

LARGE-SCALE WATER MANAGEMENT PROJECTS IN ROMAN CENTRAL-SOUTHERN ITALY*

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*Tot aquarum tam multis necessariis molibus pyramidas videlicet otiosas compares aut cetera inertia sed fama celebrata opera Graecorum.*¹

One may plainly compare such indispensable and enormous structures, carrying so much water, with the indolent pyramids and the other useless yet renowned and celebrated works of the Greeks.

*quod si quis diligentius aestumaverit abundantiam aquarum in publico, balineis, piscinis, euripis, domibus, hortis, suburbanis villis, spatia aquae venientis, exstructos arcus, montes perfossos, convalles aequatas, fatebitur nil magis mirandum fuisse in toto orbe terrarum.*²

If anyone were to consider more carefully the vast amount of water for the use of the public, in baths, in pools, in channels, in homes, in gardens and in suburban villas, the distances traversed by the water, the arcades constructed, the mountains pierced and the valleys levelled, he would say that there was nothing more amazing in the whole world.

Extensive alteration of hydrologic systems was a conspicuous feature of ancient Roman civilization. Water was channelled and directed for a myriad of different purposes: drinking, aesthetic display, bathing, irrigation, industrial uses, land reclamation and waste disposal. Rows of arcades supporting water channels were dominant features on the Italian plains. Such arcades maintained the elevation of water brought from the Apennines so that it could reach the very highest points of urban centres. Building on Etruscan practices, marshes and lakes were drained partially or entirely in order to reclaim land for farming.³

This paper considers two case studies, both involving inter-basin transfers of water, in order to investigate elite Roman attitudes towards the use

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¹ Frontinus, *De Aquis* 1.16.

² Pliny the Elder, *Naturalis Historia* 36.24.123.

³ Purcell 1996, 190–199.

of water resources, particularly their attitudes towards deleterious consequences of such use on other communities and the wider environment. Before turning to the case studies, we must first consider how the hydrological cycle has changed in Central-Southern Italy since antiquity so that we can make use of modern data, and also consider the usage and legal control of water in rural areas.

HYDROLOGICAL AND CLIMATE CHANGE IN CENTRAL-SOUTHERN ITALY

Variables of particular interest to the hydrologic cycle are temperature, which affects evaporation and transpiration (evaporative loss of water from plants), and rainfall. These two variables exert a powerful influence on river flow (including flooding) and groundwater recharge, which, in turn, controls spring flow rates.⁴

The basic picture of the Mediterranean climate, that of a marked seasonality with dry summers and abundant rainfall only in winter, seems to have been begun between 550 and 50 BC and has remained until the present day.⁵ This seasonal variation, and the resulting reliance on spring water during summer, is confirmed for the Apennine springs of Campania in the early fifth century AD by Paulinus of Nola.⁶ The numerical values of rainfall and temperature in antiquity, however, would not necessarily have been comparable to those of today. Even over the short period of time since the beginning of record keeping, annual rainfall in Central-Southern Italy has decreased by 18%.⁷ The rainfall pattern has also changed, resulting in fewer, more intense rain events, which lead to more run-off, decreased infiltration and hence decreased groundwater recharge.

In general, in Central-Southern Italy over the last 3000 years, the climate has alternated between warm, dry periods and cool, wet periods.⁸ The warm, dry periods, through increased evapo-transpiration and decreased rainfall, would have seen reduced river and spring flow rates. The opposite would have been true for the cool, wet periods, which, through increased rainfall, saw increased flooding and sediment transport in rivers. Giraudi and co-workers have recently provided the first comprehensive reconstruc-

⁴ Chen, Grasby, et al. 2004; Fiorillo et al. 2007; Dragoni and Sukhija 2008, 4.

⁵ Peyron et al. 2011.

⁶ *Carmen* 21.752–753.

⁷ Fiorillo and Esposito 2006, 1.

⁸ Dragoni 1998, 261.

tion of climate in Central-Southern Italy over the past 10,000 years.⁹ They used Apennine glacial advances and retreats (which basically correlate during our period with those of other European mountain chains and with evidence for large amounts of ice in the North Atlantic) and related processes as proxies for temperature. Lake levels and $\delta^{18}\text{O}$ (stable oxygen isotope composition) of carbonate deposits from caves (including stalagmites) and lakes (shells) were used to estimate the water balance (precipitation versus evapo-transpiration). These data are believed to represent climatic, rather than human-induced, changes, although this is less true with regard to lake levels (see below). The period encompassed by our case studies, that is to say between the late first century BC and the fifth century AD, lay between cool and wet periods dated to 850–650 BC and AD 550–750. Apart from some evidence for a minor increase in rainfall in the late 2nd/early 3rd century AD discussed below, Central-Southern Italy seems to have been undergoing a warm, dry climate at this time. The most recent cool, wet period was between AD 1450–1650, during the period known as the Little Ice Age. Hence, the late 19th and 20th century were also a comparatively warm and dry period, happily rendering the period of instrumental records of climate a reasonable analogue for our period of interest.¹⁰ Temperatures and probably also rainfall, and hence spring discharge, were seemingly comparable to the only data we have available (but see the discussion of flood history below).

Flood History

The situation regarding the flood history of Central-Southern Italy is more complex. The flood history of the Tiber River (and of the Po) and the levels of Lakes Fucino (east of Rome) and Accesa (in Tuscany) (Fig. 1) are well-correlated with Alpine glacial retreat and advance, a proxy for regional temperature change.¹¹ The exception is the warm period between the 3rd century BC and the 3rd century AD, a time of increased flooding in the Tiber despite warmer temperatures. Giraudi claims that this period was one of increased rainfall, citing increases in the levels of Lake Fucino and Lake Ledro in northern Italy, and coeval flooding in the Po Basin, while also allowing that human action in the Tiber Basin may have played a major role.¹²

⁹ Giraudi et al. 2011.

¹⁰ Lamb 1995, 157–159.

¹¹ Giraudi 2011, 8–9.

¹² Giraudi 2005; Giraudi 2011, citing Giraudi 1998 for the Lake Fucino data.

