2017

Geoarchaeology and Miscellaneous Reports: Cathlapotle and Meier Archaeological Sites, Lower Columbia River

Kenneth M. Ames  
*Portland State University, amesk@pdx.edu*

Katie Henry  
*Portland State University*

Melissa Darby  
*Portland State University*

Stephen Coursalt Hamilton  
*Portland State University*

Charles P. Hodges

*See next page for additional authors*

Let us know how access to this document benefits you.
Follow this and additional works at: [https://pdxscholar.library.pdx.edu/anth_fac](https://pdxscholar.library.pdx.edu/anth_fac)

This Technical Report is brought to you for free and open access. It has been accepted for inclusion in Anthropology Faculty Publications and Presentations by an authorized administrator of PDXScholar. For more information, please contact pdxscholar@pdx.edu.
GEOARCHAEOLOGY AND MISCELLANEOUS REPORTS:
CATHLAPOTLE AND MEIER ARCHAEOLOGICAL SITES,
LOWER COLUMBIA RIVER

Kenneth M. Ames and Katie Henry, Editors

With Contributions
by

Melissa C. Darby, Stephen C. Hamilton, Charles P. Hodges,
Kendal L. McDonald, Leslie M. O’Rourke
and
Jonathan M. White

Wapato Valley Archaeological Project Report #13
Cultural Resource Series Number 21

Portland State University
U.S. Fish & Wildlife Service
Copyright © 2017 by U.S. Fish & Wildlife Service
all rights reserved

Geoarchaeology and Miscellaneous Reports: Cathlapotle and
Meier Archaeological Sites, Lower Columbia River

Wapato Valley Project Archaeological Report #13
Cultural Resource Series Number 21

Published by Cultural Resources Team,
U.S. Fish & Wildlife Service Region 1, Portland, Oregon
# TABLE OF CONTENTS

List of Tables .......................................................................................................................... vi

List of Figures ......................................................................................................................... x

Acknowledgements................................................................................................................ xv

## PART I

Chinookan Households on the Lower Columbia River: Contact and Complexity by
Kenneth M. Ames .................................................................................................................. 3

Preface by Kenneth M. Ames .................................................................................................. 36

## PART II

Response to Chronic Flooding at Cathlapotle (45CL1) Clark County, Washington Stratigraphic
Analysis of Profile D, 155-159 N/W92 by Charles Hodges ................................................. 41

## PART III

Results of Offsite Geoarchaeological Trenching at Cathlapotle Town (45CL1) Ridgefield National
Wildlife Refuge, Carty Unit Clark County, Washington by Charles Hodges .......................... 53

Appendix A ............................................................................................................................... 71

Appendix B ............................................................................................................................... 75

## PART IV

Particle Size Analysis and Geologic Interpretation of Soils Found at the Meier and Cathlapotle
Archaeological Sites in the Columbia River Basin by Jonathan M. White ............................... 77

Appendix A ............................................................................................................................... 82

Appendix B ............................................................................................................................... 116

## PART V

The Wapato Valley Predictive Model: Prehistoric Archaeological Site Location on the Floodplain of the Columbia River in the Portland Basin by Leslie Marietta O’Rourke .......................... 119

Preface .................................................................................................................................... 123

Chapter 1 Introduction.............................................................................................................. 125

Chapter 2 Conceptual Framework............................................................................................ 141

Chapter 3 Development of the Wapato Valley Prehistoric Archaeological Site
Database .................................................................................................................................... 149

Chapter 4 Building the Model Part I: Preliminary Data Analysis ........................................ 159

Chapter 5 Building the Model Part II: Logistic Regression .................................................. 182

Chapter 6 Evaluating the Model ............................................................................................... 198

Chapter 7 Bringing the Results of Logistic Regression into Arcview .................................. 212

Chapter 8 Wapato Valley Predictive Model Site Probability Maps ....................................... 227

Chapter 9 Explanatory Context ............................................................................................... 242

Chapter 10 Conclusions .......................................................................................................... 246

Appendix A Geology of the Wapato Valley ........................................................................... 249
LIST OF TABLES

PART I

Chinookan Households on the Lower Columbia River: Contact and Complexity by Kenneth M. Ames

1.1 Traits of generalized and complex hunter-gatherers (Kelly 1995) .................................................. 9
1.2 Sites used in this study ....................................................................................................................... 11

PART V

The Wapato Valley Predictive Model: Prehistoric Archaeological Site Location on the Floodplain of the Columbia River in the Portland Basin by Leslie Marietta O’Rourke

5.1 Summary Statistics for all 276 Archaeological Sites Versus all 327 Null Points .................................. 162
5.2 Independent Samples Tests: Levene’s Test for Equality of Variances and t-test for Equality of Means of the Independent Variables for Archaeological Sites Versus Null Points ...................................................................................................................... 179
5.3 Mann-Whitney U Test for Difference in Median Values of the Independent Variables for Archaeological Sites Versus Null Points ...................................................................................................................... 179
5.4 Two-Sample Kolmogorov-Smirnov Z Test for Differences in the Distribution of the Independent Variables for Archaeological Sites Versus Null Points ................................................................. 180
5.5 Results of the First Logistic Regression Analysis Using the Enter Method ........................................ 183
5.6 Results of the Second Logistic Regression Analysis Using the Enter Method .................................... 186
5.7 Results of First Stepwise Logistic Regression Analysis Using the Forward Conditional Method ................................................................. 188
5.8 Results of Final Forward Conditional Stepwise Logistic Regression Analysis ..................................... 190
5.9 Comparison of the Regression Coefficients and Wald Statistics for the Three Independent Variables, Run Singly and in the Model ........................................................................................................... 192
5.10 Results of Forward Conditional Stepwise Logistic Regression for Interaction Terms .................................... 195
5.11 Change in Classification Success of Training Sample of Archaeological Sites and Null Points after Adjusting y-Intercept Constant ........................................................................................................... 196
5.12 Distribution of Training Sample (n = 510) of Archaeological Sites and Null Points through Probability Classes, Before and after Adjusting the y-Intercept Constant ........................................................................................................... 196
5.13 An Example of the Effect of the Change in Training Sample Site Classification Rates Accompanying a Change in the Cutpoint for Site Definition from .5 to .6 ......................................................................................... 201
5.14 Effect of Change in Site Definition Cutpoint on the Classificatory Success of 510 Training Sample Cases ............................................................................................................................................... 201
5.15 Comparison of Accuracy of the Wapato Valley Predictive Model with Other Predictive Models ............................................................................................................................................ 210
5.16 Wapato Valley Predictive Model Probability Classes and Ranges of Values ........................................ 222
5.17 Stream Order of Navigable Waterbodies Nearest to Village (n = 50) and Non-Village (n = 226) Archaeological Sites of the Wapato Valley ........................................................................................................... 247
5.B.1 Soils of the Wapato Valley Prehistoric Archaeological Sites .................................................................... 252
5.F.1 Mean and Range of Wapato Valley Predictive Model Variables by Probability Class ........................................ 266
5.F.2 Case Summaries of Training Sample Sites in Probability Class 5 .................................................................. 272
5.F.3 Suggested Ranges of Predictor Variables by Probability Class, and the Percent
PART VI

Wapato for the People: An Ecological Approach to Understanding the Native American Use of Sagittaria Latifolia on the Lower Columbia River by Melissa Cole Darby

6.1 Number of Identified Specimens (NISP) of remains of three small mammals at the Meier Site (35CO5) .................................................. 433
6.2 Nutrient composition of selected root foods ........................................ 449
6.3 Sauvie Island Village populations in the two versions of Lewis and Clark’s “Estimate of the Western Indians” (Boyd and Hajda, 1987, Table 1) ........ 452
6.4 Productivity experiments by date and location ..................................... 458
6.5 Cost/Benefit Ratios of Selected Wild Root ........................................ 458

PART VII

Archaeological Applications of Magnetometry and Ground Penetrating Radar on Flood Plains of the Pacific Northwest by Kendal Lyle McDonald

7.1 Magnetometer Survey Areas, Cathlapotle ........................................ 508
7.2 Cathlapotle Timeline of Events ...................................................... 509
7.3 Newell Homestead Timeline of Events at Champoeg State Heritage Area .... 521
7.4 Survey Area 1 calculated anomaly depths using the half-width rule .......... 524
7.5 Survey Area 2 calculated anomaly depths using the half-width rule .......... 524
7.6 Survey Area 5 calculated anomaly depths using the half-width rule .......... 531

PART VIII

Meier Site Catchment Analysis by Stephen Coursalt Hamilton

8.1 Habitats and Associated Resources in the Meier Catchment Area ............ 552
8.2 Mid-Willamette Valley Prairie Grasses and Associated Forbs ............... 554
8.3 Portland Basin Floral Resources Known from the Ethnohistoric and Archaeological Records ......................................................... 555
8.4 Archaeologically Recovered Fauna from the Meier Site and Seasons Available .... 560
8.5 Resource Season and Habitat ...................................................... 562
8.6 Ethnohistorically Known Season of Exploitation of Food Resources .......... 564
8.7 Most Likely Seasons of Exploitation of Fauna and Flora Represented at the
PART IX

Postscript to Geoarchaeology and Miscellaneous Reports: Cathlapotle and Meier Archaeological Sites, Lower Columbia River by Kenneth M. Ames

9.1 Summary Table of White’s (This Volume) Particle Size Analysis, Drawn from Appendix B .................................................................................................................................578
# LIST OF FIGURES

## PART I

**Chinookan Households on the Lower Columbia River: Contact and Complexity by Kenneth M. Ames**

<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1</td>
<td>Shaded relief map of the Greater Lower Columbia River Region</td>
<td>3</td>
</tr>
<tr>
<td>1.2</td>
<td>Lower Columbia River archaeological sequence</td>
<td>6</td>
</tr>
<tr>
<td>1.3</td>
<td>Locations of archaeological sites discussed in the text</td>
<td>8</td>
</tr>
<tr>
<td>1.4</td>
<td>Meier excavations</td>
<td>12</td>
</tr>
<tr>
<td>1.5</td>
<td>Topographic map of Cathlapotle showing inferred positions of houses</td>
<td>14</td>
</tr>
<tr>
<td>1.6</td>
<td>Location of Cathlapotle excavations relative to the houses</td>
<td>14</td>
</tr>
<tr>
<td>1.7</td>
<td>Typical sequence of historic trade goods at Cathlapotle</td>
<td>15</td>
</tr>
<tr>
<td>1.8</td>
<td>Excavations and houses at Clahlellah</td>
<td>15</td>
</tr>
<tr>
<td>1.9</td>
<td>Cross-section of Cathlapotle through House 1 showing complex interbedding in the trench complexes in profile</td>
<td>16</td>
</tr>
<tr>
<td>1.10</td>
<td>Interior contexts in excavated houses</td>
<td>17</td>
</tr>
<tr>
<td>1.11</td>
<td>Meier house analytical units or segments</td>
<td>17</td>
</tr>
<tr>
<td>1.12</td>
<td>Block excavation of the southern section of the Meier house looking south showing facilities</td>
<td>18</td>
</tr>
<tr>
<td>1.13</td>
<td>The scalar relationships among the data sets employed in the project</td>
<td>19</td>
</tr>
<tr>
<td>1.14</td>
<td>Meier and Cathlapotle pit/cellar features</td>
<td>20</td>
</tr>
<tr>
<td>1.15</td>
<td>Hearths and hearth peripheries</td>
<td>21</td>
</tr>
<tr>
<td>1.16</td>
<td>Cathlapotle wall trench, north wall House 4</td>
<td>22</td>
</tr>
<tr>
<td>1.17</td>
<td>Meier and Cathlapotle midden and yard deposits</td>
<td>22</td>
</tr>
<tr>
<td>1.18</td>
<td>Cathlapotle schematic indicating major topographic/depositional units and house segment labels</td>
<td>23</td>
</tr>
<tr>
<td>1.19</td>
<td>Model of debris flows through the Meier/Cathlapotle plankhouses</td>
<td>24</td>
</tr>
<tr>
<td>1.20</td>
<td>Profile west section (W96-107) of trench N159-160/W79-107</td>
<td>37</td>
</tr>
<tr>
<td>1.21</td>
<td>Example of interbedded sheet midden and overbank deposits west of House 1</td>
<td>38</td>
</tr>
</tbody>
</table>

## PART II

**Response to Chronic Flooding at Cathlapotle (45CL1) Clark County, Washington Stratigraphic Analysis of Profile D, 155-159 N/W92 by Charles Hodges**

<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.1</td>
<td>Portion of Columbia River flood plain showing the location of Cathlapotle (45CL1) and some major landmarks in the vicinity of the site</td>
<td>44</td>
</tr>
<tr>
<td>2.2</td>
<td>Portion of Site Ridge showing locations of 1998 offsite trenches and trenches re-opened in 2000</td>
<td>45</td>
</tr>
<tr>
<td>2.3</td>
<td>Cross-section from the meadow to east bank of Lake River across Brush Ridge</td>
<td>46</td>
</tr>
<tr>
<td>2.4</td>
<td>West Wall Profile D showing texture groups and depositional units exposed in south-north section</td>
<td>48</td>
</tr>
</tbody>
</table>

## PART III

**Results of Offsite Geoarchaeological Trenching at Cathlapotle Town (45CL1) Ridgefield National Wildlife Refuge, Carty Unit Clark County, Washington by Charles Hodges**

<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.1</td>
<td>Portion of Columbia River flood plain showing the location of Cathlapotle (45CL1) and some major landmarks in the vicinity of the site</td>
<td>57</td>
</tr>
</tbody>
</table>
3.2 Portion of Site Ridge showing locations of 1998 offsite trenches and trenches reopened in 2000

3.3 Trench 1, south wall, west face of Site Ridge, Cathlapotle (45CL1)

3.4 Trench 2, north wall, top and upper east slope of Site Ridge

3.5 North wall, Trench 3, lower east slope of Site Ridge above swale, Cathlapotle (45CL1)

3.6 Exploratory Trenches (in swale) and 5 (on levee east of swale), Cathlapotle (45CL1)

3.7 Sketch of island bar and cutbank downstream from Cathlapotle (45CL1) at mouth of Lake River

3.8 Cross-section from the meadow to east bank of Lake River across Brush Ridge

3.9 Schematic 3-D view of southern portion of Site Ridge and surrounding area just upstream of site

PART V

The Wapato Valley Predictive Model: Prehistoric Archaeological Site Location on the Floodplain of the Columbia River in the Portland Basin by Leslie Marietta O’Rourke

5.1 Location map of the Wapato Valley

5.2 Political map of the greater Wapato Valley (USGS 1979 Vancouver Washington-Oregon)

5.3 Figure 4.3. Wapato (Pujar and MacKinnon 1994)

5.4 Two Views of a Canoe, April 2, 1806, Voorhis No. 2

5.5 Idealized logistic regression of two groups of objects (sites and nonsites) across two independent variables

5.6 Archaeological sites and random null points of the Wapato Valley Predictive Model

5.7 Error bar charts of Feet Above Mean Sea Level and Feet Above River Level for all archaeological sites and null points

5.8 Error bar charts of Meters to Nearest Permanent Water and Meters to Navigable Water for all archaeological sites and null points

5.9 Error bar charts of Percent Slope and Degrees Aspect for all archaeological sites and null points

5.10 Histogram of archaeological sites and null points of Feet Above Mean Sea Level

5.11 Histogram of archaeological sites and null points of Feet Above River Level

5.12 Histogram of archaeological sites and null points of Meters to Nearest Permanent Water

5.13 Histogram of archaeological sites and null points of Meters to Navigable Water

5.14 Histogram of archaeological sites and null points of Percent Slope

5.15 Histogram of archaeological sites and null points of Degrees Aspect

5.16 Bar graph of Feet Above Mean Sea Level comparing archaeological sites and null points

5.17 Bar graph of Feet Above River Level comparing archaeological sites and null points

5.18 Bar graph of Meters to Nearest Permanent Water comparing archaeological sites and null points

5.19 Bar graph of Meters to Navigable Water comparing archaeological sites and
PART VI

Wapato for the People: An Ecological Approach to Understanding the Native American Use of Sagittaria Latifolia on the Lower Columbia River by Melissa Cole Darby

6.1 Wapato Valley and the Greater Lower Columbia ................................................................. 419
6.2 Clark’s drawing of a shovelnose canoe ........................................................................... 420
6.3 Extensive wapato patch at Crane Lake, Sauvie Island .................................................. 424
6.4 Sagittaria latifolia, reprinted with the permission of the Missouri Botanical Garden. (Rept. Mo. Bot. Gard., Vol. 6) ............................................................ 428
6.5 Female Flower .................................................................................................................. 429
6.6 Plant showing rhizomes and tubers ................................................................................ 430
6.7 Tubers .............................................................................................................................. 430
6.8 Central Wapato Valley Population by Town Circa 1805 .................................................. 453
6.9 Coast and Geodetic Survey Chart: Sauvie Island ............................................................ 456

PART VII

Archaeological Applications of Magnetometry and Ground Penetrating Radar on Flood Plains of the Pacific Northwest by Kendal Lyle McDonald

7.1 Modified 1834 map (from Hussey 1967:42) .................................................................. 483
7.2 Fire pit signature at a northern latitude such as Portland, Oregon (adapted from Breiner 1973:25, Figure 27) ................................................................. 485
7.3 Schematic of the Earth’s magnetosphere and incoming solar wind particles ............... 486
7.4 Ambient magnetic field intensity measured near Eugene on August 8, 1986 ............. 487
7.5 Magnetic contour map showing a dipole anomaly ............................................................ 488
7.6 Magnetic contour maps with the same data presented in Figure 6.5 at a contour interval of a) 1 nT and b) 10 nT ................................................................. 489
7.7 Magnetic 3-D surface map generated with the same data as Figures 6.5 and 6.6 ........ 489
7.8 Schematic of reflection hyperbola as an antenna crosses over a “point source” .......... 491
7.9 A radargram showing the reflection hyperbola generated from a buried metal bar at 110 cm, visible at 13 nanoseconds ................................................... 491
PART VIII

Meier Site Catchment Analysis by Stephen Coursalt Hamilton
8.1 Map of the Lower Columbia River Region showing the Wapato Valley and the location of the Meier and Cathlapotle Sites ................................................................. 548
8.2 The Meier Site Excavation Units in Relation to House 1B ............................................. 549
8.3 Map of Reconstructed Habitat Distributions within the Meier Site Catchment Area .......... 551

PART IX
Postscript to Geoarchaeology and Miscellaneous Reports: Cathlapotle and Meier Archaeological Sites, Lower Columbia River by Kenneth M. Ames

9.1 20 cm contour map of the Cathlapotle landform, the houses, 1994 excavations and core locations ........................................................................................................... 574
9.2 Three dimensional rendering of the Cathlapotle landform based on the map in Figure 9.1 ......................................................................................................................... 575
9.3 Locations of trenches in Figures 9.4 – 9.7 ........................................................................ 576
9.4 Central portion (N159/W83-95) of N159-160/W79-103 trench bisecting House 1D .............................................................................................................................. 577
9.5 East portion (N159/W79-88) of N159-160/W79-103 trench bisecting House 1D ............... 577
9.6 West section (N159/W95-107) of W79-103/N159-160 trench bisecting House 1D .............. 578
9.7 West end of N52-54/W99-105 trench showing dipping beds at bottom ......................... 579
9.8 Location of Meier on Columbia River floodplain prior to diking ..................................... 580
9.9 Meier excavation block with underlying gravel bar exposed ........................................... 581
ACKNOWLEDGEMENTS

The preparation of this series of reports is supported by U.S. Fish and Wildlife contract number F14PX00232. Kenneth M. Ames is the editor of this series, Kathryn Henry is the production manager. We want to thank Anan Raymond for his unflagging support of the Wapato Valley Archaeological Project and the work at Cathlapotle since 1991, including his finding the money to produce this report series. Beyond Anan, there are a lot of people and institutions to thank.

Supporting Institutions

Portland State University ♦ Chinook Indian Nation ♦ Confederated Tribes of the Grand Ronde ♦ U.S. Fish and Wildlife Service ♦ Portland State University Department of Anthropology, & College of Liberal Arts and Sciences ♦ National Science Foundation ♦ National Endowment for the Humanities ♦ Wenner Gren Foundation for Anthropological Research ♦ National Park Service ♦ University of Michigan ♦ Simon Fraser University ♦ Jean and Ray Auel Foundation ♦ Friends of the Wapato Valley

Individuals and Groups

Gary Johnson ♦ Tony Johnson ♦ Sam Robinson ♦ Cinde Ede ♦ Virginia Parks, Alex Bourdeau, Nick Valentine: Regional USFWS Staff ♦ Staff of Ridgefield Wildlife Refuge – too many to list ♦ Friends of the Ridgefield Refuge ♦ Don Meier ♦ People of Scappoose, Oregon ♦ People of Ridgefield and Clark County Washington

Colleagues

Cameron Smith, Portland State University ♦ Elizabeth Sobel, Missouri State University ♦ Jon Daehnke, University of California, Santa Cruz ♦ Ann Trieu Gahr, Southern Illinois University ♦ R. Lee Lyman, University of Missouri ♦ Virginia Butler, Portland State University ♦ Gay Frederick, Pacific ID ♦ Dong-ya Yang, Simon Fraser University ♦ Loren Davis, Oregon State University ♦ Kory Cooper, Purdue University ♦ Greg Baker, Portland State University ♦ William Gardner-O’Kearny, Portland State University

This list does not include Portland State University Field School students from 1987 – 1996, the field school staffs, nor the many paid and volunteer lab workers. To them we owe a particularly deep debt of gratitude.
PART I
CHINOOKAN HOUSEHOLDS ON THE LOWER COLUMBIA RIVER: CONTACT AND COMPLEXITY

Kenneth M. Ames

PREFACE

Kenneth M. Ames
This report is one in a series on the archaeology of the Wapato Valley region of the Lower Columbia River (Figure 1.1). Most of the reports discuss aspects of the excavations and archaeology of two sites, the Meier site (35CO5) and Cathlapotle site (45CL1) for reasons detailed below. Other related topics are also treated. Most of the reports are revised and edited M.A. theses and Ph.D. dissertations but some contain previously unpublished/unavailable specialists’ reports. The latter are generally descriptive with interpretation and discussion to follow later, but we wish to make the data available. These reports are the final versions of these documents, superseding any previous versions. Discussions and conclusions have been updated where appropriate. In some instances statistical analyses have been redone to accommodate new data or new understanding of the site. Where there are differences in artifact counts between the original document and this report, the counts in this report are final.

Each report has at least four sections; the first section, which you are currently reading, is an overall introduction to the series and project and is standard across all of the reports and is in essence “boilerplate”, which provides a standard and consistent introduction to all the reports. It is intended to provide enough detail on the overall project and the excavations to understand the report, but lacks the detail of a final excavation report. The second section is an introduction to the particular volume itself, presenting background peculiar to the volume in hand. The third section is the report’s actual contribution. This may include one or more theses or technical reports. The fourth section is essentially a postscript which explicitly links those contributions to the project’s broader goals.

Regional Background

The Greater Lower Columbia River (GL-CRR) encompasses the final 200 miles of the Columbia River and adjacent portions of the Pacific

Figure 1.1. Shaded relief map of the Greater Lower Columbia River Region.
coastline (See Sobel et al. 2013 for a more detailed discussion). The region was one of several interaction spheres comprising the Northwest Coast culture area (Hajda 1984, Suttles, 1990, Ames and Maschner 1999). Hajda (1984) defined it using local and regional patterns of social and economic interaction. The documentary record is primarily the accounts of explorers such as Lewis and Clark, of individuals in the fur trade, and early settlers (e.g. Gairdner 1841, Simpson 1847, Coues 1897, Franchere 1967, Moulton 1990, see also Lang 2013). There is not the voluminous ethnographic record that exists for portions of the coast further north (e.g. Boas 1894, Ray 1938; see also Suttles and Lang 2013).

The area is topographically and ecologically diverse (Ellis 2013, Sobel et al. 2013). At its eastern edge, the Columbia Gorge breaches the Cascade Mountain range. West of the Gorge, the river passes through the Portland Basin, Lewis and Clark’s Wapato Valley, the name used by this project. Here, the broad floodplain once contained extensive wetlands. Below the lowland, the river penetrates the Coast Range, a long, rugged chain of low, heavily forested mountains, enters its wide fjord-like estuary, and meets the Pacific Ocean. The climate west of the mountains is maritime, with heavy rains and moderate temperatures.

Several ethno-linguistic groups occupied the GLCRR at contact. Speakers of Chinookan languages were the most numerous (Hajda 1984, Silverstein 1990) with large comparatively dense populations. Boyd conservatively estimates precontact populations at 34,000 people (Boyd 1990, 1999a, 2013). Most were concentrated on the major rivers and tributaries, particularly in the Wapato Valley. Chinookan social organization and economy had much in common with other Northwest Coast societies (Hajda 1984, 2013; Silverstein 1990). The household was the basic socio-economic unit, and the village or town the maximal unit (Hajda, 2013, Ames and Sobel 2013). Households lived in large post and beam plankhouses of western red cedar (*Thuja plicata*). Society was divided into two broad classes, free and slave (Donald 1997, Hajda 2005). Free people were subdivided into a chiefly elite and commoners. Chiefly status was based on heredity, wealth, and widespread social and economic ties (Hajda 1984). The slave population in the late 18th and early 19th centuries may have been 25% of the total (Mitchell 1985, Ames 2008).

Contact began c. 1775, with the first documented exploratory voyages along the coast (Hajda 1984, Gibson 1992). Ongoing contact on the Columbia began in 1792 with the European discovery of its mouth (Vancouver 1926), and the start of the maritime fur trade. The fur trade brought the GLCRR into an “internationalized ocean basin” (Igler 2004) and mercantile and colonial systems spanning the world. Competition among Spain, Great Britain, and Russia (Cole and Darling 1990, Gibson 1992, Lightfoot 1997, Igler 2004) fueled exploration. By the 1790s the United States replaced Spain and competed directly with Britain in the GLCRR. Annually, an average of 12 vessels operated on the Northwest Coast between 1785 and 1841 (Gibson 1992) with at least one probably entering the Lower Columbia River annually (Robert Boyd pers. comm.). Vessels sailed from the GLCRR to Canton, South America, Hawaii, and elsewhere (Igler 2004). Before 1811, the fur trade was entirely maritime, with ships dependent on native people for furs and fresh provisions. The Lewis and Clark expedition spent the winter of 1805-1806 near the river’s mouth. In 1811, Fort Astoria, the first permanent Euro-American base in the GLCRR (Franchere 1967, Jones 1999, Lang 2013), was established. The Hudson’s Bay Company (HBC) in 1824 placed the headquarters for its entire Columbia Department at Ft Vancouver, in the Wapato Valley. The region became part of United States territory in 1848. By then, epidemics had decimated the GLCRR’s original people. Contact-era epidemics were not everywhere as severe as even recently thought (e.g. papers in Larsen and Milner 1994, Baker and Kaelhofer 1996). However, they devastated the GLCRR (Boyd 1999, 2013). The effects differed within the region, with the Wapato Valley worst hit. Its population decline probably exceeded 90% between 1792 and 1832. The GLCRR’s archaeological record is poorly known (Ames 1994a, Sobel et al. 2013). Limited evidence (e.g. Pettigrew 1981, Minor 1983, Losey 2002, Sobel et al. 2013) suggests cultural evolution in the GLCRR followed the broader trends of the Pacific Northwest (e.g. Ames 2000, Ames and Maschner 1999, Matson and Coupland 1995, Sobel et al. 2013). The Wapato Valley Archaeological Project (WVAP) was ini-
tiated to help fill that void.

**Wapato Valley Archaeology Project**

The Wapato Valley Archaeological Project (WVAP) was conceived in the late 1980s as a long term archaeological research project focusing primarily, although not exclusively, on the Columbia River flood plain between the mouth of the Sandy River on the east and the Cowlitz River to the north (Figure 1.1). The name “Wapato Valley” was taken from Lewis and Clark who used two names for the area: the Columbian Valley and the Wappato Valley. “Wapato Valley” was chosen to reflect the centrality of Wapato (*Sagittaria latifolia*) in local and regional Native economies. The project area is essentially coterminous with the Portland Basin and with the greater Portland/Vancouver metropolitan area. It was an umbrella project under which more specific projects could be undertaken as opportunities arose but which would focus on a common set of problems. At the time, the expectation was that there might be an array of projects including those arising from on-going field school excavations, and grant and contract-based projects through PSU’s then Laboratory of Anthropology and Archaeology. The field school was central to this. WVAP’s research program had two broad sets of research problems: the first and more fundamental was to refine and extend the area’s cultural historical sequence; and the second was to investigate hunter-gatherer complexity in the project area.

There were two local cultural sequences for the Lower Columbia River at the time (Figure 1.2): Pettigrew’s for the Portland Basin (Pettigrew 1981) and Minor’s for the Columbia River Estuary (Minor 1983). Both were developed as part of dissertation projects at the University of Oregon. Both were preliminary and based on very limited data sets. Pettigrew tested seven sites and surface collected three more, coupling the results of this work with 25 radiocarbon dates to construct a cultural sequence for the Portland Basin floodplain that essentially remains intact in 2013. He excavated single 6m x 2m trenches in 1’ arbitrary levels in each site. The work was done with volunteers. Pettigrew also examined extensive private collections made from sites in the Basin, including those produced by the Oregon Archaeological Society in the course of their sometimes enormous excavations. His sequence was temporarily short, spanning only the last 2600 years or so, although sites in surrounding uplands (e.g. Newman 1966; Woodward 1972; Daugherty et al. 1987a, 1987b) contained Early and Middle Holocene cultural deposits and, upstream, the Columbia River basin held late Pleistocene occupations on the Snake and Clearwater Rivers. Private collections made on Sauvie Island and in the near-by Scappoose, Oregon area also contained Early/Middle Holocene materials (e.g. Cascade points). Thus the medium/long term goal was to flesh out Pettigrew’s sequence and extend it back in time. The areal focus would be Sauvie Island and environs. A key element to this program would be developing a Holocene alluvial chronology for the Portland Basin, or at least for the Sauvie Island area. None existed at the time (and still doesn’t but see Minor and Peterson 2013, Peterson et al 2011, 2012, 2014 for recent work). The complexity of this task was significantly underestimated and remains undone as of this writing (2013).

Given the general paucity of archaeological data, the Lower Columbia River had played little or no role in research on Complex Hunter-Gatherers elsewhere along the Pacific coast although the documentary record showed very large aboriginal populations at contact and other characteristics then associated with hunter-gatherer complexity (e.g. Price 1981, Kelly 1995, Koyama and Thomas, 1981, Price and Brown 1985). The project’s initial central focus again was chronological – to construct a sequence for the development of complexity in the Wapato Valley and to look at causal factors that might be accessible via the local archaeological record. Saleeby (1983) hypothesized that the ancient residents of the Wapato Valley had been fully sedentary. Her hypothesis was based on her analyses of the faunal assemblages from Pettigrew’s excavations. Given the importance of sedentism in theories and models of social evolution generally (e.g. Testart 1982 and hunter-gatherers particularly (e.g. Kelly 1991) testing Saleeby’s hypothesis with larger, better controlled samples was the first issue to be addressed by the field school excavations. Testing Saleeby’s hypothesis meant simultaneously testing a model of local mobility patterns proposed by Dunnell et al. (1973) based on survey around Vancouver Lake.
<table>
<thead>
<tr>
<th>Calendar Years Before Present</th>
<th>Region</th>
<th>Estuary</th>
<th>Wapato Valley</th>
</tr>
</thead>
<tbody>
<tr>
<td>AD 1850</td>
<td>Early</td>
<td>Early</td>
<td>Early</td>
</tr>
<tr>
<td>AD 1750</td>
<td>Modern</td>
<td>Modern</td>
<td>Modern</td>
</tr>
<tr>
<td>500</td>
<td>Late</td>
<td>Ilwaco 1</td>
<td>Multnomah Phase</td>
</tr>
<tr>
<td>1000</td>
<td>Pacific</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1500</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2000</td>
<td></td>
<td>Ilwaco2</td>
<td>Merrybell Phase</td>
</tr>
<tr>
<td>2500</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3000</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3500</td>
<td></td>
<td>Sea Island Phase</td>
<td></td>
</tr>
<tr>
<td>4000</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4500</td>
<td>Early</td>
<td></td>
<td>???</td>
</tr>
<tr>
<td>5000</td>
<td>Pacific</td>
<td></td>
<td>???</td>
</tr>
<tr>
<td>5500</td>
<td></td>
<td>???</td>
<td></td>
</tr>
<tr>
<td>6000</td>
<td></td>
<td>???</td>
<td></td>
</tr>
<tr>
<td>6500</td>
<td></td>
<td>???</td>
<td></td>
</tr>
<tr>
<td>7000</td>
<td></td>
<td>???</td>
<td></td>
</tr>
<tr>
<td>7500</td>
<td></td>
<td>???</td>
<td></td>
</tr>
<tr>
<td>8000</td>
<td></td>
<td>???</td>
<td></td>
</tr>
<tr>
<td>8500</td>
<td></td>
<td>Young's River Complex</td>
<td>???</td>
</tr>
<tr>
<td>9000</td>
<td>Archaic</td>
<td></td>
<td>???</td>
</tr>
<tr>
<td>9500</td>
<td></td>
<td>???</td>
<td></td>
</tr>
<tr>
<td>10000</td>
<td></td>
<td>???</td>
<td></td>
</tr>
<tr>
<td>10500</td>
<td></td>
<td>???</td>
<td></td>
</tr>
<tr>
<td>11000</td>
<td></td>
<td>???</td>
<td></td>
</tr>
<tr>
<td>11500</td>
<td></td>
<td>???</td>
<td></td>
</tr>
<tr>
<td>12000</td>
<td></td>
<td>???</td>
<td></td>
</tr>
<tr>
<td>12500</td>
<td></td>
<td>???</td>
<td></td>
</tr>
<tr>
<td>13000</td>
<td></td>
<td>???</td>
<td></td>
</tr>
<tr>
<td>13500</td>
<td>Clovis/Stemmed Pts</td>
<td></td>
<td></td>
</tr>
<tr>
<td>14000</td>
<td>Stemmed Pts?</td>
<td></td>
<td>???</td>
</tr>
<tr>
<td>14500</td>
<td>Paisley Cave</td>
<td></td>
<td>???</td>
</tr>
</tbody>
</table>

Figure 1.2. Lower Columbia River Archaeological Sequence. Modified from Sobel et al. 2014.
The original plan for the field school was to begin by returning to Pettigrew’s sites and to more formally test each over one or two field seasons. This was planned for pragmatic and ethical reasons. The pragmatic reason was that Pettigrew’s sites were known, at least in a preliminary way, based on his test excavations and, together, they formed the backbone of his chronology. The ethical reason was trying to operate within the concept of conservation archeology (Lipe 1974). Most, if not all, had suffered damage from development, ongoing use and/or looting, thus the field school would not be impacting intact sites but rather retrieving information from damaged or threatened sites on private land, i.e. sites not then protected by state or federal law or regulations.

The formal field school excavations commenced at the Meier site (35CO5) in 1987 and, for reasons developed below, the WVAP’s focus quickly shifted to the excavation/analyses of two, large complex sites, Meier and Cathlapotle (45CLII). The original goals and plans were rapidly modified. As a consequence, there has been no formal test or development of Pettigrew’s original local sequence, although there has been ongoing CRM work in the area (Ames et al. 1994). The WVAP did conduct other projects besides the Meier and Cathlapotle excavations. These include:

- Excavations of the Early Holocene Burnett Site in Lake Oswego (Burnett 1991)
- Exploratory work at the Trojan Nuclear site in anticipate of a headquarters building that was never built (Burtchard 1989)
- Preparation of a Portland Basin Context Statement for Oregon SHPO (Ames et al. 1994)
- Preparation of a National Landmark nomination for the Sunken Village site (35MU4); (Newman 1991) and participation in testing of the site (Fagan 2004 Pettigrew and Lebow 1987)
- Survey and testing of portions of the Ridgefield National Wildlife Refuge (Daehnke 2007, Daehnke et al. 2010)
- Joint PSU/NPS excavations of the Middle Village site (45PC106) in the Columbia River Estuary (Wilson et al. 2009)

In addition, Sobel (2004) included Clahclellah in the Columbia Gorge in her dissertation (see below), thus extending the WVAP’s data base east. Her analysis of Clahclellah is included in this report series.

Ongoing work:

Field work for the WVAP was suspended in 1996 because of the great volume of materials from Meier and Cathlapotle requiring analysis. Geoarchaeological field work was conducted at Cathlapotle in 1998 (Hodges 1999) and 2000 (Hodges 2002) and geophysical surveys in 1998 and 2000 (McDonald 2002). Laboratory analysis of some 25,000 tools and 150,000 plus other objects has been ongoing with work on both sites proceeding together and as of this writing (October 2013) is complete. The collections from both sites are curated at the federal curation facility at Ft. Vancouver National Historic Site.

Outreach:

In addition to the academic products, the project has been actively involved in community outreach, particularly with its Cathlapotle partners, the Chinook Tribe and the U.S. Fish and Wildlife Service. In 2002 the project received the Advisory Council for Historic Preservation’s first Chairman’s Award for Federal Achievement in Historic Preservation. Activities include teaching kit geared for 3 – 6th graders, workshops for teachers, innumerable public and school lectures, special events and a published booklet on the site for the general public (Daehnke 2002, 2005). Our principle outreach project is a 37’ x 78’ plankhouse on the Ridgefield NWR about a mile from Cathlapotle. This ongoing project involves the Chinook Tribe, the U.S. Fish and Wildlife Service, Portland State University and large numbers of community volunteers. Construction required over 3500 volunteer hours. The plankhouse opened March 29th 2005. Its construction was based in part on the excavated structures at Meier and Cathlapotle and combines authentic materials and techniques with accessible features for public safety. It is the focal point for most, but not all, of our public outreach and interpretation activities. These include on go-
ing plankhouse construction and maintenance, tours given by volunteer docents, lecture series, and festivals. The plankhouse is also be used by the Chinook tribe for cultural events. Daehnke (2007) analyzes the issues of heritage and tribal sovereignty as they intersected at the Plankhouse. Project partners speak regularly to the public on various aspects of the project’s results to community groups usually in the Portland-Vancouver Metropolitan area, but also as far away as Vancouver British Columbia and Fayetteville Arkansas.

The project has benefited greatly from its sustained relationships with the Chinook tribe and the Confederated Tribes of Grand Ronde. This is perhaps best exemplified in the recently published Chinookan Peoples of the Lower Columbia (Boyd et al. 2014). One of the co-editors and several authors are Chinookan peoples including Tony Johnson, one of the co-editors and a member of the Chinook Tribe and David Lewis, Chuck Williams and Eirik Thorsgard of the Grand Ronde Tribe.

Methodological and Theoretical Background to the WVAP excavations at Meier\Cathlapotle

The project’s research used multiple and diverse lines of evidence at multiple spatial and temporal scales to investigate the political economies of households within these communities and within the broader region before and during the maritime fur trade (see Ames 2008). It is, at the same time, research into the political economy of complex hunter-gatherers. The research is conducted within the methodological framework of household archaeology.

Household Archaeology, Political Economy, and Household Production:

The project’s methodology is framed by household archaeology (e.g. Blanton 1994, Deagan 2005, Hendon 1996, Rogers and Smith1995, Sobel, Gahr and Ames 2006, Wattenmaker 1998, Wilk and Rathje 1982), political economy (e.g. Netting 1993, Muller 1997), and household pro-
duction (Ames 2006, 2008). The household is the key methodological unit in fieldwork, hypothesis testing and interpretation. Our rationale for household studies is: “[T]he individual patterns of choice and strategic behavior can be placed within larger social structures and economic–ecological contexts. Societies adapt in only the most abstract sense of the word, but households adapt in concrete and observable ways (Wilk 1997; 31).” The larger social, economic and ecological contexts include the GLCRR and the fur trade era.

We build our approach to household production and economy on the work of several scholars who used documentary and archaeological sources in tandem (e.g. Gallant 1991, Muller 1997, Nevet 1999) and on certain key ethnographies (e.g. Suttles 1951, Oberg 1973, Fricke 1986, Netting 1993, Wilk 1997, see also Ames 2006) and Flannery’s The Mesoamerican Village (Flannery 1976) with its clear, scalar archaeological methodology. In many ways, it has not been superseded. Our approach is exemplified by Sobel, Gahr and Ames (2006).

Household archaeology begins with the household’s economic and ecological context, including the habitats used, the array of resources (number and relative proportions) harvested, the distributions in productive activities in time and space, and the relative costs and risk of production (Ames 2006, Muller 1997: 225). The next level is production, consumption and distribution (e.g. Muller 1997, Costin 2001) within households, including task organization (Ames and Maschner

---

Table 1.1. Traits of Generalized and Complex Hunter-Gatherers (Kelly 1995).

<table>
<thead>
<tr>
<th></th>
<th>Generalized</th>
<th>Complex</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Environment</strong></td>
<td>Unpredictable or variable</td>
<td>Highly predictable or less variable</td>
</tr>
<tr>
<td><strong>Diet</strong></td>
<td>Terrestrial Game</td>
<td>Marine or plant foods</td>
</tr>
<tr>
<td><strong>Settlement size</strong></td>
<td>Small</td>
<td>Large</td>
</tr>
<tr>
<td><strong>Residential Mobility</strong></td>
<td>Medium to high</td>
<td>Low to none</td>
</tr>
<tr>
<td><strong>Demography</strong></td>
<td>Low population density relative to food resources</td>
<td>High population density relative to food resources</td>
</tr>
<tr>
<td><strong>Food storage</strong></td>
<td>Little to no dependence</td>
<td>Medium to high dependence</td>
</tr>
<tr>
<td><strong>Social Organization</strong></td>
<td>No corporate groups</td>
<td>Corporate descent groups (lineages)</td>
</tr>
<tr>
<td><strong>Political organization</strong></td>
<td>Egalitarian</td>
<td>Hierarchical, classes (ranks) based on wealth or descent</td>
</tr>
<tr>
<td><strong>Occupational specialization</strong></td>
<td>Only for older persons</td>
<td>Common</td>
</tr>
<tr>
<td><strong>Territoriality</strong></td>
<td>Social-boundary defense</td>
<td>Perimeter defense</td>
</tr>
<tr>
<td><strong>Warfare</strong></td>
<td>Rare</td>
<td>Common</td>
</tr>
<tr>
<td><strong>Slavery</strong></td>
<td>Absent</td>
<td>Frequent</td>
</tr>
<tr>
<td><strong>Ethic of competition</strong></td>
<td>Not tolerated</td>
<td>Encouraged</td>
</tr>
<tr>
<td><strong>Resource ownership</strong></td>
<td>Diffuse</td>
<td>Tightly controlled</td>
</tr>
<tr>
<td><strong>Exchange</strong></td>
<td>Generalized reciprocity</td>
<td>Wealth objects, competitive feasts</td>
</tr>
</tbody>
</table>

---

1 Risk in this context refers to the potential for failure – it is, in a sense, a measure of environmental variability and the effectiveness of subsistence techniques. It does not refer to danger (Ames 2006).
1999), the division of labor, and possible forms (e.g. Brumfield and Earle 1987, Ames 1995) and degrees (Cobb, 1996, Costin 1991, Spielman 2002) of specialization. This involves reconstructing production chains (e.g. Smith 2004, 2008), the spatial distribution of production (Smith 2008), fabrication of utilitarian and prestige items (Hayden 1998), and the relationship among specialization, elite status (e.g. Ames 1995, Spielman 2002) and patterns of consumption. These analyses are expanded to interhousehold level, then the community (sensu Varien 1999) level, and then between communities, including production differences related to local environmental differences and those that are not. Investigating distribution and exchange at all these levels has been central to the project since its inception (e.g. Hamilton 1994; Sobel 2004, 2006, 2011).

Hajda’s (1984) definition of the GLCRR is based on local and regional patterns of exchange and distribution that link different areas and levels of organization (e.g. Crumley 1995). She postulates two separate networks, one for processed resources (e.g. dried salmon) and a second, separate system for prestige goods. Studies of the distribution of prestige goods must rely both on ethnographic (e.g. Hayden and Schulting 1997) and archaeological data (e.g. Sobel 2004, 2006). For the latter, differences and similarities in artifact styles are crucial. Sobel (2004) also provides a rich ethnohistorical ethnoarchaeology of Chinookan plankhouse based on the documentary record, which is extremely useful.

Complex Hunter-Gatherers:

The existence of complex hunter-gatherer societies in different times and places is a major archaeological discovery of the past 30 years (e.g. Ames 1985, 1994b; Arnold 1996, 2001; Chapman 2003; Fitzhugh 2003; Hayden 1995, Hayden and Cannon 1982, Koyama and Thomas 1981, Lightfoot 1995, Maschner 1992; Price 1981; Price and Brown 1985; Sassaman 2004). Table 1.1 summarizes a recent definition of “complexity” among hunter-gatherers. This research is significant in a number of ways: “[R]ecent research on complex hunter-gatherers has not only expanded the empirical record of sociocultural formations once deemed anomalous and/or derivative of European contact but also has contributed to the ongoing process of clarifying concepts of cultural complexity and how this process ultimately restructures Anthropological Theory. (Sassaman 2004: 227)”.

Corporate households, such as those in the GLCRR, were central actors in the development of permanent elites among hunter-gatherers (e.g. Arnold 2001; Ames 1985, 1994; Coupland 1985a, 1985b, 1996; Hayden and Cannon 1982, Kuijt 2000, Pauketat 1996).

Most research is geared toward explaining the origins and development of complexity and inequality. In contrast, this project is based on the premise that a detailed understanding of the economics and organization of these households is essential to any consideration of origins and development. A single case study cannot explain the evolution of inequality in human societies, but it can be a crucial test of theoretically derived expectations. The project defines complexity broadly, and includes high population densities, sedentism, and so on (Table 1.1).

Most archaeological research on complex hunter-gatherers relies heavily on analogies drawn from the Northwest Coast’s voluminous ethnographic record. Most ethnographically-described complex hunter-gatherer societies lived either along the Northwest Coast or in California (e.g. Binford 2001). One goal of this project since its inception has been to test generalizations based on that record against the archaeological record, both in terms of using multiple lines of evidence and by testing them against each other (e.g. Sobel 2004, Ames 2008, Ames and Martindale 2014) as recommended by Leone and Potter (1984), Lightfoot (1995) and Rubertone (2000). The signs of social inequality in small-scale societies can be ambiguous (e.g. Feinman and Nietzel 1984). It is in part because of this ambiguity that we rely on multiple lines of evidence (e.g. Sobel 2004, Smith 2006).

The Fur Trade and Contact2 on the Northwest Coast and GLCRR:

There is a vast literature on Contact in

---

2 Silliman (2005b) has critiqued the term “Contact” arguing that it should be reconceived as Colonialism. However, the term “contact” is embedded in the literature (e.g. Gosden 2004, papers in Cusick 1998, Murray 2004) and so is used here.
the Pacific Northwest in Anthropology, History and Geography among other disciplines. This literature is so large it is impossible to summarize (See Suttles and Lang 2013). However, anthropological (including ethnohistory and archaeology) studies of the fur trade era share many of the goals, issues, and problems with contact studies elsewhere in North America (e.g. Silliman 2005a). Much of it is framed by the Direct Historical Approach; intended to bridge an archaeological past and an ethnographic present and to write ethnography using ethnohistory (e.g. Hajda 1984, Boyd 1996) and, to a much lesser extent, archaeology.

The consensus among anthropologists is that the fur trade actually had little impact on native societies (e.g. Cole and Darling 1990, Acheson and Delgado 2004) beyond the exchange of goods and an intensification of trends already present (e.g. increasing social differentiation, heightened levels of warfare) despite the devastating effects of epidemics. Precontact patterns are thought to have continued well into the contact period when they were recorded by ethnographers (Cole and Darling 1990). A minority view, primarily held by some archaeologists, is that depopulation was so devastating that pre- and post-contact cultures were very different (e.g. Dobyns 1983, 1991; Dunnell 1991).

Most of the region’s fur trade archaeology focuses on fur trade forts such as Fort Vancouver (e.g. Carley 1982, Chance and Chance 1976, Ross 1976, Thomas 1987, Thomas and Hibbs 1984), Fort Spokane (e.g. Combs 1964) Fort Langley (none published yet) – all Hudson’s Bay Company posts - and Fort Ross (Lightfoot et al. 1991, 1997, 1998), the Russian fur-trading post in northern California. There are important exceptions focusing on native responses to the fur trade (Fladmark 1973; Marshall 1993; MacDonald 1989; Martindale 1999, 2005; Prince 1998; Rahn 2002) that use archaeological data such as changing settlement, subsistence and food patterns (Graesch et al. 2010). There is also a lengthy tradition of excavating contact era native sites to supplement ethnographies (de Laguna 1960). Thirty years ago, Fladmark argued archaeology should be used to test rather than supplement the ethnographic record (Fladmark, 1973). While this is now increasingly being pursued (e.g. Martindale 1999), archaeology has had little impact on fur trade scholarship in the Northwest beyond the trading posts (see Klimko 2004).

This circumstance mirrors broader, even

<table>
<thead>
<tr>
<th>Site</th>
<th>Middle Village</th>
<th>Ieier</th>
<th>Cathlapotle</th>
<th>Clahclellah</th>
</tr>
</thead>
<tbody>
<tr>
<td>Smithsonian #</td>
<td>45PC106</td>
<td>35CO5</td>
<td>45CL1</td>
<td>45SA11</td>
</tr>
<tr>
<td>Age</td>
<td>AD 1792-1792?</td>
<td>AD 1400</td>
<td>AD 1450-c</td>
<td>AD 1700-1799</td>
</tr>
<tr>
<td>Site Area</td>
<td>60 x 30 m</td>
<td>300 x 60 m</td>
<td>170 x 40 m</td>
<td>2 m</td>
</tr>
<tr>
<td>Mean Depth</td>
<td>0.7 m</td>
<td>1.5 m</td>
<td>2 m</td>
<td>2 m</td>
</tr>
<tr>
<td>Number of Houses</td>
<td>NA</td>
<td>1</td>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td>Mean House Size ±σ</td>
<td>NA</td>
<td>420 m²</td>
<td>413 ± 187 m²</td>
<td>76 ± 23 m²</td>
</tr>
<tr>
<td>Excavated</td>
<td>78 + m²</td>
<td>154.6 m²</td>
<td>309 m²</td>
<td>50%</td>
</tr>
<tr>
<td>% of Total Site Volume Sampled</td>
<td>1.7</td>
<td>5.7</td>
<td>1.1</td>
<td>NA</td>
</tr>
<tr>
<td>Shaped artifacts</td>
<td>2000+</td>
<td>12825</td>
<td>10047</td>
<td>100,000+</td>
</tr>
</tbody>
</table>
global, problems in contact-era archaeology. These include how best to conceptualize the period and its issues (e.g. Paynter 2000a, 2000b, Silliman 2004, 2005a, 2005b; Book); the extent to which contact era studies should focus on the local and particular and to generalizing and theory building; what, beyond description, are the research goals (e.g. Lightfoot and Martinez 1995); what is archaeology’s role in researching a period with rich documentary records; what is the relationship between the archaeological and historical records (broadly defined – to include oral traditions) and how can each be most fruitfully used (e.g. Ames 2010; Cusick 1998; Wylie 1999, 2000).

As the WVAP project evolved, it followed an emerging consensus on some of these questions (e.g. Sobel 2011). It is essential for research to tack between the particular of local case studies and broader issues. Archaeology is not a “handmaiden,” supplementing and filling gaps in an inherently superior written record. These two are each the products of very different creative dynamics that may overlap, but may not (e.g. Ames 2008, Silliman 2004, Wylie 1999). Rather than a weakness this is a methodological opportunity. Leone and Potter (1988) outline a methodology based on Binford’s version of middle range theory (see Wylie 1989, 2000). We updated that using his concept of “frames of reference (Binford 2001)”.

The different kinds of data - historical, archaeological, environmental - that the project employs are frames of reference projected against each other to identify contradictions and ambiguities (Binford 2001). These become targets of productive future research. Archaeology provides the long-term frameworks essential to investigating Contact. The temporal scale appropriate for studying the Contact era is necessarily larger than that era itself (Lightfoot 1995) because “[t]he study of long-term change in both prehistoric and historic contexts is necessary to evaluate the full implications of Columbian consequences (epidemics, novel trade items, alien fauna and flora) (Lightfoot 1995: 210 – 211).” Relevant archaeological data is often rare (Fitzhugh 1985; Chilton 2001). Contact-era research must be multidisciplinary (Chilton 2001; Lightfoot 1995; Murray 2004; Rubertone 2000; Silliman 2005a, 2005b; Wesson and Rees 1997; Williamson 2004). It requires multiple lines of evidence (or frames of reference or “ca-

bles of inference (Wylie 1989)) from many disciplines and from different research areas within archaeology itself, drawing upon the integration of, for example, environmental archaeology (e.g. Deagan 1996), lithic analyses (e.g. Cobb 2003a, 2003b; Silliman 2004), discard behavior (e.g. Lightfoot et al. 1998), and household archaeology (e.g. Deagan 2005) among others.

The Archaeological Sites

Meier (35CO5) (Table 1.2, Figures 1.3 and 1.4):

The Meier site is on the western edge of the Wapato Valley. It was the focus of major excavations between 1987 and 1991. The excavations exposed a large plankhouse, exterior midden deposits, and activity areas (Ames et al. 1992, Smith 1996, 2005). Accessible by boat via small channels, it is about 5 km from the Columbia and 1.3 km miles from the nearest major waterway. It contains fur trade era European goods (Banach 2002, Kaehler 2002) but no Euroamerican accounts

Figure 1.4. Meier excavations. Rectangle indicates approximate position and size of the house. Lettered squares are excavation units. Meier units had both standard grid addresses (i.e N0-2/W24-26) and an alphabetic code. The letters in the units are its alphabetic code. Map by Emily Shepard.
mention the site. Late Pacific – Early Modern period Native residential sites at or near the downstream end of Sauvie Island. Prior to our excavations, the site was well known in professional and amateur archaeological circles as a very rich site and was suffering (and still suffers) from looting. Portions of it were also being damaged by farm related activities and it was threatened, and continues to be, by near-by gravel quarrying. These are among the reasons it was selected for field school excavations: it was well known, was threatened and had already suffered damage.

The site had also witnessed a variety of excavations. Pettigrew excavated his 6x2 m trench in 1973 (Pettigrew 1977) as part of his dissertation research. For her dissertation, Saleebey (1983) analyzed the faunal remains recovered by Pettigrew at six of the tested sites, including Meier. In the early 1970s, Dennis Torresdahl conducted excavations at the Meier site with his Scappoose Middle School science class. Finally, Willamette Associates, a Cultural Resources Management firm, tested the site in 1984. Our excavations were not going to impact a pristine site. Additionally, the landowner was willing. Ellis had held field school excavations at the Briar Site (35CO35) in 1986. The Briar site is on the Meier property about 1 km from Meier. There has been no work at the site since 1991 and the end the PSU excavations. The site has been monitored for looting, which continues at a small scale and for potential industrial damage from the adjacent quarrying.

Meier was also central to Saleebey’s sedentism hypothesis; faunal preservation was good so one to two seasons excavation’s was thought to be sufficient to produce a faunal sample adequate to test her hypothesis. As it turned out, we worked at the Meier site until 1991. By the end of the first summer, it was clear that the midden deposits, expected to be the source of the zooarchaeological assemblage, were severally damaged by looting. However, intact deposits were encountered east of the midden, which required exploring. It became clear by the end of 1988 that we were excavating a large plankhouse and that became of the focus of the work. Work ceased 1991 not because the information potential was exhausted but because the site is so rich the analytical load of each additional unit was too great. Approximately 160 m$^3$ were excavated. The house proved to be approximately 30m x 14m, dating between ca. AD 1400 and 1820 or so.

Cathlapotle (45CL1) (Table 1.2, Figures 1.3, 1.5, and 1.6):

Cathlapotle is on the U.S. Fish and Wildlife’s Ridgefield Wildlife Refuge (Ames et al. 1999). It was one of the Wapato Valley’s major Chinookan towns with estimated populations as high as 900 (Boyd and Hajda 1987); Ames estimates a population between 700 and 800 (Ames 2008). Cathlapotle, which is spelled variously in the ethnohistoric record, was visited by Lewis and Clark on March 29th, 1806 and described in detail in their journal accounts for that day. They describe a town of 14 wooden houses. It appears frequently in other Euroamerican accounts from 1792 on (Sobel 2004). Ames was approached by Anan Raymond, Archaeologist for the Fish and Wildlife Service, in the winter of 1990-1991 about initiating field work on the Ridgefield Wildlife Refuge near Vancouver, WA to locate the Cathlapotle Town site and conduct excavations to evaluate the site and provide USFWS with data with which to manage it. The proximity of the site to metropolitan Vancouver WA and Portland OR was seen as providing a potential for public education about Native cultures in the area, its archaeology and the mission of the USFWS. The town’s location had been an issue and a topic of controversy since 1948. The first task was to locate it. Work began in December 1991, proceeding with augering and test excavations through 1993. Major field school excavations were conducted 1994-1996. Excavations were originally planned to continue for 10 years, through 2004. It was clear by 1995 that we lacked the fiscal and logistical capacity to sustain that plan. The sampling strategy was consequently scaled back. It was intended to wrap up excavations in 1997, however, the threat of flooding and the absence of funding precluded field work; a lab field school was conducted in 1997.

Cathlapotle has six large house depressions on its surface (Figure 1.5), marking the locations of plankhouses, four of which were divided into compartments. We mapped 14 – 16 compartments, matching or exceeding Lewis and Clark’s count. We excavated 240 m$^3$ of deposit focusing on the largest house (House 1) and one of the smallest (House 4). House 1 is 69 x 15m and House 2
Figure 1.5. Topographic map of Cathlapotle showing inferred positions of houses. Dark areas are lowest areas in the house depressions. Letters in the House 1 segments designate the segment: e.g. House 1D.

Figure 1.6. Location of Cathlapotle excavations relative to the houses. From Sobel 2004.
is 20 x 10m (Figure 1.6). The village was established in its current position ca. AD 1450 and it was abandoned sometime after 1830. It is notable for the clarity of contact in its deposits. The initiation of the fur trade at the site is archaeologically distinct (Figure 1.7). Trade goods appear abruptly about 70 cm. below surface in deposits 2 m deep. The excavations were preliminarily reported in 1999 (Ames et al. 1999).

**Clahclellah (45SA11) (Table 1.2, Figures 1.3 and 1.8):**

Clahclellah is in the Columbia River Gorge (Figure 1.2). It was excavated as a data recovery project (Minor, Toepel and Beckham 1989, Sobel 2004). Sobel (2004) incorporated it into the larger WVAP project, analyzing samples of artifacts from each of its seven houses to compare Cathlapotle. It did not have multiple linkages to the fur trade although it is mentioned by Lewis and Clark (Moulton 1990). The site was probably occupied for two centuries (Sobel 2004).

**Middle Village (45PC106) (Table 1.2, Figure 1.3) (Wilson et al. 2009):**

Middle Village, formerly McGowan/Station Camp, is on the Columbia’s north bank at Baker Bay, a major fur trade anchorage across the river from Fort Astoria. The site was the subject of a joint data recovery project between the National Park Service and Portland State University. The artifact assemblage is important for comparisons and will be used for that purpose. The site is at or near Lewis and Clark’s Station Camp where they spent November 15 – 24th, 1805 (Moulton 1990) and an historic Chinook summer village (Silverstein 1990: 534). It is neither of those. It contains evidence of temporary structures and a remarkable Native American fur trade era artifact assemblage (Wilson and Cromwell 2005, Ames 2005b). It appears to date between ca. 1790 – 1820/1830. The site may represent a Chinookan trading locality.

![Figure 1.7. Typical sequence of historic trade goods at Cathlapotle. The metal at levels 18 and 17 dates to ca. AD 1450.](image)

![Figure 1.8. Excavations and houses at Clahclellah. At Clahclellah, the analytical units were samples within the houses (Sobel 2004).](image)
Structure of the Meier and Cathlapotle Data Sets

Sampling and Excavation Methodology

The Meier excavations were originally intended to sample the site’s midden (Figure 1.4, units C2, T, U, V and D2) to acquire a zooarchaeological assemblage. However, as noted above, the damage sustained by that portion of the midden from looting and the discovery of the house required a shift in excavation tactics to sampling along the house’s long axis to acquire samples relevant to the issue discussed above. Sampling outside the structure was limited by the extent of looting although intact midden and non-midden exterior deposits were found and sampled.

Investigations at Cathlapotle (Figures 1.4 and 1.5) were intended to 1) locate the site of the town visited by Lewis and Clark, 2) test the site and 3) conduct excavations to investigate a range of research questions (Ames 1993). The goal of the Cathlapotle sampling design was to: 1) Establish whether large depressions visible on the site’s surface were house structures. Four of the five were tested to accomplish this; 2) produce a stratigraphic profile across the site to link interior and exterior deposits. We could not do this at Meier. A trench was hand-dug across the site that spanned the non-cultural deposits at the rear (away from water) to the non-cultural deposits at its front (towards water) and linked interior and exterior deposits in a single continuous profile (Figure 1.9); 3) Sample two houses (Figure 1.6). The intrahouse sampling design was geared to producing data sets comparable to those from Meier to address the same range of questions, and 4) Sample precontact and fur-trade era deposits.

At both sites excavation was done by closely supervised field school students using trowels, brushes, etc. The students worked in 1 x 4m and 2x2 m excavation units with 1 m$^2$ blocks the basic horizontal recording and collecting units. All artifacts (including ecofacts) without point provenience were collected within their respective 1 m$^2$ unit, and, within that, their associated feature if present, and excavation level/stratum. Units were excavated in 10cm levels unless natural or cultural stratigraphy intervened. Sometimes, when it was necessary to accelerate excavation, 15 cm units were used. Screening was through 1/4 and 1/8th inch mesh. At both sites constant volume (cv) bulk samples for water screening were collected from all features (hearths, storage pits, post holes etc). Increment cv samples were also collected from the northwest quadrant of each excavation unit from each excavation level/stratum. At Meier, two liter samples were collected, at Cathlapotle, 10 liter samples. Over 1700 samples were collected at Meier; over 700 at Cathlapotle. The samples were water screened through nested screens with meshes of 4 mm, 2mm, 1mm and 0.5mm and sorted in the lab. Organic preservation is generally excellent. Charred plant tissues preserve reasonably well and the sites contain microscopic plant tissues. Bone preservation is excellent. All profiles were drawn and sampled. Geoarchaeological work at Cathlapotle continued after excavations ceased.

Figure 1.9. Cross-section of Cathlapotle through House 1 showing complex interbedding in the trench complexes in profile. The top and bottom of the central hearth periphery are indicated, showing the accumulation of hearths and floor laminae.
Figure 1.10. Interior contexts in excavated houses. Note: the storage pits are too shallow in this drawing.

At both sites, sampling of structures used a model of the archaeological features of Northwest Coast house interiors based on the Ozette excavations (e.g. Samuels 1983, 1991, 2005; Mauger 1991) modified to fit the details of Chinookan houses (Ames et al. 1992). Those details came primarily from the excavations at Clahclellah and the ethnographic and ethnohistoric records (e.g. Vastokas 1966). This model was refined in the course of the Meier (Ames et al 1992) and Cathlapotle excavations. The model divides the interior into archaeologically recognizable zones and architectural features (Figure 1.10). When possible, the houses are also divided into segments. Following standard Northwest Coast practice, these segments are based on the position of hearths (Figure 1.11) or interior walls (Figure 1.5 and 1.6). At Clahclellah, the houses are small enough not to be segmented (Figure 1.8). It is assumed these segments represent subdivisions of the household although there is debate within the research team as to whether the physical segments are separate households (Smith 2004, Sobel 2004) or household subdivisions. Exterior deposits are...
distinguished by their relationship to the houses (e.g. toft, yard), their formation processes, and form (e.g. midden [Beck and Hill 2004], sheet midden (Wilson 1994). These latter categories are not mutually exclusive (yards, sheet midden).

From the project’s beginning, the sampling methodology was designed to measure artifact variation in space and time. “Artifact” is broadly defined and includes shaped tools, debris and waste, animal and plant remains, etc. To control for space, artifacts are assigned to first to unit and stratum or level, then to feature (post hole, pit, etc) if possible, then to analytical units (AUs, e.g. Smith 2004, Sobel 2004, Ames 2005c) that are organized hierarchically from very fine scale, (individual feature or stratum) to less fine scale (e.g. house wall, northern house segment, Meier, post-contact) (Figure 1.12) to medium scale (Cathlapotle, house 1) to coarser scale (Cathlapotle) to coarsest comparative scale (GLCRR) (Figure 1.12). Temporal control is provided by dating the analytical units using radiocarbon dates and time-sensitive artifacts (e.g. trade beads, projectile point styles). Thus, for example, at Meier and Cathlapotle, all materials recovered only from house walls can be compared; all precontact midden deposits can be compared or treated as an analytical unit separately from all post-contact midden deposits. High and lower status house segments can be compared, or houses can be treated as analytical and comparative units. This also permits comparisons among AUs using all of the AUs’ contents (e.g. artifacts, animal remains, plant remains).

Depositional/Architectural AUs

- Interior: contexts within houses (Figures 1.10, 1.12, and 1.14-1.15)
  - Bench (Figure 1.12): Meier: deposits beneath sleeping platforms
  - Pit/Cellar (Figures 1.12 and 1.14): Meier: deposits within massive trench-like pit complexes extending the length of the houses between bench and central hearth row. These features were 1-2 meters deep. Bench/Cellar: Cathlapotle: At Cathlapotle, the pit complexes were beneath the sleeping platforms so the site lacks separate Bench deposits. Hearth/Periphery: Meier and Cathlapotle, deposits in and around the

Figure 1.12. Block excavation of the southern section of the Meier house looking south showing facilities: A) hearth periphery with storage pits and plank-molds beneath where central hearth boxes had been located; B) Bench or area beneath sleeping platform; C) pathway under the Meier floor in the cellar (large rectangle); D) Pit rim constructed from mix of pitfill and silt clay loam substrate; E) pit rims constructed of planks as in drawing (Figure 1.10).
central hearths, not in pits. This AU is subdivided by individual hearth.

- Wall (Figure 1.15): Meier and Cathlapotle: deposits within trenches for exterior house wall.

  • Exterior: contexts outside houses (Figure 1.17)

  - Midden and midden lobes: Meier and Cathlapotle (Figure 1.18): refuse and artifact rich dumps (secondary refuse aggregates [Wilson 1994]), secondary deposits, high organic content, lenses of mollusk shells. They are the product of “deliberate and sequential accumulation of refuse at one location (Needham and Spence 1997: 80).” At Cathlapotle midden accumulated in deposits between structures and formed deep lobes extended in front of them and sometimes burying portions of older houses. At both sites, midden also accumulated on stream banks in front of the community.

  - Sheet midden: Cathlapotle: wide thin lenses rich in charcoal, organics, artifacts, hearths, etc (identical in color etc to midden) interbedded with culturally sterile overbank (flood) sediments in front of Cathlapotle houses. These contained many small hearths, earth ovens and isolated

![Figure 1.13](image)

Figure 1.13. The scalar relationships among the data sets employed in the project. The analytical units at each level are comparable (features with features, site with sites). The alternating colors of the AUs indicates pre and post contact age. The small houses at Clahlellah have been compared with house segments at Cathlapotle but can also be compared with the complete houses; the position of Station Camp is ambiguous in terms of this diagram since it does not appear to represent house or village deposits but a specialized trading locality. The diagram does not fully separate all exterior deposits. Exterior deposits can be linked to specific structures; however, at Cathlapotle, not all those structures were excavated. These will be analyzed separately to understand intrasite variation and change across the site and aggregated to make comparisons at the community level. That linkage can be made for Cathlapotle houses 1 and 4 and for Meier.
structural features (postholes, plank molds, etc.). This class is similar to Wilson’s “sheet trash (Wilson 1994: 43 – 44).” The layers merge with midden deposits. It is possible to subdivide this AU stratigraphically and temporally. The apparent absence of sheet midden at Meier may be a consequence of sampling or the effects of looting.

- “Yards”: Exterior, non-midden cultural deposits at Meier. Artifact bearing but very low in organic content; lack the hearths and ovens found at Cathlapotle.

- Toft: Exterior deposits resting against the house walls and presumably beneath the overhanging eves of the houses (e.g. Hayden and Cannon 1983). Toft deposits are present at Meier and Cathlapotle.

Midden and sheet middens at both Meier and Cathlapotle can be stratigraphically associated with particular houses and house segments (e.g. Beck and Hill 2005). Meier contained only one house, so all exterior deposits are linked to that house. At Cathlapotle, sheet midden can be stratigraphically directly linked to House 1. The midden lobe associated with house 1 is between House 1 and 2 and so was probably produced by occupants of both houses. Part of this lobe buries an early portion of House 4.

**House Segments**

The houses are subdivided into analytical segments based on Northwest Coast archaeological practice and architectural evidence. These seg-
Figure 1.15. Hearths and hearth peripheries. a) Excavation of bottom of hearth box at south end of Meier house; b) Bisected hearth bowl and indurated ash, Meier; c) Hearth periphery with multiple post or peg holes, Meier; d) A central hearth showing lahar lining, House 1d, Cathlapotle; e) Hearth box, House 1c, Cathlapotle; f) Hearth on floor of House 1b, with lahar lining, Cathlapotle.
Figure 1.16. Cathlapotle wall trench, north wall House 4. a) original image; b) wall trench settings and resetting marked in white lines and white dashed lines which indicate less certainty in placement. The wall trench transects sheet midden visible at image right.

Figure 1.17. Meier and Cathlapotle midden and yard deposits. a) Meier midden southwest of the house, b) Meier exterior deposits, note the contrast between a and b in relative stoniness, c) Cathlapotle Midden Lobe B, with shell lenses and truncated overbank deposits, d) sheet midden west of House 6, House 6 wall trench is visible near the top of the profile.
ments are have been used to investigate social and economic differentiation within the houses. At Meier, the segments are based on hearths (Figure 1.11). These are somewhat arbitrary but follow widespread practice on the coast. Ethnographic evidence indicates that members of extended families shared a hearth (Sobel 2004). Cathlapotle House 4 is also analytically segmented this way. Cathlapotle House 1 was comprised of four compartments, each separated from the other by a wall (Figure 1.5). Three of these compartments were sampled (Figure 1.6). Based on its size and contents, segment 1D was the high status portion of House 1 (Sobel 2004). At Meier, we believe the northern most segment was the high status end of the house (Smith 2004). All AUs are identified by house segment.

The Clahclellah houses each contain a single hearth (Figure 1.8), and Sobel (2004) treated each separately. In her analysis she compared the Clahclellah houses with the house segments at Cathlapotle. Smith compared the house segments at Meier with the house segments at Cathlapotle. The Clahclellah house contents can also be compared with the full house contents for Meier and Cathlapotle (i.e. the combined contents of all segments).

Analytical units are dated with radiocarbon dates, the presence/absence of trade goods and stratigraphic position. Cathlapotle has 52 radiocarbon dates (Ames and Sobel 2009); Meier 19. In many contexts at Cathlapotle, glass trade beads appear abruptly in the deposits 70 cm below the modern surface (Figure 1.7). This is particularly so in the sheet midden. It is therefore often possible at Cathlapotle to possible to separate the deposits into three chronological blocks stratigraphically: No trade goods, only metal, metal and glass beads. This sequence matches the popularity trends of European trade goods (Gibson). Effectively, however, the deposits are divided into pre and post-contact deposits. The upper 70cm of deposits can also be arbitrarily divided. At Meier, while there is less clarity in the deposition of trade goods, it is similarly possible to identify pre and post-contact deposits.

Ames and Sobel (2009) date the initial occupation of Cathlapotle to ca AD 1450, although there are earlier radiocarbon dates. Trade goods suggest a terminal date ca. mid 1830s which is line with the town being abandoned as a consequence of the malaria epidemics of the early 1830s. The Meier house was built ca AD 1400-1450. An analysis of the ceramics at both sites (Cromwell 2010) shows they were both occupied during the early years of the fur trade and there is

---

**Figure 1.18. Cathlapotle schematic indicating major topographic/depositional units and house segment labels.**

---
evidence suggesting people at Meier responded to the fur trade in interesting ways (Fuld 2011). On the other hand, the site has a relatively small number of trade goods when compared to Cathlapotle and Middle Village leading to the inference it was abandoned sometime earlier than Cathlapotle, perhaps ca. 1820 – 1830.

**Site Formation Processes**

A central methodological issue has been understanding site formation processes at Meier and Cathlapotle (e.g. Ames 2008, Hodges and Smith 2002, Smith 2006). The large pit complex/cellar features have been a particular concern since they appear to be unique (Ames et al. 2008) and functioned both as storage facilities and as artifact, food, food waste and debris traps. We developed a model of debris flows through the houses (Figure 1.9) and hypothesized that the pit features served in part as staging areas for trash etc. prior to its moving to exterior dumps. Smith (2006) evaluates a range of taphonomic processes that might have affected the in-house deposits.

To better understand the formation processes at work in and outside these structures, sediment samples from both sites were processed (White 2010). The parent material for both sites is alluvial sily sand, which accumulated slowly. The key difference between the two sites is that Meier sediments contain about twice the organic matter as Cathlapotle. Organic matter is rather uniformly distributed at both sites (across the cellars, middens, and sheet middens). Deposits with very high organic content occur both in the cellars and in the middens at both sites, but overall, levels of organic matter and other constituents are homogeneous across each site.

We also looked at how different artifact classes were deposited. We learned that different classes of material and artifacts followed different pathways. Some generally stayed in the houses (e.g. complete projectile points); others (e.g. thermally altered rock) moved from the hearths ultimately out to the middens (Ames 2008). We also discovered that functionally related tool categories (cores, hammerstones) did not follow similar pathways. Thus our model was broadly correct, but the reality was much more complicated.
REFERENCES CITED

Acheson, Steven and James P. Delgado

Ames, Kenneth M.


Ames, Kenneth M. and Andrew Martindale

Ames, Kenneth M. and Herbert D.G. Maschner
1999 Peoples of the Northwest Coast: Their Archaeology and Prehistory. Thames and Hudson Ltd., London.

Ames, Kenneth M. and Elizabeth A. Sobel

Arnold, Jeanne E.

Baker, Brenda J and Lisa Kealhofer

Binford, Lewis R.

Blanton, Richard E.

Boas, Franz

Boyd, Robert T.


Brumfiel, Elizabeth M. and Timothy K. Earle


Burnett, Robert M.

Burtchard, Greg C.
1989  Archaeological Evaluation of the Trojan Locality, 35CO1. Laboratory of Archaeology and Anthropology, Portland State University.

Butler, Virginia L. and Michael Martin

Carley, Caroline D

Chance, David H. and Jennifer V. Chance
1976  Kanaka Village/Vancouver Barracks, 1794. Office of Public Archaeology, University of Washington, Seattle, WA.

Chapman, Robert

Chilton, Elizabeth S.

Cobb, Charles R.


2003  Stone Tool Traditions in the Contact Era. The University of Alabama Press, Tuscaloosa.

Cole, Douglas and David Darling

Combes, John D.
Washington State University, Pullman, WA.

Costin, Cathy Lynne


Coues, Elliot (editor)

Cromwell, Robert J.
2010 *A Typological Analysis of the Historic Ceramic Ware Sherds Recovered from the Cathlapotle (45CL1) site and the Meier (35CO5) Site*. Report on File, Portland State University.

Crumley, Carole L.

Cusick, James G.

Daehnke, Jon D.


Daugherty, Richard D, J Jeffrey Flenniken and Jeanne M Welch

Deagan, Kathleen A.


Dobyns, Henry F.

Douglass, John G. and Nancy Gonlin (editors)  


Dunnell, Robert L., James C. Chatters and Lar V. Salo  

Ellis, David V.  

Fagan, John L.  
2004  *Archaeological Exploration at 34MU4 The Sunken Village Site A National Historic Landmark in Multnomah County, Oregon*. Archaeological Investigations Northwest.

Fladmark, Knut R.  


Fitzhugh, William W. (editor)  

Fladmark, Knut R.  

Flannery, Kent V. (editor)  

Franchere, Gabriel  

Fricke, Thomas E.  

Fuld, Kristen A.  

Gahr, D. Anne Trieu., Elizabeth A. Sobel and Kenneth M. Ames  

Gahr, D. Ann Trieu  
Gairnder, Meredith

Gallant, Thomas W.

Gibson, James R.

Gosden, Chris
2004 *Archaeology and Colonialism: Cultural Contact from 5000 BC to the Present*. Cambridge University Press.

Graesch, Anthony P., Julienne Bernard and Anna C. Noah

Grier, Colin, Jangsuk Kim and Junzo Uchiyama (editors)

Hajda, Yvonne


Hayden, Brian

Hayden, Brian and Rick Schulting

Hendon, Julia A.

Hodges, Charles M.
1999 Results of Offsite Geoarchaeological Trenching at Cathlapotle Town (45CL1) Ridgefield National Wildlife Refuge, Carty Unit Clark County, Washington.

2002 Response to Chronic Flooding at Cathlapotle (45CL1) Clark County, Washington: Stratigraphic Analysis of Profile D, 155-159 N/W92.

Igler, David

Jones, Robert F. (editor)

Kelly, Robert L.

Klimko, Olga

Koyama, Shuzo and David Hurst Thomas (editors)

Laguna, Federica de

Lang, William L.

Larsen, Clark Spencer and George R Milner
1994  In the Wake of Contact: Biological Responses to Conquest. Wiley-Liss New York.

Leone, Mark P. and Parker B. Jr. Potter

Lightfoot, Kent G.


Lightfoot, Kent G., Antoinette Martinez and Ann M. Schiff

Lightfoot, Kent G. and Antoinette Matinez

Lightfoot, Kent G., Ann M. Schiff and Thomas A. Wake (editors)


Lightfoot, Kent G., Thomas A. Wake and Ann M. Schiff

Lipe, William D

Losey, Robert J.
2002  Communities and Catastrophe: Tillamook Response to the AD 1700 Earthquake and Tsunami, Northern Oregon Coast. Ph.D. Dissertation, Department of Anthropology, University Of Oregon, Eugene.

MacDonald, George F.

Marshall, Yvonne

Martindale, Andrew


Maschner, H. D. G.

Matson, R. G. and Gary Coupland

McDonald, Kendal Lyle

McGuire, Randall L.

Minor, Rick

Minor, Rick and Curt Peterson

Mitchell, D.

Moulton, Gary E. (editor)

Muller, Jon

Murray, Tim

Netting, Robert McC.

Nevett, Lisa C.

Newman, Maureen McNassar

Oberg, Kalvero

Paynter, Robert
2000  *Historical and Anthropological Archae-


Rahn, Robert Brian 2002 Spatial Analysis of Archaeological Sites in Barkley Sound, Vancouver Island (British Columbia). Unpublished M.A. Thesis, Department of Anthropology, University of Manitoba Winnipeg, M.B.


Rogers, J. Daniel and Bruce D. Smith 1995 *Mississippian Communities and Households*. University of Alabama Press, Tuscaloosa.


Sassaman, Kenneth E.

Schwartz, Glenn M. and Steven E. Falconer (editors)

Shnirlman, Victor A.

Silliman, Stephen W.


Sobel, Elizabeth A.
2008 *The Organization of Production Among Sedentary Foragers of the Southern Pacific Northwest Coast.* Archaeopress, Oxford.

Sobel, Elizabeth A., Kenneth M. Ames and Robert J. Losey

Spielman, Katherine A.

Suttles, Wayne

Smithsonian Institution, Washington D.C.

Suttles, Wayne and William L. Lang

Testart, Alain

Thomas, Bryn

Thomas, Bryn and Charles Hibbs

Vancouver, George

Varien, Mark D.

Wattenmaker, Patricia

Wesson, Cameron B. and Mark A. Rees

White, Joyce C.

Wilk, Richard R.

Wilk, Richard R. and William L. Rathje

Williamson, Christine

Wilson, Douglas C., Kenneth Ames, Kristine M. Bovy, Virginia Butler, Robert Cromwell, Loren G. Davis, Christopher R. DeCorse, Brian F. Harrison, R. Lee Lyman, Michele L. Punke, Cameron Smith and Nancy A. Stenholm
2009 *Historical Archaeology at the Middle Village: Station Camp/McGowan Archaeological Site (45CPC106)*, Station Camp Unit, Lewis & Clark National Park, Pacific County, Washington. National Park Service.

Wilson, Peter J.

Wolf, Eric
1982 *Europe and the People Without History*. 

34
Wylie, Alison

Understanding the geomorphological context of both sites was central to the WVAP’s research design. At Meier, that work was done by project personnel, primarily Ames. At Cathlapotle, an effort was made to bring in specialists. To this end, the site was visited by James O’Conner of the USGS and Scott Burns of Portland State University. O’Connor looked at the profile in the deepest excavated unit at Cathlapotle and Burns examined profiles and excavated a soil exposure in the meadow east of the site. He also arranged for a graduate student to undertake a geomorphology project at the site, but, as is not uncommon with student projects, that did not eventuate. Eventually we arranged for Charles Hodges of Edaphos Research to undertake two projects, one on the general geomorphic context of the site and the second on the community’s responses to the regular flooding of the landform. Both of those reports are included. Burns also arranged for a mechanical analysis of dirt samples collected from both Meier and Cathlapotle. That report, by Jonathon White, is also included.

Hodges’ study of the geomorphological context was conducted to answer questions about the evolution of the landform on which the site sits. That landform, dubbed “Brush Ridge (Ames et al. 1999) is a series of north-south trending scroll ridges. The site itself sits athwart the most easterly of these ridges, of which there are two more between the site and Lake River, leading us to conclude the landform had built westward. Assuming the site was on Lake River when it was founded, it is now several score meters east of the river. The only evidence we originally had of the age of the scroll ridges on which the site was built was a single radiocarbon date of 2346±53 (TX8286) (Ames and Sobel 2009) recovered from a scroll bar immediately west of House 1 (Figure 1) leading to the hypothesis that the landform had some antiquity and to the question as to why the village was only established there ca AD 1450 (a date since revised to AD 1350 [Ames and Brown 2015]).

The second study was to investigate the effects of regular flooding on Cathlapotle. The site’s profiles showed multiple instances of overbank sediments interbedded with midden and sheet midden deposits (Figure 2). The absence of even incipient soil development indicated that the site was immediately reoccupied after each episode.

In addition to local flooding, the Project was interested in finding evidence for, and assessing the possible impact of, the Bridge of the Gods flood. Massive landslides in the Columbia Gorge, where Bonneville Dam now stands, dammed the Columbia River creating a natural reservoir. At some point that natural dam collapsed or eroded, releasing the reservoir downstream. The timing and downstream impact of that release had long been a subject of debate. At the time of the Cathlapotle project, it was dated to ca. 830 BP (ca. AD 1120). Pettigrew (1981) argued that the flood was catastrophic, destroying many villages and perhaps even altering the shape of the floodplain. His support for this was that at the time of his work, all but one known site dated either or before the flood. He placed pre flood occupations into his Multnomah 1 or 2 phases, post-flood Multnomah 3. The single exception, 35MU1, had a thick deposit of silt separating the Multnomah 2 and 3 deposits. We looked for these flood silts at both Meier and Cathlapotle.

The volume also contains three reports that originated as MA theses. Melissa Darby’s study of wapato (Sagittaria latifolia) was partially inspired by and undertaken as a test of Thom’s (1989) study of camas use and intensification. Wapato was a keystone (Gahr 2013) vegetal resource in the Wapato Valley and Darby wanted to understand it from botanical, economic and cultural standpoints. At the time she initiated the project, there was little focused anthropological work on the plant and she filled an important lacunae. She has subsequently published a chapter (Darby 2005) based on the thesis in the seminal book Keeping it Living: Traditions of Plant Use and Cultivation on the Northwest Coast of North America (Deur and Turner 2015). Leslie O’Rourke developed a
Figure 1.20. Profile west section (W96-107) of trench N159-160/W79-107 showing the location of date TX 8286 (Specimen #150123).
GIS-based predictive model for site locations on the floor of the Wapato Valley. This was done, despite misgivings about predictive models, to aid in planning and site location in an area undergoing rapid development and alteration. One of the original goals of the WVAP was to contribute to heritage management in the valley, and this study contributes significantly to that goal. Last, but not least, the volume includes Kendal McDonald’s thesis reporting on GPR surveys of Cathlapotle and Champoeg Park. Her work at Cathlapotle was essentially an experiment: will it work. It did work, even with the site’s dense forest cover. She went on to apply the technique elsewhere, including to the Bachelor Island site (45CL43), on Bachelor Island (McDonald 2009). Our usual practice for this series is to edit out matter not directly germane to the WVAP, which, in McDonald’s case, would be her survey work at Champoeg Park. We decided not to do so since it would leave the report disjointed and the Champoeg work is valuable.
REFERENCES CITED

Ames, Kenneth M. and Thomas J. Brown

Ames, Kenneth M. and Elizabeth A. Sobel

Darby, Melissa

Deur, Douglas and Nancy J. Turner (editors)

Gahr, D. Ann Trieu

McDonald, Kendal

Pettigrew, Richard M.

Thoms, Alston V.
PART II

RESPONSE TO CHRONIC FLOODING AT CATHLAPOTLE (45CL1)
CLARK COUNTY, WASHINGTON

STRATIGRAPHIC ANALYSIS OF PROFILE D, 155-159 N/W92

Charles Hodges
Introduction

In November, 2000, portions of previously excavated archaeological trenches in the vicinity of House Depression 1 at 45CL1 were exhumed and cleaned for the purpose of geoarchaeological field examination. The trenches consisted of contiguous archaeological units excavated by volunteers and Portland State University field school crews between 1992 and 1996 under the auspices of the Wapato Valley Archaeological Project. A total of five profile sections were examined during the reopening; however, this report focuses on stratigraphic analysis of Profile D, a 4-meter-long north-south section located along the 92W wall extending between 155N to 159N. The section is significant because it exhibits a vertical sequence showing the interaction between the site inhabitants and flood events that affected the site landscape and the immediately surrounding landscape.

Background

Cathlapotle is located in the Portland Basin north of Bachelor Island in the Ridgefield National Wildlife Refuge, Carty Unit, near the mouth of Lake River in Clark County, Washington (Figure 2.1). The site occupies the easternmost of three subparallel scroll ridges, known collectively as Brush Ridge, in forested ridge-and-swale topography (Figure 2.2). South of Gee Creek and east of the main site, the woodlands give way to an open grassy meadow called Long Meadow. This open area is flanked along its eastern margins by low-lying outcrops of Grande Ronde Basalt; the upland rising to the northeast is underlain by sediments belonging to the Troutdale Formation (Phillips 1987; Walsh et al. 1987). The scroll ridge occupied by the site, called Site Ridge, now lies about 100 m east of Lake River (Ames et al. 1998).

The ridge-and-swale topography of Brush Ridge is well-defined north of the site. The tops of the sandy ridges are forested and the intervening swales are floored with grasses growing in muddy sediments. In the immediate vicinity of the site, forest and understory vegetation extends onto the swale floors but the scroll ridges are still well-defined. The ridge-and-swale topography becomes increasingly subdued south of the site and the ridges converge toward a natural levee adjacent Lake River about 1/8 mile south of the site. This levee forms the upper east bank of Lake River and can be traced south along the riverbank to the base of bedrock bluffs below Ridgefield.

Previous Geoarchaeological Research

In 1998 Edaphos Research (Bourdeau 1999) excavated five backhoe trenches just south of Cathlapotle during offsite geoarchaeological investigations (Figure 2.2). The backhoe trenches were excavated along a west-to-east transect that crossed Site Ridge and extended east through a small swale and ended at the western edge of Long Meadow. Vertical sequences of sand-silt couplets exposed in the trenches showed that Site Ridge was the first of a series of three comparatively rapidly constructed scroll ridges that laterally accreted westward and now comprise Brush Ridge. However, small amounts of silty and sandy alluvium continued to accumulate on the surface of the scroll ridge so that the surface of Site Ridge continued to upbuild after its main period of construction. Rates of accumulation on Site Ridge substantially slowed through time as distance from Lake River increased due to construction of the next two scroll ridges lying to the west. The Brush Ridge landform is a complex stratigraphic record that tracks both the lateral growth of landform elements (ridges) and ongoing vertical accumulation (accretion).

Radiocarbon assays on charcoal recovered during the course of the offsite trenching project indicated that construction of the Brush Ridge landform began late in the Holocene sometime after 1310 B.P. with the basal platform for Site Ridge itself established by 670 B.P. (Figure 2.3). After the formation of Site Ridge two more scroll ridges were added to the west of Site Ridge with the final ridge probably constructed during the early historic period. Although the landform experienced substantial lateral expansion to the west, ongoing vertical accretion on Site Ridge was occurring as indicated by a vertical sequence in the upper 150 cm of the ridge sediments consisting of sand-silt couplets representing individual flood events that overtopped the ridge.

Objectives

The evidence for chronic flooding of the landform retrieved by the 1998 trenching program
Figure 2.1. Portion of Columbia River flood plain showing the location of Cathlapotle (45CL1) and some major landmarks in the vicinity of the site.
Figure 2.2. Portion of Site Ridge showing locations of 1998 offsite trenches (yellow) and trenches reopened in 2000 (red). Letters show locations of profiles (map modified from Fowler 1998).
Figure 2.3. Cross-section from the meadow to east bank of Lake River across Brush Ridge (not to scale).

Calibrated 1-sigma age ranges of C-14 samples recovered from trenches:

Sample #11/1/98-2, Trench 3, 3 mbs: 743 - 771 AD
693 - 729 AD
869 - 854 AD
670 - 684 AD

Sample #11/1/98-4, Trench 4, 3 mbs: 976 - 1021 AD
962 - 967 AD
969 - 1015 AD

Sample #11/1/98-1, Trench 1, 4 mbs: 1343 - 1394 AD
1381 - 1384 AD
1281 - 1334 AD

Legend:

C-14 Sample Location
Total Excavated Depth of Trench
Trench Location

Figure 2.4. Cross-section from the meadow to east bank of Lake River across Brush Ridge (not to scale).

Legend:

C-14 Sample Location
Total Excavated Depth of Trench
Trench Location

Direction of Point Bar Construction
Brush Ridge
indicated that a similar record of flood events may be preserved among the site deposits. Furthermore, the flood events may be intercalated with anthropic deposits in such a way that interactions between the river and the human inhabitants of Cathlapotle may be documented. The published profiles from the archaeological excavations (Ames et. al 1999) suggest that some of the excavation units retain a record of human response to flood events and episodes of landform construction.

Methods

Based on stratigraphic drawings provided by the Wapato Valley Archaeological Project, five previously excavated and backfilled trench sections of varying lengths were reopened and cleaned. The sections then were examined in detail and compared to the stratigraphic drawings and matrix descriptions compiled during excavation of the trench. None of the reopened sections were redrawn but adjustments to the positions of bounding contacts were noted directly on the field profiles. A log of more extensive comments and descriptions regarding the stratigraphic sequences were maintained for each profile and these have been filed with the site documentation kept at the archaeological laboratories of the Wapato Valley Archaeological Project on the PSU campus. This additional documentation was synchronized with the profile drawings using a note numbering system comprised of the day’s date and assigning a number to each comment in sequence. For example, the first note for November 9 was designated as 1109-1 and this number was directly added to the profile drawing at the appropriate location. The numbering sequence started over for each day.

The sediments exposed in the reopened sections of the excavation trenches were arranged into major textural groups based on the dominant particle size reported by the excavators. Within each textural group individual layers were differentiated based on variation in matrix color, layer thickness, lateral extent, and to a lesser degree, by the inclusion of other constituents such as charcoal flecking. These layers are individuated as facies within the larger groups and include minor layers (microfacies) that were not formally individuated.

Results

Figure 2.4 illustrates the vertical sequence exposed in Profile D, located at 155-159 N/W92 along the west wall of the excavation trench showing the major textural groups and facies distribution. The sequence has been divided into three textural groups consisting of a basal fine loam (fSL) capped by a thick massive well-sorted fine sand. The upper two textural groups consist of a coarse sandy loam (cLS) overlain by a silt loam (Sil) in which the modern soil is forming. An informal fourth group (Facies 3) is located in the north (right) portion of the profile and consists of culturally modified sediments comprising the interior of House 1D.

The depositional sequence outside the house boundary exhibits a general coarsening-upward trend in grain size until about the upper 30 cm where the sediment abruptly changes from a coarse loamy sand to a silt loam. This change in texture is due partially to organic matter additions from soil-forming processes and partially as a result of sediment deposition by flood events of decreasing energy. The basal deposits have been truncated by house excavation during early occupation and sediments carried by several small flood events were deposited against the exterior house margins. These small flood deposits are capped by a thick flood deposit associated with a comparatively large flood event that is also deposited against the outside of the house. The topography of the bounding contact at the north end of this flood deposit suggests that a house structural member, probably a plank, that was partially buried by these flood sediments was lifted and reset into the top of the deposit. Above this thick deposit the sequence is characterized by a coarser sandy matrix which includes thin layers of well-sorted sands indicating a number of small flood events. The extension of the coarse loamy sand matrix over the feature fill at the north end of the profile and the preservation of these thin flood deposits suggests less trampling on the surface outside the house and perhaps declining use of House 1D during the last stages of sediment accumulation on the landform.

**Fine Sandy Loam (fSL) Texture Group**

The base of the profile is dominated by
Figure 2.4: West Wall Profile D showing texture groups and depositional units exposed in south-north section.
two thick massive (that is, no bedding structures were observed in the section) depositional units consisting of fine sandy loam (Facies 1 and 2). Although Facies 1 and 2 are texturally very similar, the basal Facies 1 is distinguished from the overlying Facies 2 by the absence of charcoal flecking and staining. The overlying Facies 2 matrix is characterized by generalized light charcoal staining and widely dispersed flecks of charcoal, and the upper portion of the layer has been modified by development of a 5-cm-thick, weakly expressed anthropic soil horizon. The upper bounding surface of Facies 2 at its north end has been eroded by several small flood events which displaced well-sorted fine sand against the exterior of House 1D. The Facies 1, 2, and 4 sequence is capped by a thin but laterally extensive flood deposit, Facies 5, whose near-surface sediments include, like the surface of Facies 2, a thin, weakly expressed anthropic soil horizon. Facies 5 also exhibits a slight fining-upward trend in grain-size representing settling of suspension load carried by flood waters onto the landform. Both Facies 2 and 5 become increasingly charcoal-stained and their upper bounding contacts more poorly defined at the north portion of their expression in section – both facies appear to represent light surface use near the exterior of House 1D during early phases of occupation.

Facies 6

Facies 6 represents a single flood event characterized by an extensive and relatively thick deposit of distinctively colored, massive, well-sorted fine to medium sand. The lack of bedding or flow structures within the deposit indicates little to no current flow was associated with the flood waters once they had accessed the this portion of the landform (unlike the smaller floods of Facies 4). The surface of Facies 6 has experienced a high amount of post-depositional mixing from anthropic churning or trampling, as indicated by the charcoal-stained matrix, but the presence of krotovina, wormcasts, and other burrow casts indicates the influence of other bioturbative agents. The irregular topography of the upper bounding contact of this facies suggests other modifications by human activities on the surface; particularly suggestive are the outlines of what appear to be two shallow pit excavations infilled with massive sand (Pits A and B, Figure 2.4) and contrastive tongues of sediment depending from the bounding contact indicating locations of possible stake molds.

Although a comparatively high amount of Facies 6 sediment was banked against the outside wall of the House 1D, occupation does not appear to have abruptly ended immediately following emplacement of this flood deposit. Instead, it appears that the inhabitants, rather than clean out the sediment deposited by the flood, opted to pull up house structural elements and reset them at a higher elevation corresponding to the new elevated surface created by Facies 6.

Coarse Loamy Sand (cLS) Textural Group

This group is a zone of organic and charcoal-stained deposits overlying Facies 6. Facies 7 is a massive, well sorted, medium to coarse sand with dispersed charcoal flecks immediately overlying the Facies 6 flood deposit; Facies 9 consists of a similar matrix but separated from Facies 7 by several lighter-colored massive silty fine sand layers within Facies 8 that represent late flood events. Facies 8 also separates the house feature fills (Facies 3) from the overlying Facies 7. Individual layers (microfacies) within Facies 8 are widely distributed laterally along the profile but are most dense north of N156 where they assume a noticeable subhorizontal orientation dipping to the north.

The distribution of microfacies within Facies 8 suggests they represent minimally two separate flood events. The individual layers tend to exhibit distinct bounding contacts where they have not been disturbed by cultural activities; they also tend to occur overlying anthropic layers that seem to be slightly less charcoal-stained. These microfacies may represent minor flood events that are contemporaneous with very late occupation of the house. The relatively better definition of Facies 8 suggests, at least, that the use of the surface (trampling) around the house diminished during the final stages of deposition.

At the very top of the sequence is the modern soil occurring within Facies 10 and confined to the upper 25-30 cm of the trench profile. The soil horizons are poorly differentiated but there is a thin lighter-colored leaching zone visible immediately below the A horizon. Even though hori-
zon differentiation has not proceeded to any great degree, the activity of soil processes has been adequate to obscure sedimentary bedding. The development of the modern soil represents stabilization of the landform surface accompanied by decreased sedimentation so that soil-forming processes have not been disrupted by periodic sediment accumulation.

House 1D Interior – Facies 3

Facies 3 represents feature fill within an interior edge of House 1D. The lack of charcoal staining in Facies 1 and the presence of a zone of anthropic charcoal staining and flecking at the top of Facies 2 suggests that Facies 2 is the surface of origin for the initial house construction as well as an exterior use-surface associated with occupation of the house. The interior edge of the house remained defined throughout the accumulation of Facies 4 and 5 against the exterior, but the sudden accumulation of the thick Facies 6 flood deposit and the offset cut suggests the inhabitants decided to rebuild in place rather than clean out the house. The matrix of Facies 3 is the same coarse loamy sand as the overlying cLS group and the lack of Facies 6 layers within Facies 3 suggests that this portion of the house had not been breached by the Facies 6 flood sediments. However, it seems likely that the interior of the house had been breached elsewhere at lower-lying elevations slightly downslope in the swale. The house interior does not appear to have been filled in until the deposition of the eLS group began and this hypothesis is supported by the inclusion of a block of sediment similar in textural characteristics to the fSL group that was probably detached from the wall of the house during infilling by Facies 3.

Discussion

The overall trend suggested by the depositional sequence is that the early (deeper) deposits represent flood events in which flood waters regularly and readily accessed the Site Ridge landform. The fine-grained fSL group and the lack of bedding structures within the facies indicate a mode of flooding predominantly characterized by very slow moving or standing flood waters carrying high amounts of suspended load. The thickness of the basal deposits also suggest that flood water remained on the flood plain long enough for significant amounts of suspended load to settle out. However, as indicated by the preservation of Facies 4, smaller more energetic floods also occurred with enough flow to create small bedding structures against roughness elements such as the exterior wall of House 1D.

The last of this style of flooding is represented by Facies 6, which emplaced a large amount of sediment against the upstream side of the house and instigated the resetting of some structural elements of the house, probably due to breaching and infilling of the house at lower elevation entry points. The inhabitants’ response to flooding prior to the deposition of Facies 6 appeared to be facility maintenance activity – cleaning out the interiors of the house and possibly replacing smaller structural elements. Excavators noted discontinuous, thin, isolated lenses and patches of noncultural sediments dispersed throughout the otherwise massive anthropic matrix which may represent spoils from cleaning up in the aftermath of these earlier flood events. Facies 6 seems to represent a threshold event regarding structure maintenance wherein it was considered more effective to reset elements of the house rather than to clean out the flood fill.

Flooding style appears to change significantly after the deposition of Facies 6. The overall sediment size is coarser and numerous individual flood events (Facies 8) are well-preserved between the top of Facies 6 and the base of the modern soil in Facies 10. This change in flooding regime coincides with the apparent abandonment of House 1D, or at least a substantial reduction in use of the structure, and the cLS group may represent the construction of the second scroll ridge and expansion of Brush Ridge to the west. Flood events of the magnitude of Facies 6 are not represented in this portion of the stratigraphic record and the lack of house definition stratigraphically suggests that the locus of domestic activities shifted elsewhere for reasons not related to the direct impact of floods on domestic structures.

The deposition of coarser sediment may be due to the initiation of a cycle of more energetic flooding, which would carry coarser sediment further onto the landform and surrounding flood plain, or it may represent introduction of a new source of sediment, perhaps due to bank ero-
sion, upstream from the site. In any case, although Facies 7 and 8 are charcoal-stained and contain dispersed charcoal flecks indicating human use of the surface(s) during deposition of these facies, the lack of a well-defined vertical boundary defining the interior of the house suggests substantial reduction in facility maintenance on this portion of Site Ridge coincident with the beginning of Facies 7 deposition.

**Conclusion**

The foregoing stratigraphic analysis suggests the following working hypothesis: that, other factors being equal, distance to the riverbank was an important decision factor regarding house placement at Cathlapotle. This was probably not the sole factor affecting house placement and would have been influenced by other cultural factors such as household size, status, and occupation density. The hypothesis generates the testable expectation that when the stratigraphic and radiocarbon data are interpolated into an overall chronostratigraphic framework, there should be a spatial and temporal drift in housing construction to the west as more scroll ridges are added to the landform.
REFERENCE CITED

Ames, K. M., Cameron M. Smith, William L. Cor-nett, Stephen C. Hamilton, and Elizabeth Sobel
1998 Archaeological Investigations (1991-
1996) at 45CL1 (Cathlapotle), Clark Coun-
ty, Washington. A Preliminary Report. De-
partment of Anthropology, Portland State
University. Portland, Oregon.

Bourdeau, A.
1999 Geoarchaeology of the Portland Basin
and Columbia River Gorge, edited by Alex
Bourdeau. Friends of the Pleistocene. Port-
land, Oregon.

Phillips, W. M.
1987 Geologic Map of the Vancouver Quad-
rangle, Washington and Oregon. Wash-
ington Division of Geology and Earth Re-

Walsh, Timothy J., Michael A. Korosec, William
M. Phillips, Robert L. Logan, Henry W. Schasse
1987 Geologic Map of Washington - South-
west Quadrant. Washington State Depart-
ment of Natural Resources, Division of
Geology and Earth Resources, Olympia,
Washington.
PART III

RESULTS OF OFFSITE GEOARCHAEOLOGICAL TRENCHING AT CATHLAPOTLE TOWN (45CL1) RIDGEFIELD NATIONAL WILDLIFE REFUGE, CARTY UNIT CLARK COUNTY, WASHINGTON

Charles M. Hodges
ABSTRACT

In November, 1998, five offsite backhoe trenches were excavated and described on Site Ridge south of Cathlapotle Town (45CL1). The results of this investigation indicate that Cathlapotle is located on the first of a series of scroll ridges formed during point bar formation in the Late Holocene. Site Ridge itself was created sometime before 670 years ago and initial village occupation probably followed shortly afterward. The two westernmost undated scroll ridges were formed during village occupation over the last 600 to 700 years.
Introduction

The U.S. Fish and Wildlife Service contracted with Edaphos Research in November, 1998, to conduct geoarchaeological trenching south of the Cathlapotle Town site (45CL1), located at the northern end of the Carty Unit within the Ridgefield National Wildlife Refuge, Washington. Five backhoe trenches were excavated across the landform occupied by the site, and the stratigraphy and macromorphological properties of the sediments and soils were recorded for each trench. This report summarizes those observations and discusses the landform history and ages of sediments exposed in those trenches.

Objectives

The primary goals of the geoarchaeological trenching program were to recover subsurface geomorphological data relating to late Holocene landscape evolution in the immediate vicinity of Cathlapotle Town, and to establish a lithostratigraphic section adjacent to, but outside of, the site boundaries. The lithostratigraphic section is to be used to evaluate the degree to which local geomorphic and cultural processes contributed to the formation of the onsite archaeological stratigraphy. Furthermore, the offsite section will be used to relate events represented in the site depositional sequence with depositional or erosional events associated with larger-scale geomorphic processes recorded in the surrounding landscape.

Local Setting

Cathlapotle Town is located north of Bachelor Island in the Ridgefield National Wildlife Refuge, Carty Unit, near the mouth of Lake River, Clark County, Washington (Figure 3.1). The site occupies the easternmost of three north-south-oriented subparallel scroll ridges in forested ridge-and-swale topography (Figure 3.2); the three ridges are known collectively as Brush Ridge. South of Gee Creek and east of the site, the forest covers opens into a grassy meadow, called Long Meadow, flanked by low-lying basalt outcrops on its eastern margins. The scroll ridge occupied by the site, called Site Ridge, lies about 100 m east of Lake River (Ames et al. 1998).

The ridge-and-swale topography north of the site is well-defined. The crests of the scroll ridges are forested and the floors of the swales are covered by grasses growing in muddy sediments. In the immediate vicinity of the site, forest vegetation extends into the swales but the scroll ridges and swales are still topographically distinguishable. South of the site the ridge-and-swale topography becomes increasingly subdued and ends at a well-defined natural levee about 1/8 mile south of the site. This levee forms the upper portion of the east bank of Lake River and extends south to the bluffs near the municipality of Ridgefield, Washington.

Methods

Five trenches were excavated with a backhoe using a 70 cm wide bucket mounted on an Extend-A-Hoe boom. Three of the trenches (Trenches 1, 2, and 3) were excavated across Site Ridge perpendicular to its main axis and about 200 m south of the main archaeological excavations (Figure 3.2). Trench 1 was on the west slope of the ridge, Trench 2 on the top and the upper east slope of the ridge, and Trench 3 on the east lower backslope. Two small exploratory trenches (5 m long) were used to search for a basal bounding contact. Trench 4 was in the shallow swale east of Site Ridge at the west edge of the meadow, and Trench 5 was on a high point in the meadow east of the swale.

Each trench was excavated in two stages. During the first stage, the trenches were excavated to 150 cm below surface (cmbs) or about five feet below surface (fbs). In Trenches 1, 2, and 3 one complete wall was profiled, and macromorphological soil and sediment features were described. In Trenches 4 and 5, a strip profile was drawn accompanied by abbreviated soil and sediment descriptions. When the profiles were completed, a section of each trench was excavated to the extent of the backhoe boom, between 300 to 400 cmbs (about 12 to 15 fbs). Sediments from the backhoe bucket were examined as the bucket was emptied but were not described. During excavation of Trench 5, a small cultural feature containing faunal material and charcoal was encountered at about 300 cmbs. The faunal material was wet sieved through 1-mm mesh and the residue sent to Dr. Virginia Butler of Portland State University for initial characterization. Charcoal samples retrieved from Trench 5, as well as from Trenches 1 and 4, were submitted for
Figure 3.1. Portion of Columbia River flood plain showing the location of Cathlapotle (45CL1) and some major landmarks in the vicinity of the site.
Figure 3.2. Portion of Site Ridge showing locations of 1998 offsite trenches (yellow) and trenches reopened in 2000 (red). Letters show locations of profiles (map modified from Fowler 1998).
radiocarbon assay by the U.S. Fish and Wildlife Service and the results are presented in this report in Figure 3.8.

Lithostratigraphic and soil descriptions are presented in tabular form in Appendix A; trench sections, accompanied by brief descriptions of the soil and sedimentary characteristics, are illustrated in Figures 3.3 through 3.6. Since no high-order bounding contacts (following Miall 1996) were encountered in the trenches, no strata numbers were assigned. Lower-order surfaces defining the tops of sand-mud couplets, however, were present in the trench sections with two in Trench 2 especially well-preserved. Not all couplets were described, but those that were selected are designated with Arabic numbers and keyed to the descriptive tables in Appendix A.

Prior to excavation of the trenches, small-diameter (8 cm and 20 cm dia., respectively) hand-augers were bored along the proposed axis of the trench excavations to determine if buried cultural materials were present. No cultural materials were encountered in the auger borings.

Results

This section presents summary descriptions of field-observable soil and sedimentary properties for each trench. Specific observations are provided in table format in Appendix A.

Trenches 1 and 2. The sedimentary structure, the size range of the sediments, and the effects of soil formation processes are similar for Trenches 1 (Figure 3.3) and 2 (Figure 3.4). Trench 1 was excavated on the west side of Site Ridge fronting a swale and Trench 2 was placed on the top and east backslope of the landform. Basal sediments for both trenches at 150 cmbs consisted of thin couplets or sets composed of well-sorted fine sands overlain by silt or occasionally a mixture of silt and clay (often called “mud”, which refers to the combined clay and silt fractions). Each sand-silt couplet represents a single depositional event and is conformably overlain by the sand at the base of the succeeding couplet. The upper muddy members of these couplets show little extensive bioturbation, but the presence of fine channels (< 2 mm diameter) and some matrix discoloration due to organic staining in the upper silt layers indicates brief periods of subaerial exposure between depositional events. In both trenches, these basal beds approximately parallel the surface slope of the ridge. In Trench 1, overall dip is at a moderate angle averaging about 20 degrees, but in Trench 2 the angle of dip is very low, averaging about 2 degrees. Bedding in the downslope section of Trench 1 shows a tendency to flatten out closer to the swale and some deposits in this portion of the trench may represent reworking of slumped cut-bank sediments along the base of the ridge.

The depth of the modern soil solum (the portion of the soil horizon sequence above the unmodified parent material or C horizon) in the upper portion of the profile extends to between 40 and 50 cmbs in both trenches. Even though the soil horizons are only weakly differentiated, soil formation has proceeded sufficiently to obscure any bedding that may have been originally present in the near-surface sediments. The thickness of the solum and the incipient soil horizon differentiation, when compared to the lack of a similar degree of pedogenic alteration in the basal sand-silt couplets, indicate cessation of active landform construction and commencement of a period of relative landscape stability on Site Ridge.

The surface horizons of the modern soil are mixed O/A horizons where organic matter in varying stages of decomposition has been mixed into the mineral A horizon. A thin Oi horizon, consisting of slightly decomposed organic matter (leaves and twigs), characterizes the surface of Trench 1; an Oe horizon (consisting of fully decomposed organic matter) is found in Trench 2. The A horizon for both trenches is a dark brown silt loam with moderate subangular blocky soil structure. Below the O/A horizons is a transitional AB horizon which is also a brown silt loam but it is differentiated from the overlying horizons by exhibiting moderate pedogenic structure and faintly discernible ferrous oxide (FeO) masses. In both trenches, the underlying BC horizon is a brown very fine sandy loam with moderate subangular soil structure but with small patches of relict bedding visible in the lower portion of the horizon. Faint FeO masses are also visible in this horizon. At the base of the profile is the C horizon consisting of pedogenically unaltered parent material in which the effects of pedogenesis have been slight and the horizon still exhibits primary sedimentary bedding.
Summary Description

Oi/A: Thin surficial litter layer overlying and slightly mixed into underlying dark brown silt loam mineral A horizon. A horizon is slightly bioturbated and humified organic material.

AB: Transitional soil horizon with organic stains, indistinct Fe masses, and weak structure in a very fine sandy loam matrix. AB horizon is a transition zone between Oi/A and BC horizons.

BC: Lower transitional soil horizon with moderate soil structure in a brown very fine sandy loam, exhibiting some relict bedding. BC horizon is brown very fine sandy loam but exhibiting some relict bedding.

C: Brown very fine sandy loam. Parent material with bedding and strong subangular blocky structure in brown silt loam matrix. C horizon is brown very fine sandy loam with weak structure and slightly mixed into underlying dark brown silt loam mineral A horizon.

O/a: Thin surficial litter layer overlying and slightly mixed into underlying dark brown silt loam mineral A horizon.

Key:
- Sand
- Bentic Surface
- Gradual Boundary
- Contact Not Traceable

Scale: 100 cm

Figure 3.3. Trench 1, south wall, west face of Site Ridge, Cathlapotle (45CL1). (Trench is 14m long.)
Oe/A: Very dark grayish brown silt loam. Contains partially decomposed plant litter (Oe) mixed into a mineral A horizon.

AB: Brown heavy silt loam. Transitional horizon dominated by a mineral A horizon containing humified organic matter. Incipient formation of a B horizon is indicated by Fe masses and weak structure.

BC: Brown very fine sandy loam. Parent material only slightly affected by soil forming processes. Contains faintly expressed relict bedding.

2AC: Grayish brown silt to silt loam. Transitional soil horizon at the top of a fining-upward sequence stained by organic additions to the mineral A horizon.

2C: Brown very fine sandy loam. Parent material only slightly affected by soil forming processes.

3AC: Similar to 2AC above.

3C: Similar to 2C above.

4C: Grayish brown silt loam to silty clay loam. Parent material only slightly affected by soil forming processes. Top of fining-upward sequence.

Figure 3.4. Trench 2, north wall, top and upper east slope of Site Ridge. (Trench is 9 m long.)
Figure 3.5. North wall, Trench 3, lower east slope of Site Ridge above swale, Cathlapotle (45Cl1). (Trench is 10m long).

Summary Description

A: Very dark grayish brown silt loam, mineral A horizon of the modern soil incorporating humified organic material from surface litter.

AB: Brown silty clay loam. Mineral A horizon incorporating humified organic material from surface litter.

Bw1: Yellowish brown silty clay loam. Slightly leached mineral soil horizon exhibiting Fe masses in the matrix.

Bw2: Brown silty clay loam. Similar to Bw1 above but differentiated by matrix color change.

Bw: Brown silt loam. Parent material.
Figure 3.6. Exploratory Trenches (in swale) and 5 (on levee east of swale), Cathlapotle (45CL1).
Informal observations (Bourdeau, pers. comm.) during hand-augering in the vicinity of Trench 1 revealed at least eight more sand-silt couplets below the base of the trench between 1.6 and 3.9 meters below surface (mbs) with a distinct light-colored sand layer found between 2.1 and 2.4 mbs. Couplets found below 3.9 mbs to termination at 5.6 mbs were characterized by sand layers that thickened with depth and were capped by thin silt drapes relative to those exposed in the trench walls. During deep trenching of Trench 1 detrital wood fragments were recovered at about 4.0 mbs. Radiocarbon assay on this sample returned an age of 670 +/- 80 BP (see Figure 3.8).

Trench 3

This trench (Figure 3.5) is located on the lower eastern slope of Site Ridge and, in contrast to Trenches 1 and 2, lacks primary sedimentary bedding because the modern soil solum extends almost to the base of the trench. The surface A horizon is a very dark grayish brown silty clay loam with moderate granular soil structure which overlies an AB horizon similar in color and texture but marked by moderate subangular blocky structure. The thick B horizon beneath the AB horizon has formed in a fine-grained matrix but is lighter in color than the overlying soil horizons and exhibits faint Fe masses.

Trench 4

This trench (Figure 3.6) is located at the base of the swale between Site Ridge and Long Meadow. As in Trench 3, primary sedimentary structures were not preserved in this trench. The dark-colored A horizon is underlain by a relatively thick eluvial (E) horizon indicating material removals, or leaching, from the soil. The thin gleyed B (Bg) horizon beneath the E horizon is characterized by a light-colored neutral matrix with prominent Fe masses and reddish sand-sized Fe concretions. Extending below the Bg horizon to the base of the trench at 150 cmbs, the profile is dominated by a grayish brown clay loam with faint Fe masses.

Blocks of sediment brought up in the backhoe bucket during deep trenching below 150 cmbs included well-defined muddy sand-silt couplets with woody debris and leaves preserved in the upper finer-grained portion of the couplets. A sample at 3.0 mbs from a well-defined layer of leaves in one of these couplets was submitted for radiocarbon assay and returned an age of 1070 +/- 40 BP (Figure 3.8).

Trench 5

This trench (Figure 3.6) was excavated to determine if the relative age of the meadow east of the site might be indicated by certain properties of the soil horizon sequence. If the meadow had been a persistent feature of the landscape during the occupation of the village, a thick dark-colored epipedon diagnostic of some grassland soils (molllic epipedon) might be present that could have formed concordant with the age of the meadow. Unfortunately, the properties exhibited by the profile in Trench 5 do not offer a solid basis for inferring the conditions under which the soil formed. The A horizon (about 20 cm thick) is similar in color and thickness to those found in the other trenches farther to the west. Below the A horizon is a zone of leaching underlain by a thin Bg horizon exhibiting a light-colored matrix and Fe concentrations, similar to the soil horizon sequence in Trench 4. The base of the soil is marked by a transitional grayish brown clay loam, and the base of the trench is characterized by two sand-silt couplets similar to those in Trenches 1 and 2. Thus, in terms of relative age, this portion of Long Meadow does not exhibit the degree of soil development one might associate with long-term landscape stability, and so the meadow does not appear to predate formation of the scroll bar complex to the west by a substantial amount of time.

During deep trenching in Trench 5, a small archaeological feature was encountered at about 3.0 mbs and was wholly removed by the backhoe. Both a faunal sample dominated by fragmentary burned fish remains (personal communication from Virginia Butler to Alex Bourdeau, 18 Nov. 1998) and charcoal for radiocarbon assay were extracted from this feature. The radiocarbon charcoal sample returned an age of 1310 +/- 40 BP (Figure 3.8).

Deep Trenching

Observations on sediments carried up in the backhoe bucket during deep trenching showed that, in general, thickness of the sand layers in sand-silt couplets tended to increase with greater
depth in all trenches. The increase in sand layer thickness was accompanied by an increase in the overall particle size of the sand (from very fine to fine in the upper 150 cms to medium sand at depth) and by a decrease in the thickness of the overlying silt layers.

**Discussion**

Soil horizons in the sand-silt couplets at the bases of the 150-cm-deep profiles in Trenches 1, 2, and 5 are notably undifferentiated, consisting of simple AC-C horizon sequences. The effects of soil-forming processes are limited to accumulation of biogenic traces, slight obliteration of primary sedimentary bedding, and discoloration or staining indicating additions of organic matter to the sediments. The biogenic traces and the overall lack of pedogenic development suggest surfaces were only briefly subaerially exposed prior to deposition of the succeeding couplet. This suggests that although construction of the Brush Ridge landform complex was relatively rapid, enough time elapsed between depositional events to support early successional vegetation and to collect detrital vegetal matter at the surface.

Landform stability is represented by development of the comparatively thick modern soil profile. As the scroll-ridge complex assumed its present configuration, and especially as it gained in elevation, the substrate supported an increased vegetation cover due to increasing intervals between major landscape sculpting events as Brush Ridge grew to the west. Any major floods that did occur no longer carried enough sediment to wholly bury the soil and the surface was subjected to less severe flooding. Thus, the combination of time, stability, and biota all contributed to pedogenic development on Site Ridge.

The thick sola in Trenches 3 and 4 associated with the low-lying areas in the landscape, however, do not necessarily represent a long period of landscape stability. The soils in these trenches are probably cumulic, in which sedimentation is continuous but burial is not enough to disrupt ongoing pedogenesis.

Figure 3.7 shows the plan-view and cross-section of a small island bar forming northwest of the site along the right bank of Lake River near its confluence with the Columbia River, and can be used as a partial analog for understanding depositional modes and soil formation at Site Ridge. The island bar is composed of sandy sediments anchored by vegetation, but upstream and downstream are small unvegetated levees of recently deposited sand. These smaller levees are in the process of accreting to the island bar and will gradually stabilize enough to support perennial vegetation. The vegetation on the island bar traps sediment and, in turn, contributes to enhanced growth of the bar including elevation gain. As the bar has grown, the stream cutbank has become more isolated from the erosional effects of flooding along Lake River and the topography between the cutbank and the island bar has been smoothed by deposition of fine-grained sediments. Between the cutbank and the bar is a small area of grasses growing in the muddy surface sediments deposited during small flood events. Over time, as deposition continues, the bar will attach to the bank, the topography will become smoother, and the combined landforms will eventually form a ridge and swale similar to those in the vicinity of Cathlapotle Town.

The scroll-and-swale topography, and the sedimentary structures exposed by Trenches 1 and 2 on Site Ridge, indicate the landform comprising Brush Ridge is a point bar. Particularly diagnostic are the moderate to steeply dipping lateral accretion surfaces on the west slope of Site Ridge and the simple planar geometry of the deposits. As Mall (1996:224) notes, this structure is characteristic of rivers in low-energy estuarine environments where the river may be subject to tidal influence. The overall fining-upward of the sediments as revealed in the augers and the deep trenching program is also characteristic of point bar formation.

On large rivers, point bars are often characterized by a series of scroll-shaped ridges alternating with depressions (swales). The ridges (scroll or bar ridges) represent channel migration during a major flood and, with repeated migration, a belt of scroll ridges will develop creating a characteristic ridge-and-swale topography (Reineck and Singh 1980). Depending on the river, point bar formation can be very rapid and large amounts of sediment can be deposited (for example, see Steinmetz 1967). Sand-mud couplets form on the point bar and infilling in the swale may eventually smooth the topography between the scroll ridge
Grasses in muddy surface sediments

Vegetated Island Bar

Cutbank

A A'

Sandy levee

Bachelor Island

Lake River

Figure 3.7. Sketch of island bar and cutbank downstream from Cathlapotle (45CL1) at mouth of Lake River (not to scale).
Calibrated 1-sigma age ranges of $^{14}C$ samples recovered from trenches:

- **Sample #11/10/98-1, Trench 1, 4 mbs:**
  - 1281 - 1331 AD
  - 1343 - 1394 AD

- **Sample #11/13/98-1, Trench 4, 3 mbs:**
  - 899 - 919 AD
  - 962 - 967 AD
  - 976 - 1021 AD

- **Sample #11/13/98-2, Trench 5, 3 mbs:**
  - 670 - 684 AD
  - 685 - 694 AD
  - 696 - 729 AD
  - 743 - 771 AD

**Legend:**
- ● C-14 Sample Location
- Total Excavated Depth of Trench
- Trench Location

Figure 3.8. Cross-section from the meadow to east bank of Lake River across Brush Ridge (not to scale).
and the floodplain (Leopold et al. 1964; Miall 1996). In some reaches island bars form and, over time, infilling attaches the bar to the flood plain. The profiles exposed on Site Ridge suggest that, following channel migration and initial definition of the scroll ridge, smaller floods continued to contribute to the final form of the ridge, perhaps in the manner indicated in Figure 3.7. As the scroll ridge gained in elevation, increasingly finer-grained material was deposited and conformed to the pre-existing topography resulting in the planar bedding especially evident in Trenches 1 and 2. The profile in Trench 1 also suggests that cutbanks probably formed along the face of the ridge fronting the river, and the resulting slumped material was reworked and deposited on a more horizontal plane in front of the cutbank.

The distribution of radiocarbon ages recovered from the trenches (Figure 3.8) indicates the point bar comprising Brush Ridge laterally expanded to the west during the late Holocene with Site Ridge constructed during initiation of point bar construction (Figure 3.9). If each scroll ridge on Brush Ridge represents an episode of channel migration during a major flood, then at least two comparatively large flood events accompanied by channel shifts to the west occurred after the founding and initial occupation of Cathlapotle (between 1180 AD and 1410 AD). The date from Trench 5 on the levee substantially predates the town occupation on Site Ridge and the Trench 4 date from the swale falls in the early phase of that occupation. The age of the Trench 1 sample falls within the middle of the first phase of town occupation. The 4.0 m depth for the Trench 1 date indicates continuous but low rates of deposition on Site Ridge after its initial formation. The brief hiatus in the cultural radiocarbon sequence at about 1400 to 1500 AD may coincide with the formation of the next scroll ridge to the west (see the radiocarbon dating discussions in Ames et al. 1998 and Ames 1999). The radiocarbon age distribution also indicates that during the initial occupation of the town, Lake River was probably immediately west of Site Ridge. During the later periods of occupation, the Lake River channel migrated further to the west but this apparently did not induce relocation of the town.

The radiocarbon age from Trench 1 also indicates that point bar growth was not limited to lateral accretion but that individual scroll ridges experienced upbuilding as well. An approximation of the sedimentation rate for the latest stages of Site Ridge growth can be calculated by dividing the radiocarbon age by the depth of the sample from the modern surface. This gives an annual sedimentation rate of about 2 cm/year, and assuming that overbank flooding along Lake River occurred every two years, then an average increment of 4-5 cms of sediment could potentially be added to the vertical growth of Site Ridge every two years. However, the sedimentation rate would decrease over time as the landform grew higher and as the ridge was distanced further from the river as the point bar grew to the west.

The search for bounding unconformities in the deeply excavated portions of the trenches was partly to determine if a record of the Bonneville Landslide had been preserved in the fluvial sediments in the vicinity of the site. Recently reported ages (410 +/- 80 BP and 360 +/- 80 BP) for the landslide (Pringle and Schuster 1998) indicate this event occurred after the formation of Site Ridge and after the initial village phase of occupation, but this trenching program did not find evidence that unequivocally supports the theory of a catastrophic flood in the wake of the Bonneville Slide.

**Conclusions**

The archaeological stratigraphic sections from Cathlapotle that have been published indicate that a fine-grained flood record is preserved within the confines of the site (Ames et al 1998, pp 55-56, Figs. 14 and 15). The interpretation of these sections will be complicated because the effects of cultural formation processes will have to be filtered from the geomorphic record (see discussion of filtering in Butzer 1982:77-97). However, the fine-grained intercalation of distinct culture-bearing deposits with sterile matrices indicates the site matrix can contribute substantially to understanding the effects of cultural and natural processes responsible for site formation at Cathlapotle Town. The detailed record of flood events and associated house-building episodes could substantially contribute to our understanding of human response to changes in the landscape at several scales, from the effects of chronic low-level flooding to the influence of major land-sculpting flood events.
The discovery of the discrete cultural feature in Trench 5 indicates that vertically segregated and spatially well-bounded features representing short-duration occupations can be expected in areas outside of the main village occupation. Radiocarbon ages from rapidly buried, vertically segregated features formed by short-duration occupations offer the potential for understanding shifts in land use associated with the establishment of Cathlapotle. The small size of the feature (<1 m diameter), however, indicates that close-interval sampling in Long Meadow will be required to discover these occupations.

The thick cumulic soil solum in the swale indicates that well-stratified, high-resolution paleoenvironmental data pertaining to the latest Holocene during town occupation may not be preserved in the swales between the scroll ridges. On the other hand, macrobotanical remains preserved at the upper bounding contacts of the deeper sand-silt couplets may be sufficient to characterize early successional biota that colonized newly formed flood-created surfaces in the vicinity of the site. Early successional communities are often characterized by high productivity and species diversity, though species composition may vary with each establishment of a community. Furthermore, patches of early successional communities often provide resources that play vital roles in human economic systems. It may well also be the case that macrobotanical analysis could offer insight into how occupation of Cathlapotle affected species composition and patch productivity in the immediate vicinity of the town.

Further geomorphic research should continue to focus on reconstructing the alluvial history of the site and its surroundings. For example, the decrease in vegetation cover downstream and the location of the island bar indicate downstream accretion in addition to the westward lateral accretion. Since the overall trend of landform construction is to the northwest, downstream accretion modes and rates of deposition may have changed as the point bar was more exposed to the effects of discharge from the Columbia and Lewis Rivers. Additionally, sediments carried out of the Gee Creek basin and deposited at the mouth of the creek may also have enhanced or controlled bar growth. More sections exposed on the westerly scroll ridges north of Cathlapotle should provide data on the style and rate of the downstream growth of the point bar.

Although it is practical to regard landscapes initially as simple two-dimensional planes, the data relating land use and landscape must ultimately be conceptualized in a four-dimensional

![Figure 3.9](image)

Figure 3.9. Schematic 3-D view of southern portion of Site Ridge and surrounding area just upstream of site. View is to the south-southwest and shows the position of Cathlapotle relative to surrounding landscape features. The point bar accreted laterally to the west as well as in downstream direction trending approximately to the northwest.
spatio-temporal framework. The results of this trenching program indicate that spatial patterning and the chronological distribution of archaeological sites in the Portland Basin should be understood in both the horizontal and vertical dimensions. Lateral accretion episodes indicate that chronological ordering of sites may occur along a horizontal plane through the same landform. Vertical accretion episodes may chronologically arrange sites along a vertical plane at particular points on the landform.
### APPENDIX A
### SOIL AND STRATIGRAPHIC DESCRIPTIONS

#### Trench 1

<table>
<thead>
<tr>
<th>Horizon</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oi/A</td>
<td>Dark brown (10YR 3/3*) silt loam; slightly hard, sticky, nonplastic; moderate, medium, subangular blocky parting to moderate, very fine subangular blocky; few live worms observed, common worm casts; common channels; many medium roots; no charcoal observed.</td>
</tr>
<tr>
<td>AB</td>
<td>Brown (7.5YR 4/3) silt loam; slightly hard, sticky, nonplastic; strong, medium, subangular to angular blocky; faint Fe masses 5YR 4/8 [reddish brown], 5-7 mm dia., ~15% of matrix; common medium roots; thin layer of charcoal at 12-13 cmbs at western portion of trench.</td>
</tr>
<tr>
<td>BC</td>
<td>Brown (7.5YR 5/3) very fine sandy loam to silt loam; slightly hard, nonsticky, nonplastic; moderate, coarse, subangular blocky parting to moderate fine, subangular blocky; faint Fe masses, 7.5YR 5/6 [strong brown], 10-15 mm dia., 20-25% of matrix; many channels &gt;1 m dia.; few medium roots.</td>
</tr>
<tr>
<td>C</td>
<td>Brown (7.5YR 5/2) very fine sandy loam; normally graded sand-silt couplets; slightly hard, slightly sticky, nonplastic; massive; Fe masses (same as BC above); few medium roots. Silt layers within the C horizon: Dark greyish brown (10YR 4/2) silty loam; slightly hard, slightly sticky, nonplastic; weak, fine, subangular blocky; many fine channels (#1 mm dia.).</td>
</tr>
</tbody>
</table>
## Trench 2

<table>
<thead>
<tr>
<th>Horizon</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oe/A</td>
<td>Very dark greyish brown (10YR 3/2) silt loam; soft slightly sticky, slightly plastic; moderate, fine, subangular blocky (most structure consists of aggregated worm casts) parting to moderate, medium, granular; few worm casts; common fine to medium roots (few &gt;5 mm); no charcoal observed.</td>
</tr>
<tr>
<td>AB</td>
<td>Brown (10YR 5/3) heavy silt loam; soft to slightly hard, sticky, slightly plastic; weak, fine, subangular blocky; indistinct mottles, 5-10 mm dia., ~ 30% of matrix; few roots, few very fine roots; many channels #1 mm dia., few channels &gt;1 mm dia.; 1 worm burrow infilled with silt wash observed; no charcoal observed.</td>
</tr>
<tr>
<td>BC</td>
<td>Brown (10YR 5/3) very fine sandy loam; ~ 10% feldspathic minerals in sand; indistinct (bioturbated) graded sedimentary structures consisting of sand-silt couplets; soft, nonsticky, nonplastic; massive; few medium roots; many channels (&lt;1 mm dia.) no charcoal observed.</td>
</tr>
<tr>
<td>2AC</td>
<td>Greyish brown (10YR 5/2) silt to silt loam; top of fining-upward sequence; slightly hard, slightly sticky, nonplastic; mostly massive but locally weak, fine, subangular blocky; local discoloration from Fe staining; many channels (&lt;1 mm dia.); few very fine roots.</td>
</tr>
<tr>
<td>2C</td>
<td>Brown (10YR 5/3) very fine sandy loam; soft, nonsticky, nonplastic; massive; normally graded; soft, nonsticky, nonplastic; few channels &lt;1 mm dia.; few fine and medium roots; very little bioturbation.</td>
</tr>
<tr>
<td>3AC</td>
<td>Similar to 2AC.</td>
</tr>
<tr>
<td>3C</td>
<td>Similar to 2C.</td>
</tr>
<tr>
<td>4C</td>
<td>Greyish brown (10YR 5/2) silt loam to silty clay loam; slightly hard, sticky, slightly plastic; massive; faint Fe masses, 5 mm dia., ~10% of matrix; many channels (&lt;1 mm dia.); no roots observed; no charcoal observed.</td>
</tr>
</tbody>
</table>
### Trench 3

<table>
<thead>
<tr>
<th>Horizon</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Very dark greyish brown (10YR 3/2) silty clay loam; soft, sticky, plastic; moderate coarse, subangular blocky parting to moderate, coarse, granular; common fine to medium roots; few live worms observed, common worm casts; no charcoal observed.</td>
</tr>
<tr>
<td>AB</td>
<td>Brown (10YR 5/3) silty clay loam; slightly hard, very sticky, very plastic; moderate, fine, subangular blocky; common medium to coarse roots; common fine channels (#1 mm); few tubules (5-7 mm dia.); faint Fe masses, 2-3 mm dia., diffused through 10-15% of matrix.</td>
</tr>
<tr>
<td>Bw1</td>
<td>Yellowish brown (10YR 5/4) silty clay loam; hard, very sticky, very plastic; strong, coarse angular blocky; faint Fe masses, 2-3 mm dia., diffused through 20-30% of matrix; many fine channels (&lt;1 mm); few tubules (5-10 mm dia.); common medium to coarse roots.</td>
</tr>
<tr>
<td>Bw2</td>
<td>Brown (10YR 5/3) silty clay loam; very hard, sticky, plastic; weak, coarse angular blocky; faint Fe mottles, 2-3 mm dia., 20-30% of matrix; few sand-sized Fe concretions; many fine channels (&lt;1 mm), few coarse channels (&gt;2 mm); few coarse roots.</td>
</tr>
<tr>
<td>C</td>
<td>Brown (7.5YR 5/4) silt loam; slightly hard, sticky, plastic; massive; many fine channels (&lt;1 mm), few coarse channels (&gt;2 mm); few medium to coarse roots; Fe staining through out matrix.</td>
</tr>
</tbody>
</table>

### Trench 4 - Abbreviated sediment and soil descriptions.

<table>
<thead>
<tr>
<th>Horizon</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Dark greyish brown (10YR 4/2) silty clay loam</td>
</tr>
<tr>
<td>E</td>
<td>Brown (7.5YR 5/2) silty clay loam; Fe stained.</td>
</tr>
<tr>
<td>Bg</td>
<td>Yellowish brown (10YR 5/4) silty clay loam; prominent Fe masses; common Fe concretions.</td>
</tr>
<tr>
<td>C</td>
<td>Greyish brown (10YR 5/2) clay loam; very sticky; faint Fe masses.</td>
</tr>
</tbody>
</table>
**Trench 5** - Abbreviated sediment and soil descriptions.

<table>
<thead>
<tr>
<th>Horizon</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Dark greyish brown (10YR 4/2) clay loam.</td>
</tr>
<tr>
<td>E</td>
<td>Greyish brown (10YR 5/2) clay loam.</td>
</tr>
<tr>
<td>Bg</td>
<td>Yellowish brown (10YR 5/2) silty clay loam to clay loam.</td>
</tr>
<tr>
<td>BC</td>
<td>Greyish brown (10YR 5/2) clay loam.</td>
</tr>
<tr>
<td>2A</td>
<td>Greyish brown (10YR 5/2) sandy loam.</td>
</tr>
<tr>
<td>2C</td>
<td>Yellowish brown (10YR 5/4) loamy sand; Fe stained.</td>
</tr>
<tr>
<td>3A</td>
<td>Similar to 2A.</td>
</tr>
<tr>
<td>3C</td>
<td>Similar to 2C.</td>
</tr>
</tbody>
</table>

* matrix colors are on moist, crushed samples; mottle colors are on moist, noncrushed samples.
Lithostratigraphy: Stratigraphic analysis based on the lithologic constituents of strata. Other methods of stratigraphic analysis include, for example, biostratigraphy, which stratifies rocks on basis of constituent organisms, or archaeostratigraphy (pace Butzer 1982) which organizes stratigraphic units on the basis of cultural remains.

