Abstract: This thesis is an investigation of the water supply strategies of Roman forts (i.e. *castella*) and fortresses (*castra*). It deals with fortifications along the Roman frontier in Great Britain in the west, and Syria and Jordan in the east. The plan of the thesis is roughly this: I first provide an overview of Roman military installations. I then summarize and present current scholarly opinion on relevant topics. Subsequently, I subject the historical and archaeological material to analysis, and offer up my findings. In the last part I assess the claims made by earlier scholars against the background of the evidence presented, discuss the implications, and render my interpretations. The conclusion is that the inter-regional differences are significant, but so are the intra-regional ones.

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The Water Supply Strategies of Roman Military Installations

Master's thesis

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Table of Contents

1. Introduction

1.1. Background

Ever since the formation of the first state societies and the establishment of permanent settlements, great attention has always been given to the obtainment of reliable and abundant sources of pure water. It is an object of prime importance to the civilized state, and one of the principal responsibilities of any government. The Romans had a highly developed system of water delivery. By way of aqueducts the cities of the empire were furnished with water. It was conveyed, from the remotest conceivable sources, with the help of only gravity, the conduits having been built at a slight, downward gradient. In the city of Rome alone, the aqueducts totaled a length of 415 kilometers. The water was directed to public bath houses, architectural and drinking fountains, latrines, etc. Plumbing and piping systems distributed the water even to private households. There is perhaps no better demonstration of the brilliance of Roman engineering than these ancient waterways, which, in many cases, have endured into our age. They represent a feat of technology that was not equaled for millennia.

A great deal of scientific effort has been invested into research on the Romans and their relationship with water. Yet, for all we know of Roman waterworks, there are still many aspects left unexplored, or insufficiently explored. One of these areas is the supply of water to the military garrisons. The forts and fortresses of the Roman army accommodated a great number of soldiers. This mass of people required large amounts of water – soldiers, moreover, due to the strenuous nature of their duties, require larger quantities of water than common men. The importance of water cannot be overstated, particularly in the case of the military. Even slight declivities of hydration can significantly impair performance, making water logistics an essential tactical consideration. A Roman commander would not likely be negligent to the importance of ensuring adequate hydration. The supply of water would thus require careful consideration, and scrupulous organization. The details of this organization is what I intend to explore in this thesis.

1.2. Purpose

The purpose of this thesis is to inquire into the means of water supply of Roman military sites. There are a number of facets I wish to explore. Firstly, I wish to examine the means by which water could be acquired for a large military force. Secondly, I am interested in exploring if it is possible to discern any kind of military convention in regards to the supply of water. Certainly, in terms of layout, as well as in numerous other aspects of organization, the legionary fortresses broadly followed the same arrangement all across the empire. However, the drastically different environmental conditions along the borders may mean that the organization of water differed along the various frontiers. Moreover, I will also attempt an analysis of the topographical situation of the encampments, which will hopefully be informative as regards the significance of water points when considering the placement of an installation.

In summary, the questions at issue are:

- Where did the water come from? I.e. what methods of water supply can be identified in historical sources and the archaeological record?
- Were the methods by which the soldiery acquired water the same in all parts of the empire, or was there a considerable degree of environmental adaption?
- Were the camps topographically situated in such a way as to make it plausible that proximity to water was superordinate to other strategic concerns (i.e. the defensibility of the position, its importance for territorial defense, etc.)?

1.3. Material

My material is threefold. The first category consists of primary sources and modern literature (i.e. secondary sources). The ancient sources are comprised mainly of military writers, but I have also included those authors who, in some respect, treat the issue of water supply. The secondary sources are comprised of an assortment of miscellaneous writers that provide information on one matter or another – hydration, water supply, military camps and fortifications, labor input calculation, digital methodology, the roman army in general, etc.

The second category is archaeological evidence. Not the physical remains themselves, but articles and reports on the excavation of Roman military stations. In this respect it is also literary, but represents a different category of evidence. The vast bulk of this material treats sites in Roman Britain, for reasons which I will explain in full in a later chapter.

The third category is digital maps and elevation models, the first of which are provided by the antiquarian authorities of England, Scotland, and Wales. The latter come at the courtesy of Google Inc. In the case of the frontier in Syria and Jordan, photographic and literary evidence completely substitute digital maps and elevation models. This will also be expounded upon in the relevant chapter.

1.4. Delimitations

The Roman Empire was vast, its boundaries practically endless. It is scarcely tenable to attempt a study of all the frontiers of the empire. I have instead elected to investigate the conditions in Roman Britain, and along the eastern *limes* in Syria and Jordan. The former located in the North Temperate Zone and the latter in the Torrid Zone. I chose to examine provinces in vastly different geographical zones as environmental conditions very likely had a significant impact on water supply strategies, and that is an aspect I would like to explore. Due to the relative abundance of excavated military sites, and published material thereon, a close study of every single fort and fortress is scarcely tenable, yet I have endeavored to include as many sites as I could possibly manage.

1.5. Methodology

In accordance with the overwhelmingly literary material, my investigation will be very literature-based. It consists of historical research and the study of excavation material by means of reading reports and articles.

A substantial portion of my thesis consists of a statistical compilation in which I have gathered data on the prevalence of different water supply methods at the forts and fortresses in my areas of study. This information has been obtained from written reports and articles. The statistical analysis consists of 153 sites in Roman Britain and 44 sites in Syria and Jordan (although I have only been able to obtain essential information for 28 of these). Apart from specifying the method of water supply I have also provided data on the proximity of military installations to their nearest water source, as well as the topographical elevation of each site. The former of these has, in the case of Great Britain, been obtained by studying detailed maps from the antiquity authorities. In the case of Syria and Jordan, such data is not publicly available, and I have therefore not been able to consistently obtain this information. In those cases when it is present in my statistics, it has been derived from secondary sources. My topographical analysis is based on height data from Google Inc. This data is very accurate (more details will follow in the pertinent chapter) as relates to Great Britain. For Syria and Jordan, topographical elevation data is only provided if I have been able to extract it from literary and/or photographic evidence.

2. Research history

2.1. Definition of terms

Before I proceed to an account of the Roman fort I feel that a definition of the terms is in order. The various writers that have treated military matters – and their number is legion — have hardly been accordant in their nomenclature when discussing fortified installations, and this lack of consistency has led to considerable terminological confusion both within and outside of academia.

In classical Latin *castrum* generally signified a large defensive construction, either an overnight camp or a more permanent, well-fortified position. The word originally singularly denoted overnight, or marching camps; in the centuries following the advent of Christ, as the borders congealed and the military practice of permanent entrenchment and fortification developed, it also acquired the meaning of fortress. *Castellum*, the diminutive of *castrum*, was used to refer to smaller defensive constructions. There is also the apparently size-agnostic term *praesidium*, which is often rendered as garrison or guard post in English, but has not seen much use either by ancient writers or in modern literature, for which reason I will omit it from my composition.[1]

Pioneering scholars of Roman archaeology would often use the terms fort, fortress, and camp interchangeably for *castra* and *castella*. Some established their own terminology and could, for instance, use *castellum* to refer to permanent fortifications and *castrum* to refer to temporary encampments, but for a long period there was no widely accepted convention. In the early twentieth century however, English classical scholars established a definite terminology. They associated larger military installations with citizen soldiers, i.e. legionaries, and called them *castra*; in English they were designated as fortresses.[2] Smaller fortifications were associated with the *auxilia*, and called *castella*; in English, forts.[3]

This dichotomy was practical, and remained the authoritative view for almost a century. “The legionary’s base was a fortress (*castrum*) covering about 50 acres; the auxiliary was stationed at a fort (*castellum*) which might vary in size from about two to seven or eight acres”, wrote Roger Wilson, one of the foremost experts of his time on Roman fortifications, in 1980.[4] In recent years however, the absolute division between legionaries and *auxilia* has been called into question. There is no consensus on the matter, but the prevailing present-day scholarly opinion regards the strict division as erroneous. The dismissals are in part based on finds of equipment generally associated with auxiliary units at sites categorized as *castra* and vice versa. In the wake of this discussion a new term has been coined, namely the composite fort, meaning a fortification garrisoned by both legionary and auxiliary forces.

In the present day most academics writing in English still use the terms fortress and fort as translations for *castrum* and *castellum* respectively, but exceptions to this are not wholly uncommon; smaller fortifications are still occasionally labeled as *castra*. [5] The sites are, however, generally no longer looked upon as exclusive to one branch of the Roman army (i.e. legionaries or *auxilia*). This is to be regarded as

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[1] Smith 1875, 244-256; Campbell 2009, 4-23. Christopher Irvine, writing in the late 17th century, uses the terms fort and great fort. In his *Caledonia Romana*, Robert Stuart writes about ‘classes of forts’, etc.

[2] Marching encampments have always been referred to as *castra*. This is perhaps the only widely agreed-upon subject.

[3] Campbell 2009, 4f.

[4] Wilson 1980, 5; the parenthesized translations are Wilsons, not mine.

[5] One occasionally also encounters the term fortlet, meaning an exceptionally small – relatively speaking – fort.

a positive development, as the Romans apparently made no distinction between the two categories of fortification, apart from a difference in size. It does appear that many of the *castella* were in fact garrisoned exclusively by auxiliary units; many of the forts along Hadrian's Wall are of this type. This notwithstanding, it was clearly not a fixed regulation.[6]

Those who are widely read in the subject will quickly intuit which type of fortification an author is referring to, irrespective of his terminology, but the lack of convention is grating, presents difficulties to the initiate, and is decidedly unscientific. I myself will mainly be using the Latin terms, but there will be places where I employ English terminology. In those cases I am adopting the terms fortress and fort, and will be using them in the way Roger Wilson did.

An additional matter of some dispute is the so-called vexillation fortress. The term was coined by Sheppard Frere in 1967, who conjectured the existence of a smaller type of fortress, meant to house a force equal to half a legion or less. *Vexillatio* is a classical Latin term signifying a legionary detachment of varying size, normally a very large one – greater than a thousand.[7] 'Vexillation fortresses' however, do not exist in ancient literature. The term was invented to explain military installations which Frere and his peers considered too small to accommodate a full legion, yet were too large to classify as forts, or *castella*. Frere believed that legions in Britain would regularly split into smaller units (vexillations) and this would explain the not quite fully-sized fortresses. He called these installations 'vexillation fortresses'. The notion is accepted by some, but it is still very much an issue of contention. Many modern reject the proposition. Graham Webster, and many with him, considers the smaller area of some fortresses as nothing other than somewhat cramped living quarters.[8] I myself hold with those who favor a complete dismissal of the term 'vexillation fortress', and will not be using it to any greater extent.

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[6] Breeze 1983, 7.
[7] Goldsworthy 1996, 26f.
[8] Brewer 2000, 56-65.

2.2. Overview of Roman fortifications

The Romans built many defensive works. The amount of material available for study is staggering. There are over four hundred known Roman military sites in Britain alone; this number includes temporary encampments as well as permanent forts and fortresses.[9] Only a very small number of these have been examined in some way, and only superficially in the majority of cases.[10] As for the circumstances along the eastern *limes*, much less is actually known. A fair number of sites have been examined, mainly by archaeologists from various European countries, but the survey work is severely lacking. This applies to most other areas once under Roman occupation. There is actually no corpus of Roman fortifications in existence, neither a global — in Roman terms — nor a regional one. Surprising perhaps, given how much interest and labor has been invested in Roman military matters.

The archaeological remains, as I said, amount to a very large quantity. To make sense of the material finds archaeologists have turned to a number of ancient texts, and although the primary sources principally address marching camps, the permanent bases were almost identically arranged. Camps were intended to provide protection for brief periods of stay, often a single night. They dated from a time when Rome had no standing army. Circumstances and conditions changed when Augustus formally instituted the professional army. There arose a need for permanent living quarters.[11] Now, as one may have surmised from the preceding definition of terms section, there are, apart from marching camps, basically two types of Roman defensive structures – the *castrum* and the *castellum*. Both of these very closely follow the organization of the marching camp. The principal disparity between marching camps and permanent fortifications is that the latter had stronger defenses – mainly due to them being constructed in more lasting materials (i.e. stone or heavy timber walls instead of wooden palisades, etc.), and that they contained actual buildings instead of tents and portable lodges. The fortresses were occupied by legions, while the auxiliary corps appear to have been divided into smaller units and stationed at the smaller *castella*, although there are clearly instances when auxiliary forces were stationed at *castra* and vice versa. Seemingly, the idea was that *castra* were self-sustaining, whereas *castella* were not; a measure of precaution, perhaps, against revolt.

Returning to the sources, the earliest of these is Polybius. The Romanized Greek historian, who sought to explain the Romans' road to world domination, was intimately familiar with military matters. For a time he even served as military advisor to Scipio Aemilianus. In his *The Histories* he offers a detailed account of the manipular army marching camp. The second essential source is *De munitionibus castrorum* (transl. 'On camp fortifications'), a treatise on military camps written between the early 2nd and early 3rd century A.D., which was formerly ascribed to Hyginus Gromaticus,[12] though he is no longer attributed with its writing. In the present the script is commonly credited to *pseudo-Hyginus*, meaning the identity of the author is highly unclear. Nevertheless, I will henceforth refer to this author as

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[9] *OCD*^{3} (2003) 283f., s.v. Camps (J.B. Campbell).

[10] Wilson 1980, 4.

[11] There are examples of semi-permanent encampments from before this time. When the Republic was engaged in a protracted war, a legion would spend the winters quartered in some city, where they would be protected from the austerity of the weather. In less civilized lands, and also at other times when the circumstances so dictated, they would have to pass the winter in camp. Caesar, for instance, kept the field all year round, and spent several winters in the Gallic wilderness. The importance of proper winter quarters is a recurring theme in *De bello gallico*. Caesar, unfortunately, does not explain how winter camps were established, but it is distinctly implicit that they are different from summer camps, i.e. the camps described by Polybius and the other ancient authors.

[12] A *gromaticus* was a land surveyor.

Hyginus. In addition to Polybius and Hyginus, which provide us with rather exhaustive accounts on the nature of *castra*, there are quite a few ancient writers who mention camps in passing – Frontinus, Caesar, Vegetius, Tacitus, Josephus, Livius, Suetonius, and others. The following paragraphs represent my endeavor to collate and present the workings of military camps as described by the ancient writers mentioned above, as well as by modern authors.

The Roman fortress, or *castrum*, is an article of contradiction. Many authors emphasize the similarity of fortresses over the whole extent of the empire, while others yet maintain their difference, and assert that no one fort is the same. At first glance they certainly appear the same, and beyond a doubt, in terms of layout, as well as in numerous other aspects of organization, the legionary fortresses broadly followed the same arrangement all across the empire. They are similarly arrayed, they all contain, more or less, the same types of structures, they are similarly fortified, and so on.[13] They did however, according to the way of things, differ in the details.[14]

The fortresses, like so many ancient cities, follow something like a hippodamian plan. They are ordered in a quadrangular grid with rounded corners – a playing card shape, as some call it. There are few exceptions to this. The total area of the fortress was determined by how many troops it had to accommodate – generally one full legion, in some cases two. A fortress was enclosed by a wall (*vallum*). Apart from four sizable gatehouses (*porta*), towers were built at regular intervals along the wall. The main gate was called the *porta praetoria*, and as a rule faced the direction of greatest danger – the front. The other gates are called, respectively, the *porta principalis dextra*, the *porta principalis sinistra*, and the *porta decumana*. Directly beyond the wall one or more ditches (*fossa*) were dug. These sometimes served as moats. The space immediately within the wall was called the *intervallum*, and was essentially an empty surface between the wall itself and the buildings within. It served to extend the distance between the structures behind the wall and any potential incendiary enemy missiles. Livestock would regularly be kept in this area. Polybius records the width of this gap at about 60 meters, while Hyginus puts it to 20 meters.[15]

So far, the authors are fairly unanimous. The internal setup of a camp, however, differs to some extent between the various authors' descriptions. This is to be expected, as some of the accounts were written centuries apart. Rather, it is surprising that they do not differ more. The hyginian camp description is the most widely used, and corresponds fairly well to archaeological evidence. According to it, a fortress is internally divided into three sections by two parallel streets (see *Fig.* 1), the *via principalis* and the *via quintana*. The three parts were called the *latera praetorii*, the *praetentura*, and the r*etentura*.

The *retentura*, which was the rearward portion, contained – in the ideal plan – some of the *centuriae* (barracks), the *quaestorium* (a holding area of sorts), the *stabuli* (stables), and the *cellae* (general storehouses).

The *latera Praetorii* was the middle section, and appropriately contained the structures of central importance. It was here that the *Principia* (headquarters), the *praetorium* (the living quarters of the commanding officer), the *fabrica* (workshop), the *horrea* and *carnarea* (granary and meat storage,

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[13] "One simple plan of camp being adopted at all times and in all places", wrote Polybius in the 2nd century B.C. Polyb. 6.26.10.
[14] Wilson 1980, 4.
[15] Polyb.6.31; Hyginus account is taken from Smith 1875, 244-256; Wilson 1980, 10-21.

respectively), and the *valetudinarium* and *veterinarium* were situated. There was also the *auguratorium* (a place where sacrifices were made and auspices taken) and the *tribunal* (a raised platform used to pronounce juridical verdicts). In addition to all this it sometimes also held a portion of the barrack blocks at the far ends.[16]

The *praetentura* was the front part of the camp. It was effectively bisected by the *via praetoria*, a street that extended from the *porta praetoria* to the *Principia*. It housed a large part of the barrack blocks, the houses of the tribunes, and the *scholae* (a type of club building for the officers).[17]

Again, I would like to clarify that my description represents an ideal of sorts, an ideal to which there are numerous exceptions. All of these buildings were not present in all fortresses. Some only existed for periods. For instance, it appears that the *auguratorium* was incorporated into the *principia* in later fortresses. Evidence uncovered at the fortress of Lambaesis suggests that an annex of the *principia* served as *scholae*. In some fortresses buildings commonly located in the *latera praetorii* were placed in the *retentura* or the *praetentura*, or the other way around.[18]

[16] Ibid.
[17] Webster 1998, 183-207.
[18] Brewer 2000, 139-145.

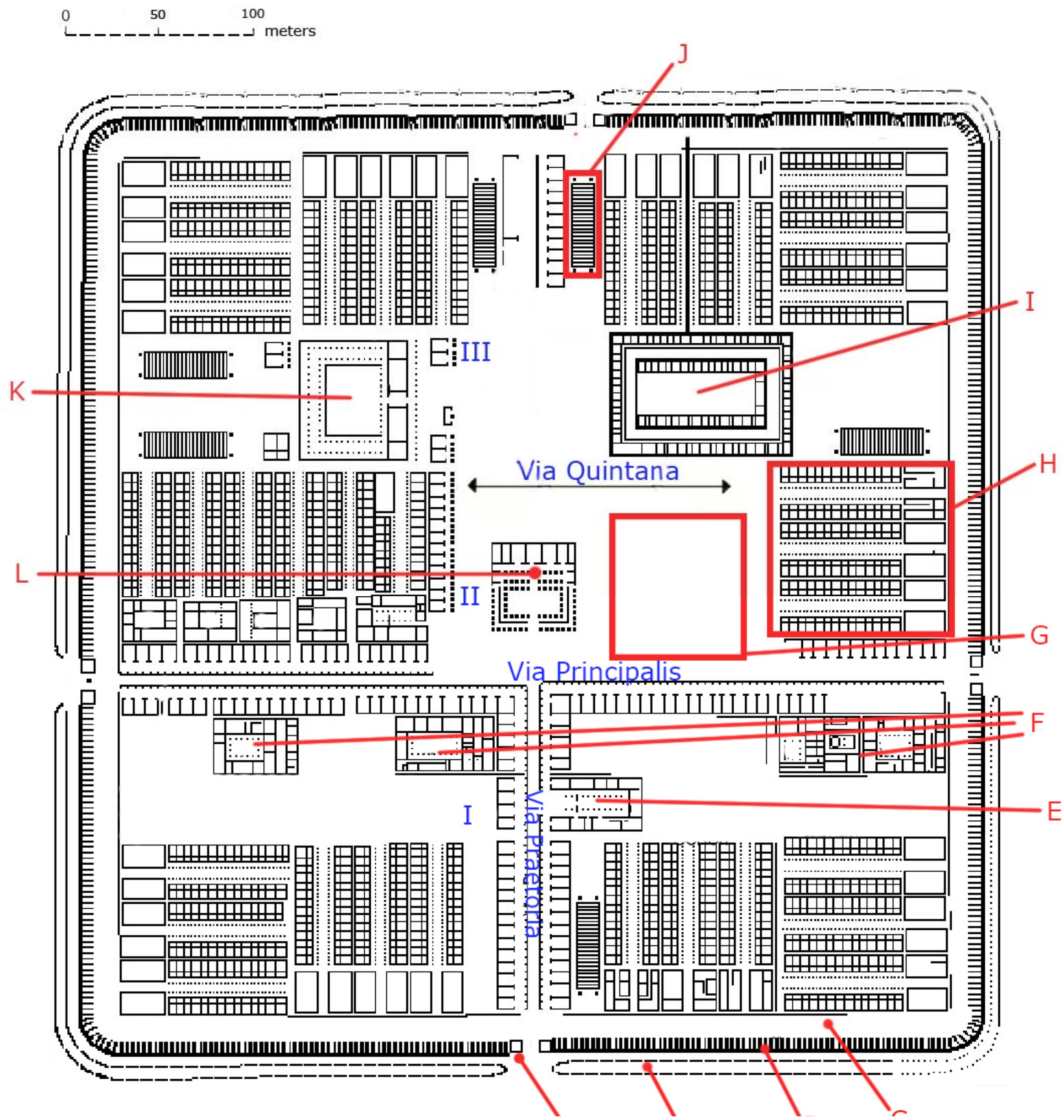

Figure 1: The Roman fortress. Image source: Shirley 2000.

