Emergent irrigation agriculture and settlement patterns in the lower Nepeña Valley, north-central coast of Peru

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EMERGENT IRRIGATION AGRICULTURE
AND SETTLEMENT PATTERNS IN THE
LOWER NEPEÑA VALLEY, NORTH-CENTRAL COAST OF PERU

A Thesis

Submitted to the Graduate Faculty of the
Louisiana State University and
Agricultural and Mechanical College
in partial fulfillment of the
requirements for the degree of
Master of Arts

in

The Department of Geography and Anthropology

by
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B.A., Texas State University, San Marcos, 2010
August 2013
ACKNOWLEDGEMENTS

Without the love and support of my family, friends and colleagues this research would not have been possible. To my advisor and friend, Dr. David Chicoine, I would not have been able to complete without your enthusiasm and confidence in me as a student. Furthermore, this research is only possible with the aid of my other committee members, Dr. Rebecca Saunders, Dr. Rob Mann, Dr. Heather McKillop, and Dr. Kent Mathewson. I would also like to extend sincere gratitude to the women at LSU that inspire me to push the boundaries and dream bigger, especially Dr. Helen Regis, Dr. Jill Brody, and Dana Sanders.

This research would not have been possible without the generosity of the LSU Department of Geography and Anthropology. The West-Russel Travel Grant allowed me to execute this study in Peru. Also, special thanks to the Solari Family for inviting me into their home in Nepeña and David Chicoine for making it possible. I would also like to thank those who have aided me in various stages of this research, especially Beverly Clement, Christopher Thompson, and Adam Rorabaugh. Thank you for lifting me up through the hard times and celebrating with me through the good.

Finally I must thank my mother, Stacy Wilkins, my grandparents, Dan and Mary Wilkins, and my aunt and uncle, Alice and Pete Garcia, for your unwavering support. Without you I would not be where I am today or know where I am going tomorrow.
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ABSTRACT

The Andes is one of many regions thought to have developed as a pristine hydraulic state; thus the region serves as a testing ground for theories on the development of irrigation. Since Wittfogel (1957) proposed a correlation between irrigation and the development of pristine states, the relationships between social organization, political power, and coordinated subsistence strategies have been hotly debated. This research will examine the role of irrigation in the transition to early urban settlements in the Nepeña Valley, on the north-central coast of Peru. I especially focus on the nature of political structure and social organization, examining the validity of Wittfogelian hierarchical models as they pertain to irrigation systems and settlement pattern shifts that coincide with changing subsistence strategies.

In order to examine shifts in patterns of subsistence and settlement, potential canals are identified for each time period based on site location as well as degrees of social complexity and political authority as indicated by architectural analysis. Influence areas for each major site are also determined from surface data. From architectural density, population estimates are calculated, which allows for an estimation of the areal extent necessary to support the settlements and validity of previously established carrying capacity.

Ultimately, it becomes apparent that irrigation strategies were present as early as the Initial Period (1800-900 BC) and firmly established by the Early Horizon (900-200 BC). Irrigation and spatial evidence suggests gradual, in-situ, intensification of irrigation systems, which highlights the intimate relationships between subsistence strategy and social complexity. This development reflects political organization characterized by heterarchy and brings into question dogmatic hierarchical models of social organization.
CHAPTER 1: INTRODUCTION

Understanding the unique relationship between irrigation systems and settlement patterns is crucial to furthering our knowledge of the social and political organization in irrigation-dependent agrarian societies, which are generally located in arid and semi-arid environments (Wittfogel 1957). This research explores the association between irrigation technologies and the way societies spatially organized themselves on the landscape. Specifically, I endeavor to expose this intimate connection in the Nepeña Valley from 2100 BC to 200 BC, a range of time marked by profound changes in subsistence strategies and social organization. By re-evaluating settlement patterns in the context of ecological adaptations, I explore how ecological factors, namely water availability, soil fertility, and topography, influenced settlement patterns and processes of increasing social complexity through time.

Although settlement patterns in the Nepeña Valley have been addressed (Daggett 1984; Proulx 1968, 1973, 1985), the role of irrigation in patterning the spatial distribution of settlements in this valley has had limited treatment. The Nepeña Valley is a valuable case study for understanding the emergence of irrigation agriculture and the social effects of this particular food production strategy. The valley is relatively small and has attracted little archaeological attention until recently (i.e., Chicoine 2010; Clement 2012; Helmer 2011; Ikehara 2010; Shibata 2010). Yet the valley has a rich prehistory materialized in more than 300 archaeological sites, extensive irrigation infrastructures, roads, and fortifications.
Figure 1. Regional Map of Peru and significant valleys (Chicoine 2011).
The goal of this research is to shed light on the relationships between irrigation and settlement patterns. Do settlement patterns reflect systems of irrigation agriculture? In order to address this question, both the sociopolitical structures that resulted from the adoption of agriculture and those that enabled its adoption in the first place must be examined. I must further question, to what degree did a centralized authority play a role in the construction of irrigation systems, specifically from the Late Preclassic through the Early Horizon in the Nepeña Valley? I hypothesize that the spatial relationships between irrigation systems and settlements reflect the social organization of irrigation management, and thus political organization. By investigating these spatial relationships and sociopolitical atmosphere I can also explore the social and political ramifications of the transition to irrigation agriculture. Different theoretical models (i.e., Boserup 1965; Carneiro 1970; Wittfogel 1957) for the development of irrigation systems will be evaluated in order to understand irrigation management practices, political organization, and settlement decisions.

In this project I re-examine patterns of site distribution previously documented in the coastal valley of Nepeña (Daggett 1984, 1987; Proulx 1968, 1973, 1985). Researchers in the 1960s-1970s identified over 300 sites including those dating between the Late Preclassic Period and Early Horizon (2100-200 BC). Two major settlement pattern shifts have been noted for the lower Nepeña Valley: (1) from coast to inland sites during the Late Preclassic-Initial Period transition, and (2) from inland riverside sites to inland valley margins during the Early Horizon. These settlement pattern shifts have been documented in other valleys on the north coast like Virú (Millaire 2010; Willey 1953), Santa (Wilson 1988), Moche (Billman 1996, 2002), and Casma (Pozorski & Pozorski 1987). Based on these studies and increasing data from the Nepeña Valley, it seems that settlement patterns are closely tied to the location of water resources. Only
when the ability for the geographic expansion of the irrigation was made possible were populations allowed more freedom in the location of their settlements. My thesis investigates these relationships further within the Nepeña Valley.

The general outline of my research begins with a review of theories regarding cultural ecology and irrigation systems. This is followed by a more nuanced look at irrigation in the Andes, the physical dynamics of gravity-based irrigation, and managerial implications for the varying degrees of irrigation. In the following chapters an outline of the Late Preclassic (2100-1800 BC), Initial Period (1800-900 BC), and Early Horizon (900-200 BC) culture history, as well as the relevant sites in the Nepeña Valley will be presented. Methods and analysis of the data are broken down into five main parts, (1) identifying irrigation systems, (2) defining user groups based on spatial analysis, (3) population estimates based on architectural remains at each site, (4) system extent and labor requirements based on measurements of the identified canals, and (5) carrying capacity in order to test the validity of the population estimates and spatial analysis. A discussion of this analysis will follow in order to organize the various sites into a developmental sequence for the valley that is centered on ecological interaction and the rise of irrigation.
CHAPTER 2:
THEORETICAL BACKGROUND:
IRRIGATION AND PROCESSES OF SOCIAL CHANGE

In order to fully comprehend human-environment interactions and the cultural core of a particular society three steps must be taken; analyze (1) the interrelationship of the exploitative technologies and environment, (2) the behavioral patterns involved in the exploitation of an environment by a particular adaptation, which depends on both the culture history as well as the environment and available flora and fauna, and (3) the extent to which associated behavior patterns affect other aspects of culture (Steward 1955:40-41). Therefore, the environment in the Andes and, more specifically on the coast, must be examined studying the cultural ecological aspects of particular societies. This allows for the understanding of the range of exploitative techniques within the context of the cultural core. In this chapter I discuss the various long-standing models that have been used in the study of irrigation systems in terms of political structure, social organization, and spatial patterning.

2.1 Irrigation and Sociopolitical Complexity

Water management is an economic and political force associated with production and social organization, which varies with the scale and complexity of the society as well as climatic and geomorphological conditions (Scarborough 2003). This is due, in large part, to the necessity of water to human survival and the ability to control water. This control shaped spatial and social power relationships. The theories for social complexity associated with irrigation stem from Wittfogel’s (1957) ‘hydraulic hypothesis’ and have received much attention, positive and negative (e.g., Boserup 1965; Lanning 1967; Moseley 1975; Netting 1977; Sanders et al. 1979).
Considered to be voluntaristic, or a peaceful submission to centralized authority through cooperation, the main opposition to the hydraulic hypothesis are touted by those that subscribe to the Carneiro’s (1970) coercive theory and, to a lesser extent, political models (Billman 1996:12-13).

In a cross-cultural comparative analysis of various case studies, Wittfogel (1957) proposed that despotic states occurred across the globe as a result of regularities in adaptations to the environment and developed patterns of absolute power. He identified several hydraulic states, including Mesopotamia, Egypt, China, the Indus Valley, Mesoamerica, and the Andes. These states are systems characterized by social and political complexity that evolved out of a particular treatment of water and adaptation to the natural environment (Price 1994:187-188; Wilson 1983:264). Essentially the hydraulic hypothesis posits that complex, and sometimes pristine, states were more likely to develop in arid regions where tension and conflict over limited water resources led to technological adaptations like irrigation to ease that tension (Price 1971:46-48; Wittfogel 1957:12). Ultimately, centralized leadership was a voluntaristic, adaptational solution to social, economic, and environmental problems. In other words, in societies in which the population allowed for voluntary subjugation, centralized authority was an adaptation to benefit the group. In irrigation societies, leadership managed initial construction and subsequent maintenance through the integration of households and larger social units. Furthermore, centralized leadership would have been responsible for allocation of potable water and dispute settlement through various forms and levels of cooperation, integration, and negotiation (Wittfogel 1957:22-48). Other similar adaptationalist theories for centralization focus on intensification of production (Cohen 1977, 1978, 1981; Johnson & Earle 1987; Sanders et al.)
1979), village specialization and redistribution (Service 1975), and regional trade (Flannery 1968; Isbell 1978; Johnson & Earle 1987), which all fall within the voluntaristic paradigm.

In the coercive model (Carneiro 1970), a limiting resource like water can become strained and has the potential to cause intercommunity competition due to overuse or some supracultural factor like climate change. This competition is a result of decreasing standards of living, social instability, and can lead to intercommunity warfare (Steward 1955). Warfare serves as a tool to gain control of limiting resources, which consolidates societies in ways that both continue to cause increases in population densities but also creates a population from which to draw a labor force (Carneiro 1970). This labor force is used as a means for expanding irrigation systems. It allows for greater densities of people to live with fewer limitations presented by water scarcity as well as lays a foundation for the development of early state societies. The coercive model implies that centralized authority emerged through the forceful consolidation of populations, or subjugation of one group by another, through warfare (Billman 1996:14; Carneiro 1970, 1972, 1981, 1990; Wilson 1983:264-266). Alternatively, armed conflict could have elicited a response that led to the development of centralized authority and control. In other words, only societies with strong political centralization could survive periods of warfare (Price 1994).

Boserup’s (1965:43) population model posits that population pressure directly influenced changing subsistence strategies. Population pressure was also the impetus for particular settlement patterns and agricultural intensification. Intensification is a term used by Boserup (1965) when discussing agricultural populations, indicating the transition from long-fallow to short-fallow systems with the introduction of multi-cropping. In other words, it is the transition away from an agricultural system where the ratio of land use to labor input is such that there is more land and little labor. The ratio becomes smaller when there is less land being used and more
labor, which indicates intensification. Intensification of agriculture is difficult to detect in the archaeological record and is vaguely referred to in the literature as an increase in input (e.g., labor, technology,) or output (e.g., agricultural goods). Similarly, the extensification versus the intensification of irrigation systems is usually conflated and cannot be inferred without direct archaeological evidence. Intensification of irrigation suggests that the ratio of land to technology is such that hydraulic density increases where there is a great amount of technology in a confined area. Expansion, in turn, refers to the overall spatial extent of a system including the irrigation and land served by those canals. Hunt (2000:272) suggests a more appropriate term, agricultural development, which recognizes that technology is at the core of intensification processes but does not always result in increased agricultural output.

Though analogous to the coercive model, political models emphasize that the wealth of an elite few can be maintained through the direct physical control of the production or distribution of limited resources or by monopolizing those resources or prestige goods (Brumfiel & Earle 1987; D’Altroy & Earle 1985; Earle 1987; Gilman 1981; Haas 1981, 1982; Moseley 1975; Webb 1975). Political models hinge on the ability of the elite to control access to resources in order to protect their economic interests. Further, they imply that social stratification developed prior to centralized political institutions (Billman 1996:12). This model is problematic in that it assumes irrigation had little influence on the development of centralized authority other than as a static, controllable resource.

While Wittfogel’s (1957) hydraulic hypothesis in many cases has been criticized, it is important to realize that this work provides the basis for many ecological studies focused on water and irrigation. Outlined above are three models for irrigation, which are often overly polarized in ways that favor one explanation over the others. In reality, the best way to answer
questions about social complexity and irrigation is through a combination of many theories. Furthermore, these models assume a top-down understanding of the processes involving centralization, the intensification of agriculture, and the expansion of irrigation systems. In the following section, I discuss the integrative capacity of irrigation and the implications for sociopolitical organization from both a hierarchical and heterarchical perspective, arguing that there is also an erroneous dichotomy between the two.

2.2 Settlement Patterns and Society

Settlement patterns are the culmination of various classes of factors that form dynamic interactions and produce identifiable, sometimes predictable, spatial distributions of a social group across a landscape and “may be a compromise among a number of conflicting determinants” (Trigger 1968:53). The distribution of people across a landscape is influenced by a myriad of social and ecological factors beyond water availability, including but not limited to: land productivity, defensibility, ideology, and the exploitation of specialized resources.