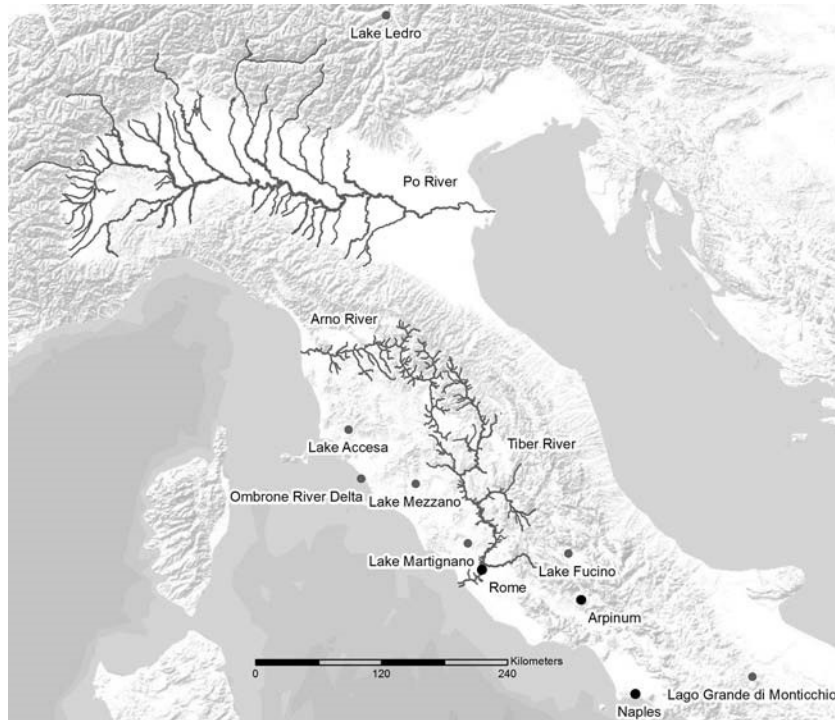


Fig. 1. The Italian Peninsula. Based on data provided by ESRI Inc.

The major relevant human activity was probably land clearance and consequent deforestation. The Greco-Roman world witnessed massive land-clearance and engaged in heavy and prolonged consumption of wood, especially perhaps in Italy.¹³ Pollen evidence attests to deforestation in most parts of Central or Southern Italy starting from around 1700 BC or even earlier, with the process seemingly reaching remote, elevated sited sites such as the Lago Grande di Monticchio (Fig. 1) around the turn of the era.¹⁴ River basins, especially the Tiber, were particular foci for the wood industry, since the rivers provided the means to transport the wood to market. Reduction of forest and other vegetation cover increases the frequency and height of flooding by reducing the amount of water retained in plants and the soil and increasing

¹³ See most recently Kaplan et al. 2009, Harris 2011a, and Harris this volume.

¹⁴ Ramrath et al. 2000; Allen et al. 2002.

erosion.¹⁵ Instead of being retained and slowed in the vegetation, more water runs off into streams and rivers more quickly. Increased erosion arising from the lack of vegetation also fills buffers, such as lakes, with silt, reducing their capacity to slow and minimize flooding. Silt also fills the channels on the flood-plains, reducing their capacity and preventing the quick movement of water out of the basin, and raises the height of the flood-plains, again increasing flood heights.

Of course, similar historical processes to those affecting the Tiber Basin were also affecting that of the Po at this time. Significant siltation and progradation at the mouth of the Po testifies to the large sediment loads carried.¹⁶ During the same period, multiple rivers in Basilicata also show evidence of similar siltation processes that have been attributed to human activity.¹⁷ Slightly later, in the 3rd century AD, we see the beginning of an acceleration of siltation in rivers at Naples and Velia that has been attributed to a combination of human activity and climate events.¹⁸ Hence, there is clear evidence for anthropogenic factors that could explain the increased flooding of the Tiber and the Po, and those of other Mediterranean rivers such as the Arno (Fig. 1) and the Rhone,¹⁹ and we need not posit increased rainfall on the basis of this evidence.

It is interesting that sediment accumulation in the Ombrone river delta (not far from Rome, Fig. 1) is well-correlated with those of the Tiber and Po (and with known climatic cool and wet periods) for the Late Holocene, except for the Roman period, where there is no large sediment accumulation.²⁰ If this is not due to marine erosion, could it be that there was little anthropogenic influence on this particular catchment?

The other evidence for increased rainfall during this period is also inconclusive. Lake levels are affected by changes in precipitation and evapotranspiration, but also by local non-climatic factors, such as changes in land use.²¹ As a result, only multiple synchronous movements in lake levels within a region should be taken as evidence of climatic change. In addition, use of lake levels as a proxy in Italy in the Holocene is hampered by a lack of comprehensive and continuous data at a sufficient number of different sites.

¹⁵ Hughes 1994, 82–84; Yin and Li 2001; Beven 2003, 529, 538; Walling 2006; Roberts, Brayshaw, et al. 2011.

¹⁶ Hughes 1994, 84.

¹⁷ Piccarreta et al. 2011.

¹⁸ See the contribution by Russo Ermolli and co-workers to this volume.

¹⁹ Magny et al. 2009.

²⁰ Magny et al. 2007, citing Bellotti et al. 2004.

²¹ Magny 2004; Giraudi et al. 2011.

There are question marks over both lakes cited by Giraudi as evidence. Regarding Lake Fucino, it is strange that the contemporary publication by Giraudi and co-workers shows no high stands of Lake Fucino within approximately 500 years of the turn of the era.²² A possible explanation is that the increased level shown by Giraudi in his 1998 publication was too small and/or short-lived to be noted in the longer-term and, hence, lower-resolution 2011 study by Giraudi and co-workers. This could be because the increase in level at Fucino cited in Giraudi's 1998 article was abruptly cut off by draining, that is to say by anthropogenic activity. The level of Lake Fucino could also reflect tectonic activity, adding another potentially confounding factor.²³

Regarding Lake Ledro, there is clear evidence for high lake levels around the turn of the era.²⁴ How relevant is this site on the southern slopes of the Alps (Fig. 1) to the climates of Lazio and Campania? If in fact we bring in a wider survey of lake levels around West-Central Europe, we see that our period of interest is bracketed by major lake high stands at 800–400 BC and AD 750 with a minor high stand at AD 150–250.²⁵

The third relevant lake is Lake Accesa. Its level steadily declined from c. 750 BC, reaching a low around AD 200 before a short-lived increase.²⁶ The next major high stand was c. AD 750. Unfortunately, the data available for Lake Mezzano are discontinuous at this period, partly due to the human action of draining the lake.²⁷ There is also some discontinuous archaeological evidence that the level of Lake Martignano (near Rome, Fig. 1) was higher than present in 2 BC and fell during the first two centuries AD to a much lower level.²⁸

With one lake (Fucino) showing level increases, one showing low levels (Accesa), and some evidence that another (Martignano) dropped in level, it seems difficult at this stage to maintain that there are multiple synchronous movements of lake levels in Central-Southern Italy. The fact that larger closed lakes, such as Lake Fucino, are more likely to reflect climate change than smaller ones, such as Lake Accesa,²⁹ is irrelevant, since multiple synchronous datasets are required. Given that

²² Giraudi et al. 2011, 109–110, Figure 3. The results for Accesa are given in Magny et al. 2007.