Legend:

A. Fossa
B. Vallum
C. Intervallum
D. Porta Praetoria
E. Scholae
F. Domi tribunarium

G. Plot for the Praetorium
H. Barrack block
I. Valetudinarium
J. Horrea
K. Fabrica
L. Principia

I. Praetentura
II. Latera Praetorii
III. Retentura

The plan in *Fig.* 1 is modeled after the legionary fortress at Inchtuthil, Scotland. In all probability, this is the very same fortress that the geographer Ptolemy calls *Pinnata Castra* in his *Geographia*. The fortress was erected by none other than Gnaeus Julius Agricola during his campaign against the Caledonian tribes. Construction on the fortress began in A.D. 82, but was abandoned prior to completion in A.D. 86 due to the withdrawal of *legio II Adiutrix* from Britain. The legion in question was reassigned to assist in Emperor Domitian's Dacian wars.[19]

Using an unfinished and somewhat atypical fortress to exemplify the typical may appear peculiar, so I feel an explanation is in order. Firstly, although the Inchtuthil fortress was technically not fully completed, it really was just shy of completion; it lacked only one highly important structure, the *praetorium*, for which an area had clearly been staked out.[20] So, for all intents and purposes, one could regard it as a fully realized fortress. Secondly, the brief period of occupation makes *Pinnata Castra* unique in that it has a fully preserved, original plan. It is quite singular in that way. We are spared the interpretative problems that arise when studying sites with a long history of occupation, where much reconstruction work has been done, layout has seen some reorganization, etc.

That concludes my description of *castra*, or fortresses. The accounts of Polybius and pseudo-Hyginus both go into much fuller detail in their depiction of the camps, and there is a mass of knowledge in the writings of the other authors I mentioned above. Those details, however, are irrelevant to the purposes of this thesis.

Before I move on I shall also venture to describe, in broad outline, *castella*, the smaller fortifications. Although fairly similar to the fortresses, new revelations indicate that *castella* were considerably more differentiated from each other, so that it seems that established practice frequently had to give way to specific circumstances. This should not be taken to mean that there was no ideal, or conventional setup, for the forts very clearly follow a pattern; specifically, just like the fortresses, the pattern of the marching camp. They also had a quadrangular plan. They were divided into three sections. They generally contained the same buildings, although these were smaller, and fewer barrack blocks were present. These constructional conventions were, however, regularly made away with. We have, for example, the fort at Newstead, which is unique in that a wall was erected between the *retentura* and the *latera praetorii*. The prevalent theory states that this was done in order to separate a legionary detachment and an auxiliary unit which were both stationed there. There are plenty examples of forts with fewer than the full four gates. At many forts the *retentura* was completely excluded. The list of these peculiar aberrations can be made very long.[21]

[19] Shirley 2000, 5f.
[20] Ibid. 7, 143.
[21] Curle 1911, 33f.

2.3. History of research on military water supply

A great deal of scientific effort has been invested into research on the Romans and their relationship with water. And yet, despite all that scholarly labor, the supply of water at military sites seems to largely have been passed over, or at least not given due attention. To my knowledge, there exist no publications that focus on water in a military context. Nevertheless, the subject has been treated in some capacity, and what now follows is my attempt to consolidate the scattered and sporadic evidence into a single composition. The issue of water supply has clearly been reflected on in many excavation reports, but I will review the archaeological findings in a later chapter.

Trevor Hodge, writer of *Roman aqueducts & water supply*, the seminal modern work on Roman water supply, only mentions the word fort twice in his book, and provides no meaningful information on military water supply. We may pardon this omission on account of him having explicitly stated his purpose as desiring to discover how "aqueduct[s] really work".[22] He does not delve very deeply into other methods of supply, but focuses on the technical aspects of Roman waterworks, and primarily studies water provision in urban contexts. Still, I find the total omission of military water supply peculiar, given the importance of the legions and the fact that we know very well that aqueducts were utilized, to some extent, in military contexts.

To find some information we must instead turn to publications on Roman fortifications or the Roman army, which are plentiful. Considering the great number of books I have reviewed, it is curious how many neglect the matter of water. I am presenting the information contained in those works which I have amassed in chronological order.

John Collingwood Bruce's *Handbook to the Roman wall* was first published in 1863. It has been updated many times since, and is still regarded as the fundamental textbook on Hadrian's Wall. I am using the thirteenth edition, revised and extended by C.M. Daniels, and published in 1978. Unfortunately, it is unclear when and by whom the various sections of the book were written, so that I have no way of determining when various water-related data were infixed. The book early states that "In selecting a site for a fort, care was clearly taken that a copious supply of water should be available."[23] In a later passage Bruce asserts that military aqueducts were commonplace, yet it is interesting to note that he only records them at four – at Haltonchester fort, Chesters fort, Greatchesters fort, and Ravenglass fort – out of some seventy fortifications examined in the publication.[24]

In 1980 Roger Wilson, in his fortification manual *Roman Forts*, briefly touched on the subject: "…some forts were provided with more or less continuous water brought by open channels from nearby streams. That serving Greatchesters on Hadrian's Wall was six miles long, and similar aqueducts have been identified at other forts, or are attested by inscriptions." Those two sentences represent the full extent of Wilson's treatment of water supply. He provides no references at all for his statements.[25]

Three years later an additional publication also entitled *Roman Forts* was published by scholar Anne Johnson. She is considerably more informative on the issue of water than any earlier author whose works I have been able to procure. Johnson's book covers the German provinces as well as Britain.

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[22] Hodge 1992, vii.
[23] Bruce 1978, 30.
[24] Ibid. 85, 111f., 183, 287.
[25] Wilson 1980, 58.

"Wells have been found in most forts where the water table was reasonably close to the surface", Johnson writes in the opening paragraph of her passage on water supply.[26] The water table is essentially the groundwater level. Johnson also offers some details on the methods of well construction. She makes no statements as to the geographical situation of these supposedly ubiquitous well findings, although she does reference a German article and in subsequent paragraphs makes mention of a number of forts along the German *limes*, leading me to conclude that they are likely of German origin. If that is so, as this thesis does not focus on that particular frontier, these specific wells would have no direct relevance to my work, yet they will naturally be taken into consideration in some way. Apart from wells, Johnson also mentions aqueducts and pipelines – not specifying how they are different from each other – and interestingly, rainwater collection. Johnson provides us with the names of four forts in Britain – which the authors previously mentioned did not refer too – at which there is evidence of aqueducts: Segontium at modern-day Carnaerfon, Concangis at Chester-le-Street, and Arbeia at South Shields, and Classis Britannica at Dover. None of these are along Hadrian's Wall, which would explain their absence from Bruce's handbook. Johnson also concisely discusses the storage of water and expounds on cisterns and settling tanks.[27]

In 1990 publication *Rome's Desert Frontier*, Oxford professor of Classics and aerial photography specialist David Kennedy, and colleague Derrick Riley, offer some insight into water supply considerations in a desert environment. They devote an entire chapter – albeit a mere seven-page one – to the concerns of water supply. The geographical area covered in their study is primarily the Roman frontier in present-day Syria and Jordan, with some data on Roman Judea (i.e. present-day Israel). Their approach to the subject is more a study of traditional desert supply strategies than an archaeological investigation of Roman sites. Few of the examples they provide have actually been dated – which the authors' openly declare – raising the question of their representativeness for the Roman era on the one hand, and the Roman military on the other. The strategy of water supply, they tell us, is collection and storage in the course of the wet season, and conservation during the dry season. Collection was partly automated by constructing artificial channels to conduct water from seasonally abundant water points into various receptacles, such as large reservoirs, cisterns, etc. There are examples of comparatively large dam structures, and wells were prevalent in those areas where geological and hydrological conditions were favorable.[28]

Relatedly, in *The Limits of Empire*, Israeli scholar Benjamin Isaac seeks to relate the circumstances of Roman rule along the eastern fringes of the empire. Most of his evidence is from Israel, well behind the actual front. Like Kennedy and Riley, he also instructs the reader about various water collection strategies in arid environments, but in addition to this also provides us with a few examples of Roman fortifications in which these seem to have been adopted. His case studies are mostly from sites where the Roman army built over already existing structures – either military ones or, for instance, road stations – and made use of a water system already in place. In addition to these reutilized sites, Isaac also brings up forts which were built on virgin sites, with some examples of wells and very sizable cisterns. The main negatives of this book are the paucity of examined sites and the frequent

[26] Johnson 1983, 202f.
[27] Ibid. 204-210.
[28] Kennedy & Riley 1990, 70-77.

employment of analogies with better recorded periods – not only the Byzantine era, but also with the Crusader, and Islamic periods, and others.[29]

Paul Bidwell, currently the head of Archaeology at Tyne and Wear Museums, and a man of extensive experience in excavating forts and fortresses, tersely negotiates the issue. Like so many Romano-British archaeologists before him, Bidwell appears supremely confident that aqueducts were a matter-of-course. For a man purposing to write a comprehensive handbook to Roman forts in Britain – entitled just that, *Roman Forts in Britain* — Bidwell strangely disregards the seeming dearth of evidence, and by conducting the question of water in a single sentence, after having stressed the importance of supply, and in fact devoting an entire chapter to it, he leaves the reader with the impression that aqueducts were commonplace.[30]

In *The Roman Shore Forts*, Andrew Person describes a network of fortifications along the southern coast of Britain. Constructed sometime in the 3rd century, their purpose remains a subject of contention among scholars. A multitude of hypotheses have been put forth; the traditional theory is that they were a measure against rampant barbarian piracy, but that notion has been challenged in recent years. Alternative reasons offered for their existence are a changing military situation in Britain, and also the idea that they possibly only served as ports, and were not in fact military in nature. That sentiment however, is widely rejected. Whatever their purpose, archaeologists have discovered inside a few of them a feature seemingly absent from forts in other parts of Britain, namely wells. [31]

The most recent – to my knowledge – written work on military water provision was published in academic journal *Britannica* in 2008, and deals with the water situation at Housesteads fort on Hadrian's Wall. Author Peter Beaumont makes a case for rainfall harvesting being the primary means of water acquisition. Housesteads fort is situated on a high ridge, precluding supply by aqueduct, which the author calls the conventional method. Wells would also have been unlikely, given the altitude. Neither are there any significant water points within a reasonable vicinity of the fort. The topographical situation therefore begs the question of which additional means of provision might have been available. Beaumont suggests that rainwater may be the answer. By studying meteorological records on precipitation, and looking at the total roof area of the buildings found within the fort he calculates that rainwater collection alone could have provided water for about 800 soldiers. Rainwater, he comments, "is high-quality water which could be used for a variety of purposes, such as cleaning, food preparation, washing, and perhaps even drinking." The author supposes the existence of fairly large collection tanks, which have not been found, and without which the whole concept would have failed. [32]

That concludes my survey of the literature. In closing I would like to sum up the information and make a few remarks. Firstly, the publications here introduced are not the only ones to mention, in some way, water supply in a military context. Far from it. What I have attempted to do is to present particularly important published material, from the more eminent scholars; their views and the facts they provide us with are echoed in a surfeit of publications by lesser known authors. I have also brought up less prevalent ideas and lesser known facts which I find noteworthy. Secondly, I must express my wonder at how neglected the issue of water provision is in general. There are many texts on the supply of the

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[29] Isaac 1990, 189f.
[30] Bidwell 1997, 31, 84f.
[31] Pearson 2002, 38, 145, 153, 159.
[32] Beaumont 2008, 59-84.

legions, but they all omit the supply of water. Water is rightly assumed to have been acquired locally. Transportation of water over long distances seems highly unlikely. Yet, subscribing to that assumption does not mean that one has answered the question of how exactly this was done. I am frankly astounded at how few have even attempted to do so. Thirdly, it is peculiar how many British archaeologists take aqueducts for granted. The evidence I am privy to, at least, does not indicate this. Anne Johnson does bring up wells in her publication, but as I have previously said, these actually seem to be from installations along the German frontier. A few of Pearson's shore forts do contain wells, but they are neither standard nor situated along the frontier. The want of conclusive findings to help us reconstruct the military water supply of Roman Britain seems to have driven many native scholars to rather spurious arguments regarding aqueducts. In a later chapter their confident assertions will be examined against the background of archaeological evidence.

2.4. Known methods of water supply

Looking only inward is a common mistake in any branch of learning, and is apt to make us blind to obvious facts. Being mindful of the full range of methods available to Romans for the supply of water may help us to find new and better answers. Before moving on to the analysis it might therefore be in our interest to study publications dealing with water organization in general – as opposed to the military context – in the ancient world. To this end I have consulted *Handbook of Ancient Water Technology*, a multi-authored work edited by Örjan Wikander, among whose contributors is Trevor Hodge.

The handbook deals with water management in an area from Mesopotamia to the Atlantic Ocean, with a distinct focus on classical antiquity – for reasons which are perhaps evident. It summarizes the extent of the knowledge on water organization – historical research, archaeological discoveries, and theoretical debate – of the time (it was published in 2000).

The methods of water supply are listed as follows:

A. Collection of water

That is to say that water was manually collected from a natural source – a spring, river, lake, etc. – into some form of container, and carried to where it was needed.

Another form of collection is, according to Hodge, done by constructing artificial cisterns – tanks constructed from watertight material – to collect it. The cistern is fed by rainwater, either the run-off from the roofs of buildings or straight from the ground (this is what Beaumont called rainfall harvesting). Cisterns are generally set in the ground, sometimes going down to three meters below surface-level. They vary considerably in size and shape. They are often covered too restrict evaporation and contamination. A flight of steps is often present along one or more sides, allowing one to descend to the bottom and collect water when levels were low.[33]

B. Wells

The handbook refers to wells as a *prime resource* in antiquity. A well is a vertical shaft sunk to tap the groundwater. It is square or round and at times lined with planks or masonry to support the walls and prevent them from collapsing. Wells can only be sunk in certain places. The water table cannot be too far down. There must be no contaminants in the soil, etc. Suitable spots are

[33] Hodge 2000, 21-28.

easier to find in temperate lands than in arid regions. Wells can dry out, in which case new wells must be sunk, or other means of supply be found. The level of the water table can sometimes be erratic. The handbook recounts the situation in Athens, where wells were utilized down to the 4th century B.C., when the groundwater level descended out of reach. The citizens instead had to resort to cisterns. In the 3rd century the water table rose again, prompting the Athenians to switch back. Wells, it seems, were much preferable to cisterns.[34]

C. Qanats

A *qanat*, or *foggara*, is a series of vertical shafts connecting with a tunnel burrowed at a slight, upward gradient into a hillside. The incline of the tunnel cannot be steeper than the hillside slope. The initial shaft(s) had to pierce the water table. This ensured that water drained into the tunnel and flowed outwards. See *Fig*. 2 for an illustration.

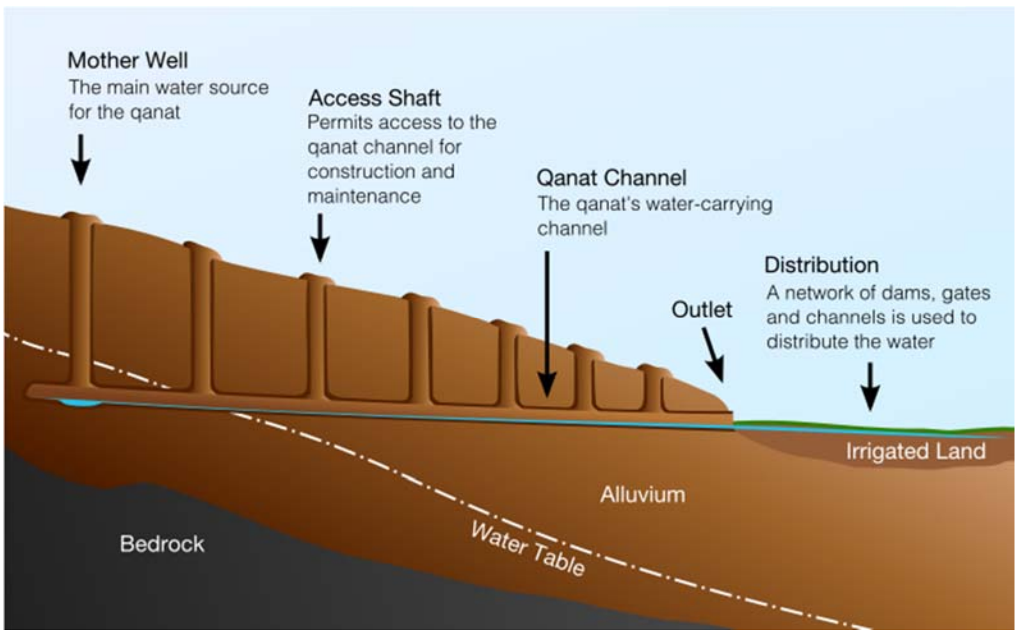

Figure 2: A Qanat. Image courtesy of Wikimedia Commons.

The tunnel walls would gradually erode and thus needed occasional maintenance. This solution originated in the Near East, and it is there, as well as on the African continent, where they were most prevalent.[35]

D. Aqueducts

Aqueducts come in many shapes. Not only the grand, vaulted bridgeworks we are all so familiar with, but humbler structures as well, often subterranean conduits. An aqueduct is, simply stated, a passage through which water courses. They come in more or less sophisticated forms – from simple terracotta pipelines running short distances and only depending on the downward gradient, to major engineering works spanning tens of kilometers, involving gigantic bridges, subterranean sections, siphons, settling tanks, and so forth. These pipelines can be constructed

[34] Ibid. 29-38.
[35] Ibid. 35-38.

> in many materials: masonry, terracotta, wood in the form of hollowed-out tree trunks, and can even be cut into rock. The earliest evidence of aqueducts comes from the Near East, where they were likely developed as a response to growing urban populations.[36] Today they are often regarded as a defining trait of the Roman civilization, mainly due to the monumental nature of the Roman variety of civic aqueducts.

These four methods represent the range of water supply methods available to the ancients.

2.5. Water requirements

Water is of singular importance to all living creatures. It is the largest component of the human body, commonly amounting to 60% of body mass. Even slight disturbances in water balance can result in substantial deterioration of strength and endurance.[37] Adequate hydration can be the difference between success and failure in any undertaking. In the case of a soldier, it can mean the difference between life and death. The statement of these facts serves to illustrate the significance of water to man in general, and fighting men in particular. It must be considered the most basic need of soldiers in the field.

This section represents my attempt to establish how much water was actually required to satisfy the needs of Roman forts and fortresses. I believe that some conception of the sheer volume that was needed is necessary for one to be able to explore and reflect on the means of supply. This is no easy task. There are many elements to factor into such a computation. Water is required for both men and horses – as well as any other animals kept on site. It is needed for drinking and for cooking food. It is needed for sanitation, both personal hygiene and general cleansing. It is needed for industry. It is likely also needed for a great many other things.

Many calculations have been attempted. Jonathan Roth, in *The Logistics of The Roman Army at War*, puts it to no lower than 2 liters per man, per day, for minimum operational efficiency.[38] The estimates can vary considerably, however. "Soldiers require for all purposes, per man per day, 15 gallons", wrote John Hurst in 1905. 15 gallons amounts to 68 liters, a hefty quantity. Cavalry horses, he continues, require eight gallons (36 liters), as do oxen, while mules and donkeys require only six (27 liters). Hurst wrote about late 19th century soldiers, though, and he must have made considerable allowance for hygiene, as he shortly afterwards mentions that a shower requires 3-6 gallons, and a "water closet flushing" requires 2-3 gallons.[39] That would account for the prodigious volume of 15 gallons per man per day. The Romans had no such amenities (i.e. water closets and showers), although bath houses were not uncommon at military installations. An attempt at calculating the water requisites of a Roman military bath house would be wildly conjectural, and I will therefore focus only on the needs of the soldiers.

In a monograph on soldier hydration published by the U.S. Army affiliated Borden Institute, the estimates are given as follows.

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[36] Ibid. 39-65.
[37] Montain & Ely 2010, 5-8.
[38] Roth 1999, 35-37.
[39] Hurst 1905, 77f.

> In temperate environments, the daily fluid requirements of soldiers typically range from 2 to 5 L/d, depending on the intensity and duration of physical activities. However, as air temperature rises, daily fluid requirements can increase substantially. In extremely hot conditions, water requirements for soldiers performing primarily sedentary activities can increase from approximately 2 to 3 L/d to 5 L/d. Water requirements for soldiers performing heavy work or long hours of moderate work (4,200–5,300 kcal/d) can increase from 4 to 6 L/d in temperate environments and from 8 to 10 L/d in extremely hot environments.[40]

This is contemporary medical data, and must be considered both accurate and reliable. The absolute minimum for operational capacity corresponds to Roth's quantity of 2 liters (an oft-cited number in theoretical discussions). It is, however, only valid for soldiers performing low-intensity tasks in a temperate setting.[41] There is a lot of variance depending on environment, conditions, type of work, and so on. That said, garrisoned soldiers were, in all likelihood, very seldom involved in heavy work. Leading Roman army expert Adrian Goldsworthy writes that most of a soldier's life was spent in barracks, doing light duties.[42] There was some exercise, patrols, etc., but the life of a soldier was not particularly taxing in times of peace. The conservative estimates of most Roman army scholars are therefore probably not grossly incorrect.