The first systematic settlement pattern study in the Andean region developed out of Willey’s (1953) intensive surface survey of the Virú Valley Project. Willey (1953:1) noted the applicability of settlement patterns to the functional interpretation of past societies. He placed a particular emphasis on human-environment interactions and noted the regular incidence of irrigation systems, as well as residential and monumental sites (Willey 1999:9-11). Since Willey (1953) originally demonstrated the usefulness of systematic settlement pattern analysis, it has been used in numerous ways, especially for the purpose of reconstructing social change. There are many critiques and noted shortcomings of the Virú Valley survey and settlement pattern
analysis (Strong & Evans 1952; Willey 1953). However, it is easy to critique the earliest application of a methodology. The most often cited criticism revolves around the method for collecting survey data and their analysis, which sought to empirically test and answer more nuanced questions of social interaction and development (e.g., Flannery 1976; Sanders et al. 1979).

Two of the most influential settlement pattern analyses to be conducted in the Americas include those by Flannery (1976) and Sanders et al. (1979). Flannery focuses on the different ways in which various units of data can be analyzed from household to polity with a focus on the village. The project goals were to reconstruct subsistence-settlement systems, obtain population estimates for geographic and sociopolitical units, and infer social structure in the Valley of Oaxaca (Flannery 1976:5). While irrigation was not a central factor in Flannery’s work, Sanders et al. (1979:5) focuses on this key technological feature in the Basin of Mexico to reconstruct the development of agriculture, different settlement types, construct a population profile, and explore the relationship between settlement patterns, agricultural techniques, and demography.

Ecological explanations for the ways populations distribute themselves across a particular landscape and environment are closely related to the subsistence and economic cultural core. In arid environments, the location of water resources is largely related to site location and distribution and, as irrigation systems expand, the area available for settlement grows as well. This idea is connected to the ability to transport this resource and often constitutes linear and non-linear settlement arrangements. Though the transportation of water across the landscape is not always directly related to subsistence, it is often tied to cultivation and agricultural intensification. Basically, as irrigation systems expand the potential for growth in agricultural productivity follows, leading to the potential for growth in population. This growth is also often
reflected in larger settlements, which is also associated with changes in political organization (Steward 1955:198-201).

Site Types and Functions

Settlement pattern analysis requires various lines of data, including site locations, sizes, and occupational histories. Early settlement pattern studies relied on associative dating and ceramic/artifact seriation or presence-absence analysis. The definition of site types and functions as well as appropriate units of analysis and sample sizes vary at different levels. It is almost impossible to retrieve this kind of data without intensive and extensive surface surveys (e.g., Sanders et al. 1979; Willey 1953; Wilson 1988).

For this research, I use definitions of site types already elaborated in the Andes (Billman 1996; Proulx 1968; Willey 1953; Wilson 1988). Willey (1953) established broad functional categories with descriptive sub-categories that included (1) living sites, (2) community and ceremonial structures, (3) fortified strongholds or places of refuge, and (4) cemeteries. The definition of site functions is often fraught with problems including biases of interpretation by the researcher, taphonomic biases of the archaeological record, and an oversimplification of various functions. However artifact assemblage, architectural style, and sometimes location of the site itself can lend a great deal of credence to these inferences. Willey’s functional categories and descriptive types correspond largely with those established by Wilson (1988:75-77), which include (1) habitation, (2) defensive, (3) civic-ceremonial, (4) and cemetery functions. Civic-ceremonial sites are closely related to Socially Integrative Facilities (SIFs), which will be discussed later. The function of a site can change over time, especially when the occupational density increases and often times sites will fall into multiple functional categories.
Occupational density is important to understand the internal and external complexities among sites and regions. Population and demography are difficult to establish. Until a more unified approach can be reached, population estimates should be restricted to regional definitions and not cross-cultural comparisons. Wilson (1988:77-78) established four categories of occupational density based on the extent and density of a site as determined by structure count per hectare. Under the assumption that an estimated 5 persons inhabited each residential structure, Wilson was able to establish the categories of occupational density including (1) low (15 p/ha), (2) low-moderate (50 p/ha), (3) moderate (100 p/ha), and (4) high (250 p/ha). Wilson also established a separate occupational category of Preclassic sites at 30 people per hectare because population estimates did not coincide with the above categories.

Wilson (1988:79-80) combines functional and occupational categories to create histograms representing varying size intervals and categories per time period that reflect diachronic and synchronic breaks between groups. These include hamlet (5-99 persons), small village (100-499), large village (500-2000+), local center (2000+), and regional center (largest population). These categories are also problematic because multicomponent sites can change in size and function through time. Furthermore, different functional categories can result in different occupational densities (see Flannery 1976 for a similar methodology developed in Mesoamerica). Regardless, the above functional and occupational categories are useful for consistency, but will be applied with due caution.
2.3 The Relationship Between Irrigation and Community

Water management requires cooperation and coordination (Netting 1993:12). At the very least, irrigation systems can be viewed as *socially integrative facilities*, a prepared space imbued with special meaning and function for the purpose of integrating individuals above the household level (Adler & Wilshusen 1990:12; Netherly 1984). Water management requires the coordination and integration of labor forces (Wittfogel 1957:22-48), which can stimulate social solidarity and identity on a daily basis and allows for the creation of social, political, and economic bases for power (Scarborough 2003). Activities like the initial construction, subsequent structure maintenance, water allocation, and, by association, management of the resulting products are coordinated strategies.

Under Wittfogel’s (1957) assumption that political centralization is directly related to the scale and complexity of irrigation systems, societies range on a developmental spectrum from *hydroagriculture* to *hydraulic agriculture*. *Hydroagriculture* is defined as small-scale irrigation that increases food supply and, potentially, population to an extent, but does not necessarily affect the patterns of social, political, or economic organization in ways that characterize a hydraulic state (Price 1994:190). *Hydraulic agriculture* is characterized by despotic states with institutionalized means and methods of power and control, which is made possible by the ability to control a limiting and life-sustaining resource (Price 1971:48; Wittfogel 1957:15-16).

Hydroagriculture and hydraulic agriculture represent two extremes that vary with *hydraulic density* and *bureaucratic density*. *Hydraulic density* is the degree of importance irrigation plays in the lives of hydraulic societies that can be modified by the “institutional weight” of monumental non-hydraulic works as well as dimensions of communication and/or military organizations (Wittfogel 1957:167). *Bureaucratic density* is defined by the political and
economic network that develops as irrigation brings together, or pushes apart, different communities and/or societies (Wittfogel 1957:169). Often bureaucratic density can be investigated through spatial distribution of seats of power. These descriptive densities are understood at the most basic level as either compact or loose. The political centers of a society may be located in areas of great agricultural wealth and surplus or at a considerable distance (Wittfogel 1957:169), the proximity of which potentially indicates the nature of sociopolitical organization and management of resources.

Hydroagriculture and hydraulic agriculture are descriptive terms that imply that societies fall on a developmental continuum, which indicates changing sociopolitical organization (Wilson 1983:264-266). This sociopolitical organization is best described in terms of hierarchies and heterarchies of hydraulic power as they are terms that also indicate degrees of centralization (Davies 2009; Scarborough 2003). A more horizontal conception of centralization, or heterarchy, suggests a “segmental state” comprised of a diverse set of hinterland activities centered around principle exchange nodes, or cities, more sparsely occupied than the hinterlands (Scarborough 2003). A heterarchy is a form of sociopolitical organization where sites or communities maintain equal levels of political power. Heterarchies can be imagined as “webs” or “networks” of economic and political relationships within and among resource specialized communities (Scarborough 2003; Service 1975). However, this horizontal organization of power and authority can be built into a larger hierarchy or have hierarchies within the system.

With this in mind, hierarchy refers to vertical organization of political control where sites or communities exhibit greater power or control over others. One of the major critiques of Wittfogel’s (1957) hydraulic hypothesis is the focus on hierarchies of large, Asiatic states when there are multiple paths to hydraulic power that also include heterarchies (Davies 2009). Site
Hierarchies imply a degree of political and economic centralization of resources under the control of a small elite, generally centered at urban hubs (Scarborough 2003). If correlated with the idea of hydraulic and bureaucratic density, a large population within a confined space should characterize sites that fall at the upper end of a hierarchy.

Hierarchical and heterarchical hydraulic systems are closely related to two types of development, 1) accretion and 2) expansion. Accretional-heterarchical development is the bottom-up, stable development of an agricultural resource that involves few long-term risks, and complicated interdependencies among groups and with the environment (Scarborough 2003:13). Irrigation associated with a heterarchical system would “manifest a weak dichotomy between consumptive and productive water system users” (Scarborough 2003:104) as well as little distinction between functional and ideological treatments of the system and water resources. Furthermore, accretional-heterarchical development implies that the irrigation and agricultural systems in place developed through the accumulation of landscape capital (i.e. arable land and associated technologies) and generational knowledge over long periods of time, primarily by a non-elite group of farmers (Erickson 2006:350). This slow and steady development would be reflected in the landscape as intensive agriculture that is often confused with labor-intensive agriculture generally associated with hierarchical or state level societies (Erickson 2006:338). Similar to Netherly’s (1984) conception of labor and social organization, Erickson’s (2006) heterarchy model indicates that local corporate groups at the family and/or village level of organization executed the construction of irrigation and maintenance with associated canals. Perhaps the only indication of hierarchy lies in the duty of resource allocation and dispute resolution where some overarching organization or authority executed these mundane functions that potentially developed into supramundane ritual (Netherly 1984).
The political and social stratification of irrigation systems and their user groups can be identified in a number of ways. First, the association of canals to sites, and the size and density of those sites can indicate the size of the population reliant on the system. It does not, however, necessarily indicate the number and level of decision-making seats in the system. By supporting this information with the spatial extent of irrigation, ratios of canal length to system length, and ratio of canal gates to the entire system, the levels of administrative centralization can be determined (Hunt 1988:343-344). Similarly, political organization and degrees of centralization can be examined through the study of settlement patterns. The ways in which people distributed themselves across the landscape can yield great amounts of information from sociopolitical structures to developmental processes. In the following chapter, I explore irrigation and settlement patterns in the specific context of Andean studies.
CHAPTER 3: RESEARCH BACKGROUND: IRRIGATION AND SETTLEMENT STUDIES IN THE ANDES

From a cultural ecological standpoint, the environmental setting must first be understood before the relationship between environment and technological developments can be analyzed. In this chapter, I briefly describe the landscape and environment of the Andes before exploring the physical properties and ethnographic studies of irrigation in the region. I conclude with a section on the relationship between irrigation and settlement patterns as they pertain to spatial organization.

3.1 Environmental Setting and Landscape

The central Andes is a region marked by a diverse set of ecological zones providing for a wide array of resource exploitation, adaptations, and cultural developments (see Figure 2). The tropical Amazon is separated from the Pacific coast by the high-elevation Cordillera Blanca and Cordillera Negra. In north-central Peru these steep mountains are bisected by the Santa River and create a productive intermontane valley called the Callejón de Huaylas, which drains most of the rainfall to the coast. There is a relatively short distance between the coast and some of the highest peaks in the world. The narrow Pacific coast of the central Andes is the driest desert in the world, marked by river oases that flow from east to west, downstream from the mountain ranges (Denevan 2001:135-137). The Inter-Tropical Front (ITF) and the Humboldt Current cause the desertification of the Peruvian coast because the soaring peaks of the Cordillera Blanca block the ITF that could otherwise provide rain to the coast from the east. In turn, the Humboldt Current cools the Pacific waters nearest to the coastline. This cooling effect combined with the sun’s intense radiation prohibits the formation of rainfall west of the Callejón de Huaylas.
However, an occasional warm current intrudes and alters this effect, resulting in an El Niño/Southern Oscillation (ENSO). The ENSO is a climatic event that brings rain to a desert area unprepared for it. Large-scale ENSO events result in flooding, landslides, and the eradication of the usual sea life followed by an infiltration of warm water species.

Despite variability associated with ENSO events, rainfall and water flow are generally predictable. The scarcity of rainfall is a defining characteristic of the Andean coast, limiting agricultural production and carrying capacity. However, this region has a surprising capacity to support substantial human populations (Contreras 2010:242-243). The same Humboldt Current that prevents significant rainfall simultaneously allows for a rich marine biomass (Moseley 1975). Agriculture is also very productive for such an arid environment. Rich sediments that flow from the mountains and ice caps to the east are deposited along the riverbanks that, combined with water, provide for highly productive agricultural zones. Human populations can modify this environment in various ways, but in order to cultivate at a significant scale, irrigation is

![Figure 2. Map of environmental regions in the Andes (adapted from Pulgar Vidal 1972).](image-url)
necessary in areas that receive less than 500 mm of annual precipitation (Denevan 2001:136).

The north coast of the central Andes is comprised of those river valleys that fall between the Chicama and Supe Valleys including the Moche, Virú, Chao, Santa, Nepeña, Casma, and Seco (Willey 1953). Nepeña is located 393 km north of the modern city of Lima in the Department of Ancash (Figure 1). The Rio Nepeña headwaters originate in the Cordillera Negra and river flow was limited until irrigation development. Nepeña and other river oases have rich, fertile soils, which make them prime for cultivation and allows them to sustain substantial populations. Coastal valleys are often divided into Lower, Middle, and Upper sections. The Lower Valley generally runs from coastline to the beginning of small hills. This then marks the beginning of the Middle Valley, which ends in an area with significantly more hills and peaks separated by canyons, or quebradas, that marks the Upper Valley up until the Cordillera Negra. In the Nepeña Valley, researchers intended to maintain these delineations in order to remain consistent. However, geographically there is only a lower coastal valley and a hilly upper valley. This is significant to this research because it alters the way in which sites within the sample are described and discussed.

3.2 Physical Properties and Social Structure of Irrigation in the Andes

Water is structured by gravity and therefore the physical method and technique of water control varies by environment and even community depending on the repertoire of technology available (Ertsen 2010; Ertsen & Van der Spek 2009). Irrigation technologies on the coast of the Andes have the same basic hydraulics as they did in prehistory (Ertsen & Van der Spek 2009). Gravity-based irrigation systems draw from the rivers that flow from the mountains. It has been
noted that the wide middle valley with gentle slopes are ideal for irrigation of fields, while upper valleys tend to have sharper slopes to irrigate, which is given to flooding and canal destruction (Billman 2002). The shape of these irrigation canals tends to replicate river flow because they are directly affected by factors like topography, elevation, and hydrology (Ertsen 2010). This kind of irrigation system can create hierarchies and social stratification within and among populations (Ertsen 2010:166).