Bounding surface: The concept that lithologic bodies can be subdivided into internally homogeneous groups of strata in a hierarchically arranged set of bedding contacts. This is the principle behind fluvial architecture models (e.g., Miall 1996).

Pedogenic (adj.): Pedology is the systematic study of soil genesis and classification; the scientific study of soils in their natural state as distinct from the study of soils for engineering or agricultural purposes.

Fe masses: Masses are non-cemented concentrations of substances that cannot be removed from the soil as a discrete unit. Commonly composed of calcium carbonate, gypsum, salts, iron, or manganese.

Solum: The part of the soil profile influenced by perennial plant roots.
REFERENCES CITED

Ames, K.M.


Butzer, K.W.

Leopold, L.B., M.G. Wolman, and J.P. Miller

Miall, A.D.

Pringle, P.T. and R.L. Schuster

Reineck, H.-E. and I.B. Singh

Steinmetz, R.
PART IV

PARTICLE SIZE ANALYSIS AND GEOLOGIC INTERPRETATION OF SOILS FOUND AT THE MEIER AND CATHLAPOTLE ARCHEOLOGICAL SITES IN THE COLUMBIA RIVER BASIN

Jonathan P. White
**Introduction**

The scope of this paper is to analyze soil samples collected at the Meier and Cathlapotle archeological sites. A particle size analysis was performed and pedologic description determined in order to gain an understanding of the geologic events which led to the deposition and formation of the soil deposits. The first section of this paper will give a general overview of the methods used to gather data in the laboratory. The next section will focus on data analysis. The two sites will be discussed in separate sections, which have been subdivided by pit classification. Finally, a geologic interpretation will be presented for both the Meier and Cathlapotle archeological sites. The laboratory data can be found in both Appendix A and Appendix B. In Appendix A, the data is broken into two sections (Meier and Cathlapotle) in order to separate the data from the two archeological sites. Within each section, the sample data is organized by pit classification and elevation. In Appendix B, the data is presented in spreadsheet form for easy comparison between archeological sites and samples. The first spreadsheet contains data obtained during laboratory analysis. The second spreadsheet contains catalog data collected in the field during the archeological dig at the Meier and Cathlapotle sites.

**Methods**

A particle size analysis was performed on all of the samples obtained from the Meier and Cathlapotle sites. The gravels and sands were each isolated using U.S. standard sieves. The silts and clays were then analyzed using the pipette method. Once separated, the percent by weight was calculated for each fraction (gravel, sand, silt and clay). In order to produce a detailed gradation curve, the sand was sieved again into five fractions and the percent by weight was calculated for each. The Munsell Color Chart was used to describe soil color following U.S. Soil Conservation Service guidelines. Percent organic matter was calculated using the ratio of sample weight before and after burning off the organics. This was accomplished by placing the samples in an oven at 500°C for four hours.

**Data**

**Meier Site**

**Cellar:** The cellar samples from the Meier site contained an abundance of sand (49-67%), moderate silt (18-33%), variable gravel (5-23%) and low clay (5-7%). The organic matter in the soils found in the cellar at the Meier site decreased with depth. The top units had the highest organic matter while the lowest units had the lowest organic matter. Find #196 was unique among the samples. The dry and wet color of this sample was very different than the other samples found in the cellar. Furthermore, the sand content in find #196 (67%) was the highest while the silt content (18%) was the lowest among the cellar samples. The organic matter in find #196 (3%) was much lower than the rest of the samples. The elevation of find #196 was not recorded. Find #596 contained excessive amounts of charcoal. Bone fragments were also found in many cellar samples from the Meier site. The petrology of the gravels included basalt and a small fraction of quartzite. The sands ranged from coarse grained to fine grained and the color was gray. The sample contained mostly sand (59%) and silt (31%) with small fractions of clay (7%) and gravel. This sample also contained charcoal.

**Cellar/Hearth Periphery.** The Meier cellar/hearth periphery contained very low gravel (3%) and contained charcoal. The petrology of the gravel found was basalt and quartzite. The sand ranged from coarse grained to fine grained and the color was gray. The sample contained mostly sand (59%) and silt (31%) with small fractions of clay (7%) and gravel. This sample also contained charcoal.

**Exterior Midden.** Among all of the samples taken from the Meier site, the exterior midden samples contained the highest fraction of clay (7-12%) and the least amount of sand (31-46%). The samples also contained moderate amounts of gravel (21-25%) and silt (26-32%). The petrology of the gravel found was basalt and quartzite. The sand ranged from coarse grained to fine grained and the color was gray. These samples also contained charcoal.

**Storage Pit.** The storage pit samples were similar to other samples found at the Meier site. They contained high sand, moderate silt, low gravel, and even less clay. The petrology of the gravel found was basalt and quartzite. The sand ranged from coarse grained to fine grained and the color was gray. These deposits contained bone fragments and charcoal.
Cathlapotle Site

**H1C Cellar.** The soils found in the Cathlapotle H1C cellar were mostly sand (~60%) and silt (~35%). The samples also contained small fractions of clay (1-6%), gravel (0-6%) and organic matter (3-9%). The gravels included boring Lava (basalt) and smaller fractions of andesite. The sands were grey to dark gray and fine grained. The H1C cellar samples also contained shells, bone and charcoal.

**H1D Cellar.** The samples in the H1D cellar at the Cathlapotle site were very similar to the samples found in the H1C cellar. The samples were also mostly sand and silt with small fractions of clay, silt and organic matter. Likewise, the gravels included boring lava and andesite and the gray/dark gray sands are fine grained. The H1D cellar samples contained charcoal and bone.

**H1D Hearth Periphery.** The Cathlapotle H1D hearth periphery samples were similar to the samples found in both Cathlapotle cellars. These samples were mostly fine grained, gray to dark gray sands and silts with minor fractions of clay, gravel and organics. The gravels were boring lava and andesite deposits. Bone and charcoal fragments were found in these samples.

**H1D Wall.** The H1D wall sample is similar to the other samples found at the Cathlapotle site. The sample was mostly sand and silt, contains low clay and organic matter, and no gravel. The sands were gray and fine grained.

**Midden.** The samples obtained from the Cathlapotle midden also contained high sand, moderate silt, and low gravel, clay and organic matter. The sands were fine grained and gray to dark gray in color. The gravels found here were classified as Boring Lava Volcanics and andesitic basalt. The samples also contain bone fragments, charcoal and shells. These similarities indicate that a common source is responsible for the deposition of the sediments found at the Cathlapotle site.

**Sheet Midden.** The sheet midden samples yielded results similar to other Cathlapotle samples; high sand, moderate silt, and low clay, gravel and organic matter. The gravel fraction in the sheet midden was extremely low (0-1%). The samples also contained manly gray, fine grained sands. These samples also contained bone and charcoal.

**Conclusion**

Overall, the soils from the Meier archaeological site are very similar. The majority of samples have a high sand fraction and low clay content. The silt content is moderate and the gravels are somewhat variable. The sands are predominantly gray and range from coarse grained to fine grained. The gravels are mostly basalts with a small fraction of quartzite present. The similarities seen in the samples are indicative of similar provenance.

The soil samples taken from various locations at the Cathlapotle archaeological site are also very similar. The soils all contain an abundance of fine grained sand, moderate fractions of silt, low clay, low organic matter, and very low gravel. The gravels found at the site are classified as Boring Lava Volcanics and andesitic basalt. The samples also contain bone fragments, charcoal and shells. These similarities indicate that a common source is responsible for the deposition of the sediments found at the Cathlapotle site.

Analysis of data indicates that the soils found at the Meier and Cathlapotle archaeological sites were deposited by fluvial processes. These processes remained constant and homogeneous over the depositional period. There is no indication that soil deposition was the result of a major flood event. Alternatively, it appears that deposition occurred over an extended period of time as the result of normal fluvial activity. Minor floods may have played a role in the deposition of sands and gravels. However, the low gravel content and homogeneity of soils sampled from various depths do not support the theory of a large scale flood. The soils from both sites would be classified as silty sands, which one would expect to find in soil near the Columbia River.

Find #195 (sample 5) from the Meier site was the only sample unique unto itself. Unfortunately, the elevation was never recorded, which makes evaluation of this sample difficult. The color and % OM of this sample was very different from the rest of the samples from the Meier site. If acquired, the elevation data may provide some insight as to why the sample is unique. If it were to follow the trend of other samples found in the Meier cellar, it would have been sampled
from greater depth than the other samples (organic matter decreases in all other Meier cellar samples as depth increases). It does appear that the provenance of this sample is different from other samples found at the Meier site. However, the data still point to fluvial processes as the likely depositional source and there is no indication of a major flood event.

Bone fragments, shells, and charcoal were also found in many soil samples from both the Meier and Cathlapotle archeological sites. These archeological finds may hold significance to those studying the Meier and Cathlapotle Sites.
APPENDIX A

Meier Site (35CO5)
Cellar

Find #767 (Sample #08)

Archaeological Data

<table>
<thead>
<tr>
<th>Site</th>
<th>Find #</th>
<th>Assoc.</th>
<th>Unit</th>
<th>Unit Code</th>
<th>Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>35CO5</td>
<td>767</td>
<td>profile</td>
<td>-</td>
<td>-</td>
<td>L2</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Elevation (cm)</th>
<th>Provenance</th>
<th>Pit Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>39-49</td>
<td>S12.53-12.66/E20</td>
<td>Cellar</td>
</tr>
</tbody>
</table>

Color

<table>
<thead>
<tr>
<th>Dry Color</th>
<th>Wet Color</th>
</tr>
</thead>
<tbody>
<tr>
<td>10YR 4/1</td>
<td>10YR 2/1</td>
</tr>
</tbody>
</table>

Organic Matter

<table>
<thead>
<tr>
<th>% Organic matter</th>
</tr>
</thead>
<tbody>
<tr>
<td>13</td>
</tr>
</tbody>
</table>

Grain Size Analysis

<table>
<thead>
<tr>
<th></th>
<th>Gravel (%)</th>
<th>Sand (%)</th>
<th>Silt (%)</th>
<th>Clay (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Sample</td>
<td>16</td>
<td>53</td>
<td>26</td>
<td>5</td>
</tr>
<tr>
<td>Total &lt; 2mm</td>
<td>N/A</td>
<td>63</td>
<td>31</td>
<td>5</td>
</tr>
</tbody>
</table>

Mineralogy

<table>
<thead>
<tr>
<th></th>
<th>Roundness</th>
<th>Max size</th>
<th>Bone/charcoal/shells</th>
<th>Petrology/description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gravels</td>
<td>Euhedral to anhedral</td>
<td>2 cm</td>
<td>Yes/yes/no</td>
<td>Basalt</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Color</th>
<th>Mineralogy</th>
<th>Bone/charcoal/shells</th>
<th>Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sands</td>
<td>Dark Grey</td>
<td>Quartz, mica</td>
<td>No/Yes/No</td>
<td>Coarse to fine</td>
</tr>
</tbody>
</table>
Find #1016 (Sample #10)

Archaeological Data

<table>
<thead>
<tr>
<th>Site</th>
<th>Find #</th>
<th>Assoc.</th>
<th>Unit</th>
<th>Unit Code</th>
<th>Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>35CO5</td>
<td>1016</td>
<td>NE Quad</td>
<td>N0-2/E18-20</td>
<td>J</td>
<td></td>
</tr>
</tbody>
</table>

Elevation (cm)  | Provenance | Pit Classification
41-42           | N1.4-2.0/E19.3-20.0 | Cellar

Color

<table>
<thead>
<tr>
<th>Dry Color</th>
<th>Wet Color</th>
</tr>
</thead>
<tbody>
<tr>
<td>10YR 3/2</td>
<td>10YR 2/1</td>
</tr>
</tbody>
</table>

Organic Matter

<table>
<thead>
<tr>
<th>% Organic matter</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
</tr>
</tbody>
</table>

Grain Size Analysis

<table>
<thead>
<tr>
<th></th>
<th>Gravel (%)</th>
<th>Sand (%)</th>
<th>Silt (%)</th>
<th>Clay (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Sample</td>
<td>9</td>
<td>52</td>
<td>32</td>
<td>7</td>
</tr>
<tr>
<td>Total &lt; 2mm</td>
<td>N/A</td>
<td>57</td>
<td>36</td>
<td>7</td>
</tr>
</tbody>
</table>

Mineralogy

<table>
<thead>
<tr>
<th></th>
<th>Roundness</th>
<th>Max size</th>
<th>Bone/charcoal/shells</th>
<th>Petrology/description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gravels</td>
<td>Euhedral to anhedral</td>
<td>1.5 cm</td>
<td>Yes/yes/no</td>
<td>Basalt</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Color</th>
<th>Mineralogy</th>
<th>Bone/charcoal/shells</th>
<th>Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sands</td>
<td>Grey</td>
<td>Quarts</td>
<td>No/yes/no</td>
<td>Coarse to fine</td>
</tr>
</tbody>
</table>
Find #1051 (Sample #09)

Archaeological Data

<table>
<thead>
<tr>
<th>Site</th>
<th>Find #</th>
<th>Assoc.</th>
<th>Unit</th>
<th>Unit Code</th>
<th>Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>35CO5</td>
<td>1051</td>
<td>SE Quad</td>
<td>N0-2/E18-20</td>
<td>J</td>
<td>4</td>
</tr>
<tr>
<td>Elevation (cm)</td>
<td>Provenance</td>
<td>Pit Classification</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>59-61</td>
<td>N 0-0.40/E19.5-20.0</td>
<td>Cellar</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Color

<table>
<thead>
<tr>
<th>Dry Color</th>
<th>Wet Color</th>
</tr>
</thead>
<tbody>
<tr>
<td>10YR 3/2</td>
<td>10YR 2/1</td>
</tr>
</tbody>
</table>

Organic Matter

<table>
<thead>
<tr>
<th>% Organic matter</th>
</tr>
</thead>
<tbody>
<tr>
<td>11</td>
</tr>
</tbody>
</table>

Grain Size Analysis

<table>
<thead>
<tr>
<th></th>
<th>Gravel (%)</th>
<th>Sand (%)</th>
<th>Silt (%)</th>
<th>Clay (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Sample</td>
<td>10</td>
<td>51</td>
<td>33</td>
<td>6</td>
</tr>
<tr>
<td>Total &lt; 2mm</td>
<td>N/A</td>
<td>57</td>
<td>37</td>
<td>6</td>
</tr>
</tbody>
</table>

Mineralogy

<table>
<thead>
<tr>
<th></th>
<th>Roundness</th>
<th>Max size</th>
<th>Bone/charcoal/shells</th>
<th>Petrology/description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gravels</td>
<td>Euhedral to subhedral</td>
<td>1.5 cm</td>
<td>No/yes/no</td>
<td>Basalt, quartzite</td>
</tr>
</tbody>
</table>
Find #596 (Sample #02)

Archaeological Data

<table>
<thead>
<tr>
<th>Site</th>
<th>Find #</th>
<th>Assoc.</th>
<th>Unit</th>
<th>Unit Code</th>
<th>Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>35CO5</td>
<td>596</td>
<td>F88</td>
<td>S12-14/E20-22</td>
<td>L2</td>
<td>-</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Elevation (cm)</th>
<th>Provenance</th>
<th>Pit Classification</th>
</tr>
</thead>
</table>

Color

<table>
<thead>
<tr>
<th>Dry Color</th>
<th>Wet Color</th>
</tr>
</thead>
<tbody>
<tr>
<td>10YR 3/1</td>
<td>10YR 2/2</td>
</tr>
</tbody>
</table>

Organic Matter

<table>
<thead>
<tr>
<th>% Organic matter</th>
</tr>
</thead>
<tbody>
<tr>
<td>17</td>
</tr>
</tbody>
</table>

Grain Size Analysis

<table>
<thead>
<tr>
<th></th>
<th>Gravel (%)</th>
<th>Sand (%)</th>
<th>Silt (%)</th>
<th>Clay (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Sample</td>
<td>23</td>
<td>49</td>
<td>23</td>
<td>5</td>
</tr>
<tr>
<td>Total &lt; 2mm</td>
<td>N/A</td>
<td>63</td>
<td>30</td>
<td>7</td>
</tr>
</tbody>
</table>
## Mineralogy

<table>
<thead>
<tr>
<th></th>
<th>Roundness</th>
<th>Max size</th>
<th>Bone/Charcoal/Shells</th>
<th>Petrology/Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Gravels</strong></td>
<td>Euhedral to Anhedral.</td>
<td>2.0 cm</td>
<td>yes=yes/no</td>
<td>Mostly basalt, some quartzite, lots of charcoal present</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Color</th>
<th>Mineralogy</th>
<th>Bone/Charcoal/Shells</th>
<th>Size</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sands</strong></td>
<td>Dark grey</td>
<td>unapparent</td>
<td>No=yes/no</td>
<td>Coarse to fine grained sands</td>
</tr>
</tbody>
</table>

### Find #364 (Sample #04)

#### Archaeological Data

<table>
<thead>
<tr>
<th>Site</th>
<th>Find #</th>
<th>Assoc.</th>
<th>Unit</th>
<th>Unit Code</th>
<th>Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>35CO5</td>
<td>364</td>
<td>F29E</td>
<td>N02/E23-25</td>
<td>K</td>
<td>-</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Elevation (cm)</th>
<th>Provenance</th>
<th>Pit Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>95-105</td>
<td>-</td>
<td>Cellar</td>
</tr>
</tbody>
</table>

#### Color

<table>
<thead>
<tr>
<th>Dry Color</th>
<th>Wet Color</th>
</tr>
</thead>
<tbody>
<tr>
<td>10YR 4/1</td>
<td>10YR 3/3</td>
</tr>
</tbody>
</table>

#### Organic Matter

<table>
<thead>
<tr>
<th>% Organic matter</th>
</tr>
</thead>
<tbody>
<tr>
<td>9</td>
</tr>
</tbody>
</table>
Grain Size Analysis

<table>
<thead>
<tr>
<th></th>
<th>Gravel (%)</th>
<th>Sand (%)</th>
<th>Silt (%)</th>
<th>Clay (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Sample</td>
<td>11</td>
<td>56</td>
<td>28</td>
<td>5</td>
</tr>
<tr>
<td>Total &lt; 2mm</td>
<td>N/A</td>
<td>63</td>
<td>32</td>
<td>5</td>
</tr>
</tbody>
</table>

Mineralogy

<table>
<thead>
<tr>
<th></th>
<th>Roundness</th>
<th>Max size</th>
<th>Bone/charcoal/Shells</th>
<th>Petrology/description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gravels</td>
<td>Euhedral to anhedral</td>
<td>2 cm</td>
<td>Yes/Yes/No</td>
<td>Basalt, quartzite</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Color</th>
<th>Mineralogy</th>
<th>Bone/charcoal/Shells</th>
<th>Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sands</td>
<td>Gray</td>
<td>Unapparent</td>
<td>No/Yes/No</td>
<td>Coarse to fine</td>
</tr>
</tbody>
</table>

Gradation Curve - 35 CO5 (Sample 4)

Find #959 (Sample #07)

Archaeological Data

<table>
<thead>
<tr>
<th>Site</th>
<th>Find #</th>
<th>Assoc.</th>
<th>Unit</th>
<th>Unit Code</th>
<th>Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>35CO5</td>
<td>959</td>
<td>F319</td>
<td>S1-3/E20-22</td>
<td>N</td>
<td>6B</td>
</tr>
</tbody>
</table>

Elevation (cm) | Provenance | Pit Classification
105            | -          | cellar

Color

<table>
<thead>
<tr>
<th>Dry Color</th>
<th>Wet Color</th>
</tr>
</thead>
<tbody>
<tr>
<td>10YR 3/2</td>
<td>10YR 2/1</td>
</tr>
</tbody>
</table>

Organic Matter

| % Organic matter | 8 |
Grain Size Analysis

<table>
<thead>
<tr>
<th></th>
<th>Gravel (%)</th>
<th>Sand (%)</th>
<th>Silt (%)</th>
<th>Clay (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Sample</td>
<td>5</td>
<td>61</td>
<td>27</td>
<td>7</td>
</tr>
<tr>
<td>Total &lt; 2mm</td>
<td>N/A</td>
<td>64</td>
<td>29</td>
<td>7</td>
</tr>
</tbody>
</table>

Mineralogy

<table>
<thead>
<tr>
<th></th>
<th>Roundness</th>
<th>Max size</th>
<th>Bone/Charcoal/Shells</th>
<th>Petrology/description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gravels</td>
<td>Euhedral to anhedral</td>
<td>1.5 cm</td>
<td>Yes/Yes/No</td>
<td>basalt</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Color</th>
<th>Mineralogy</th>
<th>Bone/Charcoal/Shells</th>
<th>Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sands</td>
<td>Brownish gray</td>
<td>Quartz, mica</td>
<td>No/Yes/No</td>
<td>Coarse to fine</td>
</tr>
</tbody>
</table>

Find #195 (Sample #05)

Archaeological Data

<table>
<thead>
<tr>
<th>Site</th>
<th>Find #</th>
<th>Assoc.</th>
<th>Unit</th>
<th>Unit Code</th>
<th>Level</th>
<th>Elevation (cm)</th>
<th>Provenance</th>
<th>Pit Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>35CO5</td>
<td>195</td>
<td>F41</td>
<td>N0-1/E25</td>
<td>K</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>Cellar</td>
</tr>
</tbody>
</table>

Color

<table>
<thead>
<tr>
<th>Dry Color</th>
<th>Wet Color</th>
</tr>
</thead>
<tbody>
<tr>
<td>10YR 5/4</td>
<td>10YR 3/4</td>
</tr>
</tbody>
</table>
### Organic Matter

<table>
<thead>
<tr>
<th>% Organic matter</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
</tr>
</tbody>
</table>

### Grain Size Analysis

<table>
<thead>
<tr>
<th></th>
<th>Gravel (%)</th>
<th>Sand (%)</th>
<th>Silt (%)</th>
<th>Clay (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Sample</td>
<td>8</td>
<td>67</td>
<td>18</td>
<td>7</td>
</tr>
<tr>
<td>Total &lt; 2mm</td>
<td>N/A</td>
<td>73</td>
<td>20</td>
<td>7</td>
</tr>
</tbody>
</table>

### Mineralogy

<table>
<thead>
<tr>
<th></th>
<th>Roundness</th>
<th>Max size</th>
<th>Bone/charcoal/Shells</th>
<th>Petrology/description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gravels</td>
<td>Subhedral to Anhedral</td>
<td>2 cm</td>
<td>No/No/No</td>
<td>basalt</td>
</tr>
<tr>
<td>Sands</td>
<td>Brownish Tan</td>
<td>Mica, quartz</td>
<td>No/No/No</td>
<td>Coarse to fine</td>
</tr>
</tbody>
</table>

![Grain Size Distribution Graph](image-url)
Cellar/Hearth Periphery

Find #70 (Sample #06)

Archaeological Data

<table>
<thead>
<tr>
<th>Site</th>
<th>Find #</th>
<th>Assoc.</th>
<th>Unit</th>
<th>Unit Code</th>
<th>Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>35CO5</td>
<td>70</td>
<td>NE Quad</td>
<td>S8-9/E21-22</td>
<td>X</td>
<td>4</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Elevation (cm)</th>
<th>Provenance</th>
<th>Pit Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>-</td>
<td>-</td>
<td>Cellar/ Hearth Periphery</td>
</tr>
</tbody>
</table>

Color

<table>
<thead>
<tr>
<th>Dry Color</th>
<th>Wet Color</th>
</tr>
</thead>
<tbody>
<tr>
<td>10YR 3/2</td>
<td>10YR 2/1</td>
</tr>
</tbody>
</table>

Organic Matter

<table>
<thead>
<tr>
<th>% Organic matter</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
</tr>
</tbody>
</table>

Grain Size Analysis

<table>
<thead>
<tr>
<th>Total Sample</th>
<th>Gravel (%)</th>
<th>Sand (%)</th>
<th>Silt (%)</th>
<th>Clay (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>N/A</td>
<td>3</td>
<td>59</td>
<td>31</td>
<td>7</td>
</tr>
</tbody>
</table>

| Total < 2mm  | N/A        | 61       | 32       | 7        |

Mineralogy

<table>
<thead>
<tr>
<th>Roundness</th>
<th>Max size</th>
<th>Bone/charcoal/shells</th>
<th>Petrology/description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gravels</td>
<td>Euhedral to subhedral</td>
<td>8 mm</td>
<td>Yes/yes/no</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Color</th>
<th>Mineralogy</th>
<th>Bone/charcoal/shells</th>
<th>Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sands</td>
<td>Grey</td>
<td>Quartz, mica</td>
<td>Coarse to fine</td>
</tr>
</tbody>
</table>
Exterior Midden (dump)

Find #967 (Sample #03)

Archaeological Data

<table>
<thead>
<tr>
<th>Site</th>
<th>Find #</th>
<th>Assoc.</th>
<th>Unit</th>
<th>Unit Code</th>
<th>Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>35CO5</td>
<td>967</td>
<td>NE Quad</td>
<td>S30-32/E30-32</td>
<td>O2</td>
<td>-</td>
</tr>
</tbody>
</table>

Elevation (cm) | Provenance | Pit Classification
--- | --- | ---
102-110 | S30.20-30.40/E32.00 | Exterior Midden (dump)

Color

<table>
<thead>
<tr>
<th>Dry Color</th>
<th>Wet Color</th>
</tr>
</thead>
<tbody>
<tr>
<td>10YR 4/2</td>
<td>10YR 2/1</td>
</tr>
</tbody>
</table>

Organic Matter

<table>
<thead>
<tr>
<th>% Organic matter</th>
</tr>
</thead>
<tbody>
<tr>
<td>12</td>
</tr>
</tbody>
</table>

Grain Size Analysis

<table>
<thead>
<tr>
<th></th>
<th>Gravel (%)</th>
<th>Sand (%)</th>
<th>Silt (%)</th>
<th>Clay (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Sample</td>
<td>25</td>
<td>31</td>
<td>32</td>
<td>12</td>
</tr>
<tr>
<td>Total &lt; 2mm</td>
<td>N/A</td>
<td>41</td>
<td>43</td>
<td>16</td>
</tr>
</tbody>
</table>

91
## Mineralogy

<table>
<thead>
<tr>
<th></th>
<th>Roundness</th>
<th>Max size</th>
<th>Bone/charcoal/shells</th>
<th>Petrology/description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Gravels</strong></td>
<td>Euhedral to anhedral</td>
<td>2 cm</td>
<td>No/no/no</td>
<td>Quartzite, basalt</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Color</th>
<th>Mineralogy</th>
<th>Bone/charcoal/shells</th>
<th>Size</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sands</strong></td>
<td>Gray</td>
<td>Unapparent</td>
<td>No/yes/no</td>
<td>Coarse to fine</td>
</tr>
</tbody>
</table>

### Gravels
- **Color:** Unapparent
- **Mineralogy:** Quartzite, basalt
- **Bone/charcoal/shells:** No/no/no
- **Size:** 2 cm

![Gradation Curve - 35 CO5 (Sample 3)](image)

**Find #922 (Sample #1)**

### Archaeological Data

<table>
<thead>
<tr>
<th>Site</th>
<th>Find #</th>
<th>Assoc.</th>
<th>Unit</th>
<th>Unit Code</th>
<th>Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>35CO5</td>
<td>922</td>
<td>NE Quad</td>
<td>S30-32/E30-32</td>
<td>O2</td>
<td>5</td>
</tr>
</tbody>
</table>

- **Elevation (cm):** 115-135
- **Provenance:** Exterior Midden (dump)
- **Pit Classification:** -

### Color

<table>
<thead>
<tr>
<th>Dry Color</th>
<th>Wet Color</th>
</tr>
</thead>
<tbody>
<tr>
<td>10YR 4/1</td>
<td>10YR 2/1</td>
</tr>
</tbody>
</table>

### Organic Matter

<table>
<thead>
<tr>
<th>% Organic matter</th>
</tr>
</thead>
<tbody>
<tr>
<td>9</td>
</tr>
</tbody>
</table>
Grain Size Analysis

<table>
<thead>
<tr>
<th></th>
<th>Gravel (%)</th>
<th>Sand (%)</th>
<th>Silt (%)</th>
<th>Clay (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Sample</td>
<td>21</td>
<td>46</td>
<td>26</td>
<td>7</td>
</tr>
<tr>
<td>Total &lt; 2mm</td>
<td>N/A</td>
<td>58</td>
<td>33</td>
<td>9</td>
</tr>
</tbody>
</table>

Mineralogy

<table>
<thead>
<tr>
<th></th>
<th>Roundness</th>
<th>Max size</th>
<th>Bone/Charcoal/Shells</th>
<th>mineralogy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gravels</td>
<td>Euhedral, well rounded</td>
<td>1.5 cm</td>
<td>yes/yes/no</td>
<td>Mostly basalt, some quartzite</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Color</th>
<th>Mineralogy</th>
<th>Bone/Charcoal/Shells</th>
<th>Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sands</td>
<td>gray</td>
<td>unapparent</td>
<td>No/yes/no</td>
<td>Coarse to fine grained sands</td>
</tr>
</tbody>
</table>

Storage Pit

Find #765 (Sample #12)

Archaeological Data

<table>
<thead>
<tr>
<th>Site</th>
<th>Find #</th>
<th>Assoc.</th>
<th>Unit</th>
<th>Unit Code</th>
<th>Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>35CO5</td>
<td>765</td>
<td>Profile</td>
<td>-</td>
<td>L2</td>
<td>-</td>
</tr>
<tr>
<td>Elevation (cm)</td>
<td>Provenance</td>
<td>Pit Classification</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>36-46</td>
<td>S13.64-13.74/E20.0</td>
<td>Storage Pit</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Color

<table>
<thead>
<tr>
<th>Dry Color</th>
<th>Wet Color</th>
</tr>
</thead>
<tbody>
<tr>
<td>10YR 3/1</td>
<td>10YR 2/1</td>
</tr>
</tbody>
</table>

93
### Organic Matter

| % Organic matter | 11 |

### Grain Size Analysis

<table>
<thead>
<tr>
<th></th>
<th>Gravel (%)</th>
<th>Sand (%)</th>
<th>Silt (%)</th>
<th>Clay (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Sample</td>
<td>13</td>
<td>55</td>
<td>27</td>
<td>4</td>
</tr>
<tr>
<td>Total &lt; 2mm</td>
<td>N/A</td>
<td>64</td>
<td>31</td>
<td>5</td>
</tr>
</tbody>
</table>

### Mineralogy

<table>
<thead>
<tr>
<th></th>
<th>Roundness</th>
<th>Max size</th>
<th>Bone/charcoal/shells</th>
<th>Petrology/description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gravels</td>
<td>Subhedral to anhedral</td>
<td>3 cm</td>
<td>No/yes/no</td>
<td>basalt</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Color</th>
<th>Mineralogy</th>
<th>Bone/charcoal/shells</th>
<th>Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sands</td>
<td>Dark gray</td>
<td>Mica</td>
<td>No/yes/no</td>
<td>Coarse to fine</td>
</tr>
</tbody>
</table>

### Archaeological Data

<table>
<thead>
<tr>
<th>Site</th>
<th>Find #</th>
<th>Assoc.</th>
<th>Unit</th>
<th>Unit Code</th>
<th>Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>35CO5</td>
<td>772</td>
<td>Profile</td>
<td>-</td>
<td>L2</td>
<td>-</td>
</tr>
</tbody>
</table>

Elevation (cm) | Provenance | Pit Classification
---------------|-------------|----------------------|
39-47          | S12.70-12.89/E22.0 | Storage Pit |
Dry Color | Wet Color
--- | ---
10YR 3/2 | 10YR 2/1

Organic Matter

<table>
<thead>
<tr>
<th>% Organic matter</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
</tr>
</tbody>
</table>

Grain Size Analysis

<table>
<thead>
<tr>
<th></th>
<th>Gravel (%)</th>
<th>Sand (%)</th>
<th>Silt (%)</th>
<th>Clay (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Sample</td>
<td>4</td>
<td>66</td>
<td>25</td>
<td>4</td>
</tr>
<tr>
<td>Total &lt; 2mm</td>
<td>N/A</td>
<td>69</td>
<td>26</td>
<td>4</td>
</tr>
</tbody>
</table>

Mineralogy

<table>
<thead>
<tr>
<th></th>
<th>Roundness</th>
<th>Max size</th>
<th>Bone/charcoal/shells</th>
<th>Petrology/description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gravels</td>
<td>Euhedral to subhedral</td>
<td>1 cm</td>
<td>No/yes/no</td>
<td>Basalt, quartzite, chert</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Color</th>
<th>Mineralogy</th>
<th>Bone/charcoal/shells</th>
<th>Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sands</td>
<td>Gray</td>
<td>Mica</td>
<td>Yes/yes/no</td>
<td>Coarse to fine</td>
</tr>
</tbody>
</table>

Gradation Curve - 35 CO5 (Sample 11)
Find #764 (Sample #13)

Archaeological Data

<table>
<thead>
<tr>
<th>Site</th>
<th>Find #</th>
<th>Assoc.</th>
<th>Unit</th>
<th>Unit Code</th>
<th>Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>35CO5</td>
<td>764</td>
<td>Profile</td>
<td>-</td>
<td>L2</td>
<td>-</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Elevation (cm)</th>
<th>Provenance</th>
<th>Pit Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>39-50</td>
<td>S14.00/E21.41-21.53</td>
<td>Storage Pit</td>
</tr>
</tbody>
</table>

Color

<table>
<thead>
<tr>
<th>Dry Color</th>
<th>Wet Color</th>
</tr>
</thead>
<tbody>
<tr>
<td>10YR 3/1</td>
<td>10YR 2/1</td>
</tr>
</tbody>
</table>

Organic Matter

<table>
<thead>
<tr>
<th>% Organic matter</th>
</tr>
</thead>
<tbody>
<tr>
<td>11</td>
</tr>
</tbody>
</table>

Grain Size Analysis

<table>
<thead>
<tr>
<th></th>
<th>Gravel (%)</th>
<th>Sand (%)</th>
<th>Silt (%)</th>
<th>Clay (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Sample</td>
<td>14</td>
<td>56</td>
<td>27</td>
<td>4</td>
</tr>
<tr>
<td>Total &lt; 2mm</td>
<td>N/A</td>
<td>65</td>
<td>31</td>
<td>4</td>
</tr>
</tbody>
</table>

Mineralogy

<table>
<thead>
<tr>
<th></th>
<th>Roundness</th>
<th>Max size</th>
<th>Bone/charcoal/shells</th>
<th>Petrology/description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gravels</td>
<td>Euhedral to anhedral</td>
<td>2.25 cm</td>
<td>Yes/yes/no</td>
<td>Basalt, quartzite</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Color</th>
<th>Mineralogy</th>
<th>Bone/charcoal/shells</th>
<th>Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sands</td>
<td>Dark gray</td>
<td>Mica</td>
<td>Yes/yes/no</td>
<td>Coarse to fine</td>
</tr>
</tbody>
</table>
Cathlapotle
H1C - Cellar

Find #19041 (Sample #25)

Archaeological Data

<table>
<thead>
<tr>
<th>Site</th>
<th>Find #</th>
<th>Assoc.</th>
<th>Unit</th>
<th>Unit Code</th>
<th>Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>45CL1</td>
<td>19041</td>
<td>108</td>
<td>N168-172/W88</td>
<td>P2</td>
<td>4/B</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Elevation (cm)</th>
<th>Provenance</th>
<th>Pit Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.65</td>
<td>N170.95/W88.5</td>
<td>H1C Cellar</td>
</tr>
</tbody>
</table>

Color

<table>
<thead>
<tr>
<th>Dry Color</th>
<th>Wet Color</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.5Y 4/2</td>
<td>2.5Y 3/2</td>
</tr>
</tbody>
</table>

Organic Matter

<table>
<thead>
<tr>
<th>% Organic matter</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
</tr>
</tbody>
</table>

Grain Size Analysis

<table>
<thead>
<tr>
<th></th>
<th>Gravel (%)</th>
<th>Sand (%)</th>
<th>Silt (%)</th>
<th>Clay (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Sample</td>
<td>0</td>
<td>64</td>
<td>35</td>
<td>1</td>
</tr>
<tr>
<td>Total &lt; 2mm</td>
<td>N/A</td>
<td>64</td>
<td>35</td>
<td>1</td>
</tr>
</tbody>
</table>

Mineralogy

<table>
<thead>
<tr>
<th></th>
<th>Roundness</th>
<th>Max size</th>
<th>Bone/charcoal/shells</th>
<th>Petrology/description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gravels</td>
<td>Subhedral</td>
<td>5 mm</td>
<td>No/no/yes</td>
<td>N/A</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Color</th>
<th>Mineralogy</th>
<th>Bone/charcoal/shells</th>
<th>Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sands</td>
<td>Medium gray</td>
<td>Mica</td>
<td>No/yes/yes</td>
<td>Fine to medium</td>
</tr>
</tbody>
</table>
Find #19043 (Sample #26)

Archaeological Data

<table>
<thead>
<tr>
<th>Site</th>
<th>Find #</th>
<th>Assoc.</th>
<th>Unit</th>
<th>Unit Code</th>
<th>Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>45CL1</td>
<td>19043</td>
<td>141</td>
<td>N168-172/88-89</td>
<td>P2</td>
<td>4/A</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Elevation (cm)</th>
<th>Provenance</th>
<th>Pit Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.66</td>
<td>N171.1/W88.1</td>
<td>HIC Cellar</td>
</tr>
</tbody>
</table>

Color

<table>
<thead>
<tr>
<th>Dry Color</th>
<th>Wet Color</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.5Y 4/2</td>
<td>2.5Y 3/2</td>
</tr>
</tbody>
</table>

Organic Matter

<table>
<thead>
<tr>
<th>% Organic matter</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
</tr>
</tbody>
</table>

Grain Size Analysis

<table>
<thead>
<tr>
<th></th>
<th>Gravel (%)</th>
<th>Sand (%)</th>
<th>Silt (%)</th>
<th>Clay (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Sample</td>
<td>1</td>
<td>57</td>
<td>36</td>
<td>6</td>
</tr>
<tr>
<td>Total &lt; 2mm</td>
<td>N/A</td>
<td>58</td>
<td>37</td>
<td>6</td>
</tr>
</tbody>
</table>

Mineralogy

<table>
<thead>
<tr>
<th></th>
<th>Roundness</th>
<th>Max size</th>
<th>Bone/charcoal/shells</th>
<th>Petrology/description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gravels</td>
<td>Subhedral to euhedral</td>
<td>4 mm</td>
<td>No/yes/no</td>
<td>Boring lava</td>
</tr>
<tr>
<td>Sands</td>
<td>Medium gray</td>
<td>mica</td>
<td>No/yes/no</td>
<td>Fine to medium</td>
</tr>
</tbody>
</table>
Find #19037 (Sample #30)

Archaeological Data

<table>
<thead>
<tr>
<th>Site</th>
<th>Find #</th>
<th>Assoc.</th>
<th>Unit</th>
<th>Unit Code</th>
<th>Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>45CL1</td>
<td>19037</td>
<td>168</td>
<td>N168-172/W88-89</td>
<td>P2</td>
<td>4/C</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Elevation (cm)</th>
<th>Provenance</th>
<th>Pit Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.67</td>
<td>N169.72/W88.14</td>
<td>H1C Cellar</td>
</tr>
</tbody>
</table>

Color

<table>
<thead>
<tr>
<th>Dry Color</th>
<th>Wet Color</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.5Y 4/2</td>
<td>10YR 2/2</td>
</tr>
</tbody>
</table>

Organic Matter

<table>
<thead>
<tr>
<th>% Organic matter</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
</tr>
</tbody>
</table>

Grain Size Analysis

<table>
<thead>
<tr>
<th></th>
<th>Gravel (%)</th>
<th>Sand (%)</th>
<th>Silt (%)</th>
<th>Clay (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Sample</td>
<td>1</td>
<td>62</td>
<td>32</td>
<td>5</td>
</tr>
<tr>
<td>Total &lt; 2mm</td>
<td>N/A</td>
<td>62</td>
<td>33</td>
<td>5</td>
</tr>
</tbody>
</table>

Mineralogy

<table>
<thead>
<tr>
<th></th>
<th>Roundness</th>
<th>Max size</th>
<th>Bone/charcoal/shells</th>
<th>Petrology/description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gravels</td>
<td>Subhedral</td>
<td>3mm</td>
<td>No/yes/no</td>
<td>Boring lava</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Color</th>
<th>Mineralogy</th>
<th>Bone/charcoal/shells</th>
<th>Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sands</td>
<td>Medium gray</td>
<td>Mica</td>
<td>No/yes/no</td>
<td>Fine to medium</td>
</tr>
</tbody>
</table>
Find #19037 (Sample #30)

**Archaeological Data**

<table>
<thead>
<tr>
<th>Site</th>
<th>Find #</th>
<th>Assoc.</th>
<th>Unit</th>
<th>Unit Code</th>
<th>Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>45CL1</td>
<td>19033</td>
<td>85</td>
<td>N168-172/W88-89</td>
<td>P2</td>
<td>4/C</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Elevation (cm)</th>
<th>Provenance</th>
<th>Pit Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.68</td>
<td>N169.45/W88.55</td>
<td>HIC Cellar</td>
</tr>
</tbody>
</table>

**Color**

<table>
<thead>
<tr>
<th>Dry Color</th>
<th>Wet Color</th>
</tr>
</thead>
<tbody>
<tr>
<td>10YR 3/2</td>
<td>10YR 2/1</td>
</tr>
</tbody>
</table>

**Organic Matter**

<table>
<thead>
<tr>
<th>% Organic matter</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
</tr>
</tbody>
</table>

**Grain Size Analysis**

<table>
<thead>
<tr>
<th></th>
<th>Gravel (%)</th>
<th>Sand (%)</th>
<th>Silt (%)</th>
<th>Clay (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Sample</td>
<td>2</td>
<td>73</td>
<td>21</td>
<td>4</td>
</tr>
<tr>
<td>Total &lt; 2mm</td>
<td>N/A</td>
<td>75</td>
<td>21</td>
<td>4</td>
</tr>
</tbody>
</table>

**Mineralogy**

<table>
<thead>
<tr>
<th></th>
<th>Roundness</th>
<th>Max size</th>
<th>Bone/charcoal/shells</th>
<th>Petrology/description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gravels</td>
<td>Subhedral</td>
<td>6 mm</td>
<td>Yes/yes/no</td>
<td>Boring Lava</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Color</th>
<th>Mineralogy</th>
<th>Bone/charcoal/shells</th>
<th>Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sands</td>
<td>Dark gray</td>
<td>Mica</td>
<td>No/yes/no</td>
<td>Fine grained</td>
</tr>
</tbody>
</table>
Find #19007 (Sample #28)

Archaeological Data

<table>
<thead>
<tr>
<th>Site</th>
<th>Find #</th>
<th>Assoc.</th>
<th>Unit</th>
<th>Unit Code</th>
<th>Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>45CL1</td>
<td>19007</td>
<td>-</td>
<td>N168-172/W88-89</td>
<td>P2</td>
<td>1/D</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Elevation (cm)</th>
<th>Provenance</th>
<th>Pit Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.06-6.12</td>
<td>N168-168.9/W88.7-89</td>
<td>H1C Cellar</td>
</tr>
</tbody>
</table>

Color

<table>
<thead>
<tr>
<th>Dry Color</th>
<th>Wet Color</th>
</tr>
</thead>
<tbody>
<tr>
<td>10YR 3/1</td>
<td>10YR 2/1</td>
</tr>
</tbody>
</table>

Organic Matter

<table>
<thead>
<tr>
<th>% Organic matter</th>
</tr>
</thead>
<tbody>
<tr>
<td>9</td>
</tr>
</tbody>
</table>

Grain Size Analysis

<table>
<thead>
<tr>
<th></th>
<th>Gravel (%)</th>
<th>Sand (%)</th>
<th>Silt (%)</th>
<th>Clay (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Sample</td>
<td>6</td>
<td>63</td>
<td>28</td>
<td>3</td>
</tr>
<tr>
<td>Total &lt; 2mm</td>
<td>N/A</td>
<td>67</td>
<td>29</td>
<td>4</td>
</tr>
</tbody>
</table>

Mineralogy

<table>
<thead>
<tr>
<th></th>
<th>Roundness</th>
<th>Max size</th>
<th>Bone/charcoal/shells</th>
<th>Petrology/description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gravels</td>
<td>Subhedral to anhedral</td>
<td>1.5 cm</td>
<td>No/yes/no</td>
<td>Boring Lava, andesite</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Color</th>
<th>Mineralogy</th>
<th>Bone/charcoal/shells</th>
<th>Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sands</td>
<td>Dark gray</td>
<td>Mica</td>
<td>No/yes/no</td>
<td>Fine to medium</td>
</tr>
</tbody>
</table>
**H1D - Cellar**

Find #12023 (Sample #19)

**Archaeological Data**

<table>
<thead>
<tr>
<th>Site</th>
<th>Find #</th>
<th>Assoc.</th>
<th>Unit</th>
<th>Unit Code</th>
<th>Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>45CL1</td>
<td>12023</td>
<td>Feat. 192</td>
<td>N159-160/W83-87</td>
<td>B2</td>
<td>10/D</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Elevation (cm)</th>
<th>Provenance</th>
<th>Pit Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.21</td>
<td>N159-159.47/W83.16-83.88</td>
<td>H1D Cellar</td>
</tr>
</tbody>
</table>

**Color**

<table>
<thead>
<tr>
<th>Dry Color</th>
<th>Wet Color</th>
</tr>
</thead>
<tbody>
<tr>
<td>10YR 4/2</td>
<td>10YR 2/2</td>
</tr>
</tbody>
</table>

**Organic Matter**

| % Organic matter | 4 |

**Grain Size Analysis**

<table>
<thead>
<tr>
<th></th>
<th>Gravel (%)</th>
<th>Sand (%)</th>
<th>Silt (%)</th>
<th>Clay (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Sample</td>
<td>1</td>
<td>55</td>
<td>39</td>
<td>5</td>
</tr>
<tr>
<td>Total &lt; 2mm</td>
<td>N/A</td>
<td>56</td>
<td>39</td>
<td>5</td>
</tr>
</tbody>
</table>

**Mineralogy**

<table>
<thead>
<tr>
<th></th>
<th>Roundness</th>
<th>Max size</th>
<th>Bone/charcoal/shells</th>
<th>Petrology/description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gravels</td>
<td>Subhedral to anhedral</td>
<td>1 cm</td>
<td>No/yes/no</td>
<td>Boring Lava</td>
</tr>
</tbody>
</table>
### Archaeological Data

<table>
<thead>
<tr>
<th>Site</th>
<th>Find #</th>
<th>Assoc.</th>
<th>Unit</th>
<th>Unit Code</th>
<th>Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>45CL1</td>
<td>43955</td>
<td>493</td>
<td>N157-159/W90-02</td>
<td>J2</td>
<td>NW</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Elevation (cm)</th>
<th>Provenance</th>
<th>Pit Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.35</td>
<td>N158.50/W91.60</td>
<td>H1D Cellar</td>
</tr>
</tbody>
</table>

### Color

<table>
<thead>
<tr>
<th>Dry Color</th>
<th>Wet Color</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.5Y 5/2</td>
<td>2.5Y 3/2</td>
</tr>
</tbody>
</table>

### Organic Matter

<table>
<thead>
<tr>
<th>% Organic matter</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
</tr>
</tbody>
</table>

### Grain Size Analysis

<table>
<thead>
<tr>
<th></th>
<th>Gravel (%)</th>
<th>Sand (%)</th>
<th>Silt (%)</th>
<th>Clay (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Sample</td>
<td>2</td>
<td>64</td>
<td>30</td>
<td>4</td>
</tr>
<tr>
<td>Total &lt; 2mm</td>
<td>N/A</td>
<td>65</td>
<td>31</td>
<td>4</td>
</tr>
</tbody>
</table>

### Mineralogy

<table>
<thead>
<tr>
<th></th>
<th>Roundness</th>
<th>Max size</th>
<th>Bone/charcoal/shells</th>
<th>Petrology/description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gravels</td>
<td>Subhedral to anhedral</td>
<td>8 mm</td>
<td>Yes/yeds/no</td>
<td>Boring Lava, bone and charcoal</td>
</tr>
</tbody>
</table>
**Color** | **Mineralogy** | **Bone/charcoal/shells** | **Size**
--- | --- | --- | ---
Sands | Medium gray | Mica | Yes, yes, no | Fine to medium

**Find #12010 (Sample #21)**

**Archaeological Data**

<table>
<thead>
<tr>
<th>Site</th>
<th>Find #</th>
<th>Assoc.</th>
<th>Unit</th>
<th>Unit Code</th>
<th>Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>45CL1</td>
<td>12010</td>
<td>Feat. 88</td>
<td>N159-160/W83-87</td>
<td>B2</td>
<td>8/D</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Elevation (cm)</th>
<th>Provenance</th>
<th>Pit Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.45-5.60</td>
<td>N156-160/W83-84</td>
<td>H1D Cellar</td>
</tr>
</tbody>
</table>

**Color**

<table>
<thead>
<tr>
<th>Dry Color</th>
<th>Wet Color</th>
</tr>
</thead>
<tbody>
<tr>
<td>10YR 4/2</td>
<td>10YR 2/2</td>
</tr>
</tbody>
</table>

**Organic Matter**

<table>
<thead>
<tr>
<th>% Organic matter</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
</tr>
</tbody>
</table>

**Grain Size Analysis**

<table>
<thead>
<tr>
<th></th>
<th>Gravel (%)</th>
<th>Sand (%)</th>
<th>Silt (%)</th>
<th>Clay (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Sample</td>
<td>0</td>
<td>59</td>
<td>37</td>
<td>4</td>
</tr>
<tr>
<td>Total &lt; 2mm</td>
<td>N/A</td>
<td>59</td>
<td>37</td>
<td>4</td>
</tr>
</tbody>
</table>

**Mineralogy**

<table>
<thead>
<tr>
<th></th>
<th>Roundness</th>
<th>Max size</th>
<th>Bone/charcoal/shells</th>
<th>Petrology/description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gravels</td>
<td>Anhedral</td>
<td>3mm</td>
<td>Yes/yes/no</td>
<td>Boring Lava, mostly charcoal/bone</td>
</tr>
</tbody>
</table>
Find #24010 (Sample #27)

Archaeological Data

<table>
<thead>
<tr>
<th>Site</th>
<th>Find #</th>
<th>Assoc.</th>
<th>Unit</th>
<th>Unit Code</th>
<th>Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>45CL1</td>
<td>24010</td>
<td>373</td>
<td>N155-157/W84-86</td>
<td>Y</td>
<td>8/NW</td>
</tr>
</tbody>
</table>

Elevation (cm) Provenance Pit Classification
5.53-5.38 N156.72-156.98/W85.13-85.53 H1D Cellar

Color

<table>
<thead>
<tr>
<th>Dry Color</th>
<th>Wet Color</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.5Y 4/2</td>
<td>10YR 2/2</td>
</tr>
</tbody>
</table>

Organic Matter

<table>
<thead>
<tr>
<th>% Organic matter</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
</tr>
</tbody>
</table>

Grain Size Analysis

<table>
<thead>
<tr>
<th></th>
<th>Gravel (%)</th>
<th>Sand (%)</th>
<th>Silt (%)</th>
<th>Clay (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Sample</td>
<td>3</td>
<td>60</td>
<td>33</td>
<td>4</td>
</tr>
<tr>
<td>Total &lt; 2mm</td>
<td>N/A</td>
<td>62</td>
<td>34</td>
<td>4</td>
</tr>
</tbody>
</table>

Mineralogy

<table>
<thead>
<tr>
<th></th>
<th>Roundness</th>
<th>Max size</th>
<th>Bone/charcoal/shells</th>
<th>Petrology/description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gravels</td>
<td>Euhedral to anhedral</td>
<td>1 cm</td>
<td>Yes/yes/no</td>
<td>Andesite, charcoal and bone</td>
</tr>
</tbody>
</table>
Find #27018 (Sample #14)

Archaeological Data

<table>
<thead>
<tr>
<th>Site</th>
<th>Find #</th>
<th>Assoc.</th>
<th>Unit</th>
<th>Unit Code</th>
<th>Level</th>
<th>Elevation (cm)</th>
<th>Provenance</th>
<th>Pit Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>45CL1</td>
<td>27018</td>
<td>-</td>
<td>N149-151/W84-86</td>
<td>V</td>
<td>-</td>
<td>5.90-5.78</td>
<td>-</td>
<td>H1D Cellar</td>
</tr>
</tbody>
</table>

Color

<table>
<thead>
<tr>
<th>Dry Color</th>
<th>Wet Color</th>
</tr>
</thead>
<tbody>
<tr>
<td>10YR 4/2</td>
<td>10YR 2/2</td>
</tr>
</tbody>
</table>

Organic Matter

<table>
<thead>
<tr>
<th>% Organic matter</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
</tr>
</tbody>
</table>

Grain Size Analysis

<table>
<thead>
<tr>
<th></th>
<th>Gravel (%)</th>
<th>Sand (%)</th>
<th>Silt (%)</th>
<th>Clay (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Sample</td>
<td>0</td>
<td>61</td>
<td>34</td>
<td>5</td>
</tr>
<tr>
<td>Total &lt; 2mm</td>
<td>N/A</td>
<td>61</td>
<td>34</td>
<td>5</td>
</tr>
</tbody>
</table>

Mineralogy

<table>
<thead>
<tr>
<th></th>
<th>Roundness</th>
<th>Max size</th>
<th>Bone/charcoal/shells</th>
<th>Petrology/description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gravels</td>
<td>Subhedral</td>
<td>2 mm</td>
<td>No/yes/no</td>
<td>Boring Lava</td>
</tr>
</tbody>
</table>
**H1D - Hearth Periphery**

Find #25017 (Sample #16)

**Archaeological Data**

<table>
<thead>
<tr>
<th>Site</th>
<th>Find #</th>
<th>Assoc.</th>
<th>Unit</th>
<th>Unit Code</th>
<th>Level</th>
<th>Elevation (cm)</th>
<th>Provenance</th>
<th>Pit Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>45CL1</td>
<td>25017</td>
<td>-</td>
<td>N153-155/W86-88</td>
<td>W</td>
<td></td>
<td>5.77-5.88</td>
<td>N155.00-155.06/W86.81-87.00</td>
<td>H1D Hearth Periphery</td>
</tr>
</tbody>
</table>

**Color**

<table>
<thead>
<tr>
<th>Dry Color</th>
<th>Wet Color</th>
</tr>
</thead>
<tbody>
<tr>
<td>10YR 4/2</td>
<td>10YR 2/2</td>
</tr>
</tbody>
</table>

**Organic Matter**

<table>
<thead>
<tr>
<th>% Organic matter</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
</tr>
</tbody>
</table>

**Grain Size Analysis**

<table>
<thead>
<tr>
<th></th>
<th>Gravel (%)</th>
<th>Sand (%)</th>
<th>Silt (%)</th>
<th>Clay (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Sample</td>
<td>1</td>
<td>67</td>
<td>28</td>
<td>4</td>
</tr>
<tr>
<td>Total &lt; 2mm</td>
<td>N/A</td>
<td>67</td>
<td>29</td>
<td>4</td>
</tr>
</tbody>
</table>
Mineralogy

<table>
<thead>
<tr>
<th></th>
<th>Roundness</th>
<th>Max size</th>
<th>Bone/charcoal/shells</th>
<th>Petrology/description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Gravels</strong></td>
<td>Anhedral</td>
<td>5 mm</td>
<td>Yes/yes/no</td>
<td>Boring Lava, bone, charcoal</td>
</tr>
<tr>
<td><strong>Color</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Mineralogy</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Bone/charcoal/shells</strong></td>
<td>Yes/yes/no</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Size</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Color | Mineralogy | Bone/charcoal/shells | Size
--- | --- | --- | ---
Dark gray | Mica | Yes/yes/no | Fine to medium

Find #25001 (Sample #15)

Archaeological Data

<table>
<thead>
<tr>
<th>Site</th>
<th>Find #</th>
<th>Assoc.</th>
<th>Unit</th>
<th>Unit Code</th>
<th>Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>45CL1</td>
<td>25001</td>
<td>-</td>
<td>N153-155/W86-88</td>
<td>W</td>
<td>-</td>
</tr>
<tr>
<td>Elevation (cm)</td>
<td>Provenance</td>
<td>Pit Classification</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5.80-5.74</td>
<td>N153.85-154.04/W88.00-88.06</td>
<td>H1D Hearth Periphery</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Color

<table>
<thead>
<tr>
<th>Dry Color</th>
<th>Wet Color</th>
</tr>
</thead>
<tbody>
<tr>
<td>10YR 4/2</td>
<td>10YR 2/2</td>
</tr>
</tbody>
</table>

Organic Matter

<table>
<thead>
<tr>
<th>% Organic matter</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
</tr>
</tbody>
</table>

Grain Size Analysis

<table>
<thead>
<tr>
<th></th>
<th>Gravel (%)</th>
<th>Sand (%)</th>
<th>Silt (%)</th>
<th>Clay (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Sample</td>
<td>5</td>
<td>61</td>
<td>29</td>
<td>5</td>
</tr>
<tr>
<td>Total &lt; 2mm</td>
<td>N/A</td>
<td>64</td>
<td>30</td>
<td>6</td>
</tr>
</tbody>
</table>
Mineralogy

<table>
<thead>
<tr>
<th>Gravels</th>
<th>Roundness</th>
<th>Max size</th>
<th>Bone/charcoal/shells</th>
<th>Petrology/description</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Subhedral</td>
<td>3 mm</td>
<td>No/yes/no</td>
<td>Boring Lava, andesite, charcoal</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Color</th>
<th>Mineralogy</th>
<th>Bone/charcoal/shells</th>
<th>Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dark gray</td>
<td>Mica</td>
<td>no/yes/no</td>
<td>Fine to medium</td>
</tr>
</tbody>
</table>

Gravels - Subhedral, 3 mm, No/yes/no Boring Lava, andesite, charcoal

Color: Dark gray
Mineralogy: Mica
Bone/charcoal/shells: no/yes/no
Size: Fine to medium

**H1D - Wall**

Find #28023 (Sample #20)

Archaeological Data

<table>
<thead>
<tr>
<th>Site</th>
<th>Find #</th>
<th>Assoc.</th>
<th>Unit</th>
<th>Unit Code</th>
<th>Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>45CL1</td>
<td>28023</td>
<td>-</td>
<td>N147-149/W86-88</td>
<td>U</td>
<td></td>
</tr>
</tbody>
</table>

Elevation (cm) 5.5

Provenance: N147.00/W87.50-87.84
Pit Classification: H1D Wall

Color

<table>
<thead>
<tr>
<th>Dry Color</th>
<th>Wet Color</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.5Y 5/3</td>
<td>2.5Y 3/3</td>
</tr>
</tbody>
</table>

Organic Matter

<table>
<thead>
<tr>
<th>% Organic matter</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
</tr>
</tbody>
</table>
Grain Size Analysis

<table>
<thead>
<tr>
<th></th>
<th>Gravel (%)</th>
<th>Sand (%)</th>
<th>Silt (%)</th>
<th>Clay (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Sample</td>
<td>0</td>
<td>62</td>
<td>34</td>
<td>4</td>
</tr>
<tr>
<td>Total &lt; 2mm</td>
<td>N/A</td>
<td>62</td>
<td>34</td>
<td>4</td>
</tr>
</tbody>
</table>

Mineralogy

<table>
<thead>
<tr>
<th></th>
<th>Roundness</th>
<th>Max size</th>
<th>Bone/charcoal/shells</th>
<th>Petrology/description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gravels</td>
<td>Anhedral</td>
<td>3 mm</td>
<td>No/no/no</td>
<td>Boring Lava</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Color</th>
<th>Mineralogy</th>
<th>Bone/charcoal/shells</th>
<th>Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sands</td>
<td>Gray</td>
<td>Mica</td>
<td>No/no/no</td>
<td>Fine to medium</td>
</tr>
</tbody>
</table>

Midden

Find #S-7032 (Sample #31)

Archaeological Data

<table>
<thead>
<tr>
<th>Site</th>
<th>Find #</th>
<th>Assoc.</th>
<th>Unit</th>
<th>Unit Code</th>
<th>Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>45CL1</td>
<td>S-7032</td>
<td>53</td>
<td>N75-77/W76-78</td>
<td>G</td>
<td>8/NE</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Elevation (cm)</th>
<th>Provenance</th>
<th>Pit</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.4-6.3</td>
<td>SE 1/4 of quadrant</td>
<td>Midden</td>
</tr>
</tbody>
</table>

Color

<table>
<thead>
<tr>
<th>Dry Color</th>
<th>Wet Color</th>
</tr>
</thead>
<tbody>
<tr>
<td>10YR 4/1</td>
<td>10YR 2/1</td>
</tr>
</tbody>
</table>

Organic Matter

<table>
<thead>
<tr>
<th>% Organic matter</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
</tr>
</tbody>
</table>
Grain Size Analysis

<table>
<thead>
<tr>
<th></th>
<th>Gravel (%)</th>
<th>Sand (%)</th>
<th>Silt (%)</th>
<th>Clay (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Sample</td>
<td>17</td>
<td>53</td>
<td>26</td>
<td>4</td>
</tr>
<tr>
<td>Total &lt; 2mm</td>
<td>N/A</td>
<td>64</td>
<td>32</td>
<td>4</td>
</tr>
</tbody>
</table>

Mineralogy

<table>
<thead>
<tr>
<th></th>
<th>Roundness</th>
<th>Max size</th>
<th>Bone/charcoal/shells</th>
<th>Mineralogy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gravels</td>
<td>Anhedral</td>
<td>1 cm</td>
<td>Yes/yes/yes</td>
<td>Mostly shells, charcoal, andesite</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Color</th>
<th>Mineralogy</th>
<th>Bone/charcoal/shells</th>
<th>Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sands</td>
<td>Dark gray</td>
<td>Mica</td>
<td>Yes/yes/yes</td>
<td>Fine to medium</td>
</tr>
</tbody>
</table>

Find #7016 (Sample #17)

Archaeological Data

<table>
<thead>
<tr>
<th>Site</th>
<th>Find #</th>
<th>Assoc.</th>
<th>Unit</th>
<th>Unit Code</th>
<th>Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>45CL1</td>
<td>7016</td>
<td>-</td>
<td>N75-77/W76-78</td>
<td>G</td>
<td>4</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Elevation (cm)</th>
<th>Provenance</th>
<th>Pit Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.8-6.7</td>
<td>-</td>
<td>Midden</td>
</tr>
</tbody>
</table>

Color

<table>
<thead>
<tr>
<th>Dry Color</th>
<th>Wet Color</th>
</tr>
</thead>
<tbody>
<tr>
<td>10YR 3/1</td>
<td>10YR 2/1</td>
</tr>
</tbody>
</table>

Organic Matter

<table>
<thead>
<tr>
<th>% Organic matter</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
</tr>
</tbody>
</table>
Grain Size Analysis

<table>
<thead>
<tr>
<th></th>
<th>Gravel (%)</th>
<th>Sand (%)</th>
<th>Silt (%)</th>
<th>Clay (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Sample</td>
<td>1</td>
<td>59</td>
<td>36</td>
<td>4</td>
</tr>
<tr>
<td>Total &lt; 2mm</td>
<td>N/A</td>
<td>60</td>
<td>36</td>
<td>4</td>
</tr>
</tbody>
</table>

Mineralogy

<table>
<thead>
<tr>
<th></th>
<th>Roundness</th>
<th>Max size</th>
<th>Bone/charcoal/shells</th>
<th>Petrology/description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gravels</td>
<td>Subhedral to anhedral</td>
<td>8 mm</td>
<td>No/yes/yes</td>
<td>Boring Lava, charcoal, shells, ash</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Color</th>
<th>Mineralogy</th>
<th>Bone/charcoal/shells</th>
<th>Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sands</td>
<td>Dark gray</td>
<td>Mica</td>
<td>No/yes/yes</td>
<td>Fine to medium</td>
</tr>
</tbody>
</table>

Sheet Midden

Find #16061 (Sample #18)

Archaeological Data

<table>
<thead>
<tr>
<th>Site</th>
<th>Find #</th>
<th>Assoc.</th>
<th>Unit</th>
<th>Unit Code</th>
<th>Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>45CL1</td>
<td>16061</td>
<td>-</td>
<td>N159-160/W99-103</td>
<td>F2</td>
<td>10/A</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Elevation (cm)</th>
<th>Provenance</th>
<th>Pit Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.15-4.85</td>
<td>-</td>
<td>Sheet Midden</td>
</tr>
</tbody>
</table>

Color

<table>
<thead>
<tr>
<th>Dry Color</th>
<th>Wet Color</th>
</tr>
</thead>
<tbody>
<tr>
<td>10YR 4/2</td>
<td>10YR 2/2</td>
</tr>
</tbody>
</table>
Organic Matter

<table>
<thead>
<tr>
<th>% Organic matter</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
</tr>
</tbody>
</table>

Grain Size Analysis

<table>
<thead>
<tr>
<th></th>
<th>Gravel (%)</th>
<th>Sand (%)</th>
<th>Silt (%)</th>
<th>Clay (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Sample</td>
<td>1</td>
<td>69</td>
<td>26</td>
<td>4</td>
</tr>
<tr>
<td>Total &lt; 2mm</td>
<td>N/A</td>
<td>70</td>
<td>26</td>
<td>4</td>
</tr>
</tbody>
</table>

Mineralogy

<table>
<thead>
<tr>
<th></th>
<th>Roundness</th>
<th>Max size</th>
<th>Bone/charcoal/shells</th>
<th>Petrology/description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gravels</td>
<td>Subhedral to anhedral</td>
<td>1 cm</td>
<td>Yes/yes/no</td>
<td>Boring Lava, bone, charcoal</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Color</th>
<th>Mineralogy</th>
<th>Bone/charcoal/shells</th>
<th>Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sands</td>
<td>Medium gray</td>
<td>Mica</td>
<td>No/yes/no</td>
<td>Fine to medium</td>
</tr>
</tbody>
</table>

Find #15018 (Sample #22)

Archaeological Data

<table>
<thead>
<tr>
<th>Site</th>
<th>Find #</th>
<th>Assoc.</th>
<th>Unit</th>
<th>Unit Code</th>
<th>Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>45CL1</td>
<td>15018</td>
<td>46</td>
<td>N159-160/W95-99</td>
<td>E2</td>
<td>6/A</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Elevation (cm)</th>
<th>Provenance</th>
<th>Pit Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.75</td>
<td>-</td>
<td>Sheet Midden</td>
</tr>
</tbody>
</table>

Color

<table>
<thead>
<tr>
<th>Dry Color</th>
<th>Wet Color</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.5Y 5/2</td>
<td>2.5Y3/2</td>
</tr>
</tbody>
</table>
Organic Matter

<table>
<thead>
<tr>
<th>% Organic matter</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
</tr>
</tbody>
</table>

Grain Size Analysis

<table>
<thead>
<tr>
<th></th>
<th>Gravel (%)</th>
<th>Sand (%)</th>
<th>Silt (%)</th>
<th>Clay (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Sample</td>
<td>0</td>
<td>56</td>
<td>39</td>
<td>5</td>
</tr>
<tr>
<td>Total &lt; 2mm</td>
<td>N/A</td>
<td>56</td>
<td>39</td>
<td>5</td>
</tr>
</tbody>
</table>

Mineralogy

<table>
<thead>
<tr>
<th></th>
<th>Roundness</th>
<th>Max size</th>
<th>Bone/charcoal/shells</th>
<th>Petrology/description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gravels</td>
<td>Subhedral to anhedral</td>
<td>3 mm</td>
<td>Yes/yes/no</td>
<td>Boring Lava, bone, charcoal</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Color</th>
<th>Mineralogy</th>
<th>Bone/charcoal/shells</th>
<th>Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sands</td>
<td>Medium gray</td>
<td>Mica</td>
<td>No/yes/no</td>
<td>Fine to medium</td>
</tr>
</tbody>
</table>
Find #15032 (Sample #29)

Archaeological Data

<table>
<thead>
<tr>
<th>Site</th>
<th>Find #</th>
<th>Assoc.</th>
<th>Unit</th>
<th>Unit Code</th>
<th>Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>45CL1</td>
<td>15032</td>
<td>-</td>
<td>N159-160/W95-99</td>
<td>E2</td>
<td>11/D</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Elevation (cm)</th>
<th>Provenance</th>
<th>Pit Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.15-5.00</td>
<td>-</td>
<td>Sheet Midden</td>
</tr>
</tbody>
</table>

Color

<table>
<thead>
<tr>
<th>Dry Color</th>
<th>Wet Color</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.5Y 5/2</td>
<td>2.5Y3/2</td>
</tr>
</tbody>
</table>

Organic Matter

<table>
<thead>
<tr>
<th>% Organic matter</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
</tr>
</tbody>
</table>

Grain Size Analysis

<table>
<thead>
<tr>
<th></th>
<th>Gravel (%)</th>
<th>Sand (%)</th>
<th>Silt (%)</th>
<th>Clay (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Sample</td>
<td>0</td>
<td>49</td>
<td>45</td>
<td>6</td>
</tr>
<tr>
<td>Total &lt; 2mm</td>
<td>N/A</td>
<td>49</td>
<td>45</td>
<td>6</td>
</tr>
</tbody>
</table>

Mineralogy

<table>
<thead>
<tr>
<th></th>
<th>Roundness</th>
<th>Max size</th>
<th>Bone/charcoal/shells</th>
<th>Petrology/description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gravels</td>
<td>Subhedral</td>
<td>2 mm</td>
<td>No/yes/no</td>
<td>Boring lava, charcoal</td>
</tr>
<tr>
<td>Sands</td>
<td>Medium gray</td>
<td>Mica</td>
<td>Yes/yes/no</td>
<td>Fine to medium</td>
</tr>
<tr>
<td>Sample #</td>
<td>Site</td>
<td>Find #</td>
<td>Assoc.</td>
<td>Unit</td>
</tr>
<tr>
<td>---------</td>
<td>----------</td>
<td>---------</td>
<td>---------</td>
<td>--------</td>
</tr>
<tr>
<td>8</td>
<td>35CO5</td>
<td>767</td>
<td>profile</td>
<td>L2</td>
</tr>
<tr>
<td>10</td>
<td>35CO5</td>
<td>1016</td>
<td>NE Quad</td>
<td>J</td>
</tr>
<tr>
<td>9</td>
<td>35CO5</td>
<td>1051</td>
<td>SE Quad</td>
<td>J</td>
</tr>
<tr>
<td>2</td>
<td>35CO5</td>
<td>596</td>
<td>F66</td>
<td>L2</td>
</tr>
<tr>
<td>4</td>
<td>35CO5</td>
<td>364</td>
<td>F29E</td>
<td>K</td>
</tr>
<tr>
<td>7</td>
<td>35CO5</td>
<td>959</td>
<td>F319</td>
<td>N</td>
</tr>
<tr>
<td>5</td>
<td>35CO5</td>
<td>195</td>
<td>F41</td>
<td>K</td>
</tr>
<tr>
<td>6</td>
<td>35CO5</td>
<td>70</td>
<td>NE Quad</td>
<td>X</td>
</tr>
<tr>
<td>3</td>
<td>35CO5</td>
<td>967</td>
<td>NE Quad</td>
<td>O2</td>
</tr>
<tr>
<td>1</td>
<td>35CO5</td>
<td>922</td>
<td>NE Quad</td>
<td>O2</td>
</tr>
<tr>
<td>12</td>
<td>35CO5</td>
<td>765</td>
<td>profile</td>
<td>L2</td>
</tr>
<tr>
<td>11</td>
<td>35CO5</td>
<td>772</td>
<td>profile</td>
<td>L2</td>
</tr>
<tr>
<td>13</td>
<td>35CO5</td>
<td>764</td>
<td>profile</td>
<td>L2</td>
</tr>
<tr>
<td>25</td>
<td>45CL1</td>
<td>19041</td>
<td></td>
<td>P2</td>
</tr>
<tr>
<td>26</td>
<td>45CL1</td>
<td>19043</td>
<td></td>
<td>P2</td>
</tr>
<tr>
<td>30</td>
<td>45CL1</td>
<td>19037</td>
<td></td>
<td>P2</td>
</tr>
<tr>
<td>24</td>
<td>45CL1</td>
<td>19033</td>
<td></td>
<td>P2</td>
</tr>
<tr>
<td>28</td>
<td>45CL1</td>
<td>19007</td>
<td></td>
<td>P2</td>
</tr>
<tr>
<td>19</td>
<td>45CL1</td>
<td>12023</td>
<td>feature</td>
<td>B2</td>
</tr>
<tr>
<td>23</td>
<td>45CL1</td>
<td>43955</td>
<td></td>
<td>J2</td>
</tr>
<tr>
<td>21</td>
<td>45CL1</td>
<td>12010</td>
<td>feature</td>
<td>B2</td>
</tr>
<tr>
<td>27</td>
<td>45CL1</td>
<td>24010</td>
<td></td>
<td>Y</td>
</tr>
<tr>
<td>14</td>
<td>45CL1</td>
<td>27018</td>
<td></td>
<td>V</td>
</tr>
<tr>
<td>16</td>
<td>45CL1</td>
<td>25017</td>
<td></td>
<td>W</td>
</tr>
<tr>
<td>15</td>
<td>45CL1</td>
<td>25001</td>
<td></td>
<td>W</td>
</tr>
<tr>
<td>20</td>
<td>45CL1</td>
<td>28023</td>
<td></td>
<td>U</td>
</tr>
<tr>
<td>31</td>
<td>45CL1</td>
<td>S-7032</td>
<td></td>
<td>G</td>
</tr>
<tr>
<td>17</td>
<td>45CL1</td>
<td>7016</td>
<td></td>
<td>G</td>
</tr>
<tr>
<td>18</td>
<td>45CL1</td>
<td>16061</td>
<td></td>
<td>F2</td>
</tr>
<tr>
<td>22</td>
<td>45CL1</td>
<td>15018</td>
<td>around</td>
<td>E2</td>
</tr>
<tr>
<td>29</td>
<td>45CL1</td>
<td>15032</td>
<td>feature</td>
<td>E2</td>
</tr>
</tbody>
</table>
PART V

THE WAPATO VALLEY PREDICTIVE MODEL: PREHISTORIC ARCHAEOLOGICAL SITE LOCATION ON THE FLOODPLAIN OF THE COLUMBIA RIVER IN THE PORTLAND BASIN

Leslie M. O’Rourke
ACKNOWLEDGMENTS

I would first like to acknowledge the encouragement of my professors at Washington State University in the late 1960s-early 1970s, especially Grover Krantz and Frank Leonhardy; and Tom Roll, director of my first field school in 1970. I had known that I had wanted to be an archaeologist since the second grade, but their instruction and guidance helped me discover that it could be a reality for me.

My interest in and desire to pursue a career in archaeology never fully faded after my undergraduate days, and was nurtured inside for years. When I reentered school in 1999, I was still not quite sure if I could make this all work, but I was willing to give it all I had.

Ken Ames has been the sounding board for my goals and aspirations. I remembered him from my undergrad days when he was a TA for one of my classes. He encouraged me from our first meeting at Portland State University when I was testing the waters, throughout my post-baccalaureate study, and as I applied for graduate school. As my advisor and chair of my graduate committee, he has always been accessible, helpful, and supportive. He challenged and inspired me, and led me to discover things I never would have seen or been. To him I offer my deepest gratitude.

To my committee members. To Virginia Butler for imparting to me her objective and scientific perspective on archaeological research, and for her enthusiasm and dedication. To Bill Lang for his commitment to public history. To Doug Wilson, for introducing me to the dark side of archaeology (historical), for his advice and guidance on predictive modeling, and for the opportunity to hone my archaeology and GIS skills at Fort Vancouver.

To members of the Portland State University community. To David Percy of the Geology Department for initiating me into the mysteries of ArcView, and for helping me make all of this work; to Robert Fountain of the Statistics Department for guidance in logistic regression; and to graduate student Wendy Obenauf for introducing me to my newfound best friends, Hosmer and Lemeshow.

To Anan Raymond and the cultural resources team at the US Fish and Wildlife Service in Sherwood, for starting me on this project, giving me an internship opportunity, and providing support and materials for my research on the Ridgefield National Wildlife Refuge.

To Ken Kvamme for his encouragement and suggestions in predictive modeling.

To the staff of the Washington State Office of Archaeology and Historic Preservation for their assistance with the Washington site and survey records. To Dennis Griffin, Oregon State Historic Preservation Archaeologist, for his help with sorting out the proper format for my site tables. To Le Gilsen, former Oregon State Historic Preservation Archaeologist, for his help with site records.

To the folks at the Oregon State Historical Society library and their invaluable help and patience with their historic maps (I always made them nervous when I wanted to photocopy their big maps!).

To Greg Bertrand at the US Army Corps of Engineers for supplying me with hydrography layers, and to David Hoy and the folks at the regional US Fish and Wildlife Service for providing me with the Ducks Unlimited GIS layers for the Ridgefield National Wildlife Refuge. These made my life so much easier.

And to Connie Cash, for being the goddess that she is, bringing order to chaos; creating the appropriate letters, forms, and signatures with a wave of her pen; and keeping the Anthropology Department in harmony with the rest of the universe.
PREFACE

This thesis began, as I suppose many do, as something quite different from what it turned out to be. When I was considering potential thesis topics, I was drawn to a large project at Cathlapotle (45CL1) on the Ridgefield National Wildlife Refuge that my advisor, Ken Ames, had been working on for years. The excavation phase was completed, however, so it seemed to me that opportunities for direct work on the site were limited. Analysis was still in progress, although I was not sure that there were any prospects for additional research or thesis work (as a naive new graduate student, I did not realize that all the potential questions about Cathlapotle or any other site could never be answered!).

I began to think about a thesis project in some way related to Cathlapotle – something having to do with the Chinookan peoples or with the area around the site. Portland State University has a close relationship with the US Fish and Wildlife Service that administers the Ridgefield National Wildlife Refuge, and with the head archaeologist for the region’s cultural resources team, Anan Raymond, so we had a meeting to discuss a thesis project that would be of significance and of interest to the Refuge.

The Refuge has never been systematically surveyed. Settlers, farmers, quarrymen, hunters, looters, and boaters had discovered archaeological sites there over the last 150 years in the course of ground disturbing activities. Although many archaeological surveys had been conducted, most of the work focused on shorelines and in areas of known sites. No one had yet set out to evaluate the entire Refuge for cultural resources. A systematic probabilistic survey would potentially lead to the discovery of more archaeological sites, answer questions about their distribution on the Refuge, facilitate better management of the cultural resources there, and help fill in the gaps in our knowledge about the Chinook and their subsistence and settlement patterns on the Columbia River floodplain. I would design the survey, and other graduate students would implement it over the next few years. It sounded great!

I studied survey and sampling methodologies, and wrote a paper about this research for my graduate seminar in archaeology. Ken arranged for an internship for me with the cultural resources department of the US Fish and Wildlife Service at Sherwood, which would allow me to study their documents on the history of the Refuge and the archaeological work that had been done there. I took a class in field GIS from David Percy in Geology that would enable me to accurately map any survey design that I developed.

It was with that field GIS class that everything began to change. I have always been drawn to maps – I am a very visual, spatial person – and I was intrigued by the possibilities with ArcView. I undertook a pilot study and preliminary analysis of the distribution of archaeological sites on the Refuge for a second GIS class in the winter of 2002. This research for this project led me to my first encounter with predictive modeling in general, and the Clark County Predictive Model (Ellis and Wilson 1994) in particular. The Clark County model had assigned a blanket level of high site probability to all areas of less than 50 feet elevation. This model was of no use in predicting areas of higher site probability on the Ridgefield National Wildlife Refuge because all of the sites on the Refuge were at an elevation of 50 feet or less. Could I design a predictive model that could tease out the variables correlating with site location on the Refuge, or for any area of 50 feet elevation or less on the floodplain of the Columbia River?

After compiling the Refuge site database for the pilot study, another turning point occurred on a fateful day in the spring of 2002. I showed the results to Ken, and he said: “this is really good – now do the same for the rest of the Wapato Valley”. Great – my study area had just expanded from 2,000 hectares on the Refuge to 550 km² (55,000 hectares) for the entire Wapato Valley, including portions of eleven 7.5-minute topographic maps, in four counties and two states!

Further research into predictive modeling led me to believe that I could somehow define probability areas with ArcView, although I was not yet sure how to do it. I read everything that I could about how archaeologists had used logistic regression and GIS to create predictive models and found my new gurus: Ken Kvamme, the pioneer in archaeological predictive modeling and GIS; Robert Warren and David Asch, whose
recent archaeological predictive model I admired and would use as a guide for my model; and David Hosmer and Stanley Lemeshow, masters of logistic regression. The entire journey came full-circle in April of 2003 when I went back to Percy for guidance. I had thought I understood how to input the equation in ArcView to generate the probability surface, but I could not make it work. Percy enlightened me by showing me how it needed to be entered for ArcView, and voilà! Even better, the model worked!

Although I had begun this thesis as a survey design for the Ridgefield National Wildlife Refuge, it has obviously become much more broad in its scope. By analyzing the environmental variables at the locations of the archaeological sites throughout the Wapato Valley, predictions of the probability of site occurrence can be made that apply to the whole region. The Wapato Valley Predictive Model provides information for the development of a survey strategy for not just the Refuge, but for anywhere in the Portland basin on the low elevation areas of the floodplain of the Columbia River. Probability maps for the Wapato Valley can guide decision making for site discovery, research, and management, giving archaeologists and planners a tool for the avoidance of sites and the preservation of the archaeological record.
CHAPTER 1
INTRODUCTION

This thesis grew out of a project to investigate the qualities of the environment that are most highly correlated with the presence of archaeological sites on the Ridgefield National Wildlife Refuge. It was intended that the findings of that project could be used to develop a survey strategy for site discovery and management on the Refuge. A study of archaeological predictive modeling led to the realization that site probability areas could be more accurately modeled through logistic regression and then mapped in GIS (Geographical Information System). The decision was made to expand the Ridgefield project to try to develop a predictive model for prehistoric archaeological site location for the entire Wapato Valley. The findings of the model could be used on the Refuge, but would also have applications for the entire region.

The purpose of this thesis was to build a predictive model for prehistoric archaeological site location for the Wapato Valley of the Columbia River in the Portland Basin, and then map the results in GIS. The Wapato Valley comprises 550 square kilometers (55,000 hectares) of the floodplain of the Columbia River, from the mouth of the Columbia River Gorge at Rooster Rock Park at River Mile 129, downriver 88 kilometers to the north end of Deer Island at River Mile 76 (Figure 5.1). The term Portland Basin is often used interchangeably with Wapato Valley, but the Portland Basin usually includes areas along the Willamette River up to the Willamette Falls at River Mile 27, as well as elevations higher than 55 feet AMSL, which were not included in this study. For the purposes of this thesis, the term Wapato Valley refers just to areas along the Columbia River floodplain, at an elevation of 55 feet or less AMSL.

This zone was targeted because the floodplain of the Columbia River is the location of the majority of the prehistoric archaeological sites in the Portland Basin. Ellis and Wilson found that 74 percent of the archaeological resources of Clark County were located at an elevation of 50 feet or less AMSL (Ellis and Wilson 1994:D:3) and assigned a high probability rating to this entire zone. One of the goals of this thesis was to test the findings of the Clark County Predictive Model, to see if the variables that correlated most strongly with archaeological site presence throughout Clark County were the same as those on the Columbia River floodplain of the Wapato Valley. However, it was hoped that the Wapato Valley Predictive Model could do more: to see if it could tease out the most significant predictors of site presence within the floodplain zone, to effectively refine the Clark County Predictive Model and define the full range of probability areas for archaeological site presence at an elevation of 55 feet or less AMSL.

A further goal was to compile a regional database, so that information from all prehistoric archaeological sites in the Wapato Valley – from both Oregon and Washington – would be summarized in one place. No one had ever assembled all these records before. This database became the foundation of the predictive model. And finally, coming full-circle, the findings of the Wapato Valley Predictive Model would be compared to the sample of sites from the Ridgefield National Wildlife Refuge, which would help validate the results of the final model. A bibliography of references used for the original Ridgefield project would be included in an appendix.

The Wapato Valley Predictive Model and this thesis are intended to serve a dual purpose. The first is as a stand-alone document for the management of the region’s archaeological resources. Ever-increasing growth and expansion in the Portland/Vancouver area requires that measures be taken to preserve and protect any intact archaeological sites, and to thoroughly document any remaining traces of prehistoric activity. A predictive model that focuses on the floodplain of the Columbia River, the area where ground-disturbing activities are most likely to impact aboriginal cultural materials, would provide an invaluable tool for archaeologists and land managers for the discovery, preservation, and protection of cultural resources, and for development planners seeking to avoid archaeological resources in their construction activities.

The second purpose of the Wapato Valley Predictive Model is to serve as a resource for
Figure 5.1. Location map of the Wapato Valley.
those seeking to build their own predictive model. The methods used are given in perhaps more detail than is necessary, but there are good reasons for this. The main purpose addresses the scientific method. Anyone should be able to take these methods and these data and reproduce these results – or alternately, use these methods with their own data and build their own predictive model. A corollary of this point stems from a previous career in research medicine and the frustration of trying to reproduce techniques from research papers when critical steps were omitted. The final reason for the detailed methods is to ease the concerns of the critics of predictive modeling who are uncomfortable with the idea of reducing complex human behaviors to a set of equations. These methods are transparent enough that they are easily followed, the statistics are clearly stated, and the results are conclusive.

The detailed review of the background environmental and cultural setting of the Wapato Valley in this chapter also serves this dual purpose. First, such an overview is appropriate for a management study to be used by regional planners and researchers alike. Second, for those reading this thesis as a guide to locational predictive modeling, a review of references concerning flora, fauna, soils, geology, and other aspects of the natural environment; as well as the cultural context of the indigenous peoples of the area, is essential. Measures of the environmental the location of archaeological sites can be evaluated as potential independent variables for predictive models. Ethnographic, ethnohistoric, and archaeological literature can provide valuable information concerning settlement patterns and subsistence, which can help the modeler determine which qualities of the environment would have been most important to people in choosing the locations for their villages and field camps.

**Organization of this Thesis**

Chapter 1 (this chapter) begins with a discussion of the environmental context of this study: the geographical, natural, and geological descriptions of the Columbia River floodplain. This is followed by the ethnohistory, a discussion of the lifeways of the precontact inhabitants of the Wapato Valley, then a summary of the cultural context and archaeology of the area. The chapter concludes with an overview and history of predictive modeling, the basis for this study.

Chapter 2 is a thorough treatment of predictive modeling: the theories behind its development, the different types of predictive models, detailed methods of how they are created, and finally how they are evaluated and applied. Chapter 3 describes how the Wapato Valley Prehistoric Archaeological Site Database was developed. This dataset is the foundation for the Wapato Valley Predictive Model.

Chapters 4 and 5 discuss the specifics of building the Wapato Valley Predictive Model: Chapter 4 deals with the preliminary analysis of the archaeological site and null point data to gauge the potential performance of the model; Chapter 5 goes through the steps of logistic regression analysis, which yields the final model. The fit, performance, and effectiveness, of the final model are analyzed in detail in Chapter 6.

Chapter 7 explains the method of applying the results of logistic regression in ArcView GIS using map algebra. Chapter 8 shows the resulting probability surfaces for each of the eleven USGS quadrangles of the Wapato Valley.

Chapter 9 is a discussion of the findings of the Wapato Valley Predictive Model and how modern hunter-gatherer theory can help explain the results. Criticisms of predictive modeling are also addressed, and answered in the context of this thesis. Chapter 10 concludes with a brief summary, a consideration of potential research using the model, and suggestions for further study.

**Environmental Context**

The Columbia River flows from the east, out of the gorge that it carves in the basaltic bedrock of the Cascade Mountains. The stream gradient drops, and the bedrock that has been confining it into a narrow channel retreats back away from the river, allowing it to spread out into a broad valley of lush green fields and wetlands. This is the Wapato Valley, at the heart of the Portland/Vancouver metropolitan area (Figure 5.2), extending along the Columbia River from the mouth of the Columbia River Gorge at Rooster Rock State Park (River Mile 129) downriver 88 kilometers to the north end of Deer Island (River Mile 76). Lewis
Figure 5.2. Political map of the greater Wapato Valley (USGS 1979 Vancouver Washington-Oregon 1:100,000, 30 x 60 minute quadrangle). Study area is outlined in red; archaeological sites are represented by red triangles.
and Clark named this area for the wapato, “that root or plants growing Spontaneously in this valley only” (Moulton 1990:24). This aquatic plant (Figure 5.3), which grows in the many shallow lakes, ponds, streams, and sloughs that are characteristic of the Columbia River floodplain in this area, produces nutritious tubers which are available for harvest from early fall to late spring, except perhaps during high water (Darby 1996:105). Wapato was a key food resource that helped enable the indigenous Chinookan peoples to be largely sedentary in this area (Darby 1996, Saleeby 1983).

Flora and Fauna

The Portland Basin has a seasonal mean temperature of 4.6°C in January and 20.3°C in July, with an average of 1,076 millimeters precipitation (Franklin and Dyrness 1973:38). This moderate climate and abundant seasonal rainfall support a wide variety of vegetation characteristic of the Interior Valley “Pinus-Quercus-Pseudotsuga” zone of (Franklin and Dyrness 1973:110). Riparian areas are characterized by hardwood forests of black cottonwood (Populus trichocarpa), willow (Salix spp.), Oregon ash (Fraxinus latifolia), bigleaf maple (Acer macrophyllum), Oregon white oak (Quercus garryana), red alder (Alnus rubra), and Ponderosa pine (Pinus ponderosa) (Franklin and Dyrness 1973:124-126), with occasional stands of conifers – mostly Douglas fir (Pseudotsuga menziesii) and western red cedar (Thuja plicata) (Franklin and Dyrness 1973:116).

Understory vegetation, in places quite dense, includes a broad array of roots, bulbs, greens, nuts, and berries. The most significant of these in the resource base of the Chinook, aside from wapato, were camas (Camassia quamash), acorn (Quercus garryana) and hazelnut (Corylus cornuta), and the many variety of berries, including: huckleberry (Vaccinium spp.), wild strawberry (Fragaria spp.), salal (Gaultheria shallon), salmonberry (Rubus spectabilis), thimbleberry (Rubus parviflorus), blackcap (Rubus leucodermis), dewberry (Rubus ursinus), gooseberry (Ribes divaricatum), and black currant (Ribes spp.) (Boyd and Hajda 1986:316-317, Saleeby 1983:171).

Seasonally abundant salmon (Onchorynchus spp.), returned in several annual runs from early spring through the late fall. Other aquatic resources included sturgeon (Acipenser transmontanus) and eulachon (Thaleichthys pacificus), as well as smaller fish and shellfish. Aquatic mammals followed the salmon runs up the river; the river is influenced by saltwater intrusion as far as 75 kilometers (Northwest Power Planning Council 2000:7) – about as far as Clatskanie, Oregon. The key terrestrial resources were deer (Odocoileus spp.), and elk (Cervus canadensis). Small mammals and waterfowl, although represented in the archaeological record, are infrequently mentioned ethnohistorically (Boyd and Hajda 1987:314).

The land both on and up off the floodplain was regularly burned by the native peoples to control underbrush and to maintain open areas, attractive to game animals (Boyd 1999a:118, Habeck 1961:67). In their environmental reconstruction based on data from early maps and soil surveys, Saleeby (1983) and Hamilton (1990) define seven microhabitats in the Wapato Valley. Their findings indicate that the floodplain of the Columbia River in the Portland Basin was an area of varied and diverse habitats that supported a remarkable variety of plant and animal resources, allowing Chinookan peoples to maintain year-round residence in the Wapato Valley (Saleeby 1983:226).

The natural environment of the Wapato Valley of today is a reflection of almost 200 years of modification by Euroamerican settlers. Extensive draining and diking to benefit agriculture and development has resulted in the reduction of wetlands and the concomitant change in the distribution of plants and animals. Where the land has been allowed to remain relatively untouched, however, the historic plant and animal communities continue to thrive.

Evolution of the Columbia River Floodplain

The hydrographic history of the Columbia River is complex and has been punctuated by many powerful geologic events over the millennia, from glaciations to volcanoes to floods. No complete study has been made of the area, but what we do know can give us a general idea of the evolution of the floodplain environment. A listing of the underlying geology of Wapato Valley archaeological sites can be found in Appendix A: “Geology of Wapato Valley Archaeological Sites”. The floodplain soils are discussed in Ap-
Depositional History

During the Pleistocene, a significant amount of the water from the oceans was tied up in the ice masses that covered the land, largely in the northern hemisphere. This effectively lowered sea level, which meant that the Columbia River channel was also significantly lower than today. The Pacific Ocean was at least 60 meters below its present level 10,000 years ago. The periodic collapse of the glacial dam at Lake Missoula in Montana at the end of the Pleistocene resulted in catastrophic floods on the Columbia River as late as 13,000 years ago, or even more recently. Known as the Missoula (Bretz) floods, these events filled the Portland Basin with water up to elevations of 120 meters. Ponding in the area, because of the inability of the floodwater to pass quickly enough down the restricted river channel, caused extensive sediments to be deposited, to a depth of at least 20 meters (O’Connor 2004:400, Trimble 1963:98). Later downcutting of these deposits was slowed by the rising sea level, rapid from 10,000 to 7,000 years ago then more gradual to about 2,000 years ago. The resulting change in river gradient caused a gradual redistribution of the Bretz deposits and the accumulation of additional alluvial materials.

More recently, in the early fifteenth century, a catastrophic landslide at River Mile 147 just upstream from the present location of Bonneville Dam may have temporarily blocked the flow of the Columbia River (Bourdeau 1999:71, O’Connor 2004:410). There is continuing debate about the duration of this so called Bridge of the Gods, and whether or not a cataclysmic flood resulted when the debris dam was breached. No deposits have yet been seen in the archaeological record that are considered definitive evidence of such a flood.

Geomorphology

The oldest geomorphologic surface related to these processes in this section of the Columbia River is the Winkle surface, from 50-100 feet in elevation, with sediments radiocarbon dated to between 5200 and 12,200 years ago. The Ingram surface at 20-50 feet was the active floodplain from approximately 550 to 3300 years ago. The period of 3300 to 5200 years ago was transitional between the two surfaces, represented by more active downcutting and sedimentation, until stability was achieved at the Ingram surface. The greatest portion of the current floodplain is represented by the Ingram surface. In spite of the regulating effect of upstream dams, limited downcutting still continues, with the recent Horseshoe surface of less than 20 feet elevation representing activity within the last 550 years (Green 1983:134).

Adding to this complex formational history, there is also an indication of subsidence occurring in Wapato Valley. The Sunken Village site (35MU4) on Sauvie Island (Newman 1991) is just one of many that are at the edge of the current normal water level and extend underwater, leading to the assumption that some localized areas have experienced a drop in elevation.

The floodplain of the Columbia River is a dynamic environment that has reached relative stability only in the last 3300 years. Currently, the oldest archaeological site in Wapato Valley dates just from this time period: the Old Channel Complex site (45CL31) on Vancouver Lake is dated to 3510 ± 100 and 3360 ± 70 radiocarbon years before present (Wessen and Daugherty 1983:134).

Ames (1994:14) suggests that the apparent profusion of sites younger than 2,000 years old is due to an increase in “livability” of the landform due to 1) changing sea levels, and 2) the maturation of the floodplain environment. I would underscore his second explanation: the surfaces that people lived on before 3300 years ago are no longer present. If the age range for the Winkle land surface is correct, corresponding to the time of the greatest rise in sea level, floodplain sites in the 3300-5200 year range may have been eroded away by the downcutting of the Columbia River. Sites of this age may yet be found up off the floodplain on this older surface. Floodplain sites older than about 5200 years would be as Ames states, drowned or buried under sediment.

Ethnohistory

Locational predictive modeling relies on the contrast between the places in the environ-
ment where archaeological sites are located and the places that they are not. It is important to learn as much as possible about the past lifeways of the individuals whose settlement patterns are to be predicted, in order to be able to acquire a sense of the qualities of the environment that were the most important to these people in the siting of their settlements. This overview discusses the aspects of the lives of the Chinookan peoples of the Wapato Valley that are the most significant in the development of this model.


Subsistence

The people of the Wapato Valley most likely made their initial entrance onto the Columbia River many thousands of years ago during the waves of coastal migration from the north (Fladmark 1979:64). These hunter-gatherers were at home on the water, accustomed to travel by boat, and adept at harvesting and utilizing the resources of the sea. It is plausible to suggest that their shift from a marine to a riverine economy was an easy one, considering the many analogous species of the Wapato Valley.

A great diversity of plants and animals was exploited for food by the indigenous people of the Wapato Valley. The patchy floodplain environment provided a range of habitats that supported seasonally abundant resources, which overlapped in their temporal distribution so that fresh food was available throughout the year (Saleeby 1983:168-183).

The Five Mile Rapids site at The Dalles (35WS4), with its assemblage of hundreds of thousands of salmon vertebrae dating from about 9,000 years BP (Before Present) (Ames and Maschner 1999:23), suggests the importance of salmon at an early date. Even if, as hypothesized, salmon runs did not attain their modern distribution until the postglacial stabilization of the landscape at about 5,000 years ago (Darby 1996:20, Saleeby 1983:9), it is apparent that they still played a critical role in the subsistence of early inhabitants of the Columbia River.

As important as salmon was, however, it would be the plant foods of the Wapato Valley that would allow these people to truly flourish as the floodplain environment matured. Within the last 3,000 years BP, the overlapping of the critical resources of salmon and wapato (high contingency versus high constancy, after Ebert and Kohler 1988:139) would have allowed for lower residential mobility and increased sedentism. Saleeby (1983) and Darby (1996) hypothesize that such year round resource abundance enabled the Chinook to be largely sedentary within the Wapato Valley, challenging the ideas of earlier anthropologists (Dunnell et al. 1973, Hajda 1984, Skolnik et al. 1979) who proposed a seasonal-round type of subsistence strategy for these people.

The Chinookan peoples of this period exhibited most if not all of the qualities of complex hunter-gatherers, or affluent foragers. Such groups are characterized by permanent villages, household-based economy, ownership and control of property, high population density, resource intensification, manipulation of the environment to increase productivity, food storage, complex material culture, social stratification, occupational specialization, and participation in trade networks (Ames and Maschner 1999:24-29). Especially important to this present study are those attributes that influence settlement location.

Villages and Population

Villages were independent units, both economically and politically, and were often named for either their locality or their chief. Chinookan villages were permanent, in the sense that they represented an established occupation at a certain location (Saleeby 1983:61). That is not to say that everyone resided there during every month of the year. The procurement of seasonal resources of-
ten took people away from the village for shorter or longer periods. Floodwaters may have even caused the entire population to temporarily relocate until the water receded (see Appendix C: “Columbia River Floods” for a detailed discussion of the effects of flooding on settlement patterns in the Wapato Valley). However, it is likely that some individuals occupied the site year round (Daehneke 2005:29).

Chinookan villages in the Wapato Valley were known for their split cedar plankhouses, some of great size. The largest house at Cathlapotle (45CL1) was greater than 60 meters long (Ames et al. 1999:37). In 1806, Lewis and Clark describe Cathlapotle as having 14 houses, and estimate the population at 900 (Moulton 1990:484).

Kroeber (1938:136) described the Wapato Valley as the locus of one of the greatest prehistoric concentrations of Native American peoples in North America. Governor George Simpson of the Hudson’s Bay Company reports that “The population on the banks of the Columbia River is much greater than in any part of North America that I have visited as from the upper Lake to the Coast it may be said that the shores are actually lined with Indian Lodges” (Simpson 1968[1824-25]:94). Clark writes on November 5, 1805, that the valley was “at this time Crouded with Indians” (Moulton 1990:24).

During the winter of 1805-1806 while at Fort Clatsop, Clark recorded in his journal a population estimate for the Chinookan peoples of the Wapato Valley of 2330 (Moulton 1990:478). A higher figure of 5490 (Moulton 1990:484) appears to have been written in a later document, and may reflect the party’s observations on their return trip (Moulton 1990:488n). This difference in estimates is probably due to the seasonal influx of individuals from other tribal groups for fishing and the harvesting of wapato (Boyd and Hajda 1986:318, Hajda 1984:71, Moulton 1991:40, Saleeby 1996:71). This figure also represents a population estimated to have been reduced by at least 30 percent after the first smallpox epidemic in the late 1700s (Boyd 1999b:21).

**Transportation and Trade**

The success and affluence of a given village was largely a function of the skill of the chief in securing prosperity for his people, primarily through effective diplomacy, marriage alliances, and control of trade (Silverstein 1990:541). Villages were often sited on the main stem of the Columbia itself or strategically at major confluences, allowing chiefs to exert control over communication and commerce on the river, as well as over access to its tributaries and to the interior (Hajda 1984:90).

The Columbia River, the superhighway that flowed past the doors of the Chinookan residents of the Wapato Valley, was central to the lifeways of her people. Travel by water was essential in order to take full advantage of the resources of the floodplain. In most areas, it was not possible to travel more than a kilometer by land without encountering one waterway or another. A useful way of looking at this landform is to think of it as a watery environment with many islands, as opposed to a dry landform with many rivers, streams, lakes, and sloughs. Such a water-based perspective can aid in understanding many aspects of the everyday lives of the Chinookan peoples, including the decisions that they made concerning residence and resources.

The people of the Wapato Valley excelled in the manufacture and use of the many sizes and types of canoes that were essential for everyday subsistence and commerce. Lewis and Clark both write extensively about Chinookan canoes on February 1, 1806, with Clark remarking that “Some of the large Canoes are upwards of 50 feet long and will Carry from 8 to 12 thousand lbs. or from 20 to 30 persons” (Mouton 1990:267). At the Ne er cho ki oo village, Clark sketches (Figure 5.4) and describes the Small Canoes which the women make use of to gather Wappato & roots in the Slashes. Those canoes are from 10 to 14 feet long and from 18 to 23 inches wide in the widest part tapering from the center to both ends in this form and about 9 inches deep and so light that a woman may with one hand haul them with ease, and they are sufficient to carry a woman an some loading. I think 100 of those canoes were piled up and scattered in different directions about in the Woods in the vicinity of this house; [Mouton 1991:57-58]
Figure 5.3. Wapato (Pojar and MacKinnon 1994). Photo courtesy of the US Fish and Wildlife Service (pacific.fws.gov/ridgefield/Wapato.jpg).

Figure 5.4. Two Views of a Canoe, April 2, 1806, Voorhis No. 2 (Moulton 1991:58). The above quote can be seen surrounding the canoe sketch.
Patrick Gass, another member of the Lewis and Clark expedition, remarks that “The natives of this country ought to have the credit of making the finest canoes, perhaps in the world, both as to service and beauty; and are no less expert in working them when made” (MacGregor 1997:172).

Because, as Lewis and Clark stated (Moulton 1990:24), wapato grew primarily in this valley only, all access and trade in this pre-eminent commodity flowed through the chiefs of the Wapato Valley. Lewis further goes on that “the wappetoe furnishes the principal article of traffic with these people which they dispose of to the nations below in exchange for beads cloth and various articles. The natives of the Sea coast and lower part of the river will dispose of their most valuable articles to obtain this root” (Moulton 1991:28). These explorers came to rely upon wapato as much as the indigenous population, making frequent purchases while on the Columbia River and at Fort Clatsop to supplement their diet of fish and game. Darby (1996:71) states that the journals of Lewis and Clark mention wapato more than ninety times.

The ease in moving around the landscape afforded to the Chinookan peoples by their canoes made them truly masters of this environment. The Columbia River was the main thoroughfare for communication and commerce, and they controlled the traffic. Their strategic position between the Coastal and Cascades native groups, together with the local resource abundance, enabled the Chinookan peoples of the Wapato Valley to take full advantage of this position as middlemen in the regional trade network.

Summary

The Chinookan peoples of the Wapato Valley were deeply linked to the Columbia River, the resources it supported, the mobility it allowed, and the opportunities it presented. The natural abundance of this land enabled them to be largely sedentary within a hunter-gatherer subsistence system, and take on the qualities of affluent foragers. Any model concerning the siting of permanent villages and temporary camps in the Wapato Valley needs to be mindful of the essential role of the Columbia River, its tributaries, and water travel, to the lifeways of the Chinookan peoples.

The Wapato Valley Predictive Model investigates and quantifies this relationship through independent variables that reflect the importance of access to water for both subsistence and travel.

Cultural Context

The modern Wapato Valley lies at the heart of the Portland/Vancouver metropolitan area, which is, according to the 2000 census, the twenty-third largest metropolitan area in the United States. The ground-disturbing activities that come with agricultural and urban development alike have definitely taken their toll on archaeological resources – as have looting, vandalism, and amateur archaeologists – yet some sites still remain untouched. The floodplain of the Columbia River was, and continues to be, the location of some of the richest prehistoric archaeological sites in the Portland Basin.


History

When Kenneth Ames, professor of anthropology at Portland State University, arrived in Portland in the mid-1980s, colleagues told him that “research on the valley floor on the later prehistory of the region was a complete waste of time because everything was disturbed or destroyed” (Ames 1994:57). Ames went on to discover the remains of the large Chinookan village of Cathlapotle (45CL1), visited by Lewis and Clark on March 29, 1806, on the Columbia River floodplain on the present Ridgefield National Wildlife Refuge. The Portland State University archaeological field school conducted excavations there for six years (Ames et al. 1999). Several other ethnographically documented villages have yet to be located.

Ames (1994) provides the definitive work

Pettigrew (in Ames 1994:49) established four periods in the history of archaeology of the Columbia River from The Dalles to the river’s mouth, beginning with the Early Amateur Period (Contact to 1923). Artifact collecting by early settlers in the 1800s and early 1900s gave way to early amateur archaeological societies in the mid-twentieth century that institutionalized artifact collecting and the looting of sites. Some private landowners and collectors continue to be a problem – even now. There still exists a widespread attitude of “finders keepers” concerning the cultural remains of indigenous peoples.

Pettigrew’s Early Professional Period (1924-1950) saw the beginning of the first research in the area. Archaeologists from the University of California, Berkeley, did limited testing on Sauvie Island in 1924, but the details of this work are not known (Ames 1994:49). Professional work began in earnest in the mid-twentieth century and began to impact attitudes about cultural resources and the way that archaeology was practiced. The first archaeological sites actually recorded in the area were in 1948, when Robert Hudziak and Clarence Smith conducted a survey along the Washington side of the Columbia River for the University of Washington. They recorded sites 45CL1-4 in the Wapato Valley as well as others farther downstream, including a site at the location of the old village of Chinookville (45PC4) just east of McGowan in Pacific County.

The Reservoir Survey Period (1951-1965) saw the maturation of archaeology as a profession in the Pacific Northwest, although much of the work associated with these projects took place east of the Wapato Valley. Two general surveys in the area were completed during this period. The local amateur organization, the Oregon Archaeological Society (OAS), conducted several large excavations at some of the better-known sites in the late 1960s and early 1970s. Attempts were made to begin to operate according to standards that were more systematic and professional. Brief written reports were even published at the end of each excavation project, however members were still allowed to pocket the artifacts they unearthed.

With the emphasis on the scientific method of the “New Archaeology” (Johnson 1999:20) and the passage of the National Historic Preservation Act in 1966, Pettigrew’s Recent Period from 1966 to the present (also known as the Developed Professional Period after Ames 1994:49) is characterized by hypothesis-driven research and cultural resources management (CRM). Pettigrew (1981) developed a culture chronology for the area, and Dunnell et al. (1973) and Skolnik et al. (1979) did the first work on site types and settlement patterns, later challenged by Saleeby (1983). Numerous sites along Lake River, Vancouver Lake and Sauvie Island were surveyed and recorded.

Most recent research projects in the Wapato Valley have taken place through Portland State University, including the excavation of a plankhouse at the Meier site (35CO5) in Scappoose, and the village of Cathlapotle (45CL1). The OAS now assists professionals in their work and does not conduct its own excavations. In 1994, Ellis and Wilson developed a predictive model for Clark County to aid in the preservation and management of archaeological sites on the Washington side of the Columbia River in the Portland Basin.

Several local private firms employ professional archaeologists and have extensively surveyed and tested in the Wapato Valley, with a few large-scale excavations. A number of projects have been associated with the development of the Columbia South Shore area near the Portland airport (Burtchard 1990, Ellis and Fagan 1993, Minor et al. 1994). Most of the CRM work is compliance-driven or salvage in nature, in advance of building or highway construction, or other ground-disturbing activities.

Archaeological Sites

The distribution of prehistoric sites in the Portland Basin is skewed strongly toward the floodplain areas along the Columbia River and its tributaries. This phenomenon can be explained in several ways. The cities of Portland and Vancouver have been built on the less flood-prone higher elevation areas. This development took place in
the days before anyone gave a second thought to destroying the vestiges of Chinookan culture, except perhaps to pause to collect a few curios. Much of this part of the archaeological record is effectively lost to us, although some sites may yet be discovered through the grace of modern cultural resource laws as rural lands are developed. Some of the earliest sites in the entire region have been found in such upland areas (Pettigrew 1990:520), which is to be expected if rising sea levels inundated the older floodplain sites.

A corollary of the first explanation has to do with the lack of systematic regional survey projects in the Wapato Valley. The distribution of archaeological sites closely follows the distribution of surveyed areas. Portions of the map (Figure 5.3) without any archaeological sites represent areas that have either had their archaeological resources destroyed, or have yet not been surveyed at all. We can expect that as more of the floodplain is surveyed, some of those blank areas will fill in.

Another reason for the preponderance of archaeological sites on the floodplain is that the land there – often not suitable for development without extensive modification because of the low water table – is largely agricultural. Extensive wetlands have also been set aside as state and federal reserves, including the Ridgefield National Wildlife Refuge. Such low impact uses have favored preservation of the archaeological record in these areas, in spite of some landowners who view sites on their property as their own private gold mine.

The most obvious reason for the abundant archaeological sites on the floodplain is that this is where the indigenous population spent most of their time. This is where the most reliable resources could be found; this is where travel was most expedient; this is where the largest villages were located. This is also where ground-disturbing activities are most likely to impact aboriginal cultural materials.

Of the 276 recorded prehistoric archaeological sites on the floodplain of the Columbia River in the Wapato Valley (as of December 2003), 50 are classified as villages, having some evidence of the remains of either plankhouses or pithouses. Eighty-eight percent of these villages are sited on the main stem of the Columbia River or on its major tributaries (see Example 2 in Chapter 10). Even a cursory glance at the map showing Wapato Valley archeological sites (Figure 5.3) reveals a definite preference for areas in proximity to waterbodies that are accessible by canoe. Archaeological sites located away from navigable water may be mostly temporary camps, or special-use sites whose purpose remains uncertain.

One of the more interesting hypotheses about prehistoric site location concerns the natural levees or elevated ridges along the Columbia River. Bourdeau (2002) proposes that these ridges were created when the Columbia River overtopped its banks during periods of greater deposition following eruptive periods of Mt. St. Helens and Mt. Hood. Lahars filled the river channel with sediment causing shoaling of the river, and subsequent deposition of the sediment load as scroll bars on the adjacent riverbank areas. Chinookan peoples took advantage of these ridges as prime real estate for village sites: close to the Columbia River, composed of well-drained sandy sediments, and relatively higher in elevation to avoid seasonal flooding. One of the oldest sites in the Wapato Valley, Merrybell (35MU9), is located on one such ridge which is now considerably inland, about halfway between the Columbia River and Multnomah Channel on Sauvie Island. If Bourdeau is correct, the Chinookan peoples of the Wapato Valley were aware of this depositional pattern over the millennia and used it to their benefit. Such ridges may host some of the oldest sites in the area.

Most archaeological sites in the Wapato Valley date from the late prehistoric period (Ames’ Late Pacific or Pettigrew’s Multnomah) since rising sea levels inundated sites older than about 5,000 years. The oldest sites on the floodplain are: the Old Channel Complex (45CL31) on Vancouver Lake, Merrybell (35MU9) on Sauvie Island, the Lewis River/Lancaster site (45CL117) on the Lewis River, and 35MU117 on Bybee Lake. These dates range from about 3510 to 2800 radiocarbon years before present, or from about 1400 to 900 BC. A complete listing of the radiocarbon dates for all of the Wapato Valley sites may be found in Appendix D: “Wapato Valley Radiocarbon Dates”.

136
Summary

The archaeology of the Wapato Valley has a back-story of artifact collecting by early settlers, organized looting by amateur archaeology groups, and continued destruction through the avoidance of compliance with modern cultural resources laws. It is a wonder, as Kenneth Ames was told to doubt, that there is actually anything left at all.

Prehistorically, this was a land of abundant resources, of large villages, and of prosperous people. Chinookan technology was, however, largely perishable – wooden and bone tools, wood and fiber boxes and baskets, skin and fiber clothing – with few stone tools. The item of material culture that would have left the greatest impact on the land was the split cedar plankhouse. After the indigenous population was virtually wiped out by smallpox, malaria, measles, and venereal disease, the vestiges of their material culture and once-sturdy houses returned to the earth, along with the remains of her people. The damp climate of the Wapato Valley, so nurturing for the growth of wapato and cedar trees, is not as considerate when it comes to organic preservation. To the casual observer, everything was gone.

However, there is a tremendous amount still here. Over 276 archaeological sites, including 50 villages, have been recorded in the Wapato Valley – and those are just in the areas where we have looked. Many parts of the floodplain have never been surveyed for archaeological resources. Numerous campsites and villages mentioned by early explorers have never been found.

The Wapato Valley Predictive Model will allow researchers to pinpoint areas that are most environmentally similar to the locations of known archaeological sites. Locations with the highest scores for site probability can be selected for survey, excavation, and research. These areas can likewise be avoided more effectively during ground-disturbing activities, helping to protect and preserve the remaining archaeological resources of the Wapato Valley.

Predictive Modeling: A Primer

Locational predictive models analyze patterns of settlement and subsistence in the archaeological record and project these patterns onto the modern landscape. In this respect, they are more properly thought of as projective models (Ebert and Kohler 1988:127). These models identify relationships between environmental and cultural variables thought to be relevant to the siting of past villages, field camps, and activity areas. Other locations in the same area that are known not to contain archaeological sites – surveyed areas where sites were not found or random null points – are typically used as a comparison set to the identified sites. It is this measurable difference between the two sets of locations that allows predictions about site presence to be made.

Places on the landscape that have characteristics similar to those at locations of known archaeological sites are considered more likely places for the future discovery of sites (Kvamme 1988b:327). This likelihood can be calculated through the multivariate statistical technique of logistic regression, which can identify the strongest predictor variables and their role in site presence. The strength of the correlation between the combined predictor variables and site presence is expressed as a probability score between 0 (low site probability) and 1 (high site probability). Locations that possess values for predictor variables similar to those of known sites can be said to have a high probability for future site discovery. These probabilities can be measured, ranked and displayed on topographic maps with the aid of GIS for use by archaeologists and other researchers, as well as by land management agencies and developers.

From Settlement-Pattern Analysis to Predictive Modeling

For decades, archaeologists have sought to discover patterns in the archaeological record to help them make sense of distributions of artifacts, features and sites, better enabling them to understand how and why people lived and made the choices they did in the past. Early work centered on the relationship of prehistoric people to the natural environment, and how qualities of their surroundings shaped the decisions that they made about where to live. The following are some high points in the development of the analysis of these patterns, which evolved from a more intuitive, subjective approach to today’s scientific practice of predictive modeling. Kohler provides an excel-

Steward’s work in cultural ecology (1938) is the foremost pioneering study in settlement-pattern analysis. He was interested in causal explanation, not just correlation; emphasized the influence of the local environment on culture; and, in his “culture core” concept, identified specific pathways through which the environment might influence culture (Kohler 1988:26). His work provided a foundation for future studies in locational modeling and continues in popularity to this day in hunter-gatherer studies (such as Bettinger 1980, 1991; Binford 1980), and in the field of evolutionary ecology (Kohler 1988:29).

Willey (1953:1), in his study in the Virú Valley in Perú, explained the term settlement pattern as “the way in which man disposed himself over the landscape in which he lived” and thereby defined a new field of study in archaeology. He was interested in the full range of possible influences on site location: environmental, but also economic, social, political, technological, sacred, and defensive. Many authors who followed Willey’s work emphasized the importance of environmental variables in the distribution of people across the landscape (Kohler 1988:30).

Catchment analysis was a natural expansion of settlement pattern studies (Roper 1979). The placement of a site was evaluated in terms of the surrounding resources, not just the immediate environment, as well as in terms of the costs in time, energy and transportation required to exploit those resources (Kohler 1988:31).

Hypothesis testing, model development, and statistical analysis entered the realm of settlement-pattern analysis in the 1970s, as researchers sought to quantify their observations about correlations between site location and environmental variables. This change parallels the adoption of the scientific method in hypothesis building and testing that came with the New Archaeology in the late 1960s and early 1970s (Johnson 1999:20). The Southwest Anthropological Research Group (SARG) helped to introduce formal statistical techniques into locational modeling, though their application was still seen to be of primary use in cultural resource management. Kohler (1988:33) notes that Sullivan and Schiffer, two of SARG’s participants, did not make the jump from the settlement-pattern type analysis to predictive modeling of the spatial distribution of archaeological sites. They failed to see the potential of these techniques to go beyond description and actually anticipate site presence, as a way of getting at the human behavior behind the patterns in the distribution and movement of people across the landscape.

Predictive Modeling Goes High-Tech

Since the 1970s, predictive modeling has moved beyond the intuitive, subjective and therefore potentially biased descriptive reports of observed correlations between site location and environment. The 1980s saw a proliferation of predictive models, although many associated techniques were still in their early stages of development. The work of Kvamme (1988a, 1988b, 1989, 1992) is by far the most influential of this period. He adapted statistical and early computer mapping techniques in the processing and analysis of the vast amounts of data that most models generate, and in the display of the results in digital format.

Within the last 20 years, the development of inexpensive, powerful computers, and the refinement of geographic information systems, have revolutionized the field of predictive modeling. The sheer volumes of manual data gathering and calculations once required to build these models, and the inaccuracies of early small scale digital maps, have been replaced by sophisticated statistical programs and readily available high resolution digital images of many kinds. Several important edited volumes contain many of the significant contributions of this period: Aldenderfer and Maschner 1996, Allen et al. 1990, Carr 1985, Judge and Sebastian 1988, Lock and Stančič 1995, and most recently Westcott and Brandon 2000.

Predictive modeling has become an effective and economical tool for the discovery and management of cultural resources. Successful models can be built using existing data and applied to large areas. One of the most ambitious and comprehensive projects incorporates the en-

Predictive models are useful to project planners, developers, and others assessing lands prior to construction or land management projects. The model’s identification of low probability areas can help streamline the process of archaeological survey when the discovery of cultural resources is not anticipated. Projects can more easily avoid high probability or potentially sensitive areas. The unanticipated discovery of archaeological materials and resulting project delays can thereby be minimized. Predictive models can help planners know what to expect, without digging.

Through their pattern-recognition ability, predictive models allow scholars and researchers to focus on those areas of the landscape where archaeological resources are most likely to occur. Perhaps more intriguing, archaeological sites that lie in low probability areas can be studied to try to determine why they are located where least expected. New insights can be gained into the lifeways of prehistoric people through the study of the distribution of probability areas revealed by the model. A predictive model can be an effective tool in the management of archaeological resources, as well as a stimulus for further research.

Conclusions

The Wapato Valley was the home of one of the most affluent indigenous groups in North America, the Chinookan peoples of the Columbia River. Ethnographic and ethnohistoric accounts, together with inferences from the archaeological record, reveal that their lives were centered on the Columbia River and its major tributaries. Travel by water was essential for subsistence, trade, communication, and social and political interactions. The inconvenience of periodic flooding was more than made up for by the expediency of locating settlements close to navigable water. The abundant year-round resources of the Wapato Valley enabled the precontact Chinook to be largely sedentary within a hunter-gatherer subsistence system.

If we projected these lifeways back at least 3,000 years, reasonable because of the relative stability of the climate, environment, and resources, what would the arrangement of villages and camps look like on the landscape? What sort of pattern of distribution of cultural remains would such people leave behind? Is there evidence of this pattern in the archaeological record? Can these patterns be detected through logistic regression, and projected through GIS for the region as a whole? What can the patterns revealed tell us about the lives of the precontact Chinookan peoples of the Wapato Valley?

This study will answer these questions through a statistical analysis of the archaeological record of the Wapato Valley. Qualities of the environment at the locations of archaeological sites were recorded, and then evaluated for significance through logistic regression analysis. The results were then applied through ArcView GIS to the entire study area, yielding a probability surface of the likelihood of the occurrence of prehistoric archaeological sites anywhere in the Wapato Valley.

This locational predictive model will be an invaluable aid for the study of the lifeways of the precontact Chinook. The database alone, pulling together information on all prehistoric sites from both Washington and Oregon, will facilitate both research and CRM projects for all archaeologists. It will also allow land agencies such as the US Fish and Wildlife Service and the Oregon Department of Fish and Wildlife to make better-informed decisions about projects and ongoing processes that could impact archaeological resources.

Planners will be able to consult the Wapato Valley Predictive Model when developing proposals for ground-disturbing activities, such as building and highway construction, or other land surface modification. A review of the archaeological site probability zones should become a part of the approval process for such projects. Before construction even begins, plans could be evaluated for high probability areas near the project site, and modified as necessary to reduce the possibility of encountering unexpected archaeological materials during construction. Clark County, Washington already uses such a predetermination process for its building permits, based on the predictive model developed by Ellis and Wilson (1994). This practice would benefit the Oregon counties of Multnomah and Columbia as well. The Wapato
Valley Predictive Model has the potential to be an invaluable tool for the protection and preservation of the archaeological record throughout the entire Wapato Valley.
CHAPTER 2
CONCEPTUAL FRAMEWORK

Archaeological predictive modeling, as it is currently practiced, has developed its own theoretical and technical perspective. There are a variety of methods used to generate models, depending on the data available, financial resources, time constraints, and the goals of the project or the research questions. However, most models are structured along similar principles. The following is an overview of the essential elements of archaeological predictive modeling. Hudak et al. 2000, Kohler and Parker 1986, Kvamme 1988a and 1988b, Rose and Altschul 1988, and Warren 1990a offer more detailed information on different aspects of model design and building. Specific applications of these principles and methods in the Wapato Valley Predictive Model are covered in subsequent chapters.

Assumptions

A few basic assumptions underlie the practice of predictive modeling. Known archaeological sites used in the development of the model must be reasonably representative of the area under study (Kvamme 1988b:327). Since human behavior is patterned, and therefore the outcome of the decisions that people made about where to live are also patterned, archaeological sites are assumed to be non-randomly distributed across the landscape (Rose and Altschul 1988:175). So it follows that the places where archaeological sites are located must necessarily be measurably different from the places where sites are not, in order to be able to distinguish between the background environment and potential sites (Warren 1990b:201).

Predictive modeling further assumes that such patterns of locational behavior can be perceived and measured through statistical analysis and generalized to the entire area (Rose and Altschul 1988:175). It is also assumed that the contemporary environment is a reasonable proxy for the paleoenvironment (Church et al. 2000:138), or that the paleoenvironment can be estimated or reconstructed.

Most archaeological predictive models rest on two additional assumptions:

First, the settlement choices made by prehistoric peoples were strongly influenced or conditioned by characteristics of the natural environment. Second, the environmental factors that directly influenced these choices are portrayed, at least indirectly, in modern maps of environmental variation across an area of interest. (Warren 1990b:202)

Models

Models are, according to David Clarke (quoted in Judge and Sebastian 1988:1), “hypotheses or sets of hypotheses which simplify complex observations whilst offering a largely accurate predictive framework structuring these observations”. A good model allows us to generalize our findings to other similar, but unknown, groups. Kohler (1988:33) defines an archaeological predictive locational model as “a simplified set of testable hypotheses, based either on behavioral assumptions or empirical correlations, which at a minimum attempts to predict the loci of past human activities resulting in the deposition of artifacts or alteration of the landscape”. Kohler (1988:35) goes on to use “operationalized” to refer to a model whose terms have been so carefully defined that the same predictions can be made from the model by different people. Such a model thereby fulfills the requirements of verifiability and replicability of the scientific method.

Types of Predictive Models

Locational predictive models are hypotheses about past human behavior that seek to describe observed patterns in site location and to project them into areas where the archaeological record is not known. These patterns can be hypothesized from what is known about that particular culture – from ethnographic and historical accounts, through deductions based on past archaeological research, and from observations about the environment (or reconstructions of the paleoenvironment) at the location of the archaeological site.

Predictive models can be classified into two broad categories: deductive and inductive (Kohler and Parker 1986:399). Deductive models, also known as behavioral or explanatory, are developed through proposing and testing hypotheses concerning assumptions about past behavior and the structure of the environment (see Dalla Bona
Such models consider how and why humans made choices concerning location – the mechanisms and goals – and define a way of measuring this in the archaeological record (Kohler and Parker 1986:432). These models can be difficult to design and implement, but have the potential to provide a good understanding of why people located their settlements and activities where they did.

Inductive models are also known as correlative or empirical. These models investigate patterned relationships between site location (the dependent variable) and observable and measurable qualities of the environment (the independent variables). Independent variables can be continuous, categorical, or even express social and cognitive values of the environment, as long as these variables are spatially based or cause spatial patterning (Gaffney and van Leusen 1995:370, Kvamme 1988b:338), and are therefore measurable. Ideas about significant correlations between past behavior and site location can help guide the selection of the independent variables (Warren 1990a:91). The results of such inductive models should be accompanied by hypotheses that seek to explain the meaning of the correlations found, in order to advance our understanding of the past (Warren 1990a:90).


**Probability Models**

Probability models, using logistic regression and other similar techniques, are an especially powerful type of inductive predictive model (Warren 1990a:91). These models measure the likelihood that a given location will contain an archaeological site. The unit of investigation is the location or land parcel, and the dependent variable is binary and coded 0 for site absence or 1 for site presence, according to whether or not there is an archaeological site at this location (Kvamme 1988b:326).

The power of these probability models relies on the contrast between archaeological sites and the background environment. “A null model of random location is absolutely essential to determining the role of environmental factors in [archaeological site] location” (Kohler and Parker 1986:415). The independent or predictor variables are measured for both the sample of sites in the model and for a set of null points randomly selected from the environment as a whole. The significance of the difference between these two sets of data is evaluated through univariate and multivariate statistics. Stepwise logistic regression analysis selects the strongest independent variables in the determination of site presence and assigns a probability score between 0 and 1 that is a measure of the strength of this correlation: the closer the score is to 1, the greater the chance that there is a site on a particular parcel of land. The researcher can assign any score cutpoint desired to define site presence, with .5 being commonly used.

In addition, or as an alternative to null points, some researchers have used points on the landscape from areas that have been surveyed for archaeological sites, where sites were not found, for their non-site sample (Ellis and Wilson 1994, Hudak et al. 2000). However, this can weaken the model through an underestimation of environmental variation. In a region that has not been well surveyed, such non-site locations can be much more similar to archaeological sites than is probably the actual case for the environment as a whole (Kvamme 1988b:356). If archaeological sites are truly rare phenomena (less than 1 percent of the total area), then a random sample of null points provides a better comparison (Kvamme 1988b:357). Such surveyed areas are also subject to sampling bias if they were not set up using the laws of probability. The Minnesota Archaeological Predictive Model (Hudak et al. 2000[7]:6) devised a separate survey probability model, but omitted any non-probabilistic surveys from their samples.

**Data Sets**

The site data used to develop empirical predictive models can come from two sources:
preexisting data, and data compiled expressly for the model. Because of the time and expense involved in conducting new surveys, most researchers try to use information that has been compiled over the years at their State Historic Preservation Office (SHPO), the repository of archaeological site forms and reports. However, there can be a considerable problem with the accuracy and consistency of these records (Kvamme 1988a:302). Sometimes extensive review and analysis needs to be done in order to verify the accuracy of the information in the site reports – especially the locational information, which is the basis of all the relationships and calculations in GIS.

The non-site points that are used for comparison to site location can come either from surveyed areas where no archaeological sites were found, or from random points in the environment (see discussion above under “Probability Models”). There should be at least as many null points as archaeological sites, although the quantities do not have to be the same. A method of correcting for the difference in sample size between the archaeological sites and null points is detailed in Warren and Asch (2000:29).

**Independent Variables**

After verifying the position of the archaeological sites and null points in the study area, all locations are measured for the environmental variables thought to have been important in the siting of villages and camps. This initial assessment of potentially significant variables is best made after a thorough study of the archaeological, ethnographic, and ethnohistoric literature about the prehistoric lifeways of the indigenous peoples of the region. This step is equivalent to hypothesis building, which is then tested statistically through preliminary data analysis and then through logistic regression.

Many different environmental qualities have been found to correlate with an increased likelihood of site presence in different regions. For the purposes of model building, these independent variables can be discrete or continuous, and measured on any scale (nominal, ordinal, interval, or ratio). However, because information is lost in the reclassification, such rescaled variables (as well as those measured on a nominal or ordinal scale) have less predictive power than interval and ratio scale data (Kvamme 1988b:333).

Some of these variables can reflect simple terrain measures such as elevation, slope, and distance to water or other critical resources. Kelly (2001:107) found a positive correlation of site presence with distance to huckleberry patches in the Oregon Cascades. Variables that can be thought of as an indirect or proxy measure of some other quality of the landscape include aspect (solar exposure); proximity to major travel corridors (ease of communication and transportation); and soil type, permeability and runoff (factors in settlement location or agriculture). Some researchers have used distance to nearest stream confluence as an independent variable (Gillings 1995, Kelly 2001). Maschner (1996:183) found that there was a positive correlation of site presence with beach quality on the Northwest Coast, with the Tlingit having favored sand and pebble beaches over rock and boulder beaches. Kvamme (1992:26) discusses the development of indices for measuring shelter (protection from wind and weather) and view shed (hunting, defense, aesthetics). Variables can also be given different weights, based on their perceived contribution to the decision making process. Dalla Bona (2000:76) assigned greater weight, and therefore greater predictive potential, to dry drainages over wet ones.

Kohler and Parker (1986:433) believe that many models strive to be overly complex, and that perhaps people keyed in on only a few significant variables in making locational decisions. Altschul (1990) developed a predictive model for a 3640-hectare area in Arizona, for which 70 percent of all site locations were predicted with just three variables. Warren and Asch (2000:16) took 24 different environmental measurements and found significant differences between sites and non-sites with 21 of the 24. However, through stepwise logistic regression, only six variables were incorporated into the model. The rest were bypassed because they correlated with more powerful predictors that had already been selected. The Clark County Predictive Model (Ellis and Wilson 1994[D]:12) found a 69 percent overall success in classification with only three variables (distance to water, elevation and soil type). “The traditional approach to statistical model building involves seeking the most parsimonious model
that still explains the data” (Hosmer and Lemeshow 2000: 92).

One final concern in the selection of independent variables is the possibility of collinearity between variables. For example, the variables of elevation and vegetation type can be highly associated with each other in areas with a significant range of elevation (Rose and Altschul 1988:185). In such a situation, both variables should not be included in the model.

**Univariate and Bivariate Analysis**

After selecting the potential variables to be included in the model and recording their values for all of the archaeological sites and null points in a database such as Excel, this information is imported into SPSS or other such statistical program. The distribution of the values is then initially examined through univariate and bivariate statistics (Rose and Altschul 1990:200). This can accomplish several things. Observable differences and similarities in values can help the researcher anticipate which variables will be valid predictors of site location and which ones may be excluded from the multivariate model. Such measures can also help determine and untangle relationships between variables (Rose and Altschul 1990:202). Descriptive statistics such as mean, median and standard deviation, combined with visual displays such as histograms, error bar charts, box plots, and stem-and-leaf plots, can help reveal how the values are distributed and if that distribution is normal. This analysis also helps determine which multivariate techniques will be appropriate for model building.

Bivariate tests can be performed to see if the archaeological sites and null points could have come from the same population, or whether the two groups are truly different. The Independent

![Idealized logistic regression](image)

**Figure 5.5. Idealized logistic regression of two groups of objects (sites and nonsites) across two independent variables (Warren and Asch 2000:9).**
Samples tests, including Levene’s Test for Equality of Variances and t-test for Equality of Means, can show the significance of the difference in the variances and means between the two groups (Drennan 1996:155, Hosmer and Lemeshow 2000:93). Even if the independent variables do not meet the assumption of a normal distribution, these tests can give a good indication (Drennan 1996:164). With a large sample, the assumption can be violated and still yield reasonably accurate results (Green et al. 2000:150).

The Mann-Whitney Test performs a similar test on the median values of the independent variables to determine if the two sets of data (the sites and the null points) could have come from the same population (Warren and Asch 2000:14). The Two-Sample Kolmogorov-Smirnov Test can be used to see if two datasets differ significantly (Green et al. 2000:342). These test are easily performed in SPSS.

Other methods, such as Spearman’s rank order correlation (Hudak et al. 2000[7]:28), Pearson’s $r$ (Green et al. 2000:234), univariable logistic regression (Hosmer and Lemeshow 2000:93), and scatterplots may also be helpful. However, Spearman’s rank order and Pearson’s $r$ are sensitive to outliers, and Pearson’s $r$ is not appropriate for relationships that are not linear.

Hosmer and Lemeshow (2000:95) suggest that any variable whose univariate or bivariate test has a p-value of < .25 is a good candidate for multivariate analysis. Apparently weaker variables can become significant predictors when used together.

**Multivariate Analysis**

After the initial assessment of the independent variables with univariate and bivariate statistics to determine their potential contribution to site presence, the strongest predictors are brought into multivariate analysis. Different methods have been successfully used to develop predictive models, including multiple regression, density transfer, density regression, significance regression, discriminant function analysis, and logistic regression (Carr 1985:117-120, Kohler and Parker 1986:421-431, Kvamme 1988b:364-373, Rose and Altschul 1988:212-241, Warren 1990a:94-96).

The last two, discriminant function analysis and logistic regression, yield equations for predicting the probability of classification in the categories (site presence or sites absence) of a binary dependent variable (Kohler and Parker 1986:420). These probability models were developed for use when the dependent variable is a categorical measure, rather than an interval or ratio scale measure (Warren 1990a:99). Of the two, logistic regression (Figure 5.5) requires no assumption of normality of the values of the independent variables, can be used with variables measured on any level (nominal, ordinal, interval, or ratio), and yields readily interpretable predictions of the probability of site-presence or site-absence (Kvamme 1988b:371, Warren 1990a:95). Kvamme is credited with developing this approach for use in archaeological predictive modeling (Warren 1990a:96). Logistic regression has been successfully used to develop site location predictive models by these and other researchers: Carmichael 1990, Duncan and Beckman 2000, Ellis and Wilson 1994, Hudak et al. 2000, Kohler and Parker 1986, Kvamme 1988b and 1992, Maschner 1996, Warren 1990b, Warren and Asch 2000, Wilson 2001.

The statistical programs that can perform logistic regression analysis include SPSS, SYSTAT, STATA, SAS, and BMDPLR, to name a few. SPSS can run logistic regression in different ways. All independent variables can be entered at once (Enter), or the variables can be entered stepwise (Forward Conditional or Backward Conditional). The stepwise methods calculate scores and their significance for each of the variables as a measure of their predictive power, and retain only the most powerful combination of predictors (Hosmer and Lemeshow 2000:96, Kvamme 1988b:362, Warren and Asch 2000:17).