By way of conclusion I would just like to state that while the Romans certainly did not possess the scientific data which I here present, and could not specifically quantify and explain the details of hydration, they absolutely understood the significance of water, and the variance in requirements depending on situation. This had surely been demonstrated over many centuries of conflict. These figures say little more than what reason and sensible experience plainly showed the ancients.

Using these figures we can calculate that a legionary fortress in Great Britain would require around 10.000 L/d, but possibly as much as 30.000 L/d, only for drinking water for the soldiers. The quantity of drinking water required for a fortress along the eastern frontier ranges from 25.000 L/d to 50.000 L/d.

The requirements of a fort would depend on the size of its garrison. Usually, they were manned by a single cohort, occasionally by two.[43] In Roman Britain a single-cohort fort would require between 1.000 L/d and, in rare cases, 3.000 L/d. A fort garrisoned by two cohorts would require between 2.000 L/d and 6.000 L/d. In Syria and Jordan, a single-cohort fort would need 2.500 L/d to 5.000 L/d., a double-cohort one would require 5.000 L/d to 10.000 L/d.

The size of the legions varied, to some degree, over time, but throughout the Principate they remained at ca. 5000. These calculations assume that legions as well as auxiliary units were at full theoretical strength, a predication that has certainly been called into question.

[40] Montain & Ely 2010, 23f.
[41] The subsistence minimum is considerably lower, but the army would hardly economize on water except in case of disaster. Food rations are mentioned in the sources, but there are no indications of water rationing outside of emergency situations, e.g. in case of siege or when marching through arid regions.
[42] Goldsworthy 2003, 82.
[43] Wilson 1980, 5-7.

3. Analysis

The analysis consists of a survey of my research into the ancient sources, and an exposition, in table form, of my investigation into the archaeological record associated with water supply at military stations.

3.1. The ancient sources

The primary sources are lamentably silent on the subject of military water provision, and fretfully terse whenever they do bring it up. This chapter amounts to a series of summaries on whatever revelations might be gleaned from each of the ancient authors, and a select sampling of quotations. The authors are arranged according to the measure of their contribution to the subject, as well as their relation to each other, opening with the military writers.

We begin with Publius Flavius Vegetius Renatus, commonly referred to as Vegetius, a late 4th century scribe who is likely the most frequently quoted Roman writer on all things military. He never dwells on the water supply, but mentions it in passing on roughly a dozen occasions. On selecting the site of a camp, Vegetius writes that:

> Its situation should be strong by nature, and there should be plenty of wood, forage and water.[44]

In a later chapter he emphasizes the duty of a commander to ensure the supply of water, noting that

> It is particularly incumbent upon the general to…secure water.[45]

In a section discussing the preservation of health among the men, he writes

> The next article is of the greatest importance: the means of preserving the health of the troops. This depends on the choice of situation and water…[46]

Vegetius often repeats himself, frequently reiterating the importance of supply.

> "Besides, scarcity of provisions, which is to be carefully guarded against in all expeditions, soon ruins such large armies where the consumption is so prodigious, that notwithstanding the greatest care in filling the magazines they must begin to fail in a short time. And sometimes they unavoidably will be distressed for want of water.
> […]
> Famine makes greater havoc in an army than the enemy, and is more terrible than the sword. Time and opportunity may help to retrieve other misfortunes, but where forage and provisions have not been carefully provided, the evil is without remedy."[47]

Water is undoubtedly one of the 'provisions' he refers to. As to exactly how a camp was furnished with water, Vegetius writes that "perpetual springs within the walls are of the utmost advantage…where

[44] Veg. *Mil*. 1.20.
[45] Ibid. 3.7.
[46] Ibid. 3.2.
[47] Ibid. 3.1., 3.3.

nature has denied this convenience, wells must be sunk."[48] In another paragraph he states that "sinking wells and bringing water into the camp" was the duty of the *praefect* of the camp.[49]

Vegetius imparts a general sense that the importance of water provision was well understood, and its implementation a non-issue. He tells us that water was either gathered in the landscape and then carried into camp, or drawn from wells or springs within the confines of the camp. There are no allusions to aqueducts, or any advanced systems of water supply. This should occasion little surprise, as the army Vegetius describes is an army on the move, an army invested in operations, not a stationary frontier defense force. The era in which Vegetius wrote was a time of great upheaval. The frontiers were being pushed back. The stability of the preceding centuries, which had enabled the development, expansion, and permanentization of fortifications, was shattered. Army fortifications had reverted to a state of temporary or semi-permanent encampments. Aqueducts were simply not feasible in such a context.

In the second century B.C. Polybius wrote more or less the same thing. On the choice of ground, he explains that it:

> …should be convenient for procuring wood, water, and forage, and which the army might enter and quit without danger of surprise.[50]

He makes additional statements to that effect, and like Vegetius, frequently stresses the importance of assured and ample supplies in general. We are given no clear information on how water was provided, but the implication is that it was gathered.

As for the supply of water in the east, there is but one Roman source — Josephus. Fortunately, his *Bellum Iudaicum* (ca. 75 A.D.) is very rewarding, speaking of water both often and at length. In describing the Galilees, Samaria, and Judea, he almost exclusively talks of the water conditions in these regions, testifying to the centrality of water to life and thought in the east.[51]

According to Josephus, one of the principal methods of water supply was rainwater collection. In his description of the fortified city of Jerusalem, he tells us that it had among its other defenses "cisterns to receive rain-water."[52] When Herod built his citadel at Masada, Josephus states that,

> He [Herod] also made a great many reservoirs for the reception of water, that there might be plenty of it ready for all uses…

And that he,

> …had cut many and great pits, as reservoirs for water, out of the rocks, at every one of the places that were inhabited, both above and round about the palace, and before the wall; and by this contrivance he [Herod] endeavored to have water for several uses, as if there had been fountains there.[53]

[48] Ibid. 4.10.
[49] Ibid. 2.5.
[50] Polyb. 6.21.
[51] Joseph. *BJ* 2.3.1-5.
[52] Ibid. 5.4.3.
[53] Ibid. 7.6.2.

In his account of the Roman siege of mount Tabor, Josephus writes that the "inhabitants only made use of rain water".[54] *Only rainwater*, he writes. I would like to strongly emphasize this point. The same is said about the people of Jotapata, a rather large city in the Lower Galilee. Yet, exclusively relying on rainwater was evidently a dangerous gamble. The defenders of Mount Tabor learned this lesson, "for their water failed them, and so they delivered up the mountain and themselves".[55] Similarly, the citizens of Jotapata also experienced this severe lecture.

> Now the besieged had plenty of corn within the city, and indeed of all necessaries, but they wanted water, because there was no fountain in the city, the people being there usually satisfied with rain water; yet is it a rare thing in that country to have rain in summer, and at this season, during the siege, they were in great distress for some contrivance to satisfy their thirst; and they were very sad at this time particularly, as if they were already in want of water entirely, for Josephus seeing that the city abounded with other necessaries, and that the men were of good courage, and being desirous to protract the siege to the Romans longer than they expected, ordered their drink to be given them by measure; but this scanty distribution of water by measure was deemed by them as a thing more hard upon them than the want of it; and their not being able to drink as much as they would made them more desirous of drinking than they otherwise had been; nay, they were as much disheartened hereby as if they were come to the last degree of thirst. Nor were the Romans unacquainted with the state they were in, for when they stood over against them, beyond the wall, they could see them running together, and taking their water by measure, which made them throw their javelins thither the place being within their reach, and kill a great many of them.
>
> Hereupon Vespasian hoped that their receptacles of water would in no long time be emptied, and that they would be forced to deliver up the city to him; but Josephus being minded to break such his hope, gave command that they should wet a great many of their clothes, and hang them out about the battlements, till the entire wall was of a sudden all wet with the running down of the water. At this sight the Romans were discouraged, and under consternation, when they saw them able to throw away in sport so much water, when they supposed them not to have enough to drink themselves. This made the Roman general despair of taking the city by their want of necessaries, and to betake himself again to arms, and to try to force them to surrender, which was what the Jews greatly desired; for as they despaired of either themselves or their city being able to escape, they preferred a death in battle before one by hunger and thirst.[56]

King Herod narrowly escaped the same disaster during the first siege of Masada by king Antigonus II Mattathias.

> Now during this time Antigonus besieged those that were in Masada, who had all other necessaries in sufficient quantity, but were in want of water; on which account Joseph, Herod's brother, was disposed to run away to the Arabians, with two hundred of his own friends, because he had heard that Malichus repented of his offenses with regard to Herod; and he had been so quick as to have been gone out of the fortress already, unless, on that very night when he was going away, there had fallen a great deal of rain, insomuch that his reservoirs were full of water.[57]

In spite of all the king's precautions, his great many reservoirs, Masada very nearly succumbed to scarcity of water. Rainwater evidently was not enough, at least not in all places, or in all the seasons of

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[54] Ibid. 4.1.8.
[55] Ibid.
[56] Ibid. 2.7.12-13.
[57] Ibid. 1.15.1.

the year. It had to be supplemented through other means. And in fact, Josephus also writes of Masada, in times of peace, that "he [Herod] brought a mighty quantity of water from a great distance, and at vast charges".[58] The conveyance of water over long distances is mentioned several times. When the Jewish historian recounts the second siege of Masada – the Roman siege – he comments that it was:

> …a place of difficulty for getting plenty of provisions; for it was not only food that was to be brought from a great distance [to the army], and this with a great deal of pain to those Jews who were appointed for that purpose, but water was also to be brought to the camp, because the place afforded no fountain that was near it.[59]

In 69 A.D. Titus marched his army from Alexandria to Judea, and at one point along this journey they encamped at a place called Ostracine. Josephus claims that "this station had no water, but the people of the country make use of water brought from other places".[60]

In addition to rainwater, and the occasionally necessary long-distance freight of water, Josephus often speaks of springs – or fountains, as they are often rendered in my translation – describing them as the purest and most ideal sources of water. Markedly absent from his text are draw wells. Not a single time are they mentioned.

Caesar, in *De bello gallico* and *De bello civili*, as well as in *De bello Africo*, *De bello Hispaniensi*, and *De bello Alexandrino* – the latter two presently being generally attributed to one of Caesar's lieutenants, rather than the man himself – often laments the difficulty of obtaining water. Water was a constant consideration. The lack of it often impeded the great general. It forced him to abandon sieges, refrain from battle, take detours, etc.[61] He himself also employed water in his stratagems, harassing the enemy by cutting off their supply.[62]

On the acquisition of water, Caesar often speaks of sending troops to 'fetch' it.[63] In *De bello Africano*, he writes that "water in fact was in short supply and had to be carried a long distance."[64] At times during the Civil war it was even shipped across the sea.[65] Wells are mentioned but once throughout the Caesarian texts. Having pitched camp on a plain near a place in North Africa called Uzitta, and being low on water, Caesar found that "it was a low‐lying tract, and quite a few wells could be sunk in it".[66] He clearly relied mainly on collecting it, though.

Vitruvius – or Marcus Vitruvius Pollio – is a veritable mine of information on water. While he does not specifically treat the military side of things – with one exception— he offers plenty of general advice on water organization. Vitruvius devotes the entirety of the eighth book of his *De architectura* on how to distinguish between good (i.e. clean) and bad water. He offers instructions on where to find clean water,

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[58] Ibid. 1.21.10.
[59] Ibid. 7.8.3.
[60] Ibid. 4.11.15.
[61] *Caes. B.Afr.* 69, 76, 79.
[62] *Caes. B.Civ.* 49; *Caes.B.Gall.* 7.36, 8.40.
[63] *Caes. B.Afr. 7, 24; Caes.B.Civ.* 66, 81.
[64] *Caes. B.Afr. 51.*
[65] *Caes. B.Civ.* 100.
[66] *Caes. B.Afr. 51.*

where to dig wells, which sources of water are the most reliable.[67] He even comments on how a city under 'blockade' might acquire water, writing that in such a case it is:

> …obtained either by digging new wells, or by collecting it from the roofs of buildings.[68]

Where circumstances are unconducive to the digging of wells, he once again advises rainwater collection.

> If the soil be hard, and there be no veins of water found at the bottom, we must then have recourse to cisterns made of cement, in which water is collected from roofs and other high places.[69]

Vitruvius if often quoted in discussions on aqueducts, but he clearly recognized that they were not suitable in every situation. He does not say how the army supplied its installations with water, but he makes it clear that the Romans possessed considerable understanding of water. They knew many ways of finding water, were fully aware of the importance of uncontaminated water, and carefully chose their sources of supply. A recurring expression among the ancient scribes is 'bad waters'. One repeatedly comes across it in the sources. Vitruvius mentions it in many places. Vegetius writes, as quoted above, that the health of an army depends on the choice of water. He also warns that "an army should not encamp in summer near bad waters", because "bad water is a kind of poison and the cause of epidemic distempers".[70] Dio Cassius, writing in the 3rd century A.D., informs us that Septimius Severus' army was "badly affected by the waters" in Britain.[71] This is indicative of a careful awareness of the bacterial dangers associated with water. The germ theory of disease was certainly not known in the ancient world, but there were indications. The Greeks subscribed to the miasmatic theory, believing that diseases could be transmitted through the air. Marcus Varro in the first century B.C. cautioned against building cities in the vicinity of standing water and swamps:

> …because there are bred there certain minute creatures which cannot be seen by the eyes, which float in the air and enter the body through the mouth and nose and there cause serious disease.[72]

They also knew how to purify contaminated water. Pliny writes that "bad water is purified if boiled down to one half".[73] Whether it was common practice for soldiers in the field to boil water from dubious sources, who can say?

That brings my examination of the sources to an end. Now, to sum it all up: Vegetius indicates that gathering water from nearby sources was common, but so were wells. Ideally one would pitch camp around a spring. Polybius only mentions foraging for water. Caesar, as it is, evidently obtained water primarily by having his troops forage for it. It was carried to camp. It was occasionally supplied over exceptionally long distances, and, episodically, wells were sunk. Josephus tells us that rainwater harvesting was a common water strategy in the east, but provides many examples of its unfeasibility as an exclusive water source. He also informs us that collecting water from near or far-away rivers and

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[67] Vitr. *De Arch.* 8.1.6., 8.6.12.
[68] Vitr. *De Arch.* 5.9.12.
[69] Vitr. *De Arch.* 8.6.14.
[70] Veg. *Mil.* 3.2., 3.7.
[71] Dio Cass. 77.13.2.
[72] Varro. *Rust*. 1.12.2.
[73] Plin. *HN* 31.23.40.

springs was common. Vitruvius addresses all of the methods, as well as aqueducts, and expounds on the nature of good and bad water, and where it is found.

As a closing statement I would just like to address the problems with the sources, the main one being that none of them are from a time when the empire enjoyed prolonged stability, and fixed, near-permanent borders – the period which the archaeology generally reflects.[74] They are either from an earlier or a later era.[75] They generally describe an army in the field. A mobile army, not one stationed in permanent fortifications, and engaged in frontier defense. This is likely why aqueducts are wholly absent from the accounts of the military authors. I previously discussed the problem as regards Vegetius, but really the same goes for all the military authors: Polybius, Caesar, and Josephus. With Josephus, of course, there is the added issue of him mainly describing the water strategies of the local, Jewish population. Vitruvius predominantly discusses water in a civilian context, and so on. All this is not to say that these ancient authors cannot be helpful to my investigation, but it does mean that they cannot be depended upon absolutely.

Finally, a short disclaimer is in order. I have, naturally, not been able to study each and every one of the ancient sources. I examined those that I regarded as the most pertinent, those which I thought would prove the most fruitful. In this, I may have overlooked some important author, or text, or piece of information. If so, that is regrettable. Neither have I included all of the authors which I actually did study. Varro, for instance, also wrote about wells, and water collection, and rainwater harvesting, etc. So did Pliny. At some point, though, repeating information already referenced in other sources ceases to strengthen one's case, and consequently, certain sources have been excluded.

[74] From roughly the mid-first to late second century A.D.

[75] Or in the case of Josephus, relatively contemporary, but nevertheless only describing an army in the field.

3.2. The archaeology of water provision

3.2.1. Introduction

The next fifteen or so pages comprise my review of available data on five different water-related factors: The presence of an aqueduct, the presence of wells, the presence equipment associated with water provision (cisterns, tanks, internal distribution systems in the form of pipes, etc.), the proximity to the nearest water point, and the topographical elevation of the installation.

The first two elements are very straightforward. The occurrence of the third may implicate the past existence of some system that enabled an abundant inflow and/or collection of water. The values of the first three attributes are given as ‘yes’, ‘no’, and ‘maybe’, with the latter signifying that there are some indications of the structure in question, but that the finds are not conclusive.

The fourth attribute may suggest how important water points were in the selection sites for military use. The source of information for data on proximity to water points is either from excavation reports, articles or the cultural preservation agencies in Great Britain (English Heritage, The Royal Commission on The Ancient and Historical Monuments in Wales, and The Royal Commission on The Ancient and Historical Monuments in Scotland). The caveat here is that nature changes, as all things do. The courses of rivers and streams may have been altered. Lakes and springs may have dried up, etc. In addition to natural transformations, the cartographers of the British Ordnance Survey may have overlooked some smaller water points. I am assuming that none of this is the case. I have rounded the distance figures up to the nearest tenth, and noted the type of water point.

The fifth data element gives us some hint of the potentiality and practicability of installing an aqueduct at a site. The elevation in question is not the altitude above sea level, but the elevation in relation to the surrounding landscape. Site elevation is determined by studying altitude maps from Google Inc.; Google uses many providers, and do not source their data, but the resolution definitely does not fall short of three arc-seconds (~90m)[76] in Britain, and is likely considerably more accurate, with some areas even using LiDAR information (<1m accuracy).[77] Any of these alternatives would be adequate for a study such as this. I have examined areas within a 5 kilometer radius around the sites in question. The values are as follows:

1. On level: Meaning that a site is on a flat piece land, and accordingly on level with the surrounding landscape.
2. Low: Meaning that a site is situated at a low point in uneven territory.
3. Middle: Meaning that a site occupies a middle position in an uneven landscape; there are both higher and lower positions in the immediate vicinity.
4. High: Meaning that a site is seated at the very top of a rolling landscape. It overlooks large stretches of land.

[76] NASA’s Shuttle Radar Topograhy Mission (SRTM) provides free-of-charge elevation data for public use at a minimum resolution of three arc-seconds for the whole world (http://www2.jpl.nasa.gov/srtm/p_status.htm).
[77] Tests by private individuals suggest the accuracy is considerably better than 1/3 arcseconds (10m) for the UK. A study at the Sudan University of Science and Technology concluded that the height accuracy of Googles data averages 1.73 meters. Given that this is the situation in the Sudan, we should be able to firmly conclude that the precision of British data is at least as good. Mohamed et al. 2013, 9.

5. Low-lying hill: Meaning that a site occupies a hilltop, a lofty position with regards to its immediate surroundings, but is still very low-lying in relation to the general landscape.

3.2.2. Roman Britain

I should like to begin with a few qualifications. The issue of water supply has certainly been reflected on in many excavation reports, journal articles, and publications of all kinds. Now, Britain has an exceptionally long history of archaeological excavation, with Roman military sites holding a privileged place in that history. I commented earlier on the immense number of identified sites – more than four hundred. While not all of these have been excavated, that number is still altogether too great for me to include all of them in this thesis. That said, my study covers a significant share of them. Beginning with a list that Roger Wilson compiled for his 1980 publication on forts in Britain, and adding to that list as best I could, I ultimately had to reconcile myself to the impracticability of attempting to include every known site and proceeding from what I had. In the end I landed at 153 sites in Britain, whereof 15 are fortresses and 137 are forts. As stated, there is some difference of opinion concerning the distinction between fort and fortress (I discussed the dispute regarding the existence of the vexillation fortress in the definition of terms section), with me keeping with Graham Webster's interpretation.[78]

Secondly, while Britain accommodates some exceptionally well-preserved military works, with many features still visible above ground level, the material record is poorly preserved in the majority of cases – this is in part counterbalanced by meticulous field work. A contributing factor is that sites have been quarried away by the local populace for reuse in new construction. The gradual expansion and intensification of agriculture and the spread of cities are other destructive forces. The progression of these destructive events has accelerated greatly in the modern era, and it appears that many structural remains have disappeared only in the comparatively recent past. There is, for example, the Roman aqueduct mentioned by 18th and 19th century authors conveying water to the fort at Haltonchesters. The area has been intensely cultivated in the last couple of centuries, and today there are no visible remains. If not for the early origins of Romano-British archaeology, my study certainly would have been poorer.

The data is grouped according to fortresses and forts. The location, in the form of closest settlement and county, is given for each fortification. The ancient name, if known, is also registered. In those cases where there have been successive installations, either overlapping each other on the same spot or in very close vicinity to each other, they have been included in the same entry.

[78] Brewer 2000, 60-63.