To this day gravity-based irrigation systems are in use in the Andes (Billman 1996; Farrington 1980; Haas et al. 2005; Wilson 1988). Modern systems potentially include canals that have been used since prehistory; indeed prehistoric canal extent may have exceeded that of modern systems (Schaedel 1986:320). Dating canals can be problematic because they are often still in use today, not to mention the cost of attempting such a task. However, modern maps of canals and water sources can be used as an analogy for the approximate trajectory of prehistoric canals due to the similar elevations, environmental conditions, and consistent technologies through time (Billman 1996; Ertsen 2010; Ertsen & Van Nooijen 2009; Ertsen & Van der Spek 2009; Netherly 1984; Wilson 1988).

Power relations and political organization are structured by geography, topography, and hydrology unique to the coastal valleys of Peru. For instance, differential access to water and levels of decision-making can be interpreted through canal systems. Main canals derive water from the river source, which is then carried it to diversion canals or secondary canals that send water to towns or fields. Tertiary canals distribute the water to individual plots of land that the landowners divert into furrows in their gardens or farms (Doolittle 1990; Ertsen 2010; Ertsen & Van der Spek 2009). However, river flow is not uniform and, therefore, water flow in canal systems are also variable (Ertsen 2010:172).
On the north coast, where rainfall only occurs seasonally from January to May at 30 mm or less, irrigation is paramount to the success of settled, nucleated agrarian populations (Denevan 2001:137). Restricted rainfall results in highly regulated water allocation where households, towns, and fields only have water directed to their canals during parts of the day or on certain days of the week from June to December. This pattern of water availability determines the growing season and, therefore, the irrigation construction season. Water allocation can also create a hierarchy among those that receive water at certain, preferable times of the day, as well as the order in which water is received and the amount of water received. For instance, it might be preferable to receive water allocations in the evening or early morning before the sun emerges and evaporates moisture from the soil or water from the canals. Likewise, the first to receive water is guaranteed to receive their share while those that receive it last maybe be subject to shortages.

Hydraulic systems have technologies to divert and distribute water according to the structure of allocation. The implementation of each section of the system can be viewed as a level of decision-making or authority above the local level (Ertsen 2010:177). Weirs made of brush or stone elevate the water in order to divert it to the main canal. These same materials are used to create weirs and dams between the main canal and secondary canals (see Figure 9). Once the secondary canals are diverted to tertiary canals and furrows, the level of decision-making lies with the local structure and/or household. Therefore, the ratio of canal gates to the extent of the irrigation system (i.e., area of fields irrigated by the system) can demonstrate the number of points of decision-making, the levels of hierarchy within the system, and the degree of sociopolitical centralization (Hunt 1988:336).
The presence of irrigation systems has been used to support the assumption that governing bodies were necessary for various roles associated with the responsibilities of canal construction, operation and maintenance, as well as conflict management (Ertsen 2010; Ertsen & Van der Spek 2009). A particularly important role of the governing body is to plan the allocation of water for the year based on the variations of water flow in the river system and water availability (Ertsen & Van der Spek 2009). However, Netherly (1984) suggests a more horizontal organization of corporate groups that did not need centralized authority to be successful, and in fact were more successful in its absence. By eliminating the assumption of centralized authority in irrigation systems, a more accurate understanding of the nature of irrigation and the role it played on the sociopolitical stage can be reached.

Ethnographic studies such as those by Trawick (2001a, 2001b) and Boelens and Gelles (2005) emphasize the communal aspect of irrigation in equitable systems particularly in regards to water rights. A similar conclusion can be reached based on ethnohistoric studies of contact period hydraulic communities (Netherly 1984). Because of the consistency of the Andean environment between modern, historic, and prehistoric times, as well as the largely unaltered natural landscape, it is easy to draw analogies between irrigation systems. The most notable ethnographic work on irrigation in the Andes presents a convincing argument for the use of the direct historical approach between post-contact north-coast populations and the prehistoric Chimú (AD 1000-1470). The evidence, derived from careful study of historic legal documents, indicates a great deal of cultural continuity between the historic population and the Chimú. However, great difficulty lies in projecting this ethnohistoric analogy further in time. Continuity becomes harder to prove in the absence of historical documentation and considerable time depth. Therefore, these ethnographic models should be tested with archaeological data.
In her study, Netherly (1984) argues for a dual corporate organization where
parcialidades or corporate groups are associated with and unified by the canals they are
responsible for constructing and maintaining as well as the lands they water. This heterarchical
system of construction and maintainence would have been balanced by an overarching authority
responsible for conflict resolution, suggestive of various degrees of centralized authority.
Furthermore, individuals or groups that did not contribute to the construction and maintenance of
a system would not have earned their rights to use the canal and would be barred from doing so
either by the corporate group or the overarching authority (Boelens & Gelles 2005:314).

3.3 Archaeological Studies of Settlements and Irrigation in the Andes

Early irrigation dates as far back as the Preceramic (see Zimmerer 1999 and Dillehay et
al. 2005 for a discussion of these dates). However, most studies focus on the historic Inka (post-
AD 1530) or the Moche of the Early Intermediate Period (AD 100-800) and their grand
intervalley canals (i.e., Billman 2002). Moche irrigation is the earliest, most complex system
preserved in the Andes (Denevan 2001). As the earliest state-level society that spanned several
valleys, the complex hydraulic systems are often equated to complex society (Billman 2002).
However, this emphasis of statehood is slowly disintegrating as valley-based studies suggest
variable social organization where irrigation was controlled and managed by local authorities
rather than the Moche state (Castillo 2010; Millaire 2010).

The rise of the Moche state during the Early Intermediate Period is most often associated
with the idea of state formation in the context of irrigation systems. However, based on a
systematic study of the role of irrigation in the political evolution of the Moche State, Billman
(2002) finds that the managerial requirements and labor organization associated with irrigation were relatively unimportant in the development of the Southern Moche State. Instead, he suggests that warfare, highland-coastal interaction, and political control of irrigation systems (i.e. water) created opportunities for leaders to form a highly centralized state. Differential access to basic resources resulted in social inequality that provided a basis for economic power and, therefore, the degree of political centralization was not related to the irrigation itself but rather the ability of individuals to manipulate the system.

In the Jequetepeque Valley, Castillo (2010:83) proposes a model that does not conform to previously established ideas of regional polities or states, but instead suggests a combination of both. Fragmented political territories defined by independent irrigation systems exhibited a great deal of political and economic autonomy that coexisted and socially integrated through rituals that took place at ceremonial centers. Social cohesion fostered by ideology also created a flexible supracommunity that was integrated above the level of independent political territories at varying

![Diagram](image.png)

**Figure 3.** Feedback model of the development of state based on population pressure, environment and climate, conflict and warfare, and external processes (Wilson 1983:212).
degrees of complexity and centralization (Castillo 2010:84-85).

Irrigation systems often do not preserve in the archaeological record for various reasons. However, settlement pattern studies can be used to infer the presence and extent of irrigation systems (Steward 1955). Building on Willey’s (1953) seminal study, Wilson (1983, 1988) conducts a comprehensive regional study of the Santa Valley. He proposed an alternative multivariate model for the development of state, taking into consideration the relative roles of population pressure, environment and climate, conflict and warfare, and external factors that weigh on the processes of social complexity (see Figure 3) (Wilson 1983:212). Wilson (1988:320) stresses the importance of studying both quantitative changes (i.e., increase in architecture, population) and qualitative changes in society. Qualitative changes may be reflected in the development of irrigation agriculture, which prompted a fundamental transformation at the regional level where architectural styles shifted from simple households to clustered multi-room dwellings, increasing social stratification becomes evident in burial practices, and the average size of early settlements increases (Wilson 1983:245-248). With this transformation also came an increase in defensive structures and regional population consistent with an increase in hierarchy of site size and function. These qualitative changes demonstrated an orderly process of demographic development that was limited during the time when a heavy reliance on marine resources characterized food procurement. However, when irrigation agriculture had become a major food source, the population increased by 600 % and the sociopolitical organization grew increasingly complex (Wilson 1983:254). An important result to come out of this research was the systematic population estimates taken from actual counts of discrete habitation sites in the Santa Valley. Here, Wilson’s (1988:324) main goal was to test Carneiro’s coercive theory and in doing so concluded that, due to the “critical survival need to establish and maintain local
irrigation systems free from any immediate danger of disruption, it is nearly inconceivable that local agriculturalists would have been so reckless as to permit a situation of serious local conflict to arise.” Therefore, the proliferation of defensive structures was interpreted as a response to external raiding from other, less productive valleys. Furthermore, the “intricacy and vulnerability” of irrigation systems would have fostered networks of intervillage cooperation (Wilson 1988:331).

This wave of interest in regional settlement pattern studies continued in the Nepeña Valley with Proulx (1968, 1973, 1985) and Daggett (1984). Proulx and Daggett conducted the most comprehensive and systematic regional study of the Nepeña Valley to date. They were able to document over 300 sites in the valley and conducted settlement pattern and ceramic analyses. With the recent surge in research, some of their surface conclusions can now be tested. For instance, many of the dates for sites were much earlier than reported and several diagnostic features like particular ceramics and architectural styles were assigned to later periods. This study uses several lines of evidence beginning with Proulx and Daggett and includes more recent studies that can corroborate much of the original survey, which will be addressed later.
CHAPTER 4:
A CASE STUDY FROM THE LOWER NEPEÑA VALLEY

A brief review of the culture history of the north-central coast of Peru is presented in order to better understand the time frame pertinent to this thesis. The review will span the Late Preceramic Period, Initial Period, and Early Horizon. Here I briefly discuss this evidence to establish a chronological sequence of sites necessary to carry out synchronic analyses. A developmental sequence based on excavations at Cerro Blanco and Huaca Partida in the Nepeña Valley established architectural phases that also coincide with many settlement pattern shifts throughout the Initial period as well as the subsequent Early Horizon (Shibata 2010). The Huambocayán and Cerro Blanco phases correspond to the Initial Period and, more or less, with the construction phases established in the neighboring Casma Valley at Pampa de las Llamas-Moxeke and Las Haldas (Pozorski & Pozorski 2002). The Nepeña and Samanco phases correspond to the Early Horizon.

Little is known about the initial Huambocayán Phase occupation at Cerro Blanco and Huaca Partida that dates to the early part of the Initial Period (see Table 1 for complete summary). In the following Cerro Blanco Phase, which dates to the second half of the Initial Period, ritual U-shaped mound construction at the site began (Ikehara & Shibata 2008; Shibata 2010:292). These sites are also characterized by sculpted clay feline figures, painted walls, and a central staircase. The Nepeña Phase (800-450 BC) correlates to the first half of the Early Horizon. Megalithic renovations begin and completely covered structures of the preceding phase where large quarry rocks measure up to 1m (Shibata 2010:299). During this phase new architectural patterns, settlement patterns, and agricultural strategies proliferate. Huambacho (PV31-103), Caylán (PV31-30), Samanco (PV31-4), Pañamarca (PV31-38), Sute Bajo (PV31-
108), and Punkurí Alto (PV31-11) emerge. As the occupation at the Initial Period sites of Cerro Blanco and Huaca Partida wane, the sudden increase of sites in drastically different settlement locations and the new architectural styles has been interpreted as a response to conflict (Daggett 1987). During the Samanco Phase (450-150 BC) megalithic renovation ceased and access points to the mound were filled (Shibata 2010:301). In the ensuing sections, I discuss the culture history on the north-central coast of Peru and how the local Nepeña sequence corresponds to that history.

**Table 1.** Local and regional chronology on the Peruvian north coast as well as the construction sequence from Cerro Blanco in the Nepeña Valley and relevant sites.
4.1 The Late Preceramic Period (2100-1800 BC)

Prior to the Late Preceramic, populations were more or less mobile groups of hunters, gatherers, and fishers (Quilter 1991). By 3000 BC, dramatic cultural changes resulted in the shift to sedentary lifestyles (Bruhns 1994; Haas & Creamer 2004). Distinct cultural traditions are recognizable in the archaeological record at the beginning of the Late Preceramic. These traditions are characterized by a distinct lack of ceramics and include large architectural complexes, cotton textiles, fishing technologies, and evidence for plant and animal domestication. These features are accompanied by increasingly stratified social structures, extensive spread of ceremonial systems, intensification of domesticates, and exchange between drastically different environmental zones (Quilter 1991).

The Late Preceramic experienced an increasing dependency on plant goods, so much so that intensified use of semi-domesticated plants begins to materialize in the archaeological record. The initial cultivation of a wide variety of food plants like maize, chili peppers (Jones 1988), beans, tubers, potatoes, and sweet potatoes probably occurred at this time (Bird et al. 1985:239-240; Callen & Cameron 1960; Quilter 1991:399; Quilter et al. 1991; Ugent et al. 1982). Wild and domesticated cotton products were utilized for industrial purposes, such as fishing, as well as for textiles of various qualities (Bird et al. 1985; Haas & Creamer 2004; Quilter 1991). At the coastal site of Huaca Prieta (3100-1300 BC), botanical evidence indicates increasing size of cotton seeds, bolls, and fibers, which suggests that the manipulation of water as well as the management and cultivation of this crop was in place (Bird et al. 1985:234-235; Quilter 1991:399). Small bone fishhooks, gourd containers (in lieu of ceramic technologies), fishing spears, and tortora reed boats are also included in the Late Archaic repertoire of technological achievements. The relative lack of chipped stone and deer or camelid remains at
coastal sites suggests that there was a focus on farming and fishing rather than hunting (Quilter 1991).

The majority of Late Preceramic sites are located near the coast and along the alluvial fan of rivers, suggesting that populations inhabiting these sites were both exploiting the marine resources as well as the fresh water and plants growing along the river (Moseley 1975; Park 1983:153; Wilson 1983:229). The emphasis on the rich marine biomass for subsistence resource allowed for sedentary populations to thrive in areas where little plant cultivation was possible (Moseley 1975). Cultigens have been recovered inland at Caral (2600-1800 BC) (Shady 2006; Shady et al. 2001), and sites in the Fortaleza and Pativilca Valleys (3000-1800 BC) (Haas & Creamer 2004; Haas et al. 2005). Here cultigens were potentially exchanged for marine resources. The site of Caral, and others in the region, is characterized by monumental architecture that would have required a large amount of human labor to construct as well as a stable source of food to support the resident population made possible by irrigation (Haas & Creamer 2004; Pozorski & Pozorski 2008:611). This has been largely discounted but these sites were not constructed in a day and there is likely some form of cultivation occurring inland.