²³ Giraudi et al. 2011.

²⁴ Magny et al. 2009.

²⁵ Magny 2004.

²⁶ Magny et al. 2007.

²⁷ Giraudi 2004.

²⁸ Dragoni 1998, 245; Giraudi 1998, 11.

²⁹ Giraudi et al. 2011.

1. the late Republican/Imperial Roman period seems to be the only exception in the late Holocene to an otherwise good correlation between low temperatures and higher rainfall, and that
2. the only evidence for this exception is ambiguous and derived from lake levels (the proxy least reliable, and most susceptible to local factors such as anthropogenic influence, among those considered by Giraudi and co-workers),

the explanation of predominantly anthropogenic activity (which is well-attested for this period), rather than increased rainfall, for the increased flooding in the Tiber and Po valleys seems to resolve the problem nicely. This also puts the Central-Southern Italian climate in sync with that of West-Central Europe, which, with the exception of Lake Ledro, shows low lake levels at this time. It therefore seems prudent, until further data from more lakes results in a more univocal testimony of climatic effect on lake levels in Central-Southern Italy, to continue to regard the Roman period as another warm and somewhat dry period within the late Holocene history of Central-Southern Italy.

I will conclude this section by noting that there are numerous problems in using written sources to reconstruct comparative flood histories. One is the uneven survival of written sources from different time periods. It has been suggested the 10th and 11th century AD Italian records are defective.³⁰ Much depends on the flood's impact on the literate elite, which may not correlate with actual flood magnitudes.³¹ Large floods whose impacts are felt largely in rural areas with low population density are less likely to be recorded. Nevertheless, for Rome from the late Republican to the middle of the imperial period we have some of the best written records of flood history from pre-modern Europe.

RURAL WATER USE AND ACCESS IN CENTRAL-SOUTHERN ITALY

A major use of water here would have been for irrigation.³² Frontinus describes the careful, time-based allotment of the water of the Aqua Crabra for irrigation of surrounding *villae*, including that of Cicero in earlier times, that was disrupted by the addition of this stream to the Aqua Iulia.³³

³⁰ Camuffo and Enzi 1996, 440.

³¹ Dragoni 1998, 243.

³² Thomas and Wilson 1994, 157–158.

³³ Frontinus. *Aq.* 1.9, Cic. *Leg. agr.* 3.9.

Similar irrigation systems, also from central Italy, were depicted in *CIL* 6.1261 and *CIL* 14.3676.³⁴ It is not clear whether they were supplied by rivers (as is more likely) or by aqueducts. The regulation of the use of water in this way shows that there was a high demand for water for irrigation and that there were concerns about scarcity.³⁵ An example of proposed aqueduct irrigation is preserved in Cicero's *Ad Quintum Fratrem* 3.1.3. Cicero urges his brother to expend 45,000 *sestertii* on the construction of an aqueduct in order to irrigate 50 *iugera* of his land, probably near Arpinum (Fig. 1).

Another use of running water in rural Central-Southern Italy was for fishing. Fresh water fishing seems to have been an important and widespread practice in Roman Italy, although there is little trace of its presence, except in Roman art.³⁶ Roman law supported public access to most large lakes and perennial rivers (*flumina*), which seem to have been treated as a commons.³⁷ This included access for fishing and hauling or drawing off water.

Case Study 1: The Aqua Augusta

The largest and most complex of the aqueducts carrying water from the Apennines to urban centres was the Aqua Augusta.³⁸ It was Roman water management on a larger scale than ever before:

1. Rather than being a focused supply for a single urban centre, the Augusta supplied 8 or 9 different towns plus numerous villas through a network of branches (Fig. 2).
2. This network had a total length of between 139 and 145 km, making the Augusta the longest single Roman aqueduct at the time of its construction in the late Republican or Augustan period, not to be significantly surpassed until the fifth-century aqueduct of Constantinople.

Simultaneous supply (as it seems) of so many different locations suggests that the Augusta carried a large amount of water. Some of the towns supplied were significant in size: Puteoli may have been the third largest town in Italy in the early Imperial period and the third largest amphitheatre in Italy was constructed there under the Flavians.³⁹ In addition to the resident

³⁴ Cf. *CIL* 8.4440 and Pomponius in *Dig.* 43.20.2.

³⁵ Bannon 2009, 48, citing Bruun 2000, 580–581.

³⁶ Toynbee 1973, 209–215; Squatriti 2002, 98–101. One reference is Varro, *Rerum Rusticarum* 3.3.5.

³⁷ Taylor 2000, 55–65; Bannon 2009, 221.

³⁸ For a more detailed introduction to this aqueduct see Keenan-Jones 2010a, 2010b.

³⁹ D'Arms 1974, 119 n. 122; Ostrow 1985, 73.