Before running logistic regression, portions of the site and null point samples are traditionally withheld from the development of the model to independently test the classification accuracy of the model at the end (Training versus Testing Samples) (Warren 1990a:109). Different methods for split sampling have been used, involving withholding various proportions of the total sample (Kvamme 1988b:395, Rose and Altschul 1988:243). Most statistical procedures consider 30 cases to be a significantly large sample (Anderson et al. 1999:265), so a Testing Sample should
be about this size.

When developing a logistic regression model with SPSS, the cases can be easily split into Training and Testing Samples. SPSS will use the Training Samples to develop the model and then apply the results to all cases. Logistic regression considers the particular combination of the values of the strongest predictor variables at each site or null point in arriving at the probability score for that location and in classifying that location as a non-site or site. The probability score as well as the classification of that case (1 = site, 0 = non-site) based on the specified cutoff point (usually .5) are saved in the data table. A crosstabulation of the success of classification of the Training Sample accompanies the model output. A Type II error in which null points are erroneously classified as sites is usually preferable over the Type I error, in which archaeological sites are misclassified as null points, because archaeologists are more concerned that sites are not missed by the model (Altschul 1988:62). A typical success of classification rate for the Training Sample used to build a predictive model is approximately 70 percent.

The percent of sites and null points correctly classified can be adjusted by simply changing the cutpoint of site definition from .5 to a different value. The goal is to optimize the model’s correct classification of sites and null points, although it may be desirable to optimize the former and accept a slightly higher degree of error in the latter (Kvamme’s “decrease gross error by increasing wasteful error” 1988b:390).

Testing the Model

There are limitless possibilities for the selection and configuration of independent variables in the building of probability models. Statistical methods for analyzing these variables are also open to a number of possibilities. Essentially, any methods can be used to create a model: the success of the model reveals if the right choices were made.

from a statistical standpoint any procedure – ranging from statistical techniques to simple mathematical rules or even armchair theory – might appropriately be used as a basis for site-location model development. What matters is how well a model works in application, how accurately it performs on future cases. Given this perspective, it is appropriate to use any type of procedure as well as any source of data (such as existing site-file information) in model development. In order to determine how well a model will perform in practice… independent testing procedures are required, and in this case methods of statistical inference must be applied [Kvamme 1988a:303; emphasis in original].

It is not enough to accept the model’s classification of the Training Sample of archaeological sites and null points as an indication of the strength of the model. The final predictive model must be evaluated against independent samples that were not used in its development. The accuracy of classification of the data that were used to build the model is expected to be high. The more significant assessment model validity is the classification success of the Testing Sample, the cases withheld from the development of the model. The best test would be to gather new data and to evaluate it with the final model, although this is rarely done because of the time and expense involved. However, a similar end can be achieved by periodically reevaluating the predictive model as new data are collected.

The model should also be assessed with internal tests of validity. The output data from logistic regression in SPSS contains several diagnostic statistical measures. The overall performance of the model can be evaluated with the Model Likelihood Ratio or Chi-Square statistic (Garson 2003:8, Whitehead 2001:5).

The \( R^2 \) statistic has no real equivalent in logistic regression (Whitehead 2001:5), however several pseudo-\( R^2 \) measures are available. SYSTAT uses the McFadden’s-\( R^2 \); the SPSS output provides the Cox & Snell-\( R^2 \), and Nagelkerke-\( R^2 \). However, these values are always low when compared to linear regression \( R^2 \) values, and some authorities recommend not routinely publishing them because of possible confusion (Hosmer and Lemeshow 2000:167). \( R^2 \) values can be of use in evaluating competing models, but the Model Chi-square value and its significance is a better test of the overall model performance.
In the “Variables in the Equation” section of the model output in SPSS, a high standard error of the regression coefficient would indicate collinear-ity of the independent variables. Interaction between independent variables can also be tested by rerunning the logistic regression with the predictor variables in combination with each other (Hosmer and Lemeshow 2000:98). The Wald statistic and its significance value measures the significance of the individual logistic regression coefficients for each independent variable (Garson 2003:3).

Other methods that can be used to assess the accuracy of the model include the Receiver Operating Characteristic (ROC) curve (Hosmer and Lemeshow 2000:160, Kvamme 1992:31, Warren and Asch 2000:20), which is a measure of the model’s ability to discriminate between sites and null points. Performance curves can also be plotted along the gradient of predicted site probability to compare the percentages of sites and land area (null points) incorporated in the model, and the percentage gain in accuracy over the random or null classification (Warren and Asch 2000:20). A model can be developed that predicts the location of all sites with 100 percent accuracy by simply classifying every location in the area as likely to contain sites (Kvamme 1988b:327). Obviously, such a model is of little use. A successful model must be able to accurately predict where sites are not likely to be found, as well as where they should occur. “If a model is able to predict 90 percent of the site locations correctly in a region representing only 50 percent of the total land area (as opposed to 90 percent of the land area), then something is gained” (Kvamme 1988b:327).

From Logistic Regression to GIS

Before the advent of Geographical Information Systems, the results of a probability model would have to be analyzed and classified to define probability areas, as is done in Appendix F: “Guidelines for Applying the Results of the Wapato Valley Predictive Model without the Probability Maps”. Kohler and Parker (1986:422) compared four different decision rules in producing simulated site probability areas based on 12 independent variables.

An alternative method of predictive model building involved manually taking hundreds of measurements of the independent variables at regularly spaced intervals (cells) throughout the region under consideration, and using those data points against information from known archaeological sites in the region to build the model. Logistic regression yielded the probability score, which was then used to create the predictive surface. However, the resolution of the model was dependent on the interval of measurement of the independent variables (cell size), which was usually quite large (.5-1 hectare or larger). This method worked reasonably well for small areas, but the number of sampled locations required for a good model prohibited its use over large regions. Kvamme used this method in some of his early studies in Colorado (Kvamme 1988b:325-428).

Geographical Information Systems such as ArcView, using the grid function of the Spatial Analyst extension (Environmental Systems Research Institute 2000), brought a quantum change in the power of predictive modeling. More and more digital images have become available at higher and higher resolution – many free or at low cost on the Internet – freeing researchers from the task of digitizing maps themselves. The resolution commonly available is 30 x 30 meters (.1 hectares) per cell (pixel) or better. USGS topographic maps at a resolution of 10 x 10 meters per pixel are readily available. Satellite images can now be obtained that have a 1 meter resolution or better.

In most cases, the values of independent variables in the environment can be measured by computer, and in many cases, instantly. Independent variables such elevation, water distances, slope, and aspect are easily calculated and displayed as grid surfaces in ArcView using the Spatial Analyst extension. The Map Calculator can apply mathematical formulae, such as the formula for logistic regression, to the combined surfaces of the independent variables, to yield a probability surface for an entire region. This surface can be classified and displayed as desired on probability maps, bringing an important tool within easy reach of scholars and civic planners alike.

Probability surfaces can be used to target areas of potential archaeological sites for research, or to define sensitive areas to avoid in construction projects. Predictive models have become an effective, efficient way of distilling the archaeological
record of an area into an equation of site probability that can be applied through GIS to large areas in which the record is largely unknown.

Conclusions

Even with all the science, statistics and sophisticated computer programs able to process vast amounts of data, the ultimate test of any predictive model, is how well it illuminates and advances our understanding of the past lifeways of the indigenous inhabitants of the area. Correlations can be made with high significance between environmental variables and site presence, but without considering the meaning of these correlations, the model lacks purpose.

The final step in model building must be interpretation. How does what we have learned through the development of the model help confirm what we believed about the past? How does it change our ideas? Does it cast our knowledge in a different light that reveals new relationships that were previously overlooked? Does it lead to further questions for which we thought we already had answers?

Predictive modeling is a tool that can help researchers discover patterns in the archaeological record, but as such, it can only go so far. Understanding the meaning of these patterns should be the ultimate goal of any such research. We must go back to where we started – to the archaeological, ethnographic, and ethnohistoric literature that was a catalyst for the model, that illuminated things sufficiently so that we could build the model in the first place – and merge this knowledge with what we have learned from the model to take our understanding to the next level. It is perhaps then that we can go beyond simple correlation and get at the nature of the dynamic human systems and the lives of the people who created the archaeological record (Church et al. 2000:146, Ebert 2000:133).
CHAPTER 3
DEVELOPMENT OF THE
WAPATO VALLEY PREHISTORIC
ARCHAEOLOGICAL SITE DATABASE

The Wapato Valley Prehistoric Archaeological Site database is comprised of locational and environmental data on the 276 known sites on both the Oregon and Washington shores of the floodplain of the Columbia River, from the mouth of the Columbia River Gorge at Rooster Rock State Park (River Mile 129) downriver 88 kilometers to the north end of Deer Island (River Mile 76). Lewis and Clark were the first to refer to the area by this name, which they used interchangeably with “Columbian Valley” (Moulton 1991:26). This database is the foundation of the Wapato Valley Predictive Model.

Many concerns arose while compiling site information for this database. When working with existing data in model building, consistency is of utmost importance (Kvamme 1988a:302). Site records submitted by countless individuals for greater than 50 years were bound to be full of irregularities and contradictions. Recording techniques and standards, forms used, and procedures followed have changed over time. Two state SHPOs with different standards were involved. Predictive models depend on the often-subtle contrast between site and non-site variables. The main concern was that the site form data be usable – valid and consistent enough to develop a predictive model using logistic regression analysis. If it were not, would it be possible to obtain the necessary information for the database without personally visiting the location of each archaeological site?

Where To Put The Dot?

The fundamental concern when undertaking this study of the distribution of archaeological sites in Wapato Valley was how to reliably and accurately determine where the sites are actually located: where to put that dot on the map. This is a more problematical task than it might initially seem. The ability to accurately determine site location is the basis of this entire study. If this could not be done, this whole body of data and any conclusions that might be drawn from it would be meaningless.

The decision was made to accept the designation of an archaeological site the way that it was defined on the site report form. The issue of “lumping versus splitting” – the judgment call made in the field to treat closely adjacent sites either as a single or as multiple sites – was left to the assessment of the recording archaeologist. To do otherwise would involve ground-truthing a significant portion of the archaeological sites in the Wapato Valley, an undertaking beyond the scope of this research project.

The choice was made to represent the location of an archaeological site as a point approximating the site centroid as accurately as possible. A point was used instead of a polygon of site area for a number of reasons. The information that is available on site report forms – especially before about 1980 – is often unreliable and at a minimum, inconsistent. Many times sites are only represented as points on the maps accompanying the site forms. The maps themselves show varying levels of sophistication, from hand-drawn sketches to copies of topographic maps at varying scales to professional Computer Aided Drafting (CAD) or GIS images. Inaccurate maps can make the interpretation of the site location difficult.

The dimensions of sites given on the forms that do address site area are a matter of even more concern. Added to the difficulty in correctly representing site location on a map, accurately reporting the extent of a site, especially in the context of a surface survey with limited subsurface testing (which is the case with most archaeological sites in this area), is an almost impossible task. Site forms ask for dimensions and total area, but in the typical context of site discovery, such reported figures can only be estimates. Many archaeologists opt for the least informative but perhaps most honest estimate of site dimensions: “unknown”. Therefore, because of the differing levels of accuracy in reporting areal information on site forms, it is not appropriate to represent sites as polygons in this study. Additionally, the locations used for the baseline environmental conditions are also measured as points, so representing sites as points makes the two data sets directly comparable.

Data Quality

Issues of data quality are paramount in

Local researchers have reported their problems with site locational data. In developing the Clark County Predictive Model (1994:3), Ellis and Wilson assumed that the records in the Washington State Historic Preservation Office were correct, trusting the information on the site forms and maps. Wilson’s updated model (2001:8) details the corrections made based on inaccuracies discovered in site data used in the original model. Blukis Onat (1997:88) grew frustrated at the incomplete and inaccurate SHPO site data in her survey around Shillapoo Lake and Lake River, and decided to approach the areas as if they had never been surveyed before. Hatz (1999:20) describes in detail his frustration with existing site location information when faced with the dilemma of where to put the dot.

A pilot study of the Ridgefield National Wildlife Refuge in the development of this thesis was begun much as Ellis and Wilson (1994) did, by assuming that the SHPO records were correct. However, when transferring site locations to Universal Trans Mercator (UTM) coordinates with the aid of the National Geographic TOPO! mapping program (2000), several inconsistencies were noticed. Kayak visits to the main waterways of the Refuge to ground-truth several site locations with a global positioning system (GPS) receiver brought out more concerns. Occasionally none of the sources agreed: the SHPO map said one thing, the site form said another, a subsequent survey report said another, the Clark County Predictive Model yet another, and ground-truthing proved them all wrong. Simple errors in recording aside, how could the differences in recorded location be resolved?

Where Am I?

When archaeologists go into the field to record the location of an archaeological site, how do they know exactly where they are? With the advent of GPS and inexpensive civilian grade receivers, it is now an easy task to accurately determine one’s position in the field. Selective Availability, a security measure that degraded the broadcasting satellites’ signals to limit the accuracy of civilian receivers, previously resulted in a horizontal accuracy of 15 to 100 meters. In May 2000, Selective Availability was removed, improving horizontal accuracy to 15 meters or less (Letham 2001:29). The new Wide Area Augmentation System (WAAS)-capable receivers have a positional accuracy of less than 3 meters (Garmin 2003). Many civilian GPS receivers also have the ability to accept differential correction, potentially increasing their accuracy to 3-5 meters. Post-processing can also increase precision by comparing readings with those of nearby known base-station locations.

Before the widespread use of GPS in the last decade, however, how did archaeologists accurately determine their field location? Reviewing site forms at the Washington SHPO can provide a revealing look back at the different methods that individuals have used over the last 55 years.

Comparison of landform with topographic features seems to be the most frequent procedure employed. Indeed, most site forms include an area map of the general vicinity on the appropriate 15- or 7.5-minute topographic map, with the site marked. Other methods employed include using a compass to triangulate between visible landmarks located on a topographic map, using measuring tapes to determine location from known points, or recording a rough estimate of latitude and longitude (or section, township, and range) from local maps. These techniques provided varying degrees of accuracy, often dependent on the individual doing the measuring. There is quite precise location information given for a few earlier-documented sites that were carefully surveyed, mapped, and excavated using a total station, however no other method approaches the accuracy of today’s GPS receiver.

Collecting site data at the Washington and Oregon SHPOs imparts an appreciation of the lack of reliability in recorded site locational data and an awareness of the need to critically evaluate all the reported information. Frequently, multiple
sources needed to be consulted to resolve the issue of exact site location. In order to build a successful model, a method for measuring site location was standardized, and then used to verify the coordinates of all recorded prehistoric archaeological sites in Wapato Valley. A preliminary study on the Ridgefield National Wildlife Refuge provided a test of this system and of the procedure for bringing the data into GIS.

**Pilot Study**

In the winter of 2002, a pilot study was conducted using ArcView GIS to look at different attributes of the location of prehistoric archaeological sites on the Ridgefield National Wildlife Refuge portion of the Columbia River floodplain (additional bibliographic references for the Refuge may be found in Appendix G). The Refuge is the location of several important sites, including 45CL1 (Cathlapotle), 45CL4 (Wapato Portage), and 45CL43 (Bachelor Island). Information for the 29 sites on the Refuge and immediate vicinity was collected at the Washington SHPO, evaluated and corrected for locational accuracy by using the coordinate display function of the TOPO! program.

A database was created in Excel to organize the information and to evaluate the significance of different factors in determining site location. A site suitability model was developed that defined areas of higher probability of containing archaeological sites as an aid to future researchers conducting cultural resource surveys on the Refuge. The results of that study suggested that elevation, distance to water, and slope are the most significant environmental measures that positively correlate with site location on the Ridgefield National Wildlife Refuge.

These preliminary findings suggest that a pattern of site location might exist for the 29 sites and 2,000 hectares of the Refuge; however, would this same pattern apply to other floodplain locations? Would these relationships hold for the rest of the Columbia River floodplain in the Portland Basin? Could a predictive model for site location be constructed for the entire Columbia River floodplain, from above the mouth of the Sandy River downstream to Deer Island, from a database of all prehistoric archaeological sites on both sides of the river?

In spite of all the work that has been done in the area over the years, including the Clark County Predictive Model (Ellis and Wilson 1994) and the Archaeological Context Statement: Portland Basin (Ames 1994), rarely had any researcher incorporated data from archaeological sites on both the Oregon and Washington sides of the river in one study. Hajda (1984) and Saleeby (1983) examined Chinook regional social organization and settlement patterns, however there is no equivalent archaeological analysis. This may be due to the nature of the funding of local archaeology, with mostly compliance-driven projects commissioned by state and local governments – and very little research. But it is important to remember that the floodplain of the Columbia River is one landscape (sensu Crumley and Marquardt 1990:74).

Political and administrative boundaries that are drawn with an arbitrary line down the middle of the Columbia River have led local archaeologists to focus on only half their data. The very feature that united the entire Wapato Valley and beyond, that created the conditions that made possible the unique lifeways of the Chinook, that served as a corridor of trade, communication and travel for millennia, is split in two as an inconsequential extension of the shoreline. The corridor had become a barrier.

The early inhabitants of the Columbia River most likely did not think of themselves as residents of “Washington” on the north and east, or of “Oregon” on the south and west. They were people of the water, who relied on their canoes and on traditional resource areas on both sides of the river. The Columbia River was a unifying feature linking the shores of a common landscape, the center of life of the prehistoric people of Wapato Valley, not a boundary line.

**Database Development**

In order to be able to assess the validity of the findings of the Ridgefield pilot study for the landscape as a whole, an expanded analysis of archaeological sites in the entire Wapato Valley was needed. A database was developed of all the known prehistoric sites on the Columbia River floodplain in the Portland Basin, summarizing the descriptive information from the archaeological
site forms on file at the Oregon and Washington State Historic Preservation Offices. Other primary data sources included more detailed site reports, survey reports, and maps on file at the SHPOs. Additional sources included: other amateur and professional archaeological site and survey reports; ethnohistoric works and early ethnographies; and historic records and maps from early explorers, Euroamerican visitors, and settlers.

Archaeological sites were included in the database based on their location on the Columbia River floodplain on one of the 11, 7.5-minute Washington and Oregon USGS topographic maps of the greater Wapato Valley (from to upriver to downriver): Washougal, Camas, Mount Tabor, Portland, Linton, Vancouver, Sauvie Island, Ridgefield, Saint Helens, Woodland, and Deer Island. Floodplain sites were defined as being 55 feet in elevation or less, to coincide with the high probability area of the Clark County Predictive Model (Ellis and Wilson 1994). That would allow this Wapato Valley Predictive Model to test the assumption of blanket high probability made by the Clark County Predictive Model (Ellis and Wilson 1994 [D]:13) for this elevation zone on this segment of the landscape.

Sites greater than 3 kilometers up the major tributaries of the Columbia were judged not to be on the floodplain proper because of distance and adjacent rising topography, and were excluded (a total of 5 sites). Isolated artifacts could be present anywhere on the landscape and therefore were not considered as sites for the purpose of this model. A total of 276 prehistoric archaeological sites were included in this database: 166 from Clark County, Washington; 29 from Columbia County, Oregon; and 81 from Multnomah County, Oregon. There are no known archaeological sites on the Columbia River floodplain in the portion of Cowlitz County, Washington that lies within the Wapato Valley.

Where The Dot Was Put

Site locations recorded on SHPO maps were transferred to paper copies printed from TOPO!. Twenty-one, 8-by-10 inch maps, at the normal 1:24,000 scale of the 7.5-minute USGS topographic map series were necessary to fully cover the Wapato Valley. All additional available data sources were reviewed when considering the final location of the dot. The dot represents, with greatest accuracy and precision possible, the centroid of the archaeological site.

Each dot was then located on the maps of the TOPO! program, using the coordinate display function. All coordinates are expressed in the Universal Transverse Mercator projection, a grid system that divides the world into 60, 6 degree north-south wedge-shaped zones (Letham 2001:89). Wapato Valley is in Zone 10 of this grid. Location is expressed in meters as a pair of coordinates: the Easting (X-coordinate), which is measured from the zone meridian, and the Northing (Y-coordinate), which is measured from the equator. The datum used in this study is the North American Datum of 1927 (NAD 27), with the Clarke 1866 ellipsoid. Vertical measurements are given in feet, referencing the National Geodetic Vertical Datum of 1929 (NGVD 29).

The GIS program used was ArcView version 3.2 with the Spatial Analyst extension version 1.1 (Environmental Systems Research Institute 2000). Data analysis was done primarily in SPSS (Version 10), and in Excel (2000 Professional). Logistic regression was run in SPSS.

Site data were organized on an Excel spreadsheet, which is easily displayed or imported into various applications or into other database programs. The Wapato Valley Prehistoric Archaeological Site Database is presented in 24 columns, from “Site Number” through “Selected References”. An abbreviated version containing the six independent variables used to run logistic regression is presented in Appendix E: “Wapato Valley Predictive Model Logistic Regression Probability Tables”. The full site database is available to archaeology professionals from the Department of Anthropology, Portland State University, or from the author. The following is an explanation of the information in each column and how it was derived.

Wapato Valley Prehistoric Archaeological Site Database

1. Site Number: Archaeological sites are identified by a national code system known as the Smithsonian trinomial designation. The first
part of the code is a two-digit number, assigned alphabetically, representing the state of the union in which the site is located. The first two digits of the code – 35 for Oregon and 45 for Washington – denote in what state the site is located.

The next part of the site number is a two-letter code for the county in which the site is located. Clark County Washington is CL, Columbia County Oregon is CO, and Multnomah County Oregon is MU. Sites that continue from one county into another are divided into two sites at the county line (as in 35CO25 and 35MU23 on Sauvie Island). The last digits of the site code represent the sequential archaeological site number (both historic and prehistoric) in that county. Thus, 45CL1 would be the first site recorded in Clark County, Washington.

2. **Site Name:** Archaeological sites may have been known by several names throughout the years. An attempt has been made to record all these aliases, often found in the records of amateur archaeological groups as well as on site reports or other professional records. Often sites are known by the name of the landowner when the site was recorded.

Emory Strong, an amateur archaeologist, was involved in early excavations in the Columbia Basin, both with professional archaeologists and with an amateur group founded in 1951, the Oregon Archaeological Society (OAS). Much of this early work is detailed in his book Stone Age on the Columbia (Strong 1959). Many site numbers were assigned by Strong and by the OAS before the advent of the current numbering system. When the Smithsonian system became the standard, many sites were given new numbers within the trinomial designation, although the old numbers can still be found in the literature. Therefore, for some of the earliest recorded sites in the area, there may be an alias that refers to Strong’s numbering system (i.e. 35MU4 is Strong’s MU 11).

Another source of alternate site names are the maps and journals of Lewis and Clark (Moulton 1983, 1990, 1991), who recorded the names of many Native American villages in Wapato Valley when they passed through the area. Both the names of villages that they visited (i.e. Cathlapotle 45CL1), and the names of villages that they did not see but were told of by the Indians (i.e. Cathlacommahtup, location unknown) are mentioned in their journals.

Researchers have weighed in over the years with their opinions of where these villages were located and their correspondence with known archaeological sites (Ames 1994, Boyd and Hajda 1983, Burtchard 1990, Darby 1996, Hajda 1984, Pettigrew 1981 and 1990, Saleeby 1983, Silverstein 1990, Spier 1936, Strong 1959). There is some agreement, but more dispute. Studying the locations for my own benefit at understanding, it became apparent that there must be confusion among many archaeologists regarding the current thought on the location of these villages. The names of villages for which there is general agreement among researchers about their correlation with a particular archaeological site are included as aliases in the database under those sites. With those of uncertain correlation, the names are followed by a question mark. Those that are largely disputed are not mentioned in the database.

3. **Topographic Map:** This column refers to the USGS 7.5-minute topographic map on which the site is located. In the TOPO! program, the Mount Tabor, Portland, Linnton, Vancouver, Sauvie Island, Ridgefield, Saint Helens, Woodland, and Deer Island maps are current to 1990. The Washougal and Camas maps are current to 1994.

4. **UTM E:** This is the Easting coordinate of the site centroid in the Universal Transverse Mercator grid system, Zone 10. Measurement units are in meters, from the zone meridian.

5. **UTM N:** This is the Northing coordinate of the site centroid in the Universal Transverse Mercator grid system, Zone 10. Measurement units are in meters, from the equator.

6. **Site Type:** The accurate classification of archaeological site type is difficult or impossible for most of the sites in Wapato Valley that have only been discovered in the survey
process and have not been excavated. Even though a principle of archaeological survey states that what is seen on the surface of the ground is a reflection of what lies below the ground, most ground surfaces of the Wapato Valley are sufficiently disturbed by cultivation and obscured by construction to nullify this rule. Therefore, the description of site type is often ambiguous and unreliable.

All site forms and available reports were reviewed and evaluated for site type designation. Villages are traditionally characterized by house depressions, although other features, remains, and artifacts may be indicative of a residential site. The presence of “site furniture” – large groundstone artifacts that one would not usually associate with temporary campsites because of the problem of portability – as well a large quantity and variety of artifacts, and the presence of midden or significant organic deposits in the soil, are also indications of a long-term occupation, either continuous or recurring. Fifty sites with these sorts of features and artifacts were classified as villages in the Wapato Valley site database.

Many other sites have been recorded as villages on site forms based solely on the presence of a little fire-cracked rock, charcoal and lithic debris. In the final analysis, half the sites that were classified as “possible villages” were reclassified as campsites.

Any sites whose specific function is known or implied, such as a quarry, fishing station or rock cairn, is listed as such. All other open sites whose extent of occupation has not or cannot be determined are referred to as camp-sites.

7. **Age or Radiocarbon Years BP (RYBP):** Two main methods of dating archaeological sites have been employed over the years: relative and absolute. One method of relative dating compares archaeological assemblages to artifacts of known age, which may have been dated indirectly or directly by an absolute method. Another method involves comparison to a typology, which is a chronological series of similar artifacts such as projectile points, showing stylistic change over time. The relative ages of these artifacts is determined by the rule of superposition, which states that in an undisturbed context in an archaeological site, artifacts found in lower strata are older than ones found in higher strata. Sites with the greatest time depth are the most useful in constructing typologies because of their internal consistency. Barring that, a typology can be constructed from several sites in an area with overlapping depth of occupation and artifact types. Tying the artifacts to absolute dates gives the chronology greater validity and usefulness. This is precisely what Pettigrew (1981) did with projectile points from 10 sites from the Sauvie Island Oregon area, which established a typology for all of Wapato Valley.

The main absolute dating method used in the Wapato Valley is 14C (radiocarbon) analysis. Dates are expressed as Radiocarbon Years Before Present (RYBP) accompanied by an error estimate. The dates given in this column of the Wapato Valley database reflect three categories in the quality of methods of measuring the age of sites:

**I (Poor):** In some cases, site ages are assigned based on a general impression of the types and forms of artifacts. These age ranges can be very broad, as in 45CL57, with a recorded age range of 1800 BC-AD 1750. What an age range like that tells us is that the archaeologist had either a wide range of types, or more likely very few non-diagnostic artifacts on which to base this estimate. Included in this grouping are sites whose age is simply given as “unknown”.

**II (Better):** Some sites record a Before Present (BP) age, as in 45CL142 (3200-1800 BP), that is not a radiocarbon date, but is at least narrower in range than the Category I group. In this same group are sites whose age is given as “late archaic”, “middle to late archaic”, “late prehistoric”, or similar phrases. Information on the site forms indicate that such estimates and terminology are based on artifacts that fall in a certain range in Pettigrew’s typology, or are comparable to other dated artifacts.
III (Best): Sites that have dated materials using the radiocarbon method are listed with their uncalibrated dates RYBP – as with 1889-2115 RYBP in the case of 45CL21. The specific dates and their error margins are not included due to lack of space, but are included in Appendix D: “Wapato Valley Radiocarbon Dates”. An excellent treatment of these dates can be found in Ames 1994 and 1999.

8. Feet Above Mean Sea Level: The elevation given is of the site centroid in feet above mean sea level (AMSL) in the National Geodetic Vertical Datum of 1929 (NGVD 29), as measured by ArcView. When X/Y points such as site coordinates are plotted on a DEM map in ArcView, that file can be turned into a 3-D file, using elevation as the “Z” value. The field calculator can then use the “getz” function to instantly calculate the elevation of that point. The table of site coordinates can then be edited to incorporate the new elevation Z values. This method was used over a simple transfer of coordinates from the site forms in order to maintain consistency. ArcView will use these same X/Y points as a basis for all its other locationally dependent calculations, such as slope or distance to water. This is what made that initial determination of site location so critical.

9) Feet Above River Level: This is the elevation of the site in feet above the mean river level for that point on the river. The problem of measuring site elevation across such a large section of the Columbia River floodplain is that the elevation of the river itself changes from 16 feet above the south end of Government Island, to 7 feet between Government Island and the downstream end of the town of Saint Helens, to 0 feet from there to its mouth. The zero point for site elevation is not consistent. A campsite on the 20-foot contour at Sauvie Island is 13 feet above the water; at Washougal though, a village on the 20-foot contour is only 4 feet above the water. Therefore, for an accurate measure of site elevation, the elevation of the Columbia River at that location was subtracted (16, 7, or 0 feet). This column reflects this normalized site elevation. Failing to normalize elevation relative to the surface of the water may have led to an erroneous conclusion of a bimodal distribution of null sample point elevations below 50 feet in the Clark County Predictive Model (Ellis and Wilson 1994[D]:3).


When considering where people lived on the floodplain, different qualities of proximity to water come into play. Access to water for household uses and transportation, as well as the proximity of one’s front door to floodwaters, are some of the many aspects of the Chinook’s relationship with water. Elevation is critical in flood time: an extra 10 feet of water on the land is not going to matter to a campsite at 13 feet at Sauvie Island, but for a village at 20 feet elevation at Washougal – normally a mere 4 feet above the river level – there is a problem. Just how the Chinook dealt with this periodic inundation – Saleeb (1993:163) explains that flood stage was only reached perhaps every second year, for a period of from 4 to 42 days – is a matter for further consideration addressed in Appendix C: “Columbia River Floods”.

10. Site Dimensions: Site dimensions given are in meters, north/south by east/west. These figures represent the best guess of the recording archaeologist, and are often incomplete or unknown. Question marks represent data that were not recorded on the site form. Sites perceived by the recording archaeologist as being circular may be expressed as a diameter measurement.

As previously stated, most sites in the Wapato Valley were discovered during archaeological survey and have not been excavated. Site di-
dimensions, therefore, often represent the extent of only what is seen on the surface. Subsurface testing, usually included now as a part of archaeological surveys, is an important diagnostic tool when surface artifacts indicate a larger or more significant site, and to help define site boundaries. More recently recorded sites are therefore likely to have more accurate site dimension estimates.

11. **Site Area:** Site area is a simple calculation from the site dimensions, expressed in square meters. If the estimated area was not provided, but the site dimensions were given, I calculated the area. Some sites did not have dimensional data reported, but did have an areal estimate. All units – feet, acres and diameter measures – have been converted to square meters for comparability.

Some discrepancies were noted, indicated by question marks in this column, when there was a lack of agreement between the recorded “Site Dimensions” and the “Site Area”. For example, in the case of 35CL80, the site dimensions were given as 200 x 80 meters, but the area was recorded as 4165 square meters. The decision was made to record the “Site Dimensions” and “Site Area” as they were reported on the site forms (converted to metric units if necessary), and not to try to figure out which of the two figures is wrong.

12. **Nearest Permanent Water:** This is the name of the nearest permanent source of water of any kind. At the very least, this would represent water for domestic use. Some archaeologists (Burtchard 1990, Ellis and Fagan 1993, Minor et al. 1994, Wilson 2001) have tried to draw correlations of site location with different water types – river, creek, slough, lake, marsh, swamp, and spring. However, although the Columbia River itself has been relatively stable over the last 3,000 years, seasonal and episodic changes in the floodplain landscape undoubtedly have occurred. This would render any fine distinctions between current observed wetland types, given such a time depth.

There is an obvious problem with determining the location of all the various seeps, springs, creeks, channels, marshes, ponds, and lakes in the past – especially in this dynamic floodplain environment. Historic maps were consulted to help determine the location of water sources before extensive draining and diking (Broughton 1792, Cunningham 1973[1896], Derby and Gibbs 1855, Goethals 1971[1883], Habersham 1888, Metsker 1937, Moulton 1983[1805-1806], Slacum 1836, Tilton 1857, US Coast and Geodetic Survey 1888-1951, US General Land Office 1854-1888, Vavasour circa 1845, Wilkes 1841). Where coverage was available from one of the historic maps, the location of those water features was taken as more representative of original conditions than contemporary maps (but see Karsmizski 2004 for a discussion on the problems associated with the use of historic maps). The first upstream hydroelectric dam, Bonneville, went on-line in 1938 and changed the dynamics of the floodplain forever.

13. **Meters to Nearest Permanent Water:** This is the distance in meters from the centroid of the archaeological site to the nearest water source named above, using the measuring tool in ArcView with the map resolution set to 1:6,000. The distance could be less from various parts of the site, but because of the general lack of confidence site dimensions, the site centroid was used for this measurement.

14) **Nearest Navigable Water:** This is the name of the nearest river or stream accessible from the Columbia River by boat. Such waterways include the Columbia River itself and major tributaries such as: Bachelor Island Slough, Burke Slough, Columbia Slough, Cunningham Slough, Deer Island Slough, Gilbert River, Lake River, Lewis River, Martin Slough, Multnomah Channel, Sandy River, Santosh Slough, Scappoose Bay, Sturgeon Lake, Vancouver Lake, Washougal River, and Willamette River. Bodies of water that are not now connected to Columbia River, but were in the past, were also included: Buckmire Slough, Shillapoo Lake, and Steigerwald Lake.

15. **Meters to Nearest Navigable Water:** This is the distance in meters to the nearest stream or river accessible by boat from the site centroid. This measure could be considered a proxy for
ease of transportation and communication.

16. **Land Type:** The land type listed is generally taken from the site form: either “floodplain” or “terrace”. From a review of the site forms, many reporting archaeologists seem too eager to classify any site on a slight rise above the water as being on a terrace. In the geologic sense, a terrace is “a large bench or steplike ledge breaking the continuity of a slope, occurring along the margin and above the level of a body of water, marking a former water level” (Hudak et al. 2000). By the definition of the geomorphic surfaces in the Wapato Valley, the Ingram surface at an elevation of 20 to 50 feet could properly be considered a terrace. Therefore, any site below approximately 20 feet in elevation above river level designated as a “terrace” on the site form was changed to “floodplain”.

17. **Percent Slope:** Slope is a measure of the flatness of the terrain, expressed as a percent, signifying the rate of change on a topographic surface (Chrisman 2002:170). The slope listed is the percent figure computed by ArcView from the Surface-Derive Slope function. A reading of 0 signifies flat terrain.

18. **Degrees Aspect:** Aspect is a measure of the direction that the site faces, also known as exposure. The aspect listed is the figure in compass degrees as measured by ArcView from the Surface-Derive Aspect function. Aspect is divided into 9 categories:

\[
\begin{align*}
337.5^\circ & - 22.5^\circ = & \text{North} \\
22.5^\circ & - 67.5^\circ = & \text{Northeast} \\
67.5^\circ & - 112.5^\circ = & \text{East} \\
112.5^\circ & - 157.5^\circ = & \text{Southeast} \\
157.5^\circ & - 202.5^\circ = & \text{South} \\
202.5^\circ & - 247.5^\circ = & \text{Southwest} \\
247.5^\circ & - 292.5^\circ = & \text{West} \\
292.5^\circ & - 337.5^\circ = & \text{Northwest}
\end{align*}
\]

A figure of -1.00 denotes flat terrain with no aspect.

19. **Soils:** The soils of the Wapato Valley floodplain show a range of types, however the majority owe their origin to the alluvial materials deposited by the Columbia River. Assignment of site location to soil series was made based on the detailed maps accompanying the soil surveys of Clark County, Washington (McGee 1972); and Columbia (Smythe 1986) and Multnomah (Green 1983) Counties, Oregon. Appendix B: “Soils of the Wapato Valley” provides more information about the various soil types.

20. **Geology:** This column identifies the underlying geology of the site. The majority of sites are located on alluvium, as would be expected on a floodplain. The underlying geology of Wapato Valley is taken largely from two 1:500,000 geologic maps: Washington (Hunting et al. 1961, revised by Schuster 1992) and Oregon (Walker and MacLeod 1991). There is an obvious concern with such coarse map resolution. References that are more detailed were consulted when possible, but full coverage of the project area was not available. Additional materials that provided a more thorough treatment for some areas include: Beeson et al. 1991 (Portland quadrangle), Mundorff 1959 (Clark County), Phillips 1987 (Vancouver quadrangle), Schuster 1992, and Trimble 1957 and 1963 (Portland quadrangle and adjacent areas). Appendix A: “Geology of the Wapato Valley” details the various geologic types.

21. **Vegetation:** The vegetation listed is taken from the land cover classification of the Lower Columbia River region from Landsat Thematic Mapper satellite imagery at a resolution of 30 meters, as provided on the Ducks Unlimited (2000) dataset. Two images were used in order to provide information on seasonal differences: August 21, 1997 for the main classes, and January 12, 1997 for seasonal flooding. Other data from the National Wetlands Inventory and other aerial photography sources were also used in the development of this coverage to aid in the accurate and consistent labeling of the classes.

There are two main problems with these data. First, the resolution of the images is fairly
coarse. With averaging over a 30-meter area, important microenvironments can be missed. Even in such a potentially homogeneous environment as the Columbia River floodplain, this can be significant.

Second, and most critically, these classifications reflect contemporary vegetation. While this area has been a wetland environment over the period of time of interest – the last 3,000 years – and the general types of vegetation may be the same, the modern transformation of much of the floodplain into agricultural fields and industrial complexes has forever changed the variety and patterns of the native vegetation. We can speculate what it may have been like, based on measures of the landscape like elevation, distance to water, aspect, and slope, and what we know of the requirements of the trees and other plants that are extant today. We can look to the accounts of early explorers to try to see what they saw on those first voyages down the Columbia. However, we will never know the past vegetation precisely, which makes these data interesting as a record of the modern conditions, but not of much use as a predictor of site location.

22. **Primary Site Form Reference:** The names and date in this column are taken directly from the site form on file at the SHPO. These are the individuals who are responsible for the initial recording of the site.

23. **Secondary Site Form Reference:** Often supplementary site forms are filed when sites are revisited at a later date, with additional information to either revise or supplement the original site form. In Clark County for example, it appears that many of the site forms were updated in 1978. The author of the update appears in this column.

24. **Selected Site and Survey Reports:** These reports were judged to contain significant information concerning the particular site. Site forms record only initial impressions, while later reports often go into much more detail, expanding on and even changing conclusions and interpretations from the site forms. An exhaustive search for these documents was not made, particularly for Oregon sites, however the reports listed were encountered in the process of researching this thesis. They should be available at the SHPOs, or through many conventional sources such as libraries, universities and CRM firms.
CHAPTER 4
BUILDING THE MODEL PART I:
PRELIMINARY DATA ANALYSIS

The steps involved in the construction of a predictive model, outlined in general terms in Chapter 2, are detailed in this chapter and in Chapters 5 as they apply to the Wapato Valley Predictive Model. This model is an inductive (correlative) probability model, in that it explores observable and measurable relationships between qualities of the environment (independent variables) and the presence of an archaeological site (dependent variable). The prediction itself is expressed in terms of probabilities – a score between 0 (low probability) and 1 (high probability) – that is a measure of the likelihood of the occurrence of an archaeological site at the given location (Warren and Asch 2000:8).

By far the most critical part of the entire model building process is the accurate determination of the location of existing archaeological sites to be used in the model, covered in Chapter 3. It is from this information that all other relationships proceed, so the importance of the quality of these data cannot be overemphasized. Models built with site location data that has not been checked for accuracy are not likely to be very effective (see Kvamme 1988a for the pitfalls of using existing data for model building).

After this initial issue is resolved, model building begins with creating the null point sample and measuring the values of the proposed independent variables for the archaeological sites and null points. A preliminary evaluation with univariate and bivariate statistics is made to determine the strength of the association of these variables with site location. These analyses are covered in the current chapter. The sites and null points are then divided into Training and Testing Samples.

The most significant variables – those that show the highest correlation with site presence – are used to develop the model through multivariate statistical analysis. Where the desired outcome is a measure of probability of a dichotomous dependent variable (site presence or absence) as in the case of the Wapato Valley Predictive Model, logistic regression is the method of choice. Stepwise methods of logistic regression offered with SPSS and other statistical software select the most significant independent variables for incorporation into the model. The results of the regression model are then assessed, and the scores are corrected for variation in sample sizes between the sites and null points. These elements of model building are covered in Chapter 5.

Define the Dataset

The first step in archaeological locational predictive model building is to define the dataset to be used. As noted previously, the sample used consists of all 276 known prehistoric archaeological sites in the study area. Alternatively, a probabilistic sampling strategy could have been used to sample a portion of the sites.

The null points that are used for comparison to site locations can come either from surveyed areas where no archaeological sites were found, from random points in the environment, or from both. In the case of the Wapato Valley Predictive Model, 327 random points were generated with the random point script "randpts.avx" (Jenness 2001) in ArcView. This script creates a specified number of random points in the same projection as a defined area, and records the location of each point in the appropriate X- and Y-coordinate format in an attribute table attached to the ArcView random point shapefile.

For the Wapato Valley, 2,000 points were generated in a large rectangle encompassing all eleven topographic maps in the study area. Of those 2,000 points, 563 were found to lie within the outline of the Wapato Valley study area, 449 of those were at 55 feet elevation or less, and 327 of those were on dry land (Figure 5.6). A few of these points are within 100 meters of an archaeological site and a few are within 100 meters of each other – this is to be expected for a simple random sample – but none was excluded. These 327 random points became the null point control sample for the Wapato Valley Predictive Model.

Independent Variables

It is essential to learn as much as possible about the landscape and the lives of the indigenous Chinookan peoples in order to make an informed decision about what qualities of the environment may have been considered most significant in the
siting of their villages and camps. In this respect, the Wapato Valley Predictive Model is not strictly inductive (Warren 1990:91). Such evaluations are an important component of deductive predictive modeling (Kohler and Parker 1986:432).


Potential predictor variables were measured at the location of each archaeological site and null point. In developing the Wapato Valley Predictive Model, it was hoped that these environmental variables would be few and that cor-
relations would be clear, unambiguous, and measurable on a continuous ratio scale. Because the environment of the floodplain of the Columbia River is fairly uniform, the potential existed for a model that was able to predict a high percentage of site locations correctly with just a few, untransformed variables. However, there was also the concern that the model might not work at all. Probability models rely on the contrast between the values of the independent variables at the location of archaeological sites versus null points. In such a uniform environment, would the differences be great enough to be significant? Based on research into the lifeways of the Chinook and the environment of the Columbia River floodplain, and a consideration of variables that had proven useful in other studies, six ratio scale measurements were taken at each archaeological site and null point location to be used in building the Wapato Valley Predictive Model: Feet Above Mean Sea Level, Feet Above River Level, Meters to Nearest Permanent Water, Meters to Navigable Water, Percent Slope, and Degrees Aspect.

Elevation above sea level is often a valid predictor of site location. In the floodplain environment, locations that were a little higher in elevation would be less likely to be subjected to seasonal flooding (see Appendix C: “Columbia River Floods”). Small differences in elevation could make a big difference in staying dry. In trying to model an area of little relief, accurate elevation measurements are critical. The surface elevation of the Columbia River itself on the USGS topographic maps changes from 0 feet to 16 feet from one end of the Wapato Valley to the other. Since this base elevation therefore is not constant, a second measure of elevation was used as well – elevation above river level – to see if it was a more accurate predictor of site presence. Hansen et al. (2002:7) also discovered that elevation above river level had a stronger relationship to site presence than did elevation above sea level.

Distance to water seems to be the most common independent variable in predictive models, reflecting dependence on reliable water sources. The Wapato Valley model considers two variations on this theme: distance to nearest permanent water and distance to navigable water. A nearby permanent water source would be suggestive of household water use. The navigable water distance would be related to food procurement, transportation, social interaction and trade.

Slope and aspect are often correlated with site presence or absence. Flatter terrain is usually more desirable for habitation sites. However, slope measurements on a largely flat floodplain can be somewhat problematical. In temperate latitudes, a south-facing aspect can be more warming and therefore more desirable. However, the exposure of sites can follow the prevailing aspect of the terrain, so this can also be a questionable association. Still, these two variables are easily measured with the aid of GIS programs, so they were included in model development. The strongest predictor variables of these six would be selected in the stepwise logistic regression model; the weaker ones would provide no significant additional predictive power and would be omitted by the model.

Other qualities of the landscape were considered for inclusion in the model, such as site type, site area, terrain, soils, underlying geology, and vegetation – indeed, these data were compiled in the Wapato Valley Prehistoric Archaeological Site Database for the 276 archaeological sites. However, after an initial examination of the distribution of these variables in this data set, it was concluded that there would probably be no significant difference in these measures between archaeological sites and null points, so the decision was made to attempt to build the model with just the six variables discussed above.

The values of the independent variables for the archaeological sites can be obtained from archaeological site forms if done with a critical eye (see the “Data Quality” section of Chapter 3), or can be measured with the help of GIS programs such as ArcView (Environmental Systems Research Institute 2000). The values of variables for which digital coverages are not available were obtained from other sources cited in Chapter 3.

The values of the six potential predictor variables for each archaeological site and null point were recorded in an Excel database and then imported into SPSS for analysis. This became the Wapato Valley Predictive Model Logistic Regression Site Probability Table (Appendix E), which was the source of data for developing the model.

Univariate Analysis
Preliminary data analysis was conducted using the entire sample of 276 archaeological sites and 327 null points in the Wapato Valley. Summary statistics were run to get an impression of the distribution of the values of the six potential predictor variables (Table 5.1). Initial inspection of this table reveals that the two sets of data are similar in some variables, but quite different in others. The mean values with their confidence intervals overlap for Feet Above Mean Sea Level, but not for Feet Above River Level. The means for Meters to Nearest Permanent Water and Meters to Navigable Water are quite different between archaeological sites and null points, and the means for Percent Slope and Degrees Aspect show moderate differences. Error bar charts with their 95 percent confidence intervals (Figures 5.7-5.9) are a good method of visualizing these differences.

Table 5.1. Summary Statistics for all 276 Archaeological Sites Versus all 327 Null Points.

<table>
<thead>
<tr>
<th>Archeological Sites</th>
<th>Feet Above Mean Sea Level</th>
<th>Feet Above River Level</th>
<th>Meters to Nearest Permanent Water</th>
<th>Meters to Navigable Water</th>
<th>Percent Slope</th>
<th>Degrees Aspect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Cases</td>
<td>2.76 276.00</td>
<td>276.00</td>
<td>276.00</td>
<td>276.00</td>
<td>276.00</td>
<td>276.00</td>
</tr>
<tr>
<td>Mean</td>
<td>15.83 6.89</td>
<td>20.85</td>
<td>90.15</td>
<td>6.61</td>
<td>104.67</td>
<td></td>
</tr>
<tr>
<td>95% Confidence</td>
<td>1.00 0.81</td>
<td>4.78</td>
<td>25.25</td>
<td>1.15</td>
<td>11.96</td>
<td></td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>8.47 6.87</td>
<td>40.30</td>
<td>213.10</td>
<td>9.73</td>
<td>100.91</td>
<td></td>
</tr>
<tr>
<td>Median</td>
<td>12.00 4.00</td>
<td>11.50</td>
<td>19.00</td>
<td>3.00</td>
<td>81.50</td>
<td></td>
</tr>
<tr>
<td>Mode</td>
<td>10.00 3.00</td>
<td>1.00</td>
<td>1.00</td>
<td>0.00</td>
<td>-1.00</td>
<td></td>
</tr>
<tr>
<td>Variance</td>
<td>71.67 47.22</td>
<td>1624.09</td>
<td>45410.70</td>
<td>94.68</td>
<td>10183.34</td>
<td></td>
</tr>
<tr>
<td>Skewness</td>
<td>1.96 2.73</td>
<td>7.69</td>
<td>4.19</td>
<td>2.20</td>
<td>0.50</td>
<td></td>
</tr>
<tr>
<td>Range</td>
<td>50.00 47.00</td>
<td>499.00</td>
<td>1599.00</td>
<td>55.00</td>
<td>321.00</td>
<td></td>
</tr>
<tr>
<td>Minimum</td>
<td>5.00 0.00</td>
<td>1.00</td>
<td>1.00</td>
<td>0.00</td>
<td>-1.00</td>
<td></td>
</tr>
<tr>
<td>Maximum</td>
<td>55.00 47.00</td>
<td>500.00</td>
<td>1600.00</td>
<td>55.00</td>
<td>320.00</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Null Points</th>
<th>Feet Above Mean Sea Level</th>
<th>Feet Above River Level</th>
<th>Meters to Nearest Permanent Water</th>
<th>Meters to Navigable Water</th>
<th>Percent Slope</th>
<th>Degrees Aspect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Cases</td>
<td>327.00</td>
<td>327.00</td>
<td>327.00</td>
<td>327.00</td>
<td>327.00</td>
<td>327.00</td>
</tr>
<tr>
<td>Mean</td>
<td>17.33 8.95</td>
<td>152.29</td>
<td>461.61</td>
<td>3.73</td>
<td>78.35</td>
<td></td>
</tr>
<tr>
<td>95% Confidence</td>
<td>1.15 1.10</td>
<td>22.82</td>
<td>56.63</td>
<td>0.72</td>
<td>11.00</td>
<td></td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>10.54 10.14</td>
<td>209.73</td>
<td>520.57</td>
<td>6.66</td>
<td>101.13</td>
<td></td>
</tr>
<tr>
<td>Median</td>
<td>13.00 4.00</td>
<td>80.00</td>
<td>300.00</td>
<td>1.00</td>
<td>24.00</td>
<td></td>
</tr>
<tr>
<td>Mode</td>
<td>10.00 3.00</td>
<td>1.00</td>
<td>1.00</td>
<td>0.00</td>
<td>-1.00</td>
<td></td>
</tr>
<tr>
<td>Variance</td>
<td>111.05 102.86</td>
<td>43987.63</td>
<td>270994.11</td>
<td>44.35</td>
<td>10227.93</td>
<td></td>
</tr>
<tr>
<td>Skewness</td>
<td>1.69 2.00</td>
<td>2.67</td>
<td>1.83</td>
<td>3.02</td>
<td>1.10</td>
<td></td>
</tr>
<tr>
<td>Range</td>
<td>51.00 48.00</td>
<td>1379.00</td>
<td>2999.00</td>
<td>40.00</td>
<td>358.00</td>
<td></td>
</tr>
<tr>
<td>Minimum</td>
<td>4.00 0.00</td>
<td>1.00</td>
<td>1.00</td>
<td>0.00</td>
<td>-1.00</td>
<td></td>
</tr>
<tr>
<td>Maximum</td>
<td>55.00 48.00</td>
<td>1380.00</td>
<td>3000.00</td>
<td>40.00</td>
<td>357.00</td>
<td></td>
</tr>
</tbody>
</table>
Figure 5.7. Error bar charts of Feet Above Mean Sea Level and Feet Above River Level for all archaeological sites and null points.
Figure 5.8. Error bar charts of Meters to Nearest Permanent Water and Meters to Navigable Water for all archaeological sites and null points.
Figure 5.9. Error bar charts of Percent Slope and Degrees Aspect for all archaeological sites and null points.
Histograms (Figures 5.10-5.15) plot the distribution of the values of each variable. An apparent bimodal distribution in Feet Above Mean Sea Level (Figure 5.10) disappears when elevation is normalized to the elevation of the Columbia River in Feet Above River Level (Figure 5.11). A skewed distribution, as in the case of Figure 5.12, Meters to Nearest Permanent Water, is easy to see in this graphic representation. There are small but significant differences in the distribution of values between archaeological sites and null points.

Bar graphs of the values of the independent variables in user-defined categories plotted against percentage of cases (Figures 5.16-5.21) can be used for a side-by-side comparison of values. Degrees Aspect (Figure 5.21) is more meaningful when categorized according to direction of exposure. Error bar charts, histograms, and bar graphs all help visually determine that there appear to be significant differences in the distribution of values of each of the six proposed independent variables between archaeological sites and null points, which occur in somewhat different environmental settings. This preliminary univariate analysis suggests that all six variables appear to be good candidates for logistic regression.

Figure 5.10. Histogram of archaeological sites and null points of Feet Above Mean Sea Level.
Figure 5.11. Histogram of archaeological sites and null points of Feet Above River Level.
Figure 5.12. Histogram of archaeological sites and null points of Meters to Nearest Permanent Water.
Figure 5.13. Histogram of archaeological sites and null points of Meters to Navigable Water.
Figure 5.14. Histogram of archaeological sites and null points of Percent Slope.
Figure 5.15. Histogram of archaeological sites and null points of Degrees Aspect.
Figure 5.16. Bar graph of Feet Above Mean Sea Level comparing archaeological sites and null points.
Figure 5.17. Bar graph of Feet Above River Level comparing archaeological sites and null points.
Figure 5.18. Bar graph of Meters to Nearest Permanent Water comparing archaeological sites and null points.
Figure 5.19. Bar graph of Meters to Navigable Water comparing archaeological sites and null points.
Figure 5.20. Bar graph of Percent Slope comparing archaeological sites and null points.
Figure 5.21. Bar graph of Degrees Aspect comparing archaeological sites and null points.
Bivariate Analysis

After initial evaluation of the values of the six proposed predictor variables with univariate statistics for the 276 archaeological sites and 327 null points, analysis proceeds with bivariate techniques. These techniques can be used to evaluate and measure the difference in the values of the independent variables between the groups of archaeological sites and null points to determine if the two groups are indeed distinct. The methods used in the Wapato Valley Predictive Model include the Independent Samples tests, including Levene’s Test for Equality of Variances and t-test for Equality of Means (Drennan 1996:155, Hosmer and Lemeshow 2000:93); the Mann Whitney U Test (Green et al. 2000:355, Warren and Asch 2000:14); and the Two-Sample Kolmogorov-Smirnov Test (Green et al. 2000:342, SPSS 1999).

The Independent Samples tests (Table 5.2) compare the variances and means for two groups of cases. Even if the independent variables do not meet the assumption of a normal distribution, and even if they contain outliers, these tests can provide a good indication of the independence of the two groups (Drennan 1996:164). With a large sample, this assumption can be violated and still yield reasonably accurate results (Green et al. 2000:150).

Levene’s Test for Equality of Variances is less dependent on the assumption of normality than the t-test (SPSS 1999). For the two groups under consideration, archaeological sites and null points, the results show that the probability that they came from the same population is very low. The F value is a measure of the difference in the variance between the two groups, and the significance given is the probability that the two groups came from the same population. For five of the six independent variables the significance is ≤ .004, and for the sixth (Degrees Aspect) it is .307. The difference in the variances is highly significant between the two groups for five of the six independent variables. This test also suggests that the two sets of archaeological sites and null points represent two separate groups.

The Mann-Whitney U is a non-parametric test that compares the medians of the two groups (Table 5.3). In the Ranks section, observations from both groups are combined and ranked. If the populations are the same in their median values, then the ranks should be randomly mixed between the two groups (Green et al. 2000:355). The Sum of Ranks of the median values of the Wapato Valley Predictive Model data are higher for the null points than the archaeological sites for all but one of the independent variables, indicating that the two groups are from two distinct populations.

Moving to the Test Statistics section, the Wilcoxon W value is the same as the Sum of Ranks value for the larger group (in this case, null points). At the .05 level of significance, the Z values must be < -1.96 or > +1.96 to reject the null hypothesis that the two groups came from the same population. The Z value of all six independent variables is < -1.96. The significance level for four of the six independent variables is .000 (.576 for Feet Above Mean Sea Level and .519 for Feet Above River Level). The results of the Mann-Whitney U analysis of medians strongly support the suggestion that two groups of archaeological sites and null points come from separate populations.

The final test that is appropriate for these sets of data is the Two Sample Kolmogorov-Smirnov Z Test (Table 5.4), a more general test that detects differences in the location and the shape of the distribution of the independent variables (SPSS 1999). When the difference is significantly large, the two distributions are considered different.

As with the Mann-Whitney U Test, the Z values must be < -1.96 or > +1.96 at the .05 level.
<table>
<thead>
<tr>
<th></th>
<th>Levene's Test for Equality of Variances</th>
<th>t-test for Equality of Means</th>
<th>95% Confidence Interval of Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$F$</td>
<td>Sig.</td>
<td>$t$</td>
</tr>
<tr>
<td>Feet Above Mean Sea Level</td>
<td>8.548</td>
<td>0.004</td>
<td>1.938</td>
</tr>
<tr>
<td>Feet Above River Level</td>
<td>28.245</td>
<td>0.000</td>
<td>2.957</td>
</tr>
<tr>
<td>Meters to Nearest Permanent Water</td>
<td>167.728</td>
<td>0.000</td>
<td>11.093</td>
</tr>
<tr>
<td>Meters to Navigable Water</td>
<td>135.052</td>
<td>0.000</td>
<td>11.786</td>
</tr>
<tr>
<td>Percent Slope</td>
<td>28.102</td>
<td>0.000</td>
<td>-4.155</td>
</tr>
<tr>
<td>Degrees Aspect</td>
<td>1.047</td>
<td>0.307</td>
<td>-3.188</td>
</tr>
</tbody>
</table>

Table 5.2. Independent Samples Tests: Levene’s Test for Equality of Variances and t-test for Equality of Means of the Independent Variables for Archaeological Sites Versus Null Points.
Table 5.3. Mann-Whitney U Test for Difference in Median Values of the Independent Variables for Archaeological Sites Versus Null Points.

<table>
<thead>
<tr>
<th>Ranks</th>
<th>Site</th>
<th>N</th>
<th>Mean Rank</th>
<th>Sum of Ranks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feet Above Mean Sea</td>
<td>site</td>
<td>276</td>
<td>297.78</td>
<td>82186.50</td>
</tr>
<tr>
<td>Level</td>
<td>null</td>
<td>327</td>
<td>305.56</td>
<td>99919.50</td>
</tr>
<tr>
<td>Feet Above River Level</td>
<td>site</td>
<td>276</td>
<td>297.14</td>
<td>82010.00</td>
</tr>
<tr>
<td>Level</td>
<td>null</td>
<td>327</td>
<td>306.10</td>
<td>100096.00</td>
</tr>
<tr>
<td>Meters to Nearest</td>
<td>site</td>
<td>276</td>
<td>205.39</td>
<td>56686.50</td>
</tr>
<tr>
<td>Permanent Water</td>
<td>null</td>
<td>327</td>
<td>383.55</td>
<td>125419.50</td>
</tr>
<tr>
<td>Meters to Navigable</td>
<td>site</td>
<td>276</td>
<td>200.38</td>
<td>55305.00</td>
</tr>
<tr>
<td>Water</td>
<td>null</td>
<td>327</td>
<td>387.77</td>
<td>126800.99</td>
</tr>
<tr>
<td>Percent Slope</td>
<td>null</td>
<td>327</td>
<td>274.14</td>
<td>89645.00</td>
</tr>
<tr>
<td>Degrees Aspect</td>
<td>site</td>
<td>276</td>
<td>279.02</td>
<td>91239.99</td>
</tr>
</tbody>
</table>

Test Statistics

<table>
<thead>
<tr>
<th></th>
<th>Feet AMSL</th>
<th>Feet ARL</th>
<th>Meters H2O</th>
<th>Percent Slope</th>
<th>Degrees Aspect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mann-Whitney U</td>
<td>43960.50</td>
<td>43784.00</td>
<td>18460.50</td>
<td>36017.00</td>
<td>37612.00</td>
</tr>
<tr>
<td>Wilcoxon W</td>
<td>82186.50</td>
<td>82010.00</td>
<td>56686.50</td>
<td>89645.00</td>
<td>91240.00</td>
</tr>
<tr>
<td>Z</td>
<td>-0.559</td>
<td>-0.644</td>
<td>-12.526</td>
<td>-4.409</td>
<td>-3.601</td>
</tr>
<tr>
<td>Asymp. Sig. (2-tailed)</td>
<td>0.576</td>
<td>0.519</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
</tr>
</tbody>
</table>

of significance, to reject the null hypothesis that the two groups came from the same population. The test statistics reveal that four of the six independent variables have Z values in this range and significance level of .000 (.552 for Feet Above Mean Sea Level and .117 for Feet Above River Level). The results of the Two-Sample Kolmogorov-Smirnov Test indicate that the differences in the distribution of the values of the independent variables are great enough to suggest that the two sets of data for archaeological sites and null points represent separate populations.

Two bivariate methods not used in this study include Spearman’s rank order correlation (Hudak et al. 2000[7]:28), which is a measure of the association between rank orders; and Pearson’s r, which evaluates the degree that the independent variables are linearly related (Green et al. 2000:234). However, Pearson’s r is not appropriate for non-linear relationships. In addition, Spearman’s rank order and Pearson’s r would be sensitive to the outliers found in the values of the predictor variables for the archaeological sites and null points and yield inaccurate test results. These outliers are actually quite important in the development of the Wapato Valley Predictive Model. A broad range of values is desirable for logistic
Table 5.4. Two-Sample Kolmogorov-Smirnov Z Test for Differences in the Distribution of the Independent Variables for Archaeological Sites Versus Null Points.

<table>
<thead>
<tr>
<th>Most Extreme Differences</th>
<th>Feet Above Mean Sea Level</th>
<th>Feet Above River Level</th>
<th>Meters to Nearest Permanent Water</th>
<th>Meters to Navigable H2O</th>
<th>Percent Slope</th>
<th>Degrees Aspect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Absolute</td>
<td>0.065</td>
<td>0.097</td>
<td>0.574</td>
<td>0.598</td>
<td>0.169</td>
<td>0.171</td>
</tr>
<tr>
<td>Positive</td>
<td>0.055</td>
<td>0.064</td>
<td>0.000</td>
<td>0.000</td>
<td>0.169</td>
<td>0.171</td>
</tr>
<tr>
<td>Negative</td>
<td>-0.065</td>
<td>-0.097</td>
<td>-0.574</td>
<td>-0.598</td>
<td>0.000</td>
<td>-0.036</td>
</tr>
<tr>
<td>Kolmogorov-Smirnov Z</td>
<td>0.795</td>
<td>1.191</td>
<td>7.023</td>
<td>7.320</td>
<td>2.073</td>
<td>2.095</td>
</tr>
<tr>
<td>Asymp. Sig. (2-tailed)</td>
<td>0.552</td>
<td>0.117</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
</tr>
</tbody>
</table>

regression so that the model will be valid over a greater variety of conditions (Robert Fountain, personal communication 2003).

The results of the four bivariate statistical analyses detailed in this section suggest that all six proposed independent variables are potential candidates for inclusion in logistic regression. There is a significant difference ($p \leq .004$) in the values of these variables between archaeological sites and null points in 75 percent of the comparisons of the six variables in the four tests, suggesting that the archaeological sites occur in environmental settings different from the average values of the landscape as a whole (Warren and Asch 2000:16). The weakest variable seems to be Feet Above Mean Sea Level, which has the lowest significance score on three of the four tests. Intuitively, it seems as if it would have the weakest correlation with site presence, since Feet Above River Level is a more accurate measure of site elevation in this study area. This relationship is also seen in the error bar charts for these two independent variables (Figure 5.7), where the range of values for Feet Above Mean Sea Level overlap between archaeological sites and null points, but do not do so for Feet Above River Level.

It is important to remember, however, that these analyses consider one independent variable at a time, or the average values of the two groups, whereas logistic regression is a multivariate technique. Hudak et al. (2000[7]:29) caution that univariate and bivariate analyses are meant only as a general screening tool for potential predictor variables. Apparently weaker variables can become significant predictors when used together. Hosmer and Lemeshow (2000:95) suggest that any variable whose univariate or bivariate test has a $p$-value of < .25 is a good candidate for multivariate analysis. All six independent variables have the potential to be significant predictors of site presence in binary multivariate logistic regression analysis, the subject of the next chapter.
CHAPTER 5  
BUILDING THE MODEL PART II:  
LOGISTIC REGRESSION

After preliminary analysis with univariate and bivariate statistics (Chapter 4), the most significant predictor variables are brought into logistic regression. Univariate and bivariate analyses indicate that all six independent variables are potential candidates for binary multivariate logistic regression: Feet Above Mean Sea Level, Feet Above River Level, Meters to Nearest Permanent Water, Meters to Navigable Water, Percent Slope, Degrees Aspect.

An abbreviated table was made of just these variables for the 276 archaeological sites and 327 null points in the Wapato Valley Predictive Model (Appendix E: “Wapato Valley Predictive Model Logistic Regression Probability Tables”) for ease of use in running logistic regression in SPSS. Sites and null points were given an ordinal number – from 1 to 327 for null points and 328 to 603 for archaeological sites – to facilitate tracking, and also a case number. For the null points, the case number represents the number of the point, from 1 to 2,000, of the 327 randomly generated points that were within the study area, at an elevation of 55 feet or less, and on dry land (see discussion in Chapter 4 under “Define the Dataset”). For the archaeological sites, the case number is the same as the Smithsonian trinomial designation for that site (i.e. 45CL1).

The topographic map name and UTM location were included to aid in the identification of the null points. For the archaeological sites, sensitive information that could be used to discover their location (such as the UTM coordinates, and the names of the topographic maps and waterways) was omitted to ensure confidentiality. The full site database is available to archaeology professionals from the Department of Anthropology, Portland State University, or from the author.

For classification purposes in logistic regression, a column was added and the cases assigned the value of 1 for archaeological sites or 0 for null points. This is how the binary dependent variable (site presence or absence) is coded in logistic regression; it also enables the two groups to be selected separately for analysis in SPSS if desired with the “Data, Select Cases” function. A column was also added and coded to distinguish the cases that were used to develop the Wapato Valley Predictive Model (Training Sample) from those that were withheld from model development and used to test the model (Testing Sample).

Training Versus Testing Samples

One of the best ways to test the classificatory accuracy of a predictive model developed through logistic regression analysis is with a set of samples independent of the ones used to develop the model (Warren and Asch 2000:15). Before running logistic regression, portions of the site and null point samples are withheld from the development of the model to independently test the classification accuracy of the model at the end (Training versus Testing Samples) (Warren 1990a:109). Different methods for split sampling have been used, involving withholding various proportions of the total sample (Kvamme 1988b:395, Rose and Altschul 1988:243). Most statistical procedures consider 30 cases to be a sufficiently large sample (Anderson et al. 1999:265), so a Testing Sample should be approximately this size.

A Testing Sample of 58 archaeological sites and 35 null points was reserved from the total number of sites and points to test the model. The 29 sites on the Ridgefield National Wildlife Refuge (to test its similarity to the rest of the Wapato Valley), as well as a random sample of 29 of the remaining archaeological sites (to reflect the region as a whole), were withheld from model development to be used as a Testing Sample at the end. A random sample of 35 null points was also withheld, bringing the total samples for model development (Training Sample) to 510: 218 archaeological sites and 292 null points. A listing of these cases is included in Appendix E: “Wapato Valley Predictive Model Logistic Regression Probability Tables”, and in Appendix F: “Guidelines for Applying the Results of the Wapato Valley Predictive Model without the Probability Maps”.

When developing a model in logistic regression with SPSS, the cases can be easily split into Training and Testing Samples by the addition of an extra column that is coded to distinguish these groups. SPSS will use the Training Sample to develop the model and then apply the results to
Preliminary Logistic Regression

A first run in logistic regression was made using the entire sample of 603 archaeological sites and null points for an initial evaluation of the likelihood of success of the Wapato Valley Predictive Model. This would provide another indication of the usefulness of the proposed independent variables and their combined strength as site predictors. All six variables were entered as covariates against the binary dependent variable of site presence or absence (using the “Enter” method), probabilities and group membership were chosen to be saved to the regression table, and a probability score of .5 was selected as the cut point for the definition of an archaeological site. The results were very encouraging (Table 5.5).

Referring to the regression output in Table 5.5, the Score value at Step 0 (Variables Not In The Equation) should be a large number – the larger the number, the greater its significance.

<table>
<thead>
<tr>
<th>Variables not in the Equation</th>
<th>Score</th>
<th>df</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feet Above Mean Sea Level</td>
<td>3.613</td>
<td>1</td>
<td>0.057</td>
</tr>
<tr>
<td>Feet Above River Level</td>
<td>8.125</td>
<td>1</td>
<td>0.004</td>
</tr>
<tr>
<td>Meters to Nearest Permanent Water</td>
<td>89.753</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Meters to Navigable Water</td>
<td>102.507</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Percent Slope</td>
<td>17.873</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Degrees Aspect</td>
<td>10.023</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Overall Statistics</td>
<td>136.014</td>
<td>6</td>
<td>0.002</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Classification Table</th>
</tr>
</thead>
<tbody>
<tr>
<td>Observed</td>
</tr>
<tr>
<td>Step 1</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Overall Percentage</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Variables in the Equation</th>
<th>B</th>
<th>S.E.</th>
<th>Wald</th>
<th>df</th>
<th>Sig.</th>
<th>Exp(B)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feet AMSL</td>
<td>0.033</td>
<td>0.030</td>
<td>1.229</td>
<td>1</td>
<td>0.268</td>
<td>1.034</td>
</tr>
<tr>
<td>Feet ARL</td>
<td>0.029</td>
<td>0.035</td>
<td>0.669</td>
<td>1</td>
<td>0.413</td>
<td>1.029</td>
</tr>
<tr>
<td>Meters to Perm H2O</td>
<td>-0.022</td>
<td>0.003</td>
<td>55.634</td>
<td>1</td>
<td>0.000</td>
<td>0.978</td>
</tr>
<tr>
<td>Meters to Nav H2O</td>
<td>-0.003</td>
<td>0.000</td>
<td>39.486</td>
<td>1</td>
<td>0.000</td>
<td>0.997</td>
</tr>
<tr>
<td>Percent Slope</td>
<td>-0.003</td>
<td>0.014</td>
<td>0.043</td>
<td>1</td>
<td>0.835</td>
<td>0.997</td>
</tr>
<tr>
<td>Degrees Aspect</td>
<td>0.000</td>
<td>0.001</td>
<td>0.192</td>
<td>1</td>
<td>0.661</td>
<td>1.000</td>
</tr>
<tr>
<td>Constant</td>
<td>0.692</td>
<td>0.300</td>
<td>5.319</td>
<td>1</td>
<td>0.021</td>
<td>2.133</td>
</tr>
</tbody>
</table>
value. Although differences are apparent in the strength of the proposed independent variables, five of the six have a significance of < .005 (p = .057 for Feet Above Mean Sea Level).

With the entry of all the variables into the logistic regression equation at Step 1, the Classification Table shows that the ability to discriminate between archaeological sites and random points in the environment for this initial model is very high: 90.9 percent for archaeological sites and 74.0 percent for null points, with an overall ability of 81.8 percent. Most predictive models with a classification accuracy of 70 percent are considered quite successful. These figures may be inflated at this point, however, because the same data were used both to build the model and to evaluate its performance (Kvamme 1998b:366). The classifications in the Final Model need to be evaluated against a Testing Sample that was not used in the development of the model.

Not only was the classification success encouraging in this initial run of all six variables in logistic regression, but the gain in correct classification of archaeological sites over random points is high. This gain statistic developed by Kvamme (1988b:329) can be used to compare the classification success of a model at different stages in its development. It is expressed as:

\[ 1 - \left( \frac{\text{percent area}}{\text{percent sites}} \right) = \text{GAIN} \]

where percent area is the percentage of the environment represented by the random points with a probability score of \( \geq .5 \), the cutoff point specified in this regression model (in this case, 26 percent); and percent sites is the percentage of known archaeological sites found in the same area (in this case, 90.9 percent). In this initial regression analysis, the gain statistic is:

\[ 1 - \left( \frac{26}{90.9} \right) = 71.4 \text{ percent gain over the random or null classification} \]

Essentially, this indicates that 90.9 percent of archaeological sites are found in just 26 percent of the land area of the Wapato Valley.

The final indication of the likelihood of success of the proposed model is in the Variables In The Equation section at Step 1 (Table 5.5). This table shows several things. The first two columns are the coefficients of the independent variables \( B \) and their standard errors. The \( B \) value is the natural logarithm of the odds ratio (the \( \text{Exp}(B) \) column). A positive value of the coefficient indicates that as the value of the independent variable increases, the probability of site presence increases; a negative value of the coefficient indicates that as the value of the independent variable decreases, the probability of site presence increases. Thus a negative value for the independent variable Meters to Nearest Permanent Water means that at lower distances to permanent water, site probability increases. This can also be seen for Meters to Navigable Water and Percent Slope. The \( B \) values and standard errors look promising for all six independent variables.

The Wald statistic and its significance level is like a chi-square measure of the significance of the logistic regression coefficient for each independent variable (Garson 2003:3): the larger the number for the Wald statistic, the greater its significance \( (p\text{-value}) \). This statistic is rather conservative, but can be a good indication of the strength of the independent variables.

The final column, \( \text{Exp}(B) \), is the odds ratio. For each unit increase in measurement of the independent variable, the odds of the occurrence of the dependent variable (in this case site presence) increases or decreases by this factor. Thus if Feet Above River Level increases by one foot, site probability increases by 3 percent. If Meters to Nearest Permanent Water increases by one meter, site probability decreases by 2 percent. The closer this value is to 1.000, the less the difference in probability seen with increases or decreases in the value of the independent variable.

Four other statistics presented in the SPSS in the logistic regression output (not shown in Table 5.5) indicate the overall strength of the model. The Model Chi-square, which is found in a table named Omnibus Tests of Model Coefficients, is a more reliable chi-square measure of model significance than the Wald test. This test is also known variously as \( G_m \), Hosmer and Lemeshow’s \( G \), \(-2LL_{\text{difference}}\), or Goodness of Fit \( G^2 \) (Garson 2003:8). For this first model, the Chi-square value is 276.884, \( df = 6 \), \( p = .000 \), showing an extremely strong relationship between the independent variables and site presence.
Another test of model performance is the Hosmer and Lemeshow Goodness-of-Fit Test. This test divides the test samples into ten groups by probability score, then runs a chi-square statistic on the observed versus expected values (Garson 2003:9). The test statistic for this model is: $C = 39.690, df = 8, p = .000$. A large p-value is desirable with this test, so the Wapato Valley Predictive Model does not perform well here. The score in this test can be adversely affected by low expected values, however, which are characteristic of the lowest four probability score groups of archaeological sites (Hosmer and Lemeshow 2000:151). Hosmer and Lemeshow (2000:156) go on to state that this test is only one of many to be considered when evaluating the fit of a model. The other tests detailed in this section demonstrate the strength of the Wapato Valley Predictive Model.

The final tests of model performance are listed in the Model Summary table. The -2 Log Likelihood value is 554.733, indicating a very significant model. Two $R^2$ statistics are also given. For this initial model the Cox and Snell $R^2$ is .368, and the Nagelkerke $R^2$ is .492. The $R^2$ statistic has no real equivalent in logistic regression (Whitehead 2001:5), and these values are always low when compared to linear regression $R^2$ values. Some authorities recommend not routinely publishing them because of possible confusion (Hosmer and Lemeshow 200:16). The Classification Table is also very similar, with the correct classifications on all six variables. Selected results are shown in Table 5.6.

The Independent Samples tests were run on the values of the regression scores of the two groups: archaeological sites and null points. Levene’s Test for Equality of Variances ($F = 207.889, p = .000$) and the t-test for Equality of Means ($t = -21.872, df = 524.635, p = .000$, equal variances not assumed) both show highly significant differences in the mean logistic regression scores between the two groups.

The results of the initial analysis of the total sample of 276 archaeological sites and 327 null points with the Enter method of logistic regression demonstrate that the six proposed independent variables are good discriminators between archaeological sites and null points. This confirms the findings of the preliminary univariate and bivariate statistical analysis that suggest that archaeological sites tend to occur at places in the environment that are measurably different from the average values of the landscape as a whole (Warren and Asch 2000:16). Some of the variables appear to be stronger predictors than others, however stepwise logistic regression should be able to select the most powerful ones to build the most parsimonious model.

Before proceeding to the stepwise method, one more run was made in logistic regression with the total sample of 603 archaeological sites and null points, this time omitting the independent variable Feet Above Mean Sea Level. It was felt intuitively all along that this variable would be the weaker of the two elevation variables; it proved weaker in the first regression analysis, and its usefulness as a predictor is compromised by its autocorrelation with the variable Feet Above River Level. Since logistic regression considers a particular combination of independent variables in arriving at the probability score, any variable that is not as strong a predictor can pull the values of the others down (Ken Kvamme, personal communication 2003). The same methods were used in this analysis as in the initial run with all six variables. The scores for the independent variables and their significance in the Variables Not In The Equation section are almost identical to the first logistic regression. The Classification Table is also very similar, with the correct classifications only 2-4 cases fewer than the initial run. Kvamme’s gain statistic is 1-(27.2/90.2) = 69.8 percent. This model seems to perform about as well as the first regression model.

The Variables in the Equation section, however, shows significant differences. The B coefficient and its standard error, as well as the Wald statistic and its significance for the Feet Above River Level variable have all improved considerably. Percent Slope and Degrees Aspect continue to be mediocre performers with the Wald statistic. The Model Chi-square value is 275.638, $df = 5, p = .000$, showing as before an extremely strong relationship between the independent variables and site presence. The -2 Log Likelihood is 555.979, the Cox and Snell $R^2$ is .367, and the Nagelkerke $R^2$ is .490, all similar to the initial results.
Table 5.6. Results of the Second Logistic Regression Analysis Using the Enter Method: All 603 Archaeological Sites and Null Points, Five Strongest Independent Variables.

<table>
<thead>
<tr>
<th>Variables not in the Equation</th>
<th>Score</th>
<th>df</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feet Above River Level</td>
<td>8.125</td>
<td>1</td>
<td>0.004</td>
</tr>
<tr>
<td>Meters to Nearest Permanent Water</td>
<td>89.753</td>
<td>1</td>
<td>0.000</td>
</tr>
<tr>
<td>Meters to Navigable Water</td>
<td>102.507</td>
<td>1</td>
<td>0.000</td>
</tr>
<tr>
<td>Percent Slope</td>
<td>17.873</td>
<td>1</td>
<td>0.000</td>
</tr>
<tr>
<td>Degrees Aspect</td>
<td>10.023</td>
<td>1</td>
<td>0.002</td>
</tr>
<tr>
<td>Overall Statistics</td>
<td>135.700</td>
<td>5</td>
<td>0.000</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Classification Table</th>
<th>Observed</th>
<th>Predicted</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Sites</td>
<td>Null Points</td>
<td>Correct</td>
</tr>
<tr>
<td>Step 1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Archaeological Sites</td>
<td>249</td>
<td>27</td>
<td>90.2</td>
</tr>
<tr>
<td>Null Points</td>
<td>89</td>
<td>238</td>
<td>72.8</td>
</tr>
<tr>
<td>Overall Percentage</td>
<td></td>
<td></td>
<td>80.8</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Variables in the Equation</th>
<th>B</th>
<th>S.E.</th>
<th>Wald</th>
<th>df</th>
<th>Sig.</th>
<th>Exp(B)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feet ARL</td>
<td>0.063</td>
<td>0.018</td>
<td>12.464</td>
<td>1</td>
<td>0.000</td>
<td>1.065</td>
</tr>
<tr>
<td>Meters to Perm H2O</td>
<td>-0.022</td>
<td>0.003</td>
<td>55.698</td>
<td>1</td>
<td>0.000</td>
<td>0.979</td>
</tr>
<tr>
<td>Meters to Nav H2O</td>
<td>-0.003</td>
<td>0.000</td>
<td>40.828</td>
<td>1</td>
<td>0.000</td>
<td>0.997</td>
</tr>
<tr>
<td>Percent Slope</td>
<td>-0.002</td>
<td>0.014</td>
<td>0.017</td>
<td>1</td>
<td>0.897</td>
<td>0.998</td>
</tr>
<tr>
<td>Degrees Aspect</td>
<td>0.001</td>
<td>0.001</td>
<td>0.259</td>
<td>1</td>
<td>0.611</td>
<td>1.001</td>
</tr>
<tr>
<td>Constant</td>
<td>0.96</td>
<td>0.181</td>
<td>28.269</td>
<td>1</td>
<td>0.000</td>
<td>2.612</td>
</tr>
</tbody>
</table>

This refined preliminary model, developed using all 276 archaeological sites and 327 null points, and omitting the less significant of the two elevation variables, provides a forecast of the results of the final stepwise logistic regression model. The significance of three of the five independent variables (Feet Above River Level, Meters to Nearest Permanent Water, Meters to Navigable Water) is .000 with the Wald statistic. The standard errors of the B coefficients are low. The classification accuracy continues to be greater than 80 percent overall – greater than 90 percent for archaeological sites. The other indications of model performance, such as the Model Chi-square and R² values, continue to be strong. The model is now ready for further development through stepwise logistic regression.

Stepwise Logistic Regression

The stepwise method of logistic regression in SPSS is based on a statistical algorithm that checks for the “importance” of variables, and either includes them (in the forward model) or excludes them (in the backward model) based on a user-defined decision rule that is a measure of
the significance of the coefficient for that variable (Hosmer and Lemeshow 2000:116). At each step of the model, the most important variable is the one that produces the greatest effect on the outcome of the analysis. Stepwise logistic regression can be an effective tool in screening large numbers of independent variables when their effect on the dependent variable is not known or well understood (Hosmer and Lemeshow 2000:116). Warren and Asch (2000:17) were able to screen 24 independent variables with stepwise logistic regression; their model ultimately selected the six strongest predictors.

The Forward Conditional method of stepwise logistic regression, which is the method used for the Wapato Valley Predictive Model, first fits the intercept only model and evaluates the significance of the potential independent variables entered into the equation at Step 0. Step 1 brings in the most significant independent variable, evaluates the strength of the resulting model and gives the coefficients for that independent variable and the constant. At Step 2, the most significant of the remaining independent variables, the one with the smallest p-value, is added to the model. At each step, the program both adds the most significant variable and then checks the strength of the resulting model. In order to do this, the first variable is deleted and the model is reevaluated with just the second variable – it is possible that once the second has been added, the first is no longer important (Hosmer and Lemeshow 2000:118). This process is recorded in the Iteration History section of the SPSS output.

These steps continue until the p-value of the variables retained in the model is less than the specified entry decision rule, and those variables eliminated from the model have p-values greater than the specified cutoff point. The default conditions in the “Probability for Stepwise” section of the “Logistic Regression: Options” menu were used in the Wapato Valley Predictive Model: a p-value of .05 for entry into the model, and a p-value of .10 for removal.

A preliminary run using the Forward Conditional method of stepwise logistic regression (Table 5.7) was made using all 603 archaeological sites and null points, as an initial evaluation of the five remaining independent variables and their potential performance in the stepwise model. The results echo the results seen with the three strongest independent variables with the Enter method of logistic regression presented in Table 5.6. Step 1 selected Meters to Navigable Water as the most significant variable; Step 2 selected Meters to Nearest Permanent Water as the second most significant; Step 3 selected Feet Above River Level as the third most significant and terminated the program. Percent Slope and Degrees Aspect bring no further discriminating power to the model and were not incorporated into it.

The resulting model at Step 3 is composed of the three strongest independent variables – Meters to Navigable Water, Meters to Nearest Permanent Water, and Feet Above River Level – all with p-values of .000 with the Wald statistic. The standard errors of the B coefficients are low. The model accurately identifies archaeological sites 89.9 percent of the time and null points 72.8 percent of the time, using a probability score of ≥ .5 for site definition, with an overall accuracy of 80.6 percent. Kvamme’s gain statistic is 1-(27.2/89.9) = 69.7 percent over the random or null classification.

Other statistics also show this to be a very significant model. The value for the Omnibus Test of Model Coefficients (the Model Chi-square), is 275.378, df = 3, p = .000, indicating a highly significant relationship between the three independent variables and site presence. The -2 Log Likelihood value is 556.239; the R² values are the same as before: the Cox and Snell R² is .367, and the Nagelkerke R² is .490. This first run of all 603 archaeological sites and null points with Forward Conditional stepwise logistic regression suggests that the final Wapato Valley Predictive Model will be just as successful.

**Preliminary Main Effects Model**

Through the assessment of the performance of the proposed Wapato Valley Predictive model with univariate and bivariate statistics, and after initial runs with all 603 archaeological sites and null points in the Enter and the Forward Conditional methods of stepwise logistic regression, the probable significance of the final model has been established. All indications from this preliminary work suggest that archaeological sites
Table 5.7. Results of First Stepwise Logistic Regression Analysis Using the Forward Conditional Method: All 603 Archaeological Sites and Null Points, Five Strongest Independent Variables.

### Variables not in the Equation

<table>
<thead>
<tr>
<th>Step 0</th>
<th>Score</th>
<th>df</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feet Above River Level</td>
<td>8.125</td>
<td>1</td>
<td>0.004</td>
</tr>
<tr>
<td>Meters to Nearest Permanent Water</td>
<td>89.753</td>
<td>1</td>
<td>0.000</td>
</tr>
<tr>
<td>Meters to Navigable Water</td>
<td>102.507</td>
<td>1</td>
<td>0.000</td>
</tr>
<tr>
<td>Percent Slope</td>
<td>17.873</td>
<td>1</td>
<td>0.000</td>
</tr>
<tr>
<td>Degrees Aspect</td>
<td>10.023</td>
<td>1</td>
<td>0.002</td>
</tr>
<tr>
<td>Overall Statistics</td>
<td>135.7</td>
<td>5</td>
<td>0.000</td>
</tr>
</tbody>
</table>

### Classification Table

<table>
<thead>
<tr>
<th>Observed</th>
<th>Predicted</th>
<th>Percentage Correct</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Sites</td>
<td>Null Points</td>
</tr>
<tr>
<td>Step 1</td>
<td>248</td>
<td>28</td>
</tr>
<tr>
<td>Archaeological Sites</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Null Points</td>
<td>89</td>
<td>238</td>
</tr>
<tr>
<td>Overall Percentage</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Variables in the Equation

<table>
<thead>
<tr>
<th>Step 1</th>
<th>B</th>
<th>S.E.</th>
<th>Wald</th>
<th>df</th>
<th>Sig.</th>
<th>Exp(B)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Meters to Nav H2O</td>
<td>-0.004</td>
<td>0.001</td>
<td>61.257</td>
<td>1</td>
<td>0.000</td>
<td>0.996</td>
</tr>
<tr>
<td>Constant</td>
<td>0.682</td>
<td>0.114</td>
<td>35.580</td>
<td>1</td>
<td>0.000</td>
<td>1.977</td>
</tr>
<tr>
<td>Step 2</td>
<td>B</td>
<td>S.E.</td>
<td>Wald</td>
<td>df</td>
<td>Sig.</td>
<td>Exp(B)</td>
</tr>
<tr>
<td>Meters to Perm H2O</td>
<td>-0.019</td>
<td>0.003</td>
<td>50.930</td>
<td>1</td>
<td>0.000</td>
<td>0.981</td>
</tr>
<tr>
<td>Meters to Nav H2O</td>
<td>-0.003</td>
<td>0.000</td>
<td>35.127</td>
<td>1</td>
<td>0.000</td>
<td>0.997</td>
</tr>
<tr>
<td>Constant</td>
<td>1.278</td>
<td>0.142</td>
<td>80.970</td>
<td>1</td>
<td>0.000</td>
<td>3.590</td>
</tr>
<tr>
<td>Step 3</td>
<td>B</td>
<td>S.E.</td>
<td>Wald</td>
<td>df</td>
<td>Sig.</td>
<td>Exp(B)</td>
</tr>
<tr>
<td>Feet ARL</td>
<td>0.064</td>
<td>0.017</td>
<td>14.751</td>
<td>1</td>
<td>0.000</td>
<td>1.066</td>
</tr>
<tr>
<td>Meters to Perm H2O</td>
<td>-0.022</td>
<td>0.003</td>
<td>59.015</td>
<td>1</td>
<td>0.000</td>
<td>0.978</td>
</tr>
<tr>
<td>Meters to Nav H2O</td>
<td>-0.003</td>
<td>0.000</td>
<td>41.716</td>
<td>1</td>
<td>0.000</td>
<td>0.997</td>
</tr>
<tr>
<td>Constant</td>
<td>0.999</td>
<td>0.154</td>
<td>41.931</td>
<td>1</td>
<td>0.000</td>
<td>2.717</td>
</tr>
</tbody>
</table>
tend to occur at places in the environment that are measurably different from the average values of the landscape as a whole. The initial runs in logistic regression indicate that there is a highly significant relationship between the three strongest independent variables – Feet Above River Level, Meters to Nearest Permanent Water, and Meters to Navigable Water – and the presence of an archaeological site.

The next step in model development is to run logistic regression with the archaeological sites and null points split into Training and Testing Samples. The Testing Sample will provide independent validation of the classification plots of the Training Sample. At the end, the results of this regression are examined, and each independent variable is analyzed so that all the important variables are included in the model and those that are excluded are statistically unimportant (Hosmer and Lemeshow 2000:97). This process yields what Hosmer and Lemeshow call the Preliminary Main Effects Model.

Through initial runs in Forward Conditional stepwise logistic regression, the three most significant independent variables have been determined; there is no reason to suppose that the outcome will be different with split sampling. There are different ways to run this final split sample regression: with all five of the strongest variables in the Forward Conditional stepwise method, with just the three most significant independent variables in the Forward Conditional method, or with the three most significant independent variables in the Enter method. Because of the advantage of being able to see the results of the stepwise selection at each step of the way, this final split sample regression will be run using all five variables in Forward Conditional stepwise logistic regression. In this particular model, however, the final results would be the same with any of the three methods.

There are 510 cases in the Training Sample: 218 archaeological sites and 292 null points. The 93-case Testing Sample was determined by a random selection of 35 of the null points and 29 of the archaeological sites, as well as by the withholding of the sample of 29 archaeological sites on the Ridgefield National Wildlife Refuge, as detailed in the previous section “Training Versus Testing Samples”. In SPSS, the Testing Sample is withheld from model development by using the extra column that was added and coded for these groups. This feature is activated in the binary logistic regression menu window under “Select”, which brings up the “Logistic Regression: Select Rule” window where the Training Sample can be selected. SPSS will use the Training Sample to develop the model and then apply the results to all cases. The results are saved to new columns in the data table by checking the “Predicted Values: Probabilities and Group Membership” boxes in the “Logistic Regression: Save New Variables” section of the menu.

The Logistic Regression menu window also allows the selection of various statistics and plots in the “Logistic Regression: Options” portion of the menu. This is also where the settings can be changed for the “Probability for Stepwise” values, as well as for the cutoff point in the probability scores for archaeological site or null point classification. The default setting for this value is .5, which is the most commonly used. However, there are instances where it might be desirable to use a higher or lower cutoff for site definition. This issue is addressed in the next chapter.

Selected results of this final split sample Forward Conditional stepwise logistic regression are detailed in Table 5.8. The full SPSS output can be found in Appendix H: “Final Model: SPSS Output of Forward Conditional Logistic Regression”. All five independent variables were entered as covariates against the binary dependent variable of site presence or absence. As with the first stepwise regression results above, Step 1 selected Meters to Navigable Water as the most significant variable; Step 2 selected Meters to Nearest Permanent Water as the second most significant; Step 3 selected Feet Above River Level as the third most significant. After Step 3, the p values of the variables Percent Slope and Degrees Aspect were below the specified threshold, so they were not incorporated into the model.

The results of this regression are similar to the results seen in the first stepwise regression with the entire sample of 603 archaeological sites and null points. In the Variables Not in the Equation section (Step 0), the larger the score value of the independent variable, the stronger it is as a predictor of site presence. The significance level
Table 5.8. Results of Final Forward Conditional Stepwise Logistic Regression Analysis: 603 Archaeological Sites and Null Points Split into Training (n = 510) and Testing (n = 93) Samples, Five Strongest Independent Variables.

<table>
<thead>
<tr>
<th>Variables not in the Equation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 0</td>
</tr>
<tr>
<td>Feet Above River Level</td>
</tr>
<tr>
<td>Meters to Nearest Permanent Water</td>
</tr>
<tr>
<td>Meters to Navigable Water</td>
</tr>
<tr>
<td>Percent Slope</td>
</tr>
<tr>
<td>Degrees Aspect</td>
</tr>
<tr>
<td>Overall Statistics</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Classification Tables</th>
</tr>
</thead>
<tbody>
<tr>
<td>Training Samples - Selected</td>
</tr>
<tr>
<td>Observed</td>
</tr>
<tr>
<td>Step 3</td>
</tr>
<tr>
<td>Null Points</td>
</tr>
<tr>
<td>Overall Percentage</td>
</tr>
</tbody>
</table>

| Training Samples - UnSelected | Predicted | Percentage |
| Observed | Sites | Null Points | Correct |
| Step 3 | Archaeological Sites | 50 | 8 | 86.2 |
| Null Points | 7 | 28 | 80.0 |
| Overall Percentage | | | 83.9 |

<table>
<thead>
<tr>
<th>Variables in the Equation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 0</td>
</tr>
<tr>
<td>Meters to Nav H2O</td>
</tr>
<tr>
<td>Constant</td>
</tr>
<tr>
<td>Meters to Perm H2O</td>
</tr>
<tr>
<td>Meters to Nav H2O</td>
</tr>
<tr>
<td>Constant</td>
</tr>
<tr>
<td>Feet ARL</td>
</tr>
<tr>
<td>Meters to Perm H2O</td>
</tr>
<tr>
<td>Meters to Nav H2O</td>
</tr>
<tr>
<td>Constant</td>
</tr>
</tbody>
</table>
for Feet Above River Level and for Degrees Aspect is less than before, however the significance of the other three variables is the same. All five variables have a $p$-value of $\leq .03$.

The probability score cutpoint of .5 was used to define a case as an archaeological site. The Classification Table for the Training Sample shows 2.3 percent fewer archaeological sites correctly classified, but 2.9 percent more null points correctly classified, for a slightly higher overall success rate of 80.8 percent with this sample. Kvamme’s gain statistic is $1-(24.3/87.6) = 72.3$ percent, which indicates that 87.6 percent of archaeological sites are found in just 24.3 percent of the land area of the Wapato Valley.

The classification success of the samples that were withheld from model development is a standard test of the accuracy of predictive models developed through logistic regression. The overall success of classification of the Testing Sample (83.9 percent) is slightly higher than that of the Training Sample (80.8 percent), which is one indication of the significance of the model. The combined effect of the three independent variables in the Wapato Valley Predictive Model predicts the presence of an archaeological site to an even greater degree of accuracy for this independent sample than with the cases used to develop the model.

The Variables in the Equation section shows the coefficients of the independent variables (B) and their standard errors at each step of the regression. For example, the negative coefficients in Step 3 of the model show that as the distance to both permanent and navigable water increases, site probability decreases. The standard errors continue to be small; large standard errors would indicate collinearity, which is not in evidence in this data set (Hosmer and Lemeshow 2000:141).

The B coefficient column also shows that there is only a modest change in the value of the coefficient for a given independent variable between steps of the model. Meters to Navigable Water goes from -.004 at Step 1, to -.003 at Step 2, to -.003 at Step 3. Meters to Nearest Permanent Water goes from .018 at Step 2 to -.020 at Step 3. This provides another indication that there is no confounding effect or interaction between the three independent variables (Hosmer and Lemeshow 2000:70).

The Variables in the Equation section also gives the Wald statistic and its significance for each independent variable at each step of the regression. The Wald statistic is like a chi-square measure of the significance of the logistic regression coefficient for each independent variable, so the larger the value, the greater its significance. The $p$-values of the water distance variables continue to be extremely strong at .000; the value for the elevation variable is also very strong at .001. Each of the three independent variables retained in the Wapato Valley Predictive Model is a highly significant predictor of site presence.

The final column in the Variables in the Equation table is the odds ratio, or Exp (B), an estimate of the change in the probability of site presence with a change of one unit of measure in the value of the independent variable. For example, in the case of Meters to Nearest Permanent Water, a one-meter decrease in the distance to water means an increase of two percent in the probability of the presence of an archaeological site. The 95 percent confidence intervals of these estimates is given in Appendix H: “Final Model: SPSS Output of Forward Conditional Logistic Regression”. For an independent variable to be considered a useful predictor of site presence, the confidence interval around the odds ratio should not include the value 1.0 (Garson 2003:2). All three independent variables in the Wapato Valley Predictive Model are considered significant predictors of site presence by the Exp (B) statistic.

Other tables in the SPSS output in Appendix H, such as Correlation Matrix, Model if Term Removed, and Variables Not in the Equation, display interim values during the regression steps. The final table shows the Casewise List of Residuals, with studentized values greater than 2.000. These are cases whose probability score deviates most from the predicted range: six archaeological sites with a score less than .1, and one null point with a score greater than .9. Only slightly more than 1 percent of cases in this model are outliers, however an examination of the six archaeological sites might reveal underlying similarities that could lead to a new understanding of factors that
influence site location.

Values in the SPSS output that are measures of the overall significance of the model include the Model Chi-square, the -2 Log Likelihood statistics, Hosmer and Lemeshow Goodness-of-Fit test, and the R² values. Whereas the Wald statistic provides chi-square values for the independent variables, the Omnibus Test of Model Coefficients provide chi-square values for the model. The statistic is computed and displayed at each stage of the stepwise regression model. The Model Chi-square value at Step 3 of the Wapato Valley Predictive Model is an extremely strong 216.526, \( df = 3, p = .000 \).

The -2 Log Likelihood figures are given at the beginning of the model at Step 0, and at each step of the regression model in the Iteration History. The final value for the -2 Log Likelihood, when subtracted from the beginning value of 696.235, yields the Model Chi-square. The model -2 Log Likelihood value at Step 3 is very significant at 479.708, indicating the strength of the relationship between the dependent and independent variables.

The Hosmer and Lemeshow Goodness-of-Fit test divides the samples into 10 groups based on predicted probabilities, then computes a score (\( \hat{C} \)) based on a chi-square of the expected versus observed values of the probability scores. The results for this model are \( \hat{C} = 33.018, df = 8, p = .000 \), which is not significant. As mentioned before, this is at least partially explained by the low site frequencies in the first four of the ten groups.

The final statistics in the Model Summary table are the R² values. The Cox & Snell R² is .346, and the Nagelkerke R² is .465. In SYSTAT, the McFadden’s R² for this model is .331. As stated previously, the R² statistic has no real equivalent in logistic regression (Whitehead 2001:5). In linear regression, R² values signify to what extent the independent variables explain the relationships described by the model. A high R² means that the majority of the variability of the dependent variable is accounted for by the independent variables in the model. The R² statistic is not valid in logistic regression because the product is a probability score; a low R² value does not imply a poor model fit (Hosmer and Lemeshow 2000:164).

Such pseudo-R² measures given in the output of logistic regression in statistical programs can be useful in comparing different models or stages of the model building process, but are always low when compared to linear regression R² values. Some scholars recommend not routinely publishing them because of possible confusion (Hosmer and Lemeshow 2000:167). The Model Chi-square value and its significance is a better test of the overall model performance.

One final test of the significance of the independent variables as predictors of site presence should be done. The values of the regression coefficients (B) and Wald statistics from this multivariate stepwise model should be compared with their values from models which each contain a single

---

Table 5.9. Comparison of the Regression Coefficients and Wald Statistics for the Three Independent Variables, Run Singly and in the Model.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Regression Coefficient (B)</th>
<th>Wald Statistic</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Alone</td>
<td>In Model</td>
<td>Alone</td>
</tr>
<tr>
<td>Elevation Above River Level</td>
<td>-0.025</td>
<td>0.059</td>
<td>5.013</td>
</tr>
<tr>
<td>Meters to Nearest Permanent Water</td>
<td>-0.022</td>
<td>-0.020</td>
<td>54.382</td>
</tr>
<tr>
<td>Meters to Navigable Water</td>
<td>-0.004</td>
<td>-0.003</td>
<td>64.197</td>
</tr>
</tbody>
</table>
variable (Hosmer and Lemeshow 2000:97). Logistic regression was run with each independent variable separately with the “Enter” method. The results can be seen in Table 5.9. The consistent values of the B coefficients, and the significance of the Wald statistic for the Meters to Nearest Permanent Water and Meters to Navigable Water variables, demonstrate the strength of their role in the Final Model. The change in the coefficient for Feet Above River Level indicates that while this particular independent variable is not a strong predictor by itself, it provides a needed adjustment of the effect of the other two variables in the model. This can be seen by the change in significance of the Wald statistic, and is further confirmed by the inclusion of this variable at Step 3 of the stepwise model.

The results of this final forward conditional stepwise logistic regression have demonstrated that this Preliminary Main Effects Model is an accurate and significant means for predicting the presence of an archaeological site on the floodplain of the Columbia River in the Portland Basin. The classification accuracy is 80.8 percent overall for the Training Sample, representing a 72.3 percent increase over the random or null classification at a cutpoint of .5. For the independent set of cases that were not used in the development of the model (Testing Sample), an even greater 83.9 percent are correctly classified. This includes a classification accuracy of 89.7 percent for the 29 archaeological sites on the Ridgefield National Wildlife Refuge, 82.8 percent for the 29 random archaeological sites, and 80 percent for the 35 random null points.

The significance of each the three retained independent variables – Feet Above River Level, Meters to Nearest Permanent Water, and Meters to Navigable Water – is .001 or better with the Wald statistic, meaning that there is only a one in one thousand likelihood that this relationship is due to chance. The Model Chi-square and -2 Log Likelihood values are also extremely significant. The Wapato Valley Predictive Model performs exceedingly well in all of these tests of variable and model significance.

**Main Effects Model**

After fitting the preliminary model, further examinations of the model parameters should be made. The independent variables are checked to see if they are scaled properly (in the case of categorical variables), or should be recoded or transformed by some mathematical operation (such as square root). This results in Hosmer and Lemeshow’s Main Effects Model (2000:98). Further testing for possible interactions between the independent variables yields the Preliminary Final Model (200:99). The Final Model, the result of further analysis of fit, is addressed in the next chapter.

The issue of the scale of categorical variables is only a concern with one of the potential independent variables in the Wapato Valley Predictive Model: Degrees Aspect. Regressions have been run all along using the ArcView-determined degree value of the aspect measure as the model value. There is a potential problem, however, with looking at aspect in this way (Ken Kvamme, personal communication 2003).

Degrees Aspect is measured relative to a 360-degree circle, which means that both 0 degrees and 360 degrees (actually, from 337.5-360 degrees on through 0-22.5 degrees) stand for the same approximate value: North. Researchers get around this problem by collapsing the west half of the compass scale over the east half, resulting in transformed Aspect values that are relative to north or south (Kvamme 1988b:337). The other concern with Degrees Aspect is that the Columbia River floodplain is an area of low relief, and consequently 27.9 percent of archaeological sites and 40.4 percent of null points have an aspect of -1.00, denoting flat terrain or no aspect. Recoding the degree measurements into nominal categories representing the compass direction or the degree of “southness” can solve the first problem, but the question of what to do about the flat terrain cases remains.

In order to help determine if Degrees Aspect is truly unimportant as an independent variable in the Wapato Valley Predictive Model, a t-test was done to evaluate transformed Aspect values in the total sample of archaeological sites and null points. The results show that with the flat category excluded, \( t = -2.167, df = 387.449, p = .031 \) (equal variances not assumed), suggesting a significant difference in the means of the archaeo-
logical site and null point transformed Aspect values. However, these results omit 35 percent of the cases.

The chi-square test was then run on the transformed Aspect, with cases from the flat category omitted, to evaluate the distribution across the remaining categories of transformed Aspect between archaeological sites and null points. The test finds that $\chi^2 = 34.043$, $df = 7$, $p = .001$, indicating that the distributions of values through the transformed Aspect categories is significantly different between archaeological sites and null points. The results, however, were again calculated on a sample omitting the flat terrain cases, which comprise more than one-third of all the cases.

Forward conditional stepwise logistic regression was then rerun with the categorical transformed Aspect values. With the flat terrain category included, the transformed Aspect variable added little additional predictive power and was not retained by the model. When the flat terrain category was excluded, the transformed Aspect variable was incorporated, and resulted in a slightly higher (1.5 percent) model classification success. In order to achieve this modest improvement, however, more than one-third of the cases must be discarded. Furthermore, eliminating these cases would result in a biased dataset. These disadvantages far outweigh the potential small increase in predictive power; consequently, the transformed Aspect variable was not used in the Wapato Valley Predictive Model.

Percent Slope also failed to be a significant predictor of archaeological site presence in the stepwise logistic regression model. There appeared to be definite differences in the Percent Slope values between archaeological sites and null points through univariate and bivariate analysis. In the final analysis, however, Percent Slope resulted in no further discriminating power, so it was not incorporated into the model.

The Main Effects Model contains the three strongest determinants of site presence: Feet Above River Level, Meters to Nearest Permanent Water, and Meters to Navigable Water. The principle of parsimony in modeling, which suggests using as few variables as possible that still explain the data (Hosmer and Lemeshow 2000:92), is preserved by the inclusion of only the most significant independent variables. In combination, they successfully classify 80.8 percent of the Training Sample and 83.9 percent of the Testing Sample, resulting in a gain of 72.3 percent over the random null point sample. The strength of the Wapato Valley Predictive Model is in its simplicity.

Preliminary Final Model

A further evaluation of possible interactions between the independent variables results in Hosmer and Lemeshow’s Preliminary Final Model (Hosmer and Lemeshow 2000:99). These tests involve rerunning the logistic regression Main Effects Model with the independent variables in combination with each other. This can be accomplished in the logistic regression menu in SPSS under “Covariates” by ctrl+selecting multiple variables and adding them as interaction terms.

The results of this analysis (Table 5.10) found that the covariates contribute little or nothing to increased classification success. The only variable that was retained in the stepwise model is the Meters to Nearest Permanent Water x Meters to Navigable Water set. The score for this interaction term at the beginning of the model is 25.561 ($p = .000$); at the end the $B$ coefficient is .000 (S.E. = .000) and the Wald statistic is 42.069 ($p = .000$). The Model Chi-square, and Hosmer and Lemeshow Goodness-of-Fit Tests are the same as in the Preliminary Main Effects Model; the -2 Log Likelihood value is slightly (but not significantly) less at 469.140; the $R^2$ values are slightly improved at .359 for the Cox and Snell, and .483 for the Nagelkerke. The classification success for the Training Sample improves by only .2 percent overall. Opting for parsimony, none of these interaction terms was added to the Final Model.

The process of analysis and refitting of independent variables that results in the Preliminary Final Model is now complete. The significance of the three independent variables selected by the Preliminary Main Effects Model – Feet Above River Level, Meters to Nearest Permanent Water, and Meters to Navigable Water – is confirmed through the above examination of the independent variables themselves and as interaction terms for inclusion into the model. Further analysis of the fit
Table 5.10. Results of Forward Conditional Stepwise Logistic Regression for Interaction Terms.

<table>
<thead>
<tr>
<th>Interaction Term</th>
<th>Retained by Model</th>
<th>Improvement in Model</th>
<th>Added to Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feet Above River Level</td>
<td>no</td>
<td>no</td>
<td>no</td>
</tr>
<tr>
<td>x Meters to Nearest Permanent Water</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Feet Above River Level</td>
<td>no</td>
<td>no</td>
<td>no</td>
</tr>
<tr>
<td>x Meters to Navigable Water</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Meters to Nearest Permanent Water</td>
<td>yes</td>
<td>slight</td>
<td>no</td>
</tr>
<tr>
<td>x Meters to Navigable Water</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Feet Above River Level</td>
<td>no</td>
<td>no</td>
<td>no</td>
</tr>
<tr>
<td>x Meters to Nearest Permanent Water</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>x Meters to Navigable Water</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

of the Wapato Valley Predictive Model is covered in the next chapter.

Correcting for Difference in Sample Sizes

Before proceeding to the final analysis of the fit of the model, one final adjustment needs to be made to the results of the Wapato Valley Predictive Model. The unequal number of cases in the archaeological site and null point groups affects the probability scores produced by the logistic regression model, with a bias toward prediction of the larger class (Hosmer and Lemeshow 2000:157, Wheatley and Gillings 2002:174). There are two ways to deal with this bias. One would be to equalize the number of null points to the number of sites; however, this would entail discarding valuable null point data. The other way would be to correct for the sample size bias after running the model. Several researchers describe this procedure (Kvamme 1983:18, Stopher and Meyburg 1979:339, Warren 1990:106, Warren and Asch 2000:29, Wheatley and Gillings 2002:175).

Group size has no effect on regression coefficients, but it can bias the y-intercept (Warren 1990:106). The logistic model provides unbiased estimators for all coefficients except the y-intercept constant (Stopher and Meyburg 1979:339). This bias can be corrected with the formula:

\[
\hat{a} = a + \ln \left( \frac{n_2}{n_1} \right)
\]

where \(\hat{a}\) is the unbiased constant, \(a\) is the biased constant (.836), \(\ln\) is a natural logarithm, \(n_2\) is the number of Training Sample cases in the larger sample of null points (\(n_2 = 292\)), and \(n_1\) is the number of Training Sample cases in the smaller sample of archaeological sites (\(n_1 = 218\)).

This calculation is easily done in SPSS by using the “Compute Variable” feature. Three steps are needed to compute the new regression coefficient. First, the new constant is calculated according to the above formula, \(\hat{a} = .836 + \ln \left( \frac{292}{218} \right)\), which yields a new unbiased y-intercept constant \(\hat{a} = 1.128\). This new constant is then entered into the regression equation in two steps: the first generating the score component of the equation; the second using this score to calculate the probability component. The regression equation is explained fully in Chapter 7. The results of the steps of this procedure to un bias the constant can be seen in Appendix E: “Wapato Valley Predictive Model Logistic Regression Probability Tables” in the final four columns labeled “Adjusted Score from New Constant”, “New Probability Score”, “Null = 0, Site = 1” and “New Probability Class (1-5)”.

Adjusting the y-intercept constant results in a sufficient alteration of probability scores to change the classification of a number of cases, using the same .5 cutpoint for archaeological site definition (Table 5.11). The overall rate of correct classification for Training Sample of 510 archaeo-
Table 5.11. Change in Classification Success of Training Sample of Archaeological Sites and Null Points after Adjusting y-Intercept Constant.

<table>
<thead>
<tr>
<th>Observed</th>
<th>Predicted</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Observed</td>
<td>Predicted</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sites</td>
<td>Null</td>
<td>Percent</td>
<td>Sites</td>
<td>Null</td>
</tr>
<tr>
<td>Archaeological Sites</td>
<td>191</td>
<td>27</td>
<td>87.6</td>
<td>202</td>
<td>16</td>
</tr>
<tr>
<td>(n=218)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Null Points</td>
<td>71</td>
<td>221</td>
<td>75.7</td>
<td>90</td>
<td>202</td>
</tr>
<tr>
<td>(n=292)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 5.12. Distribution of Training Sample (n = 510) of Archaeological Sites and Null Points through Probability Classes, Before and after Adjusting the y-Intercept Constant.

<table>
<thead>
<tr>
<th>Probability Score</th>
<th>Initial Classification</th>
<th>With Adjusted Constant</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Sites</td>
<td>%</td>
</tr>
<tr>
<td>Class 5 (.1-.8)</td>
<td>14</td>
<td>6.4</td>
</tr>
<tr>
<td>Class 4 (.8-.6)</td>
<td>151</td>
<td>69.2</td>
</tr>
<tr>
<td>Class 3 (.6-.4)</td>
<td>37</td>
<td>17.0</td>
</tr>
<tr>
<td>Class 2 (.4-.2)</td>
<td>8</td>
<td>3.7</td>
</tr>
<tr>
<td>Class 1 (.2-0)</td>
<td>8</td>
<td>3.7</td>
</tr>
</tbody>
</table>

The distribution of case probability scores also changes accordingly. By dividing the cases into five equal-interval classes by probability score, the effect of adjusting the y-intercept constant can be seen more clearly. The most noticeable effect is in the consistent upward shift of archaeological site cases into higher probability classes toward correct classification (Table 5.12). The null point cases experience a moderate upward shift in the lower classes and a downward shift in the higher classes, decreasing the classification accuracy for this group.

The purpose of transforming the logistic regression probability scores is the elimination of bias caused by unequal sample sizes of archaeological sites and null points. This procedure generally results in an increase in the value of individual...
probability scores overall, however the increase in scores for archaeological sites is greater than the increase in scores for null points: the net effect is an increase in classification accuracy for archaeological sites and a decrease in classification accuracy for null points. However, these transformed probability scores more accurately reflect the discriminating ability of the model, with its associated strengths and weaknesses.

If the classification accuracy of 69.2 percent for null points is not acceptable, the cutoff point for archaeological site definition can be changed from .5 to a higher value. There is an optimum cutoff point for the Wapato Valley Predictive Model that maximizes correct classification of both archaeological sites and null points; however, increasing the classification accuracy for null points would mean accepting a lower classification accuracy for archaeological sites. This topic is covered in detail in the next chapter.

**Conclusions**

The process of creating a successful predictive model has been described systematically in the last two chapters. The final stage of the modeling process is to consider the fit of the model: its internal consistency and how well it explains the data at hand. The main goal of using logistic regression to develop the Wapato Valley Predictive Model is to classify the archaeological sites and null points in the database as accurately as possible; this has been accomplished. The resulting regression coefficients fit the data well enough to explain most of the variability in the location of archaeological sites in the study area. The fit of these coefficients is key, because they will be used to create maps of archaeological site probability areas through combining surfaces of the independent variables in ArcView (see Chapter 7).

The various statistics from the logistic regression output have been investigated thoroughly and show excellent discrimination between archaeological sites and null points with the Preliminary Final Model. However, there are additional tests that can be employed to further analyze the fit of the model and to bring it to its final form. These tests are covered in the next chapter.
CHAPTER 6
EVALUATING THE MODEL

This chapter further assesses model fit and model performance with additional statistical tests, analyzes the distribution of probability scores between the archaeological sites and null points in the model, considers the regression probability score cutpoint used for site definition, and evaluates the classificatory accuracy and discriminatory ability of the model. These steps will yield the final or fitted model (Hosmer and Lemeshow 2000:184). The accuracy of the Wapato Valley Predictive Model can then be compared to other predictive models developed using similar methods.

Cohen’s Kappa

Before any model is used for inferences, it must be assessed for adequacy and fit (Hosmer and Lemeshow 2000:99). The Goodness of Fit statistics in the logistic regression output for the Wapato Valley Predictive Model (Model Chi-square G², and the Hosmer and Lemeshow Ĉ) were explained in the previous chapter. An additional statistic that can be explored is Cohen’s Kappa, a Goodness of Agreement measure (Bonham-Carter 1994:245).

Cohen’s Kappa is a measure of accuracy of prediction of group membership that corrects for chance agreements (Green et al. 2000:286). After determining the observed and expected proportions in a standard crosstabulation, Kappa measures the amount of agreement between attributes and corrects for the expected amount of agreement (Bonham-Carter 1994:248).

The value of Cohen’s Kappa for the Training Sample of cases is .593, SE = .034, p = .000. A value of 1 indicates perfect correlation; a value of 0 indicates that prediction is no better than chance. The Kappa value of .593 is further evidence of the correlative accuracy of the Wapato Valley Predictive Model.

Values of the Probability Scores

The probability scores for the individual cases of archaeological sites and null points determined through logistic regression are a multivariate function of the three independent variables included in the model (Warren and Asch 2000:19). The preliminary final logistic regression model can be further evaluated by looking at the differences in values of these probability scores between the two Training Sample groups of archaeological sites and null points (Figure 5.22). These histograms show that there is some overlap between the two groups, which indicates that the model does not provide perfect separation between archaeological sites and null points. However, there is clear separation of modes: the majority of archaeological sites score in the high site probability range (.5-1), whereas the majority of null points score in the low site probability range (0-.5) (Warren and Asch 2000:19).

The Levene’s Test for Equality of Variances and the t-test for Equality of Means are both significant at the .000 level for differences in the values of the probability scores between the two groups of cases. The Chi-Square result for the difference in the distribution of probability scores between the two groups is also significant at the .000 level. The Mann-Whitney U, Wilcoxon W, Two-Sample Kolmogorov-Smirnov, Wald-Wolfowitz, Spearman’s rank order correlation, and Pearson’s r are all significant at the .000 level. These tests reaffirm that, based on the probability scores generated through logistic regression, the cases constituting the Training Sample groups of archaeological sites and null points have less than a one in one thousand chance of having come from the same population.

Classification Tables

The correct classification percentages seen in the table of the regression output in the previous chapter are a product of the specified cutpoint of .5 for site definition. However, simply changing the cutpoint for site definition changes the classification results (Table 5.13). This fluid quality presents a problem when using classification tables to evaluate the strength of a model. Classification tables also reduce a probabilistic model, where the outcome is measured on a continuum, to a dichotomous model where the outcome is binary (Hosmer and Lemeshow 2000:157).

This suggests that statistical tests that are based on the classification table should not be the sole means used to evaluate model performance because they are heavily dependent on the distri-
distribution of probabilities in the model (Hosmer and Lemeshow 2000:158). In addition, cases close to the cutpoint stand a greater chance of being misclassified. For practical purposes, there might not be much difference between two cases with probability scores of .49 and .51, but if the cutpoint used were .5, they would be classified differently. The classification table is most appropriately used for model evaluation when classification is the goal of analysis, however it is not a substitute for other more rigorous methods of assessment of fit that have been applied in this and the previous chapter (Hosmer and Lemeshow 2000:160).

For the Wapato Valley Predictive Model, the main goal of the study is to define graduated areas of site probability through applying the logistic regression coefficients to the landscape. Regression analysis looks at the environmental characteristics of known archaeological sites as a multivariate function of the three independent variables included in the model. It arrives at coefficients for each variable that, taken together, most closely define the combined environmental characteristics that would correctly classify a location as an archaeological site 100% of the time. The probability score for such a location would be 1. It then computes a probability score for each archaeological site and null point used to develop the model (Training Sample) that compares the combined values of the independent variables for each of these cases to the “ideal” or 1 probability location. The correct classification of cases into archaeological sites or null points is merely a crosstabulation of the probability scores based on the desired cutpoint for site definition.

Logistic regression uses known archaeological sites and null points to develop the regression coefficients, and then provides a probability score for the cases used to develop these coefficients. However, ArcView uses only the coefficients in applying the results to the landscape (detailed in the next chapter); the case classifications are not directly represented on the probability maps.

Areas are defined in ArcView according to their similarity or dissimilarity to locations that contain archaeological sites. An area that represents a probability of .8-.9, for example, would define places in the environment that are most similar to cases (mostly archaeological sites) having a probability score of .8-.9. An area that represents a probability of .2-.3 would define places in the environment that are most similar to cases (mostly null points) having a probability score of .2-.3.

In the next chapter, the Wapato Valley is split into five probability areas, however any divisions that meet the needs of a particular application can be made. Ultimately, the research and management questions of the individuals applying the model will govern the definition of probability areas, as well as the approaches taken for discovery and preservation of archaeological resources in these areas.

Site Definition Cutpoint

A table of correct classification by cutpoint probabilities can be used to show the difference in the discriminatory power of the model at different points along the curve. Table 5.14 shows how changing the probability score cutpoint for site definition changes the classificatory accuracy for archaeological sites and null points in the Training Sample of the Wapato Valley Predictive Model. Sensitivity refers to correct classification of archaeological sites, and specificity refers to the correct classification of null points (Hosmer and Lemeshow 2000:160).

These data can be graphed to further illustrate the effect of the change in cutpoint on the classificatory performance of the model (Figure 5.23). Along this gradient is seen a decline in the accuracy of prediction of archaeological sites and an increase in the accuracy of prediction of null points (Warren and Asch 2000:20). The point where the Training Sample curves intersect, at approximately .622, represents the cutpoint at which the maximum number of archaeological sites and null points are classified correctly (83 percent). The intersection point of the curves for the Testing Sample is only slightly lower at an optimum cutpoint value of .595, for a correct classification rate of 82.8 percent for both archaeological sites and null points.

The results for the Wapato Valley Predic-

---

2 There are only 10 archaeological sites and 22 null points with probability scores of .45-.55 in the Training Sample of the Wapato Valley Predictive Model.
Figure 5.22. Distribution of Training Sample archaeological sites and null points ($n = 510$) through the range of probability scores. The two groups are significantly different ($p = .000$): the majority of archaeological sites score in the high site probability range (.5-1), whereas the majority of null points score in the low site probability range (0-.5).
Table 5.13. An Example of the Effect of the Change in Training Sample Site Classification Rates Accompanying a Change in the Cutpoint for Site Definition from .5 to .6.

| Cutpoint | Observed Sites (n=218) | Predicted Sites | Null Points | Percent Correct | Observed Sites (n=292) | Predicted Sites | Null Points | Percent Correct |
|----------|------------------------|-----------------|-------------|----------------|------------------------|-----------------|-------------|----------------|----------------|----------------|-----------------|----------------|
| .5       | 202                    | 16              | 92.7        |                | 185                    | 33              | 84.9        |                |                |                | 90              | 202            | 69.2        |                |                |
| .6       | 90                     | 202             | 69.2        |                | 65                     | 227             | 77.7        |                |                |                | 145             | 246            | 66.5        |                |                |

Overall Classification Success

Table 5.14. Effect of Change in Site Definition Cutpoint on the Classificatory Success of 510 Training Sample Cases (Archaeological Sites n = 218, Null Points n = 292).

<table>
<thead>
<tr>
<th>Cutpoint</th>
<th>Correct Predictions</th>
<th>Incorrect Predictions</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Archaeological Sites (sensitivity)</td>
<td>Null Points (specificity)</td>
</tr>
<tr>
<td>#</td>
<td>%</td>
<td>#</td>
</tr>
<tr>
<td>0.0</td>
<td>218</td>
<td>100</td>
</tr>
<tr>
<td>0.1</td>
<td>213</td>
<td>97.7</td>
</tr>
<tr>
<td>0.2</td>
<td>212</td>
<td>97.2</td>
</tr>
<tr>
<td>0.3</td>
<td>207</td>
<td>95.0</td>
</tr>
<tr>
<td>0.4</td>
<td>207</td>
<td>95.0</td>
</tr>
<tr>
<td>0.5</td>
<td>202</td>
<td>92.7</td>
</tr>
<tr>
<td>0.6</td>
<td>185</td>
<td>84.9</td>
</tr>
<tr>
<td>0.7</td>
<td>145</td>
<td>66.5</td>
</tr>
<tr>
<td>0.8</td>
<td>32</td>
<td>14.7</td>
</tr>
<tr>
<td>0.9</td>
<td>4</td>
<td>1.8</td>
</tr>
<tr>
<td>1.0</td>
<td>0</td>
<td>0.0</td>
</tr>
</tbody>
</table>
Figure 5.23. Accuracy of Wapato Valley Predictive Model. The curves show the percent of correct predictions along the gradient of probability cutpoints for the Training and Testing Samples of archaeological sites versus null points. The point where the curves intersect represents the optimum correct classification rate for both groups.
tive Model presented in the previous chapter use a probability score cutpoint of .5 for site definition, resulting in correct classification of 92.7 percent of archaeological sites and 69.4 percent of null points. In light of the new information placing the optimal cutpoint closer to .6 for the maximization of the correct classification of archaeological sites and null points at approximately 83 percent, should the cutpoint for site definition for the model be changed to .6?

The guidelines for establishing the cutpoint to use for site definition in predictive models such as these are based on the needs of the user. As has been explained, a probability score cutpoint can be placed anywhere along the curve, depending on the use of the model and the goals for its application. Although one intent of the model is to correctly classify the maximum number of archaeological sites and null points, it may be desirable to optimize the former and accept a slightly higher degree of error in the latter (Kvamme’s “decrease gross error by increasing wasteful error” 1988b:390).

Land managers and development planners may be more comfortable with accepting the cutpoint of .6 for site definition because of its overall greater accuracy level. Those concerned with management of cultural resources and archaeologists engaged in research may choose to adopt the more conservative probability score cutpoint of .5, which correctly classifies archaeological sites at a higher rate at the sacrifice of an increase in misclassification of null points.

When the results of the Final Model are brought into GIS, it is a simple matter to classify the Wapato Valley probability areas as desired. If high probability areas are to be targeted, portions of the region representing regression scores of .5-1, or from .6-1 (or whatever range required), are equally well displayed in ArcView.

Performance Curves

Another way to assess the performance of the Wapato Valley Predictive Model is to measure its gain in accuracy over the random or null classification (Kvamme 1992:31). This can be done if we assume that the null points in the model are representative of the background environment or land area (Warren and Asch 2000:20). The actual proportion of the Wapato Valley that contains archaeological sites is very small. The total area covers approximately 550 square kilometers, with the land area of known archaeological sites at approximately .5 percent of that area (calculated from the Wapato Valley Prehistoric Archaeological Site Database). This means that there is a prior probability of only .5 percent that a random point in the environment is actually part of an archaeological site (perhaps one or two of the 327 points in the null sample). This is probably an underestimate because the archaeological resources of the Wapato Valley have been inadequately sampled. The assumption, however, is that the overall background environment of the Wapato Valley is free from archaeological materials approximately 99.5 percent of the time.

These performance curves compare the percentages of archaeological sites and land area (null points) incorporated in the model and the percent gain over the random or null classification (after the method of Warren and Asch 2000:20). Referring back to Table 5.13, the performance curve is a graph comparing the percent of correct prediction of archaeological sites (sensitivity) to the percent of incorrect prediction of null points (1-specificity).

There are two different methods used in the predictive modeling literature to compute gain. The first is to simply calculate the difference between the percentage of correct site prediction and the percentage of incorrect prediction of null points (sensitivity minus 1 – specificity). Using the Training Sample of this model as an example, at a cutpoint of .5, the 1 specificity figure represents the 30.8 percent of the land area at a probability score of ≥ .5 that contains 92.7 percent of the archaeological sites. The difference, or gain, is 61.9 percent.

The second method is Kvamme's gain statistic (Kvamme 1988b:329) used in Chapter 5 to evaluate the model in different stages of its development: 1 – (percentage area / percentage of sites). Kvamme's method gives a slightly higher score than the first method for the same Training Sample: 1-(30.8/92.7) = 66.8 percent. However, the first method is more intuitive and conservative, so that is the method ultimately used for these performance curves.
a. Performance Curve

![Performance Curve Graph]

b. Percent Gain

![Percent Gain Graph]

Figure 5.24. Training Sample performance curve and percent gain over random or null classification.
Figure 5.24 shows the performance curve for the Training Sample: at a probability cut-point of .5, the Wapato Valley Predictive Model incorporates 92.7 percent of archaeological sites in only 30.8 percent of the land area, for a gain of 61.9 percent over the random or null classification. The accompanying gain curve shows the predictive power of the model over the random or null classification along the gradient of probability cutpoints. Cross-validation is done with the Testing Sample: Figure 5.25 shows that at a probability cutpoint of .5, the Wapato Valley Predictive Model incorporates 91.4 percent of archaeological sites in only 20.0 percent of the land area, for a gain of 71.4 percent over the random or null classification.

These performance curves provide further evidence of the strength of the association of the independent variables and the presence of archaeological sites in the Wapato Valley Predictive Model. Although they are based on the classificatory success of the model, the similar curves seen with the Testing Sample serve to validate the results. Averaging the Training and Testing Sample percentages, these analyses of the classificatory results of logistic regression show that the overall model predictions are correct 83 percent of the time, and represent a gain of 66.7 percent over chance classification.

ROC Curve

One further test of the strength of the Wapato Valley Predictive Model plots sensitivity versus 1-specificity over all possible cutpoints (Hosmer and Lemeshow 2000:162). The ROC Curve (Receiver Operating Characteristic), originating from signal detection theory, is a measure of model performance that “shows how a receiver operates the existence of signal in the presence of noise” (Hosmer and Lemeshow 2000:160). Whereas the classification tables in the logistic regression output rely on a single cutpoint for archaeological site definition, the ROC Curve plots the probability of detecting a true signal (sensitivity) and a false signal (1-specificity) for the entire range of possible cutpoints.

The area under the ROC Curve (Figure 5.26) measures the ability of the Wapato Valley Predictive Model to discriminate between archaeological sites and null points. This discrimination is a measure of the likelihood that an archaeological site will have a higher probability score than a null point. The area under the curve is .859 (SE = .017). As a general rule:

If ROC = .5: this suggests no discrimination
If .7 ≤ ROC < .8: this is considered acceptable discrimination
If .8 ≤ ROC < .9: this is considered excellent discrimination
If ROC ≥ .9: this is considered outstanding discrimination

[Hosmer and Lemeshow 2000:162]

It is extremely unusual to observe areas under the ROC Curve greater than .9, which would indicate near complete separation between the two groups. The ROC Curve serves as yet another means of validating the strength of the Wapato Valley Predictive Model.

Testing Samples

The distribution of the probability scores of the 93 Testing Sample cases – 58 archaeological sites and 35 null points (Figure 5.27) – mirrors that of the Training Sample in Figure 5.22. The classificatory accuracy at a cutpoint of .5 for site definition is 91.4 percent for archaeological sites and 80 percent for null points in the Testing Sample, similar to the 92.7 percent for archaeological sites and 69.2 percent for null points in the Training Sample. As with the Training Sample, the Levene’s Test for Equality of Variances and the t-test for Equality of Means are both significant at the .000 level for differences in the values of the probability scores, showing that the two groups indeed come from separate populations.

Two different sets of archaeological sites comprise the Testing Sample, however: 29 random archaeological sites, and the 29 archaeological sites on the Ridgefield National Wildlife Refuge. These two groups have been considered together up to this point. Yet, one of the goals of this thesis is to evaluate the pilot study described in Chapter 3 and determine how well the final model applies for the Ridgefield National Wildlife Refuge, as well as for the rest of the Wapato Valley. This can be done by comparing the Testing Sample probability score distribution of the 29 sites on the
Figure 5.25. Testing Sample performance curve and percent gain over random or null classification.
Refuge with the random sample of 29 sites, and with the Training Sample of 218 archaeological sites from throughout the Wapato Valley. This will enable US Fish and Wildlife Service archaeologists to make future management decisions based on any similarities or differences revealed by the model.

Therefore, certain questions about the characteristics of archaeological sites on the Refuge need to be answered. Is the Ridgefield sample similar to the random sample of sites? Do the probability scores for the sites on the Refuge reflect the same distribution as in the sites in the Wapato Valley as a whole? Will the principles of prehistoric site location established with the Wapato Valley Predictive Model hold on the Ridgefield National Wildlife Refuge?

The similarities in the distribution of Testing Sample probability scores can be seen more easily when the three groups of archaeological sites are graphed together (Figure 5.28). The percent of correct predictions at a cutpoint of .5 for site definition is 93.1 percent for Ridgefield sites and 89.7 percent for the random sites, very similar to the 92.7 percent for the Training Sample of archaeological sites.

The two Ridgefield archaeological sites that have a probability score of less than .5 are 45CL22 (.40011) and 45CL278 (.24250). By consulting the Wapato Valley Predictive Model Logistic Regression Probability Tables (Appendix E), it appears that the lower scores may be a result of 45CL22 being a little too far from permanent water, and of 45CL278 being a little too far from navigable water. Three of the random Testing Sample archaeological sites have probability scores of less than .5.

In general, the distribution of probability

![Figure 5.26. ROC (Receiver Operating Characteristic) Curve of discriminatory ability for the Training Sample of the Wapato Valley Predictive Model. The area under the curve is .859, which is considered excellent discrimination.](image)
Figure 5.27. Distribution of Testing Sample archaeological sites and null points (n = 93) through the range of probability scores. The two groups are significantly different (p = .000); the majority of archaeological sites score in the high site probability range (.5-1), whereas the majority of null points score in the low site probability range (0-.5).
scores across all three sets of archaeological sites is very consistent. The Wapato Valley Predictive Model seems to apply equally well to all three groups. It can be expected that the probability areas defined by the model for the Ridgefield National Wildlife Refuge are just as valid as those in any other part of the Columbia River floodplain in the Wapato Valley. This consistency is most likely due to the similarity of the Refuge landscape to the floodplain environment as a whole.

Comparison with Other Predictive Models

The Wapato Valley Predictive Model equals or exceeds the performance of other predictive models done in recent years. It is difficult to directly compare the results of such models because of the differences in their goals and in the ways in which they were derived and reported. However, Table 5.15 presents the results compiled from the literature for several models that were generated through logistic regression analysis, as well as for some that used other methods.

One of the criticisms of predictive models – that they provide little advantage over chance classification (Ebert 2000:133) – is true in only a few of these cases. Predictive models that perform poorly probably do not make it into print; however, the number of successful models constructed in the last fifteen years demonstrates the potential value of this undertaking. The Wapato Valley Predictive Model performs among the best.

Other Methods of Model Validation

One method of model validation that has not been used in this study is to perform new cultural resources surveys to validate the model. Most predictive models do not include this step.
<table>
<thead>
<tr>
<th>Predictive Model</th>
<th>Site Probability Cutpoint</th>
<th>Site Classification or Testing Sample</th>
<th>% Accuracy</th>
<th>Kyamme Gain Statistic (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Training or Testing</td>
<td>Sites</td>
<td>Null</td>
</tr>
<tr>
<td>O'Rourke 2004(^a)</td>
<td>0.5</td>
<td>Training</td>
<td>92.7</td>
<td>69.2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Testing</td>
<td>91.4</td>
<td>80</td>
</tr>
<tr>
<td>Dalla Bona 2000</td>
<td>deductive model</td>
<td></td>
<td>84%</td>
<td>in high</td>
</tr>
<tr>
<td>Duncan and Beckman 2000</td>
<td></td>
<td>Training</td>
<td>75%</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Testing</td>
<td>78%</td>
<td></td>
</tr>
<tr>
<td>Hudak et al. 2000(^a)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Warren and Asch 2000(^a)</td>
<td>0.5</td>
<td>Training</td>
<td>77.2</td>
<td>77.4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Testing</td>
<td>69.9</td>
<td>73.3</td>
</tr>
<tr>
<td>Westcott and Kuiper 2000</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Site Classification</td>
<td>91.3%</td>
<td>in high</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Gain</td>
<td>79%</td>
<td>in high</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Site Classification</td>
<td>8.7%</td>
<td>in medium potential areas</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Gain</td>
<td>0%</td>
<td>in low potential areas</td>
</tr>
<tr>
<td>Maschner 1996(^a)</td>
<td>0.5</td>
<td>Testing</td>
<td>92</td>
<td>82</td>
</tr>
<tr>
<td>Ellis and Wilson 1994(^a)</td>
<td>0.5</td>
<td>Training</td>
<td>67</td>
<td>71(^b)</td>
</tr>
<tr>
<td>Kyamme 1992(^a)</td>
<td>0.5</td>
<td>Training</td>
<td>70</td>
<td>60</td>
</tr>
<tr>
<td></td>
<td>0.42</td>
<td>Testing(^c)</td>
<td>86.2</td>
<td>39</td>
</tr>
<tr>
<td>Kyamme 1988(^b)</td>
<td>0.5</td>
<td>Training</td>
<td>70.1</td>
<td>66.2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Samples(^d)</td>
<td>68.2</td>
<td>72.6</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>82.5</td>
<td>65.4</td>
</tr>
</tbody>
</table>

\(\text{\(^a\) logistic regression model}\)
\(\text{\(^b\) surveyed non-site points}\)
\(\text{\(^c\) independent testing survey}\)
\(\text{\(^d\) three different models}\)
in model validation because of the cost and time involved. However, periodically reevaluating the model by consulting the Oregon and Washington State Historic Preservation Offices for records on newly discovered sites would serve much the same purpose.