Direct evidence for irrigation that supported agricultural production in the Late Preceramic is scarce. It is likely that many coastal canals are not identifiable in the archaeological record because flooding or modern use obscures them. In the highlands however, there is evidence for utilitarian and religious use of irrigation at the highland site of La Galgada as early as 3000 BC, but could also date as late as 1500 BC. Sites in the highlands and upper valleys have yielded earlier dates for irrigation but these are often problematic (see Dillehay et al. 2005:17241; Dillehay et al. 2007; Piperno 2011; Zimmerer 1995). As an alternative to irrigation, there is some evidence for sunken gardens on the coast, however these tend to be
isolated occurrences in the Chilca Valley and surrounds (Rowe 1969). Inland sites like Caral in the Norte Chico region and La Paloma may have been the earliest communities to experiment and subsequently implement irrigation (Haas & Creamer 2004; Moseley 1974; Quilter 1991). However, in the case of Caral increasing evidence suggests an extensive degree of irrigation and agricultural production associated with early political centralization, possibly even a state (Shady Solis et al. 2001), but this is probably not the case for coastal valleys to the north.

4.2 Late Preceramic Sites in Nepeña

There is little data available for sites that date to this period other than an assumption based on the absence of ceramic materials. However, settlement patterns in the region indicate that coastal sites lacking ceramics should date to the Late Preceramic Period (see Figure 4). Sites that conform to this pattern include PV31-208 and PV31-209, which are quite similar in terms of architecture and artifacts. Both are small and lack ceramic materials and public architecture. They include rectangular habitation structures and immense quantities of marine refuse. However, Punkurí Bajo (PV31-10) dates to the Late Preceramic Period yet does not conform to the patterns seen at sites PV31-208 and PV31-209.

Punkurí Bajo is located in the upper reaches of the lower valley just after the natural bottleneck in the river, demarcating the boundary between upper and lower valleys. This site dates to the Late Preceramic Period and is characterized by a low terraced mound with a central staircase, semi-subterranean rooms, polychrome friezes, and sculpted clay features. Tello (1943) reported three phases of construction that have since been confirmed (Bischoff 1997; Daggett 1987; Samaniego 2006; Vega-Centeno 1998)
Punkuri Bajo is a mound structure with some graded access. The decorative art styles and architectural canons generally associated with elite or ritual construction seems to represent a ritual temple mound. Furthermore, the placement and careful treatment of a female burial uncovered by Tello (1943) supports a religious function. The function of this site is considered a public ritual with an open plaza area. It falls under the descriptive category of mound centers because of the nature of architecture.

**Figure 4.** Late Preceramic Period site distribution in the lower Nepeña Valley (drawing by Caitlyn Y. McNabb).
Punkuri Bajo was assigned to the Late Preceramic Period based on the recent studies at the site (Samaniego 1992). The excavations resulted in the identification of the clay feline bust in addition to clay friezes and murals, which Tello interpreted as evidence for Chavín infiltration into the coast, (Proulx & Daggett 1980; Tello 1943). In Tello’s view, Punkuri Bajo represented a satellite of the Chavín cult established on the coast for the purpose of expansion or proselytization.

Researchers like Bischoff (1997), Kan (1972), and Vega-Centeno (1998) have all discussed the chronology issues with Punkuri Bajo. These authors interpret similarities to Cerro Blanco and Huaca Partida as pointing toward an Initial Period date. On the other hand, Huayata (2009) compares the architecture at Punkuri Bajo to Cerro Sechín in the Casma Valley to suggest a Late Preceramic date ranging from 2100-1800 BC. These dates seem quite early in comparison to the Cerro Blanco sequence, and it is more likely that the population associated with Punkuri Bajo was transitional from aceramic to ceramic technology. It could even indicate a conscious rejection of the ceramic technology (Pozorski & Pozorski 1990, 1993, 2008).

4.3 The Initial Period (1800-900 BC)

The Initial Period (1800-900 BC) marks the beginnings of the use of ceramics on the Andean coast. It is also associated with increasing reliance on agriculture and an apparent expansion of irrigation (Fung 1988). This is a period of drastic social change visible in stylistic assemblages, spreading architectural features, and changing settlement patterns. Evidence for increasing and diversifying cultigens supports the idea for irrigation agriculture growing in intensity and extensivity. The drastic increase in monumental architecture in the coastal valleys
has been explained as a result of a boom in population associated with increased use of irrigation agriculture (Kembel & Rick 2008: 53).

Sites on the north-central coast are characterized by a central platform mound and staircase often aligned with circular sunken and rectangular plazas. Occasionally, architectural evidence from this region is reminiscent of the U-shaped tradition (Chicoine 2006b:34). Platform mounds were often terraced or built into the side of a hill to take advantage of the natural height (Daggett 1984:118; Pozorski & Pozorski 1993:47). Generally constructed of conical adobes associated with the Cupisnique architectural tradition of the north coast (Daggett 1984:111), these platform mounds-complexes are characterized by bilateral symmetry resulting from subsequent construction around the main mound. U-shaped layouts typically face up valley toward the source of water (Pozorski & Pozorski 1987; Williams 1985:230). At numerous sites in the Casma Valley sculpted and painted murals indicate stylistic similarities with the Cupisnique area to the north. These sculpted friezes represent anthropomorphic or zoomorphic figures that scholars have used to label these sites as religious in nature (Donnan 1985). Cerro Sechín, Pampa de las Llamas-Moxeke, Las Haldas, Sechin Bajo, and Sechin alto all share these characteristics (Pozorski & Pozorski 1986, 1987, 1995, 2005; Tello 1956). Other features of the Cupisnique tradition identified by Daggett (1984:111-115) include architectural columns, idols, niches, central staircases, and rounded corners on buildings.

The transition from the Late Preceramic to the Initial Period is marked by a settlement pattern shift. Coastal sites were abandoned and inland sites were established along the riverbanks (Pozorski & Pozorski 1993:48; Willey 1953:39-61). Because populations were significantly removed from the marine resources, this shift is closely associated with a more permanent form of irrigation agriculture. The proliferation of mound-plaza complexes requiring a greater and
more stable labor force also suggest permanent and increasingly organized populations (Pozorski & Pozorski 1993:48). Cultigens that were previously present such as cotton, gourds, and chili peppers increase in number, the use of maize expanded, and new cultigens are introduced, emphasizing the importance of agricultural products.

4.4 Initial Period Sites in Nepeña

In Nepeña the shift in settlement patterns, subsistence, and material culture is quite clear (see Figure 5). Except for PV31-105, which is located slightly more inland than its precursors but is still along the coast, all other sites dating to the Late Preceramic Period are located inland. Half way through the Initial Period, construction began at Cerro Blanco (PV31-36, 37) and Huaca Partida (PV31-125) (Shibata 2010). As construction continued through the end of the Initial Period, La Carbonera (PV31-27, 192) was established along the periphery of the present area of cultivation.

Sites that were occupied during the transition from coastal to inland habitation include Punkuri Bajo as well as PV31-105. The former was occupied as early as the Late Preceramic Period through the Initial Period. PV31-105 is a refuse area clustered around the base of a hill that contains both marine and terrestrial remains including maize as well as poorly preserved ceramics. Natural and artificial wells are located nearby. Though no habitations or structures were identified at the site, several burials were scattered around the refuse area (Proulx 1968:138). This settlement reflects a shifting subsistence procurement strategy based on the presence of maize and site location near to the coast as well as proximity to the wells.
The more significant settlement pattern shift includes the sites of La Carbonera (PV31-2/192), Cerro Blanco (PV31-36/37), and Huaca Partida (PV31-125). Cerro Blanco comprises a low mound (PV31-36) and a large terraced mound (PV31-37) that, if the two sites are interpreted as one, form a U-shaped mound complex (Bischoff 1997) with a red and white painted central staircase, an open plaza, evidence for megalithic architecture later in occupation, some semi-subterranean rooms, and sculpted clay reliefs. The site is considered as public-ceremonial. The initial occupation of the site is described as an activity area. However, the subsequent establishment of the U-shaped mound followed by megalithic renovations and evidence for feasting events imply that the ceremonial function persisted for the remainder of the occupation at Cerro Blanco. Daggett (1984) established an Initial Period date for Cerro Blanco and excavations conducted by Shibata (2010) have confirmed this early date in addition to an occupation lasting into the Early Horizon.

Huaca Partida is a large artificial mound constructed of fieldstone and mud measuring. It is located on the valley floor near the river (Proulx 1973:152; Shibata 2010). Proulx (1973) noted the presence of a ventilator shaft as well as burials in some of the terraces. Shibata (2010) sees a correspondence between Huaca Partida and Cerro Blanco based on monumental art. Huaca Partida most likely functioned as a public-ceremonial center due to the sheer size of the terraced mound, and the presence of monumental art similar to other ceremonial sites in the valley (e.g., Cerro Blanco) (Shibata 2010). This site dates to the Initial Period and Early Horizon Period based on comparative studies conducted by Shibata (2010), he lumps into the same Cerro Blanco Phase.
In contrast, the site of La Carbonera appears to be abandoned at the end of the Initial Period. This site is located on the northern border of the middle valley at a significant distance from the river on the northern periphery of modern cultivation. La Carbonera, initially documented by Tello (1943), was designated as two separate mound sites (PV31-27 and PV31-192). PV31-27 is described as a cluster of three small mounds that do not exceed 15 m in height, characterized by conical adobe construction, and it is likely those formed a U-shaped layout (Proulx 1968:69-70; 1973:205). Furthermore, a large rectangular enclosure built of fieldstones

Figure 5. Initial Period site distribution in the lower Nepeña Valley (drawing by Caitlyn Y. McNabb).
was also documented at the site (Proulx 1968:69). PV31-192 is described as a large huaca or mound and is potentially religious in nature given the presence of mounds in a U-shaped formation with burials surrounding the area (Proulx 1973:205-206). Additionally, the large size of the PV31-192 mound suggests some public or ritual function of the site complex.

Furthermore, Proulx (1973:69) noted a distinct lack of habitation structures at either of the mound sites. La Carbonera was assigned to the Cerro Blanco Phase due to the presence of conical adobe and the great architectural resemblance to Cerro Blanco and Huaca Partida (Proulx 1985:218; Shibata 2010).

### 4.5 The Early Horizon (900-200 BC)

The Early Horizon (900-200 BC) experienced a pattern of incipient urbanization as well as increasing social and political complexity that occurred alongside the intensification of agriculture, the introduction of camelid herding, and the development of more complex irrigation technologies. Site distribution during the Early Horizon period notably shifts from the valley floor flood plain to valley peripheries (Proulx 1985; Willey 1953; Wilson 1988). Where once all of the Initial Period mound centers were located within 1 km of the river, in the Early Horizon they occupied the periphery of the fertile valley bottom.

This time marked a sequence of reorganization from ceremonial mound centers to new domestic settlements with increased social segmentation (Chicoine 2006a, 2006b:45). Furthermore, as valley floor flood plain mound-centers of the Initial Period declined, planned Early Horizon sites were established along the margin of the valleys (Daggett 1984; Proulx 1985; Willey 1953; Wilson 1988). The impetus for this change and apparent rejection of the Chavin
influence at some sites has been the center of discussion regarding the Chavín phenomenon (Chicoine 2006a).

During the first half of the Early Horizon, approximately 900-700 BC, the previously established U-shaped ceremonial centers experienced an influx of foreign materials and ceased new construction on the temples (Shibata 2010). On the central coast, sites were abandoned, as is the case with Cardal around 800 BC (Burger and Salazar-Burger 1980). On the north-central and north coast, construction also ceases at U-shaped centers around 900-800 BC but is followed by the emergence of new centers with significantly different architectural styles (Chicoine 2006b; Pozorski & Pozorski 1987).

Some architectural features from the Initial Period persist at these new, decidedly distinct centers such as low platform mounds, corridors, and plazas centered around a dense monumental nucleus (Chicoine 2006a:17). Sites are often enclosed by rectangular stone walls defined by orthogonal construction techniques (Chicoine 2006b:87) including La Galgada (Grieder et al. 1988), Cerro Arena in the Moche Valley (Brennan 1980), Sechín Alto in the Casma Valley (Pozorski & Pozorski 2005), and Sute Bajo alongside Huambacho and Caylán (Cotrina et al. 2003:9).

Research at the sites of San Diego and Pampa Rosario in the Casma Valley (Pozorski & Pozorski 1987), and Huambacho and Caylán in Nepeña demonstrate a significant change in the use of architectural canons (Chicoine 2006a, 2006b; Chicoine & Ikehara 2010). Especially indicative of this change is the lack of conical adobes, rejection of the feline motif, and introduction new geometric art styles. Furthermore, Early Horizon sites lack lateral mounds and circular sunken courts (Chicoine 2006a, 2006b).
Perhaps more significant is the planned construction and consistency in the complex spatial organization characterized by multiple enclosed ceremonial spaces indicating that a centralized authority must have managed construction (Chicoine 2006a:18). Centralized authority would have mobilized local labor forces to initiate construction as evidenced by the dense orthogonal buildings at Caylán that have been interpreted as habitation areas (Chicoine & Ikehara 2010).

4.6 Early Horizon Sites in Nepeña

Cerro Blanco and Huaca Partida, which continued to be occupied through the Nepeña Phase, experienced major renovations that included filling in of previous structures as well as the introduction of megalithic architecture to the site. An influx of foreign objects like obsidian and the first appearance of maize as well as a significant density of ceramic materials characterize the transition from the Cerro Blanco to the Nepeña. The florescence of foreign material and density of comestible plants has been interpreted as feasting events that took place with greater frequency or, perhaps, on a notably grander scale associated with the renovation and expansion of the temple (Ikehara & Shibata 2008; Shibata 2010). This transition is demonstrated by the implementation of megalithic architecture and the appearance of Nepeña Phase ceramics at Cerro Blanco and Huaca Partida, which were abandoned by the end of the Early Horizon-Samanco Phase. Five additional sites were established around the beginning of the Samanco Phase including Huambacho, Samanco, Sute Bajo, Punkurí Alto, and Caylán (see Table 1, Figure 6).

