517	0.00020167
518	0.00023424
519	0.00022466
520	0.00017768
521	0.00011889
522	0.00008847
523	0.0000522

524	0.00003672
525	0.00003184
526	0.00002916
527	0.0000275
528	0.00002416
529	0.00002319
530	0.00002191
531	0.0000125
532	0.0000125
537	0.0000211
538	0.00002206
539	0.000024
540	0.00002385
541	0.00002394
542	0.00002382
543	0.00011522
544	0.00002385
545	0.00002065
546	0.00002073
547	0.00002111
548	0.00002192
549	0.00002274
550	0.00002584
551	0.00004047
552	0.00002421
553	0.00002479
554	0.00002585
555	0.00002676
556	0.00002789
557	0.00002792
558	0.00002841
559	0.00002795
560	0.00002684
561	0.00002603
562	0.00002444
563	0.00002311
564	0.00002199
565	0.00002158
566	0.00002067
567	0.00002056

568	0.00002014
569	0.00002024
570	0.00002024
571	0.00001992
572	0.00001962
573	0.00001915
574	0.0000187
575	0.00001816
576	0.00001789
577	0.00001792
578	0.00001735
579	0.00001727
580	0.00001653
581	0.00001663
582	0.00002628
583	0.00001967
584	0.00002125
585	0.00002396
586	0.00002554
587	0.00002704
588	0.0000282
589	0.00002894
590	0.00002856
591	0.00002767
592	0.0000255
593	0.0000234
594	0.00002109
595	0.00001798
596	0.00001466
597	0.00001088
598	0.00000582
599	0.0000092
600	0.00001387
601	0.00001848
602	0.00002264
603	0.00002611
604	0.0000281
605	0.00003131
606	0.00003276
607	0.0000335

608	0.00003319
609	0.00003253
610	0.00003157
611	0.00003047
612	0.00002893
613	0.00002918
614	0.00002805
615	0.00002868
616	0.00002859
617	0.00003031
618	0.00003353
619	0.000037
620	0.00004049
621	0.00003726
622	0.00003804
623	0.00003616
624	0.00003548
625	0.00003831
626	0.00003026
627	0.00002871
628	0.00002581
629	0.00002384
630	0.0000239
631	0.00001866
632	0.00002223
633	0.00002312
634	0.00002445
635	0.00002556
636	0.00002772
637	0.00003898
638	0.00003846
639	0.00003883
640	0.00003875
641	0.00003683
642	0.00003545
643	0.00003427
644	0.00003401
645	0.00003613
646	0.00003992
647	0.00004507

648	0.00004875
649	0.00005221
650	0.00004946
651	0.00004343
652	0.00003548
653	0.00002618
654	0.00001617
655	0.00002082
656	0.00002715
657	0.00003238
658	0.0000346
659	0.00003749
660	0.00004178
661	0.00004697
662	0.00005421
663	0.00006054
664	0.00006689
665	0.00007522
666	0.00007973
667	0.00008894
668	0.000098
669	0.00010197
670	0.0001016
671	0.00009418
672	0.00008039
673	0.00006449
674	0.00004999
675	0.0000413
676	0.00003568
677	0.00003125
678	0.00003041
679	0.00003107
680	0.00003278
681	0.00003476
682	0.00003646
683	0.00003846
684	0.00004128
685	0.00004604
686	0.00005352
687	0.00006257

688	0.00007331
689	0.00008434
690	0.00009348
691	0.00010033
692	0.00010469
693	0.00010669
694	0.00010681
695	0.00010413
696	0.00009771
697	0.0000868
698	0.00006914
699	0.0000501
698	0.00004802
699	0.00007159
700	0.00008972
701	0.0001186
702	0.00013285
703	0.00013801
704	0.00014766
705	0.00015521
706	0.00016282
707	0.00016682
708	0.00016724
709	0.00016419
710	0.00015888
711	0.00015446
712	0.00015176
713	0.00015267
714	0.00015709
715	0.00016507
716	0.00017524
717	0.00018927
718	0.00020195
719	0.00021082
720	0.00021549
721	0.00021568
722	0.00021385
723	0.00021248
724	0.00021296
725	0.00021539

726	0.00021986
727	0.00022695
728	0.00023628
729	0.00024643
730	0.00025291
731	0.0002555
732	0.00025243
733	0.00024706
734	0.00023904
735	0.00022829
736	0.00021672
737	0.00019883
738	0.0001708
739	0.00013859
740	0.00009963
741	0.00013859
742	0.00017491
743	0.00020251
744	0.00021994
745	0.00023253
746	0.00024277
747	0.00025148
748	0.00026056
749	0.00026732
750	0.00027271
751	0.00027749
752	0.00028607
753	0.0002977
754	0.0003096
755	0.00032111
756	0.0003277
757	0.00032308
758	0.00033195
759	0.00033514
760	0.00034081
761	0.00034727
762	0.00035339
763	0.00035834
764	0.00036292
765	0.00036806

766	0.00037296
767	0.00037632
768	0.00037835
769	0.00037782
770	0.00037727
771	0.00037902
772	0.00038424
773	0.00039388
774	0.00040775
775	0.00042407
776	0.00044088
777	0.00046083
778	0.00047717
779	0.00049297
780	0.00050682
781	0.00051584
782	0.00052074
783	0.00052351
784	0.0005247
785	0.0005221
786	0.00051633
787	0.00051065
788	0.00050645
789	0.00050067
790	0.00049468
791	0.00048862
792	0.00048366
793	0.00048372
794	0.00048895
795	0.00049571
796	0.00049951
797	0.00049701
798	0.00048521
799	0.00046673
800	0.00044009
801	0.00040461
802	0.00035307
803	0.00029051
804	0.00022059
805	0.00014755

APPENDIX C

BATTLE GROUND LAKE BG04A LOSS-ON-IGNITION DATA

Depth (cm)	Bulk density (%)	Organic content (%)	Carbonate content (%)
4.0	75.5	22.4	
5.0	64.9	12.8	
6.0	69.9	16.3	
7.0	77.7	24.1	4.1
8.0	88.1	50.8	
9.0	88.2	51.9	
10.0	88.5	46.0	
11.0	88.8	51.6	
12.0	88.7	57.8	3.3
13.0	88.6	54.6	
14.0	88.6	54.9	
15.0	88.3	54.8	
16.0	88.7	54.2	
17.0	88.7	53.9	4.4
18.0	88.7	54.0	
19.0	88.4	54.0	
20.0	88.6	55.0	
21.0	88.7	55.1	
22.0	88.9	57.7	3.3
23.0	88.9	57.3	
24.0	89.2	61.0	
25.0	89.0	63.2	
26.0	89.2	64.5	
27.0	89.4	65.8	1.6
28.0	89.5	65.8	
29.0	88.9	62.9	
30.0	88.1	56.6	
31.0	87.7	57.0	
32.0	88.6	59.0	2.8
33.0	88.5	59.2	
34.0	88.9	60.5	
35.0	88.5	61.6	
36.0	88.4	59.9	2.8

37.0	87.8	55.4	
38.0	85.7	54.8	
39.0	86.5	57.2	
40.0	86.5	56.4	
41.0	87.3	56.4	2.7
42.0	86.7	55.6	
43.0	88.3	56.1	
44.0	87.2	54.5	
45.0	87.7	55.8	
46.0	87.6	55.7	2.9
47.0	84.3	55.8	
48.0	87.9	54.7	
49.0	88.0	56.3	
50.0	86.2	56.9	
51.0	89.3	56.8	2.3
52.0	89.4	57.3	
53.0	88.7	58.9	
54.0	88.2	56.8	
55.0	88.7	56.9	
56.0	89.6	57.2	
57.0	81.1	30.9	1.5
58.0	87.7	52.7	
59.0	88.9	55.6	
60.0	86.7	56.9	
61.0	87.7	54.5	
62.0	88.1	57.2	2.7
63.0	87.6	56.0	
64.0	82.2	35.5	
65.0	85.2	45.8	
66.0	88.8	63.8	3.1
67.0	89.1	64.1	
68.0	88.8	64.1	
69.0	89.3	62.9	
70.0	89.9	62.0	
71.0	89.9	59.2	5.9
72.0	89.4	59.2	
73.0	89.7	58.4	
74.0	89.5	57.2	
75.0	89.2	56.7	
76.0	89.1	56.4	6.3

77.0	88.9	55.5	
78.0	88.7	54.7	
79.0	88.6	55.2	
80.0	88.2	55.2	
81.0	88.7	55.4	5.4
82.0	88.2	55.7	
83.0	88.7	56.5	
84.0	88.4	57.3	
85.0	88.3	57.1	
86.0	88.0	57.5	4.6
87.0	87.9	59.6	
88.0	89.0	62.7	
89.0	89.0	64.0	
90.0	89.0	65.6	
91.0	88.9	64.2	4.8
92.0	88.7	64.3	
93.0	89.0	64.5	
94.0	89.1	65.1	
95.0	89.7	65.2	
96.0	89.0	65.3	4.4
97.0	89.4	63.7	
98.0	88.9	60.2	
99.0	88.4	58.3	
100.0	88.7	57.0	
101.0	89.2	57.3	3.6
102.0	89.0	58.1	
103.0	89.1	57.7	
104.0	88.7	56.3	
105.0	89.2	56.5	
106.0	89.0	55.1	3.8
107.0	87.7	54.2	
108.0	87.7	52.6	
109.0	87.9	51.8	
110.0	87.7	50.4	
111.0	87.5	49.6	3.9
112.0	87.3	49.2	
113.0	87.9	48.7	
114.0	88.3	51.4	
115.0	88.1	51.6	
116.0	88.3	52.1	4.8

117.0	88.2	52.7	
118.0	88.3	54.2	
119.0	88.1	54.9	
120.0	88.5	54.6	
121.0	88.3	55.8	4.5
122.0	88.4	55.5	
123.0	88.6	55.8	
124.0	88.5	55.3	
125.0	89.7	64.4	
126.0	86.2	44.4	4.1
127.0	87.9	49.2	
128.0	87.8	47.6	
129.0	87.5	47.7	
130.0	87.1	46.4	
131.0	85.5	45.4	4.4
132.0	86.5	44.9	
133.0	86.8	46.5	
134.0	87.7	48.5	
135.0	87.7	50.6	
136.0	88.2	51.6	4.6
137.0	86.8	54.9	
138.0	84.9	51.2	
139.0	86.5	50.9	
140.0	86.3	52.4	
141.0	86.6	52.8	3.9
142.0	87.2	57.8	
143.0	87.6	55.9	
144.0	88.0	56.8	
145.0	87.7	56.3	
146.0	88.4	55.9	4.2
147.0	87.0	51.3	
148.0	87.7	52.2	
149.0	88.2	53.2	
150.0	89.0	52.1	
151.0	88.9	52.1	4.8
152.0	88.4	50.8	
153.0	88.3	51.7	
154.0	88.4	51.1	
155.0	88.8	50.9	
156.0	88.4	50.9	5.1

157.0	88.5	52.5	
158.0	88.6	53.0	
159.0	88.2	53.0	
160.0	88.7	54.8	
161.0	88.6	57.3	5.8
162.0	88.4	58.3	
163.0	88.9	61.5	
164.0	88.7	55.6	
165.0	89.2	58.4	
166.0	88.6	55.3	6.3
167.0	88.6	54.1	
168.0	88.7	54.2	
169.0	89.2	53.0	
170.0	87.2	47.2	
171.0	87.3	47.6	5.7
172.0	87.4	48.3	
173.0	87.0	46.7	
174.0	85.7	43.2	
175.0	87.0	47.0	
176.0	86.9	46.2	
177.0	75.8	22.0	2.4
178.0	88.0	49.6	
179.0	87.5	49.5	
180.0	87.6	51.1	
181.0	87.5	52.0	
182.0	87.4	55.7	3.1
183.0	87.8	56.0	
184.0	88.6	58.9	
185.0	84.4	41.1	
186.0	88.1	59.8	2.6
187.0	88.7	62.5	
188.0	87.8	57.5	
189.0	86.8	52.1	
190.0	87.2	52.9	
191.0	87.0	52.9	3.2
192.0	86.0	49.7	
193.0	86.7	49.5	
194.0	86.3	47.8	
195.0	86.7	50.7	
196.0	87.3	52.7	6.5

197.0	87.1	54.8	
198.0	87.6	55.8	
199.0	87.7	56.6	
200.0	87.7	55.1	
201.0	87.4	56.5	0.7
202.0	87.8	58.9	
203.0	87.3	59.0	
204.0	88.1	61.2	
205.0	88.1	60.7	
206.0	87.9	61.3	1.9
207.0	88.1	59.5	
208.0	87.8	58.7	
209.0	87.5	56.3	
210.0	87.5	56.3	
211.0	86.9	58.9	2.6
212.0	88.0	56.7	
213.0	87.4	56.3	
214.0	87.5	55.2	
215.0	87.0	52.3	
216.0	82.5	36.7	
217.0	77.2	24.9	1.3
218.0	87.6	54.3	
219.0	87.9	58.8	
220.0	87.8	59.1	
221.0	86.7	55.8	1.3
222.0	87.3	52.8	
223.0	86.6	55.1	
224.0	84.8	43.8	
225.0	83.2	36.8	
226.0	35.9	3.3	1.8
227.0	75.9	25.2	
228.0	82.2	37.1	
229.0	84.1	42.8	
230.0	86.9	53.3	
231.0	86.6	50.9	4.1
232.0	85.9	77.4	
233.0	82.7	37.2	
234.0	87.1	54.7	
235.0	87.0	54.3	
238.0	84.2	52.9	

239.0	86.1	56.3	5.6
240.0	86.9	56.5	
241.0	87.0	58.1	1.3
242.0	86.7	58.4	
243.0	86.8	56.6	
244.0	86.6	55.9	
245.0	87.0	56.0	
246.0	86.4	56.4	6.2
247.0	86.6	55.8	
248.0	87.2	55.7	
249.0	86.7	55.5	
250.0	85.9	54.3	
251.0	86.0	55.6	4.3
252.0	86.1	56.0	
253.0	86.3	57.4	
254.0	86.8	57.0	
255.0	86.9	55.8	
256.0	86.7	55.3	4.6
257.0	86.5	56.2	
258.0	87.5	59.5	
259.0	87.5	59.1	
260.0	87.0	57.6	
261.0	86.4	55.0	7.1
262.0	85.6	51.6	
263.0	86.2	53.0	
264.0	85.1	50.7	
265.0	84.5	50.8	
266.0	86.4	56.8	
267.0	84.1	48.3	4.5
268.0	87.1	57.9	
269.0	87.0	56.9	
270.0	86.9	57.3	
271.0	86.3	53.1	
273.0	83.9	43.8	3.4
272.0	43.7	5.4	
274.0	46.3	6.0	
275.0	54.5	8.9	
276.0	87.5	62.5	
277.0	84.6	54.3	3.5
278.0	82.8	42.8	

279.0	87.3	57.8	
280.0	87.3	57.9	
281.0	86.6	55.7	5.1
282.0	86.3	56.8	
283.0	85.5	55.1	
284.0	84.6	53.8	
285.0	85.2	55.0	
286.0	84.7	57.5	
287.0	86.4	60.4	6.4
288.0	87.2	59.6	
289.0	86.1	57.2	
290.0	86.1	56.1	
291.0	85.5	54.6	
292.0	86.4	57.8	2.9
293.0	85.2	54.1	
294.0	84.9	55.6	
295.0	85.6	53.5	
296.0	85.2	54.0	
297.0	84.3	54.9	2.2
298.0	86.2	56.1	
299.0	86.2	56.0	
300.0	86.3	54.3	
301.0	85.4	57.3	
302.0	87.4	58.6	2.0
303.0	86.7	56.3	
304.0	85.8	54.1	
305.0	86.4	57.2	
306.0	87.1	58.5	
307.0	87.7	61.9	2.7
308.0	87.0	58.3	
309.0	86.4	59.4	
310.0	86.8	56.5	
311.0	86.5	57.9	2.5
316.0	86.6	59.4	2.7
321.0	86.1	58.6	3.7
326.0	85.6	58.3	3.5
331.0	84.1	51.3	3.7
335.5	87.9	63.9	4.5
341.0	87.3	58.4	5.1
346.0	86.8	59.7	3.5

351.0	86.1	58.1	4.6
356.0	86.8	61.6	3.6
361.0	87.2	63.9	2.3
366.0	86.5	59.9	3.5
371.0	86.2	57.9	3.4
376.0	84.8	54.4	3.5
381.0	85.1	57.2	3.1
386.0	85.9	54.9	3.8
391.0	85.7	58.4	3.2
396.0	83.6	52.1	3.4
401.0	86.3	62.9	3.5
406.0	85.6	58.8	3.7
411.0	85.8	56.8	3.7
416.0	85.0	52.3	3.6
421.0	87.0	58.3	5.4
426.0	86.3	62.1	3.1
431.0	87.4	68.5	3.7
436.0	83.2	52.6	3.8
441.0	74.7	41.8	3.3
446.0	79.7	47.4	3.0
451.0	82.0	51.5	1.2
456.0	81.8	51.0	4.0
461.0	81.5	48.5	1.4
466.0	83.1	53.1	2.8
471.0	83.4	56.3	4.3
476.0	82.9	57.9	5.4
481.0	80.6	53.6	1.8
486.0	79.0	50.1	6.8
491.0	79.2	46.0	3.2
496.0	79.8	49.7	2.2
501.0	79.7	46.7	2.3
506.0	80.7	52.9	3.5
511.0	81.1	55.1	2.1
521.0	79.3	49.5	3.2
526.0	77.7	51.7	3.9
531.0	80.1	51.8	2.5
536.0	77.9	51.5	5.7
541.0	79.3	53.1	0.2
546.0	81.3	59.8	1.2
551.0	81.0	52.6	2.4

556.0	74.4	45.6	2.9
561.0	72.0	37.9	3.1
566.0	78.4	52.9	8.2
571.0	77.2	47.0	2.6
576.0	76.4	43.3	7.2
581.0	79.1	55.3	4.4
586.0	75.9	42.0	5.5
591.0	77.0	39.9	2.8
596.0	80.1	49.9	4.1
601.0	77.9	44.7	2.8
606.0	75.4	37.2	5.1
611.0	74.5	41.6	3.8
616.0	73.4	43.8	3.2
621.0	74.2	38.5	5.1
626.0	76.7	42.9	5.6
631.0	76.2	48.6	5.2
636.0	73.4	43.7	3.0
641.0	71.2	41.7	3.4
646.0	74.6	50.8	2.6
651.0	70.9	38.6	3.5
656.0	70.5	43.6	2.1
661.0	67.5	32.2	3.5
666.0	65.4	30.5	3.1
671.0	66.4	32.3	3.1
676.0	70.4	39.4	3.6
681.0	69.6	35.6	3.2
686.0	67.9	28.4	3.0
691.0	60.0	18.2	3.6
696.0	60.6	17.4	3.6
701.0	59.8	17.5	3.3
706.0	59.3	15.8	2.6
711.0	56.1	15.0	2.8
716.0	54.6	14.3	3.0
721.0	59.5	14.0	3.0
726.0	62.4	15.2	2.9
731.0	55.3	13.1	2.7
736.0	59.1	14.9	3.2
741.0	60.2	13.3	3.9
746.0	56.5	13.3	3.4
751.0	53.1	11.5	3.2

756.0	56.1	12.1	2.5
761.0	55.0	12.5	3.3
766.0	52.8	10.7	3.1
771.0	51.5	11.7	2.7
776.0	49.7	10.9	2.9
781.0	53.0	10.9	2.9
786.0	52.7	11.1	2.6
791.0	53.9	12.1	3.0
796.0	50.5	11.5	2.9
801.0	51.5	11.2	3.0

APPENDIX D

BATTLE GROUND LAKE BG05B CHARCOAL DATA

Depth (cm)	Age (cal yr BP)	Age (AD)	Charcoal Particles >250 μm	Charcoal Particles >125 μm	Charcoal concentration (particles/cm^3)	Herbaceous Charcoal (%)
0.0	-55.0	2005.0	0	6	6	16.7
0.5	-50.3	2000.3	2	21	23	52.2
1.0	-45.6	1995.6	1	15	16	6.3
1.5	-40.9	1990.9	1	28	29	6.9
2.0	-36.4	1986.4	2	53	55	9.1
2.5	-32.0	1982.0	4	77	81	7.4
3.0	-27.7	1977.7	8	83	91	7.7
3.5	-23.6	1973.6	6	81	87	2.3
4.0	-19.7	1969.7	8	49	57	1.8
4.5	-15.9	1965.9	6	102	108	3.7
5.0	-12.4	1962.4	8	107	115	1.7
5.5	-9.1	1959.1	12	96	108	0.0
6.0	-5.9	1955.9	6	90	96	2.1
6.5	-2.9	1952.9	7	68	75	0.0
7.0	-0.1	1950.1	4	68	72	1.4
7.5	2.5	1947.5	5	95	100	2.0
8.0	5.1	1944.9	12	95	107	2.8
8.5	7.5	1942.5	5	97	102	3.9
9.0	9.8	1940.2	9	85	94	0.0
9.5	12.1	1937.9	1	77	78	2.6
10.0	14.5	1935.5	3	56	59	0.0
10.5	16.8	1933.2	76	257	333	7.2
11.0	19.3	1930.7	70	304	374	2.4
11.5	21.9	1928.1	34	179	213	2.3
12.0	24.8	1925.2	14	78	92	2.2
12.5	27.9	1922.1	31	207	238	4.2
13.0	31.3	1918.7	105	545	650	4.9
13.5	35.2	1914.8	93	287	380	1.8
14.0	39.5	1910.5	58	220	278	3.2
14.5	44.4	1905.6	46	142	188	6.9
15.0	50.0	1900.0	12	78	90	10.0
15.5	65.1	1884.9	10	57	67	25.4

16.0	73.3	1876.7	13	33	46	10.9
16.5	81.5	1868.5	3	19	22	9.1
17.0	89.7	1860.3	3	12	15	13.3
17.5	97.8	1852.2	1	9	10	20.0
18.0	105.8	1844.2	6	18	24	16.7
18.5	113.8	1836.2	6	14	20	15.0
19.0	121.7	1828.3	3	26	29	6.9
19.5	129.6	1820.4	4	48	52	3.8
20.0	137.4	1812.6	6	35	41	2.4
20.5	145.1	1804.9	4	33	37	10.8
21.0	152.8	1797.2	5	25	30	13.3
21.5	160.5	1789.5	8	44	52	5.8
22.0	168.0	1782.0	35	97	132	6.8
22.5	175.5	1774.5	3	37	40	2.5
23.0	183.0	1767.0	2	38	40	5.0
23.5	190.4	1759.6	2	23	25	0.0
24.0	197.7	1752.3	4	20	24	4.2
24.5	205.0	1745.0	27	116	143	16.1
25.0	212.2	1737.8	10	55	65	3.1
25.5	219.4	1730.6	11	47	58	13.8
26.0	226.5	1723.5	7	67	74	9.5
26.5	233.5	1716.5	10	64	74	6.8
27.0	240.5	1709.5	3	30	33	0.0
27.5	247.4	1702.6	12	38	50	4.0
28.0	254.3	1695.7	8	28	36	5.6
28.5	261.1	1688.9	5	28	33	3.0
29.0	267.8	1682.2	4	25	29	6.9
29.5	274.5	1675.5	1	33	34	8.8
30.0	281.2	1668.8	4	32	36	2.8
30.5	287.7	1662.3	6	43	49	14.3
31.0	294.2	1655.8	6	31	37	5.4
31.5	300.7	1649.3	2	32	34	5.9
32.0	307.1	1642.9	6	39	45	4.4
32.5	313.4	1636.6	2	31	33	0.0
33.0	319.7	1630.3	9	36	45	2.2
33.5	325.9	1624.1	1	29	30	3.3
34.0	332.1	1617.9	5	31	36	16.7
34.5	338.2	1611.8	2	37	39	12.8
35.0	344.3	1605.7	1	26	27	14.8
35.5	350.2	1599.8	8	41	49	2.0

36.0	356.2	1593.8	2	53	55	5.5
36.5	362.1	1587.9	4	55	59	3.4
37.0	367.9	1582.1	7	35	42	7.1
37.5	373.6	1576.4	6	58	64	12.5
38.0	379.3	1570.7	6	50	56	3.6
38.5	385.0	1565.0	14	61	75	2.7
39.0	390.5	1559.5	8	55	63	7.9
39.5	396.1	1553.9	4	43	47	14.9
40.0	401.5	1548.5	2	46	48	8.3
40.5	406.9	1543.1	0	58	58	5.2
41.0	412.3	1537.7	5	52	57	1.8
41.5	417.5	1532.5	3	45	48	8.3
42.0	422.8	1527.2	3	53	56	7.1
42.5	427.9	1522.1	9	49	58	10.3
43.0	433.1	1516.9	8	54	62	12.9
43.5	438.1	1511.9	8	42	50	4.0
44.0	443.1	1506.9	18	45	63	6.3
44.5	448.0	1502.0	12	50	62	8.1
45.0	452.9	1497.1	10	36	46	6.5
45.5	457.7	1492.3	3	28	31	0.0
46.0	462.5	1487.5	4	49	53	11.3
46.5	467.2	1482.8	7	27	34	0.0
47.0	471.8	1478.2	13	49	62	3.2
47.5	476.4	1473.6	10	32	42	2.4
48.0	480.9	1469.1	22	72	94	11.7
48.5	485.4	1464.6	10	68	78	2.6
49.0	489.8	1460.2	23	92	115	10.4
49.5	494.2	1455.8	5	45	50	12.0
50.0	498.5	1451.5	14	73	87	10.3
50.5	502.7	1447.3	4	53	57	7.0
51.0	506.9	1443.1	14	92	106	14.2
51.5	511.0	1439.0	16	90	106	10.4
52.0	515.0	1435.0	9	114	123	6.5
52.5	519.0	1431.0	7	116	123	6.5
53.0	523.0	1427.0	10	117	127	7.1
53.5	526.9	1423.1	8	68	76	5.3
54.0	530.7	1419.3	11	97	108	1.9
54.5	534.5	1415.5	1	89	90	1.1
55.0	538.2	1411.8	2	54	56	0.0
55.5	541.8	1408.2	1	45	46	2.2

56.0	545.4	1404.6	3	67	70	4.3
56.5	548.9	1401.1	8	107	115	2.6
57.0	552.4	1397.6	17	152	169	1.8
57.5	555.8	1394.2	85	356	441	7.5
58.0	559.2	1390.8	64	333	397	8.3
58.5	562.5	1387.5	15	176	191	6.3
59.0	565.7	1384.3	21	200	221	2.7
59.5	568.9	1381.1	19	210	229	1.7
60.0	572.0	1378.0	11	103	114	1.8
60.5	575.1	1374.9	5	87	92	0.0
61.0	578.1	1371.9	5	89	94	2.1
61.5	581.0	1369.0	10	90	100	2.0
62.0	583.9	1366.1	30	140	170	2.9
62.5	586.7	1363.3	73	501	574	4.2
63.0	589.5	1360.5	144	708	852	4.2
63.5	592.2	1357.8	111	591	702	2.3
64.0	594.9	1355.1	112	332	444	2.7
64.5	597.5	1352.5	41	212	253	5.5
65.0	600.0	1350.0	23	120	143	2.1
65.5	602.5	1347.5	11	97	108	1.9
66.0	604.9	1345.1	46	204	250	3.6
66.5	607.3	1342.7	51	224	275	4.0

APPENDIX E

BATTLE GROUND LAKE BG05B POLLEN DATA

Depth (cm)	Age (cal yr BP)	Age (AD)	Total *Pinus*	*Picea*	*Abies*	*Pseudotsuga*-type	*Thuja*-type
0.25	-55.0	2005.0	2	0	2	59	28
5.25	-12.4	1962.4	1	2	2	25	45
10.25	14.5	1935.5	4	3	5	25	42
15.25	56.7	1893.3	10	1	0	85	69
20.25	137.4	1812.6	3	1	4	49	85
25.25	212.2	1737.8	3	2	5	118	55
30.25	281.2	1668.8	4	2	5	97	40
40.25	401.5	1548.5	3	5	3	100	63
50.25	498.5	1451.5	8	1	3	53	52
55.25	540.0	1410.0	9	2	2	52	25
60.25	572.0	1378.0	5	3	4	64	69
65.25	600.0	1350.0	7	0	4	60	57