Table 1. Castra in Roman Britain

Location	Ancient name	Aqueduct	Wells	Cisterns	Proximity to water	Topog. elev.
Carlaeon, Gwent[79]	*Isca Augusta/Silurum*	Maybe	Yes	No	~200m, river	Low
Carpow, Fife[80]	*Horrea Classis*	Maybe	No	Yes	~50m, river	Low
Chester, Cheshire[81]	*Deva Victrix*	Yes	No	No	~200m, river	Low
Colchester, Essex[82]	*Camulodunum*	Yes	No	No	~600m, river	Low
Exeter, Devon[83]	*Isca Dumnoniorum*	Yes	No	No	~400m, river	Middle
Gloucester, Gloucestershire[84]	*Glevum*	Yes	No	No	~500m, brook	Low
Inchtuthil, Tayside[85]	*Pinnata Castra*	No	No	Yes	~20m, river	Middle
Kinvaston, Staffordshire[86]		No	No	No	~50m, brook	Low
Leicester, Leicestershire[87]	*Ratae Coritanorum*	Yes	No	No	No data	Low
Leighton, Shropshire		No	No	No	~10m, brook	Low
Lincoln, Lincolnshire[88]	*Lindum*	Yes	Yes	No	~500m, river	On level
Longthorpe, Cambridgeshire[89]		No	Yes	Yes	~100m, river	Low
Rossington Bridge, South Yorkshire[90]		Maybe	No	No	~200m, river	Low
Usk, Gwent[91]	*Burrium*	No	Yes	Yes	~150m, river	Low
Wroxeter, Shropshire[92]	*Viroconium Cornoviorum*	Yes	No	No	~250m, river	Low

[79] Nash-Williams 1942, 22; Zienkiewicz 1986, 344. An 18th century antiquarian interpreted a finding as part of an aqueduct.
[80] Birley 1965, 187, 191, 196.
[81] Stephens, 1986, 59–61,
[82] Crummy 1977, 100.
[83] Webster 1988, 91-119.
[84] Webster 1988, 48-73.
[85] Shirley 2000, 117f.
[86] St. Joseph 1953, 83f; St. Joseph 1958, 94f; Welfare & Swan 1995, 175-180.
[87] Wacher 1974, 126-132, 319f.
[88] Thompson1955, 106; Pastscape, Lindum Colonia (http://www.pastscape.org/hob.aspx?hob_id=326486).
[89] Frere et al. 1974, 24, 28f.
[90] Pastscape, Monument no. 1439042 (http://www.pastscape.org.uk/hob.aspx?hob_id=1439042).
[91] Manning 1989, 21-29, 53-59.
[92] Webster 1988, 120-145; Grew et al. 1980, 337.

Castella in Britain

LOCATION	ANCIENT NAME	AQUEDUCT	WELLS	CISTERNS	PROXIMITY TO WATER	TOPOG. ELEV.
AMBLESIDE, CUMBRIA[93]	*Galava*	No	No	No	<10m, lake	Low
ARDOCH, TAYSIDE[94]	*Alauna Veniconum*	No	No	No	~120m, river	Low
AUCHENDAVY, STRATHCLYDE[95]		No	Maybe	No	~40m, river	Low
BAGINTON, WARWICKSHIRE[96]		No	Yes	No	~200m, river	Middle
BAINBRIDGE, NORTH YORKSHIRE[97]	*Virosidum*	No	No	Maybe	~300m, river	Low
BALMUILDY, STRATHCLYDE[98]		Yes	No	No	~150m, river	Low
BAR HILL, STRATHCLYDE[99]		No	Yes	Yes	~400m, river	High
BEARSDEN, STRATHCLYDE[100]		No	No	No	~50m, river	High
BEAUFRONT, NORTHUMBERLAND[101]		No	Yes	No	~30m, brook	Middle
BECKFOOT, CUMBRIA[102]	*Bibra*	Yes	No	No	~120m, lake	On level
BENWELL, TYNE AND WEAR[103]	*Condercum*	Maybe	Yes	Yes	~900m, river	High
BERTHA, TAYSIDE[104]		No	No	No	~100m, river	Low
BEWCASTLE, CUMBRIA[105]	*Fanum Cocidii*	No	No	No	~130m, brook	Low
BINCHESTER, DURHAM[106]	*Vinovium*	Yes	No	Yes	~80m, river	High
BIRDOSWALD, CUMBRIA[107]	*Banna*	Maybe	No	Yes	Spring inside	High

[93] Pastscape, Galava (http://www.pastscape.org.uk/hob.aspx?hob_id=10240).
[94] Breeze 1973, 122-128.
[95] Keppie & Walker 1985, 31f.
[96] Frere 1984, 295; Pastscape, Lunt Roman fort (http://www.pastscape.org.uk/hob.aspx?hob_id=335746).
[97] Bidwell 2012, 45-113.
[98] Miller 1921, 277-279.
[99] Keppie & Walker 1990, 151-153; RCAHMS, Bar Hill Roman fort (http://canmore.rcahms.gov.uk/en/site/45920/).
[100] Keppie 1980, 80-84.
[101] Pastscape, Monument no. 18276 (http://www.pastscape.org.uk/hob.aspx?hob_id=18276).
[102] Bruce 1978, 267-269.
[103] Bruce 1978. 65; Taylor 1945, 79-92.
[104] Adamson & Gallagher 1986, 195-204.
[105] Bruce 1978, 198-206.
[106] Steer 1938, 98.
[107] Biggins et al. 1999, 115.

BIRRENS, DUMFRIES & GALLOWAY[108]	*Blatobulgium*	Maybe	No	Yes	~100m, river	Low
BITTERNE, HAMPSHIRE[109]	*Clausentum*	No	Yes	No	~70m, river	Low
BOCHASTLE, CENTRAL[110]		No	No	No	~110m, river	Low
BOTHWELLHAUGH, LANARKSHIRE[111]		No	No	Yes	~100m, river	Low
BOWES, DURHAM[112]	*Lavatris*	Yes	No	No	~200m, river	Middle
BOWNESS-ON-SOLWAY, CUMBRIA[113]	*Maia*	No	No	No	~200m, brook	On level
BRADWELL, ESSEX[114]	*Othona*	No	No	No	~250m, lake	On level
BRANCASTER, NORFOLK[115]	*Branodunum*	No	No	No	~250m, brook	On level
BRECON GAER, POWYS[116]	*Cicucium*	No	Yes	No	~150m, river	Low
BROUGHAM, CUMBRIA[117]	*Brocauum*	Yes	Yes	No	~100m, river	Low
BROUGH-BY-BAINBRIDGE, NORTH YORKSHIRE[118]	*Virosidum*	Yes	No	No	~200m, river	High
BROUGH-ON-NOE, DERBYSHIRE[119]	*Navio*	Maybe	Yes	No	~20m, river	Low
BRYN-Y-GEFEILIAU, CONWY[120]		No	No	No	~20m, river	Low
BURGH-BY-SANDS, CUMBRIA[121]	*Aballava*	No	No	No	~300m, brook	On level
BURGH CASTLE, NORFOLK[122]	*Gariannonum*	No	No	No	~200m, river	On level
BURROW WALLS, CUMBRIA[123]	*Magis*	No	No	No	~100m, lake	Middle

[108] Robertson 1977, 459; Bruce 1978, 315-320.
[109] Cottrell 2011, 29.
[110] Anderson 1953, 13f; RCAHMS, Bochastle (http://canmore.rcahms.gov.uk/en/site/24337/details/bochastle/).
[111] Maxwell 1975, 21; RCAHMS, Bothwellhaugh Roman fort (http://canmore.rcahms.gov.uk/en/site/45661/details/bothwellhaugh/).
[112] Tomlin 1973, 181-189.
[113] Bruce 1978, 255-258.
[114] Johnson 1976, 42-44.
[115] Ibid. 34-37.
[116] Wheeler 1926, 48f.
[117] Birley 1932, 124-139.
[118] Wade 1952, 13.
[119] Garstang 1904, 188-192; Pastscape, Navio Roman Fort (http://www.pastscape.org.uk/hob.aspx?hob_id=309471).
[120] Hopewell et al. 2005, 237-242.
[121] Bruce 1978, 247f.
[122] Johnson 1976, 37-40; Hills 1995, 62f.
[123] Bruce 1978, 279-281.

BURY BARTON, DEVON[124]	*Nemeto statio*	No	No	No	~10m, pond	Low
CADDER, STRATHCLYDE[125]		No	Yes	No	<10m, river	Low
CAERAU, POWYS[126]		No	No	No	~100m, river	High
CAERHUN, GWYNEDD[127]	*Canovium*	Yes	No	No	<10m, river	Low
CAERMOTE, CUMBRIA[128]		No	No	No	~50m, brook	High
CAERNARFON, GWYNEDD[129]	*Segontium*	Yes	Yes	No	~350m, river	Low
CAPPUCK, BORDERS[130]	*Eburocaslum*	No	No	No	<10m, brook	Low
CARDEAN, TAYSIDE[131]		No	No	No	~100m, river	Middle
CARDIFF, SOUTH GLAMORGAN[132]		No	No	No	<10m, river	High
CARLISLE, CUMBRIA[133]	*Luguvalium*	Yes	No	No	~150m, river	Low
CARRAWBURGH, NORTHUMBERLAND[134]	*Brocolitia*	No	Yes	No	~100m, brook	Middle
CARRIDEN, CENTRAL[135]	*Velvniate*	Yes	No	No	~120m, lake	Low
CARVORAN, NORTHUMBERLAND[136]	*Magna*	Maybe	No	No	~300m, brook	High
CASTELL COLLEN, POWYS[137]		No	No	Yes	<10m, river	Low
CASTLECARY, STRATHCLYDE[138]		No	No	No	Brook inside fort	Low
CASTLEDYKES, STRATHCLYDE[139]		No	No	No	~500m, brook	Middle
CASTLESTEADS, CUMBRIA[140]	*Camboglanna*	No	No	No	~100m, river	High

[124] Todd 1985, 49-55.
[125] Buchanan 1855, 170-174; RCAHMS, Cadder (http://canmore.rcahms.gov.uk/en/site/45279/).
[126] Jarret 1969, 46-48.
[127] Hopewell et al. 2005, 242-247.
[128] Pastscape, Caermote Roman fort (http://www.pastscape.org.uk/hob.aspx?hob_id=9904).
[129] Stephens 1985, 228-230; Goodburn et al. 1979, 269-271.
[130] Bruce 1978, 304-306.
[131] Robertson 1968, 2; Robertson 1970, 4; Robertson 1971, 2; Robertson 1972, 2; Robertson 1973, 6; Robertson 1974, 9; Robertson 1975, 8.
[132] Ward 1908, 29-64.
[133] Bruce 1978, 239-243; Bede. *HE*. 27.
[134] Bruce 1978. 125-132.
[135] Webster 1998, 577-594; RCAHMS, Carriden Roman Fort (http://canmore.rcahms.gov.uk/en/site/49589/).
[136] Bruce 1978, 187-191; Richmond & Steer 1959, 1-6.
[137] Alcock 1955, 46-49; Alcock 1956, 10-21; Alcock 1957, 5-11.
[138] Christison 1903, 271-285; Buchanan 1903, 286-330; Anderson 1903, 330-346.
[139] Robertson 1953, 11f; Archer 1986, 30.
[140] Bruce 1978, 228f.

CEFN CAER, PENNAL[141]		No	No	No	~30m, brook	Low
CHESTER-LE-STREET, DURHAM[142]	*Concangis*	Yes	No	No	~200m, river	Low
CHESTERS, NORTHUMBERLAND[143]	*Cilurnum*	Yes	Maybe	No	~50m, brook	Low
CHEW GREEN, NORTHUMBERLAND[144]		No	No	No	~150m, brook	High
CIRENCESTER, GLOUCESTERSHIRE[145]	*Corinium Dobunnorum*	Yes	No	No	~300m, river	Low
CLYRO, POWYS[146]		No	No	No	~150m, river	Low-lying hill
COLWYN CASTLE, POWYS[147]		No	No	No	~130m, brook	Low-lying hill
CORBRIDGE, NORTHUMBERLAND[148]	*Corstopitum*	No	No	Yes	~150m, river	Low
CRAMOND, LOTHIAN[149]		No	Yes	Yes	~50m, river	Low
CRAWFORD, STRATHCLYDE[150]		No	No	No	~200m, river	Low
CROY HILL, STRATHCLYDE[151]		No	Yes	Yes	Spring inside	High
DALGINROSS, TAYSIDE[152]		No	No	No	~140m, river	Low
DALSWINTON, DUMFRIES & GALLOWAY[153]		No	No	No	~100m, river	Low
DORCHESTER, OXFORDSHIRE[154]	*Durnovaria*	Yes	No	No	~150m, river	Low
DOUNE, PERTHSHIRE[155]		No	No	No	~150m, river	Low
DOVER, KENT[156]		Yes	No	No	~300m, river	Low

[141] Hopewell et al. 2005, 254-259.
[142] Steer 1938, 252-264.
[143] Bruce 1978, 109-120.
[144] Pastscape, Chew Green.
[145] Stephens 1985, 202.
[146] Nash-Williams 1954, 4; Sylvester 2004, 27.
[147] Frere 2004, 115-120.
[148] Bishop & Dore 1988, 21.
[149] Rae et al. 1974, 183f; RCAHMS, Cramond Roman Fort (http://canmore.rcahms.gov.uk/en/site/50409/).
[150] Maxwell 1972, 147-200.
[151] Macdonald 1932, 243-276; Macdonald 1937, 32-71; RCAHMS, Croy Hill Roman Fort (http://canmore.rcahms.gov.uk/en/site/45875/).
[152] Robertson 1961, 40f; Wooliscraft 1999, 70; Hall 1999, 70; Dalland 2006, 131.
[153] St. Joseph 1974, 31; Birley 1958, 9-13; Hüssen et al. 2009, 59f.
[154] Stephens 1985, 199-207.
[155] Maxwell 1984, 217-223; Masser 2008, 5-12.
[156] Philp 1981, 76-90.

DRUMBURGH, CUMBRIA[157]	*Concavata*	No	No	No	~300m, river	Middle
DRUMQUHASSLE, CENTRAL[158]		No	No	No	~50m, spring	Low-lying hill
DURISDEER, DUMFRIES & GALLOWAY[159]		No	No	No	~200m, river	Low
EBCHESTER, DURHAM[160]	*Vindomora*	Maybe	Yes	No	~150m, brook	Middle
ELSLACK, NORTH YORKSHIRE[161]	*Olenacum*	No	No	No	<10m, brook	Low
FENDOCH, TAYSIDE[162]		Yes	No	Yes	~20m, brook	Low-lying hill
GELLIGAER, MID GLAMORGAN[163]		No	Yes	Yes	Spring inside	Middle
GREAT CASTERTON, LEICESTERSHIRE[164]		No	No	No	~100m, river	Middle
GREAT CHESTERFORD, ESSEX[165]		No	No	No	~30m, spring	Low
GREATCHESTERS, NORTHUMBERLAND[166]	*Aesica*	Yes	No	No	~100m, brook	Low
GRETA BRIDGE, NORTH YORKSHIRE[167]		Maybe	Maybe	No	~50m, river	Low
HALTONCHESTER, NORTHUMBERLAND[168]	*Onnum*	Yes	No	Yes	~20m, brook	Middle
HALTWHISTLE BURN, NORTHUMBERLAND[169]		No	No	No	~40m, river	Middle
HARDKNOTT, CUMBRIA[170]	*Mediobogdum*	Maybe	No	No	~30m, river	Middle

157 Bruce 1978, 250f.
158 Masser et al. 2002, 147-168.
159 Gibson 2004, 35.
160 Steer 1938, 225-251.
161 Pastscape, Burwen castle (http://www.pastscape.org.uk/hob.aspx?hob_id=46272).
162 Richmond & McIntyre 1936, 400-406; Richmond 1939, 110-154.
163 Ward 1909, 25-69.
164 Wilson & Wright 1966, 203-205; Todd 1981, 297f.
165 Rodwell 1972, 290-293.
166 MacKay 1990, 285-289; Bruce 1978, 179-183.
167 Casey et al. 1998, 131, 137.
168 Bruce 1978, 84-89:
169 Ibid. 176-179; Simpson 1974, 317-339.
170 Hutchinson 1794, Map; Collingwood 1928, 351.

HAYTON, HUMBERSIDE[171]		No	No	Yes	~80m, river	Middle
HIGH ROCHESTER, NORTHUMBERLAND[172]	*Bremenium*	No	No	No	~100m, brook	Middle
HOD HILL, DORSET[173]		No	No	No	~150m, brook	High
HOLYHEAD, GWYNEDD[174]		No	No	No	~800m, brook	On level
HOUSESTEADS, NORTHUMBERLAND[175]	*Vercovicium*	Yes	Yes	Yes	~300m, brook	High
HUNTCLIFF, NORTH YORKSHIRE[176]	*Dictium*	No	No	No	~200m, brook	Middle
ILKLEY, WEST YORKSHIRE[177]	*Verbeia*	No	No	No	~130m, river	Low
LAKE FARM, DORSET[178]		No	Yes	No	~50m, brook	Low
LAKE MENTEITH, CENTRAL[179]		No	No	No	~150m, lake	Low
LANCASTER, LANCASHIRE[180]		No	No	No	~130m, river	Low-lying hill
LANCHESTER, DURHAM[181]	*Longovicium*	Yes	No	No	~550m, river	High
LEINTWARDINE, HEREFORD & WORCESTER[182]	*Bravonium*	No	Maybe	No	~250m, brook	Low
LLANUWCHLLYN, GWYNEDD[183]		No	No	No	~150m, brook	Middle
LLANFOR, GWYNEDD[184]		No	No	No	~50m, brook	Low
LLYN-Y-BRAIN, POWYS[185]		No	No	No	~150m, river	Low
LONDON, GREATER LONDON[186]	*Londonium*	-	-	-	-	-

171 Johnson et al. 1978, 69.
172 Bruce 1978, 295-301.
173 Dawkins 1897, 52-68.
174 Nash-Williams 1954, 99; Jarrett 1969, 136f.
175 Daniels 2009, 37f, 56, 222, 242, 258f; Bruce 1978, 138-155.
176 Hornsby et al. 1912, 215-232.
177 Pastscape, Verbeia Roman Fort (http://www.pastscape.org.uk/hob.aspx?hob_id=49938).
178 Pastscape, Lake Farm Roman Fort (http://www.pastscape.org.uk/hob.aspx?hob_id=457187).
179 St. Joseph 1974, 52.
180 Wilson et al. 1971, 254; Wilson et al. 1972, 312f.
181 Steer 1938, 210-213.
182 Hassal et al. 1972, 317.
183 Hopewell et al. 2005, 260-265.
184 Ibid. 247-254.
185 St. Joseph 1958, 86-101.
186 Wallace 2013, 275-288; Jarret 1969, 66.

LOUDON HILL, EAST AYRSHIRE[187]		No	No	No	~250m, river	High
LOUGHOR, WEST GLAMORGAN[188]	*Leocarum*	No	No	No	~100m, river	Low
LYMPNE, KENT[189]	*Portus Lemanis*	No	No	No	~50m, brook	High
LYNE, BORDERS[190]		No	No	Yes	~170m, river	Low-lying hill
MALTON, NORTH YORKSHIRE[191]	*Derventio*	Yes	Yes	No	~90m, river	Low
MANCETTER, WARWICKSHIRE[192]	*Manduessedum*	Maybe	Yes	No	~200m, river	Low
MANCHESTER, MANCHESTER[193]	*Mamucium*	No	No	No	~500m, river	On level
MARTINHOE, DEVONSHIRE[194]		No	No	No	~300m, brook	Middle
MARYPORT, CUMBRIA[195]	*Alauna*	No	Yes	No	~500m, river	Low
METCHLEY, WEST MIDLANDS[196]		No	No	No	~300m, brook	Low
MELANDRA CASTLE, DERBYSHIRE[197]	*Ardotalia*	No	Maybe	Maybe	~150m, river	Low-lying hill
MORESBY, CUMBRIA[198]	*Gabrosentum*	No	No	No	~100m, brook	Low
MUMRILLS, CENTRAL[199]		No	No	No	~200m, river	Middle
NANSTALLON, CORNWALL[200]	*Statio Deventiasteno*	No	No	No	~180m, brook	Middle
NETHERBY, CUMBRIA[201]	*Castra Exploratorum*	No	No	No	~300m, brook	On level
NEWCASTLE, TYNE & WEAR[202]	*Pons Aelius*	No	No	Yes	~150m, river	On level

[187] St. Joseph 1948, 5f; Robertson 1954, 7f; Kennedy 1976, 286f.
[188] Wilson 1970, 272; Wilson 1971, 245f; Wilson et al. 1972, 300-302.
[189] Johnson 1976, 53-56.
[190] Richmond 1941, 39-43.
[191] Hassal et al. 1972, 361; Wilson et al. 1971, 252f; Mitchelson 1966, 209-261.
[192] Oswald & Gathercole 1958, 30-52.
[193] Wilson et al. 1973, 283; Goodburn et al. 1976, 319.
[194] Breeze et al. 1974, 135-151.
[195] Wilson & Caruana 2004, 102-133; Bruce 1978, 273-278.
[196] Duncan 2008, 1-14; McNicol 2008, 1-14; Pastscape, Metchley Roman fort (http://www.pastscape.org.uk/hob.aspx?hob_id=329307).
[197] Conway 1906, 22-64.
[198] Bruce 1978, 281-283.
[199] Steer 1963, 86-130.
[200] Fox et al. 1972, 56-111.
[201] Bruce 1978, 311-314.
[202] Ibid. 61-63.