The Wapato Valley Predictive Model was also not tested against a random sample of points taken from areas that had been surveyed for archaeological resources, for which no sites were found (see Ellis and Wilson 1994). The reasons for this were explained in Chapter 2. In regions which have not been thoroughly surveyed, such as the Wapato Valley, these non site locations can be much more similar to archaeological sites than is probably the actual case for the environment as a whole (Kvamme 1988b:356). A glance at the map of site location (Figure 5.6) plainly shows the areas in the Wapato Valley that have been surveyed for archaeological sites: they are the areas where sites have been found.

Surveyed areas are also subject to sampling bias if they were not set up using the laws of probability (Hudak et al. 2000). Given the wide variety of methods for conducting archaeological surveys that have been used in the Portland Basin over the past 50 years, many surveys would not qualify for inclusion in the model because of methodological problems. A random sample of null points provides a better comparison.

Conclusions

The final statistical tests and measures of model significance addressed in this chapter show that the Wapato Valley Predictive Model, its present form, can discriminate to a very high degree between the locations of archaeological sites and random null points in the environment. The model holds equally well on the Ridgefield National Wildlife Refuge as it does in the rest of the Wapato Valley. A comparison with other recent predictive models shows that this model ranks with the best.

This final model fits the data extremely well, and can be used with a high degree of confidence to investigate and make inferences about archaeological site location throughout the Wapato Valley. The results of the model can be applied to the landscape in ArcView GIS to present a map that displays the probability of the occurrence of an archaeological site anywhere in the Wapato Valley. The independent variables are turned into grid surfaces, the corresponding logistic regression coefficients are applied, and a surface of site probability is thereby created. This procedure is the subject of the next chapter.
CHAPTER 7
BRINGING THE RESULTS OF LOGISTIC REGRESSION INTO ARC VIEW

The product of the logistic regression analysis used to build the Wapato Valley Predictive Model consists of coefficients for each of the three key determinants of prehistoric site location, representing their relative weight in the model, plus a constant. Positive coefficients indicate that high values of the variables are associated with site presence; negative coefficients indicate that low values of the variables are associated with site presence (Kvamme 1988b:387). Thus, a negative coefficient of -.02 in the case of Meters to Nearest Permanent Water, one of the three predictors of site location in this model, indicates that site probability is greater at shorter distances to permanent water.

The outcome of logistic regression is a probability rating of from 0 to 1 for each of the archaeological sites or null points used in the development of the model. There are two components to the logistic regression formula to compute this: the score component and the probability component (Warren and Asch 2000:18). When SPSS runs the regression, it computes the score component by summing the constant with the product of each variable multiplied by its coefficient. In the case of the Wapato Valley Predictive Model, this equation is:

\[
\text{SCORE} = 1.128 + (\text{Feet Above River Level} \times 0.059) + (\text{Meters to Nearest Permanent Water} \times -0.02) + (\text{Meters to Navigable Water} \times -0.003)
\]

SPSS then uses this score value to compute the probability component using the equation:

\[
\text{PROBABILITY} = \frac{e^{\text{SCORE}}}{1 + e^{\text{SCORE}}}
\]

where \(e\) is Euler’s Constant, equal to approximately 2.7183. For example, if the \(\text{SCORE} = .627\), then \(e^{\text{SCORE}} = 1.872\). The natural logarithm of the 1.872 is .627 (Drennan 1996:57).

To use an example from the Wapato Valley Predictive Model Testing Sample, the site 45CL1 is at an elevation of 11 feet above river level, is 50 meters to the nearest permanent water, and is 50 meters to navigable water. The score component would be: \(1.128 + 11(0.059) + 50(-0.02) + 50(-0.003) = .627\). The probability component would be: \(e^{.627} / 1 + e^{.627}\), for a final probability score of .652. This means that the probability of an archaeological site being at a location on the landscape with an elevation of 11 feet above river level, 50 meters from permanent water and 50 meters from navigable water is approximately .65. With the probability cutpoint of .5 used in this model, 45CL1 is accurately predicted as an archaeological site.

Displaying the Results in ArcView

SPSS automatically computes the probability values and saves them in the table of site and null point data (see Appendix E: “Wapato Valley Predictive Model Logistic Regression Probability Tables”). Each site and null point has a probability score of from 0 to 1. These locations could simply be displayed by their probabilities on a map in ArcView. However, considering that only 510 locations were used to develop this model over the entire 550 square kilometer area of Wapato Valley, such a map would offer only a vague impression of the distribution of archaeological sites and the areas of greater likelihood for sites on the floodplain of the Columbia River.

Logistic regression evaluates the strength of the predictive value of each variable and the particular combination of variables, in order to arrive at an estimate of probability. A point on the landscape may have qualities that are more indicative of those associated with a high probability of site location, but only for one or two variables. For example, a point might be close to permanent water but at a greater distance from navigable water and at a higher elevation. Logistic regression considers the combination of values. Even though one or more of the variables might be outside what one would consider as an optimum value for site location, that location could still have a high probability rating when the variables are taken together.

While it is possible to display the trends of each of the three predictor variables separately
in ArcView, this would not tell us about the consequence of their combined relationship. It would also not be accurate because the slope of the trends is not constant, which can be seen in Figure 5.29. This is supported by the difference in the coefficients for each predictor variable, because slope is a function of these coefficients (Drennan 1996:207). Logistic regression considers the interaction of the variables in determining site probability. By entering the Score and Probability formulae through the Map Calculation function of the Spatial Analyst extension, ArcView has the ability to apply the model’s regression coefficients to the entire Wapato Valley.

Methods

ArcView has the ability to display the results of logistic regression in its raster-based grid data format. It is necessary to have the Spatial Analyst extension loaded in order to perform these calculations. The layers necessary for this analysis consist of one grid layer for each of the three predictor variables in the Wapato Valley Predictive Model. The coefficients and constant are obtained through running the logistic regression in SPSS, SYSTAT, or other statistical program, as seen in Chapter 5.

The base maps used for this project are the Digital Elevation Model (DEM) maps of the eleven USGS quadrangles of the Wapato Valley, at a resolution of 10 meters per pixel (Regional Ecosystem Office 2002, MapMart 2002). What this means is that each of the 10 x 10 meter pixels in the DEM has a single elevation value. Because of these known values, it is a simple matter for ArcView to calculate distances, area, volume, density, proximity, slope, aspect, hillshade, and viewed. Figure 5.30 shows a portion of the DEM from the Saint Helens quadrangle, at the confluence of the Columbia River, Lake River, Lewis River, Multnomah Channel, and Scappoose Bay, with the permanent water boundaries included for ease of recognition. The DEM is the grid layer needed to calculate the first model variable, Feet Above River Level.

![Figure 5.29](image)

Figure 5.29. Mean values of predictor variables by probability class for Training Sample sites. The mean value of Feet Above River Level actually increases from 5.2 feet for Probability Class 4, to 14.3 feet for Probability Class 5.
Figure 5.30. Portion of the DEM of the Saint Helens quadrangle. Contour interval is 3 feet on the lowland portion (blues, greens, yellow), and 10 feet in the areas of higher elevation (golds, oranges, reds, browns, black).
Because the DEMs consist of elevation values above mean sea level, it is necessary to change the elevation value in the table associated with the DEM layer to reflect elevation above river level. This was done by editing the layer table, subtracting the appropriate number of feet, and saving the values in a new column labeled feet_arl. For example, the elevation of the Columbia River is 7 feet for the Saint Helens DEM, so 7 feet was subtracted from the values of each pixel. A pixel with a value of 18 became 11. Then when the regression formula was entered, these elevation above river level values were used instead of the elevation above sea level values.

The other two grid surfaces used to display the results of the logistic regression analysis consist of the vector (line) layers of permanent water and navigable water (Ducks Unlimited 2000, US Army Corps of Engineers 2002). Waterbodies judged to be permanent sources of water by consulting modern maps were selected with the Select Feature tool in ArcView from the entire hydrography layer for each of the eleven quadrangles. If historic maps were available for a particular area (such as Sheet 5 of the 1881 US Coast and Geodetic Survey map shown in Figure 5.31), those water boundaries were assumed to reflect more accurately the precontact conditions, and were used instead of the modern maps. The historic maps also helped determine the location of water sources that no longer exist because of draining and diking. These sources were digitized and added to the water layers.

The permanent water layer was then clipped with the GeoProcessing Wizard feature of the Spatial Analyst extension to include only the portions of streams below an elevation of 55 feet. Navigable waterways were selected in a similar manner. Separate layers for permanent water and for navigable water were made for each USGS quadrangle. Examples of these water layers for the Saint Helens quadrangle are shown in Figures 5.32-5.33.

The Find Distance function in Analysis menu was then applied to each water layer, setting the Output Grid Extent the same as the DEM, and the Output Grid Cell Size at 10 meters. This Spatial Analyst operation creates a grid layer containing the distance to the specified feature – in this case, the hydrography lines – named “Dist1”, or whatever number would follow next in sequence after the last Find Distance layer. These layers can be renamed in Layer Properties to something more meaningful, such as “Meters to Nearest Permanent Water” and “Meters to Navigable Water” (Figures 5.34-5.35). These two distance layers are the others needed to calculate the probability surface.

With these three layers, the logistic regression equation can then be entered using the Map Calculator in the Analysis menu. The Map Calculator allows the application of a mathematical formula to one or many grid layers to create a new output grid layer. The input grid layers are the grid layers of the three predictor variables; the output layer is a map of probability for the entire DEM.

The first part of the formula yields a layer of the Score component:

\[
\text{SCORE} = 1.128 + (\text{DEM.Feet}_\text{ARL} \times 0.059) + (\text{Meters to Nearest Permanent Water} \times -0.02) + (\text{Meters to Navigable Water} \times -0.003)
\]

ArcView will call this new layer “Calc1”, or whatever number would follow next in sequence after the last Map Calculation. It can be renamed in Layer Properties to something more meaningful, such as “Score” (Figure 5.36).

The second part of the regression formula yields the probability:

\[
\text{PROBABILITY} = \frac{e^{\text{SCORE}}}{1 + e^{\text{SCORE}}}
\]

However, in ArcView the two halves of this equation must be calculated separately. For the top half, the layer just created above, “Score”, is entered into the Map Calculator, then the logarithmic function \(e^{\text{SCORE}}\) for base \(e\) is selected. ArcView calculates \(e^{\text{SCORE}}\), creating a new layer which it will name “Calc2”. The bottom half of the equation is then similarly calculated, entering \(1 + e^{\text{SCORE}}\) in order to calculate \(1 + e^{\text{SCORE}}\). The “AsGrid” button must be entered after
Figure 5.31. 1881 US Coast and Geodetic Survey map of the confluence of the Lake, Lewis, and Columbia Rivers, Scappoose Bay, and Multnomah Channel.
$\text{Archaeological Sites}$
$\text{Wapato Valley}$
$\text{St. Helens Permanent Water}$

Figure 5.32. Permanent waterbodies of the Saint Helens quadrangle.
Figure 5.33. Navigable water of the Saint Helens quadrangle.
Figure 5.34. Grid surface of the Find Distance function applied to the vector layer Saint Helens Permanent Water, classified into 10 equal interval classes.
Figure 5.35. Grid surface of the Find Distance function applied to the vector layer Saint Helens Navigable Water, classified into 10 equal interval classes.
Figure 5.36. Grid surface of the score component of the logistic regression equation of the Wapato Valley Predictive Model, applied to the Saint Helens DEM, and classified into 10 equal interval classes.
the number 1 to apply that value to every cell. ArcView names this new layer “Calc3”.

With the two halves of the probability equation calculated, the final operation consists of a simple division. The formula in the Map Calculator is simply “Calc2” / “Calc3”. The layer produced is called “Calc4” by ArcView, has values between 0 and 1, and is the final map of probability for the DEM. This map can then be classified as desired. Table 5.16 defines the ranges of values for the five probability classes used in the Wapato Valley Predictive Model.

Table 5.16. Wapato Valley Predictive Model Probability Classes and Ranges of Values.

<table>
<thead>
<tr>
<th>Probability Class</th>
<th>Probability Score Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>1.0 - .8</td>
</tr>
<tr>
<td>4</td>
<td>.8 - .6</td>
</tr>
<tr>
<td>3</td>
<td>.6 - .4</td>
</tr>
<tr>
<td>2</td>
<td>.4 - .2</td>
</tr>
<tr>
<td>1</td>
<td>.2 - 0</td>
</tr>
</tbody>
</table>

Helens DEM and water boundary maps, using the Map Calculation function of the Spatial Analyst extension of ArcView. Probability maps of the floodplain of the Columbia River throughout the entire Wapato Valley can be generated in like manner using the DEM, permanent water, and navigable water layers for each of the remaining 11 quadrangles. The basic images of these maps are shown in the next chapter.

The resulting probability surface can be layered over a DEM or Digital Raster Graphic (DRG) map (a digital topographic map) of the quadrangle, for ease in identifying desired probability areas. Figure 5.38 presents the DRG of the same selected portion of the Saint Helens quadrangle with lowest probability area (Class 1) made transparent so that other probability areas are easier to locate. All portions of the landscape that are less than 55 feet in elevation and not within the colored areas are of the lowest probability class.

The probability classes themselves can be displayed separately if desired. If, for example, an individual is only interested in the highest probability areas (Class 5 and Class 4) the other areas can be made transparent. In Figure 5.39, illustrates this effect on that same portion of the Saint Helens DRG.

It is also easy to display these maps in any magnification and color scheme desired so that probability areas are easier to distinguish. Figure 5.40 shows a zoomed in view of the probability areas at the confluence of the Columbia, Lake and Lewis Rivers near 45CL1 (Cathlapotle), displayed in grayscale over the Saint Helens DRG.

ArcView’s ability to apply mathematical formulae to map surfaces, and its versatility in displaying the results, makes the product of this analysis of prehistoric archaeological site location in the Wapato Valley of the Columbia River all the more meaningful and useful. Without GIS, estimates of ranges of values within probability classes can be made, but this would lack the full force of the ability of modern computers and GIS programs to precisely apply the results of logistic regression to an entire landscape.

It may be useful at times to be able to apply the findings of the Wapato Valley Predictive Model to areas on the landscape without having ready access to the probability maps. Through an analysis of the ranges of values of the three predictor variables and their distribution on the probability maps, guidelines can be suggested for the identification of probability areas in the field. This issue is covered in Appendix F: “Guidelines for Applying the Results of the Wapato Valley Predictive Model without the Probability Maps”.

222
Figure 5.37. Probability surface of a portion of the Saint Helens quadrangle.
Figure 5.38. Portion of the Saint Helens DRG with an overlay of the probability surface. The area of the lowest probability class has been made transparent.
Figure 5.39. Class 5 and Class 4 high probability areas of a portion of the Saint Helens DRG.
Figure 5.40. Magnified portion of the Saint Helens DRG at the confluence of the Columbia, Lake and Lewis Rivers. Probability classes are displayed in grayscale.
CHAPTER 8
WAPATO VALLEY PREDICTIVE MODEL
SITE PROBABILITY MAPS

These probability maps are a product of the logistic regression analysis of the values of the three predictor variables (Feet Above River Level, Meters to Nearest Permanent Water, and Meters to Navigable Water) for the Training Sample of the known archaeological sites on the floodplain of the Columbia River in the Portland Basin. The regression coefficients for the three predictor variables, which are the product of this analysis, are applied to the combined grid surfaces of these variables through the use of the Map Calculator function in ArcView. This process is explained in detail in the previous chapter: “Bringing the Results of Logistic Regression into ArcView”.

The probability maps (Figure 5.41 provides a location map) are organized from upriver at the Washougal quadrangle, to downriver at the Deer Island quadrangle (Figures 5.42-5.53). The Mount Tabor quadrangle is split into east and west halves (Figures 5.44-5.45), because the elevation of the river changes within that map. This must be done to ensure the accuracy of the Feet Above River Level variable calculations. A probability map of the entire Wapato Valley is presented in Figure 5.54.

The probability areas are displayed as five classes: Class 5: 1.0-.8, Class 4: .8-.6; Class 3: .6-.4; Class 2: .4-.2; Class 1: .2-0. The probability areas could be defined differently, however, depending on the needs of the user.

These images are intended to convey a general impression of probability areas and site location in the Wapato Valley. Their resolution at this scale does not provide the detail necessary for these images to be used in the field. This is intentional. Archaeological site location is sensitive information that must be safeguarded from those who would seek to profit from the destruction of the archaeological record.

A full version of the probability maps is available on CD to archaeology professionals from the Department of Anthropology, Portland State University, or from the author. This disc includes the DEM and DRG, permanent water and navigable water boundaries, and probability map of each of the eleven quadrangles in the study area, as well as the full version of the Wapato Valley Prehistoric Archaeological Site Database. Archaeologists will understand this minor inconvenience, and appreciate these measures taken to protect the archaeological record of the Wapato Valley. The metadata for these files can be found in Appendix I: “Wapato Valley Prehistoric Archaeological Site Probability Map Metadata”.

227
Figure 5.41. Location map of the eleven quadrangles of the Wapato Valley.
Figure 5.42. Probability map of the Washougal quadrangle.
Figure 5.43. Probability map of the Camas quadrangle.
Figure 5.44. Probability map of the east half of the Mount Tabor quadrangle.
Figure 5.45. Probability map of the west half of the Mount Tabor quadrangle.
Figure 5.46. Probability map of the Portland quadrangle.
Figure 5.47. Probability map of the Linnton quadrangle.
Figure 5.48. Probability map of the Vancouver quadrangle.
Figure 5.49. Probability map of the Sauvie Island quadrangle.
Figure 5.50. Probability map of the Ridgefield quadrangle.
Figure 5.51. Probability map of the Saint Helens quadrangle.
Figure 5.52. Probability map of the Woodland quadrangle.
Figure 5.53. Probability map of the Deer Island quadrangle.
Figure 5.54. Probability map of the entire Wapato Valley.
CHAPTER 9
EXPLANATORY CONTEXT

The goal of this study was to develop a successful predictive model for prehistoric archaeological site location on the floodplain of the Columbia River in the Wapato Valley. This has been accomplished with the methods detailed in the preceding chapters. However, the larger goal is to use this information to further our knowledge of the lifeways of the precontact Chinook. Have the model results confirmed our understandings, or has the model revealed new patterns and relationships?

This thesis began with the hypothesis that certain qualities of the environment were significant to the Chinookan peoples of the Wapato Valley in making locational decisions about the siting of villages and campsites, and that these qualities could be identified through logistic regression analysis. The study of archaeological, ethnographic, and ethnohistoric records guided the selection of the model’s independent variables. The process of choosing these variables, and running logistic regression to see which variables were retained in the model, served to test the hypothesis.

What do the retained variables (Meters to Permanent Water, Meters to Navigable Water and Feet Above River Level) tell us about our hypothesis concerning the factors that were most important to the Chinook in the location of their settlements? Is there a reason why this model performs so well? Do the behavioral patterns of Chinook settlement and subsistence that created the archaeological record detected by the Wapato Valley Predictive Model fit any particular theoretical framework? How does the Wapato Valley Predictive Model measure up to criticisms of predictive modeling?

The Predictable Chinook

Ebert and Kohler, in their chapter on the theoretical basis of archaeological predictive modeling in Quantifying the Present and Predicting the Past (1988:97-171), provide a detailed discussion about the concept of prediction and the conditions under which these models might be the most successful. The particular characteristics of the settlement and subsistence patterns of the Chinookan peoples of the Wapato Valley in the period of the last 3,000 years exhibit most of the qualities described by these authors as favoring site discovery and therefore prediction.

Predictability is a function of the potential visibility of the remains of settlements and camps in the archaeological record. Postdepositional processes aside, the greatest factor that influences site visibility and thus discovery is the impact that the particular settlement or activity area had on the land. The greater the impact – the greater the amount of cultural materials discarded either during a single episode or over time – the greater the likelihood that these materials will be discovered in the present.

The Chinook of the Wapato Valley were largely sedentary, utilizing a logistic type of subsistence strategy. Binford (1980:10) maintains that for logistically mobile groups, field camps can become as large and archaeologically visible as residential sites. Field camps of groups practicing logistic mobility can outnumber residential camps by as much as 4:1 (Ebert and Kohler 1988:120). With 50 villages among the 276 archaeological sites in the Wapato Valley, this is effectively the precise ratio predicted by Ebert and Kohler.

Predictability increases in such a collector society with the intensification of use of resources accompanying sedentism, population increase, and increased sociopolitical complexity (Ebert and Kohler 1988:132). The remains of Chinookan settlements, and field camps that were regularly used, can be expected to have high visibility on the land.

In addition to greater impacts on the landscape favoring site discovery, the temporal and spatial variability of critical resources in the Wapato Valley plays a key role in predictability (Ebert and Kohler 1988:132). High contingency resources are those such as the annual salmon runs, whose availability can be accurately predicted based on the season. High constancy resources such as wapato are almost continually available (Darby 1996:113). An overlapping of these critical resources favors lower residential mobility, increased sedentism, and greater site predictability (Ebert and Kohler 1988:139).

Archaeological sites in the Wapato Valley fulfill Ebert and Kohler’s criteria for high predict-
ability. The high potential visibility of cultural remains, and a favorable distribution of critical resources, suggests that a predictive model in the Wapato Valley has the potential to perform quite well with a limited number of variables.

The high degree of fit of the Wapato Valley Predictive Model indicates that the three independent variables retained in the model have a strong correlation with archaeological site presence. This has been demonstrated statistically in previous chapters; and it has now been shown that the past lifeways of the Chinookan peoples of the Wapato Valley favor such predictability.

**Criticisms of Predictive Models**

Many find fault with archaeological predictive models, in spite of their demonstrated value in protection, planning, management, and research. The main concern is with models that merely find correlations through various statistical techniques, and then stop without analyzing the reasons for these correlations.

Inductive models proceed from observed correlations, and may have a more difficult time explaining the past behavior that resulted in these correlations. Deductive models are hypothesis-driven, with the relationships between predictor variables and locational behavior interpreted using behavioral theory (Altschul 1988:72). Deductive models have the potential to provide a better understanding of the influence of non-environmental factors on choices that people made about the location of their settlements and activity areas.

Gaffney and van Leusen (1995:367-382) each take a side on the issue of predictive models as environmental determinism. Gaffney cautions that statistical methods should not be used to discover patterns in archaeological site location without a consideration of the cultural processes that resulted in the patterns. He calls for a more contextual approach to these analyses. Van Leusen defends that many cultural variables are either spatially based, or cause spatial patterning which can be detected in the archeological record. Predictive modeling with GIS tends to be environmentally deterministic because the variables most easily modeled in GIS are measures of the terrain (although cognitive aspects of the landscape cannot be modeled as well). Both authors caution that models that establish correlations without a consideration of their significance fall short of their full potential.

Ebert (2000:130) criticizes that the correlations seen with predictive models merely connect archaeological remains with conditions observed in the present. These coincidences must then be linked to the past through explanation. He also questions the validity of the importance of proximity to predictor variables. The straight-line distance may not necessarily be the most efficient travel route, so the factor of travel time must be considered as well.

Ebert (2000:130-131) also questions the concept of “site” entirely, in favor of a more holistic perspective that considers the continuum of use of the landscape. Sites are components of human systems whose location depends upon the location of other components of that system. Considering sites as discrete entities ignores the complexities of occupation, transportation, mobility, travel time, resource distribution, seasonality, and social organization – to name just a few factors – and what lies between the sites, not just near them. He believes that sites cannot be assumed to be single-purpose, or even single-occupation.

Church et al. (2000:135) also advocate for a landscape perspective in predictive modeling. Most models rely on indirect measures or an implied cultural value of environmental variables – many of poor resolution – out of context with the landscape as a whole. Many measurements commonly regarded as environmental (such as slope, aspect, and elevation) are merely measures of terrain and address only issues of shelter. They also do not address the temporal dimension: the duration of occupation of the landscape, the seasonality of resource availability, climate change, and geomorphologic processes. In order to successfully interpret the past, archaeological remains need to be put into the context of the environmental and cultural systems that were operating on the landscape at the time of occupation.

**In Defense of the Wapato Valley Predictive Model**

Several of the concerns raised above have been addressed in the development of the Wapato Valley Predictive Model. This study does not
address differences in site type, because it is believed that this would be too difficult to accurately determine, given the state of the existing records used to build the model. An analysis of the model outliers might reveal that some are special-use sites or that they have some common non environmentally-based cultural significance. Taphonomic processes affecting site preservation and discovery are also not addressed in this study. Sites were defined as recorded at the Washington and Oregon SHPOs, discovered through a variety of methods over the past 50-plus years.

Ebert’s question (2000:130-131) of the concept of “site” is a valid concern in parts of the Wapato Valley. A good example is around Vancouver Lake, where site density appears to be so great that the question of “lumping versus splitting” arises. Postdepositional process, including the draining and diking of lakes and channels, agriculture, and erosion, may have scattered cultural remains so that a single site may appear to be several. Other sites may appear to be discrete entities, but even studies of the geomorphologic and taphonomic processes presumed to have been at work may never successfully resolve site boundaries. This situation has been likened to “the tendency to survey a town and record each building as a separate site” (Blukis Onat 1997:126). A decision had to be made for this study concerning how to treat closely adjacent sites. In the Wapato Valley Predictive Model, sites were defined as they were recorded at the SHPO; however, the accuracy of this approach to site definition could be questioned, especially in the area of Vancouver Lake.

It is true that the Wapato Valley Predictive Model reveals correlations between site location and present conditions in the environment, although every attempt was made to reconstruct old shoreline boundaries using historic maps, which reflect conditions on the floodplain before extensive draining and diking was done to reclaim land for agriculture. Distance to critical resources, expressed as a time-distance function rather than a straight-line function, is not as much of a concern with the Wapato Valley Predictive Model, which considers only water resources, ubiquitous on the floodplain. Travel by water brought many distant resources within an easy day’s canoe trip.

The concern about predictive models dealing best with static phenomena, and not being able to easily model change over time, is not a major factor with the Wapato Valley Predictive Model. The period targeted in this study spans approximately the last 3,000 years. Our current knowledge suggests that during this period, the climate was stable, modern river channels and depths had been achieved after the floods at the end of the Pleistocene and the concomitant rise in sea level, and critical resources – notably the salmon runs – had attained their modern distribution in time and space. These environmental conditions resulted in relative cultural stability, with any change largely a function of population growth and intensification of use of resources. This has made possible the construction of a predictive model with high precision.

Another methodological issue concerns the potential explanatory advantage of deductive over inductive model building. Warren (1990:91) states that most models make use of both theory and observation, with the theorized biological and cultural needs of a society guiding the selection of independent variables. Although the Wapato Valley Predictive Model began as an inductive model, the potential predictor variables were not chosen without first studying of the lifeways of the Chinook and considering the qualities of the environment that would have been important in the siting of their settlements. The Wapato Valley Predictive Model, with the hypothesis driven choice of prospective site predictor variables, combines elements of both inductive and deductive models.

Conclusions

The results of the Wapato Valley Predictive Model have provided another line of evidence in support of our current understanding of the lifeways of the precontact Chinook. The Chinookan peoples of the Wapato Valley were largely sedentary, practicing a collector type of subsistence strategy. Intensification of use of resources generated villages and field camps that had a high impact on the land, resulting in archaeological sites with high visibility, favoring discovery in the present. The high degree of fit of the Wapato Valley Predictive Model demonstrates that these distinct patterns on the landscape can be detected through logistic regression analysis. This model offers the potential to reveal new aspects of the lives of the...
Chinookan peoples of the Wapato Valley.

The Wapato Valley Predictive Model also stands up well to standard criticisms of archaeological predictive modeling. Many anthropologists have a problem with a methodology that reduces human behavior to a set of equations. This thesis has demonstrated, however, that a careful and conscientious approach can yield a predictive model with impressive results.
CHAPTER 10
CONCLUSIONS

The Wapato Valley Predictive Model has shown that a successful probability model of prehistoric archaeological site location can be constructed for the floodplain of the Columbia River. The final model is a multivariate function of just three independent variables selected through logistic regression analysis. The classificatory accuracy for sites used to build the model is 92.7 percent. These sites are found in just 30.8 percent of the Columbia River floodplain, providing a 61.9 percent gain over chance.

Cross-validation testing shows similar results. The classificatory accuracy of the sample withheld from model development is 91.4 percent for sites, in just 20 percent of the Columbia River floodplain, providing a 71.4 percent gain over chance. The probability scores for the Testing Sample sites on the Ridgefield National Wildlife Refuge mirror the random site Testing Sample, showing that the model performs equally well on the Refuge and throughout the Wapato Valley. Statistical tests of consistency and validity establish that this model can be reliably used to define areas of higher site probability in this environment.

There are definite, measurable differences on the floodplain of the Columbia River between the places where sites are located, and the places where they are not. The contrast between these two sets of locations can be projected into areas where the archaeological record is unknown by applying the results of logistic regression to grid surfaces in ArcView GIS. The final product is a map of archaeological site probability for the entire Portland Basin. The discriminatory ability of the Wapato Valley Predictive Model offers a considerable advantage to archaeologists, land managers, and development planners alike for the identification and preservation of cultural resources.

CRM Applications

The probability maps of the eleven quadrangles of the Wapato Valley have the potential to facilitate the permitting process for construction projects on the floodplain of the Columbia River. Protocols can be developed for archaeological survey and monitoring based on the probability class of the target area and the scale of the ground-disturbing activity planned, as in the Clark County Predictive Model (Ellis and Wilson 1994, Wilson 2001). Areas where the likelihood of encountering archaeological resources and planned impacts are low might not require survey (potentially up to 70 percent of the Wapato Valley); large-scale projects with extensive excavation in high probability areas would trigger the highest level of survey and testing. This predictive advantage is now available for the entire Wapato Valley.

Research Possibilities

The site probability maps, as well as the database from which they were derived, can also help answer questions about the precontact lifeways of the Chinookan peoples of the Columbia River floodplain. The archaeological site database, included in the complete version of this thesis available to archaeology professionals, is a compilation of information about all 276 archaeological sites in the Portland Basin, on both sides of the Columbia River. Until now, researchers have been hampered in their efforts to study this landscape by the need to consult two separate State Historic Preservation Offices. This regional synthesis of knowledge about all of the Wapato Valley floodplain archaeological sites will facilitate research, and has the potential to reveal new aspects of settlement and subsistence of the Chinookan peoples in this area. The following examples illustrate possible applications.

Example 1: The Role of Elevation in the Siting of Camps and Villages

The distribution of the values of the predictor variables has the potential to answer questions about the importance of elevation in the siting of villages and camps. The mean values of the model’s predictor variables through the five probability classes show an interesting trend, previously seen in Figure 5.29. Although the values for Meters to Nearest Permanent Water and Meters to Navigable Water steadily decrease, the value for Feet Above River Level actually increases from Probability Class 4 to Class 5. The area of highest site probability is on elevated ground, close to permanent and navigable water. Most archaeologists would readily agree with this statement based on ethnographic and ethnohistoric knowledge of the
Chinook; however, the Wapato Valley Predictive Model provides another line of evidence to support this assertion.

Example 2: The Siting of Villages on High-Order Streams

Another area where the Wapato Valley Predictive Model can provide additional insight involves the location of the 50 archaeological sites identified as villages in the Wapato Valley Prehistoric Archaeological Site Database. The model reveals no correlation between elevation above river level and the siting of villages. It might be expected, since villages represent a greater investment of time and resources for the construction of houses than do temporary camps, that they may have been preferentially sited on landforms high enough to escape flooding, but close enough to navigable water to provide easy access to nearby resources. There is, however, no difference in the distribution of probability scores between the 50 villages and the 226 non-villages. The mean values of the predictor variables for these two groups also show no significant differences. This suggests that to the Chinook, the advantage of siting their settlements close to the Columbia River and its navigable tributaries far outweighed the inconvenience of having to temporarily relocate because of the occasional flood. See Appendix C: “Columbia River Floods” for a discussion about seasonal flooding and the siting of villages.

An analysis of village location based on stream order supports this finding and suggests a possible explanation. The Strahler system (Dincauze 2000:207) begins with streams initiating surface flow, which are “first order”, and progresses to higher orders as streams meet those of equal orders. In this example, the Columbia River is a sixth order stream, its direct tributaries (the Lewis, Lake, and Washougal Rivers; Columbia and Bachelor Island Sloughs; Scappoose Bay; and Multnomah Channel) are fifth order, their tributaries are fourth order, and so on. Table 5.17 shows that the nearest navigable water source for villages tends to be fifth and sixth order streams: 88 percent versus 59.8 percent for non-villages. The difference in stream order of navigable waterbodies for village and non-village archaeological sites is highly significant (χ² = 14.662, p = .001).

From what we know ethnographically and ethnohistorically of the Chinook, access to navigable water for subsistence, transportation, and communication was of fundamental importance. Travel by water was essential in order to take full advantage of the plentiful year-round resources of the floodplain, which enabled the Chinookan people to be largely sedentary within the Wapato Valley, probably for at least the last 3,000 years. Such a distribution of resources, characterized by high density and reliability, favored a subsistence strategy of logistic rather than residential mobility (after Binford’s forager-collector model). Sedentism minimized energy expenditure; there was no need for the entire group to move periodically in order to gain access to needed resources (Saleeby 1983:156).

What would a settlement pattern of sedentism look like in the archaeological record of the Wapato Valley? Villages would be sited to reflect the requirements of logistic mobility, and on the Columbia River floodplain, this would mean ready access to major bodies of water. Even though the means of the Meters to Navigable Water predictor variable shows no significant difference between

Table 5.17. Stream Order of Navigable Waterbodies Nearest to Village (n = 50) and Non-Village (n = 226) Archaeological Sites of the Wapato Valley.

<table>
<thead>
<tr>
<th>Stream Order</th>
<th>Villages</th>
<th>Non-Villages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number</td>
<td>Percent</td>
<td>Number</td>
</tr>
<tr>
<td>6</td>
<td>11</td>
<td>22</td>
</tr>
<tr>
<td>5</td>
<td>33</td>
<td>66</td>
</tr>
<tr>
<td>4</td>
<td>6</td>
<td>12</td>
</tr>
</tbody>
</table>

247
village and non-village sites (t = .941, p = .349, possibly because of a high standard deviation of the means), there is a significantly greater incidence of village sites on high-order streams. This observation is in keeping with the expectations of models that explain hunter-gatherer behavior in terms of optimizing resource return for energy expenditure, such as in various forms of optimal foraging theory (Bettinger 1991:83). The location of villages, analyzed with information from the Wapato Valley Predictive Model database, supports the findings of Saleeby (1983) and Darby (1996) for sedentism in the Wapato Valley.

Future Research

The previous examples have illustrated only two questions that the Wapato Valley Predictive Model can help answer about the mobility, subsistence, and settlement patterns of the Chinookan peoples of the Columbia River floodplain. Another such line of investigation would be to look at the qualities of the misclassified archaeological sites (14 total, including 6 outliers with scores ≥ 2 SD from the mean) and analyze how and why they do not fit the model. Van Leusen (Gaffney and van Leusen 1995:370) even suggests that predictive models can be used for “data cleaning” to detect this non-patterned part of the archaeological record. The results of catchment analysis done by Saleeby (1983) and Hamilton (1990) could be expanded, in light of the findings of this model, to further study the relationship of subsistence and settlement patterns in the Wapato Valley.

Inductive models such as the Wapato Valley Predictive Model have a difficult time addressing change over time. Because the period of occupation under consideration in this model is relatively short, and the subsistence and settlement patterns within that period were relatively stable, the Wapato Valley Predictive Model performs rather well. However, further insight may be gained from the study of the age of archaeological sites against their probability scores and location on the floodplain.

The Wapato Valley Predictive Model can also be tested in other locations on the Columbia River or in other environments with similar year round resource abundance. The probability surfaces displayed on the topographic maps can be used to facilitate the development of survey protocols and can also guide research questions. The possibilities for further study are limited only by the imagination of the researcher.

This model should be updated periodically to include newly discovered archaeological sites. Testing the model with the results of new archaeological surveys would help validate the model, or might suggest possibilities for refinement. A predictive model specifically targeting surveyed areas in the Wapato Valley could also be developed as an adjunct to this model.

Predictive models have been shown to be an effective tool for managing and preserving archaeological resources. Such an analysis based on site location reveals spatial patterning that can lead to insights and explanations. Predictive models themselves do not provide the reasons for the correlations seen. Archaeologists must still question these relationships and ask themselves “why?”. The Wapato Valley Predictive Model, bringing together archaeological site information from throughout the Portland Basin, will enable researchers to better formulate these questions as they seek to advance our understanding of the lifeways of the Chinookan peoples of the Wapato Valley.
APPENDIX A
GEOLOGY OF THE WAPATO VALLEY

The following underlying geology of Wapato Valley is taken largely from two 1:500,000 geologic maps: Washington (Huntting et al. 1961, revised by Schuster 1992) and Oregon (Walker and MacLeod 1991). There is an obvious concern with such coarse map resolution. References that are more detailed were consulted when possible, but full coverage of the project area was not available. Additional materials that provided a more thorough treatment for some areas include: Besson et al. 1991 (Portland quadrangle), Mundorff 1959 (Clark County), Phillips 1987 (Vancouver quadrangle), Schuster 1992, Trimble 1957 and 1963 (Portland quadrangle and adjacent areas).

A quick glance at the distribution (Figure 5.A.1) will reveal that the majority of archaeological sites on the Columbia River floodplain in this area are found on alluvial deposits. Only a few sites are found on materials of any other kind. The background environmental distribution of geologic types parallels that of the archeological sites, so geologic type was not judged to be a good predictor of site location.

There is noticeable overlap in the description of some of the geologic categories. This is due to differences in the classification systems between the states of Washington and Oregon. In spite of these minor differences, the broader categories remain the same.

<table>
<thead>
<tr>
<th>Geologic types</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pliocene Nonmarine Rocks</td>
<td>0</td>
</tr>
<tr>
<td>Pliocene-Pleistocene Volcanic Rocks</td>
<td>0</td>
</tr>
<tr>
<td>Quaternary Nonmarine Deposits</td>
<td>100</td>
</tr>
<tr>
<td>Columbia River Basalt Group</td>
<td>0</td>
</tr>
</tbody>
</table>

Figure 5.A.1. Geology of Wapato Valley archaeological sites.
Geology of Wapato Valley Prehistoric Archaeological Sites

Pc  **Pliocene Nonmarine Rocks**
Conglomerate, sandstone, shale and mudstone. Tuffaceous in part, contains alluvial fan type material locally. Includes Troutdale Formation. [CL18, 19, 20, 119, 279, 491, 544]

PQv  **Pliocene-Pleistocene Volcanic Rocks**
Light-gray andesite, andesite porphyry and open-textured basalt flows with minor associated mudflows and breccia. Includes Boring Lavas. [CL6, 7, 118, 258]

Qal  **Quaternary Alluvial Deposits (Holocene)**
Mostly unconsolidated sand, gravel, silt and some clay, forming floodplains and filling channels of present streams. In places includes low-level terrace, marsh, artificial fill, talus and slope wash. Locally includes soils containing abundant organic material and thin peat beds. [Majority of sites]

Qcl  **Quaternary Nonmarine Deposits (mostly Early and Middle Pleistocene)**
Periglacial lacustrine deposits. Light-brown well-sorted and bedded clayey sandstone and sandy clay with interbeds of volcanic ash and calcareous cemented gravels. Includes older alluvium. [CL143, 309, 545]

Tc  **Columbia River Basalt Group and related flows (Miocene)**
Subaerial basalt and minor andesite lava flows and flow breccia. Submarine palagonitic tuff and pillow complexes of the Columbia River Basalt Group. Locally includes invasive basalt flows such as the Grande Ronde Basalt. [CL45, 278 and CO 26]
APPENDIX B
SOILS OF THE WAPATO VALLEY

The soils of Wapato Valley show a range of types, however the majority owe their origin to the alluvial materials deposited by the Columbia River. Figure 5.B.1 shows that more than 80 percent of sites are located on silt loam or silty clay loam, and over 96 percent of those are of “recent” (geologically speaking) origin (Green 1983).

Almost 75 percent of sites are on soils that are poorly drained or very poorly drained. This suggests that the soil quality of rapid runoff versus ponding was probably not the most important factor to the Chinook in the siting of their camps and villages. Proximity to water seems to have overruled drainage concerns. Table 5.B.1 includes a complete listing of Wapato Valley archaeological sites by soil type.

The updated Clark County Predictive Model (Wilson 2001:16) finds a correlation between site location and these hydric soils, which are also indicative of historic wetlands in upland areas (above 50 feet elevation). These areas would have marked the location of important water sources that would have supported a variety of plants and animals, important food resources for early resident of Wapato Valley.

Assignment of site location to soil series was made based on the detailed maps accompanying the soil surveys of Clark County, Washington (McGee 1972), and Columbia (Smythe 1986) and Multnomah (Green 1983) Counties, Oregon. The Oregon maps are also available online at: http://www.or.nrcs.usda.gov/soil/mo/mo_reports_

Figure 5.B.1. Soil types of Wapato Valley archaeological sites. Explanations of abbreviations and full soil series descriptions follow in the text.
Table 5.B.1. Soils of the Wapato Valley Prehistoric Archaeological Sites.

<table>
<thead>
<tr>
<th>Code</th>
<th>Series</th>
<th>% Slope</th>
<th>Archaeological Sites*</th>
</tr>
</thead>
<tbody>
<tr>
<td>BuA</td>
<td>Burlington fine sandy loam</td>
<td>0-8</td>
<td>MU 11, 12</td>
</tr>
<tr>
<td>Fn</td>
<td>fill land</td>
<td></td>
<td>CL 7, 401</td>
</tr>
<tr>
<td>HIC</td>
<td>Hillsboro loam</td>
<td>0-8</td>
<td>CL 704, 531</td>
</tr>
<tr>
<td>HoA</td>
<td>Hillsboro silt loam</td>
<td>0-3</td>
<td>CL 16, 17, 123, 204</td>
</tr>
<tr>
<td>HoB</td>
<td>Hillsboro silt loam</td>
<td>3-8</td>
<td>CL 98, 99</td>
</tr>
<tr>
<td>HoC</td>
<td>Hillsboro silt loam</td>
<td>8-15</td>
<td>CL 30</td>
</tr>
<tr>
<td>HoG</td>
<td>Hillsboro silt loam</td>
<td>30-65</td>
<td>CL 279</td>
</tr>
<tr>
<td>LgB</td>
<td>Lauren gravelly loam</td>
<td>0-8</td>
<td>CL 545</td>
</tr>
<tr>
<td>MuA</td>
<td>Multnomah loam</td>
<td>0-3</td>
<td>CO 26</td>
</tr>
<tr>
<td>NbA</td>
<td>Newberg silt loam</td>
<td>0-3</td>
<td>CL 48, 49</td>
</tr>
<tr>
<td>NbB</td>
<td>Newberg silt loam</td>
<td>3-8</td>
<td>CL 44, 60, 61, 62, 63, 64, 65, 66, 67, 68, 69a, 69b, 72, 73, 128, 304</td>
</tr>
<tr>
<td>OrC</td>
<td>Olympic very stony clay loam, shallow variant</td>
<td>5-15</td>
<td>CL 278</td>
</tr>
<tr>
<td>PhA</td>
<td>Pilchuck sand</td>
<td>0-3</td>
<td>MU 2, 13, 14</td>
</tr>
<tr>
<td>PhB</td>
<td>Pilchuck find sand</td>
<td>0-8</td>
<td>CL 32, 33, 34, 35, 126, 308</td>
</tr>
<tr>
<td>PhU</td>
<td>Pilchuck-Urban Land Complex</td>
<td>0-3</td>
<td>MU 47, 48, 49, 50, 109, 110, 112</td>
</tr>
<tr>
<td>PoU</td>
<td>Powell-Urban Land Complex</td>
<td>0-3</td>
<td>MU 89</td>
</tr>
<tr>
<td>QfA</td>
<td>Quafeno loam</td>
<td>0-3</td>
<td>MU 31</td>
</tr>
<tr>
<td>QtB</td>
<td>Quatama Loam</td>
<td>3-8</td>
<td>MU 84</td>
</tr>
<tr>
<td>QTC</td>
<td>Quatama Loam</td>
<td>8-15</td>
<td>MU 43</td>
</tr>
<tr>
<td>RfA</td>
<td>Rafton silt loam</td>
<td>0-2</td>
<td>CO 6, 25; MU 5, 16, 18, 23</td>
</tr>
<tr>
<td>Ra</td>
<td>Riverwash (sandy)</td>
<td></td>
<td>CL 473, 491</td>
</tr>
<tr>
<td>Rk</td>
<td>Rockland</td>
<td></td>
<td>CL 18, 19, 20, 119, 533</td>
</tr>
<tr>
<td>SmA</td>
<td>Sauvie silt loam</td>
<td>0-3</td>
<td>CO 2, 3, 8, 24, 92; MU 6, 15, 17, 19, 20, 21, 22, 45, 51, 52, 60, 76, 105, 111, 117</td>
</tr>
</tbody>
</table>

*Sauvie silt loam, protected* 0-2 CO 7; MU 1, 3, 4, 8, 9, 24, 26, 30, 35, 36, 37, 61, 62, 63, 65, 66, 67, 68, 69, 70, 77, 78, 82, 83, 103, 106, 107, 119

* CL = Clark County, Washington
CO = Columbia County, Oregon
MU = Multnomah County, Oregon
Table 5.B.1 cont.

<table>
<thead>
<tr>
<th>Code</th>
<th>Series</th>
<th>% Slope</th>
<th>Archaeological Sites*</th>
</tr>
</thead>
<tbody>
<tr>
<td>SmB</td>
<td>Sauvie silt loam</td>
<td>3-8</td>
<td>CL 4, 12, 45, 82, 83, 89, 90</td>
</tr>
<tr>
<td>SnA</td>
<td>Sauvie silt loam, sandy substratum</td>
<td>0-3</td>
<td>CL 9, 10, 21, 23, 28</td>
</tr>
<tr>
<td>SpB</td>
<td>Sauvie silty clay loam</td>
<td>0-8</td>
<td>CL 1, 14, 22, 24, 43, 103, 104, 105, 106, 107, 108, 110, 111, 117, 276, 277, 280, 281, 282, 284</td>
</tr>
<tr>
<td></td>
<td>Sauvie silty clay loam, protected</td>
<td>0-2</td>
<td>CL 15, 36, 37, 38, 39, 41, 42, 58, 70, 74, 75, 76, 77, 78, 79, 80, 81, 85, 94, 100, 102, 127, 129, 130, 131, 137, 138, 288, 289, 290, 291, 292, 293, 294, 297, 298, 299, 302, 303, 305, 306, 307, 402, 409, 455, 459, 498, 505, 510; CO 5, 20, 22, 34, 37, 45, 47; MU 57, 80, 81, 85, 97, 118</td>
</tr>
<tr>
<td>SRU</td>
<td>Sauvie-Rafton-Urban Land complex</td>
<td>0-3</td>
<td>MU 44, 46, 113</td>
</tr>
<tr>
<td>SiA</td>
<td>Sifton loam</td>
<td>0-3</td>
<td>CO 35, 46</td>
</tr>
<tr>
<td>SvA</td>
<td>Sifton gravelly loam, occasionally flooded</td>
<td>0-3</td>
<td>MU 10</td>
</tr>
<tr>
<td>WgB</td>
<td>Washougal gravelly loam</td>
<td>0-8</td>
<td>CL 8, 25, 410, 429</td>
</tr>
<tr>
<td>WRb</td>
<td>Wind River gravelly loam</td>
<td>0-8</td>
<td>CL 411</td>
</tr>
<tr>
<td>XrA</td>
<td>Xeropsamments, nearly level</td>
<td>0-3</td>
<td>CO 27, 43</td>
</tr>
</tbody>
</table>

* CL = Clark County, Washington  
CO = Columbia County, Oregon  
MU = Multnomah County, Oregon

or.htm.

The designation “complex” indicates a mixture of the indicated soil types. The term “protected” indicates that the area is protected from flooding by dikes and levees.

**Soil Series Descriptions**

This information is compiled from the soil surveys of Clark county Washington (McGee 1972), and Columbia (Smythe 1986) and Multnomah (Green 1983) counties Oregon. The Oregon surveys are also available online at: http://www.or.nrcs.usda.gov/soil/mo/mo_reports_or.htm.

*Burlington Series*

These very deep, somewhat excessively drained soils are on low terraces along the lower Columbia River and its tributaries. These soils formed in alluvium that has been reworked by wind to form rolling dunelike topography. Elevation is 25-50 feet. Vegetation in areas not cultivated is Douglas fir, Oregon white oak, western redcedar, bigleaf maple, western hazel, common snowberry, tall Oregon grape, creambush oceanspray, rose, willow, trailing blackberry, brackenfern, forbs, and grasses. Permeability is rapid; available water capacity is 7-8 inches. Runoff is slow, and the hazard of erosion is slight.

*Fill Land*

Fill land consists of nearly level areas that have been artificially filled with earth, trash or both, and then smoothed over. Large areas along
the Columbia River waterfront have been filled in by dredging of sand and silt from the river. These areas do not have any clearly defined soil characteristics.

**Hillsboro Series**

These are deep, well-drained soils on terraces. They are of medium texture, and developed in old deposits of Columbia River alluvium. The native vegetation is dominantly Douglas fir and a scattering of grand fir, bigleaf maple, and western dogwood; with an understory principally of salal, ferns, Oregon grape, and vine maple. These soils are well drained, moderately permeable, and the available water capacity is high. Surface runoff and erosion hazard vary with slope, from very low to quite high in the 30-65 percent slope areas.

**Lauren Series**

These are deep, well-drained soils on terraces and terrace escarpments. They were formed in old alluvium and loess containing volcanic ash. Typical elevations are 150 to 300 feet. The native vegetation is Douglas fir, western redcedar, grand fir, bigleaf maple, and red alder; with an understory of vine maple, salal, Pacific dogwood, trailing blackberry, Oregon grape, brackenfern, and swordfern. They show moderately permeability in the upper portion and rapid permeability in the underlying material.

**Multnomah Series**

These deep, well-drained soils are on old terraces. They formed in old gravelly or cobbly alluvium. Elevation is 50-200 feet. The native vegetation in areas not cultivated is mainly Douglas fir, Oregon white oak, bigleaf maple, western hazel, Pacific dogwood, vine maple, thimbleberry, rose, blue elderberry, and western swordfern. Permeability is moderate to a depth of 27 inches then rapid below this depth. Available water capacity is about 4-6 inches, runoff is slow, and the hazard of water erosion is slight.

**Newberg Series**

These are deep, nearly level to gently sloping soils on the floodplain of the Columbia River. They are loamy soils that developed mainly in recent alluvium derived from basic igneous parent material. The native plant cover is mixed deciduous and coniferous vegetation. The soils are well drained. Permeability is moderately rapid and available water capacity is high. Surface runoff is slow to very slow, and erosion hazard is slight.

**Olympic Series**

These are moderately fine textured soils that formed on mountainous foot slopes in weathered igneous lava flows. The native vegetation is Douglas fir, grand fir, hemlock, western redcedar, and Oregon white oak; with an understory of vine maple, salal, Oregon grape, ferns, and grasses. This soil is well drained. Permeable is moderately slow, and available water capacity is moderately high. Surface runoff is slow to medium, and the erosion hazard is slight to moderate, depending on slope. The Very Stony Clay Loam variant is on ridgetops and benches that are dissected by steep slopes that lead into creeks and drainageways. It has a very stony surface.

**Pilchuck Series**

These very deep, excessively drained soils are on broad floodplains of the Columbia River. They are sandy soils that formed in parent material of recent sandy alluvium or dredge spoils. Elevation is 10-30 feet. In areas where vegetation has become established, black cottonwood, willow, trailing blackberry, forbs, and grasses are dominant. Permeability is very rapid; available water capacity is 3-6 inches. Runoff is slow, and the hazard of erosion from overflow is high. These soils are subject to frequent flooding from November through April. In the Pilchuck-Urban Land Complex, fill has raised the surface to an elevation above the annual flood stage.

**Powell-Urban Land Complex**

The Powell series consists of moderately deep, somewhat poorly drained soils on broad, high terraces. These soils formed in silty materials. This complex consists of Powell soils that have been graded, cut, filled or otherwise disturbed. Typical elevation is 300-600 feet. Native vegetation is Douglas fir, western redcedar, red alder, bigleaf maple, willow, Pacific dogwood, rose, wild cherry, western hazel, thimbleberry, salal, vine maple, trailing blackberry, tall Oregon grape, swordfern, common snowberry, forbs, and
grasses. In areas where the soils are relatively undisturbed, permeability is slow and available water capacity is 5-7.5 inches. Runoff is slow and the hazard of erosion is slight.

Quafeno Series

These very deep, moderately well drained soils are on old, low terraces. These soils formed in mixed, loamy alluvium. Elevation is 40-100 feet. The vegetation in areas not cultivated is Douglas fir, Oregon white oak, western redcedar, bigleaf maple, willow, western hazel, creambush oceanspray, rose, trailing blackberry, salal, tall Oregon grape, common snowberry, Pacific dogwood, brackenfern, forbs, and grasses. Permeability is moderately slow; available water capacity is 9-12 inches. Runoff is slow, and the hazard of erosion is slight.

Quatama Series

These very deep, moderately well drained soils are on old, low terraces. These soils formed in mixed, loamy alluvium. Elevation is generally 75-400 feet. The vegetation in areas not cultivated is Douglas fir, Oregon white oak, western redcedar, bigleaf maple, willow, western hazel, creambush oceanspray, rose, trailing blackberry, salal, tall Oregon grape, common snowberry, Pacific dogwood, brackenfern, forbs, and grasses. Permeability is moderately slow; available water capacity is 8-10 inches. Runoff is slow, and the hazard of erosion is slight to moderate.

Rafton Series

This series soils consist of very deep, very poorly drained soils in concave areas on broad, low floodplains of the Columbia River. They formed in recent silty alluvium with some mixing of volcanic ash. Elevation is 10-20 feet. The vegetation in areas not cultivated is mainly black cottonwood, Oregon ash, willow, rose, common snowberry, sedges, cattail; the native vegetation on the Sauvie soil is mainly black cottonwood, common snowberry, tall Oregon grape, grasses, and forbs. Permeability is slow to moderately slow, with available water capacity about 9-12 inches overall. Runoff is slow to ponded, and the hazard of water erosion is slight. This complex is subject to frequent periods of flooding and ponding in the winter and spring.

Rafton-Sauvie-Moag Complex

This unit is on floodplains of the Columbia River. Composition is 40 percent Rafton Silt Loam, 30 percent Sauvie Silt Loam and 20 percent Moag Silty Clay Loam, intermingled. These soils are deep, and poorly to very poorly drained. Elevation is 10-20 feet. The native vegetation on the Moag and Rafton soils is mainly Oregon ash, willow, rose, reed canarygrass, sedges, and cattail; the native vegetation on the Sauvie soil is mainly black cottonwood, common snowberry, tall Oregon grape, grasses, and forbs. Permeability is slow to moderately slow, with available water capacity about 9-12 inches overall. Runoff is slow to ponded, and the hazard of water erosion is slight. This complex is subject to frequent periods of flooding and ponding in the winter and spring.

Riverwash

Riverwash consists of nearly level unconsolidated alluvium on streambanks along major rivers. Cobbly Riverwash is stratified and variable in texture. Many areas are gravelly, cobbly and stony and are subject to frequent change through periodic stream overflow. Sandy Riverwash is subject to continual change as the river level fluctuates, and to further modification by channel dredging. This land type supports little or no vegetation.

Rock Land

Rock Land consists of steep and very steep areas made up largely of rock outcrops and very shallow soil. Most of this land type is in the mountainous eastern and northeastern parts of Clark County.

Sauvie Series

These very deep, poorly drained soils are in broad, convex areas on floodplains of the Columbia River. They formed in recent silty or clayey alluvium, with some mixing of volcanic ash. Elevation is 10-20 feet. The native vegetation is mainly black cottonwood, Oregon white oak, Oregon ash, willow, rose, common snowberry, trailing blackberry, forbs, and grasses. Permeability is moderately slow; available water capacity is about 11-13 inches. Runoff is slow, and the hazard of water erosion can be high because of flooding. These soils are subject to frequent periods of flooding in winter and spring, except where diked.
Sauvie-Rafton-Urban Land Complex

This complex consists of very deep, poorly drained Sauvie soils and very poorly drained Rafton soils. Large areas of these soils have been filled, graded, cut, or otherwise disturbed. This complex is on broad floodplains along the Columbia River. Elevation is 10-20 feet. In areas of undisturbed soils, the predominant vegetation for Sauvie and Rafton soils is the same as in their separate series listing. Permeability is moderate to moderately slow. Available water capacity is 11-13 inches, runoff is slow to very slow, and erosion hazard is slight.

Sifton Series

These very deep, somewhat excessively drained soils are on broad, low terraces along the Columbia River. They formed in gravelly alluvium mixed with volcanic ash. Elevation is 30-100 feet. The vegetation in areas not cultivated is mainly Douglas fir, Oregon white oak, common snowberry, rose, tall Oregon grape, grasses, and forbs. Permeability is moderate to a depth of 24 inches and very rapid below this depth. Available water capacity is about 4-6 inches, runoff is slow, and the hazard of water erosion is slight. Sifton Gravelly Loam is found at elevations of 15-25 feet, is more permeable, but is subject to occasional flooding in the winter and spring. The hazard of erosion from overflow is high.

Washougal Series

These loamy soils formed on low terraces in alluvium deposited by swiftly flowing rivers and streams. Most of the material is of volcanic origin. They are somewhat excessively drained and underlain by sand and gravel at a depth of 26-40 inches. The original vegetation was Douglas fir, vine maple, dogwood, snowberry, blackberry ferns, and grasses. Permeability is moderate but very rapid in the substratum, and available water capacity is moderate. Surface runoff is low and the hazard of erosion is slight.

Wind River Series

These are gravelly soils that formed in Columbia River alluvium of mixed origin. They are deep and somewhat excessively drained, at typical elevations of 150-500 feet. The original vegetation was Douglas fir, grand fir and Oregon white oak; with an understory of hazel, dogwood, vine maple, salal, and ferns. Permeability is moderately rapid in the upper part but rapid in the substratum. The available water capacity is moderate, surface runoff is slow, and hazard of erosion is slight.

Xeropsamments

These deep, somewhat excessively drained soils are on floodplains along the Columbia River. They formed in recent coarse-textured dredge spoil material. Elevation is 5-20 feet. Large areas are barren or only sparsely vegetated. In areas where vegetation has become established, black cottonwood, trailing blackberry Himalayan blackberry, forbs, and grasses are most common. Permeability is rapid or very rapid; available water capacity is variable. Runoff is slow, and the hazard of water erosion is slight to moderate. These soils are subject to frequent periods of flooding in the winter and spring.
APPENDIX C
COLUMBIA RIVER FLOODS

Severe floods regularly inundated the low areas along the Columbia River in Wapato Valley. However, this reality of life on the floodplain was not a deterrent to settlement, as can be seen from the tremendous number of locations on the landscape where Native Americans left the remains of their camps and villages. Rather, the Chinook dealt with this inconvenience by temporarily relocating until the waters subsided. Saleeby (1983:163) cites a 1933 US Army Corps of Engineers publication which estimates that on this stretch of the Columbia River, significant flooding would have occurred only about once in every three years. The advantage of living in such a rich environment, convenient to resources, communication and transportation, far outweighed the disadvantage of possible seasonal dislocation.

How Much Water?

The basic concern in this study is the degree of inundation by floodwaters at various points on the Columbia River throughout Wapato Valley: on how high a landform did a Chinook village or camp need to be to escape regular flooding? When we talk about a flood stage of 36 feet at Vancouver, as in the flood-of-record in 1894 (Sinclair 2003), what does that mean at different points on the river?

The normal elevation of the Columbia River in Wapato Valley is 16 feet between Bonneville Dam and Government Island, and 7 feet between Government Island and Deer Island. Did the 1894 flood reach to the 36-foot elevation contour throughout the entire Wapato Valley, so that there would be 20 feet of water on the land above Government Island and 29 feet of water between Government Island and Deer Island? Alternatively, did the entire landscape experience an extra 36 feet of floodwater – or perhaps only an extra 29 feet, since the river elevation at Vancouver is 7 feet? Is the maximum flood stage at Vancouver indicative of the general degree of flooding throughout Wapato Valley?

Ellis and Fagan (1993:21) state that an average spring flood reached 20 feet. The same question applies: is this a fairly uniform blanket of 20 feet of additional water regardless of your location in Wapato Valley, or do those living above Government Island experience only an extra 4 feet of water on the land, while those below are inundated with 13 feet of water? The difference would have serious implications for people whose houses were on the 20-foot elevation contour.

Columbia River Streamflow Statistics

In order to resolve these questions we must turn to the flood records. These data are from the US Geological Survey National Water Information System Web Data for USA (2003), unless otherwise cited. River gauges are at approximately sea level\(^3\), so flood stages measured by the river gauges are measuring feet of water above sea level. A flood stage of 29 feet as measured by a river gauge on the Columbia River at Vancouver will flood to the 29-foot elevation contour. However, what does this mean higher up on the river where the base elevation of the river is higher? If there were a river gauge at Camas, where the base elevation of the Columbia River is 16 feet, what would the equivalent measurement be at that location? Would it still read 29 feet (22 feet above the normal river level at Vancouver), or would it be closer to 38 feet (22 feet above the river level at Camas)?

Records for Columbia River discharge go back almost 150 years at The Dalles. Annual mean streamflow records have been kept since 1879; peak streamflow records have been kept since 1858. The greatest discharge ever measured there was 1,240,000 cubic feet per second on June 6, 1894, at a gauge height of 106.5 feet just downstream from the dam. The normal elevation of the water pool between The Dalles and Bonneville dams is currently 75 feet, so this would represent 31.5 feet above today’s normal river level. Historic accounts place the maximum flood stage at Vancouver for the 1894 flood at 33 feet (American Institute of Hydrology 2003), 36 feet (Sinclair 2003), or anecdotally at 39 feet (Minor et al. 1993).

\(^3\) The following are the heights of the river gauges on this part of the Columbia River: sea level for just below The Dalles and Bonneville dams, 1.8 feet above sea level at Vancouver, and 1.5 feet above sea level at the Columbia Slough near its junction with the Willamette River. Therefore, a gauge height of 27.5 feet at Vancouver means that floodwaters reached height of approximately 29 feet above sea level or 22 feet above the normal river level.
There was no river gauge at Vancouver in 1894 to tell us for certain, so the middle figure of 36 feet will be used.

For comparison, during the most recent severe flood in February 1996 the maximum discharge at The Dalles Dam was 408,000 cubic feet per second, with a gauge height of 82 feet, or 7 feet above the normal river level (less than you would expect because of the regulatory effect of upstream dams). The data downstream at the gauge just below Bonneville Dam showed a maximum height of 35 feet, or 19 feet above the normal river level of 16 feet between Bonneville Dam and Government Island. The river level at Vancouver peaked at a maximum gauge height of 27.5 feet (29 feet above sea level, or 22 feet above the normal river level), and at a maximum gauge height of 27.3 feet (28.8 feet above sea level or 21.8 feet above normal); the gauge at Quincy, Oregon (near Clatskanie, outside of Wapato Valley) measured just over 13 feet (13 feet above normal).

What the 1996 Flood Tells Us about the 1894 Flood

The only information that we have from the flood of 1894 is the peak data from The Dalles and from Vancouver. We do not have the average river level data from 1894, nor do we have data from any other recording stations. However, we may extrapolate the effects of the 1894 flood from the information that we do have from the 1996 flood. From this extrapolation, we can make inferences about the effects of the average and the most severe Columbia River floods on the prehistoric population of Wapato Valley.

At Vancouver (River Mile 106), the 1996 flood peaked at 22 feet above the normal level of the Columbia River. The other recording stations in the greater Wapato Valley show similar flood stages: 19 feet above normal below Bonneville Dam (River Mile 145), 21.8 feet above normal at the Columbia Slough (River Mile 101), and down to 13 feet above normal downriver at Quincy (River Mile 54), which is 22 miles beyond the study area. We see a consistent degree of flooding throughout the Greater Wapato Valley (roughly from River Mile 129 to River Mile 76). If we exclude the Quincy figure, the 1996 flood impacted the land with and average of an extra 20 feet of water throughout the area, from just below Bonneville Dam past Vancouver, probably at least as far as Deer Island.

This implies that the flood-of-record in 1894 would have produced a similar flood pattern throughout Wapato Valley. A peak river level of 36 feet in Vancouver, 29 feet above the normal river level, could be expected to correlate with comparable flood levels throughout Wapato Valley. Flooding would have reached the 36-foot elevation contour at Vancouver, and the 45 foot elevation contour upstream at Camas.

The data for the 1894 flood-of-record also tell us something about the flood of 1996. The American Institute of Hydrology (2003) states that if not for the dams on the Columbia River, the flood levels in 1996 would have been 6 feet higher. This means that the 1996 flood, instead of being 29 feet at Vancouver, would have been perhaps 35 feet, implying that the severity of the 1996 flood was almost as great as that of the 1894 flood, which reached 36 feet at Vancouver. Aside from a possible catastrophic outburst flood from the Bonneville Landslide in the early fifteenth century (Bourdeau 1999:71), these events probably represent the greatest flood levels experienced by residents of the Wapato Valley since the area stabilized geologically in the last few thousand years.

Annual Freshets

The usual season of greatest streamflow was in the spring from May 10 to July 1, with the mean being in early to mid-June and averaging 20 feet. The winter flood season was typically from November 19 to April 18, with the mean in January-February and averaging 13 feet (Ellis and Fagan 1993:21).

I assume what Ellis and Fagan mean by this is that floodwaters would have reached the 20-foot elevation contour at Vancouver and the 29-foot contour above Government Island, which is 9 feet higher. Saleeby (1983:163) confirms this with data from the US Army Corps of Engineers (1934) stating that flood stage for unlevied lowlands occurred when the discharge at The Dalles reached 600,000 cubic feet per second (pre-dam
era), which corresponds to a river gauge measurement of 20 feet at the mouth of the Willamette River. From the maximum yearly discharge data at The Dalles, this level was reached 44 times in the 80 years from 1858 to 1937 (US Geological Survey 2003). Clearly, in many years, flood stage was not reached and much of the floodplain escaped inundation.

How High is High Enough?

What do these figures tell us that would help us understand the impact of Columbia River flooding on the prehistoric inhabitants of Wapato Valley? How did the Chinook decide where to site their permanent villages, knowing what they did about the periodic flooding of their environment? Was the threat of great enough concern to prevent settlement in certain areas? Alternatively, was flooding treated as just a fact of everyday life to be managed as with problems with other resources? The flood data allow us to extrapolate back into the past to evaluate the importance of elevation in site location in Wapato Valley.

Did the Chinook favor places on the landscape for their permanent villages that were above a certain elevation, to escape damage from all but the worst floods? Villages represent a greater investment of time and resources for the construction of houses than do temporary camps, and it is reasonable to assume that the Chinook would have built them so that the need to move would be minimized. Were such permanent locations preferentially sited on landforms that were high enough to escape regular flooding, but close enough to the Columbia or on a major tributary to provide easy access to nearby resources?

Wapato Valley is an area of such year-round resource abundance that it allowed the Chinook to be largely sedentary within this valley. Early explorers recorded the names of many permanent native villages along the shores of the Columbia River. Saleeby (1983:61) states that ethnographic evidence indicates that a “permanent” village was one that is known for its fixed location, rather than its year-round occupancy.

Indeed, this seems to be the case with Neerchokioo village (located at the present site of the Portland International Airport), visited by Lewis and Clark on both their outward and return journeys. On November 4, 1805, Clark writes:

we landed at a village of 25 Houses: 24 of those houses we[re] thatched with Straw, and covered with bark, the other House is built of boards in the form of those above, except that it is above ground and about 50 feet in length and covered with broad Spilt boards This village contains about 200 men of the Skil-loot nation I counted 52 canoes on the bank in front of this village money of them verry large and raised in bow. [Moulton 1990:17]

On their return trip, the appearance of the village had changed. On April 2, 1806, Clark writes:

at 3 P. M. I landed at a large double house of the Ne-er-cho-ki-oo tribe of the Shah-ha-la Nation. at this place we had Seen 24 additional Straw Huts as we passed down last fall and whome as I have before mentioned reside at the Great rapids of the Columbia. on the bank at different places I observed Small Canoes which the women make use of to gather Wappato & roots in the Slashes…. I think 100 of those canoes were piled up and Scattered in different directions about in the Woods in the vecinity of this house, the pilot informed me that those Canoes were the property of the inhabitants of the Grand rapids who used them occasionally to gather roots. [Moulton 1991:57]

Although this was a permanent village, there was obviously some seasonal variation in population. Clark was told that the people he had seen in the fall were visiting from upriver. With the coming of spring and the first salmon runs, they returned to their summer villages at the “Great Rapids of the Columbia” (the rapids known as the Cascades of the Columbia, which were destroyed in the construction of Bonneville Dam).

Permanent villages such as the ones mentioned by Lewis and Clark are mostly located along the banks and natural levees of the Columbia River and its major tributaries. The average elevation of these landforms is less than 10 feet above river level, leading us to conclude that the possibility of seasonal flooding was of no great consequence to the Chinook. For a people whose lives were so entirely centered on the water, the economic, social, and political advantages of such
locations far outweighed the occasional inconvenience of having to temporarily relocate.

In his Columbia South Shore report, Burtchard (1990:26) initially assumed that “the heaviest concentration of sites, particularly residential localities, would be biased toward higher ground near the Columbia River, with secondary concentrations of task-specific sites on elevated ground inland”. He later concluded, though, that the most intensive use of the landform was in areas “that maximize resource return and provide ease of water borne transportation” (Burtchard 1990:33), which includes locations in proximity to wetlands. There may be a greater site density around wetlands than on the main river channels, if for no other reason than there is physically more area involved in wetlands than on the main watercourses. Wetland areas also tend to be the locations of many temporary camps that were satellite locations for main villages, so it would be expected that there are more of these types of sites. However, the Wapato Valley Predictive Model has revealed that there is no correlation of village locations with elevated areas of the floodplain: Burtchard was correct in his later appraisal. The areas with the highest probability for both villages and camps are close to the Columbia River and its navigable tributaries, regardless of elevation (see Table 5.F.1 in Appendix F: “Guidelines for Applying the Results of the Wapato Valley Predictive Model without the Probability Maps”). Access to these areas by boat is the key factor in the siting of 85 percent of villages and camps.

Conclusions

The extensive and varied resources of the floodplain allowed the Chinook to be largely sedentary within the Wapato Valley (Darby 1996, Saleeby 1983). Many of the staples of their diet – salmon, sturgeon, smelt, wapato, camas, berries, deer, small mammals, waterfowl – were only a short canoe trip away. The abundance of temporary campsites, marked by the ubiquitous fire-cracked rock, are evidence of food-gathering or other activities that necessitated a stay of one or many nights. These campsites could have represented a base of operations for an upland hunt, a processing site for fish or game, a location for roasting camas, a fishing station, or an area where people met for other economic and social activities away from the main villages. The locations for these camps throughout the Wapato Valley are as diverse as their purposes. Seasonal flooding may have determined the time of year when access to some of these areas was possible, however it did not affect their fundamental use.

Villages appear to be located without too much concern for flood potential. Other factors seem to have been more important to the Chinook than the possible need to temporarily relocate. Access to resources, communication and transportation for 11 months out of the year (Saleeby [1983:163] reports that severe floods could last from 4 to 42 days perhaps only every other year) far outweighed the inconvenience of displacement by flood.

The average elevation of villages in Wapato Valley was no higher than that of temporary campsites; there was no deliberate attempt in their siting to elude floodwaters. All but the highest landforms along the floodplain were periodically inundated: this was just another condition of the bond that linked the Chinook and the Columbia River. The river provided, but the river imposed limitations. This study of the flood records of the last 150 years has helped us better understand the location of archaeological sites in Wapato Valley, and the dynamics of the relationship between the Chinook and the Columbia River.
APPENDIX D
WAPATO VALLEY RADIOCARBON DATES

The following radiocarbon dates are those that have been returned on samples from sites in the Wapato Valley database, namely prehistoric archaeological sites in Clark County, Washington and in Columbia and Multnomah Counties, Oregon, on the floodplain of the Columbia River. Only sites that are at an elevation of 55 feet or less are included in this table.

The uncalibrated radiocarbon dates were taken directly from lists provided by the Oregon and Washington State Historic Preservation Offices, and from the Cathlapotle site report (Ames et al. 1999:64) and supplemental Cathlapotle data (Kenneth Ames, personal communication, 2003). No attempt was made to further verify this information. Any omissions follow the original records. Question marks were included when used in the original; spaces were left blank when done so in the original.

There appears to be two duplications of dates in sites 35MU29 and 35MU32. These sites are adjacent, so perhaps there was some uncertainty as to which site the samples would eventually be attributed. These two sets of duplicates have been noted in the table.
APPENDIX E
WAPATO VALLEY PREDICTIVE MODEL
LOGISTIC REGRESSION
PROBABILITY TABLES

The following tables consist of those relevant columns of the Wapato Valley Prehistoric Archaeological Site Database that were brought into SPSS for logistic regression analysis. Preliminary analysis identified six potential predictor variables: Feet Above Mean Sea Level, Feet Above River Level, Meters to Nearest Permanent Water, Meters to Navigable Water, Percent Slope, and Degrees Aspect. The master site database was simplified to include just these variables.

The null point cases were also measured for these six potential predictor variables (Table 5.E.1). Sensitive information that would allow the discovery of the location of archaeological sites (such as the UTM coordinates, and the names of the topographic maps and waterways) has been omitted on this site table (Table 5.E.2) to ensure confidentiality. The full site database is available to archaeology professionals from the Department of Anthropology, Portland State University, or from the author.

A random sample of 35 of the 327 null points, 29 of the 276 archaeological sites, and the 29 Ridgefield National Wildlife Refuge sites were all withheld from model development and used afterwards as Testing Samples. Forward stepwise logistic regression was run on the remaining 510 null points and archaeological sites. See Chapter 4: “Building the Model, Part I: Preliminary Data Analysis”, and Chapter 5: “Building the Model, Part II: Logistic Regression”, for full details on the development of the Wapato Valley Predictive Model.

A brief discussion of the entries in the regression table follows. More detailed information about the table values may be found in Chapter 3: “Development of the Wapato Valley Prehistoric Archaeological Site Database”. Figures 5.E.1 and E-2 show the orientation of the pages of the probability tables for the null points and archaeological sites.

Logistic Regression Probability Tables

1. **Ordinal Number**  The sequential number of the point or site. The Ordinal Number column is included on every page of the table.

2. **Case Number**  Null Points: the number of the randomly-generated null points that were used in the development of the model. Of the 2,000 points generated, 327 were in the Wapato Valley, within the desired elevation range, and not in water. Archaeological Sites: the site number, as expressed in the Smithsonian trinomial designation. The Case Number column is included on every page of the table.

3. **UTM East**  Easting of the null point. These data are omitted for the archaeological sites to ensure confidentiality.

4. **UTM North**  Northing of the null point. These data are omitted for the archaeological sites to ensure confidentiality.

5. **Topographic Map**  The name of the USGS 7.5-minute topographic quadrangle of the location of the null point. These data are omitted for the archaeological sites to ensure confidentiality.

6. **Feet AMSL**  Null point or archaeological site elevation Above Mean Sea Level, measured in feet.

7. **Feet ARL**  Elevation in feet of the null point or archaeological site Above River Level. Depending on the location on the Columbia River, the differences between the two elevation figures is 16, 7, or 0 feet.

8. **Nearest Permanent Water**  Name of the nearest year-round source of water. This name is omitted for the archaeological sites to ensure confidentiality.

9. **Meters to Nearest Permanent Water**  Distance to water source in #8 above, measured in meters.

10. **Nearest Navigable Water**  Name of nearest navigable water source connecting to the Columbia River. This name is omitted for the archaeological sites to ensure confidentiality.

11. **Meters to Navigable Water**  Distance to navigable water in #10 above, measured in meters.
12. **Percent Slope**  
Slope of location, given as a percent.

13. **Degrees Aspect**  
Aspect of location, given in degrees.

14. **Training = 0, Testing = 1**  
These values show whether a particular null point or site was part of the Training Sample or Testing Sample.

15. **Probability Score**  
The Probability Score recorded after stepwise (Forward Conditional) binary multivariate logistic regression with the three strongest predictor variables: Feet Above River Level, Meters to Nearest Permanent Water, and Meters to Navigable Water. The score, measured from 0 to 1, represents the probability of the occurrence of an archaeological site at that specific location, given the values of the three environmental variables at that particular location.

16. **Null = 0, Site = 1**  
With a cutpoint of .5 on the Probability Score, whether the model classifies this particular location as a null point or an archaeological site, based on the values of the predictor variables.

17. **Probability Class (1-5)**  
Probability Class of the null point or site, based on the Probability Score from #15 above: 5 = 1.0-.8, 4 = .8-.6, 3 = .6-.4, 2 = .4-.2, 1 = .2-0.

18. **Adjusted Score from New Constant**  
After the intercept value (constant) from the regression equation was adjusted for the difference in sample sizes between the null point and site samples, the score and probability components of the regression equation were run again. This is the value of the score component of the regression equation.

19. **New Probability Score**  
This score is the new value of the probability component of the regression equation after adjusting the constant for the difference in sample sizes.

20. **Null = 0, Site = 1**  
After adjusting the constant from the regression equation, at a Probability Score cutpoint of .5, whether the model classifies this particular location as a null point or an archaeological site, based on the values of the predictor variables.

21. **New Probability Class (1-5)**  
New Probability Class of the null point or archaeological site, after adjusting the constant for the difference in sample sizes, based on the Probability Score from #19 above.
**Figure 5.E.1.** Diagram of orientation of pages in Logistic Regression Null Point Table E-1. Table is in a 2x8 page configuration.
Figure 5.E.2. Diagram of orientation of pages in Logistic Regression Archaeological Site Table E-2. Table is in a 2x7 page configuration.
APPENDIX F
GUIDELINES FOR APPLYING THE
RESULTS OF THE WAPATO VALLEY
PREDICTIVE MODEL WITHOUT THE
PROBABILITY MAPS

Armed with a set of probability maps for the area of interest, the archaeologist sets out to survey the site of a new construction project. However, even with a GPS receiver and a detailed probability map overlaid on a DRG base map, it can be difficult to know exactly where something is located. The situation may arise that it is hard to judge what probability zones(s) the impact area contains, especially on the boundaries between high and low probability zones. This problem could affect everyone on the project and the entire scope of work – from the archaeologist responsible for developing and executing a survey, to the workers’ ability to successfully complete the project – because of potential delays due to the unanticipated discovery of archaeological materials.

What if an archaeologist did not have ready access to the probability maps? The occasion also might arise where an archaeologist or other site planner is moving around the floodplain, and was not able to anticipate the maps needed for the project. Can the Wapato Valley Predictive Model provide elevation and distance guidelines for the identification of probability areas that could be easily applied in the field without the probability maps?

Analyzing Values within Probability Classes

Through an analysis of the distribution of the values of the predictor variables within the five probability classes, it is possible to define general elevation and distance ranges that can be used to help in the identification of probability areas. Indeed, before GIS, this is one of the primary ways that probability areas could be defined (see Kohler and Parker 1986, and Kvamme 1988b). A consideration of the mean values and ranges of the three predictor variables in the Training Sample sites (Table 5.F.1) gives an initial impression of possible groupings. Trends in the data can be seen, such as the bimodal relationship of elevation versus the unimodal relationship of the water distances and site probability. However, such a summary table falls short in its ability to provide the details necessary to define useable probability zones.

Histgrams can also provide an indication of the distribution of the predictor variables within probability classes (Figures 5.F.1 through 5.F.5). They offer a clearer picture of the values of the individual sites in the probability classes, their frequency, and their distribution through the range of values. However, this method too fails to provide enough detail so that statements about elevation and distance values can be made as quantitative guidelines for the probability classes.

Since the probability scores in logistic regression result from the particular combination of variables for each site location, the first two methods detailed above are inadequate because they consider the three predictor variables separately. A more accurate way to establish quantitative values

<table>
<thead>
<tr>
<th>Probability Class of Training Sample Sites (Probability)</th>
<th>#</th>
<th>%</th>
<th>Feet Above River Level</th>
<th>Meters to Nearest Permanent Water</th>
<th>Meters to Navigable Water</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 (1.0-.8)</td>
<td>32</td>
<td>14.7</td>
<td>14.3 (5-42)</td>
<td>8.5 (1-45)</td>
<td>23.2 (1-420)</td>
</tr>
<tr>
<td>4 (.8-.6)</td>
<td>153</td>
<td>70.2</td>
<td>5.2 (0-39)</td>
<td>14.9 (1-60)</td>
<td>39.2 (1-600)</td>
</tr>
<tr>
<td>3 (.6-.4)</td>
<td>22</td>
<td>10.1</td>
<td>5.4 (0-22)</td>
<td>32.6 (1-100)</td>
<td>229.2 (40-550)</td>
</tr>
<tr>
<td>2 (.4-.2)</td>
<td>5</td>
<td>2.3</td>
<td>9.8 (1-23)</td>
<td>60.0 (5-150)</td>
<td>524.0 (120-850)</td>
</tr>
<tr>
<td>1 (.2-0)</td>
<td>6</td>
<td>2.8</td>
<td>16.5 (12-32)</td>
<td>184.2 (20-500)</td>
<td>946.7 (280-1350)</td>
</tr>
</tbody>
</table>
for the probability classes requires a careful study of the individual cases in each probability class.

The probability classes for the Wapato Valley Predictive Model were summarized in SPSS for the 218 archaeological sites in the Training Sample and the 58 sites in the Testing Sample. The individual cases are displayed with their values for the three predictor variables: Feet Above River Level, Meters to Nearest Permanent Water, and Meters to Navigable Water. An example of this is shown in Table 5.F.2, which details the values of the predictor variables for the 32 sites in Probability Class 5 of the Training Sample sites. Complete tables of the case values for both the Training and Testing Sample sites are located at the end of this appendix (Tables 5.F.4 through 5.F.14).

It can be seen from this summary table that patternings in the data are evident. In spite of outliers, ranges for the three predictor variables can be proposed based on the values of the variables for individual sites. By considering the dis-

Figure 5.F.1. Histograms of frequency of predictor variables for Training Sample archaeological sites, Probability Class 5.
tributions through all five probability classes, it is possible to develop a model for the ranges of values of the predictive variables that optimizes the number of correct classifications across all probability classes.

Table 5.F.3 presents the suggested elevation and distance ranges proposed for the five probability classes of the Wapato Valley Predictive Model after an analysis of the data from the Training Sample site summary tables, histograms and case summaries. The success rates of correct classification are given for both the Training and Testing Sample archaeological sites. The percentages of overall correct classification, less for Probability Classes 1 and 2, may be due in part to the small numbers of cases in these classes (6 cases in Class 1 and 5 cases in Class 2 of the Training Sample; 0 cases in Class 1 and 3 cases in Class 2 of the Testing Sample). There would be perhaps a greater level of confidence in the suggested ranges of predictor values for Class 1 and Class 2 if there were more cases on which to base the classification. However, it must be remembered that cases

Figure 5.F.2. Histograms of frequency of predictor variables for Training Sample archaeological sites, Probability Class 4.
Figure 5.F.3. Histograms of frequency of predictor variables for Training Sample archaeological sites, Probability Class 3.
Figure 5.F.4. Histograms of frequency of predictor variables for Training Sample archaeological sites, Probability Class 2.
Figure 5.F.5. Histograms of frequency of predictor variables for Training Sample archaeological sites, Probability Class 1.
Table 5.F.2. Case Summaries of Training Sample Sites in Probability Class 5.

<table>
<thead>
<tr>
<th>Case Number</th>
<th>Feet Above River Level</th>
<th>Meters to Nearest Permanent Water</th>
<th>Meters to Navigable Water</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>332</td>
<td>10</td>
<td>6</td>
</tr>
<tr>
<td>2</td>
<td>337</td>
<td>12</td>
<td>10</td>
</tr>
<tr>
<td>3</td>
<td>343</td>
<td>22</td>
<td>6</td>
</tr>
<tr>
<td>4</td>
<td>344</td>
<td>17</td>
<td>13</td>
</tr>
<tr>
<td>5</td>
<td>352</td>
<td>14</td>
<td>8</td>
</tr>
<tr>
<td>6</td>
<td>370</td>
<td>15</td>
<td>25</td>
</tr>
<tr>
<td>7</td>
<td>376</td>
<td>7*</td>
<td>4</td>
</tr>
<tr>
<td>8</td>
<td>380</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>9</td>
<td>381</td>
<td>13</td>
<td>14</td>
</tr>
<tr>
<td>10</td>
<td>390</td>
<td>6*</td>
<td>3</td>
</tr>
<tr>
<td>11</td>
<td>410</td>
<td>10</td>
<td>8</td>
</tr>
<tr>
<td>12</td>
<td>426</td>
<td>10</td>
<td>6</td>
</tr>
<tr>
<td>13</td>
<td>447</td>
<td>5*</td>
<td>1</td>
</tr>
<tr>
<td>14</td>
<td>474</td>
<td>5*</td>
<td>1</td>
</tr>
<tr>
<td>15</td>
<td>486</td>
<td>30</td>
<td>8</td>
</tr>
<tr>
<td>16</td>
<td>491</td>
<td>26</td>
<td>30*</td>
</tr>
<tr>
<td>17</td>
<td>492</td>
<td>5*</td>
<td>1</td>
</tr>
<tr>
<td>18</td>
<td>494</td>
<td>19</td>
<td>30*</td>
</tr>
<tr>
<td>19</td>
<td>508</td>
<td>42</td>
<td>45*</td>
</tr>
<tr>
<td>20</td>
<td>519</td>
<td>13</td>
<td>2</td>
</tr>
<tr>
<td>21</td>
<td>528</td>
<td>9</td>
<td>1</td>
</tr>
<tr>
<td>22</td>
<td>533</td>
<td>36</td>
<td>15</td>
</tr>
<tr>
<td>23</td>
<td>557</td>
<td>13</td>
<td>3</td>
</tr>
<tr>
<td>24</td>
<td>560</td>
<td>7*</td>
<td>3</td>
</tr>
<tr>
<td>25</td>
<td>561</td>
<td>8</td>
<td>3</td>
</tr>
<tr>
<td>26</td>
<td>562</td>
<td>10</td>
<td>3</td>
</tr>
<tr>
<td>27</td>
<td>568</td>
<td>27</td>
<td>5</td>
</tr>
<tr>
<td>28</td>
<td>569</td>
<td>11</td>
<td>1</td>
</tr>
<tr>
<td>29</td>
<td>570</td>
<td>8</td>
<td>1</td>
</tr>
<tr>
<td>30</td>
<td>576</td>
<td>11</td>
<td>1</td>
</tr>
<tr>
<td>31</td>
<td>587</td>
<td>16</td>
<td>5</td>
</tr>
<tr>
<td>32</td>
<td>593</td>
<td>13</td>
<td>5</td>
</tr>
</tbody>
</table>

Mean 14.31 8.53 23.19
Minimum 5 1 1
Maximum 42 45 420

Entries with asterisk fall outside the suggested ranges for this class:
- greater than 8 feet above river level
- within 25 meters of permanent water
- within 50 meters of navigable water
in Classes 1 and 2 are misclassified archaeological sites, so it is actually appropriate that there are so few cases there.

The suggested values of the ranges of predictor variables by probability class are general guidelines, and as such should not be taken as the final word on probability areas. The predictive surface generated in ArcView through the application of the results of logistic regression to the combined grid maps of the predictor variables should be considered the ultimate authority.

**Comparison with Probability Maps**

An additional step that can be taken to assess the fit of the above classification system is to compare the suggested ranges with the ArcView probability maps. The extent of the individual probability zones themselves can be evaluated. Color-coding of elevation areas allows the values of the Feet Above River Level variable to be easily distinguished. The water distance variables, which determine the width of the probability zones, can be measured in ArcView by using the measurement tool.

When examining selected areas of the probability surface of the St. Helens quadrangle, it appears that these suggested ranges work better in some areas than in others. Figure 5.F.6 shows a magnified portion of the Saint Helens DRG, at the confluence of the Columbia, Lake and Lewis Rivers, with the probability surface overlaid and the Class 1 area made transparent. The main problem
Figure 5.F.6. Close-up of probability zones of the Saint Helens DRG at the confluence of the Columbia, Lake, and Lewis Rivers. The Class 1 area has been made transparent.
with establishing the suggested ranges by means of a visual inspection of the probability maps is the difficulty in mentally separating the results of the two water distance measurements from each other, due in part to the navigable water source being the same as the permanent water source for some areas. There are places on the map, however, where the differences can be more easily seen.

Area A in the upper right corner shows the interaction of two of the variables – elevation and permanent water – at a distance of .5-.75 kilometers from navigable water. The full range of probability areas can be seen around this permanent water source next to an elevated landform. Area B in the lower left corner shows the more broad, complex pattern of interaction between permanent and navigable water in an area of generally low elevation. It is difficult to judge which parts of the probability areas are based on distance to permanent water and which are based on distance to navigable water.

Fortunately, we are relieved of defining the probability areas ourselves, as researchers had to do before GIS – ArcView applies the logistic regression equation to the maps for us. The resulting probability surface says it all, and much better than any estimates of ranges of values that we can extract from them.

The above exercise demonstrates that any ranges of values assigned to the probability areas can only be estimates, due to the complex interaction of the predictor variables. The suggested ranges are meant as guidelines only. They are offered only as a complement to – not as a substitute for – the probability maps. Although the values of the predictor variables of the archaeological sites used to develop and test the Wapato Valley Predictive Model largely agree with the suggested ranges, these figures should be used with caution. To reduce the results of the regression equation to these few measures is misleading and belies the true complexity of the probability surfaces. Because ArcView incorporates the logistic coefficients, which are measures of the strength of the predictor variables, for each unique combination of predictors in the applying the logistic regression formula to the map surfaces, the maps should be regarded as the ultimate authority for probability areas. There is really no adequate substitute for the probability maps of the Wapato Valley Predictive Model.

**Summaries of the Values of Predictor Variables of Training and Testing Sample Sites by Probability Class**

The following tables detail the values of the three predictor variables for all archaeological sites in each of the five probability classes, along with their means and ranges. Within the Training Sample and Testing Sample sections, the sites are listed by case number, which can be referenced in the Wapato Valley Predictive Model Logistic Regression Site Probability Tables (Appendix E) if more information about a particular site is desired.

Asterisks next to table values denote those variables that are outside the suggested ranges for that particular class. The six archaeological sites in Probability Class 1 for the Training Sample are ≥ 2 SD from the mean and should be considered outliers.
### Wapato Valley Predictive Model

**Case Summaries of Sites by Probability Class**

**Training Sample**

<table>
<thead>
<tr>
<th>Case Number</th>
<th>Feet Above River Level</th>
<th>Meters to Nearest Permanent Water</th>
<th>Meters to Navigable Water</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>332</td>
<td>10</td>
<td>6</td>
</tr>
<tr>
<td>2</td>
<td>337</td>
<td>12</td>
<td>10</td>
</tr>
<tr>
<td>3</td>
<td>343</td>
<td>22</td>
<td>6</td>
</tr>
<tr>
<td>4</td>
<td>344</td>
<td>17</td>
<td>13</td>
</tr>
<tr>
<td>5</td>
<td>352</td>
<td>14</td>
<td>8</td>
</tr>
<tr>
<td>6</td>
<td>370</td>
<td>15</td>
<td>25</td>
</tr>
<tr>
<td>7</td>
<td>376</td>
<td>7*</td>
<td>4</td>
</tr>
<tr>
<td>8</td>
<td>380</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>9</td>
<td>381</td>
<td>13</td>
<td>14</td>
</tr>
<tr>
<td>10</td>
<td>390</td>
<td>6*</td>
<td>3</td>
</tr>
<tr>
<td>11</td>
<td>410</td>
<td>10</td>
<td>8</td>
</tr>
<tr>
<td>12</td>
<td>426</td>
<td>10</td>
<td>6</td>
</tr>
<tr>
<td>13</td>
<td>447</td>
<td>5*</td>
<td>1</td>
</tr>
<tr>
<td>14</td>
<td>474</td>
<td>5*</td>
<td>1</td>
</tr>
<tr>
<td>15</td>
<td>486</td>
<td>30</td>
<td>8</td>
</tr>
<tr>
<td>16</td>
<td>491</td>
<td>26</td>
<td>30*</td>
</tr>
<tr>
<td>17</td>
<td>492</td>
<td>5*</td>
<td>1</td>
</tr>
<tr>
<td>18</td>
<td>494</td>
<td>19</td>
<td>30*</td>
</tr>
<tr>
<td>19</td>
<td>508</td>
<td>42</td>
<td>45*</td>
</tr>
<tr>
<td>20</td>
<td>519</td>
<td>13</td>
<td>2</td>
</tr>
<tr>
<td>21</td>
<td>528</td>
<td>9</td>
<td>1</td>
</tr>
<tr>
<td>22</td>
<td>533</td>
<td>36</td>
<td>15</td>
</tr>
<tr>
<td>23</td>
<td>557</td>
<td>13</td>
<td>3</td>
</tr>
<tr>
<td>24</td>
<td>560</td>
<td>7*</td>
<td>3</td>
</tr>
<tr>
<td>25</td>
<td>561</td>
<td>8</td>
<td>3</td>
</tr>
<tr>
<td>26</td>
<td>562</td>
<td>10</td>
<td>3</td>
</tr>
<tr>
<td>27</td>
<td>568</td>
<td>27</td>
<td>5</td>
</tr>
<tr>
<td>28</td>
<td>569</td>
<td>11</td>
<td>1</td>
</tr>
<tr>
<td>29</td>
<td>570</td>
<td>8</td>
<td>1</td>
</tr>
<tr>
<td>30</td>
<td>576</td>
<td>11</td>
<td>1</td>
</tr>
<tr>
<td>31</td>
<td>587</td>
<td>16</td>
<td>5</td>
</tr>
<tr>
<td>32</td>
<td>593</td>
<td>13</td>
<td>5</td>
</tr>
</tbody>
</table>

**Table 5.F.4. Probability Class 5 Case Summaries of Training Sample Sites.**

<table>
<thead>
<tr>
<th>Case Number</th>
<th>Feet Above River Level</th>
<th>Meters to Nearest Permanent Water</th>
<th>Meters to Navigable Water</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>332</td>
<td>10</td>
<td>6</td>
</tr>
<tr>
<td>2</td>
<td>337</td>
<td>12</td>
<td>10</td>
</tr>
<tr>
<td>3</td>
<td>343</td>
<td>22</td>
<td>6</td>
</tr>
<tr>
<td>4</td>
<td>344</td>
<td>17</td>
<td>13</td>
</tr>
<tr>
<td>5</td>
<td>352</td>
<td>14</td>
<td>8</td>
</tr>
<tr>
<td>6</td>
<td>370</td>
<td>15</td>
<td>25</td>
</tr>
<tr>
<td>7</td>
<td>376</td>
<td>7*</td>
<td>4</td>
</tr>
<tr>
<td>8</td>
<td>380</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>9</td>
<td>381</td>
<td>13</td>
<td>14</td>
</tr>
<tr>
<td>10</td>
<td>390</td>
<td>6*</td>
<td>3</td>
</tr>
<tr>
<td>11</td>
<td>410</td>
<td>10</td>
<td>8</td>
</tr>
<tr>
<td>12</td>
<td>426</td>
<td>10</td>
<td>6</td>
</tr>
<tr>
<td>13</td>
<td>447</td>
<td>5*</td>
<td>1</td>
</tr>
<tr>
<td>14</td>
<td>474</td>
<td>5*</td>
<td>1</td>
</tr>
<tr>
<td>15</td>
<td>486</td>
<td>30</td>
<td>8</td>
</tr>
<tr>
<td>16</td>
<td>491</td>
<td>26</td>
<td>30*</td>
</tr>
<tr>
<td>17</td>
<td>492</td>
<td>5*</td>
<td>1</td>
</tr>
<tr>
<td>18</td>
<td>494</td>
<td>19</td>
<td>30*</td>
</tr>
<tr>
<td>19</td>
<td>508</td>
<td>42</td>
<td>45*</td>
</tr>
<tr>
<td>20</td>
<td>519</td>
<td>13</td>
<td>2</td>
</tr>
<tr>
<td>21</td>
<td>528</td>
<td>9</td>
<td>1</td>
</tr>
<tr>
<td>22</td>
<td>533</td>
<td>36</td>
<td>15</td>
</tr>
<tr>
<td>23</td>
<td>557</td>
<td>13</td>
<td>3</td>
</tr>
<tr>
<td>24</td>
<td>560</td>
<td>7*</td>
<td>3</td>
</tr>
<tr>
<td>25</td>
<td>561</td>
<td>8</td>
<td>3</td>
</tr>
<tr>
<td>26</td>
<td>562</td>
<td>10</td>
<td>3</td>
</tr>
<tr>
<td>27</td>
<td>568</td>
<td>27</td>
<td>5</td>
</tr>
<tr>
<td>28</td>
<td>569</td>
<td>11</td>
<td>1</td>
</tr>
<tr>
<td>29</td>
<td>570</td>
<td>8</td>
<td>1</td>
</tr>
<tr>
<td>30</td>
<td>576</td>
<td>11</td>
<td>1</td>
</tr>
<tr>
<td>31</td>
<td>587</td>
<td>16</td>
<td>5</td>
</tr>
<tr>
<td>32</td>
<td>593</td>
<td>13</td>
<td>5</td>
</tr>
</tbody>
</table>

**Mean** 14.31 8.53 23.19

**Minimum** 5 1 1

**Maximum** 42 45 420

Entries with asterisk fall outside the suggested ranges for this class:
- greater than 8 feet above river level
- within 25 meters of permanent water
- within 50 meters of navigable water
Table 5.F.5. Probability Class 4 Case Summaries of Training Sample Sites.

<table>
<thead>
<tr>
<th>Case Number</th>
<th>Feet Above River Level</th>
<th>Meters to Nearest Permanent Water</th>
<th>Meters to Navigable Water</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>2</td>
<td>3</td>
<td>11*</td>
<td>30</td>
</tr>
<tr>
<td>3</td>
<td>4</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>4</td>
<td>4</td>
<td>4</td>
<td>50</td>
</tr>
<tr>
<td>5</td>
<td>1</td>
<td>3</td>
<td>30</td>
</tr>
<tr>
<td>6</td>
<td>3</td>
<td>3</td>
<td>20</td>
</tr>
<tr>
<td>7</td>
<td>3</td>
<td>15*</td>
<td>50</td>
</tr>
<tr>
<td>8</td>
<td>1</td>
<td>12</td>
<td>12</td>
</tr>
<tr>
<td>9</td>
<td>3</td>
<td>16</td>
<td>16</td>
</tr>
<tr>
<td>10</td>
<td>7</td>
<td>16</td>
<td>16</td>
</tr>
<tr>
<td>11</td>
<td>0</td>
<td>18</td>
<td>18</td>
</tr>
<tr>
<td>12</td>
<td>3</td>
<td>18</td>
<td>18</td>
</tr>
<tr>
<td>13</td>
<td>3</td>
<td>16</td>
<td>16</td>
</tr>
<tr>
<td>14</td>
<td>3</td>
<td>18</td>
<td>18</td>
</tr>
<tr>
<td>15</td>
<td>3</td>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td>16</td>
<td>3</td>
<td>26</td>
<td>26</td>
</tr>
<tr>
<td>17</td>
<td>4</td>
<td>26</td>
<td>26</td>
</tr>
<tr>
<td>18</td>
<td>3</td>
<td>12*</td>
<td>30</td>
</tr>
<tr>
<td>19</td>
<td>10*</td>
<td></td>
<td>25</td>
</tr>
<tr>
<td>20</td>
<td>9*</td>
<td>30</td>
<td>30</td>
</tr>
<tr>
<td>21</td>
<td>3</td>
<td>18</td>
<td>18</td>
</tr>
<tr>
<td>22</td>
<td>3</td>
<td>20</td>
<td>25</td>
</tr>
<tr>
<td>23</td>
<td>9*</td>
<td>20</td>
<td>160*</td>
</tr>
<tr>
<td>24</td>
<td>3</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>25</td>
<td>3</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>26</td>
<td>3</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>27</td>
<td>3</td>
<td>14</td>
<td>14</td>
</tr>
<tr>
<td>28</td>
<td>3</td>
<td>13</td>
<td>13</td>
</tr>
<tr>
<td>29</td>
<td>3</td>
<td>25</td>
<td>25</td>
</tr>
<tr>
<td>30</td>
<td>8</td>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td>31</td>
<td>3</td>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td>32</td>
<td>3</td>
<td>18</td>
<td>18</td>
</tr>
<tr>
<td>33</td>
<td>9*</td>
<td>25</td>
<td>25</td>
</tr>
<tr>
<td>34</td>
<td>9*</td>
<td>14</td>
<td>14</td>
</tr>
<tr>
<td>35</td>
<td>3</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>36</td>
<td>3</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>37</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>38</td>
<td>4</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>39</td>
<td>8</td>
<td>25</td>
<td>65*</td>
</tr>
<tr>
<td>40</td>
<td>9*</td>
<td>25</td>
<td>160*</td>
</tr>
<tr>
<td>41</td>
<td>8</td>
<td>30</td>
<td>160*</td>
</tr>
<tr>
<td>Case Number</td>
<td>Feet Above River Level</td>
<td>Meters to Nearest Permanent Water</td>
<td>Meters to Navigable Water</td>
</tr>
<tr>
<td>-------------</td>
<td>------------------------</td>
<td>----------------------------------</td>
<td>---------------------------</td>
</tr>
<tr>
<td>42</td>
<td>397</td>
<td>13*</td>
<td>18</td>
</tr>
<tr>
<td>43</td>
<td>398</td>
<td>13*</td>
<td>8</td>
</tr>
<tr>
<td>44</td>
<td>400</td>
<td>4</td>
<td>37</td>
</tr>
<tr>
<td>45</td>
<td>401</td>
<td>3</td>
<td>25</td>
</tr>
<tr>
<td>46</td>
<td>402</td>
<td>3</td>
<td>30</td>
</tr>
<tr>
<td>47</td>
<td>403</td>
<td>3</td>
<td>20</td>
</tr>
<tr>
<td>48</td>
<td>404</td>
<td>3</td>
<td>8</td>
</tr>
<tr>
<td>49</td>
<td>407</td>
<td>3</td>
<td>20</td>
</tr>
<tr>
<td>50</td>
<td>408</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>51</td>
<td>409</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>52</td>
<td>429</td>
<td>11*</td>
<td>20</td>
</tr>
<tr>
<td>53</td>
<td>430</td>
<td>3</td>
<td>15</td>
</tr>
<tr>
<td>54</td>
<td>431</td>
<td>6</td>
<td>13</td>
</tr>
<tr>
<td>55</td>
<td>432</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>56</td>
<td>433</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>57</td>
<td>434</td>
<td>9*</td>
<td>35</td>
</tr>
<tr>
<td>58</td>
<td>435</td>
<td>3</td>
<td>20</td>
</tr>
<tr>
<td>59</td>
<td>436</td>
<td>3</td>
<td>20</td>
</tr>
<tr>
<td>60</td>
<td>437</td>
<td>3</td>
<td>25</td>
</tr>
<tr>
<td>61</td>
<td>438</td>
<td>3</td>
<td>15</td>
</tr>
<tr>
<td>62</td>
<td>439</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>63</td>
<td>440</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>64</td>
<td>441</td>
<td>3</td>
<td>10</td>
</tr>
<tr>
<td>65</td>
<td>442</td>
<td>3</td>
<td>30</td>
</tr>
<tr>
<td>66</td>
<td>443</td>
<td>3</td>
<td>20</td>
</tr>
<tr>
<td>67</td>
<td>444</td>
<td>14*</td>
<td>50</td>
</tr>
<tr>
<td>68</td>
<td>457</td>
<td>7</td>
<td>12</td>
</tr>
<tr>
<td>69</td>
<td>460</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>70</td>
<td>461</td>
<td>10*</td>
<td>45</td>
</tr>
<tr>
<td>71</td>
<td>462</td>
<td>5</td>
<td>40</td>
</tr>
<tr>
<td>72</td>
<td>464</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>73</td>
<td>467</td>
<td>10*</td>
<td>35</td>
</tr>
<tr>
<td>74</td>
<td>469</td>
<td>14*</td>
<td>33</td>
</tr>
<tr>
<td>75</td>
<td>470</td>
<td>13*</td>
<td>41</td>
</tr>
<tr>
<td>76</td>
<td>472</td>
<td>3</td>
<td>15</td>
</tr>
<tr>
<td>77</td>
<td>473</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>78</td>
<td>475</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>79</td>
<td>476</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>80</td>
<td>478</td>
<td>12*</td>
<td>50</td>
</tr>
<tr>
<td>81</td>
<td>479</td>
<td>6</td>
<td>10</td>
</tr>
<tr>
<td>82</td>
<td>485</td>
<td>4</td>
<td>6</td>
</tr>
</tbody>
</table>
Table 5.F.5 Cont.

<table>
<thead>
<tr>
<th>Case Number</th>
<th>Feet Above River Level</th>
<th>Meters to Nearest Permanent Water</th>
<th>Meters to Navigable Water</th>
</tr>
</thead>
<tbody>
<tr>
<td>83</td>
<td>488</td>
<td>27*</td>
<td>60*</td>
</tr>
<tr>
<td>84</td>
<td>489</td>
<td>7</td>
<td>10</td>
</tr>
<tr>
<td>85</td>
<td>490</td>
<td>4</td>
<td>35</td>
</tr>
<tr>
<td>86</td>
<td>493</td>
<td>39*</td>
<td>35</td>
</tr>
<tr>
<td>87</td>
<td>495</td>
<td>3</td>
<td>15</td>
</tr>
<tr>
<td>88</td>
<td>496</td>
<td>2</td>
<td>6</td>
</tr>
<tr>
<td>89</td>
<td>497</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>90</td>
<td>498</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>91</td>
<td>499</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>92</td>
<td>500</td>
<td>6</td>
<td>15</td>
</tr>
<tr>
<td>93</td>
<td>501</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>94</td>
<td>502</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>95</td>
<td>503</td>
<td>3</td>
<td>8</td>
</tr>
<tr>
<td>96</td>
<td>504</td>
<td>3</td>
<td>35</td>
</tr>
<tr>
<td>97</td>
<td>506</td>
<td>4</td>
<td>10</td>
</tr>
<tr>
<td>98</td>
<td>509</td>
<td>2</td>
<td>10</td>
</tr>
<tr>
<td>99</td>
<td>510</td>
<td>3</td>
<td>8</td>
</tr>
<tr>
<td>100</td>
<td>511</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>101</td>
<td>512</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>102</td>
<td>513</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>103</td>
<td>516</td>
<td>3</td>
<td>20</td>
</tr>
<tr>
<td>104</td>
<td>517</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>105</td>
<td>520</td>
<td>3</td>
<td>10</td>
</tr>
<tr>
<td>106</td>
<td>522</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>107</td>
<td>523</td>
<td>4</td>
<td>10</td>
</tr>
<tr>
<td>108</td>
<td>524</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>109</td>
<td>526</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>110</td>
<td>527</td>
<td>3</td>
<td>20</td>
</tr>
<tr>
<td>111</td>
<td>529</td>
<td>3</td>
<td>12</td>
</tr>
<tr>
<td>112</td>
<td>530</td>
<td>13*</td>
<td>20</td>
</tr>
<tr>
<td>113</td>
<td>531</td>
<td>20*</td>
<td>50</td>
</tr>
<tr>
<td>114</td>
<td>532</td>
<td>24*</td>
<td>5</td>
</tr>
<tr>
<td>115</td>
<td>534</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>116</td>
<td>535</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>117</td>
<td>536</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>118</td>
<td>537</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>119</td>
<td>538</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>120</td>
<td>539</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>121</td>
<td>540</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>122</td>
<td>541</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>123</td>
<td>542</td>
<td>3</td>
<td>3</td>
</tr>
</tbody>
</table>

279
<table>
<thead>
<tr>
<th>Case Number</th>
<th>Feet Above River Level</th>
<th>Meters to Nearest Permanent Water</th>
<th>Meters to Navigable Water</th>
</tr>
</thead>
<tbody>
<tr>
<td>124</td>
<td>2</td>
<td>2</td>
<td>50</td>
</tr>
<tr>
<td>125</td>
<td>3</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>126</td>
<td>0</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>127</td>
<td>7</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>128</td>
<td>4</td>
<td>10</td>
<td>45</td>
</tr>
<tr>
<td>129</td>
<td>0</td>
<td>1</td>
<td>50</td>
</tr>
<tr>
<td>130</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>131</td>
<td>4</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>132</td>
<td>3</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>133</td>
<td>2</td>
<td>10</td>
<td>20</td>
</tr>
<tr>
<td>134</td>
<td>4</td>
<td>25</td>
<td>95*</td>
</tr>
<tr>
<td>135</td>
<td>3</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>136</td>
<td>3</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>137</td>
<td>3</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>138</td>
<td>3</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>139</td>
<td>8</td>
<td>40</td>
<td>40</td>
</tr>
<tr>
<td>140</td>
<td>5</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>141</td>
<td>9*</td>
<td>45</td>
<td>45</td>
</tr>
<tr>
<td>142</td>
<td>4</td>
<td>25</td>
<td>25</td>
</tr>
<tr>
<td>143</td>
<td>5</td>
<td>25</td>
<td>25</td>
</tr>
<tr>
<td>144</td>
<td>0</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>145</td>
<td>4</td>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td>146</td>
<td>13*</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>147</td>
<td>4</td>
<td>10</td>
<td>160*</td>
</tr>
<tr>
<td>148</td>
<td>4</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>149</td>
<td>4</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>150</td>
<td>3</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>151</td>
<td>4</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>152</td>
<td>4</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>153</td>
<td>3</td>
<td>1</td>
<td>50</td>
</tr>
</tbody>
</table>

| Mean        | 5.15                   | 14.9                             | 39.17                      |
| Minimum     | 0                      | 1                                | 1                          |
| Maximum     | 39                     | 60                               | 600                        |

Entries with asterisk fall outside the suggested ranges for this class:
- greater than 8 feet above river level
- within 50 meters of permanent water
- within 50 meters of navigable water
Table 5.F.6. Probability Class 3 Case Summaries of Training Sample Sites.

<table>
<thead>
<tr>
<th>Case Number</th>
<th>Feet Above River Level</th>
<th>Meters to Nearest Permanent Water</th>
<th>Meters to Navigable Water</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3</td>
<td>48</td>
<td>48</td>
</tr>
<tr>
<td>2</td>
<td>3</td>
<td>40</td>
<td>40</td>
</tr>
<tr>
<td>3</td>
<td>5</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>4</td>
<td>3</td>
<td>5</td>
<td>500*</td>
</tr>
<tr>
<td>5</td>
<td>3</td>
<td>15</td>
<td>400*</td>
</tr>
<tr>
<td>6</td>
<td>6</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>7</td>
<td>9</td>
<td>37</td>
<td>200</td>
</tr>
<tr>
<td>8</td>
<td>22*</td>
<td>100*</td>
<td>100</td>
</tr>
<tr>
<td>9</td>
<td>0</td>
<td>2</td>
<td>260</td>
</tr>
<tr>
<td>10</td>
<td>13*</td>
<td>100*</td>
<td>100</td>
</tr>
<tr>
<td>11</td>
<td>4</td>
<td>3</td>
<td>300</td>
</tr>
<tr>
<td>12</td>
<td>0</td>
<td>40</td>
<td>40</td>
</tr>
<tr>
<td>13</td>
<td>4</td>
<td>15</td>
<td>320</td>
</tr>
<tr>
<td>14</td>
<td>5</td>
<td>15</td>
<td>350</td>
</tr>
<tr>
<td>15</td>
<td>7</td>
<td>25</td>
<td>300</td>
</tr>
<tr>
<td>16</td>
<td>4</td>
<td>15</td>
<td>320</td>
</tr>
<tr>
<td>17</td>
<td>7</td>
<td>25</td>
<td>220</td>
</tr>
<tr>
<td>18</td>
<td>4</td>
<td>2</td>
<td>550*</td>
</tr>
<tr>
<td>19</td>
<td>5</td>
<td>20</td>
<td>250</td>
</tr>
<tr>
<td>20</td>
<td>4</td>
<td>75</td>
<td>75</td>
</tr>
<tr>
<td>21</td>
<td>3</td>
<td>1</td>
<td>350</td>
</tr>
<tr>
<td>22</td>
<td>4</td>
<td>35</td>
<td>220</td>
</tr>
</tbody>
</table>

Mean          | 5.36                  | 32.64                            | 229.23                    |
Minimum       | 0                     | 1                                | 40                        |
Maximum       | 22                    | 100                              | 550                       |

Entries with asterisk fall outside the suggested ranges for this class:

- greater than 8 feet above river level
- within 75 meters of permanent water
- within 350 meters of navigable water
Table 5.F.7. Probability Class 2 Case Summaries of Training Sample Sites.

<table>
<thead>
<tr>
<th>Case Number</th>
<th>Feet Above River Level</th>
<th>Meters to Nearest Permanent Water</th>
<th>Meters to Navigable Water</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>341</td>
<td>23*</td>
<td>150*</td>
</tr>
<tr>
<td>2</td>
<td>411</td>
<td>11*</td>
<td>10</td>
</tr>
<tr>
<td>3</td>
<td>412</td>
<td>1</td>
<td>15</td>
</tr>
<tr>
<td>4</td>
<td>465</td>
<td>8</td>
<td>120*</td>
</tr>
<tr>
<td>5</td>
<td>484</td>
<td>6</td>
<td>5</td>
</tr>
</tbody>
</table>

Entries with asterisk fall outside the suggested ranges for this class:

- greater than 8 feet above river level
- within 10 meters of permanent water
- within 350 meters of navigable water

Table 5.F.8. Probability Class 1 Case Summaries of Training Sample Sites.

<table>
<thead>
<tr>
<th>Case Number</th>
<th>Feet Above River Level</th>
<th>Meters to Nearest Permanent Water</th>
<th>Meters to Navigable Water</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>445</td>
<td>15</td>
<td>500</td>
</tr>
<tr>
<td>2</td>
<td>483</td>
<td>12</td>
<td>100</td>
</tr>
<tr>
<td>3</td>
<td>551</td>
<td>32</td>
<td>180</td>
</tr>
<tr>
<td>4</td>
<td>556</td>
<td>14</td>
<td>25*</td>
</tr>
<tr>
<td>5</td>
<td>588</td>
<td>12</td>
<td>280</td>
</tr>
<tr>
<td>6</td>
<td>602</td>
<td>14</td>
<td>20*</td>
</tr>
</tbody>
</table>

Entries with asterisk fall outside the suggested ranges for this class:

- greater than 8 feet above river level
- within 100 meters of permanent water
- within 350 meters of navigable water
Wapato Valley Predictive Model
Case Summaries of Sites by Probability Class
Testing Sample

Table 5.F.9. Probability Class 5 Case Summaries of Testing Sample Sites.

<table>
<thead>
<tr>
<th>Case Number</th>
<th>Feet Above River Level</th>
<th>Meters to Nearest Permanent Water</th>
<th>Meters to Navigable Water</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>445</td>
<td>15</td>
<td>500</td>
</tr>
<tr>
<td>2</td>
<td>483</td>
<td>12</td>
<td>100</td>
</tr>
<tr>
<td>3</td>
<td>551</td>
<td>32</td>
<td>180</td>
</tr>
<tr>
<td>4</td>
<td>556</td>
<td>14</td>
<td>25*</td>
</tr>
<tr>
<td>5</td>
<td>588</td>
<td>12</td>
<td>280</td>
</tr>
<tr>
<td>6</td>
<td>602</td>
<td>14</td>
<td>20*</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Mean 12.89</td>
<td>8.89</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Minimum 7</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Maximum 23</td>
<td>28</td>
</tr>
</tbody>
</table>

Entries with asterisk fall outside the suggested ranges for this class:
- greater than 8 feet above river level
- within 25 meters of permanent water
- within 50 meters of navigable water

Table 5.F.10. Probability Class 4 Case Summaries of Testing Sample Sites.

<table>
<thead>
<tr>
<th>Case Number</th>
<th>Feet Above River Level</th>
<th>Meters to Nearest Permanent Water</th>
<th>Meters to Navigable Water</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>328</td>
<td>11*</td>
<td>50</td>
</tr>
<tr>
<td>2</td>
<td>329</td>
<td>8</td>
<td>42</td>
</tr>
<tr>
<td>3</td>
<td>331</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>4</td>
<td>339</td>
<td>3</td>
<td>16</td>
</tr>
<tr>
<td>5</td>
<td>345</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>6</td>
<td>349</td>
<td>3</td>
<td>13</td>
</tr>
<tr>
<td>7</td>
<td>351</td>
<td>7</td>
<td>10</td>
</tr>
<tr>
<td>8</td>
<td>364</td>
<td>3</td>
<td>8</td>
</tr>
<tr>
<td>9</td>
<td>365</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>10</td>
<td>384</td>
<td>8</td>
<td>20</td>
</tr>
</tbody>
</table>
Entries with asterisk fall outside the suggested ranges for this class:
- greater than 8 feet above river level
- within 50 meters of permanent water
- within 50 meters of navigable water
Table 5.F.11. Probability Class 3 Case Summaries of Testing Sample Sites.

<table>
<thead>
<tr>
<th>Case Number</th>
<th>Feet Above River Level</th>
<th>Meters to Nearest Permanent Water</th>
<th>Meters to Navigable Water</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>347</td>
<td>13*</td>
<td>100*</td>
</tr>
<tr>
<td>2</td>
<td>399</td>
<td>3</td>
<td>50</td>
</tr>
<tr>
<td>3</td>
<td>413</td>
<td>3</td>
<td>20</td>
</tr>
<tr>
<td>4</td>
<td>455</td>
<td>3</td>
<td>18</td>
</tr>
<tr>
<td>5</td>
<td>505</td>
<td>3</td>
<td>50</td>
</tr>
<tr>
<td>6</td>
<td>515</td>
<td>4</td>
<td>45</td>
</tr>
<tr>
<td>7</td>
<td>546</td>
<td>7</td>
<td>25</td>
</tr>
<tr>
<td>8</td>
<td>603</td>
<td>5</td>
<td>45</td>
</tr>
</tbody>
</table>

| Mean        | 5.13                   | 44.13                            | 151.25                    |
| Minimum     | 3                      | 18                               | 45                        |
| Maximum     | 13                     | 100                              | 420*                      |

Entries with asterisk fall outside the suggested ranges for this class:
- greater than 8 feet above river level
- within 75 meters of permanent water
- within 350 meters of navigable water

Table 5.F12. Probability Class 2 Case Summaries of Testing Sample Sites.

<table>
<thead>
<tr>
<th>Case Number</th>
<th>Feet Above River Level</th>
<th>Meters to Nearest Permanent Water</th>
<th>Meters to Navigable Water</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>450</td>
<td>47</td>
<td>12</td>
</tr>
<tr>
<td>2</td>
<td>481</td>
<td>3*</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>521</td>
<td>13</td>
<td>120*</td>
</tr>
</tbody>
</table>

| Mean        | 21                     | 44.13                            | 806.67                    |
| Minimum     | 3                      | 1                                | 120                       |
| Maximum     | 47                     | 120                              | 1600                      |

Entries with asterisk fall outside the suggested ranges for this class:
- greater than 8 feet above river level
- within 100 meters of permanent water
- within 350 meters of navigable water
Table 5.F.13. Probability Class 1 Case Summaries of Testing Sample Sites.

<table>
<thead>
<tr>
<th>Case Number</th>
<th>Feet Above River Level</th>
<th>Meters to Nearest Permanent Water</th>
<th>Meters to Navigable Water</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

No Testing Sample sites fell in this Probability Class

The suggested ranges for this class:
- greater than 8 feet above river level
- within 100 meters of permanent water
- within 350 meters of navigable water
APPENDIX G
BIBLIOGRAPHY OF ARCHAEOLOGY ON THE RIDGEFIELD NATIONAL WILDLIFE REFUGE AND ENVIRONS

The purpose of this annotated bibliography is to provide a listing of archaeological references useful to those doing cultural resources work on the Ridgefield National Wildlife Refuge. Included are various materials studied in the course of research for this thesis. This information includes, but is not limited to: archaeological site reports, site information not contained in the site report forms, archaeological survey reports, local histories, newspaper articles, correspondence, and notes and transcriptions from conversations and oral histories. Maps are listed in their own section. Not included are the more well known historic and ethnographic works – they are in the main bibliography. The formal archaeological reports and site forms are on file at the Washington State Office for Historic Preservation; the correspondence and other anecdotal information is on file at the Cultural Resources Office of the US Fish and Wildlife Service, Region 1, Portland.

Included with these materials are some important early professional works that were done in the area to the south of the present Ridgefield National Wildlife Refuge along Lake River and Vancouver Lake (Dunnell et al. 1973, Hibbs and Ross 1972, Jermann et al. 1975, Munsell 1973, Ross and Starkey 1975, Skolnik et al. 1979, Wessen and Daugherty 1983). Also significant are early reports by the local amateur group, the Oregon Archaeological Society (Foreman and Foreman 1977, Slocum and Matsen 1968 and 1972, Steele 1980). Although not directly on Refuge property, there is no denying that the entire Lake River-Vancouver Lake corridor was valuable to prehistoric people. The remains of their villages and camps can be found there in abundance (in some places they are virtually continuous), which indicates a consistent pattern of occupation and use of these waterways and wetland areas. These early archaeological reports helped establish the culture history of the area through their extensive surveys and accompanying historical and environmental reviews, and set the stage for the more significant work done since then.

Also included in this bibliography are several reports of cultural resource surveys near the Ridgefield National Wildlife Refuge, in upland areas or on the Columbia River. This information can only help add to our understanding of the settlement and land use patterns in the greater Lake River-Vancouver Lake area.

If it is not clear from the title exactly what area is covered by a report or document, I have included a brief parenthetical statement about the subject of the material.

Bibliography

Abramowitz, Alan


Ames, Kenneth M., Cameron M. Smith, William L. Cornett, Elizabeth A. Sobel, Stephen C. Hamilton, John Wolf, and Doria Raetz

Baker, Doug
1972 Interview with Jim Carty. The Oregonian, 13 June.

Bourdeau, Alex

Carty, James E.
2000 Transcript of 1½-hour conversation and tour of the Carty Unit of the Ridgefield National Wildlife Refuge, October.

Carty, Mary et al.
1966 Tracts.

Davy, Douglas M.
1998 Archaeological Records Search Results for the Pacific Fiber Link Fiber Optic Cable (Portland, Oregon to Ferndale, Washington Segment). Foster Wheeler Environmental Corporation, Sacramento. [Vicinity of sites CL133 and CL134 south of the RNWR on Lake River.]

Ducks Unlimited, Inc.

Dunnell, Robert C., J. C. Chatters and L. V. Salo

Ellis, David V., and Douglas C. Wilson

Foreman, Cam and Dave Foreman

Forgeng, Eric
1993 Cultural Resources Investigation of the Clark County Frenchman’s Bar/Vancouver Lake Regional Park Project Phase One. Archaeological Investigations Northwest, Portland.

Gerrell, Philip R.

Hibbs, Charles H. and Lester Ross

Hodges, Charles M.

Jermann, J. V. and J. Hollenbeck

Archaeology, Institute for Environmental Studies, University of Washington, Seattle.

Johnson, Ann
1997 *Cultural/Historic Resource Assessment and Report: Outstanding Timber Sale Section 7, Township 4 North, Range 1 East, W.M.* Washington State Department of Natural Resources. [Upland area east of the Carty Unit of the RNWR.]

Keeler, Robert W.


Kennedy, Hal

Kent, Ron
1980 *Cultural Resources Affected by the Vancouver Lake Rehabilitation Project, Clark County, Washington.* Report to the Port of Vancouver. Cooper & Associates, Portland. [Area south of RNWR along Lake River and Vancouver Lake.]

Minor, Rick, and Robert R. Musil

Minor, Rick, and Kathryn Anne Toepel


1985b *Lewis and Clark College Field School: 45CL1 and 45CL284.* Heritage Research Associates, Eugene. [Lewis and Clark field school at CL4 (thought to be CL1).]


Morgan, Ridian
1992 Notes from a telephone conversation with Anan Raymond, 24 February.

Munsell, David A.
1973 *An Archaeological Survey of the Clark County Park at Vancouver Lake, Vancouver, Clark County, Washington.* Report to the Clark County Parks and Recreation Commission, Vancouver, Washington. [Early survey of sites on the western shore of Vancouver Lake, south of the RNWR.]

Oetting, Albert D., and Rick Minor

The Oregonian [Portland, Oregon]
1925 Letters to the Editor about Cathlapoodle in Olden Days. 6, 8, and 15 November. Portland, Oregon.
Parchman, Mary, and Tana Hickey

Pettigrew, Richard M.

Ranck, Glenn H.
1915 Indian Queen is Among Last of Once Big Race. The Oregonian, 8 August.

Ridgefield National Wildlife Refuge, Cultural Resources Correspondence
1971-1989 General correspondence, including the nomination of the Basalt Cobblestone Quarries District to the National Register of Historic Places.

1975-1984 Concerning the nomination to the National Register of Historic Places of 45CL4 as Cathlapotle.


1984-1995 Correspondence about Cathlapotle 45CL1.

Ross, Lester A., and Judy Starkey
1975 Archaeological Survey of Lower Lake River and Bachelor Island Slough, Clark County, Washington. Manuscript on file, US Fish and Wildlife Service Region 1, Portland. [RNWR sites along Lake River and Bachelor Island Slough.]

Roulette, Bill R.

Scheans, Daniel J. and Alison T. Stenger

Silver Star Junior Women’s Club

Silverstein, Michael

Skolnik, Arthur M., Mary Ann Duncan, David W. Harvey, and Katheryn H. Krafft

Slocum, Robert G., and Kenneth H. Matsen


Speulda, Lou Ann

Steele, Harvey

Thomas, Bryn and Jerry R. Galm  

Wessen, Gary and Richard D. Daugherty  

Wilson, Douglas C.  


Woodward, John A.  

Zehendner, Maureen, Judith S. Chapman and John L. Fagan  

Zimmerly, Enid  
n.d.  *“The Zimmerly Box”*. Bachelor Island, Ridgefield National Wildlife Refuge: Ridgefield. [A box of documents, papers and photos given to the Refuge by Mrs. Zimmerly after the fire in 1978 that destroyed her house on Bachelor Island. Includes materials used by Harvey Steele (of the OAS) and Mrs. Zimmerly in writing a book together on the prehistory and history of Bachelor Island.]

### Maps and Aerial Photographs

**Boundary Claims Commission**  
1863 Plat of the Hudson’s Bay Company claim at Fort Vancouver. (surveyed May 1854). Copy of map obtained at Fort Vancouver, Vancouver.

**Broughton, William R.**  
1792 *Chart of the Exploration of the Columbia River, from Cape Disappointment to Point Vancouver*. Oregon Historical Society Map Library, Portland.

**Cunningham, J. H.**  

**Derby, George H. and George Gibbs**  

**Evergreen Pacific**  

**Goethals, George W.**  

Habersham, R. A.

Metsker, Charles F.

Moulton, Gary E. (editor)

Slacum, W. A.
1836 Chart of the Columbia River for 90 Miles from its Mouth. Drawn from several surveys in the possession of W.A. Slacum U.S.S. by M.C. Ewing, Civil Engineer. Oregon Historical Society Map Library, Portland.

US Army Corps of Engineers

1940 Aerial photos of the Ridgefield National Wildlife Refuge, numbers 2459, 2461, 2464, 2466 and 2485. Portland District Map Library, Portland.


1960 Aerial photo of the Carty and Bachelor Island units, June 4. Portland District Map Library, Portland.

US Coast and Geodetic Survey


1930 Portland Basin, Chart 6155, 1:20,000, including Multnomah Channel, Southern Part, 1:10,000: Washington DC. Oregon Historical Society Map Library, Portland.

1933 Columbia River, Chart 6154: St. Helens to Willamette River, including Vancouver and Portland, 1:40,000: Washington DC. Oregon Historical Society Map Library, Portland.


US General Land Office

1887 Map of Sauvies Island, compiled from Government Survey Notes, roads and dyke sketched from maps. Martin Gillihan Collection, Oregon Historical Society Map Library, Portland.

US Geological Survey


1918 Hillsboro, Oregon-Washington 15-minute topographic map.

1954 Ridgefield, Washington 7.5-minute topographic map.

1954 St. Helens, Oregon-Washington 7.5-min-
ute topographic map.


1954 Sauvie Island, Oregon-Washington 7.5-minute topographic map.

1954 Vancouver, Washington- Oregon 7.5-minute topographic map.

Vavasour, Merwin

c.a. 1845 Rough Chart of the Columbia River from the Head of the Navigation to the Pacific Ocean, from a sketch belonging to the Hudson’s Bay Company. Oregon Historical Society Map Library, Portland.

Wilkes, Charles

1841 Map of the Columbia River (Sheet 5) from the 1838-1842 Wilkes Expedition. Oregon Historical Society Map Library, Portland.

Zimmerly, Enid

1975 The “Zimmerly Map” of Bachelor Island.
Initial runs in logistic regression indicated that only the first three independent variables – Feet Above River Level, Meters to Nearest Permanent Water, and Meters to Navigable Water – would be retained by the stepwise model. This proved to be the case, with a classification success rate of 87.6 percent for archaeological sites and 75.7 percent for the null point sample (80.8 percent overall) at a cutpoint of .5. These classification percentages are for the logistic regression scores before being adjusted for the difference in sample size between the number of archaeological sites and null points (see Chapter 5: “Building the Model II: Logistic Regression”).

Forward Conditional Logistic Regression:
Training versus Testing Samples, Five Strongest Independent Variables

<table>
<thead>
<tr>
<th>Case Processing Summary</th>
<th>N</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unweighted Cases (a)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Selected Cases</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Included in Analysis</td>
<td>510</td>
<td>84.6</td>
</tr>
<tr>
<td>Missing Cases</td>
<td>0</td>
<td>0.0</td>
</tr>
<tr>
<td>Total</td>
<td>510</td>
<td>84.6</td>
</tr>
<tr>
<td>Unselected Cases</td>
<td>93</td>
<td>15.4</td>
</tr>
<tr>
<td>Total</td>
<td>603</td>
<td>100.0</td>
</tr>
</tbody>
</table>

a. If weight is in effect, see classification table for the total number of cases.
Block 0: Beginning Block

<table>
<thead>
<tr>
<th>Iteration History (a, b, c)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Iteration</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Step 0</td>
</tr>
<tr>
<td>1</td>
</tr>
<tr>
<td>2</td>
</tr>
</tbody>
</table>

a. Costant is included in the model.
c. Estimation terminated at iteration number 2 because log-likelihood decreased by less than .010 percent.