Huambacho is located 150 m E of the Pan-American Highway at Cerro Popo, about 8 km from the coast. The most recent research at this site was conducted by Chicoine (2006a,
Huambacho consists of two distinct architectural compounds, including the Main Compound and North Compound, which cover a total area of 12 hectares. The entire site is internally complex and spatially extensive and is characterized by areas of dense structures with graded access. Architectural features include courtyards, platform complexes with sunken plazas, interior colonnades, monumental walls, perishable roof structures, rectangular pillars, rectangular notches or niches, relief clay friezes, geometric designs, and rectangular rooms. Huambacho is considered a planned building project and many of the features can be traced back to Initial Period traditions (Chicoine 2006:85). Faunal remains included camelid, rodent, fish, bird, and other unknown specimens. Food remains are dominated by maize, at 60% of the recovered botanical materials, in addition to peanuts, manioc, pacae, lucuma, avocado, squash, and beans (Chicoine 2006:163-174).

Samanco is located on the north edge of the lower valley near the coast and along the original course of the Rio Nepeña located at the base of a large cerro or mountain (Proulx 1968:46-50). The site is characterized by three main areas of construction separated by deep, natural gullies, cemetery areas, and minor constructions. The most elaborate construction is located at the highest point of the site. Around these buildings several structures surrounded the central area and are interpreted as potential habitation sites (Proulx 1968). Cemeteries occur frequently and randomly across the site with no obvious separation from the habitation areas. Images from GoogleEarth indicate a much more intricate and dense layout, characterized by numerous stone enclosures. There is a distinctive profusion of shell remains of several varieties across the site that was not noted in the original survey. Ceramic sherds are also quite abundant, but Proulx (1968) described the assemblage as suffering from significant weathering and lacking in diagnostic sherds. Samanco probably functioned as a habitation area with areas of elite
residence and some civic-ceremonial structures as well. Access to many of the structures is graded and, compared to Caylán and Huambacho, likely has some public plaza or area that functioned similarly to plazas found other Early Horizon sites. Subsequent research at Caylán and Huambacho suggests that this architectural style dates to the Early Horizon and is possibly associated with an emergent coastal tradition after the abandonment of the temple mound sites.

Caylán is likely the most important site within the Nepeña Valley. Chicoine and Ikehara (2010, 2011) have confirmed the Early Horizon date based on excavations. Caylán is by far the largest site that dates to the Early Horizon. It is located on the periphery of the modern cultivation area on the northern border of the lower valley. The site has been described as an extensive area characterized by rectangular stone enclosures interpreted as habitations (Proulx 1968:72). The initial description also noted that the construction crept up the skirts of the natural formation of Pan de Azucar, a small hill adjacent to the site interpreted as a fortress or habitation structures with defensive features. Furthermore, Caylán seems to be organized into various sectors and a large stone wall bisects the site before running up the hill to the ridgetop platforms (Daggett 1984:217). The most recent research carried out by the Proyecto de Investigación Arqueológica Caylán and provides the most detailed description of the site. The site covers over 200 hectares on the border of the modern zone of agriculture. The dense monumental nucleus of the site is approximately 50 hectares and the total surface area with evidence of architecture is calculated at more than 80 hectares (Chicoine & Ikehara 2010:350). This site is accompanied by zones of terraced hills, modified gullies, and activity areas with minor-scale architecture. The monumental zone is characterized by an agglomeration of dense spaces of approximately 350 orthogonal structures constructed with quarried rock organized in a series of enclosed patios, plazas, and corridors (Chicoine & Ikehara 2010:350). A large mound is characterized by clay
friezes associated with monumental benches, and interior columns with clay friezes. Additionally, sculpted clay cones were found adjacent to the southern wall of a corridor, four of which bear sculpted circular designs at the base. The cones are interpreted as decorative elements of the monumental architecture. Caylán can be described as a multi-component site with religious, administrative, and domestic functions. Proulx (1968) and Daggett (1984) interpreted the dense orthogonal structures as domestic architecture while recent excavations realized by PIAC interpreted various features at the Principal Mound and adjacent plaza as evidence for religious activities or public ritual.

Potentially associated with the Early Horizon is Punkurí Alto. This site is built into the side of a hill, just east of the natural bottleneck in the valley. Punkurí Alto is located 700 m E of Punkurí Bajo (PV31-10) and 1.9 km SW of Hacienda San Jacinto. Originally documented by Proulx (1968:57-58), the site is described as an area rising in three main terraces that contain rectangular structures. The most elaborate architecture is located on the highest terrace. There is also note of an “arabesque” wall and ornamental niches. Around the three main terraces are cemeteries and further habitation structures. Additionally, extensive shell remains were present as well as corncobs. The layout of the site is quite similar to other Early Horizon sites like Caylán, Samanco, and Huambacho. While lower valley sites were not the focus of his work, Daggett (1987:409, Table 8-1) later identified the circle-and-dot style as evidence for an Early Horizon presence.

Sute Bajo is located 1.9 km SE of Hacienda Cerro Blanco south of river on the periphery of modern cultivation. This site is dominated by two large, adobe buildings that are most likely colonial churches (Proulx 1973:140). Surrounding the buildings are both historic and prehistoric graves that number in the hundreds. Other structures were later identified in Sute Bajo area that
are characterized by stone enclosure compounds (Cotrina et al. 2003). This site is included in the sample based on the identification of the rectangular stone enclosures. Based on comparison to other stone enclosure sites, it seems that Sute Bajo may have had a religious, public-ceremonial function alongside a private, administrative or elite domestic function.

The final site identified as Early Horizon is dated to this period with very little data. Pañamarca is known as a Moche site, which post-dates the time periods discussed here. This site...
is located at the halfway point to the upper valley south east of Caylán on the same side of the river. Pañamarca is a large, rectangular adobe pyramid that rises as high as 60 to 70 m and is surrounded by large rooms, walled courtyards, and cemetery areas (Proulx 1968:78-80). This site is included in the sample because Proulx (1968:68) noted that Chavín ceramic sherds had been collected at the site thus indicating an Early Horizon date. There is a stone temple at Pañamarca just south of the Moche phase adobe pyramid associated with the Early Horizon.

Summary

A general trend of increasing frequency of sites through time alongside a shift in architectural styles and changing subsistence strategies demonstrates the need to further investigate this relationship. Subsistence strategies appear to shift inland, suggesting cultivation and agriculture as primary modes of subsistence, and settlement patterns became positively correlated to irrigation systems and cultivable land. Prior to the establishment of irrigation systems, settlement patterns are closely linked to primary resources like water or marine goods. Furthermore, increasing site densities and a shift in site function also accompany the shift to agriculture and increasing proliferation of sites. Table 2 summarizes each of the sites discussed here including coordinates, architecture, construction materials, and area as well as presence-absence for marine remains, cultigens, and ceramics.
Table 2  Summary of sites in study sample. LVM- lower valley middle, LVU- lower valley upper. LPC- late Preceramic period, IP- initial period, EH- early horizon.

<table>
<thead>
<tr>
<th>Site</th>
<th>Period</th>
<th>Sector</th>
<th>Function</th>
<th>Architecture</th>
<th>Material</th>
<th>Ceramics</th>
<th>Cultigens</th>
<th>Marine</th>
<th>Area (ha)</th>
<th>Coordinates</th>
</tr>
</thead>
<tbody>
<tr>
<td>PV31-1</td>
<td>EH</td>
<td>LVM</td>
<td>Cemetery</td>
<td>-</td>
<td>-</td>
<td>X</td>
<td>X</td>
<td>-</td>
<td>-</td>
<td>09 11°30.35&quot; S</td>
</tr>
<tr>
<td>PV31-4</td>
<td>EH</td>
<td>Coastal</td>
<td>SIF/Habitation</td>
<td>rectangular enclosure compound; plaza area</td>
<td>mixed</td>
<td>X</td>
<td>X</td>
<td>-</td>
<td>-</td>
<td>09 15°47.68&quot; S</td>
</tr>
<tr>
<td>Samanco</td>
<td></td>
<td></td>
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<td>28°16.65&quot; W</td>
<td></td>
</tr>
<tr>
<td>PV31-10</td>
<td>LPC, IP</td>
<td>LVM</td>
<td>SIF</td>
<td>low temple mound; semi-subterranean rooms; polychrome friezes; feline motifs</td>
<td>mixed</td>
<td>X</td>
<td>-</td>
<td>X</td>
<td>3</td>
<td>09 09'19.07&quot; S</td>
</tr>
<tr>
<td>Punkuri Bajo</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>18°14.98&quot; W</td>
<td></td>
</tr>
<tr>
<td>PV31-11</td>
<td>EH</td>
<td>LVU</td>
<td>SIF/Habitation</td>
<td>rectangular enclosure compound; plaza area</td>
<td>mixed</td>
<td>X</td>
<td>X</td>
<td>-</td>
<td>-</td>
<td>09 09°13&quot; S</td>
</tr>
<tr>
<td>Punkuri Alto</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>17°15&quot; W</td>
<td></td>
</tr>
<tr>
<td>PV31-27</td>
<td>IP</td>
<td>LVM</td>
<td>SIF</td>
<td>mounds, burial areas, low wall</td>
<td>mixed;</td>
<td>X</td>
<td>-</td>
<td>-</td>
<td>6.75</td>
<td>09 09°53.38&quot; S</td>
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<tr>
<td>PV31-192</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>conical adobe</td>
<td></td>
<td></td>
<td></td>
<td>22°36.07&quot; W</td>
<td></td>
</tr>
<tr>
<td>La Carbonera</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>22°36.07&quot; W</td>
<td></td>
</tr>
<tr>
<td>PV31-30</td>
<td>EH</td>
<td>LVM</td>
<td>SIF/Habitation</td>
<td>rectangular enclosure compound, plaza areas, storage, domestic structures</td>
<td>mixed;</td>
<td>X</td>
<td>X</td>
<td>-</td>
<td>80</td>
<td>09 11°29.83&quot; S</td>
</tr>
<tr>
<td>Caylán</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>conical adobe</td>
<td></td>
<td></td>
<td></td>
<td>23°33.82&quot; W</td>
<td></td>
</tr>
<tr>
<td>PV31-36</td>
<td>IP, EH</td>
<td>LVM</td>
<td>SIF</td>
<td>U-shaped temple, sunken plaza, several construction phases, red and white</td>
<td>mixed;</td>
<td>X</td>
<td>X</td>
<td>-</td>
<td>2.9</td>
<td>09 11°02.67&quot; S</td>
</tr>
<tr>
<td>Cerro Blanco</td>
<td></td>
<td></td>
<td></td>
<td>staircase, polychrome friezes</td>
<td>conical adobe</td>
<td></td>
<td></td>
<td></td>
<td>20°48.43&quot; W</td>
<td></td>
</tr>
<tr>
<td>PV31-37</td>
<td>IP, EH</td>
<td>LVM</td>
<td>SIF</td>
<td></td>
<td>megalithic</td>
<td>X</td>
<td>-</td>
<td>-</td>
<td>2.9</td>
<td>09 11°00.74&quot; S</td>
</tr>
<tr>
<td>PV31-38</td>
<td>EH</td>
<td>LVM</td>
<td>SIF</td>
<td></td>
<td></td>
<td>X</td>
<td>-</td>
<td>-</td>
<td>3</td>
<td>09 20°54.42&quot; W</td>
</tr>
<tr>
<td>Pañamarca</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>22°32.43&quot; W</td>
<td></td>
</tr>
<tr>
<td>PV31-103</td>
<td>EH</td>
<td>LVM</td>
<td>SIF/Habitation</td>
<td>rectangular enclosure compound, plaza areas, storage, domestic structures</td>
<td>mixed;</td>
<td>X</td>
<td>X</td>
<td>-</td>
<td>12</td>
<td>09 16°04.33&quot; S</td>
</tr>
<tr>
<td>Huambacho</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>conical adobe</td>
<td></td>
<td></td>
<td></td>
<td>25°08.51&quot; W</td>
<td></td>
</tr>
<tr>
<td>PV31-105</td>
<td>IP</td>
<td>Coastal</td>
<td>Midden</td>
<td></td>
<td>-</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>-</td>
<td>09 17°50.84&quot; S</td>
</tr>
<tr>
<td>PV31-108</td>
<td>EH</td>
<td>LVM</td>
<td>SIF</td>
<td>rectangular enclosure compound, plaza area</td>
<td>mixed</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>1.36</td>
<td>09 11°36.94&quot; S</td>
</tr>
<tr>
<td>Sute Bajo</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>19°42.02&quot; W</td>
<td></td>
</tr>
<tr>
<td>PV31-125</td>
<td>IP, EH</td>
<td>LVM</td>
<td>SIF</td>
<td>U-shaped temple, polychrome friezes</td>
<td>mixed;</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>1</td>
<td>09 11°36.94&quot; S</td>
</tr>
<tr>
<td>Huaca Partida</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>conical adobe</td>
<td></td>
<td></td>
<td></td>
<td>19°42.02&quot; W</td>
<td></td>
</tr>
<tr>
<td>PV31-208</td>
<td>LPC</td>
<td>Coastal</td>
<td>Habitation/Midden</td>
<td>rectangular rooms</td>
<td>marine refuse</td>
<td>-</td>
<td>X</td>
<td>0.5</td>
<td>18°42.21&quot; S</td>
<td></td>
</tr>
<tr>
<td>Las Salinas</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>29°10.42&quot; W</td>
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</tr>
<tr>
<td>PV31-209</td>
<td>LPC</td>
<td>Coastal</td>
<td>Habitation</td>
<td>rectangular rooms</td>
<td>marine refuse</td>
<td>-</td>
<td>X</td>
<td>0.16</td>
<td>17°42.06&quot; S</td>
<td></td>
</tr>
</tbody>
</table>

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CHAPTER 5:
METHODS AND ANALYSIS

The goal of this research is to explore the relationship between settlement patterns and subsistence strategies that require irrigation technologies. Archaeologists have employed ethnographic analogy and modern data on water use and canal construction for the purpose of scientific research on water dependent systems (i.e., Ertsen 2010; Netherly 1984). It is especially helpful when, as is the case in Nepeña, many of the features needed for analysis are still currently in use. Based on modern irrigation maps, analogies can be drawn between the distribution of existing communities and prehistoric populations. Here, I execute this study by (1) identifying the recent modern canals and eliminating them from the maps, and (2) drawing associations between prehistoric sites and potential canals. The spatial distribution of prehistoric sites and canals should provide a basic understanding of the importance water played in early urbanism and the development of political centralization.

Other studies conducted in north coast valleys like Santa and Moche can provide a second analogue for the study of settlement patterns and irrigation systems. The landscape, climate, and cultural identity of the prehistoric populations are very closely related between these valleys and Nepeña. Socially and politically though, the environments are very different. Wilson (1988) determined the carrying capacities for the Santa Valley and used those calculations to estimate carrying capacity for neighboring valleys. Similarly, population estimates from the same study based on actual counts of discrete domestic structures will be applied to the data available for Nepeña.