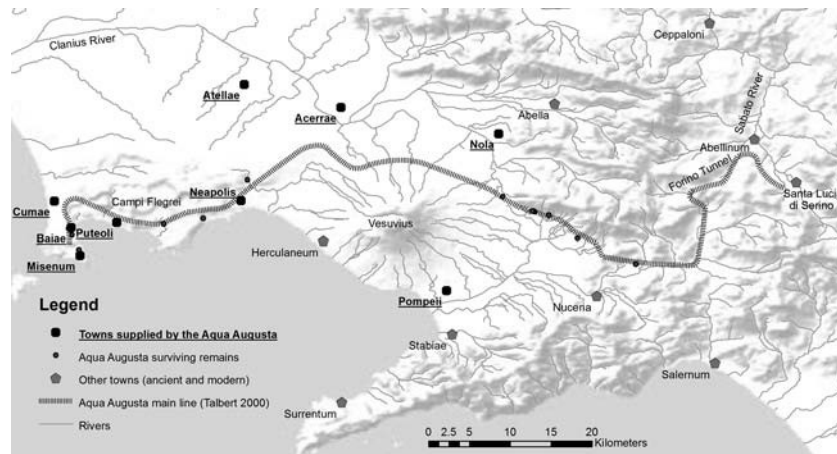


Fig. 2 The Bay of Naples in the Roman Period showing the Aqua Augusta. Based on data provided by ESRI Inc.

population, as a major port it had many visitors as well as many vessels requiring water for long voyages. Several sets of public baths, at least 8 public fountains and numerous large cisterns have so far been uncovered in the city.⁴⁰ Puteoli's demand for water would have been large, and it is not clear whether Puteoli's other aqueduct, the Campanian aqueduct, was functioning during the life of the Augusta.⁴¹

The other towns supplied were also of considerable size. Estimates of Naples' population during the Roman period range up to 35,000.⁴² On the poorly-watered western end of the bay were Baiae and Misenum. Baiae, according to Strabo (5.4.7), was as large as Puteoli. Even allowing for exaggeration, the closely-spaced yet luxurious villas of the Roman elite for which Baiae was famous would have had a large (and conspicuous) consumption

⁴⁰ Known public baths include Via Ragnisco (Republican, Gialanella 1993a, 88) and the 'Tempio di Nettuno' (early 2nd century AD, Sommella 1978, 32). Fountains: Sommella 1978, 26 (#12) & #39; Gialanella 1993b, 89; De Caro 1999, 651; De Caro and Gialanella 2002, 19; De Caro 2003, 593–594. Cisterns of note range from those on the scale of 2 or 3 interconnected vaulted rooms (Sommella 1978, #1, 11, 14 and 36) to the cavernous Piscina di Lusciano (Sommella 1978, 48), Cento Camerelle (De Caro 2003, 593–594) and Piscina Cardito (Sommella 1978, 61).

⁴¹ Maiuri (1958, 58) and Döring (2007, 110) suggested it pre-dated the Aqua Augusta. *Opus reticulatum* found in an access stair (Dubois 1907, 271) suggests the Campanian aqueduct was operational at some point during the first centuries BC and AD.

⁴² Arthur 2002, 22.

of water. Misenum, the home of the western Imperial fleet, had an estimated population of 10,000 sailors and up to 4000 civilians of citizen rank during the early Empire, who were catered to by the enormous Piscina Mirabilis cistern.⁴³

The demand for the water of the Augusta would have been great and it seems very unlikely that all these towns and villas could have been supplied to everyone's satisfaction.⁴⁴ This would have been particularly the case in summer, as we shall see below. One surviving piece of written evidence suggests greater demand for the Augusta's water than could be supplied. A constitution promulgated in AD 399 following a repair of the Augusta stipulated heavy penalties for use of its water by any private individual.⁴⁵

The Aqua Augusta represents a conscious decision, almost certainly on the part of Augustus himself, to transfer a significant quantity of water out of an Apennine river basin to supply urban centres on the plains around the Bay of Naples. How large was this transfer and what were the effects of the removal of this water at the source? Quantifying the flow rate (or flux) of the Augusta is difficult. Like all ancient aqueducts, modelling or even estimation of ancient flows is frustrated by the partial survival and limited accessibility of the channel. In the case of the Augusta, it is complicated even further by bradyseism, the slow fluctuations in ground level due to the movement of water and magma beneath volcanoes, such as Vesuvius and the Campi Flegrei (Fig. 3). This renders the all-important gradient of the aqueduct very difficult to reconstruct, at least where the aqueduct crosses the coastal plains.

One starting point in attempting to estimate the flow-rate is the flow available to the Augusta at its source, i.e. the maximum amount of water it could have carried. The Augusta was supplied by two main, perennial springs, Acquaro and Pelosi, and a minor spring, Acquarolo, all located near Santa Lucia di Serino. These springs were, and still are, fed by the Terminio aquifer, which is composed of calcareous (calcium carbonate-rich) and calcareous-dolomite (calcium magnesium carbonate-rich) strata.⁴⁶ While travelling from the aquifer to the surface, the water passes through overlying Quaternary (i.e. more recent) deposits of alluvium and volcanic ash.

⁴³ Starr 1941, 16; Keppie 1984, 103; D'Arms 2000, 134.

⁴⁴ Keenan-Jones 2010a, 4, and 6 Fig. 2. This is implicit in the inscription commemorating the repairs carried out under Constantine, *AE* 1939 no. 151.

⁴⁵ *Codex Theodosianus* 15.2.8.

⁴⁶ Fiorillo and Esposito 2006, 2.

In order to reconstruct the operation of the Acquaro and Pelosi springs during the time the Augusta functioned, we need to consider the recent history of the springs. This has been laid out in detail by a team from the Università degli Studi del Sannio in two recent publications,⁴⁷ upon which this section is largely based. The discharge data for Acquaro and Pelosi, and for another nearby spring supplied by the Terminio aquifer, Urciuoli, are available from 1887 to the present day. Rainfall data from the area are available from 1918 to the present day. Analysis of these data has revealed that over that period the mean flow of Acquaro was 300–800 litres per second (L/s) and that of Pelosi was 100–600 L/s, giving a combined mean flow rate of 400–1400 L/s (34,500 m³/day—121,000 m³/day). The range is seasonal, as the spring discharge is related to the amount of water recharging the aquifer. The recharge is a function of the effective rainfall, or the amount of rainfall over the aquifer's catchment area less any evapotranspiration.

As discussed above, this part of Italy has had a standard Mediterranean climate over this period, where the seasonal cycles of rainfall and evapotranspiration (related to temperature and humidity) are almost exactly opposite. Rainfall is lowest and evapotranspiration highest in July and there is zero effective rainfall from June to August. After a time delay related to water percolation from the surface into and through the aquifer and back to the surface, this leads to minimum spring discharge in November. From September, rainfall increases, peaking in November, and evapotranspiration decreases, reaching a minimum in December/January. First, the Quaternary deposits covering the aquifer are refilled, and once they have reached capacity, the aquifer is recharged. This and the effects of snowmelt lead to maximum spring discharge in April and May. The delay in aquifer recharge means that individual rainstorms do not affect the flow: discharge varies as a smooth curve throughout the year. The delay is a very useful feature for water supply, as minimum spring discharge does not coincide with minimum rainfall, when the spring would be most needed.