<table>
<thead>
<tr>
<th>Classification Table (c, d)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Observed</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Step 0</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>

a. Selected cases Training vs Testing samples EQ 0.
b. Unselected cases Training vs Testing samples NE 0.
c. Constant is included in the model.
d. The cut value is .500

<table>
<thead>
<tr>
<th>Variables in the Equation</th>
</tr>
</thead>
<tbody>
<tr>
<td>B</td>
</tr>
<tr>
<td>Step 0</td>
</tr>
</tbody>
</table>
### Variables Not in the Equation

<table>
<thead>
<tr>
<th>Variables</th>
<th>Score</th>
<th>df</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>FEET_ARL</td>
<td>5.169</td>
<td>1</td>
<td>0.023</td>
</tr>
<tr>
<td>PERM_H2O</td>
<td>72.615</td>
<td>1</td>
<td>0.000</td>
</tr>
<tr>
<td>NAV_H2O</td>
<td>83.959</td>
<td>1</td>
<td>0.000</td>
</tr>
<tr>
<td>SLOPE</td>
<td>17.002</td>
<td>1</td>
<td>0.000</td>
</tr>
<tr>
<td>ASPECT</td>
<td>8.104</td>
<td>1</td>
<td>0.004</td>
</tr>
</tbody>
</table>

**Overall Statistics**

<table>
<thead>
<tr>
<th></th>
<th>Score</th>
<th>df</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>112.453</td>
<td>5</td>
<td>0.000</td>
</tr>
</tbody>
</table>

### Block 1: Method = Forward Stepwise (Conditional)

### Iteration History (a, b, c, d, e)

<table>
<thead>
<tr>
<th>Iteration</th>
<th>(-2) Log Likelihood</th>
<th>Coefficients</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Constant</td>
</tr>
<tr>
<td>Step 1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>597.510</td>
<td>0.254</td>
</tr>
<tr>
<td>2</td>
<td>572.447</td>
<td>0.453</td>
</tr>
<tr>
<td>3</td>
<td>567.813</td>
<td>0.548</td>
</tr>
<tr>
<td>4</td>
<td>567.621</td>
<td>0.568</td>
</tr>
<tr>
<td>5</td>
<td>567.620</td>
<td>0.568</td>
</tr>
<tr>
<td>Step 2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>567.767</td>
<td>0.368</td>
</tr>
<tr>
<td>2</td>
<td>515.396</td>
<td>0.725</td>
</tr>
<tr>
<td>3</td>
<td>496.272</td>
<td>0.960</td>
</tr>
<tr>
<td>4</td>
<td>492.502</td>
<td>1.070</td>
</tr>
<tr>
<td>5</td>
<td>492.303</td>
<td>1.097</td>
</tr>
<tr>
<td>6</td>
<td>292.302</td>
<td>1.099</td>
</tr>
<tr>
<td>Step 3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>565.843</td>
<td>0.301</td>
</tr>
<tr>
<td>2</td>
<td>507.419</td>
<td>0.565</td>
</tr>
<tr>
<td>3</td>
<td>484.515</td>
<td>0.724</td>
</tr>
<tr>
<td>4</td>
<td>479.983</td>
<td>0.808</td>
</tr>
<tr>
<td>5</td>
<td>479.710</td>
<td>0.835</td>
</tr>
<tr>
<td>6</td>
<td>479.708</td>
<td>0.836</td>
</tr>
</tbody>
</table>

- **a.** Method: Forward Stepwise (Conditional).
- **b.** Constant is included in the model.
- **c.** Initial \(-2\) Log Likelihood: 696.235.
- **d.** Estimation terminated at iteration number 5 because parameter estimates changed by less than .001.
- **e.** Estimation terminated at iteration number 6 because log-likelihood decreased by less than .010 percent.
### Omnibus Tests of Model Coefficients

<table>
<thead>
<tr>
<th>Step</th>
<th>Chi-square</th>
<th>df</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step</td>
<td>128.614</td>
<td>1</td>
<td>0.000</td>
</tr>
<tr>
<td>Block</td>
<td>128.614</td>
<td>1</td>
<td>0.000</td>
</tr>
<tr>
<td>Model</td>
<td>128.614</td>
<td>1</td>
<td>0.000</td>
</tr>
</tbody>
</table>

### Step 2

<table>
<thead>
<tr>
<th>Step</th>
<th>Chi-square</th>
<th>df</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step</td>
<td>75.318</td>
<td>1</td>
<td>0.000</td>
</tr>
<tr>
<td>Block</td>
<td>203.933</td>
<td>2</td>
<td>0.000</td>
</tr>
<tr>
<td>Model</td>
<td>203.933</td>
<td>2</td>
<td>0.000</td>
</tr>
</tbody>
</table>

### Step 3

<table>
<thead>
<tr>
<th>Step</th>
<th>Chi-square</th>
<th>df</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step</td>
<td>12.594</td>
<td>1</td>
<td>0.000</td>
</tr>
<tr>
<td>Block</td>
<td>216.526</td>
<td>3</td>
<td>0.000</td>
</tr>
<tr>
<td>Model</td>
<td>216.526</td>
<td>3</td>
<td>0.000</td>
</tr>
</tbody>
</table>

### Model Summary

<table>
<thead>
<tr>
<th>Step</th>
<th>-2 Log Likelihood</th>
<th>Cox &amp; Snell R Square</th>
<th>Nagelkerke R Square</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>567.620</td>
<td>0.223</td>
<td>0.299</td>
</tr>
<tr>
<td>2</td>
<td>492.302</td>
<td>0.330</td>
<td>0.443</td>
</tr>
<tr>
<td>3</td>
<td>479.708</td>
<td>0.346</td>
<td>0.465</td>
</tr>
</tbody>
</table>

### Hosmer and Lemeshow Test

<table>
<thead>
<tr>
<th>Step</th>
<th>Chi-square</th>
<th>df</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>37.558</td>
<td>8</td>
<td>0.000</td>
</tr>
<tr>
<td>3</td>
<td>33.018</td>
<td>8</td>
<td>0.000</td>
</tr>
<tr>
<td></td>
<td>Null Points</td>
<td>Archaeological Sites</td>
<td>Total</td>
</tr>
<tr>
<td>-------</td>
<td>-------------</td>
<td>----------------------</td>
<td>-------</td>
</tr>
<tr>
<td></td>
<td>Observed</td>
<td>Expected</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>47</td>
<td>50.487</td>
<td>4</td>
</tr>
<tr>
<td>2</td>
<td>43</td>
<td>44.368</td>
<td>6</td>
</tr>
<tr>
<td>3</td>
<td>45</td>
<td>40.156</td>
<td>7</td>
</tr>
<tr>
<td>4</td>
<td>38</td>
<td>32.071</td>
<td>12</td>
</tr>
<tr>
<td>5</td>
<td>38</td>
<td>25.099</td>
<td>11</td>
</tr>
<tr>
<td>6</td>
<td>29</td>
<td>21.748</td>
<td>22</td>
</tr>
<tr>
<td>7</td>
<td>9</td>
<td>18.583</td>
<td>38</td>
</tr>
<tr>
<td>8</td>
<td>10</td>
<td>17.424</td>
<td>36</td>
</tr>
<tr>
<td>9</td>
<td>15</td>
<td>19.543</td>
<td>38</td>
</tr>
<tr>
<td>10</td>
<td>18</td>
<td>22.521</td>
<td>44</td>
</tr>
</tbody>
</table>

**Step 2**

<table>
<thead>
<tr>
<th></th>
<th>Null Points</th>
<th>Archaeological Sites</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Observed</td>
<td>Expected</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>53</td>
<td>53.911</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>48</td>
<td>49.631</td>
<td>3</td>
</tr>
<tr>
<td>3</td>
<td>48</td>
<td>44.889</td>
<td>3</td>
</tr>
<tr>
<td>4</td>
<td>43</td>
<td>35.989</td>
<td>8</td>
</tr>
<tr>
<td>5</td>
<td>33</td>
<td>29.750</td>
<td>24</td>
</tr>
<tr>
<td>6</td>
<td>20</td>
<td>22.111</td>
<td>33</td>
</tr>
<tr>
<td>7</td>
<td>15</td>
<td>18.360</td>
<td>40</td>
</tr>
<tr>
<td>8</td>
<td>6</td>
<td>15.533</td>
<td>48</td>
</tr>
<tr>
<td>9</td>
<td>9</td>
<td>12.436</td>
<td>38</td>
</tr>
<tr>
<td>10</td>
<td>17</td>
<td>9.390</td>
<td>20</td>
</tr>
</tbody>
</table>

**Step 3**

<table>
<thead>
<tr>
<th></th>
<th>Null Points</th>
<th>Archaeological Sites</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Observed</td>
<td>Expected</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>50</td>
<td>50.937</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>49</td>
<td>49.976</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>48</td>
<td>46.104</td>
<td>3</td>
</tr>
<tr>
<td>4</td>
<td>42</td>
<td>37.589</td>
<td>9</td>
</tr>
<tr>
<td>5</td>
<td>36</td>
<td>27.652</td>
<td>15</td>
</tr>
<tr>
<td>6</td>
<td>18</td>
<td>21.540</td>
<td>33</td>
</tr>
<tr>
<td>7</td>
<td>10</td>
<td>17.707</td>
<td>41</td>
</tr>
<tr>
<td>8</td>
<td>18</td>
<td>14.960</td>
<td>31</td>
</tr>
<tr>
<td>9</td>
<td>9</td>
<td>14.206</td>
<td>42</td>
</tr>
<tr>
<td>10</td>
<td>12</td>
<td>11.327</td>
<td>41</td>
</tr>
</tbody>
</table>
### Classification Table (c)

<table>
<thead>
<tr>
<th>Observed</th>
<th>Predicted</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Selected Cases (a)</td>
<td>Unselected Cases (b)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Null Point/ Site</td>
<td>Percentage Correct</td>
<td>Null Point/ Site</td>
<td>Percentage Correct</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Null</td>
<td>Site</td>
<td></td>
<td>Null</td>
<td>Site</td>
</tr>
<tr>
<td>Step 1</td>
<td>Null Point</td>
<td>194</td>
<td>98</td>
<td>66.4</td>
<td>24</td>
</tr>
<tr>
<td></td>
<td>Site</td>
<td>36</td>
<td>182</td>
<td>83.5</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>Overall Percentage</td>
<td></td>
<td></td>
<td></td>
<td>73.7</td>
</tr>
<tr>
<td>Step 2</td>
<td>Null Point</td>
<td>215</td>
<td>77</td>
<td>73.6</td>
<td>29</td>
</tr>
<tr>
<td></td>
<td>Site</td>
<td>29</td>
<td>189</td>
<td>86.7</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Overall Percentage</td>
<td></td>
<td></td>
<td></td>
<td>79.2</td>
</tr>
<tr>
<td>Step 3</td>
<td>Null Point</td>
<td>221</td>
<td>71</td>
<td>75.7</td>
<td>28</td>
</tr>
<tr>
<td></td>
<td>Site</td>
<td>27</td>
<td>191</td>
<td>87.6</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>Overall Percentage</td>
<td></td>
<td></td>
<td></td>
<td>80.8</td>
</tr>
</tbody>
</table>

a. Selected cases Training vs Testing samples EQ 0.
b. Unselected cases Training vs Testing samples NE 0.
c. The cut value is .500

### Variables in the Equation

<table>
<thead>
<tr>
<th>Variables in the Equation</th>
<th>B</th>
<th>S.E.</th>
<th>Wald</th>
<th>df</th>
<th>Sig.</th>
<th>Exp(B)</th>
<th>95% C.I. for Exp (B)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Lower</td>
</tr>
<tr>
<td>Step 1(a)</td>
<td>NAV_H2O</td>
<td>-0.004</td>
<td>0.001</td>
<td>61.257</td>
<td>1</td>
<td>0.000</td>
<td>0.999</td>
</tr>
<tr>
<td></td>
<td>Constant</td>
<td>0.568</td>
<td>0.125</td>
<td>20.775</td>
<td>1</td>
<td>0.000</td>
<td>1.766</td>
</tr>
<tr>
<td>Step 2(b)</td>
<td>PERM_H2O</td>
<td>-0.018</td>
<td>0.003</td>
<td>37.952</td>
<td>1</td>
<td>0.000</td>
<td>0.983</td>
</tr>
<tr>
<td></td>
<td>NAV_H2O</td>
<td>-0.003</td>
<td>0.000</td>
<td>30.541</td>
<td>1</td>
<td>0.000</td>
<td>0.997</td>
</tr>
<tr>
<td></td>
<td>Constant</td>
<td>1.099</td>
<td>0.151</td>
<td>53.012</td>
<td>1</td>
<td>0.000</td>
<td>3.000</td>
</tr>
<tr>
<td>Step 3(c)</td>
<td>FEET_ARL</td>
<td>0.059</td>
<td>0.017</td>
<td>11.509</td>
<td>1</td>
<td>0.001</td>
<td>1.061</td>
</tr>
<tr>
<td></td>
<td>PERM_H2O</td>
<td>-0.02</td>
<td>0.003</td>
<td>44.058</td>
<td>1</td>
<td>0.000</td>
<td>0.980</td>
</tr>
<tr>
<td></td>
<td>NAV_H2O</td>
<td>-0.003</td>
<td>0.001</td>
<td>34.514</td>
<td>1</td>
<td>0.000</td>
<td>0.997</td>
</tr>
<tr>
<td></td>
<td>Constant</td>
<td>0.836</td>
<td>0.165</td>
<td>25.708</td>
<td>1</td>
<td>0.000</td>
<td>2.308</td>
</tr>
</tbody>
</table>

a. Variable entered on step 1: NAV_H2O.
b. Variable entered on step 2: PERM_H2O.
c. Variable entered on step 3: FEET_ARL.
## Correlation Matrix

<table>
<thead>
<tr>
<th></th>
<th>Constant</th>
<th>NAV_H2O</th>
<th>PERM_H2O</th>
<th>FEET_ARL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Constant</td>
<td>1.000</td>
<td>-0.589</td>
<td></td>
<td></td>
</tr>
<tr>
<td>NAV_H2O</td>
<td>-0.589</td>
<td>1.000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Step 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Constant</td>
<td>1.000</td>
<td>-0.377</td>
<td>-0.513</td>
<td></td>
</tr>
<tr>
<td>PERM_H20</td>
<td>-0.513</td>
<td>1.000</td>
<td>-0.151</td>
<td></td>
</tr>
<tr>
<td>NAV_H2O</td>
<td>-0.377</td>
<td>1.000</td>
<td>-0.151</td>
<td>-0.395</td>
</tr>
<tr>
<td>Step 3</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FEET_ARL</td>
<td>-0.395</td>
<td>-0.270</td>
<td>-0.288</td>
<td>1.000</td>
</tr>
<tr>
<td>PERM_H20</td>
<td>-0.333</td>
<td>-0.057</td>
<td>1.000</td>
<td>-0.288</td>
</tr>
<tr>
<td>NAV_H2O</td>
<td>-0.224</td>
<td>1.000</td>
<td>-0.057</td>
<td>-0.270</td>
</tr>
</tbody>
</table>

### Model if Term Removed (a)

<table>
<thead>
<tr>
<th></th>
<th>Score</th>
<th>df</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1</td>
<td>NAV_H2O</td>
<td>353.262</td>
<td>138.903</td>
</tr>
<tr>
<td>Step 2</td>
<td>PERM_H2O</td>
<td>-289.460</td>
<td>86.618</td>
</tr>
<tr>
<td></td>
<td>NAV_H2O</td>
<td>-271.201</td>
<td>50.099</td>
</tr>
<tr>
<td>Step 3</td>
<td>FEET_ARL</td>
<td>-246.226</td>
<td>12.743</td>
</tr>
<tr>
<td></td>
<td>PERM_H2O</td>
<td>-292.406</td>
<td>105.104</td>
</tr>
<tr>
<td></td>
<td>NAV_H2O</td>
<td>-268.777</td>
<td>57.846</td>
</tr>
</tbody>
</table>

* a. Based on conditional parameter estimates.

### Variables not in the Equation

<table>
<thead>
<tr>
<th></th>
<th>Score</th>
<th>df</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1</td>
<td>FEET_ARL</td>
<td>0.201</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>PERM_H2O</td>
<td>50.085</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>SLOPE</td>
<td>5.607</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>ASPECT</td>
<td>4.633</td>
<td>1</td>
</tr>
<tr>
<td>Overall Statistics</td>
<td>59.607</td>
<td>4</td>
<td>0.000</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Score</th>
<th>df</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 2</td>
<td>FEET_ARL</td>
<td>12.440</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>SLOPE</td>
<td>1.520</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>ASPECT</td>
<td>3.290</td>
<td>1</td>
</tr>
<tr>
<td>Overall Statistics</td>
<td>13.304</td>
<td>3</td>
<td>0.004</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Score</th>
<th>df</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 3</td>
<td>SLOPE</td>
<td>0.049</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>ASPECT</td>
<td>0.972</td>
<td>1</td>
</tr>
<tr>
<td>Overall Statistics</td>
<td>0.977</td>
<td>2</td>
<td>0.614</td>
</tr>
<tr>
<td>Case</td>
<td>Selected Status (a)</td>
<td>Observed</td>
<td>Predicted</td>
</tr>
<tr>
<td>------</td>
<td>---------------------</td>
<td>----------</td>
<td>-----------</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Null point=0/ Site=1</td>
<td></td>
</tr>
<tr>
<td>307</td>
<td>S</td>
<td>0**</td>
<td>0.949</td>
</tr>
<tr>
<td>445</td>
<td>S</td>
<td>1**</td>
<td>0.000</td>
</tr>
<tr>
<td>483</td>
<td>S</td>
<td>1**</td>
<td>0.024</td>
</tr>
<tr>
<td>551</td>
<td>S</td>
<td>1**</td>
<td>0.077</td>
</tr>
<tr>
<td>556</td>
<td>S</td>
<td>1**</td>
<td>0.084</td>
</tr>
<tr>
<td>588</td>
<td>S</td>
<td>1**</td>
<td>0.008</td>
</tr>
<tr>
<td>602</td>
<td>S</td>
<td>1**</td>
<td>0.061</td>
</tr>
</tbody>
</table>

a. S=Selected, U=Unselected cases, and **=Misclassified cases.
b. Cases with studentized residuals greater than 2.000 are listed
APPENDIX I
WAPATO VALLEY PREDICTIVE MODEL METADATA

This appendix contains detailed information on how the Wapato Valley Predictive Model was created in ArcView. The ArcView Methods section describes the creation of the predictor variable shapefiles, the steps taken in the generation of the probability surface for each separate topographic map, and the structure of each ArcView project contained on the CD available to archaeology professionals.

The ArcView Shapefiles section includes a summary table of the historic maps used as references for digitizing the permanent waterbodies for each topographic map. This section then proceeds with the metadata from the ArcView shapefiles created for this thesis: first for those shapefiles applicable for the Wapato Valley as a whole, and then separate headings for the shapefiles for each topographic map.

ArcView Methods

ArcView 3.2 was used throughout this project to create and edit the shapefiles for each potential predictor variable for logistic regression analysis, and to process them into the probability surfaces for each map. The procedures to accomplish this are detailed in this section, which concludes with a description of the structure of the project for each topographic map.

Predictor Variable Shapefiles

The steps for completing the map calculations to generate the probability surface for each of the 11 topographic maps of the Wapato Valley require three themes: the topographic map DEM, the shapefile for permanent water, and the shapefile for navigable water. Initial creation of the water shapefiles was done in a preparatory project in ArcView. Permanent water coverage was created by editing modern water boundaries to reflect the historic conditions, using the 1888 US Coast and Geodetic Survey maps as the main reference. This permanent water coverage was then clipped with a 0-55 foot AMSL shapefile (generated by selecting this elevation range from the DEM, then converting it to a shapefile), resulting in a permanent water coverage extending to an elevation of 55 feet or less. This was done so that the extent of the waterbodies matches the elevation range specified in this study.

The navigable water shapefile was created by copying the permanent water shapefile in Explore or other file management programs, and renaming this copy “(topo map)_nav_water”. This shapefile was then imported into the preparatory ArcView project, and all non-navigable waterbodies were deleted. These two water shapefiles were then copied into the final ArcView project folder for the topographic map.

The topo map DEM was copied into the final ArcView project folder, imported into the project, and edited to target only the 0-55 foot elevation range of concern in this study. The procedures to accomplish this are detailed below. This clipped DEM was then used instead of the whole DEM in the map calculations to produce the probability surface for that topographic map.

The one exception to these methods is the Mount Tabor topographic map. Because the elevation of the Columbia River changes from 7 to 16 feet in the middle of that map, and because Elevation Above River Level is one of the variables in the regression equation, each half of the DEM had to be calculated separately. This was done by creating a polygon boundary mask for each half of the map:

1. View, New Theme, Polygon. Draw a polygon of the area to be masked.
2. Theme, Convert to Grid. Grid Name: Tabor (East or West). Grid Extent: same as Tabor (East or West) polygon. Cell size: same as DEM. Join Feature Attributes to Grid? No. Add Grid as Theme to View? Yes.
3. Analysis Properties. Analysis Extent: same as the DEM. Analysis Cell Size: same as the DEM. Analysis Mask: Tabor (East or West).
4. Analysis, Map Calculator. DEM, Evaluate. Load the map legend, being sure that there is a No Data entry in the legend, set to transparent.
5. Follow instructions above to clip the permanent water shapefile for each half of the Mount Tabor map.
Probability Surfaces

The following procedures begin after the creation of the clipped permanent water and navigable water shapefiles for each map. These are the steps taken in building the new ArcView project and associated files, including the probability surface, for each topographic map in the Wapato Valley. The Camas project folder is used as an example in the following methods.

1. Create a new folder under the “WVPM” folder, named for the topographic map (i.e. “Camas”).

2. Open a new project in ArcView. Open a new view. Set working directory to c:\wvpm\camas (maximum of 14 characters, no spaces). Activate these 5 extensions: Geoprocessing, JPEG (JFIF) Image Support, Metadata Collection Tool, Projection Utility Wizard, Spatial Analyst.

3. Rename View “Camas”. Set scale in View Properties: Map Units: Meters, Distance Units: Meters.

Move files into folder:

4. Cut and paste 5 shapefiles into Camas folder:
   wv_sites.shp, random_points.shp, wapato_valley.shp, Camas_perm_water.shp, Camas_nav_water.shp.

5. Cut and paste other files into Camas folder:
   wv_site_table.txt, random_point_table.txt, metadata2.avx, template.def, Camas_E445122.DEM, Camas_legend.avl, e445122.tif, e445122.tfw.

6. Rename e445122.tif to “Camas_e445122.tif”; rename e445122.tfw to “Camas_e445122.tfw”.

In ArcView Project:

7. Import DEM through the Import Data Source, USGS DEM, name it Camas_dem, Add Grid as Theme to View? Yes. Load Camas legend and layout template.

8. Add site and random point tables as text files. Table, Add.

9. Add shapefiles through Add Theme:
   a. wv_sites.shp: triangle size 16, color black. random_points.shp: dot size 8, color gray. wapato_valley.shp: outline size 2, color dark red.
   b. Camas_perm_water.shp: light blue color.
   c. Camas_nav_water.shp: dark blue color.
   d. e445122.tif: rename e445122.tif “Camas_drg” in Theme Properties.

Deriving the Probability Surface:

10. Add Feet Above River Level Column to DEM. DEM as active theme, open table, Table, Start Editing; Edit, Add Field; Name: Feet_ARL, OK. With the Feet_ARL column active, Calculate, Value -16 (or -7 if map is in the main part of the study area), Table, Stop Editing, Save Edits. (NOTE: This addition of a column for the adjusted elevation above river level does not have to be done for the Deer Island topo map, since the elevation of the Columbia in that area is 0.)

11. Isolate elevation range of 0-55 feet AMSL by selecting those rows in the table (turns yellow). Can use Query builder: Value ≤ 55. Go back to the View, Theme; Convert to Grid; Add Grid to View? YES. Name it “0-55Camas”. Classify into 5 classes, no decimals, orange color ramp.

12. Analysis, Find Distance for camas_perm_water.shp. Output Grid Extent: same as DEM; Output Grid Cell Size: same as DEM. Reclassify into 10 classes, no decimals, green color ramp. Rename “Meters to Camas_perm_water”.

13. Analysis, Find Distance for Camas_nav_water.shp. Output Grid Extent: same as DEM; Output Grid Cell Size: same as DEM. Reclassify into 10 classes, no decimals, blue color ramp. Rename “Meters to Camas_nav_water”.

14. Calculate SCORE portion of equation: Analysis, Map Calculator:
   (“0-55Camas.Feet_ARL” x 0.059)
+ (“Meters to Camas_perm_water” x -0.02)
+ (“Meters to Camas_nav_water” x -0.003)
+ 1.128 → EVALUATE = Map Calculation 1 (calc1). 
Rename “Score” in Theme Properties. Reclassify into 10 classes, no decimals, Beige to Brown color ramp.

15. Calculate next portion of equation: 
Analysis, Map Calculator:
(“Score” x EXP) → EVALUATE = Map Calculation 2 (calc2). Do not bother to reclassify.

16. Calculate next portion of equation: 
Analysis, Map Calculator:
(1 x AsGrid) + (“Score” x EXP) → EVALUATE = Map Calculation 3 (calc3). Do not bother to reclassify.

17. Calculate last portion of equation: 
Analysis, Map Calculator:
(calc2/calc3) → EVALUATE = Map Calculation 4 (calc4). 
Rename “Camas Probability Surface” in Theme Properties. Reclassify into 5 classes, round values at “d.d”, high to low, colors red (Class 5), blue (Class 4), green (Class 3), yellow (Class 2), transparent (Class 1 and No Data).

Order of shapefiles, from the top: archaeological sites, Wapato Valley polygon, random null points, navigable water, permanent water, Camas Probability Surface, DRG, DEM, Map Calculation 3, Map Calculation 2, Score, 0-55camas, Meters to Camas_perm_water, Meters to Camas_nav_water. Turn on these shapefiles: archaeological sites, Wapato Valley polygon, permanent water, Camas Probability Surface, DRG.

Make a layout of Camas Probability Surface for thesis figure:

18. Open a new layout, and name it “Camas”. Compose layout, with map, scale bar, north arrow, symbol legend, and probability class legend. Save this as a template. Copy this template into the project file for each topographic map, so that the layout for every subsequent map will be the same. For each new topographic map, open and name the new layout, go to Layout, Use Template, select the saved template, and all the layout elements automatically appear with the new map. One note of caution. If the subsequent maps are at a different scale (the map that the template was built with was at 1:74,000), then the scale bar must be redone to reflect the scale of the new map.

19. Export the layout as both a .bmp and a .jpeg. These images can be used in Word documents, PowerPoint or other applications. Copies of these .jpeg images are included on the WVPM CD in the folder “Probability Surface Images” under “Documents and Images”.

20. Save the Project as “Camas_project” in c:\wvpm\camas, making sure that it is saved to the correct file (this operates independent of the working directory – needs to be set in both places).

ArcView Projects

These projects were created in ArcView 3.2, with the file structure converted to relative pathnames. The main directory is “WVPM”, with files for each topographic map directly below. There are 12 of these separate files in the WVPM folder, named for each of the maps in the study area (10 individual maps, with 2 for the Mount Tabor map as explained above). Each file contains one ArcView Project, named for the map, and each project has only one View and one Layout. All the shapefiles required for the Project are contained in each file.

There is an additional file in the WVPM folder (“Documents and Images”) containing the Wapato Valley Predictive Model Database and an explanatory document, the Logistic Regression Probability Tables and an explanatory document, and a folder (Probability Surface Images) containing .jpeg images of the probability surfaces of each topographic map.

ArcView Shapefiles

This section features the metadata on the various shapefiles used in the Wapato Valley Predictive Model, beginning with those applicable to the entire study area. Following these general shapefiles is the metadata specific to each topographic map. The shapefiles under the map headings include only the metadata for the permanent
DEMs

DEMs used in this project are: Washougal, Washington-Oregon; Camas, Washington-Oregon; Mount Tabor, Oregon-Washington; Portland, Oregon-Washington; Linnton, Oregon; Vancouver, Washington-Oregon; Sauvie Island, Oregon-Washington; Ridgefield, Washington; Saint Helens, Oregon-Washington; Woodland, Washington; Deer Island Oregon-Washington. These maps were digitized from the 7.5-minute topographic maps by the USGS, and obtained from the Regional Ecosystem Office (http://www.reo.gov/gis/gisdata.htm, accessed October 2002), with the exception of the Linnton, Oregon DEM, which was purchased from MapMart (http://www.mapmart.com, accessed November 2002). The metadata for these maps corresponds to the USGS 1:24,000 scale topographic quadrangle maps series and can be found at: http://rmmcweb.cr.usgs.gov/public/nmpstds/demstds.html. Basic data characteristics: NAD 27 Datum; UTM Projection; Planar units in meters; Elevation Units in feet, relative to the National Geodetic Vertical Datum of 1929; Resolution: 10 meters per pixel.

DRGs

DRGs used in this project are: Washougal, Washington-Oregon; Camas, Washington-Oregon; Mount Tabor, Oregon-Washington; Portland, Oregon-Washington; Linnton, Oregon; Vancouver, Washington-Oregon; Sauvie Island, Oregon-Washington; Ridgefield, Washington; Saint Helens, Oregon-Washington; Woodland, Washington; and Deer Island Oregon-Washington. These maps were scanned from the 7.5-minute topographic maps by the USGS and obtained from the Regional Ecosystem Office (http://www.reo.gov/gis/gisdata.htm, accessed October 2002). The metadata for these maps corresponds to the USGS 1:24,000 scale topographic quadrangle maps series, and can be found at: http://rmmcweb.cr.usgs.gov/public/nmpstds/drgstds.html. Basic data characteristics: NAD 27 Datum; UTM Projection; Planar units in meters; Elevation Units in feet, relative to the National Geodetic Vertical Datum of 1929 (NGVD 29).
This shapefile consists of points for all the known prehistoric archaeological sites in the Wapato Valley of the Portland Basin, at an elevation of 55 feet AMSL or less. These data were compiled from the site forms and reports at the State Historic Preservation Offices in Oregon and Washington. The site table summarizes the information from these forms and reports.

Purpose:
These data were compiled to create a predictive model for prehistoric archaeological site location on the floodplain of the Columbia River in the Portland Basin.

Supplemental Information:
Study area includes these topographic maps: Washougal, Washington-Oregon; Camas, Washington-Oregon; Mount Tabor, Oregon-Washington; Portland, Oregon-Washington; Linnton, Oregon; Vancouver, Washington-Oregon; Sauvie Island, Oregon-Washington; Ridgefield, Washington; Saint Helens, Oregon-Washington; Woodland, Washington; Deer Island Oregon-Washington

Time_Period_of_Content:
Time_Period_Information:
Range_of_Dates/Times:
Beginning_Date: 2002
Ending_Date: 200309
Currentness_Reference: 20050504

Status:
Progress: Complete
Maintenance_and_Update_Frequency: None planned

Spatial_Domain:
Bounding_Coordinates:
West_Bounding_Coordinate: -122.8658
East_Bounding_Coordinate: -122.2446
North_Bounding_Coordinate: 45.9714
South_Bounding_Coordinate: 45.5450

Keywords:
Theme:
Theme_Keyword: archaeology
Theme_Keyword: ArcView 3.2
Theme_Keyword: predictive model
Theme_Keyword: prehistoric archaeological sites
Place:
Place_Keyword: United States
Place_Keyword: Northwest
Place_Keyword: Washington
Place_Keyword: Clark County
Place_Keyword: Oregon
Place_Keyword: Multnomah County
Place_Keyword: Columbia County
Place_Keyword: Wapato Valley
Place_Keyword: Portland Basin
Place_Keyword: Columbia River
Place_Keyword: floodplain
Place_Keyword: Washougal, Washington-Oregon
Place_Keyword: Camas, Washington-Oregon
Place_Keyword: Mount Tabor, Oregon-Washington
Place_Keyword: Portland, Oregon-Washington
Place_Keyword: Linnton, Oregon
Place_Keyword: Vancouver, Washington-Oregon
Place_Keyword: Sauvie Island, Oregon-Washington
Place_Keyword: Ridgefield, Washington
Place_Keyword: Saint Helens, Oregon-Washington
Place_Keyword: Woodland, Washington
Place_Keyword: Deer Island Oregon-Washington

Access_Constraints:
Restricted. Dataset only available to registered archaeology professionals. The Freedom of Information Act does not apply to archaeological site location.

Use_Constraints:
None.

Point_of_Contact:
Contact_Information:
  Contact_Organization: Portland State University, Department of Anthropology
  Contact_Person: Leslie M. O’Rourke
  Contact_Position: MA, RPA
  Contact_Address:
    Address_Type: mailing and physical address
    Address: 1211 Orchard Street
    City: West Linn
    State_or_Province: Oregon
    Postal_Code: 97068
    Country: USA
  Contact_Voice_Telephone: 503.656.6567 or 503.656.1365
  Contact_Electronic_Mail_Address: orourkel@pdx.edu

Native_Data_Set_Environment:
ArcView version 3.2 shapefile format
c:\arcview\thesis1\archaeological_sites.shp (same as Wv_sites.shp)

DATA_QUALITY_INFORMATION

Attribute_Accuracy:
Attribute_Accuracy_Report:
Archaeological site location was digitized using the TOPO! map program as a reference. Site location was determined by reviewing all available sources, including maps at the Oregon and Washington State Historic Preservation Offices, maps and descriptions on site forms, and maps and descriptions in written reports. Problems with determining the exact site location were encountered when references did not agree with each other. Site point represents the best determination of actual site location, after a review of all possible sources. Site point is located in approximately the centroid of the site. Information about the total extent of sites was often inconsistent and unreliable.

Logical_Consistency_Report:
Completeness_Report:
Archaeological sites include those recorded at the Oregon and Washington respective State Historic Preservation Offices by September 2003.

Positional_Accuracy:
Horizontal_Positional_Accuracy:
Horizontal_Positional_Accuracy_Report:
The site locations were determined by comparing paper site maps at varying degrees of accuracy with USGS 7.5-minute 1:24,000 scale topographic maps.

Vertical Positional Accuracy:
Vertical Positional Accuracy Report:
The site locations were determined by comparing paper site maps at varying degrees of accuracy with USGS 7.5-minute 1:24,000 scale topographic maps.

Lineage:
Source Information:
Source Citation:
- Citation Information:
  - Publication Date: 200309
  - Title: archaeological site information
  - Geospatial Data Presentation Form: map
- Publication Information:
  - Publication Place: Olympia, Washington
  - Publisher: Office of Archaeology and Historic Preservation
Source Scale Denominator: 24,000
Type of Source Media: paper
Source Time Period of Content:
Time Period Information:
- Range of Dates/Times:
  - Beginning Date: 1948
  - Ending Date: 200309
Source Contribution:
  Information on the location of archaeological sites in Clark County, Washington at an elevation of 55 feet AMSL or less.

Source Information:
Source Citation:
- Citation Information:
  - Publication Date: 200309
  - Title: archaeological site information
  - Geospatial Data Presentation Form: map
- Publication Information:
  - Publication Place: Salem, Oregon
  - Publisher: State Historic Preservation Office
Source Scale Denominator: 24,000
Type of Source Media: paper
Source Time Period of Content:
Time Period Information:
- Range of Dates/Times:
  - Beginning Date: 1973
  - Ending Date: 200309
Source Contribution:
  Locational information of archaeological sites in Multnomah and Columbia counties, at an elevation of 55 feet AMSL or less.

Process Step:
Process Description:
The centroid of archaeological sites was measured in the TOPO! mapping program then transferred to an Excel spreadsheet. The spreadsheet was then saved as a text file, added to ArcView 3.2, and imported as a point shapefile.
Process Date: 20050504
Process Contact:
Contact Information:
  Contact Organization: Portland State University, Department of Anthropology
  Contact Person: Leslie M. O’Rourke
  Contact Position: MA, RPA
Contact Address:
  Address Type: mailing and physical address
  Address: 1211 Orchard Street
  City: West Linn
  State or Province: Oregon
  Postal Code: 97068
  Country: USA
  Contact Voice Telephone: 503.656.6567 or 503.656.1365
  Contact Electronic Mail Address: orourkel@pdx.edu

SPATIAL_DATA_ORGANIZATION_INFORMATION

Direct_Spatial_Reference_Method: Point
Point_and_Vector_Object_Info:
  SDTS_Terms_Description:
  SDTS_Point_and_Vector_Object_Type: Point
  Point_and_Vector_Object_Count: 276

SPATIAL_REFERENCE_INFORMATION

Horizontal_Coordinate_System_Description:
  Planar:
    Grid_Coordinate_System:
      Grid_Coordinate_System_Name: Universal Transverse Mercator
      Universal_Transverse_Mercator:
        UTM_Zone_Number: 10
      Transverse_Mercator:
        Scale_Factor_at_Central_Meridian: 0.999600
        Longitude_of_Central_Meridian: -123.000000
        Latitude_of_Projection_Origin: 0.000000
        False_Easting: 500000.000000
        False_Northing: 0.000000
    Planar_Coordinate_Information:
      Planar_Coordinate_Encoding_Method: Row and column
      Planar_Distance_Units: Meters
    Geodetic_Model:
      Horizontal_Datum_Name: North American Datum of 1927
      Ellipsoid_Name: Clarke 1866
      Semi-major_Axis: 6378206.400000
      Denominator_of_Flattening_Ratio: 294.98
  Vertical_Coordinate_System_Description:
    Altitude_System_Description:
      Altitude_Datum_Name: National Geodetic Vertical Datum of 1929
      Altitude_Distance_Units: feet
      Altitude_Encoding_Method: Implicit coordinate

ENTITY_AND_ATTRIBUTE_INFORMATION
Detailed_Description:
Entity_Type:
Entity_Type_Label: archaeological_sites.dbf
Entity_Type_Definition: Shapefile Attribute Table
Entity_Type_Definition_Source: None
Attribute:
Attribute_Label: Site_numbe
Attribute_Definition: Smithsonian trinomial designation, sequentially numbered by state and county.
Attribute_Definition_Source:
Attribute_Domain_Values:
Unrepresentable_Domain: 35 = Oregon State; 45 = Washington State;
CL = Clark County, Washington; CO = Columbia County, Oregon;
MU = Multnomah County, Oregon.
Attribute:
Attribute_Label: Name
Attribute_Definition: Common site name
Attribute_Definition_Source: Various
Attribute_Domain_Values:
Unrepresentable_Domain: Character Field
Attribute:
Attribute_Label: Topo_map
Attribute_Definition: Name of the 7.5-minute USGS topographic map on which the archaeological site is located
Attribute_Definition_Source:
Attribute_Domain_Values:
Unrepresentable_Domain: Washougal, Washington-Oregon; Camas, Washington- Oregon; Mount Tabor, Oregon-Washington; Portland, Oregon-Washington; Linnston, Oregon; Vancouver, Washington-Oregon;
Sauvie Island, Oregon-Washington; Ridgefield, Washington; Saint Helens, Oregon-Washington; Woodland, Washington; and Deer Island Oregon-Washington
Attribute:
Attribute_Label: Utm_e
Attribute_Definition: UTM Easting coordinate of location of archaeological site
Attribute_Definition_Source: UTM Zone 10
Attribute_Domain_Values:
Range_Domain:
Range_Domain_Minimum: 510479
Range_Domain_Maximum: 558525
Attribute:
Attribute_Label: Utm_n
Attribute_Definition: UTM Northing coordinate of location of archaeological site
Attribute_Definition_Source: UTM Zone 10
Attribute_Domain_Values:
Range_Domain:
Range_Domain_Minimum: 5043548
Range_Domain_Maximum: 5090661
Attribute:
Attribute_Label: Site_type
Attribute_Definition: Village or field camp
Attribute_Definition_Source: Various
Attribute Domain Values:
  Unrepresentable Domain: Character Field
Attribute:
  Attribute Label: Age_or_rcy
  Attribute Definition: Age estimate or radiocarbon date range
  Attribute Definition Source: Various
  Attribute Domain Values:
    Unrepresentable Domain: Character Field
Attribute:
  Attribute Label: Elevation_
  Attribute Definition: Elevation Above Mean Sea Level of archaeological site
  Attribute Definition Source: Topographic map
  Attribute Domain Values:
    Range Domain:
      Range Domain Minimum: 5
      Range Domain Maximum: 55
Attribute:
  Attribute Label: Elevation_
  Attribute Definition: Elevation Above River Level of archaeological site
  Attribute Definition Source: Topographic map
  Attribute Domain Values:
    Range Domain:
      Range Domain Minimum: 0
      Range Domain Maximum: 47
Attribute:
  Attribute Label: Site_dimen
  Attribute Definition: Dimensions of archaeological site, if known
  Attribute Definition Source: Archaeology site form
  Attribute Domain Values:
    Unrepresentable Domain: Character Field
Attribute:
  Attribute Label: Nearest_wa
  Attribute Definition: Name of nearest permanent water source
  Attribute Definition Source: Modern and historic maps
  Attribute Domain Values:
    Unrepresentable Domain: Character Field
Attribute:
  Attribute Label: Distance_t
  Attribute Definition: Distance to nearest permanent water source
  Attribute Definition Source: Measured in ArcView
  Attribute Domain Values:
    Range Domain:
      Range Domain Minimum: 1
      Range Domain Maximum: 500
Attribute:
  Attribute Label: Nearest_na
  Attribute Definition: Name of nearest navigable water source
  Attribute Definition Source: Modern and historic maps
  Attribute Domain Values:
    Unrepresentable Domain: Character Field
Attribute:
Attribute Label: Distance_t
Attribute Definition: Distance to nearest navigable water source
Attribute Definition Source: Measured in ArcView
Attribute Domain Values:
  Range Domain:
    Range Domain Minimum: 1
    Range Domain Maximum: 1600
Attribute:
  Attribute Label: Land_type
  Attribute Definition: Floodplain or terrace
  Attribute Definition Source: Topographic map
  Attribute Domain Values:
    Unrepresentable Domain: Character Field
Attribute:
  Attribute Label: Slope__per
  Attribute Definition: Slope of centroid of site
  Attribute Definition Source: ArcView Derive Slope
  Attribute Domain Values:
    Range Domain:
      Range Domain Minimum: 0
      Range Domain Maximum: 55
Attribute:
  Attribute Label: Aspect__de
  Attribute Definition: Aspect of centroid of site
  Attribute Definition Source: ArcView Derive Aspect
  Attribute Domain Values:
    Range Domain:
      Range Domain Minimum: -1
      Range Domain Maximum: 320
Attribute:
  Attribute Label: Soil_type
  Attribute Definition: Type of soil at site location
  Attribute Definition Source: Soil maps
  Attribute Domain Values:
    Unrepresentable Domain: Character Field
Attribute:
  Attribute Label: Geology
  Attribute Definition: Underlying geology site location
  Attribute Definition Source: Geological maps
  Attribute Domain Values:
    Unrepresentable Domain: Character Field
Attribute:
  Attribute Label: Vegetation
  Attribute Definition: Type of vegetation at site location
  Attribute Definition Source: Vegetation maps
  Attribute Domain Values:
    Unrepresentable Domain: Character Field
Attribute:
  Attribute Label: Primary_si
  Attribute Definition: Primary reference, usually date on first site form
  Attribute Definition Source: State Historic Preservation Office, Oregon
and Washington

Attribute_Domain_Values:
  Unrepresentable_Domain: Character Field

Attribute:
  Attribute_Label: Secondary
  Attribute_Definition: Secondary reference(s), usually additional site forms, or larger site or survey reports
  Attribute_Definition_Source: Various
  Attribute_Domain_Values:
    Unrepresentable_Domain: Character Field

Attribute:
  Attribute_Label: Selected_s
  Attribute_Definition: Other reports containing information about the site
  Attribute_Definition_Source: Various
  Attribute_Domain_Values:
    Unrepresentable_Domain: Character Field

Overview_Description:
Entity_and_Attribute_Overview:
  Point file determined by UTM Easting and Northing columns of the archaeological site table. Site information is summarized from site report forms in 24 columns detailed in this section.

Entity_and_Attribute_Detail_Citation:
  Complete information about the development of the archaeological site database and the data it contains can be found in the Wapato Valley Predictive Model.

DISTRIBUTION_INFORMATION

Distributor:
Contact_Information:
  Contact_Organization: Portland State University, Department of Anthropology
  Contact_Person: Leslie M. O’Rourke
  Contact_Position: MA, RPA
  Contact_Address:
    Address_Type: mailing and physical address
    Address: 1211 Orchard Street
    City: West Linn
    State_or_Province: Oregon
    Postal_Code: 97068
    Country: USA
  Contact_Voice_Telephone: 503.656.6567 or 503.656.1365
  Contact_Electronic_Mail_Address: orourkel@pdx.edu

Resource_Description:
  wv_sites.shp (same as archaeological_sites.shp)

Custom_Order_Process:
  Shapefile available to archaeology professionals only.
  Please contact the author or Portland State University, Department of Anthropology.

METADATA_REFERENCE_INFORMATION

Metadata_Date: 20050429
Metadata_Review_Date:
Metadata_Contact:
Contact Information:
  Contact Organization: Portland State University, Department of Anthropology
  Contact Person: Leslie M. O’Rourke
  Contact Position: MA, RPA
  Contact Address:
    Address Type: Mailing and physical address
    Address: 1211 Orchard Street
    City: West Linn
    State_or_Province: Oregon
    Postal_Code: 97068
    Country: USA
  Contact Voice Telephone: 503.656.6567 or 503.656.1365
  Contact Electronic Mail Address: orourkel@pdx.edu
  Metadata Standard Name: FGDC CSDGM

Metadata for Random_points.shp

IDENTIFICATION_INFORMATION

Citation:
  Citation Information:
    Originator: Leslie M. O’Rourke
    Publication_Date: 20050504
    Title: Random Null Control Points on the Floodplain of the Columbia River in the
    Wapato Valley
    Edition: 1
    Geospatial Data Presentation Form: Map
  Publication Information:
    Publication Place: Portland State University, Portland, Oregon
    Publisher: Leslie M. O’Rourke
    Other Citation Details:
      Master’s Thesis, Portland State University 20050504
  Online Linkage:

Larger Work Citation:
  Citation Information:
    Originator: Leslie M. O’Rourke
    Publication_Date: 20050504
    Title: The Wapato Valley Predictive Model: Prehistoric Archaeological Site
    Location on the Floodplain of the Columbia River in the Portland Basin
  Publication Information:
    Publication Place: Portland, Oregon
    Publisher: Portland State University, Department of Anthropology
  Online Linkage:

Description:
  Abstract:
    This shapefile consists of 327 randomly points generated with the “randpts.avx” script
    (Jenness) in ArcView 3.2, which were used as a null control for the Wapato Valley
    Predictive Model.
  Purpose:
    These points were compiled as a sample of the background environmental conditions to
    compare to the Wapato Valley archaeological sites in logistic regression.
Supplemental Information:
Study area includes these topographic maps: Washougal, Washington-Oregon; Camas, Washington-Oregon; Mount Tabor, Oregon-Washington; Portland, Oregon-Washington; Linnton, Oregon; Vancouver, Washington-Oregon; Sauvie Island, Oregon-Washington; Ridgefield, Washington; Saint Helens, Oregon-Washington; Woodland, Washington; Deer Island Oregon-Washington

Time Period of Content:
Time Period Information:
Range of Dates/Times:
Beginning Date: 2003
Ending Date: 2003
Currentness Reference: 20050504

Status:
Progress: Complete
Maintenance and Update Frequency: None planned

Spatial Domain:
Bounding Coordinates:
West Bounding Coordinate: -122.8735
East Bounding Coordinate: -122.2847
North Bounding Coordinate: 45.9954
South Bounding Coordinate: 45.5389

Keywords:
Theme:
Theme Keyword: archaeology
Theme Keyword: ArcView 3.2
Theme Keyword: predictive model
Theme Keyword: random null points
Place:
Place Keyword: United States
Place Keyword: Northwest
Place Keyword: Washington
Place Keyword: Clark County
Place Keyword: Oregon
Place Keyword: Columbia County
Place Keyword: Multnomah County
Place Keyword: Wapato Valley
Place Keyword: Portland Basin
Place Keyword: Columbia River
Place Keyword: floodplain
Place Keyword: Washougal, Washington-Oregon
Place Keyword: Camas, Washington-Oregon
Place Keyword: Mount Tabor, Oregon-Washington
Place Keyword: Portland, Oregon-Washington
Place Keyword: Linnton, Oregon
Place Keyword: Vancouver, Washington-Oregon
Place Keyword: Sauvie Island, Oregon-Washington
Place Keyword: Ridgefield, Washington
Place Keyword: Saint Helens, Oregon-Washington
Place Keyword: Woodland, Washington
Place Keyword: Deer Island Oregon-Washington

Access Constraints:
None

**Use_Constraints:**
None

**Point_of_Contact:**
Contact_Information:
  Contact_Organization_Primary:
    Contact_Organization: Portland State University, Department of Anthropology
    Contact_Person: Leslie M. O'Rourke
    Contact_Position: MA, RPA
  Contact_Address:
    Address_Type: mailing and physical address
    Address: 1211 Orchard Street
    City: West Linn
    State_or_Province: Oregon
    Postal_Code: 97068
    Country: USA
    Contact_Voice_Telephone: 503.656.6567 or 503.656.1365
    Contact_Electronic_Mail_Address: orourkel@pdx.edu

**Native_Data_Set_Environment:**
ArcView version 3.2 shapefile format
c:\arcview\thesis1\random_points.shp

**DATA_QUALITY_INFORMATION**

**Attribute_Accuracy:**
Attribute_Accuracy_Report: Points were retained in the sample based on their location within the study area as defined by the Wapato Valley polygon, on dry land, and at an elevation of 55 feet AMSL or less. A recent slight adjustment in the Wapato Valley polygon left one null point just outside the boundaries of the study area on the Woodland topographic map, but it was retained in the sample.

**Logical_Consistency_Report:**

**Completeness_Report:**

**Positional_Accuracy:**
Horizontal_Positional_Accuracy:
Horizontal_Positional_Accuracy_Report: Null point location was recorded in UTM Easting and Northing as part of the process of generating the points with the “randpts.avx” script in ArcView 3.2.
Vertical_Positional_Accuracy:
Vertical_Positional_Accuracy_Report: Null point elevation was determined with the “getz” function in ArcView 3.2.

**Lineage:**
Source_Information:
Source_Citation:
  Originator: Leslie M. O'Rourke
  Publication_Date: 20050504
  Title: Random null control points
  Edition: 1
  Geospatial_Data_Presentation_Form: map
Publication_Information:
  Publication_Place: Portland, Oregon
  Publisher: Leslie M. O’Rourke
Points were generated through the “randpts.avx” ArcView script (Jenness 2001). A large rectangle was drawn encompassing the entire study area, and 2000 points were generated. Points were then omitted that were outside the study area, greater than 55 feet AMSL in elevation, and in water. This left 327 points on land, at an elevation of 55 feet AMSL or less, and within the study area. The UTM location of the points was automatically recorded by the script, and elevation was calculated using the “getz” function in ArcView 3.2. The resulting Excel table was added to ArcView as a text file, then imported as a shapefile.

Process_Date: 20050504

Process_Contact:

Contact Information:

Contact Person Primary:

Contact Organization: Portland State University, Department of Anthropology

Contact Person: Leslie M. O’Rourke

Contact Position: MA, RPA

Contact Address:

Address Type: mailing and physical address

Address: 1211 Orchard Street

City: West Linn

State or Province: Oregon

Postal Code: 97068

Country: USA

Contact Voice Telephone: 503.656.6567 or 503.656.1365

Contact Electronic Mail Address: orourkel@pdx.edu
Direct_Spatial_Reference_Method: Point

Point_and_Vector_Object_Information:
  SDTS_Terms_Description:
    SDTS_Point_and_Vector_Object_Type: Point
    Point_and_Vector_Object_Count: 327

SPATIAL_REFERENCE_INFORMATION

Horizontal_Coordinate_System_Definition:
  Planar:
    Grid_Coordinate_System:
      Grid_Coordinate_System_Name: Universal Transverse Mercator
    Universal_Transverse_Mercator:
      UTM_Zone_Number: 10
    Transverse_Mercator:
      Scale_Factor_at_Central_Meridian: 0.999600
      Longitude_of_Central_Meridian: -123.000000
      Latitude_of_Projection_Origin: 0.000000
      False_Easting: 500000.000000
      False_Northing: 0.000000
  Planar_Coordinate_Information:
    Planar_Coordinate_Encoding_Method: Row and column
  Coordinate_Representation:
    Abscissa_Resolution:
    Ordinate_Resolution:
    Planar_Distance_Units: Meters

Geodetic_Model:
  Horizontal_Datum_Name: North American Datum of 1927
  Ellipsoid_Name: Clarke 1866
  Semi-major_Axis: 6378206.400000
  Denominator_of_Flattening_Ratio: 294.98

Vertical_Coordinate_System_Definition:
  Altitude_System_Definition:
    Altitude_Datum_Name: National Geodetic Vertical Datum of 1929
    Altitude_Resoluation:
    Altitude_Distance_Units: feet
    Altitude_Encoding_Method: Implicit coordinate

ENTITY_AND ATTRIBUTE_INFORMATION

Detailed_Description:
  Entity_Type:
    Entity_Type_Label: random_points.dbf
    Entity_Type_Definition: Shapefile Attribute Table
    Entity_Type_Definition_Source: None
  Attribute:
    Attribute_Label: Point_numb
    Attribute_Definition: Sequential number of null point
    Attribute_Definition_Source:
    Attribute_Domain_Values:
      Range_Domain:
        Range_Domain_Minimum: 7
Attribute:
Attribute_Label: Utm_e
Attribute_Definition: UTM Easting coordinate of location of null point
Attribute_Definition_Source:
Attribute_Domain_Values:
  Range_Domain:
    Range_Domain_Minimum: 509877
    Range_Domain_Maximum: 555392
Attribute:
Attribute_Label: Utm_n
Attribute_Definition: UTM Northing coordinate of location of null point
Attribute_Definition_Source:
Attribute_Domain_Values:
  Range_Domain:
    Range_Domain_Minimum: 5042844
    Range_Domain_Maximum: 5093330
Attribute:
Attribute_Label: Topo_map
Attribute_Definition: Name of the 7.5-minute USGS topographic map on which the
null point is located
Attribute_Definition_Source:
Attribute_Domain_Values:
  Unrepresentable_Domain: Washougal, Washington-Oregon; Camas, Washington-Oregon; Mount Tabor, Oregon-Washington; Portland, Oregon-Washington; Linnton, Oregon; Vancouver, Washington-Oregon; Sauvie Island, Oregon-Washington; Ridgefield, Washington; Saint Helens, Oregon-Washington; Woodland, Washington; and Deer Island Oregon-Washington
Attribute:
Attribute_Label: Elevation_
Attribute_Definition: Elevation Above Mean Sea Level of null point
Attribute_Definition_Source:
Attribute_Domain_Values:
  Range_Domain:
    Range_Domain_Minimum: 4
    Range_Domain_Maximum: 55
Attribute:
Attribute_Label: Elevation_
Attribute_Definition: Elevation Above River Level of null point
Attribute_Definition_Source:
Attribute_Domain_Values:
  Range_Domain:
    Range_Domain_Minimum: 0
    Range_Domain_Maximum: 48
Attribute:
Attribute_Label: Nearest_wa
Attribute_Definition: Name of nearest permanent water source
Attribute_Definition_Source:
Attribute_Domain_Values:
  Unrepresentable_Domain: Character Field
Attribute:
Attribute Label: Dist_to_h2
Attribute Definition: Distance to nearest permanent water source
Attribute Definition Source:
Attribute Domain Values:
  Range Domain:
  Range Domain Minimum: 1
  Range Domain Maximum: 1380

Attribute Label: Nearest_na
Attribute Definition: Name of nearest navigable water source
Attribute Definition Source:
Attribute Domain Values:
  Unrepresentable Domain: Character Field

Attribute Label: Dist_to_na
Attribute Definition: Distance to nearest navigable water source
Attribute Definition Source:
Attribute Domain Values:
  Range Domain:
  Range Domain Minimum: 1
  Range Domain Maximum: 3000

Attribute Label: Slope
Attribute Definition: Slope of null point
Attribute Definition Source:
Attribute Domain Values:
  Range Domain:
  Range Domain Minimum: 0
  Range Domain Maximum: 40

Attribute Label: Aspect
Attribute Definition: Aspect of null point
Attribute Definition Source:
Attribute Domain Values:
  Range Domain:
  Range Domain Minimum: -1
  Range Domain Maximum: 357

Overview Description:
Entity and Attribute Overview:
Location of point determined by UTM Easting and Northing columns resulting from the generation of these points with the “randpts.avx” script. Elevation was calculated with the “getz” function in ArcView. Information similar to that in the archaeological site database was recorded for the null points, so that this sample of the background environment of the Wapato Valley can be used in logistic regression.

Entity and Attribute Detail Citation:
Abstract:
This polygon describes the boundaries of the study area for the Wapato Valley Predictive Model. The northern boundary is the north edge of the Deer Island, Oregon-Washington 7.5-minute topographic map. The eastern boundary is the east edge of the Washougal, Washington-Oregon 7.5-minute topographic map. The rest of the shape roughly parallels the Columbia River, encompassing all of the area at an elevation of 55 feet AMSL. Areas above 55 feet AMSL that are included within the outline of the study area are deselected in the process of generating the probability surfaces for the model, so the boundaries of the shape do not have to be exact.

Purpose:
To define the area of study for the Wapato Valley Predictive Model.

Supplemental Information:
The 7.5-minute USGS topographic maps included in the study area are: Washougal, Washington-Oregon; Camas, Washington-Oregon; Mount Tabor, Oregon-Washington; Portland, Oregon-Washington; Linnton, Oregon; Vancouver, Washington-Oregon; Sauvie Island, Oregon-Washington; Ridgefield, Washington; Saint Helens, Oregon-Washington; Woodland, Washington; Deer Island Oregon-Washington.

Time_Period_of_Content:
Time_Period_Information:
Range_of_Dates/Times:
Beginning_Date: 2002
Ending_Date: 20050504

Currentness_Reference: 20050504

Status:
Progress: Complete
Maintenance_and_Update_Frequency: None planned

Spatial_Domain:
Bounding_Coordinates:
West_BoundingCoordinate: -122.8761
East_BoundingCoordinate: -122.2433
North_BoundingCoordinate: 46.0002
South_BoundingCoordinate: 45.5359

Keywords:
Theme:
Theme_Keyword: archaeology
Theme_Keyword: ArcView 3.2
Theme_Keyword: predictive model
Theme_Keyword: Wapato Valley polygon

Place:
- Place_Keyword: Camas, Washington-Oregon
- Place_Keyword: Clark County, Washington
- Place_Keyword: Columbia County, Oregon
- Place_Keyword: Columbia River
- Place_Keyword: Deer Island Oregon-Washington
- Place_Keyword: floodplain
- Place_Keyword: Linnton, Oregon
- Place_Keyword: Mount Tabor, Oregon-Washington
- Place_Keyword: Multnomah County, Oregon
- Place_Keyword: Northwest
- Place_Keyword: Oregon
- Place_Keyword: Portland Basin
- Place_Keyword: Portland, Oregon-Washington
- Place_Keyword: Ridgefield, Washington
- Place_Keyword: Saint Helens, Oregon-Washington
- Place_Keyword: Sauvie Island, Oregon-Washington
- Place_Keyword: United States
- Place_Keyword: Vancouver, Washington-Oregon
- Place_Keyword: Wapato Valley
- Place_Keyword: Washington
- Place_Keyword: Washougal, Washington-Oregon
- Place_Keyword: Woodland, Washington

Access_Constraints:
None

Use_Constraints:
None

Point_of_Contact:
Contact_Information:
- Contact_Organization_Primary:
  - Contact_Organization: Portland State University, Department of Anthropology
  - Contact Person: Leslie M. O’Rourke
  - Contact Position: MA, RPA

Contact_Address:
- Address_Type: mailing and physical address
- Address: 1211 Orchard Street
- City: West Linn
- State_or_Province: Oregon
- Postal_Code: 97068
- Country: USA
- Contact_Voice_Telephone: 503.656.6567 or 503.656.1365
- Contact_Electronic_Mail_Address: orourkel@pdx.edu

Native_Data_Set_Environment:
ArcView version 3.2 shapefile format
c:\arcview\thesis\wapato_valley.shp

DATA_QUALITY_INFORMATION

Attribute_Accuracy:
Attribute_Accuracy_Report:
Wapato Valley polygon shape was digitized in ArcView 3.2 to outline the study area of the
Wapato Valley Predictive Model. The northern boundary is the north edge of the Deer Island, Oregon-Washington 7.5-minute topographic map. The eastern boundary is the east edge of the Washougal, Washington-Oregon 7.5-minute topographic map. The rest of the shape roughly parallels the Columbia River, encompassing all of the area at an elevation of 55 feet AMSL.

**Logical_Consistency_Report:**

**Completeness_Report:**

**Positional_Accuracy:**

**Horizontal_Positional_Accuracy:**

**Vertical_Positional_Accuracy:**

**Lineage:**

**Source_Information:**

**Source_Citation:**

**Citation_Information:**

**Publication_Date:** 20050504

**Title:** Wapato Valley Polygon

**Edition:** 1

**Geospatial_Data_Presentation_Form:** map

**Publication_Information:**

**Publication_Place:** Portland, Oregon

**Publisher:** Leslie M. O’Rourke

**Other_Citation_Details:**

**Online_Linkage:**

**Larger_Work_Citation:**

**Citation_Information:**

**Originator:** Leslie M. O’Rourke

**Publication_Date:** 20050504

**Title:** The Wapato Valley Predictive Model: Prehistoric Archaeological Site Location on the Floodplain of the Columbia River in the Portland Basin

**Publication_Information:**

**Publication_Place:** Portland, Oregon

**Publisher:** Portland State University, Department of Anthropology

**Online_Linkage:**

**Source_Scale_Denominator:**

**Type_of_Source_Media:** digital

**Source_Time_Period_of_Content:**

**Time_Period_Information:**

**Range_of_Dates/Times:**

**Beginning_Date:** 2002

**Ending_Date:** 20050504

**Source_Currentness_Reference:** 20050504

**Source_Citation_Abbreviation:** Wapato_valley.shp

**Source_Contribution:**

**Process_Step:**

**Process_Description:**

The Wapato Valley polygon was created as a shapefile in ArcView 3.2.

**Source_Used_Citation_Abbreviation:**

**Process_Date:** 2002
Source_Produced_Citation_Abbreviation:
Process_Contact:
Contact_Information:
  Contact_Person_Primary:
    Contact_Organization: Portland State University, Department of Anthropology
    Contact_Person: Leslie M. O'Rourke
    Contact_Position: MA, RPA
  Contact_Address:
    Address_Type: mailing and physical address
    Address: 1211 Orchard Street
    City: West Linn
    State_or_Province: Oregon
    Postal_Code: 97068
    Country: USA
    Contact_Voice_Telephone: 503.656.6567 or 503.656.1365
    Contact_Electronic_Mail_Address: orourkel@pdx.edu

SPATIAL_DATA_ORGANIZATION_INFORMATION

Direct_Spatial_Reference_Method: Vector
Point_and_Vector_Object_Information:
  SDTS_Terms_Description:
    SDTS_Point_and_Vector_Object_Type: GT-polygon composed of chains
    Point_and_Vector_Object_Count: 1

SPATIAL_REFERENCE_INFORMATION

Horizontal_Coordinate_System_Definition:
  Planar:
    Grid_Coordinate_System:
      Grid_Coordinate_System_Name: Universal Transverse Mercator
      Universal_Transverse_Mercator:
        UTM_Zone_Number: 10
        Transverse_Mercator:
          Scale_Factor_at_Central_Meridian: 0.999600
          Longitude_of_Central_Meridian: -123.000000
          Latitude_of_Projection_Origin: 0.000000
          False_Easting: 500000.000000
          False_Northing: 0.000000
    Planar_Coordinate_Information:
      Planar_Coordinate_Encoding_Method: Coordinate pair
      Abscissa_Resolution:
      Ordinate_Resolution:
      Planar_Distance_Units: Meters
  Geodetic_Model:
    Horizontal_Datum_Name: North American Datum of 1927
    Ellipsoid_Name: Clarke 1866
    Semi-major_Axis: 6378206.4000000
    Denominator_of_Flattening_Ratio: 294.98

Vertical_Coordinate_System_Definition:
  Altitude_System_Definition:
Altitude_Datum_Name: National Geodetic Vertical Datum of 1929
Altitude_Resolution:
Altitude_Distance_Units: feet
Altitude_Encoding_Method: Implicit coordinate

ENTITY_AND_ATTRIBUTE_INFORMATION

Overview_Description:
Entity_and_Attribute_Overview:
Wapato Valley polygon shapefile describes the study area of the Wapato Valley Predictive Model.
Entity_and_Attribute_Detail_Citation:

DISTRIBUTION_INFORMATION

Distributor:
Contact_Information:
Contact_Organization_Primary:
Contact_Organization: Portland State University, Department of Anthropology
Contact_Person: Leslie M. O’Rourke
Contact_Position: MA, RPA
Contact_Address:
Address_Type: mailing and physical address
Address: 1211 Orchard Street
City: West Linn
State_or_Province: Oregon
Postal_Code: 97068
Country: USA
Contact_Voice_Telephone: 503.656.6567 or 503.656.1365
Contact_Electronic_Mail_Address: orourkel@pdx.edu

Resource_Description:
Wapato_valley.shp

Custom_Order_Process:
Please contact the author, or Portland State University, Department of Anthropology.

METADATA_REFERENCE_INFORMATION

Metadata_Date: 20050430
Metadata_Review_Date:
Metadata>Contact:
Contact_Information:
Contact_Organization_Primary:
Contact_Organization: Portland State University, Department of Anthropology
Contact_Person: Leslie M. O’Rourke
Contact_Position: MA, RPA
Contact_Address:
Address_Type: Mailing and physical address
Address: 1211 Orchard Street
City: West Linn
State_or_Province: Oregon
Postal_Code: 97068
Country: USA
Contact_Electronic_Mail_Address: orourkel@pdx.edu
Metadata for the Permanent Water and Navigable Water Shapefiles for the Eleven Topographic Maps of the Wapato Valley

The following section contains metadata for the permanent water and navigable water shapefiles created for the Wapato Valley Predictive Model. In the interest of saving space and eliminating redundancy, the information for these files that is shared in common is listed only once, and summarized in a general metadata document for both the permanent and navigable water shapefiles. Supplementary metadata documents then follow, with headings for each of the topographic maps, which have metadata information specific to the permanent and navigable water shapefiles for each map. The metadata sections included in these supplementary documents include: portions of the Identification Information, the Lineage and Process sections of the Data Quality Information, the Spatial Data Organization Information, the Spatial Reference Information, and the Resource Description section of the Distribution Information. Each full metadata document is also available through its shapefile in ArcView.

These shapefiles were all created in the same manner, by editing modern water shapefiles obtained from two agencies: the US Fish and Wildlife Service (prepared by Ducks Unlimited, Inc.) for the Portland, Linnton, Vancouver, Sauvie Island, Ridgefield, Saint Helens, Woodland, and Deer Island topographic maps; and the US Army Corps of Engineers for the Washougal, Camas, and Mount Tabor topographic maps. The specific metadata for these source shapefiles is not in my possession, however, the individual agencies indicated that these are the standard waterbodies digitized by the USGS from 7.5-minute 1:24,000 scale topographic maps (NAD 27 Datum, UTM Projection, Planar units in meters). Contacts for each agency are included in the Process portion of the Data Quality Information section of the metadata.

The modern waterbodies were edited in ArcView 3.2 with the help of historic maps, to more accurately reflect the prehistoric conditions of the floodplain of the Columbia River. The US Coast and Geodetic Survey maps from the 1880s served as the primary references, but for areas that were farther from the Columbia River, or when earlier maps were available, other historic maps were able to provide the needed information. Table I-1 provides details on which of these maps were used to help digitize the waterbodies for each of the eleven topographic maps of the Wapato Valley. The complete references for these maps may be found under the heading “List of Maps and Digital Images Consulted” on page 272 of the References Cited. The metadata do not contain a listing of all the maps used to help digitize each water shapefile, but instead refer to this table in this document.
Table 5.1.1. Maps and Digital Images Used as References for Digitizing the Historic Water Boundaries.

<table>
<thead>
<tr>
<th>Map/Digital Image</th>
<th>Dear Island</th>
<th>Woodland</th>
<th>Saint Helens</th>
<th>Ridgefield</th>
<th>Sauvie Island</th>
<th>Vancouver</th>
<th>Linton</th>
<th>Portland</th>
<th>Mount Tabor</th>
<th>Camas</th>
<th>Washougal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boundary Claims Commission, 1867, Plat of the Hudson's Bay Company claim at Fort Vancouver (surveyed May 1854)</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Broughton, 1792, Chart of the Exploration of the Columbia River, from Cape Disappointment to Point Vancouver</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Cunningham, 1973 [1896], Cyclists road map of Portland District</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Derby and Gibbs, 1855, Map of the US Military Road from Columbia Barracks to Fort Steilacoom</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Ducks Unlimited, 2000, Ridgefield National Wildlife Refuge Complex GIS Database</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Habersham, 1888, Map of Clarke County, Washington Territory</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>MapMart, 2003, Digital image of 1979 Vancouver Washington-Oregon 1:100,000 30x60 minute quadrangle</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Metsker, 1937, Metsker’s Atlas of Clark County</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>
### Table 5.1.1 cont.

<table>
<thead>
<tr>
<th>Map/Digital Image</th>
<th>7.5 - minute Topographic Map</th>
</tr>
</thead>
<tbody>
<tr>
<td>National Geographic Maps, 2000, TOPO! Seamless USGS Topographic Maps</td>
<td>X X X X X X X X X X X X X X X X</td>
</tr>
<tr>
<td>Regional Ecosystem Office, 2002, Digital Elevation Model maps of Washington and Oregon</td>
<td>X X X X X X X X X X X X X X X X</td>
</tr>
<tr>
<td>Regional Ecosystem Office, 2002, Digital Raster Graphic maps of Washington and Oregon</td>
<td>X X X X X X X X X X X X X X X X</td>
</tr>
<tr>
<td>Slacum, 1836, Chart of the Columbia River for 90 Miles from its Mouth</td>
<td>X X X X X X X X X X X X X X X X</td>
</tr>
<tr>
<td>US Coast and Geodetic Survey, 1888, Columbia River Chart 6144, Sheet 5: Kalama to Fale’s Landing, 1:40,000</td>
<td>X X X X X X X X X X X X X X X X</td>
</tr>
<tr>
<td>US Coast and Geodetic Survey, 1916, Columbia River Chart 6146, Sheet 7: Vancouver to Reed Island, 1:40,000</td>
<td>X X X X X X X X X X X X X X X X</td>
</tr>
<tr>
<td>US Coast and Geodetic Survey, 1925, Columbia River Chart 6154: Saint Helens to Willamette River, including Vancouver and Portland, 1:40,000</td>
<td>X X X X X X X X X X X X X X X X</td>
</tr>
</tbody>
</table>

329
<table>
<thead>
<tr>
<th>Map/Digital Image</th>
<th>7.5 - minute Topographic Map</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>US Coast and Geodetic Survey,</strong> 1930, Portland Basin Chart 6155, 1:20,000, including Multnomah Channel, Southern Part, 1:10,000</td>
<td>X X X X X X X X X X X X</td>
</tr>
<tr>
<td><strong>US Coast and Geodetic Survey,</strong> 1933, Columbia River Chart 6154: Saint Helens to Willamette River, including Vancouver and Portland, 1:40,000</td>
<td>X X X X X X X X X X X X</td>
</tr>
<tr>
<td><strong>US Coast and Geodetic Survey,</strong> 1941, Columbia River Chart 6156: Vancouver to Bonneville, 1:40,000</td>
<td>X X X X X X X X X X X X</td>
</tr>
<tr>
<td><strong>US Coast and Geodetic Survey,</strong> 1949, Columbia River Chart 6154: Saint Helens to Willamette River, including Vancouver and Portland, 1:40,000</td>
<td>X X X X X X X X X X X X</td>
</tr>
<tr>
<td><strong>US Coast and Geodetic Survey,</strong> 1951, Portland Basin, Chart 6155, 1:20,000, including Multnomah Channel, Southern Part, 1:10,000</td>
<td>X X X X X X X X X X X X</td>
</tr>
<tr>
<td><strong>US General Land Office,</strong> 1887, Map of Sauvies Island, compiled from Government Survey Notes</td>
<td>X X X X X X X X X X X X</td>
</tr>
<tr>
<td><strong>Vavasour,</strong> 1845, Rough Chart of the Columbia River from the Head of the Navigation to the Pacific Ocean</td>
<td>X X X X X X X X X X X X</td>
</tr>
<tr>
<td><strong>Wilkes,</strong> 1841, Map of the Columbia River (Sheet 5)</td>
<td>X X X X X X X X X X X X</td>
</tr>
</tbody>
</table>
**Table 5.1.1 cont.**

<table>
<thead>
<tr>
<th>US General Land Office, 1852-1887, Donation Land Claim Maps</th>
<th>7.5 - minute Topographic Map</th>
</tr>
</thead>
<tbody>
<tr>
<td>Township and Range</td>
<td>Dear Island</td>
</tr>
<tr>
<td>6N1W</td>
<td>1856</td>
</tr>
<tr>
<td>5N1W</td>
<td>1854 1854</td>
</tr>
<tr>
<td></td>
<td>1854 1862</td>
</tr>
<tr>
<td>4N1W</td>
<td>1863 1866</td>
</tr>
<tr>
<td>4N1E</td>
<td>1854</td>
</tr>
<tr>
<td>3N1W</td>
<td>1860 1860 1860 1862 1862</td>
</tr>
<tr>
<td>3N1E</td>
<td>1854 1854</td>
</tr>
<tr>
<td>2N1W</td>
<td>1854 1862 1862 1862</td>
</tr>
<tr>
<td>2N1E</td>
<td>1854 1862 1865 1887</td>
</tr>
<tr>
<td>1N1E</td>
<td>1860 1863</td>
</tr>
<tr>
<td>1N2E</td>
<td>1856 1860</td>
</tr>
<tr>
<td>1N3E</td>
<td>1856 1862</td>
</tr>
<tr>
<td>1N4E</td>
<td>1856 1862</td>
</tr>
<tr>
<td>US Geological Survey Topographic Maps</td>
<td>Dear Island</td>
</tr>
<tr>
<td>-------------------------------------</td>
<td>-------------</td>
</tr>
<tr>
<td>1905 Portland, 1:62,500</td>
<td>X</td>
</tr>
<tr>
<td>1905 Vancouver, 15-minute</td>
<td></td>
</tr>
<tr>
<td>1918 Hillsboro, 15-minute</td>
<td></td>
</tr>
<tr>
<td>1918 Troutdale, 15-minute</td>
<td></td>
</tr>
<tr>
<td>1939 Hillsboro, 15-minute</td>
<td></td>
</tr>
<tr>
<td>1939 La Center, 15-minute</td>
<td>X</td>
</tr>
<tr>
<td>1940 Portland, 15-minute</td>
<td></td>
</tr>
<tr>
<td>1940 Saint Helens, 15-minute</td>
<td></td>
</tr>
<tr>
<td>1942 Camas, 15-minute</td>
<td></td>
</tr>
<tr>
<td>1943 Saint Helens, 15-minute</td>
<td></td>
</tr>
<tr>
<td>1954 Camas, 15-minute</td>
<td></td>
</tr>
<tr>
<td>1954 Deer Island, 7.5-minute</td>
<td>X</td>
</tr>
<tr>
<td>1954 La Center, 15-minute</td>
<td></td>
</tr>
<tr>
<td>1954 Linnton, 7.5-minute</td>
<td></td>
</tr>
<tr>
<td>1954 Mount Tabor, 7.5-minute</td>
<td></td>
</tr>
<tr>
<td>1954 Portland, 7.5-minute</td>
<td></td>
</tr>
<tr>
<td>1954 Ridgefield, 7.5-minute</td>
<td></td>
</tr>
<tr>
<td>1954 Saint Helens, 15-minute</td>
<td></td>
</tr>
<tr>
<td>1954 Saint Helens, 7.5-minute</td>
<td></td>
</tr>
<tr>
<td>1954 Sauvie Island, 7.5-minute</td>
<td></td>
</tr>
<tr>
<td>1954 Vancouver, 7.5-minute</td>
<td></td>
</tr>
</tbody>
</table>
Metadata for the Permanent Waterbodies of the Wapato Valley

IDENTIFICATION_INFORMATION

Citation:
Citation_Information:
Originator: Leslie M. O’Rourke
Publication_Date: 20050504
Title: 7.5-minute Topographic Map Permanent Water
Edition: 1
Geospatial_Data_Presentation_Form: Map
Publication_Information:
Publication_Place: Portland State University, Portland, Oregon
Publisher: Leslie M. O’Rourke
Other_Citation_Details:
Online_Linkage:
Larger_Work_Citation:
Citation_Information:
Originator: Leslie M. O’Rourke
Publication_Date: 20050504
Title: The Wapato Valley Predictive Model: Prehistoric Archaeological Site Location on the Floodplain of the Columbia River in the Portland Basin
Publication_Information:
Publication_Place: Portland, Oregon
Publisher: Portland State University, Department of Anthropology
Online_Linkage:

Description:
Abstract:
Permanent waterbodies of the 7.5-minute topographic map. Shapefile edited from the modern waterbodies with the help of historic maps, to more accurately reflect the prehistoric conditions on the floodplain of the Columbia River. The US Coast and Geodetic Survey maps from the 1880s served as the primary references, but for areas that were farther from the Columbia River, or when earlier maps were available, other historic maps were able to provide the needed information. Table I-1 in Appendix I of the Wapato Valley Predictive Model provides details on which of these maps were used to help digitize the waterbodies for each of the eleven topographic maps of the Wapato Valley.

Purpose:
Shapefile digitized as one of the predictor variables for the Wapato Valley Predictive Model.

Supplemental_Information:
Study area includes these topographic maps: Washougal, Washington-Oregon; Camas, Washington-Oregon; Mount Tabor, Oregon-Washington; Portland, Oregon-Washington; Linniton, Oregon; Vancouver, Washington-Oregon; Sauvie Island, Oregon-Washington; Ridgefield, Washington; Saint Helens, Oregon-Washington; Woodland, Washington; Deer Island Oregon-Washington.

Time_Period_of_Content:
Time_Period_Information:
Range_of_Dates/Times:
Beginning_Date: 2004
Ending_Date: 20050504
Currentness_Reference: 20050504

Status:
Progress: Complete
Maintenance_and_Update_Frequency: None planned

Keywords:
Theme:
Theme_Keyword: archaeology
Theme_Keyword: ArcView 3.2
Theme_Keyword: permanent waterbodies
Theme_Keyword: predictive model
Place:
Place_Keyword: Columbia River
Place_Keyword: floodplain
Place_Keyword: Northwest
Place_Keyword: Oregon
Place_Keyword: Portland Basin
Place_Keyword: United States
Place_Keyword: Wapato Valley
Place_Keyword: Washington

Access_Constraints:
None

Use_Constraints:
None

Point_of_Contact:
Contact Information:
Contact_Organization_Primary:
Contact_Organization: Portland State University, Department of Anthropology
Contact_Person: Leslie M. O’Rourke
Contact_Position: MA, RPA
Contact_Address:
Address_Type: mailing and physical address
Address: 1211 Orchard Street
City: West Linn
State_or_Province: Oregon
Postal_Code: 97068
Country: USA
Contact_Voice_Telephone: 503.656.6567 or 503.656.1365
Contact_Electronic_Mail_Address: orourkel@pdx.edu

Native_Data_Set_Environment:
ArcView version 3.2 shapefile format

DATA_QUALITY_INFORMATION

Attribute_Accuracy:
Attribute_Accuracy_Report:
Permanent waterbodies were edited from modern water shapefile generated from 7.5-minute 1:24,000 USGS topographic maps. Shapefile edited in ArcView 3.2 by comparison with DEMs, DRGs, USCGS maps, GLO maps, and other historic maps, to more accurately reflect the prehistoric conditions on the floodplain of the Columbia River. The US Coast and Geodetic Survey maps from the 1880s served as the primary references, but for areas that were farther from the Columbia River, or when earlier
maps were available, other historic maps were able to provide the needed information. Table 5.1.1 in Appendix I of the Wapato Valley Predictive Model provides details on which of these maps were used to help digitize the waterbodies for each of the eleven topographic maps of the Wapato Valley. Final decision on inclusion and location of waterbodies made by author.

**Logical_Consistency_Report:**

**Completeness_Report:**

**Positional_Accuracy:**

**Horizontal_Positional_Accuracy:**

**Horizontal_Positional_Accuracy_Report:**

The data were created by delineating the boundary off a USGS 7.5 minute Topographic Map at 1:24000 scale. Therefore, the horizontal accuracy is assumed to be within National Map Accuracy Standards, with a horizontal accuracy of 45.6 feet at the 95% confidence level.

**Vertical_Positional_Accuracy:**

**Vertical_Positional_Accuracy_Report:**

The data were delineated off a USGS 7.5 minute Topographic Map at 1:24000 scale. Therefore, the vertical accuracy is assumed to be within National Map Accuracy Standards, with a vertical accuracy of 11.9 feet at the 95% confidence level.

**ENTITY_AND_ATTRIBUTE_INFORMATION**

**Overview_Description:**

Entity_and_Attribute_Overview:

Entities are lines representing the permanent waterbodies of the 7.5-minute topographic map.

Entity_and_Attribute_Detail_Citation:

**DISTRIBUTION_INFORMATION**

**Distributor:**

Contact_Information:

Contact_Organization_Primary:

Contact_Organization: Portland State University, Department of Anthropology

Contact_Person: Leslie M. O’Rourke

Contact_Position: MA, RPA

Contact_Address:

Address_Type: mailing and physical address

Address: 1211 Orchard Street

City: West Linn

State_or_Province: Oregon

Postal_Code: 97068

Country: USA

Contact_Voice_Telephone: 503.656.6567 or 503.656.1365

Contact_Electronic_Mail_Address: orourkel@pdx.edu

**Resource_Description:**

(name of topo map)_perm_water.shp

**Custom_Order_Process:**

Please contact the author, or Portland State University, Department of Anthropology.

**METADATA_REFERENCE_INFORMATION**

**Metadata_Date:**

20050430
Metadata_Review_Date:  
Metadata_Contact:  
Contact_Information:  
   Contact_Organization_Primary:  
      Contact_Organization: Portland State University, Department of Anthropology  
      Contact_Person: Leslie M. O’Rourke  
      Contact_Position: MA, RPA  
   Contact_Address:  
      Address_Type: Mailing and physical address  
      Address: 1211 Orchard Street  
      City: West Linn  
      State_or_Province: Oregon  
      Postal_Code: 97068  
      Country: USA  
      Contact_Voice_Telephone: 503.656.6567 or 503.656.1365  
      Contact_Electronic_Mail_Address: orourkel@pdx.edu  
Metadata_Standard_Name: FGDC CSDGM  

Metadata for the Navigable Waterbodies of the Wapato Valley  

IDENTIFICATION_INFORMATION  

Citation:  
Citation_Information:  
   Originator: Leslie M. O’Rourke  
   Publication_Date: 20050504  
   Title: 7.5-minute Topographic Map Navigable Water  
   Edition: 1  
   Geospatial_Data_Presentation_Form: Map  
Publication_Information:  
   Publication_Place: Portland State University, Portland, Oregon  
   Publisher: Leslie M. O’Rourke  
Other_Citation_Details:  
Online_Linkage:  
Larger_Work_Citation:  
Citation_Information:  
   Originator: Leslie M. O’Rourke  
   Publication_Date: 20050504  
   Title: The Wapato Valley Predictive Model: Prehistoric Archaeological Site Location on the Floodplain of the Columbia River in the Portland Basin  
Publication_Information:  
   Publication_Place: Portland, Oregon  
   Publisher: Portland State University, Department of Anthropology  
Online_Linkage:  

Description:  
Abstract:  
Navigable waterbodies of the 7.5-minute topographic map. Shapefile edited from the modern waterbodies with the help of historic maps, to more accurately reflect the prehistoric conditions on the floodplain of the Columbia River. The US Coast and Geodetic Survey maps from the 1880s served as the primary references, but for areas that were farther from the Columbia River, or when earlier maps were available, other
historic maps were able to provide the needed information. Table 5.I.1 in Appendix I of the Wapato Valley Predictive Model provides details on which of these maps were used to help digitize the waterbodies for each of the eleven topographic maps of the Wapato Valley.

**Purpose:**
Shapefile digitized as one of the predictor variables for the Wapato Valley Predictive Model.

**Supplemental Information:**
Study area includes these topographic maps: Washougal, Washington-Oregon; Camas, Washington-Oregon; Mount Tabor, Oregon-Washington; Portland, Oregon-Washington; Linnton, Oregon; Vancouver, Washington-Oregon; Sauvie Island, Oregon-Washington; Ridgefield, Washington; Saint Helens, Oregon-Washington; Woodland, Washington; Deer Island Oregon-Washington.

**Time_Period_of_Content:**
Time_Period_Information:
Range_of_Dates/Times:
Beginning_Date: 2004
Ending_Date: 20050504
Currentness_Reference: 20050504

**Status:**
Progress: Complete
Maintenance_and_Update_Frequency: None planned

**Keywords:**
Theme:
Theme_Keyword: archaeology
Theme_Keyword: ArcView 3.2
Theme_Keyword: navigable waterbodies
Theme_Keyword: predictive model

Place:
Place_Keyword: Columbia River
Place_Keyword: floodplain
Place_Keyword: Northwest
Place_Keyword: Oregon
Place_Keyword: Portland Basin
Place_Keyword: United States
Place_Keyword: Wapato Valley
Place_Keyword: Washington

**Access_Constraints:**
None

**Use_Constraints:**
None

**Point_of_Contact:**
Contact_Information:
Contact_Organization_Primary:
Contact_Organization: Portland State University, Department of Anthropology
Contact_Person: Leslie M. O’Rourke
Contact_Position: MA, RPA
Contact_Address:
Address_Type: mailing and physical address
Address: 1211 Orchard Street
City: West Linn
State or Province: Oregon
Postal Code: 97068
Country: USA
Contact Voice Telephone: 503.656.6567 or 503.656.1365
Contact Electronic Mail Address: orourkel@pdx.edu

Native Data Set Environment:
ArcView version 3.2 shapefile format

DATA QUALITY INFORMATION

Attribute Accuracy:
Attribute Accuracy Report:
Navigable waterbodies were edited from modern water shapefile generated from 7.5-minute 1:24,000 USGS topographic maps. Shapefile edited in ArcView 3.2 by comparison with DEMs, DRGs, USCGS maps, GLO maps, and other historic maps, to more accurately reflect the prehistoric conditions on the floodplain of the Columbia River. The US Coast and Geodetic Survey maps from the 1880s served as the primary references, but for areas that were farther from the Columbia River, or when earlier maps were available, other historic maps were able to provide the needed information. Table 5.I.1 in Appendix I of the Wapato Valley Predictive Model provides details on which of these maps were used to help digitize the waterbodies for each of the eleven topographic maps of the Wapato Valley. Final decision on inclusion and location of waterbodies made by author.

Logical Consistency Report:
Completeness Report:

Positional Accuracy:
Horizontal Positional Accuracy:
Horizontal Positional Accuracy Report:
The data were created by delineating the boundary off a USGS 7.5 minute Topographic Map at 1:24000 scale. Therefore, the horizontal accuracy is assumed to be within National Map Accuracy Standards, with a horizontal accuracy of 45.6 feet at the 95% confidence level.

Vertical Positional Accuracy:
Vertical Positional Accuracy Report:
The data were delineated off a USGS 7.5 minute Topographic Map at 1:24000 scale. Therefore, the vertical accuracy is assumed to be within National Map Accuracy Standards, with a vertical accuracy of 11.9 feet at the 95% confidence level.

ENTITY AND ATTRIBUTE INFORMATION

Overview Description:
Entity and Attribute Overview:
Entities are lines representing the navigable waterbodies of the 7.5-minute topographic map.
Entity and Attribute Detail Citation:

DISTRIBUTION INFORMATION

Distributor:
Contact Information:
Contact Organization Primary:
Contact_Organization: Portland State University, Department of Anthropology
Contact_Person: Leslie M. O'Rourke
Contact_Position: MA, RPA
Contact_Address:
  Address_Type: mailing and physical address
  Address: 1211 Orchard Street
  City: West Linn
  State_or_Province: Oregon
  Postal_Code: 97068
  Country: USA
  Contact_Voice_Telephone: 503.656.6567 or 503.656.1365
  Contact_Electronic_Mail_Address: orourkel@pdx.edu

Resource_Description:
(name of topo map)_nav_water.shp

Custom_Order_Process:
Please contact the author, or Portland State University, Department of Anthropology.

METADATA_REFERENCE_INFORMATION

Metadata_Date: 20050430
Metadata_Review_Date:
Metadata_Contact:
  Contact_Information:
    Contact_Organization_Primary:
      Contact_Organization: Portland State University, Department of Anthropology
      Contact_Person: Leslie M. O'Rourke
      Contact_Position: MA, RPA
      Contact_Address:
        Address_Type: Mailing and physical address
        Address: 1211 Orchard Street
        City: West Linn
        State_or_Province: Oregon
        Postal_Code: 97068
        Country: USA
        Contact_Voice_Telephone: 503.656.6567 or 503.656.1365
        Contact_Electronic_Mail_Address: orourkel@pdx.edu
    Metadata_Standard_Name: FGDC CSDGM

Additional Metadata Specific to Washougal_perm_water.shp

IDENTIFICATION_INFORMATION

Citation:
  Citation_Information:
    Title: Washougal 7.5-minute Topographic Map Permanent Water

Spatial_Domain:
  Bounding_Coordinates:
    West_Bounding_Coordinate: -122.3756
    East_Bounding_Coordinate: -122.2494
    North_Bounding_Coordinate: 45.5896
    South_Bounding_Coordinate: 45.5360

Keywords:
Place:
Place_Keyword: Clark County, Washington
Place_Keyword: Multnomah County, Oregon
Place_Keyword: Washougal, Washington-Oregon

Native_Data_Set_Environment:
ArcView version 3.2 shapefile format
c:\wvpm\washougal\washougal_perm_water.shp

DATA_QUALITY_INFORMATION

Lineage:
Source_Information:
Source_Citation:
Citation_Information:
Originator:
Publication_Date: 2002
Title: Washougal Hydrography Shapefile
Edition: 1
Geospatial_Data_Presentation_Form: map
Publication_Information:
Publication_PLACE: Portland, Oregon
Publisher: US Army Corps of Engineers
Other_Citation_Details:
originally digitized by the USGS form 7.5-minute topographic map.

Online_&nbsplinkage:
Larger_Work_Citation:
Citation_Information:
Originator:
Publication_Date:
Title:
Publication_Information:
Publication_PLACE:
Publisher:
Online_&nbsplinkage:
Source_Scale_Denominator: 24,000
Type_of_Source_Media: paper
Source_Time_Period_of_Content:
Time_Period_Information:
Range_of_Dates/Times:
Beginning_Date:
Ending_Date:
Source_Currentness_Reference: 2002
Source_Citation_Abbreviation:
Source_Contribution:
These hydrography shapefiles served as base maps for edits made to more closely
reflect prehistoric conditions on the Columbia River floodplain.

Process_Step:
Process_Description:
Source_Used_Citation_Abbreviation:
Process_Date:
Source_Produced_Citation_Abbreviation:
Process_Contact:
Contact Information:
Contact Person Primary:
  Contact Organization: US Army Corps of Engineers
  Contact Person: Gregg Bertrand
  Contact Position: Geographer
Contact Address:
  Address Type: mailing and physical address
  Address: 333 SE First Avenue
  City: Portland
  State or Province: Oregon
  Postal Code: 97204
  Country: USA
Contact Voice Telephone: 503.808.4859
Contact Electronic Mail Address: Gregg.M.Bertrand@nwp01.usace.army.mil

SPATIAL_DATA_ORGANIZATION_INFORMATION

Direct Spatial Reference Method: Vector
Point and Vector Object Information:
  SDTS Terms Description:
  SDTS Point and Vector Object Type: Complete Chain
  Point and Vector Object Count: 99

SPATIAL_REFERENCE_INFORMATION

Horizontal Coordinate System Definition:
Planar:
  Grid Coordinate System:
    Grid Coordinate System Name: Universal Transverse Mercator
    Universal Transverse Mercator:
      UTM Zone Number: 10
      Transverse Mercator:
        Scale Factor at Central Meridian: 0.999600
        Longitude of Central Meridian: -123.000000
        Latitude of Projection Origin: 0.000000
        False Easting: 500000.000000
        False Northing: 0.000000
  Planar Coordinate Information:
    Planar Coordinate Encoding Method: Coordinate pair
    Coordinate Representation:
      Abscissa Resolution:
      Ordinate Resolution:
      Planar Distance Units: Meters
  Geodetic Model:
    Horizontal Datum Name: North American Datum of 1927
    Ellipsoid Name: Clarke 1866
    Semi-major Axis: 6378206.400000
    Denominator of Flattening Ratio: 294.98

Vertical Coordinate System Definition:
Altitude System Definition:
  Altitude Datum Name: National Geodetic Vertical Datum of 1929
  Altitude Resolution:
Altitude_Distance_Units: feet
Altitude_Encoding_Method: Implicit coordinate

DISTRIBUTION_INFORMATION

Resource_Description:
washougal_perm_water.shp

Additional Metadata Specific to Washougal_nav_water.shp

IDENTIFICATION_INFORMATION

Citation:
Citation_Information:
Title: Washougal 7.5-minute Topographic Map Navigable Water

Spatial_Domain:
Bounding_Coordinates:
West_Bounding_Coordinate: -122.3756
East_Bounding_Coordinate: -122.2493
North_Bounding_Coordinate: 45.5896
South_Bounding_Coordinate: 45.5360

Keywords:
Place:
Place_Keyword: Clark County, Washington
Place_Keyword: Multnomah County, Oregon
Place_Keyword: Washougal, Washington-Oregon

Native_Data_Set_Environment:
ArcView version 3.2 shapefile format
c:\wvpm\washougal\washougal_nav_water.shp

DATA_QUALITY_INFORMATION

Lineage:
Source_Information:
Source_Citation:
Citation_Information:
Originator:
Publication_Date: 2002
Title: Washougal Hydrography Shapefile
Edition: 1
Geospatial_Data_Presentation_Form: map
Publication_Information:
Publication_Place: Portland, Oregon
Publisher: US Army Corps of Engineers
Other_Citation_Details:
Originally digitized by the USGS form 7.5-minute topographic map.

Online_Linkage:
Online_Linkage:
Larger_Work_Citation:
Citation_Information:
Originator:
Publication_Date:
Title:
These hydrography shapefiles served as base maps for edits made to more closely reflect prehistoric conditions on the Columbia River floodplain.

**Process Step:**

**Source Used Citation Abbreviation:**

**Process Date:**

**Source Produced Citation Abbreviation:**

**Process Contact:**

**Contact Information:**
- **Contact Person Primary:** US Army Corps of Engineers
- **Contact Person:** Gregg Bertrand
- **Contact Position:** Geographer
- **Address Type:** mailing and physical address
- **Address:** 333 SW First Avenue
- **City:** Portland
- **State or Province:** Oregon
- **Postal Code:** 97204
- **Country:** USA
- **Contact Voice Telephone:** 503.808.4859
- **Contact Electronic Mail Address:** Gregg.M.Bertrand@nwp01.usace.army.mil

**SPATIAL DATA ORGANIZATION INFORMATION**

**Direct Spatial Reference Method:** Vector

**Point and Vector Object Information:**
- **SDTS Terms Description:**
- **SDTS Point and Vector Object Type:** Complete Chain
- **Point and Vector Object Count:** 45

**SPATIAL REFERENCE INFORMATION**

**Horizontal Coordinate System Definition:**

**Planar:**
- **Grid Coordinate System:**
  - **Grid Coordinate System Name:** Universal Transverse Mercator
  - **Universal_Transverse_Mercator:**
UTM_Zone_Number: 10
Transverse_Mercator:
  Scale_Factor_at_Central_Meridian: 0.999600
  Longitude_of_Central_Meridian: -123.000000
  Latitude_of_Projection_Origin: 0.000000
  False_Easting: 500000.000000
  False_Northing: 0.000000
Planar_Coordinate_Information:
  Planar_Coordinate_Encoding_Method: Coordinate pair
  Coordinate_Representation:
    Abscissa_Resolution:
    Ordinate_Resolution:
    Planar_Distance_Units: Meters
Geodetic_Model:
  Horizontal_Datum_Name: North American Datum of 1927
  Ellipsoid_Name: Clarke 1866
  Semi-major_Axis: 6378206.400000
  Denominator_of_Flattening_Ratio: 294.98
Vertical_Coordinate_System_Definition:
  Altitude_System_Definition:
    Altitude_Datum_Name: National Geodetic Vertical Datum of 1929
    Altitude_Resolution:
    Altitude_Distance_Units: feet
    Altitude_Encoding_Method: Implicit coordinate

DISTRIBUTION_INFORMATION

Resource_Description:
  washougal_nav_water.shp

Additional Metadata Specific to Camas_perm_water.shp

IDENTIFICATION_INFORMATION

Citation:
  Citation_Information:
    Title: Camas 7.5-minute Topographic Map Permanent Water

Spatial_Domain:
  Bounding_Coordinates:
    West_Bounding_Coordinate: -122.5004
    East_Bounding_Coordinate: -122.3744
    North_Bounding_Coordinate: 45.5925
    South_Bounding_Coordinate: 45.5367

Keywords:
  Place:
    Place_Keyword: Camas, Washington-Oregon;
    Place_Keyword: Clark County, Washington
    Place_Keyword: Multnomah County, Oregon

Native_Data_Set_Environment:
  ArcView version 3.2 shapefile format
c:\wvpm\camas\camas_perm_water.shp

DATA_QUALITY_INFORMATION
These hydrography shapefiles served as base maps for edits made to more closely reflect prehistoric conditions on the Columbia River floodplain.
City: Portland
State or Province: Oregon
Postal Code: 97204
Country: USA
Contact Voice Telephone: 503.808.4859
Contact Electronic Mail Address: Gregg.M.Bertrand@nwp01.usace.army.mil

**SPATIAL_DATA_ORGANIZATION_INFORMATION**

**Direct_Spatial_Reference_Method:** Vector

**Point_and_Vector_Object_Information:**

SDTS_Terms_Description:

- SDTS_Point_and_Vector_Object_Type: Complete Chain
- Point_and_Vector_Object_Count: 142

**SPATIAL_REFERENCE_INFORMATION**

**Horizontal_Coordinate_System_Definition:**

Planar:

- GridCoordinateSystem:
  - Grid_Coordinate_System_Name: Universal Transverse Mercator
- Universal_Transverse_Mercator:
  - UTM_Zone_Number: 10
  - Transverse_Mercator:
    - Scale_Factor_at_Central_Meridian: 0.999600
    - Longitude_of_Central_Meridian: -123.000000
  - Latitude_of_Projection_Origin: 0.000000
  - False_Easting: 500000.000000
  - False_Northing: 0.000000

- Planar_Coordinate_Information:
  - Planar_Coordinate_Encoding_Method: Coordinate pair
  - Coordinate_Representation:
  - Abscissa_Resolution:
  - Ordinate_Resolution:
  - Planar_Distance_Units: Meters

- Geodetic_Model:
  - Horizontal_Datum_Name: North American Datum of 1927
  - Ellipsoid_Name: Clarke 1866
  - Semi-major_Axis: 6378206.400000
  - Denominator_of_Flattening_Ratio: 294.98

**Vertical_Coordinate_System_Definition:**

- Altitude_System_Definition:
  - Altitude_Datum_Name: National Geodetic Vertical Datum of 1929
  - Altitude_Resolution:
  - Altitude_Distance_Units: feet
  - Altitude_Encoding_Method: Implicit coordinate

**DISTRIBUTION_INFORMATION**

**Resource_Description:**
camas_perm_water.shp
Additional Metadata Specific to Camas_nav_water.shp

IDENTIFICATION_INFORMATION

Citation:
Citation_Information:
Title: Camas 7.5-minute Topographic Map Navigable Water

Spatial_Domain:
Bounding_Coordinates:
West_Bounding_Coordinate: -122.5004
East_Bounding_Coordinate: -122.3745
North_Bounding_Coordinate: 45.5902
South_Bounding_Coordinate: 45.5379

Keywords:
Place:
Place_Keyword: Camas, Washington-Oregon;
Place_Keyword: Clark County, Washington
Place_Keyword: Multnomah County, Oregon

Native_Data_Set_Environment:
ArcView version 3.2 shapefile format
c:\wvpm\camas\camas_nav_water.shp

DATA_QUALITY_INFORMATION

Lineage:
Source_Information:
Source_Citation:
Citation_Information:
Originator:
Publication_Date: 2002
Title: Camas Hydrography Shapefile
Edition: 1
Geospatial_Data_Presentation_Form: map
Publication_Information:
Publication_Date: Portland, Oregon
Publisher: US Army Corps of Engineers
Other_Citation_Details:
Originally digitized by the USGS form 7.5-minute topographic map.
Online_Linkage:
Larger_Work_Citation:
Citation_Information:
Originator:
Publication_Date:
Title:
Publication_Information:
Publication_Date:
Publisher:
Online_Linkage:
Source_Scale_Denominator: 24,000
Type_of_Source_Media: paper
Source_Time_Period_of_Content:
Time_Period_Information:
These hydrography shapefiles served as base maps for edits made to more closely reflect prehistoric conditions on the Columbia River floodplain.

**Process Step:**

**Source Used Citation Abbreviation:**

**Process Date:**

**Source Produced Citation Abbreviation:**

**Process Contact:**

**Contact Information:**

**Contact Person Primary:**

**Contact Organization:** US Army Corps of Engineers

**Contact Person:** Gregg Bertrand

**Contact Position:** Geographer

**Contact Address:** 333 SE First Avenue

**Address Type:** mailing and physical address

**Address:**

**City:** Portland

**State or Province:** Oregon

**Postal Code:** 97204

**Country:** USA

**Contact Voice Telephone:** 503.808.4859

**Contact Electronic Mail Address:** Gregg.M.Bertrand@nwp01.usace.army.mil

**Spatial Data Organization Information**

**Direct Spatial Reference Method:** Vector

**SDTS_Terms_Description:**

**SDTS_Point_and_Vector_Object_Type:** Complete Chain

**Point and Vector Object Count:** 71

**Spatial Reference Information**

**Horizontal Coordinate System Definition:**

**Planar:**

**Grid Coordinate System:**

**Grid Coordinate System Name:** Universal Transverse Mercator

**Universal Transverse Mercator:**

**UTM_Zone_Number:** 10

**Transverse Mercator:**

**Scale_Factor_at_Central_Meridian:** 0.999600

**Longitude_of_Central_Meridian:** -123.000000

**Latitude_of_Projection_Origin:** 0.000000

**False_Easting:** 500000.000000

**False_Northing:** 0.000000

**Planar Coordinate Information:**
Planar_Coordinate_Encoding_Method: Coordinate pair
Coordinate_Representation: Abscissa_Resolution
Ordinate_Resolution: Planar_Distance_Units: Meters
Geodetic_Model: Horizontal_Datum_Name: North American Datum of 1927
Ellipsoid_Name: Clarke 1866
Semi-major_Axis: 6378206.4000000
Denominator_of_Flattening_Ratio: 294.98
Vertical_Coordinate_System_Definition:
Altitude_System_Definition: Altitude_Datum_Name: National Geodetic Vertical Datum of 1929
Altitude_Resolution:
Altitude_Distance_Units: feet
Altitude_Encoding_Method: Implicit coordinate

DISTRIBUTION_INFORMATION

Resource_Description:
camas_nav_water.shp

Additional_Metadata_Specific_to_Mttabor_east_perm_water.shp

IDENTIFICATION_INFORMATION

Citation:
Citation_Information:
Title: Mount Tabor East Half 7.5-minute Topographic Map Permanent Water
Spatial_Domain:
Bounding_Coordinates:
West_Bounding_Coordinate: -122.5770
East_Bounding_Coordinate: -122.4996
North_Bounding_Coordinate: 45.6044
South_Bounding_Coordinate: 45.5564
Keywords:
Place:
Place_Keyword: Clark County, Washington
Place_Keyword: Mount Tabor, Oregon-Washington;
Place_Keyword: Multnomah County, Oregon
Native_Data_Set_Environment:
ArcView version 3.2 shapefile format
c:\wvpm\mttabor_east\mttabor_east_perm_water.shp

DATA_QUALITY_INFORMATION

Lineage:
Source_Information:
Source_Citation:
Citation_Information:
Originator:
Publication_Date: 2002
Title: Mount Tabor Hydrography Shapefile
These hydrography shapefiles served as base maps for edits made to more closely reflect prehistoric conditions on the Columbia River floodplain.

**Process Step:**

**Process Description:**

**Source Used Citation Abbreviation:**

**Process Date:**

**Source Produced Citation Abbreviation:**

**Process Contact:**

**Contact Information:**

**Contact Person Primary:**

**Contact Organization:** US Army Corps of Engineers

**Contact Person:** Gregg Bertrand

**Contact Position:** Geographer

**Contact Address:**

**Address Type:** mailing and physical address

**Address:** 333 SE First Avenue

**City:** Portland

**State or Province:** Oregon

**Postal Code:** 97204

**Country:** USA

**Contact Voice Telephone:** 503.808.4859

**Contact Electronic Mail Address:** Gregg.M.Bertrand@nwp01.usace.army.mil

**Spatial Data Organization Information**
Direct_Spatial_Reference_Method: Vector
Point_and_Vector_Object_Information:
  SDTS_Terms_Description:
  SDTS_Point_and_Vector_Object_Type: Complete Chain
  Point_and_Vector_Object_Count: 87

SPATIAL_REFERENCE_INFORMATION

Horizontal_Coordinate_System_Definition:
  Planar:
    Grid_Coordinate_System:
      Grid_Coordinate_System_Name: Universal Transverse Mercator
    Universal_Transverse_Mercator:
      UTM_Zone_Number: 10
    Transverse_Mercator:
      Scale_Factor_at_Central_Meridian: 0.999600
      Longitude_of_Central_Meridian: -123.000000
      Latitude_of_Projection_Origin: 0.000000
      False_Easting: 500000.000000
      False_Northing: 0.000000
    Planar_Coordinate_Information:
      Planar_Coordinate_Encoding_Method: Coordinate pair
      Coordinate_Representation:
        Abscissa_Resolution:
        Ordinate_Resolution:
      Planar_Distance_Units: Meters
  Geodetic_Model:
    Horizontal_Datum_Name: North American Datum of 1927
    Ellipsoid_Name: Clarke 1866
    Semi-major_Axis: 6378206.400000
    Denominator_of_Flattening_Ratio: 294.98

Vertical_Coordinate_System_Definition:
  Altitude_System_Definition:
    Altitude_Datum_Name: National Geodetic Vertical Datum of 1929
    Altitude_Resolution:
    Altitude_Distance_Units: feet
    Altitude_Encoding_Method: Implicit coordinate

DISTRIBUTION_INFORMATION

Resource_Description:
  mttabor_east_perm_water.shp

Additional Metadata Specific to Mttabor_east_nav_water.shp

IDENTIFICATION_INFORMATION

Citation:
  Citation_Information:
    Title: Mount Tabor East Half 7.5-minute Topographic Map Navigable Water

Spatial_Domain:
  Bounding_Coordinates:
West_Bounding_Coordinate: -122.5770
East_Bounding_Coordinate: -122.4996
North_Bounding_Coordinate: 45.6044
South_Bounding_Coordinate: 45.5564

Keywords:
Place:
  Place_Keyword: Clark County, Washington
  Place_Keyword: Mount Tabor, Oregon-Washington;
  Place_Keyword: Multnomah County, Oregon

Native>Data_SetEnvironment:
  ArcView version 3.2 shapefile format
c:\wvpm\mttabor_east\mttabor_east_nav_water.shp

DATA_QUALITY_INFORMATION

Lineage:
  Source_Information:
    Source_Citation:
      Citation_Information:
        Originator:
          Publication_Date: 2002
        Title: Mount Tabor Hydrography Shapefile
        Edition:
          Geospatial_Data_Presentation_Form: map
        Publication_Information:
          Publication_Date: Portland, Oregon
          Publisher: U Army Corps of Engineers
        Other_Citation_Details:
          Originally digitized by the USGS form 7.5-minute topographic map.

  Online_Linkage:

  Larger_Work_Citation:
    Citation_Information:
      Originator:
      Publication_Date:
      Title:
      Publication_Information:
      Publisher:
      Online_Linkage:

  Source_Scale_Denominator: 24,000
  Type_of_Source_Media: paper
  Source_Time_Period_of_Content:
    Time_Period_Information:
      Range_of_Dates/Times:
      Beginning_Date:
      Ending_Date:
    Source_Currentness_Reference: 2002
  Source_Citation_Abbreviation:
  Source_Contribution:
    These hydrography shapefiles served as base maps for edits made to more closely reflect prehistoric conditions on the Columbia River floodplain.

Process_Step:
Process_Description:
Source_Used_Citation_Abbreviation:
Process_Date:
Source_Produced_Citation_Abbreviation:
Process>Contact:

Contact_Information:
Contact_Person_Primary:
  Contact_Organization: US Army Corps of Engineers
  Contact_Person: Gregg Bertrand
  Contact_Position: Geographer
Contact_Address:
  Address_Type: mailing and physical address
  Address: 333 SE First Avenue
  City: Portland
  State_or_Province: Oregon
  Postal_Code: 97204
  Country: USA
  Contact_Voice_Telephone: 503.808.4859
  Contact_Electronic_Mail_Address: Gregg.M.Bertrand@nwp01.usace.army.mil

SPATIAL_DATA_ORGANIZATION_INFORMATION

Direct_Spatial_Reference_Method: Vector

Point_and_Vector_Object_Information:
SDTS_Terms_Description:
  SDTS_Point_and_Vector_Object_Type: Complete Chain
  Point_and_Vector_Object_Count: 37

SPATIAL_REFERENCE_INFORMATION

Horizontal_Coordinate_System_Definition:
Planar:
  Grid_Coordinate_System:
    Grid_Coordinate_System_Name: Universal Transverse Mercator
  Universal_Transverse_Mercator:
    UTM_Zone_Number: 10
    Transverse_Mercator:
      Scale_Factor_at_Central_Meridian: 0.999600
      Longitude_of_Central_Meridian: -123.000000
      Latitude_of_Projection_Origin: 0.000000
      False_Easting: 500000.000000
      False_Northing: 0.000000
  Planar_Coordinate_Information:
    Planar_Coordinate_Encoding_Method: Coordinate pair
    Coordinate_Representation:
      Abscissa_Resolution:
      Ordinate_Resolution:
      Planar_Distance_Units: Meters
  Geodetic_Model:
    Horizontal_Datum_Name: North American Datum of 1927
    Ellipsoid_Name: Clarke 1866
    Semi-major_Axis: 6378206.4000000
Denominator_of_Flattening_Ratio: 294.98

**Vertical_Coordinate_System_Definition:**
Altitude_System_Definition:
Altitude_Datum_Name: National Geodetic Vertical Datum of 1929
Altitude_Resolution:
Altitude_Distance_Units: feet
Altitude_Encoding_Method: Implicit coordinate

**DISTRIBUTION_INFORMATION**

**Resource_Description:**
mttabor_east_nav_water.shp

**Additional Metadata Specific to Mttabor_west_perm_water.shp**

**IDENTIFICATION_INFORMATION**

**Citation:**
Citation_Information:
Title: Mount Tabor West Half 7.5-minute Topographic Map Permanent Water

**Spatial_Domain:**
Bounding_Coordinates:
West_BoundingCoordinate: -122.6254
East_BoundingCoordinate: -122.5733
North_BoundingCoordinate: 45.6171
South_BoundingCoordinate: 45.5693

**Keywords:**
Place:
Place_Keyword: Clark County, Washington
Place_Keyword: Mount Tabor, Oregon-Washington;
Place_Keyword: Multnomah County, Oregon

**Native_Data_Set_Environment:**
ArcView version 3.2 shapefile format
c:\wvpm\mttabor_west\mttabor_west_perm_water.shp

**DATA_QUALITY_INFORMATION**

**Lineage:**
Source_Information:
Source_Citation:
Citation_Information:
Originator:
Publication_Date: 2002
Title: Mount Tabor Hydrography Shapefile
Edition:
Geospatial_Data_Presentation_Form: map
Publication_Information:
Publication_PLACE: Portland, Oregon
Publisher: US Army Corps of Engineers
Other_Citation_Details:
Originally digitized by the USGS form 7.5-minute topographic map.

**Online_Linkage:**
Larger_Work_Citation:
These hydrography shapefiles served as base maps for edits made to more closely reflect prehistoric conditions on the Columbia River floodplain.

**Process Step:**

**Process Description:**

**Source Used Citation Abbreviation:**

**Process Date:**

**Source Produced Citation Abbreviation:**

**Process Contact:**

**Contact Information:**

**Contact Person Primary:**

**Contact Organization:** US Army Corps of Engineers

**Contact Person:** Gregg Bertrand

**Contact Position:** Geographer

**Contact Address:**

**Address Type:** mailing and physical address

**Address:** 333 SE First Avenue

**City:** Portland

**State or Province:** Oregon

**Postal Code:** 97204

**Country:** USA

**Contact Voice Telephone:** 503.808.4859

**Contact Electronic Mail Address:** Gregg.M.Bertrand@nwp01.usace.army.mil

### SPATIAL_DATA_ORGANIZATION_INFORMATION

**Direct Spatial Reference Method:** Vector

**Point and Vector Object Information:**

**SDTS Terms Description:**

**SDTS Point and Vector Object Type:** Complete Chain

**Point and Vector Object Count:** 56

### SPATIAL_REFERENCE_INFORMATION

**Horizontal Coordinate System Definition:**
Planar:
Grid_Coordinate_System:
  Grid_Coordinate_System_Name: Universal Transverse Mercator
Universal_Transverse_Mercator:
  UTM_Zone_Number: 10
  Transverse_Mercator:
    Scale_Factor_at_Central_Meridian: 0.999600
    Longitude_of_Central_Meridian: -123.000000
    Latitude_of_Projection_Origin: 0.000000
    False_Easting: 500000.000000
    False_Northing: 0.000000
Planar_Coordinate_Information:
  Planar_Coordinate_Encoding_Method: Coordinate pair
  Coordinate_Representation:
    Abscissa_Resolution:
    Ordinate_Resolution:
    Planar_Distance_Units: Meters
Geodetic_Model:
  Horizontal_Datum_Name: North American Datum of 1927
  Ellipsoid_Name: Clarke 1866
  Semi-major_Axis: 6378206.400000
  Denominator_of_Flattening_Ratio: 294.98
Vertical_Coordinate_System_Definition:
  Altitude_System_Definition:
    Altitude_Datum_Name: National Geodetic Vertical Datum of 1929
    Altitude_Resolution:
    Altitude_Distance_Units: feet
    Altitude_Encoding_Method: Implicit coordinate

DISTRIBUTION_INFORMATION

Resource_Description:
  mttabor_west_perm_water.shp

Additional Metadata Specific to Mttabor_west_nav_water.shp

IDENTIFICATION_INFORMATION

Citation:
  Citation_Information:
    Title: Mount Tabor West Half 7.5-minute Topographic Map Navigable Water

Spatial_Domain:
  Bounding_Coordinates:
    West_Bounding_Coordinate: -122.6254
    East_Bounding_Coordinate: -122.5733
    North_Bounding_Coordinate: 45.6147
    South_Bounding_Coordinate: 45.5693

Keywords:
  Place:
    Place_Keyword: Clark County, Washington
    Place_Keyword: Mount Tabor, Oregon-Washington;
    Place_Keyword: Multnomah County, Oregon

Native_Data_Set_Environment:
DATA_QUALITY_INFORMATION

Lineage:
Source_Information:
Source_Citation:
  Citation_Information:
  Originator:
  Publication_Date: 2002
  Title: Mount Tabor Hydrography Shapefile
  Edition:
  Geospatial_Data_Presentation_Form: map
Publication_Information:
  Publication_Place: Portland, Oregon
  Publisher: US Army Corps of Engineers
Other_Citation_Details:
  Originally digitized by the USGS form 7.5-minute topographic map.
Online_Linkage:
Larger_Work_Citation:
  Citation_Information:
  Originator:
  Publication_Date:
  Title:
  Publication_Information:
    Publication_Place:
    Publisher:
  Online_Linkage:
Source_Scale_Denominator: 24,000
Type_of_Source_Media: paper
Source_Time_Period_of_Content:
  Time_Period_Information:
    Range_of_Dates/Times:
      Beginning_Date:
      Ending_Date:
    Source_Currentness_Reference: 2002
Source_Citation_Abbreviation:
Source_Contribution:
  These hydrography shapefiles served as base maps for edits made to more closely
  reflect prehistoric conditions on the Columbia River floodplain.
Process_Step:
Process_Description:
Source_Used_Citation_Abbreviation:
Process_Date:
Source_Produced_Citation_Abbreviation:
Process>Contact:
  Contact_Information:
    Contact_Person_Primary:
      Contact_Organization: US Army Corps of Engineers
      Contact_Person: Gregg Bertrand
    Contact_Position: Geographer
Contact_Address:
  Address_Type: mailing and physical address
  Address: 333 SE First Avenue
  City: Portland
  State_or_Province: Oregon
  Postal_Code: 97204
  Country: USA
  Contact_Voice_Telephone: 503.808.4859
  Contact_Electronic_Mail_Address: Gregg.M.Bertrand@nwp01.usace.army.mil

SPATIAL_DATA_ORGANIZATION_INFORMATION

Direct_Spatial_Reference_Method: Vector
Point_and_Vector_Object_Information:
  SDTS_Terms_Description:
    SDTS_Point_and_Vector_Object_Type: Complete Chain
    Point_and_Vector_Object_Count: 37

SPATIAL_REFERENCE_INFORMATION

Horizontal_Coordinate_System_Definition:
  Planar:
    Grid_Coordinate_System:
      Grid_Coordinate_System_Name: Universal Transverse Mercator
    Universal_Transverse_Mercator:
      UTM_Zone_Number: 10
    Transverse_Mercator:
      Scale_Factor_at_Central_Meridian: 0.999600
      Longitude_of_Central_Meridian: -123.000000
      Latitude_of_Projection_Origin: 0.000000
      False_Easting: 500000.000000
      False_Northing: 0.000000
  Planar_Coordinate_Information:
    Planar_Coordinate_Encoding_Method: Coordinate pair
    Coordinate_Representation:
      Abscissa_Resolution:
      Ordinate_Resolution:
    Planar_Distance_Units: Meters
  Geodetic_Model:
    Horizontal_Datum_Name: North American Datum of 1927
    Ellipsoid_Name: Clarke 1866
    Semi-major_Axis: 6378206.400000
    Denominator_of_Flattening_Ratio: 294.98

Vertical_Coordinate_System_Definition:
  Altitude_System_Definition:
    Altitude_Datum_Name: National Geodetic Vertical Datum of 1929
    Altitude_Resolution:
    Altitude_Distance_Units: feet
    Altitude_Encoding_Method: Implicit coordinate

DISTRIBUTION_INFORMATION

Resource_Description:
Additional Metadata Specific to Portland_perm_water.shp

IDENTIFICATION_INFORMATION

Citation:
Citation_Information:
  Title: Portland 7.5-minute Topographic Map Permanent Water

Spatial_Domain:
Bounding_Coordinates:
  West_Bounding_Coordinate: -122.7503
  East_Bounding_Coordinate: -122.6247
  North_Bounding_Coordinate: 45.6252
  South_Bounding_Coordinate: 45.5757

Keywords:
Place:
  Place_Keyword: Clark County, Washington
  Place_Keyword: Multnomah County, Oregon
  Place_Keyword: Portland, Oregon-Washington

Native_Data_Set_Environment:
  ArcView version 3.2 shapefile format
c:\wvpm\portland\portland_perm_water.shp

DATA_QUALITY_INFORMATION

Lineage:
Source_Information:
  Source_Citation:
    Citation_Information:
      Originator: Ducks Unlimited, Inc.
      Publication_Date: 20000407
      Title: Hydro24 Shapefile
      Edition:
      Geospatial_Data_Presentation_Form: map
    Publication_Information:
      Publication_Place: Portland, Oregon
      Publisher: US Fish and Wildlife Service
    Other_Citation_Details:
      Prepared for the US Fish and Wildlife Service by Ducks Unlimited, Inc. Originally
digitized by the USGS from 7.5-minute topographic map.

Online_Linkage:
Larger_Work_Citation:
  Citation_Information:
    Originator: Ducks Unlimited, Inc.
    Publication_Date: 20000407
    Title: Ridgefield Complex NWR GIS Database
    Publication_Information:
      Publication_Place: Portland, Oregon
      Publisher: US Fish and Wildlife Service
    Online_Linkage:
Source_Scale_Denominator: 24,000
Type_of_Source_Media: paper
These hydrography shapefiles served as base maps for edits made to more closely reflect prehistoric conditions on the Columbia River floodplain.

**Process Step:**

**Source Used Citation Abbreviation:**

**Process Date:**

**Source Produced Citation Abbreviation:**

**Process Contact:**

**Contact Information:**

- **Contact Person Primary:**
  - **Contact Organization:** US Fish and Wildlife Service-RPL
  - **Contact Person:** David Hoy

**Contact Address:**

- **Address Type:** mailing and physical address
- **Address:** 911 NE 11th Avenue
- **City:** Portland
- **State or Province:** Oregon
- **Postal Code:** 97232-4181
- **Country:** USA
- **Contact Voice Telephone:** 503.231.2230
- **Contact Electronic Mail Address:** david_hoy@fws.gov

**SPATIAL_DATA_ORGANIZATION_INFORMATION**

**Direct Spatial Reference Method:** Vector

**Point and Vector Object Information:**

- **SDTS Terms Description:**
  - **SDTS Point and Vector Object Type:** Complete Chain
  - **Point and Vector Object Count:** 134

**SPATIAL_REFERENCE_INFORMATION**

**Horizontal Coordinate System Definition:**

- **Planar:**
  - **Grid Coordinate System:**
    - **Grid Coordinate System Name:** Universal Transverse Mercator
  - **Universal Transverse Mercator:**
    - **UTM Zone Number:** 10
    - **Transverse Mercator:**
      - **Scale Factor at Central Meridian:** 0.999600
      - **Longitude of Central Meridian:** -123.000000
      - **Latitude of Projection Origin:** 0.000000
      - **False Easting:** 500000.000000
False_Northing: 0.000000
Planar_Coordinate_Information:
  Planar_Coordinate_Encoding_Method: Coordinate pair
  Coordinate_Representation:
    Abscissa_Resolution:
    Ordinate_Resolution:
  Planar_Distance_Units: Meters
Geodetic_Model:
  Horizontal_Datum_Name: North American Datum of 1927
  Ellipsoid_Name: Clarke 1866
  Semi-major_Axis: 6378206.4000000
  Denominator_of_Flattening_Ratio: 294.98

Vertical_Coordinate_System_Definition:
  Altitude_System_Definition:
    Altitude_Datum_Name: National Geodetic Vertical Datum of 1929
  Altitude_Resolution:
  Altitude_Distance_Units: feet
  Altitude_Encoding_Method: Implicit coordinate

DISTRIBUTION_INFORMATION

  Resource_Description:
    portland_perm_water.shp

Additional Metadata Specific to Portland_nav_water.shp

IDENTIFICATION_INFORMATION

  Citation:
    Citation_Information:
      Title: Portland 7.5-minute Topographic Map Navigable Water

  Spatial_Domain:
    Bounding_Coordinates:
      West_BoundingCoordinate: -122.7503
      East_BoundingCoordinate: -122.6247
      North_BoundingCoordinate: 45.6252
      South_BoundingCoordinate: 45.5757

  Keywords:
    Place:
      Place_Keyword: Clark County, Washington
      Place_Keyword: Multnomah County, Oregon
      Place_Keyword: Portland, Oregon-Washington

Native_Data_Set_Environment:
  ArcView version 3.2 shapefile format
c:\wvpm\portland\portland_nav_water.shp

DATA_QUALITY_INFORMATION

  Lineage:
    Source_Information:
      Source_Citation:
        Citation_Information:
          Originator: Ducks Unlimited, Inc.
These hydrography shapefiles served as base maps for edits made to more closely reflect prehistoric conditions on the Columbia River floodplain.
SPATIAL_DATA_ORGANIZATION_INFORMATION

Direct_Spatial_Reference_Method: Vector
Point_and_Vector_Object_Information:
   SDTS_Terms_Description:
      SDTS_Point_and_Vector_Object_Type: Complete Chain
      Point_and_Vector_Object_Count: 66

SPATIAL_REFERENCE_INFORMATION

Horizontal_Coordinate_System_Definition:
   Planar:
      Grid_Coordinate_System:
         Grid_Coordinate_System_Name: Universal Transverse Mercator
         Universal_Transverse_Mercator:
            UTM_Zone_Number: 10
            Transverse_Mercator:
               Scale_Factor_at_Central_Meridian: 0.999600
               Longitude_of_Central_Meridian: -123.000000
               Latitude_of_Projection_Origin: 0.000000
               False_Easting: 500000.000000
               False_Northing: 0.000000
      Planar_Coordinate_Information:
         Planar_Coordinate_Encoding_Method: Coordinate pair
         Coordinate_Representation:
            Abscissa_Resolution:
            Ordinate_Resolution:
            Planar_Distance_Units: Meters
      Geodetic_Model:
         Horizontal_Datum_Name: North American Datum of 1927
         Ellipsoid_Name: Clarke 1866
         Semi-major_Axis: 6378206.400000
         Denominator_of_Flattening_Ratio: 294.98

Vertical_Coordinate_System_Definition:
   Altitude_System_Definition:
      Altitude_Datum_Name: National Geodetic Vertical Datum of 1929
      Altitude_Resolution:
      Altitude_Distance_Units: feet
      Altitude_Encoding_Method: Implicit coordinate

DISTRIBUTION_INFORMATION

Resource_Description:
   portland_nav_water.shp

Additional_Metadata_Specific_to_Linnton_perm_water.shp

IDENTIFICATION_INFORMATION

Citation:
   Citation_Information:
      Title: Linnton 7.5-minute Topographic Map Permanent Water

363
Spatial_Domain:
Bounding_Coordinates:
  West_BoundingCoordinate: -122.8136
  East_BoundingCoordinate: -122.7499
  North_BoundingCoordinate: 45.6251
  South_BoundingCoordinate: 45.6028
Keywords:
  Place:
    Place_Keyword: Linnton, Oregon
    Place_Keyword: Multnomah County, Oregon
Native_Data_Set_Environment:
  ArcView version 3.2 shapefile format
c:\wvpm\linnton\linnton_perm_water.shp

DATA_QUALITY_INFORMATION

Lineage:
Source_Information:
Source_Citation:
  Citation_Information:
    Originator: Ducks Unlimited, Inc.
    Publication_Date: 20000407
    Title: Hydro24 Shapefile
  Edition:
    Geospatial_Data_Presentation_Form: map
Publication_Information:
    Publication_Place: Portland, Oregon
    Publisher: US Fish and Wildlife Service
Other_Citation_Details:
    Prepared for the US Fish and Wildlife Service by Ducks Unlimited, Inc. Originally
digitized by the USGS from 7.5-minute topographic map.
Online_Linkage:
Larger_Work_Citation:
  Citation_Information:
    Originator: Ducks Unlimited, Inc.
    Publication_Date: 20000407
    Title: Ridgefield Complex NWR GIS Database
Publication_Information:
    Publication_Place: Portland, Oregon
    Publisher: US Fish and Wildlife Service
      Online_Linkage:
      Source_Scale_Denominator: 24,000
Type_of_Source_Media: paper
Source_Time_Period_of_Content:
  Time_Period_Information:
    Range_of_Dates/Times:
      Beginning_Date:
      Ending_Date: 20000407
Source_Currentness_Reference: publication date
Source_Citation_Abbreviation: hydro24
Source_Contribution:
  These hydrography shapefiles served as base maps for edits made to more closely
reflect prehistoric conditions on the Columbia River floodplain.

**Process Step:**

**Process Description:**

**Source Used Citation Abbreviation:**

**Process Date:**

**Source Produced Citation Abbreviation:**

**Process Contact:**

**Contact Information:**

**Contact Person Primary:**

**Contact Organization:** US Fish and Wildlife Service-RPL

**Contact Person:** David Hoy

**Contact Position:**

**Contact Address:**

**Address Type:** mailing and physical address

**Address:** 911 NE 11th Avenue

**City:** Portland

**State or Province:** Oregon

**Postal Code:** 97232-4181

**Country:** USA

**Contact Voice Telephone:** 503.231.2230

**Contact Electronic Mail Address:** david_hoy@fws.gov

**SPATIAL_DATA_ORGANIZATION_INFORMATION**

**Direct Spatial Reference Method:** Vector

**Point and Vector Object Information:**

**SDTS Terms Description:**

**SDTS Point and Vector Object Type:** Complete Chain

**Point and Vector Object Count:** 41

**SPATIAL_REFERENCE_INFORMATION**

**Horizontal Coordinate System Definition:**

**Planar:**

**Grid Coordinate System:**

**Grid Coordinate System Name:** Universal Transverse Mercator

**Universal Transverse Mercator:**

**UTM Zone Number:** 10

**Transverse Mercator:**

**Scale Factor at Central Meridian:** 0.999600

**Longitude of Central Meridian:** -123.000000

**Latitude of Projection Origin:** 0.000000

**False Easting:** 500000.000000

**False Northing:** 0.000000

**Planar Coordinate Information:**

**Planar Coordinate Encoding Method:** Coordinate pair

**Coordinate Representation:**

**Abscissa Resolution:**

**Ordinate Resolution:**

**Planar Distance Units:** Meters

**Geodetic Model:**

**Horizontal Datum Name:** North American Datum of 1927

365
Ellipsoid_Name: Clarke 1866
Semi-major_Axis: 6378206.400000
Denominator_of_Flattening_Ratio: 294.98

**Vertical_Coordinate_System_Definition:**
Altitude_System_Definition:
Altitude_Datum_Name: National Geodetic Vertical Datum of 1929
Altitude_Resolution:
Altitude_Distance_Units: feet
Altitude_Encoding_Method: Implicit coordinate

**DISTRIBUTION_INFORMATION**

*Resource_Description:*
linnton_perm_water.shp

**Additional_Metadata_Specific_to_Linnton_nav_water.shp**

**IDENTIFICATION_INFORMATION**

*Citation:*
Citation_Information:
Title: Linnton 7.5-minute Topographic Map Navigable Water

**Spatial_Domain:**
Bounding_Coordinates:
West_BoundingCoordinate: -122.8136
East_BoundingCoordinate: -122.7499
North_BoundingCoordinate: 45.6251
South_BoundingCoordinate: 45.6028

**Keywords:**
Place:
Place_Keyword: Linnton, Oregon
Place_Keyword: Multnomah County, Oregon

**Native_Data_Set_Environment:**
ArcView version 3.2 shapefile format
c:\wvpm\linnton\linnton_nav_water.shp

**DATA_QUALITY_INFORMATION**

*Lineage:*
Source_Information:
Source_Citation:
Citation_Information:
Originator: Ducks Unlimited, Inc.
Publication_Date: 20000407
Title: Hydro24 Shapefile
Edition:
Geospatial_Data_Presentation_Form: map
Publication_Information:
Publication_Place: Portland, Oregon
Publisher: US Fish and Wildlife Service
Other_Citation_Details:
Prepared for the US Fish and Wildlife Service by Ducks Unlimited, Inc. Originally digitized by the USGS from 7.5-minute topographic map.
These hydrography shapefiles served as base maps for edits made to more closely reflect prehistoric conditions on the Columbia River floodplain.

**Process Step:**

**Direct Spatial Reference Method:** Vector

**Point and Vector Object Information:**
- SDTS Terms Description:
- SDTS Point and Vector Object Type: Complete Chain
- Point and Vector Object Count: 20
Horizontal Coordinate System Definition:
Planar:
Grid Coordinate System:
  Grid Coordinate System Name: Universal Transverse Mercator
Universal Transverse Mercator:
  UTM Zone Number: 10
  Transverse Mercator:
    Scale Factor at Central Meridian: 0.999600
    Longitude of Central Meridian: -123.000000
    Latitude of Projection Origin: 0.000000
    False Easting: 500000.000000
    False Northing: 0.000000
Planar Coordinate Information:
  Planar Coordinate Encoding Method: Coordinate pair
  Coordinate Representation:
    Abscissa Resolution:
    Ordinate Resolution:
    Planar Distance Units: Meters
Geodetic Model:
  Horizontal Datum Name: North American Datum of 1927
  Ellipsoid Name: Clarke 1866
  Semi-major Axis: 6378206.400000
  Denominator of Flattening Ratio: 294.98

Vertical Coordinate System Definition:
Altitude System Definition:
  Altitude Datum Name: National Geodetic Vertical Datum of 1929
  Altitude Resolution:
  Altitude Distance Units: feet
  Altitude Encoding Method: Implicit coordinate

DISTRIBUTION INFORMATION

Resource Description:
  linnton_nav_water.shp

Additional Metadata Specific to Vancouver_perm_water.shp

IDENTIFICATION INFORMATION

Citation:
  Citation Information:
    Title: Vancouver 7.5-minute Topographic Map Permanent Water

Spatial Domain:
  Bounding Coordinates:
    West Bounding Coordinate: -122.7506
    East Bounding Coordinate: -122.6779
    North Bounding Coordinate: 45.7500
    South Bounding Coordinate: 45.6248

Keywords:
  Place:
    Place Keyword: Clark County, Washington
    Place Keyword: Multnomah County, Oregon
    Place Keyword: Vancouver, Washington-Oregon
Native_Data_Set_Environment:
ArcView version 3.2 shapefile format
c:\wvpm\vancouver\vancouver_perm_water.shp

DATA_QUALITY_INFORMATION

Lineage:
Source_Information:
Source_Citation:
Citation_Information:
Originator: Ducks Unlimited, Inc.
Publication_Date: 20000407
Title: Hydro24 Shapefile
Edition:
Geospatial_Data_Presentation_Form: map
Publication_Information:
Publication_Place: Portland, Oregon
Publisher: US Fish and Wildlife Service
Other_Citation_Details:
Prepared for the US Fish and Wildlife Service by Ducks Unlimited, Inc. Originally
digitized by the USGS from 7.5-minute topographic map.

Online_Linkage:
Larger_Work_Citation:
Citation_Information:
Originator: Ducks Unlimited, Inc.
Publication_Date: 20000407
Title: Ridgefield Complex NWR GIS Database
Publication_Information:
Publication_Place: Portland, Oregon
Publisher: US Fish and Wildlife Service

Source_Scale_Denominator: 24,000
Type_of_Source_Media: paper
Source_Time_Period_of_Content:
Time_Period_Information:
Range_of_Dates/Times:
Beginning_Date: 
Ending_Date: 20000407
Source_Currentness_Reference: publication date
Source_Citation_Abbreviation: hydro24
Source_Contribution:
These hydrography shapefiles served as base maps for edits made to more closely
reflect prehistoric conditions on the Columbia River floodplain.

Process_Step:
Process_Description:
Source_Used_Citation_Abbreviation:
Process_Date:
Source_Produced_Citation_Abbreviation:
Process_Contact:
Contact_Information:
Contact_Person_Primary:
Contact_Organization: US Fish and Wildlife Service-RPL
Contact Person: David Hoy
Contact Position:
Contact Address:
Address_Type: mailing and physical address
Address: 911 NE 11th Avenue
City: Portland
State_or_Province: Oregon
Postal_Code: 97232-4181
Country: USA
Contact_Voice_Telephone: 503.231.2230
Contact_Electronic_Mail_Address: david_hoy@fws.gov

SPATIAL_DATA_ORGANIZATION_INFORMATION

Direct_Spatial_Reference_Method: Vector
Point_and_Vector_Object_Information:
SDTS_Terms_Description:
SDTS_Point_and_Vector_Object_Type: Complete Chain
Point_and_Vector_Object_Count: 90

SPATIAL_REFERENCE_INFORMATION

Horizontal_Coordinate_System_Definition:
Planar:
Grid_Coordinate_System:
Grid_Coordinate_System_Name: Universal Transverse Mercator
Universal_Transverse_Mercator:
UTM_Zone_Number: 10
Transverse_Mercator:
Scale_Factor_at_Central_Meridian: 0.999600
Longitude_of_Central_Meridian: -123.000000
Latitude_of_Projection_Origin: 0.000000
False_Easting: 500000.000000
False_Northing: 0.000000
Planar_Coordinate_Information:
Planar_Coordinate_Encoding_Method: Coordinate pair
Coordinate_Representation:
Abscissa_Resolution:
Ordinate_Resolution:
Planar_Distance_Units: Meters
Geodetic_Model:
Horizontal_Datum_Name: North American Datum of 1927
Ellipsoid_Name: Clarke 1866
Semi-major_Axis: 6378206.400000
Denominator_of_Flattening_Ratio: 294.98

Vertical_Coordinate_System_Definition:
Altitude_System_Definition:
Altitude_Datum_Name: National Geodetic Vertical Datum of 1929
Altitude_Resolution:
Altitude_Distance_Units: feet
Altitude_Encoding_Method: Implicit coordinate

DISTRIBUTION_INFORMATION
**Resource_Description:**
vancouver_perm_water

**Additional Metadata Specific to Vancouver_nav_water.shp**

**IDENTIFICATION_INFORMATION**

**Citation:**
Citation_INFORMATION:
Title: Vancouver 7.5-minute Topographic Map Navigable Water

**Spatial_Domain:**
Bounding_Coordinates:
West_Bounding_Coordinate: -122.7506
East_Bounding_Coordinate: -122.6818
North_Bounding_Coordinate: 45.7500
South_Bounding_Coordinate: 45.6248

**Keywords:**
Place:
Place_Keyword: Clark County, Washington
Place_Keyword: Multnomah County, Oregon
Place_Keyword: Vancouver, Washington-Oregon

**Native_Data_Set_Environment:**
ArcView version 3.2 shapefile format
c:\wvpm\vancouver\vancouver_nav_water.shp

**DATA_QUALITY_INFORMATION**

**Lineage:**
Source_Information:
Source_Citation:
Citation_INFORMATION:
Originator: Ducks Unlimited, Inc.
Publication_Date: 20000407
Title: Hydro24 Shapefile
Edition:
Geospatial_Data_Presentation_Form: map
Publication_Information:
Publication_Place: Portland, Oregon
Publisher: US Fish and Wildlife Service
Other_Citation_Details:
Prepared for the US Fish and Wildlife Service by Ducks Unlimited, Inc. Originally digitized by the USGS from 7.5-minute topographic map.

**Online_Linkage:**
Larger_Work_Citation:
Citation Informationen:
Originator: Ducks Unlimited, Inc.
Publication_Date: 20000407
Title: Ridgefield Complex NWR GIS Database
Publication_Information:
Publication_Place: Portland, Oregon
Publisher: US Fish and Wildlife Service
Online_Linkage:
Source_Scale_Denominator: 24,000
These hydrography shapefiles served as base maps for edits made to more closely reflect prehistoric conditions on the Columbia River floodplain.