After site catchment, carrying capacity, and population estimates have been established for Nepeña, a discussion of social integration between contemporary sites and the political
ramifications is possible for each chronological phase. Once a greater understanding of the synchronic relationships is reached, a discussion of these developments through time will allow for a formal statement on the developmental chronology in Nepeña. This discussion will be dedicated to the earliest developments of irrigation, the dependence on water throughout the landscape, and the social and political ramifications of that dependence.

5.1 Identifying Irrigation Systems

In order to determine irrigation canals with potential prehistoric origins, I analyze site distributions in relation to available resources through time. Using modern irrigation maps provided by the Comisión de Regantes de Nepeña as well as extensive use of GoogleEarth and ArcGIS tools, I identify potential canals for each site. An approximate trajectory and linear measurement will also be noted. This data will later be used to calculate potential hectares (ha) of land under cultivation at each site and in total for each period. The use of gravity-based irrigation technologies characteristic of the prehistoric Andes persist in current systems used by modern populations (Billman 1996; Denevan 2001; Ertsen 2010). Of course modern construction should not be considered entirely analogous to prehistoric systems because of their documented construction and notable differences in canal morphology. Specifically, prehistoric canals are generally parabolic in shape with the canal intake originating somewhere in the middle-to-upper valley but also in an area with a broad valley plain (Denevan 2001). Parabolic canals expand away from the river in a generally curvilinear shape, generally as far as water flow allows, before turning back toward the river. This shape allows for more land to be irrigated by a single canal. Should a tendency to settle in areas without direct access to water occur through time, and
especially if the sites have large population estimates, then it is highly likely the modern canal in the area has some ancient origins or that the trajectory of an ancient canal was in the general area.

In the absence of absolute dates for canals and stratigraphic data, it is difficult to assign dates to irrigation systems. Through association with sites at a distance greater than 1 km from the river, canals dating prior to the historic period were identified. Only the canals of derivation, or those canals that take water directly from the river and distribute water to lower level works, should be used for this associative dating because lower level canals change shape and direct on a seasonal to yearly basis. Based on Netherly’s (1984) study, it can be assumed that sites located along the canal were user groups for that system in particular.

Five canals were identified as having a high probability for ancient origins. These are labeled the Punkuri-Caylán A and B Canals, the Sute A and B Canals, and the Huambacho Canal. All five are parabolic, stretching to the extent of cultivable land before curving back toward the river or ending in a water catchment. They are also serpentine, indicating a direct influence of the natural topography on the construction of the canal that is no longer as significant a factor in modern canal construction. Finally, though the Samanco resource area did not necessarily need irrigation, the large population density and likely reliance on marine resources suggest that they were probably irrigating off the original river south into the open plain just east of the littoral. Therefore, a canal associated with the site of Samanco may be obscured by changing river trajectory or modern activity.
(Clockwise) **Figure 7.** Modern canal with cement lining and linear structure, **Figure 8.** Modern canal resembling prehistoric construction techniques, **Figure 9.** Modern canal with temporary dam using ephemeral materials suspected to have been used in the past, **Figure 10.** Modern canal with modern dam construction. (Photos by: Caitlyn Y. McNabb)
Three sites date to the Late Preceramic Period (PV31-208, PV31-209, PV31-10). Of these three sites only one, Punkurí Bajo (PV31-10), demonstrates an association with modern irrigation canals though it is located close enough to the river to negate the need for a large primary canal. Continued occupation along the same primary canal in the Initial Period and Early Horizon further indicate that Punkurí Bajo and the associated population may have been responsible for the initial construction of a primary canal in the Nepeña Valley.

This canal is labeled the Punkurí-Caylán (P-C) Canal as it originates near the site of Punkurí and ends at the Early Horizon site of Caylán. Canals A (red) and B (blue) indicate two different trajectories. According to the ONERN (1972) maps, the A canal is an acequia or periodically dry water run (see Figure 11). In years with heavy or shifting rainfall and river flow, this acequia would serve as a second river stream that could serve as flooding strategy. It is likely that this acequia was eventually culturally modified to standardize water flow in heavy years, but this probably occurred in a later period when downstream sites were more greatly affected by fluctuating flow. It is assumed that at one point the river flowed along the same path as P-C Canal A before being diverted by natural causes like flooding, drought, or earthquakes. This is supported by the salinity map (Figure 11), which indicates the salinity levels of soils on the valley floor. The map shows a pattern of high salinity levels in areas along the P-C Canal B removed from the modern river flow.

Soil salinity is caused by a number of processes, especially the weathering of rocks or irrigation. Soil salinity rarely occurs in situ (Abrol et al. 1988). Salts originate from the crust of the earth and are generally transported via ground water streams, which gradually concentrate as water moves from more humid to arid environments. In environments where groundwater is the only available source for irrigation the high salinity of irrigation water
can cause a buildup of salts in the soils, especially when soil drainage is restricted or inadequate in irrigation systems. Problems with soil salinity occur more frequently in arid and semi-arid environments where the pH balance is disrupted by irrigation. The process of salinization appears in soil chemistry after long periods of time. Therefore, modern maps of soil salinity
(ONERN 1972) may reflect ancient irrigation use that would have created highly salinated soils over a long period of time.

As will be discussed later, the early occupation of La Carbonera during the Initial Period along this same trajectory suggests that either the original river flow followed this path or there is a much earlier date for significant irrigation systems. Excluding the Punkuri-Caylán Canal system, the other irrigation works in the valley do not indicate a date earlier than the Early Horizon based on the data currently available.

5.2 Defining User Groups

Based on Netherly’s (1984) work, communities that rely on irrigation systems are integrated by the canals that serve them and the canals that they maintain. Thus each distribution canal represents one sociopolitical organization. It is not until the Early Horizon that irrigation systems significantly shape these sociopolitical organizations and, for the purposes of this research, four irrigation communities have been identified. Woodson (2010:70-71) found the application of focal settlement analysis to linear communities shaped by the river and irrigation systems alone inadequate. He suggests instead that social and political boundaries are limited by the shape of a canal and, when more than one contemporary site is present on a canal, then a site hierarchy could indicate a “focal village”. The general concept of the focal village is that each community includes a set of interrelated settlements within a bounded territory that has a center with public architecture. A linear community is a territory that by definition is commensurate with the extent of the canal system (Woodson 2010:70). In traditional models of political boundaries, circles or polygons of varying dimensions are used to define focal villages.
However, in irrigation systems this is an unsatisfactory method. It is important to reference the physical layout of the canal system, location of sites along the canal systems, and priority of community in deciding where to locate new settlements (Woodson 2010:70-71). Furthermore, natural geographic features probably served as social boundaries, albeit permeable. Instead of using a circle to model the community territories, it was found that the territories could be modeled better by linear or oval-shaped boundaries that extend upstream along the main canal segments.

The method employed here is a modification of Woodson’s (2010) focal/linear community arrangement, as well as an adaptation of site catchment analysis. To determine site catchment, a simple equation was applied measuring the total distance between two sites. By using surface area (ha) ratios between them, a ratio could be created for spatial extent of each site. Site catchment is the analysis of resources available to sites at a particular distance. These distances are often measured based on foraging patterns and the assumption that individuals will only venture for resources to the extent that will allow them to travel there and back in a single day (Flannery 1976:165-168). Areas in Mesoamerica have used site catchment estimates that range from 2-5 km where an hour walking distance is approximately 2.5 km. While walking estimates are probably much lower on the Andean coast for several reasons including different topography and vegetation, this estimate works well for this research. This is so because as populations become increasingly sedentary it seems that the distance individuals would be willing to go on a regular basis should decrease.

Site catchment can be calculated using various shapes of polygons, in particular Thiessen Polygons, where the distance from one site to another is bisected by a perpendicular line that marks the border between two areas of influence (Hodder & Orton 1976:59-60, and Figure 4.4).
However, problems arise with this model since Thiessen Polygons give equal weight to sites of different sizes (Hodder & Orton 1976:188). The polygons suggested here represent areas of potential habitation or relation based on the assumption that many sites may have been subject to differential preservation. The polygons indicate areas of potential agriculture associated with each site.

During any one period, measurements were taken between two sites of closest distance as well as between any one site and Caylán, as it is the hypothesized regional center (highest population and density). Following this, I determined ratios that establish a perpendicular line between the two sites at a corrected distance than that of a traditional Thiessen Polygon. It is significant that these lines often correlate to natural boundaries that were not previously thought of as barriers or buffer zones. For instance, the boundary between Samanco and Huambacho lies along the river. For Huambacho and Caylán, the barriers end in approximately the same place.
where the river valley narrows. The distance from Caylán to Sute Bajo also ends at the river. These patterns were applied when delineating areas of influence and resulted in a patterned site distribution based on distance and size (see Figure 12).

The sites discussed here should be understood as Woodson’s (2010) focal villages. He found that the largest focal villages tended to be located at the distal end of canals, implying they had some influence on the construction of these canals to ensure water would be diverted to their settlement. It should also be noted that there were probably numerous linear communities located along the canals that have since been destroyed as a result of post-abandonment activities.

Figure 12. Map indicating influence areas, or those areas likely to be controlled by various sites based on ratios of site size and density.
5.3 Population Estimates

In order to understand the expansion of sites and sociopolitical organization through time, population estimates are a useful tool along side architecture density. Based on population estimates derived from analysis of habitation structures and sherd densities for the Santa Valley, four density levels were established (Wilson 1988:75-78); (1) Low (15 people/ha), (2) Low-Moderate (50 people/ha), Moderate (100 people/ha), and High (250 people/ha). These densities are based on the assumption that a household unit is composed of 5 individuals. By applying these densities to surface area and number of structures, estimated from GoogleEarth images if the data was not available in literature, approximate population ranges are provided relative to sites within the valley itself (see Millaire & Estaugh 2011:295-296 for a comparison with Virú).

Population estimates are problematic, but if they are understood in this relative sense then settlement patterns and changes through time can be analyzed in relative averages rather than in absolute terms. Once population estimates are established levels of social integration and hierarchy can be investigated.

The above calculations were applied to all sites with data available within the defined study range. There is a significant bias toward Early Horizon habitation centers due to the preservation of domestic structures and construction material while the civic-ceremonial mound sites of the Cerro Blanco, Nepeña, and Samanco Phase during the Initial Period and Early Horizon do not leave evidence for habitation structures or have yet to be investigated. Given the function of these mound sites, population estimates and occupational density cannot be determined in the same way that activity or habitation areas can be. Civic-ceremonial mound sites acted as socially integrative facilities where the population that utilized the space lived around the site, rather than on the site. In a cross cultural study of integrative facilities, derived
mainly from Human Relations Area Files data, Adler & Wilshusen (1990) determined that these types of sites could represent populations ranging anywhere from 75 to 500 depending on the size of the site and to what degree it served as a socially integrative facility. High-level integrative facilities served no less than 300 people and no more than 600, though the largest structure size in the sample is 2 ha less than Punkuri Bajo (Adler & Wilshusen 1990:137, Figure 1).

There is no way to know, given the available data on PV31-208 and 209, whether the structures at these sites were habitations or how many there were. It is difficult to determine population and occupational density of sites that do not reflect areas of habitation such as the Late Preceramic sites. With further excavation of the middens and architecture at PV31-208 and 209 the occupational sequence at these sites could be determined as well as the size of the occupant group. Calculating 5 people per household is an invalid method for estimating population when the number and function of the structures is indeterminate. Based on the descriptions given for PV31-208 and 209, it seems the former is larger than the latter where four structures were documented. Assuming that these structures were in fact households, a minimum estimated population of 20 people is postulated for PV31-209, the estimate for PV31-208 should be greater. Unfortunately there is no documentation of the number of structures at PV31-208. Adler and Wilshusen (1990:137, Figure 1) find that populations at low-level integrative facilities or structures of generalized use under 1 ha in size, like the functions hypothesized for the coastal sites, can reach as many as 100 people.

Using a ratio of site size between the sites it is possible to estimate a population for 208 of approximately 60, falling well within the 100 person maximum estimate. The occupational densities for PV31-208 (low-moderate) and PV31-209 (low) suggest that both sites can be
considered hamlets, lacking socially integrative facilities, and probably economically autonomous of each other despite their general proximity.

Punkuri Bajo represents a very different kind of settlement that has been compared to analogues ranging from the Late Preceramic (Huayata 2009), Initial Period (Bischoff 1997; Daggett 1987; Vega-Centeno 1998) to the Early Horizon (Proulx 1968; Tello 1943). As compared to sites in the Casma Valley, the dates at this site range from 2100-1800 BC (Huayata 2009), though it is also characterized by architectural similarities and spatial proximity to Cerro Blanco (Shibata 2010). Regardless, a minimum population estimate of 500 people can be reached for Punkuri Bajo based on this study though it reflects a dispersed population. La Carbonera estimates are around 169 persons based on architectural density and up to 500 people based on

Table 4. Range of population estimates calculated from site density (structures/hectare) with most likely populations boxed.

