CULTURAL RESILIENCY AT POMPEII: THE SPATIAL RELATIONSHIP BETWEEN PAINTED FOUNTAINS AND PRIVATE WATER ACCESS, 62-79 CE

A Thesis

Presented to the Faculty of the Graduate School

of Cornell University

In Partial Fulfillment of the Requirements for the Degree of

Master of Arts

by

Erin Elizabeth Wright

December 2017

ABSTRACT

This thesis examines the spatial relationship between painted fountains and private water access as a maker of human resilience at Pompeii. Seventeen years prior to the 79 CE eruption that sealed the city, Pompeian citizens experienced an earthquake that disrupted the city's water system. Over the course of the city's remaining years, its people attempted to return the city to its former standards, including renovating public and private water systems and restoring the décor of their homes. Were fountain paintings created when actual fountains could not be used? Using chi-square analysis to calculate the relationship between variables, the results indicates there is no statistically significant relationship between painted fountains and private water access. Instead, painted fountains represent a realistic representation of gardens as a psychological mechanism to bring order to the chaotic natural world in the aftermath of the earthquake.

BIOGRAPHICAL SKETCH

Erin Wright received her Master's degree in Archaeology from Cornell University in 2017. She graduated from Indiana University of Pennsylvania (IUP) in 2015 with a Bachelor's degree in Anthropology with a concentration in Archaeology and a minor in History. She has participated in field work at a French and Indian War site, Hanna's Town, near Greensburg, Pennsylvania. Her research interests include the collection, storage, and manipulation of water in ancient urban settings.

ACKNOWLEDGMENTS

I would like to express my deepest thanks to Drs. Kathryn Gleason (Landscape Architecture) and Caitlín Barrett (Classics) of Cornell University for their guidance, support, and advice throughout this project; Dr. Ben Ford (Anthropology) of IUP for his advisement on the spatial analysis used in this research; Ashley Swenson for her editorial aid throughout the writing process; Hal McCulloch for his help creating the figures for this project; and to my family and friends for their support and understanding during this process.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF EQUATIONS

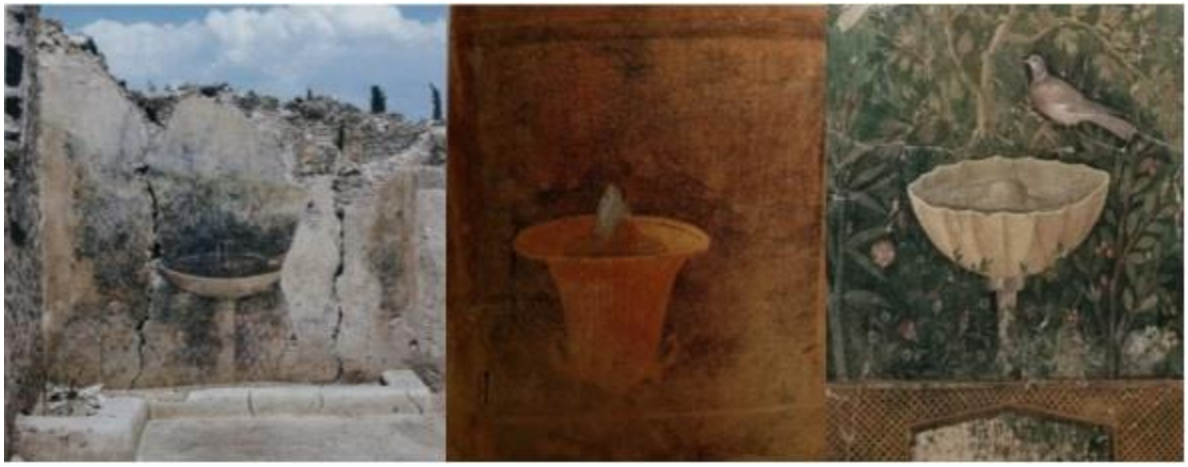

Figure 1 Examples of painted fountains. From left: I.xii.16, VI.xv.1 Casa dei Vettii, and VI.xvii.42 Casa del Bracciale d'Oro. From the Wilhelmina F. Jashemski Trust at the University of Maryland.

Introduction

Human resilience to environmental challenges is seen most prominently in the aftermath of disaster. Resilience, "the capacity to persist…in the face of changes" (Folke 2006, 254), has been used in urban planning to understand interactions between a community and environment (Mehmood 2015, 407). This research aims to enhance existing debates regarding water, garden paintings[1], and gardens in Roman society as they relate to human resilience, particularly in its cultural expression, following the earthquake of 62 CE at Pompeii. Within the city, citizens manipulated water for both utilitarian and ornamental uses, with the ornamental uses within private homes signifying a display of wealth due to the cost of water to individual residences (Jones and Robinson 2005, 707). Garden paintings frequently represent ornamental water displays set in garden landscapes (Jashemski 1979, 80). To better understand the spatial distribution of physical and visual displays of water wealth, the following research examines the spatial relationship between painted fountains (Figure 1) and homes with evidence of private water access. This thesis deploys chi-square analysis to examine the co-occurrence of painted fountains and private water

[1] The term "garden painting" can have two meanings: (1) a painting *in* the garden and (2) a painting *of* gardens. Therefore, "garden painting" refers in this work to a painting *in* a garden and "painted garden/pictorial garden" refers in this work to a painting *of* a garden.

access within the same dwelling and/or same Region, the spatial relationship between painted fountains and the Regions of Pompeii[2], and the spatial relationship between homes with private water access and the Regions. It also examines the spatial relationship between painted fountains and painted gardens as well as the spatial relationship between homes with private water access and workshops needing large quantities of water to function.

Typically, imagery in garden paintings has not been used as a means of understanding human resilience. Following the 62 CE earthquake, the residents of Pompeii rebuilt their homes, and repaired city's broken water system with the hopes that it would not fail again (Keenan-Jones 2015, 192-194). As an example of resiliency, a logical hypothesis might be that the residents installed paintings of fountains and gardens, with their rich religious and secular meanings to the household in lieu of those features that could no longer be sustained after the destruction of the aqueduct and water system. Historically, scholars of garden paintings have viewed them as creating the illusion of space and pulling the viewer out of the city and into the country (Jashemski 1979, 56, Leach 2004, 129) and as a means of mirroring reality for the purpose of displaying one's cultivation (Bergmann 2002b, 23-24). Fountains are one of the most prominent elements found in these garden paintings (Jashemski 1979, 80). Gardens, fountains, and garden paintings were more than simple décor, they were an important investment in the household. They were also a means of gaining control over nature. Nature was chaotic by Roman definition, often associated with Bacchus, and it needed to be controlled (von Stackelberg 2009, 15). Could paintings, an important bearer of Roman cultural meaning, have been installed after the earthquake before the water infrastructure was restored?

[2] Throughout this paper, I reference Giuseppe Fiorelli's "Regions." They are discussed in more detail below, but briefly, Regions are a modern construct used to divide Pompeii.

This thesis employs the chi-square test to analyze the relationship between the physical evidence of water usage and the visual depictions of water usage in relation to the city's resilience following a destructive earthquake. This method was chosen because it can demonstrate non-random associations by comparing the frequency of association (van Pool and Leonard 2011, 238). Ultimately attractive as this hypothesis has been at conferences and other venues[3], the analysis of the data indicates there is no statistically significant evidence for a spatial relationship between painted fountains and/or garden scenes and the presence or absence of private water access. Pompeian citizens did not use visual representations of water wealth as a means of resilience to maintain their status. Nonetheless, the process of investigating this topic leads to a better understanding of how the people of Pompeii reacted and responded to disaster, and what elements of life were important to restore. The results indicate a clear relationship between Regions and the restoration of private water supply, and so while the paintings do not indicate use to replace actual gardens or fountains, it does suggest that the paintings are related to the restoration of gardens and house décor once a workable water system was restored.