It requires an effective rainfall of c. 250 mm to fill the overlying Quaternary deposits and begin to recharge the aquifer. If recharge is less than spring discharge during the wet season, then the spring discharge continues to decrease where it would normally increase. This has only happened on two occasions since records began, 1948–1949 and 2001–2002. The discharge profiles for the Serino springs for these two years differ markedly from

⁴⁷ Fiorillo and Esposito 2006; Fiorillo et al. 2007.

the norm. In 2001–2002, the drought was exacerbated by large-scale groundwater extraction and dramatic temperature increases. Thus 1948–1949 is a better indicator of a typical Serino spring drought. The combined monthly discharge for this year decreased from around 1500 L/s before flatlining at a minimum figure of around 1000 L/s. This was the minimum even in 2001–2002 and thus probably represents the maximum effect of a short-term fluctuation such as a one- or two-year drought. Unfortunately, this figure does not show the relative contributions of Acquaro/Pelosi and Urciuoli for these two years. Given that Acquaro and Pelosi are far more sensitive to fluctuations in rainfall than Urciuoli, they were probably more severely affected during times of drought. The flow rate of Urciuoli at the beginning of the 1948–1949 drought would have been around 1200 L/s. The Acquaro and Pelosi springs (and the artesian wells near the springs) dried up completely during the 2001–2002 drought⁴⁸ and hence it can be assumed that the minimum flow rate of Urciuoli is 1000 L/s even in the worst droughts. It seems that Acquaro and Pelosi were completely dry for 3–5 months during the 1948–1949 drought.⁴⁹

The return time of these Serino Spring droughts has been calculated to be 70 years based on the data for 1887–2007. This return time seems to have begun to decrease (i.e. droughts have started to become more frequent) during the late 20th and early 21st centuries due to the large-scale groundwater extraction and dramatic temperature increases mentioned above.

Now that some quantification of the water transferred by the Augusta has been carried out, the effects of this transfer will be considered. None of the towns supplied by the Augusta were in the Sabato (ancient Sabatus) basin, which contained the Acquaro and Pelosi springs, and there is no archaeological evidence of supply to locations within that basin. The Augusta functioned as a continuous transfer of water from the Sabato basin to the Clanius basin (containing Nola, Acerrae and Atella) and the basins draining into (or, in the case of Cumae, very near to) the Bay of Naples (containing the other towns supplied) via the 6 km long Forino tunnel. The long distance transport of water from a rural source to an urban centre obviously resulted in less water available at the source, with concomitant social and environmental impacts.

The Acquaro, Pelosi and Urciuoli springs at Serino are far and away the largest springs along the course of the Sabato. The other springs, those

⁴⁸ Personal communication from Azienda Risorse Idriche Napoli staff.

⁴⁹ Fiorillo et al. 2007, Fig. 5.

at Sorbo Serpico and the Tornola (200–400 L/s and 3–5 L/s respectively) have only a fraction of the flow of those at Serino.⁵⁰ The flow of the Serino springs is currently diverted to Naples for drinking water supply. If the springs were allowed to flow into the Sabato River, however, the Acquaro and Pelosi would account for 19 % and Urciuoli 30 % of the flow of the Sabato at Ceppaloni (Fig. 3), more than 20 km downstream.⁵¹ Thus, they would together account for almost half the median flow of the river at this point and a greater share further upstream. The water from the springs would be especially important to river health due to the time lag between the springs' flow cycle and that of rainfall, described above. Thus, the springs continue to provide water even during the dry summer period when rainfall is almost non-existent. The present diversion of the Acquaro and Pelosi often causes the river to be dry downstream of these springs during the summer.

As discussed above, the modern data are a reasonable approximation for the Serino springs during the period of the Augusta's operation. This requires the assumption that the vegetation cover above the aquifer was not drastically different in these two periods, which seems reasonable. Precipitation and hence river flow when the Augusta was constructed seem to have been similar to that of the 20th Century. Both the sets of springs at Serino were tapped, and possibly dammed, in the Roman period to supply urban centres. It is not clear how much of the available water from these springs was diverted to the aqueducts. Certainly, the diversion was not as comprehensive as the modern exploitation of the springs, which also draws water directly from the aquifer using artesian wells near the Acquaro and Pelosi springs. Remains of a sluice gate visible at the entrance to the aqueduct in the 16th century suggest that the proportion of water diverted to the Augusta in Roman times was variable.⁵² The summer would have been the period of highest demand for the water of the Augusta, however, so we should not expect that extra water was released to the river at this time.

Evidence survives for the use of the water of the Sabato for irrigation. Upstream of Abellinum, signs of centuriation have been identified in the fertile valley and adjacent hills.⁵³ The effects of the removal of a significant proportion of the flow of the river on irrigated agriculture in this area had the potential to be dramatic, particularly during summer.

⁵⁰ Regione Campania A.G.C. Sviluppo 2011, 59.

⁵¹ Calculated from the figures provided in Provincia di Avellino 2009, 39–40, 48.

⁵² Lettieri 1560, 399.

⁵³ Spadea 1998, 35.

The environmental effects on the river could also have been pronounced. Rapid reductions in the flow rate of a river can severely disrupt ecosystems that have developed on a longer timescale. This is particularly the case where certain reaches of the river become disconnected, even if only temporarily. Research on modern rivers around the world has shown that the fish numbers often drop and some species become extinct in rivers under these conditions.⁵⁴

Since the Sabato River was probably a commons in the Roman period, as discussed above, damage to fish stocks in the Sabato River would have removed a source of income and/or dietary protein from those who could ill afford to lose it. In this way, the use of the water of the Acquaro and Pelosi and Urciuoli springs for urban populations was comparable to an enclosure of an *ager publicus*.

Both these impacts, on water available for irrigation and on the river itself, would have been most severe closest to the springs at Serino. Further downstream, as the catchment area of the river increased, the impact of the removal of Serino spring water would have been lessened.

Case Study 2: Tiber Flood Control

In the previous case study, the voices of upstream users of water from Central-Southern Italian rivers have remained largely mute. One case where we should be able to recover the voice of these upstream users is in the proposal to prevent the flooding of the Tiber narrated by Tacitus in his *Annales* 1.76 and 79. There is good reason to believe that Tacitus was drawing his account directly or at least indirectly from the *acta senatus*, the written records of senate business⁵⁵ and thus that he was using records of the actual speeches of the delegations from these communities.