<table>
<thead>
<tr>
<th>Site #</th>
<th>(ha)</th>
<th>structures</th>
<th>density structures/(ha)</th>
<th>Low (15)</th>
<th>Low-Moderate (50)</th>
<th>Moderate (100)</th>
<th>High (250)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PV31-1</td>
<td>0</td>
<td>0</td>
<td>0.00</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>PV31-4</td>
<td>19</td>
<td>90</td>
<td>4.74</td>
<td>285</td>
<td>950</td>
<td>1900</td>
<td>4750</td>
</tr>
<tr>
<td>PV31-10</td>
<td>5</td>
<td>1</td>
<td>0.20</td>
<td>-</td>
<td>-</td>
<td>500</td>
<td>1250</td>
</tr>
<tr>
<td>PV31-11</td>
<td>2.64</td>
<td>6</td>
<td>2.27</td>
<td>39.6</td>
<td>132</td>
<td>264</td>
<td>660</td>
</tr>
<tr>
<td>PV31-27/192</td>
<td>11.25</td>
<td>4</td>
<td>0.36</td>
<td>-</td>
<td>169</td>
<td>500</td>
<td>-</td>
</tr>
<tr>
<td>PV31-30</td>
<td>50</td>
<td>300</td>
<td>6.00</td>
<td>750</td>
<td>2500</td>
<td>5000</td>
<td>12500</td>
</tr>
<tr>
<td>PV31-36/37</td>
<td>4.8</td>
<td>3</td>
<td>0.63</td>
<td>72</td>
<td>240</td>
<td>480</td>
<td>1200</td>
</tr>
<tr>
<td>PV31-38</td>
<td>0</td>
<td>0</td>
<td>0.00</td>
<td>15</td>
<td></td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>PV31-103</td>
<td>12</td>
<td>80</td>
<td>6.67</td>
<td>180</td>
<td>600</td>
<td>1200</td>
<td>4750</td>
</tr>
<tr>
<td>PV31-105</td>
<td>0</td>
<td>0</td>
<td>0.00</td>
<td>15</td>
<td></td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>PV31-108</td>
<td>1.36</td>
<td>4</td>
<td>2.94</td>
<td>20.4</td>
<td>68</td>
<td>136</td>
<td>4750</td>
</tr>
<tr>
<td>PV31-125</td>
<td>1.67</td>
<td>1</td>
<td>0.60</td>
<td>84</td>
<td>136</td>
<td>200</td>
<td>-</td>
</tr>
<tr>
<td>PV31-208</td>
<td>0.5</td>
<td>0</td>
<td>0.00</td>
<td>15</td>
<td>60</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>PV31-209</td>
<td>0.16</td>
<td>0</td>
<td>0.00</td>
<td>15</td>
<td>40</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Total</td>
<td>108.38</td>
<td>485</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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Adler and Wilshusen’s calculations. Huaca Partida is also considered a socially integrative facility similar to Punkuri Bajo although smaller than other similar sites. Based on architectural density, the population here is approximately 84 people but applying Adler and Wilshusen’s model gives estimates ranging from 136-200 people dispersed across the landscape.

The Early Horizon-Nepeña Phase marks the introduction of new sites and site types characterized by agglutinated habitation areas. Ultimately a general trend in the increase of site frequency is evident through the phases. What is more significant, along with the change in site distribution, architectural style, size, and density, the shifts occurring from Cerro Blanco Phase to Nepeña Phase and ultimately the Samanco Phase indicates a quick and massive move from former civic-ceremonial mound sites to stone enclosure habitation areas where construction was realized in a short time (Chicoine 2006). These stone enclosure compounds are generally characterized by at least one plaza area and dense orthogonal structures that have been interpreted as habitations. The estimates for Caylán are by far the largest, ranging from 5000-12500 persons at a Moderate and High density calculation, respectively. Samanco is estimated similarly at 1900-4750 persons, as is Huambacho from 1200-3000. Sute Bajo and Punkuri Alto are calculated at Low-Moderate ranges for estimates of 136 and 264 persons respectively. There was no data for PV31-38 that would allow spatial or population estimates, though ongoing research at this site will reveal new information about the Early Horizon occupation in the near future.
5.4 System Extent and Labor Requirements

Mabry used a 4 m$^3$ per day excavation rate in the American Southwest as a way to estimate the time it would take for groups of various sizes to excavate an irrigation canal (Mabry 2002). However, Billman (2002) used a calculation of 1 m$^3$ per person day. Though both are problematic I applied Billman’s estimates to each of the major canal systems, however conservative, in order to remain consistent in the region.

The extent of the Punkurí-Caylán Canal A (15.4 km) and B (13.6 km), the most likely prehistoric canal trajectories, with an average 2 m width and 1.5 m depth allow for the calculation of labor requirements for these canals. At an excavation rate of 1 m$^3$ per person per day with a total volume of 46,200 m$^3$, it would take 46,200 person days to construct Punkurí-Caylán Canal A. If 150 people comprised the labor group the Punkurí-Caylán A could potentially be constructed in 308 days. It is not likely that construction would have taken place year round as labor would have been needed for building construction, field maintenance, and planting/harvesting. Therefore a construction season of 150 days suggests that this canal could be built in two years. The 150-person labor force is working under the assumption that irrigation construction was a concerted effort of a centralized authority. If it was not organized by the central government then an appropriate labor force would be around 10 people could construct the labor force over approximately 30 years. This estimate reflects a slow accretion of construction over a long period of time. Punkurí-Caylán B would require 40,800 person days to construct, 272 days with a 150-person labor force or two years (see Table 5).

Sute Canals A and B are considerably smaller than the Punkurí-Caylán system. At 5.9 and 4.8 km in length respectively, Sute A and B would have required 17,700 and 14,400 person-
Table 5. Calculations of labor estimates (person days) for initial construction of total canal lengths. These are further broken down based on estimates of various group sizes that potentially constructed canals.

<table>
<thead>
<tr>
<th>Canal</th>
<th>Extent (km)</th>
<th>Volume ( (m^3) )</th>
<th>Person Days ( (1\ m^3) )</th>
<th>Labor Estimates</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>150</td>
<td>50</td>
</tr>
<tr>
<td>Punkuri-Caylán A</td>
<td>15.4</td>
<td>46,200</td>
<td>46200</td>
<td>308</td>
</tr>
<tr>
<td>Punkuri-Caylán B</td>
<td>13.6</td>
<td>40,800</td>
<td>40800</td>
<td>272</td>
</tr>
<tr>
<td>Sute A</td>
<td>5.9</td>
<td>17,700</td>
<td>17700</td>
<td>118</td>
</tr>
<tr>
<td>Sute B</td>
<td>4.8</td>
<td>14,400</td>
<td>14400</td>
<td>96</td>
</tr>
<tr>
<td>Huambacho</td>
<td>10.7</td>
<td>32,100</td>
<td>32100</td>
<td>214</td>
</tr>
<tr>
<td></td>
<td><strong>50.4</strong></td>
<td><strong>151200</strong></td>
<td></td>
<td>1008</td>
</tr>
</tbody>
</table>

50.4 \( \times \) 151,200 person-days to complete. Considering the Sute area has a much lower population density, it is likely that the labor groups ranged from 25-50 people. In this case the days required for construction would range from 708-354 and 576-288 days for each size group. That means that these canals would have required anywhere from 2-5 construction seasons to complete. The Huambacho canal falls in the range between the Punkuri-Caylán and Sute systems. At 10.7 km in length, this canal would have required 32,100 person-days to complete. At a more moderate estimation than the Sute system, it appears that this canal would have taken a group of 150 people approximately 214 days to construct or at least 2 construction seasons.

In all, if the construction of these canals was directed by a centralized authority with a specialized task force assigned to complete the irrigation systems, it would have taken only 10 construction season/years to complete. However, it is more likely that the construction sequence for these irrigation systems was incremental. If this were the case, the canals would still be constructed in about 1-2 generations, which is still more rapid than a multi-generational, slow accretion of irrigation technology.
5.5 Carrying Capacity

The estimated population for the entire valley at any one given period/phase shows a trend of steady growth until the Early Horizon period and generally maintains that population until the end of the period. If calculated with high population densities at the appropriate sites, these high estimates are above the carrying capacity estimated for the Nepeña Valley of 16,400 maximum population (Wilson 1988:347, Table 24). However, this carrying capacity is based on 1 harvest per year of purely maize agriculture on 6360 ha of irrigated land and is likely much lower than the actual carrying capacity. Before the Moche expansions in the Santa Valley the population is estimated to be approximately 37% of the maximum carrying capacity and other valleys probably experienced similar ratios at this time. Therefore, relative to the Santa Valley estimates the Nepeña Valley should not have exceeded 6068 persons before the Early Intermediate Period. This estimate suggests that there was an occupational density of 1 person per hectare of irrigated land. This is considerably lower than the most conservative calculation of 8500, which indicates a discrepancy between these population estimates and Wilson’s (1988) carrying capacity.

Table 6. Hectares needed to support population estimates by site and period.

<table>
<thead>
<tr>
<th>Period</th>
<th>Site</th>
<th>Low Pop</th>
<th>High Pop</th>
<th>Low (ha)</th>
<th>High (ha)</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Early Horizon</strong></td>
<td>Caylán</td>
<td>5000</td>
<td>12500</td>
<td>2000</td>
<td>5000</td>
<td>(2000-5000 ha)</td>
</tr>
<tr>
<td></td>
<td>Huambacho</td>
<td>1200</td>
<td>3000</td>
<td>492</td>
<td>1230</td>
<td>(1200-3000 ha)</td>
</tr>
<tr>
<td></td>
<td>Samanco</td>
<td>1900</td>
<td>4750</td>
<td>779</td>
<td>1947.5</td>
<td>(1900-4750)</td>
</tr>
<tr>
<td></td>
<td>Sute Bajo</td>
<td>136</td>
<td>0</td>
<td>55.76</td>
<td>0</td>
<td>(136 ha)</td>
</tr>
<tr>
<td></td>
<td>Punkuri Alto</td>
<td>264</td>
<td>0</td>
<td>108.24</td>
<td>0</td>
<td>(264 ha)</td>
</tr>
<tr>
<td><strong>Initial Period</strong></td>
<td>Huaca Partida</td>
<td>84</td>
<td>200</td>
<td>34.44</td>
<td>82</td>
<td>(34.5-82 ha)</td>
</tr>
<tr>
<td></td>
<td>Cerro Blanco</td>
<td>240</td>
<td>500</td>
<td>98.4</td>
<td>205</td>
<td>(240-500 ha)</td>
</tr>
<tr>
<td></td>
<td>La Carbonera</td>
<td>169</td>
<td>500</td>
<td>69.29</td>
<td>205</td>
<td>(169-500 ha)</td>
</tr>
<tr>
<td><strong>Late Preceramic</strong></td>
<td>Punkuri Bajo</td>
<td>300</td>
<td>500</td>
<td>123</td>
<td>205</td>
<td>(300-500 ha)</td>
</tr>
<tr>
<td>Period</td>
<td>208</td>
<td>60</td>
<td>0</td>
<td>24.6</td>
<td>0</td>
<td>(25 ha)</td>
</tr>
<tr>
<td>Period</td>
<td>209</td>
<td>20</td>
<td>0</td>
<td>8.2</td>
<td>0</td>
<td>(8 ha)</td>
</tr>
</tbody>
</table>
Woodson (2010:74) generated a rough estimate of the number of people that could be supported annually on crops grown in the Hohokam region. A family of 5 could survive on irrigation farmland averaging 0.85-2.15 ha or an individual could live on 0.04 ha per year. Influence areas were calculated previously, but here I generate a rough estimate of how much land would be necessary to support the previously established population estimates for each site. I propose likely occupation areas based on the concept of linear communities. This is purely conjecture but, considering much of the evidence for domestic structures were likely Destroyed by modern farming, it can provide a model on which to build when more evidence is available in the future.

The potential hectares under cultivation necessary to support the population estimates are presented in Table 6. Based on estimates of land necessary to sustain the estimated populations, it is apparent that Caylán would have needed almost the entire extent of the influence area just to support the population at the site core. It also likely received produce from Punkuri Alto (see Figure 13). The Sute Bajo area was much more dispersed and could have survived on much less land than the established influence area, which could indicate a system of redistribution. To support the populations at Samanco and Huambacho, the communities would not have had enough farmland to sustain 0.40 ha per person annually, especially since the lower valley is more susceptible to water shortages. However, proximity to the coast probably allowed the populations to rely more heavily on marine resources rather than agricultural resources.

Summary

These analyses have mixed results. There is strong evidence for extensive irrigation use by the Early Horizon period. The identification of Early Horizon canals allowed for the spatial analysis of site dating to this period, yielding user groups or influence areas. Population
estimates are always controversial. What is more significant are the labor estimates calculated for the total canal lengths, that would represent main canals and associated labor rather than secondary and tertiary canals, which would require more labor than calculated here.

**Figure 13.** Approximate spatial areas necessary to support population estimates. Note that almost the same cultivable areas are necessary as influence areas were calculated in Figure 12.
In this research I have attempted to identify ancient irrigation systems using maps of modern systems. I identified significant irrigation systems associated with three sites dating to the Early Horizon. The most significant in terms of understanding the role of irrigation in settlement distribution and centralized management is the Punkuri-Caylán system, which demonstrates both a chronological sequence for understanding development of irrigation through time and a hierarchical relationship between sites on the same canal for understanding the sociopolitical features during the Early Horizon. In order to explore the development of irrigation through time as well as site and irrigation hierarchies spatial user groups were defined, population estimates calculated, labor requirements calculated, and carrying capacity tested against these results. I discuss my results by each time period in an effort to understand the developmental processes as well as sociopolitical structures associated with irrigation agriculture.

6.1 Late Preceramic Period

PV31-208 and 209 are both activity areas located on the littoral with middens comprised largely of marine refuse and some evidence for architecture. Both sites measure less than 1 hectare (ha) at .5 ha and .16 ha respectively. These two sites are strategically located to take advantage of the marine resources nearby as well as near enough to fresh water that not too much energy was necessary to obtain it. They are also situated in such a way that protects the sites from the elements. Though poorly documented, the architecture at these sites is assumed to
represent domestic structures. Each of these sites represents extended family groups, which, in addition to evidence for stone architecture, suggests that these were fairly sedentary family groups that ventured inland for terrestrial resources.

Punkurí Bajo is distinct from PV31-208 and 209. It was a socially integrative facility that probably functioned as a civic-ceremonial center for an inland, riverine population. Though no habitations have been documented in association with Punkurí Bajo, it probably served to unify a dispersed, ephemeral population. What is striking is the strategic location of the site, situated in an area subject to subsequent occupations through time as well as at the head gates of the major Punkurí-Caylán Canal identified in this research. Furthermore, the population was reaping the benefits of a riverine ecological zone, close enough to travel to the coast in about a day, and near enough to the upper valley and highland to engage in wider networks of interaction. It is no wonder that this area continued to be occupied through the end of the Early Horizon. However, there is little evidence for urbanization or irrigation, though all populations were probably controlling or diverting potable water in some way, either for drinking or farming. The settlement patterns, resource areas, and subsistence strategies reflect the characteristics of a population that slowly built toward hydroagricultural social organization in later periods.

6.2 Initial Period

After the Late Preceramic, it is apparent that coastal populations made a rapid settlement pattern shift inland to take advantage of the fertile land. Due to significant advances in the chronology in the valley (Chicoine 2006a, 2010; Chicoine & Ikehara 2010; Shibata 2010), a more refined understanding of this period allows for a better interpretation. During this time
there is evidence for irrigation beyond that of flood plain farming. While Punkurí Bajo continued to be occupied during the Initial Period, four additional sites were established (PV31-105, PV31-27/192, PV31-36/37, PV31-125), demonstrating the trend in increasing habitation of the lower valley.