Regions

In the late 1800s, Fiorelli divided Pompeii into nine Regions[4] that have been used to help identify the city's structures. Every structure can be identified by its region, insula, and door numbers. Thus, the nine Regions are a modern construct as opposed to an ancient one. Modern scholars have suggested that electoral notices found in Pompeii demonstrate the division of the city into *vici* (wards) (Laurence 1994, 38), but how the people of Pompeii divided their city continues to be unclear. Little epigraphic evidence remains for the *vici*; there is debate over

[3] Refers most recently to the Hortus Inclusus conference, Rome, June 28, 2017 (Gleason 2017).
[4] See Figure 3 for the location of the nine Regions.

whether cross-roads altars mark the center of *vici* or their boundaries, and while public fountains might mark the center of a *vicus,* it is merely an assumption that people used the nearest fountain (Laurence 1994, 40-50). Fiorelli's Regions primarily divide Pompeii by the major streets through the city. The Via Stabiana provided a direct route through the city from North to South, connecting the Porta Vesuvio and the Porta di Stabia. The Via dell'Abbondanza also connected two city gates, the Porta Marina and the Porta di Sarno, as well as linking the civic center and the amphitheater. Although it does not connect two gates, the Via di Nola did have access to one gate, Porta Nola, and is considered a through-route (Laurence 1994, 91). Using these three through-routes and the city walls, Fiorelli established the boundaries for Regions VI, VII, and VIII. Via di Nocera, which leads to the Porta Nocera, divides Regions I and II. The streets dividing Regions III and IX and Regions IV and V are the most arbitrary of Fiorelli's boundaries because they do not connect directly to one of the city's gates. However, with most of the boundaries determined by a major street, it is possible that Fiorelli's Regions correspond to ancient conceptions of dividing the city. Through-streets had high occurrences of doorways and shops (Laurence 1994, 91, 66). The boundaries of Regions were thus areas of high activity and traffic.

While Pompeii's Regions may be problematic for understanding ancient conceptions, they provide an opportunity to divide the data into spatial segments beneficial for chi-square analysis. The Regions condense the data into larger groups than if insulae were used. The data sources provide samples that include between 40 and 60 examples for each category, a relatively small sample for this type of analysis. Spreading the data out over the various insulae may skew the results, leading to a misunderstanding of the relationships being analyzed, which will be discussed in a later section. Therefore, it is possible that information regarding water wealth is hidden using the Regions. The chi-square analysis provides a starting point for investigating human resilience

via visual and physical representations of water wealth and future research using other methods of spatial analysis, such as nearest neighbor, may provide further illumination.

Prior Research

Urban planning has developed a focus on resilience in response to the previous emphasis on sustainability. As a concept, resiliency is "more dynamic, it is non-linear and cross-linked, complex so to say, and it embraces uncertainty" as it concentrate on networks, self-renewal and survival (Stumpp 2013, 165). When speaking of resiliency connections are frequently made to ideas about resistance to change and returning to an original state (Mehmood 2015, 410). Resilience, however, originates in other fields, such as IT, material science, and psychology (Stumpp 2013, 164) and has developed definitions based on engineering, ecology, and social science (Mehmood 2015, 410). Specifically, social resilience describes "the ability of groups or communities to cope with external stresses and disturbances as a result of social, political, and environmental changes" (Adger 2000, 347).

Multiple researchers have presented information about the incorporation of private water access into homes at Pompeii. Hans Eschebach's articles about private water access will be discussed in a later section (1979, 1983). Gemma Jansen produced two articles investigating aqueduct systems via metal detecting for pipes, distribution, and closing valves (2001, 2005), as well as other articles about the water systems of Pompeian gardens (1996, 2007, 2017b). Through these projects, Jansen hypothesized how water was piped through individual houses based on observed piping and reconstructed piping, and she identified houses that had a connection to the aqueduct system. The 1996 article identifies 24 houses with a connection and the 2001 article includes additional houses to the original 24 for a total of 91 (Jansen 2017a). Balázs Kapossy

studied fountains within private homes in his study, *Brunnenfiguren der hellenistischen und römischen Zeit*, identifying 60 fountains from 30 different homes in Pompeii (1969).

One of the most recent, comprehensive works involving domestic water at Pompeii, Hélène Dessales' *Le Partage de l'Eau: Fountaines et Distribution Hydraulique dans l'Habitat Urban de l'Italie Romaine,* details typological, functional, and spatial analysis of the water systems within domestic structures generally in Roman Italy, with an emphasis on Pompeii (2013). She catalogues 117 domestic structures from Pompeii with evidence of basins and/or fountains. Within this catalogue, Dessales notes 24 structures with evidence verifying their connection to the public network and 43 structures that were probably connected to the public network, but whose connection cannot be proven definitively. This catalogue, which also includes domestic structures from Pompeii's surrounding area, as well as from Herculaneum and its surrounding area, provides insight into the design and use of water installations in the architectural, functional, and socio-cultural setting of the house.

However, prior research addressing the relationship between these water installations and visual representation of fountains is limited. Jansen deliberately avoids addressing wall paintings as a source of information when looking at the use of water and water technology in five cities and/or villas of the Roman world (2017b, 403). In her discussion of Pompeii, Jansen states that she will not address wall paintings because of the appearance of only two types of fountains (those shaped like kraters or other bowls and those supported by statues of nymphs) and the unrealistic depiction of those fountains lacking feeding mechanism and the overflow mechanism.

Research over the years has explored the city's water system through various private and public uses (Andersson 1994, Eschebach 1979, Jansen 2007, Olsson 2015). These works do not

attempt to incorporate elements relating to visual depictions of water and how that might provide information about the use of water throughout the city. Bettina Bergmann, whose work examines landscape in Greek and Roman art, regards wall paintings at Pompeii, and the surrounding area, as valuable sources into the relationship between the visual and the physical. While paintings reflect actual architecture, "it is unlikely that wall painters had either specific sites or text in mind while filling the allotted spaces within the large wall design" (Bergmann 1991, 49). Using variations of a standard format, artists developed a form of "descriptive realism" that "[achieved] an illusion of lifelikeness" (Bergmann 1991, 51). The depiction of a physical object within a visual setting creates a new setting, thus giving the objects a new meaning (Bergmann 1992, 31). More recently, Bergmann has used the Villa A at Oplontis as a case study to explore how paintings act as 'mirrors' for the viewer; the painted views reflect views seen elsewhere (2002b). At the Villa A, there are at least two instances of a physical marble sculpture in one garden and a similar painted sculpture in another garden (Bergmann 2002b, 24). In another article, Bergmann emphasizes how movement, memory, and repetition of a theme or image "challenge the viewer to assess [a theme or image's] different realities" in a similar manner to the mirroring effect (2002a, 110). Bergmann's perspectives on the use and meaning of wall paintings represent some of the newest insights into the long-studied medium, enlarging upon Wilhelmina Jashemski's interpretations of garden paintings.

Background

Water Use

Due to the lack of information about the founding and early years of Pompeii, most reconstructions of the earliest water system are speculative. Richard Olsson suggests that in those unknown early years, the city relied primarily on cisterns to provide water for public and private

needs (2015, 9). While cisterns, which collected rain water, may have been the main method of procuring water, some people dug a few wells within the city. Difficulties with digging and maintaining wells arose because of the "layers of porous volcanic material and hard lava banks" present at Pompeii and the depth needed to reach the groundwater (Jansen 2007, 257). It is only after the city's incorporation into the Empire that information becomes readily available concerning the water system. Pompeii participated in the Social Wars together with other Italian allies of Rome, resulting in the city's status as a colony of Rome after 80 BCE (Descœudres 2007, 15-16). The water system following Pompeii's incorporation divides into three phases (Keenan-Jones 2015, 192-200): Augustan, post-Earthquake, and reconstruction.

During the reign of Augustus, Pompeii established its first phase of the aqueduct system to bring water into the city, though it remains unclear where the aqueduct water came from and how it came to the city (Keenan-Jones 2015, 195-196). The aqueduct dramatically changed the ways in which the city and its citizens could use water. Public uses, such as baths, display fountains, and drinking fountains, took precedence over private uses for the aqueduct water (Juuti et. al. 2015, 2343, Keenan-Jones 2015, 196-197). To successfully manipulate water for fountains and other displays in both public and private contexts, people needed to pressurize that water (Jansen 2017b, 415). Primarily, aqueducts achieved the pressure necessary for such displays, enabling ornamental water uses. Other means of pressurizing water existed, and do appear in Pompeii in the form of private water towers. Eventually these ornamental water displays became a way that people with the means and ability to procure private water access could display their wealth and status (Jones and Robinson 2005, 700, Hansen 1983, 3-4).

This system was disrupted or destroyed in 62 CE when the earthquake devastated the area surrounding Mount Vesuvius (Descœudres 2007, 18, Keenan-Jones 2015, 195, Olsson 2015, 9).

Many buildings within the city continued to show signs of damage and continuing repair attempts 17 years later when Vesuvius erupted and buried the city (Descœudres 2007, 18-19). The extent to which the aqueduct system faltered remains disputed. Arguments have been made for a total loss of aqueduct water, a partial loss of aqueduct water, and little change in aqueduct water (Keenan-Jones 2015, 191). Instead of abandoning their homes or their city, evidence indicates that the citizens rallied after the earthquake to rebuild and renovate their homes: some home owners within the city restructured how water was used within dwellings following the earthquake by removing pipes leading to private baths or to garden and/or atrium pools (Jones and Robinson 2005, 702-706), while in a few homes, such as Casa di Trebio Valente and Casa dell'Efebo, private water towers post-dating the earthquake maintained water displays (Dessales 2006, 366). These towers collected rainwater and, using gravity, pressurized the water. These changes, along with repairs to the public portions, constitute the second phase of the water system in Pompeii.