Process Step:
Source_Used_Citation_Abbreviation:
Process_Date:
Source_Produced_Citation_Abbreviation:
Process_Contact:
Contact_Information:
    Contact_Person_Primary:
        Contact_Organization: US Fish and Wildlife Service-RPL
        Contact_Person: David Hoy
        Contact_Position:
        Contact_Address:
            Address_Type: mailing and physical address
            Address: 911 NE 11th Avenue
            City: Portland
            State_or_Province: Oregon
            Postal_Code: 97232-4181
            Country: USA
            Contact_Voice_Telephone: 503.231.2230
            Contact_Electronic_Mail_Address: david_hoy@fws.gov

SPATIAL_DATA_ORGANIZATION_INFORMATION

Direct_Spatial_Reference_Method: Vector
Point_and_Vector_Object_Information:
    SDTS_Terms_Description:
        SDTS_Point_and_Vector_Object_Type: Complete Chain
        Point_and_Vector_Object_Count: 51

SPATIAL_REFERENCE_INFORMATION

HorizontalCoordinateSystemDefinition:
Grid_Coordinate_System:
    Grid_Coordinate_System_Name: Universal Transverse Mercator
Universal_Transverse_Mercator:
    UTM_Zone_Number: 10
    Transverse_Mercator:
        Scale_Factor_at_Central_Meridian: 0.999600
        Longitude_of_Central_Meridian: -123.000000
        Latitude_of_Projection_Origin: 0.000000
False_Easting: 500000.000000
False_Northing: 0.000000
Planar_Coordinate_Information:
  Planar_Coordinate_Encoding_Method: Coordinate pair
  Coordinate_Representation:
    Abscissa_Resolution:
    Ordinate_Resolution:
    Planar_Distance_Units: Meters
Geodetic_Model:
  Horizontal_Datum_Name: North American Datum of 1927
  Ellipsoid_Name: Clarke 1866
  Semi-major_Axis: 6378206.400000
  Denominator_of_Flattening_Ratio: 294.98
Vertical_Coordinate_System_Definition:
  Altitude_System_Definition:
    Altitude_Datum_Name: National Geodetic Vertical Datum of 1929
    Altitude_Resolution:
    Altitude_Distance_Units: feet
    Altitude_Encoding_Method: Implicit coordinate

DISTRIBUTION_INFORMATION

  Resource_Description:
    vancouver_nav_water

Additional Metadata Specific to Sauvieisland_perm_water.shp

IDENTIFICATION_INFORMATION

  Citation:
    Citation_Information:
      Title: Sauvie Island 7.5-minute Topographic Map Permanent Water

  Spatial_Domain:
    Bounding_Coordinates:
      West_Bounding_Coordinate: -122.8750
      East_Bounding_Coordinate: -122.7495
      North_Bounding_Coordinate: 45.7502
      South_Bounding_Coordinate: 45.6249

  Keywords:
    Place:
      Place_Keyword: Clark County, Washington
      Place_Keyword: Columbia County, Oregon
      Place_Keyword: Multnomah County, Oregon
      Place_Keyword: Sauvie Island, Oregon-Washington

Native_Data_Set_Environment:
  ArcView version 3.2 shapefile format
c:\wvpm\sauvie_island\sauvieisland_perm_water.shp

DATA_QUALITY_INFORMATION

  Lineage:
    Source_Information:
      Source_Citation:
These hydrography shapefiles served as base maps for edits made to more closely reflect prehistoric conditions on the Columbia River floodplain.

**Process Step:**

**Process Description:**

**Source Used Citation Abbreviation:**

**Process Date:**

**Source Produced Citation Abbreviation:**

**Process Contact:**

**Contact Information:**

**Contact Person Primary:**

**Contact Organization:** US Fish and Wildlife Service-RPL

**Contact Person:** David Hoy

**Contact Position:**

**Contact Address:**

**Address Type:** mailing and physical address

**Address:** 911 NE 11th Avenue

**City:** Portland

**State or Province:** Oregon

**Postal Code:** 97232-4181

**Country:** USA
Spatial Data Organization Information

Direct Spatial Reference Method: Vector

Point and Vector Object Information:
- SDTS Terms Description:
- SDTS Point and Vector Object Type: Complete Chain
- Point and Vector Object Count: 321

Spatial Reference Information

Horizontal Coordinate System Definition:
- Planar:
  - Grid Coordinate System:
    - Grid Coordinate System Name: Universal Transverse Mercator
  - Universal Transverse Mercator:
    - UTM Zone Number: 10
    - Transverse Mercator:
      - Scale Factor at Central Meridian: 0.999600
      - Longitude of Central Meridian: -123.000000
      - Latitude of Projection Origin: 0.000000
      - False Easting: 500000.000000
      - False Northing: 0.000000
  - Planar Coordinate Information:
    - Planar Coordinate Encoding Method: Coordinate pair
    - Coordinate Representation:
      - Abscissa Resolution:
      - Ordinate Resolution:
      - Planar Distance Units: Meters
    - Geodetic Model:
      - Horizontal Datum Name: North American Datum of 1927
      - Ellipsoid Name: Clarke 1866
      - Semi-major Axis: 6378206.400000
      - Denominator of Flattening Ratio: 294.98

Vertical Coordinate System Definition:
- Altitude System Definition:
  - Altitude Datum Name: National Geodetic Vertical Datum of 1929
  - Altitude Resolution:
  - Altitude Distance Units: feet
  - Altitude Encoding Method: Implicit coordinate

Distribution Information

Resource Description:
- sauvieisland_perm_water.shp

Additional Metadata Specific to Sauvieisland_nav_water.shp

Identification Information

Citation:
- Citation Information:
Title: Sauvie Island 7.5-minute Topographic Map Navigable Water

Spatial_Domain:
Bounding_Coordinates:
  West_Bounding_Coordinate: -122.8689
  East_Bounding_Coordinate: -122.7495
  North_Bounding_Coordinate: 45.7502
  South_Bounding_Coordinate: 45.6249

Keywords:
Place:
  Place_Keyword: Clark County, Washington
  Place_Keyword: Columbia County, Oregon
  Place_Keyword: Multnomah County, Oregon
  Place_Keyword: Sauvie Island, Oregon-Washington

Native_Data_Set_Environment:
  ArcView version 3.2 shapefile format
c:\wvpm\sauvie_island\sauvieisland_nav_water.shp

DATA_QUALITY_INFORMATION

Lineage:
Source_Information:
  Source_Citation:
    Citation_Information:
      Originator: Ducks Unlimited, Inc.
      Publication_Date: 20000407
      Title: Hydro24 Shapefile
    Edition:
      Geospatial_Data_Presentation_Form: map
    Publication_Information:
      Publication_Place: Portland, Oregon
      Publisher: US Fish and Wildlife Service
    Other_Citation_Details:
      Prepared for the US Fish and Wildlife Service by Ducks Unlimited, Inc. Originally
digitized by the USGS from 7.5-minute topographic map.

Online_Linkage:

Larger_Work_Citation:
  Citation_Information:
    Originator: Ducks Unlimited, Inc.
    Publication_Date: 20000407
    Title: Ridgefield Complex NWR GIS Database
  Publication_Information:
    Publication_Place: Portland, Oregon
    Publisher: US Fish and Wildlife Service
  Online_Linkage:

Source_Scale_Denominator: 24,000
Type_of_Source_Media: paper
Source_Time_Period_of_Content:
  Time_Period_Information:
    Range_of_Dates/Times:
      Beginning_Date:
      Ending_Date: 20000407
    Source_Currentness_Reference: publication date
These hydrography shapefiles served as base maps for edits made to more closely reflect prehistoric conditions on the Columbia River floodplain.

**Process Step:**

**Process Description:**

**Source Used Citation Abbreviation:**

**Process Date:**

**Source Produced Citation Abbreviation:**

**Process Contact:**

**Contact Information:**

- **Contact Person Primary:**
  - **Contact Organization:** US Fish and Wildlife Service-RPL
  - **Contact Person:** David Hoy
  - **Contact Position:**
  - **Contact Address:**
    - **Address Type:** mailing and physical address
    - **Address:** 911 NE 11th Avenue
    - **City:** Portland
    - **State or Province:** Oregon
    - **Postal Code:** 97232-4181
    - **Country:** USA
  - **Contact Voice Telephone:** 503.231.2230
  - **Contact Electronic Mail Address:** david_hoy@fws.gov

**SPATIAL DATA ORGANIZATION INFORMATION**

**Direct Spatial Reference Method:** Vector

**SDTS Terms Description:**

- **SDTS Point and Vector Object Type:** Complete Chain
- **Point and Vector Object Count:** 120

**SPATIAL REFERENCE INFORMATION**

**Horizontal Coordinate System Definition:**

**Planar:**

- **Grid Coordinate System:**
  - **Grid Coordinate System Name:** Universal Transverse Mercator
- **Universal Transverse Mercator:**
  - **UTM Zone Number:** 10
  - **Scale Factor at Central Meridian:** 0.999600
  - **Longitude of Central Meridian:** -123.000000
  - **Latitude of Projection Origin:** 0.000000
  - **False Easting:** 500000.000000
  - **False Northing:** 0.000000

**Planar Coordinate Information:**

- **Planar Coordinate Encoding Method:** Coordinate pair
- **Coordinate Representation:**
  - **Abscissa Resolution:**
  - **Ordinate Resolution:**
Planar_Distance_Units: Meters
Geodetic_Model:
Horizontal_Datum_Name: North American Datum of 1927
Ellipsoid_Name: Clarke 1866
Semi-major_Axis: 6378206.4000000
Denominator_of_Flattening_Ratio: 294.98

**Vertical_Coordinate_System_Definition:**
Altitude_System_Definition:
Altitude_Datum_Name: National Geodetic Vertical Datum of 1929
Altitude_Resolution:
Altitude_Distance_Units: feet
Altitude_Encoding_Method: Implicit coordinate

**DISTRIBUTION_INFORMATION**

**Resource_Description:**

sauvieisland_nav_water.shp

**Additional Metadata Specific to Ridgefield_perm_water.shp**

**IDENTIFICATION_INFORMATION**

**Citation:**
Citation_Information:
Title: Ridgefield 7.5-minute Topographic Map Permanent Water

**Spatial_Domain:**
Bounding_Coordinates:
West_Bounding_Coordinate: -122.7505
East_Bounding_Coordinate: -122.7163
North_Bounding_Coordinate: 45.8751
South_Bounding_Coordinate: 45.7499
Place:
Place_Keyword: Clark County, Washington
Place_Keyword: Ridgefield, Washington

**Native_Data_Set_Environment:**
ArcView version 3.2 shapefile format
c:\wvpm\ridgefield\ridgefield_perm_water.shp

**DATA_QUALITY_INFORMATION**

**Lineage:**
Source_Information:
Source_Citation:
Citation_Information:
Originator: Ducks Unlimited, Inc.
Publication_Date: 20000407
Title: Hydro24 Shapefile
Edition:
Geospatial_Data_Presentation_Form: map
Publication_Information:
Publication.Place: Portland, Oregon
Publisher: US Fish and Wildlife Service
Other_Citation_Details:
These hydrography shapefiles served as base maps for edits made to more closely reflect prehistoric conditions on the Columbia River floodplain.
SPATIAL_REFERENCE_INFORMATION

**Horizontal_Coordinate_System_Definition:**

*Planar:*
  *Grid_Coordinate_System:*
    *Grid_Coordinate_System_Name: Universal Transverse Mercator*
  *Universal_Transverse_Mercator:*
    *UTM_Zone_Number: 10*
  *Transverse_Mercator:*
    *Scale_Factor_at_Central_Meridian: 0.999600*
    *Longitude_of_Central_Meridian: -123.000000*
    *Latitude_of_Projection_Origin: 0.000000*
    *False_Easting: 500000.000000*
    *False_Northing: 0.000000*

*Planar_Coordinate_Information:*
  *Planar_Coordinate_Encoding_Method: Coordinate pair*
  *Coordinate_Representation:*
    *Abscissa_Resolution:*
    *Ordinate_Resolution:*
    *Planar_Distance_Units: Meters*

*Geodetic_Model:*
  *Horizontal_Datum_Name: North American Datum of 1927*
  *Ellipsoid_Name: Clarke 1866*
  *Semi-major_Axis: 6378206.400000*
  *Denominator_of_Flattening_Ratio: 294.98*

**Vertical_Coordinate_System_Definition:**

*Altitude_System_Definition:*
  *Altitude_Datum_Name: National Geodetic Vertical Datum of 1929*
  *Altitude_Resolution:*
  *Altitude_Distance_Units: feet*
  *Altitude_Encoding_Method: Implicit coordinate*

DISTRIBUTION_INFORMATION

**Resource_Description:**

ridgefield_perm_water.shp

Additional Metadata Specific to Ridgefield_nav_water.shp

IDENTIFICATION_INFORMATION

**Citation:**

Citation_Information:
  *Title: Ridgefield 7.5-minute Topographic Map Navigable Water*

**Spatial_Domain:**

Bounding_Coordinates:
  *West_Bounding_Coordinate: -122.7505*
  *East_Bounding_Coordinate: -122.7163*
  *North_Bounding_Coordinate: 45.8751*
  *South_Bounding_Coordinate: 45.7499*

**Keywords:**

Place:
  *Place_Keyword: Clark County, Washington*
DATA_QUALITY_INFORMATION

Lineage:

Source_Citation:
  Originator: Ducks Unlimited, Inc.
  Publication_Date: 20000407
  Title: Hydro24 Shapefile
  Edition:
  Geospatial_Data_Presentation_Form: map
  Publication_Info:
    Publication_Place: Portland, Oregon
    Publisher: US Fish and Wildlife Service
  Other_Citation_Details:
    Prepared for the US Fish and Wildlife Service by Ducks Unlimited, Inc. Originally
digitized by the USGS from 7.5-minute topographic map.

Online_Linkage:
Larger_Work_Citation:
  Originator: Ducks Unlimited, Inc.
  Publication_Date: 20000407
  Title: Ridgefield Complex NWR GIS Database
  Publication_Info:
    Publication_Place: Portland, Oregon
    Publisher: US Fish and Wildlife Service
  Online_Linkage:
Source_Scale_Denominator: 24,000
Type_of_Source_Media: paper
Source_Time_Period_of_Content:
  Time_Period_Info:
    Range_of_Dates/Times:
      Beginning_Date:
      Ending_Date: 20000407
    Source_Currentness_Reference: publication date
Source_Citation_Abbreviation: hydro24
Source_Contribution:
  These hydrography shapefiles served as base maps for edits made to more closely
reflect prehistoric conditions on the Columbia River floodplain.

Process_Step:

Process_Description:
Source_Used_Citation_Abbreviation:
Process_Date:
Source_Produced_Citation_Abbreviation:
Process_Contact:
  Contact_Information:
    Contact_Person_Primary:
Contact Organization: US Fish and Wildlife Service-RPL
Contact Person: David Hoy
Contact Position:
Contact Address:
Address Type: mailing and physical address
Address: 911 NE 11th Avenue
City: Portland
State or Province: Oregon
Postal Code: 97232-4181
Country: USA
Contact Voice Telephone: 503.231.2230
Contact Electronic Mail Address: david_hoy@fws.gov

SPATIAL_DATA_ORGANIZATION_INFORMATION

Direct_Spatial_Reference_Method: Vector

Point and Vector Object Information:
SDTS_Terms_Description:
SDTS_Point_and_Vector_Object_Type: Complete Chain
Point_and_Vector_Object_Count: 22

SPATIAL_REFERENCE_INFORMATION

Horizontal Coordinate System Definition:
Planar:
Grid Coordinate System:
Grid Coordinate System Name: Universal Transverse Mercator
Universal Transverse Mercator:
UTM Zone Number: 10
Transverse Mercator:
Scale Factor at Central Meridian: 0.999600
Longitude of Central Meridian: -123.000000
Latitude of Projection Origin: 0.000000
False Easting: 500000.000000
False Northing: 0.000000

Planar Coordinate Information:
Planar Coordinate Encoding Method: Coordinate pair
Coordinate Representation:
Abscissa Resolution:
Ordinate Resolution:
Planar Distance Units: Meters

Geodetic Model:
Horizontal Datum Name: North American Datum of 1927
Ellipsoid Name: Clarke 1866
Semi-major Axis: 6378206.4000000
Denominator of Flattening Ratio: 294.98

Vertical Coordinate System Definition:
Altitude System Definition:
Altitude Datum Name: National Geodetic Vertical Datum of 1929
Altitude Resolution:
Altitude Distance Units: feet
Altitude Encoding Method: Implicit coordinate
DISTRIBUTION_INFORMATION

Resource_Description:
ridgefield_nav_water.shp

Additional Metadata Specific to Sainthelens_perm_water.shp

IDENTIFICATION_INFORMATION

Citation:
Citation Information:
Title: Saint Helens 7.5-minute Topographic Map Permanent Water

Spatial_Domain:
Bounding_Coordinates:
West_BoundingCoordinate: -122.8751
East_BoundingCoordinate: -122.7494
North_BoundingCoordinate: 45.8751
South_BoundingCoordinate: 45.7498

Keywords:
Place:
Place_Keyword: Clark County, Washington
Place_Keyword: Columbia County, Oregon
Place_Keyword: Saint Helens, Oregon-Washington

Native_Data_Set_Environment:
ArcView version 3.2 shapefile format
c:\wvpm\saint_helens\sainthelens_perm_water.shp

DATA_QUALITY_INFORMATION

Lineage:
Source_Information:
Source_Citation:
Citation Information:
Originator: Ducks Unlimited, Inc.
Publication_Date: 20000407
Title: Hydro24 Shapefile
Edition:
Geospatial_Data_Presentation_Form: map
Publication_Information:
Publication Place: Portland, Oregon
Publisher: US Fish and Wildlife Service
Other_Citation_Details:
Prepared for the US Fish and Wildlife Service by Ducks Unlimited, Inc. Originally
digitized by the USGS from 7.5-minute topographic map.

Online_Linkage:
Larger_Work_Citation:
Citation Information:
Originator: Ducks Unlimited, Inc.
Publication_Date: 20000407
Title: Ridgefield Complex NWR GIS Database
Publication_Information:
Publication Place: Portland, Oregon
Publisher: US Fish and Wildlife Service
These hydrography shapefiles served as base maps for edits made to more closely reflect prehistoric conditions on the Columbia River floodplain.

**Process Step:**

**Source Used Citation Abbreviation:**

**Process Date:**

**Source Produced Citation Abbreviation:**

**Process Contact:**

**Contact Information:**

**Contact Person Primary:**

**Contact Organization:** US Fish and Wildlife Service-RPL

**Contact Person:** David Hoy

**Contact Position:**

**Contact Address:**

**Address Type:** mailing and physical address

**Address:** 911 NE 11th Avenue

**City:** Portland

**State or Province:** Oregon

**Postal Code:** 97232-4181

**Country:** USA

**Contact Voice Telephone:** 503.231.2230

**Contact Electronic Mail Address:** david_hoy@fws.gov

**Spatial Data Organization Information**

**Direct Spatial Reference Method:** Vector

**Point and Vector Object Information:**

**SDTS Terms Description:**

**SDTS Point and Vector Object Type:** Complete Chain

**Point and Vector Object Count:** 408

**Spatial Reference Information**

**Horizontal Coordinate System Definition:**

**Planar:**

**Grid Coordinate System:**

**Grid Coordinate System Name:** Universal Transverse Mercator

**Universal Transverse Mercator:**

**UTM Zone Number:** 10

**Transverse Mercator:**

**Scale Factor at Central Meridian:** 0.999600
Longitude of Central Meridian: -123.000000
Latitude of Projection Origin: 0.000000
False Easting: 500000.000000
False Northing: 0.000000

Planar Coordinate Information:
    Planar Coordinate Encoding Method: Coordinate pair
    Coordinate Representation:
        Abscissa Resolution:
        Ordinate Resolution:
        Planar Distance Units: Meters

Geodetic Model:
    Horizontal Datum Name: North American Datum of 1927
    Ellipsoid Name: Clarke 1866
    Semi-major Axis: 6378206.400000
    Denominator of Flattening Ratio: 294.98

Vertical Coordinate System Definition:
    Altitude System Definition:
        Altitude Datum Name: National Geodetic Vertical Datum of 1929
        Altitude Resolution:
        Altitude Distance Units: feet
        Altitude Encoding Method: Implicit coordinate

DISTRIBUTION INFORMATION

Resource Description:
sainthelens_perm_water.shp

Additional Metadata Specific to Sainthelens_nav_water.shp

IDENTIFICATION INFORMATION

Citation:
    Citation Information:
        Title: Saint Helens 7.5-minute Topographic Map Navigable Water

Spatial Domain:
    Bounding Coordinates:
        West Bounding Coordinate: -122.8606
        East Bounding Coordinate: -122.7494
        North Bounding Coordinate: 45.8751
        South Bounding Coordinate: 45.7498

Keywords:
    Place:
        Place Keyword: Clark County, Washington
        Place Keyword: Columbia County, Oregon
        Place Keyword: Saint Helens, Oregon-Washington

Native Data Set Environment:
    ArcView version 3.2 shapefile format
c:\wvpm\saint_helens\sainthelens_nav_water.shp

DATA QUALITY INFORMATION

Lineage:
    Source Information:
These hydrography shapefiles served as base maps for edits made to more closely reflect prehistoric conditions on the Columbia River floodplain.
Postal Code: 97232-4181
Country: USA
Contact Voice Telephone: 503.231.2230
Contact Electronic Mail Address: david_hoy@fws.gov

SPATIAL_DATA_ORGANIZATION_INFORMATION

Direct_Spatial_Reference_Method: Vector
Point_and_Vector_Object_Information:
SDTS_Terms_Description:
  SDTS_Point_and_Vector_Object_Type: Complete Chain
  Point_and_Vector_Object_Count: 146

SPATIAL_REFERENCE_INFORMATION

Horizontal_Coordinate_System_Definition:
  Planar:
    Grid_Coordinate_System:
      Grid_Coordinate_System_Name: Universal Transverse Mercator
      Universal_Transverse_Mercator:
        UTM_Zone_Number: 10
    Transverse_Mercator:
      Scale_Factor_at_Central_Meridian: 0.999600
      Longitude_of_Central_Meridian: -123.000000
      Latitude_of_Projection_Origin: 0.000000
      False_Easting: 500000.000000
      False_Northing: 0.000000
    Planar_Coordinate_Information:
      Planar_Coordinate_Encoding_Method: Coordinate pair
      Coordinate_Representation:
        Abscissa_Resolution:
        Ordinate_Resolution:
        Planar_Distance_Units: Meters
    Geodetic_Model:
      Horizontal_Datum_Name: North American Datum of 1927
      Ellipsoid_Name: Clarke 1866
      Semi-major_Axis: 6378206.400000
      Denominator_of_Flattening_Ratio: 294.98

Vertical_Coordinate_System_Definition:
  Altitude_System_Definition:
    Altitude_Datum_Name: National Geodetic Vertical Datum of 1929
    Altitude_Resolution:
    Altitude_Distance_Units: feet
    Altitude_Encoding_Method: Implicit coordinate

DISTRIBUTION_INFORMATION

Resource_Description:
  sainthelens_nav_water.shp

Additional Metadata Specific to Woodland_perm_water.shp

IDENTIFICATION_INFORMATION
Citation:
Citation Information:
Title: Woodland 7.5-minute Topographic Map Permanent Water

Spatial Domain:
Bounding Coordinates:
West_BoundingCoordinate: -122.7502
East_BoundingCoordinate: -122.7222
North_BoundingCoordinate: 45.9312
South_BoundingCoordinate: 45.8750

Keywords:
Place:
Place_Keyword: Clark County, Washington
Place_Keyword: Cowlitz County, Washington
Place_Keyword: Woodland, Washington

Native Data Set Environment:
ArcView version 3.2 shapefile format
c:\wvpm\woodland\woodland_perm_water.shp

DATA QUALITY INFORMATION

Lineage:
Source Information:
Source Citation:
Citation Information:
Originator: Ducks Unlimited, Inc.
Publication Date: 20000407
Title: Hydro24 Shapefile
Edition:
Geospatial Data Presentation Form: map
Publication Information:
Publication Place: Portland, Oregon
Publisher: US Fish and Wildlife Service
Other Citation Details:
Prepared for the US Fish and Wildlife Service by Ducks Unlimited, Inc. Originally digitized by the USGS from 7.5-minute topographic map.

Online Linkage:
Larger Work Citation:
Citation Information:
Originator: Ducks Unlimited, Inc.
Publication Date: 20000407
Title: Ridgefield Complex NWR GIS Database
Publication Information:
Publication Place: Portland, Oregon
Publisher: US Fish and Wildlife Service
Online Linkage:
Source Scale Denominator: 24,000
Type of Source Media: paper
Source Time Period of Content:
Time Period Information:
Range of Dates/Times:
Beginning Date:
Ending Date: 20000407
These hydrography shapefiles served as base maps for edits made to more closely reflect prehistoric conditions on the Columbia River floodplain.

**Process Step:**

**Process Description:**

**Source Used Citation Abbreviation:**

**Process Date:**

**Source Produced Citation Abbreviation:**

**Process Contact:**

**Contact Information:**

**Contact Person Primary:**

**Contact Organization:** US Fish and Wildlife Service-RPL

**Contact Person:** David Hoy

**Contact Position:**

**Contact Address:**

**Address Type:** mailing and physical address

**Address:** 911 NE 11th Avenue

**City:** Portland

**State or Province:** Oregon

**Postal Code:** 97232-4181

**Country:** USA

**Contact Voice Telephone:** 503.231.2230

**Contact Electronic Mail Address:** david_hoy@fws.gov

**SPATIAL_DATA_ORGANIZATION_INFORMATION**

**Direct Spatial Reference Method:** Vector

**SDTS Terms Description:**

**SDTS Point and Vector Object Type:** Complete Chain

**Point and Vector Object Count:** 18

**SPATIAL_REFERENCE_INFORMATION**

**Horizontal Coordinate System Definition:**

**Planar:**

**Grid Coordinate System:**

**Grid Coordinate System Name:** Universal Transverse Mercator

**Universal Transverse Mercator:**

**UTM Zone Number:** 10

**Transverse Mercator:**

**Scale Factor at Central Meridian:** 0.999600

**Longitude of Central Meridian:** -123.000000

**Latitude of Projection Origin:** 0.000000

**False Easting:** 500000.000000

**False Northing:** 0.000000

**Planar Coordinate Information:**

**Planar Coordinate Encoding Method:** Coordinate pair

**Coordinate Representation:**

**Abscissa Resolution:**
Ordinate Resolution: Planar Distance Units: Meters
Geodetic Model:
Horizontal Datum Name: North American Datum of 1927
Ellipsoid Name: Clarke 1866
Semi-major Axis: 6378206.400000
Denominator of Flattening Ratio: 294.98

Vertical Coordinate System Definition:
Altitude System Definition:
Altitude Datum Name: National Geodetic Vertical Datum of 1929
Altitude Resolution:
Altitude Distance Units: feet
Altitude Encoding Method: Implicit coordinate

DISTRIBUTION INFORMATION

Resource Description:
woodland_perm_water.shp

Additional Metadata Specific to Woodland_nav_water.shp

IDENTIFICATION INFORMATION

Citation:
Citation Information:
Title: Woodland 7.5-minute Topographic Map Navigable Water

Spatial Domain:
Bounding Coordinates:
West Bounding Coordinate: -122.7489
East Bounding Coordinate: -122.7223
North Bounding Coordinate: 45.9167
South Bounding Coordinate: 45.8750

Keywords:
Place:
Place Keyword: Clark County, Washington
Place Keyword: Cowlitz County, Washington
Place Keyword: Woodland, Washington;

Native Data Set Environment:
ArcView version 3.2 shapefile format
c:\wvpm\woodland\woodland_nav_water.shp

DATA QUALITY INFORMATION

Lineage:
Source Information:
Source Citation:
Citation Information:
Originator: Ducks Unlimited, Inc.
Publication Date: 20000407
Title: Hydro24 Shapefile
Edition:
Geospatial Data Presentation Form: map
Publication Information:
These hydrography shapefiles served as base maps for edits made to more closely reflect prehistoric conditions on the Columbia River floodplain.

**Process Step:**

**Source Used Citation Abbreviation:**

**Process Date:**

**Source Produced Citation Abbreviation:**

**Process Contact:**

**Contact Information:**

**Contact Person Primary:**

**Contact Organization:** US Fish and Wildlife Service-RPL

**Contact Person:** David Hoy

**Contact Position:**

**Contact Address:**

**Address Type:** mailing and physical address

**Address:** 911 NE 11th Avenue

**City:** Portland

**State or Province:** Oregon

**Postal Code:** 97232-4181

**Country:** USA

**Contact Voice Telephone:** 503.231.2230

**Contact Electronic Mail Address:** david_hoy@fws.gov

**Spatial Data Organization Information**

**Direct Spatial Reference Method:** Vector

**Point and Vector Object Information:**
SDTS_Terms_Description:
SDTS_Point_and_Vector_Object_Type: Complete Chain
Point_and_Vector_Object_Count: 8

SPATIAL_REFERENCE_INFORMATION

Horizontal_Coordinate_System_Definition:
Planar:
Grid_Coordinate_System:
Grid_Coordinate_System_Name: Universal Transverse Mercator
Universal_Transverse_Mercator:
UTM_Zone_Number: 10
Transverse_Mercator:
Scale_Factor_at_Central_Meridian: 0.999600
Longitude_of_Central_Meridian: -123.000000
Latitude_of_Projection_Origin: 0.000000
False_Easting: 500000.000000
False_Northing: 0.000000
Planar_Coordinate_Information:
Planar_Coordinate_Encoding_Method: Coordinate pair
Coordinate_Representation:
Abscissa_Resolution:
Ordinate_Resolution:
Planar_Distance_Units: Meters
Geodetic_Model:
Horizontal_Datum_Name: North American Datum of 1927
Ellipsoid_Name: Clarke 1866
Semi-major_Axis: 6378206.400000
Denominator_of_Flattening_Ratio: 294.98

Vertical_Coordinate_System_Definition:
Altitude_System_Definition:
Altitude_Datum_Name: National Geodetic Vertical Datum of 1929
Altitude_Resolution:
Altitude_Distance_Units: feet
Altitude_Encoding_Method: Implicit coordinate

DISTRIBUTION_INFORMATION

Resource_Description:
woodland_nav_water.shp

Additional_Metadata_Specific_to_Deerisland_perm_water.shp

IDENTIFICATION_INFORMATION

Citation:
Citation_Information:
Title: Deer Island 7.5-minute Topographic Map Permanent Water

Spatial_Domain:
Bounding_Coordinates:
West_Bounding_Coordinate: -122.8750
East_Bounding_Coordinate: -122.7494
North_Bounding_Coordinate: 46.0001
South_Bounding_Coordinate: 45.8749

**Keywords:**
Place:
- Place_Keyword: Columbia County, Oregon
- Place_Keyword: Cowlitz County, Washington
- Place_Keyword: Deer Island Oregon-Washington

**Native_Data_Set_Environment:**
ArcView version 3.2 shapefile format
c:\wvpm\deer_island\deerisland_perm_water.shp

**DATA_QUALITY_INFORMATION**

**Lineage:**
Source_Information:
Source_Citation:
Citation_Information:
Originator: Ducks Unlimited, Inc.
Publication_Date: 20000407
Title: Hydro24 Shapefile
Edition:
Geospatial_Data_Presentation_Form: map
Publication_Information:
Publication_Date: Portland, Oregon
Publisher: US Fish and Wildlife Service
Other_Citation_Details:
Prepared for the US Fish and Wildlife Service by Ducks Unlimited, Inc. Originally digitized by the USGS from 7.5-minute topographic map.
Online_Linkage:
Larger_Work_Citation:
Citation_Information:
Originator: Ducks Unlimited, Inc.
Publication_Date: 20000407
Title: Ridgefield Complex NWR GIS Database
Publication_Information:
Publication_Date: Portland, Oregon
Publisher: US Fish and Wildlife Service
Online_Linkage:
Source_Scale_Denominator: 24,000
Type_of_Source_Media: paper
Source_Time_Period_of_Content:
Time_Period_Information:
Range_of_Dates/Times:
Beginning_Date: 20000407
Ending_Date: Source_Currentness_Reference: publication date
Source_Citation_Abbreviation: hydro24
Source_Contribution:
These hydrography shapefiles served as base maps for edits made to more closely reflect prehistoric conditions on the Columbia River floodplain.

**Process_Step:**
Process_Description:
Source_Used_Citation_Abbreviation:
Process_Date:
Source_Produced_Citation_Abbreviation:
Process_Contact:
  Contact_Information:
    Contact_Person_Primary:
      Contact_Organization: US Fish and Wildlife Service-RPL
      Contact_Person: David Hoy
    Contact_Position:
    Contact_Address:
      Address_Type: mailing and physical address
      Address: 911 NE 11th Avenue
      City: Portland
      State_or_Province: Oregon
      Postal_Code: 97232-4181
      Country: USA
      Contact_Voice_Telephone: 503.231.2230
      Contact_Electronic_Mail_Address: david_hoy@fws.gov

SPATIAL_DATA_ORGANIZATION_INFORMATION

Direct_Spatial_Reference_Method: Vector
Point_and_Vector_Object_Information:
  SDTS_Terms_Description:
    SDTS_Point_and_Vector_Object_Type: Complete Chain
    Point_and_Vector_Object_Count: 191

SPATIAL_REFERENCE_INFORMATION

Horizontal_Coordinate_System_Definition:
  Planar:
    Grid_Coordinate_System:
      Grid_Coordinate_System_Name: Universal Transverse Mercator
    Universal_Transverse_Mercator:
      UTM_Zone_Number: 10
      Transverse_Mercator:
        Scale_Factor_at_Central_Meridian: 0.999600
        Longitude_of_Central_Meridian: -123.000000
        Latitude_of_Projection_Origin: 0.000000
        False_Easting: 500000.000000
        False_Northing: 0.000000
    Planar_Coordinate_Information:
      Planar_Coordinate_Encoding_Method: Coordinate pair
      Coordinate_Representation:
        Abscissa_Resolution:
        Ordinate_Resolution:
      Planar_Distance_Units: Meters
    Geodetic_Model:
      Horizontal_Datum_Name: North American Datum of 1927
      Ellipsoid_Name: Clarke 1866
      Semi-major_Axis: 6378206.400000
      Denominator_of_Flattening_Ratio: 294.98

Vertical_Coordinate_System_Definition:
Altitude_System_Definition:
Altitude_Datum_Name: National Geodetic Vertical Datum of 1929
Altitude_Resolution:
Altitude_Distance_Units: feet
Altitude_Encoding_Method: Implicit coordinate

DISTRIBUTION_INFORMATION

Resource_Description:
deerisland_perm_water.shp

Additional Metadata Specific to Deerisland_nav_water.shp

IDENTIFICATION_INFORMATION

Citation:
Citation_Information:
Title: Deer Island 7.5-minute Topographic Map Navigable Water

Spatial_Domain:
Bounding_Coordinates:
West_Bounding_Coordinate: -122.8717
East_Bounding_Coordinate: -122.7771
North_Bounding_Coordinate: 46.0002
South_Bounding_Coordinate: 45.8750

Keywords:
Place:
Place_Keyword: Columbia County, Oregon
Place_Keyword: Cowlitz County, Washington
Place_Keyword: Deer Island Oregon-Washington

Native_Data_Set_Environment:
ArcView version 3.2 shapefile format
c:\wvpm\deer_island\deerisland_nav_water.shp

DATA_QUALITY_INFORMATION

Lineage:
Source_Information:
Source_Citation:
Citation_Information:
Originator: Ducks Unlimited, Inc.
Publication_Date: 20000407
Title: Hydro24 Shapefile
Edition:
Geospatial_Data_Presentation_Form: map
Publication_Information:
Publication Place: Portland, Oregon
Publisher: US Fish and Wildlife Service
Other_Citation_Details:
Prepared for the US Fish and Wildlife Service by Ducks Unlimited, Inc. Originally
digitized by the USGS from 7.5-minute topographic map.

Online_Linkage:
Larger_Work_Citation:
Citation_Information:
These hydrography shapefiles served as base maps for edits made to more closely reflect prehistoric conditions on the Columbia River floodplain.

**Process Step:**

Process Description:

Source Used Citation Abbreviation:

Process Date:

Source Produced Citation Abbreviation:

Process Contact:

Contact Information:

Contact Person Primary:

Contact Organization: US Fish and Wildlife Service-RPL

Contact Person: David Hoy

Contact Position:

Contact Address:

Address Type: mailing and physical address

Address: 911 NE 11th Avenue

City: Portland

State or Province: Oregon

Postal Code: 97232-4181

Country: USA

Contact Voice Telephone: 503.231.2230

Contact Electronic Mail Address: david_hoy@fws.gov

**SPATIAL_DATA_ORGANIZATION_INFORMATION**

Direct Spatial Reference Method: Vector

Point and Vector Object Information:

SDTS Terms Description:

SDTS Point and Vector Object Type: Complete Chain

Point and Vector Object Count: 39

**SPATIAL_REFERENCE_INFORMATION**

Horizontal Coordinate System Definition:

Planar:
Grid Coordinates System:
  Grid Coordinate System Name: Universal Transverse Mercator
Universal Transverse Mercator:
  UTM Zone Number: 10
  Transverse Mercator:
    Scale Factor at Central Meridian: 0.999600
    Longitude of Central Meridian: -123.000000
    Latitude of Projection Origin: 0.000000
    False Easting: 500000.000000
    False Northing: 0.000000
Planar Coordinate Information:
  Planar Coordinate Encoding Method: Coordinate pair
  Coordinate Representation:
    Abscissa Resolution:
    Ordinate Resolution:
    Planar Distance Units: Meters
Geodetic Model:
  Horizontal Datum Name: North American Datum of 1927
  Ellipsoid Name: Clarke 1866
  Semi-major Axis: 6378206.400000
  Denominator of Flattening Ratio: 294.98
Vertical Coordinate System Definition:
  Altitude System Definition:
    Altitude Datum Name: National Geodetic Vertical Datum of 1929
    Altitude Resolution:
    Altitude Distance Units: feet
    Altitude Encoding Method: Implicit coordinate

DISTRIBUTION INFORMATION

Resource Description:
  deerisland_nav_water.shp
REFERENCES CITED

Aldenderfer, Mark, and Herbert D. G. Maschner (editors)

Allen, Karen M. S., Stanton W. Green, and Ezra B. W. Zubrow (editors)

Altschul, Jeffrey H.

American Institute of Hydrology

Ames, Kenneth M.

Ames, Kenneth M. and Herbert D. G. Maschner
1999 Peoples of the Northwest Coast: Their Archaeology and Prehistory. Thames and Hudson, London.

Ames, Kenneth M., Cameron M. Smith, William L. Cornett, Elizabeth A. Sobel, Stephen C. Hamilton, John Wolf, and Doria Raetz

Anderson, David R., Dennis J. Sweeney, and Thomas A. Williams
1999 Statistics for Business and Economics. South-Western College, Cincinnati.

Beeson, M. H., T. L. Tolan, and I. P. Madin

Berreman, Joel V.

Bettinger, Robert L.


Binford, Lewis R.

Blukis Onat, Astrid R., Melissa Darby, Rachel J. Stallings, and George B. Bishop

Boas, Franz
1894 Chinook Texts. Smithsonian Institution Bureau of Ethnology, Washington DC.

Bonham-Carter, Graeme F.

Bourdeau, Alex C.

2002 Human Response to Eruption-Induced

Drennan, Robert D.

Ducks Unlimited, Inc.

Duncan, Richard B., and Kristen A. Beckman

Dunnell, Robert C., James C. Chatters, and Lawr V. Salo

Ebert, James I.

Ebert, James I., and Timothy A. Kohler

Ellis, David V., and John L. Fagan

Ellis, David V., and Douglas C. Wilson

Environmental Systems Research Institute

Foreman, Cam, and Dave Foreman

Fladmark, Knut R.

Franchère, Gabriel

Franklin, Jerry F., and C. T. Dyrness

Gaffney, V., and P. M. van Leusen

Garmin International

Garson, G. David

Gibbs, George

Gillings, M.

Green, George L.

Green, Samuel B., Neil J. Salkind, and Theresa M. Akey

Habeck, James R.

Hajda, Yvonne P.

Hansen, David T., G. James West, Barbara Simpson, and Pat Welch

Hamilton, Stephen C.

Hatz, Russell R.

Hibbs, Charles H., and Lester Ross

Hosmer, David W., and Stanley Lemeshow

Hudak, G. Joseph, Elizabeth Hobbs, Allyson Brooks, Carol Ann Sersland, and Crystal Phillips (editors)

Hunting, Marshall T., W. A. G. Bennett, Vaughn E. Livingston Jr., and Wayne S. Moen

Jenness, Jeff

Jermann, Jerry V., Dennis E. Lewarch, and Sarah K. Campbell
Studies, University of Washington, Seattle.

Jochim, Michael A.

Johnson, Matthew

Jones, Roy F.
1972 Wappato Indians of the Lower Columbia River Valley, privately printed.

Judge, W. James, and Lynne Sebastian (editors)

Kane, Paul

Karsmizski, Kenneth W.

Kelly, Cara M.
2001 Prehistoric Land-Use Patterns in the North Santiam Subbasin on the Western Slopes of the Oregon Cascade Range. Master’s thesis, Department of Anthropology, Oregon State University, Corvallis.

Kennedy, Hal

Kohler, Timothy A.

Kohler, Timothy A., and Sandra C. Parker

Kroeber, A. L.

Kvamme, Kenneth L.


Leopold, Estella B., and Robert Boyd

Letham, Lawrence

Lock, Gary, and Zoran Stančič (editors)

MacGregor, Carol L. (editor)

MapMart


Marozas, Bryan A., and James A. Zack

Maschner, Herbert D. G.

McGee, Dale A.

Minor, Rick
1983 *Aboriginal Settlement and Subsistence at the Mouth of the Columbia River*. Ph.D. dissertation, Department of Anthropology, University of Oregon, Eugene.

Minor, Rick, Robert R. Musil, and Kathryn Anne Toepel

Moulton, Gary E. (editor)


Mundorff, M. J.

National Geographic Maps

National Oceanic and Atmospheric Administration
2003 Lower Columbia/Southwest Washington Interior River and Hydro meteorological Information. Western Region Headquarters, National Weather Service Forecast Of-
Newman, Maureen McNassar  
1991 *Description and Management Plan for 35MU4, the Sunken Village Archaeological Site at Sauvie Island, Multnomah County, Oregon.* Master’s thesis, Department of Anthropology, Portland State University, Portland.

Northwest Power Planning Council  

O’Connor, Jim E.  

Oetting, Albert D., and Rick Minor  

Oregon Natural Resources Conservation Service  

O’Rourke, Leslie M.  

Pettigrew, Richard M.  

Phillips, William M.  

Pojar, Jim and Andy MacKinnon  
1994 *Plants of the Pacific Northwest Coast.* Lone Pine, Vancouver, BC.

Ray, Verne F.  
1938 *Lower Chinook Ethnographic Notes, Volume 7, #2.* University of Washington Publications in Anthropology, Seattle.

Regional Ecosystem Office  

Roper, Donna C.  

Rose, Martin R., and Jeffrey H. Altschul  

Ross, Alexander  
Ross, Lester A., and Judy Starkey
1975 Archaeological Survey of Lower Lake
River and Bachelor Island Slough, Clark
County, Washington. Manuscript on file,
US Fish and Wildlife Service Region 1,
Portland.

Ruby, Robert H., and John A. Brown
1976 The Chinook Indians: Traders of the
Lower Columbia River. University of Oklahoma
Press, Norman.

Saleeby, Becky M.
1983 Prehistoric Settlement Patterns in the
Portland Basin of the Lower Columbia
River: Ethnohistoric, Archaeological and
Biogeographic Perspectives. Ph.D. disserta-
tion, Department of Anthropology, University
of Oregon, Eugene.

Saleeby, Becky, and Richard M. Pettigrew
1983 Seasonality of Occupation of Ethnohis-
torically-Documented Villages of the Low-
er Columbia River. In Prehistoric Places
on the Southern Northwest Coast, edited by
Robert E. Greengo, pp. 169-193. Thomas
Burke Memorial Washington State Museum,
University of Washington, Seattle.

Schuster, J. Eric
1992 Geologic Map of Washington. Wash-
ington State Department of Natural Resources,
Division of Geology and Earth Resources,
Olympia. Electronic document, http://stu-
dents.washington.edu/gwyneth/WAGeol-

Silverstein, Michael
1990 Chinookans of the Lower Columbia. In
Northwest Coast, edited by Wayne Suttles,
Indians, Volume 7, W. C. Sturtevant, gen-
eral editor. Smithsonian Institution Press,
Washington, DC.

Simpson, George
Fur Trade and Empire, edited by Frederick
Merck, pp. 3-174. Belknap Press, Cam-
bridge.

Sinclair, Donna
2003 Columbia Slough Community History
Exhibit, Center for Columbia River His-
crrh.org/comm/slough/main.htm, accessed

Skolnik, Arthur M., Mary Ann Duncan, David W.
Harvey, and Katheryn H. Krafft
1979 Cultural Resources Investigation in the
Vancouver Lake Project Area, Washington.
Report to the US Army Corps of Engineers,
Portland District. The Conservation Com-
pany, Seattle.

Slocum, Robert G., and Kenneth H. Matsen
1968 Shoto Clay: A Description of Clay Arti-
facts from the Herzog Site (45CL4) in the
Lower Columbia Region. Oregon Archaeo-
logical Society Publication No. 4. Binford
& Mort, Portland.

1972 Duck Lake Archaeological Site Report
45CL6A. Oregon Archaeological Society
Publication No. 6. Oregon Archaeological
Society, Portland.

Smythe, Richard T.
1986 Soil Survey of Columbia County, Or-
egon. US Department of Agriculture, Soil
Conservation Service, in cooperation with
Oregon Agricultural Experiment Station.
US Government Printing Office, Washing-
ton, DC.

Spencer, Omar C.
1950 The Story of Sauvies Island. Binford
& Mort, Portland.

Spier, Leslie
1936 Tribal Distribution in Washington. Gen-
eral Series in Anthropology, Number 3.
Banta, Menasha, Wisconsin.

SPSS Statistical Software
1999 SPSS Version 10.0.5 for Windows.
SPSS, Chicago.

Steele, Harvey
1980 Bachelor Island 45CL43. Oregon Ar-
chaeological Society Report No. 8. Oregon
Archaeological Society, Portland.

Steward, Julian H.
1938 Basin-Plateau Aboriginal Sociopolitical
Groups. Smithsonian Institution Bureau of
American Ethnology Bulletin 150, Washington DC.


Vaughn, Thomas, editor


Francis, London.

Wheatley, David, and Mark Gillings

Whitehead, John C.

Willey, Gordon R.

Wilson, Douglas C.

Wuerch, William L.
List of Maps and Digital Images Consulted

Modern digital maps were obtained from the Regional Ecosystem Office, Ducks Unlimited (US Fish and Wildlife Service), the US Army Corps of Engineers, MapMart, and the National Geographic Maps TOPO! program. These sources are listed both here and in the main references cited section.

The other maps listed here, while not cited in the thesis, were essential to the GIS component of this study. Historic maps were obtained from the National Oceanic and Atmospheric Administration, the Oregon State Historical Society, the Clark County Historical Museum, Fort Vancouver National Historic Site, and from other sources. These modern and historic maps were all used as references in digitizing the historic water boundaries of the Wapato Valley (Table 5.1.1 in Appendix I provides details on which maps were used for each of the eleven topographic maps of the Wapato Valley).

Boundary Claims Commission
1867 Plat of the Hudson’s Bay Company claim at Fort Vancouver (surveyed May 1854). Copy of map obtained at Fort Vancouver National Historic Site, Vancouver.

Broughton, William R.
1792 Chart of the Exploration of the Columbia River, from Cape Disappointment to Point Vancouver. Oregon Historical Society Map Library, Portland.

Cunningham, J. H.

Derby, George H., and George Gibbs

Ducks Unlimited, Inc.

Farmer, Judith A.

Goethals, George W.

Habershon, R. A.
1888 Map of Clarke County, Washington Territory. Clark County Historical Museum, Vancouver.

Heupel, Neal H. (complier)

MapMart


Metsker, Charles F.

Moulton, Gary E. (editor)

National Geographic Maps


Slacum, W. A. 1836 Chart of the Columbia River for 90 Miles from its Mouth. Drawn from several surveys in the possession of W. A. Slacum U.S.S. by M. C. Ewing, Civil Engineer. Oregon Historical Society Map Library, Portland.


1918 Hillsboro, Oregon-Washington 15-minute topographic map.


1887 Map of Sauvies Island, compiled from Government Survey Notes, roads and dyke sketched from maps. Martin Gillihan Collection, Oregon Historical Society Map Library, Portland.


1918 Hillsboro, Oregon-Washington 15-minute topographic map.

1918 Troutdale, Oregon (now Camas, Wash-
ingston-Oregon) 15-minute topographic map.

1939 Hillsboro, Oregon-Washington 15-minute topographic map.

1939 La Center, Washington 15-minute topographic map.

1940 Portland, Oregon-Washington 15-minute topographic map.

1940 Saint Helens, Oregon-Washington 15-minute topographic map.


1943 Saint Helens, Oregon-Washington 15-minute topographic map.


1954 Deer Island, Oregon-Washington 7.5-minute topographic map.

1954 La Center, Washington 15-minute topographic map.

1954 Linnton, Oregon 7.5-minute topographic map.

1954 Mount Tabor, Oregon-Washington 7.5-minute topographic map.

1954 Portland, Oregon-Washington 7.5-minute topographic map.

1954 Ridgefield, Washington 7.5-minute topographic map.


1954 Saint Helens, Oregon-Washington 7.5-minute topographic map.

1954 Sauvie Island, Oregon-Washington 7.5-minute topographic map.

1954 Vancouver, Washington-Oregon 7.5-minute topographic map.

Vavasour, Merwin
c.a. 1845 Rough Chart of the Columbia River from the Head of the Navigation to the Pacific Ocean, from a sketch belonging to the Hudson’s Bay Company. Oregon Historical Society Map Library, Portland.

Wilkes, Charles
1841 Map of the Columbia River (Sheet 5) from the 1838-1842 Wilkes Expedition. Oregon Historical Society Map Library, Portland.
PART VI

WAPATO FOR THE PEOPLE:
AN ECOLOGICAL APPROACH TO UNDERSTANDING THE NATIVE AMERICAN USE OF SAGITTARIA LATIFOLIA ON THE LOWER COLUMBIA RIVER

Melissa C. Darby
ABSTRACT

*Sagittaria latifolia* Willd. was an important root food and trade commodity for the Indians who lived along the Lower Columbia River in early historic times. This plant was prolific in the extensive wetlands of the Lower Columbia from about the great Cascades to the Kalama River. The tubers of this plant were called ‘wapato’ in Chinook Jargon, the local trade language. The wetlands, and this plant that grew there, occupied a vast extent of the Lower Columbia territory; so much so that this valley was named ‘Wapato Valley’ by Lewis and Clark in 1805. This thesis will provide pertinent information on botanical characteristics, habitat, productivity, and traditional harvesting and preparation techniques of this species. Nutritional analyses show that wapato could have provided meaningful quantities of energy (carbohydrates), fiber, and trace elements.

Ecological data pertaining to this species, and ethnographic and archaeological data from North America and especially the Lower Columbia, are used to address the following research question: Was wapato intensively exploited by the Indians of the Greater Lower Columbia River (Hajda 1984) in early prehistoric times? A test of root food intensification using ecological and ethnohistoric data demonstrated: 1) that wapato was a cost effective food to harvest; 2) that the annual productivity of this root food in Wapato Valley could have fed a larger population than was estimated to exist in the valley at contact; 3) that root-food intensification may not always be indicated by the presence of large earth ovens and ground stone tools. In this study I conclude that wapato was sufficiently productive and predictable to be intensively exploited and to function as a staple food resource. This assessment illustrates the need to reconsider some commonly accepted ideas about the intensification of root foods and the archaeological characteristics of root processing sites.
ACKNOWLEDGEMENTS

I wish to offer my heartfelt thanks to Ken Ames for his inspiration and guidance during this endeavor. I shall be forever grateful to John Kallas for his advice and support. I will always remember the professional camaraderie we shared in pursuit of the wild wapato. I would like to particularly acknowledge the assistance of Bill Kinyoun and Terry Dufour of the Oregon Fish and Wildlife Department for their support, and for giving me access to the wapato patches. I especially want to thank Bill for that great ride down the Gilbert River. I would like to thank the members of my committee for their suggestions and clarifications, particularly to Yvonne Hajda, Carol Carter and Virginia Butler. Tadayoshi Tanimoto’s assistance with productivity data was invaluable, and I thank him for his help. Finally I would like to thank Denny, my husband, for his support and patience. This is dedicated to my daughter, Kathleen Rose Louise Darby.
CHAPTER 1
INTRODUCTION

*Sagittaria latifolia* Willd. is a wetland plant that produces starchy tubers that were once an important root food for the Indians of the Lower Columbia River. Early ethnohistoric accounts describe wapato as an essential food staple and trade commodity of the Chinookan peoples. It was also noted for its resemblance in taste and texture to a white potato, though it is typically smaller, averaging between 35 and 55 mm in length, and weighing about 7.5 grams when fully ripened.

The word ‘wapato’ refers to both the plant and the edible root. In historic accounts it is variously spelled: wappatoe, wapattoo, wap’tu, ‘pota, and papato among others. French (cited in Zenk 1976) suggested that since some dialects of Chinook and Kalapuyan languages share the -ptu portion of the word (‘wa-ptu’), that ‘wapato’ is actually the Chinook feminine singular form of the word (French, personal communication in Zenk 1976:85).

Organization of the Study

This chapter (Chapter one) begins with an introduction to the subject, and geographic and environmental descriptions of the region. The next major section is a description of the people who lived along and adjacent to the lower part of the Columbia River in early historic times. The last major section of this chapter outlines the theoretical framework of this thesis, including the research parameters. This section explains why the study of the intensification of a root food in the Lower Columbia region is important. Intensification is defined as the net increase in annual food production per capita, or as an increase in the efficiency of food production (Bender 1978). Ecological theories that are relevant to the subject are reviewed.

Ethnographic, ethnohistoric, archaeological and ecological data are employed in this thesis to address the question of whether wapato was an intensifiable and intensified food source on the Lower Columbia. The intensifiability of wapato will be assessed using five criteria under which the intensive and sustained exploitation of roots would be expected (Thoms 1989:81). Following Thoms, intensifiable roots must have the following: (1) carbohydrate-rich bulbs, corms or tubers, etc., (2) reproductive systems well-adapted to regularly churned soils; (3) extensive abundance in accessible settings; (4) readily available (relative ease of digging) and (5) resilience to environmental fluctuations (Thoms 1989:175).

In light of these criteria, Chapter Two has two main purposes. The first is to provide ecological data about *Sagittaria* species, principally relating to botanical features, reproduction and population structure. The second section is a description of wapato’s place in the trophic schema, and its decline-- due in part to introduced predators. The third chapter is an overview of archaeological, ethnohistoric and ethnographic accounts describing the use of this plant in North America and Asia. This chapter contains information pertinent to root food intensification relating to seasonality, harvesting, cooking, and storage techniques employed by aboriginal populations specifically for this species. One purpose of this chapter is to describe the cosmopolitan use of the roots of this plant. There is specific emphasis on ethnohistoric accounts of wapato from the Greater Lower Columbia region. These data will be used to address the question of intensification on the Lower Columbia.

Chapter Four will discuss subsistence on the Lower Columbia. The nutritional composition of wapato, and its place within the diet of the people of the Lower Columbia will be considered.

In order to address the questions of abundance and productivity, an ecological model of annual wapato production on Sauvie Island is presented in Chapter Five. Five aboriginal villages were located on the island in 1804. Sauvie Island was chosen for this model because a large human population was juxtaposed with a high concentration of wapato patches. In addition the island has definable boundaries, and there are good maps of the lakes and ponds and wetlands that existed in early historic times. This chapter is divided into three parts. In part one, productivity of wapato patches on the island will be calculated by hectare. Part two is a cost/benefit analysis of wapato compared to other important root foods in the Northwest. The second part of this chapter discusses human population estimates for the Lower Columbia River at contact, and in late prehistoric...
(pre-epidemic) times. In Chapter Six the significance of this species to the people of the Lower Columbia will be analyzed within the theoretical context of Thoms’ ecological model for geophyte intensification (Thoms 1989). Chapter Seven contains a brief summary, conclusions and identifies subjects for further study.

**Background**

**Geography**

The lower Columbia River, from The Dalles to the sea, including the area from Willamette Falls to Multnomah Channel, and from the mouth of the river north to Willapa Bay, and south to Tillamook Bay was, in early historic times inhabited chiefly by Chinookan-speaking Indians (see Figure 6.1). This area as well as the lower Willamette River region (occupied by Kalapuyan speakers from Willamette Falls south) is referred to here as the Greater Lower Columbia, following Hajda (1984). *Sagittaria latifolia* was prolific in the broadest part of the river’s estuarine zone, referred to here as Wapato Valley, following Lewis and Clark. Wapato Valley begins at about the Sandy River where the Columbia River Gorge opens into a fertile basin that is surrounded on the east by the lower foothills of the Cascade Mountains. This basin extends westward to about the Cowlitz River and to Willamette Falls on the south. This region has also been referred to as the Portland Basin (Saleeby 1983, Clarke 1975).

The principal watersheds that discharge into the Columbia in the region are the Willamette, Sandy, Kalama, Lewis, and the Washougal Rivers (Clarke 1975:3). At Longview (just down river from Wapato Valley) the main channel of the Lower Columbia is approximately 0.75 miles wide, and the mean annual flow is approximately 220,000 cfs (Clarke 1975:7). The river’s large discharge and minimal gradient have resulted in the development of extensive meander floodplain features including lakes, islands, and sloughs. Saltwater intrusion from the Pacific Ocean can reach as far as Longview in the summer (Terry Link, personal communication). Daily tidal fluctuations are experienced throughout most of Wapato Valley. At St. Helens, near the northern point of Sauvie Island, the mean diurnal range is 2.5 feet, and the high water interval is 4 hours, 40 minutes (US Coast and Geodetic Survey 1930).

Lewis and Clark named this valley ‘Wapato Valley’ in 1805 because the plant grew “Spontaneously [sic] in this valley only” (Clark in Thwaites 1959, 3:202). Wapato stands grew dense and lush in slackwater bays, on low marshy islands in the channel, and in myriad ponds, lakes and sloughs. It was especially prolific in the many lakes and ponds of Sauvie Island, centered in Wapato Valley, at the confluence of the Columbia and Willamette Rivers. Accordingly, Lewis and Clark named this island ‘Wapato Island’.

**Biota**

Vegetation is made up of plant communities within the Franklin and Dryness’ Interior Valley Zone of western Oregon and Washington (1973:124-126). In pre-contact times much of the low land was prairie, maintained by the native peoples with the use of fire [This was done in order to preserve and fertilize important sources of wild food (Norton 1979:175-179)]. The valley floor is flat or gently undulating, and was composed of a complicated mosaic of wetland, prairie, oak savanna (*Quercus garryana*, *Salix scoulerurana*), pine-wood coppice (*Pinus ponderosa*, *Pinus contorta*), with riparian communities of cottonwood and willow along shorelines (*Populus* spp., *Salix scoulerurana*). Coniferous forests with Douglas fir (*Pseudotsuga menziesii*), Western red cedar (*Thuja plicata*) and many broad-leaved trees were abundant on the low foothills and slopes of the Coast Range and the Cascades, and in patches on the valley floor.

**Fauna**

The area supported abundant fish, bird, and mammal populations, the former two groups including significant numbers of both migratory and resident taxa. Some of the larger mammals found in this area include the Roosevelt elk (*Cervus canadensis*), Columbian black-tailed deer (*Odocoileus hemionus*), Oregon white-tailed deer (*O. vurgubuabys*) and the black bear (*Ursus americanus*). Sea mammals, principally the harbor seal (*Phoca vitulina*) and sea lions can be found in the Columbia and Willamette Rivers, typically during fish runs. The principal fish are salmon (*Oncorhynchus sp.*), smelt (*Thaleichthyys pacificus*), and sturgeon (*Acipenser transmontanus*). Important
Figure 6.1. Wapato Valley and the Greater Lower Columbia.
migratory bird species include Canadian geese (*Branta sp.*), swans (*Cygnus sp.*), sandhill cranes (*Crus canadensis*) and several species of ducks (*Anas sp.*).

The People

Introduction

Culturally, the people who lived along the Greater Lower Columbia occupied a portion of the southern coast of the Northwest Coast cultural area (Ames 1994). The Northwest Coast people shared some basic traits: salmon were a dietary staple; resource areas were controlled; and the people were sedentary or semi-sedentary depending on resource predictability and productivity (Ames 1994). The basic social division was between free and slave, and rank was determined by wealth and inherited status (Boyd and Hajda 1986:310).

Language

Although the Chinookan language family has no close affiliates, it has been grouped into the Penutian phylum along with Kalapuyan and Takelman (Hajda, personal communication 1996). The Chinooken language family is composed of two main languages; Lower Chinook and Upper Chinook. Upper Chinook is divided further into several dialects, though the exact number is not known. These include Kathlamet, “Multnomah”, Hood River, Wasco, Wishram and Clackamas. Lower Chinook was spoken at the mouth of the Columbia, and Upper Chinook from Kathlamet to The Dalles.

Chinook was not the only language family on the river. The Greater Lower Columbia was occupied by groups speaking languages from many linguistic stocks:

The ribbon of Chinookan peoples from the Dalles to the mouth of the Columbia was interrupted by pockets of natives bearing other family designations—the Cowlitz, a Salish people on the north bank from just east of Oak Point (Washington) to the Cowlitz River, and the Klatskanies, an Athabaskan people across the Columbia from the Salish at a point about fifty miles from its mouth (Ruby and Brown 1976:5).

Using historical records, ethnohistoric accounts and genealogies, Hajda studied regional unity and subdivision among the groups in the Greater Lower Columbia. She found that these groups were connected by links which she categorized as follows: marriage, visiting, conflict, resource collecting and trade (Hajda 1984:123). “Numerous unrelated languages were spoken, so most villages, and many individuals, were multilingual, a situation resulting from the marriage and slavery patterns,” (Boyd and Hajda 1987:310).

Occupations

The chief occupations of the people of the Greater Lower Columbia were fishing and trading. They built several types of canoes, each specialized for a specific purpose. According to Ray (1938) the finer canoes were painted red, and had inlaid shells. He describes hunting and sealing canoes, and their various paddle styles (1938). The Chinook canoe was typically twenty to thirty-five feet long with a flat bottom and a high prow well adapted for riding high waves. This style was widespread in coastal Washington and Oregon. Lewis and Clark noted that some canoes were fifty feet long. The cutwater canoe was thirty to thirty-five feet long and could carry a considerable amount of cargo. This canoe had a lower prow and an undercut stern. The double cutwater canoe was

Figure 6.2. Clark’s drawing of a shovelnose canoe.
usually thirty-five feet or longer and was distinctive because it had carved figures mounted on both the prow and the stern.

Another type of canoe was the small shovel-nose canoe, used for short distance forays, principally by women. Clark drew a picture of a typical shovel-nose canoe from the examples he saw near the village of Neerchokioo, (Figure 6.2) and described it as follows:

I observed small canoes which the women make use of to gather wappato & roots in the Slashes. those canoes are from 10 to 14 feet long and from 18 to 23 inches wide in the widest part tapering from the center to both ends in this form and about 9 inches deep and so light that a woman may with one hand handle them with ease,

and they are sufficient to carry a woman an[d] some loading. I think 100 of these canoes were piled up and scattered in different directions in the woods in the vicinity of this house (Clark in Thwaites Vol. 4:237, spelling as in original).

Settlement

Throughout the Greater Lower Columbia aboriginal settlements were in the form of either villages, containing several houses, or hamlets with only one or two permanent houses. These villages and hamlets in Wapato Valley swelled with visiting friends and relatives during resource collecting times. People came in the fall for the elk and wapato seasons, and again in the spring for fish resources (Hajda 1984:175).

Food was collected in areas controlled by people with whom the collectors had immediate consanguineal ties (Hajda 1984). Some reciprocity may have been assumed or expected. Some of these ties were created by marriages, which “were undertaken to strengthen commercial relations’---presumably, to promote trade with groups among whom one found wives,” (Hajda 1984:130).

Trade

“A thorough-going occupation with commerce dominated Chinook life.” (Ray 1938:99). They had both a currency (dentaila shells) and a trade language--Chinook Jargon. Hajda suggests that dentalia were not a currency for all goods, only for valuables in normal circumstances (Hajda, personal communication 1996). Raw materials and subsistence goods (like wapato) were exchanged for other raw materials or subsistence goods, rather than purchased with dentaila shells. Trading conditions were ideal due to the juxtaposition of a rich habitat which supplied a surplus of goods, and waterways which facilitated transportation (Ray 1938).

Wapato may have been an important attraction for foreigners during the typical time of food shortages; late winter, and early spring. In early April on their return journey Lewis and Clark reported meeting migrants from upriver that were nearly starving, and had came into the valley “in search of subsistence which they find easy to procure in this...valley,” (Thwaites 4:228,230).

A variety of goods and services were available in the region. There were three centers of trade: The Dalles, Willamette Falls on the Willamette River, and the mouth of the Columbia. Ray summarized the trade practices as follows:

From Willapa Bay to the mouth of the river steadily flowed large quantities of dried shell-fish. These were arranged on sticks of salmonberry wood, each about two feet long. From the Kwalhiokwa the Willapa Bay people received furs of the larger animals and dried meat packed in tule bags. The bay people furnished the Kwalhiokwa with shell-fish likewise; and again, with goods received from the Columbia. Home products of the Columbia, which were distributed in all directions, included dried salmon, pulverized salmon, dried smelt, dried seal meat, blubber and canoes.... Some (of these products) especially blubber and canoes, were almost exclusively exports. The upriver groups brought, above all, wapato and camas to the coastal people. These foods were highly prized on the coast and were imported in great quantities (Ray 1938:99).

There was a standardization of products, as the above passage suggests for dried shellfish and dried meat. Alexander Ross mentions that dried smoked ulichans are prepared for “distant market” by stringing them head to tail, and sell-
ing them by the fathom (Ross 1966). Skarsten’s (1964) narrative of George Drouillard service as a hunter and interpreter for Lewis and Clark has a passage describing dried salmon being sold by the crate at The Dalles: “The crates were the size and shape of an apple crate and would hold from ninety to one hundred pounds of fish...In one village Clark counted one hundred seven stacks of these crates, twelve baskets per stack amounting, possible to ten thousand pounds,” (Skarsten 1964:154). Lewis and Clark refer to procuring “parcels” and “basquits” of wapato, as well as “bushels”. There may have been a standard weight or basket size for wapato but it was not recorded.

Referring to the people of Wapato Valley, Meriwether Lewis wrote that wapato was the “principal article of traffic” traded from the people of the valley to people at the mouth of the river in exchange for “beeds, cloath and various articles. The nativs of the sea coast and lower part of this river will dispose of their most valuable articles to obtain this root,” (Lewis in Thwaites 1969 4:222, spelling as in original).

Population

Prior to contact with whites, the region had one of the densest populations in America north of Mexico (Hajda 1984:67). By 1805 the people of the Greater Lower Columbia had suffered through two epidemics. These were probably smallpox epidemics, which occurred in 1775 and again in 1801. Boyd estimates that the mortality rate for the 1775 epidemic was minimally 33%, and suspects that the mortality rate in 1801 was slightly less because some individuals had developed an immunity in the previous epidemic (Boyd 1985).

Lewis and Clark estimated the population from the mouth of the Columbia to The Dalles in 1805-6 to be 27,000 or 18,040 depending on which of their estimates is used (Hajda 1984:70). These figures are derived from two sources: Clark’s “Estimate of the Western Indians (Thwaites 1969 6:113-120) and an unpublished estimate of Clark’s based on figures obtained upon arrival in the region in the fall of 1805. Boyd and Hajda suggest both estimates are correct, and reflect seasonal fluctuations in population (Boyd and Hajda 1987).

The people of the Greater Lower Columbia were felled in great numbers by subsequent epidemics. In sequential order these were: probably smallpox or measles 1824-1825; malaria 1830-1832; dysentery 1844; measles 1848; and smallpox 1853 (Boyd 1985:270). The malaria epidemic in the 1830’s was incredibly devastating, depopulating whole villages. Between 1805 and 1840 over 86% of the total native population was lost to disease.

Summary

This brief overview of the people of the Greater Lower Columbia made the following points: 1) The Greater Lower Columbia valley was occupied by several linguistically diverse groups; 2) Outside groups had access to food resources in Wapato Valley; 3) These groups typically had blood or marriage ties to the local permanent population; 4) resource areas were controlled; 5) Trade was formalized with a trade language, a currency, and standardization of products; 5) in late prehistoric and early historic times this region had a dense population which was subsequently reduced by epidemics.

Theoretical Framework

Research Parameters

The study of subsistence practices on the Northwest Coast is of theoretical interest, for the following two reasons identified by Suttles:

First, their rich, maritime, temperate-zone habitat is a type in which few food-gathering peoples survived until historic times, partly because this very type of habitat elsewhere saw the growth of more advanced forms of subsistence. Second, the Northwest coast peoples seem to have attained the highest known levels of cultural complexity achieved on a food-gathering base and among the highest known levels of population density (Suttles 1969:56).

“Changing subsistence practices, including the relative roles of salmon and other resources in the diet, are major issues in Northwest archaeology.” (Ames et al. 1995:104). Evidence of wapato use in both time and space is necessary to address change in subsistence practices. Due to poor preservation of plant tissues in archaeologi-
cal contexts, evidence of wapato use before white contact is scant. This thesis addresses whether wapato was an intensifiable resource within a specific time period and place: the Greater Lower Columbia at contact and in early historic times, circa 1790-1840.

Intensification is defined as the net increase in annual food production per capita, or as an increase in the efficiency of food production (Bender 1978:205-206). Resource intensification is a process by which the total productivity per areal unit of land is increased. The intensification potential of a resource is assessed by resource abundance, predictability, stability, and distribution over the landscape. Abundance has been described in qualitative terms such as “bountiful” runs of salmon and “vast quantities” of roots (Saleeby 1983:154). What is needed is a more quantitative approach to determine abundance.

This paper analyzes primary production of wapato roots using the “human ecosystem approach” as defined by Butzer (1990) to elucidate the role of wapato as an intensifiable food source exploited by Indians of the Lower Columbia region. This approach analyzes ecological data, archaeological data, and information from historical sources within a theoretical framework of ecology and systems theory.

I begin this section with a general overview of ecological theory. The next section is a discussion of intensification and the increased complexity of hunter-gatherer groups, including groups in the Northwest. Next, is an overview of general theories and models addressing the transition of groups from complex hunter-gatherers to agriculturists. Included in this section is discussion of tools as indicators (in archaeological sites) for plant food intensification.

Ecological Theories: The Ecosystem Approach

This paper uses Butzer’s ‘human ecosystem’ approach to the research and evaluation of wapato on the Lower Columbia. Butzer (1990) emphasizes an interdisciplinary methodology. He demonstrated the value of using contemporaneous written records and other historical data, combined with archaeological data, in order to elucidate how economic structures functioned, and to answer research questions. Written records had, of course, been used by archaeologists in North America, Europe, the Middle East and elsewhere. What Butzer proposed was collecting and setting up the data so it could be analyzed within an ecological theoretical framework. This way, written records can be used to test human ecological models through time and space, and on various scales (Butzer 1990).

Written records of explorers, traders, missionaries and settlers, and ethnographic accounts are used in this study of Sagittaria latifolia use on the Lower Columbia. Descriptions of vast patches of wapato on the Lower Columbia in many of the accounts led to field investigations which located isolated large stands of wapato (Figure 6.3). Ecological data was collected from the field, and analyzed within an ecological theoretical framework.

Information found in historical records and accounts is applied to questions of intensification, seasonality, and artifact and features types. Ethnohistoric descriptions of harvesting assisted this worker in reconstructing harvest methods, which led to estimates of harvest time and production.

Butzer’s ecosystem approach had its roots in previous work. In 1953 the modern concept of the ‘ecosystem’ crystallized in Eugene Odum’s Fundamentals of Ecology. He defined the ecosystem as an organizing principle emphasizing obligatory and causal relationships that maintain an equilibrium (Moran 1990:5). This work influenced a whole generation of biologists. Ecosystem research required the study of complex interactions, often in large scale units such as the polar region and the rainforest, but also within ecosystems as small as a pond. Studies of trophic levels and energy flow required quantitative techniques to measure energy flow through a system. Biologists developed ways of measuring and analyzing energy flow through trophic levels, and began modeling ecosystems.

Geertz (1963) was one of the first to apply the ecosystem approach to anthropology. He argued that “the ecosystem approach attempts to achieve a more exact specification of the relations between selected human activities, biological transactions and physical processes by including them within a single analytical system, an
Ecosystem models measure energy flow and materials through a generalized ecosystem, and provide a way of testing hypotheses about the role subsistence plays in population dynamics (Belovsky 1988:330). Optimal foraging models, intensification models, predictive settlement and subsistence models, economic models, and others, became devices to explain the human condition in the past.

The use of the ecosystem approach as applied to human behavior was rooted in organic analogy (Moran 1990:6). As Winterhalder points out, the ecosystem approach was attractive to anthropologists for a number of reasons, including that “It was elaborated in terms of structure, function, and equilibrium that suggested the possibility of common principles in biology and anthropology” (Winterhalder 1984:302). Ecological models are dynamic, and their predictive power for explaining developments through time and space was compelling. However, models based on organic analogy often failed to predict human behavior. Human behavior, always the wild card, proved difficult to model even when the ‘optimal solution’ seemed clear (for example see Reidhead 1980). Butzer argues that the use of the ecosystem approach in anthropology requires the use of some restrictions because human ecosystems differ from biological ecosystems, in kind as well as degree (Butzer 1990:93).

Intensification

Introduction

The study of the intensification process in various settings and with various plants helps us understand the function and evolution of past agricultural systems, increased complexity of hunter-gatherer groups, sedentism, advances in storage techniques, food processing technology, and the development of agriculture. The study of wapato intensification on the Lower Columbia by the Chinook is relevant to the above questions. The following section introduces several theories about how social complexity developed in the Northwest.

Intensification and Social Complexity in the Northwest

The relationship between the development of social complexity and intensification of

Figure 6.3. Extensive wapato patch at Crane Lake, Sauvie Island.
resource use on the Northwest Coast has recently been a major topic of theoretical interest. Several authors have proposed models to explain the development of social complexity of Northwest Coast hunter-gatherer societies. A brief review of their models is presented below. The intensification of salmon is a component in each of these models.

Fladmark argued that complexity on the coast resulted from the exploitation (intensification) of regular, large salmon runs which began on the coast ca 5000 B.P., when post-glacial sea levels and river drainage stabilized (Fladmark 1975:vi). Schalk argues that salmon storage and preservation technology was the cause of complexity (Schalk 1977). Arnold has recently proposed that advances in water transportation technology affected the degree in which prehistoric peoples became maritime oriented and hierarchically organized (Arnold:1995). She uses the Northwest Coast as an example. She argues that the ramifications of “advanced water transport technology” (i.e. good canoes) include political, symbolic and practical impacts. Among the practical impacts she explores are the opportunities availed for intensifying subsistence, communication, networks of exchange, and hierarchy through advanced boat technology.

Burley’s model of the development of complexity is based on his study of the Marpole culture, a culture history unit described for the Gulf of Georgia area, coastal B.C. He suggests that complexity occurred along streams, in part because salmon exploitation was easier in streams, particularly the Fraser River, rather than on the coast proper (Burley 1980:74). Matson suggests that intensification, sedentism, and ownership of patches evolved when resources were sufficiently abundant, predictable, and limited geographically and temporally (Matson 1983:142). Since not all groups had access to the same resources, inequalities would occur between groups and individuals within a group. This would result in a ranked society.

Ames (1994) has proposed a multivariate and dynamic model explaining complexity as an interplay among the following variables: circumscription, specialization in salmon and other resource-collection methods, population growth, sedentism, and ritual promotion (Ames 1994:212).

*The Emergence of Intensification and Plant Domestication*

Intensification requires an ecosystem where flora and fauna flourish. According to a model put forward by Harris (1977), the dynamics of an emergent stable agricultural system would include a generalized ecosystem with high species and pattern diversity, crop ecology that lends itself to intensification, and the intensive management of the resources within the ecosystem. Abundance and predictability are key variables necessary for intensification of plant foods.

Binford (1983) postulated that hunter-gatherer groups were in equilibrium systems homeostatically regulated below the carrying capacity of the local food supply. He inquired if there was no adaptive pressure to increase the food supply, what was the stimulus? According to Binford there could be only two sets of conditions that lead to increased productivity: 1) A change in the physical environment which brings about a reduction in the biotic mass of the region, which would stimulate the population to intensify their efforts at food procurement; 2) Change in the demographic structure of a region which brings about the impingement of one group on the territory of another (Binford 1964:328). Binford postulated that agriculture would arise at the boundaries (tension zones) where the lands of less sedentary groups were in the process of being occupied by other groups from more sedentary populations.

Binford’s observations of the change from mobility to sedentism among the Nunamiut led him to postulate that demographic consequences led to plant intensification, and eventually agriculture. He saw a worldwide pattern of a reduction in mobility as being an integral part of the change from subsistence based on wild foods to one based on domesticated foods (Binford 1983). Binford’s work influenced David Harris who postulated a ‘stress model’ of the transition from hunter-gatherers to agriculturists (Harris 1977:189).

Rindos suggests that there is a co-evolved relationship between plants and primates (Rindos 1984:127), and that several centers of agricultural origin independently emerged. Therefore, according to Rindos, there must be some aspect inher-
ent to agriculture that is the factor responsible for the elaboration of developed agricultural systems. Plowing, weeding, harvesting, storage and planting are farming techniques that affect the environment in which a cultivated plant grows. According to Rindos, the origin of agriculture is due in part to the origin and development of these techniques. Clearing the land and weeding removes competing plants, increasing the plant’s dependence on human protection. Planting introduces uniform germination, but also reduces variation. The result of some or all of these techniques was that there was a growing specialization in diet, and society gradually became dependent on agriculture (Rindos 1984:267).

Chang discusses environmental change on the macro scale to explain changes in intensification patterns. He argues that after the last glacial period in Asia, a hypothermism was reached between about 8,000 to 4,000 B.P which resulted in a moist environment with thicker vegetation, and a greater abundance of faunal and floral resources than had been found during the previous glacial advance (Chang 1979:176).

One of the great theorists who addressed the advent of agriculture was Carl Sauer, who proposed the earliest cradle of agriculture to be Southeastern Asia (Indochina and India) (Sauer 1952). His model described the first farmers as fisherfolk who lived in a wooded and organically diverse environment on freshwater streams. These people grew crops vegetatively, rather than by planting seed. He reasoned that since plant cuttings are identical to the parent, selection of traits was easy: one just planted part of the parent to produce a clone. Over time this led to plants that lost their capacity to bear viable seeds.

Food Processing Technologies

The development of food processing technologies is of theoretical interest in the context of the development of plant intensification. Meat from big game species was a major dietary staple for people during the Pleistocene period while the human population was small in relation to the biomass of available fauna (Eaton and Konner 1985:284). By the end of the upper Paleolithic, plants were being intensified, as evidenced by the tools found in sites from this period. In the new world, root foods are believed to have not been a dietary staple for humans until 7,000 to 8,000 years ago (Cohen 1977). The change from a meat-based diet to one that included more vegetables is attributed to population growth and circumspection, overhunting, and climatic change (Eaton and Konner 1985:284).

In archaeological sites where root foods were exploited, Thoms argues that tools for mashing fresh roots and tools for grinding dried food or grains would likely be present (Thoms 1989:87). The tool types he describes that are commonly associated with plant exploitation include grinding stones, mortars, pestles, manos and tools for their manufacturing and maintenance. Also in the stone tool assemblage would be components for digging sticks such as stone tips and weights, and worked bone and antler handles. A variety of simple chipped stone knives and scrapers for slicing, peeling and trimming of vegetables would also be indicators.

In addition to artifactual correlates, Thoms proposes that certain features also are correlates of root food intensification:

Bulk processing of lily family and other geophytes tends to entail the use of substantial storage facilities as well as large earth ovens, the use of which should result in the massive accumulation of byproducts, always charcoal and commonly fire-cracked rock. Processing sites tend to be located either near procurement sites or well-removed from residential structures (Thoms 1989:120).

These correlates are part of Thoms’ general model of geophyte intensification. Thoms states that the utility of his model is subject to assessment using data for any wild edible geophyte that grows in northern settings. Thoms model is assessed using ethnohistoric and ethnographic data relating how Sagittaria latifolia was processed, what tools were necessary, and if procurement sites were away from residential structures.

My research demonstrates that wapato does not require processing with grinding or mashing tools, or tools for cutting or trimming. Nor did wapato require large earth ovens, or masses of fire cracked rock. Ethnohistoric evidence presented in Chapter 3 demonstrate that wapato was most often
baked, and eaten whole. This leads to the conclusion that the intensification of roots may not always be indicated by the presence of large earth ovens, and ground stone tools.
CHAPTER 2  
ASPECTS OF THE ECOLOGY OF  
SAGITTARIA SPECIES

Botanical Features

For botanical nomenclature and taxonomic classification I referred to Hitchcock and Cronquist (1994), Gilkey and Dennis (1980) and Smith’s “A Revision of the North American Species of Sagittaria and Lophotocarpus,” (1894). Some of the following observations are my own. I have studied two taxa of *Sagittaria* species on the Lower Columbia River: *Sagittaria latifolia* and *Sagittaria cuneta* Sheld. The former is a larger plant, and more prolific than the later, which tends to grow in sandy substrates, from about the Cascades to The Dalles. The tubers of both species were used by the Indians of the Lower Columbia. This study focuses on the more common taxa, *S. latifolia*. (Figures 6.4-6.5).

*Sagittaria latifolia* is a species of water plant of the water plantain family, Alismataceae. This genus is widely distributed across North America, from Newfoundland to Mexico (Smith 1894). Wild populations of *Sagittaria latifolia* are not abundant in many parts of its former range in the Northwest, though it was considered common on the Lower Fraser River and the Lower Columbia River prior to the 1880’s.

The Army Corps of Engineers conducted a survey of aquatic macrophytes of the Columbia and Snake River Drainage. Their descriptions of the occurrence of this plant are a measure of the

Figure 6.4. *Sagittaria latifolia*, reprinted with permission of the Missouri Botanical Garden.
abundance of this water plant in several locations. They referred to *Sagittaria* spp. as a “nuisance” species in at least one lake or waterway in each of the following counties: Harney County, Oregon, Elko County, Nevada, Kootenai, Adams, Valley Counties in Idaho, and Flathead County, Montana. A “nuisance occurrence” of this taxon was when growths were “aesthetically offensive”, impeded water flow in channels, clogged water intakes, hindered boating or swimming (Falter et al 1974).

Some of *S. latifolia*’s common names include tule potato, duck potato, arrowhead (after the arrow shaped leaf blades) and swan potato. It grows in shallow water (up to four feet in depth), and on the margins of lakes between seasonal high and low water lines, as well as in slow streams and perennial wetlands. It ranges from sea level to timberline.

It is a perennial herb with an erect growth habit. The leaves are sessile, and long-petioled, meaning that they emerge from a single base (a thickened rootstock) at ground level, and have long leaf stalks that do not branch. The leaves are sheathing, and glabrous; smooth and without hair or glands. Though all the leaf forms are three-lobed and sagittate, there is some variation in form and size. “As in most aquatics, the leaves vary through wide limits in the same species, and characters founded on leaf differences, at least among the Sagittifoliae, are of little value,” (Smith 1894:29). The plants can grow to 150 centimeters tall, but are typically a meter or less. Leaves of *S. latifolia* can be as long as 25 cm., and almost that broad (Smith 1894, Hitchcock and Cronquist 1994). The flowers are white, in whorls of three petals, on a simple leafless raceme (Figure 6.5). The flower stem can have as many as ten whorls. There are generally between 25-40 stamens on male flowers. The fruiting heads grow to 25 mm in diameter. The fruit is an achene.

The overwintering part of this plant is a tuber [Thoms 1988: 47, as adapted from Craighead, Craighead, and Davis (1963 xxvii-xxvi)]. In *Sagittaria* spp., tubers are formed on the ends of rhizomes, which are horizontally creeping stems (Figure 6.6). These slender white rhizomes can be as long as four feet, but are typically less than three feet. If a rhizome is broken into several fragments, each fragment is capable of producing shoots above and roots below. The rhizomes have a pointed tip at the distal end which eventually forms into a tuber. This rhizome also assists the plant to spread. During the spring and mid-summer, these tubers (still attached to the mother plant through the rhizome) produce other plants. By late August on the Lower Columbia, these tubers cease to send up shoots, rather they thicken and develop into the starchy overwintering organ (Figure 6.7). In the fall and spring, these enlarged tubers have

![Figure 6.5. Female flower.](image)
Figure 6.6. Plant showing rhizomes and tubers.

Figure 6.7. Tubers.
the ability to float. Not all tubers are buoyant at any one time. This may be dependent on where the tuber is in its maturation process, or whether it is growing on a lake margin or submerged (some of the tubers that were harvested in November and December (1994) from hydric soils on the margin of Steelman Lake did not float).

Population Structure: The Monoecious and Dioecious Condition

A usual part of the specific description of this species is to note the prevalence of dioecious populations. This species is typically dioecious (meaning that individual plants are a single gender, not both) in the Northwest, and parts of its northern range, from Prince Edward Island to British Columbia and southward to New York, Kentucky and Nebraska (Smith 1894:38). There is some overlap in range between the monoecious and dioecious varieties. In its southern range, from Massachusetts west to Colorado, and south to Florida and Louisiana, it is typically monoecious, (having male and female flowers on the same plant).

Since plants are either male or female, the structure of the population in an ecosystem is divided by sex. At Steelman Lake and Crane Lake on Sauvie Island, the population structure is ordered in a mosaic pattern, with patches of male plants adjacent to patches of female plants. The patches vary in size generally from ten to twenty meters in diameter. The edges of the patches are distinct, the sexes do not intermix. Wooten studied a dioecious S. latifolia population in a pond that was composed of approximately 500 female plants on one side of the pond, a population of about 1000 Sagittaria cuneata plants in the middle of the pond, and 300 male S. latifolia plants on the other side of the pond. In their study of the plant, Muenchow and Delesalle observed that a patch several meters wide and consisting of more than a hundred ramets (clones) can be a single genet. They noted that single gender patches are often that large (Muenchow and Delesalle 1992).

From her experiments on Sagittaria latifolia, Wooten concluded that dioecious populations of this species produce seeds that do not readily germinate, and that the plants reproduce vegetatively, and spread clonally (Wooten 1971).

Wapato in the Food Web: Profitable Prey

The following section discusses wapato predation by waterfowl, muskrats, pigs, cattle, and carp. Understanding wapato’s place in the trophic schema is important to understanding the historic environment of Wapato Valley and the current status of this plant. Sagittaria spp. are r-strategists, that is, they produce many more offspring than survive to reproduce, thus providing an abundance of food for their predators. This section illustrates that this abundance of wapato supported other predators besides humans. The estimated impact of waterfowl predation on below-ground biomass calculated in this section will be applied to the model of available wapato productivity presented in Chapter 5. Also in this web was the muskrat. Muskrats favor the roots and rhizomes of marsh plants, and were once a common animal in the Lower Columbia estuarine zone.

Waterfowl Predation

In fall and spring as many as one million ducks, geese, and swans arrive on the Lower Columbia. Modern aerial waterfowl surveys count as many as 100,000 ducks, geese and swans present on any day in November and December on Sauvie Island during peak migration (Oregon Fish and Wildlife Statistics 1994).

Wapato is an important food for several waterfowl species. Hunters noticed that when wapato became all but extinct (as discussed later) on the Lower Columbia in the 1890’s, canvasback ducks also all but disappeared (Anonymous, Oregonian 1898). Lewis and Clark noted that swans particularly favor wapato. Wildlife managers on Sauvie Island have reported that swans are commonly found grazing in wapato patches. They have also been observed grazing in agricultural fields where potatoes are growing (Terry Dufour, personal communication).

Waterfowl and Sagittaria spp. have co-evolved in a mutually beneficial relationship. Waterfowl grubbing breaks up rhizomes which float away and produce new plants. This activity also releases tubers from the substrate. Those that are not eaten reestablish themselves. Waterfowl also assist in dispersing the seeds, which stick to the skin on their feet and legs.
Several studies have estimated the impact of herbivores on net below-ground primary production of various wetland plant species. These studies found that even though large amounts of plant material are removed by waterfowl in tidal and freshwater marshes, marsh vegetation is resilient and the effect of waterfowl grazing on the primary production of biomass is minimal.

Smith and Odum estimated that snow geese removed an average of 58% below-ground biomass in coastal salt marshes of the Atlantic Coast (1981 as quoted in Giroux and Bedard 1987). In a study of food habits of wintering canvasesbacks in Louisiana, Hohman et al. (1989) found that dry mass of Sagittaria latifolia tubers and American bulrush rhizomes in sites ungrazed by ducks was four times as high as the disturbed sites. Hohman and his colleagues found that canvasesbacks have minimal effect on reducing the density of plant foods because duck herbivory was patchy; the area of mud flats remaining undisturbed was greater than the disturbed area (Hohman, Woolington and Devries 1989).

Giroux and Bedard (1987) conducted an experiment to estimate grazing damage from waterfowl use on the wetland plant Scirpus americanus. Using an equation relating above-and below-ground biomass, Giroux and Bedard estimated that after two years of goose exclusion, the below-ground biomass in grazed plots of Scirpus americanus was 252 dry grams per square meter per year. The ungrazed plots yielded 661 dry grams. Geese had removed approximately 62% of the below-ground biomass. Even in the most intensively grazed plots, Giroux and Bedard found that there was no gradual decrease in net above-ground primary production. It was fairly constant per square meter per year over three years. They concluded that the system was a low level steady-state, even with a 62% reduction of below-ground biomass.

**Muskrat Predation**

Muskrats (Ondatra spp.) were once common in Sagittaria habitat on the Lower Columbia. This habitat was extensive, so it follows that muskrats were numerous. This section looks at the importance (previously undescribed) of muskrats to the peoples of the Lower Columbia. Muskrats may have been an important winter food source, as well as a good source of pelts. Blankets made of muskrat pelts are reported in the ethnographic literature, where they are described as items traded out from Wapato Valley to peoples on the coast (Clark in Thwaites Vol 3).

Muskrats live in marshy environments, and make their low, conical lodges from the stems of marsh plants. They can produce as many as fourteen offspring per litter. Muskrats gather Sagittaria spp. roots and store them for the winter. Ethnographic accounts from the Midwest recorded that muskrats and beaver store large covered caches of the root, which the Indians recognized and appropriated, which saved them the trouble of collecting it themselves (Smith 1923:254).

The effect of furbearer predation on Sagittaria latifolia production in Wapato Valley is unknown. According to Clark and Kroeker, “muskrats are the most significant resident vertebrate consumer of emergent vegetation in many North American wetlands, and their feeding activities may play an important role in vegetation decomposition” (Clark and Kroeker 1993:1620). At times, muskrats can exceed the carrying capacity of a marsh resulting in ‘eat outs’ of emergent vegetation (Clark and Kroeker 1993:1621).

In their description of the clothing of the Indians at the mouth of the Columbia, Lewis and Clark mention “they procure a roabe from the natives above [in Waptao Valley], which is made of Skins of a Small animal about the Size of a cat, which is light and durable and highly prized by those people,” (Clark in Thwaites Vol. 3:242, my brackets, spelling as in original). Paul Kane describes the clothing of the Chinook men as consisting of “a musk-rat skin robe, the size of our ordinary blanket, thrown over the sholder, without any breech-cloth, moccasins, or leggings,” (Kane 1968). Women, he noted, wear the blanket in very severe weather.

Blankets made from woodchuck or groundhog pelts are mentioned in several stories taken down by Boas (Chinook Texts pp. 220, 231, and Kathlamet Texts pp. 51). Woodchucks and groundhogs are not found in Chinook territory, and Ray suggests that these robes and blankets were most likely made from the pelts of mountain beaver (Aplodontia) or wood rat (Neotoma) (Ray...
Archaeological evidence from the Meier Site (35CO5) excavations in 1973 and 1987-1991 clearly indicates that the muskrat was taken in larger quantities than either the mountain beaver or the wood rat (see Table 6.1). In addition, muskrat is the third most frequently recovered mammalian taxa, after deer (Odocoileus) and elk (Cervus) with NISP values of 3,780 and 935 respectively (Ames 1995, Table 3).

A population density study of muskrats at Delta Marsh in Manitoba, Canada found that the average density was .4/ha in May and 21.3/ha in October (Clark and Kroeker 1993:1625). This study also found that adult muskrats (living in a stable environment) did not lose mass over a typical winter, and juveniles gained weight.

The density of muskrats and their eating habits on the Lower Columbia have not been studied. The above data from Manitoba may not be directly applicable, but raises some questions about the importance of this animal to the people of the Lower Columbia.

If the above densities and animal biomass data are applicable to the Lower Columbia, muskrats could have provided fresh meat--rich in fat--during the winter months when fish were scarce, and large game animals were lean. To what extent the Indians used muskrat meat remains unclear, and is a subject for further study. Clearly the Indians utilized muskrats, and muskrats were common in Sagittaria habitat.

**Summary Prehistoric Predation**

In ecological terms wapato is a 'producer' and an r-strategist. Wapato provided an abundance of food for its predators. Although annual waterfowl predation was significant, early historic accounts from the Lower Columbia and ecological data suggest that a sustained yield situation (for wapato) had been maintained.

Annual waterfowl herbivory reduced the annual net below-ground biomass of *Sagittaria latifolia* by a factor of approximately 60%. This estimate will be used in the model of productivity presented in Chapter 5. Given the lack of study of muskrat feeding habits, the annual biomass loss due to muskrat predation in *Sagittaria latifolia* habitat on the Lower Columbia is difficult to assess. For the purpose of this study, their effects are assumed to be negligible. However, I wanted the reader to be aware of the presence of muskrat in the trophic schema.

**Modern Predation**

No discussion of *Sagittaria latifolia* would be complete without a discussion of why wild populations of wapato are presently not abundant in many parts of its former range. This is due to wetland abatement practices, introduction of domestic animals, and infestation of the Lower Columbia waters by carp (*Cyprinus carpio*).

Domestic hogs were in the region as early as 1811 when the Pacific Fur Company established a trading post at Fort George. They brought with them 50 hogs (Franchere 1967:44). This company merged with the Hudson’s Bay Company. In the 1830’s the HBC established a farm on Wapato Island, (later named Sauvie Island) and set a few hogs loose on it. Thomas J. Farnham traveled through the Oregon country in 1839. This is how he described the island: “The Hudson Bay Company, some years ago, placed a few hogs upon it, which have subsisted entirely upon

<table>
<thead>
<tr>
<th>GENUS</th>
<th>COMMON NAME</th>
<th>NISP</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alplodontia</td>
<td>mountain beaver</td>
<td>7</td>
<td>0.001</td>
</tr>
<tr>
<td>Neotoma</td>
<td>wood rat</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Ondatra</td>
<td>muskrat</td>
<td>374</td>
<td>0.058</td>
</tr>
</tbody>
</table>

Table 6.1. Number of Identified Specimens (NISP) of remains of three small mammals at the Meier Site (35CO5). Church and Lyman, Ames et al 1995.

Total NISP = 6421.
roots [probably camas and wapato], acorns, &c. (sic) and increased to many hundreds” (Farnham 1906:14). On a boat trip from Fort Vancouver to Cowlitz, his group stopped on the island for lunch. “Having eaten our cold lunch, we left Wappatoo Island to the dominion of its wild hogs, and took again to our boats” (Farnham 1906:67).

Swedish botanist Peter Kalm observed a similar situation on travels in Pennsylvania and New Jersey in 1770. He described how the Iroquois harvested the tubers of *Sagittaria latifolia*, and noted that these roots used by the Iroquois “were said to have been almost destroyed by hogs, which were exceedingly greedy for them. The cattle are very fond of their leaves” (Benson 1770:259).

It has been my observation that a typical lake margin in *Sagittaria* spp. habitat where cattle are present has a band several meters wide where the plants grow sparingly, and those that do grow are cropped off to the ground. Plants that had spread into this band of the lake margin during high-water are at risk as the water recedes. If the substrate is firm, cattle will wade in to graze. If the substrate is unconsolidated (such as in silted-up lakes), cattle avoid it. The leaves of *Sagittaria* spp. are nutritious forage for cattle and are grown in China principally for forage (Hu 1992:265).

The predator that probably had the most disastrous effect on wapato was the carp, which lives largely on a vegetable diet. The German carp was imported by Captain John Harlow. He was the founder of Troutdale, situated where the Sandy River discharges into the Columbia. The town was named Troutdale after the ponds he stocked for the local fish markets. In 1880 he imported thirty-five carp from San Francisco. This fish was hailed as the “most toothsome table fish of them all” (Lampman 1946:11). A flood in May of 1881 washed 3000 newly hatched fry into the Columbia River. The fecund fish proved to be an ecological disaster. They destroyed much of the wapato and permanently muddied the waters.

A dozen years later The Oregonian reported that commercial fishermen were offering to supply carp as fertilizer in any quantity to farmers at $5.00 a ton. Then all the lowland waters were silted by the ceaseless grubbing of the carp—never again to be clear (Lampman 1946:14).

Thomas Howell, a botanist whose family home was on Sauvie Island, noted in his book *A Flora of Northwest America* (1903) that “this species [*Sagittaria latifolia*] was very abundant along the Lower Columbia river, but is now almost exterminated by the Carp,” (1901:679). In 1898 The Oregonian reported that wapato was making a limited comeback, and theorized the loss of the wapato was due in part due to a heavy silt load deposited in the great floods of the 1890’s.

Sportsmen will remember that several years since the wapatoes which grew so luxuriantly in many ponds, lakes and sloughs on Sauvie’s Island and in other places along the Columbia and which were the favorite food of the canvas-back duck totally disappeared. Their loss was mourned by all sportsmen, as with the wapatoes disappeared almost entirely the flight of canvas-backs they used to attract (anonymous in The Oregonian, OHS Scrapbook 35:43).

Carp had caused ecological disaster in other waters as well. In 1891 Lake Merced (one of the reservoirs of San Francisco) was so “roiled by carp as well nigh to be useless,” (Lampman 1946:24). That year, 19 sea lions were placed in the lake.

So epic was the slaughter for the sea lions played and rioted among the carp, that men then were hired to patrol the lake and its shores, picking up the many fragments of fish that endangered the purity of the water. In 1895 the lake was seined, but no fish of any sort were found—and the sea lions had become emaciated (Lampman 1946:24).

**Summary**

In early historic times, domestic livestock had a deleterious effect on wapato patches. The grubbing of the carp eliminated *Sagittaria latifolia* from open water areas of its former range, such as bays, lakes, ponds and sloughs (Lampman 1946). It has been my observation that *Sagittaria latifolia* continues to flourish in silt-filled lakes and wet areas that drain to the extent that the carp are unable to reach the plants. Cattle prefer wapato foliage to grass, and will wade into ponds and on the margins of silt-filled lakes to graze.
CHAPTER 3
ETHNOGRAPHIC, ETHNOHISTORIC &
ARCHAEOLOGICAL ACCOUNTS

Introduction

The following are descriptions of the use of *Sagittaria* spp. in East Asia, the American East, the American Midwest, the American West, and the Greater Lower Columbia. These accounts were selected because they describe traditional harvesting, preparation and storage techniques used by Native Americans and Asians for this species. Notes on the use of this plant were from several sources. This is not intended to be an exhaustive collection of every citation of this plant in the literature, but rather a general overview of how this plant was used over a broad geographic area. Many of the references from the Midwest and the East were found in *Food Plants of the North American Indians*, published by the U.S. Department of Agriculture in 1928, and reprinted in *The North American Indian* (Thomas 1986). The preparers of this publication searched ethnographies, articles, books, and journals for references to plant foods. This publication is an excellent index that lists the resulting reference material for each plant by author, title and page. Twenty eight titles contained information on the native use of *Sagittaria* spp. *The Handbook of Indian Foods and Fibers of Arid America* provided ethnographic information on how this plant was used in California and Colorado (Ebeling 1986). *Sagittaria* spp. grow well in the South, especially Florida and Louisiana, but I was unable to obtain information on the aboriginal use of this species in these areas. Ethnohistoric accounts from the Northwest, and especially the Greater Lower Columbia region contributed detailed descriptions of wapato harvesting, cooking techniques and trade practices. The best descriptions of wapato are from the journals of Lewis and Clark in 1805 and 1806. In the index of the Thwaites’ Lewis and Clark Journals ‘wapato’ (and versions of the word) are cited over ninety times.

Ethnographic Accounts From East Asia

*Sagittaria sagittifolia* and *Sagittaria trifolia* are cultivated crops of China, Japan and Korea. *Sagittaria* spp. have largely been displaced by the white potato, which was introduced into China primarily by French Catholic missionaries in the eighteenth and nineteenth centuries (Anderson 1988:122). The tubers of *Sagittaria* spp. are often mentioned as being similar in taste and texture to the potato. As noted above, it is still cultivated in China principally for the use of the leaves as forage. “The use of water surfaces and wet land to produce forage in China is common, and results in good productivity,” (Hu 1992:265).

*Sagittaria trifolia* var. *edulis* (Sieb.) Ohwi is grown in Japan and referred to as Chinese Arrowhead. The common name is ‘Kuwai’. It is an important ingredient of traditional dishes for the New Year in Japan (Tanimoto 1989:345). It is typically steamed on wooden skewers, and dipped in a soy-based sauce. It is eaten by squeezing the pulp out of the skin into one’s mouth, and discarding the skin.

There are three cultivars of this plant in Japan; Aokuwai, Shirokuwai, and Suitakuwai. The first two varieties originated in China. One was brought to Japan in the late 10th century by a Chinese delegate to the emperor’s court (personal communication Tanimoto 1995). The third is thought to be a domesticated variety derived from a paddy field weed, *S. trifolia* (L.). The Chinese variety, Aokuwai, is the most popular in Japan because it exhibits ‘good quality in tuber shape and color’ (Tanimoto 1993:623). However it is slightly bitter, and not as productive as the ‘paddy weed’ variety Suitakuwai, which produces small, though better tasting tubers.

The use of wild *Sagittaria* spp. in Japan in prehistoric times is poorly understood, in part because the taphonomy of root crops in general is poor. However, several Jomon sites southeast of Hida in Japan yielded the charred remains of starchy cakes made from a finely ground meal. Their outer surfaces were charred, and bore the imprints of leaves in which the cakes had been wrapped. These cakes were found adjacent to a milling stone. Researchers tried to duplicate the process. They ground and combined several plant materials, and formed them into cakes. The only cake that held together and resembled the prehistoric cakes was one made from portions of “sticky, potato-like roots” and rice and wheat grains (Aikens and Higuchi 1982:182). This “potato-like root” was unfortunately not identified in the article.
Ethnographic Accounts from the Eastern United States

The Iroquois boiled the tubers, and according to Parker, they were sometimes eaten raw “but in this state the bitter milky juice made them repugnant to anyone but a starving person” (Parker 1910:105). Peter Kalm, a Swedish botanist who traveled to North America in 1770, spent some time with the Swedish settlers in Pennsylvania and New Jersey. “Some of the old Swedes were yet alive who in their younger years had intercourse with the Indians and had thoroughly observed their manners” (Benson 1770:258). He described the Native Americans that had formerly occupied the vicinity as farmers who cultivated corn, beans and squash, but principally relied on wild foods such as fish and game. The Iroquois name for *Sagittaria* spp. was “Katniss.” At the time Kalm visited, the Swedes still referred to the species by that name.

“The root is long, commonly an inch and a half long, and one inch and a quarter broad in the middle; but some of the roots are as big as a man’s fist. The Indians either boiled this root or roasted it in hot ashes. Some of the Swedes ate it with much relish at the time when the Indians were so near the coast; but at present none of them make any use of the roots. Nils Gustafson told me that he had often eaten these roots when he was a boy... He added that the Indians, especially the women, travelled to some islands, at about Whitsuntide, dug out the roots...while they had them they desired no other food” (Benson 1770:259).

Ethnographic Accounts from the Midwest

The Meskwaki and the Menomini people refer to the plant as wapasi’piniak, also known as ‘white potato’, and wild goose or swan potato.

This is one of their valued potatoes. The round corms are attached by a slender rootlet to the main cluster of fibrous roots, and in digging for a specimen one is very apt to detach them from their rootlets. The muskrats gather these corms for their winter store of food, and along a stream where these grow one can often find a cache of them. When the Indians find them it saves the trouble of digging them. These white potatoes are boiled, then sliced and strung on a piece of basswood string and hung in the rafters for the winter supply (Huron Smith 1923a:254).

The Ojibwe call this plant wabasi’pin which means white potato. They too would often gather these from muskrat nests or beaver dens, but they would dig for them if they could not be more easily obtained (Smith 1932:327). These tubers were also known as a remedy for indigestion among the Pillerag Ojibwe.

The Dakota called this tuber ‘pshitola’; the Omaha-Ponca referred to it simply as “Si”. In the Omaha myths, “Ishtinike and the Four Creators” and “How the Big Turtle Went to War” Si is mentioned. The Winnebago called it Si-poro, and the Pawnee called it Kirit (Gilmore 1919:65). These tribes, according to Gilmore, used the tuber in much the same way. It was prepared by boiling or roasting. “The Pawnee must have some other use for the plant because an old medicine-man showed excited interest when he saw a specimen in my collection, but he did not communicate to me what the use is,” (Gilmore 1919:65). The Chippewa have names for *Sagittaria latifolia* and *Sagittaria arifolia* (Nutt.). These names share the same root-word which means “heron-leg” (Gilmore in Thomas 1986:125).

The Cocopa occupied the Lower Colorado river basin where *Sagittaria latifolia* grew abundantly. “They were never stored, but were gathered only for immediate consumption. This fact, plus the considerable labor involved in digging them, made the tubers the only food product valuable enough to use in gambling games,” (Ebeling 1984:414).

Ethnographic Accounts from the Far West

In the *Handbook of Indian Foods and Fibers of Arid America* (Ebeling 1986), wapato is referred to as tule potato. It was “much used” for food by the Indians. This species grew “abundantly” on islands on the lower Sacramento and San Joaquin rivers. They were harvested in late summer by women pushing canoes. They were cooked whole on the embers of a fire, and skinned. This source says that the Chinese immigrants recognizing this plant, began to cultivate it for the roots (Ebeling 1986).

The Klamath of Northern California and Southern Oregon referred to the tuber as cho-a’.
“From the fact that the tubers bear a general resemblance to those of the cultivated potato the name cho-a’ was at once applied to that plant when it first became known to the Klamaths,” (Coville 1897:90). The Chewaucan River (wapato river) empties into a large marsh known as Chewaucan (place of wapato) that drains into the Lake Abert Basin in Southeast Oregon. The marsh was a traditional place to collect wapato. When Captain Fremont explored this region in mid-December 1843, he described the scene as follows:

The rapid stream of pure water [Chewaucan River] roaring along between banks overhung with aspens and willows, was a refreshing and unexpected sight; and we followed down the course of the stream, which brought us soon into a marsh, or dry lake, formed by the expanding waters of the stream...Large patches of ground had been torn up by the squaws in digging for the roots, as if a farmer had been preparing the land for grain” (Fremont 1849:593).

He noted ‘frequent trails’ and fresh tracks of Indians. He tried to see what they had been digging but was unable to find any roots.

The Modoc of Northern California were neighbors of the Klamath people. Marcella Rawe in a letter dated September 7, 1974 to author Harriet Smith, writes about how a Modoc woman dried wapato:

The wapato was about the size of a pullet’s egg and almost tasteless. It was baked in its jacket and wrinkled and dark on the outside. Mrs. Moses (informant-Modoc) said that she did not think they had dried or parched that batch enough. It takes steady drying for several weeks. In a typical Indian style they piled a couple of bushels on the sunny side of the shed, and they would turn the tubers every few days with a pitch fork. The only trouble was that it rained a lot that year and those on the bottom did not dry out (Harriet Smith 1982:3).

**Accounts from the Northwest Coast Area**

The Katzie of the Lower Fraser River lived in an ecosystem similar to the Lower Columbia, one very favorable to the *Sagittaria* spp.:

“...the unusual extent of low, seasonally flooded lands in Katzie territory gave them an unusual abundance of several bog and marsh plants. The two most important of these were the cranberry and the wapato” (Suttles 1951:26).

The Katzie wapato harvest was in October and November. The tubers were gathered by “wading and treading on the plants, ‘dancing’ until they came floating up” (Suttles 1951:27). They were taken home raw and unwashed, and would keep for several months. They were baked in hot ashes as they were needed.

Some patches belonged to the Katzie tribe, while others belonged to families. Suttles informant could name nine patches that belonged to his father’s family. There was also a large public patch. Families could seasonally claim parts of it by clearing tracts several hundred feet long along the shore so the plants could be collected more easily (Suttles 1951:27).

Katzie territory was famous for cranberries and wapato, and “in the fall outsiders came from a number of other tribes to gather them” (Suttles 1951:27). Suttles’ informant said that permission was not refused to outsiders to harvest the cranberries, nor did they exact any tribute. Suttles inferred that “ownership of ...a rich cranberry bog was its own reward in that it permitted the owners to play the role of hosts. A host at one time and place is potentially a guest at another,” (Suttles 1951:27).

Haeberlin, an ethnologist, worked on the Tulalip Reservation in 1916-1917, principally with members of the Snohomish and Snoqualmi tribes of the Puget Sound lowlands of Western Washington. His manuscript and notes were edited and published by Gunther in 1930. His informants described wapato as an important and widespread food which grew in shallow lakes and streams, and further that “this plant can be easily grown and transplanted” (Gunther 1930). Gunther, in her footnote, said that “this reference is the only reference of any kind to cultivation. In 1854 the Sound Indians are supposed to have raised 11,000 bushels of potatoes. The species is not stated. These may have been ordinary potatoes, Indian potatoes or wappato,” (Gunther 1930:21, citing Gibbs).
Ethnohistoric Accounts:
The Greater Lower Columbia

Men of the Sea

The Northwest Coast was not charted until the voyages of the Spanish explorers Perez, Heceta, Bodega, and Arteaga in the years 1774 to 1779 (Darby 1991:174). In 1778, Captain Cook explored the coast for the British, purchasing sea otter skins at Nootka Sound, and sold them in China at high prices. Thus began the fur trade by sea. It was not long before both British and American vessels came to exploit this trade (Hussey 1949:3).

The first ship to enter the Columbia River was Columbia Rediviva in May of 1792, which was commanded by Captain Robert Gray. John Boit’s log of that voyage describes a ‘ground nut’ that grows on the banks of the river. This reference is probably describing wapato. On May 18, Boit described the scene as follows:

The river abounds with excellent salmon and most other river fish, and the woods with moose and deer, the skins of which were brought to us in great plenty. The banks produce a ground nut, which is an excellent substitute for bread and potatoes (Johansen 1960:).

The next historical account of *Sagittaria* spp. along the Columbia River was made that same year by Lieutenant W.R. Broughton of the brig *Chatham*, which was one of the ships of the exploring squadron under the command of Captain George Vancouver. Broughton and his men rowed up the river for several days, reaching about 100 miles upstream of the mouth. On the last week of October, 1792, Lieutenant Broughton mentioned that his crew ate a “bulbous root about the size and not unlike the crocus, that ate much like a mealy potatoe,” (Broughton 1792:39). Like Boit, he doesn’t mention a name for this root, however he was on the river during peak harvest time for wapato.

Thomas Manby, the master of the *Chatham*, also made note of this root. On November 4, 1792 while they were waiting in Bakers Bay for calm water to cross the Columbia River Bar, Manby decided to hunt water fowl in a “swamp” four miles from the cove near the mouths of the Chinook and Wallacut Rivers. He met with a small party of Indians who supplied him with salmon and “a basket of roots not much unlike small potatoes and a little inferior to them in taste” (Howay and Elliot 1942:325).

The *Ruby* crossed the Columbia River bar the first week of June, 1795. Captain Charles Bishop wrote an account of this voyage. He described their purpose as chiefly a trading episode, though during the stay “the ship was ballasted, the hold restowed, and wood and water for three months put on board” (Howay 1927:14). The captain planned to winter at the mouth of the Columbia, and had the crew plant beans, potatoes, peas and sowed mustard, cress, celery and radishes on a small island. Though there was considerable trade between the crew and the Indians, no mention was made of wapato in Bishop’s log until they returned in October for the winter. Captain Bishop’s description of wapato is as follows:

As none of us are acquainted with Bottoney, I can offer nothing on that head, but what is described in the account of Nootkan Productions, in Cooks voyage we found here, except the Wild Potatoe called by the natives “Wapattoe” which we have seen nowhere else, they in general are of the size of a Pidgeons Egg, and appear to grow like an onion or Turnip, above the surface of the Earth are found in swampy grounds, and when boiled or roasted, eat not unlike potatoes, but it is observed that if they continue boiling longer than necessary they harden in the room of desolving to a flour or paste (Elliot 1927:274, spelling as in original).

The garden they had planted in the summer produced a good crop of potatoes, and a few beans. However, the crew that winter subsisted chiefly on salmon, cranberries, wapato and wild game supplied by the natives.

Lewis and Clark Journals

It is notable that though many of the explorers, travelers and adventurers that came to the Lower Columbia had considerable experience with other Native American groups, only one man, Wilson Price Hunt, a commander of the overland Astoria fur party expedition in 1811-1812, mentioned seeing wapato being used by a Na-
tive American group other than the people on the Columbia. Certainly Sacajawea of the Lewis and Clark party was familiar with this root, because when the vote was taken on where to camp for the winter, she voted to be near the wapato grounds: “Janey [Sacajawea? -ed] in favor of a place where there is plenty of Pota [sic],” (Thwaites Vol. 3: 247).

Lewis and Clark’s first encounter with wapato occurred on November 4, 1805. In Clark’s first draft he describes eating a “round root near the size of a hens egg” at a village past the mouth of what is now known as the Sandy River. The roots were roasted in the embers until they became soft (Thwaites Vol. 3:194). In his second draft describing the same day, he noted that the Chinese cultivate this plant in great quantity and it is called the common arrowhead or Saggiti folia [sic], and mentioned that it had “an agreeable taste and answered well in place of bread”. They purchased four bushels and divided it among their party (Thwaites Vol. 3:196-197).

They noted that it grew in great profusion on an island farther downstream. Lewis described the island as “about 20 miles long and from 5 to 10 in width; the land is high and extremely fertile and intersected in many parts with ponds which produce great quantities of the sagittaria Sagitifolia (sic), the bulb of which the natives call wappetoe, (Lewis in Thwaites Vol.3. pg 218). They named this island Wappato Island, and they named this part of the Lower Columbia Valley “Wap-pa-too Valley from that root or plants growing Spontaneously [sic] in this valley only “ (Clark, Thwaites Vol.3 pg. 202).

On November 7, two days after their original encounter with wapato, they met some Indians who took them to their village which was “Situated on the Stard. side behind a cluster of Marshey Islands, on a narrow chan. of the river,” (Clark in Thwaites Vol 3:208). Clark described the four houses that made up the village. These were described as being entirely above the ground, with eaves about five feet from the ground to the eave-line (suggesting a gabled roof) and with doors on the side of the house. Americans in New England and the South placed doors on the roof-slope side of a house rather than the gable-end, so this description probably suggests that the door was on the gable-end side. Clark also noted that the door was in a ‘corner’, i.e. not centrally located on the facade as was typical of American houses of this era. This would give the natives more unbroken length to use for storage space. Clark noted that their beds were along the walls, about four feet above ground level. This would give only one foot of head space at the wall, along the slope side of the building, but provided more storage space than if the beds were lower. Clark noted baskets of dried fish, berries and wapato were stored under bed platforms.

The party purchased some wapato roots, three dogs and two otter skins for some fish hooks. They stayed at this village one and a half hours before continuing to the main channel of the river. While they were en route, near what is now known as Tenasillihee Island, several “canoes came along Side with Skins, roots fish &c. to Sell, and had a temporey residence on this Island,” (Clark Nov. 7 1805, in Thwaites Vol. 3:209). The party landed at another village fourteen miles below the previous village, where for the second time in the same day they purchased wapato roots and a dog. Between November 7 and November 14, all the wapato and dogs had been eaten, and there was nothing to eat but pounded fish (Clark in Thwaites Vol. 3:221).

Near the mouth of the Columbia the corps traded again for wapato and other roots. Clark noted that in this region “the Wapto root is scerce, and highly valued by these people, this root they roste in hot ashes like a potato and the outer skin peals off, tho this is a trouble they seldom perform,” (Thwaites Vol. 3:240).

On November 26, Clark described the Cat-tar-bets (Cathlahma) people occupying a village of nine houses. “They live on fish & Elk and Wapto roots, of which we bought a few at a high prices,” (Thwaites Vol. 3:250).

The Lewis and Clark party wintered at Fort Clatsop on the Pacific Ocean. They occasionally were able to trade for wapato, which was a welcome addition to their diet. On December 31, they purchased one and a half bushels of wapato, for which they were grateful since they had been living on spoiled elk, which was “disagreeable to the smel. as well as the taste” (Clark in Thwaites
On Saturday, January 4 Lewis wrote, “The hunters were all sent in different directions, and we are now becoming more anxious for their success since our store of wappato is all exhausted,” (Allen 1914, Vol 2:105). They record one other episode that winter when they were able to obtain wapato. On January 10 they were presented with “a basquit of woppetoe” from a chief of the Cathlamet people.

In March of 1806 they began their return journey. In Wapato Valley they stopped at a village (Cathlapohtle) near the mouth of the Lewis River, and noted an abundance of sturgeon and wapato. They camped near a pond about a mile above the village. The following description is probably from an interview.

...in this pond the natives inform us they collect great quantities of p[w]appato, which the women collect by getting into the water, sometimes to their necks holding by a small canoe and with their feet loosen the wappato or bulb of the root from the bottom from the Fibers, and it immediately rises to the top of the water. they collect & throw them into the canoe, those deep roots are the largest and best roots (Clark in Thwaites: March 29, 1806: Vol. 4: 217, spelling as in original).

The Biddle version of this passage written in 1814, perhaps with further clarification by Clark, records that the roots were collected “chiefly by the women” who would remain in the water for several hours even in the “depth of winter.” (Allen 1914:225).

Lewis wrote that wapato is taken in great quantities from the ponds around Cahtlapohtle. It was the “principal article of traffic with those Tribes which they dispose of to the natives below in exchange for beads, cloth, and various articles” (Lewis in Thwaites 4:222). They purchased “a considerable quantity of wappetoes, 12 dogs, and 2 Sea otter skins of these people,’ (Thwaites Vol. 4:215). On Monday, March 31 the party had reached a small hamlet belonging to the Shah-ha-la Nation (Cascades people) which they had visited the November before. On their first visit, there were 24 straw houses and one wooden house. Lewis remarked that all these houses are destroyed.

The inhabitants [of these houses] as the indians inform us have returned to the great rapids of this river which is their permanent residence; the house which remains is inhabited; soon after we landed two canoes came over from this house with 4 men and a woman. they informed us that their relations who were with them last fall usually visit them at that season for the purpose of hunting deer and Elk and collecting wappetoe....These indians frequently visit this valley at every season of the year for the purpose of collecting wappetoe which is abundant and appears never to be out of season at any time of the year. (Thwaites Vol. 4: 223).

The above quote was from Lewis’ first draft. In the second draft he states that the people who live in this house “inform us that their relations also visit them frequently in the spring to collect this root which is in great quantities on either side of the Columbia,” (Thwaites Vol 4:226). The second draft mentioned that it was harvested in the spring, as well as the fall, and this information is consistent with my field observations of this plant.

Clark observed about 100 small canoes which were piled up and scattered in different directions in the woods, on the river bank and in the vicinity of the house. Clark went into the house and offered several articles to the people in exchange for wapato, but they were not inclined to trade. So he performed a trick for them. He had a one inch length of ‘port fire match’ which he put into the fire creating a bright colorful fire which lasted awhile and alarmed the natives. Clark also took out his magnet and ran it around his compass so the needle turned with the magnet. The natives, very alarmed, immediately placed several parcels of wapato at his feet and asked him to leave. The women and children were cowering in their beds, and an old blind man was imploring his god’. Clark gave them some ‘smoke’ and something in trade for the roots (Thwaites Vol. 4:237).

On April 7, 1806 Sergeant Gass and Collins and Windsor returned from a hunting party without the female bear they were hunting, but brought three bear cubs instead. The Indians who
visited the party that day wanted the cubs and traded some wapato for them. The last mention of wapato in the journals was on April 9, 1806 when they purchased five dogs and some wapato from people who lived near Beacon Rock, on what is now the Washington side of the Columbia River.

Accounts from the Fur Trade Era

Trade goods were introduced in large quantities after 1810 when the inland fur trade began with the establishment of a small post by traders from Boston at the mouth of the Columbia River. This post lasted less than a year (Hajda 1984:39). In 1811 Fort Astoria was constructed at the mouth of the Columbia by John Jacob Astor’s Pacific Fur Company. This was taken over by the Northwest Company in 1812, which dominated the fur trade on the Columbia River until 1821 when it merged with the Hudson’s Bay company (Hussey 1949).

Several members of the Astorian expedition published personal narratives about their adventures on the Columbia River, including Gabriel Franchere, Ross Cox and Alexander Ross who mentioned wapato. Alexander Ross described wapato as “a perennial root, of the size, shape, and taste of the common potato, is a favourite article of food at all times of the year” (Ross in Thwaites, Vol. 7: 109). Ross Cox described the root as excellent, “In size they resemble a small potatoe, for which it is a good substitute when roasted or boiled; it has a very slight tinge of bitterness, and is highly esteemed by the natives, who collect vast quantities of it for their own use and for barter” (Cox 1957:79). Franchere found the wapato root to be a “good substitute for potatoes,” and procured a quantity for the staff at Fort George during an upriver trade excursion in the first week of October, 1812 (Franchere 1904:278).

Wilson Price Hunt commanded the Astoria party of fur trappers who traveled overland from the Arikara villages near the present site of Pierre, South Dakota to Fort Astoria. They arrived at Fort Astoria in the winter of 1812. Hunt described a trading episode with the Native Americans of the Lower Columbia where wapato, dogs, beaver pelts, and dried salmon were received in a trade. In his journal he noted that this root is called ‘ouapasippin’ on the Mississippi (Franchere 1973).

Fort Vancouver was the headquarters of the Hudson’s Bay Company’s Columbia Department. Established in 1825, one hundred miles upstream from the mouth of the Columbia River, it was situated on the north side of the river, in the center of Wapato Valley. The river was navigable, and Fort Vancouver became an important land and sea trading center. Trade goods were imported from Great Britain, New York, and Canton via the Sandwich Islands (Ross 1979:21), and distributed to over 30 satellite posts within the HBC Columbia Department, which embraced present-day British Columbia, Washington, Oregon, and Idaho.

Five years after the establishment of Fort Vancouver, a malaria epidemic struck the region (Boyd 1985). Mortality was high, perhaps as much as 75% along parts of the lower Columbia. Sauvie Island had no villages left after 1836 (Hajda 1984:44).

On the heels of the fur traders were missionaries, botanists and government officials. Wapato occasionally received a passing note in the journals that these men kept. Slacum was sent to the Oregon territory by President Jackson in 1835 to obtain information about the native inhabitants. He reported “...the ease with which they procure food, fish, and fowl, with the delicious vegetables the “Wapspitoo” and “Kamass” engenders the most indolent habits among these people,” (Scott 1912:200).

Catholic missionary Father Blanchet mentioned that on March 11, 1841 he visited Wapato Lake “where the Indians of the Clackamas tribe were assembled to dig the wapato root on the right shore of the Willamette” (Bagley, 1932:99). The botanist, David Douglas, mentions eating wapato during an episode when he was stormbound at Cape Shoalwater (the outer coast of Washington) in October (Harvey 1947:63).

Dr. White, and his wife were missionaries to the Oregon country from 1837 to 1847. The following is a story they related in their journal about their travels. The missionaries arrived at the mouth of the river in May, and proceeded upriver in a canoe with a crew and a pilot. They decided to stop for the night. On the shore they noticed
an Indian man and woman near a large fire. The Indians were so intent on what they were cooking that they didn’t notice the intruders until the canoe landed. Upon seeing them, the woman fled into the forest, and the man momentarily hid behind a tree and pointed a gun at the canoe. The crew walked to the fire, and stood for a few moments. After awhile, the Indian man joined them, apparently “convinced of their inoffensiveness.” The missionaries and their group settled around the fire, and the Indian woman came out of the woods and joined them. The woman served them some roasted wapatoes, which the missionaries found to be not as good as potatoes, but “as their appetites were sharpened, tasted well” (Allen 1850:59).

The Reverend Samuel Parker visited the Oregon Territory in the 1830’s. In describing the geography, he mentioned Wapato Island “so called for a nutritive root found in the small lakes in the interior, which is much sought for by Indians as an article of food [Parker (1838) 1967:141].

Hall Jackson Kelly wrote that by 1834 the Multnomah Indians “who formerly occupied the Wappatoo islands, and the country around the Wallamette (sic) and who numbered 3,000 souls, are all dead, and their villages reduced to desolation (Powell 1917:294).

Settler Era 1850-1870

In 1852 James Swan left a prosperous New England business, a wife and two children, and moved to a remote part of the Northwest Coast, Willapa Bay. This is just north of the mouth of the Columbia River. He lived for three years among the Chinook, and recorded first hand impressions of many aspects of Chinook life. He writes of the wapato:

On the Columbia River, an excellent root called the wappatoo, which is the bulb of the common Saggitafolia or arrow-head, is found in abundance, and is a favorite food of the wild swans, which are very plentiful. The wappatoo is an article much sought after by the interior Indians, but there is none found along the coast except in small quantities (Swan 1977:89-90).

Though wapato was rare on the lowest portion of the river, it grew in the marshes a few miles upstream from the mouth. The local harvest was not enough to sustain the population, and wapato was imported from upriver to the people at the mouth.

Jim Attwell’s father had a claim of 320 acres near Skamania, located just upriver from the Cascades on the Washington side of the river. However, he was born on the Oregon side of the river. He the first male child born in Hood River County, Oregon on January 5, 1855. According to the boy, 300 Indians lived on the Skamaina area claim.

As a boy, my playmates were Indian Children. The older Indians almost considered me another Indian boy. I was often invited into their homes. Adult Indians loved their children and allowed them to do as they pleased from the time they could walk until they were teenagers (Atwell 1974:6).

He mentions that they cooked meat in a wooden bowl or a water-tight woven basket by putting red hot stones into the water. “Sometimes an herb or wapatoe was added with the meat and then the ashes and smoke on the stones helped flavor the stew,” (Atwell 1974:7).

The following account is by Robert Brown, who traveled through the Northwest in 1865. He visited several groups, including the Chinook, Nisqually, the Nez Perce, Kootanie, and Colville.

The roots of the Sagittaria sagittaria, Linn., were at one time very extensively eaten by the Indians, under the name of Wappatoo; and on the Columbia River there is an Island called Wappatoo Island, from the abundance of this plant. Since the introduction of the potato the use of the roots of the Sagittaria has much declined, and the name is now transferred to the potato. In the vicinity of nearly every Indian village are small patches of potatoes; but the ground is merely scratched up, and the cultivation far from being properly attended to. (Brown 1868:379).

Later in the article he states that they have no other cultivated plant besides the potato, though he mentions that “Some of the Indians of Oregon used to grow a little wild tobacco, but they now buy it from the whites,” (Brown 1868:385).
Ethnographic Accounts: The Greater Lower Columbia

Ethnographic materials for the people of the Greater Lower Columbia are quite limited, largely due to the epidemics which eliminated most groups prior to visits by anthropologists. Fieldwork with the few survivors was limited to mainly memory ethnography (Hajda 1984:4). Though Gibbs did some ethnology in the 1850’s, the first ethnographic work in the region was Albert S. Gatschet, a linguist with the U.S. Government. He spent two months among the Tualatin and others on the Grand Ronde Reservation in 1877. In 1890 and 1891 Boas was able to obtain descriptions of previous lifeways from Charles Cultee, who was Clatsop, Chinook, Kathlamet and Kwalhio-kwa. This data was generally in the form of stories which Boas recorded for the Bureau of American Ethnology, under the title Chinook Texts published in 1893, and Kathlamet Texts in 1901. In 1931 and 1936 Vern Ray worked with two elderly Lower Chinook (downriver Indians) who lived on Willapa Bay. They were part Lower Chehalis, and spoke very little Chinook. His Lower Chinook Ethnographic Notes was published in 1938. He relied on Boas’ previous work as well as ethnographic data from various aspects of the Lower Chinook culture. In 1929 and 1930 Melville Jacobs collected Clackamas Chinook myths, tales and songs from Victoria Howard, one of the last two surviving speakers of the Clackamas dialect of Chinook. Leslie Spier and Edward Sapir wrote an ethnology of the Wishram people (1930). These were upriver speakers of Chinook who lived around The Dalles.

The Tualatin

The Tualatin branch of the Kalapuyan called S. latifolia ma’mptu (Zenk 1976:85). The Kalapuyan occupied most of the lowlands of the Willamette River drainage basin above Willamette Falls. The group living nearest to Wapato Valley were the Tualatin, which occupied upwards of 15-20 winter villages in the Tualatin Valley, which is the next major drainage system south and west of Waptato Valley. They were participants in a regional network of economic and political interrelationships centered in Wapato Valley (Zenk 1976:5). Manifestations of this interrelationship included marriages between and Chinookan families, and the existence of the practice of head-flattening among the band of the Kalapuyan (but not Kalapuyan bands further south).

Zenk, in his thorough study of the Tualatin, noted that they were one of the better documented Kalapuyan divisions (Zenk 1976:12). In 1877 Albert S. Gatschet spent two months among the Tualatin and others on the Grand Ronde Reservation. His main informants were Peter Kenoyer, the son of a prominent chief, and Dave Yatchkawa, a shaman. Gatschet’s manuscripts and notes contain information on ethnobotany, subsistence, village locations, and linguistic data. This material was reviewed and partially corrected in ca. 1915 by Frachtenberg who interviewed Peter Kenoyer’s son, Louis. He left an unfinished typescript that Melville Jacobs worked on, again with Louis, in 1936. Though incomplete due to Louis’ death in 1936, this material was published by Jacobs in 1945.

The ethnobotanical descriptions these informants provide for the Tualatin Valley are probably the closest reflection of how wapato was used in Wapato Valley in early historic times. The following is Zenk’s rendering of Jacob’s rendering of Gatschet’s text based on an interview (probably Peter Kenoyer) describing the harvest at Wapato Lake:

I myself know that in autumn the wapato were gathered. The women dug them, they made holes...and they put them in it so that they could preserve them for wintertime to be eaten in wintertime. They got them at the lake, the women got (wapato) underneath the ground, they picked them up, they got them. When the lake was overflooded we named it ‘step in the water,’ the women stepped in the water (Zenk 1976:56). Zenk notes that the storage pits for wapato described in the Gatschet manuscript were four or five feet deep.

The following is a description of a wapato oven built by a Tualatin group. Though the informant is un referenced, Evelyn Dickson interviewed several native informants for her thesis *Food Plants of Western Oregon* (1946), including John Hudson (according to Zenk 1976:57).
The Indians near Gaston, Oregon [Wapato Lake] would build a fire on top of the ground as you build a bonfire today. They, would spread the ashes apart, put the Wapato in these ashes and cover them up with more ashes. Over the top of the fire the natives spread a layer of dirt and cooked the tubers for 15 to 20 minutes. When done, the Wappato was mealy like a potato (Dickson 1946:38).

Chinook

Franz Boas collected the following story in 1891 from a speaker of the “Upper Chinook dialect which was spoken farthest down the river, from Astoria to Rainier” (Boas 1901). Famine was a concept the Chinook understood, and they took precautions to ensure that salmon would return each year. There must have been knowledge of failed runs in their cultural memory. John Kirk Townsend wrote in his journal that the Indians invariably remove the heart of each salmon they trade to the whites. Townsend said this was done for ‘superstitious reasons’ (Townsend 1812). The following segment is from a story about a salmon run failure, and how the plants saved the people. It is titled Myth of the Salmon (Boas 1901:6).

The people of mythical times were dying of hunger. They had only sagittaria-roots to eat. They had only small sagittaria-roots and skunk-cabbage and ---roots and rush roots to eat. In the spring of the year the Salmon went up the river. They went some distance. Then the Skunk-cabbage said: “At last my brother’s son has arrived. If it had not been for me your people would have been dead long ago.”

The story continues with the Salmon people giving the Skunk-cabbage gifts. They continued their journey, and Sagittaria root addressed the Salmon in the same way, and identified herself as the Salmon’s aunt, saying if it weren’t for her all their people would be dead. The Salmon gave the Sagittaria root three woodchuck [muskrat] blankets and some dentalia. The same thing happened with the large Sagittaria root, except that she got five woodchuck blankets and some dentalia. The same theme is repeated with the rush root. The story ends at the Cascades. The stated moral of the story is that it takes five days to reach the Cascades from the sea (Boas 1901; No.26:50-54). An implied lesson is that plant foods, including two forms of Sagittaria, saved the people from starving in mythical times.

Wishram Chinook

The Wishram had several words that referred to different ‘potatoes’. Their word for wapato was wakxa’t (Spier and Sapir 1930:183). They describe a “wild dwarf potato” which may be Sagittaria cuneta, which grows on the Columbia River shore from about Bonneville Dam to The Dalles.

Archaeological Contexts

Introduction

In archaeological sites where root foods were exploited Thoms argues that there would be tools for mashing fresh roots a variety of chipped stone knives and scrapers, and an abundance of fire cracked rock (Thoms 1989:310). Root processing sites would either be located near procurement sites or well-removed from residential structures (Thoms 1989:120). The bulk processing of camas (another important root food discussed below) required large earth ovens that were typically built near the procurement site for several reasons including minimizing the load to be taken to a storage facility, and to prevent spoilage. Wapato does not need to be cooked or processed before it is stored, so large bulk processing sites would not be an indicator of intensification.

The following descriptions are of sites where wapato has been found. Physical evidence in archaeological sites of wapato are rare. Wapato needs little processing, and was often consumed whole. Starch grain and phytolith analysis of the surfaces of ground stone tools are useful for identifying plant remains that were processed with the ground stone tools, but not ones that were not. In archaeological contexts plant tissues have a lower chance of survival than faunal materials. It is also possible that the lack of archaeological evidence for wapato exploitation indicates that wapato was not exploited.

Great Basin

There is archaeological evidence for the use of Sagittaria spp. from coprolites found
in Dryden Cave, Nevada (Neuman et al. 1989). Analysis indicated that the prehistoric population exploited fish, freshwater tubers and seeds. The tubers were identified as *Sagittaria*, most likely from the *latifolia* species. The coprolite data suggested a lacustrine pattern of diet and subsistence at this site. The data was compared to data from other sites in Nevada and Utah. One of the sites was Lovelock Cave, where coprolites were also found to have “tuber fragments.” These comparisons suggested to the authors that many native peoples in the Great Basin foraged along lake margins.