NEWSTEAD, BORDERS[203]	*Trimontium*	No	Yes	Yes	~200m, river	Low
OAKWOOD, BORDERS[204]		No	No	No	~100m, brook	High
OKEHAMPTON, DEVON[205]		No	No	No	~350m, river	Middle
OLD CARLISLE, CUMBRIA[206]	*Maglona/Carvet iorum*	Yes	No	No	~30m, brook	Middle
PEN LLYSTIN, GWYNEDD[207]		No	No	No	~50m, pool	Low-lying hill
PENRITH, CUMBRIA[208]	*Voreda*	Yes	No	Yes	~200, brook	Low
PENYDARREN, MID GLAMORGAN[209]		No	Yes	No	~350m, river	Low-lying hill
PEN-Y-GAER, POWYS[210]		No	No	No	~200m, brook	Low
PEVENSEY, EAST SUSSEX[211]	*Anderida*	No	No	No	~250m, river	On level
PIERCEBRIDGE, DURHAM[212]	*Morbium*	Yes	No	No	<10m, brook	On level
PORTCHESTER, HAMPSHIRE[213]	*Portus Adurni*	No	No	No	~3200m, brook	Low
RAVENGLASS, CUMBRIA[214]	*Glannoventa*	No	Yes	No	~50m, river	Low
RECULVER, KENT[215]	Regulbium	No	No	No	~100m, brook	On level
REDSHAW BURN, STRATHCLYDE[216]		No	No	Maybe	~150m, river	Low
RIBCHESTER, LANCASHIRE[217]	*Bremetenacum Veteranorum*	No	Yes	No	~30m, river	Low
RICHBOROUGH, KENT[218]	*Rutupiae*	No	No	No	<10m, brook	On level

[203] Ibid. 307-311; Curle 1911, 47f, 60f
[204] Steer & Feachem 1952, 81-105.
[205] Bidwell et al. 1979, 255-258.
[206] Pastscape, Maglona Roman fort (http://www.pastscape.org.uk/hob.aspx?hob_id=9942)
[207] Hopewell et al. 2005, 235-237.
[208] Bell 2012, 40, 61-72.
[209] James 1906, 193-208.
[210] Jarrett 1969, 108-110.
[211] Johnson 1976, 56-59.
[212] Steer 1938, 68f.
[213] Johnson 1976, 59-62.
[214] Bruce 1978, 283-286.
[215] Johnson 1976, 44-48.
[216] Hunter 2000, 86.
[217] Hopkinson 1928, 13.
[218] Johnson 1976, 48-51.

RISINGHAM, NORTHUMBERLAND[219]	*Habitancum*	No	No	No	~30m, brook	Low
RUDCHESTER, NORTHUMBERLAND[220]	*Vindovala*	No	No	No	~300m, brook	High
RUTHIN, CLWYDR[221]		No	Yes	Yes	~300m, river	Low-lying hill
SLACK, WEST YORKSHIRE[222]	*Cambodunum*	No	No	Maybe	~150m, brook	Middle
SOUTH SHIELDS, TYNE & WEAR[223]	*Arbeia*	Yes	No	No	~150m, river	On level
STANWIX, CUMBRIA[224]	*Uxelodunum*	No	No	No	~180m, river	On level
STRACATHRO, TAYSIDE[225]		No	No	No	<10m, brook	Low
STRAGEATH, TAYSIDE[226]		Yes	No	Yes	~20m, river	Low
TASSIESHOLM, DUMFRIES & GALLOWAY[227]		No	No	No	~50m, brook	Low-lying hill
TOMEN-Y-MUR, GWYNEDD[228]		Yes	No	No	~80m, brook	High
CHESTERHOLM, NORTHUMBERLAND[229]	*Vindolanda*	No	No	Yes	~60m, brook	Middle
WADDON HILL, DORSET		No	No	No	~500m, brook	High
WALLSEND, TYNE & WEAR[230]	*Segedunum*	No	No	Yes	~300m, river	On level
WALTON CASTLE, SUFFOLK[231]		No	No	No	~500m, brook	Low
WHITLEY CASTLE, NORTHUMBERLAND[232]	*Epiacum*	Yes	No	No	Spring inside	Middle

[219] Bruce 1978, 289-294.
[220] Ibid. 76-81.
[221] Waddelove et al. 1989, 249-254.
[222] Wilson et al 1971, 254.
[223] Bruce 1978, 51; Steer 1938, 265-280.
[224] Ibid. 236-239.
[225] St. Joseph 1970, 163-178.
[226] Frere & Wilkes 1989, 12.
[227] Clarke 1950, 197-201.
[228] Driver & Browne 2008, 5.
[229] Bruce 1978, 156-163.
[230] Bruce 1978, 55-59; Pastscape, Wallsend Roman Fort (http://www.pastscape.org.uk/hob.aspx?hob_id=26535).
[231] Pearson 2002, 19-22.
[232] Went & Ainsworth 2013, 111, 114.

3.2.3. Roman Syria and Jordan

The situation in Syria and Jordan is in diametric opposition to the one in Britain. Instead of an overwhelming number of sites, there are very few. It is only through great difficulty that one may discover meaningful and relevant information on more than a relative handful of military installations. While it is true some of the most important and well-preserved sites – e.g. Dura-Europos— are located in this region, they are few in number, and most have not been excavated, while information is lacking on the smaller and more obscure sites.

The most extensive work done along this frontier are surveys conducted by Antoine Poidebard in the late 1920's. The French scholar and missionary was a pioneering aerial archaeologist who spent four years mapping the Roman frontier in Syria. Poidebard combined extensive aerial reconnaissance with field surveys and small-scale excavations. He single-handedly identified and documented the vast majority of all sites that are known in the area today.[233] Two other important figures in the exploration of the eastern *limes* are Alois Musil and Sir Aurel Stein. Musil was a Franco-Hungarian writer and explorer active during the early decades of the 20th century. He published detailed itineraries describing his expeditions across the Near East. He reported on many sites in both Jordan and Syria. Poidebard frequently used Musil's writings to locate desert sites. Stein was a Hungarian-British archaeologist who saw much merit in Poidebards undertakings and carried on his in the British mandated areas of Transjordan and Palestine.[234] Very little has been done post-Poidebard and Stein. There is the relatively recent American-funded *Limes Arabicus* Project, which examined a small number of sites in Jordan, focusing on the legionary fortress of El-Lejjun.[235] Apart from that, very few sites have been extensively excavated. In 1990 David Kennedy and Derrick Riley, whom I mentioned in the chapter on research history, collated information on all sites excavated prior to the writing of their book.

The area is problematic in many respects. Later events have dealt harshly with the frontier. The near east has been highly contested territory since long before the time when the Romans first emerged from Italy. Even in our 21st century it is still frequently wracked by war. As I write these sentences Syria is embroiled in a bloody civil war. The conflict just entered its fourth year. War is destructive to the material record and obstructive to any archaeological work which might be accomplished. Beyond war, there are the same problems that we see in Britain – the quarrying away of ancient sites, intense agriculturalization, the growth of towns, etc.

A particularly problematic issue is in the east is the complex stratigraphy. In those cases when a Roman site is actually excavated, there is often a confusing succession of Roman, Byzantine, Arabic, and sometimes even Crusader fortifications on the same location – and frequently a long history of pre-Roman occupation as well. Accordingly, very little is preserved from the Roman period, and it is sometimes very difficult for archaeologists to make sense of.

Compared with Britain, it has proven difficult to find some of the evidence that I required for my statistical evaluation. This principally concerns the last two data sets, the proximity to water, and the topographical evaluation. The antiquity authorities of Syria and Jordan do not provide online databases of known sites and accurate maps of their location. And, as I have been unable to establish the locations

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[233] Kennedy & Riley, 51f.
[234] Ibid. 52f.
[235] Parker 1991, 117.

of included installations with any degree of certainty, I have only included information on the last two data sets if it is provided in the archaeological publications I have at hand. I have left cells blank in those cases where I feel that the evidence is too weak (for instance, if my only source is for a certain site is Poidebard, and all he did was to take aerial photographs and conduct a short ground survey, not even convincingly dating the site). I have still included them in order to provide an extensive list of known fortifications.

Castra in Syria and Jordan

Location	Ancient name	Aqueduct	Wells	Cisterns	Proximity to water	Topog. elev.
Bosra Eski-Sham, Syria[236]		No	No	Yes	Spring nearby	-
Salihiyeh, Syria[237]	*Dura-Europos*	No	No	No	On river	-
El-Lejjun, Jordan[238]	*Betthorus*	Yes	No	Yes	Spring nearby	-
Halebiyeh, Syria[239]		-	-	-	On river	-
Tadmor, Syria[240]	*Palmyra*	Yes	No	Yes	-	-
Udruh, Jordan[241]		No	Yes (Q)[242]	No	Spring nearby	-
Resafa, Syria[243]	*Sergiopolis*	No	No	Yes	-	-
Souriya, Syria[244]	*Sura*	-	-	-	On river	On level
Tayibeh, Syria[245]	*Oresa*	-	-	-	-	High
Tunainir, Syria[246]	*Thanuris*	-	-	-	On river	-

[236] Kennedy & Riley 1990, 125.
[237] Weiss 1991, 736-740; Weiss 1995, 154-158; Kennedy & Riley 1990, 111-114.
[238] Parker 1989, 117-141; Parker 1980, 18f.
[239] Kennedy & Riley 1990, 117f.
[240] Kennedy & Riley 1990, 134-137.
[241] Kennedy & Riley 1990, 131-133.
[242] A Qanat, not the customary draw well.
[243] Kennedy & Riley 1990, 116f.
[244] Kennedy & Riley 1990, 115f.
[245] Kennedy & Riley 1990, 137.
[246] Kennedy & Riley 1990, 118-121.

Castella in Syria and Jordan

Location	Ancient name	Aqueduct	Wells	Cisterns	Proximity to water	Topog. elev.
Abd, Syria[247]		No	No	No	-	-
Ad-Diyatheh, Syria[248]		No	No	No	-	-
Araban, Syria[249]	*Oroba*	Maybe	No	No	-	-
Bazi, Syria[250]		No	No	Yes	-	High
Bir Haidar, Syria[251]		-	-	-	-	-
Bir Madhkur, Jordan[252]		No	Maybe	Yes	Spring nearby	-
Da'Janiya, Jordan[253]		No	No	Yes	Spring nearby	-
Deir el-Kahf, Jordan[254]	*Speluncae*	No	No	Yes	-	-
Deir Semali, Syria[255]		-	-	-	-	-
El-Qdeyr, Syria[256]		-	-	-	-	-
Et-Telah, Jordan[257]	*Toloha*	Yes	No	Yes	-	-
Gharandal, Jordan[258]	*Arieldela*	Yes	No	Yes	-	-
Hlehleh, Syria[259]	*Helela*	No	Yes	Yes	River nearby	-
Humayma, Jordan[260]	*Auara*	Yes	No	Yes	15km, spring	-
Khan Aneybeh, Syria[261]	*Anabatha*	No	No	Yes	-	-
Khan el-Hallabat, Syria[262]	*Veriaraca*	-	-	-	River nearby	-

247 Weiss 1997, 97-100.
248 Kennedy & Riley 1990, 196f.
249 Kennedy & Riley 1990, 156.
250 Weiss 1997, 108-111.
251 Kennedy & Riley 1990, 148f.
252 Smith 2005, 57-75.
253 Parker 1989, 134-141.
254 Kennedy & Riley 1990, 179.
255 Kennedy & Riley 1990, 210f.
256 Kennedy & Riley 1990, 209f.
257 Kennedy & Riley 1990, 205-207.
258 Kennedy & Riley 1990, 207-209.
259 Kennedy & Riley 1990, 155.
260 Eadie & Oleson 1986, 49-76; Savage et al. 2005, 554f; Kennedy & Riley 1990, 146-148.
261 Kennedy & Riley 1990, 205.
262 Kennedy & Riley 1990, 203f.

Khan el-Manqoura, Syria[263]	*Vallis Albana*	Yes	No	Yes	Spring nearby	-
Khan el-Qattar, Syria[264]	*Carneia*	No	Maybe	Yes	Spring nearby	-
Khirbet el-Fityan, Jordan[265]		No	No	No	Spring nearby	-
Khirbet es-Samra, Jordan[266]	*Adtitha*	No	No	Yes	-	-
Khirbet Hassan Aga, Syria[267]		-	-	-	-	-
Nedwiyat el-Qdeyr, Syria[268]		-	-	-	-	-
Qasr Bashir, Jordan[269]		No	No	Yes	-	-
Qasr el-Azraq, Jordan[270]	*Dasianis*	-	-	-	Spring nearby	-
Qasr el-Feifeh, Jordan[271]		-	-	-	-	-
Qasr el-Hallabat, Jordan[272]		No	No	No	-	-
Qasr el-Uweinid, Jordan[273]	*Castellum et Praesidium Severianum*	No	No	No	Spring nearby	-
Qreiyeh, Syria[274]		-	-	-	River nearby	-
Sa'neh, Syria[275]		-	-	-	-	-
Tell Brak, Syria[276]		No	No	No	River nearby	-
Tell Zenbil, Syria[277]		-	-	-	River nearby	-
Umm el-Jammal, Jordan[278]		No	No	No	-	-
Umm el-Quttein, Jordan[279]		-	-	-	-	-

263 Poidebard 1934, 45f; Kennedy & Riley 1990, 181-183.
264 Kennedy & Riley 1990, 204f.
265 Kennedy & Riley 1990, 175f
266 Kennedy & Riley 1990, 198f
267 Kennedy & Riley 1990, 151f.
268 Kennedy & Riley 1990, 149-151.
269 Kennedy & Riley 1990, 176-178
270 Kennedy & Riley 1990, 179-181.
271 Kennedy & Riley 1990, 144f.
272 Kennedy & Riley 1990, 199-202.
273 Kennedy & Riley 1990, 159-162.
274 Kennedy & Riley 1990, 153f.
275 Kennedy & Riley 1990, 189.
276 Kennedy & Riley 1990, 215.
277 Kennedy & Riley 1990, 155f.
278 Kennedy & Riley 1990, 183-185.
279 Kennedy & Riley 1990, 141-144.

Umm el-Resas, Jordan[280]		No	No	Yes	-	-

[280] Kennedy & Riley 1990, 189-193.

3.3. Summary and visualization of the archaeological data

This section is meant only as a brief summary of the documentation work contained in the tables above. Charts and figures are only briefly presented. We will come back to them in the discussion in chapter 4.

3.3.1. Roman Britain

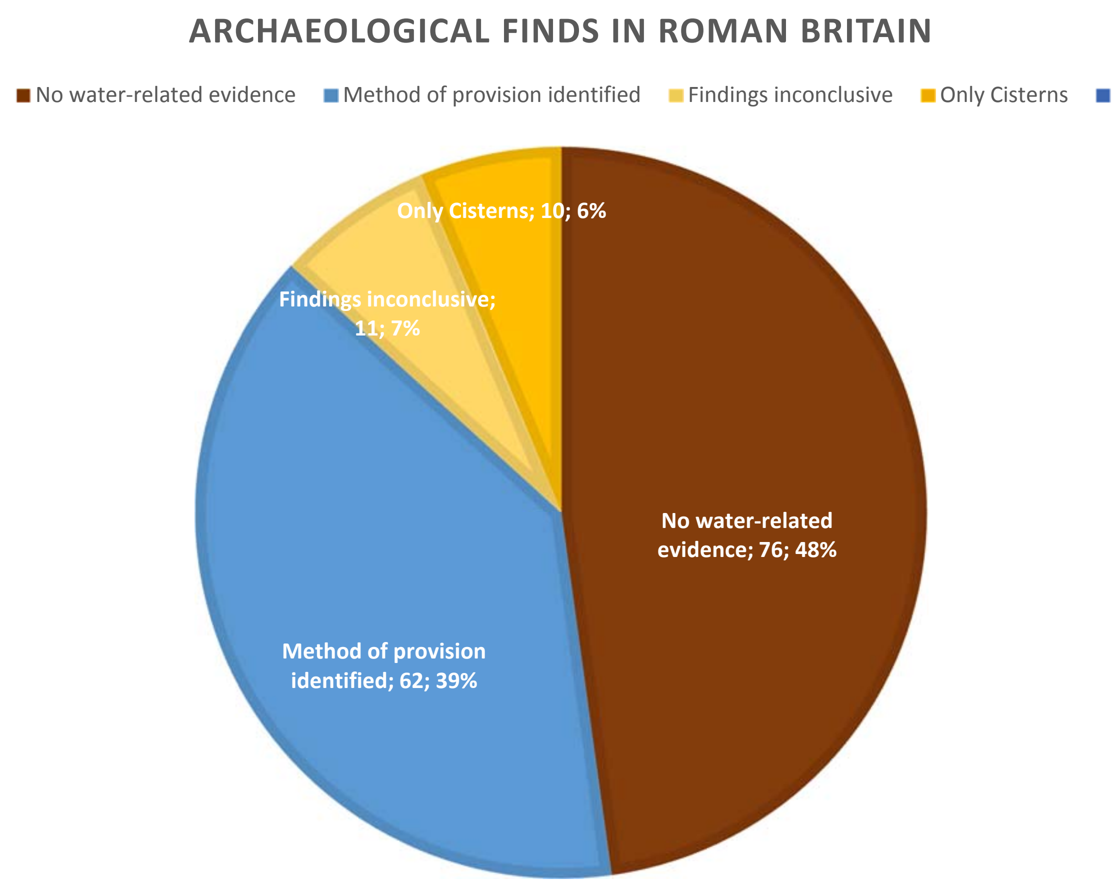

Figure 3: Illustrating the frequency of water-related findings at examined sites

Looking at all of the sites in the statistical analysis, *castra* and *castella* (*Fig.* 3), a sum total of 156 sites, we see that a water supply system has been identified at 62 sites (or 39%). At 10 sites (~6%) there are no water-related finds beyond water tanks or cisterns. The presence of cisterns or tanks alone is conventionally not in itself regarded as conclusive with reference to the supply method, so these sites are in their own category. At 11 sites (~7%) there are some indications that there might be water-related structures present, but nothing has been proven convincingly. At 76 sites (48%) no clues regarding the water supply have been found.

If we separate the fortresses and the forts, we see a marked difference (*Figs.* 4 & 5). Beginning with the forts, we find aqueducts at 20 sites (15%), wells at 18 (14%). Another four sites (3%) exhibit signs of aqueducts, and four (3%) have indications of wells. At five sites (4%) there are both aqueducts and wells. The sites with only cisterns number 10 (7%).

In fortresses, wells are singularly present at only three sites (23%), aqueducts at six (46%). Another three (23%) have features that may indicate aqueducts, and one site (8%) has both an aqueduct and wells.

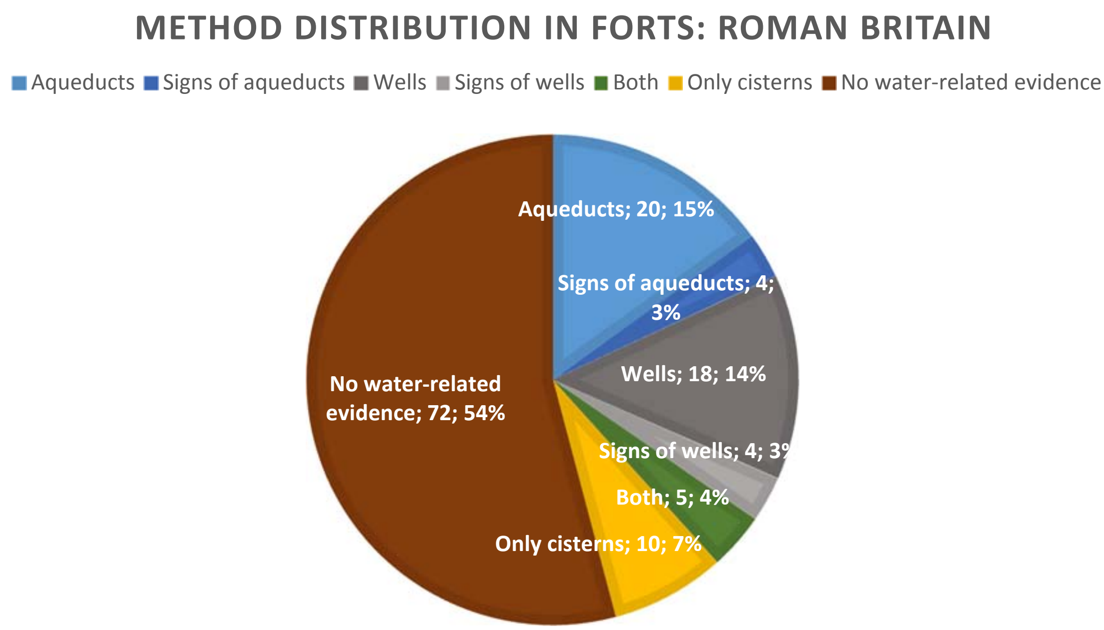

Figure 4: Method distribution in forts.