Tsuga heterophylla	*Taxus brevifolia*	*Alnus rubra*-type	*Corylus*	*Betula*	*Salix*	*Populus trichocarpa*-type
9	0	69	12	0	3	0
4	0	54	9	1	1	0
14	0	41	12	1	3	0
11	0	21	7	0	2	4
2	0	32	12	0	1	2
8	1	21	6	0	3	2
13	0	24	6	0	3	0
6	0	27	6	1	1	0
7	0	67	11	0	3	0
14	0	46	16	0	3	1
11	0	19	12	0	2	1
7	2	30	14	2	5	4

Fraxinus	*Quercus*	*Sambucus*	*Acer circinatum*	*Acer macrophyllum*	Rosaceae	*Spiraea*-type	*Rubus*
7	2	1	2	2	3	3	1
5	2	1	0	0	1	3	1
4	0	0	0	0	0	3	0
3	1	0	1	0	0	1	0
6	1	0	0	1	0	3	0
10	0	0	3	4	0	4	0
8	0	0	2	0	0	5	0
4	1	0	1	0	0	1	0
7	2	0	0	1	0	5	0
7	1	0	0	0	0	4	0
3	4	0	0	0	1	4	0
4	0	0	0	1	0	2	0

Potentilla	*Ceanothus*	*Cornus*	*Castanea*	Poaceae	Cyperaceae	*Artemisia*	*Ambrosia*
0	0	0	2	25	0	0	0
0	0	0	0	17	1	1	0
1	1	0	0	5	2	1	0
0	0	0	0	2	1	0	0
0	0	0	0	7	2	2	0
0	1	0	0	1	0	1	0
0	0	0	0	0	0	2	0
0	0	0	0	1	0	0	1
0	0	0	0	4	0	1	0
0	0	1	0	1	0	2	0
0	0	1	0	0	0	0	0
0	0	0	0	2	3	0	0

Other Tubuliflorae	Chenopodiaceae	*Rumex*	*Galium*	*Plantago*-type	*Pteridium*	*Dryopteris*-type
2	0	0	0	0	6	6
0	0	1	0	3	27	2
0	2	5	1	2	49	3
0	1	0	0	0	6	5
0	0	0	0	0	7	4
1	0	0	0	1	11	3
0	1	0	0	0	14	3
1	0	0	0	0	20	1
0	0	0	0	0	26	3
1	0	0	0	0	44	5
2	0	1	1	0	14	8
2	0	0	0	1	28	7

Polypodiaceae	*Sparganium*-type	*Ruppia*	*Sagittaria*	Indeterminate	Unknown	*Lycopodium* tracer
0	0	0	1	13	0	57
1	0	0	0	5	2	36
0	0	0	0	0	1	37
0	0	0	0	0	0	38
0	0	0	0	0	0	28
0	0	0	0	2	0	22
0	0	0	0	3	0	29
0	0	0	0	1	3	20
0	0	0	0	3	1	18
0	0	1	0	1	3	18
0	0	0	0	6	1	13
0	1	0	0	4	0	20

Total	AP/(AP+NAP)
260	0.84
217	0.75
230	0.69
231	0.94
224	0.90
266	0.93
232	0.91
250	0.90
258	0.87
241	0.78
236	0.89
247	0.82

APPENDIX F

BEAVER LAKE BL05B CHARCOAL DATA

Depth (cm)	Age (cal yr BP)	Woody particles >125 µm	Herbaceous particles >125 µm	Lattice particles >125 µm	Charcoal concentration (particles/cm3)	Sedimentation rate (cm/yr)
0.0	-55.00	9	8	0	17.0	0.65
0.5	-54.23	7	6	0	13.0	0.53
1.0	-53.29	6	6	0	12.0	0.39
1.5	-52.00	8	0	0	8.0	0.24
2.0	-49.90	7	3	0	10.0	0.16
2.5	-46.87	7	2	0	9.0	0.14
3.0	-43.22	8	1	0	9.0	0.13
3.5	-39.24	8	2	0	10.0	0.13
4.0	-35.26	7	2	0	9.0	0.14
4.5	-31.59	6	3	0	9.0	0.16
5.0	-28.53	3	2	0	5.0	0.23
5.5	-26.40	10	5	0	15.0	0.34
6.0	-24.93	7	2	0	9.0	0.38
6.5	-23.62	7	10	0	17.0	0.43
7.0	-22.47	6	4	0	10.0	0.48
7.5	-21.43	5	0	0	5.0	0.54
8.0	-20.50	17	11	2	30.0	0.59
8.5	-19.65	18	1	0	19.0	0.63
9.0	-18.86	14	6	0	20.0	0.66
9.5	-18.10	7	5	0	12.0	0.70
10.0	-17.38	9	5	0	14.0	0.77
10.5	-16.73	4	0	0	4.0	0.83
11.0	-16.13	7	2	0	9.0	0.88
11.5	-15.56	5	0	0	5.0	0.92
12.0	-15.01	11	4	0	15.0	0.94
12.5	-14.48	11	1	0	12.0	0.94
13.0	-13.95	5	1	0	6.0	0.91
13.5	-13.40	17	0	0	17.0	0.94
14.0	-12.87	8	0	0	8.0	1.01
14.5	-12.37	8	0	0	8.0	1.06
15.0	-11.90	7	1	0	8.0	1.08
15.5	-11.44	20	0	0	20.0	1.05
16.0	-10.96	8	0	0	8.0	0.99

16.5	-10.46	4	0	0	4.0	0.91
17.0	-9.91	15	1	0	16.0	0.82
17.5	-9.29	5	1	0	6.0	0.72
18.0	-8.60	6	1	0	7.0	0.60
18.5	-7.76	9	1	0	10.0	0.49
19.0	-6.75	12	1	0	13.0	0.43
19.5	-5.59	5	0	0	5.0	0.39
20.0	-4.32	3	1	0	4.0	0.37
20.5	-2.98	2	1	0	3.0	0.36
21.0	-1.60	1	0	0	1.0	0.36
21.5	-0.20	6	0	0	6.0	0.34
22.0	1.27	26	1	0	27.0	0.31
22.5	2.86	13	0	0	13.0	0.30
23.0	4.55	11	1	0	12.0	0.29
23.5	6.29	8	0	0	8.0	0.29
24.0	8.04	2	0	0	2.0	0.29
24.5	9.77	2	1	0	3.0	0.30
25.0	11.44	5	1	0	6.0	0.32
25.5	13.00	4	0	0	4.0	0.35
26.0	14.45	4	0	0	4.0	0.37
26.5	15.81	7	0	0	7.0	0.38
27.0	17.11	3	0	0	3.0	0.39
27.5	18.40	11	0	0	11.0	0.38
28.0	19.70	5	0	0	5.0	0.37
28.5	21.04	0	0	0	0.0	0.35
29.0	22.47	1	0	0	1.0	0.33
29.5	24.00	0	0	0	0.0	0.31
30.0	25.63	7	0	0	7.0	0.30
30.5	27.32	1	0	0	1.0	0.28
31.0	29.09	1	0	0	1.0	0.27
31.5	30.94	11	1	0	12.0	0.26
32.0	32.88	4	1	0	5.0	0.25
32.5	34.91	6	0	0	6.0	0.23
33.0	37.05	3	0	0	3.0	0.22
33.5	39.30	3	3	2	8.0	0.21
34.0	41.70	2	0	6	8.0	0.19
34.5	44.29	28	0	141	169.0	0.18
35.0	47.04	3	0	21	24.0	0.17
35.5	49.93	2	0	5	7.0	0.17
36.0	52.95	2	0	353	355.0	0.16
36.5	56.08	3	0	4	7.0	0.16
37.0	59.30	5	0	8	13.0	0.15

37.5	62.60	8	0	20	28.0	0.15
38.0	65.87	3	0	11	14.0	0.16
38.5	69.09	4	0	1	5.0	0.15
39.0	72.37	4	0	12	16.0	0.14
39.5	75.83	11	0	33	44.0	0.13
40.0	79.59	13	14	4	31.0	0.12
40.5	83.74	5	0	6	11.0	0.11
41.0	88.41	3	0	19	22.0	0.09
41.5	93.70	10	0	15	25.0	0.09
42.0	99.48	6	0	2	8.0	0.08
42.5	105.53	5	0	33	38.0	0.08
43.0	111.83	6	0	43	49.0	0.08
43.5	118.39	4	0	7	11.0	0.07
44.0	125.20	16	3	1	20.0	0.07
44.5	132.26	10	3	0	13.0	0.07
45.0	139.55	20	3	1	24.0	0.07
45.5	147.07	10	5	3	18.0	0.06
46.0	154.82	92	4	0	96.0	0.06
46.5	162.78	4	5	0	9.0	0.06
47.0	170.97	15	1	0	16.0	0.06
47.5	179.36	16	5	0	21.0	0.06
48.0	187.95	10	1	0	11.0	0.06
48.5	196.75	10	2	4	16.0	0.06
49.0	205.73	7	0	3	10.0	0.05
49.5	214.90	16	1	2	19.0	0.05
50.0	224.25	4	3	0	7.0	0.05
50.5	233.78	29	17	0	46.0	0.05
51.0	243.47	10	1	2	13.0	0.05
51.5	253.33	3	5	3	11.0	0.05
52.0	263.35	7	5	0	12.0	0.05
52.5	273.51	15	3	1	19.0	0.05
53.0	283.83	29	4	1	34.0	0.05
53.5	294.28	23	3	1	27.0	0.05
54.0	304.87	15	0	1	16.0	0.05
54.5	315.59	13	2	1	16.0	0.05
55.0	326.44	19	4	2	25.0	0.05
55.5	337.40	16	0	1	17.0	0.05
56.0	348.47	17	4	1	22.0	0.04
56.5	359.65	21	1	1	23.0	0.04
57.0	370.93	19	5	1	25.0	0.04
57.5	382.30	20	2	0	22.0	0.04
58.0	393.77	26	7	0	33.0	0.04

58.5	405.32	19	2	3	24.0	0.04
59.0	416.94	44	1	2	47.0	0.04
59.5	428.64	20	3	4	27.0	0.04
60.0	440.41	27	2	1	30.0	0.04
61.0	464.11	30	3	2	35.0	0.04
62.0	488.02	30	2	3	35.0	0.04
63.0	512.08	18	5	4	27.0	0.04
64.0	536.24	14	5	109	128.0	0.04
65.0	560.47	31	7	12	50.0	0.04
66.0	584.71	11	2	13	26.0	0.04
67.0	608.93	53	1	82	136.0	0.04
68.0	633.07	20	0	20	40.0	0.04
69.0	657.09	14	3	0	17.0	0.04
70.0	680.94	13	5	1	19.0	0.04
71.0	704.58	16	5	1	22.0	0.04
72.0	727.96	55	23	3	81.0	0.04
73.0	751.05	22	19	3	44.0	0.04
74.0	773.78	17	6	3	26.0	0.04
75.0	796.12	28	4	4	36.0	0.05
76.0	818.02	16	4	0	20.0	0.05
77.0	839.43	62	3	0	65.0	0.05
78.0	860.32	13	2	1	16.0	0.05
79.0	880.63	19	3	1	23.0	0.05
80.0	900.32	13	2	2	17.0	0.05
81.0	919.34	25	6	1	32.0	0.05
82.0	937.64	21	1	1	23.0	0.06
83.0	955.20	8	0	2	10.0	0.06
84.0	971.94	36	0	5	41.0	0.06
85.0	987.91	48	9	4	61.0	0.06
86.0	1003.46	16	2	2	20.0	0.07
87.0	1018.69	49	1	3	53.0	0.07
88.0	1033.60	11	6	2	19.0	0.07
89.0	1048.20	12	2	2	16.0	0.07
90.0	1062.51	11	6	2	19.0	0.07
91.0	1076.53	22	3	8	33.0	0.07
92.0	1090.29	15	3	2	20.0	0.07
93.0	1103.80	9	2	0	11.0	0.08
94.0	1117.06	16	5	2	23.0	0.08
95.0	1130.09	15	3	1	19.0	0.08
96.0	1142.91	59	1	0	60.0	0.08
97.0	1155.52	10	2	2	14.0	0.08
98.0	1167.94	16	3	2	21.0	0.08

99.0	1180.17	24	3	4	31.0	0.08
100.0	1192.25	14	0	2	16.0	0.08
101.0	1204.16	102	3	6	111.0	0.08
102.0	1215.94	17	2	2	21.0	0.09
103.0	1227.59	32	2	2	36.0	0.09
104.0	1239.12	13	1	1	15.0	0.09
105.0	1250.55	20	4	9	33.0	0.09
106.0	1261.88	86	14	9	109.0	0.09
107.0	1273.14	16	7	0	23.0	0.09
108.0	1284.33	14	2	4	20.0	0.09
109.0	1295.47	8	0	1	9.0	0.09
110.0	1306.57	21	0	1	22.0	0.09
111.0	1317.64	13	0	0	13.0	0.09
112.0	1328.70	10	0	0	10.0	0.09
113.0	1339.75	16	0	5	21.0	0.09
114.0	1350.81	16	5	1	22.0	0.09
115.0	1361.90	17	1	5	23.0	0.09
116.0	1373.02	15	4	1	20.0	0.09
117.0	1384.19	12	0	1	13.0	0.09
118.0	1395.42	14	6	0	20.0	0.09
119.0	1406.72	5	1	0	6.0	0.09
120.0	1418.11	9	2	0	11.0	0.09
121.0	1429.59	4	1	0	5.0	0.09
122.0	1441.19	12	4	1	17.0	0.09
123.0	1452.91	26	3	0	29.0	0.08
124.0	1464.77	11	4	1	16.0	0.08
125.0	1476.78	141	1	1	143.0	0.08
126.0	1488.94	30	5	0	35.0	0.08
127.0	1501.29	23	5	0	28.0	0.08
128.0	1513.82	17	2	2	21.0	0.08
129.0	1526.54	21	4	3	28.0	0.08
130.0	1539.48	20	6	0	26.0	0.08
130.5	1546.04	15	3	2	20.0	0.08
131.0	1552.65	10	2	1	13.0	0.07
131.5	1559.32	12	5	0	17.0	0.07
132.0	1566.05	11	4	0	15.0	0.07
132.5	1572.85	15	6	0	21.0	0.07
133.0	1579.71	22	7	2	31.0	0.07
133.5	1586.63	18	8	1	27.0	0.07
134.0	1593.62	9	8	0	17.0	0.07
134.5	1600.68	9	3	0	12.0	0.07
135.0	1607.81	10	1	0	11.0	0.07

135.5	1615.02	23	3	0	26.0	0.07
136.0	1622.29	12	2	0	14.0	0.07
136.5	1629.64	33	8	1	42.0	0.07
137.0	1637.07	15	8	0	23.0	0.07
137.5	1644.58	16	10	0	26.0	0.07
138.0	1652.16	27	17	1	45.0	0.07
138.5	1659.83	15	5	2	22.0	0.06
139.0	1667.58	20	10	4	34.0	0.06
139.5	1675.42	30	8	0	38.0	0.06
140.0	1683.34	29	16	0	45.0	0.06
140.5	1691.35	28	6	0	34.0	0.06
141.0	1699.44	37	5	2	44.0	0.06
141.5	1707.63	11	16	0	27.0	0.06
142.0	1715.92	25	7	1	33.0	0.06
142.5	1724.29	21	4	3	28.0	0.06
143.0	1732.76	15	4	0	19.0	0.06
143.5	1741.33	25	18	0	43.0	0.06
144.0	1750.00	30	18	2	50.0	0.06
144.5	1758.79	17	7	1	25.0	0.06
145.0	1767.72	16	6	0	22.0	0.06
145.5	1776.78	19	1	0	20.0	0.05
146.0	1785.99	11	4	1	16.0	0.05
146.5	1795.33	16	14	1	31.0	0.05
147.0	1804.81	18	5	4	27.0	0.05
147.5	1814.41	30	7	1	38.0	0.05
148.0	1824.15	74	19	1	94.0	0.05
148.5	1834.02	17	5	0	22.0	0.05
149.0	1844.01	39	14	2	55.0	0.05
149.5	1854.13	15	5	1	21.0	0.05
150.0	1864.38	25	5	0	30.0	0.05
150.5	1874.75	22	10	0	32.0	0.05
151.0	1885.24	35	0	3	38.0	0.05
151.5	1895.85	11	8	0	19.0	0.05
152.0	1906.57	29	8	10	47.0	0.05
152.5	1917.42	13	5	0	18.0	0.05
153.0	1928.38	22	10	1	33.0	0.05
153.5	1939.45	12	4	0	16.0	0.04
154.0	1950.63	14	7	0	21.0	0.04
154.5	1961.93	15	4	0	19.0	0.04
155.0	1973.33	14	8	0	22.0	0.04
155.5	1984.84	15	10	0	25.0	0.04
156.0	1996.45	12	12	1	25.0	0.04

156.5	2008.17	31	8	0	39.0	0.04
160.0	2092.97	55	5	8	68.0	0.04
160.5	2105.46	38	4	0	42.0	0.04
161.0	2118.04	26	3	0	29.0	0.04
161.5	2130.71	38	6	0	44.0	0.04
162.0	2143.46	32	9	0	41.0	0.04
162.5	2156.30	26	7	0	33.0	0.04
163.0	2169.22	32	5	2	39.0	0.04
163.5	2182.22	30	13	0	43.0	0.04
164.0	2195.30	34	12	1	47.0	0.04
164.5	2208.46	27	17	1	45.0	0.04
165.0	2221.70	23	8	0	31.0	0.04
165.5	2235.01	57	19	0	76.0	0.04
166.0	2248.39	33	12	0	45.0	0.04
166.5	2261.85	31	9	16	56.0	0.04
167.0	2275.37	34	7	1	42.0	0.04
167.5	2288.97	12	4	0	16.0	0.04
168.0	2302.63	30	11	0	41.0	0.04
168.5	2316.36	26	11	0	37.0	0.04
169.0	2330.15	52	17	3	72.0	0.04
169.5	2344.00	34	28	0	62.0	0.04
170.0	2357.91	63	14	2	79.0	0.04
170.5	2371.88	51	11	1	63.0	0.04
171.0	2385.91	10	16	1	27.0	0.04
171.5	2400.00	37	8	2	47.0	0.04
172.0	2414.14	22	17	1	40.0	0.04
172.5	2428.33	25	7	1	33.0	0.04
173.0	2442.57	12	7	0	19.0	0.03
173.5	2456.86	45	11	0	56.0	0.03
174.0	2471.20	13	11	0	24.0	0.03
174.5	2485.59	12	5	1	18.0	0.03
175.0	2500.02	21	17	2	40.0	0.03
175.5	2514.49	27	7	1	35.0	0.03
176.0	2529.00	47	24	1	72.0	0.03
176.5	2543.56	33	12	4	49.0	0.03
177.0	2558.15	20	11	0	31.0	0.03
177.5	2572.78	77	4	0	81.0	0.03
178.0	2587.44	33	5	0	38.0	0.03
178.5	2602.14	58	9	2	69.0	0.03
179.0	2616.87	44	16	2	62.0	0.03
179.5	2631.63	47	7	3	57.0	0.03
180.0	2646.41	45	20	0	65.0	0.03

180.5	2661.23	49	13	1	63.0	0.03
181.0	2676.06	72	14	0	86.0	0.03
181.5	2690.93	50	26	0	76.0	0.03
182.0	2705.81	63	9	1	73.0	0.03
182.5	2720.72	50	14	0	64.0	0.03
183.0	2735.64	78	9	0	87.0	0.03
183.5	2750.58	45	22	0	67.0	0.03
184.0	2765.54	43	13	0	56.0	0.03
184.5	2780.51	32	14	0	46.0	0.03
185.0	2795.50	43	16	0	59.0	0.03
185.5	2810.49	43	24	0	67.0	0.03
186.0	2825.49	53	20	0	73.0	0.03
186.5	2840.51	36	18	0	54.0	0.03
187.0	2855.52	39	20	0	59.0	0.03
187.5	2870.55	40	27	0	67.0	0.03
188.0	2885.57	43	10	0	53.0	0.03
188.5	2900.60	35	14	0	49.0	0.03
189.0	2915.62	33	13	0	46.0	0.03
189.5	2930.65	36	8	0	44.0	0.03
190.0	2945.67	40	11	0	51.0	0.03
190.5	2960.68	24	15	2	41.0	0.03
191.0	2975.69	29	15	22	66.0	0.03
191.5	2990.69	51	9	1	61.0	0.03
192.0	3005.68	26	22	0	48.0	0.03
192.5	3020.66	18	16	0	34.0	0.03
193.0	3035.63	18	11	0	29.0	0.03
193.5	3050.58	32	19	0	51.0	0.03
194.0	3065.52	20	8	16	44.0	0.03
194.5	3080.43	29	20	1	50.0	0.03
195.0	3095.33	14	18	1	33.0	0.03
195.5	3110.21	42	23	0	65.0	0.03
196.0	3125.06	15	4	0	19.0	0.03
196.5	3139.89	28	12	0	40.0	0.03
197.0	3154.70	25	9	0	34.0	0.03
197.5	3169.47	35	13	0	48.0	0.03
198.0	3184.22	32	15	1	48.0	0.03
198.5	3198.94	31	23	0	54.0	0.03
199.0	3213.62	37	19	0	56.0	0.03
199.5	3228.27	37	7	0	44.0	0.03
200.0	3242.88	12	4	0	16.0	0.03
200.5	3257.46	58	15	1	74.0	0.03
201.0	3272.00	19	6	1	26.0	0.03

201.5	3286.50	17	10	0	27.0	0.03
202.0	3300.96	25	12	2	39.0	0.03
202.5	3315.37	14	16	0	30.0	0.03
203.0	3329.74	20	23	0	43.0	0.03
203.5	3344.06	28	15	1	44.0	0.04
204.0	3358.33	19	13	1	33.0	0.04
204.5	3372.56	22	15	0	37.0	0.04
205.0	3386.73	31	19	7	57.0	0.04
205.5	3400.85	24	13	0	37.0	0.04
206.0	3414.91	24	10	0	34.0	0.04
206.5	3428.92	19	8	1	28.0	0.04
207.0	3442.87	26	6	0	32.0	0.04
207.5	3456.76	32	2	0	34.0	0.04
208.0	3470.59	14	3	0	17.0	0.04
208.5	3484.35	15	20	1	36.0	0.04
209.0	3498.06	17	2	1	20.0	0.04
209.5	3511.69	18	11	0	29.0	0.04
210.0	3525.26	12	2	1	15.0	0.04
210.5	3538.76	33	17	0	50.0	0.04
211.0	3552.19	30	8	0	38.0	0.04
211.5	3565.55	15	8	0	23.0	0.04
212.0	3578.83	21	12	1	34.0	0.04
212.5	3592.04	4	0	2	6.0	0.04
213.0	3605.17	10	4	0	14.0	0.04
213.5	3618.22	15	4	1	20.0	0.04
214.0	3631.19	24	6	0	30.0	0.04
214.5	3644.08	15	14	1	30.0	0.04
215.0	3656.89	19	3	0	22.0	0.04
215.5	3669.61	6	0	1	7.0	0.04
216.0	3682.24	1	1	0	2.0	0.04
216.5	3694.79	15	4	1	20.0	0.04
217.0	3707.24	18	3	4	25.0	0.04
217.5	3719.61	16	3	7	26.0	0.04
218.0	3731.88	8	3	4	15.0	0.04
218.5	3744.05	10	2	2	14.0	0.04
219.0	3756.13	12	0	3	15.0	0.04
219.5	3768.12	17	0	0	17.0	0.04
220.0	3780.00	23	2	11	36.0	0.04
220.5	3791.82	15	6	4	25.0	0.04
221.0	3803.61	19	3	4	26.0	0.04
221.5	3815.38	10	1	4	15.0	0.04
222.0	3827.13	19	3	2	24.0	0.04

222.5	3838.85	6	0	2	8.0	0.04
223.0	3850.54	17	5	5	27.0	0.04
223.5	3862.21	15	3	1	19.0	0.04
224.0	3873.85	14	1	4	19.0	0.04
224.5	3885.47	39	2	2	43.0	0.04
225.0	3897.07	37	5	5	47.0	0.04
225.5	3908.64	24	6	4	34.0	0.04
226.0	3920.19	46	2	4	52.0	0.04
226.5	3931.72	16	3	5	24.0	0.04
227.0	3943.22	21	8	5	34.0	0.04
227.5	3954.70	26	3	13	42.0	0.04
228.0	3966.16	21	3	8	32.0	0.04
228.5	3977.59	23	2	0	25.0	0.04
229.0	3989.01	71	2	2	75.0	0.04
229.5	4000.40	15	1	3	19.0	0.04
230.0	4011.77	17	1	7	25.0	0.04
230.5	4023.11	21	0	2	23.0	0.04
231.0	4034.44	12	0	8	20.0	0.04
231.5	4045.74	11	1	0	12.0	0.04
232.0	4057.03	14	3	3	20.0	0.04
232.5	4068.29	21	4	10	35.0	0.04
233.0	4079.53	14	9	5	28.0	0.04
233.5	4090.75	17	2	13	32.0	0.04
234.0	4101.95	11	2	3	16.0	0.04
234.5	4113.13	16	17	4	37.0	0.04
235.0	4124.29	27	11	1	39.0	0.04
235.5	4135.43	12	4	1	17.0	0.04
236.0	4146.56	14	3	3	20.0	0.05
236.5	4157.66	7	1	1	9.0	0.05
237.0	4168.74	14	11	1	26.0	0.05
237.5	4179.81	7	6	2	15.0	0.05
238.0	4190.85	12	1	3	16.0	0.05
238.5	4201.88	19	5	6	30.0	0.05
239.0	4212.89	18	2	3	23.0	0.05
239.5	4223.88	11	1	10	22.0	0.05
240.0	4234.86	16	2	6	24.0	0.05
240.5	4245.81	8	0	7	15.0	0.05
241.0	4256.75	29	1	4	34.0	0.05
241.5	4267.68	12	0	8	20.0	0.05
242.0	4278.58	20	2	2	24.0	0.05
242.5	4289.47	12	1	17	30.0	0.05
243.0	4300.34	18	2	6	26.0	0.05

243.5	4311.20	18	0	2	20.0	0.05
244.0	4322.03	10	0	2	12.0	0.05
244.5	4332.86	23	0	7	30.0	0.05
245.0	4343.67	41	10	3	54.0	0.05
245.5	4354.46	22	2	2	26.0	0.05
246.0	4365.23	15	2	14	31.0	0.05
246.5	4376.00	9	0	8	17.0	0.05
247.0	4386.74	30	1	13	44.0	0.05
247.5	4397.48	35	2	13	50.0	0.05
248.0	4408.19	41	7	7	55.0	0.05
248.5	4418.90	13	1	8	22.0	0.05
249.0	4429.59	18	6	7	31.0	0.05
249.5	4440.26	29	1	28	58.0	0.05
250.0	4450.92	25	1	7	33.0	0.05
250.5	4461.57	23	1	2	26.0	0.05
251.0	4472.21	23	1	14	38.0	0.05
251.5	4482.83	13	1	8	22.0	0.05
252.0	4493.44	15	0	4	19.0	0.05
252.5	4504.04	21	3	3	27.0	0.05
253.0	4514.62	13	4	6	23.0	0.05
253.5	4525.19	16	1	1	18.0	0.05
254.0	4535.75	25	6	4	35.0	0.05
254.5	4546.30	20	5	6	31.0	0.05
255.0	4556.84	19	1	4	24.0	0.05
255.5	4567.36	11	2	4	17.0	0.05
256.0	4577.88	22	1	12	35.0	0.05
256.5	4588.38	28	3	6	37.0	0.05
257.0	4598.87	20	5	4	29.0	0.05
257.5	4609.35	7	4	3	14.0	0.05
258.0	4619.83	9	1	1	11.0	0.05
258.5	4630.29	18	4	2	24.0	0.05
260.0	4661.61	19	7	19	45.0	0.05
261.0	4682.45	42	6	3	51.0	0.05
262.0	4703.25	23	10	8	41.0	0.05
263.0	4724.02	42	5	7	54.0	0.05
264.0	4744.75	29	3	4	36.0	0.05
265.0	4765.46	14	5	10	29.0	0.05
266.0	4786.13	11	6	12	29.0	0.05
267.0	4806.78	21	7	9	37.0	0.05
268.0	4827.40	14	12	6	32.0	0.05
269.0	4848.00	6	6	8	20.0	0.05
270.0	4868.57	21	4	2	27.0	0.05