This Lacustrine Subsistence Pattern was presumably the product of a long-term increasingly intense subsistence regime that may have developed in the Early Archaic (8000-6000 yr B.P) as a means of exploiting the post-Lahontan lakes that were prevalent in this region...The data suggests that rhizomatus plants comprised a portion of the diet for the early inhabitants of the Great Basin region and that *Sagittaria* was more likely a dietary component rather than medicinal (Neumann et al. 1989).

**Northwest Coast**

Macro remains of *Sagittaria latifolia* roots have recently been recovered in excavations near Puyallup, Washington at the White Lake Site (45Kl438 and 45Kl438A). These remains were recovered in two features. The first was a “pavement hearth”, composed of hot stones placed close together. Typically pavement hearths were used to steam food, and in the case of this hearth it was probably used to cook mussels and wapato. The second feature containing wapato was a basin-shaped pit that also contained charcoal (Lynn Larson, personal communication).

**Summary and Discussion**

The accounts of *Sagittaria* spp. use in east Asia and North America demonstrate the cosmopolitan use of this root for food. Asian and American species of *Sagittaria* grow in similar environments and share the following botanical traits: sagittate leaves, white flowers with three petals, and the late summer production of starchy tubers. Descriptions of the taste (slightly bitter) and texture (like a potato) of the vegetable are in accordance. Chinese immigrants in California and Colorado recognized this wild plant as a relative of the Chinese Arrowhead, and harvested the roots. Widespread utilization of *Sagittaria latifolia* roots by aboriginal groups in what is now the United States is indicated by the above ethnographic and ethnohistoric descriptions. There are some consistencies in descriptions of harvesting, cooking, storage and seasonal availability.

**Harvest**

*Sagittaria* spp. roots were harvested both by digging and by treading the substrate in shallow water. The Iroquois and groups who lived on the San Joaquin and Sacramento Rivers harvested the root on river islands. The latter two groups used canoes while harvesting (suggesting the treading method). Accounts of the Kalapuyan Tualatin, Chinook (both of the Greater Lower Columbia) and the Katzie of the Lower Fraser River also describe how women treaded on the substrate until the roots floated up to the surface of the water. The Klamath dug for the roots on the banks of the Chewakan River. The Cocopa of the Lower Colorado river also reportedly dug the roots. Some of the midwest Indians collected the roots from muskrat and beaver caches.

**Cooking**

A variety of cooking methods were described, though roasting the roots in ashes or boiling were the most frequently mentioned. In my trial experiments I found that the roots cook in 10 minutes when roasted in hot ashes. Roasting eliminated the bitter taste more effectively than boiling. When roasted the tubers have a flavor similer to corn. The tubers burn if exposed to embers.

The most detailed description of cooking was from the Tualatin ethnography (Zenk 1976). They roasted wapato in the ashes left from a ‘bonfire’. Archaeological evidence from the Puget Sound area described two types of hearth features where macro-remains of wapato were recovered; a “pavement” hearth and a pit oven (Larsen, personal communication). Ethnographic descriptions of both cooking methods are found in Kuhnlein, et al. (1982) of clover and Pacific silverweed roots used by Native people on the coast of British Columbia.

The Nitinaht used a pit technique where
hot rocks lined the bottom and specific vegetation was used in layers separating bundles of silverweed roots, clover roots and camas bulbs...The Nuxalk Indians preferred clover roots cooked on top of hot rocks either in pits or on top of the ground (Kuhnlein, Turner and Kluckner 1982:90).

Storage

The accounts of storage indicate that wapato could keep well under several conditions. Wapato can be dried whole or in fragments, stored in baskets or in underground pits, or “stored” in the marsh and collected as needed. In my trial experiments I found that in this region in late October, wapato dries to a hard nugget over a period of seven to ten days, depending on air temperature and humidity. The dried tubers which needs several hours of soaking in water before it can be cooked. If kept dry, it can be stored indefinitely.

The Tualatin of the Greater Lower Columbia area stored wapato in pits. At least one group of Chinook (Shahalas at Neerchokioo) stored wapato in baskets under bed platforms (Clark in Thwaites 4:208). Lewis remarked that when they first visited this village it had twenty-four straw houses and one wooden one. By spring only the wooden one was left, and the explanation given to Lewis was that relatives came in the fall to hunt game and collect wapato. This house was a low, rectangularly massed (probably gabled) structure 50’ in length built on the grade (i.e. not semi-subterranean). The location of the door was on one side of the gable-end (rather than centrally located) which may have been advantageous in providing more unbroken length for storage space. This house may have functioned as a permanent dwelling for a few of the Shahala people, and warehouse for stores belonging to the greater Shahala population who lived in several villages around the Cascades. The nearest Shahala village was Wahclellah, twenty-seven miles upstream (Hajda 1984:119).

Seasonality

The journals of Lewis and Clark mention wapato over ninety times. Their first reference to wapato in their diary is on November 4, 1805 near what is now the Sandy River, in Wapato Valley. This plant dies back considerably after a hard frost, and apparently temperatures had been moderate because Lewis and Clark noted that this plant was growing throughout the valley. Since the plants were still visible, and roots were served to the corps, one can only conclude that the roots were being harvested before the plants had died back completely. Wapato was procured from the people at the mouth of the river for the corps on several occasions in November, December, and early January.

The Journals do not mention wapato procurement between January 11 and March 23, 1806. This gap in procurement may reflect a gap in availability. Lake levels are at their highest point in late January and February (Wessen 1984:8). During the low water months (August, September, October) women would be wading in water from knee level to neck level. High water would preclude harvest altogether in the deeper areas. High lake levels, and cool water temperatures were likely limiting factors for a late winter harvest of wapato. Some winter harvest could have occurred in the shallower areas. Water begins to recede in March, opening up the patches to harvest once again.

On their return journey, Lewis and Clark stopped at Neerchokioo (Figure 6.8), a village of the Upper Chinook Shahalas. They were informed that the relatives whose permanent residence was at the Cascades, had just returned home, presumably to prepare for salmon fishing. These relatives would have had at least three weeks prior to their leaving when the water levels would have permitted a spring wapato harvest.

Spring harvest would be over by the end of May, when the tubers sprout and begin to form new plants. I found no specific mention of wapato being traded or consumed in the summer months in any of the journals and accounts I reviewed. In one case, the absence of a mention was conspicuous: Bishop’s detailed log of the voyage of the Ruby on the Columbia in June of 1795 doesn’t mention wapato, though he wrote an excellent description of the root upon their return in October of that year. Wapato was available at least until May 9, as evidenced by the account of Dr. White and his wife who ate roasted wapato at an Indian campfire around May 9, 1837 (Allen, 1850). I am assuming they were roasting fresh roots. John Boit’s “ground Nut” that grows along the river
banks and was a good substitute for bread or potatoes was probably wapato. Boit was on the river between May 12 and May 20, and this reference was written on May 18, 1788. Ground nut is an archaic term that was used to refer to root foods.
CHAPTER 4
DIET AND SUBSISTENCE

Introduction

In this section I discuss major subsistence resources reported for Wapato Valley. Binomials and common names of these resources are in Table 6.2. Several authors have made estimates of the use and contribution to the native diet of particular food types (Keeley 1980, Hunn 1981, Norton 1980, Schalk 1977). The relative contribution of these food types is discussed, as well as the nutrient composition of several important root foods.

Some Major Subsistence Resources

A major economic investment of the native people of the Lower Columbia was the seasonal capture and processing of several species of salmon (Norton et al. 1984, Schalk 1977). Fish were a principal food of the Chinook, and enormous quantities of salmon were dried and processed by several techniques for later use. Six species of salmon (Oncorhynchus) serially enter the Columbia River. These include chinook, sockeye, coho, humpback, steelhead, and chum, the most important of which were chinook and coho (Boyd and Hajda 1987:Table 2, Ray 1938). These were not the only important fish; large shoals of eulachon migrated up the Columbia, and were caught in dip nets or raked. White Sturgeon was important because a single catch could supply a large quantity of food, often several hundred pounds.

Elk, whitetail deer and blacktail deer were important mammalian species used for food as reported in the ethnographic literature (Boyd and Hajda 1987:Table 2). Major root foods and greens reported ethnographically for Wapato Valley are as follows: Wapato, camas (considered staples); thistle, lupine, bracken, horsetail, bitterroot (Boyd and Hajda 1987:Table 2). Important berries were huckleberry (three varieties), blackberry, bearberry, cranberry and salal.

Over 40 edible species of berries are recorded for the Northwest, and Norton et al (1984) contend that berries were as much a mainstay of the pre-contact diet as salmon. That may be an overstatement, but its clear that diversity was significant. Dickson described over 100 plant species that were used as food in western Oregon in aboriginal times (Dickson 1946). Gunther lists even more for western Washington, and included medicinal plants (Gunther 1974).

Subsistence Dependence

In this section I present an overview of various estimates of caloric contribution of food types for aboriginal peoples in the Northwest. Hunn and Norton have made estimates of the percentage of caloric intake from a particular food type for the Native American pre-contact diet. Hunn’s estimates are for the Columbia Plateau, and Norton’s are for west of the Cascades [These estimates are reported as personal communication in Keeley (1980)].

Hunn estimated that the diet of people occupying the Columbia Plateau south of the 49th parallel consisted of 30% fish, 48% roots, 12% fruits, and 10% small and large game animals (Hunn, in Keely 1980). Previous workers did not rate the contribution of roots higher than the contribution of fish (Murdock 1967, Ray 1933). Hunn (1981) developed this model using ethnohistoric data to calculate per capita consumption rates, annual harvest totals and lengths of harvest season for various root sources. He also used his own time-and-motion studies of contemporary Indian root-digging. There was a close accord between his estimates of daily harvest of Lomatium coui (1 bushel in 7.5 hours) and the ethnohistoric data (Hunn 1981:129). He reasoned that since this food was available, and numerous ethnohistoric accounts describe large scale harvest of other specific root foods, that these foods contributed greatly to the aboriginal diet.

For the region west of the Cascades, Norton gives a higher figure for the contribution of fish (Norton, in Keely 1980). Her estimates are as follows: 40% fin fish, 10% shell fish, 49% plant foods (29% roots and sprouts, 20% fruits), and 1% small game and animals. The difference between the contribution of salmon on the east side of the Cascade mountains and the west is due in part to the loss of body fat and mass in salmon as they ascend the river.

Schalk estimated that the Chinook ate over 500 kg of salmon per capita per year (Schalk 1986, in Thoms 1989:239). Salmon average 170
This would mean that each individual ate over 2,300 calories of salmon per day, every day of the year. This seems high. A value of 2000 kcal/person/day is the Minimal Daily Requirement (MDR) accepted by Hunn in the absence of estimates of body weight and population structure for aboriginal groups on the Columbia Plateau (Hunn 1981). Thoms suggests that the MDR was closer to 2500 kcal (Thoms 1989:221). If one accepts Schalk’s estimates of salmon consumption, the caloric contribution of other game, roots, berries and sprouts would be less than Norton estimated, unless the MDR was much higher. Ethnographic and ethnohistoric data describe a varied diet for the Chinook (Boyd and Hajda 1987), so it is difficult to reconcile Schalk’s salmon consumption estimates with these data. Schalk’s estimates of salmon consumption are probably too high.

There are nutritional problems associated with high-protein, low-carbohydrate diets like the diet that would result if Schalk’s estimates of salmon consumption are correct. These include elevated metabolic rates with correspondingly higher caloric requirements, and deficiencies in essential fatty acids. Both fat and carbohydrates enhance a high protein diet, but carbohydrate is a more effective supplement than fat (Speth and Spielmann 1982:1). Applying this evidence to the intensification process, it would mean that as the carbohydrate source became intensified, the metabolic rates of the consumers would drop along with their caloric requirements. This evidence has applications towards understanding sedentism.

Salmon provided protein in adequate amounts, as well as vitamin A and D (Hunn 1981). Berries and shoots were a significant source of ascorbic acid and minerals. Fresh and dried native roots contributed to the calcium, iron, magnesium and zinc content of the aboriginal diet (Keeley 1980). According to Turner and Kuhnlein (1983) the carbohydrate composition of root foods contributed the major proportion of carbohydrate energy and fiber in pre-contact Northwest Coast native diets.

Nutrient composition of wapato compared to other Northwest selected roots foods, and cultivated species per gram dry weight are expressed in Table 6.3. These are among the foods analyzed by Norton, Hunn, Martinsen and Keeley (1984).

<table>
<thead>
<tr>
<th>ROOTS</th>
<th>Calories kcal</th>
<th>Protein (g)</th>
<th>Carbohydrates (g)</th>
<th>Ca (mg)</th>
<th>Fe (mg)</th>
<th>Mg (mg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wapato</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sagittaria latifolia</td>
<td>3.60</td>
<td>0.16</td>
<td>0.80</td>
<td>0.35</td>
<td>0.41</td>
<td>0.63</td>
</tr>
<tr>
<td>Biscuit Roots</td>
<td>3.81</td>
<td>0.08</td>
<td>0.85</td>
<td>3.05</td>
<td>0.25</td>
<td>0.57</td>
</tr>
<tr>
<td>Lomatium canbyi</td>
<td>3.97</td>
<td>0.05</td>
<td>0.93</td>
<td>1.18</td>
<td>0.03</td>
<td>0.23</td>
</tr>
<tr>
<td>Lomatium cous</td>
<td>3.97</td>
<td>0.13</td>
<td>0.80</td>
<td>1.67</td>
<td>0.23</td>
<td>0.40</td>
</tr>
<tr>
<td>Camas</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Camassia quamash</td>
<td>3.90</td>
<td>0.10</td>
<td>0.85</td>
<td>2.35</td>
<td>0.33</td>
<td>0.74</td>
</tr>
<tr>
<td>Bitterroot</td>
<td>3.87</td>
<td>0.15</td>
<td>0.71</td>
<td>2.02</td>
<td>0.88</td>
<td>0.96</td>
</tr>
<tr>
<td>Lewisia rediviva</td>
<td>3.45</td>
<td>0.04</td>
<td>0.21</td>
<td>0.41</td>
<td>0.91</td>
<td>0.08</td>
</tr>
<tr>
<td>Riceroot</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fritillaria pudica</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Silverweed</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Potentilla pacifica</td>
<td>3.76</td>
<td>0.10</td>
<td>0.85</td>
<td>0.35</td>
<td>0.03</td>
<td>1.09</td>
</tr>
<tr>
<td>Potato</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Solanum tuberosum</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Values for fresh potato are used for comparison because it is this food which native people say has replaced traditional foods (Kuhnlein, Turner, Kluckner 1982:92). Wapato contains an average of 0.16 grams protein per gram, dry weight, which is slightly more than potato, which contains 0.10 grams protein. Camas has 0.13 grams protein. Wapato has the same amount of calcium as potato (0.35 gram) and only 0.63 grams of magnesium compared to 1.09 for the potato. Wapato is richer than potato in protein, carbohydrates, iron and zinc.

The nature and digestibility of the “starch” component in wapato has not been analyzed. The preferred native cooking methods for Camassia spp. and wapato, namely prolonged pit-cooking for the former and rapid baking or boiling for the latter, can be linked to the difference in the nature of their carbohydrates. Lengthy cooking is necessary for maximum conversion of the inulin in camas to fructose (Turner and Kuhnlein 1983:214). The main carbohydrate component of wapato may be starch, which is digestible in the raw state or with short term cooking.

Discussion and Conclusions

The Lower Columbia had abundant and diverse flora and fauna resources which could have provided the full range of necessary chemical molecules in ratios suitable for optimum nutrition (Wing and Brown 1979:169). Nutritional analyses show that Sagittaria latifolia roots used as a staple would have provided aboriginal populations with substantial quantities of energy (carbohydrates), fiber, and trace elements. Wapato meets Thoms’ criteria that an intensifiable root food should be rich in carbohydrates (Thoms 1989:175).
CHAPTER 5
WAPATO PRODUCTION ON SAUVIE ISLAND

Introduction

In order to address the questions of abundance and productivity, and the potential use of this resource as a staple for the local population, an ecological model of annual wapato production on Sauvie Island is presented in the first part of this chapter. This is followed by a cost/benefit analysis of wapato production which is then compared to other important root foods found in the Northwest.

This model is not intended to be representative of the whole Greater Lower Columbia region. As a model, it is an artificial construct. The main purpose is to illustrate the amount of food available in a year, compared to population estimates of people that were on or visiting Sauvie Island when Lewis and Clark make their calculations. It is important to understand that wapato was an important resource and trade commodity in a region where many groups were linked by systems of exchange, and rights to resources. This model assumes that the people who lived on the island all had rights to the resource, and that no others from the region came in to exploit it. This was not the case in the region, but was a necessary assumption to construct the model.

Five aboriginal villages were located on the island in 1805-6. Sauvie Island had a denser human population, at least in spring, than the rest of the region, and was richer in wapato as well. This model calculates the annual available productivity of this particular location, and how many people this could have fed. The results are compared with aboriginal population estimates.

The Setting: Sauvie Island

Sauvie Island is 15.1 miles long and 4.55 miles wide at its widest point, comprising 24,064 acres of land and lakes (Spencer 1950:3). The island was formed by alluvial deposits from both the Columbia and the Willamette Rivers. Water covers much of the surface of the island. There were at least 79 named lakes on the island before the island was diked, and much of the wetlands and lakes were drained in the first part of this century. The largest lake is Sturgeon Lake, located in the center of the island.

One of the tenets of this thesis is that stands such as the one that currently exists at Crane Lake on Sauvie Island, covered much of the island. The Crane Lake patch is over a mile long and one quarter mile wide. A thick stand of wapato covers over 90% of its surface in summer (Figure 6.3 in Chapter 1). The U.S. Surveyor General Office surveyed the townships covering Sauvie Island in 1853 and 1854. The surveyor’s notes describe the water level in the lakes as follows:

The lakes in this township at lowest stage of water are shoal & muddy & can be forded in many places. They are affected some by the tide, which ebbs and flows with a very strong current through the Gilbert River (notes, 22 Nov 1853, 3N 1W WM, spelling as in original).

In another entry the surveyor records that there are “really high banks on the rivers and bayoues & low indefinite ones on the lakes (unreadable) swamps,” (notes for 3N 1W, WM, spelling as in original). On the north boundary of section 3, 2N 1W, the surveyor intersected “a shoal muddy lake filled with wapatoes,” (3N 1W WM, notes pg. 59).

Before dike construction in 1938, the lowlands of the island were frequently flooded. Figures published by the U.S. Army Corps of Engineers indicate that flooding occurred when the discharge at the Dalles reached 600,000 second-feet, which happened 43 times in a 73 year period between 1858 and 1930 (Saleeby 1983:163-164).

Native American Villages on Sauvie Island

A large group of Indians, collectively referred to by Lewis and Clark as “Wappato Indians” were concentrated on Sauvie Island. Lewis and Clark identified five villages on Sauvie Island; Clannarminamon, Cathlahnaquiah and Clanninata on Multnomah Channel, and Clannaqueh and Multnomah on the Columbia River. Each village was within one mile or less of a pond or lake (Figure 6.4). Lewis and Clark reported two population figures for each village. Boyd and Hajda argue that both estimates accurately depict seasonal variations in Lower Columbia populations. The first estimate was made in October and Novem-
ber of 1805. This was recorded in the Codex 1 manuscript (Table 6.3). The second estimate was taken on the return journey in the spring, when the Lower Columbia permanent population was hosting many friends and relatives. Both estimates are deemed correct, and reflect the population shifts during those seasons. The following descriptions are from the Journals, maps and manuscripts of the Corp. These were all villages of Chinookan people.

Clannarminnamun. This was a village of twelve houses located on the west side of the northernmost lobe of the island above Warrior Rock. This whole section was low and marshy, with a few small ponds. This was across Multnomah Channel from Scappoose Bay, called by Lewis and Clark “Wappato Inlet”.

Clannahqueh. This was a village of at least one house on the east side of Sauvie Island. This was adjacent to numerous small sloughs and ponds and two small islands.

Multnomah. This was a mile or so south of Clannahqueh, and a much larger village consisting of six houses.

Clanninata. This was on Multnomah Channel on the west coast of the island, adjacent to many lakes including Steelman Lake, which is still extant and has many patches of wapato.

Cathlahnaquiah. This was on Multnomah Channel and south of Clanninata by three or four miles. It was adjacent to several shallow lakes, most now drained.

### Quantifying Productivity

**Productivity**

Wetlands (estuaries and marshes) are resilient because they are the most highly productive ecosystems in the world, producing between 8,800 and 9,600 kilocalories of energy per square meter per year. In comparison, temperate forests produce about 5,600 kilocalories per square meter annually, and agricultural land produces an average of only 2,400 kcal (Miller 1993:94). Many wetland plant species such as *Sagittaria latifolia* are r-strategists, producing a large quantity of offspring, of which only a small percent survive to reproduce.

Annual production as expressed in dry weight in grams per square meter, per year of below-ground biomass of *Sagittaria* spp. has been calculated by two researchers. Visser (1989) measured the end of season underground biomass productivity in a freshwater marsh in Louisiana. She was interested in documenting differences in vegetation under various conditions (including grazing), so her study discusses productivity range. This productivity ranged from 233 to 1199 (fresh) grams per-meter per year, depending on elevation and flooding.

Gilbert (1990) was looking for average or normal productivity in the ecosystem. In her careful study of above- and below-ground annual productivity of vascular plants in the freshwater marsh of the St. Lawrence River near the Quebec City, Gilbert determined that *Sagittaria latifolia* reached its peak above-ground biomass at the end.
of August (Gilbert 1990:855). By the end of September on the St. Lawrence, the below-ground biomass of the tubers reaches approximately 300-400 dry grams per square meter, (approximately 600-800 grams of fresh tubers).

The normal productivity measured by Gilbert fits well into the range of productivity estimated by Visser for this plant. The productivity data from Gilbert’s study provides the best analogy for the Lower Columbia. This study will use the productivity estimates generated by Gilbert’s work on the St. Lawrence. Both study areas (the Columbia and the St. Lawrence) are in the northern part of *Sagittaria latifolia*’s range. This study is interested in normal or typical productivity as was Gilbert. In addition the specific variety of *Sagittaria latifolia* Gilbert was studying is the same taxonomic variety found on the Lower Columbia; i.e. Smith’s ‘northern dieocious’ variety (Smith 1895:38, Giroux and Bedard 1987:773).

My own informal trials indicate that Gilbert’s estimates of tuber productivity per meter correspond to a typically productive patch on Sauvie Island. Gilbert excavated several areas throughout the growing season, and dried the total biomass at a constant temperature. It was not within the scope of this study to replicate her experiments. If the average density of the plants per square meter, and the average number of tubers per plant, and the average weight of the tubers were known, productivity could be calculated.
I designed two experiments to calculate productivity. My first experiment was to measure four meter-square units and count the number of plants within each unit. The plants are thick in typical patches, and there are plants of all sizes growing adjacent to each other, though most of the plants are about the same maturity. The uniform density of the patches made it easy to find a typically productive patch. I found that in early October the average number of plants per square meter in a typically productive patch on Sauvie Island is 28 plants.

In the second experiment, conducted in the beginning of October when the plants were still green, but beginning to deteriorate. I pulled up over forty plants chosen randomly from a typically productive patch. This was done in order to find the number of tubers produced by each plant by counting the number of rhizomes attached to the base of each plant. I found that there were 2 to 5 rhizomes on each plant at any one time, with an average of 2.8 rhizomes, indicating the presence of that many tubers. This is a conservative estimate because rhizome production is on-going, and evidence of earlier rhizome production may not be evident. Another reason I believe it is conservative is that earlier in the season I pulled up several plants, and counted more tubers per plant than later when this trial was conducted.

The average weight per tuber recovered in my harvesting experiments is 7.75 grams. Calculating that there are conservatively 2.8 tubers produced per plant, and 28 plants per square meter, tuber productivity per square meter would be approximately 78 wapato per square meter, or 604 fresh grams. The close accord between my estimates and Gilbert’s figure (600-800 grams per meter) is encouraging.

It is possible that this is an underestimate. Under controlled conditions in a greenhouse, with a single plant per container, plants from Lower Columbia Sagittaria latifolia seeds produced an average of eight tubers each. These weighed 1 to 12 grams, averaging 6 grams each (Tanimoto, personal communication). Based on these estimates, annual tuber production per meter would be 1,344 grams. However, under controlled conditions plant grown can vary significantly, and not be comparable to field conditions.

For this model, the most conservative productivity estimate of 600 fresh grams per meter annual production will be used. Based on this figure, the annual production of wapato per hectare is six metric tons.

In order to insure viability and equilibrium, a certain number of the tubers need to survive in order to reproduce. As mentioned above in a typical patch there are on average 28 plants per square meter. Almost all the plants exhibited a lateral rhizome, indicating that the plant either grew from a rhizome thrown off by a parent plant, or was the parent itself. It is difficult to estimate the number of tubers necessary to survive in order to maintain an equilibrium. It has been my observation that even plants just beginning to emerge are forming rhizomes which produce new plants in short order. Potentially, in one growing season, one tuber could produce a plant that throws off several more rhizomes from spring through the summer, creating several growing plants, which in turn create more plants, and subsequently more tubers. A conservative estimate on the number of tubers necessary for reproduction to be maintained, would be half the count of the number of plants per meter present in a typical patch, or fourteen tubers. This is 18% of the total productivity of 78 tubers per meter.

Waterfowl grazing has already been discussed. In Chapter 2, it was estimated that waterfowl foraging on Sauvie Island reduced the below-ground biomass in Sagittaria habitat by about 60%, leaving 22% of productivity for humans, muskrats and other predators.

Quantifying Surface Area of Sauvie Island

Method

In order to quantify productivity, it was necessary to estimate the surface area of Sauvie Island that was prime Sagittaria habitat. Current maps show that much of the southern portion of the island is now farmland. Historically much of this area was occupied by lakes, ponds, marshes and sloughs. The survey for the nautical charts of the Lower Columbia was done by the Coast and Geodetic Survey in 1890. These maps were updated periodically (1914, 1923, 1940) but the original lake and slough configurations were not changed. The only information updated on the charts con-
cerned the navigation channels. The subsequent maps were in essence showing ‘relic’ lakes and sloughs, many of which have been drained. I used the 1940 nautical chart (with the 1890 era lake and wetland designations) to calculate *Sagittaria* spp. habitat. Therefore, the estimates are based on marshes and sloughs that existed in 1890, and given the dynamic nature of shallow alluvial lakes, they may not be representative of a contact-era configuration (Figure 6.5).

There were no depths indicated for the lakes on Sauvie Island on this chart, though most of the lakes were probably not more than two meters deep. The chart indicates that Vancouver Lake had an average depth of one meter over most of its area. Since *Sagittaria* spp. can grow from a meter’s depth or more, Vancouver Lake may have been almost completely covered with *Sagittaria*.

Using the 1940 nautical chart I measured the square meter area of marsh and lake habitat. This was calculated by drawing a grid on the chart, and estimating the overall fraction of marsh and lake area within each 1000 x 1000 meter grid square. Most of Sturgeon Lake was not counted because much of this lake is known to be deeper than four feet. The fractions were added, and the estimated area of wapato habitat analyzed on this map totaled over 2,985 hectares. If the lake coverage indicated on the 1940 (1890) map is typical, there would have been a total of 17,910 metric tons of wapato produced on Sauvie Island annually.

**Available Harvest**

The equation for estimating the total amount of wapato available to humans on Sauvie Island is as follows: 60% of the net below-ground primary production (NBPP) is the proportion of wapato removed by waterfowl herbivory; subtract .18 (NBPP), which is the proportion of wapato not preyed upon to insure viability; which equals (X), energy available to the human population. The condensed formula is as follows:

\[ .60 \times \text{NBPP} - .18 \times \text{NBPP} = X \]

Thus, with a NBPP of 17,910 the mass available to the human population is 3,940.2 metric tons.

One of the limiting factors in the harvest would have been what percentage of the tubers float at any one time. This is difficult to ascertain, and further experiments need to be done to quantify this production with accuracy. However, during my field research wapato was harvested on five occasions by one to two people.

The methodology of these experiments was simple. The gatherers waded into the water and agitated the substrate with their feet. The work was done in measured areas. The amount of time gathering was noted, and the production of wapato was counted and weighed. The first two occasions were in April and May of 1995 at Catfish Slough on Sauvie Island.

Spring harvest production varied; between 9 tubers and 29 tubers floated up out of the substrate per square meter. The heaviest person weighed approximately 160 lbs, and was more productive perhaps because he sank in deeper, and agitated the substrate more effectively than the person who weighed 130 lbs. Twenty-nine wapato per meter were recovered by the heavier person, and ten recovered by the lighter person. Another explanation may be that the heavier person was harvesting in an area that was overlooked by waterfowl and other predators, while the lighter person was in an area that had been harvested by predators. There was some evidence of fur-bearer predation in this slough. The lighter person matched the productivity of the heavier person during the October 1995 harvest, where 29 wapato per meter were recovered.

If the average number of buoyant tubers per meter recovered in water was the “low” recovery of 10 tubers, (average weight 7.75 gms), the total metric tons available on Sauvie Island would be 2,313 tons per year. The harvesting efficiency would be 59% of available biomass.

**Population**

With estimates of yields in hand, one of the pertinent, productivity-dependent questions is: how many people could the Sauvie Island wapato production support per year? The energy necessary to support an individual or populations is a function of their metabolic rate (Ellen 1991:102). Daily caloric requirements vary according to sex, age, weight, activity, climate and diet (Thoms 1989:221). My model will borrow two assumptions that Thoms (1989) uses for his model of
Figure 6.9. Coast and Geodetic Survey Chart: Sauvie Island.
camas intensification. The first assumption is that the caloric requirements for the average member of an average hunter-gatherer family in the Pacific Northwest is 2,500 kcal per person/day. The second assumption is that roots provided at least 20% of the annual caloric intake of each individual.

Using the estimates developed by Thoms, the annual caloric intake of a family of five would be 4,562,500 kcal, of which 20% or 912,500 kcal would come from root foods. Thoms estimates it would require a metric ton of fresh camas (1000 kg) to provide enough calories for a family of five when accounting for “spoilage, wastage, and other losses (eg. rodents) and including an extra portion in lieu of unanticipated shortfalls, or 125% of the required minimum (Thoms 1989:222).

Fresh camas contains approximately 70% moisture (Thoms 1989), and fresh wapato contains approximately 50% moisture (calculated from Keeley 1980:31). The minimum amount of fresh wapato that would be needed to provide the same caloric contribution would be .507 metric tons (507 kilograms). Following Thoms, 125% of this amount is 633 kilograms (.633 metric tons) per year of wapato. The high estimate of available wapato on Sauvie Island in a typical year is 4,656 metric tons. The low estimate, based on what percentage of tubers floats, is 2,313 metric tons. If .633 metric tons of wapato would feed a family of five, the highest estimated annual wapato harvest would feed 36,777 people. If we use the low estimate of 2,313 metric tons, this production would feed 18,270 people. Lewis and Clark’s highest population estimate for the island is 1,810. I have already noted the highest estimate for the region in 1805-6 was 27,000 (excluding Tualatin)(Lewis and Clark in Hajda 1984). Estimated wapato production on Sauvie Island could have supported a significantly higher population than has been reported for the island. This number is representative of early nineteenth century populations “and are probably significantly below the pre-contact totals, which would have been much reduced by the 1775 and 1801 smallpox epidemics,” (Boyd 1989:286).

Boyd estimates that the mortality rate for the 1770 epidemic was minimally 33%, and suspects that the mortality for the 1801 epidemic was probably slightly less than in 1775, due to some individuals having developed an immunity in the previous epidemic. Estimating a 25% population reduction in 1801, and a 33% population reduction in 1775, there may have been about 3,008 individuals living on and/or seasonally visiting the island before the epidemics. This is still significantly below the estimated populations that could have been supported by the annual wapato harvest.

Cost/Benefit Analysis

Following Lawton (1973 in Ellen 1982:99) there are six kinds of activity in the appropriation of food: locating food supply, gathering food, transport and storage, maintaining food supply, processing food supply, and eating. In the case of wapato, the local residents lived adjacent to the wapato patches on the island, so locating and transporting wapato were very low cost activities. The storage and maintenance of wapato involved digging storage pits, and the weaving of carrying and storage baskets. Other activities that have high energy costs are the building and maintenance of houses to store the food, and the construction of canoes to collect the wapato. Canoes and houses last for years, and were used for other purposes than storing wapato, so the costs of these will not be figured into this model. Settlements were located adjacent or close to wapato habitat, so locating and traveling to resource areas was not a large energy drain. Wapato requires little or no processing, so processing costs were low, and will not be considered here.

It is difficult to measure how many calories would have been burned by individuals, generally women, while they ‘danced’ around on the wapato-bearing substrate in cool water temperatures for several hours at a time. The native women of the Lower Columbia were described by Clark as follows:

The Womin of the Chinnook Nation have handsom faces [they are] low and badly made with large legs and thighs which are generally swelled from a stopage of the circulation in the feet (which are Small) by many strands of Beeds or curious Strings which are drawn tight around the leg above the ankle, their legs are also picked [i.e. tattooed] with different figures. (spelling as in original,
Deposits of subcutaneous fat on the women’s legs and thighs would have provided some insulation from cool water temperatures. For this model I have estimated that the effort needed to harvest wapato may have been about equal to riding a bike, which would be 4.5 kcal per hour, per kilogram of body weight. Estimating the average weight of these women is also conjecture. For this model we will estimate body weight to be 140 lbs, or 63.5 kilograms. Based on an eight hour day, each woman would expend 2,286 kcal during the eight hours she spent on the harvest.

Wapato was gathered on four occasions. The first was on April 27, 1995 where I was in the patch for fifteen minutes and recovered 38 wapato tubers. If I had sustained this recovery rate and continued gathering for one hour, I may have recovered approximately 152 wapato, or approximately 1,178 grams of fresh wapato. The second gathering was on May 19, 1995 when a male colleague gathered for fifteen minutes and recovered 88 wapato. This person was heavier, and more effectively agitated the substrate than I did, resulting in a high recovery of wapato. If he had sustained this recovery rate for one hour he would have recovered 352 wapato, or approximately 2,728 grams of fresh wapato. In the fall of 1995 this worker returned to the same patch (Catfish Slough on Sauvie Island) and gathered for fifteen minutes and recovered 58 wapato. If I had sustained this rate for one hour, I may have recovered 232 wapato, weighing about 1,798 grams. The range of recovery per hour in these studies was 152 to 352 wapato per hour. These results are summarized by date and location in Table 6.4.

These time and motion studies indicate that between 1,178 and 2,728 grams of fresh wapato could be extracted in one hour. This must be qualified by the fact that we are inexperienced gatherers. People who gathered wapato on a regular basis may have developed techniques to expedite the process.

For this model, I will use the 1,800 gram

<table>
<thead>
<tr>
<th>Date</th>
<th>Method</th>
<th>Location</th>
<th>(N)</th>
<th>GMS</th>
<th>gm/corm</th>
</tr>
</thead>
<tbody>
<tr>
<td>November 18, 1994</td>
<td>Digging</td>
<td>Steelan Lake</td>
<td>33</td>
<td>152</td>
<td>4.6</td>
</tr>
<tr>
<td>December 1, 1994</td>
<td>Digging</td>
<td>Steelan Lake</td>
<td>22</td>
<td>224</td>
<td>10.18</td>
</tr>
<tr>
<td>April 27, 1995</td>
<td>Tramping</td>
<td>Catfish Slough</td>
<td>38</td>
<td>309</td>
<td>8.13</td>
</tr>
<tr>
<td>May 19, 1995</td>
<td>Tramping</td>
<td>Catfish Slough</td>
<td>69</td>
<td>512</td>
<td>7.42</td>
</tr>
<tr>
<td>May 19, 1995</td>
<td>Tramping</td>
<td>Catfish Slough</td>
<td>88</td>
<td>741</td>
<td>8.42</td>
</tr>
<tr>
<td>October 6, 1995</td>
<td>Tramping</td>
<td>Catfish Slough</td>
<td>58</td>
<td>450</td>
<td>7.76</td>
</tr>
<tr>
<td>November 14, 1997</td>
<td>Tramping</td>
<td>Farmers Field</td>
<td>231</td>
<td>3005</td>
<td>13.3</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td>539</td>
<td>5393</td>
<td>11.05</td>
</tr>
</tbody>
</table>

Table 6.4. Productivity Experiments by Date and Location.

<table>
<thead>
<tr>
<th>Species</th>
<th>Common Name</th>
<th>cost (kcal)</th>
<th>gross (kcal)</th>
<th>cost/benefit</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Lomatium canbyi</em></td>
<td>desert parsley</td>
<td>200</td>
<td>3631</td>
<td>1 to 18.15</td>
<td>Couture et al.</td>
</tr>
<tr>
<td><em>Lomatium cous</em></td>
<td>biscuit root</td>
<td>200</td>
<td>1019</td>
<td>1 to 5</td>
<td>Couture et al.</td>
</tr>
<tr>
<td><em>Lewisia rediviva</em></td>
<td>bitterroot</td>
<td>200</td>
<td>1174</td>
<td>1 to 5.87</td>
<td>Couture et al.</td>
</tr>
<tr>
<td><em>Camassia quamash</em></td>
<td>camas</td>
<td>200</td>
<td>5279</td>
<td>1 to 26.39</td>
<td>Thoms</td>
</tr>
<tr>
<td><em>Sagittaria latifolia</em></td>
<td>wapato</td>
<td>286</td>
<td>5418</td>
<td>1 to 18.9</td>
<td>This model</td>
</tr>
</tbody>
</table>

Sources: Thoms 1989, Couture, Ricks, Housley 1986.
per hour figure for recovery estimates based on the fall gathering episode, which generated approximately 1,800 grams of wapato per hour. This amount is close to the average recovery of all these events, and was the only fall gathering that was recorded. Fall is when the below-ground biomass is at its peak, prior to predation.

Based on the 1,800 productivity estimate, the daily harvest would be 14,400 grams. The dry weight of this amount is 7,200 grams. The calories available per dry gram of *Sagittaria latifolia* tubers is 3.6 kcal. The calories harvested in one day would be 25,920 kcal. The cost/benefit ratio is 2,286/25,920 or 1 kcal expended for every 11.32 kcal gained.

Comparative cost/benefit ratios of several important root foods found in the Northwest are in Table 6.5. Daily harvest estimates have been analyzed by Couture, Ricks and Housley (1986) for desert parsley (*Lomatium canbyi*), biscuit root (*Lomatium cous*), and bitterroot (*Lewisia rediviva*). The harvest data was from observed collection practices of contemporary Burns Paiute women. The cost benefit analysis was calculated figuring a 200 kcal/per hour expenditure for digging roots, as compared to a higher 285.75 kcal/per hour cost for tramping wapato patches, due to exposure in cold water. Wapato was a cost-effective root to harvest, grossing 3,240 kcal per hour, though estimates of hourly yields of camas and desert parsley were higher, 5,279 kcal and 3,631 kcal respectively.

Calculating handling costs to arrive at an overall net gain figure requires inclusion of all costs incurred for transportation, processing and storage, which is beyond the scope of this study. The cost/benefit analysis only compares daily harvest costs and benefits of extracting the roots, and does not address transportation or processing costs, which would reduce the cost-effectiveness of these roots. In general it can be said that wapato was lower in transportation and processing costs than bitterroot, biscuit root, desert parsley and camas. Often in the case of camas and bitterroot, root grounds were not adjacent to habitation sites and roots had to be hauled overland to their destination. Camas required baking in large earth ovens in order for it to be preserved well. It was often further processed into cakes. Biscuit root can be eaten fresh, and was often dried and ground for future use, as was bitterroot and desert parsley. These roots need to be peeled before drying (Hilty 1980), whereas wapato does not require peeling.

Hunn (1981) estimates the harvest season for biscuit root to be 30-40 days, bitterroot 60 days, and camas from 14 to 21 days. Thoms (1989) suggests that the camas season lasted about 35 days. The people who relied on these roots needed to concentrate their efforts during the short time when these roots were available. My studies indicate that wapato is in season over 250 days of the year (see Chapter 2). At an extraction rate of 14,400 fresh grams per day, it would take a woman 44 days to harvest enough wapato for a family of five. The long season would give the food provider several options on how best to supply her family, and she would not have to concentrate her harvest efforts within a short time span. The ethnohistoric evidence suggests that the main harvests were in the fall and spring.

**Discussion and Conclusions**

The quantitative model presented here demonstrates that wapato was abundant and productive, and could have fed a larger population than was estimated to live on the island in pre-epidemic times. Wapato was a cost-effective root to harvest, and compares well with other important wild roots of the Northwest in harvest cost and net caloric gain. Wapato habitat was close to permanent village sites in wapato valley, and transportation costs were minimal for the local population. As modeled, wapato meets Thoms’ criteria that an intensifiable root food should be available and predictable, and accessible.
CHAPTER 6
ADDRESSING THOMS MODEL OF ROOT-FOOD INTENSIFICATION

Introduction

Land use intensification models developed in population ecology have been employed to examine subsistence intensification, particularly as it relates to the development of community sedentism, agriculture, and complex social systems. These models have met with varying degrees of predictive success. However a foraging-based population model for hunter-gatherers can be very useful to anthropologists and archaeologists as a means of constructing and testing hypotheses about the role subsistence plays in human population dynamics. These models can be judged by how well they fit with the predicted outcome.

Thoms has proposed a model for the intensification of wild roots in his dissertation The Northern Roots of Hunter-Gatherer Intensification: Camas and the Pacific Northwest (1989). His model includes conditions, causes and consequences of geophyte intensification, as well as spatial components, and archaeological correlates. Thoms devised a test of his model of geophyte intensification composed of five expectations.

Research Design and Methods

I compared Sagittaria spp. to Thom’s expectations for the role of camas in the Pacific Northwest from his model of geophyte intensification. To the extent that wapato is consistent with his geophyte intensification model, the archaeological, ethnohistorical, ethnographic and ecological data should be consistent with the following five expectations that Thoms outlines as part of his model for camas exploitation (Thoms 1989:184). These expectations are copied from his text, except I substituted the word “wapato” for camas (Thoms 1989):

1. Given the tendency toward optimal foraging, groups relying on wapato as a staple resource should be those lacking adequate supplies of higher ranked and intensifiable foods. Other things being equal, the intensity of geophyte exploitation should vary inversely with the availability of anadromous fish.

In his assessment of the “fit” between his modeled expectations for camas exploitation and the ethnographic data Thoms found that this expectation was not met for all groups. “It is evident that groups using camas as a staple were not confined to regions lacking ready access to salmon” (Thoms 1988:238). He found that groups living directly on the Northwest Coast conformed to the predicted pattern of this expectation. However, he argues that this was due to the limited availability of camas rather than the abundance of higher ranked resources. Interior groups who had limited access to salmon included the Coure d’Alene, Kalispel, and Flathead. This expectation for camas exploitation fits these groups, but not the Nez Perce, Klickitat, Yakima, Wanapum, Palus and others.

He found that his model especially did not fit the Chinook, who consumed 500 kg. of salmon per capita per year (Schalk 1986). “The Chinook... used more salmon than any other group, but, like other coastal groups, camas was probably a managed supplemental resource, and it may have been of secondary important to arrow-head root or wapato,” (Thoms 1989:238).

In my assessment of the “fit” between this modeled expectation for wapato exploitation and the ethnographic data, I have found that there is no inverse correlation between the availability of salmon and the exploitation of wapato. Wapato was available fresh from early fall to late spring (except during high water), which partially overlapped the times of various anadromous fish runs on the Lower Columbia. Chinook salmon were available in the spring and summer. Coho runs occurred in the fall. Chum salmon were in the river in October. Steelhead were available in the summer and early fall (Hajda and Boyd 1987: Table 1). For the lower Fraser River, Hanson notes in his study of the Katz site, that the “appearance of wappatoes coincides with the passing of ...sockeye and chinook runs. Coho salmon pass Katz from early October to mid-November, and chum salmon spawn in the Fraser below Hope from mid-November until the end of December,” (Hanson 1973:45).

One reason why this expectation of a correlation between the availability of anadromous fish and the intensity of geophyte exploitation is not met is that Thoms makes the assumption that
all foods are ranked on the same scale, and will be selected by rank. Carbohydrates and proteins satisfy different needs. Though salmon may be a higher ranked food, the body needs carbohydrates to function well. One does not replace the other. Norton (1980) estimated the pre-contact diet of groups who lived west of the Cascade Mountains had a varied died rich in roots and sprouts and fruits as well as protein foods. It is evident that a suite of food types was desirable, and necessary for a balanced diet.

2. Given the principle of optimal foraging and the lack of adequate supplies of less costly foods, and other things being equal, there should be a positive correlation between the intensity of wapato exploitation and the size of productive wapato grounds in a group’s territory.

This expectation is met. There is a positive correlation between the intensity of wapato exploitation and the size of productive wapato grounds on the Lower Columbia. Lewis and Clark noted that wapato grew extensively in the center part of the Greater Lower Columbia Valley, and named it Wapato Valley. Ecological data support the contention that wapato habitat was once much more extensive than it is at the present. Ethnohistoric and ethnographic data suggest that wapato was an important food, as well as a trade commodity for the people of the region.

This expectation assumes that a lack of less costly foods would be a circumstance that would direct the people to intensify the use of the resource in direct proportion to the size of the productive grounds. I have demonstrated that wapato is a cost effective food to procure. The ecological data demonstrate that wapato was intensifiable, the ethnohistoric and ethnographic data describe wapato as being very abundant in the area very important to the people. These data sets combined indicate that wapato was intensively exploited on the Lower Columbia. I suggest that it was not a lack of less costly foods that drove intensification, but it was the quantity and cost effectiveness of this resource that caused it to be intensively exploited. In conclusion, there is a positive correlation between the intensity of wapato exploitation and the size of productive wapato grounds in a group’s territory.

3. Wapato is a bulky food, and as such, its intensive use is likely to be dependent on ease of transportation. The use of wapato as a staple should be evident among groups with productive wapato grounds near winter village sites where much of the wapato is likely to be consumed, as well as by groups whose territories also encompassed low gradient watercourses conducive to watercraft transportation, or substantial grasslands where large horse herds could be maintained. Horses and watercraft transportation would significantly reduce transportation costs and increase the potential to exploit wapato grounds located at some distance from overwintering sites. Other things being equal, the degree to which groups rely on wapato should vary inversely with transportation costs.

This prediction is well supported by the data. Lewis and Clark noted that wapato was often collected in canoes that may have been made especially for women who may have chiefly used them for food gathering. Transportation costs were minimal for the local groups because there were many areas to harvest wapato. Chinookan villages clustered in strategically favorable areas along the river’s banks, often directly adjacent to low marshy islands or ponds where wapato could have been procured.

The expected positive correlation between low gradient navigable watercourses and the exploitation of wapato is obvious. One can expect that wapato would be heavily exploited in part because the transportation costs were so low. The ethnohistoric and ethnographic data support this supposition.

4. From the principle that people tend to select and use habitats optimally, it follows that they should exploit wapato in a cost-effective manner, given the nutritional needs of the population in question. Other things being equal, there should be a positive correlation between the use of wapato as a staple, and bulk processing as measured by the use of large earth ovens and storage facilities.

This expectation is only partially consistent with the available data. The ethnographic and ethnohistoric accounts consistently describe wapato as being like a potato, and cooked like a potato either by boiling or baking on embers. One account mentions that if wapato is overcooked, it
dissolves and becomes a paste. In my experience, wapato cooks fast, and can be pierced with a fork after about ten minutes of cooking. Camas, on the other hand, needs to be baked for long periods of time. It is more likely that large earth ovens are an indicator of camas, rather than wapato use.

However, large storage facilities would be necessary if each family of five needed almost a metric ton of wapato per year. Wapato has been described as not needing to be washed before it is stored (Suttles 1951), and it keeps well without any processing. Clark noted that wapato was stored in baskets under the bed platforms. The Tualatin stored wapato in large storage cellars, or pits, under the floors of houses (Zenk 1976).

The ethnographic evidence indicates that there is a positive correlation between the use of wapato as a staple, and bulk processing as measured by the use of earth ovens and storage facilities. This should be amended with the note that wapato ovens were generally smaller and designed for shorter baking times than the camas ovens which were often built for mass quantities of camas and lengthy baking times. Wapato is available over a long period of time, so storage needs would be minimal except for warehousing surplus for trade.

5. Given the principle that normal population growth is a force toward instability in the ratio between the supply of available goods and the demands of the population, there should be a positive correlation between the intensity of “management” techniques at wapato grounds and population density. Manifestations of this relationship should include ownership and management of root grounds.

If one accepts the ecological data on annual wapato production and population estimates, there was apparently not enough population pressure on wapato to create instability in the ratio of supply and demand, though control and inheritance of wapato patches may have existed. The assumption this expectation makes is that population growth and packing creates an unstable relationship between supply and demand, and is a major causal factor in geophyte intensification and management of a limited supply of geophytes. On the Lower Columbia, population density was high, but the ecological evidence and human population estimates suggest that the supply of wapato was not nearly tapped.

The existence of control and management of the root grounds was not a reaction to control of an increasingly scarce resource, but rather (I suggest) a reaction to the density of the population, and the need to clarify where specific groups could congregate and harvest in order to avoid conflict or chaos.

In order to address this expectation, it is necessary to understand how the people of the Lower Columbia defined ‘territory’. In a letter from Captain William Clark to Biddle in 1810, Clark described a group he identified as the ‘Shahalas’ which had four settlements around the Cascades of the Columbia River where they maintained permanent settlements, and “the little colony of Neckokee [probably Neerchokioo] near the Multnomah [Willamette River] where they gather Wappatoe,” (Jackson 1962:543, Clark to Biddle 1810, my brackets). This suggests a pattern of exclusive use of specified resource areas that other groups recognize and respect. The Cascades, occupied by the ‘Shahalas’ was a well known fishing site for migrating salmon. Their ‘colony’ was specifically occupied in the fall and spring for the purpose of collecting wapato (Jackson 1962:543).

In 1851, after most of the Indians in western Oregon had died from disease, the local Indian Agent was given the task of grouping together the remaining people. However, the people resisted, and were reluctant to move elsewhere. In a letter from agent to his superior he wrote the following:

“...the natives of western Oregon, so far as we have seen, without exception, are possessed of local attachments of the strongest kind...the habitations of these people are, so far as regards place, not only permanent, but hereditary. Divided into bands or families, now reduced in number, but retaining each their separate chiefs, occupying their own lodges in the different districts of the country...it has been found generally impossible to amalgamate portions of even the same people,” (Dart 1851 as quoted in Boyd 1985:469).

Territoriality on the Lower Columbia may resemble territoriality expressed by the Katzie
who lived on the Lower Fraser River where some patches belonged to the Katzie tribe, while others belonged to families. Families could seasonally claim parts of a patch by clearing along the shore so the plants could be collected more easily (Suttles 1951:27).

In terms of supply and demand ratios, Harris (1977) makes the point that “past and present hunter-gatherer populations have normally stabilized at levels below the maximum carrying capacity of the environment exploited at a given level of technology,” (Harris 1977:180). He goes on to say that this equilibrium with their local environment is from limiting population levels, rather than a lack of correlation between population density and available food resources (Harris 1977). This brings up the question of whether population levels were controlled in the region, and if they were, how were they controlled. The possibility exists also that our estimates of pre-epidemic population levels may be incorrect, and that there were considerably more people in the region just before contact.

Thoms’s expectation that the people “managed” root gathering grounds is supported by at least one account. Harriet Smith wrote a book about wapato and her experiences harvesting wapato in Skamania County with a family descended from the original Native American population. She mentioned that she successfully harvested wapato, though it was difficult because the root mat and substrate need to be thoroughly tramped on and loosened up every year in each patch. A properly maintained loose root mat released more roots (Harriet Smith, personal communication).

*Sagittaria latifolia* often grows with a companion plant, *Ludwigia palustris* (L), which is an herbaceous small-leafed plant, growing close to the surface of the water. Underwater it forms a network of small, brittle twigs through which *Sagittaria l.* grow easily. I have found that this brittle mat needs to be punctured and agitated in order for the wapato in the substrate to effectively be released and float to the surface. I have also noticed that the twigs of this plant scratch and cut the skin on my legs as I am tramp the substrate. This work would be easier, and more productive if the brittle Ludwigia twigs were broken up. There are some flat, heavy cobble tools (weighing over 300 grams) which are peripherally flaked over 180 degrees that are found in archaeological sites near wapato collection areas, including Vancouver Lake (Wessen 1984) and the site where Indians from Cathlapotle portaged their canoes to the pond where they collected wapato. These tools may have been used to break up the Ludwigia root mat. The use of this tool has never been fully analyzed, and its possible use in this context needs to be tested.

**Discussion and Conclusions**

I conclude with an assessment of the predictions made earlier about the expected role of wapato in the Greater Lower Columbia region in the ethnographic period. Thoms’ first expectation that the there would be an inverse relationship between the exploitation of wapato and the availability of anadromous fish is not met at all. The Lower Columbia was one of the world’s best salmon streams. The second expectation regarding a positive correlation between the intensity of wapato exploitation and the size of productive wapato patches is met.

Expectation 3, regarding a correlation between transportation costs and intensive use is met. There were remarkably low transportation costs for wapato for the permanent population because their settlements were adjacent to wapato patches. Wapato was traded out of the area by canoe to the mouth of the river and to the interior regions. Expectation 4 asserts a correlation between the use of large ovens and storage facilities and wapato intensity. This expectation is only partially met, due in part to the fact that large earth ovens are not necessary to process wapato.

Expectation 5 states that normal population growth is a force toward instability and increased control over the resource. Though there was increased control of the resource, it may have been driven by a need for order rather than an increased scarcity of the plant resource itself.
CHAPTER 7
CONCLUSIONS

Several important findings have emerged from this study. I have demonstrated that wapato was intensifiable, and an intensively exploited root food in the Greater Lower Columbia Region in early historic times. This finding is based on ethnohistoric and ethnographic accounts, and ecological data. The ecological data demonstrate that wapato was intensifiable, and the ethnographic and ethnohistoric accounts describe wapato as being a staple. These data sets combined demonstrate that wapato was intensively exploited in the Greater Lower Columbia region. This finding has implications in regards to economic issues such as trade, exchange systems, and wealth in the region.

Another important finding that gives us a better understanding of settlement patterns and population movement in the Greater Lower Columbia region was that wapato was in season over a remarkably long period of time for a wild root food growing in the Northwest. It was available from early fall to late spring, with a harvest hiatus of a month (more or less) during high water in mid-winter.

In a discussion about salmon intensification, Ames (1994) notes that documenting the history of salmon's non-subsistence role is a major cultural-historical problem. This is true for wapato as well. The earliest accounts of contact with people of the Lower Columbia describe the use of wapato. The uniformity of these and other early reports makes it extremely likely that wapato intensification preceded contact.

If the intensification of a plant puts the gatherers on the continuum towards an agricultural lifeway, where on this continuum were the Chinook? The region had the elements Harris (1980) identifies are necessary for an emergent stable agricultural system: high species diversity, crop ecology that lends itself to intensification, and the intensive management of the resources within the ecosystem (Harris in Green 1980:332). Gorman (1977) suggested that agriculture began in marsh environments in Southeast Asia with crops such as rice and yams. The Greater Lower Columbia region fits some of Sauer's model of the 'first farmers' who were fisherfolk who lived in a wooded and diverse environment on freshwater streams in the tropics (Sauer 1952). According to Sauer, the first agriculturists grew crops vegetatively which made the selection of desirable traits easy, and eventually led to plants that lost their capacity to bear viable seeds.

Plowing, weeding, selecting and planting are farming techniques that change the genetics of a plant, and increase the plant's dependence on human protection. Wooten demonstrated that *Sagittaria latifolia* exhibits deep dormancy of its seeds, which is occasionally cited as an indicator of domestication. Ethnographic and ethnohistoric evidence suggests that this plant was intensively exploited by the human population. However, there is scant evidence that wapato had become domesticated. Seed dormancy in *Sagittaria latifolia* was most likely a product of waterfowl grazing on the seedheads, not selection of desirable traits by humans. There is one late ethnographic account that indicates that the Indians of the Puget Sound region transplanted wapato from one area to another (Haeberlin 1930). Ethnohistoric and ecological evidence suggests that the plant was sufficiently prolific naturally in Wapato Valley, and did not need to be transplanted.

On the Northwest Coast several theorists link the evolution of complex hunter-gatherer societies in part to salmon intensification (Matson 1983, Fladmark 1975, Schalk 1977, Burley 1994). Burley's model suggests that salmon intensification occurred first in streams, particularly the Fraser River, rather than the coast, because salmon were more easily caught in streams (Burley 1994). Wapato was exploited in the Fraser River as well, and intensification of both resources may have led to complexity in this location. This is a matter of further study.

Ames suggests that circumscription played a part in the development of complexity in the Northwest. The Greater Lower Columbia had a high population density, but the effects of circumscription that Binford cites such as tension zones between sedentary and migratory populations, and defense of boundaries did not appear to manifest themselves as one would expect if circumscription was a crucial element in the development of complexity in the Greater Lower Columbia area. However, the Greater Lower Co-
lumbia is too small an area of study to draw implications about complexity for the entire Northwest Coast.

Another subject of further study is to determine how, when and to what extent the Chinook utilized muskrat. I suggest that muskrat was an important late winter food, and provided a unique trade commodity; the muskrat skin robe. Burley notes that an effect of a food surplus beyond subsistence needs would be a widespread trading pattern in non-utilitarian or primitive wealth items. A secondary effect would be specialization in crafts for the trade market (Burley 1980:71). The muskrat skin robe may have been just such a specialized craft item produced in Wapato Valley, and traded to the coast and other locations, along with baskets of wapato.

One tool type that may be associated with wapato intensification is a large, flat, peripherally flaked cobble tool that has been found on the Vancouver Lake shore, and at a portage site linking Lake River with a pond where the people of Cathlapotle gathered wapato (45CL04). These tools show little or no use-wear. This tool may have been used to break up the Ludwigia bed, and its presence may be an indicator of intensification of wapato where wapato grows in association with Ludwigia palustris. This is also a matter of future study.

Another important finding that has emerged from this study is that large earth ovens and ground stone tools are not always indicators of the intensive use of a root food. Ethnographic and ethnohistoric accounts from the region describe wapato as being roasted whole and generally eaten, peel and all. Tools for processing plant foods such as grindstones, mortars and pestles, and knives and scrapers for peeling and cutting vegetables are considered indicators of plant food intensification. These tool types are common in archaeological sites on the Lower Columbia, but ethnographic information suggests that these tools were typically used for plant foods other than wapato. The implication of this is that evidence of exploitation of wapato by humans would be difficult to find archaeologically, both due to the taphonomy of root parts in general, and because stone tools and large amounts of fire cracked rock would not be use indicators. Archaeologists need to look for other lines of evidence to study the exploitation of Sagittaria latifolia roots. This applies specifically to questions of human subsistence in the late Pleistocene in The Great Basin and northern United States, where this plant is believed to have been much more prolific than it is today (Stuckey 1993:289).
REFERENCES CITED

Aikens, Melvin C. and Takayasu Higuchi  

Aikens, Melvin C.  

Allen, A. J.  
1850 Ten Years in Oregon; Travels and Adventures of Doctor E. White and Lady, West of the Rocky Mountains. Press of Andrus, Gaulett, & Co., Ithaca, N.Y.

Allen, Paul  


Ames, Kenneth M.  


Ames, Kenneth M., Alan G. Marshall  

Anderson, E. N.  

Anonymous  

Anonymous  

Anonymous  
1925 Wapatoo, An Indian Food Found on Sauvies Island. Oregonian, September 14, 1925.

Arnold, Jeanne E.  

Atwell, Jim  

Bagley, Clarence B.  
1932 Early Catholic Missions in Old Oregon, Volume 1. Lowman and Hanford Company, Seattle.

Belovsky, Gary E.  
Bender, Barbara

Bender, Barbara

Benson, Adolf (editor)

Binford, Lewis R.

Blakenship, J.W.
1905 *The Native Economic Plants of Montana*. Montana Agricultural Department Experiment Station Bulletin 56, pp. 36.

Boas, Franz

Boas, Franz

Boyd, Robert T.

Boyd, Robert T. and Yvonne P. Hajda

Bronson, Bennet

Broughton, W.R. Lieutenant

Brown, R.

Burley, David V.

Butzer, Karl W.

Canniff, Kiki

Carter, George

Chang, K.C.

Child, V.G.

Clark, William R. and Darryl W. Kroeber

Clarke, Chuck

Cohen

Couture, Marilyn D.

Coville, F. V.

Cox, Ross
1957 *The Columbia River or scenes and adventures during a residence of six years on the western side of the Rocky Mountains among various tribes of Indians hitherto unknown; together with "A Journey across the American Continent,"*. (1832) Edited by Edgar I. Stewart and Jane R. Stewart. University of Oklahoma Press.

Darby, Melissa

Delesalle, V. A. and S. Blume

Delesalle, V. A. and Menchow

Densmore, F.

Dickson, Evelyn M.
1946 *Food Plants of Western Oregon Indians*. MA thesis, Stanford University, Palo Alto, CA.

Dufour, Terry
1996 *personal communication*, Oregon Fish and Wildlife Department.

Eaton, Boyd S. and Melvin Konner

Ebeling, Walter

Ellen, Roy

Elliott, T.C. editor

Falter, C. Michael, James Leonard, Richard Nasukali, Fred Rabe, Helen Bobisud

Fee, Chester Anders

Farnham, Thomas J.

Fladmark, Knut R.
1975 *A Paleoecological Model for Northwest Coast Prehistory*. National Museum of

Franchere, Gabriel

Franchere, Gabriel (translated and edited by Hoyt Franchere)

Franchere, Hoyt C.

Franklin, Jerry F., and C.T. Dyrness

Gatschet, Albert S.

Geertz, Clifford

Gilbert, Helene

Gilkey, Helen M. and La Rea J. Dennis

Gilmore, M. R.

Giroux, J.F. and J. Bedard

Godfrey, Robert K., Jean W. Wooten

Gorman, Chester

Green, Stanton W.

Gruenhagen, Ned M. and Leigh H. Fredrickson

Gunther, Erna


Haeberlin, Hermann and Erna Gunther

Hajda, Yvonne P.

Hale, Horatio
1846 Ethnography and Philology, United

Hanson, Gordon William

Harris, David R.

Harris, David R. and Gordon C. Hillman

Harvey, Athelstan George

Havard, V.

Higham, F. G.

Hilty, I. E., Jean Peters, Eva Benson, Margaret Edwards, Lorraine Miller

Hitchcock, Leo C., Arthur Cronquist

Hodge, Frederick Webb

Hohman, William and Dennis W. Woolington

Howay, F. W. and T. C. Elliott

Howay, F. W.
1927 Early Followers of Captain Grey. Washington Historical Quarterly 18(1).

Howell, Thomas

Hu, Peter, David B. Hannaway, Harold W. Youngberg
1992 Forage Resources of China. Beijing Agricultural University and Oregon State University, Pudoc Wageningen.

Hunn, Eugene S.

Hussey, John A.

Jackson, Donald


Jackson, Donald and Mary Lee Spence (editors)
Jacobs, Melville

Dorothy O. Johansen (editor)

Jones, Roy
1972 *Wappato Indians of the Lower Columbia River Valley*. Privately Printed.

Kane, Paul

Kaul, Robert B.

Keely, Patrick Byron

Kew, M.

Kuhnlein, H.V. and Nancy J. Turner
1982 Nutritional Significance of Two Important Root Foods (Springbank Clover and Pacific Silverweed) used by the Native People on the Coast of British Columbia. *Ecology of Food and Nutrition* 12:89-95.

Lampman, Ben Hur
1946 *The Coming of the Pond Fishes*, Binfords and Mort, Portland, Oregon.

Larson, Lynn
1995 personal communication.

Link, Terry

Lucas, Jannette May

Mackey, Harold
1974 *The Kalapuyans, A Sourcebook on the Indians of the Willamette Valley*. Published by the author in cooperation with the Mission Mill Museum Association, Salem, Oregon.

MacNeish, Richard S.

Matson, R.G.

Megaw, J.W.S. (editor)

Miller, G. Tyler

Minor, Rick

Moran, Emilio F. (editor)

Moulton, Gary E. (editor)
Muenchow G., and W.A. Delesalle

Muenchow, G., W.A. Delesalle

Nash, Ronald J.

Neumann, Alan, Richard Holloway and Colin Busby

Norton, H.H. E.S. Hunn, C.S. Martinson, and P. B. Keely

Norton, Helen H.

Oregon Department of Fish and Wildlife

Parker, A. G.

Parker, Samuel

Peterson-del Mar, David

Powell, Fred Wilber

Powell, Fred Wilber (editor)

Ray, Vern


Reed, Charles A. (editor)

Reidhead, Van

Rindos, David

Ross, Alexander
1966 *Adventures of the First Settlers on the Columbia River*. Ann Arbor, University Microfilms, Inc.

Ruby, Robert and John H. Brown

Saleeby, Becky Margaret
1983 *Prehistoric Settlement Patterns in the Portland Basin of the Lower Columbia River: Ethnohistoric, Archaeological, and Biogeographic Perspectives*. Ph.D. Disser-
Saleeby, Becky and Richard M. Pettigrew

Salaman, Redcliffe N.

Sauer, C.O.

Schalk, Randall

Schiffer, Michael B. (editor)

Sidorskii, A.

Sims, Laura S., Beatrice Paolucci, and Portia M. Morris

Skarsten, M. O.

Slacum, William

Smith, Harriet L.

Smith, H.H.


Spier, Leslie and Edward Sapir

Speth, John D. and Katherine A. Spielmann

Stoffle, Richard W. and David B. Halmo

Stuckey, R.L.

Tation. Department of Anthropology, University of Oregon.

ogy in British Columbia, Memoirs Nos. 2 and 3.

Suttles, Wayne

Suttles, Wayne

Swan, James G.

Tanimoto, Tadayoshi

Thomas, David Hurst (editor)

Thoms, Alston

Thwaites, Ruben Gold (editor)


Thwaites, Reuben Gold, editor

Turner, Nancy J.

Turner, Nancy J. and Harriet V. Kuhnlein

U.S. Department of Commerce

U.S General Land Office
1853-1854 Willamette Meridian T4N,R1W (maps and notes).

Visser, Jenneke Maria

Wessen, Gary

White, Joyce C.

Winterhalder, B.

Wooten, Jean W.
Wright, Herbert E. Jr.

Zenk, Henry B.
PART VII

ARCHAEOLOGICAL APPLICATIONS OF MAGNETOMETRY AND GROUND PENETRATING RADAR ON FLOOD PLAINS OF THE PACIFIC NORTHWEST

Kendal Lyle McDonald
ABSTRACT

Two remote sensing techniques used in archaeology are magnetometry and ground penetrating radar. These non-destructive techniques can be useful for documenting subsurface cultural remains, if it is appreciated that past human activities disturbed the natural sedimentary structure through feature construction and artifact deposition. Archaeologists document past cultural remains by recording the natural background conditions and then discerning anomalies and relating them to cultural activities.

In 1998 and 2000 magnetic surveys were performed to locate additional subsurface features at the Pacific Northwest Village Chinookan Village of Cathlapotle. It was anticipated that prior excavation units and plank house features would produce detectable magnetic anomalies. A cesium magnetic survey at Cathlapotle was used to identify such anomalies and to assist with the placement of a backhoe trench for a geoarchaeological study. The survey identified anomalies that were likely prior excavation units and a variety of house features. Areas of little or no magnetic disturbance were also detected and indicated areas of low or no cultural activity.

In 1998 and 1999 remote sensing surveys were performed to locate the original homestead of Champoeg, Oregon’s co-founder, Robert Newell. Bricks and other artifacts and numerous features (wells, outhouses, house foundations) produce detectable anomalies that can be identified using magnetometry and ground penetrating radar. Ground penetrating radar and magnetic surveys at Champoeg were used to identify such anomalies and to assist with the placement of excavation units. The magnetic survey identified several anomalies, which were subsequently tested through excavation; a possible house foundation was located. The ground penetrating radar survey identified changes in the subsurface sediments.

This study has established that features associated with house construction can be identified using magnetometry and in turn suggests that future projects should incorporate such field methods. Geophysical baseline records now exist for Cathlapotle and Champoeg. At Cathlapotle there is the beginnings of a comparative magnetic model of a semi-subterranean plank house.

This study highlights the value of these technologies as labor saving tools that minimize archaeological impact to historically significant properties. The study also encourages archaeologists to consider geophysical techniques as part of a minimal acceptable standard in archaeology.
CHAPTER 1
INTRODUCTION

Remote sensing can encompass many techniques. Most of the techniques were developed for purposes other than archaeological, such as geologic (mineral exploration and fault zone location), military (detection of unexploded ordnance), and environmental (detection of landfill boundaries). The common link among all the technologies is that they are non-destructive methods of detecting what is beneath the surface without excavation. The most common remote sensing technique used in archaeology is undoubtedly aerial photography. Aerial photography involves looking at the ground from a birds-eye view and detecting earthworks, soil-marks or subtle changes in flora that may be the result of cultural modification of the soil. Another often-used technique is magnetometry, which measures spatial changes in the earth’s magnetic field. Both aerial photography and magnetometry are passive techniques as they send out no signal but capture the naturally occurring condition of the ground. Resistivity, seismology, and ground penetrating radar (GPR) are also non-destructive to archaeological sites, but a signal is sent out and a return signal is recorded.

Magnetometry and GPR are important non-destructive remote sensing methods that have been used by archaeologists for several decades to detect buried artifacts and features that are not visible from the ground surface (Aitken 1959 from Clark 1996; Weymouth and Nickel 1977; Bevan 1982). In basic terms magnetometry measures the magnetic field and GPR, the electrical permittivity of the subsurface. Such methods can be useful for documenting subsurface cultural remains, assuming that past human activities disturbed the natural sedimentary structure through feature construction (houses, pits, fire hearths) and artifact deposition. Archaeologists use such methods to document past cultural remains by recording the natural background conditions and then discerning “distortions” or “anomalies” and relating them to potential cultural activities. With information gathered from remote sensing surveys, one can make more informed decisions about the placement of excavation units and minimize destruction of archaeological sites.

When remote sensing techniques have been used as part of archaeological investigations, they have contributed valuable information. The potential exists that exceedingly fine magnetic signatures in the soil can become visible. In one magnetic survey, Weymouth and Nickel (1977) identified the location of houses and fire pits, detected the location of house entrances, and the order of construction of two earth lodges in a North Dakota Sakakawea Village. Similarly, Kvamme identified stratigraphic relationships from a magnetic survey in Northern Ireland (1996). He distinguished some features as contemporaneous and others where the chronological order of buried feature construction was apparent. Hathaway and Burtchard (1986) performed a magnetic survey in the Calispell Valley of northeastern Washington and discovered magnetic signatures that were strongly correlated to distinct types of cultural features and artifacts, such as camas processing ovens, fire-cracked rock scatter, and metal fragments. Fine resolution that allows for the identification, depth, and size of the source of magnetic anomalies without the need to excavate every instance is beneficial to the field of archaeology.

Ground penetrating radar has also been used successfully in archaeology to detect a variety of features. As expected with any remote sensing technique, it is often the larger features that have the greatest potential for detection. GPR surveys have located prior excavation units and features such as walls (Kenyon 1977; Stove and Addyman 1989), and detected voids, such as underground storage vaults (Kenyon 1977) and burials (King et al. 1993; Goodman and Nishimura 1993).

In addition to potentially locating structures, GPR also can provide information about the orientation and depth below the surface of the artifact or feature that produced the anomaly, often more quickly and with more precision than a magnetic survey. GPR has the potential to create a detailed recording of the subsurface to a depth relevant to most archaeological investigation. At a site in York, a Roman building was revealed with the radar continuing to penetrate to culturally sterile sediments over seventeen meters below the surface (Stove and Addyman 1989:341).

Advancements in remote sensing equip-
ment, electronic data recorders, and graphical mapping software have made magnetometry and GPR cost efficient. Survey maps can be generated within minutes. Remote sensing methods can quickly identify culturally disturbed areas within a site that can be targeted for excavation. Alternatively, survey results can be used to designate areas within a site that require preservation and protection.

In spite of the demonstrated value of remote sensing techniques to the field of archaeology, researchers and cultural resource managers use the methods infrequently (Thomas 1998). Bruce Bevan has researched, performed, and promoted a number of different remote sensing techniques in the field of archaeology. His network of contacts in archaeogeophysics has helped him maintain a database that contains a listing of over 5000 archaeological surveys performed since 1938. Significantly, Bevan estimated that since the 1980s in the Americas, only two percent of archaeological surveys included some form of geophysical investigation (1999:2). In the Pacific Northwest, the methods have been used very rarely (for exceptions see Connolly et al. 1999; Bell 1998; Brauner et al. 1995; Hathaway and Burtchard 1986).

This study will primarily use magnetometry and to a lesser extent GPR to survey a late prehistoric/proto-historic and an historic site on flood plains in the Pacific Northwest (Figure 7.1). Cathlapotle, a Chinookan village, is located along a tributary of the Columbia River, about 20.9 km (13 river miles) north of Portland, Oregon. The historic town site of Champoeg is 96.5 km (60 river miles) south of Portland, along the banks of the Willamette River. At Champoeg the survey focused on the original homestead of Robert Newell, slightly down river and east of the town.

The results of the surveys contribute to our specific knowledge about subsurface anomalies at these sites. The information gathered has already been used to plan research activities at each location. Finally, results generated will demonstrate the potential value of remote sensing methods to the practice of archaeology and by example, encourage others in the region to apply these important tools.
Figure 7.1. Modified 1834 map (from Hussey 1967:42).
CHAPTER 2
OVERVIEW OF MAGNETROMETRY AND GROUND PENETRATING RADAR

Magnetometry

Introduction

The earth behaves as a giant bar magnet, which is thought to be produced by the earth’s outer liquid iron core. Like any bar magnet there is a north and south pole. People take advantage of the magnetic field that envelops the earth when they use a compass. The iron in the compass needle is attracted to the opposite pole in the earth. Contrary to what most people believe, the geographic north pole of the earth is physically the magnetic south pole. However, convention states that the direction the compass arrow points determines the magnetic pole (Breiner 1973:5). Therefore, magnetic north is roughly aligned with the geographic north pole of the earth. The magnetic north-south field, which extends out into space, is referred to in geophysics as the magnetosphere.

Magnetometers passively record the earth’s magnetic field at surface level. These magnetic fields are not only generated by iron deep in the earth, but are also generated by traces of iron that are found in most surface level sediments. The most common mineral found in surface sediments is magnetite (Monroe and Wicander 1995:258). A lack of iron can also be detected. The earth’s magnetic field is measured in a unit of measure called gammas or nanoteslas. There is a 1:1 relationship between gammas and nanoteslas. Nanotesla, abbreviated nT, is the current standard unit used in magnetometry (Clark 1996:64). The earth’s naturally occurring magnetic field ranges from 60,000 nT at the poles to 25,000 nT at the equator (Barrows and Rocchio 1990). In general terms, the magnetometer is able to detect small disturbances in the magnetic field lines of flux, if the size of the disturbance is greater than the naturally occurring variations in the survey area. In magnetometry, geologic variations or differences in iron content are termed “anomalies”.

Magnetometry was developed in geophysics and is used to identify structural variations in the Earth’s subsurface. Archaeology utilizes the same theories and equipment, but typically searches for more subtle magnetic changes at shallower depths. In naturally deposited sediments, ferromagnetic grains are randomly aligned and the area will be weakly magnetic. Disturbances in the magnetic field, often at a strength of not more than ± 10 nT (Kvamme 1996:83) could indicate cultural modification.

Buried artifacts such as bricks or pieces of iron can produce anomalies. Cultural disturbances from features such as refuse and outhouse pits, buried ditches, and walls, can stand out from the surrounding subsurface because of a different proportion of ferromagnetic material. For this reason, how excavated units are backfilled is important to know, if remote sensing technology will be used at a later date.

Magnetism can be induced or remnant. When magnetism is induced an object itself acts as a magnet and enhances the local ambient field. Alternatively, objects can show signs of remnant magnetism, if they are rocks, or permanent magnetism, if they are metal (Breiner 1973:8). An example of remnant magnetization can occur if a material such as clay is heated to a very high temperature and then allowed to cool. The ferromagnetic compounds contained in the clay will realign and become re-magnetized concordant with the earth’s magnetic field. Similarly, fire pit features, if the fires were heated to very high temperatures, can be detected because they have a different magnetic signature than the surrounding material. A fire hearth is one type of feature that generates a very recognizable magnetic signature. In northern latitudes an undisturbed fire pit will produce a crescent shaped signature with a magnetic low to the north and a circular magnetic high to the south (Figure 7.2).

What can affect a magnetic survey?

Most archaeological magnetic signatures are exceedingly fine, usually less than 10 nT, but can range from 1 to 100 nT (Bevan 1998:19). Magnetometers today are sensitive to a fraction of a nanotesla and can pick up very subtle changes. However, above ground disturbances can also be picked up by these highly sensitive
machines. Magnetic surveys cannot be conducted near electrical currents and therefore overhead power lines must be avoided. Individuals operating the magnetometer or close to the survey area cannot wear iron or erroneous data will be collected. The survey area must also be away from large metal objects, such as cars, railroad tracks, and metal fences that would skew the magnetic readings. Such above ground disturbances need to be removed from the survey area or filtered out from the data recorded.

Above ground disturbances can also come from space, in particular, from the sun. This is referred to as solar wind or solar weather, which is actually fast-moving charged particles or plasma. Solar flares on the sun cause bursts of particle activity that hit the earth’s protective magnetosphere. When the plasma or charged particles enter the Earth’s atmosphere at the poles, Northern and Southern Lights are the result. Interestingly, these charged particles are not only visible to the naked eye, but can be heard by sensitive equipment that record sounds such as static, pops, chirps, and whistles (McGreevy 1999). Additionally, periodic bursts of plasma from the sun, called micropulses, sneak through the earth’s protective magnetosphere at any latitude and can be small to tens of nanoteslas (Breiner 1973:6).

Another consideration when performing a magnetic survey is the angle of the magnetic field surrounding the earth, as the angle changes with latitude. The inclination of the area surveyed is used to align the angle of the magnetometer sensor to avoid dead zones, which are the angles around the sensor that do not produce data due to the magnetic lines of force passing through the sensor (Smith 1997:6). In Portland, Oregon, the inclination of the Earth’s vertical field is approximately 70 degrees (Breiner 1973). At a 70 degree inclination, the sensors do not need to be tilted, but can be held at 90 degrees or perpendicular to the ground. Failure to adjust the sensors properly will result in what are termed “heading errors”.

Besides solar storms and the angle of the magnetic field, there is also a cyclical aspect to solar weather that can affect a magnetic survey. As the earth rotates in a 24-hour period, the side of the magnetosphere closest to the sun is compressed or “squashed”; this produces a diurnal variation that can be detected by magnetometers (Figure 7.3). If a magnetometer is set up in a single spot as a base station and readings are taken once every minute for a 12-hour period, the readings will be high in the morning, lower at noon, and increase again toward dusk. The change in diurnal variation can be as much as 100 nT (Breiner 1973:6). A second magnetometer set up as a base station is often used to control for solar weather. Changes detected in magnetic readings at the nearby base station can be added or subtracted from the magnetic survey readings and cancel out solar interference and diurnal variation. Figure 7.4 demonstrates the diur-
nal variation and an atmospheric anomaly or solar micropulse recorded by a proton magnetometer at a base station.

Depending on the type and configuration of magnetometer used in a survey, solar weather can affect magnetic results; solar micropulses may be incorrectly interpreted as archaeologically significant anomalies. Fortunately, solar weather is monitored and predicted by the Space Environment Center under the joint direction of the National Oceanic and Atmospheric Administration and the U. S. Air Force. Real-time information and space weather forecasts are available off the Space Environment Center’s main web site: http://www.sec.noaa.gov/index.html.

Concerns about solar weather interference during a survey can be addressed using several methods. If there is a strong solar storm in the forecast, it may be desirable to postpone the magnetic survey. This is particularly true if only...
one magnetometer is available, since a single sensor will detect the total magnetic field. If a second magnetometer is available, then at the very least, on days when there is a high probability of solar storms, the frequency of base station readings should be increased (Bevan 1998). If the forecast is for low levels of solar activity, multiple readings at the same coordinates can be used to correct for some magnetic field disturbances. Ideally, a gradiometer, which eliminates solar weather disturbances during data collection, can be used. A gradiometer measures the difference or vertical gradient between the two fields and will automatically correct for variation in the solar weather. Such an instrument obviously saves time and resources. Another benefit of gradiometers is that they can provide higher resolution of items that are in close proximity to one another (Breiner 1973:49; Bevan 1998:19). However, the extra sensitivity that the gradiometer provides also increases the importance that the operator is demagnetized. Zippers, rings, and even metal eyelets on shoes, if they are magnetic, will be detected by the gradiometer.

The type of magnetometer used determines how rapidly magnetic measurements can be recorded. Discrete recordings over data points are taken with proton magnetometers since several seconds are required before the reading can be taken and displayed. Both discrete and continuous recording of data points are options with cesium magnetometers, since they calculate readings at rates as rapidly as ten per second. At such a short cycle time, the measurements are sufficiently close together that a person can maintain a slow walking pace and continuously record data. If the data are recorded in a continuous mode, and transect lengths are greater than 15 to 20 m or the ground topography is not level, then fiduciary or waypoint marks should be entered into the data logger. These marks will assist the graphical software by recording a known location and then use it to interpolate magnetic strength between points. Continuous recording of measurements via cesium magnetometers is a substantial timesaving compared to proton magnetometers where the person must stop at uniform points along the transect line. The downside of continuous recording, as stated earlier, is that the software must interpolate the location of magnetic readings between known points and a person must walk at a uniform speed.

**Mapping Software**

Generally the end product of a magnetic survey is a map. There are many ways the data can be represented on a map. One common format is a contour map. A magnetic contour map is superficially like a topographic map, however, instead of the contours representing incremental change in elevation, the isolines represent strength of the magnetic field over a given point. Magnetic anomalies are represented on contour maps with greater compression between the contour lines. For example, Figure 7.5 shows areas of both positive and negative magnetic field strength. Position 1 marks a depression or negative magnetic field, which is noted by the hachure lines. This anomaly could be caused by natural or cultural differences in the subsurface. At position 2 there is a peak. This represents a positive magnetic field. Without excavation, the causes of the anomalies are usually uncertain. If the magnetometer is working properly, there is no operator error, and solar disturbances have been ruled out, then the anomaly can be reasonably assumed to be the result of a subsurface disturbance.

All anomalies are dipoles, having both a positive and negative field. Yet if the opposite field is not detected, the anomaly appears to have a single magnetic pole and is referred to as a monopole. References to dipole and monopole anomalies in archaeological contexts are used primarily for descriptive purposes. However, as will be discussed later, depth to source calculations are slightly different for dipole versus monopole anomalies. Also, when using magnetic data to guide excavation unit placement it is important to distinguish between dipole and monopole anomalies.

The placement of excavation units is usually centered directly over monopole anomalies. However, excavation units should be centered between the magnetic low and high fields for dipole anomalies. Source locations are approximate, because the anomaly produced will vary based on the depth, position, and shape of the item buried in the ground. Also, the location is dependent on the graphical software interpolation algorithm and
the consistency of the person recording the data both in terms of walking speed and their ability to position the sensors directly over the guideline.

The map contour interval selected in the final presentation is subjective. To illustrate, I have redrawn the data from Figure 7.5 at 1 nT and 10 nT (Figure 7.6a and b). At the 10 nT contour interval the anomalies are not as pronounced. If there are too few contour lines, there may be no isolines generated near the anomaly of interest and it will be missed. For example, numerous small anomalies in the central and lower region of Figure 7.6a do not appear in Figure 7.6b. These smaller anomalies could be crucial in discovering buried feature patterns. On the other hand, if too many contour lines are displayed at the finer contour interval, the map will appear cluttered and the items of interest may be obscured because of the noise of other isolines.

In addition to two-dimensional contour plots, magnetic survey data can be plotted in three dimensions. Figure 7.7 is generated from the same data as shown in Figures 7.5 and 7.6. The 3-D display can highlight feature patterns. It can also help one to visualize the comparative strength of the magnetic highs and lows. The magnetic low and high are very apparent at positions 1 and 2.
Figure 7.6. Magnetic contour maps with the same data presented in Figure 6.5 at a contour interval of a) 1 nT and b) 10 nT.

Figure 7.7. Magnetic 3-D surface map generated with the same data as Figures 6.5 and 6.6. A magnetic low is indicated at location 1 and a magnetic high is indicated at location 2.
Magnetic Anomaly Depth Calculations

In addition to generating maps, it is possible to roughly estimate the depth to the item that produced the anomaly. The formula most often used for calculating depth to source is termed the half-width rule. (There is a slight modification to the formula based on the buried item’s shape.) If one assumes the buried object is a sphere, then for a monopole anomaly one uses \( z = 2x^{1/2} \), or for a dipole anomaly, \( z = 2.5x^{1/2} \), where \( z \) is depth and \( x \) is the distance between the principle maximum and minimum of the anomaly (Breiner 1973:30-31). In Figure 7.5, the length of the dipole anomaly is indicated. The data values for the length of the anomaly are plotted to determine \( x \), the distance between the principle maximum and minimum of the anomaly. The height of the sensor above ground must also be subtracted from \( z \) to know the depth below surface. However, the results of the half-width rule are not very accurate and most results tend to be considered the maximum depth of the source that created the anomaly (Breiner 1973:31). Even so, this estimate is usually sufficient for most archaeological purposes (Bevan 1998:24).

It should be noted when estimating depth that the width of an anomaly will appear broader with depth, however, the strength of the anomaly attenuates with depth. This is referred to as the fall-off rate or rate of decay (Breiner 1973:24).

Ground Penetrating Radar

Introduction

Unlike magnetometers, GPR transmits as well as receives a signal and is consequently more complicated to operate. The electronic signal transmitted is termed radar, which is an abbreviation for RA(dio) D(etecting) A(nd) R(anging). Ground penetrating radar uses radio waves directed into the ground to locate artifacts or features. From an antenna pulled along the surface, the radar unit sends electronic pulses into the ground. Each electronic pulse reflects off all material with which it comes in contact; a portion of the pulse is reflected back to the receiver in the GPR unit. Each signal sent and received is called a trace. Multiple traces produce a two dimensional profile of the subsurface called a radargram. More traces per second will increase the resolution of the radargram. One way to accomplish this is by pulling the antenna slower.

Generally the radar signal or footprint disperses into the ground in an elliptical cone shape. The object of interest is detected not only when the antenna is directly over the object, but also before and after the antenna passes over the source, creating a reflection hyperbola (Figure 7.8). A sample of a hyperbola shaped reflection produced when an antenna was pulled over a buried pipe is shown in Figure 7.9.

It is necessary to select an electromagnetic radio wavelength frequency prior to a radar survey. Antenna operating frequencies range from 10 to 1000 megahertz (MHz). Antennae transmitting in the lower frequency range of 10 to 120 MHz have longer wavelengths and can penetrate to greater depths, often over 50 m. Conversely, higher MHz antennae have shorter electrical wavelengths and penetrate to shallower depths, but with greater resolution. To achieve good resolution the wavelength must be shorter than the profile height of the artifacts or features of interest or they will not be detected (Conyers and Goodman 1997:47). In archaeology, where cultural features are typically buried less than 3 m, 400 MHz or 500 MHz antennae are often used to obtain optimal resolution (Bell 1998, personal communication Larry Conyers 2001).

Conyers and Goodman note that good radar penetration occurs when two conditions of the subsurface matrix are met (1997:32-35). First, the subsurface should have low magnetic permeability. This is the ability of the subsurface to become magnetized, and hence if the matrix has low magnetic permeability, the signal will not weaken as quickly. Second, the subsurface should have low electrical conductivity, or a low ability to conduct an electrical current. Salt water, wet clays, and fertilized fields tend to have higher electrical conductivity and the signal is basically “… conducted … into the earth and … lost” (Conyers and Goodman 1997:34). What is desired is a highly dielectric material, so that electromagnetic energy can pass without dissipating (Conyers and Goodman 1997:32).
Figure 7.8. Schematic of reflection hyperbola as an antenna crosses over a “point source” (from Conyers and Goodman 1997:30, Figure 3).

Figure 7.9. A radargram showing the reflection hyperbola generated from a buried metal bar at 110 cm, visible at 13 nanoseconds (6.5 ns each direction) (from Conyers and Goodman 1997:111, Figure 19).
To determine whether GPR is appropriate for a given context, it is important to estimate RDP (relative dielectric permittivity). For example, air has a RDP rating of 1, dry sand ranges from 3 to 5, and clay ranges from 5 to 40 (Conyers and Goodman 1997:33). The velocity of the radar wave slows as the RDP increases. Using the RDP, the speed of the electronic pulse can be determined and the depth of the item that produced the anomaly can be estimated. Depth is calculated based on the time it takes the radar wave to travel from the transmitter, encounter the feature, and bounce back to the receiver. The velocity of the radar signal is measured in cm/nanoseconds and appears on the Y-axis of a radargram. One nanosecond, abbreviated ns, is one billionth of a second. In a void, the radar signal travels at 30 cm/ns (the speed of light), in wet sand the signal travels at roughly 5 cm/ns (Conyers and Goodman 1997:27). By knowing the velocity in cm/ns one will know the approximate depth to source.

Using the RDP, one can calculate the velocity of the radar waves using the formula $\sqrt{K} = \frac{C}{V}$, where $K = \text{RDP}$, $C = \text{speed of light}$ ($0.2998 \text{ m/ns}$), and $V = \text{velocity of the radar energy}$ as it passes through the ground (Conyers and Goodman 1997:33). At the Ceren site in El Salvador, the RDP at a given location changed with the weather. On a rainy day the RDP was 12 and the velocity of the radar wave was 8.7 cm/ns, yet during a dry day the RDP was 5 and the radar velocity was 13.4 cm/ns (Conyers and Goodman 1997:109). Because GPR is so sensitive to moisture, even shadows from nearby trees must taken into account when calculating RDP and estimating depth.

**GPR Pattern Recognition and Mapping Techniques**

While there are many recent advances in GPR modeling software, some use 3-dimensional imaging and time slicing, which takes the data from the entire survey area at a given cm/ns or depth of each reflection profile and displays the depth data as a plan map. However, the most basic and commonly used method of interpreting reflections is visual observation. Each printed reflection or radargram is mounted on a board and the boards are lined up one behind the other. Then one must look for linear or other feature patterns that appear in each profile at the same point in each transect of the survey area (Figure 7.10). After reviewing these profiles a map is drawn. This visual observation method was used at Champoeg, OR (Bell 1998).

**Components of a Geophysical Survey**

There are several key components to a geophysical survey: site selection, survey size, transect spacing, and alignment. The first component is site selection. Certain geologic environments will be better for magnetometry and GPR than others. Sediments in a flood plain are likely to yield acceptable results for archaeology since the sediments are of a consistent, fine matrix. Larger items in this matrix are likely to be culturally deposited. Level surfaces, like those on flood plains, are also easier to survey, since both magnetometry and GPR equipment can be awkward to carry or subject to erroneous data collection if tilted. The history of the site will provide a general indication of what is likely to produce a magnetic or radar anomaly. However, even if the site selected is not considered to have optimal conditions, experience suggests trying it before discounting the location as poor.

The size of each magnetic or GPR survey area is determined by such factors as expected size and distribution of subsurface features, consistency across site, obstacles on the surface, and software file size implications. It is best to extend the boundaries of the survey area by several meters beyond the area of suspected cultural features. This provides needed background or local gradient information that can be used in assessing the anomalies. If one is using a data recorder, there may be file size limitations. Select a survey size where the amount of data collected can be downloaded and manipulated relatively quickly. Small-
er survey areas are preferable because if the data stored in the data recorder is found to be corrupt, then not too much time has been lost. Another benefit of smaller survey areas is that the scale fits well on standard 8 1/2 by 11-inch paper. If the GPR unit uses cables, the size of the survey will be limited to the cable length between the GPR unit and the antenna.

If the survey area is not obstructed with vegetation or natural or cultural features, then I found that an area of 20 x 20 m. is desirable. In this thesis the largest survey size selected for a magnetic survey performed with a data recorder was about 30 x 30 m. These suggested dimensions do not have to be strictly adhered to if the topography or archaeological area of interest does not warrant it. Additionally, multiple smaller data sets can be combined to display a larger section of the entire survey area. If multiple data sets are joined, it is important to know if the mapping software can handle irregularly shaped areas. Some software is only able to map square or rectangular areas. Software limitations might alter the plan for the survey footprint.

After defining the size of the survey unit, one needs to determine the transect spacing. The transect spacing should bisect or come near the anticipated archaeological artifacts or features. For magnetometry, Bevan suggests “… that the spacing between … measurements [transects] be about the same as or smaller than the height of the sensor above the ground or above the features” (1998:21). The spacing between transects can be reduced if the initial survey does not provide adequate resolution. At the Marajo Archaeological Project in Brazil, Roosevelt varied her spacing between 2.0 m and 0.1 m, depending on the expected size of the buried features (1991:201-207). She returned to several of the survey areas in succeeding years to increase the resolution of her magnetometer surveys by reducing the distance between the transect spacing (1991:201). Perhaps the best recommendation when performing a magnetic or GPR remote sensing survey is to select the smallest transect interval that money and time will permit.

When using continuous record mode for a magnetic survey, one simply walks along the transects at a uniform pace, typically in a back and forth manner to minimize time spent walking the lines (Figure 7.11). Importantly, however, if data are collected in a continuous mode and a back and forth pattern is used, striping can occur. Striping happens when the time to walk one direction is consistently less than the opposite direction, such as when there is an elevation change. The transect walked along the decline may take a shorter time to walk that the uphill transect. Striping can be reduced by recording more fiduciary marks and to some extent within the graphical software by using smoothing algorithms.

If possible, for a magnetic survey, the orientation of the transects should be aligned in a magnetic north-south direction as this will “… maximise the discrimination of archaeological magnetic anomalies” (David 1995:18). However, for both magnetometry and GPR, transect direction is important if elongated features exist in the study unit. It is better to attempt to bisect elongated features to improve the chances of detecting and recording their signals along the transect route than adhere to the north-south orientation rule. If it appears that a linear anomaly exists parallel to a transect, a second survey should be performed set off 90 degrees from the first.

Once the data are collected, it is usually loaded into a graphical software package for mapping. Graphical software is quite flexible and requires that a data interpolation formula be chosen. For magnetic archaeological surveys minimum curvature and kriging methods are typically used. Both of these methods of data interpolation tend to give an exact or slightly smoothed interpolation of
the data (Keckler 1997). Another option that can be used to improve the esthetics of the map is contour smoothing. An example of when one might use contour smoothing is when a continuously recorded walking survey is performed in a back and forth pattern over an area with a grade. Contour smoothing can reduce the effects of striping. The local gradient is also often subtracted from survey data. A gradiometer will perform these calculations automatically (Breiner 1973:49).

Application of Multiple Methods

Magnetometry and GPR measure different properties of the underlying sediments to acquire an image of the subsurface. Each technique is affected differently by soil conditions, the surrounding environment (e.g. overhead power lines), and the material content of the buried artifacts or features. For example, magnetometry and GPR are differentially affected by soil moisture. Because the earth’s magnetic field is not affected by variations in subsurface moisture, magnetometers are not hindered by damp weather and are thus suitable for use throughout the year in the Pacific Northwest. GPR is more sensitive to soil conditions, such as moisture. The electronic radar signals travel faster through air, such as open chambers, and attenuate rapidly in wet environments. Since the signal cannot deeply penetrate damp soils, the use of GPR can be constrained by the local climate.

As these techniques each provide a unique picture of the subsurface, multiple techniques are commonly utilized to cover the same survey area (Stove and Addyman 1989; Butler et al. 1994; Roosevelt 1991; Bell 1998; McDonald 1998). Data recovered from two or more methods can refine the attributes of the artifact or feature that produced the anomaly, and improve estimates of depth, size, and position. However, it should be remembered that interpretation of the images created from the magnetic and GPR data is subjective and partly an art. Ultimately some form of ground truthing (auger holes, test pits, excavation units) usually needs to be performed to confirm or disprove the hypothesized source of the detected anomalies. The one possible exception is utility pipes that contain large quantities of iron. Utility pipes produce distinct linear linking north-south dipole anomalies. Thus, while often quite accurate, these methods cannot yet replace physical excavation to identify or locate constructed features and culturally deposited artifacts.

Nationally, there are several remote sensing test sites where practice with multiple types of machinery and transect spacing can be performed in a controlled environment. Test sites include those at Western Michigan University, Kalamazoo, MI, Stanford University, Stanford, CA, and the U.S. Department of Energy Hanford Site, Richland, WA. The Stanford University Environmental Geophysical test site covers a 100 x 100 m area and is sectioned off in 20 x 20 m units, with each unit containing artifacts such as buried drums or pipes (Geometrics, Inc. 1995). The test sites are used to ground truth interpretations without digging and establishes the kinds of anomalies expected under controlled conditions.

The costs associated with remote sensing equipment can be quite high. However, results can reduce the amount of unnecessary excavation, reducing labor costs over the course of a project. Furthermore, targeted excavation areas can minimize destruction of archaeological sites. In June 2000, I conducted a magnetic survey for the United States Forest Service to find the location of a Civilian Conservation Corp dump site. Prior to my work, field archaeologists had dug test units and a backhoe trench and were unable to find the dump. However, after approximately three hours of magnetic data collection and analysis, I located the dump, which subsurface testing later confirmed. When the potential benefit is understood, the costs are reasonable.

Several companies in the United States rent magnetometer and GPR equipment. I found that there is usually a one-time charge for mobilization of the unit. Based upon my inquiries with two suppliers, as of October, 2001, this fee ranged from $80 to $95 to rent a single sensor cesium magnetometer (personal communication, Geometrics, Inc. 2001; personal communication, Exploration Instruments, 2001). As the magnetometer equipment can be heavy (35 to 58 lbs.) and expensive, shipping and insurance can run between $50 and $225. The daily rental fee for a single sensor cesium magnetometer ranged from $59-$80 and must include the time from the moment the equipment leaves the shipping dock to
the time it returns. Rentals for proton magnetometers are less, as are monthly rental charges. A second option is to purchase the equipment. The purchase price of a dual sensor cesium magnetometer is about $26,160; a single sensor proton magnetometers is much less expensive, starting at $4950 (personal communication, Geometrics, Inc. 2001). A handheld fluxgate gradiometer available through Geoscan Research is priced at approx. $19,000, which includes a copy of the Geoplot software (personal communication, Geoscan Research 2001). GPR units with antennae specifically designed for archaeological purposes sell for between $15,000 and $25,000 (personal communication, Sensors and Software, Inc. 2001). Mapping software quality varies but can range in price from free to several thousand dollars. Surfer (ver. 7.0), by Golden Software, Inc., currently sells for $599. A third option is to hire an archaeogeophysical contract firm. There are numerous contract firms that will perform remote sensing surveys and eliminate the inconvenience of equipment rental or machine maintenance.

This Project

My study will evaluate the strengths and weaknesses of using magnetometry and GPR to identify subsurface archaeological artifacts and features in the Pacific Northwest. Remote sensing surveys were performed at two archaeological sites, which illustrate a number of conditions that one is likely to encounter in riverine environments. The first survey was conducted at a late prehistoric and proto-historic site (Cathlapotle, Ridgefield, WA), where remote sensing techniques were used to enhance information about plank house boundaries and detect areas that lack cultural remains. The second survey was conducted to locate house foundations or other cultural features and artifacts associated with a 19th century homestead near the historic town site of Champoeg, OR.
CHAPTER 3
SITE BACKGROUND

The Cathlapotle village and Champoeg town sites are located beside large rivers that are prone to floods. It is in low flow velocity alluvial environments, such as river terraces, where the potential exists for a strong contrast between artifacts and constructed features and the surrounding naturally deposited sediments. Since relatively large or regularly patterned anomalies are not apt to be the result of transported items in a low flow velocity alluvial environment, detected anomalies are likely to be the result of cultural deposition. Each flood event in these alluvial environments likely dropped sediments over the areas of interest. In the case of Cathlapotle, a geoarchaeological survey indicated that through the later half of the Holocene the ridge and swale landform had accreted westward, away from the site (Hodges 1999). Prior archaeological excavations and geoarchaeological testing at Cathlapotle showed that the sediments are generally fine, indicative of a low flow alluvial environment and that cultural remains occur at a depth between approximately 0.25 m and 2.50 m below ground surface (Ames et al. 1999:24-26; Hodges 1999). The low flow alluvial history at Cathlapotle has been conducive to the preservation of the site.

The town of Champoeg was destroyed by a flood in 1861. The flood was so large that eyewitnesses reported homes lifted off their foundation and carried down river (Brauner et al. 1995:72-75). Cultural remains of the early inhabitants not carried away by the water remain encased within and resting upon the flood plain. Archaeological excavations between 1990 and 1992 in the old town center of Champoeg located historic artifacts and features from the surface to roughly a depth of 60 cm (Brauner et al. 1995).

Cathlapotle

Characteristics of Northwest Villages and Plank House Features

An understanding of the layout and architecture of a Northwest village is necessary to appreciate the archaeological site of Cathlapotle and the subsurface disturbances that may be detected through magnetometry or other remote sensing techniques. The historic drawing in Figure 7.12 depicts a village at Nookta Sound on Vancouver Island, BC. As seen in this figure, homes often paralleled the riverfront and canoes were docked along the beach. House forms could include plank houses and pithouses (Ames and Maschner 1999:151). Pithouses were semi-subterranean structures with a central post or posts that support-

Figure 7.12. View of the Habitation in Nookta Sound, located in the Pacific Northwest. Oregon Historical Society.
ed a roof made of poles and mats covered with sod (Ames and Maschner 1999:151-152). Plank houses generally were permanent cedar post and beam frame construction with a gabled roof and split cedar plank siding (Ames 1992:276).

Plank houses were constructed to hold many people; by one estimate over 100 people per household (Ames et al. 1999:14). Therefore, several families often lived in the larger homes. Historical accounts record large villages with plank houses. On November 4, 1805, at a location below the Columbia Gorge, Clark noted a village he passed that consisted of 25 houses. He counted twenty-four houses built of straw and bark and one wooden structure, a plank house, he estimated to be 50 feet long (DeVoto 1953:275). Excavations at the Meier site, located across the Columbia River from Cathlapotle and occupied at roughly the same time, indicated that the dimension of one rectangular plank house was 14 x 35 m (Ames et al. 1992:275).

Ames et al. suggest that large communal plank houses ranged in size from 60-137 m in length, but more typically ranged from 4.5 - 9 m in width to 6 - 15 m in length (1992:277). The longer houses could contain room dividers across the long axis of the house, forming individual apartments (Ames et al. 1999:19; Chatters 1989:169). Some plank houses were semi-subterranean. Lewis described the plank houses they saw in 1806. “[T]he floors of most of their houses are on level with the surface of the earth tho’ some of them are sunk two or 3 feet beneath” (Moulton 1990 [7] 26-29 from Ames et al. 1999:16).

Plank house construction techniques reveal large quantities of rock below surface. If this rock is substantially distinct from surrounding fine sediments, it could generate magnetic anomalies. Fire cracked rock has been found packed against the plank walls, perhaps to assist with the structural support (Ames et al. 1992:279). At the Sbabadid longhouse in the Puget Sound, fire-cracked rock and other detritus was found against the side of what might have been a room partition (Chatters 1989:171). At Meier the larger cedar posts ranged from 5 cm to 1 m in diameter and the postholes were “… packed with stones and fire-cracked rock” (Ames et al. 1992:279), possibly to extend the life of the wood by removing it from contact with the wet ground. At the bottom of the larger 1-m diameter corner postholes, 100 lb. boulders were discovered (Ames et al. 1992:280).

The interior of a plank house also contained cultural modification of the sediments.

![Figure 7.13. Interior of Chinookan Lodge from Wilkes Expedition. Oregon Historical Society.](image-url)
From a historic drawing of the interior of a plank house (Figure 7.13), several features are apparent. Large cedar support posts existed in the corners, benches ran the length of the house, and fire pits or boxes were located in the center or down the long axis of the room. The framed fire boxes were 2.5 to 3.0 m square (Ames et al. 1992:278). Storage pits were found along the corridors, if the floor was covered by boards, or beneath the bench area. At Meier, the pits located in the corridors were, “...straight walled, flat bottomed, about 1 meter in depth and with a mean diameter of 86 cm” (Ames et al. 1992:282). Large ground stone artifacts were located in these storage pits (Ames et al. 1992:283).

In excavations from the Meier site, it was determined that the interior fires burned very hot and baked the bowl shaped clay hearths (Ames et al. 1992:280). Furthermore, thick ash deposits extended from these clay bowls 1 to 2 m and at Meier were bounded by a plank box (Ames et al. 1992:280). There is a strong potential that if left undisturbed, the hearths could produce a detectable magnetic anomaly due to the magnetic realignment of the ferrous elements in the sediments. Ames et al. provide a plan view and cross section of a “typical” large Chinookan house (Figure 7.14).

Excavations at multiple village sites throughout the Pacific Northwest have demonstrated the presence of midden or refuse both inside and outside house features. Evidence of hearth cleaning was found in pits next to the hearths and in outside middens at Meier (personal communication, Cameron Smith 2001). These secondary discard locations were also located at Cathlapotle during excavation (Ames et al. 1999).
An understanding of village population size and duration of occupation can give an indication of the likelihood of detecting subsurface anomalies. Generally, the more people that occupy a site and the longer they remain, the greater the likelihood that they will leave detectible traces. Pacific Northwest Native American villages often had high population densities. Pre-contact population estimates during peak seasonal habitation at Cathlapotle could have exceeded 1560 people\(^2\).

Hajda estimated Cathlapotle’s post-contact population numbers in the early 1800s ranged from 300 inhabitants in the winter and swelled to 900 inhabitants in the spring (Hajda 1984 from Ames et al. 1999:13). Historical accounts of the quantity and sizes of canoes in the villages give an indication of the number of inhabitants in the lower Columbia and Willamette basin. In the spring of 1806, Clark noted in his journal that he observed approximately 100 single person canoes in and around a village eight miles from the mouth of the Willamette River (DeVoto 1953:340). Furthermore, archaeological evidence indicates that Chinookan village locations were inhabited hundreds of years and individual house frames may have stood in excess of 400 years (Ames et al. 1992:287).

**Site Description and History of Research**

Cathlapotle was a Chinookan Village located on a terrace along a backwater slough of the Columbia River. Today it is located in the Ridgefield National Wildlife Refuge near Ridgefield, WA (Figure 7.1). Although the site is heavily vegetated primarily with black cottonwood (Populus trichocarpa), willow (Salix spp.), bracken fern (Pteridium aquilinum), blackberry (Rubus spp.), elderberry (Sambucus sp.), and the ever-popular friend of archaeologists, stinging nettle (Urtica dioica), the depressions of semi-subterranean collapsed plank houses are still evident (Ames et al. 1999:36). Today the site is set back roughly 115 meters from Lake River and is on the third ridge or natural levee. In between the natural levees are swales containing wetter, marsh environments.

From 1991 through 1996, the Portland State University archaeological field school, under the direction of Dr. Kenneth M. Ames, carried out research at this site. Topographical maps of the area have been created. Cathlapotle is estimated to cover an area of over 17,500 square meters, of which slightly over 0.01 percent (224 m\(^2\)) has been excavated (Ames et al. 1999:27-33, 35).

**Lewis and Clark** both mentioned the village of Cathlapotle in their journals. On March 29, 1806, Lewis noted that Cathlapotle “…consisted of 14 large wooden houses” (Ames et al. 1999:15 from Moulton [7]:26-29). From surface topography, historic documents, and archaeological research, Ames et al. created a rough schematic of the village (Figure 7.16). They identified and labeled six depressions as houses. Most appeared to be plank houses, however, it is possible that House 5 was a pit house (Ames et al. 1999:41). The largest house documented at Cathlapotle is House 1. Ames et al. estimated its dimensions to be roughly 63 by 10 m (1999:37).

House 1 and House 2 are especially pertinent to this study since a magnetic survey was placed over sections of both houses. It is therefore notable that the majority of excavation work at Cathlapotle focused on the southeastern end of House 1. Inside of House 1, Ames et al. located multiple hearth features including one, feature 478, contained within a hearth box (1999:37). Corridor pits beneath the sleeping platforms were also discovered. Attesting to the longevity of the site occupation, numerous post molds were found, which suggest multiple construction phases. House 2 was the most visible depression with house dimensions estimated at 50 x 12 m (Ames et al. 1999:39).

Based on 29 radiocarbon dates and feature and artifact analysis, Ames et al. estimates Cathlapotle was inhabited from ca. AD 1000 to approximately 1860 (Ames et al. 1999:86). There is documented evidence that Indians, although possibly not Chinookan, still inhabited the village site in 1835 (Ames et al. 1999:17 from Wuerch 1979). Even after catastrophic post-contact depopulation, there is evidence that the Cathlapotle...

---

\(^2\) The pre-contact population estimate is based on combined calculations from Hajda (1984) and Ames (1994). \((8040-14000)/8040 = .74\%\) increase of summer maximum estimate. 900 summer inhabitants x 1.74 = 1566 inhabitants in the summer (from Ames et al. 1999:13).
Figure 7.15. CAD drawing of Cathlapotle (45-CL-1) showing elevation contour lines, prior excavation units, known and hypothesized plank house locations, and the magnetic survey areas 1 through 4. The fifth magnetic survey area is approximately 40 meters south of this map, but along the same ridgeline. (Portland State University.)
area might have been occupied as late as 1853-54 (Ames et al. 1999:18 from General Land Office USGS 1853). Based upon the existence of large homes and a multitude of possessions, it is likely that the hunter-gatherer inhabitants of Cathlapotle were semi- to fully sedentary. The year-round occupation of large numbers of people over long periods of time at permanent home sites increases the likelihood that telltale marks of habitation still can be detected using remote sensing techniques. The Portland State University excavation work at Cathlapotle is likely to have left a mark detectable to remote sensing techniques. Knowing how the units were backfilled could make a substantial difference in the interpretation of the magnetic data. For example, were rocks redeposited in the units or left on the surface? Was the unit backfilled with dirt, straw, or some other material? Were metal markers placed in the bottom of the pit? Also, the location of where dirt from units was screened might explain the position of some anomalies.

At Cathlapotle, excavation units were backfilled with straw if the expectation was to reopen them the following field season (personal communication, Ames 2000). Also, the general practice was to remove the rocks and weigh them at a central location. Rocks that were not culturally modified or archaeologically significant were discarded in the nearest excavation unit in need of backfill (personal communication, Ames 2000). Unfortunately for this study, the Cathlapotle records were not always explicit about how individual units were backfilled.

**Research Goals**

Cathlapotle was selected for this thesis research for many reasons. First, it met the initial criteria of location on a flood plain. Second, a large number of structural features have been documented (through excavation and ground surface topography), and thus it would be possible to assess the usefulness of remote sensing methods to identify subsurface features. Third, I have access to field notes, recovered cultural material, and information about soil conditions, which would allow me to evaluate the survey results. The detection and identification of previously excavated units will provide a means to ground truth the magnetic contour maps that will be generated with the magnetic data. Also, the planned placement of a trench for geoarchaeological purposes coincided well with the timing of my study. The trench would also provide a means of ground truthing the magnetic results.

The goal of my project at Cathlapotle was to use magnetometry to provide further information on the locations of walls and fire pits beyond what can be observed from surface contours, inferred from ethnological sources, or generalized from Cathlapotle or other archaeological excavations in the Pacific Northwest. If useful magnetic results can be collected at Cathlapotle, the results from my project could assist Ames and others in their ongoing work on site structure and use. Future researchers may elect to avoid or place their excavation units directly over these magnetic anomalies. Additionally, a magnetic signature of a semi-subterranean Pacific Northwest plank house

![Schematic Illustration of Major Site Features 45-CL-1](adapted from Ames et al. 1999:83, Figure 59).
could provide a comparative model for researchers to utilize and encourage others to incorporate nondestructive remote sensing methods in their work.

Champoeg

History of Town Site

The town of historic Champoeg, Oregon is located along the Willamette River, seven miles east of Newberg, and thirty-five miles south of Portland, and is part of the Champoeg State Heritage Area. Champoeg played a significant role in the Pacific Northwest during the mid-19th century and the westward expansion of America. Beginning in 1811, fur trappers employed by the Pacific Fur Company (1811-1813), the NorthWest Company (1813-1821), and eventually the Hudson Bay Company (1821-1850s) began to make greater and greater use of the Willamette Valley (Brauner et al. 1995:27). In the 1830s, the Hudson Bay Company allowed fur trappers (including British subjects and American citizens) to settle in the area and become farmers. The area they occupied centered on French Prairie, a grassland roughly “18 miles long (N-S) and 15 miles wide (E-W)” (Brauner et al. 1995:11). In 1842 the Willamette Valley population increased by 140 people. In 1843 there were 700-900 new arrivals, followed by 1,400 and 3,000 in the successive two years (Hussey 1967:130-131). Many of the new arrivals moved to Oregon City or Champoeg.

Champoeg was founded in 1843 by Andre Longtain and Robert Newell. One of the most notable events in Oregon history, a vote for a provisional American government, occurred there on May 2, 1843. The vote was called because the more established pioneers in the Willamette Valley became concerned about property rights (Hussey 1967:136), particularly since the population was growing and the Oregon Country was still jointly controlled by the British and Americans (Hussey 1967:32). The British-owned Hudson Bay Company was also concerned about their property and the collection of debt (Hussey 1967:171). So, in early May of 1843, people from the surrounding area gathered at Champoeg and voted in favor of a provisional American government (Hussey 1967:178). The vote was the first of several that eventually led to Oregon statehood in 1846.

Champoeg was one of several fledgling towns where people gathered and the population grew. Lots in the town of Champoeg were sold as early as 1844, although the town was not platted until 1853 (Brauner et al. 1995:40). By the 1850s the town of Champoeg competed with Portland, Oregon City, and Salem as the economic hub of commerce in the Willamette Valley (Brauner et al. 1995:3). A photograph of Oregon City (Figure 7.17) and a sketch of Portland (Figure 7.18) taken in the 1850s are provided to indicate the conceivable size of the town and architecture of Champoeg during this time period in the Willamette Valley. At its economic peak the town of Champoeg contained somewhere between 29 and 60 homes, a mill, loading dock, several mercantile stores and saloons, a hotel, schoolhouse, and nearby brickyard (Brauner et al. 1995:53-56). Hussey also noted that the town contained “a Masonic Hall,…a bowling alley,…warehouses,…blacksmith shops,…and an Episcopal church” (1967:215). Additionally, the British owned Hudson Bay Company continued to have holdings in French Prairie where it operated a granary at Champoeg until at least 1851 and continued to rent the building out until the flood of 1861 (Hussey 1967:114).

Champoeg’s geography and location made it a desirable transportation center. The town had three steamboat landings that were used to help transport people, products, and the communication of ideas up and down the river. A ferry landing in town allowed for passage across the Willamette River. The town also boasted a stagecoach line and several livery stables (Brauner et al. 1995:53-56). It was a time of boom and bust towns in the west. All indications at Champoeg suggest a thriving, growing town linked and trad-

3 It must be remembered that Portland’s first home was constructed in 1843 (Hussey 1967:78-79). It was not until approximately 1855 that Portland was able to claim the title of most populous city in Oregon Country (Hussey 1967:116).

4 Hussey (1967:215) noted two estimates of the number of homes in Champoeg in 1861. The first was based on the 1860 census, where Hussey estimated a population of 180 persons and 29 residences. Hussey also noted that Newell claimed there were 60 houses destroyed by the flood. If there were 60 inhabited homes, the population would have been significantly larger since there were often more than three people per household.
Figure 7.17. Photograph of Geo. Abernethy Store in Oregon City, 1850s. First brick building in Oregon. Oregon Historical Society.

Figure 7.18. Sketch of Portland, Oregon in 1854. Oregon Historical Society.
ing with other small towns in the west.

Unfortunately, the position of Champoeg on an active flood plain of the Willamette River made the town extremely vulnerable to flooding. The town was flooded in 1843 and 1853, and in 1861 floods virtually destroyed the town when about 60 homes were washed away. Only limited effort was spent to rebuild the town after the 1861 flood. In the last 150 years, as many as five more floods have overtopped the banks at Champoeg, depositing fine sediments on the remnant cultural features and artifacts left from 19th century occupation.

Given the historic significance of the town site, eventually the land became an Oregon State Park. The first piece of land acquired was “one rod square” (Hussey 1995:254) to place a monument at the spot where the first provisional American government in Oregon was elected. In 1906, 2.19 acres of land around the monument site was acquired (Hussey 1995:257) and the park, originally known as Provisional Government Park, was established. The size of the park continued to grow and today Champoeg State Park consists of 615 acres of land (personal communication, Dennis Wiley 2001).

During 1990 and 1991, historic archaeology was carried out at Champoeg by field schools under the direction of Dr. David Brauner of Oregon State University. This work included extensive archival research about the town and the land ownership of its inhabitants. Remote sensing techniques (GPR, magnetometry, resistivity, seismic, and aerial photography) were used extensively and results were used to place excavation units. Excavations were focused on the core twelve blocks of the town center, where over 52,000 artifacts from homes and businesses were collected and analyzed (Brauner et al. 1995). The survey and excavation did not extend outside of the main town area. Most recently, the State Park has become interested in learning more about the homestead of Robert Newell, co-founder and early settler of the town and contracted again with Oregon State University in 1999 to identify this homestead and develop a testing program in this part of the park.

Robert Newell, born in Ohio in 1807, was a fur trapper (Hussey 1967:192-193). In 1843-44 he arrived with his family and claimed land adjacent to that of Andre Longtain in French Prairie (Hussey 1967:195). Together, the two men set out to build a town centered between their land claims. Ten years passed before the town was finally platted in 1853 (Brauner et al. 1995:40), though all the while Newell actively participated and invested in the emerging town. During the years Newell lived in Champoeg he owned two keelboats, a general mercantile store and warehouse (Brauner et al. 1995:53), a flour mill (Hussey 1967:219-220), and ran the post office where he served as the postmaster (Hussey 1967:210). In 1860 Newell served in the first Oregon State Legislature (Hussey 1967:235).

Aside from his business interests, the diplomatic skills he developed as a trapper in his youth were called upon when he briefly participated in the treaty negotiations that began in 1851 and were held in Champoeg “… for the removal of all western Oregon Indians to lands east of the Cascade Range” (Brauner et al. 1995:21). However, Congress “abolished all commissions” and invalidated the efforts of Newell and others (Brauner et al. 1995:23). The negotiations with the Kalapuya bands took place at Robert Newell’s house on French Prairie (Brauner et al. 1995:56).

The exact location of the Newell home is unknown, but one of the goals of my thesis was to help find it. According to existing documents, the homestead of one of Champoeg’s founders, Robert Newell, was east of the town. Historic records show that Walter Pomeroy first owned the homestead area (Hussey 1967:195), and used the land to cultivate wheat. Pomeroy sold the land to Newell in either 1843 or 1844 (Hussey 1967:195). Newell shared this home with his wife, Kitty, who was a Nez Perce Indian, and their five sons (Hussey 1967:193-195). Kitty died in 1845 and by 1846 Newell had remarried. With his second wife, Rebecca Newman, he had eleven more children (Hussey 1967:201). Sometime around 1852 Newell began to build a new home on higher ground, where he may have moved in 1854 (Hussey 1967:206). In 1857 he sold his old homestead to Donald Manson, an ex-Hudson Bay Company clerk (Hussey 1967:48). Donald Manson, his wife, Félicité Lucier, and their two Indian
boys lived at the homestead until the flood of December, 1861 (Hussey 1967:225-226). During the Newell and Manson occupation of the homestead, it is likely that manual laborers (including Indians) or travelers periodically lived there also. In short, the homestead was occupied for a period of 18 years and over this duration approximately 20 people would have called the farm site home.

After the 1861 flood, Manson continued to live on the property, but he rebuilt his home on higher ground that he acquired adjacent to his claim (Hussey 1967:232). No new structures were built at the site of the original Newell home and barn sites after the 1861 flood (Hussey 1967:232-235). The land possibly was fallow for a time, but it also served as pastureland for sheep as recently as 1990 (personal communication, Dennis Wiley 2001). In 1995 the land was plowed by machine and used to grow rye grass (personal communication, Dennis Wiley 2001). Overall, the area east of the town site, where Newell and Manson lived, has been little modified by human activities since the 1861 flood.

A survey of the homestead was completed prior to the 1857 sale to Manson and the map clearly shows the presence of a house and barn (Figure 7.19). Newell’s business pursuits attest to his access to capital. As a prosperous man in the valley, his home might have been more substantial than most. As noted previously, the homestead was chosen to be the gathering location of the Kalapuya negotiations in 1851 and which leads to the speculation that the home was more substantial than many in the area.

There was a wide range of house construction styles in the Willamette Valley. One of the most common architectural styles selected by early settlers was a French-Canadian influenced style called post-on-sill or post-in-the-sill. Many Hudson Bay Company buildings in the area were built in the post-on-sill style (Brauner 1995:49). The sill is a beam lying parallel to, but probably not directly in contact with the ground, and the posts fit in groves perpendicular to the sill. Bricks might have been used as pylon supports at the corners and spaced roughly every five feet to support a sill in the post-on-sill construction method. Nails were not needed to form the walls of a building, but would have been used to anchor wood floors and roofs. Figure 7.20 shows a model house built in the post-on-sill style.

Since different housing styles existed in and near Champoeg, I present the home descriptions below as feasible comparisons to the New-
ell homestead. Hussey noted of the early 1840s homes,

[a] few of the French-Canadians lived in substantial hewn log or frame houses, neatly painted, surrounded by thrifty orchards…. But most of the settlers, … lived during this early period in small, unpainted log houses of various styles and shapes. For most prairie farmers, fireplaces were made of sticks plastered with clay. There were few stoves. Cooking generally was done over the coals or in kettles swung on cranes in fireplaces. (1967:117)

Two of the more substantial early pioneer’s homes were that of Dr. and Mrs. Bailey and Joseph Gervais. The home of Dr. and Mrs. Bailey, located in the town of Champoeg was described in 1839 as a “neat hewn log cabin” (Farnham in Hussey 1967:90). It was further described as having “two rooms on the ground floor, one fireplace, four windows, one piazza, one flight of stairs, and a garret” (Hussey 1967:91). Joseph Gervais, an ex-trapper in the Willamette Valley, began to build his home and barn sometime after 1831. The house was described as “…a ‘substantial’ structure, 2 stories high and 18 by 24 feet in size. It was built of heavy, square-hewed timbers anchored into mortised upright posts after the fashion of Canada” (Hussey 1967:54). These dimensions would have made the post-on-sill home 864 square feet. Hussey also recorded that “[t]he barn, 40 by 50 feet, was built in the same heavy post-in-the-sill manner” (1967:54).

Also important to the remote sensing surveys and later archaeological interpretation is how the land around the Newell house and barn were used. It is documented that Newell owned “…horses, mules, milch cows, work oxen, other cattle, and swine …. “ (Hussey 1967:205-206). It is probable that Manson would have owned similar livestock. Both families also likely raised domesticated animals such as chickens, pigs, sheep, and cattle for food (Brauner 1995). The families undoubtedly had a garden and grew some of their food. Fences would have separated the animals from the garden areas.

The homestead would have had a well, but it was likely not deep. “The ground water table was originally so high that shallow wells would usually supply a households needs” (Helen Austin:personnal communication in Brauner et al. 1995:31). In addition to a well for water, there would also likely have been a hole dug as part of an outhouse.

The more modest the home, barn and other structures, I believe the less likely it is that GPR or magnetometry would detect traces of their existence. Yet even a simple clay fireplace can be lined with rocks and consequently could generate a subsurface anomaly. Concentrations of bricks and nails or intact fireplaces can be detected by magnetometry. Concentrations of bricks can also
be detected by GPR as an electronic pulse would bounce off them at a different speed than the surrounding matrix. Likewise, if conditions are adequate, instances where post molds of fences that enclose gardens and animals can be detected by either method. Furthermore, the debris of everyday living whether plant based, animal waste, or simply a broken dish would have been discarded near to their home in pits, mounds, or scattered about the yard. This debris might be detectable by magnetometry or GPR. Similarly, voids such as cellars and wells, filled with significantly different substances from the surrounding sediments, can produce anomalies detectable with remote sensing techniques.

The possessions that the Manson family had in the home at the time of the 1861 flood might have consisted of homemade furniture such as tables, chairs, and a bed. Nails would have been used in the construction of some of the furniture. In addition to what the Manson family owned, it should be noted again that the town of Champoeg was upriver from the Newell homestead and flood debris from the town might have been deposited on the Newell land. The size, location, strength, and relationship to other anomalies might shed light on what lies below the surface.

The topography at the site was excellent for conducting a magnetometer survey. The area surveyed was on top of a natural levee in the Willamette River flood plain. The survey area was nearly flat, dipping gently northward toward the river along the east-west axis. The terrain yielded easy walking conditions with no obstructions and no surface indications of cultural features. However, in 1995 after the land was tilled, artifacts were exposed in the topsoil. The artifacts were still fairly large and undamaged by repeated plowing.

Research Goals

As noted previously, the Newell Homestead has become the recent focus of historical archaeological research at Champoeg. Given this and my interest in geophysical methods and their potential for assisting in feature location, in 1998 I began collaborating with Dr. Brauner (OSU) and Dennis Wiley, the Champoeg State Park manager, to assist in locating the homestead.

Also, I had access to field notes, recovered cultural material, and information about soil conditions, which allowed me to evaluate the survey results. The relatively flat, cleared survey location made Champoeg an ideal study area where I could assess the usefulness of remote sensing methods in identifying subsurface features. Additionally, planned excavation coincided with the remote sensing surveys. The excavations would help to ground truth the maps generated with the magnetic and GPR data.
CHAPTER 4
METHODS AND RESULTS:
CATHLAPOTLE

Survey Methods

The topography and vegetation at Cathlapotle affected the type of remote sensing I performed. Although originally planned, ground penetrating radar (GPR) was not used at the Cathlapotle site, mainly because dense ground cover and uneven topography in the survey areas of interest made antenna ground contact questionable. The GPR system that was available operated with the use of cables that would have snagged on fallen branches and other obstructions. If a GPR survey is undertaken in the future, it should be performed at the end of the summer when the soil conditions are at their driest and the radar has the greatest chance of penetrating to a depth that will include most cultural material.

A magnetic survey was performed, which was more feasible because the sensors are carried above the ground. My research focused on five (5 x 10 to 10 x 18 m) areas that were selected for magnetic survey in consultation with Dr. Ames. Four of the survey areas were located within the site boundary as determined by augers and prior excavation units, and a fifth, off-site control survey area, was located some distance away. Each survey area vertically intersected one or more of the following: the wall of a partially excavated plank house, a partially excavated hearth, areas that exhibit changes in elevation that suggest the boundaries of plank houses, and areas without cultural modification (Table 7.1). The corners of the five magnetic survey locations were marked with wooden stakes. Their position was later recorded via total station and incorporated into the site map (Figure 7.15).

Decisions regarding survey area orientation and specific placement were based on the need to maximize data collection over known features and avoid large trees and dense understory. While I wanted to orient the survey areas on a north-south axis and did so for Survey Area 1, the local terrain, vegetation, and subsurface feature position made this impractical for the four other survey areas.

After the survey area boundaries were defined, an assistant walked over the area with a Seco Manufacturing Company, Numec FMD-4 metal detector to potentially locate pin flags, metal pens, or other items that might have been dropped by archaeologists, volunteers, or visitors during the 1991 - 1996 surveys and excavations.

<table>
<thead>
<tr>
<th>Survey Area</th>
<th>Size (meters)</th>
<th>Surface Features</th>
<th>Known and Potential Subsurface Features</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>7 x 15 m</td>
<td>Elevation change</td>
<td>Interior/exterior of plank house, wall, hearth. No prior excavation units. Area covers part of House 2 and possibly House 5.</td>
</tr>
<tr>
<td>2</td>
<td>5 x 15 m</td>
<td>Elevation change</td>
<td>Interior/exterior of plank house wall, hearth. One prior excavation unit. Area covers part of House 2.</td>
</tr>
<tr>
<td>3</td>
<td>10 x 18 m</td>
<td>Elevation change</td>
<td>Interior of plank house, many prior excavation units, partially excavated hearth. Area covers part of House 1.</td>
</tr>
<tr>
<td>4</td>
<td>10 x 14 m</td>
<td>Level</td>
<td>Little cultural modification anticipated. One prior excavation unit.</td>
</tr>
<tr>
<td>5</td>
<td>5 x 10 m</td>
<td>Level</td>
<td>No cultural modification anticipated. No prior excavation units. Placed along offsite trench line.</td>
</tr>
</tbody>
</table>

Table 7.1. Magnetometer Survey Areas, Cathlapotle.
Such items could introduce noise to the magnetic results. Before beginning the magnetic survey, the magnetometer operator was double-checked for metal objects including rings, keys, wallets, and credit cards. All metal items were removed and placed far away from the areas to be surveyed. The only metal near the magnetometer that produced erroneous data were from the first surveys when the metal tips on the ends of the tape measures, which were placed on the ground to assist with transect spacing, were too close to the cesium sensor.

Transect spacing was 0.5 m for all survey areas. Highly visible pink strings were used to guide the magnetometer operator along the transects. Halfway or fiduciary marks were recorded for the larger survey areas to help with later data interpolation. For the purpose of efficiency, the transects were walked in a back and forth pattern. The back and forth pattern eliminated the need for the surveyor to retrace their steps and approach all transects from the same direction. The cesium sensor was oriented parallel to the vertical bar (Figure 7.21), as indicated by geophysical inclination calculation for Cathlapotle’s latitude. The cycle time on the magnetometer was set to 0.1 second for all surveys, which means that the data logger recorded 10 measurements each second. The manufacture sensitivity at a 0.1 cycle rate is 90% of readings sensitive to 0.05 or 1/20th of a nT (Geometrics 1998).

Magnetic surveys were carried out on two separate days using two different instruments. In October 1998, I rented a Geometrics 858 with a single sensor. I had hoped to complete the survey of all five areas in one day. However, my lack of familiarity with the instrument, the size of survey areas and the limited rental time (24 hours), prevented me from completing all required work. Also, analysis of data from Survey Areas 1, 2, and 3 indicated certain errors that could not be resolved without resurvey. By Spring 2000, I had purchased a cesium magnetometer (Geometrics 858-G), which could be configured as a gradiometer, and I resurveyed areas 1, 2, and 3 again. The wooden corner stakes from the 1998 survey were located, save one. The position of the one missing corner stake was easily remeasured.

The first magnetic survey was conducted in mid-Fall 1998, after the first freeze, so the stinging nettle were easily pushed down by foot and only in a few instances were machetes needed to break apart particularly troublesome tangles of blackberry vines. The first magnetic survey was

<table>
<thead>
<tr>
<th>Date</th>
<th>Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1991-1996</td>
<td>Portland State University Investigations and Excavations</td>
</tr>
<tr>
<td>October 24, 1998</td>
<td>Auger and Magnetic Survey Area Setup</td>
</tr>
<tr>
<td>October 31, 1998</td>
<td>First Magnetic Survey</td>
</tr>
<tr>
<td>November, 1998</td>
<td>Off Site Backhoe Trench and Geoarchaeological Analysis</td>
</tr>
<tr>
<td>March 15, 2000</td>
<td>Second Magnetic Survey</td>
</tr>
</tbody>
</table>
The dimensions of Survey Area 1 were 7 x 15 m and the area was positioned in a magnetic north-south alignment. A waypoint was recorded at the midpoint (7.5 m) of the transect length. There were no prior excavation units in this survey area. The survey area overlaid a section of an approximate 1 m topographic depression, which was part of the interior of House 2. Based primarily on the surface topography as indicated on site maps, the survey area included the western wall of House 2, the area between House 2 and House 5, and also overlapped a possible corner of House 5 (Ames, et al. 1999). I expected the location of the walls to be detected fairly well by the magnetometer. I also expected that storage pits might be detected along the walls and fire hearths might be detected down the centerline of the plank house.

The contour map of Survey Area 1 shows much magnetic disturbance (Figure 7.22). No local magnetic gradient was evident. To the west of the House 2 centerline there are three magnetic depressions (Anomalies 1.1, 1.2, and 1.3). Given their location within the house and their linear arrangement, they are likely to be cultural and might represent storage pits or other features.

A second area of interest within House 2 is Anomaly 1.4. This anomaly is located along the centerline of the house. It is possible that this anomaly represents a fire hearth feature. Figure 7.23 shows a profile of the magnetic readings over Anomaly 1.4, which was used to calculate depth to the source below surface. Using the half-width rule, the source of the magnetic anomaly is approximately \( z = (2.5 \times 1/2) - h \), where \( z \) = depth below surface, \( x \) = width of anomaly, and \( h \) = the height of the sensor above the ground surface (Breiner 1973:31). The estimated depth of Anomaly 1.4 ranged between 0.03 to 0.58 m. The average depth of the fire hearths found in House 1\(^5\) was 0.2 m (Ames et al. 1999; Cathlapotle Feature Catalog 2001). Therefore, the interpretation that this might be a fire hearth is supported by the depth calculation result. However, this interpretation is quite tentative given the anomaly is located on the edge of the survey area.

The area between House 2 and 5 contains many anomalies, too. These disturbances might be natural, but I think they are more likely indicative of artifacts or possibly features, such as middens or ovens.

The magnetic results from Survey Area 1 provide additional information beyond what can be seen at ground level. A potential location of several storage pits and a fire hearth was identified. The footprint of the survey area is not large enough to be conclusive, but it does appear that a magnetically positive signal follows the centerline of the plank house. Furthermore, Survey Area 1 is certainly a good example of the magnetic disturbances inside and outside of an unexcavated plank house.

Survey Area 2 (House 2)

The size of Survey Area 2 was 5 x 15 m. A waypoint was recorded at the midpoint (7.5 meters) of the transect length. The long axis of Survey Area 2 was aligned perpendicular to the ridgeline. The survey area overlaid an approximate 1 m topographic depression and was placed to bisect the middle of the plank house labeled House 2. One 1 x 4 m unit (N106-107/W77-81) was excavated at the northeastern end of the survey area (Ames et al. 1999). The excavated unit was likely backfilled at the end of the 1994 field season with dirt and not straw (personal communication, Ames 2000). The rocks that were not considered culturally modified or archaeologically significant might not have been returned to the excavation unit. The total volume of rocks placed back into this unit was unknown, as were the types of rocks and their iron content. It was also unknown at what depth the rocks were discarded and if they were dumped into a single pile or dispersed throughout the unit.

Similar to Survey Area 1, this survey overlaid the interior of a house and I therefore expected this area to be magnetically disturbed. I expected magnetic signals associated with house walls, storage pits, and fire hearths to be detected. I also expected the prior excavation unit to produce a magnetic disturbance.