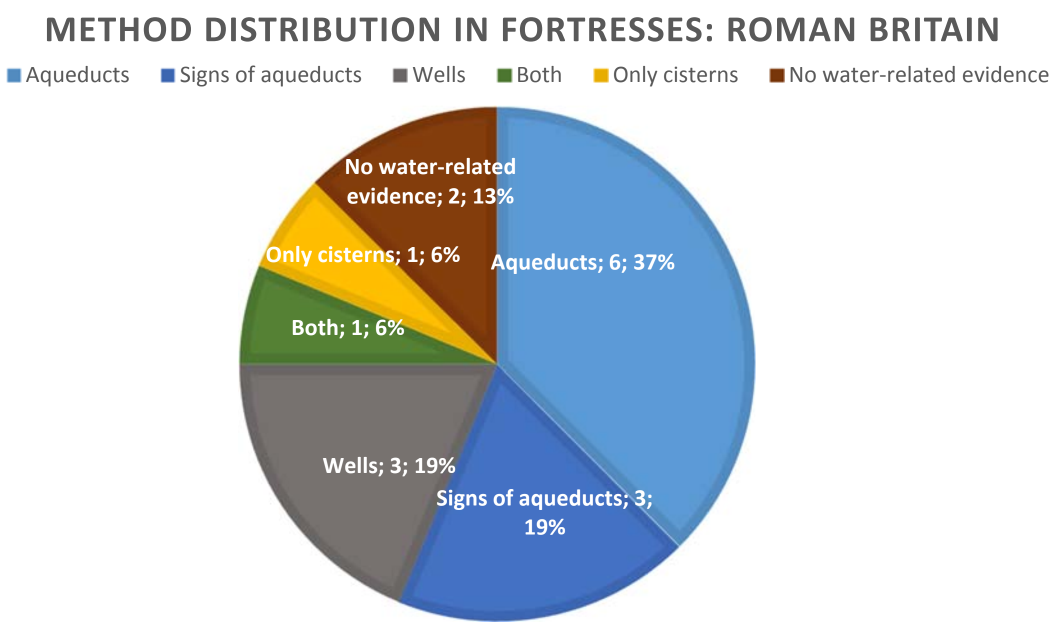

Figure 5: Method distribution in fortresses.

3.3.2. Syria and Jordan

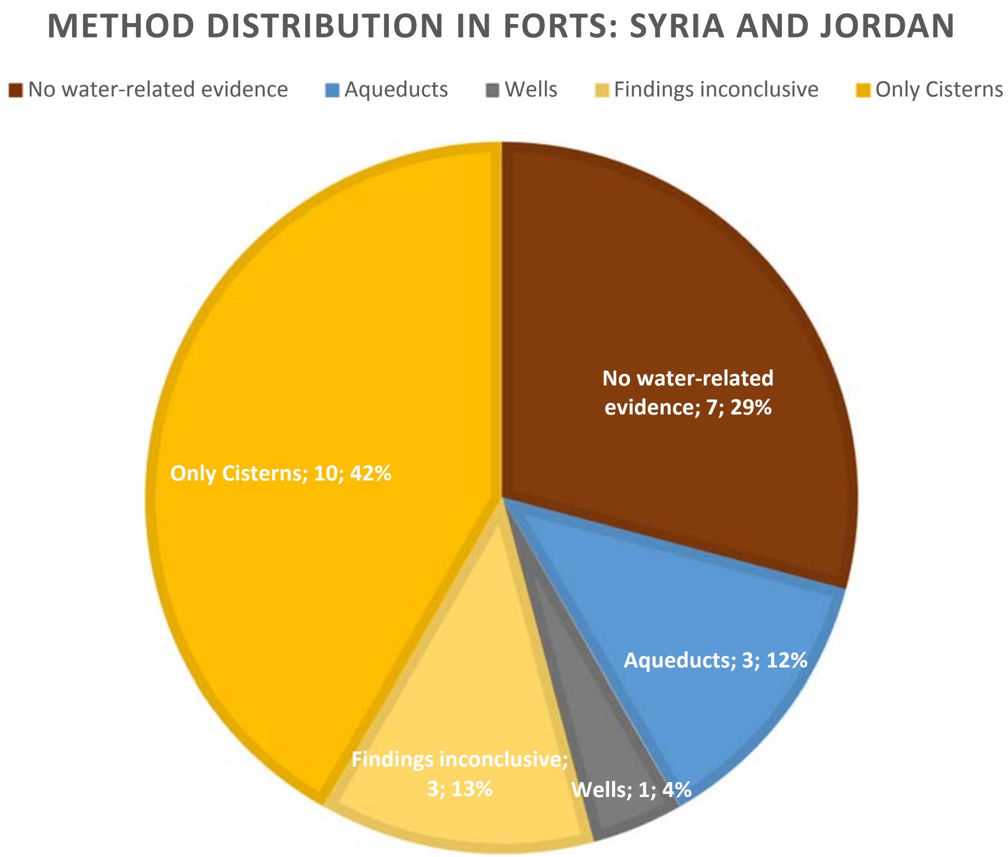

Figure 6: Water-findings in Syria and Jordan.

The structure of the presentation here is slightly different from that for Roman Britain above. This is mainly due to the simple reason that the fortresses are so few that separate charts are uncalled for. Furthermore, combining wells and aqueducts in a label termed "methods of provision identified" as above would have been misleading in this case; the implication would be that reservoirs were not viable as the sole means of water supply. However, because of the large proportion of sites apparently only having reservoirs, and since these are in themselves, in literature concerning these regions, sometimes regarded as the singular means of supply, such a suggestion would be improper. I will instead summarize the fortress finds in writing and discuss the methodology in the relevant section of the discussion Here, I have only included a chart on the distribution of finds in forts (*Fig.* 6).

As for the numbers, we can see that investigations in Syria and Jordan have found that the prime share of sites (10 sites, amounting 42%) only had cisterns. Aqueducts are present at three sites (12%), and wells at only one (4%). All six of these also had cisterns. Findings are inconclusive at three sites (13%). All three of these sites had reservoirs, but there may also have been wells at two of them, and an aqueduct at one. At seven sites (29%), no water-related features have been encountered. All in all, there are cisterns at 16 sites out of those 24 sites for which I had reliable data; that amounts to 67%.

4. Discussion

4.1. Feasibility of the identified water sources

Before launching into a discussion on which water supply methods were actually used where, we must examine if the methods identified are adequate. Can they provide sufficient volumes of water to cover the needs of forts and fortresses? The requirements are discussed in section 2.5. Fortresses in Britain required 10.000-30.000 L/d. Their counterparts in Syria and Jordan required 25.000 to 50.000 L/d. Forts in Britain needed 1.000 to 3.000 L/d or 2.000 to 6.000 L/d, depending on whether it was manned by one or two cohorts. In Syria and Jordan the numbers are 2.500-5.000 or 5.000-10.000 L/d. Note that these figures are for drinking water only, and that a low-to-mid range number is most likely, the high-end only applying to situations of intense physical exertion.

Aqueduct: An aqueduct's rate of discharge is very difficult to determine. It depends on the diameter of the pipe, how high the water rises in it, and the rate of flow. Yet, even a modest and inefficient aqueduct was able to furnish more than enough water for any military installation. This matter requires little discussion. Even the most ineffective aqueduct that Hodge lists provided above and beyond what a fort or fortress required. The aqueduct in question is the one at Segovia, Spain, which discharged 1.728m^3 (1.728.000 liters) per 24 hours. Compare this with the *Anio Novus* in Rome, which provided 189.520m^3 (189.520.000 liters) in a 24 hour period.[281] Granted, Hodge discusses civic aqueducts, but logic dictates that labor would not be invested for the building of an aqueduct unless its source was abundant. A functioning aqueduct could always meet the water requirements of any Roman military installation. Let us instead move on to wells.

Wells: A well's rate of discharge depends on the depth of the well, the size of the bucket and the method for drawing water. A wide variety of methods were known to the Romans, the plainest of which was to simply tie a bucket to the end of a rope. The bucket is then lowered and hauled up either manually, or by use of animal power. Very shallow wells – down to approximately 4 meters in depth – could be fitted with a so-called *shadouf*, a seesaw-like construction with a bucket at one end and a counterweight on the other; this would enable the well operator to raise full buckets with negligible effort. Another method was different kinds of pulley solutions. A pulley is basically a wheel with a grooved rim. This wheel is suspended above the center of the well, and a rope or chain passed through the rim. A bucket is affixed to the rope, which is then lowered and pulled up manually; the pulley allows an operator to pull downward, using his body weight instead tugging upwards with only the help of his muscle strength. A pulley well could also be rigged with a windlass. A system with a windlass could carry two buckets, one ascending as the other was lowered.[282] Finally, we have the so-called bucket chain, a mechanical lifting device that carries a large number of water boxes on a chain (*Fig.* 7). As for the question at hand – whether the rate of discharge is adequate – it is difficult to determine for the manual systems. The factors involved are too variable for any precise estimate to be made, but certainly, even a manually operated well, if manned for the entirety of a work day (~10 hours) could output thousands of liters. A good-sized bucket (20L) and a generous three-minute draw time would yield 100 liters in 15 minutes. In 10 hours it would output 4000 liters. This is likely on the low side. Mechanical systems like the bucket chain are immensely more effective. Several bucket chains have been recovered in Britain.

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[281] Hodge 1992, 346-348.
[282] Wikander 2000, 30-32A.

They are of two different types. The earliest, from the first century A.D., have been estimated by engineers to have a capacity of about 0.75 liters per second. That amounts to 45 liters per minute, or 2.700 liters per hour. If manned for the duration of the work day, a single well fitted with such a device could provide 27.000 liters. The other type has a capacity of at least 2 liters per second, possibly as much as 3.7 liters per second; in 10 hours the lower output adds up to 72.000 liters, the higher one to a staggering 133.200 liters.[283]

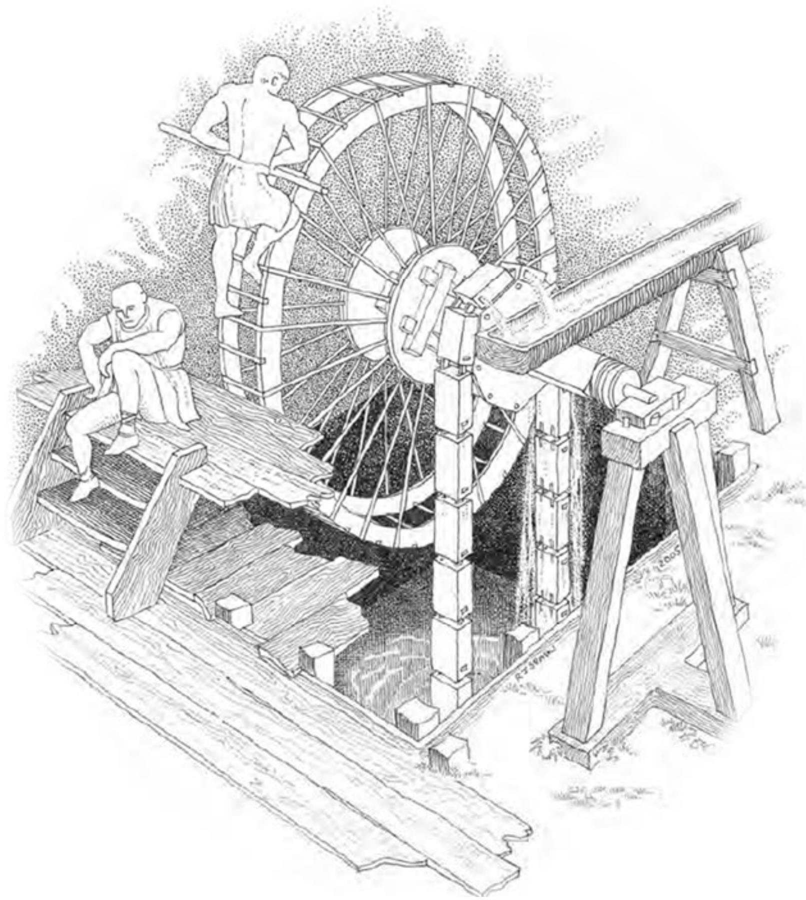

Figure 7: Reconstruction drawing of a Roman bucket chain recovered in London. Image source: Blair et al. 2006.

From this we may conclude that even a single well with a primitive draw method could likely supply any fort with at least its drinking water. In certain situations, however – e.g. in forts with double-cohort garrisons in arid environments, forts with large cavalry detachments, and so on – a single well without a mechanical lifting device might not provide enough drinking water for soldiers to remain in optimal condition, but it would certainly yield well over the subsistence minimum. For any purposes in addition to drinking, a single well within a fort in an extremely hot environment would likely need to be supplemented either by additional wells or by other means. When it comes to fortresses, a single, manual well would not provide enough drinking water for even the lowest estimates. A single well fitted with a bucket chain, of course, could provide enough water even for the largest of fortresses in the very worst environments.

283 Blair et al. 2006, 41-43.

Rainwater harvesting: The practicability of rainwater harvesting is determined by three factors: Precipitation, the capacity of the cisterns in place, and, assuming only roof run-off was used for drinking, the total roof area of all buildings within an installation. Water collected from the ground is serviceable for a range of applications, but it is not suitable for drinking.

Peter Beaumont suggested in 2008 that rainwater collection may have been the method of supply at Housestead's fort. He calculated that the annual collection would run up to 7.739.000 liters per year, or 21.200 liters per day, well in excess of what the 800 soldiers garrisoned there would have required. When adjusted for evaporation, higher dispersion and lower run-off rates during certain months, the amount left would still be well in excess of 20 liters per man per day. This assumes very large storage capacities, however, as the yield during the summer months would be considerably lower. With relatively small storage tanks a yield of 15 liters per man per day may still be sustained. [284] This is amply sufficient even in relation to the highest estimates of drinking water requirements, and might even have covered all water requirements beyond drinking. If surface run-off was also used to some degree, such a system would definitely have provided all necessary water. If we assume that the total roof area is relatively proportional to the size of the garrison, then all installations situated in adequately precipitous areas would be able to supply themselves by rainwater collection. For comparison, Housestead's fort has an annual precipitation of 890mm.[285]

Collection: Manual water collection is never really considered in scientific literature as a possible long-term means of water supply for garrisoned soldiers. Yet, as the sources make clear, this was the predominant manner in which water provision was managed for an army in the field. I will attempt here to assess if it might be viable for permanent military installations as well.

Elizabeth Shirley, in her report on the excavation of the fortress at Inchtuthil, noted that there did not seem to be any traces of a means of water supply.[286] What she actually meant is that there were no traces of an aqueduct. There were actually fairly many water tanks that might have been used for rainwater harvesting. She does acknowledge that rainwater may have been a valuable source of water, but in the end she concludes that an aqueduct was going to be installed, because it was "logical".[287] The important object here is that she also asked how the legion at Inchtuthil might have been supplied with water until such a time as her projected aqueduct was finished. She proposed that it might have been manually moved in barrels, on four-wheeled carts from the ~500 meters distant river Tay. Shirley also calculated the labor investment required for doing so.

Her calculations are for 2.5 liters of drinking water per man per day for 600 days (the estimated total construction time for the fortress) for a half-legion. She possibly also includes water needed for the working animals (which she puts at 450 mules, 200 oxen, and 200 horses); it is not very clear in the text. I am assuming that she is not, and that her labor estimate of 10.000 man-hours is only for drinking water for the soldiers.[288] Using her calculations as a basis, and adjusting them to 10 liters per man per day for a year for one cohort and one full legion respectively, that comes out to ~4.867 man-hours to provide a cohort with a year's supply of drinking water, and ~48.667 man-hours to supply a legion. This means

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[284] Beaumont 2008, 78-81.
[285] Beaumont 2008, 61.
[286] Shirley 2000, 117.
[287] Ibid. 79.
[288] Ibid. 179f.

that continuous provision of a fortress could be sustained with a labor force of 14 men working full-time (10 hours/day), and only two men to supply a fort. Now, this is far from a perfect calculation. The figures cannot be scaled like this unproblematically. One could probably not do this kind of work being only two men, for instance. But, assuming that Shirley was roughly in the right with her initial estimates, it suggests that manual collection was a quick, practical, and inexpensive way of providing water, supposing that there was an abundant source within a reasonable vicinity of the installation.

The conclusion here is that all the methods could work as a sole source of water supply under the right circumstances. We will reexamine all of them with regards to our two regions in the subsequent sections of the discussion.

4.2. Military water supply methods in Roman Britain: A discussion

If we examine the numbers now, and try to arrive at some kind of answer, we find that they immediately suggest that there was, in fact, no standard way of supplying water to military installations, not even on a regional level (i.e. Britain). I will begin with a discussion on forts, and after that go over fortresses.

4.2.1. Forts in Roman Britain

In the preceding chapter we looked at the feasibility of the different methods as the sole means of supply, and found that they were in fact, with a few qualifications, all feasible. Before drawing any conclusions, let us examine the viability of the different methods of water supply in Great Britain specifically.

We begin with wells. As we have found, even one primitive well (i.e. sans a mechanical lifting device) could likely provide the water needed for a fort; two or more could definitely do so. Now, whether wells could actually be sunk at the locations of all our forts is difficult to determine. The water table does not necessarily reflect the surface topography. It is influenced by a variety of geological factors. Very seldom is data on these conditions found in archaeological literature; this being so, I must be content with saying that wells may have been possible at many sites where they have not been found, and move on to the other methods

The viability of rainwater catchment, as we have concluded, is primarily dependent on precipitation. Looking at all of Great Britain (*Fig.* 8), and keeping in mind that Housestead's fort yielded, at an annual precipitation rate of 890mm, in excess of even what a soldier in the desert would require under the worst possible circumstances, we can safely conclude that the harvesting of roof run-off would be a feasible method of supplying drinking water for anywhere in Great Britain, even at an installation with a relatively modest water storage capacity. There would even be quite a lot of water to spare for other applications. Depending on how much was required for other purposes, however – and this is difficult to determine with any degree of certainty – the roof run-off might need to be supplemented by other means.

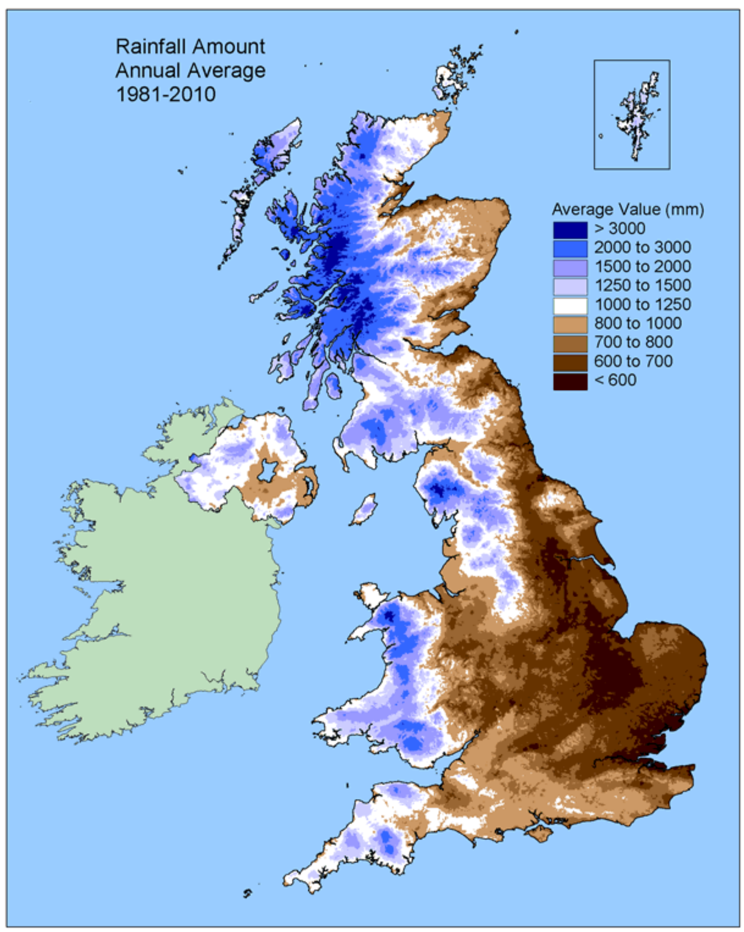

Figure 8: Annual precipitation in Great Britain. Map produced by the Met Office.

Thirdly, we have aqueducts, the method preferred by British classical scholars. The feasibility of installing aqueducts at military bases is in part determined by the situation of said bases. *Fig*. 9 displays the topographical elevation of forts in Roman Britain. A significant proportion of forts are lowly positioned in the landscape. This is contrary to both conventional military wisdom, and assertions made by many classical scholars. "It has been pointed out repeatedly that Roman military bases tended to be sited on strategically dominant higher ground", wrote Siegmar Von Schnurbein in an anthological publication on Roman fortifications in 2000.[289] This was apparently not the case in *Britannia*, although it should be noted that sites on low-lying hills are possibly underrepresented, as hills and ridges have been flattened in many urban areas.