Evidence shows the city's continuing resilience and optimism in its last years with a third phase that was partially constructed when the 79 CE eruption destroyed the city (Jones and Robinson 2005, 706, Keenan-Jones 2015, 199-200, Olsson 2015, 9). Archaeologists have discovered open trenches in the sidewalks throughout the city, indicating the project was only partially completed when the city was destroyed (Olsson 2015, 9). The designers intended to place the city's pipes further underground than the old system, possibly in the hope that the greater depth would protect from future earthquakes (Keenan-Jones 2015, 200).

Garden Paintings

Because of the eruption of 79 CE, conditions were highly suitable at Pompeii for paintings to be preserved until their excavation. Once they were exposed to the modern air, these paintings quickly began to fade, resulting in their loss in some cases, or in their removal to museums. Late

in the nineteenth century, August Mau developed a system of categorizing these paintings into four styles, a method that continues to be used with some refinement of his original chronology (Strocka 2007, 304). Most garden paintings belong to the Fourth Style, dating them between 40/50 and 79/100 CE (Jashemski 1979, 56, Strocka 2007, 315). Some Fourth Style paintings predate the 62 CE earthquake, but because of the damage inflicted by environmental conditions, the surviving garden paintings likely postdate the earthquake. Unlike an interior painting protected from sunlight, rain, and wind by walls and a roof, an exterior garden painting, "exposed as it was on an outdoor wall to all the vicissitudes of weather," would deteriorate at such a rate that it had a "transitory character" (Jashemski 1979, 55). Thus, the fountains appearing in the paintings would likely have been incorporated after the earthquake, as garden paintings probably "date…from the last years of the city" (Jashemski 1979, 55)[5]. These new paintings would have then coincided with the water system redesigns that followed the earthquake.

Major Sources

The research presented herein draws data from two major sources, the first being Jashemski's work *The Gardens of Pompeii* (1993). While the first volume was essential for understanding the nature of Pompeii's gardens (Jashemski 1979), the second volume provided the information necessary for understanding the distribution of garden paintings throughout the city. It is within the second volume that Jashemski provides three appendices for the gardens of Pompeii: a description of all the excavated gardens in the Vesuvian area; a catalogue of garden paintings from the Roman world; and a listing of flora and fauna from Vesuvian gardens, either from paintings or organic remains recovered during excavation (1993). Jashemski includes

[5] Jashemski does not cite precise evidence about the exact rate of decay when paintings are exposed to the elements. However, her views concerning the decay of garden paintings are plausible. Therefore, I operate on the assumption that most garden paintings post-date 62 CE.

information discovered from her own extensive work at Pompeii, as well as what she could gather from interviewing and reading field notes of prior researchers. As much as she is able, Jashemski details the locations and images of those Pompeian paintings that are either located in gardens or depict gardens.

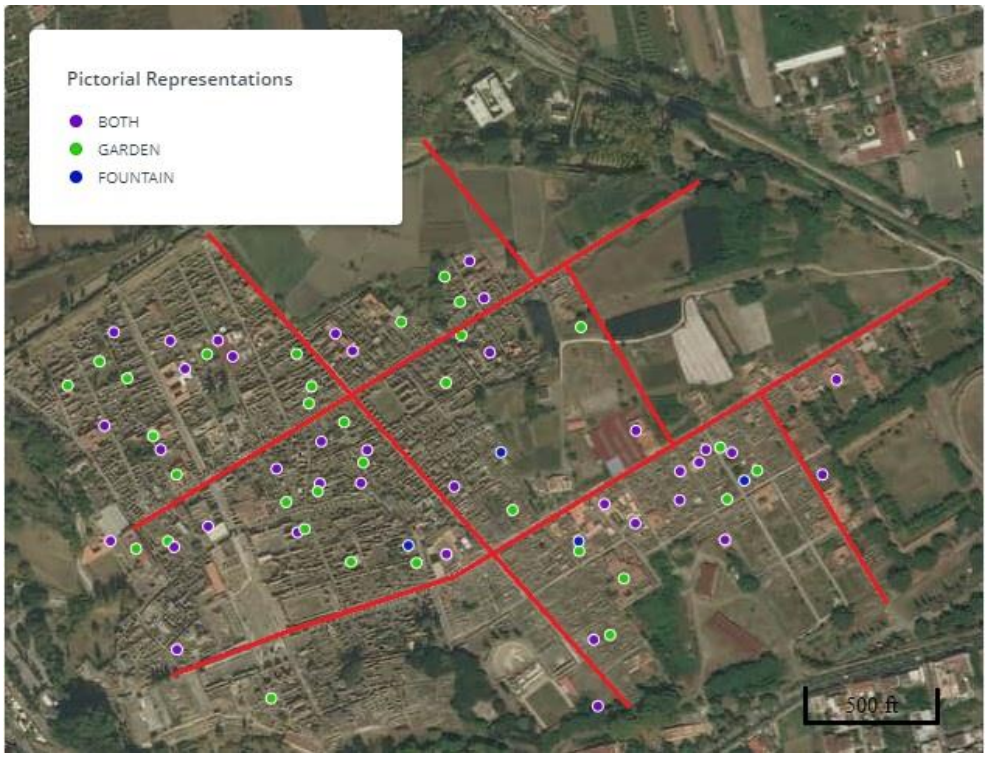

Figure 2 Map showing location of fountain and garden representations from Jashemski 1993.

It is through these descriptions that I have compiled a list of 41 houses whose gardens contain at least one painting with one or more depiction of fountains.[6] According to Jashemski, fountains are one of the most prominent images to appear in garden paintings (Jashemski 1979, 80). Typically, these fountains appear within paintings of a garden, which, like painted fountains, express water wealth visually and potentially act as a replacement for the physical. Before the advent of aqueducts, Pompeians filled their gardens with plants that used minimal water; with the

[6] Field testing this list through future research would be highly desirable. This field testing would involve in-person study of the paintings in question that are still extant, either *in situ* or in museums, such as the Naples Museum.

introduction of the aqueduct, however, more water-dependent plants appear in gardens (Jashemski 1979, 33). In total, 71 houses contain at least one painting of a garden. Investigating the relationship between fountain depictions and garden depictions facilitates a better understanding of the spread of water wealth motifs in garden paintings throughout the city. With the addresses provided by Jashemski, these paintings were mapped for further analysis using Carto (Figure 2).

The second major source for data comes from the work of Olsson, *The Water-Supply System in Roman Pompeii* (2015). As part of his thesis, Olsson modified earlier work conducted by Hans Eschebach. In an article from 1983, Eschebach identified 63 houses with private water access (Olsson 2015, 23). Along with private homes, he also identified workshops that would need large amounts of water to operate (laundries, dye houses, and tanneries)[7] (Eschebach 1979, 16), but does not clearly describe how these workshops were affected by the 62 CE earthquake (Figure 3). However, Amedeo Maiuri has dated most of the city's workshops to the years between the earthquake and the eruption (Flohr 2011, 88). Maiuri bases this interpretation on evidence of structural restoration, advertisements for the shop's goods, and maintained interior decorations, suggesting that the restoration of the economic establishments occurred more quickly and effectively than in public buildings and private homes (Maiuri 1942, 162). Penelope Allison's database (2004b) cataloguing the artifact assemblages for thirty houses in Pompeii identifies 9 homes with *tabernae* ("rooms at front of house open to street [shop]") (Allison 2004a, 64) that shed light on some loose contents and fixtures found in the workshops identified by Olsson. 'Loose contents' includes utilitarian domestic materials (industrial and commercial materials), amphorae, food preparation and serving vessels, personal/gaming materials, and building materials. Fixtures

[7] Eschebach also notes the location of the Pompeian bakeries. Olsson does not include them in his analysis of the city's water system, therefore they are not included in this research.

found in these spaces were shelving, niches, counters/fixed *dolia* (storage vessels), podia, and downpipes (Allison 2004a, 113). While Olsson and Eschebach do not directly state evidence for the workshops in operation following the earthquake, excavators likely found evidence of production that enabled them to infer the workshops were operational during the final years of the city.[8]