271.0	4889.13	32	6	10	48.0	0.05
272.0	4909.66	25	6	4	35.0	0.05
273.0	4930.18	23	4	4	31.0	0.05
274.0	4950.68	28	8	2	38.0	0.05
275.0	4971.17	23	18	7	48.0	0.05
276.0	4991.65	23	14	3	40.0	0.05
277.0	5012.11	48	17	1	66.0	0.05
278.0	5032.57	27	10	0	37.0	0.05
279.0	5053.01	40	20	0	60.0	0.05
280.0	5073.46	55	24	0	79.0	0.05
281.0	5093.89	80	54	0	134.0	0.05
282.0	5114.33	34	19	0	53.0	0.05
283.0	5134.76	38	26	0	64.0	0.05
284.0	5155.20	44	23	0	67.0	0.05
285.0	5175.63	36	14	1	51.0	0.05
286.0	5196.07	78	91	1	170.0	0.05
287.0	5216.52	45	13	2	60.0	0.05
288.0	5236.97	47	22	0	69.0	0.05
289.0	5257.44	35	28	1	64.0	0.05
290.0	5277.91	24	14	3	41.0	0.05
291.0	5298.39	29	5	5	39.0	0.05
292.0	5318.89	18	12	3	33.0	0.05
293.0	5339.41	21	9	5	35.0	0.05
294.0	5359.94	19	8	2	29.0	0.05
295.0	5380.49	34	12	4	50.0	0.05
296.0	5401.06	28	14	7	49.0	0.05
297.0	5421.65	22	11	0	33.0	0.05
298.0	5442.27	20	10	3	33.0	0.05
299.0	5462.91	15	6	3	24.0	0.05
300.0	5483.58	33	8	3	44.0	0.05
301.0	5504.28	26	10	4	40.0	0.05
302.0	5525.01	12	5	2	19.0	0.05
303.0	5545.77	8	7	4	19.0	0.05
304.0	5566.56	20	8	5	33.0	0.05
305.0	5587.39	26	5	2	33.0	0.05
306.0	5608.26	122	16	0	138.0	0.05
307.0	5629.16	14	0	4	18.0	0.05
308.0	5650.11	13	2	1	16.0	0.05
309.0	5671.10	8	8	2	18.0	0.05
310.0	5692.13	29	7	2	38.0	0.05
311.0	5713.20	8	5	1	14.0	0.05
312.0	5734.32	5	6	0	11.0	0.05

313.0	5755.50	27	6	1	34.0	0.05
314.0	5776.72	9	3	3	15.0	0.05
315.0	5797.99	13	1	0	14.0	0.05
316.0	5819.32	9	5	1	15.0	0.05
317.0	5840.68	17	0	3	20.0	0.05
318.0	5861.96	13	4	0	17.0	0.05
319.0	5883.14	6	2	0	8.0	0.05
320.0	5904.22	10	2	0	12.0	0.05
321.0	5925.21	24	0	1	25.0	0.05
322.0	5946.12	22	2	2	26.0	0.05
323.0	5966.94	14	2	2	18.0	0.05
324.0	5987.69	15	2	1	18.0	0.05
325.0	6008.35	15	3	2	20.0	0.05
326.0	6028.95	34	6	1	41.0	0.05
327.0	6049.48	25	7	0	32.0	0.05
328.0	6069.94	14	7	3	24.0	0.05
329.0	6090.35	14	1	0	15.0	0.05
330.0	6110.70	27	5	3	35.0	0.05
331.0	6130.99	19	4	5	28.0	0.05
332.0	6151.24	27	1	0	28.0	0.05
333.0	6171.44	41	20	9	70.0	0.05
334.0	6191.60	16	8	6	30.0	0.05
335.0	6211.73	41	5	9	55.0	0.05
336.0	6231.82	25	1	2	28.0	0.05
337.0	6251.88	26	7	6	39.0	0.05
338.0	6271.92	22	5	2	29.0	0.05
339.0	6291.94	42	15	6	63.0	0.05
340.0	6311.94	40	21	7	68.0	0.05
341.0	6331.92	36	19	1	56.0	0.05
342.0	6351.90	35	36	0	71.0	0.05
343.0	6371.87	28	19	0	47.0	0.05
344.0	6391.84	44	23	52	119.0	0.05
345.0	6411.81	8	4	0	12.0	0.05
346.0	6431.79	15	2	0	17.0	0.05
347.0	6451.77	10	3	0	13.0	0.05
348.0	6471.77	13	4	3	20.0	0.05
349.0	6491.79	20	5	2	27.0	0.05
350.0	6511.83	27	10	4	41.0	0.05
351.0	6531.90	16	10	6	32.0	0.05
352.0	6551.99	18	6	3	27.0	0.05
353.0	6572.12	30	4	0	34.0	0.05
354.0	6592.28	28	15	0	43.0	0.05

355.0	6612.49	15	5	3	23.0	0.05
356.0	6632.74	15	1	3	19.0	0.05
357.0	6653.04	28	6	2	36.0	0.05
360.0	6714.26	16	4	2	22.0	0.05
361.0	6734.79	26	9	2	37.0	0.05
362.0	6755.39	17	13	1	31.0	0.05
363.0	6776.07	18	31	1	50.0	0.05
364.0	6796.81	18	10	1	29.0	0.05
365.0	6817.64	19	9	1	29.0	0.05
366.0	6838.55	51	39	0	90.0	0.05
367.0	6859.55	16	12	0	28.0	0.05
368.0	6880.64	24	4	0	28.0	0.05
369.0	6901.83	8	1	0	9.0	0.05
370.0	6923.11	31	36	1	68.0	0.05
371.0	6944.50	28	9	0	37.0	0.05
372.0	6965.99	22	11	0	33.0	0.05
373.0	6987.60	22	7	0	29.0	0.05
374.0	7009.32	19	6	1	26.0	0.05
375.0	7031.15	14	6	1	21.0	0.05
376.0	7053.11	25	8	4	37.0	0.05
377.0	7075.20	22	6	2	30.0	0.05
378.0	7097.42	19	1	1	21.0	0.04
379.0	7119.77	18	11	3	32.0	0.04
380.0	7142.26	55	15	0	70.0	0.04
381.0	7164.89	35	35	1	71.0	0.04
382.0	7187.67	49	35	0	84.0	0.04
383.0	7210.59	33	12	0	45.0	0.04
384.0	7233.67	18	10	1	29.0	0.04
385.0	7256.91	18	6	1	25.0	0.04
386.0	7280.31	19	2	5	26.0	0.04
387.0	7303.87	23	11	2	36.0	0.04
388.0	7327.61	18	8	0	26.0	0.04
389.0	7351.51	17	6	2	25.0	0.04
390.0	7375.60	12	6	1	19.0	0.04
391.0	7399.86	19	4	1	24.0	0.04
392.0	7424.31	22	8	1	31.0	0.04
393.0	7448.94	41	19	0	60.0	0.04
394.0	7473.77	19	22	0	41.0	0.04
395.0	7498.80	17	5	0	22.0	0.04
396.0	7524.02	10	4	1	15.0	0.04
397.0	7549.45	15	3	0	18.0	0.04
398.0	7575.09	15	3	2	20.0	0.04

399.0	7600.94	21	4	2	27.0	0.04
400.0	7627.00	19	3	2	24.0	0.04
401.0	7653.91	11	6	0	17.0	0.04
402.0	7682.24	48	8	3	59.0	0.03
403.0	7711.93	27	3	1	31.0	0.03
404.0	7742.90	14	6	3	23.0	0.03
405.0	7775.07	18	8	0	26.0	0.03
406.0	7808.39	14	5	0	19.0	0.03
407.0	7842.77	14	4	0	18.0	0.03
408.0	7878.15	17	11	4	32.0	0.03
409.0	7914.46	47	18	0	65.0	0.03
410.0	7951.62	5	4	0	9.0	0.03
411.0	7989.56	4	0	1	5.0	0.03
412.0	8028.21	6	0	0	6.0	0.03
413.0	8067.50	10	1	0	11.0	0.03
414.0	8107.36	2	2	0	4.0	0.02
415.0	8147.72	6	1	0	7.0	0.02
416.0	8188.50	4	0	0	4.0	0.02
417.0	8229.63	11	13	1	25.0	0.02
418.0	8271.05	0	1	4	5.0	0.02
419.0	8312.69	4	1	0	5.0	0.02
420.0	8354.46	14	11	3	28.0	0.02
421.0	8396.30	5	4	0	9.0	0.02
422.0	8438.14	6	0	0	6.0	0.02
423.0	8479.90	6	1	0	7.0	0.02
424.0	8521.52	6	4	0	10.0	0.02
425.0	8562.93	5	2	1	8.0	0.02
426.0	8604.05	5	0	1	6.0	0.02
427.0	8644.80	6	5	0	11.0	0.02
428.0	8685.13	4	0	1	5.0	0.03
429.0	8724.96	19	9	0	28.0	0.03
430.0	8764.22	58	9	0	67.0	0.03
431.0	8802.83	59	17	0	76.0	0.03
432.0	8840.72	41	14	0	55.0	0.03
433.0	8877.83	16	17	0	33.0	0.03
434.0	8914.08	5	7	0	12.0	0.03
435.0	8949.40	3	1	1	5.0	0.03
436.0	8983.72	12	1	2	15.0	0.03
437.0	9016.97	11	9	0	20.0	0.03
438.0	9049.08	17	14	0	31.0	0.03
439.0	9079.97	20	6	4	30.0	0.03
440.0	9109.58	14	9	0	23.0	0.04

441.0	9137.83	17	17	0	34.0	0.04
442.0	9164.65	20	15	0	35.0	0.04
443.0	9189.97	0	10	0	10.0	0.04
444.0	9213.72	2	16	0	18.0	0.05
445.0	9235.83	2	22	0	24.0	0.05
446.0	9256.23	4	30	0	34.0	0.05
447.0	9274.84	1	18	0	19.0	0.06
448.0	9291.59	5	54	0	59.0	0.07
449.0	9306.42	1	12	0	13.0	0.08
450.0	9319.24	2	27	0	29.0	0.09
451.0	9330.00	0	16	0	16.0	0.10
452.0	9339.65	2	40	0	42.0	0.10
453.0	9349.19	1	11	0	12.0	0.11
454.0	9358.63	14	5	0	19.0	0.11
455.0	9367.97	13	3	0	16.0	0.11
456.0	9377.21	13	5	0	18.0	0.11
457.0	9386.35	5	1	0	6.0	0.11
458.0	9395.39	9	6	0	15.0	0.11
460.0	9413.18	15	5	0	20.0	0.11
460.5	9417.56	13	7	0	20.0	0.11
461.0	9421.92	11	3	0	14.0	0.12
461.5	9426.26	22	23	0	45.0	0.12
462.0	9430.57	18	16	0	34.0	0.12
462.5	9434.86	30	36	0	66.0	0.12
463.0	9439.13	6	10	0	16.0	0.12
463.5	9443.37	8	6	0	14.0	0.12
464.0	9447.59	16	16	0	32.0	0.12
464.5	9451.78	17	8	0	25.0	0.12
465.0	9455.95	14	9	0	23.0	0.12
465.5	9460.10	68	0	0	68.0	0.12
466.0	9464.23	50	88	0	138.0	0.12
466.5	9468.33	63	5	0	68.0	0.12
467.0	9472.41	14	1	0	15.0	0.12
467.5	9476.47	17	5	0	22.0	0.12
468.0	9480.50	14	3	0	17.0	0.12
468.5	9484.51	8	4	0	12.0	0.13
469.0	9488.50	13	1	0	14.0	0.13
469.5	9492.46	7	0	0	7.0	0.13
470.0	9496.41	8	1	0	9.0	0.13
470.5	9500.33	6	0	0	6.0	0.13
471.0	9504.23	2	1	0	3.0	0.13
471.5	9508.10	2	3	0	5.0	0.13

472.0	9511.96	2	11	0	13.0	0.13
472.5	9515.79	5	2	0	7.0	0.13
473.0	9519.60	4	3	0	7.0	0.13
473.5	9523.39	8	2	0	10.0	0.13
474.0	9527.16	4	0	0	4.0	0.13
474.5	9530.90	4	1	0	5.0	0.13
475.0	9534.62	5	1	0	6.0	0.14
475.5	9538.33	8	0	0	8.0	0.14
476.0	9542.01	10	1	0	11.0	0.14
476.5	9545.67	6	0	0	6.0	0.14
477.0	9549.31	1	1	0	2.0	0.14
477.5	9552.93	2	0	0	2.0	0.14
478.0	9556.52	15	2	0	17.0	0.14
478.5	9560.10	5	0	0	5.0	0.14
479.0	9563.66	6	0	0	6.0	0.14
479.5	9567.19	7	2	0	9.0	0.14
480.0	9570.70	15	3	0	18.0	0.14
480.5	9574.20	10	6	0	16.0	0.14
481.0	9577.67	12	3	0	15.0	0.14
481.5	9581.13	13	1	0	14.0	0.15
482.0	9584.56	23	10	0	33.0	0.15
482.5	9587.97	5	3	0	8.0	0.15
483.0	9591.37	9	0	0	9.0	0.15
483.5	9594.74	14	1	0	15.0	0.15
484.0	9598.09	4	1	0	5.0	0.15
484.5	9601.43	3	1	0	4.0	0.15
485.0	9604.74	8	1	0	9.0	0.15
485.5	9608.04	10	3	0	13.0	0.15
486.0	9611.31	6	4	0	10.0	0.15
486.5	9614.57	4	0	0	4.0	0.15
487.0	9617.81	2	0	0	2.0	0.16
487.5	9621.02	19	22	0	41.0	0.16
488.0	9624.22	14	3	0	17.0	0.16
488.5	9627.40	8	4	0	12.0	0.16
489.0	9630.56	10	3	0	13.0	0.16
489.5	9633.71	7	2	0	9.0	0.16
490.0	9636.83	0	0	0	0.0	0.16
490.5	9639.94	6	1	0	7.0	0.16
491.0	9643.02	12	6	0	18.0	0.16
491.5	9646.09	9	2	0	11.0	0.16
492.0	9649.14	4	1	0	5.0	0.16
492.5	9652.17	6	0	0	6.0	0.17

493.0	9655.19	6	1	0	7.0	0.17
493.5	9658.18	13	3	0	16.0	0.17
494.0	9661.16	9	3	0	12.0	0.17
494.5	9664.12	16	4	0	20.0	0.17
495.0	9667.07	12	10	0	22.0	0.17
495.5	9669.99	6	1	0	7.0	0.17
496.0	9672.90	13	1	0	14.0	0.17
496.5	9675.79	16	3	0	19.0	0.17
497.0	9678.66	11	1	0	12.0	0.18
497.5	9681.52	9	3	0	12.0	0.18
498.0	9684.36	4	5	0	9.0	0.18
498.5	9687.18	16	1	0	17.0	0.18
499.0	9689.99	11	1	0	12.0	0.18
499.5	9692.77	10	2	2	14.0	0.18
500.0	9695.54	6	0	0	6.0	0.18
500.5	9698.30	12	0	0	12.0	0.18
501.0	9701.04	8	0	0	8.0	0.18
501.5	9703.76	4	0	1	5.0	0.18
502.0	9706.47	5	0	0	5.0	0.19
502.5	9709.15	4	0	0	4.0	0.19
503.0	9711.83	0	1	0	1.0	0.19
503.5	9714.48	3	2	0	5.0	0.19
504.0	9717.13	0	0	0	0.0	0.19
504.5	9719.75	1	0	0	1.0	0.19
505.0	9722.36	8	1	0	9.0	0.19
505.5	9724.95	20	0	0	20.0	0.19
506.0	9727.53	9	3	0	12.0	0.20
506.5	9730.10	9	8	0	17.0	0.20
507.0	9732.64	6	4	0	10.0	0.20
507.5	9735.17	14	2	0	16.0	0.20
508.0	9737.69	9	3	0	12.0	0.20
508.5	9740.19	22	8	0	30.0	0.20
509.0	9742.68	41	11	0	52.0	0.20
509.5	9745.15	21	4	0	25.0	0.20
510.0	9747.61	13	5	0	18.0	0.20
510.5	9750.05	34	37	0	71.0	0.21
511.0	9752.48	8	2	0	10.0	0.21
511.5	9754.89	20	7	0	27.0	0.21
512.0	9757.29	22	6	0	28.0	0.21
512.5	9759.67	7	3	0	10.0	0.21
513.0	9762.04	18	1	0	19.0	0.21
513.5	9764.40	14	4	0	18.0	0.21

514.0	9766.74	14	11	0	25.0	0.21
514.5	9769.07	13	5	0	18.0	0.22
515.0	9771.38	19	1	0	20.0	0.22
515.5	9773.68	10	3	1	14.0	0.22
516.0	9775.97	17	13	3	33.0	0.22
516.5	9778.24	17	8	2	27.0	0.22
517.0	9780.50	18	0	0	18.0	0.22
517.5	9782.75	28	7	0	35.0	0.22
518.0	9784.98	28	2	0	30.0	0.23
518.5	9787.20	13	4	0	17.0	0.23
519.0	9789.41	22	8	1	31.0	0.23
519.5	9791.60	24	5	0	29.0	0.23
520.0	9793.78	4	0	0	4.0	0.23
520.5	9795.95	16	14	0	30.0	0.23
521.0	9798.11	15	4	0	19.0	0.23
521.5	9800.25	8	8	0	16.0	0.23
522.0	9802.38	17	0	0	17.0	0.24
522.5	9804.50	2	4	0	6.0	0.24
523.0	9806.60	11	5	0	16.0	0.24
523.5	9808.69	38	0	0	38.0	0.24
524.0	9810.77	7	3	0	10.0	0.24
524.5	9812.84	6	4	0	10.0	0.24
525.0	9814.90	12	1	0	13.0	0.24
525.5	9816.94	23	2	0	25.0	0.25
526.0	9818.98	15	8	1	24.0	0.25
526.5	9821.00	7	0	0	7.0	0.25
527.0	9823.01	3	2	0	5.0	0.25
527.5	9825.01	2	0	0	2.0	0.25
528.0	9826.99	7	1	0	8.0	0.25
528.5	9828.97	4	1	0	5.0	0.25
529.0	9830.93	5	0	0	5.0	0.26
529.5	9832.89	10	6	0	16.0	0.26
530.0	9834.83	7	11	4	22.0	0.26
530.5	9836.76	26	29	0	55.0	0.26
531.0	9838.68	19	24	1	44.0	0.26
531.5	9840.59	18	11	2	31.0	0.26
532.0	9842.49	12	15	0	27.0	0.26
532.5	9844.38	23	8	1	32.0	0.27
533.0	9846.26	11	3	0	14.0	0.27
533.5	9848.12	18	4	0	22.0	0.27
534.0	9849.98	10	8	1	19.0	0.27
534.5	9851.83	31	36	0	67.0	0.27

535.0	9853.67	38	32	0	70.0	0.27
535.5	9855.49	65	53	2	120.0	0.28
536.0	9857.31	53	37	0	90.0	0.28
536.5	9859.12	28	12	0	40.0	0.28
537.0	9860.92	52	37	2	91.0	0.28
537.5	9862.71	41	11	0	52.0	0.28
538.0	9864.48	19	3	0	22.0	0.28
538.5	9866.25	22	10	0	32.0	0.28
539.0	9868.01	9	4	1	14.0	0.29
539.5	9869.77	35	10	1	46.0	0.29
540.0	9871.51	31	4	0	35.0	0.29
540.5	9873.24	19	15	0	34.0	0.29
541.0	9874.96	24	7	0	31.0	0.29
541.5	9876.68	20	9	3	32.0	0.29
542.0	9878.39	36	82	3	121.0	0.29
542.5	9880.08	31	9	0	40.0	0.30
543.0	9881.77	27	0	0	27.0	0.30
543.5	9883.45	20	5	0	25.0	0.30
544.0	9885.13	8	2	0	10.0	0.30
544.5	9886.79	19	8	0	27.0	0.30
545.0	9888.45	16	9	0	25.0	0.30
545.5	9890.09	15	7	0	22.0	0.30
546.0	9891.73	15	2	0	17.0	0.31
546.5	9893.37	8	3	0	11.0	0.31
547.0	9894.99	13	5	0	18.0	0.31
547.5	9896.61	16	13	1	30.0	0.31
548.0	9898.22	16	4	0	20.0	0.31
548.5	9899.82	43	17	0	60.0	0.31
549.0	9901.41	21	3	0	24.0	0.32
549.5	9903.00	9	13	0	22.0	0.32
550.0	9904.58	20	14	0	34.0	0.32
550.5	9906.15	20	8	1	29.0	0.32
551.0	9907.72	26	7	0	33.0	0.32
551.5	9909.28	14	1	1	16.0	0.32
552.0	9910.83	27	7	0	34.0	0.32
552.5	9912.37	25	8	0	33.0	0.33
553.0	9913.91	24	5	0	29.0	0.33
553.5	9915.44	24	6	0	30.0	0.33
554.0	9916.97	99	21	0	120.0	0.33
554.5	9918.49	34	10	0	44.0	0.33
555.0	9920.00	27	33	0	60.0	0.33
555.5	9921.50	19	4	0	23.0	0.34

556.0	9922.99	9	1	0	10.0	0.34
556.5	9924.46	13	4	0	17.0	0.34
560.0	9934.34	35	30	0	65.0	0.37
560.5	9935.69	39	20	0	59.0	0.37
561.0	9937.03	36	16	0	52.0	0.38
561.5	9938.36	29	24	0	53.0	0.38
562.0	9939.67	29	5	0	34.0	0.38
562.5	9940.97	25	10	0	35.0	0.39
563.0	9942.26	40	16	0	56.0	0.39
563.5	9943.53	53	5	1	59.0	0.40
564.0	9944.79	25	9	0	34.0	0.40
564.5	9946.04	29	7	0	36.0	0.40
565.0	9947.28	13	7	0	20.0	0.41
565.5	9948.50	23	6	0	29.0	0.41
566.0	9949.72	13	8	0	21.0	0.42
566.5	9950.92	12	8	0	20.0	0.42
567.0	9952.10	59	70	0	129.0	0.42
567.5	9953.28	35	27	0	62.0	0.43
568.0	9954.45	11	9	0	20.0	0.43
568.5	9955.60	10	11	1	22.0	0.44
569.0	9956.74	13	11	2	26.0	0.44
569.5	9957.88	12	12	0	24.0	0.45
570.0	9959.00	19	2	0	21.0	0.45
570.5	9960.11	36	20	1	57.0	0.45
571.0	9961.21	37	20	0	57.0	0.46
571.5	9962.30	73	25	2	100.0	0.46
572.0	9963.38	46	10	0	56.0	0.47
572.5	9964.45	47	18	0	65.0	0.47
573.0	9965.51	49	72	0	121.0	0.48
573.5	9966.57	30	17	0	47.0	0.48
574.0	9967.61	73	36	0	109.0	0.48
574.5	9968.64	29	13	0	42.0	0.49
575.0	9969.67	77	19	0	96.0	0.49
575.5	9970.68	84	27	6	117.0	0.50
576.0	9971.69	54	52	0	106.0	0.50
576.5	9972.69	58	18	3	79.0	0.50
577.0	9973.68	49	25	0	74.0	0.51
577.5	9974.66	87	21	0	108.0	0.51
578.0	9975.64	62	20	0	82.0	0.52
578.5	9976.61	36	10	0	46.0	0.52
579.0	9977.57	28	13	0	41.0	0.52
579.5	9978.52	36	9	0	45.0	0.53

580.0	9979.47	23	17	0	40.0	0.53
580.5	9980.40	24	19	0	43.0	0.54
581.0	9981.34	26	14	0	40.0	0.54
581.5	9982.26	11	4	0	15.0	0.54
582.0	9983.18	12	11	0	23.0	0.55
582.5	9984.09	7	1	0	8.0	0.55
583.0	9985.00	7	7	0	14.0	0.56
583.5	9985.90	20	13	0	33.0	0.56
584.0	9986.79	11	10	0	21.0	0.56
584.5	9987.68	20	10	0	30.0	0.57
585.0	9988.57	17	2	0	19.0	0.57
585.5	9989.45	25	5	0	30.0	0.57
586.0	9990.32	52	25	0	77.0	0.58
586.5	9991.19	44	18	0	62.0	0.58
587.0	9992.05	12	8	0	20.0	0.58
587.5	9992.91	14	5	0	19.0	0.58
588.0	9993.77	10	5	0	15.0	0.59
588.5	9994.62	27	40	0	67.0	0.59
589.0	9995.47	17	17	0	34.0	0.59
589.5	9996.31	29	25	0	54.0	0.60
590.0	9997.15	20	5	0	25.0	0.60
590.5	9997.98	27	48	0	75.0	0.60
591.0	9998.82	13	11	0	24.0	0.60
591.5	9999.65	26	10	0	36.0	0.60
592.0	10000.47	13	13	0	26.0	0.61
592.5	10001.30	14	12	0	26.0	0.61
593.0	10002.12	15	10	0	25.0	0.61
593.5	10002.94	13	17	0	30.0	0.61
594.0	10003.76	19	31	0	50.0	0.61
594.5	10004.57	26	17	0	43.0	0.61
595.0	10005.38	24	25	0	49.0	0.62
595.5	10006.20	13	9	0	22.0	0.62
596.0	10007.01	13	3	0	16.0	0.62
596.5	10007.81	20	8	0	28.0	0.62
597.0	10008.62	21	10	0	31.0	0.62
597.5	10009.43	75	27	0	102.0	0.62
598.0	10010.23	33	29	0	62.0	0.62
598.5	10011.04	51	7	0	58.0	0.62
599.0	10011.84	27	10	0	37.0	0.62
599.5	10012.65	40	10	0	50.0	0.62
600.0	10013.45	49	10	0	59.0	0.62
600.5	10014.26	24	11	0	35.0	0.62

601.0	10015.06	26	10	0	36.0	0.62
601.5	10015.87	20	5	1	26.0	0.62
602.0	10016.67	28	6	0	34.0	0.62
602.5	10017.48	54	5	0	59.0	0.62
603.0	10018.28	15	8	0	23.0	0.62
603.5	10019.09	21	2	0	23.0	0.62
604.0	10019.90	23	5	0	28.0	0.62
604.5	10020.71	20	2	0	22.0	0.62
605.0	10021.53	17	5	0	22.0	0.61
605.5	10022.34	12	0	0	12.0	0.61
606.0	10023.16	31	9	0	40.0	0.61
606.5	10023.97	12	3	0	15.0	0.61
607.0	10024.80	8	0	0	8.0	0.61
607.5	10025.62	12	7	0	19.0	0.61
608.0	10026.45	28	8	0	36.0	0.60
608.5	10027.27	19	11	0	30.0	0.60
609.0	10028.11	25	7	0	32.0	0.60
609.5	10028.94	24	8	0	32.0	0.60
610.0	10029.78	19	2	0	21.0	0.59
610.5	10030.62	20	7	0	27.0	0.59
612.0	10033.17	22	4	0	26.0	0.58
612.5	10034.03	24	1	0	25.0	0.58
613.0	10034.89	32	3	0	35.0	0.58
613.5	10035.76	17	2	0	19.0	0.57
614.0	10036.63	14	2	0	16.0	0.57
614.5	10037.51	19	6	0	25.0	0.57
615.0	10038.39	16	0	0	16.0	0.56
615.5	10039.28	32	2	2	36.0	0.56
616.0	10040.17	25	0	0	25.0	0.56
616.5	10041.07	26	4	0	30.0	0.55
617.0	10041.98	15	5	0	20.0	0.55
617.5	10042.89	46	18	0	64.0	0.55
618.0	10043.81	42	6	0	48.0	0.54
618.5	10044.73	24	6	0	30.0	0.54
619.0	10045.66	38	3	0	41.0	0.53
619.5	10046.59	16	5	0	21.0	0.53
620.0	10047.54	26	8	0	34.0	0.53
620.5	10048.49	39	13	0	52.0	0.52
621.0	10049.45	30	3	0	33.0	0.52
621.5	10050.41	47	3	0	50.0	0.51
622.0	10051.39	22	6	0	28.0	0.51
622.5	10052.37	24	3	0	27.0	0.51