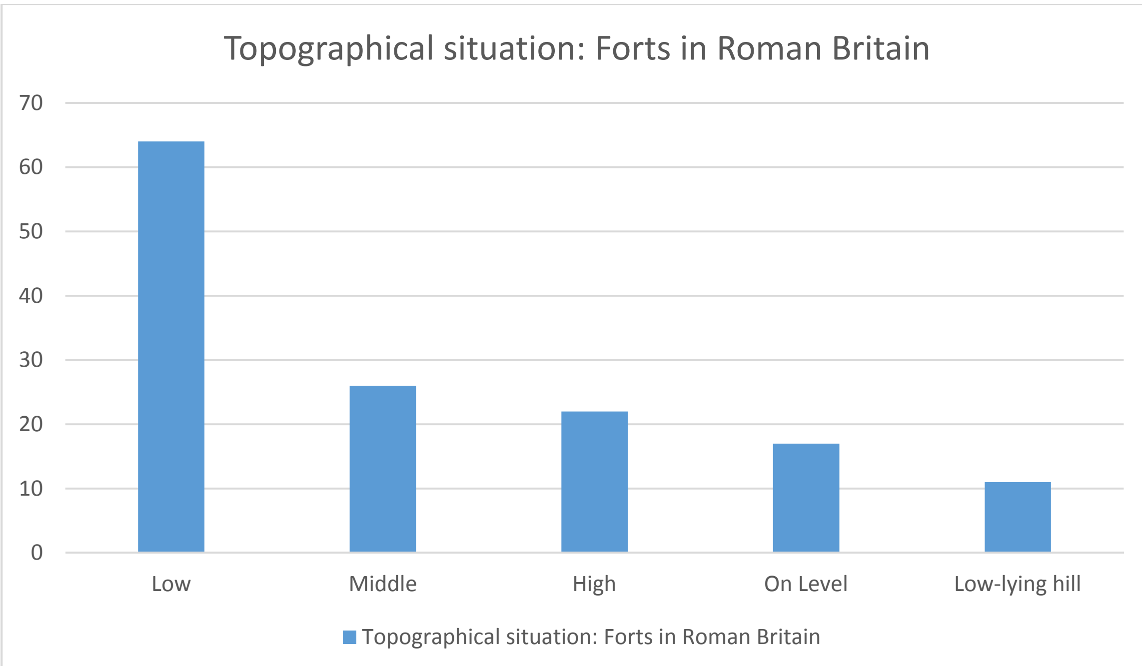

Figure 9: The topography of fort positions in Roman Britain.

A lowland position renders the construction of an aqueduct simpler. Sites in middle positions can likewise be supplied with an aqueduct, provided there is a water source at a higher position. Sites on low-lying hills can be supplied with the help of inverted siphons. Sites in elevated positions are unlikely to have had aqueducts – the Romans did not have the technology to conduct water upwards – but may of course have been supplied from very remote (that is, outside of my area of analysis, which covers a 5 kilometer radius from the installations), higher-lying sources. That goes for sites situated on flatland as well. There is, however, only one example of a military aqueduct of such length in Roman Britain – the one at Greatchesters fort. Then again, this may be because we generally do not know the sources of most military aqueducts. These qualifications aside, we may regard the likelihood of the existence of an aqueduct as higher in low-lying installations than in high-lying ones. All said, that still means that aqueducts were fairly practicable at a very large proportion of the sites. It is simple to look at all this and conclude that aqueducts must have been fairly standard – because the Romans possessed the technology, and so many sites were conveniently positioned. In fact, this is what many Romano-British

[289] Schnurbein 2000, 30.

scholars have done. Yet, the skeptic is obliged to ask if it is any less probable that they occupy low-lying positions in the landscape not to enable the construction of aqueducts, but because of their proximity to water. Watercourses always flow downwards, following the path of least resistance. Consequently, they are generally in the lowest position in the land. The same goes for water aggregations like lakes and ponds.

This, of course, leads us to the last of our methods: Manual collection. Let us look at the distance between military installations and their nearest water point (*Fig*. 10).

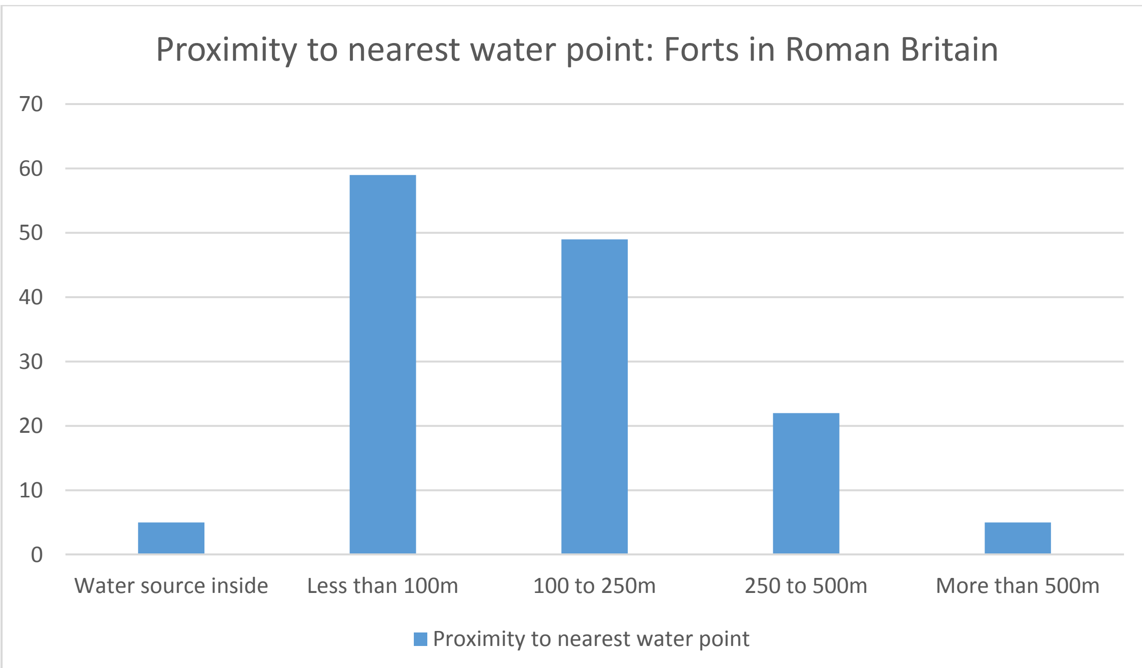

Figure 10: Proximity of forts to their nearest water point in Roman Britain.

All but five forts had a water source less than half a kilometer away (a few have running water within the enclosure of the fort). This is approximately the distance from the fortress at Inchtuthil to the river Tay, between which Elizabeth Shirley calculated the labor requirements of moving water. This means that collection would be cheap and simple at all forts in Britain.

So what is the take-away here? We have found that rainwater catchment and manual collection could conceivably supply all forts in Roman Britain. Aqueducts were practicable at a fairly large number of sites (~73% if we count sites in low and middle positions, as well as those on low-lying hills), but not everywhere. As for wells, it is nigh impossible to say where they could or could not be sunk without conducting practical experiments on-site. Ultimately, all the methods appear feasible. Something being feasible is of course no guarantee for its use, so we must again look to the archaeological side of things.

Archaeological finds of water-related structures are only present at about half of the forts in the analysis (*Fig.* 11). Aqueducts and wells are present at roughly the same amount sites, at 17% and 16% respectively (counting ambiguous findings). Sites with only cisterns make up about 7%, and 3% are sites with both aqueducts and wells (in some cases also tanks or cisterns). The remaining 57% have no apparent features.

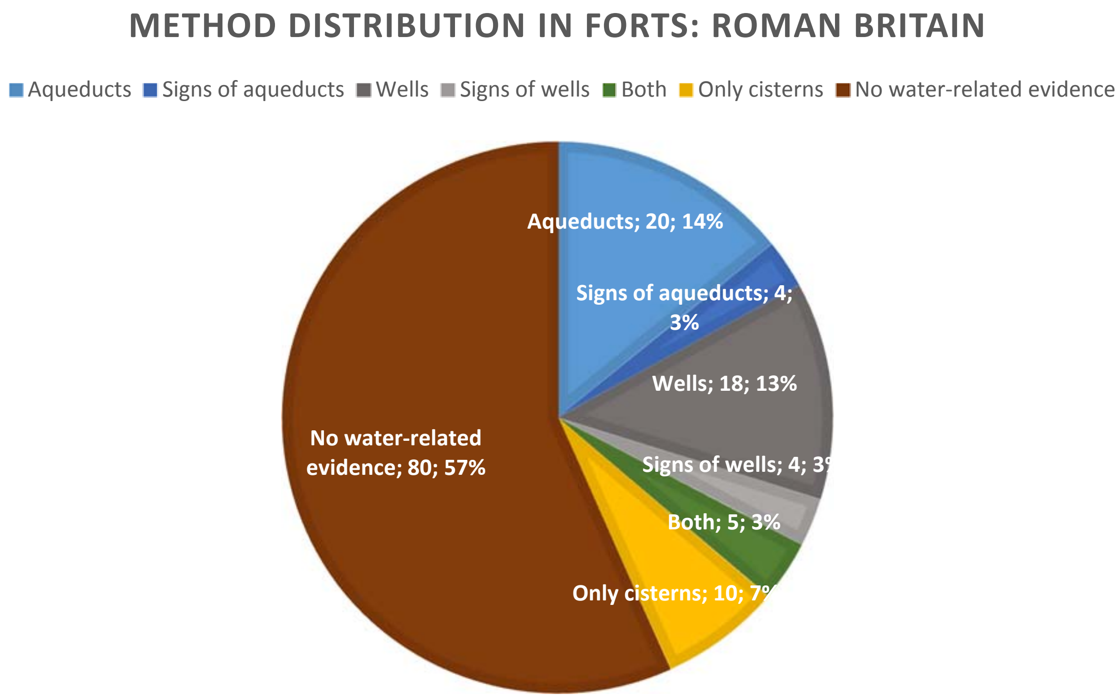

Figure 11: The water supply methods of forts in Roman Britain.

We can discern two problems here. The first is determining whether sites with only cisterns were actually set up to receive rainwater, or if they were previously fed by aqueducts or wells, or water was brought to them from water points in the landscape. Alas, this issue cannot be settled with any degree of certainty. We simply do not know how the cisterns were fed. Nevertheless, we may recall Vitruvius' statement on rainwater catchment, when he advises it only in those cases when the soil is unconducive to the digging of wells.[290] This is only a single quote, but coupled with the fact that no other author mentions this method –except for Josephus, who is arguably only valid for the state of things along the eastern border – may bespeak some preferred avoidance of rainwater, or at least some predilection for other water sources (for drinking).

The second, and more significant problem here is the fact that no relevant features have been uncovered at 57% of sites (numbering 80). This must of course be addressed. It is partly the archaeological bias at work. The archaeological record is inherently biased against many materials of which aqueducts, wells, and cisterns could be composed. Pliny mentions water pipes made of leather, hollowed tree trunks, etc., and these are frail materials. [291] Many wells were lined with planks, and wood is a relatively impermanent material except under certain conditions. Masonry will survive any period of deposition, but it will not survive looting, which is another significant factor of bias; it can affect practically all water-related features which we have gone over. The stone slabs that lined many aqueducts, wells and cisterns have been carried away. They were coveted as building material.[292] Wood, lead, and earthenware features may have suffered the same fate. There is also intensive plowing, which is assuredly responsible for the destruction of a large proportion of features. Beyond this, we have

[290] Vitr.*De Arch.* 8.6.14.
[291] Vitr.*De Arch*. 8.7.6; Plin.*HN* 5.31.34, 16.42.81.
[292] Beaumont 2008, 69.

sloppy – or, if you will, early – archaeological work, where some features were not reported because they were not recognized for what they were, or not deemed important enough. The reverse is also possible – and, in fact, likely. Features recorded as water-related may have been mislabeled. Furthermore, there is the possibility that some types of features, like wells or cisterns, were placed outside of an installation. This is exceedingly common in Syria and Jordan, and there are a few cases where this has been observed in Great Britain as well. However, many British excavations do not stretch beyond the enclosure of a fortification, in which case these external features would not be discovered.

Ultimately, there is a strong possibility that many sites once had water-related features of some kind, but they are now gone. Yet, even if we take all these elements into consideration – looting, the impermanence of certain materials, intensive agriculture, negligent archaeological work, human error, etc. – it is still unlikely that they will account for the total mass of sites with no apparent features. I would like to propose here the possibility of manual collection. With practically every military installation within a few hundred meters of a water source, and the labor investment for collecting large volumes of water being so small, manual collection must be seriously considered as a potential means of long-term supply – especially as we lack evidence saying otherwise at so many sites. A few men on water collection duty every day would more than cover the drinking water requirements of a fort. As I previously stated, this was the predominant manner in which water provision was managed for an army in the field. It is also conceivable that this work was managed not by soldiers, but by slaves. Roman society was, after all, to a large extent based on slave labor. Another possibility is that water supply was the responsibility of villagers from a nearby *vicus*.[293] These may then have been paid laborers. It is difficult to imagine, however, that a fort garrison could not manage such a slight investment of labor without any outside help.

Allow me to clarify that I am certainly not saying that all the sites where no water-related evidence has been encountered are all sites where water was manually collected. I am saying we should not exclude the possibility that this was actually a method that was used. It is a very moderate proposal.

In the end it is impossible to provide a single, straightforward answer. It is difficult to pursue these questions productively, and there is very little that we can determine definitely. Wells and aqueducts were decidedly used at 33% of forts (16% & 17%, respectively) in Roman Britain. At 3% of forts both these methods were employed. At 7% of sites we have only cisterns, but we cannot say whether these were fed by rainwater or by other means. As for the rest of the sites, we must be content with suggesting how it may have been. Some of these forts may have been manually supplied. This method would of course leave no material traces. Now, absence of evidence should never be regarded as evidence of absence, and it is in fact highly likely that aqueducts, wells and cisterns are all underrepresented in the finds, but I would urge that we consider manual collection as a potential method. There is nothing to say that several methods were not employed, e.g. rainwater for industry and other practical applications, and manually collected water for drinking (or any other combination).

Such an indefinite conclusion may be unsatisfying, but that is the way it must be. Science demands a tolerance for ambiguity. Skepticism should only be surrendered in the face of solid evidence.

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[293] *OCD*[3] (2003), 1598, s.v. Vicus (N. Purcell). *Vicus* is a term signifying a small settlement. These often sprang up nearby Roman military installations.

4.2.2. Fortresses in Roman Britain

The arguments and conclusions in the discussion on forts are very much relevant here, but fortresses do require a limited, separate discussion. Fortresses differ from forts in several respects that are pertinent to a debate on water supply strategies. The first one is obvious – they housed a greater number of soldiers. A second difference is that a fortress was the stage of substantial industrial activity. I will attempt no calculation of the water requirements of this activity, but we may assume that they were considerable. Thirdly, the settlements that were established in connection with the fortresses grew quite large. My point is that fortresses required much more water than forts, even beyond the drinking water requirements discussed in section 2.5. This must have had some influence on water supply strategy. This may be the reason for the discrepant statistical results between forts and fortresses.

We can observe marked differences in the archeological material (*Fig.* 12). Aqueducts or signs of aqueducts have been found at 9 sites (~62%), with one of these (~6%) also having wells. Wells alone have been encountered at 3 sites (~19%). One site only had cisterns, this being Inchtuthil (which, as you may recall, was unfinished). At only two sites (~13%) are there no traces of a water supply system.

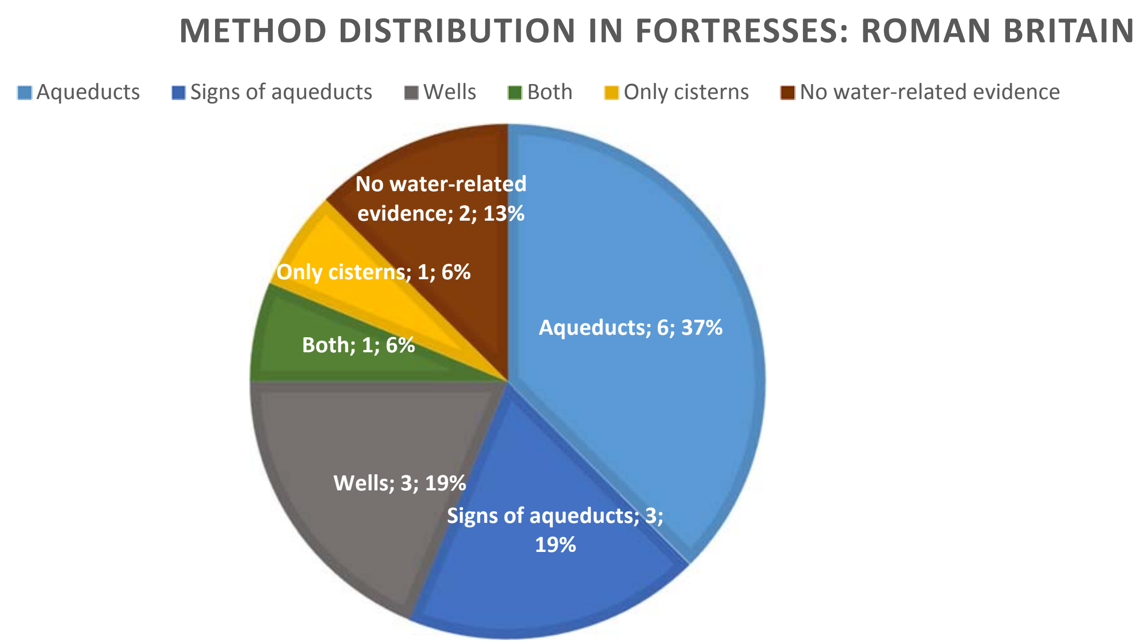

Figure 12: The water supply methods of fortresses in Roman Britain.

I would like to make a point out of the relative fewness of excavated fortresses with no water-related features. It ought to lend some strength to my proposition that water may have been manually moved to many forts, as this method would have left no material remains, and so many forts lack any water-related features. Another explanation for this variance may be that fortresses have received much more attention, and are more thoroughly excavated, but I do not believe that is the case. When it comes to fortresses, I am more inclined to agree with the verdict of Romano-British scholars saying that aqueducts were standard – at least when fortresses assumed relatively permanent positions.[294]

[294] From the Claudian invasion of Great Britain to the early second century legionary dispositions shifted frequently (Hassal 2000, 51-53). This subject is well-covered in literature, but there is no consensus on exactly where the legions were based, the dating of the transfers, or even which sites were actual fortresses (as discussed in section 2.1.). The transitory nature of early fortresses is likely to have had some influence on decisions such as whether to construct an aqueduct or not.

Rainwater catchment, as always, could have been feasible, but it would require a tremendous storage capacity. Manual collection would also have been a viable method; the labor investments would not be that significant in relation to the number of soldiers stationed in a fortress. However, I feel that there is something to be said for the practicality of these methods supplying such a large number of people. The cisterns required for rainwater catchment would occupy much space, and the archaeological finds just do not support this method being used at any fortress in Britain. In the case of manual collection, the in- and outflow of carts would considerable, and the question is whether this would be a functional or elegant solution for a fortress, especially as they grew and became cities. It is one thing for a frontier fort garrisoned by a single cohort with a small number of animals, and little need of water except for drinking to supply themselves this way, and another entirely for a full-strength legion with its complement of work animals, quartered in a fortress with a number of industrial functions, encircled by a growing settlement, to do the same. In the long-term, at least, they would presumably have desired a more effective water delivery system, either an aqueduct or a number of productive wells.

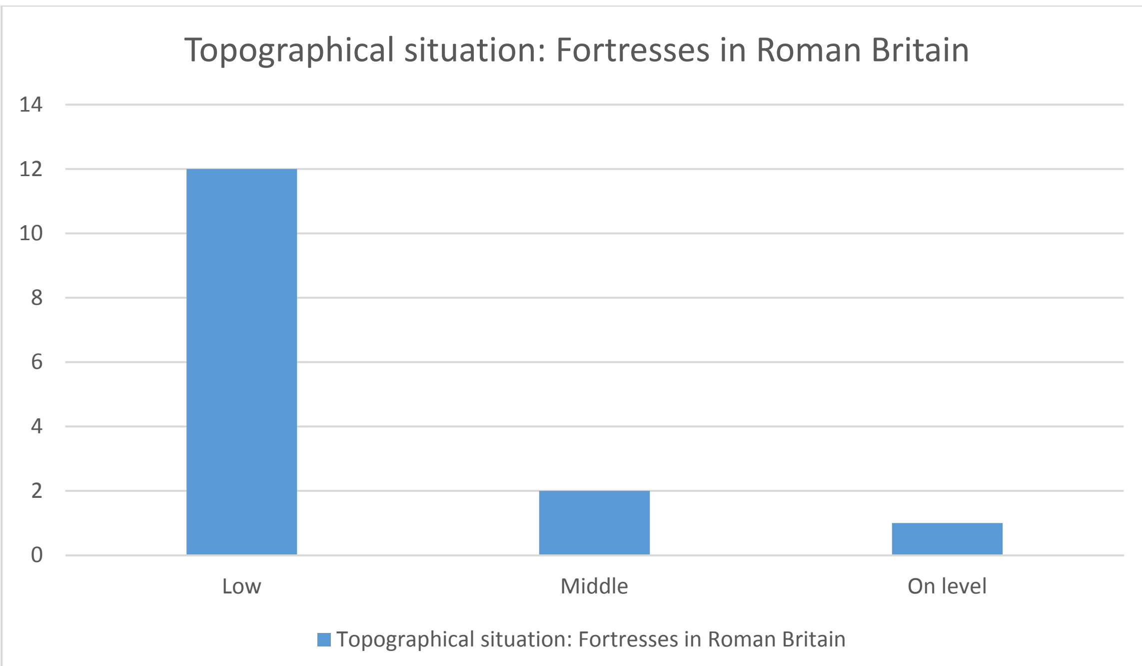

Figure 13: Topographical emplacement of fortresses in Roman Britain.