Also that year (AD15), the rising of the Tiber, swollen by constant rain, inundated the level parts of the city. Large-scale loss of life and building damage followed the receding of its waters. Asinius Gallus therefore suggested that the Sibylline books be consulted. Tiberius indicated his denial with a nod of his head, drawing a veil over both human and divine affairs at the same time. However, the task of keeping the river within its banks was committed to Ateius Capito and L. Arruntius. (*Annals* 1.76)

This flood was towards the end of one of the worst, sustained flooding episodes in the known history of the Tiber. The 1st centuries BC and AD were

⁵⁴ Poff et al. 1997; Bunn and Arthington 2002; Richter et al. 2003.

⁵⁵ Syme 1981, 366; Swan 1987.

second only to the Little Ice Age in terms of flood events,⁵⁶ with the possible exception of a spike at the beginning of the 2nd century BC.⁵⁷ The turn of the era even exceeded the Little Ice Age in the frequency of exceptionally large flood events.⁵⁸ The AD 15 flood was the 8th recorded in 45 years.⁵⁹

There were major incentives for Tiberius and the Senate to seek to remedy the situation. Tacitus highlights the loss of life and damage to buildings. Important areas such as the Forum Romanum and the Forum Boarium would always have been prone to flooding. Moreover, the pressure for monumental space and housing in the growing city had led to an increasing number of permanent public structures in the Campus Martius, a marshy area that was one of the first to be flooded when the Tiber rose. Public building had begun in the southern part of the Campus Martius in the 3rd century BC with a series of temples associated in some way with, tellingly, water.⁶⁰ More temples, a circus and porticoes followed in the late 3rd and 2nd centuries BC. The late Republic saw the grandiose building program of Pompey, including the Theatre of Pompey, and some activity by Caesar,⁶¹ but it was in the Augustan period that building in the Campus really accelerated. The list of Augustan buildings shows the importance of the area in the Augustan monumental program: the Baths of Agrippa, Ustrinum Agrippae, Saepta, Pantheon, Mausoleum of Augustus, Porticus Argonautorum, temple of Bonus Eventus, Laconicum Sudatorium, Porticus Octavia and Octaviae, theatres of Marcellus and Balbus, Stagnum Agrippae, Ara Pacis and the horologium.⁶²

In addition, the flooding of the Tiber also caused Rome's sewers to overflow, inundating low-lying areas such as the Forum and the Campus Martius with sewage.⁶³ Tacitus may have been alluding to the widespread health problems this would have caused when he stated that the loss of life followed the receding of the waters.

Early attempts to mitigate the flooding of the Tiber included raising the height of low areas, such as the Forum, by the addition of large quantities of earth.⁶⁴ As the monumental character of the Campus Martius grew (and

⁵⁶ Bersani and Bencivenga 2001, as cited in Giraudi 2011, Fig. 7.

⁵⁷ Camuffo and Enzi 1995, 1996.

⁵⁸ Calenda et al. 2009, Fig. 2.

⁵⁹ Aldrete 2007, 242–243.

⁶⁰ Torelli 2006, 92, 96–99.

⁶¹ Coarelli 1997, 532–590.

⁶² Shipley 1931; Coarelli 1997, Fig. 140.

⁶³ Hughes 1994, 163.

⁶⁴ Aldrete 2007, 177–178.

also the population of the city), so did the scale of the solutions to remedy the problem. Julius Caesar had apparently canvassed a plan to divert the Tiber alongside the Vatican in order to enable further construction on the Campus Martius.⁶⁵ Probably in an attempt to do something about the flooding problem that was adversely affecting so many of his new constructions, Augustus further raised the level of the Forum, widened and deepened the Tiber and, according to Suetonius, seems to have appointed *curatores alvei et riparum Tiberis* (commissioners of the bed and banks of the Tiber).⁶⁶ Dio, in discussing Tiberius' response to this same flood, mentions his institution of something very similar: a permanent five-man committee chosen by lot and tasked with ensuring the even, constant flow of the Tiber.⁶⁷

Of the two men entrusted with giving advice after the flood of 15AD, one at least is known to have possessed some expertise. C. Ateius Capito (a former consul and a legal expert) had been *curator aquarum* (water supply commissioner) for two years by AD 15,⁶⁸ so he was probably the senator with the most water-related legal and technical expertise. L. Arruntius was also a former consul but is not known to have possessed any relevant expertise. We next hear of them from Tacitus a few chapters later:

Next an item was raised in the Senate by Arruntius and Ateius regarding whether, in order to moderate the floods of the Tiber, the rivers and lakes through which it was swelled should be diverted. Embassies from towns and colonies were heard, with the Florentines pleading that the Clanis not be removed from its normal bed and transferred into the Arno river, so that this would not bring disaster upon themselves. There was similarity in the matters that the Interamnates discussed, stating that the most fertile fields of Italy would be ruined if the river Nar, having been led away through channels (for this was being prepared), spread over them and formed a lake. Nor were the Reatines silent, rejecting the damming of Lake Velinus (which there pours itself out into the Nar) after which it would necessarily overflow into the surrounding areas. Nature, they argued, which gave to rivers their sources and their courses, had considered human affairs most carefully: as it gave a beginning, so it gave limits. They further argued that the cults of the allies, which have consecrated sanctuaries, sacred groves and altars to the streams of their native lands, should be respected, and that the Tiber itself did not want to flow onwards with reduced glory, deprived of its tributaries. Either the

⁶⁵ Cicero, *Ad Atticum* 13.33.4.

⁶⁶ *Divine Augustus* 37. Cf. Aldrete 2007, 177–178, 198–199.

⁶⁷ Dio 57.14.8.

⁶⁸ Frontinus, *De Aquis* 102.2. One wonders whether he was related to the Ateius Capito who told Cicero about Caesar's plan to divert the Tiber (above, n. 66).