623.0	10053.35	17	5	0	22.0	0.50
623.5	10054.35	12	5	0	17.0	0.50
624.0	10055.36	31	7	0	38.0	0.49
624.5	10056.37	32	5	0	37.0	0.49
625.0	10057.39	28	4	0	32.0	0.48
625.5	10058.42	28	3	0	31.0	0.48
626.0	10059.46	29	5	0	34.0	0.48
626.5	10060.51	35	2	0	37.0	0.47
627.0	10061.57	32	9	0	41.0	0.47
627.5	10062.64	25	1	0	26.0	0.46
628.0	10063.72	18	6	0	24.0	0.46
628.5	10064.81	23	7	0	30.0	0.46
629.0	10065.90	31	12	0	43.0	0.45
629.5	10067.01	21	2	0	23.0	0.45
630.0	10068.13	20	3	0	23.0	0.44
630.5	10069.26	19	2	0	21.0	0.44
631.0	10070.40	12	2	0	14.0	0.43
631.5	10071.55	16	6	0	22.0	0.43
632.0	10072.71	17	2	0	19.0	0.43
632.5	10073.89	14	14	0	28.0	0.42
633.0	10075.07	17	5	0	22.0	0.42
633.5	10076.27	17	5	0	22.0	0.41
634.0	10077.48	15	12	0	27.0	0.41
634.5	10078.70	43	72	0	115.0	0.41
635.0	10079.93	40	31	0	71.0	0.40
635.5	10081.18	34	25	0	59.0	0.40
636.0	10082.43	14	14	0	28.0	0.39
636.5	10083.70	19	10	0	29.0	0.39
637.0	10084.99	31	11	0	42.0	0.39
637.5	10086.28	39	8	0	47.0	0.38
638.0	10087.59	48	38	0	86.0	0.38
638.5	10088.91	48	22	0	70.0	0.37
639.0	10090.25	117	59	0	176.0	0.37
639.5	10091.60	79	34	0	113.0	0.37
640.0	10092.96	79	29	0	108.0	0.36
640.5	10094.34	89	21	0	110.0	0.36
641.0	10095.74	61	23	0	84.0	0.36
641.5	10097.14	71	50	0	121.0	0.35
642.0	10098.56	46	16	0	62.0	0.35
642.5	10100.00	66	21	0	87.0	0.35
643.0	10101.45	42	11	0	53.0	0.34
643.5	10102.90	53	30	0	83.0	0.34

644.0	10104.36	28	6	0	34.0	0.34
644.5	10105.83	47	35	0	82.0	0.34
645.0	10107.31	70	12	0	82.0	0.34
645.5	10108.79	68	30	0	98.0	0.34
646.0	10110.28	45	13	0	58.0	0.33
646.5	10111.78	35	11	0	46.0	0.33
647.0	10113.28	29	19	0	48.0	0.33
647.5	10114.79	11	16	0	27.0	0.33
648.0	10116.31	24	27	0	51.0	0.33
648.5	10117.83	33	23	0	56.0	0.33
649.0	10119.36	30	19	0	49.0	0.33
649.5	10120.90	23	8	0	31.0	0.32
650.0	10122.45	24	12	0	36.0	0.32
650.5	10124.00	54	16	1	71.0	0.32
651.0	10125.56	28	28	0	56.0	0.32
651.5	10127.12	11	11	1	23.0	0.32
652.0	10128.69	40	10	0	50.0	0.32
652.5	10130.27	45	6	0	51.0	0.32
653.0	10131.86	43	7	0	50.0	0.31
653.5	10133.45	42	4	0	46.0	0.31
654.0	10135.05	35	10	0	45.0	0.31
654.5	10136.66	36	6	0	42.0	0.31
655.0	10138.27	45	18	0	63.0	0.31
655.5	10139.89	42	17	0	59.0	0.31
656.0	10141.51	33	6	0	39.0	0.31
656.5	10143.15	21	10	0	31.0	0.31
657.0	10144.79	40	12	0	52.0	0.30
657.5	10146.43	36	7	0	43.0	0.30
658.0	10148.08	23	13	0	36.0	0.30
658.5	10149.74	32	4	4	40.0	0.30
659.0	10151.41	20	11	0	31.0	0.30
659.5	10153.08	33	13	1	47.0	0.30
660.0	10154.76	10	9	0	19.0	0.30
660.5	10156.44	20	8	1	29.0	0.30
661.0	10158.14	23	9	1	33.0	0.29
661.5	10159.83	17	16	0	33.0	0.29
662.0	10161.54	18	12	0	30.0	0.29
662.5	10163.25	23	9	0	32.0	0.29
663.0	10164.97	21	12	0	33.0	0.29
663.5	10166.69	27	11	0	38.0	0.29
664.0	10168.42	27	13	0	40.0	0.29
664.5	10170.16	13	8	0	21.0	0.29

665.0	10171.90	19	8	0	27.0	0.29
665.5	10173.65	30	13	1	44.0	0.28
666.0	10175.40	28	6	1	35.0	0.28
666.5	10177.17	20	6	0	26.0	0.28
667.0	10178.93	30	4	1	35.0	0.28
667.5	10180.71	38	21	0	59.0	0.28
668.0	10182.49	12	4	0	16.0	0.28
668.5	10184.28	17	4	0	21.0	0.28
669.0	10186.07	6	6	0	12.0	0.28
669.5	10187.87	27	14	0	41.0	0.28
670.0	10189.67	19	13	0	32.0	0.28
670.5	10191.48	20	4	0	24.0	0.28
671.0	10193.30	9	2	0	11.0	0.27
671.5	10195.12	6	5	0	11.0	0.27
672.0	10196.95	16	11	0	27.0	0.27
672.5	10198.79	46	13	0	59.0	0.27
673.0	10200.63	19	12	0	31.0	0.27
673.5	10202.48	32	21	0	53.0	0.27
674.0	10204.33	13	6	0	19.0	0.27
674.5	10206.19	32	21	0	53.0	0.27
675.0	10208.06	50	8	0	58.0	0.27
675.5	10209.93	26	5	0	31.0	0.27
679.0	10223.20	45	7	0	52.0	0.26
679.5	10225.12	17	2	0	19.0	0.26
680.0	10227.05	11	4	0	15.0	0.26
680.5	10228.98	15	2	0	17.0	0.26
681.0	10230.91	21	12	0	33.0	0.26
681.5	10232.86	9	0	0	9.0	0.26
682.0	10234.81	9	2	0	11.0	0.26
682.5	10236.76	9	3	0	12.0	0.26
683.0	10238.72	12	3	0	15.0	0.25
683.5	10240.68	7	1	0	8.0	0.25
684.0	10242.66	15	6	0	21.0	0.25
684.5	10244.63	10	2	0	12.0	0.25
685.0	10246.61	15	6	0	21.0	0.25
685.5	10248.60	9	3	0	12.0	0.25
686.0	10250.60	10	6	0	16.0	0.25
686.5	10252.60	20	9	0	29.0	0.25
687.0	10254.60	61	37	0	98.0	0.25
687.5	10256.61	10	7	0	17.0	0.25
688.0	10258.63	6	2	0	8.0	0.25
688.5	10260.65	33	14	0	47.0	0.25

689.0	10262.68	22	10	0	32.0	0.25
689.5	10264.71	15	4	0	19.0	0.25
690.0	10266.75	39	11	0	50.0	0.24
690.5	10268.79	13	7	0	20.0	0.24
691.0	10270.84	13	7	0	20.0	0.24
691.5	10272.89	62	19	0	81.0	0.24
692.0	10274.95	23	19	0	42.0	0.24
692.5	10277.02	21	10	0	31.0	0.24
693.0	10279.09	19	2	0	21.0	0.24
693.5	10281.16	13	10	0	23.0	0.24
694.0	10283.25	26	5	0	31.0	0.24
694.5	10285.33	19	9	0	28.0	0.24
695.0	10287.42	14	8	0	22.0	0.24
695.5	10289.52	8	4	0	12.0	0.24
696.0	10291.62	45	21	0	66.0	0.24
696.5	10293.73	32	20	0	52.0	0.24
697.0	10295.84	59	8	0	67.0	0.24
697.5	10297.96	19	11	0	30.0	0.24
698.0	10300.09	14	8	0	22.0	0.23
698.5	10302.22	7	2	0	9.0	0.23
699.0	10304.35	16	9	0	25.0	0.23
699.5	10306.49	15	2	0	17.0	0.23
700.0	10308.63	15	1	0	16.0	0.23
700.5	10310.78	25	8	0	33.0	0.23
701.0	10312.94	6	1	0	7.0	0.23
701.5	10315.10	10	8	0	18.0	0.23
702.0	10317.26	10	3	0	13.0	0.23
702.5	10319.43	4	9	0	13.0	0.23
703.0	10321.60	11	4	0	15.0	0.23
703.5	10323.78	8	2	0	10.0	0.23
704.0	10325.97	15	11	0	26.0	0.23
704.5	10328.16	29	8	0	37.0	0.23
705.0	10330.35	20	5	0	25.0	0.23
705.5	10332.55	27	7	0	34.0	0.23
706.0	10334.76	30	14	0	44.0	0.23
706.5	10336.97	36	5	0	41.0	0.23
707.0	10339.18	10	4	0	14.0	0.23
707.5	10341.40	4	2	0	6.0	0.22
708.0	10343.62	34	25	0	59.0	0.22
708.5	10345.85	23	4	0	27.0	0.22
709.0	10348.09	19	13	0	32.0	0.22
709.5	10350.32	24	41	0	65.0	0.22

710.0	10352.57	10	3	0	13.0	0.22
710.5	10354.82	11	4	0	15.0	0.22
711.0	10357.07	9	5	0	14.0	0.22
711.5	10359.33	22	5	0	27.0	0.22
712.0	10361.59	29	3	0	32.0	0.22
712.5	10363.86	32	6	0	38.0	0.22
713.0	10366.13	34	2	0	36.0	0.22
713.5	10368.40	9	3	0	12.0	0.22
714.0	10370.68	20	12	0	32.0	0.22
714.5	10372.97	58	24	0	82.0	0.22
715.0	10375.26	15	13	0	28.0	0.22
715.5	10377.56	12	1	0	13.0	0.22
716.0	10379.86	20	2	0	22.0	0.22
716.5	10382.16	23	8	0	31.0	0.22
717.0	10384.47	46	12	0	58.0	0.22
717.5	10386.78	30	2	0	32.0	0.22
718.0	10389.10	51	5	0	56.0	0.22
718.5	10391.42	37	3	0	40.0	0.21
719.0	10393.75	42	3	0	45.0	0.21
719.5	10396.08	22	5	0	27.0	0.21
720.0	10398.41	20	2	0	22.0	0.21
720.5	10400.75	12	6	0	18.0	0.21
721.0	10403.10	33	5	0	38.0	0.21
721.5	10405.45	34	16	0	50.0	0.21
722.0	10407.80	49	17	0	66.0	0.21
722.5	10410.16	36	21	0	57.0	0.21
723.0	10412.52	43	15	0	58.0	0.21
723.5	10414.89	45	12	0	57.0	0.21
724.0	10417.26	20	7	0	27.0	0.21
724.5	10419.63	5	4	0	9.0	0.21
725.0	10422.01	12	7	0	19.0	0.21
725.5	10424.40	12	11	0	23.0	0.21
726.0	10426.78	18	13	0	31.0	0.21
726.5	10429.18	18	7	0	25.0	0.21
727.0	10431.57	15	5	0	20.0	0.21
727.5	10433.97	20	7	0	27.0	0.21
728.0	10436.38	17	10	0	27.0	0.21
728.5	10438.79	22	3	0	25.0	0.21
729.0	10441.20	28	4	0	32.0	0.21
729.5	10443.61	10	6	0	16.0	0.21
730.0	10446.04	8	1	0	9.0	0.21
730.5	10448.46	8	3	0	11.0	0.21

731.0	10450.89	30	7	0	37.0	0.21
731.5	10453.32	4	10	0	14.0	0.21
732.0	10455.76	11	15	0	26.0	0.20
732.5	10458.20	9	10	0	19.0	0.20
733.0	10460.65	5	2	0	7.0	0.20
733.5	10463.10	13	9	0	22.0	0.20
734.0	10465.55	11	9	0	20.0	0.20
734.5	10468.01	9	4	0	13.0	0.20
735.0	10470.47	5	4	0	9.0	0.20
735.5	10472.93	7	10	0	17.0	0.20
736.0	10475.40	13	27	0	40.0	0.20
736.5	10477.88	15	5	0	20.0	0.20
737.0	10480.35	13	3	0	16.0	0.20
737.5	10482.83	4	5	0	9.0	0.20
738.0	10485.32	20	5	0	25.0	0.20
738.5	10487.81	14	15	0	29.0	0.20
739.0	10490.30	13	6	0	19.0	0.20
739.5	10492.79	6	6	0	12.0	0.20
740.0	10495.29	2	9	0	11.0	0.20
740.5	10497.80	35	16	0	51.0	0.20
741.0	10500.30	6	1	0	7.0	0.20
741.5	10502.82	8	7	0	15.0	0.20
742.0	10505.33	6	14	0	20.0	0.20
742.5	10507.85	18	21	0	39.0	0.20
743.0	10510.37	11	5	0	16.0	0.20
743.5	10512.90	14	9	0	23.0	0.20
744.0	10515.42	11	12	0	23.0	0.20
744.5	10517.96	17	1	0	18.0	0.20
745.0	10520.49	16	1	0	17.0	0.20
745.5	10523.03	27	14	0	41.0	0.20
746.0	10525.58	10	2	0	12.0	0.20
746.5	10528.12	8	3	0	11.0	0.20
747.0	10530.67	4	5	0	9.0	0.20
747.5	10533.23	25	2	0	27.0	0.20
748.0	10535.79	7	21	0	28.0	0.20
748.5	10538.35	16	22	0	38.0	0.19
749.0	10540.91	34	55	0	89.0	0.19
749.5	10543.48	7	12	0	19.0	0.19
750.0	10546.05	3	12	0	15.0	0.19
750.5	10548.63	8	5	0	13.0	0.19
751.0	10551.20	8	9	0	17.0	0.19
751.5	10553.79	6	14	0	20.0	0.19

752.0	10556.37	11	13	0	24.0	0.19
752.5	10558.96	19	23	0	42.0	0.19
753.0	10561.55	9	6	0	15.0	0.19
753.5	10564.15	2	7	0	9.0	0.19
754.0	10566.74	14	8	0	22.0	0.19
754.5	10569.34	10	4	0	14.0	0.19
755.0	10571.95	5	4	0	9.0	0.19
755.5	10574.56	9	3	0	12.0	0.19
756.0	10577.17	13	15	0	28.0	0.19
756.5	10579.78	23	1	0	24.0	0.19
757.0	10582.40	2	2	0	4.0	0.19
757.5	10585.02	6	2	0	8.0	0.19
758.0	10587.64	9	5	0	14.0	0.19
758.5	10590.27	4	3	0	7.0	0.19
759.0	10592.90	1	4	0	5.0	0.19
759.5	10595.53	10	5	0	15.0	0.19
760.0	10598.17	3	4	0	7.0	0.19
760.5	10600.81	4	0	0	4.0	0.19
761.0	10603.45	6	2	0	8.0	0.19
761.5	10606.10	2	4	0	6.0	0.19
762.0	10608.75	7	7	0	14.0	0.19
762.5	10611.40	5	5	0	10.0	0.19
763.0	10614.05	9	5	0	14.0	0.19
763.5	10616.71	27	6	0	33.0	0.19
764.0	10619.37	7	1	0	8.0	0.19
764.5	10622.03	17	2	0	19.0	0.19
765.0	10624.70	7	0	0	7.0	0.19
765.5	10627.37	8	2	0	10.0	0.19
766.0	10630.04	5	4	0	9.0	0.19
766.5	10632.71	6	9	0	15.0	0.19
767.0	10635.39	2	6	0	8.0	0.19
767.5	10638.07	3	4	0	7.0	0.19
768.0	10640.75	5	2	0	7.0	0.19
768.5	10643.44	5	6	0	11.0	0.19
769.0	10646.13	7	4	0	11.0	0.19
769.5	10648.82	6	13	0	19.0	0.19
770.0	10651.51	2	3	0	5.0	0.19
770.5	10654.21	6	9	0	15.0	0.19
771.0	10656.91	6	5	0	11.0	0.19
771.5	10659.61	5	2	0	7.0	0.18
772.0	10662.32	5	6	0	11.0	0.18
772.5	10665.02	5	4	0	9.0	0.18

773.0	10667.73	4	1	0	5.0	0.18
773.5	10670.45	1	2	0	3.0	0.18
774.0	10673.16	7	15	0	22.0	0.18
774.5	10675.88	8	4	0	12.0	0.18
775.0	10678.60	5	7	0	12.0	0.18
775.5	10681.32	1	10	0	11.0	0.18
776.0	10684.05	4	9	0	13.0	0.18
776.5	10686.78	2	3	0	5.0	0.18
777.0	10689.51	10	9	0	19.0	0.18
777.5	10692.24	3	5	0	8.0	0.18
778.0	10694.98	1	0	0	1.0	0.18
778.5	10697.71	6	2	0	8.0	0.18
779.0	10700.45	8	9	0	17.0	0.18
779.5	10703.20	11	4	0	15.0	0.18
780.0	10705.94	4	5	0	9.0	0.18
780.5	10708.69	4	11	0	15.0	0.18
781.0	10711.44	2	3	0	5.0	0.18
781.5	10714.19	3	2	0	5.0	0.18
782.0	10716.95	2	4	0	6.0	0.18
782.5	10719.70	5	11	0	16.0	0.18
783.0	10722.46	3	3	0	6.0	0.18
783.5	10725.22	17	10	0	27.0	0.18
784.0	10727.99	2	0	0	2.0	0.18
784.5	10730.75	5	7	0	12.0	0.18
785	10733.52	4	17	0	21	0.18
785.5	10736.29	6	11	0	17	0.18
786	10739.06	5	4	0	9	0.18
786.5	10741.84	4	6	0	10	0.18
787.0	10744.62	6	7	0	13	0.18
787.5	10747.40	2	4	0	6	0.18
788.0	10750.18	9	9	0	18	0.18
788.5	10752.96	10	21	0	31	0.18
789.0	10755.74	0	3	0	3	0.18
789.5	10758.53	1	4	0	5	0.18
790.0	10761.32	5	7	0	12	0.18
790.5	10764.11	3	9	0	12	0.18
791.0	10766.91	3	4	0	7	0.18
791.5	10769.70	5	11	0	16	0.18
792.0	10772.50	4	7	0	11	0.18
792.5	10775.30	2	1	0	3	0.18
793.0	10778.10	6	8	0	14	0.18
793.5	10780.90	8	13	0	21	0.18

794.0	10783.71	4	3	0	7	0.18
794.5	10786.51	7	2	0	9	0.18
795.0	10789.32	13	11	0	24	0.18
795.5	10792.13	4	2	0	6	0.18
796.0	10794.95	1	7	0	8	0.18
796.5	10797.76	3	8	0	11	0.18
797.0	10800.58	0	2	0	2	0.18
797.5	10803.40	4	2	0	6	0.18
798.0	10806.22	2	5	0	7	0.18
798.5	10809.04	5	1	0	6	0.18
799.0	10811.86	12	28	0	40	0.18
799.5	10814.68	5	3	0	8	0.18
800.0	10817.51	11	4	0	15	0.18
800.5	10820.34	3	0	0	3	0.18
801.0	10823.17	8	1	0	9	0.18
801.5	10826.00	4	0	0	4	0.18
802.0	10828.83	4	3	0	7	0.18
802.5	10831.67	4	2	0	6	0.18
803.0	10834.51	5	0	0	5	0.18
803.5	10837.34	3	1	0	4	0.18
804.0	10840.18	1	0	0	1	0.18
804.5	10843.03	3	2	0	5	0.18
805.0	10845.87	4	11	0	15	0.18
805.5	10848.71	3	0	0	3	0.18
806.0	10851.56	0	1	0	1	0.18
806.5	10854.41	5	5	0	10	0.18
807.0	10857.25	1	3	0	4	0.18
807.5	10860.1	3	3	0	6	0.18
808.0	10862.96	1	4	0	5	0.18
808.5	10865.81	0	2	0	2	0.18
809.0	10868.66	4	2	0	6	0.18
809.5	10871.52	5	4	0	9	0.18
810.0	10874.38	5	17	0	22	0.17
810.5	10877.23	3	0	0	3	0.17
811.0	10880.09	1	1	0	2	0.17
811.5	10882.95	2	1	0	3	0.17
812.0	10885.82	0	1	0	1	0.17
812.5	10888.68	6	1	0	7	0.17
813.0	10891.55	3	3	0	6	0.17
813.5	10894.41	6	0	0	6	0.17
814.0	10897.28	1	0	0	1	0.17
814.5	10900.15	1	0	0	1	0.17

815.0	10903.02	2	4	0	6	0.17
815.5	10905.89	1	1	0	2	0.17
816.0	10908.76	2	2	0	4	0.17
816.5	10911.63	2	0	0	2	0.17
817.0	10914.51	2	1	0	3	0.17
817.5	10917.38	6	2	0	8	0.17
818.0	10920.26	3	0	0	3	0.17
818.5	10923.14	1	0	0	1	0.17
819.0	10926.02	0	1	0	1	0.17
819.5	10928.90	5	1	0	6	0.17
820.0	10931.78	1	0	0	1	0.17
820.5	10934.66	1	2	0	3	0.17
821.0	10937.54	2	0	0	2	0.17
821.5	10940.42	5	0	0	5	0.17
822.0	10943.31	4	3	0	7	0.17
822.5	10946.19	11	4	0	15	0.17
823.0	10949.08	0	1	0	1	0.17
823.5	10951.97	2	0	0	2	0.17
824.0	10954.86	0	1	0	1	0.17
824.5	10957.74	3	1	0	4	0.17
825.0	10960.63	3	1	0	4	0.17
825.5	10963.52	4	0	0	4	0.17
826.0	10966.42	3	1	0	4	0.17
826.5	10969.31	2	2	0	4	0.17
827.0	10972.20	9	0	0	9	0.17
827.5	10975.10	4	0	0	4	0.17
828.0	10977.99	4	0	0	4	0.17
828.5	10980.89	9	0	0	9	0.17
829.0	10983.78	4	0	0	4	0.17
829.5	10986.68	5	1	0	6	0.17
830.0	10989.58	3	2	0	5	0.17
830.5	10992.47	3	1	0	4	0.17
831.0	10995.37	3	0	0	3	0.17
831.5	10998.27	3	1	0	4	0.17
832.0	11001.17	1	1	0	2	0.17
832.5	11004.07	4	0	0	4	0.17
833.0	11006.97	1	0	0	1	0.17
833.5	11009.87	3	0	0	3	0.17
834.0	11012.78	3	0	0	3	0.17
834.5	11015.68	4	1	0	5	0.17
835.0	11018.58	7	0	0	7	0.17
835.5	11021.48	5	0	0	5	0.17

836.0	11024.39	2	0	0	2	0.17
836.5	11027.29	5	0	0	5	0.17
837.0	11030.20	6	1	0	7	0.17
837.5	11033.10	8	0	0	8	0.17
838.0	11036.01	10	3	0	13	0.17
838.5	11038.92	5	0	0	5	0.17
839.0	11041.82	10	0	0	10	0.17
839.5	11044.73	86	1	0	87	0.17
840.0	11047.64	17	3	0	20	0.17
840.5	11050.54	39	0	0	39	0.17
841.0	11053.45	4	0	0	4	0.17
841.5	11056.36	11	0	0	11	0.17
842.0	11059.27	7	0	0	7	0.17
842.5	11062.18	13	1	0	14	0.17
843.0	11065.08	12	0	0	12	0.17
843.5	11067.99	7	0	0	7	0.17
844.0	11070.90	10	0	0	10	0.17
844.5	11073.81	13	1	0	14	0.17
845.0	11076.72	12	1	0	13	0.17
845.5	11079.63	13	0	0	13	0.17
846.0	11082.54	5	1	0	6	0.17
846.5	11085.45	13	1	0	14	0.17
847.0	11088.36	15	0	0	15	0.17
847.5	11091.27	20	1	0	21	0.17
848.0	11094.18	7	0	0	7	0.17
848.5	11097.09	8	2	0	10	0.17
849.0	11100.00	12	1	0	13	0.21
849.5	11102.42	7	0	0	7	0.21
850.0	11104.84	0	1	0	1	0.21
850.5	11107.26	0	0	0	0	0.21
851.0	11109.69	1	0	0	1	0.21
851.5	11112.11	1	0	0	1	0.21
852.0	11114.53	11	0	0	11	0.21
852.5	11116.95	11	2	0	13	0.21
853.0	11119.37	4	1	0	5	0.21
853.5	11121.79	2	1	0	3	0.21
854.0	11124.21	5	0	0	5	0.21
854.5	11126.63	5	0	0	5	0.21
855.0	11129.06	1	0	0	1	0.21
855.5	11131.48	1	0	0	1	0.21
856.0	11133.9	3	0	0	3	0.21
856.5	11136.32	4	2	0	6	0.21

857.0	11138.74	9	0	0	9	0.21
857.5	11141.16	12	1	0	13	0.21
858.0	11143.58	5	0	0	5	0.21
858.5	11146.00	5	0	0	5	0.21
859.0	11148.43	5	1	0	6	0.21
859.5	11150.85	3	1	0	4	0.21
860.0	11153.27	6	1	0	7	0.21
860.5	11155.69	9	0	0	9	0.21
861.0	11158.11	10	0	0	10	0.21
861.5	11160.53	12	1	0	13	0.21
862.0	11162.95	10	0	0	10	0.21
862.5	11165.38	12	0	0	12	0.21
863.0	11167.80	5	0	0	5	0.21
863.5	11170.22	5	0	0	5	0.21
864.0	11172.64	9	0	0	9	0.21
864.5	11175.06	1	0	0	1	0.21
865.0	11177.48	8	0	0	8	0.21
865.5	11179.90	2	0	0	2	0.21
866.0	11182.32	0	0	0	0	0.21
866.5	11184.75	0	0	0	0	0.21
867.0	11187.17	4	0	0	4	0.21

APPENDIX G

BEAVER LAKE BL05B MAGNETIC SUSCEPTIBILITY DATA

Depth (cm)	Magnetic susceptibility (emu)
0	0.00000745
1	0.00000865
2	0.00000919
3	0.00000937
4	0.00000916
5	0.00000948
6	0.00000953
7	0.00001016
8	0.00000878
9	0.00001122
10	0.00001049
11	0.00000853
12	0.00000874
13	0.00000885
14	0.00000895
15	0.00000908
16	0.00000852
17	0.00000845
18	0.00000877
19	0.00000914
20	0.00000980
21	0.00000815
22	0.00000837
23	0.00001193
24	0.00000889
25	0.00000878
26	0.00000839
27	0.00000855
28	0.00000789
29	0.00000743
30	0.00000732
31	0.00000675

32	0.00000688
33	0.00000665
34	0.00000646
35	0.00000709
36	0.00000576
37	0.00000534
38	0.00000523
39	0.00000534
40	0.00000541
41	0.00000533
42	0.00000534
43	0.00000550
44	0.00000491
45	0.00000496
46	0.00000478
47	0.00000474
48	0.00000471
49	0.00000491
50	0.00000400
51	0.00000488
52	0.00000596
53	0.00000710
54	0.00000657
55	0.00000737
56	0.00000621
57	0.00000592
58	0.00000656
59	0.00000632
60	0.00000615
61	0.00000644
62	0.00000656
63	0.00000694
64	0.00000667
65	0.00000677
66	0.00000707
67	0.00000713
68	0.00000716
69	0.00000723