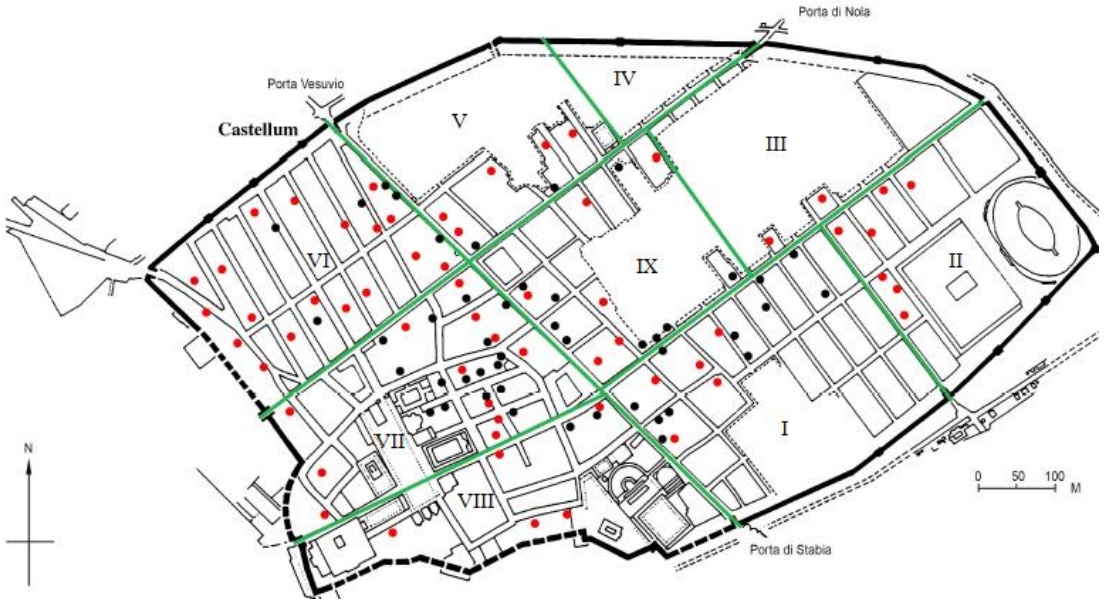

Figure 3 Map showing private homes with water access (red) and workshops needing water (black) based on Figure 4.1 and Figure 4.8 from Olsson 2015.

Looking at the distribution of these types of buildings with water access provides an opportunity to explore their spatial relationship to each other and to the paintings. Eschebach's article does not provide specific addresses for the buildings he identified as having private water or needing copious amounts of water (1983). Olsson provides some addresses for the private homes identified by Eschebach, but only those 32 that also overlap in the work of both Jansen and Kapossy (Olsson 2015, 104-5). Both articles do provide maps showing the rough locations for the buildings being discussed. From these maps, it is possible to identify the Regions of Pompeii that

[8] Future work will investigate original site reports and the assemblages for the evidence that enabled researchers to infer the workshops were operational in 79 CE.

seem to have retained water access, enabling statistical analysis of the relationships between paintings and the possibility of private water access.

Methodology – Statistical Analysis

To understand the relationship between painted garden fountains and private access to water, this research will use the chi-square test to analyze the data. This method of analysis allows researchers to compare the expected outcome, where the results are even and fair across all expressions of the variable, and the observed outcome, where the results represent reality. If the data can be expressed in a nominal format, analysis can be conducted to support or reject a null hypothesis.

As stated in the Introduction, separating the data into larger groups benefits chi-square analysis. An assumption of chi-square analysis holds that a small sample size loses the distribution shape. It is widely accepted that chi-square analysis should follow the rule of five, where 80% of expected frequencies must be five or more (van Pool and Leonard 2011, 249). This measure of sample size was established in the 1950s, and more recent work indicates that the chi-square test can be used when a substantial portion of the expected values are lower than five (Everit 1992, 13-14,39, Larntz 1978, 31, van Pool and Leonard 2011, 249). However, research using less than the rule of five is still often seen as suspect (van Pool and Leonard 2011, 249). Having the data divided between the nine Regions allows for better adherence to the rule of fives leading to more acceptable results.

Once the chi-square test has been conducted, the null hypothesis can be accepted or rejected. If the resulting p-value is less than the chosen level of significance, the null hypothesis is rejected. Rejection of the null hypothesis indicates that some of the observed values and the expected values differ significantly (van Pool and Leonard 2011, 244). By convention, researchers

use 0.05 most often as the level of significance (Shennan 1997, 53, van Pool and Leonard 2011, 106). In the end, it is up to the individual to determine which level of significance best suits their project. This project uses the conventional 0.05 as the level of significance.

However, the chi-square test does not provide information about which values are significantly different. To determine that information, the chi-square residual needs to be calculated.

Equation 1: Chi-square residual

$$e_{ij} = (O_{ij}\text{-}E_{ij})/\sqrt{E}_{ij}$$

This number, whether positive or negative, can then be compared with the critical values from the standardized normal distribution, and when the residual value is greater than the positive or negative critical value, there is a significant difference (van Pool and Leonard 2011, 246). However, because the chi-square residual is prone to Type II errors, an adjusted chi-square residual will be used.

Equation 2: Adjusted chi-square residual

$$d_{ij} = e_{ij}/\sqrt{(1 - \frac{CT}{GT})(1 - \frac{RT}{GT})}$$

Through these calculations, the relationship between the variables can be determined and specified to the Region in which they occur.

Data

Using Jashemski's descriptions of the numerous gardens identified within Pompeii, I compiled information regarding the number of painted fountains and painted gardens per Region (Table 1). In total, 41 buildings contained paintings depicting fountains and 71 buildings contained paintings depicting gardens, resulting in 112 total depictions.

Table 1: Number of dwellings with instances of pictorial fountain or gardens by Region

	I	II	III	IV	V	VI	VII	VIII	IX
Fountains	11	2	0	0	4	8	11	1	4
Gardens	16	2	0	0	8	17	19	2	7

Regions III and IV do not contain any examples of these types of depictions, or any evidence of garden paintings whatsoever (Jashemski 1993, 312-368). While Region III does include a few gardens, per Jashemski's catalogue, there are no gardens excavated in Region IV. It is understandable that these two Regions would have few examples of gardens, let alone garden paintings. At present, they are some of the most unexcavated Regions in Pompeii (Figure 3). It is likely that if future excavations focus on those areas, more examples of garden paintings will be uncovered. Because of the lack of examples in Regions III and IV, they are omitted from the calculation. The chi-square cannot be correctly determined if any expected frequencies are below 1, because "the corresponding term in the equation for calculating chi-squared will be infinity" (Shennan 1997, 114).

Other elements of note regarding the imagery of garden paintings include the high number of both fountain depictions and garden depictions in gardens from Regions I, VI, VII. It is likely that Region I contains more examples of garden paintings, since a small portion has yet to be excavated. Region VI is entirely excavated and located next to where the aqueduct entered Pompeii, leading to the numerous examples of visual water wealth. Region VII, with its high number of paintings, contains many of the city's civic buildings along with private residences. The civic buildings do not show evidence of gardens or garden paintings; the high numbers come strictly from the private residences (Jashemski 1993, 312-368). Because Pompeii lacks socio-economic zoning (see infra), explanations for the high number of paintings are unlikely to come from segregation of the elite from the non-elite around the city's civic institutions.

Table 2: Number of homes with private water access and workshops needing large water supply by Region

	I	II	III	IV	V	VI	VII	VIII	IX
Homes	5	7	2	0	6	18	14	5	6
Workshops	11	0	0	0	2	6	16	2	9

Based on maps provided in Olsson's thesis, Table 2 shows the distribution of homes with water access and workshops requiring substantial amounts of water. The 109 buildings identified by Olsson can be grouped into 63 houses and 46 workshops. Region IV does not, at present, contain any examples of either houses with private water or workshops that used large amounts of water. It should also be noted that while Regions II and III contain homes with water access, at present neither Region shows evidence of workshops that would have needed substantial amounts of water. With regards to Region III, as well as Region IV, this lack of presence is likely a result of lack of excavation. In the case of Region II, the lack could be because a large portion of the Region houses the Palestra and Amphitheater, limiting the area's use for workshops.

Unlike the paintings, buildings showing evidence of private water access do not cluster in any Region. This pattern conforms to prior research on zoning within Pompeii. Research indicates that there are no traits indicative of socio-economic zoning present in Pompeii (Laurence 1994, 18-19, Raper 1977, 217-218). Areas of the city were not regulated to segregate certain parts of its population. Factors such as street access and privacy played a role in where and how workshops were placed throughout the city, but economic status did not. As Laurence states, "Pompeii and the urban space it contains were social products rather than planned entities" (1994, 19); how people lived in the city determined how the city looked.