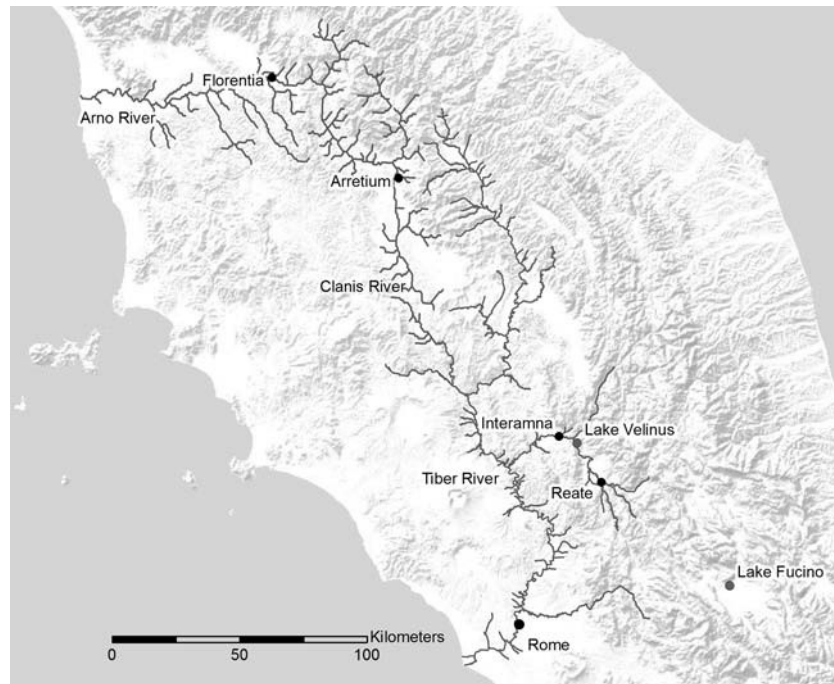


Fig. 3. The area of the proposed Tiber flood prevention works. Based on data provided by ESRI Inc.

pleas of the colonies, or the difficulty of the works, or superstition, prevailed such that at the motion of Piso, who had expressed the opinion that nothing should be changed, the plan was abandoned. (*Annals* 1.79)

We are unfortunately given few details about the planned scheme. It involved the diversion of at least two *flumina* (also described as *amnes*) and one *lacus* (but possibly more) away from the Tiber to lessen its maximal flow. Writing closer to the event than Tacitus, Pliny regarded the Clanis as one of the two major tributaries in the upper reaches of the river.⁶⁹ Figure 3 shows the Clanis after its comparatively recent diversion into the Arno. Pliny suggests that in his day the Clanis drained land as far north as Arretium into the Tiber. The Nar was reckoned by Pliny as the second largest of the Tiber tributaries below the Clanis. Hence, these were two of the major tributaries to

⁶⁹ *Naturalis Historia* 3.5.53–54.

the river, although neither was navigable (of all the Tiber tributaries, only the Anio claimed this distinction). The damming of the Velinus had ironically been advocated by the Interamnates in 54 BC (presumably to lessen flooding around Interamna), at which time it had also been strenuously opposed by the Reatines.⁷⁰ AD 15 saw the two communities making common cause.

The effectiveness of these measures, had they been carried out, is hard to judge. The diversion of the Clanis, eventually completed c. 1700, was followed by a drop in the frequency and severity of Tiber flood events.⁷¹ The major cause of this drop, however, was the end of the Little Ice Age, and numerous damaging floods still occurred after that time.

As we saw above, *flumina* (larger, perennial rivers) were regarded legally as public, with public rights of access. Unlike in the first case study, access to public water does not form the basis of the complaints brought by communities upstream, however. The communities here faced the opposite problem: a surfeit rather than a shortage of water.

Given the seriousness of the underlying problem, the communities needed to present the Senate with strong arguments in favour of the status quo. Central to the Roman elite's perception of their relationship to the natural environment was an idea of continual improvement to make land more productive and profitable.⁷² Stoic philosophy, an important influence on Roman aristocratic thinkers, placed an emphasis on such agricultural improvement, as did Cicero and Strabo, among others.⁷³ The flooding of prime agricultural land was the antithesis of this process. In particular, the outflow of Lake Velinus to be dammed had actually been created by Manius Curius Dentatus centuries before in order to reclaim agricultural land.⁷⁴

The Reatines appealed to more abstract concepts that were helpful to their cause: *natura*, *religio* and the *gloria* of the Tiber itself. Their argument was that *natura* knows best and should not be tampered with. This line of reasoning, clearly in tension with the belief in improvement described above, also stretches back a long way in complex and varying world of Greco-Roman thought.⁷⁵ It can also be seen in the writings of the Roman elite, with Cicero stating a few generations earlier that 'nature's ... administration has no component that could be criticised. The best possible outcome has been

⁷⁰ Cicero, *Ad Atticum* 4.15.5, *Pro Scauro* 27.

⁷¹ Alexander 1984; Camuffo and Enzi 1996; Giraudi 2011.

⁷² Hughes 1994, 196; Purcell 1996.

⁷³ Hughes 1994, 68; Potheary 2002.

⁷⁴ Cicero, *Ad Atticum* 4.15.5.

⁷⁵ Hughes 1994, 69.

produced from the existing elements. If someone were to think it could be better (although no one ever will), and desired to correct something, they would either make it worse or seek to do the impossible'.⁷⁶

Scale and the relevance to agriculture seem to have been important to ancient thinkers in resolving this conflicting tradition. Large-scale projects criticised by ancient Greek and Roman writers (including Pliny the Elder) as offending nature and related religious entities, such as bridges and canals that created islands out of isthmuses,⁷⁷ had benefits for transportation but not agriculture. Nevertheless, because of such transportation benefits such projects were still championed by Roman rulers such as Julius Caesar and Nero.⁷⁸ The project put forward by Capito and Arruntius was certainly on a large scale and would have negatively impacted both agriculture and transportation. The Tiber was vital in the trade of goods to Rome.⁷⁹ With the flow in the Tiber reduced, the navigable distance and navigable season of the river would also have been reduced. There is evidence of concerns at this time that occasionally the Tiber might not be navigable in summer. As we saw above, according to Dio, Tiberius' five-man committee was to ensure also that the Tiber might not 'fail in summer'.⁸⁰

No doubt the Reatines knew what they were doing when they appealed to *religio*. Sacred groves, in theory at least, were strongly protected.⁸¹ While Livy cites a widespread abandonment of the ominous conception of floods,⁸² it remained a persistent theme in history and other writing. Livy himself ascribes divine causation to 5 of the 8 floods he describes.⁸³ Julius Obsequens (unsurprisingly), Aurelius Victor and Claudian (once each) as well as the *Historia Augusta* (twice) also see divine forces at work in floods. Dio Cassius, in his brief account of the AD15 flood, notes that many at the time

⁷⁶ *De Natura Deorum* 2.34.86–87: 'cuius quidem administratio nihil habet in se quod reprehendi possit; ex his enim naturis quae erant quod effici optimum potuit effectum est ...'.