70	0.00000968
71	0.00000800
72	0.00000808
73	0.00000835
74	0.00000876
75	0.00000874
76	0.00000854
77	0.00000874
78	0.00000753
79	0.00001044
80	0.00000890
81	0.00000871
82	0.00000887
83	0.00000883
84	0.00000893
85	0.00000894
86	0.00000854
87	0.00000821
88	0.00000795
89	0.00000745
90	0.00000868
91	0.00000743
92	0.00000694
93	0.00000715
94	0.00000702
95	0.00000731
96	0.00000757
97	0.00000769
98	0.00000749
99	0.00000766
100	0.00000815
101	0.00000825
102	0.00000900
103	0.00000876
104	0.00000845
105	0.00000843
106	0.00000796
107	0.00000755

108	0.00000708
109	0.00000658
110	0.00000758
111	0.00000585
112	0.00000451
113	0.00000805
114	0.00000461
115	0.00000427
116	0.00000449
117	0.00000459
118	0.00000481
119	0.00000505
120	0.00000457
121	0.00000458
122	0.00000460
123	0.00000566
124	0.00000450
125	0.00000458
126	0.00000428
127	0.00000493
128	0.00000508
129	0.00000469
130	0.00000551
131	0.00000442
132	0.00000433
133	0.00000439
134	0.00000416
135	0.00000428
136	0.00000414
137	0.00000419
138	0.00000401
139	0.00000400
140	0.00000420
141	0.00000419
142	0.00000406
143	0.00000408
144	0.00000405
145	0.00000375

146	0.00000334
147	0.00000290
148	0.00000217
150	0.00000893
151	0.00000830
152	0.00000928
153	0.00000886
154	0.00000639
155	0.00000577
156	0.00000546
157	0.00000523
158	0.00000559
159	0.00000475
160	0.00000491
161	0.00000583
162	0.00000613
163	0.00000562
164	0.00000511
165	0.00000530
166	0.00000536
167	0.00000555
168	0.00000560
169	0.00000540
170	0.00000838
171	0.00000539
172	0.00000577
173	0.00000489
174	0.00000476
175	0.00000458
176	0.00000453
177	0.00000534
178	0.00000450
179	0.00000526
180	0.00000459
181	0.00000382
182	0.00000567
183	0.00000505
184	0.00000502

185	0.00000492
186	0.00000457
187	0.00000471
188	0.00000494
189	0.00000463
190	0.00000620
191	0.00000537
192	0.00000499
193	0.00000514
194	0.00000566
195	0.00000655
196	0.00000717
197	0.00000822
198	0.00000893
199	0.00000998
200	0.00001135
201	0.00001267
202	0.00001338
203	0.00001433
204	0.00001450
205	0.00001498
206	0.00001490
207	0.00001433
208	0.00001453
209	0.00001541
210	0.00001529
211	0.00001606
212	0.00001549
213	0.00001566
214	0.00001566
215	0.00001627
216	0.00001663
217	0.00001649
218	0.00001746
219	0.00001762
220	0.00001803
221	0.00001843
222	0.00001807

223	0.00001740
224	0.00001732
225	0.00001718
226	0.00001740
227	0.00001806
228	0.00001852
229	0.00001874
230	0.00001980
231	0.00001096
232	0.00001527
233	0.00001799
234	0.00001714
235	0.00001635
236	0.00001519
237	0.00001473
238	0.00001427
239	0.00001428
240	0.00001472
241	0.00001547
242	0.00001566
243	0.00001543
244	0.00001447
245	0.00001360
246	0.00001211
247	0.00001047
248	0.00000850
249	0.00000558
250	0.00001114
251	0.00001262
252	0.00001526
253	0.00001622
254	0.00001619
255	0.00001568
256	0.00001538
257	0.00001490
258	0.00001427
259	0.00001399
260	0.00001313

261	0.00001249
262	0.00001210
263	0.00001135
264	0.00001092
265	0.00001066
266	0.00000691
267	0.00001177
268	0.00000926
269	0.00001035
270	0.00001095
271	0.00001137
272	0.00001175
273	0.00000912
274	0.00000624
275	0.00001073
276	0.00001010
277	0.00001050
278	0.00001070
279	0.00001146
280	0.00001196
281	0.00001247
282	0.00001316
283	0.00001378
284	0.00001396
285	0.00001480
286	0.00001479
287	0.00001520
288	0.00001551
289	0.00001481
290	0.00001678
291	0.00001865
292	0.00001663
293	0.00001874
294	0.00002075
295	0.00002383
296	0.00002734
297	0.00003180
298	0.00003555

299	0.00003897
300	0.00004229
301	0.00004620
302	0.00005076
303	0.00005496
304	0.00005961
305	0.00006461
306	0.00006892
307	0.00007071
308	0.00007077
309	0.00006869
310	0.00006639
311	0.00006429
312	0.00006361
313	0.00005625
314	0.00005085
315	0.00004211
316	0.00003487
317	0.00003017
318	0.00002768
319	0.00002547
320	0.00002447
321	0.00002413
322	0.00002311
323	0.00002000
324	0.00001682
325	0.00001495
326	0.00001372
327	0.00001256
328	0.00001217
329	0.00001262
330	0.00001419
331	0.00001875
332	0.00002040
333	0.00002834
334	0.00003571
335	0.00004910
336	0.00006178

337	0.00007168
338	0.00007515
339	0.00007468
340	0.00007149
341	0.00006737
342	0.00006461
343	0.00006125
344	0.00005756
345	0.00005110
346	0.00004159
347	0.00003224
350	0.00003491
351	0.00005127
352	0.00007154
353	0.00007777
354	0.00009682
355	0.00010697
356	0.00011382
357	0.00011261
358	0.00010976
359	0.00010648
360	0.00010424
361	0.00010427
362	0.00010733
363	0.00011076
364	0.00011945
365	0.00012628
366	0.00013002
367	0.00013008
368	0.00012994
369	0.00012974
370	0.00012943
371	0.00013062
372	0.00013661
373	0.00014157
374	0.00014686
375	0.00015002
376	0.00015136

377	0.00015192
378	0.00015201
379	0.00015184
380	0.00015527
381	0.00015518
382	0.00016152
383	0.00017215
384	0.00018497
385	0.00019614
386	0.00020406
387	0.00020437
388	0.00020018
389	0.00019387
390	0.00018906
391	0.00018480
392	0.00018485
393	0.00018859
394	0.00019739
395	0.00020967
396	0.00022871
397	0.00025104
398	0.00027465
399	0.00029360
400	0.00031248
401	0.00032408
402	0.00033084
403	0.00033546
404	0.00033394
405	0.00032493
406	0.00031522
407	0.00030575
408	0.00030132
409	0.00030170
410	0.00029878
411	0.00028913
412	0.00027381
413	0.00025148
414	0.00020737

415	0.00020462
416	0.00018597
417	0.00016988
418	0.00016319
419	0.00016330
420	0.00017222
421	0.00019084
422	0.00021270
423	0.00023200
424	0.00024743
425	0.00025328
426	0.00024687
427	0.00023163
428	0.00021622
429	0.00021016
430	0.00021347
431	0.00022810
432	0.00024510
433	0.00025628
434	0.00026079
435	0.00025853
436	0.00025106
437	0.00023957
438	0.00022685
439	0.00021599
440	0.00021087
441	0.00021625
442	0.00023476
443	0.00025544
444	0.00027792
445	0.00028557
446	0.00026906
447	0.00022154
448	0.00016262
450	0.00008743
451	0.00011849
452	0.00014635
453	0.00017134

454	0.00019053
455	0.00021861
456	0.00025101
457	0.00028635
458	0.00032355
459	0.00034943
460	0.00035822
461	0.00035326
462	0.00034156
463	0.00033267
464	0.00032791
465	0.00032823
466	0.00032998
467	0.00033254
468	0.00033556
469	0.00033953
470	0.00034651
471	0.00034647
472	0.00034671
473	0.00034484
474	0.00034191
475	0.00033706
476	0.00033262
477	0.00032622
478	0.00031946
479	0.00031437
480	0.00031008
481	0.00030844
482	0.00030718
483	0.00030388
484	0.00029998
485	0.00029447
486	0.00029098
487	0.00029020
488	0.00029135
489	0.00029406
490	0.00029989
491	0.00030238

492	0.00030563
493	0.00030628
494	0.00029805
495	0.00028363
496	0.00026351
497	0.00023750
498	0.00021923
499	0.00020012
500	0.00018659
501	0.00017531
502	0.00016425
503	0.00015512
504	0.00014552
505	0.00014052
506	0.00013783
507	0.00013691
508	0.00013718
509	0.00013808
510	0.00014140
511	0.00014384
512	0.00014785
513	0.00015162
514	0.00015266
515	0.00015044
516	0.00014946
517	0.00015134
518	0.00015760
519	0.00016418
520	0.00016757
521	0.00016483
522	0.00015602
523	0.00014620
524	0.00013560
525	0.00012544
526	0.00011734
527	0.00011110
528	0.00010664
529	0.00010356

530	0.00010379
531	0.00010412
532	0.00010799
533	0.00011323
534	0.00011704
535	0.00011906
536	0.00011943
537	0.00012178
538	0.00012747
539	0.00013481
540	0.00014266
541	0.00014339
542	0.00013703
543	0.00012535
544	0.00010866
545	0.00009494
546	0.00007384
547	0.00005178
550	0.00009627
551	0.00014281
552	0.00019029
553	0.00022413
554	0.00024530
555	0.00024791
556	0.00023308
557	0.00020868
558	0.00018829
559	0.00017250
560	0.00015964
561	0.00015347
562	0.00014738
563	0.00014336
564	0.00014109
565	0.00014399
566	0.00015070
567	0.00016106
568	0.00017981
569	0.00020103

570	0.00022511
571	0.00024293
572	0.00025593
573	0.00025800
574	0.00024349
575	0.00021843
576	0.00018818
577	0.00016161
578	0.00014062
579	0.00012970
580	0.00012214
581	0.00011594
582	0.00011182
583	0.00010888
584	0.00010665
585	0.00010419
586	0.00010142
587	0.00010063
588	0.00010291
589	0.00010855
590	0.00011725
591	0.00013340
592	0.00015177
593	0.00016899
594	0.00018047
595	0.00018367
596	0.00017916
597	0.00016533
598	0.00014510
599	0.00012104
600	0.00008971
602	0.00012186
603	0.00017149
604	0.00020717
605	0.00022568
606	0.00022905
607	0.00022221
608	0.00021032

609	0.00019332
610	0.00017910
611	0.00016567
612	0.00015493
613	0.00014782
614	0.00014534
615	0.00014375
616	0.00014416
617	0.00014799
618	0.00014705
619	0.00014790
620	0.00014890
621	0.00014957
622	0.00015344
623	0.00015686
624	0.00015700
625	0.00015240
626	0.00014355
627	0.00013378
628	0.00012643
629	0.00011994
630	0.00011596
631	0.00011209
632	0.00010904
633	0.00010691
634	0.00010733
635	0.00010918
636	0.00011275
637	0.00011812
638	0.00012224
639	0.00012894
640	0.00013702
641	0.00014604
642	0.00015366
643	0.00016119
644	0.00017032
645	0.00018223
646	0.00019425

647	0.00019821
648	0.00019410
649	0.00018255
650	0.00017167
651	0.00016419
652	0.00016006
653	0.00015938
654	0.00016106
655	0.00016166
656	0.00015891
657	0.00015207
658	0.00014331
659	0.00013393
660	0.00012791
661	0.00012627
662	0.00012440
663	0.00012153
664	0.00011021
665	0.00008634
666	0.00006550
669	0.00006979
670	0.00010487
671	0.00014351
672	0.00017927
673	0.00020282
674	0.00021436
675	0.00021278
676	0.00020249
677	0.00018364
678	0.00016780
679	0.00014976
680	0.00013798
681	0.00012963
682	0.00012466
683	0.00012172
684	0.00011939
685	0.00011688
686	0.00011679

687	0.00011987
688	0.00012896
689	0.00014395
690	0.00015453
691	0.00016952
692	0.00018055
693	0.00018535
694	0.00018556
695	0.00018487
696	0.00018570
697	0.00018752
698	0.00018971
699	0.00019342
700	0.00019018
701	0.00018943
702	0.00018802
703	0.00018398
704	0.00018183
705	0.00018172
706	0.00018522
707	0.00019160
708	0.00019763
709	0.00020449
710	0.00020419
711	0.00020310
712	0.00019879
713	0.00019498
714	0.00018953
715	0.00018611
716	0.00018598
717	0.00018904
718	0.00019510
719	0.00019963
720	0.00020291
721	0.00020340
722	0.00019665
723	0.00018457
724	0.00016344

725	0.00014617
726	0.00012714
727	0.00010945
728	0.00009930
729	0.00008978
730	0.00008547
731	0.00008353
732	0.00008219
733	0.00008160
734	0.00008093
735	0.00008040
736	0.00008107
737	0.00008476
738	0.00009177
739	0.00010157
740	0.00009167
741	0.00010019
742	0.00010984
743	0.00011560
744	0.00011738
745	0.00011560
746	0.00011067
747	0.00010452
748	0.00009972
749	0.00009937
750	0.00010459
751	0.00011875
752	0.00013389
753	0.00015072
754	0.00016753
755	0.00017931
756	0.00019368
757	0.00020837
758	0.00022206
759	0.00024033
760	0.00025572
761	0.00027535
762	0.00029376

763	0.00030740
764	0.00031578
765	0.00031966
766	0.00031677
767	0.00030258
768	0.00026827
769	0.00020762
769	0.00016639
770	0.00022077
771	0.00026341
772	0.00029725
773	0.00031616
774	0.00032591
775	0.00033601
776	0.00034175
777	0.00034656
778	0.00035292
779	0.00036321
780	0.00038200
781	0.00039218
782	0.00041016
783	0.00042381
784	0.00043858
785	0.00042382
785	0.00045719
786	0.00048350
787	0.00050925
788	0.00053697
789	0.00055708
790	0.00057383
791	0.00058536
792	0.00059975
793	0.00061539
794	0.00062994
795	0.00064539
796	0.00065846
797	0.00067306
798	0.00069031

799	0.00071223
800	0.00074140
801	0.00077977
802	0.00081808
803	0.00084861
804	0.00087801
805	0.00090086
806	0.00092203
807	0.00093399
808	0.00094979
809	0.00095325
810	0.00096354
811	0.00097322
812	0.00098409
813	0.00099917
814	0.00101680
815	0.00103603
816	0.00105192
817	0.00106031
818	0.00106104
819	0.00106209
820	0.00106709
821	0.00107793
822	0.00109091
823	0.00109986
824	0.00110126
825	0.00109792
826	0.00110089
827	0.00111281
828	0.00112992
829	0.00115625
830	0.00116412
831	0.00115887
832	0.00114117
833	0.00111572
834	0.00109179
835	0.00108562
836	0.00109029

837	0.00110277
838	0.00112709
839	0.00114608
840	0.00115625
841	0.00115855
842	0.00115360
843	0.00114720
844	0.00113448
845	0.00111240
846	0.00109361
847	0.00107087
848	0.00105289
849	0.00105350
850	0.00106061
851	0.00107700
852	0.00107818
853	0.00103807
854	0.00096298
855	0.00086783
856	0.00070509
857	0.00053854
858	0.00039224
859	0.00025975

APPENDIX H

BEAVER LAKE BL05B LOSS-ON-IGNITION DATA

Depth (cm)	Bulk density (%)	Organic content (%)	Carbonate content (%)
0.5	75.5	33.9	6.3
5.5	63.3	29.3	6.4
10.5	63.5	27.1	5.5
15.5	52.8	25.1	4.2
20.5	54.2	25.3	3.8
25.5	56.6	27.8	4.1
30.5	60.2	23.3	4.1
35.5	68.5	33.3	4.8
40.5	78.3	45.2	4.9
45.5	81.8	41.7	5.1
50.5	74.8	31.0	5.1
55.0	80.3	56.8	2.3
60.0	80.9	53.5	2.2
65.0	78.3	40.8	3.1
70.0	78.4	40.4	3.1
75.0	74.2	35.5	2.7
80.0	72.9	33.7	2.9
85.0	76.2	36.9	3.1
90.0	77.2	38.5	3.0
95.0	80.3	46.2	2.7
100.0	74.6	36.4	3.7
105.0	72.2	31.1	3.2
110.0	79.0	40.4	3.1
115.0	83.4	55.4	2.4
120.0	84.4	50.4	3.6
125.0	82.0	45.6	3.7
130.0	83.3	41.3	4.1
135.0	84.3	45.1	4.2
140.0	84.9	40.0	5.1
145.0	84.2	45.4	4.6
151.5	64.0	31.3	2.7
156.5	84.5	43.1	3.3
161.5	84.8	43.0	4.9

166.5	84.6	44.7	1.9
171.5	84.9	41.7	2.4
176.5	85.5	41.1	2.3
181.5	84.8	39.8	4.7
189.0	85.2	37.9	5.1
194.0	83.5	35.7	2.0
199.0	77.2	22.6	2.4
204.0	62.8	12.9	2.6
209.0	69.2	20.8	2.4
214.0	68.2	24.2	2.6
219.0	69.4	26.3	2.4
224.0	72.1	29.1	2.4
229.0	65.1	20.8	2.6
234.0	69.7	29.0	0.5
239.0	53.0	14.1	1.3
244.0	63.0	20.5	3.4
254.0	72.3	27.4	3.6
259.0	76.1	30.1	3.9
264.0	74.7	28.6	4.2
269.0	73.8	19.4	4.3
274.0	76.0	20.3	5.8
279.0	75.6	22.5	4.8
284.0	69.1	20.4	4.2
289.0	74.3	29.2	4.8
294.0	73.5	26.2	4.9
299.0	69.3	22.4	4.2
304.0	65.1	18.3	3.9
309.0	67.5	20.0	3.3
314.0	69.6	21.1	3.6
319.0	80.2	32.6	4.3
324.0	79.3	36.0	4.0
329.0	79.9	35.9	4.3
334.0	75.9	20.1	5.5
339.0	67.0	19.2	2.9
344.0	69.1	20.0	3.3
348.0	69.4	20.6	3.3
354.0	69.4	16.1	3.2
359.0	65.3	14.1	2.8
364.0	67.3	16.4	2.9
369.0	62.6	13.4	2.7

375.0	65.0	15.5	3.2
379.0	63.2	12.5	3.1
384.0	68.6	13.4	3.8
389.0	59.6	12.3	2.8
394.0	59.5	12.5	3.3
399.0	60.1	10.6	3.8
404.0	50.2	8.7	2.3
409.0	52.0	9.3	2.4
414.0	56.3	10.7	2.3
419.0	59.1	10.6	2.7
424.0	55.0	9.3	2.3
429.0	64.0	11.8	2.7
434.0	56.7	10.9	2.2
439.0	59.7	10.2	2.5
444.0	57.2	8.8	2.7
449.0	52.9	10.3	2.2
453.5	60.0	11.1	3.8
458.5	46.1	7.4	3.1
463.5	51.2	8.1	3.6
471.0	46.9	8.4	2.7
476.0	47.5	8.1	2.6
481.0	51.2	8.9	2.9
488.0	48.9	8.2	2.9
493.0	48.8	8.4	3.0
498.0	63.3	15.9	2.9
506.0	62.0	16.1	3.3
511.0	65.5	19.1	2.9
516.0	59.4	14.5	3.3
523.5	59.3	11.4	4.9
528.5	68.2	18.5	4.7
533.5	68.8	15.5	5.5
541.0	57.1	13.1	4.6
546.0	59.3	12.0	5.1
551.0	69.7	20.1	4.0
556.0	54.2	10.1	3.2
561.0	63.2	14.8	3.9
566.0	67.1	15.7	4.1
571.0	55.2	10.6	3.3
576.0	67.8	16.2	3.9
581.0	70.2	14.5	4.9

586.0	68.0	13.9	5.3
591.0	70.4	14.1	6.6
596.0	56.7	9.2	5.6
600.5	62.3	11.4	4.9
606.0	58.4	12.8	2.0
611.0	68.7	18.8	2.3
616.0	66.8	17.7	2.3
621.0	64.2	16.9	2.3
626.0	61.1	12.0	2.5
631.0	68.3	16.5	2.5
636.0	69.7	16.9	2.9
641.0	71.8	20.5	2.8
646.0	64.0	15.3	2.9
651.0	65.7	14.5	2.7
656.0	61.7	14.5	2.9
661.0	63.2	12.9	3.4
666.0	60.6	15.4	2.9
671.0	64.0	15.8	3.1
676.0	52.3	8.9	2.9
681.0	69.7	12.9	4.9
686.0	72.2	15.7	4.3
691.0	58.8	10.5	3.2
696.0	59.7	10.9	3.5
701.0	60.0	10.0	3.2
706.0	64.3	14.5	3.2
711.0	60.4	11.3	4.9
716.0	63.6	13.1	3.1
721.0	61.3	11.6	3.2
726.0	68.7	16.1	3.8
731.0	69.0	16.5	4.1
736.0	72.2	21.8	4.1
741.0	65.4	12.5	4.0
746.0	69.6	17.0	4.4
751.0	62.5	15.4	1.6
756.0	60.8	12.6	1.7
761.0	58.0	9.4	1.5
766.0	57.5	9.7	1.6
771.0	59.1	9.9	1.7
776.0	56.0	9.3	1.6
781.0	53.7	8.9	1.5

786.0	54.1	8.8	1.7
791.0	48.1	6.4	1.7
796.0	46.2	6.0	1.5
801.0	45.5	5.6	1.7
806.0	39.5	4.7	2.2
811.0	38.3	4.8	1.8
816.0	35.0	3.8	2.1
821.0	33.7	4.1	1.9
826.0	32.1	3.8	1.7
831.0	29.1	3.6	1.7
836.0	32.5	3.9	1.9
841.0	25.2	3.2	1.9
846.0	27.6	3.1	2.0
851.0	30.3	3.6	2.2
856.0	23.1	3.1	2.3
858.0	25.2	3.9	2.8

APPENDIX I

BEAVER LAKE BL05B POLLEN DATA

Depth (cm)	Age (cal yr BP)	Age (AD)	Total *Pinus*	*Picea*	*Abies*	*Pseudotsuga*-type	*Thuja*-type
2.5	-46.9	1996.9	5	0	6	12	12
7.5	-21.4	1971.4	4	0	4	14	8
17.5	-9.3	1959.3	5	0	5	8	9
22.5	2.9	1947.1	3	0	5	8	9
27.5	18.4	1931.6	4	2	12	15	19
32.5	34.9	1915.1	2	0	1	6	12
37.5	62.6	1887.4	4	0	9	14	5
42.5	105.5	1844.5	3	0	10	15	9
47.5	179.4	1770.6	7	0	7	9	12
52.5	273.5	1676.5	4	3	15	4	18
57.5	382.3	1567.7	5	1	11	12	10
62.5	500.0	1450.0	9	1	9	8	15

Tsuga heterophylla	*Taxus brevifolia*	*Alnus rubra*-type	*Corylus*	*Betula*	*Salix*	*Populus trichocarpa*-type
6	0	20	7	1	52	14
5	1	22	3	1	81	8
9	0	16	78	0	147	5
6	0	9	22	0	142	9
7	0	13	9	0	150	6
1	1	6	2	0	277	2
9	0	5	5	0	157	4
6	1	4	3	0	157	3
7	1	20	4	1	140	4
9	1	15	4	0	153	4
7	0	5	1	0	150	2
4	1	22	4	1	143	3

Fraxinus	*Quercus*	*Sambucus*	*Acer circinatum*	*Acer macrophyllum*	Rosaceae	*Spiraea*-type
32	6	0	1	2	0	0
25	4	1	1	1	3	2
15	4	0	0	0	1	2
11	4	0	0	0	0	2
24	4	2	0	0	2	1
12	2	0	0	0	2	4
10	13	0	0	1	3	12
22	11	0	0	0	3	4
32	14	0	1	0	3	8
22	3	1	0	0	3	6
31	12	0	0	0	0	6
27	11	0	0	0	2	3

Ceanothus	*Cornus*	*Cantanea*	*Rhus*	*Juglans*	Other trees and shrubs	Poaceae
0	1	1	3	1	1	173
0	0	0	1	3	1	181
0	0	2	0	0	1	78
0	0	5	0	0	1	83
0	0	3	0	0	3	39
0	0	5	0	0	0	11
0	0	4	0	0	0	17
0	0	0	0	0	0	19
0	1	1	0	0	0	12
0	0	5	0	0	1	19
0	0	1	0	0	1	35
1	0	0	0	0	1	35

Cyperaceae	*Artemisia*	*Iva xanthifolia*-type	*Helianthus*-type	*Agoseris*-type	Other Tubuliflorae
24	0	0	2	0	0
34	0	0	4	0	0
26	0	0	4	0	0
53	0	0	1	4	0
93	1	0	1	25	0
41	0	0	2	0	0
32	1	1	2	0	0
32	0	0	2	0	0
35	0	0	1	0	0
25	0	0	2	0	2
32	0		1	0	0
22	0	0	3	0	0

Chenopodiaceae	*Salsola*-type	Umbelliferae	Brassicaceae	Caryophyllaceae	*Polygonum*
0	0	1	11	0	1
0	1	2	5	0	2
0	0	4	3	0	1
0	2	4	0	0	0
1	0	5	1	0	0
0	0	7	0	0	0
0	0	14	0	1	0
0	0	6	0	0	0
0	0	7	0	0	0
0	0	2	0	0	0
0	0	3	0	0	0
0	0	3	0	0	1

Galium	Saxifragaceae	*Plantago-type*	*Pteridium*	*Dryopteris*-type	Other herbs	*Equisetum*
0	0	3	16	9	1	1
0	0	2	20	4	0	0
0	0	1	17	4	0	20
1	0	3	35	4	2	4
1	0	0	16	7	0	24
0	0	0	23	2	0	3
0	0	2	16	6	0	17
0	0	0	5	3	0	25
0	0	0	6	7	0	3
0	0	0	9	7	0	5
0	1	0	12	11	0	0
1	0	0	16	8	1	4

Botrychium-type	*Selaginella*-type	Polypodiaceae	*Typha latifolia*-type	*Sparganium*-type	*Potamogeton*
0	0	0	3	5	50
0	0	0	9	0	43
0	0	6	8	0	6
0	0	4	4	0	0
0	0	12	2	0	14
0	0	1	1	0	0
1	0	7	17	0	4
0	1	5	3	0	4
2	0	0	11	0	4
0	0	4	16	1	7
1	0	0	7	2	3
0	0	0	9	1	9

Myriophyllum	*Sagittaria*	*Nuphar*	*Brasenia*	*Isoetes*	Other aquatics	Indeterminate
2	1	2	0	0	1	13
0	0	1	1	0	0	10
1	1	8	1	0	1	20
0	1	1	0	0	1	13
1	1	4	1	0	1	5
0	0	2	0	0	18	2
0	1	9	7	0	5	6
1	0	4	5	1	4	4
1	1	9	0	0	0	2
1	1	4	1	0	0	1
0	1	2	4	0	3	3
1	1	7	10	0	0	6

Unknown	*Lycopodium* tracer	Total	AP/(AP+NAP)
0	28	502	0.43
2	22	514	0.43
0	31	517	0.66
0	30	456	0.55
0	34	531	0.56
0	22	448	0.79
1	44	422	0.70
0	67	375	0.73
0	62	373	0.79
0	71	378	0.79
1	66	377	0.73
1	93	404	0.74