Some observations about the city may explain why buildings with private water access appear in certain Regions. Region VII has the most workshops, perhaps because that Region contains many of the city's civic buildings. Even without evidence for formal zoning, one might

view Region VII as the central core of the city because it held structures used for administrative, religious, political, symbolic, economic, and social purposes (Laurence 1994, 16, 103). Region VI contains the most homes with private water access. The aqueduct system would have brought water into the city via the gate between Regions V and VI (Keenan-Jones 2015, 195, Jansen 2007, 260, Olsson 2015, 27), potentially explaining the high numbers in Region VI. A lack of excavation may explain the low numbers for Region V when compared to Region VI.

Results

After the data were gathered, calculations were completed with the aid of Kristopher J. Preacher's online chi-square calculation tool (Preacher 2001). Those figures were then compared to calculations done by hand via Microsoft Excel, with results consistently matching between the two calculations.

In the case of the relationship between Pompeii's Regions and types of painting depictions, the chi-square sum is 0.8062 and the degrees of freedom equal six. The resulting P-value is 0.9919. Because the P-value is greater than the set level of significance, 0.05, the null hypothesis cannot be rejected, and therefore, *there is not a significant relationship between Pompeii's Regions and types of painting depictions.*

Moving on to the relationship between Pompeii's Regions and buildings with private water access, the chi-square equals 19.0818. The degrees of freedom equal seven. The resulting P-value is 0.0079. This number is less than 0.05, meaning the null hypothesis can be rejected and *there is a statistically significant relationship between the Regions and private water access.*

In the final set of calculations (Table 3), the chi-square for the relationship between Pompeii's Regions and depictions of fountains and homes with private access is 10.5174. The

degrees of freedom equal seven. In this calculation, the resulting P-value is 0.16112. Again, as this value is greater than 0.05, the null hypothesis cannot be rejected and thus *there is not a statistically significant relationship between Regions and depictions of fountains and homes with private water access.*

Table 3: Number of pictorial fountains and homes with private water access by Region

	I	II	III	IV	V	VI	VII	VIII	IX
Fountains	11	2	0	0	4	8	11	1	4
Homes	5	7	2	0	6	18	14	5	6

Because the second chi-square test was the only one to result in a significant relationship, it was the only test for which an adjusted chi-square residual was calculated. The chi-square residual should not be used when the null hypothesis is not rejected. Doing so leads to Type I errors and faulty conclusions (van Pool and Leonard 2011, 247). In cases where the null hypothesis is not rejected, such as the first and third tests, the conclusion is that none of the differences between expected and observed values are larger than those likely by chance. The results of the adjusted chi-square residual are shown in Table 4. The results from the adjusted chi-square residual are compared to the critical z-value for 0.05 from a standardized normal distribution, which is 1.96. Any results that fall outside 1.96 and -1.96 are deemed significant (van Pool and Leonard 2011, 246). For private homes, the Regions falling into this range include Regions I, II, VI, VII, and IX, and for workshops include Regions I, III, VI, and IX.

Table 4: Adjusted Chi-square residual for homes with private water access and workshops needing large water supple by Region.

	I	II	III	V	VI	VII	VIII	IX
Homes	-2.328	3.598	1.878	1.575	2.974	-2.232	1.161	-2.314
Workshops	2.328	-3.074	-1.604	-1.346	-2.541	1.907	-0.993	1.977

Discussion

The results of the chi-square test indicate that, for most of the questions posed in this project, the evidence does not support a spatial relationship. There is insufficient evidence to

indicate any difference in spatial distribution between painted fountains and painted gardens or a difference in the spatial distribution of fountain paintings and houses with private water access. The analysis does indicate a difference in the spatial distribution of homes with private water access and workshops needing large quantities of water.

Based on the analysis, painted fountains are not direct evidence of cultural resilience following a natural disaster, in the sense of standing in for real fountains. Yet they potentially do so in other ways as a form of realistic representation. While some houses show evidence of restructuring water usage following the earthquake, physical fountains have been found throughout the city, sometimes alongside pictorial fountains (Dessales 2013, 397-494, Jashemski 1993, 312-368, Jones and Robinson2005, 702-706). Previous scholars have interpreted garden paintings as a means of enlarging a space, creating the illusion of an extended boundary (Jashemski 1979, 56). It would make sense for pictorial representations of a garden to incorporate elements frequently found in physical gardens.[9] Other studies of garden paintings have described them as examples of mirroring, "whereby one medium is transformed through another" (Bergmann 2002b, 23). In these interpretations, the representations echo those views seen in the surrounding garden. Dessales establishes fountains as regular features of Pompeian gardens in her catalogue (2013, 397-494), though their appearance differs from pictorial representations which lack depictions of feeding and overflow mechanisms (Jansen 2017b, 403). Instead of using pictorial fountains to replace physical fountains, the evidence suggests that pictorial fountains appear in gardens because physical fountains were also a regular element of gardens. When restoring a city following a natural

[9] See Jashemski 1993, Appendix III for a list of plants and animals found in paintings and in archaeological evidence from Vesuvian gardens and vineyards. *The Natural History of Pompeii* (Jashemski and Meyers 2002) also compiles plant and animal evidence recovered from various sources (paintings, mosaics, faunal evidence, archaeobotanical remains, etc.).

disaster, certain elements take priority over others; Maiuri suggests restoring businesses and workshops was prioritized over private homes and public buildings (Maiuri 1942, 162). In the case of water supply and garden paintings, water supply was the priority, then gardens and décor.

The chi-square test on the spatial distribution of homes with private water access and workshops needing water does show a significant relationship, leading to a second analysis using the adjusted chi-square residual (Table 4). This second analysis determined that the observed and expected values differed significantly in Regions I, II, VI, VII, and IX for homes and Regions I, II, VI, and IX for workshops. More homes were found in Regions II and VI than were predicted, where the residuals were positive, and fewer were found in I, VII, and IX than expected, where the residuals were negative. More workshops were found in Regions I and IX than anticipated and fewer were found in II and VI than predicted.

Regions I and IX have only been partially excavated, possibly accounting for these Regions having fewer than expected homes and more than expected workshops. Many of the workshops in Regions I and IX are clustered near the city's through-routes, the Via Stabiana and the Via dell'Abbondanza, and this clustering provides a possible reason for the high number of workshops (Laurence 1994, 103). Foot traffic along these streets would have been heavy, a benefit to the workshops stationed along it. Further excavations would uncover the interior sections of the Regions which are more likely to contain homes. Region VII includes the major civic buildings for Pompeii, leading to fewer homes in the Region. Along with being the site of the Great Palestra and Amphitheater, Region II also included several insulae that were largely planted, taking room away from workshops; more than half of II.iv.3, the Praedia of Julia Felix, was planted, and II.v was a large vineyard (Jashemski 1993, 88-89). Region VII appears to be a predominantly residential area of the city.

In order to better understand how painted fountains and private water access overlap, one needs to examine Dessales' catalogue (2013, 397-494). Dessales' catalogue includes 117 buildings from Pompeii. I divided this list into four categories according to their connection to the public water system: definite connection, probable connection, no connection, and uncertain. These categories derive from Dessales' commentary on each house's water system (*système hydraulique*) and the floorplans Dessales provides for each house. In most cases, she clearly states whether a house has a definite, probable, or no connection to the public network.