Their topographical placement (*Fig.* 13) would allow for such a conclusion. A greater proportion of fortresses are lowly situated as compared to forts, and aqueducts have been encountered at a greater proportion of them. It certainly seems that aqueducts were typical, although perhaps not present in quite all permanent fortresses. Keep in mind that the statistical basis for the fortresses is weaker by roughly an order of magnitude – 15 fortresses compared with 139 forts. Accordingly, any conclusions derived are less authoritative.

4.3. Military water supply methods in Roman Syria and Jordan: A discussion

As for the fortresses in the discussion above, I must acknowledge that the basis upon which this discussion rests is not nearly as solid as the one for forts in Roman Britain. I only have data about the first three attributes in my table for 28 sites (6 fortresses and 22 forts), and even less sites for the last two attributes. That said, I still feel that the material is more than strong enough for a meaningful discussion. Like I did with Roman Britain, I will begin with forts and end with fortresses.

4.3.1. Forts in Syria and Jordan

Some portions of the above discussion on forts in Britain are equally valid here. The problems with determining where wells are viable, for instance, have been covered. There is, regrettably, little discussion to be had on wells without information on the hydrological conditions underlying our military installations.

Regarding rainwater catchment, I have had some trouble in acquiring precise data on precipitation in Syria and Jordan. BBC Weather maintains that all of Syria east of Damascus and Aleppo (i.e. the desert or semi-desert regions that accommodate the Roman frontier) has an annual rainfall of less than ~200mm.[295] *Fig.* 14 shows the annual precipitation in the entire Middle East for the 1961-1990 period according to GCCP (Global Precipitation Climatology Centre). Most of the Roman frontier is in areas with an annual precipitation of 100-250 mm. This is a very wide range, and in addition to this, the inter-annual variability is at 30%.[296] There is also a considerable seasonal (or intra-annual) variability, with almost no precipitation at all during the three summer months. When collecting rainwater, we may assume that both initial dispersion due to heat, as well as continuous evaporation, are higher. All in all, it appears to be a very difficult environment for sustainable rainwater harvesting. A military installation in such a region would need to collect run-off from a large area, but more importantly, their storage capacity would have to be immense. The intra-annual variability would require

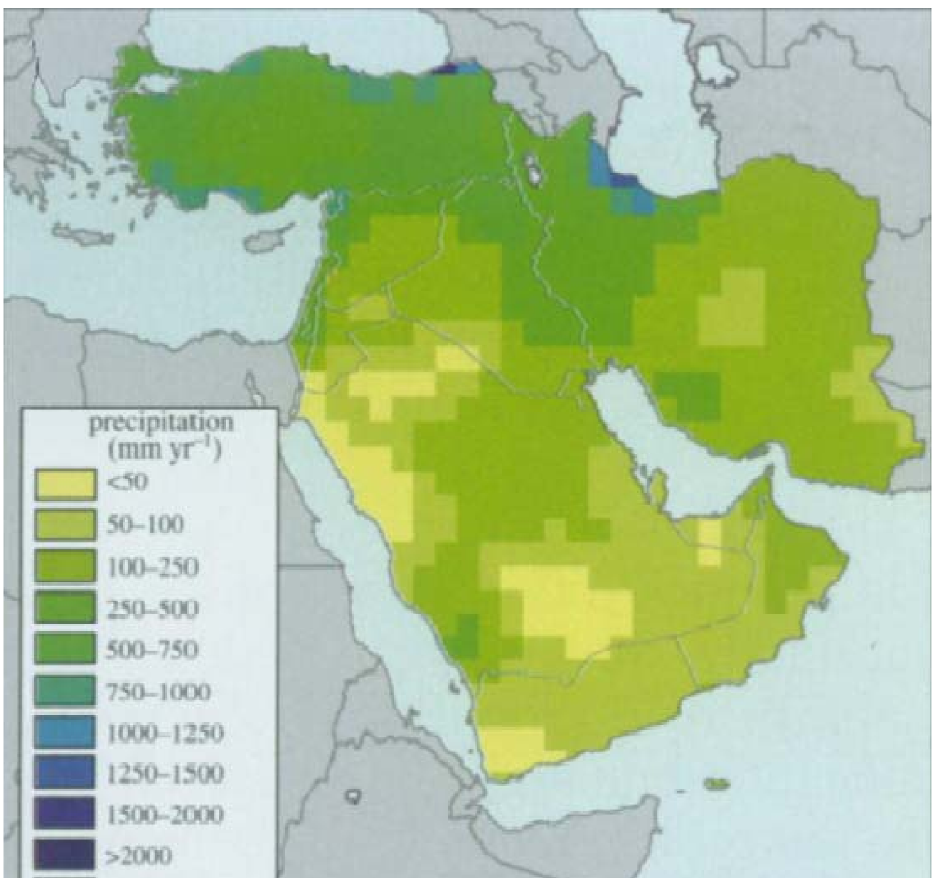

Figure 14: Annual precipitation (1961-1990) in the Near- and Middle East according to the GCCP.

[295] http://www.bbc.com/weather/features/18039209
[296] Black 2010, 5113; Hemming et al. 2010, 5118.

accumulation of enough water during the fall, winter, and spring, to last three rainless months during summer. The considerable inter-annual variability would make it dangerous do depend on. In the end, rainwater harvesting might still be viable as the sole source of water if considerable storage facilities are in place, and if we assume drinking requirements in the lower-to-middle range of the estimates.

To briefly address Josephus statements about entire cities in Judea only relying on rainwater, it must be said that his claims are actually not as unreasonable as they may appear. The Jewish homeland has considerably more precipitation than the Roman frontier in Syria and Jordan. The places specifically mentioned, Mount Tabor and Jotafata, are in the Lower Galilee, a region with an annual precipitation exceeding 600mm.[297] Rainwater harvesting is certainly more feasible in this region than along the Roman frontier.

The feasibility of both aqueducts and manual collection are difficult to settle in a decisive manner. I have only been able to determine the elevation of three sites, an amount much too small to lend itself to analysis. I can therefore not say at how many sites aqueduct may have been practicable.

There is more information available on the proximity of forts to water points, but I have had no means by which to measure the exact distance, which I was able to do for British sites. The information originates from secondary sources, either from texts or from flight photographs. From the information I possess, it appears as if forts were generally built close to water points. For all forts but one for which such information is available, that is the case.

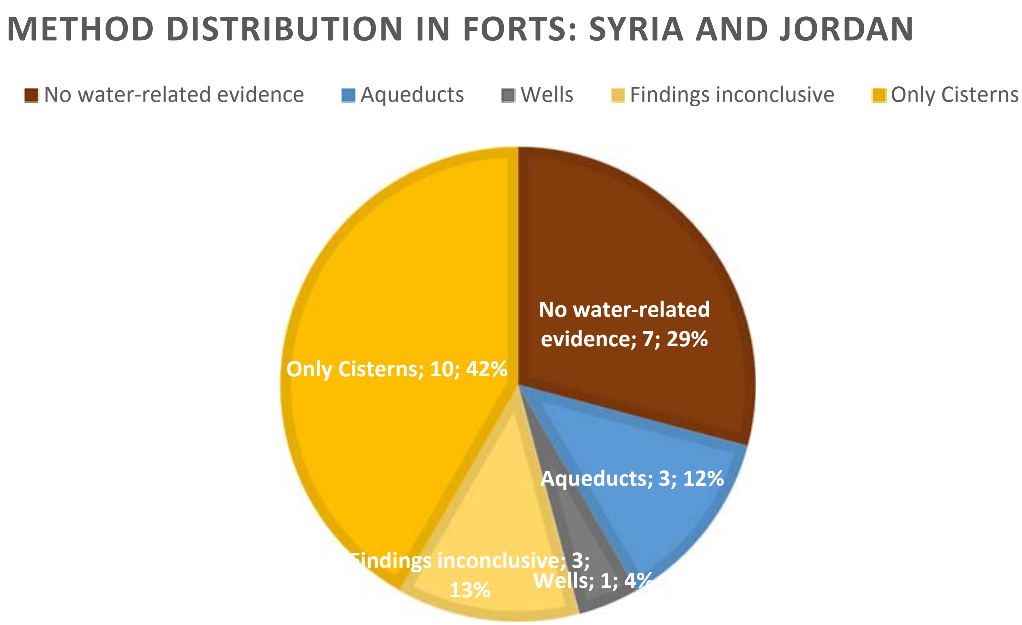

Figure 15: The water supply methods of forts in Syria and Jordan.

If we inspect the material evidence, it records cisterns alone as the most common water-related feature; they are found at 10 sites (42%). Three sites had aqueducts (12%) and one had a well (4%). One site (4%) had several wells and a qanat. The evidence was weak at three sites, but one of these possibly had an aqueduct (4%) and two may have had wells (8%). Seven sites (29%) exhibit no water-related evidence.

[297] Black 2010, 5112.

Some proportion of absent features can, as I previously discussed, be attributed to archaeological bias
Some proportion of absent features can, as I previously discussed, be attributed to archaeological bias, and much of it to insufficient archaeological work.

The archaeology (*Fig.* 15) seemingly supports the traditional view on water supply in the east, which states that command of important water points in the environment was essentially the whole strategy of Roman frontier control in the east. Water being so sparse in the desert, this could be done very economically in terms of manpower. Water was collected and stored in the wet season, and conserved during the dry season. Cisterns have been encountered at the majority of sites, not only those 42% mentioned above whose sole water-related features were cisterns. All sites which had aqueducts or wells also had cisterns, so the proportion of sites with cisterns is actually 67%.

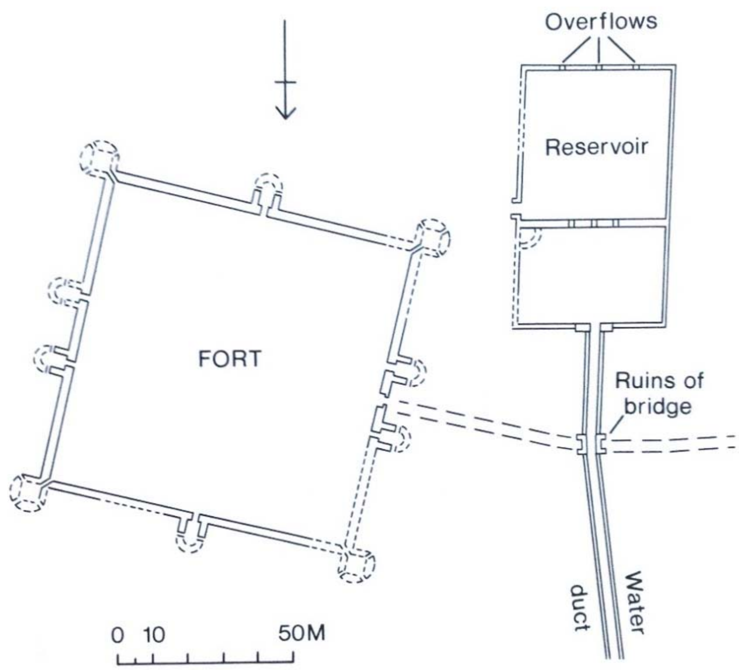

Figure 16: The fort at Khan-el-Manqoura. Note the size of the reservoir. Image source: Kennedy & Riley 1990.

Collection, it seems, was accomplished mainly by conducting rainwater run-off into cisterns. As stated, there are many sites with no features aside from cisterns. We can see enormous reservoirs (*Fig.* 16) in these regions. Unlike cisterns in Roman Britain, these are without exception sited externally, undoubtedly because of their sheer size. The same size may have made rainwater collection possible as the sole source of water, though it is possible that it may have needed supplementation at certain times – very long summers, droughts, etc. In some cases water was directed from water points via aqueducts. However, even in cases where an aqueduct is present, the inflow of water is not necessarily constant. The reservoir at the fort of Khan-el-Manqoura in *Fig.* 16, for instance, was fed from a so-called *wadi*. *Wadis* are river beds with only intermittent streams. There is running water only during the wet season. Thus, even forts fitted with aqueducts may have needed to exercise strict conservation of water during the dry season. Of course, some forts may have been supplied by perennial streams, or springs, etc. By all appearances wells were relatively rare, but were used in some places. Since water points were so rare in the desert, and many of them were not perpetual, it would have been harder, if not impossible, to rely on manual movement of water in this environment. Some installations were located near rivers which flowed year-round, and in these cases manual collection would naturally have been possible. In summary, forts in the east subsisted mainly on rainwater collection, although some had aqueducts, and wells were sunk only in rare cases. Some indeterminate proportion may relied on manual movement of water.

4.3.2. Fortresses in Syria and Jordan

This investigation is comprised of only six eastern fortresses, and the data is poor. It is difficult, on the basis of our limited knowledge of these installations, to conduct thorough and authoritative discussion.

All the fortresses except for El-Lejjun were situated in already existing cities. This is a crucial difference between western and eastern fortresses. Those in the east were typically placed in sizable cities. The infrastructural provisions for supplying large masses of people with water were already in place. The army probably adopted existing systems.

Examining the archaeology, we find that there are both aqueducts and cisterns at two fortresses (33%). One had wells and qanats, but no cisterns (17%). In two of them only cisterns have been found (33%), and one – Dura-Europos – exhibits no water-related evidence at all (17%). Again, cisterns are present at a large majority (66%) of sites.

As I stated in the discussion on fortresses in Britain, the water demands of a fortress exceed those of a fort for several reasons, not only the additional drinking water needed for the higher number of men. We should also recall that in the desert regions that these fortresses occupy, water requirements are even higher. Fortresses with aqueducts fed by perennial sources, or those which had productive wells, would not have faced any problems, but rainwater catchment is probably out of the question as the sole source of water. If Josephus records that cities in Judea – which has a threefold higher precipitation – sometimes had problems in sustaining water supply with only rainwater catchment, it would be impossible for desert cities. Consider the size of the reservoir at Khan-el-Manqoura (*Fig.* 16) in relation to the size of the fort. Imagine the size of a reservoir a fortress city would require, and how large an area the run-off would need to be collected from. It borders on the absurd. That said, rainwater catchment was likely utilized *to some extent*, and covered some share of the water requirements, but it is difficult to believe a situation in which it would not need supplementation – at least in the dry season. All six fortresses are located in the vicinity of abundant sources of water, either rivers or perpetual springs, so manually moved water would be a possible additional means of supply.

Ultimately, if I were to speculate, I would say that it is likely that the majority of fortresses had aqueducts. Cities in this region have such a long history of habitation, with so many destructive events, so many sequences and layers, that it is a wonder that any meaningful and precise information at all may be extracted from archaeological excavations. The small number of sites and the poor evidence makes any discussion problematic.

4.4. A comparison

Despite the imbalance of data between the two regions, it is plain that there was a marked difference in water supply strategies on the eastern and the western frontier. It may have appeared self-evident all along. A foregone conclusion. Britain has abundant water and a clement climate, while Syria and Jordan are hot, parched, and relatively waterless, and so, the water strategies must have been different. Such a conclusion was initially, however, based only on a plausibility argument, derived from the climatological circumstances, whereas we now have hard data to support such a position.

What are the differences, then? They are less pronounced in the case of fortresses than forts. In the east, fortresses were generally sited in already existing cities, and took advantage of extant water supply systems. In the west fortresses were an impetus for urbanization; cities were founded and grew around them, and the army managed their own water supply. Aqueducts were common both in the west and in the east, probably because there are few realistic, or at least practical, alternatives for securing an inflow of water that would meet the demands of a fortress and its adjoining settlement or city. Some – few – fortresses in both regions made use of wells. The reason for this is in all likelihood that wells without bucket-chains do not provide very much water even if they are manned around the clock. They could have supplied a fortress with drinking water, but would not have met the demands of other activities requiring water. For that, several wells would be required. Rainwater catchment was decidedly much more common in the east, and may not have been used at all in the west except in rare circumstances. It is highly unlikely that it was the sole source of water for any fortress in the east, however, considering the slight precipitation rates in the region. Manual movement of water was likely not a long-term solution for a fortress on any front, though it may have been used as a supplementary means, especially in the east, where other methods were subject to considerable intra-annual and inter-annual variability. This is likely the reason that fortresses were sited very near abundant water points on both fronts. Initially, before a fortress was finished, and until such a time as another supply system was in place, it must have been the only way to provide water.

The differences between forts in the two regions is much more strongly marked. The main difference is a greater need for conservation in the east. We see a larger quantity cisterns, and they are generally much larger in size than those in Roman Britain. In the east rainwater catchment seems to have been typical, and may have represented the main, sometimes sole, means of water supply. We cannot definitely say that it was ever actually employed in Britain, even if the climate was very conducive to it. The reason for this is likely that rainwater catchment was a necessity in a place where there is little water in the landscape, and its availability varies with the seasons. In Britain, on the other hand, there were alternatives. Aqueducts and wells were more common in western forts than in their eastern counterparts, and may even be underrepresented with regards to the archaeological finds, but there is the possibility that manual movement of water was the model at a considerable portion of forts.

In the end, the inter-regional differences are significant, but so are the intra-regional ones.

5. Summary, conclusions, and ending remarks

Let me relate back to the three questions stated at the outset of the thesis.

1. Where did the water come from? I.e. what methods of water supply can be identified in historical sources and the archaeological record?

2. Were the methods by which the soldiery acquired water the same in all parts of the empire, or was there a considerable degree of environmental adaption?

3. Were the camps topographically situated in such a way as to make it plausible that proximity to water was superordinate to other strategic concerns (i.e. the defensibility of the position, its importance for territorial defense, etc.)?

The first question was answered throughout chapter 2 and 3. The secondary and primary sources give us four basic methods: 1. Manual collection, 2. Rainwater catchment, 3. Wells, and 4. Aqueducts.

I will answer the third question before moving on to the second, as that one is more complex and will require a longer answer. As the charts on topographical elevation (*Figs.* 9 & 13) demonstrate, sites in Britain were, remarkably, typically situated in lowland positions. The term “remarkably”, I suppose, conveys something about the unexpectedness of this result. It contradicts conventional military wisdom, which upholds that fortifications are constructed on elevated sites. Elevation provides visibility and defensibility. This is a basic strategic tenet. Now, we do not know whether this was done in order to facilitate the construction of an aqueduct, or to simply for the nearness to water, but it is difficult to imagine that such a conventionally non-strategic placement was not somehow water-related. Accordingly, the answer is that it certainly seems that water was superordinate to other strategic concerns.

The second question was partly treated in the comparison above. The answer is no. There was no pan-Roman military convention of water supply. It varied from fort to fort, and from fortress to fortress, although aqueducts were likely prevalent in fortresses on both fronts. There was need for such quantities of water – for many uses – that aqueducts were often, if not an actual necessity, then at least a considerable practical convenience. Forts, to a greater extent, exhibit a strongly marked variance. There were definitely regionally predominant methods in forts, even if they were not absolute. Rainwater catchment was typical in the east, but all the methods were used to some degree. It certainly appears that rainwater catchment was seldom, if ever, the utilized in Britain, even if Beaumont has demonstrated that it would easily have been feasible. This may have something to do with varying desirability of different water sources. Considering how seldom rainwater catchment was apparently employed in Britain, despite climatic advantages, it may be that rainwater was not actually desirable as drinking water. In Britain, the Romans preferred and chose other means. In the east, they were not afforded the luxury of choice. Forts in Britain made more frequent use of aqueducts and wells, especially at larger, more permanent installations, but the notion that aqueducts were standard has little basis in facts, and should be reassessed. I would like to finish off with a few comments on why this view is so prevalent.

Let us consider the facts:

1. The vast bulk of installations could potentially be fitted with aqueducts (*Figs.* 10 & 13),
2. Most of these sites lack any kind of water-related features, and
3. The Romans were capable of building aqueducts.

Many distinguished British scholars have contemplated these circumstances and then concluded that the archaeological bias is responsible for the lack of evidence, and aqueducts must have been the standard method of supply. We can recognize a shortcoming here – a rather serious one – in that line of reasoning. We do not know for a fact that forts were situated in low-lying positions in the landscape to enable the construction of aqueducts. The archaeology certainly does not support such a conclusion. So why is this idea so prevalent? Why do so many scholars nurture it? Well it is, for one, not entirely irrational to think that soldiers possessing the know-how would have installed aqueducts for their convenience – it may even seem obvious. But if there is anything that modern science ought to have taught us by know, it is that nothing that seems obvious is necessarily true. An appeal to convenience is not a well-founded or tenable argument. I think there may be something else as well. I think that the idea speaks to us – the Romans and their aqueducts. But our preferences do not count. An additional reason for the prevalence of this view is doubtlessly that no one has really considered manual movement of water as a real, long-term alternative. Yet, as we have seen, every single site was located very near a water point, and the labor costs of moving the required volume of water would be very cheap, although constant. To what a degree, if any, the Romans viewed a continuous commitment of labor as a difficulty that needed solving is difficult to tell. Probably not at all, considering we are speaking about a slave society. I am not suggesting that manual movement of water represented the method of supply at a substantial proportion of those sites for which we lack evidence, but we should consider it as a potential method. And maybe, sometimes, absence of evidence ought to be considered evidence of absence.

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Abbreviations according to the *AJA* guide for contributors and the *Oxford Classical Dictionary*.

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