APPENDIX J

LAKE OSWEGO LO05A CHARCOAL DATA

Depth (cm)	Age (cal yr BP)	Years (AD)	Charcoal particles >250 µm	Charcoal particles >125 µm	Charcoal concentration (particles/cm^3)	Herbaceous charcoal (%)
0.0	-55.0	2005.0	0	1	1	0.0
0.5	-54.4	2004.4	0	0	0	0.0
1.0	-53.8	2003.8	0	1	1	0.0
1.5	-53.2	2003.2	0	0	0	0.0
2.0	-52.5	2002.5	0	0	0	0.0
2.5	-51.7	2001.7	1	0	1	0.0
3.0	-50.9	2000.9	0	0	0	0.0
3.5	-50.1	2000.1	0	2	2	0.0
4.0	-49.3	1999.3	2	2	4	25.0
4.5	-48.5	1998.5	2	0	2	0.0
5.0	-47.8	1997.8	0	1	1	0.0
5.5	-47.0	1997.0	0	1	1	0.0
6.0	-46.3	1996.3	0	0	0	0.0
6.5	-45.6	1995.6	0	0	0	0.0
7.0	-44.8	1994.8	0	1	1	0.0
7.5	-44.2	1994.2	0	0	0	0.0
8.0	-43.5	1993.5	0	0	0	0.0
8.5	-42.9	1992.9	0	0	0	0.0
9.0	-42.3	1992.3	0	1	1	0.0
9.5	-41.6	1991.6	0	3	3	33.3
10.0	-40.9	1990.9	0	4	4	0.0
10.5	-40.0	1990.0	0	1	1	0.0
11.0	-39.2	1989.2	1	1	2	50.0
11.5	-38.7	1988.7	1	0	1	0.0
12.0	-38.3	1988.3	0	0	0	0.0
12.5	-37.9	1987.9	0	2	2	0.0
13.0	-37.5	1987.5	0	1	1	0.0
13.5	-37.1	1987.1	0	1	1	0.0
14.0	-36.6	1986.6	1	4	5	0.0
14.5	-35.9	1985.9	0	1	1	100.0
15.0	-34.9	1984.9	0	1	1	0.0
15.5	-33.5	1983.5	1	4	5	0.0

16.0	-31.8	1981.8	0	2	2	50.0
16.5	-30.0	1980.0	0	2	2	0.0
17.0	-28.2	1978.2	0	4	4	0.0
17.5	-26.3	1976.3	0	3	3	0.0
18.0	-24.3	1974.3	0	4	4	0.0
18.5	-22.2	1972.2	1	4	5	0.0
19.0	-20.2	1970.2	0	2	2	0.0
19.5	-18.5	1968.5	0	0	0	0.0
20.0	-17.2	1967.2	0	2	2	100.0
20.5	-16.1	1966.1	2	3	5	0.0
21.0	-15.0	1965.0	0	2	2	50.0
21.5	-13.8	1963.8	0	3	3	0.0
22.0	-12.3	1962.3	0	4	4	50.0
22.5	-10.5	1960.5	0	2	2	0.0
23.0	-8.4	1958.4	0	5	5	20.0
23.5	-6.0	1956.0	0	0	0	0.0
24.0	-3.1	1953.1	0	0	0	0.0
24.5	0.4	1949.6	0	1	1	0.0
25.0	5.4	1944.6	0	3	3	33.3
25.5	12.4	1937.6	0	4	4	50.0
26.0	20.3	1929.7	1	7	8	0.0
26.5	28.2	1921.8	0	4	4	0.0
27.0	34.8	1915.2	0	4	4	50.0
27.5	40.6	1909.4	0	0	0	0.0
28.0	46.4	1903.6	0	0	0	0.0
28.5	52.1	1897.9	0	3	3	100.0
29.0	57.8	1892.2	0	1	1	0.0
29.5	63.6	1886.4	0	6	6	33.3
30.0	69.3	1880.7	1	3	4	25.0
30.5	75.0	1875.0	0	5	5	0.0
31.0	80.7	1869.3	0	2	2	0.0
31.5	86.3	1863.7	0	1	1	0.0
32.0	92.0	1858.0	1	0	1	100.0
32.5	97.7	1852.3	1	1	2	0.0
33.0	103.3	1846.7	0	2	2	50.0
33.5	109.0	1841.0	0	2	2	50.0
34.0	114.6	1835.4	0	2	2	0.0
34.5	120.2	1829.8	0	2	2	0.0
35.0	125.8	1824.2	1	2	3	0.0
35.5	131.4	1818.6	2	4	6	0.0

36.0	137.0	1813.0	0	0	0	0.0
36.5	142.5	1807.5	0	2	2	0.0
37.0	148.1	1801.9	0	0	0	0.0
37.5	153.7	1796.3	0	3	3	0.0
38.0	159.2	1790.8	0	4	4	0.0
38.5	164.7	1785.3	0	2	2	0.0
39.0	170.2	1779.8	0	1	1	0.0
39.5	175.7	1774.3	0	2	2	0.0
40.0	181.2	1768.8	0	1	1	0.0
40.5	186.7	1763.3	0	0	0	0.0
41.0	192.1	1757.9	0	4	4	0.0
41.5	197.6	1752.4	0	1	1	0.0
42.0	203.0	1747.0	0	2	2	0.0
42.5	208.5	1741.5	0	0	0	0.0
43.0	213.9	1736.1	0	2	2	0.0
43.5	219.3	1730.7	0	1	1	0.0
44.0	224.7	1725.3	0	1	1	0.0
44.5	230.1	1719.9	1	5	6	16.7
45.0	235.4	1714.6	1	2	3	0.0
45.5	240.8	1709.2	0	2	2	0.0
46.0	246.1	1703.9	0	1	1	0.0
46.5	251.4	1698.6	0	1	1	0.0
47.0	256.8	1693.2	2	5	7	0.0
47.5	262.1	1687.9	0	3	3	0.0
48.0	267.3	1682.7	0	5	5	40.0
48.5	272.6	1677.4	0	10	10	10.0
49.0	277.9	1672.1	2	12	14	21.4
49.5	283.1	1666.9	0	4	4	25.0
50.0	288.4	1661.6	2	6	8	12.5
50.5	293.6	1656.4	0	2	2	50.0
51.0	298.8	1651.2	0	10	10	10.0
51.5	304.0	1646.0	3	8	11	0.0
52.0	309.2	1640.8	0	7	7	0.0
52.5	314.3	1635.7	0	10	10	10.0
53.0	319.5	1630.5	1	21	22	9.1
53.5	324.6	1625.4	1	20	21	0.0
54.0	329.8	1620.2	2	12	14	7.1
54.5	334.9	1615.1	0	9	9	0.0
55.0	340.0	1610.0	0	21	21	19.0
55.5	345.1	1604.9	0	26	26	11.5

56.0	350.1	1599.9	1	7	8	0.0
56.5	355.2	1594.8	2	25	27	3.7
57.0	360.2	1589.8	0	33	33	0.0
57.5	365.3	1584.7	4	20	24	0.0
58.0	370.3	1579.7	3	28	31	3.2
58.5	375.3	1574.7	4	30	34	5.9
59.0	380.3	1569.7	3	32	35	2.9
59.5	385.2	1564.8	2	19	21	4.8
60.0	390.2	1559.8	2	28	30	6.7
60.5	395.1	1554.9	3	34	37	2.7
61.0	400.0	1550.0	4	18	22	4.5
61.5	405.0	1545.0	4	24	28	0.0
62.0	409.8	1540.2	1	33	34	11.8
62.5	414.7	1535.3	2	40	42	4.8
63.0	419.6	1530.4	3	47	50	2.0
63.5	424.4	1525.6	3	35	38	2.6
64.0	429.3	1520.7	3	32	35	0.0
64.5	434.1	1515.9	2	24	26	0.0
65.0	438.9	1511.1	2	32	34	0.0
65.5	443.7	1506.3	8	14	22	4.5
66.0	448.5	1501.5	16	42	58	0.0
66.5	453.2	1496.8	3	28	31	6.5
67.0	458.0	1492.0	6	33	39	0.0
67.5	462.7	1487.3	4	46	50	0.0
68.0	467.4	1482.6	3	51	54	3.7
68.5	472.1	1477.9	6	49	55	0.0
69.0	476.8	1473.2	3	42	45	6.7
69.5	481.4	1468.6	4	35	39	0.0
70.0	486.1	1463.9	1	40	41	0.0
70.5	490.7	1459.3	1	41	42	0.0
71.0	495.3	1454.7	2	34	36	0.0
71.5	499.9	1450.1	2	48	50	0.0
72.0	504.5	1445.5	2	42	44	0.0
72.5	509.1	1440.9	1	35	36	0.0
73.0	513.6	1436.4	12	64	76	1.3
73.5	518.1	1431.9	4	76	80	3.8
74.0	522.7	1427.3	11	61	72	0.0
74.5	527.2	1422.8	10	75	85	1.2
75.0	531.6	1418.4	2	60	62	0.0
75.5	536.1	1413.9	4	67	71	4.2

76.0	540.5	1409.5	7	55	62	0.0
76.5	545.0	1405.0	4	51	55	0.0
77.0	549.4	1400.6	10	60	70	1.4
77.5	553.8	1396.2	3	45	48	0.0
78.0	558.2	1391.8	2	42	44	0.0
78.5	562.5	1387.5	3	27	30	0.0
79.0	566.9	1383.1	5	48	53	0.0
79.5	571.2	1378.8	9	43	52	0.0
80.0	575.5	1374.5	8	35	43	0.0
80.5	579.8	1370.2	10	65	75	0.0
81.0	584.1	1365.9	15	62	77	0.0
81.5	588.3	1361.7	7	62	69	0.0
82.0	592.6	1357.4	5	62	67	1.5
82.5	596.8	1353.2	0	77	77	2.6
83.0	601.0	1349.0	5	49	54	0.0
83.5	605.2	1344.8	9	47	56	0.0
84.0	609.3	1340.7	9	57	66	0.0
84.5	613.5	1336.5	4	70	74	1.4
85.0	617.6	1332.4	4	57	61	4.9
85.5	621.7	1328.3	6	37	43	0.0
86.0	625.8	1324.2	3	36	39	0.0
86.5	629.9	1320.1	9	68	77	0.0
87.0	634.0	1316.0	5	45	50	0.0
87.5	638.0	1312.0	7	76	83	1.2
88.0	642.0	1308.0	4	49	53	1.9
88.5	646.0	1304.0	16	93	109	0.0
89.0	650.0	1300.0	7	57	64	0.0
89.5	654.0	1296.0	7	47	54	1.9
90.0	657.9	1292.1	6	52	58	3.4
91.0	665.6	1284.4	6	39	45	4.4
92.0	673.2	1276.8	4	40	44	4.5
93.0	680.6	1269.4	9	53	62	4.8
94.0	688.0	1262.0	2	53	55	0.0
95.0	695.1	1254.9	10	61	71	1.4
96.0	702.2	1247.8	5	52	57	1.8
97.0	709.2	1240.8	12	47	59	0.0
98.0	716.0	1234.0	6	51	57	0.0
99.0	722.7	1227.3	13	84	97	2.1
100.0	729.3	1220.7	13	87	100	3.0
101.0	735.9	1214.1	15	43	58	3.4

102.0	742.3	1207.7	19	57	76	3.9
103.0	748.6	1201.4	8	32	40	2.5
104.0	754.8	1195.2	9	49	58	0.0
105.0	761.0	1189.0	9	48	57	5.3
106.0	767.1	1182.9	5	52	57	1.8
107.0	773.1	1176.9	8	78	86	3.5
108.0	779.0	1171.0	9	8	17	0.0
109.0	784.9	1165.1	9	52	61	1.6
110.0	790.7	1159.3	14	69	83	4.8
111.0	796.4	1153.6	14	56	70	11.4
112.0	802.1	1147.9	11	53	64	10.9
113.0	807.7	1142.3	8	54	62	3.2
114.0	813.3	1136.7	6	50	56	7.1
115.0	818.9	1131.1	7	56	63	12.7
116.0	824.4	1125.6	15	65	80	10.0
117.0	829.9	1120.1	5	51	56	3.6
118.0	835.4	1114.6	14	66	80	3.8
119.0	840.8	1109.2	19	56	75	5.3
120.0	846.2	1103.8	13	56	69	2.9
121.0	851.6	1098.4	6	30	36	0.0
122.0	857.0	1093.0	11	53	64	4.7
123.0	862.4	1087.6	13	38	51	11.8
124.0	867.8	1082.2	6	30	36	27.8
125.0	873.2	1076.8	5	36	41	17.1
126.0	878.6	1071.4	1	19	20	0.0
127.0	884.0	1066.0	5	17	22	0.0
128.0	889.5	1060.5	5	25	30	10.0
129.0	894.9	1055.1	2	32	34	2.9
130.0	900.4	1049.6	3	35	38	0.0
131.0	905.9	1044.1	6	46	52	3.8
132.0	911.4	1038.6	2	28	30	0.0
133.0	917.0	1033.0	2	28	30	0.0
134.0	922.6	1027.4	2	28	30	6.7
135.0	928.3	1021.7	3	38	41	2.4
136.0	934.0	1016.0	9	41	50	4.0
137.0	939.8	1010.2	10	60	70	5.7
138.0	945.6	1004.4	6	47	53	3.8
139.0	951.5	998.5	7	33	40	10.0
140.0	957.5	992.5	2	25	27	7.4
141.0	963.5	986.5	9	50	59	13.6

142.0	969.7	980.3	6	34	40	2.5
143.0	975.9	974.1	4	36	40	15.0
144.0	982.1	967.9	7	28	35	5.7
145.0	988.5	961.5	4	39	43	14.0
146.0	995.0	955.0	8	36	44	13.6
147.0	1001.6	948.4	11	64	75	12.0
148.0	1008.2	941.8	6	45	51	15.7
149.0	1015.0	935.0	9	62	71	9.9
150.0	1021.9	928.1	2	47	49	16.3
151.0	1028.9	921.1	5	49	54	7.4
152.0	1036.0	914.0	12	52	64	20.3
153.0	1043.3	906.7	6	77	83	9.6
154.0	1050.7	899.3	8	80	88	4.5
155.0	1058.2	891.8	3	84	87	8.0
156.0	1065.9	884.1	3	37	40	10.0
157.0	1073.7	876.3	14	63	77	9.1
158.0	1081.6	868.4	15	70	85	11.8
159.0	1089.7	860.3	16	55	71	4.2
160.0	1098.0	852.0	4	47	51	17.6
161.0	1106.4	843.6	5	42	47	8.5
162.0	1115.0	835.0	8	24	32	3.1
163.0	1123.7	826.3	6	46	52	9.6
164.0	1132.6	817.4	4	45	49	8.2
165.0	1141.7	808.3	2	60	62	8.1
166.0	1151.0	799.0	19	47	66	1.5

APPENDIX K

LAKE OSWEGO LO05A MAGNETIC SUSCEPTIBILITY DATA

Depth (cm)	Magnetic susceptibility (emu)
12	0.00001138
13	0.00001752
14	0.00002336
15	0.00003031
16	0.00003468
17	0.00003959
18	0.00004551
19	0.00005093
20	0.00005843
21	0.00006499
22	0.00006924
23	0.00007308
24	0.00007630
25	0.00007742
26	0.00007512
27	0.00007317
28	0.00006575
29	0.00006011
30	0.00005419
31	0.00005272
32	0.00005334
33	0.00005567
34	0.00005579
35	0.00005643
36	0.00005711
37	0.00005597
38	0.00005765
39	0.00006083
40	0.00006621
41	0.00007132
42	0.00007754
43	0.00008053
44	0.00008365

45	0.00008521
46	0.00008679
47	0.00008845
48	0.00009053
49	0.00009224
50	0.00009389
51	0.00009580
52	0.00009802
53	0.00010013
54	0.00010373
55	0.00010520
56	0.00010417
57	0.00010369
58	0.00010373
59	0.00010437
60	0.00010614
61	0.00010896
62	0.00011275
63	0.00011598
64	0.00012036
65	0.00012446
66	0.00012792
67	0.00013064
68	0.00013319
69	0.00013340
70	0.00013151
71	0.00012857
72	0.00012432
73	0.00012041
74	0.00011537
75	0.00010281
76	0.00008726
77	0.00006395
78	0.00004275
79	0.00006050
80	0.00007755
81	0.00009332
82	0.00010878
83	0.00011947
84	0.00012100

85	0.00012691
86	0.00013430
87	0.00013951
88	0.00014273
89	0.00014491
90	0.00014050
91	0.00014714
92	0.00014041
93	0.00013681
94	0.00012873
95	0.00012044
96	0.00010817
97	0.00009854
98	0.00008963
99	0.00008098
100	0.00007298
101	0.00006594
102	0.00005952
103	0.00005211
104	0.00004642
105	0.00004238
106	0.00003670
107	0.00003396
108	0.00003085
109	0.00002929
110	0.00002987
111	0.00002681
112	0.00002715
113	0.00002775
114	0.00002787
115	0.00002783
116	0.00002818
117	0.00002612
118	0.00002568
119	0.00002535
120	0.00003123
121	0.00002894
122	0.00002735
123	0.00002926
124	0.00002738

125	0.00002763
126	0.00002681
127	0.00002612
128	0.00002806
129	0.00002771
130	0.00002355
131	0.00002099
132	0.00002104
133	0.00002124
134	0.00001936
135	0.00001906
136	0.00001958
137	0.00001921
138	0.00001971
139	0.00002075
140	0.00002021
141	0.00001791
142	0.00001859
143	0.00001699
144	0.00001614
145	0.00001722
146	0.00001669
147	0.00001688
148	0.00001818
149	0.00001975
150	0.00002221
151	0.00002065
152	0.00002122
153	0.00002245
154	0.00002122
155	0.00002027
156	0.00001945
157	0.00001904
158	0.00002098
159	0.00001741
160	0.00001826
161	0.00001652
162	0.00001580
163	0.00001760
164	0.00001711

165	0.00001723
166	0.00001682

APPENDIX L

LAKE OSWEGO LO05A LOSS-ON-IGNITION DATA

Depth (cm)	Bulk density (%)	Organic content (%)	Carbonate content (%)
5.0	95.8	24.7	9.5
7.5	93.2	22.1	7.6
10.0	91.4	15.7	9.2
12.5	87.7	12.4	8.6
15.0	84.7	12.5	7.9
17.5	75.7	11.8	6.1
20.0	77.4	12.3	6.1
22.5	75.7	11.8	6.4
25.0	79.0	11.7	7.2
27.5	76.8	13.6	6.4
30.0	75.4	12.4	5.9
32.5	74.2	13.0	3.5
35.0	74.8	13.1	4.3
37.5	77.6	13.8	4.9
40.0	74.4	11.9	4.0
42.5	69.3	11.7	3.6
45.0	68.1	11.2	3.1
47.5	71.2	11.5	4.0
50.0	68.9	11.4	3.6
52.5	68.7	11.5	4.0
55.0	69.3	11.3	4.4
57.5	67.1	10.8	4.6
60.0	68.5	10.5	5.0
62.5	67.9	10.5	6.0
65.0	66.5	10.2	6.3
67.5	65.0	10.3	5.7
70.0	65.1	10.2	5.9
72.5	64.7	10.5	6.0
75.0	74.8	10.5	5.8
77.5	61.9	10.1	5.4
80.0	63.5	10.2	5.7
82.5	60.7	9.7	5.9

85.0	62.4	10.0	5.9
87.5	60.9	10.8	4.2
90.0	60.2	10.6	5.7
92.0	64.8	13.1	2.5
97.0	65.8	13.3	2.1
102.0	73.9	17.1	2.7
107.0	78.9	21.4	2.7
112.0	81.2	23.3	3.3
117.0	81.4	23.8	3.6
122.0	81.1	21.9	4.1
127.0	80.6	21.3	3.9
132.0	80.7	19.0	4.2
137.0	79.7	18.2	4.2
142.0	79.5	17.3	4.6
147.0	78.8	16.9	6.5
152.0	78.9	18.9	6.1
157.0	79.1	18.8	6.0
162.0	79.4	19.3	6.1
167.0	78.7	18.6	6.1
172.0	78.9	17.6	6.5
177.0	78.6	18.9	6.5
187.0	78.1	18.4	2.4
192.0	78.3	17.8	3.1
197.0	78.4	18.0	3.1
202.0	79.3	18.4	2.9
207.0	81.0	21.0	3.3
212.0	81.2	22.0	3.3
217.0	80.8	21.6	3.0
222.0	80.8	20.7	3.0
227.0	81.0	20.3	3.5
232.0	80.5	19.6	3.4
237.0	80.6	19.4	3.3
242.0	80.2	18.9	2.9
247.0	81.0	17.5	5.1
252.0	80.1	18.3	4.7
257.0	79.3	19.2	4.5
262.0	78.7	19.2	4.4
267.0	77.2	18.8	3.9
272.0	79.4	20.5	5.1
277.0	79.5	19.7	4.9

282.0	67.2	10.8	4.0

APPENDIX M

LAKE OSWEGO LO05A POLLEN DATA

Depth (cm)	Age (cal yr BP)	Age (AD)	Total *Pinus*	*Picea*	*Abies*	*Pseudotsuga*-type
1.25	-53.5	2003.5	19	5	3	40
4.25	-48.9	1998.9	21	1	4	63
6.25	-45.9	1995.9	26	2	10	44
11.25	-39.0	1989.0	16	0	2	63
16.25	-30.9	1980.9	12	0	3	39
21.25	-14.4	1964.4	21	2	6	57
26.25	24.3	1925.7	4	0	3	27
31.25	83.5	1866.5	3	1	2	66
36.25	139.8	1810.2	2	1	2	33
41.25	194.9	1755.1	6	0	5	18
46.25	248.8	1701.2	3	0	3	20
51.25	301.4	1648.6	2	0	4	20
56.25	352.7	1597.3	3	0	1	23
61.25	402.5	1547.5	4	0	2	28
66.25	450.8	1499.2	1	1	8	14
71.25	497.6	1452.4	1	0	4	18
76.25	542.8	1407.2	3	0	2	12
81.25	586.2	1363.8	2	0	4	31
86.25	627.9	1322.1	3	0	4	20
89.75	655.9	1294.1	2	0	7	21
94.5	691.6	1258.4	7	0	0	34
104.5	757.9	1192.1	11	0	10	102
115.5	821.7	1128.3	9	1	12	117
134.5	925.5	1024.5	7	0	8	127
164.5	1137.1	812.9	10	1	8	79

Thuja-type	*Tsuga heterophylla*	*Taxus brevifolia*	*Myrica*	Ericaceae	*Alnus rubra*-type	*Corylus*	*Betula*
43	5	1	1	0	73	3	9
53	8	4	6	1	82	8	7
44	6	6	13	0	83	7	12
48	15	0	8	0	86	4	19
46	7	7	4	0	99	10	11
32	5	2	3	0	111	8	20
73	6	4	14	0	130	5	6
56	3	1	10	0	146	6	1
76	3	2	11	0	115	1	4
28	5	2	10	1	115	3	8
22	7	0	36	0	112	3	4
27	5	5	11	0	115	2	3
15	7	1	16	0	144	1	1
18	8	2	14	0	179	1	1
13	5	2	20	0	157	1	1
18	4	3	14	0	178	7	1
10	2	2	11	0	127	0	0
11	7	2	9	0	102	1	0
10	8	0	12	0	105	0	0
13	12	0	8	0	87	0	0
26	8	1	6	0	46	0	0
28	28	1	9	0	57	1	1
34	19	2	5	0	79	2	0
29	23	1	13	0	87	2	0
41	17	2	16	0	93	3	0

Salix	*Populus trichocarpa*-type	*Fraxinus*	*Quercus*	*Sambucus*	*Acer circinatum*	*Acer macrophyllum*
4	8	15	6	1	0	6
4	5	22	11	0	0	6
2	5	23	17	0	0	8
3	3	24	9	1	0	6
7	6	28	9	1	0	3
5	8	39	15	0	2	3
4	5	40	8	1	0	3
5	7	30	13	1	1	9
3	5	27	7	2	0	4
7	2	40	9	4	0	1
6	5	48	12	0	1	4
5	2	44	7	1	0	2
8	5	55	9	1	2	2
7	4	49	6	2	0	2
7	3	49	7	2	0	0
10	6	56	8	1	0	1
9	4	31	4	0	0	0
13	3	22	3	2	0	1
5	6	29	8	0	0	0
13	6	17	3	3	0	2
6	3	23	5	1	0	1
2	1	20	9	0	0	0
0	1	17	8	0	0	1
3	2	16	5	1	0	2
5	2	22	6	0	0	1

Rosaceae	*Prunus*	*Spiraea*-type	*Rubus*	*Ceanothus*	*Cornus*	*Castanea*	*Rhus*
1	0	0	0	0	1	0	0
1	0	0	0	0	1	1	0
0	0	1	0	2	1	1	1
0	0	0	0	0	0	0	0
0	0	1	0	0	1	0	2
0	0	1	0	0	1	0	0
1	0	1	0	0	4	1	0
0	0	4	0	0	1	1	0
2	0	1	0	0	1	0	0
1	0	0	0	4	2	1	0
1	0	1	0	0	3	0	0
2	0	3	0	3	0	1	0
1	0	1	0	3	3	0	0
1	0	1	0	0	0	0	0
2	0	1	0	3	0	0	0
2	0	1	0	0	0	0	0
1	0	2	0	1	1	1	0
0	0	1	0	2	1	0	1
1	0	0	4	1	1	0	0
2	0	0	1	0	1	0	0
3	0	0	0	2	0	0	2
0	0	0	0	0	1	0	0
4	0	0	0	0	1	0	0
0	0	0	0	0	0	0	1
1	0	0	0	0	1	0	0

Juglandaceae	Other trees and shrubs	Poaceae	Cyperaceae	*Helianthus*-type	*Agoseris*-type	*Salsola*-type
5	2	48	0	2	0	0
1	1	31	0	1	0	1
3	1	40	0	1	1	1
3	0	28	0	2	0	1
3	1	47	0	1	2	0
4	0	47	0	0	0	0
1	1	41	0	0	0	5
4	0	41	1	0	0	1
1	4	45	0	1	3	1
0	0	61	1	0	2	3
2	0	63	2	0	2	0
0	0	63	1	0	2	2
1	1	50	0	2	2	2
0	2	47	0	1	2	4
1	0	44	0	0	2	1
2	1	45	2	0	1	2
0	0	43	1	0	1	1
0	0	29	2	2	1	1
0	1	32	1	0	3	1
1	1	29	0	4	2	1
0	0	14	2	0	0	0
0	0	1	5	0	0	1
0	0	5	4	0	0	0
0	0	4	0	1	0	0
0	0	9	1	1	0	0

Ranunculus	Umbelliferae	Brassicaceae	Caryophyllaceae	*Polygonum*	*Rumex*
0	0	0	0	0	2
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	1
1	0	0	0	0	0
0	3	0	0	1	0
0	1	0	1	0	0
0	1	0	1	0	0
0	1	0	0	1	0
0	2	0	0	0	3
0	3	0	0	0	2
0	1	0	0	0	2
0	0	1	0	1	2
0	1	0	0	0	2
0	0	0	0	0	3
0	0	1	0	0	2
0	0	1	1	0	3
0	1	0	0	0	9
0	1	0	0	0	11
0	3	0	0	0	8
0	2	0	0	0	4
0	1	0	0	0	2
0	2	1	0	0	0
0	0	0	0	0	0
0	0	1	0	0	0

Scrophulariaceae	Saxifragaceae	Legumaceae	*Plantago-type*	*Pteridium*	*Dryopteris*-type	Other herbs
0	0	0	0	1	10	0
0	0	0	0	2	4	0
0	0	0	0	10	11	0
0	0	0	0	5	10	0
0	0	0	2	12	14	0
0	0	1	1	6	14	0
0	1	0	0	9	10	0
0	0	0	5	8	13	0
0	0	0	2	11	10	2
0	1	0	1	24	12	2
0	1	0	3	31	24	2
0	0	0	6	33	13	2
0	1	0	11	38	19	4
0	0	0	6	50	21	1
0	0	0	9	70	33	1
0	0	0	12	61	43	0
0	0	0	11	103	34	0
0	0	0	3	95	27	1
2	0	0	12	108	19	1
0	0	0	9	129	34	0
0	0	0	0	124	37	1
0	0	0	0	54	38	0
0	0	0	0	53	25	1
0	0	0	0	26	22	0
0	0	0	0	55	24	1