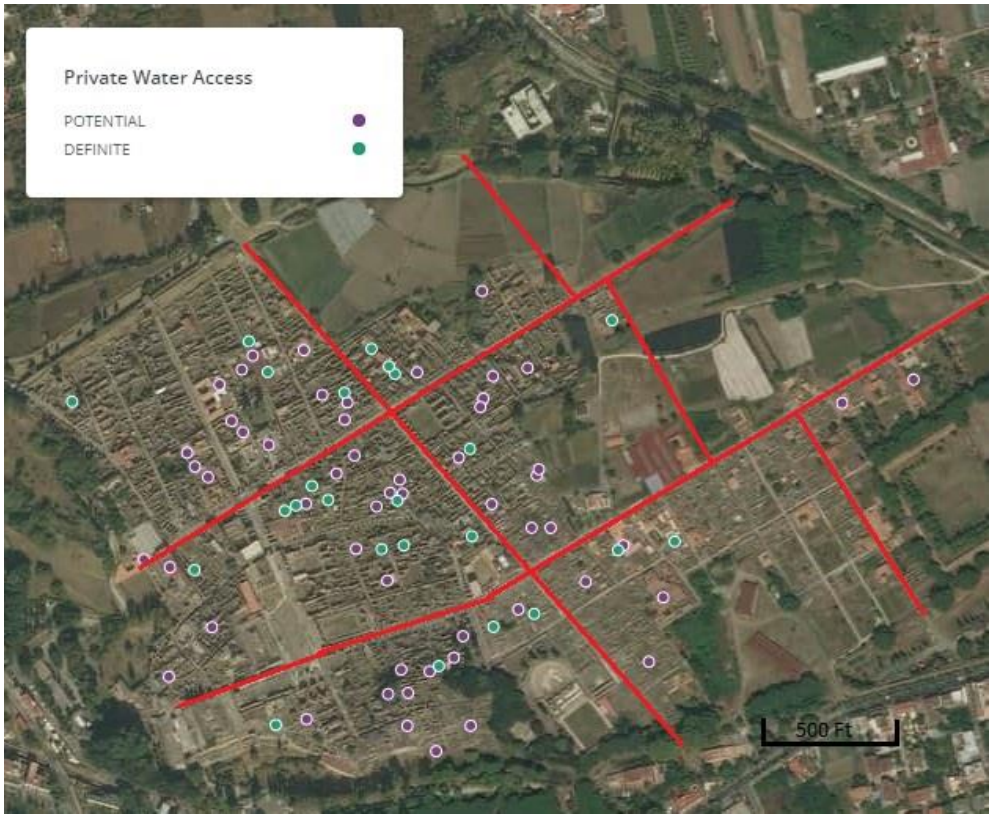

Figure 4 Map showing location of homes with private water access from Dessales 2014.

By combining the definite and potential connection categories, Dessales provides 76 homes to compare to the 41 with painted fountains and the 71 with painted gardens from Jashemski (Figure 4). Thirteen houses have both pictorial fountains and private water access, six with a definite connection and seven with a potential connection, accounting for 32% of the total number of houses with pictorial fountains. Seven homes with fountain representations (17% of the total)

do not have a connection to Pompeii's water system or private water towers. In comparison, 24 houses have both pictorial gardens and private water access, and this figure accounts for 34% of the total number of houses with pictorial garden. Six homes have a definite connection and 18 homes have a potential connection. Another nine homes with painted gardens (13% of the total) have no water connection or private water tower. The evidence does not suggest there is substantial overlap between painted fountains and private water.

While the chi-square test does not support a relationship between pictorial fountains and private water access, another data source gives indications that there is a relationship between the two variables. Thirteen houses from Allison's work (Allison 2004b, a) overlap with the data used for this project. Three houses from Allison's catalogue overlap with those containing painted fountains (Appendix A; I.vi.15, I.xi.11, IX. xiii.1-3), seven from Allison's collection overlap with those with private water access (Appendices C and D; I.vi.4, I.x.4, V.ii.1, VI.xvi.7, VIII.ii.14-16, VIII.ii.28, VIII.ii.29-30), and three houses overlap with houses in both categories (Appendices A, C, and D; I.vii.10-12, I.vii.19[10], VI.xv.1). In the houses containing fountain representations but without evidence for private water access, Allison's database does not list a fountain in the artifact assemblages or room descriptions. There are no statues or pedestals/bases described as having the ability to function as a fountain or pools/impluvia that had a fountain within them. However, houses that had both pictorial fountains and private water access do contain the remains of fountain apparatuses in their artifact assemblages. These take the form of a colonnetta in the center of an impluvium (e.g. I.vii.9) or larger-scale fountains structures (e.g. VI.xv.1). Almost all the houses with private water access have some form of fountain apparatus, with the exceptions being I.vi.4 and VIII.ii.14-16. Obviously, such a small sample of houses is not enough to completely negate

[10] Allison treats I.vii.19 as a separate house, while Jashemski and Dessales treat it as part of I.vii.10-12.

the findings of the chi-square test, but Allison's work does provide an avenue for further exploration. Cataloguing the artifact assemblages of more houses with fountain paintings and private water access will provide a clearer picture as to how these variables interacted in daily Pompeian life.

Future excavations in Regions I, III, IV, V, and IX could augment the current findings. These Regions all include large areas that have remained unexcavated. Either the discovery of new garden paintings or more information regarding the transportation of water through Pompeii would change the project's data set. Because of the current, small sample size, any relationship must be highly marked for the analysis to show a significant relationship. In a larger sample, weak relationships become more evident (Shennan 1997, 114-115). Current efforts to maintain and preserve the ruins at Pompeii have led to a plan to open new excavations in certain areas of the city (Osanna 2016). Depending on what evidence is recovered, these excavations could provide more details pertaining to this research.

Conclusion

The original goal of this project was to determine whether a relationship existed between pictorial fountains and private water access to better understand the cultural aspect of human resilience following natural disasters. However, chi-square tests on the data indicate there is no statistically significant relationship between the location of pictorial fountains and the locations of homes with private water access. These data do not permit the conclusion that pictorial fountains were stand-ins for physical fountains, so pictorial fountains cannot be taken as evidence of human resilience in the first years following a disaster. The chi-square analysis supports at least focused associations between private water supply and Regions, and thus the priority of restoring water

systems. In the 17 years between the earthquake and the city's destruction, Pompeii was rebuilding – just not by painting fountains to replace physical fountains.

Recent scholarship suggest that garden paintings depicted how Pompeian gardens actually looked, and the chi-square analysis suggest that the paintings are associated with the late period of recovery from the earthquake, in the last years before the eruption of 79 CE. The data suggests, although it does not prove, that the installation of garden paintings, fountains, and gardens took place at the same time and emphasizes their potential interrelationship. By representing a visual garden within a physical garden, citizens added luxury and meaning to their private sphere, evoking natural landscapes while enabling viewers to remain protected and comfortable (Bergmann 1999, 105). Within the confines of a city, citizens desired to tame the wildness of nature, bring it into their private life, and enjoy its wonders without ever leaving their dwelling, achieving "harmony between human (art) and nature that was so lacking in [their] contemporary world" (Spencer 2010, 140). Through the use of hedges, fences, paths, and walls, gardens epitomized "how nature was controlled for the benefits of man" (von Stackelberg 2009, 131). It is through this desire for and expression of control that the people of Pompeii express their resilience. In the aftermath of the earthquake, the need to tame the chaotic natural world would have been strong. By restoring and developing their gardens, Pompeian citizens could exercise their ability to shape nature to their will as they recovered from nature's destructive forces. For Romans, an understanding of landscape is deeply rooted in the control of nature (von Stackelberg 2009, 15). The people of Pompeii wanted to return their city to what it was before the earthquake quickly to regain command over their world. This showing of control appears in the largest homes and the smallest shops; gardens are present in every corner of the city (Jashemski 1993, 312-368). Painted fountains may not represent a marker of resilience by replacing physical fountains, but painted

gardens and gardens themselves stand as evidence of resilience because they demonstrate the Roman need and ability to control nature.

Furthermore, while the chi-square test does not support a relationship between pictorial fountains and private water access, Allison's catalogue provides the beginnings of a counterargument that would support a relationship between the variables. In the thirteen homes from Allison's catalogue that overlap with the data collected from Jashemski and Dessales, those homes with fountain depictions do not have fountain apparatuses in their artifact assemblages. The small sample from Allison's work does not overrule the findings of the chi-square test. However, Allison's work does offer enough evidence to indicate future research avenues that may indicate pictorial fountains have a relationship to water supply and garden design. With large portions of the city still unexcavated, it is likely that more painted fountains and more homes with private water access remain to be found. While future research may reverse the results of the presented investigation, the results presented refine our comprehension of what human resilience looks like as portrayed by the citizens of Pompeii: restoring order to the chaos of an earthquake first by restoring infrastructure, then by seeking expressions of an orderly reconnection with the natural world appropriate to life in the city.