\(^5\) The level in which hearth features 485, 478, 332, and 19 were first contacted were used to calculate the average fire hearth depths in House 1. The depth of the hearth features ranged from 0.12 to 0.32 m and averaged 0.2 m.
Figure 7.22. Magnetic contour map of Survey Area 1. The possible location of House 5 and the western half of House 2 are indicated and are based on Ames et al. (1999).
also conducted shortly before an offsite geoarchaeological trench study was performed at Cathlapotle. The second survey was conducted in early spring before the stinging nettle had grown more than one foot in height. The timing of the excavations and other studies at Cathlapotle are shown in Table 7.2.

The instrument used in October 1998 does not compensate for solar micro pulses. Although the solar interference can be somewhat controlled for by surveying the area twice or by using a second magnetometer as a base station, this was not done at Cathlapotle for Survey Areas 4 or 5. The instrument used in the later survey was a gradiometer, which automatically compensates for potential solar interference.

Once the data from the surveys were collected by the data logger, they were downloaded to a laptop computer. All plots of the data were produced using Surfer for Windows, Version 6.0. I selected minimum curvature as the data interpolation formula in the generation of all magnetic contour maps.

After obtaining contour plots of a survey area, I identified anomalies, or areas of high and low magnetic concentration, noting dipoles, monopoles, size and shape of the anomaly and possible anomaly patterns that could indicate archaeological features. In remote sensing surveys, the most common method of evaluating anomalies involves subsurface testing. This study used testing when possible (Survey Area 5), but in general evaluated anomalies based on: prior knowledge of excavation unit locations, and hypothesized locations of house walls, fire boxes, and other cultural features based on ethnohistoric and archaeological records of such features.

In the following pages, for each survey area, I review prior knowledge about the area, discuss the kinds and distribution of subsurface features likely to be present, and then evaluate the results of the magnetic survey against these pre-
The resulting contour map shows much magnetic disturbance (Figure 7.24). There are six anomalies associated with Survey Area 2. Curiously, in Survey Area 2 the exterior of House 2 was more magnetically disturbed than the interior.

Anomalies 2.1 and 2.2 are positioned on either side of the plank house centerline. These anomalies could indicate the location of buried fire hearths or possibly two individual artifacts containing a relatively large amount of iron in relation to the surrounding sediments. Soil disturbance associated with the 1994 excavation might be responsible. However, the screening area that contained the backfill dirt for the excavation unit was located several meters distant, probably east of the unit, and likely fell outside of the magnetic survey area (personal communication, Cameron Smith 2001). I do not think Anomalies 2.1 and 2.2 were caused by sediment disturbance from the excavation unit. Furthermore, the fact that the data from this survey was gathered using a gradiometer configuration should allow for better definition of discrete anomalies.

Anomaly 2.3, however, does align closely with the excavation unit. The interpretation of excavation unit (N106-107/W77-81) was that it intersected the wall and a bench/cellar of a plank house (Ames et al. 1999). Unfortunately, the footprint of the magnetic survey area truncated the excavation unit and the entire boundary of Anomaly 2.3 was not recorded. Based on the location of this anomaly, I think the increase in the magnetic field strength was the result of the excavation unit dug almost six years earlier.

Anomaly 2.4 was a series of four magnetic depressions that correspond to the exterior boundary of the house wall. The magnetic signals could be generated by rocks or other detritus placed along the outer walls of the plank house. A larger survey area would need to be done to determine if the linear anomaly continued to follow the wall or was just a coincidence.

Anomaly 2.5 was located 0.5 m from the west corner of the survey area. I think this anomaly was produced by an artifact or feature. Although possible, I do not believe that the anomaly was related to the sensor’s proximity to measuring tape’s metal tip at the survey corner. However, prior to any excavation work targeted for this location it would be advisable to resurvey this corner of the survey area to confirm the hypothesis that this was a true subsurface magnetic anomaly.

Anomaly 2.6 was located southwest of House 2. Anomaly 2.6 could be an individual anomaly or might be two separate anomalies since there is a 0.5-meter distance between the positive and negative signals. Based on its size and magnetic strength I think Anomaly 2.6 represents a single buried artifact.

**Survey Area 3 (House 1)**

The size of Survey Area 3 was 10 x 18 m. A waypoint was recorded at the transect midpoint (9 m). The survey area was placed inside a topographic depression that in some areas was greater than 1 m in depth. The entire survey area was contained within the southeastern interior of House 1 (Figure 7.25). Multiple excavation units are present in Survey Area 3. During field excavation at least seven hearths were located primarily down the centerline of the house and storage pits were found beneath the sleeping platforms (Ames et al. 1999:37; Cameron Smith, personal communication 2001).

I expected Survey Area 3 to be magnetically disturbed because it was located completely within the interior of the plank house. I expected magnetic signals associated with storage pits and fire hearths to produce anomalies. I also expected this survey area to be magnetically disturbed due to the presence of earlier excavation units. There was one long trench that extended the length of the x-axis and intersected the y-axis between 12 and 13 m that was backfilled with straw (personal communication, Ames 2000). I expected the trench feature to produce a unique linear anomaly because of the material used to backfill the excavation.

The magnetic survey results presented in Figure 7.25 shows significant magnetic disturbance. The extent of prior excavation work within Survey Area 3 made magnetic interpretation of unexcavated areas extremely difficult. As suggested in Survey Area 2, (and as will be noted later in Survey Area 4), prior excavation units did produce anomalies. The shapes of the anomalies are not confined to the original sharply defined ex-
Figure 7.24. Magnetic contour map of Survey Area 2 with the 1994 excavation unit N106-107/W77-81 indicated. This area is considered part of 45CL1, the Cathlapotle archaeological site, and intersects the interior of House 2.
Figure 7.25. Magnetic contour map of Survey Area 3. This area is in the southern interior of a House 1. Excavation units are superimposed upon the magnetic contour map. Location of excavation units in House 1 from Ames et al. (1999).
cavated dimensions, but form a cloud around the ground disturbance. Contrary to my expectations, even the long trench that was backfilled with straw was not uniquely discernible. Similarly, all other excavation units within House 1 were not individually identifiable.

**Survey Area 4 (Front Yard)**

Survey Area 4 was in the so-called “front yard” of the Cathlapotle village (Ames, et al. 1999). This area was archaeologically interpreted as a sheet midden or debris field. It also was likely the canoe-docking beach of the village. The size of Survey Area 4 was 10 x 14 m. The topography was relatively flat, with an approximate increase in elevation of 1 meter from the west to east. Because the transect line distance was only 14 m and the terrain was almost level, no waypoints were recorded. One survey was performed on Survey Area 4 using a single sensor magnetometer. Therefore, it is possible that solar micropulsations might be recorded and interpreted as subsurface anomalies.

Within Survey Area 4, a 2 x 2 m unit (N179-181, W101-103) excavated in 1994, detected artifacts (e.g., anvil, awl, bowl and cobbles), although not in the quantities that are found in some of the units within house cellars and middens (Ronnigen 1994; Engstrom 1994; Ames et al. 1999). Several features were also detected, including a wall trench and a deeply buried camas oven located at 0.55 m below surface (Ames et al. 1999; Ronningen 1994; Engstrom 1994). The field notes indicated that bales of straw would be used to help fill in the excavation units at the end of the 1994 field season, however, it was not recorded if straw was actually used in this particular unit. There were no plans to reopen the unit, so Ames felt strongly that dirt was used to backfill the unit (personal communication, 2000). Furthermore, it was highly unlikely that the culturally unmodified rocks from the unit were returned, as this unit was not near to the area where the rocks were weighed, but was on the periphery of the units excavated in 1994. The screening area location that contained the backfill dirt for the unit could not be determined from the original field notes (Ronnigen 1994, Engstrom 1994). However, the screening area was likely to have been roughly two meters away from the unit, not directly adjacent to the unit. During excavation people approached the unit from either the south or east (Ames personal communication 2001).

Given that Survey Area 4 did not contain any surface depressions or other indications of house construction, I expected the survey area to be less magnetically disturbed than those with house features. I expected that the low number of features recorded and artifacts collected from the excavated unit were an indication of what might still exist buried nearby. I expected that excavation unit (N179-181, W101-103) would produce a magnetic anomaly.

The magnetic contour map shows a relatively culturally sterile area with two obvious exceptions (Figure 7.26). The smaller of the two disturbances in size and strength was located in the southeast corner of the survey and is labeled Anomaly 4.1. The 1994 excavation unit (N179-181, W101-103), located in the northeast section of the contour map, was roughly centered in the middle of the larger anomalous area. On the northern, eastern, and southern sides of the excavation unit there are magnetic disturbances for a distance of approximately 1.5 m. It should be noted that the data was gathered using a single cesium sensor, which does not allow for the finer definition of discrete anomalies that a dual sensor gradiometer configuration would. The width of an anomaly is also dependent on sensor height, as the magnetic field widens with depth.

Based on the location and strength of Anomaly 4.1, I attribute its generation to operator error, as the metal tip on the end of the tape measure was likely too close to the magnetometer sensor. However, the larger anomalous area in the northeastern corner I think was generated by the unit excavated four years prior to the magnetic survey. Depth calculations were not performed for the anomalous area, as we know the unit disturbance began at ground level. Anomaly 4.2 might
Figure 7.26. Magnetic contour map of Survey Area 4. This area is considered part of the front yard of the Cathlapotle Village. The location of the 1994 excavation unit N179-181/W101-103 is indicated on the map.
be a discrete anomaly or it might be part of the general disturbance caused by the excavation unit.

There is another line of evidence to support the interpretation that the remainder of the magnetometer survey area was culturally sterile. While the local magnetic gradient was not as smooth as what will be presented for Survey Area 5, it was not as disturbed as those in Survey Areas 1 through 3. Similar to what will be shown in Survey Area 5, the ambient magnetic background gradient increased from the northwest to southeast by approximately 170 nT over a distance of 14 meters, or a rate of 12 nT/meter.

Features and artifacts that might exist in this area are not producing detectable magnetic signatures possibly because they are numerically too few, buried too deep, or their magnetic signals too weak to be detected at the surface. The interpretation that Survey Area 4 was comparatively sterile seems to agree with the Cathlapotle excavation data.

Survey Area 5 (Offsite)

Survey Area 5, a control area, was placed on the same geologic landform, but 40 m southeast of known cultural deposits determined by augers. The topography was relatively flat and was blanketed with low ground cover (grass). The size of Survey Area 5 was 5 x 10 m. The short transect

Figure 7.27. Magnetic contour map of Survey Area 5. This area is considered outside of the Cathlapotle archaeological site.
distance of 10 m and almost level terrain negated the need for waypoints. One magnetic survey of Survey Area 5 was performed using a single cesium sensor magnetometer and no base station to correct for solar weather. It is therefore possible that a magnetic anomaly could actually be the result of a solar interference.

The final survey area was chosen in anticipation of digging a backhoe trench for geoarchaeological study. Ames wanted to place the trench in an area free of cultural features. We decided to use magnetometry to establish whether cultural features were present. Following the magnetic survey, a backhoe trench was dug, which allowed for ground truthing the magnetic survey results.

The week prior to the first magnetic survey, several Portland State students, under the direction of Dr. Ames, cleared underbrush from the path that the backhoe would later follow. The magnetic survey area overlapped ten m along the length of the anticipated backhoe trench line. Along the line they dug auger holes and marked out the location of Survey Area 5. One auger hole was placed within the magnetic survey area. The sediment from the auger hole was screened through 1/8 inch mesh and as anticipated no cultural artifacts were found (personal communication, Ames 2000). There were no excavation units contained within the survey area.

I anticipated that no cultural anomalies, including the auger hole, would be magnetically detected in the offsite area. If the results of the auger holes and the magnetic survey results both supported the conclusion that the site was off the main archaeological site, then the backhoe trench would be placed at that location. However, if the auger holes dug along the backhoe trench line and the magnetic survey results were in conflict, then it was likely that more auger holes would be dug or a new location for the backhoe trench would be selected.

The magnetic survey results support the conclusion that Survey Area 5 lacked cultural features (Figure 7.27). No significant anomalies were apparent on the magnetic contour map. The auger hole was not detected on the map at a 3 nT contour interval. The ambient background magnetic gradient appeared uniform with few anomalies and increased from the southwest to northeast by approximately 150 nT over a distance of 10 meters, or 15 nT/m. The higher magnetic readings in the northeast, southeast, and southwest corners of the survey I have attributed to operator error. The metal tips on the end of the tape measures were too close to the survey area and the magnetometer picked up the higher iron content increasing the magnetic field by up to 50 nT. A second, but highly unlikely possibility was that the magnetic peaks in the corners were atmospheric disturbances attributable to solar weather.

The magnetic contour maps from all five survey areas were created and reviewed within 24 hours of data collection. Because Survey Area 5 appeared culturally sterile, both compared to the other survey areas and because there were no unexplainable magnetic anomalies, the plans to dig the trench the following week proceeded as scheduled and trenches were placed directly to the northeast and southwest of the Survey Area 5. As anticipated, the backhoe trenches dug on either side to the magnetic survey area, exposed no archaeological features or artifacts (personal communication, Ames 2000).

Summary

The magnetic signals from the five survey areas at Cathlapotle were very subtle with magnetic maps produced at contour intervals ranging from two to five nT. The sensors detected the subtle magnetic changes and the maps exhibit a strong contrast between areas in or near house features and those away from the Cathlapotle site. As expected, a magnetically sterile area was detected offsite for the geophysical trench study. More magnetically disturbed areas near plank houses likely were generated by middens. Within house features hearths, walls, and possible storage pits might have been detected.

Prior excavation units were also detected in Survey Areas 2 and 4. In the case of Survey Area 3, which was positioned within House 1, prior excavation units introduced so much magnetic noise into the area that the more subtle archaeologically significant signals were overwhelmed. I was unable to add additional information on unexcavated areas within Survey Area 3.

Even without further excavation to ground
truth the anomalies, a magnetic survey over a larger portion of Cathlapotle could refine the magnetic interpretations of subsurface features detected. The results from this survey are the start of a magnetic baseline record for Pacific Northwest plank houses.
CHAPTER 5
METHODS AND RESULTS: CHAMPOEG

Magnetic and GPR surveys were carried out at Champoeg State Heritage Area in the location thought to hold the first homestead of Champoeg’s co-founder, Robert Newell. I conducted a magnetic survey to help locate the homestead (ORMA41). In addition, I had access to GPR survey data generated by James Bell of Linn-Benton Community College (1998). Results from the two surveys helped guide the plans for the excavation that Oregon State University and the Champoeg State Heritage Area carried out the summer of 1999 and 2000. The results of the surface collection survey and excavation were used to ground truth the GPR and magnetic surveys. Table 7.3 provides a timeline of events related to the Newell Homestead research at Champoeg State Heritage Area.

GPR Survey: August 1998

James Bell of Linn-Benton Community College performed the GPR survey in August of 1998 that was tied into the English grid system of the site established by previous work of Dr. Brauner at Champoeg (Brauner et al. 1995). A few days before the GPR survey approximately 3 ft high rye grass was mowed; the cut grass was distributed in well-defined rows. A Geophysical Survey Systems (SIR-2) instrument was used to perform the GPR survey. The transect lines for the survey were spaced every 6 ft, along which a 400 MHz antenna was pulled for a length of 80 ft (Bell 1998; Cromwell et al. 2000:27). Fiduciary marks were recorded every 10 feet (personal communication, Bell 2001). Unfortunately, the transect lines were not parallel with the rye grass windrows. In order for the antenna to stay in contact with the ground, the grass in the windrows was temporarily pulled aside to allow the antenna to pass (Figure 7.28). Bell noted that the ground beneath each windrow might contain more moisture than the bare soil exposed to the sun and probably would alter the speed at which the electronic signal passed through and bounced off the buried sediments (1998). Bell noted the potential moisture pattern and referred to it during the interpretation of the reflections.

Each GPR trace produced a visual image on a display screen, which was not electronically saved, and a paper printout. Bell monitored the visual screen as the antenna was pulled along the transect. After the completion of each transect, he walked the length of the transect with the paper printout in hand (Figure 7.29). He noted locations of windrows and rodent holes on the paper printout. He later lined up all paper profiles and manually produced a map of the anomalies. Bell did not specifically note the estimated RDP in his report, but he estimated that the radar was penetrating to a depth of between 3 and 4 m (1998).

Magnetic Survey: August 1999

The 1999 archaeological field work at the Newell Site began with a magnetic survey in August. I tied the magnetic survey into the grid system established by earlier research under the direction of Dr. David Brauner. Five survey areas (named Survey Area 1 – 5) were established, each 100 x 100 ft square. The survey areas were roughly centered where the highest density of exposed surface artifacts were found. Figure 7.30 shows the location of the GPR and magnetic surveys.

The equipment I used was a Geometrics 858G cesium magnetometer configured as a gra-

<table>
<thead>
<tr>
<th>Date</th>
<th>Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1996</td>
<td>ORMA41 First Encountered</td>
</tr>
<tr>
<td>Aug-98</td>
<td>GPR Survey</td>
</tr>
<tr>
<td>August 2-3, 1999</td>
<td>Magnetic Survey</td>
</tr>
<tr>
<td>August 4-13, 1999</td>
<td>First Surface Collection and Excavation</td>
</tr>
<tr>
<td>August 7-25, 2000</td>
<td>Second Excavation</td>
</tr>
</tbody>
</table>
Figure 7.28. GPR survey at Champoeg. Adam Bell pulls the antenna along the transect. Note grass windrows.

Figure 7.29. James Bell recording locations of windrows and rodent holes on the GPR paper printout.

Figure 7.30. Schematic of the GPR and magnetic survey areas.
Figure 7.31. Footprint of the five magnetic survey areas at Champoeg. Three of the survey areas had a transect interval of 2 feet (Survey Areas 1, 2, and 5) and two had a transect interval of 5 feet (Survey Areas 3 and 4).

Figure 7.32. Location of GPR anomalies.
diometer, which eliminated any effects from diurnal variation or solar flare disturbances. The magnetometer was set to record continuously along the transects. The cycle time of magnetic data collection was set to 0.1 per second, which provided 90% of readings sensitive to 0.05 or 1/20th of a nT (Geometrics, Inc. 1998). I began by surveying two areas at 2 ft transect intervals and two areas at 5 ft transect intervals. After reviewing the preliminary results, I elected to collect data from the final fifth area using the finer 2 ft transect interval (Figure 7.31). Transects were aligned along the north-south axis and the data were collected in a back and forth pattern over each area. Since measurements were continuously recorded, one fiduciary mark or waypoint was placed at 50 ft along each transect. The data interpolation method I selected in the graphical mapping software (Surfer for Windows, Version 6.0) was minimum curvature. I also selected the low contour smoothing option in the generation of the maps.

There were no surface depressions that might indicate buried features. Historical records and the surface scatter of artifacts indicated that the survey was in the vicinity of the Newell homestead. My expectation was that large features still existed that could produce magnetic anomalies and that the survey would be able to locate the large magnetically disturbed areas. The terrain yielded no clues where the anomalies would be located in the survey area.

**Surface Survey and Collection: August 1999**

The day after the magnetic survey was completed, surface artifacts were collected and their locations were mapped. As it was toward the end of summer, the rye grass had been harvested and the hard, dry ground was exposed. A team of people walked over the five magnetic survey areas and surrounding areas and placed metal pin flags beside all visually detected artifacts. The position of each artifact was recorded with a transit, compass, and tapes. Artifacts inside and outside the magnetic survey area were counted. All surface artifacts were collected with the exception of very small brick fragments (Cromwell et al. 2000:30).

**Excavations: 1999 and 2000**

Although the GPR and magnetic surveys were conducted on grids using the established English system, a decision was made to switch to metric for excavation work. The survey area distances were converted to metric and five 1 x 1 m or 1 x 2 m test units (7 m²) were excavated in 1999 to ground truth the GPR and magnetic results (Cromwell et al. 2000:30). In 2000 a block

<table>
<thead>
<tr>
<th>Anomaly Number</th>
<th>Estimated Minimum Depth (in meters)</th>
<th>Estimated Maximum Depth (in meters)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1</td>
<td>0.5</td>
<td>1.3</td>
</tr>
<tr>
<td>1.2</td>
<td>2.4</td>
<td>3.3</td>
</tr>
<tr>
<td>1.3</td>
<td>0.5</td>
<td>1.5</td>
</tr>
<tr>
<td>1.4</td>
<td>0.2</td>
<td>2.0</td>
</tr>
<tr>
<td>1.5</td>
<td>1.5</td>
<td>2.0</td>
</tr>
</tbody>
</table>

**Table 7.4. Survey Area 1 calculated anomaly depths using the half-width rule.**

<table>
<thead>
<tr>
<th>Anomaly Number</th>
<th>Estimated Minimum Depth (in meters)</th>
<th>Estimated Maximum Depth (in meters)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.1</td>
<td>0.7</td>
<td>1.3</td>
</tr>
<tr>
<td>2.2</td>
<td>0.9</td>
<td>1.3</td>
</tr>
<tr>
<td>2.3</td>
<td>0.4</td>
<td>0.8</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Anomaly Number</th>
<th>Estimated Minimum Depth (in meters)</th>
<th>Estimated Maximum Depth (in meters)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.1</td>
<td>0.7</td>
<td>1.3</td>
</tr>
<tr>
<td>2.2</td>
<td>0.9</td>
<td>1.3</td>
</tr>
<tr>
<td>2.3</td>
<td>0.4</td>
<td>0.8</td>
</tr>
</tbody>
</table>

**Table 7.5. Survey Area 2 calculated anomaly depths using the half-width rule.**

524
Figure 7.33. Survey Area 1 magnetic contour map. Transect spacing of 2 feet. Contour interval is 2 nT. Anomalies discussed are labeled 1.1 through 1.5.
Champoeg Anomaly 1.1

Half nT delta \( \frac{(54638 \text{ nT} - 54609 \text{ nT})}{2} = 14.5 \text{ nT} \)

Half distance \( 54609 \text{ nT} + 14.5 \text{ nT} = 54623.5 \text{ nT} \)

South
- 1/2 width = approx. 19"  
- 2.5* 19" = 38"  
- 38"-20" = 18" depth est.  
- sensor height = 18" depth est.

North
- 1/2 width = approx. 36"  
- 2.5* 36" = 72"  
- 72"-20" = 52" depth est.  
- sensor height = 52" depth est.

Champoeg Anomaly 1.4

Half nT delta \( \frac{(54699 \text{ nT} - 54620 \text{ nT})}{2} = 39.5 \text{ nT} \)

Half distance \( 54620 \text{ nT} + 39.5 \text{ nT} = 54659.5 \text{ nT} \)

South
- 1/2 width = approx. 40"  
- 2.5* 40" = 100"  
- 100"-20" = 80" depth est.  
- sensor height = 80" depth est.

North
- 1/2 width = approx. 14"  
- 2.5* 14" = 35"  
- 35"-20" = 15" depth est.  
- sensor height = 15" depth est.

Figure 7.34. Cross section and example of half-width rule depth calculation for monopole anomaly a) 1.1 and dipole anomaly b) 1.4.
Figure 7.35. Survey Area 2 magnetic contour map. Transect spacing of 2 feet. Contour interval is 2 nT.
Figure 7.36. Survey Area 3 magnetic contour map. Transect spacing of 5 feet. Contour interval is 1 nT. Excavation Unit A is noted on the figure.
Figure 7.37. Survey Area 4 magnetic contour map. Transect spacing of 5 feet. Contour interval is 1 nT.
Figure 7.38. Survey Area 5 magnetic contour map. Transect spacing of 2 feet. Contour interval is 2 nT.
excavation was opened (40 m2) (Cromwell 2000). All sediments were screened using ¼ inch mesh.

**Results from GPR Survey**

James Bell isolated several GPR anomalies. The locations of the GPR anomalies are shown in Figure 7.32. The anomalous areas are located in the central and northern section of the area surveyed.

**Results from Magnetic Survey**

Detailed contour maps of the five magnetic survey areas are presented below. The magnetic contour maps include the location of excavation units in Survey Areas 1 and 3, however, the units were dug after all remote sensing surveys were complete.

**Survey Area 1**

Magnetic results from Survey Area 1 show five anomalies (Figure 7.33). Anomalies 1.1 and 1.2 are monopoles. Anomalies 1.3, 1.4, and 1.5 are dipoles with distinct positive and negative magnetic field alignments.

To gain a better understanding of what might have produced the five anomalies, I calculated the depth to source of each of the anomalies using the half-width rule. The width of each anomaly is needed for the half-width rule calculation. The cross section length of anomalies 1.1, 1.2, and 1.3 run south to north, the same direction as the magnetic readings were collected along the transects. For these three anomalies there were many magnetic readings that were used to estimate the width of the anomaly since their length followed the direction of the transect and the magnetometer was recording 10 readings per second. The cross section length of anomalies 1.4 and 1.5 are perpendicular to the direction of the transect lines. For this reason, the magnetic reading that was interpolated closest to the Y-axis line was selected for each north-south (X-axis) transect line. The cross section and an example of the depth calculation for anomalies 1.1 and 1.4 are shown in Figure 7.34. Table 7.4 shows the calculated depths of the five identified anomalies in Survey Area 1.

The depth calculations of each of the five anomalies in Survey Area 1 range from 0.2 to 3.3 m. The depths are only an estimate and usually they represent the maximum that the source of the anomaly is buried. Frequently the source of the anomaly is shallower. The best information that we can gather from these depth estimates can already be roughly determined from the contour map. Anomaly 1.4 is compact and is probably at a shallower depth than Anomaly 1.2, which in comparison is quite broad. The source of Anomaly 1.2 could be compact and strongly magnetic, but buried rather deep, or else the other extreme is a feature spread out over a larger area, but magnetically weaker and buried at a shallower depth.

An anomaly pattern in Survey Area 1 is also evident. The magnetic field variations at the southern 15 to 20 ft of Survey Area 1 are more uniform in size, spacing, and strength than the northern 80 to 85 ft. I interpret this southern area to be relatively culturally undisturbed.

Based on the shape, strength, and calculated depths of the anomalies, I think anomalies 1.3, 1.4, or 1.5 are equally likely candidates for features or artifacts related to the Newell homestead. These three anomalies also are located within the more magnetically disturbed northern area of Survey Area 1.

**Survey Area 2**

Table 7.6. Survey Area 5 calculated anomaly depths using the half-width rule.

<table>
<thead>
<tr>
<th>Anomaly Number</th>
<th>Estimated Minimum Depth (in meters)</th>
<th>Estimated Maximum Depth (in meters)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.1</td>
<td>0.4</td>
<td>1.0</td>
</tr>
<tr>
<td>5.2</td>
<td>0.1</td>
<td>0.1</td>
</tr>
<tr>
<td>5.3</td>
<td>0.5</td>
<td>0.6</td>
</tr>
</tbody>
</table>
Figure 7.39. Footprint of the five contiguous magnetic survey areas highlighting the path of magnetic anomalies.

Figure 7.40. Locations of block excavation, the five excavation units, and surface artifact scatter (adapted from Cromwell et al. 2000:33 Figure 12).
The magnetic survey results from Survey Area 2 are presented in Figure 7.35. Three anomalies were more distinct than the rest. The first anomaly, 2.1, was a magnetically negative monopole. Anomaly 2.1 had the strongest magnetic signature in Survey Area 2. Anomalies 2.2 and 2.3 were positive and negative monopole anomalies, respectively. The depth calculations for the three anomalies ranged between 0.4 and 1.3 m (Table 7.5). Based on its shape, strength, and calculated depth, Anomaly 2.1 could indicate the location of a buried feature or artifact.

There was also a magnetic anomaly pattern in Survey Area 2. The southern three-quarters of Survey Area 2 contained magnetic anomalies in a variety of shapes, sizes, and strengths. I interpreted the southern section as a culturally disturbed area.

**Survey Areas 3 and 4**

Data collection at Survey Areas 3 and 4 was performed using the wider transect spacing of 5 ft (Figures 7.36 and 7.37). No clearly defined anomalies are evident. Based on the results, I now believe a transect spacing of 5 ft was too wide to be useful in detecting the smaller size of artifacts or features likely encountered at the Newell homestead. However, there is a slight anomaly pattern in Survey Areas 3 and 4. The northern half of Survey Area 3 and the northern quarter of Survey Area 4 are more magnetically disturbed than the southern sections. To get a better view of the magnetic variability within the two areas, I recommend resurveying the areas at the smaller 2 ft transect spacing.

**Survey Area 5**

A magnetic survey of Survey Area 5 was carried out the day after data from the first four survey areas were analyzed. The smaller transect spacing produced much more detailed results so I decided upon a transect spacing of 2 ft for the final survey area.

I note three anomalies in the contour map for Survey Area 5 (Figure 7.38). The first is a monopole anomaly, 5.1, although negative fields exist to the north and southeast. This anomaly was roughly in line with anomaly 1.3 in Survey Area 1 as they both followed the natural levee. Monopole anomaly 5.2 and dipole anomaly 5.3 are the two magnetically strongest anomalies in Survey Area 5. The depths of anomalies 5.2 and 5.3 are calculated to be quite shallow (Table 7.6). Anomaly 5.2, which potentially exists at the shallowest depth, is more likely to be an artifact than a feature. This interpretation is likely since I know the field has been plowed and features located at shallow depths were probably destroyed.

The southern third of Survey Area 5, showed few signs of magnetic disturbance and had magnetic field patterns that ran parallel to the natural levee. I interpret the magnetically undisturbed southern section as a relatively culturally sterile area.

**Anomaly Patterns across Survey Areas**

Survey Areas 1, 3, 4, and 5 had more magnetic disturbance across the northern sections of each area. Survey Area 2 had more magnetic disturbance in its southern section. Therefore, the most magnetically disturbed region of the contiguous area is across the central section, suggesting the presence of cultural modification (Figure 7.39).

No overall pattern of discrete magnetic anomalies that might indicate a structural foundation or a line of postholes was detected across the five survey areas. This could be because Survey Areas 3 and 4 were performed at a coarse transect spacing and did not yield the desired results that would reveal a pattern or because a well-defined strong magnetic pattern no longer exists. Viewed as individual anomalies any of the disturbances could be generated by a portion of a structure or may indicate a well, outhouse pit, or individual artifact.

**Ground Truthing**

**Surface Collection**

The data gathered from the surface collection survey was used to ground truth the magnetic results. Within the five magnetic Survey Areas 248 artifacts were recorded on the surface, including four iron objects and 115 brick fragments (Cromwell et al. 2000:32-36). Figure 7.40 shows the location of the artifact surface scatter.
The GPR and magnetic anomalies did not detect the same subsurface features or artifacts, however, both the GPR and magnetic surveys detected anomalies in areas of the highest concentration of artifact surface scatter. The magnetic contour maps agree with the pattern of artifacts detected in the surface collection. The area of greatest magnetic disturbance lies in the 100 to 160 ft centered roughly on the east-west baseline as shown in Figure 7.39. This follows the path of surface scatter visible in Figure 7.40.

The wider transect spacing in Survey Areas 3 and 4 made the magnetic disturbance pattern only vaguely visible. These two areas should be resurveyed at a smaller transect spacing which is consistent with the rest of the site. Furthermore, I think magnetic data on three more survey areas (north of Survey Areas 3, 4, and 5) should be collected, thereby expanding the entire survey into a 200 x 800 ft rectangular region. Concatenating the data from a rectangular area would allow for easier mapping and review of the entire area.

Excavation

The excavation work did allow for some ground truthing of results. Five units were excavated in 1999 (Cromwell et al. 2000). The units were positioned over GPR and magnetic anomalies and in an area that was considered culturally sterile. Time constraints prevented excavation to a sterile depth in several of the units. The excavation revealed that modern farm equipment had established the plow zone in the ryegrass field to a depth of approximately 0.25 m (Cromwell et al. 2000:30).

A block excavation was opened in 2000, but, again, due to time constraints, the entire area was not dug to a sterile depth (Cromwell 2000, Stone 2000). There are plans to reopen the block excavation during the summer of 2002.

Unit A. Based upon the GPR results, magnetic results, and the small number of items detected from the surface survey, Excavation Unit A was placed at what was considered a culturally sterile location within Survey Area 3. The GPR results indicated an area free of anomalies. The magnetic contour map did not indicate anomalies in the area chosen although the wider transect spacing made the magnetic results in this area less defined. In fact, this 1 x 1 m unit, dug to a depth of 0.55 m yielded only 9 artifacts (Cromwell et al. 2000:36-37). The results appear to validate the GPR and magnetic interpretations.

Unit B. One excavation unit (Unit B) was selected in Survey Area 4, but was never opened due to resource constraints. Unit B was located over what I initially thought was an archaeologically significant linear magnetic anomaly. I now think that the linear anomaly was not the result of a subsurface feature, but the result of the interpolation formula in the mapping software.

Units C and E. Two excavation units in Survey Area 1 were placed over GPR anomalies (Units C and E). Unit C, a 1 x 1 m unit, possibly detected two 12-cm diameter post molds (Cromwell et al. 2000:37). Although a total of 316 artifacts were recovered in Unit C, no other architectural remains were found. Cromwell et al. (2000:37) used the presence of bricks, nails, and window glass to suggest the test unit is located near a structure of some kind. Excavation Unit E, a 1 x 2 m unit, contained a “…deep pocket of dark, loamy sandy-clay with burned organic material intermixed throughout, that extended as deep as we could excavate” (Cromwell et al. 2000:42). A soil sample was sent to a lab to check the pH and phosphorous content, but ultimately no final determination could be made to conclude whether the anomalous soil conditions were naturally occurring geological formations or the result of cultural deposition (Cromwell et al. 2000:42).

Unit D. Excavation Unit D, in Survey Area 1, was to be positioned over magnetic anomaly 1.3, however, through field miscalculations it was misplaced approximately 10 ft north of the magnetic disturbance. Within this 1 x 2 m unit three post molds were found, all between 10 and 12 cm in diameter. The post molds and numerous artifacts, including 388 brick fragments and 52 machine-cut nails, suggest that this unit is near a structure (Cromwell et al. 2000:39). The post mold features and artifacts did not produce detectable magnetic signatures on the contour map. Significantly, no magnetic anomaly was identified

---

7 Twenty-one artifacts were found on the surface within Survey Area 3 as compared to 106 in Survey Area 1 (Cromwell et al. 2000:32)
Figure 7.41. Champoeg, Magnetic Survey Area 1, Excavation Unit F at a) 0.6 m showing tops of bricks and wood and b) concentration of bricks at 0.8 m (McDonald 1999; Cromwell 2000).
where the test unit was actually placed.

Unit F. Excavation Unit F, in magnetic Survey Area 1, was placed over magnetic anomaly 1.5. In 1999, the 1 x 1 m unit was excavated to a depth of 0.62 m (Cromwell et al. 2000:44). Two nearly whole bricks were detected in this unit at 0.47 m and 0.57 m (Cromwell et al. 2000:44). In total 668 brick fragments and 69 machine-cut nails were recovered from Unit F (Cromwell et al. 2000:46). However, due to time constraints, Unit F was not dug to a sterile depth in 1999.

In the summer of 2000, Unit F was re-opened as part of a larger block excavation. At greater depths (0.8 m) more bricks were encountered in a remarkable configuration (Figure 7.41) (Stone 2000). This accumulation of bricks, possibly a brick lined cellar or a house foundation, undoubtedly was the source of the magnetic anomaly detected by the magnetic survey. Again, due to time constraints, Unit F and much of the block was not dug to a sterile depth.

The block excavation in 2000 also incorporated magnetic anomaly 1.4. A textile fragment, probably an oilcloth, was exposed just below the plow zone (Stone 2000). Unfortunately, this area of the block excavation was not excavated to the sterile layer. It is not know what was below this artifact, as the field season came to a close. Either the items associated with the oilcloth produced the magnetic anomaly or the source lies deeper in the ground. Discovering the source of the remaining magnetic anomalies (1.1, 1.2, and 1.3) must wait until future work is performed.

Summary

Even with the limited number of survey areas, the information produced by the magnetic survey was exceptional. Unit F, which contained the enormous cache of bricks, was selected based upon the magnetic survey results. Cromwell et al. noted after the 1999 excavation that “[o]ther than the Willamette Mission site … there have been no other early Euro-American settlement sites on the French prairie that have been found with intact archaeological deposits and possible architectural features” (2000:47). The year 2000 excavation at Unit F confirmed that the bricks were part of an architectural feature, perhaps a cellar or house foundation. Without the assistance of the magnetic maps, the feature would have only been found through chance or extensive block excavations.

The magnetic data did appear to produce better results than the GPR survey, but too few anomalies have been tested to make a convincing argument. The GPR survey might have detected the 12 cm post molds in Unit C. In Unit E the GPR detected anomalous soil conditions. However, the dramatic find of the stack of bricks in the single magnetic anomaly 1.4 and the swath of anomalies that correspond to the artifact surface scatter, certainly weigh in strongly for the case of a successful magnetic survey at this location along the Willamette River.

The GPR survey was conducted using wide (6 ft) transect spacing. The GPR survey might have yielded better results with smaller transect spacing. The smaller transect spacing certainly gave better magnetic results. The strongest and most distinct magnetic anomalies were evident in Survey Areas 1, 2, and 5, where the data were collected using 2 ft transect spacing. The magnetic anomalies were often very subtle. There was little background noise to drown out magnetic signals of archaeological interest. The small nanotesla range across the magnetic survey areas allowed all magnetic maps to be presented at a 1 or 2 nT contour interval and attests to the need for shorter distances between transects.
CHAPTER 6
CONCLUSIONS

GPR and magnetic surveys are non-destructive methods of locating features and artifacts within archaeological sites. This study was performed to increase awareness of what can be garnered from GPR and magnetometry in particular, and promote their use in archaeology. The flood plains of the Pacific Northwest show great promise for both magnetometry and other remote sensing techniques. At Cathlapotle and Champoeg, both situated on flood plains, magnetic variations in the underlying soil matrix were detected. At Champoeg, GPR anomalies were detected as well. This study showed how remote sensing could be used, in conjunction with surface surveys, topography, historic documents, and other lines of evidence to detect the horizontal (and potentially vertical) extent of a site and provide specific knowledge about subsurface anomalies not apparent from ground level. Information gathered from the remote sensing surveys influenced the excavation sampling strategy undertaken at Champoeg. The information helped to determine where to excavate. Some anomalies were marked as areas for immediate excavation or as locations for further investigation at a later date while others were marked as areas to avoid. This study revealed how GPR and magnetic survey results helped to make informed decisions regarding excavations at both the late prehistoric site of Cathlapotle and a historic archaeological site in Champoeg State Heritage Area.

Cathlapotle

During the town’s 500-plus year existence, thousands of people ate, slept, and participated in the communal life in and around the Cathlapotle plank houses. Each of the five survey areas produced informative magnetic results. In Survey Areas 1 and 2, which covered a portion of House 2, discrete anomalies were detected. However, the area surveyed within House 2 was small and conclusive identification of magnetic patterns for walls and fire hearths are suspect. Magnetic anomalies abounded in Survey Area 3, the heavily excavated southern section of House 1. Unfortunately, too much magnetic noise was generated within Survey Area 3 by the prior excavation units and subtle archaeological items of interest were masked. The magnetometer was able to detect the location of a prior excavation unit in Survey Area 4. Finally, the magnetic readings helped to confirm that Survey Area 5, selected for an off-site trench, was indeed a culturally sterile area. When all area maps are compared against one another, Survey Areas 1 through 3 demonstrated more magnetic disturbances than those of Survey Area 4, the front yard, and Survey Area 5, the off-site trench area.

The magnetic survey covered only a small portion of the Cathlapotle archaeological site. Part of the reason for the small survey size was that vegetation was problematic in the spring and summer. Larger expanses of the archaeological site are accessible after the first frost and before the spring growing season begins. This is also the time when the house depressions are the most obvious. Based on my results, the conditions at Cathlapotle are conducive to magnetic studies. If the vegetation were cleared over a larger area, more feature patterns might become evident on the magnetic contour maps. Future testing performed at Cathlapotle will help ground truth the anomalies not caused by prior excavation units and confirm or reject the interpretation of the magnetic data. While preliminary, my results show that the ability to detect and interpret individual signatures of items, such as fire hearths and walls, is possible at Cathlapotle.

Champoeg

The magnetic survey at Champoeg and ground truthing support the hypothesis that the Newell home was at or very near to the region investigated. The substantial quantity of surface artifacts certainly lends strong support to the probable location of the Newell homestead. The row of bricks located in Survey Area 1, Unit F, are probably part of a cellar or architectural foundation. This conclusion can be evaluated further in future testing, when larger block excavations are exposed.

The magnetic survey transect spacing of 5 ft did not produce high-resolution magnetic contour maps. Likewise, the GPR survey with a transect spacing of 6 ft was probably too wide. A recent GPR survey at Ft. Clatsop, OR, spaced transects every 0.5 m (1.64 ft) (personal com-
munication, Conyers 2001). I believe the transect spacing for both remote sensing instruments was too wide for the smaller size of artifacts and features likely encountered at the Newell homestead. My initial assumption was 1 m wide features buried at a shallow depth. In fact, the features and artifacts were much smaller than I had anticipated. I am now a firm believer that 0.5 m transect spacing produces the best results for most archaeological research. I recommend that Survey Area 3 and Survey Area 4 be resurveyed with a magnetometer at a 2 ft (0.61 m) transect spacing. Resurveying the two areas at 2 ft would also make the data sampling consistent across all areas and allow the data sets to be merged. Based upon the location of anomalies presented in this paper and the results of the surface collection, I feel it would be beneficial to perform a magnetic survey on three additional 100 x 100 ft areas located directly north of Survey Areas 3, 4, and 5.

Magnetic Equipment Operation and Impressions

The first magnetic survey at Cathlapotle I performed using a rented magnetometer with a single sensor. Although the machine functioned well, prior familiarity with the magnetometer or an extra day with the machine at the site would have been beneficial. When renting magnetometers, I recommend including one day prior to a survey to practice using the equipment and associated software. The survey schedule should also include time to resurvey areas that might have questionable data or expand survey areas when a particularly interesting anomaly appears along a border or a survey of a nearby area might shed light on an emerging pattern of anomalies. Additionally, I would recommend using two magnetic sensors configured as a gradiometer to eliminate solar disturbances from the data.

“Noise” Created by Prior Archaeological Excavation

One somewhat surprising factor that I had to deal with in interpreting magnetic results was the “noise” created by previous archaeology. Cathlapotle provided an interesting situation where prior excavation units when surveyed were magnetically detectable. However, one issue became apparent; how the units were backfilled was important when later remote sensing surveys cover the area. How and at what level uncollected rocks were placed back into units does make a difference as does knowing what other backfill material (e.g., straw) was used. A more thorough record of how units are backfilled, foot traffic patterns, and other site use areas, such as the location of where rocks are weighed, is helpful and perhaps necessary when remote sensing techniques are to be introduced at a site with prior archaeological activity.

Will backfill procedures become more relevant in the future? Will more documentation be necessary on how an archaeological site is closed? My recommendation is that a few sentences or photographs record the placement of equipment and location of people during excavation work. Furthermore, a sentence or two should record how each unit was backfilled.

Future Implications of Remote Sensing Technologies in Archaeology

Geophysical data are part of the archaeological record (Thomas 1998:155). Noninvasive geophysical techniques have been used in culturally sensitive areas where archaeologists are forbidden to dig. Goodman and Nishimura used radar to examine the internal structure of sixth-century royal burial mounds (Thomas 1998:150). The data collected is now part of the baseline archaeological record. The need for noninvasive geophysical techniques to make subsurface observations is not likely to decrease in the near future.

In addition to collecting the geophysical data as part of the baseline archaeological record, archeologists have used data results as a predictive tool for unexcavated portions of sites. Excavations at Marajo Island, Brazil showed that geophysical anomalies had detected hearths (Roosevelt 1991:226-227). Where there were hearths, there were homes. The size and number of anomalies were studied for a better understanding of community organization (Roosevelt 1991:197).

Archaeologists that study prehistoric archaeology in the Pacific Northwest are interested in understanding community patterning and changes in organization of community structure over the 10,000 or so years people have lived in the region. The identification of houses and un-
derstanding their internal organization provides important information on community patterning. Importantly, only in the last twenty years of concerted archaeological work have house features been identified and still the number of such house sites is small. My work has established that features associated with house construction can be identified using magnetometry and in turn suggests that future projects should incorporate such field methods. Geophysical baseline records now exist for Cathlapotle and Champoeg. At Cathlapotle there is the beginnings of a comparative magnetic model of a semi-subterranean plank house.

Site geophysical baseline studies have become an indispensable part of some archaeological investigations. Magnetic and radar surveys were performed on St. Catherine Island, Georgia, to locate the Santa Catalina Spanish mission. The magnetic survey revealed a well, walls surrounding a kitchen area, and graves near the church (Thomas 1998:134). The radar generated anomalies from the palisades, bastions, and moats around the central mission (Thomas 1998:143-144). So beneficial was this data deemed to be that the archaeologists said they “… worried about extending … excavations into areas not first surveyed geophysically” (Thomas 1998:144). Thomas makes a forceful argument that not only are geophysical survey beneficial to archaeology, but that in the near future field archaeology should include them at some level as part of a minimal acceptable standard (1998:154).
APPENDIX A

Equipment and Software List

*Equipment:*

- GeoMetrics model G-816 Portable Proton Magnetometer
- Geometrics model 858 Cesium Magnetometer (single and dual sensor)
- SIR-2 GPR Unit (Geophysical Survey Systems) with 400 MHz antenna. Color Digital Control Unit and terminal printer to provide hardcopy of profiles.

*Software:*

REFERENCES CITED

Aitken, Martin J.
1959 The Listener 61, 325.

Ames, Kenneth M., Doria F. Raetz, Stephen Hamilton, and Christine McAfee

Ames, Kenneth M. and Herbert D. G. Maschner

Ames, Kenneth M.

Barrows, Larry and Judith E. Rocchio.

Bell, James

Bevan, Bruce W.


Brauner, David, Rebecca McClelland Poet, and James Bell

Breiner, Sheldon

Butler, Dwain K., Janet E. Simms, and Daryl S. Cook

Cathlapotle Feature Catalog
2000 Cathlapotle Feature Catalog. Department of Anthropology, Portland State University, Portland.

Chatters, James C.

Clark, Anthony

Connolly, Tom, Guy L. Tasa, and Carolyn J. Armstrong
Conyers, Lawrence B. and Dean Goodman

Cromwell, Robert J.
1999 Champoeg (ORMA41) Field Notes. Department of Anthropology, Oregon State University, Corvallis.
2001 Champoeg (ORMA41) Field Notes. Department of Anthropology, Oregon State University, Corvallis.

Cromwell, Robert J., Helen Delight Stone, and David R. Brauner

David, Andrew

DeVoto, Bernard

Engstrom, Laura

Geometrics, Inc.
1995 New Environmental Test Site Installed at Stanford University. Geometrics, Inc., San Jose, California.

Goodman, Dean and Yashushi Nishimura

Hajda, Y.

Hathaway, J. Holly and Greg C. Burtchard

Hodges, Charles M.

Hussey, John A.

Justen, Lane

Keckler, Doug

King, Julia L.

King, Julia A., Bruce Bevan, and Robert J. Hurry
1993 The Reliability of Geophysical Surveys at Historic-Period Cemeteries: An Example from the Plains Cemetery, Mechanicsville, Maryland. Historical Archaeology 27(3):4-16.

Kvamme, Kenneth L.

McCoy, Darin
McDonald, Kendal L.
1998 Champoeg State Heritage Area Magnetometer Survey. Final Project, Archaeological Field Methods, Portland State University.

McGreevy, Steve

Monroe, James S. and Reed Wicander

Moulton, G. E.

Ronnigen, Cherilyn

Roosevelt, Anna C.

Smith, Kenneth

Stone, Helen Delight
1999 Champoeg (ORMA41) Field Notes. Department of Anthropology, Oregon State University, Corvallis.

2000 Champoeg (ORMA41) Field Notes. Department of Anthropology, Oregon State University, Corvallis.

Stove, G. Colin and P. V. Addyman

Thomas, David Hurst

Weymouth, John W. and Robert Nickel

Wuerch
1979 History of the Middle Chinooks to the Reservation Era. University of Oregon, Eugene.
PART VIII

MEIER SITE CATCHMENT ANALYSIS

Stephen Coursalt Hamilton
Introduction

The following report is a site-catchment analysis of the Meier site (35C05) located in the Portland Basin. The site is a Chinookan residential site which had at least one plank house during a given occupation. The site dates from 720 +/- 75 bp. (Pettigrew 1981) to the early 1700’s A.D. (Ames personal communication). Data for this study was primarily obtained from Meier site archaeological material and regional ethnographic and ecological studies. The primary focus of the analysis was to determine if the resources available within the Meier site catchment area allowed for year round occupation of the site. A similar study for the Sauvie Island catchment area has previously been conducted by Becky Saleeby (1983). My analysis uses much of her basic data and some faunal assemblage interpretations, but is more fine-grained in terms of landform and habitat distribution within the Meier site catchment area.

Theoretical Perspective

Roper (1979) points out two general approaches to locational analysis. One set emphasizes man-man relationships in determining a community’s spatial structure. These are concerned-with band spacing and population density (ie. central place theory; gravity models). The other set, which includes site-catchment analysis, focuses more on man-land relationships as determinants of site location. For site catchment analysis, the catchment area is defined as a zone of resource exploitation within a reasonable travel distance of a given village (Flannery 1976). This distance is commonly set at 6 kilometers. The approach assesses resource availability, abundance, spacing, and seasonality within the boundaries of the catchment area in order to explicate subsistence possibilities and constraints related to resource characteristics within the 6 kilometer radius of the site. The Meier site is considered to be the focal point of an area throughout which subsistence activities were performed. The catchment is that area from which the occupants of the site could have plausibly appropriated their resources during a single daily activity set.

Vita-Finzi and Higgs first defined the term site-catchment analysis as “the study of the relationship between technology and those natural resources lying within economic range of individual sites” (1970 cited in Roper 1979:120). Hence, site catchment analysis rests on assumptions of optimization derived from optimal foraging theory. It is assumed that the farther one moves from an inhabited focal point (the site), the greater the amount of energy that must be expended for procurement of resources. The time and energy of getting to and from the habitats in which the resources occur is of primary concern in site catchment analysis. The analysis assumes that the intensity of exploitation of the surrounding territory decreases as one moves away from the locus. Theoretically, there exists a distance at which appropriation of resources is inefficient. Thus, a boundary around the site can be deduced. The area within the energy efficient boundary is the assumed catchment area.

There are two general approaches to site catchment analysis – inductive and deductive. The inductive approach takes the resources as given and reconstructs the size of the catchment area. In contrast, the deductive approach takes the catchment area as given and deduces the resource use within by considering habitat attributes.

The Meier Site Catchment Analysis

Analytical Procedure

For the Meier Site catchment analysis, I use the deductive approach. There are a number of ways to determine the catchment boundaries. For this study, time travel is used as the primary basis for defining the catchment boundary. The area considered is defined by the distance the inhabitants could travel, appropriate the resource and return in a single day. Once the catchment area is defined, I infer habitat distribution from soil distribution, ecology of plants, and various topographical and land survey maps. I then assess the more important animal and plant resources found within the site catchment area. Special reference is made to those plant resources stressed in the ethnographic literature as significant Chinookan subsistence. Regarding animal resources, faunal material recovered from the Meier site is discussed in relation to habitat distribution and seasonal availability. Finally, I argue that the Meier site is situated in a location that allowed for year-
The Portland Basin and Settlement Patterns

The Lower Columbia River passes through several physiographic and geological regions. Franklin and Dyrness (1976:6) define these as the Columbia Basin, High Cascades, Western Cascades, Southern Washington Cascades, Willamette Valley, Puget Trough and the Coast Ranges (Figure 8.1). For cultural studies concerning the stretch of Lower Columbia River occupied by Chinookan speakers, many investigators have divided the region into three major environmental zones- the Cascades, the Portland Basin, and the Coast (Map 1: e.g. Saleeby 1983, Saleeby and Pettigrew 1983). These zones correlated in an east-west direction with those regions defined by Franklin and Dyrness (1976). The Coast zone includes the Coast Ranges, the Cascade zone the High Cascades, Southern Washington Cascades and Western Cascades and the Portland Basin by the Puget Trough and the Willamette Valley. More specifically, the Portland Basin consists of the northern most portion of the Willamette Valley and southern most portion of the Puget Trough.

Given the physiological and geological differences between the three zones, it follows that the Portland Basin is environmentally different from the Coast zone and Cascade zone. The Coast zone is marked by 4 general habitat areas: (1) maritime habitats at the ocean, (2) an estuary habitat at the mouth of the Columbia River and eastward up the Columbia 37 km and (3) a narrow riverain habitat bordered by (4) steep hills where the Columbia passes through the Coast range (Minor 1983). The Cascade zone is characterized by a rugged mountain environment with the Columbia cutting through the Cascade mountains creating a deep gorge (Saleeby 1983). The Portland Basin is primarily a broad floodplain bordered by rolling
and steep hills.

The Meier site is located in the Portland Basin on the mainland, west of Sauvie Island (Figure 8.2). Unfortunately, because the Portland Basin was hit the hardest by the 1830s “malaria” epidemic (Boyd and Hajda 1986) this area was the least recorded historiographic and ethnographic information of the three regions. Researchers have had to rely almost exclusively on the early journals of Lewis and Clark. This has led to unwarranted analogies for Portland Basin subsistence patterns based on the Coast zone and Cascade zone ethnohistoric accounts.

Many researchers have suggested a general settlement pattern of biseasonal movement for the entire Lower Columbia region while others have argued for variability in settlement patterns between these three zones. Regarding the Vancouver Lake/Lake River region of the Portland Basin, Robert Dunnell et al. (1978) used archaeological and ethnohistorical data to argue that functionally different sites were located in particular microenvironments and that these sites were used during a seasonal-round subsistence strategy. Following his lead, many archaeologists have generalized his model to the Portland Basin (Saleeby 1983). In contrast, Beck Saleeby and Richard Pettigrew used ethnographic, archaeological, and ecological evidence to argue that the Portland Basin, with its resource abundance and richness, allowed for full sedentism of its inhabitants (Saleeby 1983; Saleeby and Pettigrew 1983). Similarly, based on ethnohistoric data, Yvonne Hajda and Robert Boyd have suggested the possibility of sedentism for a portion of the Portland Basin population, particularly in the Sauvie Island locale, while groups from the hinterland moved in only during times of stress and prime wapato and salmon fishing seasons (Boyd and Hajda 1986; Hajda 1984).

The environmental differences between the three zones imply different resource bases, therefore, differences in subsistence strategies are expected. As Saleeby wrote, “humans have always been obliged to accommodate their lifestyles to patterns in the overall availability, distribution, abundance, and predictability of critical resources” (1983:4). A cultural and linguistic boundary between the Portland Basin and the Coast zone (Minor 1383) may reflect just such a difference in subsistence patterns as those proposed by Hajda and Saleeby. The environmental differences between the zones makes analogies from one zone to another problematic, especially when considering a part of culture, such as subsistence, that is so intimately involved in the ecological setting.

The Meier Ecological Context

The regional uniqueness of the Portland Basin environmental zone is created by a broad floodplain and the confluence of the Columbia and Willamette rivers (Figure 8.1). The Portland Basin stretch of the Columbia River is characterized by a mass of islands and meandering waterways. The floodplain formation, with its fertile soils, allows for a high diversity of habitats. For example, the abundant floodplain marshes and ponds provided the densest wapato distribution known in the Northwest (an important food resource) as well as an excellent habitat for migrating waterfowl. Another unique characteristic of the Portland Basin was the high density of Oak woodlands. These supplied the local inhabitants with acorns and hazelnuts both of which were important in the Chinookan diet (Saleeby 1983). Furthermore, Loy et.
al. (1976:144-145) states that the alluvial bottomlands forming the Portland Basin supported prairies, riparian deciduous vegetation, the douglas-fir forests which, in combination, make an excellent habitat for white-tailed deer (Maser et. al. 1981).

The high diversity and abundance of resources on the floodplain was supplemented with salmon and other anadromous fish runs reported to be the primary subsistence resource for the entire Lower Columbia region. The Columbia River, Multnomah Channel, and the Willamette River are all a part of the Riverain habitat providing a variety of associated food stuffs for the occupants of this zone. It should also be noted that the Portland Basin had the highest Native American population of the three zones (Hajda 1984; Saleeby 1983), possibly reflecting the documented richness of resources in the area.

The Portland Basin climate is characterized by mild winters and moderate summers with a narrow temperature range averaging 4-5 degrees Celsius in winter and 10-20 degrees Celsius in summer. Precipitation is almost entirely in the form of rain between 1000 and 1200 mm/yr. which falls during a period of 140-160 days/yr.

Saleeby (1983) asserts that except for the loss of the grizzly bear, California condor, and the grey wolf, the types of animals present in the Portland Basin has been stable for the last 5,000 years. However, stability does not mean that the abundance and proportions of animals have been constant for this entire period. In fact, the expectation is that through time proportions varied considerably with human population density and climatic fluctuation. The dates posited for the Meier site indicate a short 1 late occupation span of (450) years. Some climatic fluctuation has been documented for this time period. However, using a small sample, Saleeby (1983) found that faunal assemblage from the Meier midden did not change significantly through time.

The Defined Catchment Area

The single day catchment area is based on time travel with terrain as an influential variable. There were two modes of transportation available to the Meier inhabitants- walking and canoeing. In reference to canoe travel, I have adopted Saleeby’s use of Lewis and Clark’s canoe travel mileage. She concludes that Chinookans must have exploited resources 17.5 km (11 miles) up- or downstream from any given focal point in a single day. The Meier site was located on the bank of the lake which would have allowed them access to waterways. Access to the network of waterways (rivers and extensive channels between bodies of water; see Figure 8.3) is particularly important as walking would have been particularly difficult on the floodplain due to the network of sloughs, lakes, and ponds and the extremely dense vegetation of the riparian and brush habitats described below. One reason for locating the residential site at this particular local along the lake mat have been that it is at the point where a deep channel (presently known as Jackson creek) was closest to the shore. This channel would have allowed waterway access during dry seasons when the lake may have been too shallow for canoe travel.

Walking is slower and makes transport of resources more difficult. When compared to canoe travel, it increases energy expenditure and therefore decreases the distance traveled for resources. The walking distance I propose is based on Richard Leo’s estimate of a 10 km catchment area for Kalahari Bushman women (Lee 1968). However, the distance is shortened by the time required to travel over rough terrain such as in the Tualatin Mountains, lakes and waterways, and dense vegetation (Figure 8.3). The inhabitance of the area undoubtedly used a combination of canoe and foot travel. For example, although Scappoose Bay might be seem as an obstacle for terrestrial travel, canoe travel through waterways beginning at the site could get them to the back and then walked from there to get at resources in the area beyond it. In general, the western boundary of the catchment area horizontally fluctuates within the eastern slope region (Figure 8.3). This fluctuation is due to topography, which is characterized by rough and rolling hills and stream canyons. By drawing an imaginary North-South line we can see that most exploitation west of the site would have been done by walking while east of the site on the floodplain, by a combination of canoe travel and walking.

On the east side of the river the same criteria was used to delimit the catchment boundary, but discussion of habitat distribution is limited. The expectation is that a similar mosaic of resources was available, but possibly in different
Figure 8.3. Map of Reconstructed Habitat Distributions within the Meier Site Catchment Area.
Table 8.1. Habitats and Associated Resources in the Meier Catchment Area.  
(Description and resources corresponding to habitat are taken from Saleeby 1983:173-174).

<table>
<thead>
<tr>
<th>Habitat</th>
<th>Description</th>
<th>Flora/Fauna Resources</th>
</tr>
</thead>
<tbody>
<tr>
<td>Riverain</td>
<td>Cold, clear waters of rivers or streams</td>
<td>Cattails, freshwater mussels, freshwater turtles, salmon, steelhead trout, sturgeon, eulachon, suckers, cyprinids (chub, squawfish, chiselmouth) kingfisher, hawk, crow, mink, river otter, harbor seal, raccoon</td>
</tr>
<tr>
<td>Lacustrine</td>
<td>Lakes or ponds with emergant vegetation and thick shoreline vegetation (includes some bayous and sloughs).</td>
<td>Cattails, wapato, sturgeon, suckers, cyprinids, water fowl kingfisher, freshwater turtle, mink, river otter, muskrat, beaver, raccoon</td>
</tr>
<tr>
<td>Palustrine</td>
<td>Freshwater marsh typified by standing water and herbaceous plants (includes some bayous and sloughs)</td>
<td>Wild celery, cattails, skunk cabbage, horsetail, wapato, waterfowl, sandhill crane, muskrat, beaver, raccoon</td>
</tr>
<tr>
<td>Ribarian</td>
<td>Water edge habitat compromised of cottonwood, willow, ash, bigleaf maple, sometimes oak, and dense undergrowth</td>
<td>Wood sorrel, wild celery, salmonberry, dewberry, thimbleberry, blackcap, osoberry, elderberry, cow parsnip, kingfisher, various non-migratory bird, mink, river otter, raccoon, deer, elk, brush rabbit</td>
</tr>
<tr>
<td>Oak woodlands</td>
<td>Woodlands dominated by oak, sometimes with the co-occurrence of Douglas-fir, and understory species such as hazelnut/swordfern or serviceberry/snowberry</td>
<td>Serviceberry, osoberry, acorn, hazelnut, non-migratory bird, deer, puma</td>
</tr>
<tr>
<td>Grasslands (prairies)</td>
<td>Grasses and forbs are dominant vegetation</td>
<td>Crabapple, bracken fern, camas, wild strawberry, sandhill crane, hawk, red fox, ground squirrel, deer</td>
</tr>
<tr>
<td>Conifer forests</td>
<td>Douglas-fir is the most common species, with Grand fir, western redcedar, bigleaf maple, and sometimes oak</td>
<td>Lupine, wood sorrel, kinnik-kinnick, dewberry, thimbleberry, blackcap, huckleberry serviceberry, osoberry, elderberry, salal, hazelnut wild strawberry, Oregon-grape, various non-migratory bird, mountain beaver, marten, porcupine, bear, bobcat, elk, black tailed deer, puma</td>
</tr>
<tr>
<td>Brush*</td>
<td>Brushy deciduous species such as ash, balmgelead rose and vines on ridges and banks of the floodplain.</td>
<td>Crabapple, gooseberry, blackberry, nettles, non-migratory bird, deer</td>
</tr>
</tbody>
</table>

* I have defined a Brush habitat based on GLO survey notes. In my opinion it is unique in comparison to the other habitats commonly defined for the Portland Basin and is widespread on the floodplain, thus, worthy of identifying as separate. Plant resources are labelled as described by GLO surveyors and animal resources are inferred.
proportions (see Norton et al. 1983). In general, the catchment area is an irregular oval shape with a radius (or ray) that fluctuates between 11 km and approximately 4 km depending on the topographic variability (Figure 8.3).

Habitat and Resource Distribution within the Catchment Area

Franklin and Dyrness (1973) and Maser et. al. (1981) suggest that the Portland Basin area is best typified by seven habitat zones—riverain, lacustrine, palustrine, riparian, oak woodlands, grassland (prairies), and conifer forests. For this analysis, I have added an eighth habitat zone I have called “brush” (see Table 8.1 for a brief description of these eight habitat zones). These habitats are typified by particular vegetational and animal communities (Table 8.1), which, in combination, provided the subsistence base for Portland Basin inhabitants. Hence, the question to be answered in this part of the analysis is what habitat type and proportions existed within the catchment area during Meier site occupation. Ultimately, from the habitats and habitat proportions, we can deduce the available resources and their relative abundance.

The three primary sources of information used to reconstruct the habitat distribution were the 1853-1854 General Land Office (GLO) survey (map and notes), the 1986 United States Department of Agriculture (USDA) soil survey, and the 1973 USDA natural vegetation study by Franklin and Dyrness cited above. The GLO survey was the earliest comprehensive land survey I was able to find for the area under investigation. The goal of the GLO survey was to describe the land of the Oregon Territory for future settlement purposes and therefore vegetation was relatively well described although the focus was more on timber resources, not those resources used by Native Americans living in the area. However, by using modern plant studies and historic accounts, one can make inferences about habitat zones and therefore plant resources from plant communities described by the survey. This is the method used in the foregoing analysis.

Soil types tend to have particular vegetational communities associated with their formation. Soils are less often substantially modified by agricultural and other cultural influences than plant communities themselves and therefore can be useful in habitat reconstructions. However, several habitats may exist on a single soil type. Therefore, soil distributions have limited value as an exclusive source for fine-grained analysis. I related soil types and the GLO survey maps to clarify and support reconstructed habitat distributions. The USDA natural vegetation studies aided in describing plant associations that were not fully described by the early GLO survey. This data, in combination, enabled the reconstruction of habitat distribution within the catchment area and before extensive Euro-American landscape alteration.

A few points regarding Euro-American influence on the landscape should be emphasized. Only 20 settlements were recorded in the catchment area during the primary survey used for habitat distribution (GLO 1853-1854) and these had small fields relative to today’s standards—approximately 1% of the land was being cultivated. A mill was also documented in the area which undoubtedly indicated some exploitation of timber in the area. A forest burn in the Tualatin Mountains may or may not have been caused by Euro-American activities. Finally, 20 years had passed since the rapid depopulation (caused by disease) of Native People residing in the Portland Basin in the 1830’s. The high population documented by Lewis and Clark and other early travelers (see Hajda 1984) may have had a significant influence on the landscape. Although particular effects are not known, if the Native Americans in the area burned to maintain grasslands (discussed below), the sudden termination of such activities would have caused significant vegetational changes within the 20 year time span from depopulation to GLO survey. In general, I maintain that the GLO survey is a reliable source of information that accurately reflects habitats in early historic and late prehistoric times.

For the following discussion, I refer the reader to Table 8.1 for important resources associated with particular habitat zones, Figure 8.3 for topography and soil distribution. In addition, Table 8.2 and Table 8.3 list flora and fauna and their respective Latin names available to the Meier inhabitance.

Figure 8.3 represents the reconstructed
Table 8.2. Mid-Willamette Valley Prairie Grasses and Associated Forbs.
(Adopted from Franklin & Dyrness 1973:121).

<table>
<thead>
<tr>
<th>Perennial Grasses</th>
<th>Common Name</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Donthonia Californica</em></td>
<td>California danthonia</td>
</tr>
<tr>
<td><em>Festuca rubra</em></td>
<td>red fescue</td>
</tr>
<tr>
<td><em>Agrostis hallii</em></td>
<td>Hall's bentgrass</td>
</tr>
<tr>
<td><em>Elymus glaucus</em></td>
<td>blue wildrye</td>
</tr>
<tr>
<td><em>Danthonia intermedia</em></td>
<td>timber danthonia</td>
</tr>
<tr>
<td><em>Stipa occidentalis var. minor</em></td>
<td>Columbia needlegrass</td>
</tr>
<tr>
<td><em>Sitanion hystrich</em></td>
<td>bottlebrush squirreltail</td>
</tr>
<tr>
<td><em>Carex spp.</em></td>
<td>(sedges etc.)</td>
</tr>
<tr>
<td><em>Dactylis glomerata</em></td>
<td>orchardgrass</td>
</tr>
<tr>
<td><em>Koeleria cristata</em></td>
<td>prairie junegrass</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Annual Grasses</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>None</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Forbs</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Ranunculus occidentalis</em></td>
<td>western buttercup</td>
</tr>
<tr>
<td><em>Vicia americana</em></td>
<td>American vetch</td>
</tr>
<tr>
<td><em>Fragaria chiloensis</em></td>
<td>coast strawberry</td>
</tr>
<tr>
<td><em>Veronica peregrine</em></td>
<td>purslane speedwell</td>
</tr>
<tr>
<td><em>Eriophyllum lanatum</em></td>
<td>common wooly sunflower</td>
</tr>
<tr>
<td><em>Achillea millefolium var. lanulosa</em></td>
<td>western yarrow</td>
</tr>
<tr>
<td><em>Sanicula bipinnatifida</em></td>
<td>purple sanicle</td>
</tr>
</tbody>
</table>

distribution of biotopes readily accessible to the Meier inhabitants based on the conglomeration of topography, soil, and early land survey data. The data suggests that all seven habitats (lacustrine, palustrine, riverain, oak-woodland, grassland, and conifer forest) plus a “brush” habitat existed within the catchment area. These habitats and resources with be described in detail below.

**Grasslands.** The nature of the Portland Basin grasslands is purely conjectural since grazing, burning and the introduction of alien species have influenced these communities. A list of grasses and forbs associated with grassland communities have been compiled by Franklin and Dyrness (1973) for the Willamette Valley. I have omitted alien species to represent as closely as possible the constituents of the habitat before Euro-American influence (Table 8.2). All of the native grasses are perennial. Habeck (1961) suggests that the shrub varieties associated with grassland include hazel, Oregon grape, rose, and ninebark. Studies done in the Willamette Valley have suggested that most grassland communities are seral. Ethnographic research suggests aboriginal burning for the maintenance of prairies throughout the East, Midwest and West. In particular, this has been documented in the Willamette Valley and Puget trough (Boyd 1986; Norton et al. 1983; Franklin and Dryness 1973; Habeck 1961). Thus in this region, much of the grasslands only exist today and existed in the past due to fire and other human disturbances and therefore are anthropogenic in origin. However, to my knowledge, no Native American burning has been documented in the Portland Basin.

Regardless of the above discussion, grasslands existed within the catchment area in 1853-1854 according to the GLO survey. These grassland habitats occurred on floodplain soils and terrace soils (Figure 8.3).

The floodplain soils are referred to as
the Sauvie-Rafton series. These are described as poorly drained silt loams and silty clay loams. This series may be divided into two types: the Rafton group which forms on concave surfaces and is characterized by ponding and wetness in winter and spring end the Sauvie group which is also poorly drained but forms on convex surfaces. Grasses as well as sedges, Oregon ash, willow, rose, common snowberry, and cattails are associated with the Rafton while the better drained Sauvie soils are typified by grasses and forbs as well as Oregon white oak, black cottonwood, common snowberry, rose, and tall Oregon grape (USGS 1986). Although the Sauvie-Rafton soil type indicates the possibility of grasslands, riparian and palustrine habitats may also occur on them. In fact, the GLO survey substantiates that all three habitats existed on the Sauvie-Rafton series. Furthermore, the Rafton silt loam exactly correlates with palustrine and lacustrine habitats documented by the GLO survey. Many of these have been drained since the survey and are presently cultivated or used for pasture. The grasslands on the flood-plain were often described in the GLO survey as grappy (refers to vine or grape) and frequently has scatterings and clumps of willows throughout. They were often narrow strips between bodies of water and “brushy” ridges and were probably naturally maintained by annual flooding (Norton et al. 1983).

The terrace soil is an excessively drained
soil referred to as the Sifton loam (USDA 1986). Included as typical associated vegetation are grasses and forbs and sparse oak and hazel. As with the flood-plain soils, other habitats may also occur on this soil type (eg. oak woodlands). The GLO survey substantiates that grasslands are associated with the terrace soils. The scappoose plains (a prairie) constitute a large portion of this area. The terrace grasslands were never described as grapy by often had scatterings of Oak (GLO 1853-1854). The plant and animal resources associated with grasslands are listed in Table 8.1. Similar to those described by Cooper in 1855, the grasslands on the terrace were likely “dry prairies”, while the floodplain grasslands were “wet prairies” (Norton et al. 1983:124-126). This is evidenced by soil type difference and survey description. The difference between the flood-plain grassland (grapy, poorly drained) and terrace grassland (well drained) undoubtedly meant different resource associations. However, the difference between the two grassland types is beyond the scope of this analysis. I refer the reader to Norton et al. (1983) for a detailed discussion grassland resource bases for the Klickitat of the Lewis River. The grasses themselves were not the important resources, but the plants and animals associated with the open areas such as scattered oak, Oregon grape, various berries, camas, and deer (Norton et al. 1983).

**Oak Woodland.** Oak woodlands are forest stands, groves, and savannas dominated by the Oregon white oak (*Quercus garryana*) with the evergreen Pacific Madron (*Arbutus meziissii*) also playing a permanent role. The main constituents of the understory include Western hazel (*Corylus cornuta*) and Saskatoon serviceberry (*Amelanchier alnifolia*) (Franklin and Dyrness 1973). In addition, Douglas-fir, common snowberry, rose, tall Oregon grape and grasses and forbs may be associates (USDA 1986). Soil distribution and GLO survey suggests that most oak woodlands occur between the Columbia flood-plain and Tualatin Hills on terrace soils described above although some also occurred on the higher ground Sauvie soils on the flood-plain. The GLO survey documents “oak groves” and “oak ridges”, as well as prairie, on this soil type. Hazel (*Corylus cornuta*) was also common as an oak associate (GLO 1853-1854). The oak woodlands would have provided a significant portion of important resources producing acorns, hazelnuts, and serviceberries (Table 8.1). The nuts would have been an important source of storable protein and is frequently mentioned in historic accounts (Norton et al. 1983; Ray 1938). In addition to vegetable resources, the oak woodland-grassland mosaic is prime habitat for many mammals, particularly white tail deer (Maser et al. 1981). For the Meier site occupants, deer were an important resource for tool raw material as well as food. This is evidenced by the huge array of bone tools made from deer metapodials.

**Conifer Forest.** Douglas fir (*Pseudotsuge mensissi*) is the most common conifer in the Portland Basin region but grand fir (*Abeis grandis*) is also a widespread conifer. The hardwoods that are typical conifer associated include the big leaf maple (*Acer macrophyllum*), Oregon white oak and Pacific Madrone (Franklin and Dyrness 1973). According to the GLO surveys, the Douglas-fir communities had cedar (western redcedar: *Thuja plicata*), maple, and/or western hemlock (*Tsugs heterophylla*) as associates, while the understory was vine, maple, hazel, alder, dogwood, “briars”, arrowwood, and young fir and hemlock. The understory of the conifer forest habitat has a high diversity of vegetal resources associated with it, particularly important were the berries (Table 8.1). Cedar played a critical role as a resource for building structures, canoes, furniture, and various other items (Ray 1938). Much of the cedar and Douglas-fir in the Tualatin Mountains was dead and fallen and a burned area was documented with young firs growing in the burn. Most Douglas-fir communities were noted in the Tualatin Mountains. Also noted in the Tualatin Mountains was an open fern ridge and scattered openings of fern. These were quite likely bracken fern, the rhizome of which was collected in the fall and was an important source of carbohydrates for Chinookan people (Ray 1938; Norton et al. 1983).

Between the Tualatin Mountains and lowlands along the Columbia, the terrain is rolling hills and the soil formations vary accordingly. The soils in this region indicate a mosaic of vegetational communities such as grasslands and oak woodlands as well as coniferous forest and the flat terrace typified by oak groves and grasslands. It is in these areas that the elk were most likely appropriated as the prefer foothill regions with semi-
open forests (Maser 1981; Larrison 1976). Elk seems to have been a very important resource to the Meier inhabitants, not only in food value, but also for tool raw material. This is indicated by the abundance of antler wedges and antler caches recovered in storage/refuse pits. Berries were probably also abundant and heavily exploited in the conifer forest and foothill region discussed above (Table 8.1).

Riparian. The riparian communities are hardwood forests typical of poorly drained sites subject to annual flooding, hence, typical of the flood-plain soils. Black cottonwood (Populus trichocarpa) is one of the most characteristic dominants along the Columbia and Willamette Rivers in the Portland Basin. On islands lining the shores these communities are commonly associated with understories of various willow (Salix spp). In addition, Oregon ash (Fraxinus latifolia) is common as an understory member in swampy and annually flooded habitats in the valleys (Franklin and Dyrness 1973). The GLO survey described most water sources as at least partially skirted by dense riparian communities (the other portion usually grapy prairie), willow being the dominant plant. Various berries and most small mammals were probably procured from this water edge habitat (Table 8.1).

Brush. While most of the lowest terrestrial area were described in the GLO survey as prairie, ridges and banks were documented as brusy, timbered with balmgelead, ash, and crabapple with a dense understorey of rose, gooseberry, blackberry, vines, and nettles. This habitat types does not fit into any of the categories mentioned by Franklin and Dyrness, Maser et al., or Saleeby, but careful investigation of GLO survey notes has led me to emphasize the substantial role these brushy habitats must have played. They occurred in the strips throughout the flood-plain and had dense berry vines and crabapples associated with them as attested by the survey. The following passages describe this habitat as observed by the surveyors:

The land consists of strips and patches of grapy prairie with willow swamps and swales and brushy ridges.

The ridges have generally a few scattering ash, balmgelead, crabapple with thick briars, vines, weeds, etc. growing on them...

Along the banks of the sloughs and streams are low ridges timbered with ash, balmgelead, crabapple etc. with a thick ridge of rosebushes, ------, vines, weeds, etc.

The GLO descriptions lead me to posit that these were a major source of crabapples and berries. Furthermore, deer may also have take refuge in such brushy ridges as the would have had easy access to “grapy” prairies and foliage within this habitat. One may call this a grassland edge habitat, but this term tends to deemphasize the significant role it must have played as a source of food.

Hater Habitats. Water habitats have been divided into three types- riverain, lacustrine and palustrine. A wide variety of descriptive terms were used to document bodies of water by the GLO surveyors. According to the surveyors, lakes, ponds, swamps, marshes, swales, creeks, bayous, channels, and sloughs divided up the “bottom lands”. Many of these, particularly on the mainland west of the Multnomah channel, have been drained for agricultural purposes and are now only represented by the Rafton silt loam described above. In fact, every area denoted on the soil survey as the Rafton silt loam was recorded as bodies of water by the GLO survey. The shapes of the soil type are almost perfect representation of the lakes, ponds, and marshes that once existed there.

Riverain. Most of the waterways on the flood-plain are best typified as lacustrine or palustrine as they were sluggish and heavily vegetated often described as marshy and/or muddy (GLO 1853-1854), not the clear waters of the riverain habitat. The three largest true riverain habitats within the catchment area are the Columbia river, Multnomah channel (Willamette slough), and Lewis river. A wide range of resources were available in this habitat including sturgeon and anadromous fish (Table 8.1). However, the catchment area did not include rapids such as Willamette falls and those in The Dalles region where salmon and steelhead extraction are most efficient and the focus of salmon fishing documented by early European travelers. The Gilbert River may also be considered riverain, GLO surveyors noted that this river has a swift ebb caused by the Columbia tide. In addition to the rivers, smaller clear run-
ning creeks drain the Tualatin Mountains. However, I do not know what resources were available from these small creeks.

Lacustrine. There were numerous lakes and ponds in the catchment area. Most of these have been drained for agricultural use. The Meier site is located on the shore of what was once a lake known as Kilmore lake. This lake is one of a string of relatively large bodies of water at the western edge of the Columbia flood-plain. In addition, most of the large lake called Sturgeon lake is within the catchment area. Many of the lakes were described as “shoal” (shallow). I expect, as did a GLO surveyor, that the shores of these lakes fluctuated significantly throughout the year, some ponds drying completely during summer months. Most of the lakes and ponds were at least partly surrounded by willows and thick brush as were many channels connecting these bodies of water. One lake was described as “…stagnant with scum around the outside that stinks”. Many lakes were described as muddy, some filled with pond lilies, a few with rushes and one with wapato. Although there was only one lake with wapato mentioned in the survey notes, absent documentation for other lakes (and ponds and marshes) with wapato is not reason to believe that wapato wasn’t present. Readers must bare in mind that the goal was a general survey, not to record all vegetation observed. Historical documentation of abundant wapato in the region should attest to its existence in lacustrine and palustrine habitats throughout the Portland Basin.

Palustrine. Many “marshes” and “swamps” were recorded during the GLO survey and are represented by the Rafton silt loam in the USDA soil survey. These were scattered throughout the flood-plain. Unfortunately, the vegetation of these was rarely documented. A few marshes and swamps were described as scattered with willow. Regardless of scanty description, the resources available from this habitat is quite easily predicted by analogy from modern examples (Table 8.1).

The flood plain is where virtually all the water habitats existed. Wapato, which grow in shallow water, is documented as a critical resource of the inhabitants of the area and is presently being intensively studied (Ames np.). The significance of Wapato is exemplified by the fact that Wapato is the traded food most often mentioned by Lewis and Clark (Hajda 1984). Sauvie island is historically well documented as having an abundance of wapato, and was concordantly called “Wappato island” by Lewis and Clark (Jones 1972:35). As I have stated, the Meier site sires on the bank of the extinct Kilmore lake. Today, Jackson creek runs along the old shore. Wapato presently grows in this creek (personal observation). I suspect that this is a remnant of the once abounding resource in the extinct lake. In addition, the one lake documented with Wapato by the GLO survey was the large lake just to the north of Kilmore lake. Unfortunately, like most other lakes and ponds, neither Kilmore lake or its shore was documented in any detail regarding Wapato or other plant resources.

In addition to the rich vegetation, the floodplain mosaic of lakes, ponds and marshes most certainly provided a temporary home for migrating waterfowl. Today, Sauvie island has a large bird refuge because of its intensive use by migrating waterfowl. In addition, sturgeon are found in the lakes and ponds of the floodplain. Sturgeon can get very large, often 10 feet or longer. I suspect that waterfowl and sturgeon have been underrated as a critical resource in the Portland Basin and both types of remains have been recovered at the Meier site in abundances (Saleeby 1983; personal observation).

Summary of Habitat and Resource Distribution

By stratifying the catchment area into uplands, terrace, and flood plain (or wetlands) we can generalize habitat distributions. The uplands are characterized by Conifer forest, the terrace by Oak woodland and grassland, and the floodplain by grassland, riparian, riverain, lacustrine, and palustrine. The excerpts from the GLO survey notes for particular townships presented in appendix B summarize their description of uplands, terrace, and floodplain regions.

All habitats identified by Franklin and Dyrness and Maser et al. For the Portland Basin, and on additional habitat I have labelled bruch, existed within the catchment area. By historic documentation and inference, we can assume that all resources associated with these habitats were available to the occupants of Meier during the ap-
propriate seasons (Table 8.1-8.3).

Flooding

It has been argued that flooding caused biseasonal movement for many village groups in the Portland Basin residing on the floodplain (Saleeby 1983). As previously mentioned, the Meier site rests on a soil transitional zone between the Columbia floodplain and terrace (Figure 8.3). Furthermore, the GLO survey documented the line of annual inundation in roughly the same area.

I should point out that the GLO surveys were during the months of September-December. A survey author estimated that the Columbia waters fluctuated approximately 20 feet throughout the year and they were surveying at mid water level approximately 8-10 ft above the lowest level of inundation (eg Appendix B:1). However, further North and closer to the Meier site, a surveyor noted that the annual inundation fluctuated between 1 and 12 ft. Regarding the area of the Meier site a surveyor commented that

“All of this township [3N1W] except a part of section 6 and 7 [where the Meier site is located], an ash ridge in sections 21 and 28 and a fir ridge in section 31 is low rich alluvial bottoms intersected with numerous lakes, ponds, marshes, and sloughs and subject to an annual inundation by the rise of the Columbia river in the months of May, June, July”.

I do not want to give the impression that the Meier site location was never flooded. The massive floods that periodically occur on the Columbia during summer flood peaks in May, June, and the beginning of July such as that which occurred in 1894 (Hodge 1938) most certainly inundated the site. These fifty or one hundred year periodic floods may account for the evidence of approximately nine reconstruction events of a plank house at the Meier site during an 800 year period (Ames np).

Given the soil transition, GLO survey documentation, and the elevation, evidence suggests that the site was located where flooding was not a yearly problem, and is therefore located in an area where year-round occupation was not inhabited by water inundation. Hence, the absence of annual flooding, yet easy access to waterways and flood-plain, conceivably added to the preference of this particular location for residence.

Archaeological Evidence: Fauna and Tools

Although the botanical remains have not been analyzed from the Meier site, Saleeby (1983) has identified and quantified faunal material from the midden area. The faunal assemblage consists of animals that inhabit all eight zones represented in the catchment area (Table 8.3 and Table 8.1). By using MNI, Saleeby estimated a total of 170 identified individuals from six 2 x 2 meter units. She grouped these into four general categories broken into percentages contributed by each taxon. Mammals consisted of the highest, representing 40% of the assemblage, followed by fish consisting (33%), birds (25%), and finally reptiles (2%). These proportions suggest that mammals and birds were a significant part of the inhabitants diet and that they were taking full advantage of the diverse habitats within the catchment area.

These faunal proportions contrast with the overwhelming emphasis that has been placed on salmon appropriation by ethnographers, ethnohistorians, and archeologists. Not only are deer and elk abundant in the assemblage (deer = 8%; elk = 5%), bu also other large and medium mammals comprising 17% of the sample. Most of these other animals are considered “fur bearing” and there seems to be some question as to their use as a food source (eg. Saleeby 1983). However, Ray (1938:118) presents a list of animals hunted for food by the Coastal Chinookans. Within this list are numerous fur bearing animals- bobcat, cougar, raccoon, beaver, squirrel, mink, and mountain beaver. These are all represented at the Meier site and there is no reason to presume that they were not used for food.

The non-food value of deer and elk was mentioned in the habitat distribution section of this paper. To further substantiate the importance of these animals as a resource, there is substantial evidence that the deer and elk long bones were used for bone marrow extraction and possibly bone grease production (Hamilton np.). This adds to the inventory of nutritional needs provided by the habitats of the Meier site catchment area.

All skeletal parts of deer and elk were represented at the site, suggestion that they were
Table 8.4. Archaeologically Recovered Fauna from the Meier Site (Saleeby 1983) and Seasons Available (Burchard 1989:6-8).

<table>
<thead>
<tr>
<th>Latin Name</th>
<th>Common Name</th>
<th>Type</th>
<th>Season</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mammal</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Odocoileus sp.</td>
<td>Deer</td>
<td>Md.</td>
<td>SpAW</td>
</tr>
<tr>
<td>Cervus canadensis</td>
<td>Elk</td>
<td>Lg.</td>
<td>AW</td>
</tr>
<tr>
<td>Ursus americanus</td>
<td>Black Bear</td>
<td>Lg.</td>
<td>AW</td>
</tr>
<tr>
<td>Lynx rufus</td>
<td>Bobcat</td>
<td>Med.</td>
<td>?</td>
</tr>
<tr>
<td>Castor canadensis</td>
<td>Beaver</td>
<td>Sm.</td>
<td>SpSuAW</td>
</tr>
<tr>
<td>Procyon lotor</td>
<td>Raccoon</td>
<td>Sm.</td>
<td>?</td>
</tr>
<tr>
<td>Canis sp.</td>
<td>Dog/Coyote</td>
<td>Sm.</td>
<td>SpSuAW</td>
</tr>
<tr>
<td>Phoca vitulina</td>
<td>Harbor seal</td>
<td>Med.</td>
<td>Sp</td>
</tr>
<tr>
<td>Felis concolor*</td>
<td>Puma</td>
<td>Lg.</td>
<td>SpSuAW</td>
</tr>
<tr>
<td>Vulpes fulva</td>
<td>Red fox</td>
<td>Sm.</td>
<td>SpSuAW</td>
</tr>
<tr>
<td>Martis americana</td>
<td>Marten</td>
<td>Sm.</td>
<td>SpSuAW</td>
</tr>
<tr>
<td>Lutra canadensis</td>
<td>River otter</td>
<td>Sm.</td>
<td>?</td>
</tr>
<tr>
<td>Ondatra zibethica</td>
<td>Muskrat</td>
<td>Sm.</td>
<td>SpSuAW</td>
</tr>
<tr>
<td>Mustela vison</td>
<td>Mink</td>
<td>Sm.</td>
<td>SpSuAW</td>
</tr>
<tr>
<td>Sylvilagus bachmani</td>
<td>Brush rabbit</td>
<td>Sm.</td>
<td>SpSuA</td>
</tr>
<tr>
<td>aplodontia rufa</td>
<td>Mountain beaver</td>
<td>Sm.</td>
<td>SpSuAW</td>
</tr>
<tr>
<td>scapanus townsendi</td>
<td>Mole</td>
<td>Sm.</td>
<td>?</td>
</tr>
<tr>
<td><strong>Reptile</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Testudinidae sp.</td>
<td>Freshwater turtles</td>
<td>Sm.</td>
<td>SpSuA</td>
</tr>
<tr>
<td><strong>Bird</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Anus sp.</td>
<td>Dabbling ducks</td>
<td>Migratory</td>
<td>AW</td>
</tr>
<tr>
<td>Anus crecca</td>
<td>Common Teal</td>
<td>Migratory</td>
<td></td>
</tr>
<tr>
<td>Aix sponsa</td>
<td>Wood duck</td>
<td>Migratory</td>
<td>Su</td>
</tr>
<tr>
<td>Branta canadensis</td>
<td>Canada goose</td>
<td>Migratory</td>
<td>AW</td>
</tr>
<tr>
<td>Branta/Anser/Chen sp.</td>
<td>Goose</td>
<td>Migratory</td>
<td>AW</td>
</tr>
<tr>
<td>Cygnus</td>
<td>Swan</td>
<td>Migratory</td>
<td>AW</td>
</tr>
<tr>
<td>Grus canadensis</td>
<td>Sandhill crane</td>
<td>Migratory</td>
<td>SpA</td>
</tr>
<tr>
<td>Buteo jamaicensis</td>
<td>Red tailed hawk</td>
<td>Non-mig.</td>
<td>SpSuAW</td>
</tr>
<tr>
<td>Megaceryle alcyon</td>
<td>Kingfisher</td>
<td>Non-mig.</td>
<td>SpSuAW</td>
</tr>
<tr>
<td>Colaptes auratus</td>
<td>Flicker</td>
<td>Non-mig.</td>
<td>SpSuAW</td>
</tr>
<tr>
<td>Corvus brachyrybchos</td>
<td>Crow</td>
<td>Non-mig.</td>
<td>SpSuAW</td>
</tr>
<tr>
<td><strong>Fish</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ptychocheilus oregonensis</td>
<td>Squawfish</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mylocheilus caurinus</td>
<td>Peamouth chub</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Acrocheilus alutaceus</td>
<td>Chiselmouth</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gila bicolor</td>
<td>Tui chub</td>
<td></td>
<td></td>
</tr>
<tr>
<td>cyprinid</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Catostomus macrocheilus</td>
<td>Sucker</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cyprinid/Catostomid</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Acipsenser transmontanus</td>
<td>White Sturgeon</td>
<td>Lg. Anadrs.</td>
<td>SpW</td>
</tr>
<tr>
<td>Oncornynchus/Salmo gairdneri</td>
<td>Salmon/Steelhead trout</td>
<td>Lg./Med. Anadrs.</td>
<td>SpSuAW</td>
</tr>
<tr>
<td>Thaleichythus pacificus</td>
<td>Eulachon (smelt)</td>
<td>Sm. Anadrs.</td>
<td>SP</td>
</tr>
<tr>
<td><strong>Shellfish</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Margnritifera sp./Anodonta sp.</td>
<td>Freshwater Mussel</td>
<td>Shellfish</td>
<td>A</td>
</tr>
</tbody>
</table>

*Identified by Kaye Reed (np.)
either killed close to the village or efficiently transported by canoe. In addition, skeletal parts of salmon and other anadromous fish were present at the site indicating that the inhabitants of the site caught and processed fish rather than merely relying on traded fish with bones already removed for preservation and trade. The removal of bone is also typical of chinooken preservation techniques for storage and trade of other animal meats (Saleeby 1983). Thus, it can be inferred that the occupants were collecting these resources within their catchment territory and processing them at the site. Furthermore, the recovery of all skeletal parts at the site indicated that it was occupied during the season of exploitation of these resources—mammals, birds, and fish. Saleeby (1983) also notes that the faunal assemblage at the site was not found to change significantly over time, suggesting an unchanging hunting/fishing pattern throughout the site’s occupation.

Artifacts recovered at the site suggest a wide range of animal and plant processing activities. Tools for capture of resources recovered from the site consist of net-weights, projectile points, and harpoon points for animal capture (Ames np.), and digging sticks for plant extraction (Pettigrew 1981). Plant and animal processing utensils recovered include pestles, mauls, mortars, and anvils (Ames np). In addition, excavators recovered numerous used flakes and three mule ear knives which were both probably used for a variety of food and material processing and production tasks.

**Lithic Raw Material**

The availability of lithic raw material has become an increasingly investigated aspect of the study of settlement systems. The type, availability, and distribution of raw material within a catchment area affects the production technologies and types of tools produced at the particular site. Without going into detail, if raw material is scarce or has to be procured from a long distance away, then people will consciously preserve as much of the material as possible by making multipurpose curated tools such as bifaces. On the other hand, if an abundance of raw material is available expedient tools that waste raw material but save time in production may be used. A detailed lithic analysis is needed to elucidate the technological variable represented at the site. To facilitate a lithic analysis relating to settlement system and lithic assemblage, the sources of raw material used at the site must be located as closely as possible.

Most fine-grained raw material represented at the site is cryptocrystalline silicates (CCS). Corticile evidence on the CCS as well as the much less abundant obsidian suggests river wear. The gravel bars in stream, river, and lake beds in all of Multnomah county and presumably many in Columbia county have CCS cobbles in abundance (Eckery 1987; Hamilton np). Because damming has limited river fluctuation compared to the past, it is difficult to locate such gravel deposits in the catchment area. Nevertheless, the residents of the Meier site exploited these gravels, probably in the catchment area. Exploitation of the gravel bars may have occurred primarily during dry seasons when gravels were most exposed. Nevertheless, exposed gravel and/or sandbars along the Columbia within the catchment area were noted and mapped by GLP surveyors during what they claimed to be mid-water level.

In addition to fine-grained lithic material, many larger lithic tools such as hammerstones and mauls were produced from quartzite, basalt, dacite and other coarse-grained heavily water worn cobbles. The terrace soils described above and the Meier site sit on a large gravel bar formed by the Missoula floods about 17,000 years ago. These flood deposits have an abundance of large cobbles and were most likely the source of material for such tools. These cobbles would have been found at the site during excavation of the foundation for the house structure and associated pits and along banks of channels and lakes. The cobbles may also have been collected in river gravel bars further from the site, but given the abundance in the immediate area, this seems unlikely.

**Faunal Seasonality**

All mammals represented at the site are non-migratory except the elk, which migrate from their summer upland range to lower elevations after the fall rut (Maser 1981; Tables 8.4-8.5). However, although the mammals were conceivably available year round, the particular habits of some mammals make it more likely that they were exploited during specific seasons. Saleeby (1983)
<table>
<thead>
<tr>
<th>Fauna</th>
<th>Habitat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deer</td>
<td>Riparian, Grassland</td>
</tr>
<tr>
<td>Beaver</td>
<td>Lacustrine, Palustrine</td>
</tr>
<tr>
<td>Ground</td>
<td>Grassland</td>
</tr>
<tr>
<td>Squirrel</td>
<td></td>
</tr>
<tr>
<td>Brush Rabbit</td>
<td>Riparian</td>
</tr>
<tr>
<td>Red Fox</td>
<td>Grassland, (uplands)</td>
</tr>
<tr>
<td>Raccoon</td>
<td>Riverain. Lacustrine, Palustrine</td>
</tr>
<tr>
<td>Mt. Beaver</td>
<td>Conifer Frst.</td>
</tr>
<tr>
<td>Marten</td>
<td>Conifer Frst.</td>
</tr>
<tr>
<td>Puma</td>
<td>Conifer Frst., Oak Woodland</td>
</tr>
<tr>
<td>Harbor Seal</td>
<td>Riverain (main channels)</td>
</tr>
<tr>
<td>Mink</td>
<td>Riverain, Lacustrine, Riparian</td>
</tr>
<tr>
<td>Muskrat</td>
<td>Lacustrine, Palustrine</td>
</tr>
<tr>
<td>Salmon</td>
<td>Riverain</td>
</tr>
<tr>
<td>Steelhead</td>
<td>Riverain</td>
</tr>
<tr>
<td>Trout</td>
<td></td>
</tr>
<tr>
<td>Sturgeon</td>
<td>Riverain</td>
</tr>
<tr>
<td>Eulachon</td>
<td>Riverain</td>
</tr>
<tr>
<td>Sandhill crane</td>
<td>Palustrine, Grassland</td>
</tr>
<tr>
<td>Flora</td>
<td>Wild Conifer Frst., Grassland</td>
</tr>
<tr>
<td>Strawberry</td>
<td></td>
</tr>
<tr>
<td>Camas (!)</td>
<td>Grassland</td>
</tr>
<tr>
<td>Bracken Fern</td>
<td>Grassland</td>
</tr>
<tr>
<td>Wood Sorrel</td>
<td>Conifer Frst., Riparian</td>
</tr>
<tr>
<td>Horsetail</td>
<td>Palustrine</td>
</tr>
<tr>
<td>Cow Parsnip</td>
<td>Riparian</td>
</tr>
<tr>
<td>Wild Celery</td>
<td>Riparian</td>
</tr>
</tbody>
</table>

**Spring**

<table>
<thead>
<tr>
<th>Fauna</th>
<th>Habitat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beaver</td>
<td>Lacustrine, Palustrine</td>
</tr>
<tr>
<td>Ground</td>
<td>Grasslands</td>
</tr>
<tr>
<td>Squirrel</td>
<td></td>
</tr>
<tr>
<td>Mink</td>
<td>Riverain, Lacustrine, Riparian</td>
</tr>
<tr>
<td>Muskrat</td>
<td>Lacustrine, Palustrine</td>
</tr>
<tr>
<td>Brush Rabbit</td>
<td>Riparian</td>
</tr>
<tr>
<td>Red Fox</td>
<td>Grasslands, Conifer Frst.</td>
</tr>
<tr>
<td>Mt. Beaver</td>
<td>Conifer Frst.</td>
</tr>
<tr>
<td>Marten</td>
<td>Conifer Frst.</td>
</tr>
<tr>
<td>Puma</td>
<td>Conifer Frst., Oak Woodland</td>
</tr>
<tr>
<td>Salmon</td>
<td>Riverain</td>
</tr>
<tr>
<td>Steelhead</td>
<td>Riverain</td>
</tr>
<tr>
<td>Trout</td>
<td></td>
</tr>
<tr>
<td>Goose</td>
<td>Grasslands, Lacustrine, Palustrine, Riparian</td>
</tr>
<tr>
<td>Wood Duck</td>
<td>Lacustrine, Palustrine, Riparian</td>
</tr>
<tr>
<td>Flicker</td>
<td>Riparian, Palustrine</td>
</tr>
</tbody>
</table>

**Summer**
<table>
<thead>
<tr>
<th>Fauna</th>
<th>Resource Habitat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deer (!)</td>
<td>Riparian, Oak Woodland, Grasslands, Conifer Frst.</td>
</tr>
<tr>
<td>Elk (!)</td>
<td>Conifer Frst., Oak Woodland</td>
</tr>
<tr>
<td>Black Bear</td>
<td>Conifer Frst.</td>
</tr>
<tr>
<td>Puma</td>
<td>Conifer Frst., Oak Woodland</td>
</tr>
<tr>
<td>Beaver</td>
<td>Lacustrine, Palustrine</td>
</tr>
<tr>
<td>Ground</td>
<td>Grasslands</td>
</tr>
<tr>
<td>Squirrel</td>
<td></td>
</tr>
<tr>
<td>Mink</td>
<td>Riverain, Lacustrine, Riparian</td>
</tr>
<tr>
<td>Muskrat</td>
<td>Lacustrine, Palustrine</td>
</tr>
<tr>
<td>Brush Rabbit</td>
<td>Riparian</td>
</tr>
<tr>
<td>Red Fox</td>
<td>Grasslands</td>
</tr>
<tr>
<td>Mt. Beaver</td>
<td>Conifer Frst.</td>
</tr>
<tr>
<td>Marten</td>
<td>Conifer Frst.</td>
</tr>
<tr>
<td>Mink</td>
<td>Riverain, Palustrine</td>
</tr>
<tr>
<td>Salmon</td>
<td>Riverain</td>
</tr>
<tr>
<td>Swan</td>
<td></td>
</tr>
<tr>
<td>Goose</td>
<td></td>
</tr>
<tr>
<td>Crow</td>
<td></td>
</tr>
<tr>
<td>Kingfisher</td>
<td></td>
</tr>
<tr>
<td>Flicker</td>
<td></td>
</tr>
<tr>
<td>Freshwater</td>
<td>Riverain</td>
</tr>
<tr>
<td>Mussel</td>
<td></td>
</tr>
<tr>
<td>Flora</td>
<td>Service Berry Conifer Frsts.</td>
</tr>
<tr>
<td></td>
<td>Hazelnuts Oak Woodlands</td>
</tr>
</tbody>
</table>

Table 8.5 cont. on next page
Table 8.5 cont.

<table>
<thead>
<tr>
<th>Resource</th>
<th>Habitat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acorns</td>
<td>Oak Woodlands</td>
</tr>
<tr>
<td>Crabapple</td>
<td>Grasslands (edge)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Winter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fauna</td>
</tr>
<tr>
<td>Deer (!)</td>
</tr>
<tr>
<td>Elk (!)</td>
</tr>
<tr>
<td>Black Bear</td>
</tr>
<tr>
<td>Puma</td>
</tr>
<tr>
<td>Beaver</td>
</tr>
<tr>
<td>Mink</td>
</tr>
<tr>
<td>Muskrat</td>
</tr>
<tr>
<td>Red Fox</td>
</tr>
<tr>
<td>Mt. Beaver</td>
</tr>
<tr>
<td>Marten</td>
</tr>
<tr>
<td>White</td>
</tr>
<tr>
<td>Sturgeon</td>
</tr>
<tr>
<td>Salmon (Chinook)</td>
</tr>
<tr>
<td>Stealhead</td>
</tr>
<tr>
<td>Trout</td>
</tr>
<tr>
<td>Dabbling Duck</td>
</tr>
<tr>
<td>Goose</td>
</tr>
<tr>
<td>Flicker</td>
</tr>
<tr>
<td>Crow</td>
</tr>
<tr>
<td>Kingfisher</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Flora</th>
</tr>
</thead>
<tbody>
<tr>
<td>(none)</td>
</tr>
</tbody>
</table>

Table 8.6. Ethnohistorically Known Season of Exploitation of Food Resources (Saleeby 1981:64).

<table>
<thead>
<tr>
<th></th>
<th>Spring</th>
<th>Summer</th>
<th>Fall</th>
<th>Winter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Salmon</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Sturgeon</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Eulachon</td>
<td>X</td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Land Mammals</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Migratory Birds</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wapato</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Berries</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Roots</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Other Plants</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stored Food</td>
<td>X</td>
<td>X</td>
<td></td>
<td>X</td>
</tr>
</tbody>
</table>

564
accounted for this seasonal variation using ethnohistoric data. She constructed tables representing ethnographically documented seasons of exploitation (Table 8.5) and the most likely season of exploitation (Table 8.6). Table 8.5 and Table 8.6 of this report are unmodified versions of those tables.

Waterfowl are present for three seasons in the Portland Basin (Table 8.3-8.4). During the fall they migrate southward from their breeding grounds. Some ducks and geese remain to winter in the wetland habitats. In the spring, great numbers pass through again when headed back north. The importance of this resource is substantiated by the high proportion of these in the Meier site assemblage and indirectly by their abundance today in the wetlands of the Portland Basin. Table 8.5 and 8.6 represent the seasons waterfowl were more likely exploited (Saleeby 1983).

Eulachon run in the winter and early spring. With the eulachon, sturgeon become more accessible as they come to shallow water while feeding on these small fish. However, eulachon runs are quite variable from year to year, possibly depending on water temperature and volume (Hajda 1984). These spring runs (including early salmon runs) were particularly important, as other food sources are not abundant at this time of year and stored foods may have been running low. Lake and pond Sturgeon may also have played an important role during this time. Runs of at least one of the five species of Pacific salmon and steelhead trout occur in every season in the Columbia (Table 8.8). Saleeby (1983) suggests that spring, summer and fall are the most likely times of exploitation of salmon resources (Table 8.5-8.6). To efficiently exploit these in high quantities, however, the inhabitation would probably have gone outside the one-day catchment areas defined here to either the Willamette Rapids or those up the Columbia nears the Dalles (eg. Cascade Rapids). Nevertheless, some were undoubtedly captured within the catchment area as evidenced archaeologically by their remains discussed above. Furthermore, this analysis supports the contention that such a trip (or exchange) may not have been necessary unless the population density of the Meier village or surrounding area (discussed below) was at such a level as to over-exploit the resources in the immediate catchment area.

Saleeby (1983:35-36) gives a brief review of ethnohistoric accounts on seasonality
Table 8.8. Salmon Species and Seasonal Runs (Ray 1938:107).

<table>
<thead>
<tr>
<th>Name</th>
<th>Latin Name</th>
<th>Months</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chinook</td>
<td><em>O. tschawytscha</em></td>
<td>Jan-Mar</td>
</tr>
<tr>
<td></td>
<td></td>
<td>May-early June</td>
</tr>
<tr>
<td></td>
<td></td>
<td>late July-early Oct</td>
</tr>
<tr>
<td>Sockeye</td>
<td><em>O. nerka</em></td>
<td>May-early June</td>
</tr>
<tr>
<td>Coho</td>
<td><em>O. kisutchka</em></td>
<td>July-Nov</td>
</tr>
<tr>
<td>humback</td>
<td><em>O. gorbuscha</em></td>
<td>not abundant</td>
</tr>
<tr>
<td>chum/dog</td>
<td><em>O. keta</em></td>
<td>mid Aug-late Nov</td>
</tr>
</tbody>
</table>

............... = available
+++++++ = most likely exploited

Table 8.9. Lewis and Clark’s Population Estimates of Villages (Hajda 1984:69) in the Portland Basin that Shared Catchment Areas with the Meier Site (supporting it was contemporaneous).

<table>
<thead>
<tr>
<th>Village</th>
<th>Spring Population</th>
<th>Fall Population</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>27</td>
<td>900</td>
<td>300</td>
<td></td>
</tr>
<tr>
<td>28</td>
<td>280</td>
<td></td>
<td></td>
</tr>
<tr>
<td>29</td>
<td>450</td>
<td>150</td>
<td></td>
</tr>
<tr>
<td>30</td>
<td>200</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>31</td>
<td>1200</td>
<td>350</td>
<td></td>
</tr>
<tr>
<td>32</td>
<td>400</td>
<td>150</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>3430</td>
<td>1050</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Total within Meier cathchment area</td>
</tr>
<tr>
<td>33</td>
<td>170</td>
<td>70</td>
<td></td>
</tr>
<tr>
<td>34</td>
<td>200</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>35</td>
<td>130</td>
<td></td>
<td></td>
</tr>
<tr>
<td>36</td>
<td>800</td>
<td>200</td>
<td></td>
</tr>
<tr>
<td>37</td>
<td>460</td>
<td>160</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>5190</td>
<td>1580</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Total that shared catchment areas</td>
</tr>
</tbody>
</table>
of appropriation in the Portland Basin. A summer of this follows. In spring, early smelt runs were exploited as were the sturgeon feeding on these smelt. Salmon was the predominant subsistence activity during the latter part of the season as was sprout and berry collecting. Finally, root collecting, was important throughout the season. During the summer roots, sprouts, and abundant berries were collected while the primary subsistence activity was salmon appropriation. In the fall there were an abundance of plants harvested including, in particular, Wapato. Salmon fishing continues into early fall but stored food began to be used. Finally, in winter harvesting eulachon and sturgeon were the primary subsistence activities. A perennial source of food was wapato. Although the reports that Saleeby presented for the Portland Basin do not mention the use of mammals and birds, it is obvious from the archaeological record that these taxa were also an important part of the Meier occupant’s resource base.

**Preservation, Storage and Exchange**

Storage may have played an essential role to sedentism. The Chinookan people had preservation technology for vegetable and animal foods. Historic accounts remark on the drying of salmon, smelt, and mammal meat and the storage of wapato (see Ray 1936; Jones 1972; Hajda 1984; Saleeby 1983). Thus, even if fresh resources were in short supply during particular seasons, such as in spring, they had at hand the technology to be prepared by the use of resource “back-ups”.

Exchange of resources through social networks is another factor to consider for the possibility of sedentism. There are numerous accounts of exchange throughout the Lower Columbia region. For example, Henry Biddle (1926 cited in Hajda 1984) reported that the Clackstars, a village group residing at the mouth of Multnomah channel, traded food items with the Tillimooks of the coast. From ethnohistoric and ethnographic data, Hajda (1984) suggests that the Chinookans engages in widespread and local exchange through kinship ties at the village and individual level. The widespread exchange network, based on social relations, would have enhanced the possibility of sedentism by distributing important resources not available in particular areas. Thus, storage and exchange could have functioned to distribute resources that were clumped in space and time, further facilitating sedentism.

**High Population and Neighbors’ Influence**

Neighboring villages and their appropriate activities undoubtedly influenced the way in which the Meier site occupants interacted with the surrounding environment. Wobst (1976) contends that social and population variables are at least as important as the natural environmental factors influencing site location. In particular, the surrounding inhabitants of other communities certainly exploited a substantial part of the habitats within the site catchment area defined here. Hajda (1984) argues that historic data does not support the division of land for exploitation of resources by particular groups except in fishing rights. Nevertheless, the sharing of resources found within catchment area by other inhabitants of the region does have an impact on resource availability, particularly in a region with a high density population such as the Sauvie Island area.

A study on population density and village site locations using both archaeological and historical documentation would facilitate explicating influences of resource use within the Meier catchment by neighboring inhabitants. Undoubtedly, contemporaneous villages existed within the catchment area at any given time of occupation. For example, Lewis and Clark mapped villages that they saw in the area during their travels along the Columbia River. If we suppose that the Meier site was in existence at the time (although no evidence suggests this), according to their observations, 6 villages were within the catchment area and 5 other just outside the boundary. All 11 of these villages plus the Meier site would have had overlapping site catchment areas and therefore would have affected one another’s exploitation systems. Hajda (1984) has collected population data for the area based on Lewis and Clark’s estimates. The six sites within the catchment area had a population totaling 3430 during spring and 1050 during the fall (Table 8.9). If we include the four sites just outside the catchment area, but with overlapping catchments, the population rises to 5020 and 1510 respectively. The high population obviously played a crucial role in determining catchment areas and influenced the resources available within them.
Although the Meier site was not necessarily occupied at this time, I presume there was a similar situation contemporaneous with its occupation. I predict the actual area exploited in a days travel by Meier site people was probably smaller to avoid other village’s immediate surroundings, although kinship ties may have stabilized this effect somewhat. The task of figuring out such an analytic component in any detail is beyond the scope of the present analysis. As discussed earlier, this analysis focuses on the man-land relationship of the Meier site, not man-man relationships, which gets into the realm of social dynamics with surrounding populations as Wobst suggests.

*Why was the Meier site located at this particular location in the Portland Basin?*

The answer I provide for this particular question is purely conjectural and I only account for some simple environmental factors discussed above. The Meier site sits at the boundary between the flood-plain and the terrace but also has the uplands within a one day exploitation distance. Elk, deer, cedar, and bracken fern were readily available in the upland and rolling hills area. In addition, to abundant berries were available on the terrace area adjacent to the site and in the rolling hills and uplands. The Meier site is located where a lake channel (presently Jackson creek) would have allowed waterway access year round. This relatively large lake, as well as others in the immediate area, most likely contained an abundance of wapato, migratory waterfowl, and sturgeon among other lacustrine resources. To the west an relatively large oak grove allowed easy access to acorns and hazelnuts. Deer were most certainly in close proximity. Annual flooding was not a problem, yet the site had immediate access to abundant floodplain resources from the grassland, brush, and various habitats. Given the village distribution provided by Lewis and Clark, surrounding villages would not have impeded access to these immediate habitats.

**Conclusion**

All seven Portland Basin habitats exist within the Meier site catchment area: conifer forest in the Tualatin Hills; oak woodland and grassland on the terrace; lacustrine, palustrine, riparian, and grassland on the floodplain. Riverian habitats were also located on the floodplain represented by the Columbia river, Multnomah channel, Gilbert river, and the mouth of the Lewis river. This mosaic of habitats allowed for a wide range of biotic resources. Archaeological faunal material demonstrates the variety of animals appropriated and reflects high diversity of the ecological setting in the catchment area.

Complete sedentism requires year-round availability of food resources within the catchment area. The range of habitats in the catchment area could have supplied them with the needed resources. Furthermore, the faunal assemblage has the required species to cover dietary needs throughout the year. In other words, there was a seasonal distribution of fauna that were representative of every season.

Seasonality of archaeological material, however, does not give undisputable empirical evidence of year-round occupation. As Saleeby (1083) maintains, there are two possible interpretations for the presence/absence of these seasonal taxa: (1) the site was occupied year round, or (2) the site was a “winter” village. If the site was only occupied during fall and winter, all the species listed were available to the site’s inhabitants (Table 8.4, 8.6). Regardless, there is no evidence to suggest that the site was not occupied during the summer or spring.

To conclude, site catchment analysis suggests that possibility of year-round occupation of the Meier site for the following reasons: (1) the site is located where necessary food resources were available for the entire year; (2) the site was in a location where frequent periodic flooding was not a problem. To relieve possible seasonal stresses, the inhabitants of the Meier site could have stored abundant seasonal resources and participated in the local and regional food exchange network. In addition, longer procurement forays, outside the one day catchment area advocated here, could have supplemented the resource base.
REFERENCES CITED

Boyd, Robert

Boyd, T. Robert and Yvonne P. Hajda

Burtchard, Greg C.
1989 Archaeological Evaluation of the Trojan Locality, 35CO1. Laboratory of Archaeology and Anthropology, Department of Anthropology. Portland State University, Portland.

Dunnell, R.C., J.C. Chatters, and L.V. Salo

Eckert, Allan W.

Flannery, Kent V.

Franklin, Jerry F. and C.T. Dyrness

Habbeck, James R.

Hajda, Yvonne

Hodge, Edwin T.

Jones, Roy T.

Larrison, Earl J.

Lee, Richard B.

Lyman, R.L.

Maser, Chris, Bruce R. Mate, Jerry F. Franklin, and C.T. Dyrness

Minor, Rick

Norton, Helen H., Robert Boyd, and Eugene S. Hunn
Ray, Verne  
1938 *Lower Chinook Ethnographic Notes.*  

Roper, Donna C.  

Saleeby, Becky M.  

Saleeby, Becky M. and R. Pettigrew  

U.S. Department of Agriculture  
1986 *Soil Survey of Columbia County, Oregon.*

U.S. Department of Interior  
1979 *Vancouver, Washington-Oregon, N4530-W12200/30X60.*

1979 *St. Helens Quadrangle: Oregon-Washington.*

U.S. Government Land Office  
1853-1854 *Willamette Meridian T2N,R1W; T3N,R1W; T4N,R1W; T2N,R2W; T3N, R2W* (maps and survey notes).
PART IX

POSTSCRIPT TO GEOARCHAEOLOGY AND MISCELLANEOUS REPORTS: CATHLAPOTHE AND MEIER ARCHAELOGICAL SITES, LOWER COLUMBIA RIVER

Kenneth M. Ames

July 2017
Geoarchaeology

Landform History

Cathlapotle. Hodges (This Volume) infers that the Brush Ridge landform is a point bar that began forming before ca. 670 cal BP (AD 1280) and the village was established there shortly thereafter. This inference is supported by a recent re-analysis (Ames and Brown 2015) Figure 9.7 West end of N52-54/W99-105 trench showing dipping beds at bottom. Our inference is that this is near the Lake River bank when the site was initially occupied. House 6 including a wall trench is visible in the upper right-hand corner.1 of the Cathlapotle radiocarbon dates that places its founding to ca. AD 1350 (600 calBP). Three dates from augers south of House 6 (Ames and Sobel 2009) also generally fit with his scenario: AD 930 – 1290 (920±201, TX7742), AD 1170- 1410 (720±150, TX7745), and AD 1180 – 1410 (740±140 TX7744) (Ames and Sobel 20092). The first two dates are in stratigraphic order and near the base of one auger (92-19) and the latter date from the base of a second auger (92-17), both taken as part of the preliminary testing of the site. They do not refine Hodges’ chronology but confirm he is in the right temporal ball park. However, this tidy picture does not account for the 2346±53 BP date cited in the preface to this volume. That date is on charcoal collected within a midden lens in the scroll ridge immediately in front of House 13, suggesting that some portion at least Brush Ridge was available and used well before the village was placed there. Either that, or the date is wrong. There are more or less contemporary dates in the immediate vicinity, at 45CL4 (Minor and Toepel 1984, 1993)

1 I apologize for having to cite a conference paper for this crucial analysis. It would have been preferable to publish the analysis as a paper before discussing its results in these reports. However, the time and fiscal budget for getting the reports done meant that paper has to wait.

2 In addition to that publication, the Cathlapotle and Meier radiocarbon dates are available on CARD: the Canadian Archaeological Radiocarbon Database (http://www.canadianarchaeology.ca/).

3 The three houses in the back house row at Cathlapotle, Houses 1 – 3, were built by taking advantage of the scroll and swale topography. They were set on the scroll ridges, straddling a small swale. The ridges were heightened with spoils from digging out the swale for the house floors and cellar complexes. The 2300 year date was taken from deposits beneath those spoils.
Figure 9.1. 20 cm contour map of the Cathlapotle landform, the houses, 1994 excavations and core locations. The village is on Brush Ridge, which rises to about 7 m. The two sets of scroll ridges in front of it are visible as is the swale that was probably the channel of Lake River when the site was initially occupied.

River to ease access.

*Meier.* We have not equivalent data for the history of the landform on which Meier sits. It is on the edge of a terrace overlooking an extensive wetland-lake system lying between the terrace and Multnomah Channel. Johnson Creek currently flows along the terrace edge, separating it from the farm land occupying the now-drained wetlands. The terrace is the eastern edge of the Scappoose plain which is underlain by ancient gravels. We have no data on when the terrace was cut. The wetlands no doubt formed as the Columbia River rose because of post-glacial sea level rise.

Our current analysis suggests the site was founded ca. AD 1000 and the house PSU excavated ca. AD 1400 (Brown and Ames 2015). The site’s midden deposits cover the bank of Johnson Creek and Pettigrew’s original test excavations appears to have been into those deposits, although we could not relocate his excavations. Pettigrew (1981) ran a single radiocarbon sample producing a date of 720±75 (GAK 5568) which has a calibrated age span of AD 1167-1403. In a recent round of radiocarbon dating, we procured a date of 1031±31 (D-AMS 007678) which has a two sigma calibrated age span of AD 967-1037. The sample, charred nut shells, was recovered at the base of cellar fill in the house excavated by PSU. We regard it as intrusive from older deposits west of the house since all other dates from the house strongly support the AD 1400 founding date for it. We believe there was at least one earlier house represented by the deep deposits between the house we excavated and the midden sampled by Pettigrew.

The PSU house’s cellar was excavated into the underlying gravels, which were exposed in some portions of the house’s cellar (Ames et al.
Figure 9.2. Three dimensional rendering of the Cathlapotle landform based on the map in Figure 9.1; panel a shows the landform without the houses, panel b with the houses outlined. 5x vertical exaggeration. Map prepared by Tyler Vick, Maul, Foster & Alongi, Inc.
Figure 9.3. Locations of trenches in Figures 9.4 – 9.7. A is trench N159-160/W79-103 (Figures 4 -6); B is Trench N52-54/W99-103.
Figure 9.4. Central portion (N159/W83-95) of N159-160/W79-103 trench bisecting House 1D.

Figure 9.5. East portion (N159/W79-88) of N159-160/W79-103 trench bisecting House 1D.
1992, 2008) (Figure 9.9) but not others. It seems likely that the bar had an irregular surface which the house’s builders used to their advantage. Otherwise, digging the house’s massive cellar out of the gravels required considerable labor with the hand tools of the day. That excavation would have generated spoils, including piles of gravel, which we did not find.

We do not know why Meier was established in this location when it was. The location itself is excellent, with access to a diverse range of habitats (Hamilton i.p.), and canoe access to Multnomah Channel and the Columbia River. The question is not why it was placed where it was, but why at the time it was. One possible answer, of course, is the Bridge of the Gods flood reorganized the floodplain making this spot more appealing, or even creating it. White’s particle size analysis is germane to that issue and to others. I turn to that before discussing flooding.

**Particle Size Analysis**

White (This Volume) found that the parent material for the dirt comprising the Meier and Cathlapotle sites to be silty-sands. Variation between them is readily explained as minor facies differences attributable to their differing locations on the flood plain. The silty-sands are alluvial, and he concluded they accumulated slowly, with no major flood events, a result which parallels Hodges’ sediment analysis for Cathlapotle, although there is clear geomorphic and stratigraphic evidence for flooding at Cathlapotle. The samples from both sites also had plentiful cultural debris including bone, charcoal, shell etc.

<table>
<thead>
<tr>
<th>Meier</th>
<th>%OM</th>
<th>% Gravel</th>
<th>% Fines</th>
<th>% Sand</th>
<th>% Clay</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>10.22</td>
<td>12.45</td>
<td>87.55</td>
<td>54.05</td>
<td>6.02</td>
</tr>
<tr>
<td>Std Dev</td>
<td>3.07</td>
<td>7.08</td>
<td>7.08</td>
<td>9.30</td>
<td>2.19</td>
</tr>
<tr>
<td>CV</td>
<td>0.30</td>
<td>0.57</td>
<td>0.08</td>
<td>0.17</td>
<td>0.36</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Cathlapotle</th>
<th>%OM</th>
<th>% Gravel</th>
<th>% Fines</th>
<th>% Sand</th>
<th>% Clay</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>5.24</td>
<td>2.32</td>
<td>97.68</td>
<td>60.75</td>
<td>4.26</td>
</tr>
<tr>
<td>Std Dev</td>
<td>1.75</td>
<td>4.04</td>
<td>4.04</td>
<td>5.02</td>
<td>1.08</td>
</tr>
<tr>
<td>CV</td>
<td>0.33</td>
<td>1.74</td>
<td>0.04</td>
<td>0.08</td>
<td>0.25</td>
</tr>
</tbody>
</table>

Table 9.1. Summary Table of White’s (This Volume) Particle Size Analysis, Drawn from Appendix B.
Figure 9.7. West end of N52-54/W99-105 trench showing dipping beds at bottom. Our inference is that this is near the Lake River bank when the site was initially occupied. House 6 including a wall trench is visible in the upper right-hand corner.
Figure 9.8. Location of Meier on Columbia River floodplain prior to diking. Coast and Geodetic Survey Chart of Sauvie Island prior to diking. Oregon Historical Society Negative OrHi 92877, OHS Map #6154.
The major textural differences between the two sites is the high proportion of gravels and organic matter in the Meier samples. The high proportion of gravels at Meier in part probably reflects its being built on and in a gravel bar. However much of White’s gravels is likely small bits of thermally altered rock (TAR). Meier produced close to 33,000 kg of TAR while Cathlapotle produced only 1100 kg. White does note that the proportion of TAR at Meier is much lower in the hearth/periphery than the storage pits. However, that is based on a single sample. The difference in organic matter suggests that the Meier cellar was more intensively used for storing organics, including no doubt food. This is another line of evidence indicating that food production was much more intensive at Meier than Cathlapotle. White observes that the OM content declines with depth. That actually may reflect differences among the units from which his samples were drawn rather than an overall pattern.

Floods

Cathlapotle and Meier provide data relevant to understanding the effects of the so-called “Bridge of the Gods” flood. The Columbia River was dammed at the site of the modern Bonneville dam by a landslide, currently dated between AD 1416 and 1452 (Pierson et al. 2016). At some point subsequently, the river breached this dam. Pettigrew (1981) proposed that this breaching caused a catastrophic flood that washed away villages and reorganized the Columbia River’s flood plain, leading to a major shift in settlement patterns. However, Minor and Peterson (2013) did not find evidence for such a flood in the bore holes they analyzed as part of the geoarchaeological study they undertook for the Columbia River Crossing Bridge.

There is no evidence for major flooding at Meier. Occupation there began well before the landslide date. There are two lines of evidence for flooding at Cathlapotle (Hodges, This Volume both). First of course is the formation of the two scroll ridges west of Site Ridge. These are undated. Given that Cathlapotle was founded ca. AD 1350, it is possible that the first scroll ridge was the result of the Bridge of the Gods flood. If so, it was well within the range of major Lower Columbia River floods, given that Site Ridge and the second scroll ridge also were produced by major floods. Second is the evidence for flooding at House 1. Unfortunately, there are no radiocarbon dates associated with or bracketing the flood deposit (Hodges’ facies 6). However, House 1 was constructed ca AD 1350 so this event postdates that. House 4 also has
evidence of flooding. It was initially constructed ca. AD 1417 (Ames and Brown 2016) so any flood damage postdates that. It is possible that this damage and associated deposits are the result of the Bridge of the Gods flood. While that is possible, it is also speculative. Perhaps the most that can be said is that the flood record at Cathlapotle indicates periodic major floods since AD 1350 but nothing catastrophic. There is no evidence at either site of major landscape reorganization.

Discussion

Cathlapotle appears to have been established on a recently formed landform. Our hypothesis is that it was moved there from another location. The Bachelor Island site, on Bachelor Island across from Cathlapotle, is a small village dating to ca 2000 calBP (Ames et al. 2008). We think it represents an early Cathlapotle and that there may be one or more such sites in the area that were occupied in the intervening centuries. The location permitted protected monitoring of river traffic on the Columbia (O’Rourke 2009) as well as access to a range of productive habitats. Two indicators of the value of its location is that Cathlapotle community members coped both with regular flooding and the building of scroll ridges between the village and Lake River. Of course, there were probably few good locations on the valley floor not subject to regular flooding.

We do not know the age of the terrace edge where Meier is situated therefore cannot speculate as to why the site was established there when it was. The location did provide access to a range of habitats and also buffered the community from the Columbia River, which was some distance away. The location likely required excavating away some gravels to create the house’s commodious cellar. It seems likely, however, that any location along that terrace would have also required excavating gravels. Meier was also subject to some level of regular flooding but there is no evidence of the kinds of flooding experienced by Cathlapotle. The settlement was probably protected from regular floods by the wetlands between it and Multnomah Channel which could absorb some high water.

There is no evidence at either site for the catastrophic flooding envisioned by Pettigrew from the Bridge of the Gods flood. Cathlapotle has evidence for major floods, including the flood deposit in House 1 and the two scroll ridges between the village and Lake River, but these events are within the normal range of variation.

Wapato

Darby’s 1996 thesis reprinted here was an early contributor to a rapidly expanding flood of scholarship on plant use and environmental management by Pacific Northwest peoples and by hunter-gatherers globally. This interest began with rethinking the role of root crops such as camas in models of culture and social change in the interior Northwest (e.g. Ames and Marshall 1980, Pokytolo and Froese 1983, Thoms 1989) and then expanded with the work of Nancy Turner (e.g. Turner 1996, Peacock and Turner 1999, Turner et al. 2003), Douglas Duer (2000, 2002) and others (e.g. Lepofsky and Lertzman 2008). The interest in management has expanded to the intertidal zones (e.g. Deur 2005) with the recognition and documentation of widespread clam gardens (e.g. Lepofsky et al. 2016). Her thesis was completed in the same year that a thesis on wapato use on the Lower Fraser River was completed at Simon Fraser University (Spurgeon 1996) and preceded Deur’s (2000) dissertation on intertidal zone gardening on the west side of Vancouver Island. The apogees of this literature are certainly Deur and Turner’s 2005 edited volume (Deur and Turner 2005), in which Darby had a chapter based on her thesis (Darby 2005), and Turner’s magisterial two volume encyclopedic treatment of plant use and management in the Northwest (Turner 2014). Lepofsky and Lyons (2013) recently review the status of paleoethnobotany in British Columbia while Lyons and Richie (i.p.) provide an recent overview of the archaeology of camas on the Northwest Coast, which includes Cathlapotle data.

However, in terms of Darby’s work, and more generally, the most significant development is the discovery and excavation of a 3800 year old wapato garden on the Fraser River above Vancouver (Hoffman et al. 2016). This was a clearly engineered feature containing a cobble and TAR pavement associated with wapato tubers and dig-
ging stick tips. Although there is only one of these known, it indicates that knowledge and techniques for maintaining high levels of wapato (and wetland) productivity has considerable time depth, at least in southern British Columbia, making it likely such knowledge and techniques was also available on the Lower Columbia River.

One of the most intriguing aspects of Darby’s work is her carrying capacity estimates for Sauvie Island. On the assumption that wapato provided 20% of the diet, she calculates that the population of Sauvie could have been between 18,000 and 37,000 people. Most published estimates rely, ultimately, on Lewis and Clark’s figures (e.g. Hajda 1984, Boyd 1999, Boyd and Hajda 1987) which put the island’s population between 3000 and 8000. Their maximum estimate for the total population of the Lower Columbia is about 16,000 with a minimum of about 5000. Boyd and Hajda (1987) hypothesize that the difference between the low and high counts results from a spring influx of people from elsewhere to take advantage of early spring resources; Lewis and Clark’s low count having been made during the winter of 1805-1806 and the high count on their return trip in the Spring of 1806. So far as I am aware, no one has grappled with Darby’s estimates. Carrying capacity estimates have their problems, but her figures should not be ignored.

Remote Sensing

McDonald’s study at Cathlapolte was undertaken as an experiment: would the equipment and techniques work in an old-growth Cottonwood grove? We also wanted to take advantage of the opportunity to check off-site locales for Hodges’ backhoe trenches. They needed to be beyond the margins of the site. The selection of survey areas on the site itself was determined by what we knew: survey areas that included localities that we knew something about something about so we could attempt to interpret her results, but also include adjacent areas about which we knew nothing. It was also determined by the forest. We could not remove trees or brush.

Area 1 encompassed a portion of House 2, where we had a single test unit, a corner of House 5, about which we knew nothing, and the intervening sheet midden. The House 2 test unit had spanned its east wall, cellar pits and portions of a central hearth, so we could expect House 2 to conform to our basic picture of the interior of Cathlapolte Houses. The survey may have identified storage pits in House 2 and a central hearth (anomaly 1.4) in Area 1. The anomalies between House 2 and House 5 could, as McDonald states, be hearths, or small earth ovens (there are many of both in the Cathlapolte middens) as well historic trade metal, among other things. In Area 2, which includes the 1994 test unit, anomalies 2.1 and 2.2 are probably a central hearth complex with multiple hearths. The 1994 unit basically clipped the edge of a hearth and these two anomalies are plausibly the rest of that feature. The survey also appears to have captured at least part of that excavation unit (anomaly 2.3). Most intriguingly perhaps is anomaly 2.4 which is four “depressions” along the west wall of House 2. McDonald suggest these may be rocks. Stones were placed at the bottoms of post holes to support posts. It’s possible these anomalies relate to that, or perhaps they are large postholes. Area 3 encompassed much of the southern and central portions of House 1D, an area that had been intensively excavated. The complex signal no doubt reflects that. The unexcavated areas likely contained hearths and storage pits as well as fur-trade era artifacts, plentiful thermally altered rock and so forth. Area 4 covered sheet midden to the west of House 1B and contained an excavation unit that produced among other things dispersed TAR and evidence of a wall trench. It is interesting therefore that aside from the area around the excavation unit, there were no anomalies. As McDonald notes, artifact densities in this unit were lower than in other and it had few features aside from the earth oven. It contrasts with the little section of sheet midden in Area 1, which was rich in anomalies.

It is unfortunate but rational that we could not, did not, do excavations to investigate the patterns McDonald methods detected. Unfortunate because we do not know what exactly she found. Rational because the analytical load for the project was already great and any additional excavations would have added to that. However, we do know that remote sensing does work under Cathlapolte-like conditions and can locate patterning worth investigating and which can be related to known classes of house feature. Remote sensing obvious-
ly worked well at Champoeg, which is outside the scope of these comments and on Bachelor Island (McDonald 2009) where McDonald located old Oregon Archaeological Society excavation units and two Cathlapotle style houses. However, the Bachelor Island site is in an open field with none of the impediments present at Cathlapotle.

**The Predictive Model**

As O’Rourke notes, an original impetus for her project was to create a management tool for the Ridgefield Wildlife Refuge, where Cathlapotle is located. This was subsequently expanded to include the entire area, on the grounds that it is being rapidly developed and the model would be a useful planning as well as a useful research tool. Her intent in writing up the project was also didactic, to essentially provide a manual on how to do this and to justify doing it.

O’Rourke found that the combination of three independent variables: elevation in feet above sea level, distance in meters to nearest water, and distance in meters to nearest navigable waters, were highly predictive of site location on the valley floor. These are not surprising for a people living on a flood plain subject to regular flooding and dependent on wetland resources and canoes for transportation and freight. Among her other findings relevant to the Wapato Valley Archaeological Project’s general goals are that site distributions are stable across time, i.e. the factors control site location and that the settlement pattern fits predictions for sedentary collectors. As readers of these reports are aware, one of the project’s initial goals was to test Saleeby’s hypothesis that the people of the Wapato Valley were sedentary. We have not been able to disprove that using many lines of evidence.

A next step that could be taken with this approach would be to inject time into it. To do so would be shrink data base of sites, since well dated sites are not common in the flood plain. Perhaps instead of looking at the distribution of sites, it would be more fruitful to look at the distribution of dates as data points. Having a sense of the geographic distribution of dates might tell us about the distribution of people through time and be a test of her conclusion that settlement patterns have been stable for the past 3000 years. It would also be a way of revisiting Pettigrew’s hypothesis (Pettigrew 1981) about the scale and effects of the Bridge of the Gods flood.

A spin-off of O’Rourke’s predictive modeling was a view shed analysis of Cathlapotle (O’Rourke 2009). In this this, she showed that Cathlapotle was visible to individuals in boats from single point in the Columbia River (essentially off Warrior Rock on Sauvie Island) where it was first noticed by the Vancouver expedition and by Lewis and Clark. However, individuals at Cathlapotle, especially if perched on the roof of one of the houses, has a wide but not totally unobstructed view up and down river and across to portions of Sauvie Island. Cathlapotle was exceeding well-placed.
REFERENCES CITED

Ames, Kenneth M. and Thomas J. Brown

Ames, Kenneth M. and Alan G. Marshall

Ames, Kenneth M., Doria F. Raetz, Stephen C. Hamilton and Christine McAfee

Ames, Kenneth M., Cameron M. Smith and Alexander Bourdeau

Ames, Kenneth M. and Elizabeth A. Sobel

Boyd, Robert T.

Boyd, Robert T. and Yvonne Hajda, P.

Brown, Thomas J. and Kenneth M. Ames

Darby, Melissa

Deur, Douglas


Deur, Douglas and Nancy J. Turner (editors)

Hajda, Y.

Hamilton, Stephen C.
Hoffmann, Tanja, Natasha Lyons, Debbie Miller, Alejandra Diaz, Amy Homan, Stephanie Huddleston and Roma Leon

Lepofsky, Dana and Ken Lertzman

Lepofsky, Dana and Natasha Lyons

Lepofsky, Dana, Nicole F. Smith, Nathan Cardinal, John Harper, Mary Morris, Gitla (Elroy White), Randy Bouchard, Dorothy I.D. Kennedy, Anne K. Salomon, Michelle Puckett and Kirsten Rowel

Lyons, Natasha and Morgan Ritchie

McDonald, Kendal

Minor, Rick and Curt D. Peterson

Minor, Rick and Kathryn Anne Toepel


Moulton, Gary E. (editor)

O’Rourke, Leslie

Peacock, Sandra and Nancy J. Turner

Pettigrew, Richard M.

Pierson, Thomas C., Russell C. Evarts and Joseph A. Bard

Pokotylo, David L. and Patricia D. Froese

Spurgeon, Terrence
1996 Wapato (*Sagittaria latifolia*) in Katzie Traditional Territory, Pitt Meadows, Brit-