Equisetum	*Selaginella*	Polypodiaceae	*Typha latifolia-*type	*Potamogeton*	*Myriophyllum*
0	0	0	0	1	0
0	0	0	0	9	0
1	0	0	1	0	0
0	0	3	0	4	0
0	0	0	0	12	1
0	1	0	0	5	0
2	0	0	1	1	0
9	0	0	0	1	0
1	0	0	0	5	1
0	0	0	1	2	0
16	0	0	0	2	1
1	0	0	1	4	0
0	0	0	1	2	0
1	0	0	2	0	0
1	0	0	4	2	0
0	0	0	0	1	0
0	1	0	0	2	0
1	0	0	1	0	0
0	0	0	2	1	0
0	0	0	1	7	1
2	0	0	0	2	0
0	0	0	0	6	0
0	0	0	1	2	0
0	0	0	1	8	0
0	0	0	0	9	0

Sagittaria	*Nuphar*	*Brasenia*	Other aquatics	Indeterminate	Unknown	*Lycopodium* tracer
1	0	0	1	2	0	623
0	0	0	0	4	0	468
0	0	2	0	11	0	339
2	0	0	0	11	0	235
1	0	0	0	5	1	176
0	0	0	0	6	0	120
2	0	0	0	9	1	106
1	0	0	0	2	1	123
0	0	1	0	3	4	104
4	0	0	0	9	2	164
3	0	0	0	4	4	147
4	0	0	0	1	2	150
3	0	0	1	5	5	145
2	0	0	1	3	2	102
2	0	1	2	4	4	84
1	0	0	1	3	1	53
6	0	0	0	10	0	62
3	0	1	0	7	2	83
3	0	2	0	0	2	77
5	0	1	1	4	2	76
3	1	2	0	2	2	83
3	0	1	0	2	2	69
1	0	0	0	2	1	103
0	0	0	1	1	1	111
4	0	1	0	1	1	112

Total	AP/(AP+NAP)
319	0.80
363	0.89
397	0.83
377	0.87
399	0.79
430	0.83
426	0.83
456	0.82
399	0.80
402	0.71
456	0.66
402	0.68
454	0.70
477	0.71
481	0.65
512	0.67
441	0.53
404	0.56
419	0.53
441	0.48
372	0.48
397	0.73
410	0.77
392	0.86
416	0.77

APPENDIX N

PORTER LAKE PL05C CHARCOAL DATA

Depth (cm)	Age (cal yr BP)	Years (AD)	Charcoal particles >250 µm	Charcoal particles >125 µm	Charcoal concentration (particles/cm^3)	Herbaceous charcoal (%)
0.0	-55.0	2005.0	0	2	2	100.0
0.5	-53.6	2003.6	2	4	6	50.0
1.0	-52.2	2002.2	1	8	9	44.4
1.5	-50.8	2000.8	0	6	6	50.0
2.0	-49.3	1999.3	1	4	5	20.0
2.5	-47.9	1997.9	0	7	7	28.6
3.0	-46.5	1996.5	0	5	5	60.0
3.5	-45.1	1995.1	0	3	3	33.3
4.0	-43.7	1993.7	2	9	11	36.4
4.5	-42.3	1992.3	0	12	12	33.3
5.0	-40.8	1990.8	0	5	5	80.0
5.5	-39.4	1989.4	0	7	7	0.0
6.0	-38.0	1988.0	0	4	4	50.0
6.5	-36.6	1986.6	0	8	8	62.5
7.0	-35.2	1985.2	1	8	9	44.4
7.5	-33.8	1983.8	0	4	4	25.0
8.0	-32.3	1982.3	0	1	1	0.0
8.5	-30.9	1980.9	0	7	7	57.1
9.0	-29.5	1979.5	1	8	9	33.3
9.5	-28.1	1978.1	0	13	13	7.7
10.0	-26.7	1976.7	0	10	10	20.0
11.0	-23.9	1973.9	0	7	7	28.6
12.0	-21.0	1971.0	3	15	18	44.4
13.0	-18.2	1968.2	2	21	23	34.8
14.0	-15.4	1965.4	0	14	14	57.1
15.0	-12.5	1962.5	2	18	20	5.0
16.0	-9.7	1959.7	2	18	20	20.0
17.0	-6.9	1956.9	4	24	28	28.6
18.0	-4.0	1954.0	4	29	33	27.3
19.0	-1.2	1951.2	4	20	24	8.3
20.0	1.6	1948.4	0	20	20	20.0
21.0	4.5	1945.5	0	28	28	28.6
22.0	7.3	1942.7	4	25	29	41.4

23.0	10.1	1939.9	1	15	16	6.3
24.0	13.0	1937.0	1	15	16	31.3
25.0	15.8	1934.2	6	19	25	16.0
26.0	18.6	1931.4	1	30	31	19.4
27.0	21.4	1928.6	0	34	34	35.3
28.0	24.3	1925.7	1	24	25	28.0
29.0	27.1	1922.9	3	41	44	11.4
30.0	29.9	1920.1	1	35	36	11.1
31.0	32.8	1917.2	2	34	36	8.3
32.0	35.6	1914.4	7	39	46	19.6
33.0	38.4	1911.6	0	48	48	14.6
34.0	41.3	1908.7	3	54	57	28.1
35.0	44.1	1905.9	6	56	62	19.4
36.0	46.9	1903.1	6	48	54	16.7
37.0	49.8	1900.2	7	46	53	11.3
38.0	52.6	1897.4	10	43	53	35.8
39.0	55.4	1894.6	6	52	58	13.8
40.0	58.3	1891.7	12	58	70	14.3
41.0	61.1	1888.9	16	98	114	20.2
42.0	63.9	1886.1	16	97	113	18.6
43.0	66.7	1883.3	9	79	88	21.6
44.0	69.6	1880.4	19	89	108	15.7
45.0	72.4	1877.6	24	133	157	11.5
46.0	75.2	1874.8	12	115	127	7.1
47.0	78.1	1871.9	18	122	140	17.1
48.0	80.9	1869.1	20	150	170	20.6
49.0	83.7	1866.3	18	128	146	17.1
50.0	86.6	1863.4	14	96	110	20.9
51.0	89.4	1860.6	5	38	43	34.9
52.0	92.2	1857.8	4	29	33	21.2
53.0	95.1	1854.9	2	22	24	62.5
54.0	97.9	1852.1	2	10	12	50.0
55.0	100.7	1849.3	1	17	18	66.7
56.0	103.6	1846.4	2	17	19	47.4
57.0	106.4	1843.6	4	17	21	57.1
58.0	109.2	1840.8	0	16	16	56.3
59.0	112.0	1838.0	1	12	13	53.8
60.0	114.9	1835.1	2	40	42	78.6
61.0	117.7	1832.3	2	13	15	66.7
62.0	120.5	1829.5	0	10	10	70.0
63.0	123.4	1826.6	0	9	9	33.3
64.0	126.2	1823.8	0	1	1	0.0

65.0	129.0	1821.0	0	4	4	100.0
66.0	131.9	1818.1	0	6	6	50.0
67.0	134.7	1815.3	2	10	12	50.0
68.0	137.5	1812.5	2	12	14	71.4
69.0	140.4	1809.6	0	16	16	50.0
70.0	143.2	1806.8	5	8	13	46.2
71.0	146.0	1804.0	2	18	20	70.0
72.0	148.9	1801.1	4	10	14	85.7
73.0	151.7	1798.3	0	13	13	46.2
74.0	154.5	1795.5	2	24	26	73.1
75.0	157.3	1792.7	0	3	3	100.0
76.0	160.2	1789.8	3	15	18	55.6
77.0	163.0	1787.0	4	10	14	92.9
78.0	165.8	1784.2	0	3	3	66.7
79.0	168.7	1781.3	3	14	17	76.5
80.0	171.5	1778.5	3	20	23	65.2
81.0	174.3	1775.7	0	17	17	52.9
82.0	177.2	1772.8	0	12	12	58.3
83.0	180.0	1770.0	1	19	20	50.0
84.0	182.8	1767.2	8	16	24	54.2
85.0	185.7	1764.3	2	11	13	38.5
86.0	188.5	1761.5	3	7	10	20.0
87.0	191.3	1758.7	2	14	16	31.3
88.0	194.2	1755.8	4	15	19	78.9
89.0	197.0	1753.0	3	9	12	25.0
90.0	199.8	1750.2	3	15	18	77.8
91.0	202.6	1747.4	3	3	6	50.0
92.0	205.5	1744.5	1	4	5	60.0
93.0	208.3	1741.7	0	10	10	30.0
94.0	211.1	1738.9	0	4	4	25.0
95.0	214.0	1736.0	2	7	9	55.6
96.0	216.8	1733.2	1	15	16	18.8
97.0	219.6	1730.4	0	9	9	55.6

APPENDIX O

PORTER LAKE PL05C LOSS-ON-IGNITION DATA

Depth (cm)	Bulk density (%)	Organic content (%)	Carbonate content (%)
3	21.6	13.6	-
8	29.7	12.6	-
13	36.6	12.2	-
17	38.2	12.9	2.7
22	34.4	13.5	2.8
27	37.1	12.2	3.0
32	37.8	11.9	2.9
37	37.9	12.6	3.0
42	38.6	12.1	2.6
47	41.3	11.6	2.6
52	37.3	11.7	3.2
57	40.5	11.3	2.9
62	38.7	11.4	3.2
67	42.2	10.9	3.3
72	42.1	11.3	3.5
77	43.2	11.6	3.6
82	40.9	12.2	3.8
87	42.1	12.3	3.8
92	42.4	12.4	4.1
97	45.7	11.1	3.7

APPENDIX P

PORTER LAKE PL05C POLLEN DATA

Depth (cm)	Age (cal yr BP)	Age (AD)	Total *Pinus*	*Picea*	*Abies*	*Pseudotsuga*-type	*Thuja*-type
0.5	-54.3	2004.3	5	0	3	19	5
2.86	-15.4	1965.4	3	0	0	4	6
2.96	13.0	1937.0	3	0	0	5	6
3.06	41.3	1908.7	6	0	3	6	10
3.16	69.6	1880.4	13	0	3	6	13
3.26	97.9	1852.1	6	1	2	7	8
3.36	126.2	1823.8	11	0	2	8	9
3.46	154.5	1795.5	11	0	4	0	12
3.56	182.8	1767.2	6	0	2	10	11
3.68	216.8	1733.2	16	0	1	15	10

Tsuga heterophylla	*Myrica*	*Alnus rubra*-type	*Corylus*	*Betula*	*Salix*	*Populus trichocarpa*-type
1	1	29	4	1	23	9
1	1	20	0	0	39	7
2	3	25	2	1	50	8
5	6	36	1	0	61	28
5	0	34	0	0	43	23
4	1	25	4	2	58	23
4	0	34	2	0	46	27
5	0	29	1	0	47	29
4	2	49	3	0	62	26
8	1	42	8	0	48	18

Fraxinus	*Quercus*	*Sambucus*	*Acer circinatum*	*Acer macrophyllum*	Rosaceae	*Prunus*	*Spiraea*-type
161	5	3	2	1	0	0	3
167	2	1	3	0	1	1	6
210	5	1	2	0	0	0	5
207	11	0	1	0	1	0	4
164	12	0	0	0	1	0	3
125	31	0	0	5	2	0	5
132	19	3	0	0	0	0	3
121	19	0	0	0	1	0	1
191	14	1	0	2	0	0	2
149	20	1	0	0	1	0	1

Rubus	*Ceanothus*	*Cornus*	*Castanea*	*Rhus*	*Juglans*	Other trees and shrubs	Poaceae
2	3	0		1	0	1	77
1	4	2	4	0	2	1	92
2	2	0	6	1	1	1	82
1	3	0	3	2	1	0	67
0	0	3	2	0	1	0	101
0	0	1	1	0	0	0	87
0	2	1	2	1	0	0	89
0	3	0	2	0	0	0	62
0	4	0	1	2	0	1	85
0	2	0	1	0	0	0	72

Cyperaceae	*Artemisia*	*Helianthus*-type	*Agoseris*-type	*Salsola*-type	Ranunculus	Umbelliferae
4	0	3	1	3	1	1
2	0	1	1	3	0	1
3	0	1	0	2	0	2
2	1	3	1	3	1	2
5	0	2	1	4	1	1
16	0	3	1	0	3	4
4	0	3	3	1	2	2
8	1	5	2	1	1	2
2	0	3	2	2	0	0
2	0	4	0	0	0	1

Brassicaceae	*Polygonum bistortoides*-type	*Polygonum californicum*-type	*Rumex*	Onagraceae	*Galium*	Lamiaceae
1	1	1	0	0	1	0
0	0	0	1	0	0	1
0	0	0	0	0	1	1
2	0	0	0	0	1	1
1	0	0	0	0	0	1
0	0	0	0	1	0	0
0	0	0	0	0	0	1
0	0	0	0	0	0	0
0	0	0	1	0	0	0
0	0	0	1	0	0	0

Saxifragaceae	*Plantago*-type	*Pteridium*	*Dryopteris*-type	Other herbs	*Equisetum*	Polypodiaceae
2	0	2	2	0	9	0
0	1	10	3	0	3	2
0	2	4	3	3	1	1
0	3	8	3	2	7	0
0	3	17	5	0	7	0
0	2	12	2	0	2	0
0	2	25	1	1	1	8
1	5	26	2	0	2	11
1	5	15	3	0	0	9
2	12	12	3	1	1	2

Typha latifolia-type	*Sparganium*-type	*Potamogeton*	*Myriophyllum*	*Sagittaria*	*Nuphar*	*Brasenia*
1	0	6	0	11	11	2
1	0	7	1	12	4	0
5	0	4	1	4	2	0
3	0	10	0	6		2
0	0	5	0	4	1	1
0	0	7	0	5		0
0	2	4	0	6	2	0
0	5	7	0	14		0
0	4	5	0	1	2	1
0	3	2	0	6	1	0

Other aquatics	Indeterminate	Unknown	*Lycopodium* tracer	Total	AP/(AP+NAP)
0	6	3	168	431	0.72
0	4	5	41	431	0.70
0	7	2	65	472	0.76
0	7	0	111	531	0.79
0	3	2	76	491	0.69
2	2	0	70	460	0.70
2	6	2	77	473	0.69
0	5	2	87	447	0.71
1	6	2	81	543	0.77
0	0	2	59	469	0.75

APPENDIX Q

WARNER LAKE WL04A CHARCOAL DATA

Depth (cm)	Age (cal yr BP)	Age (AD)	Charcoal particles >250 µm	Charcoal particles >125 µm	Charcoal concentration (particles/cm^3)	Herbaceous charcoal (%)
0.0	-56.3	2006.3	2	4	23	21.7
0.5	-54.3	2004.3	1	5	25	24.0
1.0	-52.3	2002.3	2	10	36	30.6
1.5	-50.3	2000.3	12	24	59	54.2
2.0	-48.2	1998.2	11	22	56	53.6
2.5	-46.1	1996.1	9	24	52	55.8
3.0	-44.1	1994.1	8	13	42	35.7
3.5	-42.1	1992.1	4	9	25	48.0
4.0	-40.1	1990.1	8	10	30	50.0
4.5	-38.2	1988.2	35	66	132	71.2
5.0	-36.3	1986.3	1	5	22	27.3
5.5	-34.4	1984.4	5	16	43	41.9
6.0	-32.6	1982.6	13	14	41	61.0
6.5	-30.7	1980.7	6	33	53	69.8
7.0	-28.9	1978.9	9	21	44	56.8
7.5	-27.2	1977.2	14	20	72	34.7
8.0	-25.6	1975.6	16	33	66	66.7
8.5	-24.2	1974.2	5	15	35	51.4
9.0	-22.9	1972.9	9	13	33	45.5
9.5	-21.6	1971.6	11	9	38	31.6
10.0	-20.5	1970.5	17	19	46	65.2
10.5	-19.4	1969.4	18	37	71	69.0
11.0	-18.3	1968.3	14	11	40	45.0
11.5	-17.3	1967.3	10	24	50	58.0
12.0	-16.2	1966.2	23	40	97	52.6
12.5	-15.1	1965.1	9	23	76	35.5
13.0	-14.0	1964.0	12	13	51	35.3
13.5	-12.8	1962.8	10	27	76	46.1
14.0	-11.4	1961.4	18	57	96	71.9
14.5	-10.1	1960.1	7	62	92	75.0
15.0	-8.7	1958.7	4	6	17	41.2
15.5	-7.2	1957.2	3	3	12	50.0
16.0	-5.8	1955.8	6	2	18	16.7

16.5	-4.3	1954.3	2	8	24	33.3
17.0	-2.9	1952.9	1	4	18	27.8
17.5	-1.6	1951.6	1	0	4	0.0
18.0	-0.2	1950.2	2	0	4	0.0
18.5	1.1	1948.9	0	0	4	0.0
19.0	2.5	1947.5	0	1	8	12.5
19.5	4.0	1946.0	0	0	10	0.0
20.0	5.5	1944.5	2	1	17	5.9
20.5	7.1	1942.9	5	1	14	14.3
21.0	8.8	1941.2	5	1	20	5.0
21.5	10.7	1939.3	2	3	22	13.6
22.0	12.8	1937.2	5	1	33	3.0
22.5	14.8	1935.2	5	1	14	7.1
23.0	16.9	1933.1	7	1	21	4.8
23.5	18.9	1931.1	2	1	20	5.0
24.0	20.8	1929.2	4	1	20	5.0
24.5	22.6	1927.4	1	0	16	0.0
25.0	24.2	1925.8	6	0	23	0.0
25.5	25.7	1924.3	1	0	7	0.0
26.0	27.2	1922.8	1	0	7	0.0
26.5	28.7	1921.3	1	0	5	20.0
27.0	30.1	1919.9	3	0	5	0.0
27.5	31.3	1918.7	0	0	3	0.0
28.0	32.5	1917.5	1	0	3	0.0
28.5	33.5	1916.5	2	0	3	0.0
29.0	34.5	1915.5	0	0	0	0.0
29.5	35.3	1914.7	1	0	2	0.0
30.0	36.0	1914.0	1	0	2	0.0
30.5	36.6	1913.4	4	0	6	0.0
31.0	37.2	1912.8	5	0	15	0.0
31.5	37.8	1912.2	3	0	8	0.0
32.0	38.4	1911.6	0	0	1	0.0
32.5	39.1	1910.9	0	0	4	0.0
33.0	39.8	1910.2	2	0	3	0.0
33.5	40.6	1909.4	2	0	5	0.0
34.0	41.5	1908.5	1	0	5	0.0
34.5	42.5	1907.5	1	0	2	0.0
35.0	44.0	1906.0	0	0	0	0.0
35.5	46.0	1904.0	0	0	2	0.0
36.0	48.4	1901.6	2	0	6	0.0
36.5	50.9	1899.1	0	0	4	0.0
37.0	53.4	1896.6	2	0	8	0.0

37.5	55.6	1894.4	18	0	53	0.0
38.0	57.6	1892.4	26	0	148	0.0
38.5	59.4	1890.6	60	0	263	0.0
39.0	61.2	1888.8	3	4	16	25.0
39.5	63.1	1886.9	3	0	13	0.0
40.0	65.2	1884.8	2	0	29	0.0
40.5	67.7	1882.3	4	1	20	5.0
41.0	70.9	1879.1	2	0	18	0.0
41.5	74.9	1875.1	0	0	1	0.0
42.0	79.4	1870.6	0	0	6	0.0
42.5	84.1	1865.9	0	0	11	0.0
43.0	88.8	1861.2	1	0	6	0.0
43.5	93.3	1856.7	0	0	4	0.0
44.0	97.6	1852.4	0	0	5	0.0
44.5	102.0	1848.0	4	3	19	15.8
45.0	106.3	1843.7	1	3	13	23.1
45.5	110.8	1839.2	10	1	20	10.0
46.0	115.3	1834.7	3	0	11	0.0
46.5	119.8	1830.2	14	0	60	0.0
47.0	124.3	1825.7	5	0	28	0.0
47.5	128.9	1821.1	1	1	16	6.3
48.0	133.5	1816.5	1	2	7	28.6
48.5	138.2	1811.8	0	0	0	0.0
49.0	142.9	1807.1	0	0	1	0.0
49.5	147.6	1802.4	0	2	5	40.0
50.0	152.3	1797.7	4	1	11	9.1
50.5	157.0	1793.0	204	0	808	0.0
51.0	161.7	1788.3	26	3	65	4.6
51.5	166.4	1783.6	70	13	168	14.9
52.0	171.2	1778.8	14	3	35	11.4
52.5	175.9	1774.1	3	3	16	25.0
53.0	180.6	1769.4	19	6	70	8.6
53.5	185.4	1764.6	206	7	319	2.5
54.0	190.1	1759.9	18	7	35	22.9
54.5	194.8	1755.2	49	19	97	29.9
55.0	199.5	1750.5	9	6	21	57.1
55.5	204.1	1745.9	45	16	101	33.7
56.0	208.8	1741.2	11	5	42	14.3
56.5	213.4	1736.6	4	7	22	40.9
57.0	218.0	1732.0	0	2	3	66.7
57.5	222.5	1727.5	2	1	11	9.1
58.0	227.0	1723.0	24	5	43	18.6

58.5	231.5	1718.5	13	13	45	44.4
59.0	235.9	1714.1	25	15	68	45.6
59.5	240.3	1709.7	18	6	78	9.0
60.0	244.6	1705.4	44	60	176	55.1
60.5	248.9	1701.1	6	9	27	37.0
61.0	253.1	1696.9	14	22	53	58.5
61.5	257.3	1692.7	5	4	32	15.6
62.0	261.3	1688.7	12	7	33	24.2
62.5	265.4	1684.6	33	22	138	20.3
63.0	269.3	1680.7	18	12	96	13.5
63.5	273.2	1676.8	6	10	35	37.1
64.0	277.0	1673.0	16	8	44	38.6
64.5	280.7	1669.3	9	7	59	15.3
65.0	284.4	1665.6	13	8	80	15.0
65.5	287.9	1662.1	3	2	31	6.5
66.0	291.4	1658.6	16	4	93	4.3
66.5	294.7	1655.3	24	52	161	39.1
67.0	298.0	1652.0	19	8	57	28.1
67.5	301.1	1648.9	1	0	15	0.0
68.0	304.2	1645.8	14	50	93	64.5
68.5	307.2	1642.8	8	12	44	29.5
69.0	310.0	1640.0	53	31	151	31.8
69.5	312.8	1637.2	91	74	258	46.1
70.0	315.5	1634.5	62	65	205	45.9
70.5	318.3	1631.7	18	30	77	50.6
71.0	321.1	1628.9	18	48	99	59.6
71.5	323.8	1626.2	8	17	47	44.7
72.0	326.5	1623.5	5	18	36	55.6
72.5	329.2	1620.8	7	2	17	11.8
73.0	331.9	1618.1	10	2	22	27.3
73.5	334.6	1615.4	2	2	13	23.1
74.0	337.3	1612.7	9	7	35	25.7
74.5	340.0	1610.0	1	3	10	30.0
75.0	342.6	1607.4	7	15	50	34.0
75.5	345.3	1604.7	14	11	58	24.1
76.0	347.9	1602.1	33	19	70	61.4
76.5	350.6	1599.4	9	7	34	32.4
77.0	353.2	1596.8	7	32	65	55.4
77.5	355.8	1594.2	4	17	40	45.0
78.0	358.4	1591.6	15	14	66	21.2
78.5	361.0	1589.0	12	16	55	40.0
79.0	363.6	1586.4	18	8	52	28.8

79.5	366.2	1583.8	52	28	111	53.2
80.0	368.7	1581.3	8	2	46	6.5
80.5	371.3	1578.7	11	12	56	25.0
81.0	373.8	1576.2	24	33	76	57.9
81.5	376.4	1573.6	51	46	132	54.5
82.0	378.9	1571.1	6	13	28	53.6
82.5	381.4	1568.6	15	7	37	35.1
83.0	383.9	1566.1	4	11	29	44.8
83.5	386.4	1563.6	7	10	31	35.5
84.0	388.9	1561.1	9	5	35	17.1
84.5	391.4	1558.6	12	7	50	18.0
85.0	393.9	1556.1	11	8	62	12.9
85.5	396.3	1553.7	6	5	25	28.0
86.0	398.8	1551.2	14	2	63	11.1
86.5	401.2	1548.8	40	16	84	39.3
87.0	403.7	1546.3	23	15	46	58.7
87.5	406.1	1543.9	5	12	27	48.1
88.0	408.5	1541.5	11	27	54	63.0
88.5	410.9	1539.1	1	4	15	26.7
89.0	413.3	1536.7	9	6	24	45.8
89.5	415.7	1534.3	12	6	32	28.1
90.0	418.1	1531.9	3	2	13	15.4
90.5	420.5	1529.5	6	5	13	76.9
91.0	422.8	1527.2	7	12	28	53.6
91.5	425.2	1524.8	13	18	43	62.8
92.0	427.5	1522.5	10	12	42	35.7
92.5	429.9	1520.1	4	5	19	31.6
93.0	432.2	1517.8	6	7	23	30.4
93.5	434.5	1515.5	6	10	26	57.7
94.0	436.8	1513.2	21	62	101	74.3
94.5	439.1	1510.9	15	10	51	25.5
95.0	441.4	1508.6	8	11	32	34.4
95.5	443.7	1506.3	48	30	176	26.1
96.0	446.0	1504.0	7	4	22	27.3
96.5	448.3	1501.7	11	19	51	45.1
97.0	450.6	1499.4	16	8	35	42.9
97.5	452.8	1497.2	16	3	52	9.6
98.0	455.1	1494.9	10	3	29	17.2
98.5	457.3	1492.7	8	10	48	25.0
99.0	459.6	1490.4	22	21	106	23.6
99.5	461.8	1488.2	24	33	85	51.8
100.0	464.0	1486.0	34	13	78	26.9

100.5	466.2	1483.8	11	9	56	17.9
101.0	468.4	1481.6	9	7	37	21.6
101.5	470.6	1479.4	7	8	35	34.3
102.0	472.8	1477.2	15	8	40	40.0
102.5	475.0	1475.0	35	91	252	41.3
103.0	477.2	1472.8	3	6	31	22.6
103.5	479.4	1470.6	2	8	19	42.1
104.0	481.5	1468.5	2	2	9	22.2
104.5	483.7	1466.3	15	9	31	54.8
105.0	485.8	1464.2	8	7	21	42.9
105.5	488.0	1462.0	3	1	6	50.0
106.0	490.1	1459.9	0	0	5	0.0
106.5	492.3	1457.7	1	1	2	50.0
107.0	494.4	1455.6	9	0	56	0.0
107.5	496.5	1453.5	9	3	104	2.9
108.0	498.6	1451.4	25	0	136	0.0
108.5	500.7	1449.3	20	5	146	3.4
109.0	502.8	1447.2	22	3	161	1.9
109.5	504.9	1445.1	37	46	207	29.0
110.0	507.0	1443.0	21	9	159	6.9
110.5	509.1	1440.9	6	2	52	3.8
111.0	511.1	1438.9	19	10	121	8.3
111.5	513.2	1436.8	49	31	203	16.7
112.0	515.3	1434.7	8	9	44	25.0
112.5	517.3	1432.7	8	14	39	43.6
113.0	519.4	1430.6	5	1	13	23.1
113.5	521.4	1428.6	0	0	5	0.0
114.0	523.4	1426.6	7	2	16	18.8
114.5	525.5	1424.5	4	9	22	45.5
115.0	527.5	1422.5	1	9	12	75.0
115.5	529.5	1420.5	8	2	35	8.6
116.0	531.5	1418.5	7	0	20	5.0
116.5	533.5	1416.5	2	2	9	33.3
117.0	535.5	1414.5	2	1	6	16.7
117.5	537.5	1412.5	0	0	4	0.0
118.0	539.5	1410.5	1	0	9	0.0
118.5	541.5	1408.5	9	9	64	15.6
119.0	543.5	1406.5	2	0	9	0.0
119.5	545.4	1404.6	4	1	13	7.7
120.0	547.4	1402.6	0	0	3	0.0
120.5	549.4	1400.6	0	1	16	6.3
121.0	551.3	1398.7	9	3	56	5.4