Appendices

A) Painted Fountains

Address	Name
I.ii.10	Casa di L. e M. Volusius Faustus
I.vi.15	Casa dei Ceii
I.vii.2-3	Casa di M. Fabius Amandus
I.vii.10-12/19	Casa dell'Efebo
I.ix.5	Casa del Frutteto
I.ix.13-14	Casa di Cerere
I.xi.6	Casa della Venere in Bikini
I.xi.16	Hospitium
I.xii.11	
I.xii.16	
I.xvii.4	Casa degli Archi
II.iii.3	Casa di Venere Marina
II.ix.6	
V.i.10/23-27	Casa di L. Caecilius Jucundus
V.i.18/11-12	Casa degli Epigrammi Greci
V.iv.1	
V.iv.c	Casa degli Ori
VI.ii.3-5	Casa di Sallustio
VI.vii.23	Casa di Apollo
VI.viii.22	Casa della Fontana Grande
VI.ix.3-5	Casa del Centauro
VI.ix.6-9	Casa dei Dioscuri
VI.xv.1/27	Casa dei Vettii
VI.xv.2	Casa di Apuleia e Narciso
VI.xvii.42	Casa del Bracciale d'Oro
VII.i.8	Terme Stabiane
VII.ii.14	Casa di Optatio
VII.ii.25	Casa delle Quadrighe
VII.ii.45	Casa dell'Orso Ferito
VII.iii.30	Casa del Panettiere
VII.iv.56	Casa del Granduca di Toscana
VII.v.2/12	Terme Foro
VII.vi.28	Casa del Peristilio
VII.vii.10/13	Casa di Romolo e Remo
VII.ix.27/40-41	
VII.xi.11/14	Hospitium Christianorum
VIII.vii.1	Caupona
IX.ii.7-8	Casa della Fontana d'Amore
IX.vii.25	*Hospitium* di MM. Fabii Memor e Celer
IX.viii.3-6	Casa del Centenario
IX.xiii.1-3	Casa di C. Julius Polybius

B) Painted Gardens

Address	Name
I.ii.10	Casa di L. e M. Volusius Faustus
I.ii.17	
I.vi.13	Casa di Stallius Eros
I.vii.2-3	Casa di M. Fabius Amandus
I.vii.10-12/19	Casa dell'Efebo
I.ix.5	Casa del Frutteto
I.ix.13-14	Casa di Cerere
I.x.4/14-17	Casa del Menandro

I.xi.6	Casa della Vernere in Bikini
I.xi.10-11	Caupona di Euxinus
I.xi.16	Hospitium
I.xii.3	Caupona di Sotericus
I.xii.8	
I.xii.16	
I.xvi.3	
I.xvii.4	Casa degli Archi
II.iii.3	Casa di Venere Marina
II.ix.6	
V.i.10/23-27	Casa di L. Caecilius Jucundus
V.i.18/11-12	Casa degli Epigrammi Greci
V.i.28	Casa di M. Tofelanus Valens
V.ii.15	
V.iii.7	
V.iii.11	
V.iv.1	
V.iv.c	Casa degli Ori
VI.ii.3-5	Casa di Sallustio
VI.ii.14	Casa delle Amazzoni
VI.v.5	Casa del Graduca Michele di Russia
VI.vii.18	Casa di Adonis
VI.vii.23	Casa di Apollo
VI.viii.5	Casa del Poeta Tragico
VI.viii.22	Casa della Fontana Grande
VI.viii.23/24	Casa della Fontana Piccola
VI.ix.3-5	Casa del Centauro
VI.ix.6-9	Casa dei Dioscuri

VI.xi.9-10	Casa del Labirinto
VI.xiv.20	Casa di Orpheus
VI.xiv.30	Casa di Laocoonte
VI.xiv.43	Casa degli Scienzati
VI.xv.1/27	Casa dei Vettii
VI.xv.2	Casa di Apuleia e Narciso
VI.xvii.42	Casa del Bracciale d'Oro
VII.i.8	Terme Stabiane
VII.ii.14	Casa di Optatio
VII.ii.16-17	Casa di M. Gavius Rufus
VII.ii.25	Casa delle Quadrighe
VII.ii.35	Casa di Mercurio
VII.ii.45	Casa dell'Orso Ferito
VII.iii.11-12	Casa di Ercole Fanciullo
VII.iii.30	Case del Panettiere
VII.iv.29	
VII.iv.56	Casa del Granduca di Toscana
VII.v.2/12	Terme Foro
VII.vi.7	
VII.vi.28	Casa del Peristilio
VII.vii.10/13	Casa di Romolo e Remo
VII.ix.27/40-41	
VII.ix.33	Casa del Re di Prussia
VII.x.3/14	Casa della Caccia Nuova
VII.xiv.14-15	
VII.xvi.16-22	Casa di Fabius Rufus
VIII.ii.14-16	Casa di L. Aelius Magnus
VIII.vii.1	Caupona

IX.i.22/29	Casa di M. Epidius Sabinus
IX.ii.7-8	Casa della Fontana d'Amore
IX.v.6/17	
IX.viii.2	Scuola di Potitus
IX.viii.3-6	Casa del Centenario
IX.xiii.1-3	Casa di C. Julius Polybius
IX.xiv.c	

C) Homes with definite connection

Address	Name
I.vi.7	Fullonica di Stephanus
I.vii.10-12/19	Casa dell'Efebo
V.i.3/7-9	Casa del Torello
V.i.18/11-12	Casa degli Epigrammi Greci
V.i.10/23-27	Casa di L. Caecilius Jucundus
VI.i.7/25	Casa delle Vestali
VI.xiv.21-22	*Fullonica* de M. Vesonius Primus
VI.xv.1/27	Casa dei Vettii
VI.xv.5	Casa di M. Pupius Rufus
VII.i.25/47	Casa dei Principi di Russia
VII.ii.45	Casa dell'Orso Ferito
VII.iv.31/51	Casa dei Capitelli Colorati
VII.iv.56	Casa del Granduca di Toscana
VII.iv.58/60	Casa delle Pareti Nere
VII.iv.62	Casa delle Forme di Creta
VII.vi.38	Casa di Cipius Pamphlus Felix
VII.xii.23	Casa del Camillo
VII.xii.28	Casa del Balcone Pensile
VIII.ii.1	Casa di Championnet I
VIII.iv.4/49	Casa di M. Holconnius Rufus
VIII.iv.15/30	Casa di C. Cornelius Rufus
VIII.v.38/15-16	
IX.iii.20	*Domus* et *pistrinum* de Papirius Sabinus
IX.xiv.2-4	Casa di M. Obellius Firmus

D) Homes with potential connection

Address	Name
I.ii.28	Casa della Grata metallica
I.iv.5/25	Casa del Citarista
I.vi.4	Casa del Sacello Iliaco
I.x.4/14-17	Casa del Menandro
II.ii.2	Casa di D. Octavius Quartio
II.iv.3	*Praedia* di Julia Felix
V.ii.1	Casa dell Nozze d'Argento
V.iii.11	
VI.viii.2/20-21	*Fullonica* di L. Veranius Hypsaeus
VI.viii.22	Casa della Fontana Grande
VI.viii.23/24	Casa della Fontana Piccola
VI.ix.6-9	Casa dei Dioscuri
VI.x.2	Casa dei Cinque Scheletri
VI.x.6	Casa di Pomponius
VI.xi.9-10	Casa del Labirinto
VI.xii.2-5	Casa del Fauno
VI.xiv.20	Casa di Orpheus
VI.xiv.39	*Domus e officina* di Axius Gun … *faber tornator*

VI.xiv.43	Casa degli Scienzati
VI.xv.2	Casa di Apuleia e Narciso
VI.xvi.7/38	Casa degli Amorini Dorati
VI.xvii.42	Casa del Bracciale d'Oro
VII.ii.16-17	Casa di M. Gavius Rufus
VII.ii.18	Casa di C. Vibius C…
VII.ii.20	Casa dei Marmi
VII.ii.48	Casa di D. Caprasius Primus
VII.iii.3/38	Casa di C. Memmius
VII.iv.48	Casa delle Caccia Antica
VII.iv.57	Casa dei Capitelli Figurati
VII.x.3/14	Casa delle Caccia Nuova
VII.xii.3	Casa di (L. Caecilius) Capella
VII.xv.12	Casa di A. Octavius Primus
VII.xvi.12-14	Casa di Aulus Umbricius Scaurus
VII.xvi.16-22	Casa di Fabius Rufus
VIII.ii.14-16	Casa di L. Aelius Magnus
VIII.ii.28	
VIII.ii.29-30	Casa di Severus
VIII.ii.36-37	Casa di L. Caecilius Pheobus
VIII.iii.14	Casa della Regina Carolina
VIII.iv.12-13	Lupanar?
VIII.v.2/5	Casa del Gallo
VIII.v.28-29	Casa della Calce
VIII.v.37	Casa delle Pareti Rosse
VIII.v.39	Casa di Acceptur e Euhodia
VIII.vi.9-10	
IX.i.20/30	Casa dei Diadumeni
IX.i.22/29	Casa di M. Epidius Sabinus
IX.ii.7-8	Casa della Fontana d'Amore
IX.iii.5/24	Casa di M. Lucretius Stabia
IX.v.6/17	
IX.v.11	
IX.v.18-21	Casa di Jasone
IX.vii.20	Casa della Fortuna
IX.vii.25	*Hospitium* di MM. Fabii Memor e Celer
IX.viii.3-6	Casa del Centenario

Works Cited

Adger, W. Neil. 2000. "Social and Ecological Resilience: Are They Related? ." *Progress in Human Geography* 24 (3):347-364.