The early Initial Period is characterized by the introduction of PV31-105 on the coast and continuity of occupation at Punkurí Bajo (PV31-10). The presence of PV31-105 on the coast indicates that marine resources continued to be a significant commodity, though a general trend of increasing population inland would soon follow. At this time, no other occupation in the valley has been identified and construction of what we now understand as a civic-ceremonial mound site was probably initiated at Punkurí Bajo. After the early Initial Period, PV31-105 was abandoned and occupation at inland sites like Cerro Blanco (PV31-36/37) and Huaca Partida (PV31-125) began during the Huambocayán Phase, though neither monumental nor informal architecture was not present. Huaca Partida and Cerro Blanco are located further inland but still on the valley floor less than 1 km from the river. These were mound centers that served as socially integrative facilities as indicated by their public art and architecture. They lack domestic structures, but probably served a dispersed population in the area for ritual and administrative purposes. While it is likely that these sites have small-scale irrigation, there is no evidence to suggest that there was any substantial population or extensive irrigation taking place. Punkurí Bajo continued to be occupied but there is no telling how this affected the population distribution associated with Cerro Blanco and Huaca Partida.

La Carbonera is a similar site to Huaca Partida and Cerro Blanco, demonstrating strikingly similar U-shaped mounds and construction styles. However, this site is located distant from the modern river, established on the periphery of modern cultivation, at just over 4 km as
the crow flies. This is much farther than the established 1 km radius thought to be the furthest a farmer will walk to a field each day without settling in a new area. It is between this site and Punkuri Bajo that the dynamic change from flood plain farming to extensive irrigation could have taken place. As discussed previously, this site could indicate an earlier course for the river or perhaps the earliest evidence for extensive irrigation. The site is abandoned after the Initial Period. It is likely that the river flowed near La Carbonera prior to and during the Initial Period before being diverted by natural or cultural forces to the modern trajectory. This would also indicate that La Carbonera predates both Cerro Blanco and Huaca Partida.

There seems to be some kind of power hierarchy associated with the treatment of river resources due to the spatial hierarchy between Punkuri Bajo and La Carbonera as well as Punkuri Alto, Cerro Blanco, and Huaca Partida (see Figure 5). The latter three sites are organized in a linear hierarchy along the river, where Punkuri Bajo had the control to either divert water to La Carbonera or Cerro Blanco and Huaca Partida. This would indicate a level of direct control, a kind of social mechanism that allows for a single group to physically and spatially control a single resource. This is often related to ideas of military states. However, the ability to exert indirect control requires a greater deal of power and authority in terms of being able to secure the resource without physically controlling it. Conversely, down-river sites could have been controlling the influx of marine resources, but either of these scenarios is unlikely. There is little evidence to suggest that the populations were large enough or the river flow low enough at this time to create a power hierarchy. However, this period is considered to be the first evidence for increasing social hierarchy that coincides with the expansion of irrigation, not warfare or foreign influence.
There is little difference in the political organization of sites within the Nepeña valley between the Late Preceramic Period and Initial Periods. Both are characterized by single mound centers with little evidence for habitation sites or significant site hierarchies and little evidence for political organization or management of irrigation systems if they are present at these times. While Late Preceramic sites tend to be located on the coast, there is not sufficient evidence to definitively state that coastal occupation was a trait characteristic of this period. What can be said is that those sites located inland, which would have required some form of plant cultivation, were located along the river presumably to take advantage of the river flood plain. At one point, this river flowed past La Carbonera to Caylán but during the Initial Period shifted more closely to the modern flow that is documented today. It is at this transition that settlement decisions would have to be made. Would the settlement pick up and move to the new river bed or bring the water to them? In the case of La Carbonera it seems that the site packed up and moved elsewhere, perhaps to nearby Caylán where the former river created a water catchment or alternatively to one of the mound centers on the new river.

Eventually, the Early Horizon population at Caylán and outlying habitations potentially attempted to recreate the original river flow by imitating the shape of the river with irrigation systems. This would have been a slow process, though could have been conducted in a year if sufficient centralized authority was able to coordinate such work. The effects of the introduction of large-scale irrigation canals to the Caylán system would have been delayed as the villagers became accustomed to a new social organization. Population pressure never seems to have been a problem as the population estimates are well below the carrying capacity and, thus, population pressure does not form an impetus for irrigation agriculture and shifts in settlement patterns.
6.3 Early Horizon

The Early Horizon Period is characterized by a significant settlement pattern shift, increase in site distribution associated with an increasing population, and changes in subsistence strategies throughout the entire occupation of the Nepeña Valley. The significant frequency of sites associated with coastal architectural traditions, increased density indicative of urbanization, and a massive population spike seem to be related to the drastic expansion of irrigation systems throughout the valley. I identify potential irrigation canals associated with Early Horizon sites. Given the lack of data on the Late Preceramic Period and Initial Period in the Nepeña Valley it is not feasible to attempt to identify canals for any earlier period. During the Early Horizon, irrigation in the valley was extensive and likely filled the valley floor even more so than it does today. There may have been intensive irrigation around Caylán based on the soil salinity levels in the area but this is tenuous evidence to use to this end because of modern activity in the area and other explanations for that phenomenon. Before the Early Horizon, emergent irrigation systems may have appeared as early as the Initial Period and as early as the Late Preceramic Period (see Figure 14). It is necessary to point out that there is neither data to suggest that population pressure prompted the transition to irrigation in the Nepeña Valley, nor did the population ever reach the carrying capacity determined by Wilson (1983). Based on a model for extensive rather than intensive farming, almost all arable land was required to support the population estimates calculated here.

Four main influence areas were identified, including a fifth if Punkurí Alto is considered separate from the Caylán system. Furthermore, three separate irrigation systems were identified for the valley, the Punkurí-Caylán System, the Sute System, and the Huambacho System. The Punkurí-Caylán system has the strongest evidence for use based on soil salinity levels.
might possibly be a fourth, assuming that Samanco was also practicing some form of intensified cultivation or agriculture. It is significant that the influence areas calculated tend to fall at natural boundaries like the river and narrowing of the valley between the coastal sites of Samanco and Huambacho and the lower valley systems (see Figure 12).

Population estimates for this research are extremely problematic and should not be considered to be a successful analysis by any means. However, for the Early Horizon these estimates provide a basis for comparison between sites. It should be noted that the Early Horizon centers may not have been permanent habitation sites or may have been centers for regionally dispersed populations to come together and exchange goods and ideas. The amount of people necessary to construct the various canal systems is calculated, which fall well below the population estimates. The estimated person-hours indicate that a small group associated with their respective influence areas likely constructed each canal over a generation or more. This accretional construction system suggests that sociopolitical organization was likely a dispersed

**Figure 14** Sites located along the Punkurí-Caylán System indicating the consistent use of the canal trajectory through time.
heterarchy with little bureaucratic density, unified by some overarching authority based on the similarity in architectural techniques and proximity of the sites in spite of little evidence for interpersonal conflict. However, the rate of excavation (1 m³) is conservative and the actual excavation rate could be higher, lessening overall canal construction time. Furthermore, these labor estimates are also problematic because they do not take into consideration daily and seasonal activities made necessary by sedimentation, flooding, and day-to-day maintenance. Future geoarchaeological studies of canal systems can provide data that may alter the results of this study and, thus, the interpretations of sociopolitical organization.

Finally, carrying capacity was calculated in reverse using the estimated populations for each influence area. If each individual could survive on 0.4 ha of land per year, the necessary land for each influence area can be estimated for each area (Figure 13). This analysis resulted in the realization that each influence area needed the calculated areas based on site density at the very least. Some system areas, like Samanco and Caylán, would need more land to support the estimated population. For Caylán in particular, this analysis demonstrates the strong relationship between this site and Punkurí Alto. For Sute Bajo, the land necessary was much less than the estimated system area. This could indicate a system of redistribution where Sute Bajo would send their products to other sites that were under-producing for the population. Regardless, this analysis demonstrates that almost the entire area of modern cultivation would have also been cultivated during the Early Horizon.

A spatial analysis of the Early Horizon stone enclosures that are assumed to be of a similar sociopolitical group, or at least different from those at the mound sites, indicates that there is a particular tendency toward patterns of site hierarchy and political centralization not directly related to irrigation. Sociopolitical organization during the Early Horizon is decidedly
different from the distinct social groups of the Initial Period. For the most part it seems that sites would have been organized into linear groups with focal villages associated with each irrigation system. There is no evidence that irrigation construction and maintenance would have linked the sites politically. However, the management of water resources in the valley may have integrated these sites politically, potentially with social/religious overtones concerning the distribution of limited water resources (i.e., Castillo 2010). The similarity in architecture, the seemingly defensive nature of the structures, and the lack of weapons indicate that these sites may have been integrated by the need to ward off advances from outside the valley (i.e., Wilson 1983). These results do not indicate that centralized authority may have been required to construct the extensive irrigation canals during the Early Horizon. There was probably an overarching authority to organize small labor forces to carry out construction activities but this does not indicate a direct authority figure was able to mobilize massive labor forces nor was it necessary.

6.4 Theoretical Implications

Ultimately, what these results and discussion tell us about irrigation agriculture is that this subsistence strategy strongly impacts settlement decisions. It was easier to move a population to the resource than bring the resource to the settlement, until large-scale irrigation was introduced during the Early Horizon. It is still questionable whether the introduction of that technology occurred rapidly or accretionally, and there is insufficient chronological data to make secure statements.

The estimated labor requirements indicate that moderately sized groups of 50 or more could construct the entirety of the main canal in a couple of years. However, the presence of
irrigation-dependent settlements along the Punkuri-Caylán canal from the Late Preceramic Period through the Early Horizon, a span of time approximating 1,600 years, suggests that this irrigation system was constructed over a long period of time and developed organically in situ. These labor estimates, lacking any secondary or tertiary canal construction data, indicate that households likely established small-scale, plastic canals that expanded as necessary, eventually reaching from the river to Caylán and beyond.

Accretional construction is often associated with heterarchical forms of sociopolitical and economic organization. As demonstrated by the autonomous nature of influence areas established here, a heterarchy is the likely political organization during the Early Horizon within the Nepeña Valley. However, based on the differences in size and monumentality, as well as spatial distribution of sites at this time, there was probably also a hierarchy to some extent. For instance, there is a site size hierarchy between Caylán and Punkurí Alto that relied on the same irrigation system. There also seems to be an upstream-downstream hierarchy where the Punkuri-Caylan system is characterized by larger sites than Sute Bajo and Huambacho, where the canal intakes are more downstream than the former. In addition to looking at the power relations in linear terms along canals and the river, it might be beneficial to interpret the Early Horizon sites as a web of social and political interactions where coastal sites provide marine resources to inland sites and inland sites distribute land-based resources to the coast where there is less arable land available.

While Wittfogel’s (1957) hydraulic hypothesis, Boserup’s (1965), and Carneiro’s (1970) hierarchical models do not fit the evidence from the Nepeña Valley, there are parts of each that are still useful for studying archaeological societies. For instance, Wittfogel defined a spectrum of hydraulic evolution, from hydroagriculture to hydraulic agriculture. Early Horizon sites in the
Nepeña Valley demonstrate characteristics of a hydroagricultural community where food production is not centralized but is extensive and, in some instances, intensive. Hydraulic agriculture, akin to corporate agriculture, is not apparent during the Early Horizon or earlier. The hydraulic density of the Punkuri-Caylán system is compact, meaning that the sites in that area are highly dependent upon irrigation technology. The other irrigation systems in the valley are less hydraulically compact, or hydraulically loose. In the same line of thought, the Punkuri-Caylán bureaucratic density is also more compact than other systems in the valley. This means that the more developed irrigation system allows for a more complex political organization with more levels of decision-making than in smaller irrigation systems. However, it is important for archaeologists to move beyond definitions and build models that fit particular case studies.

Based on the results of this study, dogmatic hierarchical models proposed by Wittfogel (1957) and others in the top-down stream of thought (i.e., Boserup 1965) are not supported. Archaeologists in the Andes have started to realize that a more heterarchical understanding of political organization is necessary in order to shed light on ancient society where sites within a single valley were fairly autonomous in spite of irrigation construction and management. Centralized authority was not necessary in order to construct these hydraulic works nor was it necessary for water allocation or conflict resolution until much later. This indicates that irrigation systems developed organically at the local level until some other base of power made it possible for rulers to maintain despotic control, thus debunking the hydraulic hypothesis in the Andes. Researchers must restructure the way we think about the role of leadership in early urban societies from a top-down to a bottom-up approach. Furthermore, we must abandon the idea that monumental construction requires centrally organized labor efforts, rather these hydraulic structures allowed for aggrandizing individuals to make claims to power.
6.5 Future Directions

This research has attempted to illuminate the relationship between irrigation and settlement patterns through spatial analysis, especially concerning emergent extensive irrigation systems like those identified for the Early Horizon in the Nepeña Valley, Peru. The settlement pattern shift from coast to inland-riverside sites between the Late Preceramic and Initial Period does not seem to be prompted by irrigation or agriculture. However, there seems to have been an increasing reliance upon plant foods, which would have grown better inland away from soils with poor drainage and high salinity. After establishing settlements inland at strategic locations (i.e. Punkurí Bajo), the second shift between the Initial Period and Early Horizon does indicate that there is a strong relationship between irrigation and the way in which societies organized themselves spatially on the landscape.

While settlement pattern studies have been conducted in Nepeña, the importance of irrigation has often been overlooked. This is the first research to address this question in the valley and has resulted in a simple but innovative method for both identifying irrigation canals and establishing areas of likely occupation in spite of the lack of direct evidence for either. However, many questions about the emergence of irrigation in the valley suffer from a lack of chronological resolution at sites as well as gaps in the archaeological data, ethnographic studies and historical texts concerning ancient irrigation canals.

Continuing research in this area could benefit from more refined studies of botanical remains and pollens in order to identify cultigen diversity as a means for understanding the complicated nature of changing subsistence systems. Furthermore, hydraulic and soil studies could contribute to a greater understanding of the intricacies of, not only primary canals as I have
studied in this thesis, but also secondary and tertiary canals, which could illuminate patterns of intra-site social organization among other things. There is a wealth of knowledge yet to be explored in the Nepeña Valley as well as in the region. Ongoing studies will surely present new problems to be addressed that will contribute to a greater understanding of society on the north coast of Peru.
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