121.5	553.3	1396.7	3	0	7	0.0
122.0	555.2	1394.8	1	1	4	25.0
122.5	557.2	1392.8	1	0	18	0.0
123.0	559.1	1390.9	6	1	59	3.4
123.5	561.0	1389.0	13	9	47	23.4
124.0	563.0	1387.0	10	24	66	40.9
124.5	564.9	1385.1	40	2	148	4.1
125.0	566.8	1383.2	11	3	34	8.8
125.5	568.7	1381.3	24	8	49	20.4
126.0	570.6	1379.4	3	6	15	46.7
126.5	572.5	1377.5	5	8	36	22.2
127.0	574.4	1375.6	10	12	42	42.9
127.5	576.3	1373.7	8	16	48	37.5
128.0	578.2	1371.8	29	16	83	25.3
128.5	580.1	1369.9	3	2	16	12.5
129.0	582.0	1368.0	0	2	7	28.6
129.5	583.9	1366.1	5	1	11	36.4
130.0	585.7	1364.3	4	4	19	21.1
130.5	587.6	1362.4	4	8	23	43.5
131.0	589.5	1360.5	7	8	31	29.0
131.5	591.3	1358.7	7	10	31	35.5
132.0	593.2	1356.8	1	2	9	22.2
132.5	595.1	1354.9	3	5	14	50.0
133.0	596.9	1353.1	0	7	21	33.3
133.5	598.8	1351.2	0	17	23	78.3
134.0	600.6	1349.4	5	2	12	33.3
134.5	602.4	1347.6	3	1	7	14.3
135.0	604.3	1345.7	1	3	6	50.0
135.5	606.1	1343.9	0	1	1	0.0
136.0	607.9	1342.1	1	3	6	66.7
136.5	609.7	1340.3	2	0	10	0.0
137.0	611.6	1338.4	7	1	20	5.0
137.5	613.4	1336.6	7	9	25	36.0
138.0	615.2	1334.8	2	11	34	35.3
138.5	617.0	1333.0	4	9	27	37.0
145.0	640.3	1309.7	3	5	20	25.0
145.5	642.0	1308.0	3	7	32	28.1
146.0	643.8	1306.2	13	16	56	35.7
146.5	645.6	1304.4	19	23	95	30.5
147.0	647.3	1302.7	7	13	35	48.6
147.5	649.1	1300.9	4	6	28	25.0
148.0	650.9	1299.1	10	7	31	35.5

148.5	652.6	1297.4	2	13	32	43.8
149.0	654.4	1295.6	6	9	32	28.1
149.5	656.1	1293.9	4	9	21	52.4
150.0	657.9	1292.1	2	7	28	32.1
150.5	659.6	1290.4	3	6	23	26.1
151.0	661.4	1288.6	4	7	24	37.5
151.5	663.1	1286.9	4	8	31	25.8
152.0	664.9	1285.1	2	5	27	22.2
152.5	666.6	1283.4	12	22	63	39.7
153.0	668.3	1281.7	1	14	44	34.1
153.5	670.1	1279.9	0	6	22	27.3
154.0	671.8	1278.2	15	14	49	42.9
154.5	673.5	1276.5	7	19	40	55.0
155.0	675.3	1274.7	3	14	28	57.1
155.5	677.0	1273.0	3	7	21	38.1
156.0	678.7	1271.3	3	10	32	31.3
156.5	680.5	1269.5	9	14	43	41.9
157.0	682.2	1267.8	2	5	16	37.5
157.5	683.9	1266.1	2	16	52	30.8
158.0	685.6	1264.4	5	8	33	33.3
158.5	687.4	1262.6	6	12	35	42.9
159.0	689.1	1260.9	2	15	37	43.2
159.5	690.8	1259.2	1	7	14	50.0
160.0	692.5	1257.5	1	2	14	14.3
160.5	694.3	1255.7	5	9	28	39.3
161.0	696.0	1254.0	9	11	38	42.1
161.5	697.7	1252.3	1	5	9	66.7
162.0	699.4	1250.6	4	2	11	36.4
162.5	701.1	1248.9	1	2	12	16.7
163.0	702.9	1247.1	2	3	12	25.0
163.5	704.6	1245.4	7	4	18	33.3
164.0	706.3	1243.7	3	0	7	0.0
164.5	708.0	1242.0	2	5	26	23.1
165.0	709.7	1240.3	3	7	23	39.1
165.5	711.4	1238.6	4	10	42	28.6
166.0	713.1	1236.9	4	5	48	10.4
166.5	714.9	1235.1	6	4	39	15.4
167.0	716.6	1233.4	3	8	42	19.0
167.5	718.3	1231.7	13	2	105	1.9
168.0	720.0	1230.0	39	0	128	0.0
168.5	722.1	1227.9	36	0	108	0.0
169.0	724.1	1225.9	10	10	91	12.1

169.5	726.2	1223.8	10	7	42	19.0
170.0	728.3	1221.7	10	9	34	29.4
170.5	730.4	1219.6	2	3	22	13.6
171.0	732.4	1217.6	4	3	15	26.7
171.5	734.5	1215.5	5	21	49	46.9
172.0	736.6	1213.4	5	23	52	46.2
172.5	738.6	1211.4	2	6	29	24.1
173.0	740.7	1209.3	14	13	61	24.6
173.5	742.8	1207.2	5	12	42	28.6
174.0	744.8	1205.2	6	10	32	37.5
174.5	746.9	1203.1	5	4	35	11.4
175.0	749.0	1201.0	27	5	71	11.3
175.5	751.1	1198.9	18	9	74	17.6
176.0	753.1	1196.9	17	6	71	12.7
176.5	755.2	1194.8	38	9	108	12.0
177.0	757.3	1192.7	13	11	89	13.5
177.5	759.3	1190.7	17	4	65	9.2
178.0	761.4	1188.6	13	9	43	23.3
178.5	763.5	1186.5	13	16	59	32.2
179.0	765.6	1184.4	12	9	49	24.5
179.5	767.6	1182.4	4	3	29	10.3
180.0	769.7	1180.3	1	5	18	27.8
180.5	771.8	1178.2	3	15	38	42.1
181.0	773.8	1176.2	4	13	38	36.8
181.5	775.9	1174.1	10	12	42	38.1
182.0	778.0	1172.0	2	4	20	20.0
182.5	780.1	1169.9	1	4	27	14.8
183.0	782.1	1167.9	2	5	28	17.9
183.5	784.2	1165.8	0	7	29	24.1
184.0	786.3	1163.7	18	13	59	28.8
184.5	788.3	1161.7	16	2	39	10.3
185.0	790.4	1159.6	5	9	27	33.3
185.5	792.5	1157.5	9	15	39	48.7
186.0	794.5	1155.5	1	9	32	28.1
186.5	796.6	1153.4	15	10	42	28.6
187.0	798.7	1151.3	6	8	29	31.0
187.5	800.8	1149.2	4	27	64	43.8
188.0	802.8	1147.2	3	6	34	20.6
188.5	804.9	1145.1	27	2	45	20.0
189.0	807.0	1143.0	16	9	39	30.8
189.5	809.0	1141.0	12	7	45	17.8
190.0	811.1	1138.9	9	3	34	20.6

190.5	813.2	1136.8	7	17	56	33.9
191.0	815.3	1134.7	11	6	41	24.4
191.5	817.3	1132.7	3	8	31	25.8
192.0	819.4	1130.6	12	7	41	24.4
192.5	821.5	1128.5	5	1	24	4.2
193.0	823.5	1126.5	8	1	29	6.9
193.5	825.6	1124.4	2	6	27	25.9
194.0	827.7	1122.3	8	7	33	24.2
194.5	829.7	1120.3	15	7	37	29.7
195.0	831.8	1118.2	7	10	29	44.8
195.5	833.9	1116.1	7	9	39	25.6
196.0	836.0	1114.0	25	6	49	36.7
196.5	838.0	1112.0	7	2	33	6.1
197.0	840.1	1109.9	25	8	61	19.7
197.5	842.2	1107.8	12	13	48	35.4
198.0	844.2	1105.8	7	6	33	24.2
198.5	846.3	1103.7	4	3	24	16.7
199.0	848.4	1101.6	2	2	27	7.4
199.5	850.5	1099.5	7	4	30	16.7
200.0	852.5	1097.5	12	7	57	17.5
200.5	854.6	1095.4	4	5	26	19.2
201.0	856.7	1093.3	9	5	40	15.0
201.5	858.7	1091.3	3	6	31	19.4
202.0	860.8	1089.2	7	8	37	24.3
202.5	862.9	1087.1	3	6	23	26.1
203.0	864.9	1085.1	10	5	49	14.3
203.5	867.0	1083.0	7	4	46	8.7
204.0	869.1	1080.9	29	12	164	10.4
204.5	871.2	1078.8	10	6	64	14.1
205.0	873.2	1076.8	31	11	90	18.9
205.5	875.3	1074.7	21	1	80	1.3

APPENDIX R

WARNER LAKE WL04A MAGNETIC SUSCEPTIBILITY DATA

Core depth (cm)	Magnetic susceptibility (emu)
0	0.0000606
1	0.0000878
2	0.0001010
3	0.0000996
4	0.0001103
5	0.0000391
6	0.0000901
7	0.0001336
8	0.0001487
9	0.0001575
10	0.0001686
11	0.0001771
12	0.0001940
13	0.0002019
14	0.0002411
15	0.0002530
16	0.0002698
17	0.0003042
18	0.0003366
19	0.0003838
20	0.0004083
21	0.0004053
22	0.0003580
23	0.0002813
24	0.0002279
25	0.0001879
26	0.0001725
27	0.0001689
28	0.0001930
29	0.0002066
30	0.0002288
31	0.0002418
32	0.0002678
33	0.0002930

34	0.0003132
35	0.0003334
36	0.0003616
37	0.0003830
38	0.0003846
39	0.0003559
40	0.0002891
41	0.0002178
42	0.0001226
43	0.0000199
46	0.0000712
47	0.0001119
48	0.0001894
49	0.0002780
50	0.0003059
51	0.0002825
52	0.0002157
53	0.0001492
54	0.0000805
55	0.0000602
56	0.0000528
57	0.0000486
58	0.0000561
59	0.0000606
60	0.0000631
61	0.0000629
62	0.0000546
63	0.0000474
64	0.0000430
65	0.0000396
66	0.0000401
67	0.0000116
68	0.0000268
69	0.0000338
70	0.0000294
71	0.0000268
72	0.0000260
73	0.0000264
74	0.0000287
75	0.0000323
76	0.0000357
77	0.0000353

78	0.0000357
79	0.0000352
80	0.0000343
81	0.0000331
82	0.0000320
83	0.0000305
84	0.0000304
85	0.0000290
86	0.0000291
87	0.0000297
88	0.0000303
89	0.0000323
90	0.0000345
91	0.0000380
92	0.0000378
93	0.0000402
94	0.0000428
95	0.0000477
96	0.0000505
97	0.0000546
98	0.0000602
99	0.0000658
100	0.0000729
101	0.0000911
102	0.0001105
103	0.0001571
104	0.0002154
105	0.0003096
106	0.0004106
107	0.0005031
108	0.0005536
109	0.0005546
110	0.0005193
111	0.0004494
112	0.0003843
113	0.0003212
114	0.0002867
115	0.0002802
116	0.0002958
117	0.0003435
118	0.0003900
119	0.0004168

120	0.0004177
121	0.0003993
122	0.0003502
123	0.0003040
124	0.0002344
125	0.0001936
126	0.0001492
127	0.0001140
128	0.0000977
129	0.0000899
130	0.0000868
131	0.0000905
132	0.0001038
133	0.0001158
134	0.0001188
135	0.0001123
136	0.0000860
146	0.0000476
147	0.0000563
148	0.0000599
149	0.0000628
150	0.0000623
151	0.0000628
152	0.0000644
153	0.0000643
154	0.0000649
155	0.0000661
156	0.0000664
157	0.0000675
158	0.0000688
159	0.0000706
160	0.0000723
161	0.0000776
162	0.0000798
163	0.0000871
164	0.0000973
165	0.0001147
166	0.0001435
167	0.0001680
168	0.0001865
169	0.0001862
170	0.0001707

171	0.0001423
172	0.0001174
173	0.0001030
174	0.0000976
175	0.0000985
176	0.0001032
177	0.0001074
178	0.0001199
179	0.0001408
180	0.0001689
181	0.0002028
182	0.0002312
183	0.0002454
184	0.0002384
185	0.0002115
186	0.0001768
187	0.0001458
188	0.0001199
189	0.0001067
190	0.0000986
191	0.0000953
192	0.0000922
193	0.0000908
194	0.0000925
195	0.0000942
196	0.0000980
197	0.0000950
198	0.0000954
199	0.0000938
200	0.0000928
201	0.0000915
202	0.0000885
203	0.0000826
204	0.0000661
205	0.0000568

APPENDIX S

WARNER LAKE WL04A LOSS-ON-IGNITION DATA

Depth (cm)	Bulk density (%)	Organic content (%)	Carbonate content (%)
0.0	76.9	10.9	
2.5	89.4	24.5	3.5
7.5	90.6	21.3	3.4
10.0	80.3	19.9	
12.5	92.3	19.5	4.2
15.0	77.9	15.3	
17.5	78.7	17.8	4.0
22.5	72.2	45.9	4.5
25.0	76.4	10.8	
27.5	78.4	11.6	3.8
30.0	75.2	11.2	
32.5	77.9	11.8	3.6
35.0	73.8	11.0	
37.5	80.7	32.8	5.4
40.0	79.6	28.1	
42.5	79.8	30.0	5.5
45.0	76.2	17.8	
47.5	85.0	24.8	5.2
50.0	79.0	55.3	
52.5	81.2	25.4	5.2
57.5	82.4	16.7	4.0
62.5	84.0	22.5	4.9
65.0	79.1	23.0	
67.5	81.9	22.4	5.3
70.0	75.5	26.6	
72.5	77.9	30.4	5.5
75.0	78.8	24.0	0.0
77.5	81.3	34.8	4.5
80.0	78.5	22.9	
82.5	80.6	27.2	6.2
85.0	79.9	25.2	
87.5	79.4	23.0	5.9

90.0	80.3	21.4	
92.5	96.1	27.1	5.3
97.5	85.6	18.2	6.0
100.0	79.3	39.2	
102.5	96.7	24.6	5.8
105.0	77.0	10.2	
107.5	76.4	11.3	4.8
110.0	72.9	12.1	
112.5	80.2	11.0	6.0
115.0	75.7	11.8	
117.5	83.1	11.3	6.0
120.0	74.3	10.4	
122.5	79.3	11.4	3.9
125.0	76.1	17.1	
127.5	82.8	22.4	4.9
130.0	79.0	23.4	
132.5	83.2	24.0	4.3
135.0	78.3	15.0	
137.5	80.6	18.7	4.3
145.0	77.2	22.9	
147.5	79.4	19.4	4.1
150.0	78.8	29.8	
152.5	80.3	32.2	4.1
155.0	78.2	27.2	
157.5	95.8	28.1	5.7
162.5	78.9	27.2	4.1
165.0	77.7	22.7	
167.5	75.6	19.8	4.1
170.0	86.7	25.3	
172.5	79.1	27.0	5.8
175.0	86.0	23.3	
177.5	78.1	26.8	3.8
180.0	84.3	21.6	
182.5	76.8	20.7	3.3
185.0	85.7	22.1	
187.5	75.4	28.4	3.7
190.0	86.0	24.3	
192.5	77.3	27.5	4.1
195.0	78.4	21.2	
197.5	77.9	24.7	5.8

200.0	76.9	18.9	
202.5	76.2	24.9	7.3
205.0	73.6	16.5	

APPENDIX T

WARNER LAKE WL04A POLLEN DATA

Depth (cm)	Age (cal yr BP)	Age (AD)	Total *Pinus*	*Picea*	*Abies*	*Pseudotsuga*-type	Cupressaceae
0.5	-54.3	2004.3	5	0	1	31	44
5.5	-34.4	1984.4	0	0	1	10	20
9.5	-21.6	1971.6	6	1	0	18	31
14.5	-10.1	1960.1	3	0	2	8	28
19.5	4.0	1946.0	7	2	0	22	35
24.5	22.6	1927.4	3	0	1	35	65
29.5	35.3	1914.7	0	1	0	1	4
39.5	63.1	1886.9	9	0	3	53	202
45.5	110.8	1839.2	3	0	3	24	76
49.5	147.6	1802.4	1	1	3	29	139
54.5	194.8	1755.2	2	0	3	46	235
59.5	240.3	1709.7	3	1	1	26	250
64.5	280.7	1669.3	5	2	3	37	344
69.5	312.8	1637.2	9	0	1	45	238
74.5	340.0	1610.0	7	0	1	55	326
79.5	366.2	1583.8	4	4	2	51	218
84.5	391.4	1558.6	6	0	1	23	254
89.5	415.7	1534.3	5	0	1	33	289
94.5	439.1	1510.9	6	0	5	37	110
99.5	461.8	1488.2	8	0	4	50	149
104.5	483.7	1466.3	5	0	3	11	73
109.5	504.9	1445.1	4	0	1	28	41
114.5	525.5	1424.5	6	0	5	18	61
119.5	545.4	1404.6	4	1	0	47	205
124.5	564.9	1385.1	4	0	2	14	82
129.5	583.9	1366.1	8	0	0	52	197
134.5	602.4	1347.6	3	1	1	30	80
149.5	656.1	1293.9	10	0	0	59	153
159.5	690.8	1259.2	7	0	1	48	80
169.5	726.2	1223.8	15	1	4	67	65
179.5	767.6	1182.4	10	2	2	34	113
189.5	809.0	1141.0	11	3	1	60	96
199.5	850.5	1099.5	6	0	2	41	107
204.5	871.2	1078.8	6	0	0	31	42

Tsuga heterophylla	*Taxus brevifolia*	*Myrica*	*Alnus rubra*-type	*Corylus*	*Betula*	*Salix*	*Populus*
7	3	1	194	0	0	0	1
0	0	0	192	0	1	1	0
2	0	0	217	2	0	2	1
1	0	0	107	5	1	1	1
1	0	0	116	3	0	9	0
3	1	0	40	7	0	0	0
0	0	0	24	0	0	0	1
4	0	2	173	3	0	2	3
6	2	0	147	12	0	1	0
5	0	1	188	5	0	1	3
7	1	0	184	7	0	2	1
6	7	0	85	4	0	1	1
5	4	2	69	2	0	3	2
5	1	0	127	0	0	1	3
2	13	1	123	2	0	1	0
10	0	0	25	2	0	2	7
3	2	0	94	1	0	6	0
4	0	0	32	1	0	1	3
2	5	0	165	7	0	2	2
9	0	1	56	5	0	1	3
3	6	0	199	6	0	4	4
1	0	0	25	9	0	4	1
2	3	1	93	13	0	11	0
20	0	0	21	9	0	0	0
5	2	1	147	7	0	2	0
15	0	0	30	7	0	2	1
2	3	0	145	1	0	9	2
3	0	3	116	5	0	5	0
6	0	4	95	2	0	2	0
3	0	3	157	7	0	3	0
3	0	4	94	8	0	3	0
1	0	8	98	5	0	3	0
5	0	2	163	1	0	1	0
5	0	0	181	6	0	2	1

Fraxinus	*Quercus*	*Sambucus*	*Acer circinatum*	*Acer macrophyllum*	Rosaceae	*Prunus*	*Spiraea*-type
5	3	0	0	4	2	0	0
5	4	0	1	2	2	0	2
14	2	1	0	1	1	0	3
10	5	1	0	1	4	0	9
7	4	0	1	1	0	0	7
11	4	0	0	0	1	0	1
3	1	0	0	0	0	0	1
13	3	1	0	3	0	0	2
8	2	0	0	1	1	0	0
7	4	3	0	1	0	0	2
11	1	0	0	1	0	0	0
6	3	0	0	0	6	1	1
8	1	0	0	0	4	0	1
7	0	0	0	1	0	0	2
3	6	1	0	3	0	0	2
5	2	0	1	3	0	0	0
4	5	0	1	3	1	0	0
8	2	0	1	5	1	0	0
8	9	0	2	4	0	0	2
2	6	0	2	7	0	0	1
7	5	0	0	2	2	0	0
7	16	1	1	4	0	0	0
6	15	0	0	1	4	0	3
2	0	0	0	0	0	0	0
12	6	0	0	0	1	0	1
7	5	0	0	2	1	0	1
20	7	2	2	1	1	0	2
5	7	0	2	0	0	0	0
4	5	0	2	1	0	0	0
8	13	0	0	2	1	0	0
11	7	0	1	2	1	0	0
16	12	1	1	3	0	0	0
30	8	0	0	1	0	0	0
18	8	1	0	0	4	0	2

Ceanothus	*Cornus*	*Castanea*	*Rhus*	*Juglans*	Other trees and shrubs	Poaceae	Cyperaceae
0	0	0	0	0	0	53	1
2	0	0	0	0	0	70	8
0	0	4	0	0	1	113	2
3	0	1	0	0	1	113	10
3	0	5	0	0	0	67	2
0	1	0	0	1	2	47	4
0	0	0	0	0	0	6	0
0	0	1	1	0	0	25	1
0	0	0	0	0	1	16	8
1	0	1	0	0	0	10	1
3	0	0	0	0	0	5	0
1	1	0	0	0	0	17	0
1	0	0	0	0	0	7	2
0	0	0	0	0	0	7	0
2	1	0	0	0	0	7	0
0	0	0	0	0	0	5	5
0	0	0	0	1	0	11	0
0	0	0	0	0	0	9	14
1	0	0	0	0	2	10	2
0	0	0	0	0	0	17	13
2	1	2	0	0	0	21	3
0	0	0	0	0	0	11	7
0	0	2	1	0	0	31	1
0	0	0	0	0	0	3	1
1	0	0	0	0	0	9	0
0	0	0	0	0	0	9	2
1	0	0	0	0	0	15	4
0	0	0	0	0	0	9	1
0	1	0	0	0	0	17	0
0	0	0	0	0	0	12	2
0	0	0	0	0	0	13	0
0	0	0	0	0	0	8	0
0	0	0	0	0	0	13	1
0	0	0	0	0	0	4	2

Artemisia	*Ambrosia*	*Helianthus*-type	*Agoseris*-type	Other Tubuliflorae	Liguliflorae	*Salsola*-type
0	0	0	0	0	0	0
1	1	0	0	0	0	0
0	0	0	0	2	0	0
1	0	1	1	0	0	1
0	0	0	0	2	0	1
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	0	1	0	0
0	0	0	0	0	0	0
0	0	0	0	1	0	0
0	0	0	0	0	0	0
0	0	0	0	1	0	0
0	0	0	0	1	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	1	0	0	0	0
1	1	0	0	0	0	0
0	0	2	0	0	0	0
0	0	0	0	1	0	0
0	0	0	0	0	0	1
0	0	0	0	1	0	0
0	0	0	0	0	0	0
0	0	0	0	0	1	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	1
0	0	0	0	1	0	0
0	0	0	0	4	0	0
0	0	0	0	1	0	0
0	0	0	0	0	0	0

Other Ranunculaceae	Umbelliferae	Brassicaceae	Other Polygonaceae	*Rumex*	Onagraceae
0	0	0	0	0	0
0	1	0	0	0	0
0	0	1	1	0	0
0	2	0	0	1	0
0	1	0	0	0	0
0	1	0	0	3	0
0	0	1	0	0	0
0	0	0	0	4	0
0	0	0	0	2	0
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
0	0	1	0	0	0
2	0	2	0	0	0
1	0	1	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
0	2	0	1	0	0
0	0	0	0	0	0
0	2	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
1	1	0	0	0	0
0	0	0	0	0	1
0	0	1	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
1	0	1	0	0	0
0	0	2	0	0	0
0	0	0	1	0	0

Scrophulariaceae	Saxifragaceae	*Plantago*-type	*Urtica*-type	*Pteridium*	*Dryopteris*-type	Other herbs
0	0	2	0	4	47	1
0	0	0	0	4	32	0
2	0	3	0	1	36	1
0	0	7	0	8	43	0
0	0	2	0	21	42	2
0	0	7	0	56	36	0
0	0	5	0	6	4	0
0	0	9	0	5	14	0
0	0	0	0	12	16	0
0	1	2	0	11	15	5
0	0	0	0	3	11	1
0	0	0	0	22	29	0
0	0	0	0	27	21	0
0	0	0	0	4	16	1
0	0	0	1	3	8	0
0	0	0	1	11	19	0
0	0	0	0	6	39	0
0	0	0	0	3	21	0
0	0	0	0	4	41	0
0	0	0	0	27	35	0
0	0	0	0	12	41	0
0	0	0	0	17	56	0
0	0	0	0	20	63	0
0	1	0	0	6	41	0
0	0	0	0	8	43	0
0	1	0	0	11	36	0
0	0	0	0	4	49	0
0	0	0	0	11	28	1
0	0	0	0	29	47	3
0	0	0	0	28	77	0
0	0	0	0	45	46	0
0	0	0	0	43	48	1
0	0	0	0	39	47	1
0	0	0	0	22	48	0

Equisetum	*Botrychium*-type	Polypodiaceae	*Typha latifolia*-type	*Sparganium*-type	*Potamogeton*
23	0	2	1	0	6
0	0	1	0	0	2
22	0	0	0	0	16
1	0	1	0	0	2
8	0	0	0	0	33
0	1	0	0	0	3
0	0	0	0	0	3
0	0	0	0	0	9
1	0	0	0	0	2
1	0	1	0	0	9
1	0	0	0	0	12
1	0	0	0	0	10
3	0	0	0	0	18
5	0	0	0	0	10
10	0	1	0	0	4
4	0	1	0	0	0
0	0	0	0	0	2
4	0	0	2	0	0
0	0	0	4	0	4
1	0	1	2	0	0
1	0	0	0	0	10
2	0	0	0	1	0
3	0	1	0	0	6
0	0	0	1	2	3
0	0	0	0	0	5
0	0	0	0	0	11
2	0	0	0	0	3
0	0	0	0	0	12
0	0	0	2	0	7
0	0	0	0	0	11
1	0	0	0	0	10
0	0	0	1	0	15
0	0	0	0	0	18
3	0	0	0	0	3

Myriophyllum	*Sagittaria*	*Nuphar*	*Brasenia*	*Lemna*	*Isoetes*	Other aquatics
36	0	8	0	0	1	2
0	1	0	0	0	0	0
18	0	0	1	0	0	0
0	0	0	0	0	0	0
2	0	0	6	0	0	2
0	0	0	0	0	0	0
0	0	0	0	0	0	0
9	0	0	1	0	0	5
3	0	0	0	0	0	0
6	0	1	5	0	0	8
2	0	0	4	0	0	14
1	0	0	8	0	0	9
0	2	0	6	0	0	12
2	5	0	1	0	0	8
1	5	0	0	0	0	3
0	0	0	0	0	0	0
2	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	0	10	0	0
0	0	0	0	0	0	0
0	0	0	1	6	0	0
0	0	0	0	0	1	0
0	0	0	3	2	0	0
0	0	0	0	0	1	0
0	0	0	0	20	0	0
0	0	0	0	0	0	0
0	0	0	0	16	0	0
0	0	0	0	0	0	0
0	0	0	0	0	1	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	1	0
0	0	0	0	14	0	0

Indeterminate	Unknown	*Lycopodium* tracer	Total	AP/(AP+NAP)
3	0	66	491	0.70
4	1	29	369	0.68
4	4	72	534	0.63
5	0	49	389	0.50
7	4	175	425	0.60
6	0	124	340	0.53
0	2	413	63	0.62
1	2	43	564	0.89
5	0	33	352	0.84
0	3	96	475	0.89
0	2	82	559	0.96
3	0	74	505	0.85
1	0	74	594	0.89
2	0	63	505	0.92
0	3	56	597	0.95
1	1	54	384	0.88
4	1	36	471	0.88
3	2	45	446	0.88
3	0	46	449	0.86
3	0	96	404	0.76
6	1	111	441	0.80
7	1	335	247	0.60
4	1	192	382	0.67
0	1	660	370	0.85
6	1	87	379	0.83
1	0	124	399	0.85
9	0	58	417	0.80
1	2	46	434	0.88
3	0	83	368	0.73
4	1	93	485	0.74
3	0	45	414	0.74
0	0	50	441	0.75
1	1	65	492	0.78
3	2	40	409	0.79

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