Allison, Penelope M. 2004a. *Pompeian Households: An Analysis of the Material Culture*. Los Angeles: Costen Institute of Archaelogy

Allison, Penelope M. 2004b. "Pompeian Households: An On-line Companion." http://www.stoa.org/projects/ph/home.

Andersson, Espen B. 1994. "Urban Water Supply in Pompeii and the Private Water Consumption." XIV Congreso Internacional de Arqueologia Clasica Tarragona.

Bergmann, Bettina. 1991. "Painted Perspective of a Villa Visit: Landscape as Status and Metaphor." In *Roman Art in the Private Sphere: New Perspectives on the Architecture and Decor of the Domus, Villa, and Insula*, edited by Elaine K. Gazda. Ann Arbor: University of Michigan Press.

Bergmann, Bettina. 1992. "Exploring the Grove: Pastoral Space on Roman Walls." *Studies in the History of Art* 26:20-46.

Bergmann, Bettina. 1999. "Rhythms of Recognition: Mythical Encounters in Roman Landscape." Im Spiegel des Mythos. Bilderwelt und Lebenswelt, Rome.

Bergmann, Bettina. 2002a. "Art and Nature in the Villa at Oplontis." In *Pompeian Brothels, Pompeii's Ancient History, Mirrors and Mystieries, Art and Nature at Oplontis, & the Herculaneum 'Basilica'* edited by T. McGinn, 87-120. Portsmouth, RI.

Bergmann, Bettina. 2002b. "Playing with Boundaries: Painted Architecture in Roman Interiors." In *The Built Surface: Architecture and the Pictorial Arts form Antiquity to the Enlightenment*, edited by Christy Anderson. Aldershot: Ashgate.

Descœudres, Jean-Paul. 2007. "History and Historical Sources." In *The World of Pompeii*, edited by John J. Dobbins and Pedar W. Foss, 9-27. New York: Routledge.

Dessales, Hélène. 2006. "Castella privata: Water Towers and Tanks in Roman Dwellings " In *Cura aquarum in Ephesus: proceedings of the twelfth International Congress on the History of Water Management and Hydraulic Engineering in the Mediterranean Region, Ephesus/Seluk, Turkey, October 2-10*, edited by Gilbert Wiplinger, 363-370. Dudley: Peeters Publishers.

Dessales, Hélène. 2013. *Le Partage de l'Eau: Fountaines et Distribution Hydraulique dans l'Habitat Urban de l'Italie Romaine*. Rome: Ecole Francaise de Rome

Eschebach, Hans. 1979. "Die Gebrauchswasserversorgung des antiken Pompeji." *Antike Welt* 10:3-24.

Eschebach, Hans. 1983. "Gebrauchswasserversorgung Pompejis." In *Journées d'etudes sur les aqueducs romains*, edited by J. P. Boucher. Paris Les Belles Lettres.

Everit, B. S. 1992. *The Analysis of Contingency Tables, Monographs on Statistics and Applied Probabilty 45*. New York: Chapman and Hall.

Flohr, Miko. 2011. "Reconsidering the Atrium House: Domestic Fullonicae at Pompeii." In *Pompeii: Art, Industry, and Infrastructure*, edited by Miko Flohr Eric Poehler, and Kevin Cole, 88-102. Oxford: Oxbow.

Folke, Carl. 2006. "Resilience: The emergence of a perspective for social-ecological systems analyses." *Global Environmental Change* 16 (3):253–267.

Gleason, Kathryn. 2017. "Personal Communication."

Hansen, Roger D. 1983. "Water and Wastewater Systems in Imperial Rome." *Journal of American Water Resources Association* 19 (2):265-269.

Jansen, Gemma. 1996. "Die Verteilung des Leitungswassers in den Häusern Pompejis " Cura aquarum in Campania : proceedings of the Ninth International Congress on the History of Water Management and Hydraulic Engineering in the Mediterranean Region : Pompeii, 1-8, 1994, Leiden.

Jansen, Gemma. 2001. "Water Pipe Systems in the Houses of Pompeii: Distribution and Use." *American Journal of Archaeology* 101 (2):356-356.

Jansen, Gemma. 2005. "Water and Water Technology in the Pompeian Garden." In *Omni Pede Stare: Saggi Architettonici e Circumvesuviani in Memoriam Jos de Waele*, 277-290. Naples Electa Napoli.

Jansen, Gemma. 2007. "The Water System: Supply and Drainage." In *The World of Pompeii*, edited by John J. Dobbins and Pedar W. Foss, 257-266. New York: Routledge.

Jansen, Gemma. 2017a. "Personal Communication."

Jansen, Gemma. 2017b. "Water and Water Technology in Roman Gardens." In *Gardens of the Roman Empire*, edited by Wilhelmina Jashemski, Kathryn Gleason, Kim Hartswide, and Anna Malek. Cambridge: Cambridge University Press.

Jashemski, Wilhelmina. 1979. *The Gardens of Pompeii, Herculaneum, and the Villas Destroyed by Vesuvius*. 2 vols. Vol. 1. New Rochelle: Caratzas Brothers Publishers.

Jashemski, Wilhelmina. 1993. *The Gardens of Pompeii, Herculaneum, and the Villas Destroyed by Vesuvius*. 2 vols. Vol. 2. New Rochelle: Aristide D. Caratzas Publisher.

Jashemski, Wilhelmina and Fredrick Meyer, ed. 2002. *The Natural History of Pompeii*. Cambridge: Cambridge University Press.

Jones, Rick and Damian Robinson. 2005. "Water, Wealth, and Social Status at Pompeii: The House of the Vestals in the First Century." *American Journal of Archaeology* 109 (4):695-710. doi: 10.3764/aja.109.4.695.

Juuti, Petri S., Georgios P. Antoniou, Walter Dragoni, Fatma El-Gohary, Giovanni De Feo,Tapio S. Katko, Riikka P. Rajala, Xiao Yun Zheng, Renato Drusiani and Andreas N. Angelakis.

2015. "Short Global History of Fountains." *WATER* 7 (5):2314-2348. doi: 10.3390/w7052314.

Kapossy, Balázs. 1969. *Brunnenfiguren der hellenistischen und römischen Zeit*. Zurich: Juris.

Keenan-Jones, Duncan. 2015. "Somma-Vesuvian Ground Movements and the Water Supply of Pompeii and the Bay of Naples." *American Journal of Archaeology* 119 (2):191-215. doi: 10.3764/aja.119.2.0191.

Larntz, K. 1978. "Small-Sample Comparison of Exact Levels for Chi-Square Goodness-of-Fit Statistics." *Journal of the American Statistical Association* 73:253-263.

Laurence, Ray. 1994. *Roman Pompeii: Space and Society*. London: Routledge.

Leach, Eleanor Winsor. 2004. *The Social Life of Painting in Ancient Roman and on the Bay of Naples*. Cambridge: Cambridge University Press.

Maiuri, Amedeo. 1942. *L'Ultima Fase Edilizia di Pompei*. Rome: Istituto di Studi Romani.

Mehmood, Abid. 2015. "Of Resilient Places: Planning for Urban Resilience." *European Planning Studies* 24 (2):407-419.

Olsson, Richard. 2015. "The water-supply system in Roman Pompeii." Dissertation/Thesis, Archaeology and Ancient History, Lund Univeristy.

Osanna, Massimo. 2016. Pompeii Great Project - New Life for the Dead City. Ithaca: Cornell University

Preacher, Kristopher J. 2001. "Calculation for the chi-square test: An interactive calculation tool for chi-square tests of goodness of fit and independence." http://quantpsy.org.

Raper, R.A. 1977. "The Analysis of the Urban Structure of Pompeii: A Sociological Study of Land Use." In *Spacial Archaeology* edited by David Clarke, 189-221. London: Academic Press Inc.

Shennan, Stephen. 1997. *Quantifying Archaeology*. Iowa City: University of Iowa Press.

Spencer, Diana. 2010. *Roman Landscape: Culture and Identity* Vol. 39, *Greece & Rome, New Surveys in the Classics*. Cambridge: Cambridge University Press.

Strocka, Volker Michael. 2007. "Domestic Decoration: Painting and the 'Four Styles'." In *The World of Pompeii*, edited by John J. and Pedar W. Foss Dobbins. New York: Routledge.

Stumpp, Eva-Maria. 2013. "New in Town? On Resilience and "Resilient Cities"." *Cities* 32:164-166.

van Pool, Todd L. and Robert D. Leonard. 2011. *Quantitative Analysis in Archaeology*. Malden: Wiley-Blackwell.

von Stackelberg, Katharine 2009. *The Roman Garden: Space, Sense, and Society*, *Routledge Monographs in Classical Studies*. London/New York: Routledge.