⁷⁷ Pliny, *Naturalis Historia* 4.4.10, Hughes 1994, 50–51, 69.

⁷⁸ Julius Caesar, Caligula and Nero favoured a canal through the Isthmus of Corinth (Suetonius, *Divine Julius* 44, *Gaius* 21, *Nero* 19; Pliny, *Naturalis Historia* 4.4.10), while canals linking Rome to better harbours at Terracina (Suetonius, *Divine Julius* 58.4) and Puteoli (Tacitus, *Annals* 15.42, Suetonius, *Nero* 31, Pliny, *Naturalis Historia* 14.8.61) were put forward by Caesar and Nero respectively.

⁷⁹ Cicero, *De Republica* 2.10; Pliny, *Naturalis Historia*, 3.54, Brunt 1980, 92, esp. n. 60.

⁸⁰ Dio 57.14.8. Compare Cicero's description of the Tiber as a *perennis amnis* (*De Republica* 2.10).

⁸¹ Lucan, *Pharsalia*, 3.433–437; Hughes 1994, 169–177.

⁸² 43.13.

⁸³ Aldrete 2007, 221–223, 296 n. 18, which is also the source for the following authors.

(like Asinius Gallus) considered it a portent,⁸⁴ as Dio himself does for 10 of the 12 floods he records. According to Pliny, Tiber floods made people more observant of *religio*.⁸⁵ One first century AD Roman was sufficiently concerned about divine intervention while constructing an aqueduct tunnel through a mountain important to the Bona Dea that he repaired her temple after its completion, probably making good on an earlier vow.⁸⁶

The political impacts of Capito's and Arruntius' project were also probably slightly against it. Clearly, there was political mileage to be made as the saviour of Rome from floods. Since the houses of the wealthy and powerful were concentrated on the hills out of reach of the floodwaters,⁸⁷ the constituency was largely the masses. Augustus and Tiberius (and before them, Caesar), as well as the Senate, had a vested interest in keeping the numerous poor occupants of Rome satisfied as a way of maintaining public order. In addition to the corn dole, one method was by maintaining un- or semi-skilled employment in public building projects.⁸⁸ These projects, of course, also distributed wealth to individuals across the socio-economic spectrum in Rome,⁸⁹ developing patronage networks with political benefits. Augustus was clearly seeking to underscore this patronage in his *Res Gestae*, and it is telling that all the construction projects mentioned in the work were located at Rome.⁹⁰ While presumably the considerable cost of the AD 15 project would technically have been paid from funds under the control of the Senate (the *aerarium*),⁹¹ it is clear even from the passage discussed above that Tiberius could have decided the project's future, if he had wished. This reality was surely known to those receiving the funds.

Julius Caesar's proposal for flood control would have secured a grateful Rome (if it had actually alleviated the flooding problem) but had the added advantage of conspicuously spending the funds in the city itself. The creation of the Aqua Augusta, considered above, while not benefiting the city of Rome, did spend its exorbitant funds at a critical place at a critical time. The proposal of Capito and Arruntius may have alleviated flooding, but the

⁸⁴ Dio 57.14.7–8.

⁸⁵ Pliny, *Naturalis Historia* 3.55.

⁸⁶ *CIL* 14.3560.

⁸⁷ Aldrete 2007, 211–217.

⁸⁸ Brunt 1980; Wilson 2002a, 4; Wilson 2006, 230–231, citing Suetonius, *Vespasian* 18; Aldrete 2007, 297 n. 23.

⁸⁹ Geiger 2009.

⁹⁰ With the exception of the Via Flaminia (20.5), which at least started at Rome.

⁹¹ Jones 1950.

funds would not have been spent in Rome or even in some other critical area. It should be added that this form of patronage does not seem to have been particularly important to Tiberius. He spent little on public building projects, especially when compared to his predecessor Augustus, preferring to accumulate funds.⁹²

The project would also have antagonized communities upstream. Florentia, Interamna and Reate probably had patrons in the Senate to act on their behalf. How much weight they carried we cannot know.

If the reasons behind the decision of the Senate not to proceed could not be determined a century later by Tacitus, himself a senator, we can hardly hope to do so now, given the chronological and cultural gulf separating us. Of course, the decision-making may not have been rational. There is, however, at least a plausible rationale to the decision, whether or not it was the proximate cause. A number of different modes of analysis (philosophical/religious and political) seem to have contributed to this line of reasoning: impacts upstream outweighed the benefits to the urban centre.

CONCLUSION: THE RETURN OF MODERNITY

Judging from these two case studies, it seems that the Roman elite around the turn of the era was prepared to consider, and to execute, plans involving large-scale alteration to the hydrologic landscape in order to benefit coastal urban centres and to serve imperial aims. At the same time, they show some mindfulness of the impacts of such projects on communities upstream, particularly *municipia* and *coloniae*, and of religious and cultural impacts. There is also evidence of a tension between a desire for productive alterations to the landscape and an unwillingness to upset the existing natural balance. These considerations could sometimes be exploited by upstream communities seeking to avoid adverse effects on their way of life from proposed changes.

The confident attitude to remaking the hydrologic landscape shown by the Roman elite prefigured, and, at least in Central-Southern Italy, served as a model for, the modernity of the 18th and following centuries.⁹³ The modern ideals of progress seemingly behind such Roman projects contrast with

⁹² Thornton 1986; Thornton and Thornton 1990.

⁹³ On modernity and water management, see Allan 2006; Balali et al. 2009; Molle et al. 2009.

other, often earlier, conceptions of regress in history, particularly human history.⁹⁴ Many of the later engineers who were involved in this work made explicit reference to Roman civilization. In the history of water management in Central-Southern Italy, the early Roman Empire is more similar to the 18th and 19th centuries than to any period between the two. There is, however, some continuity in the intervening period, with much effort being expended in maintaining more modest water supply systems.

The last recorded repair of the Aqua Augusta was shortly before AD 399 and it seems to have finally broken down even before the major eruption of Somma-Vesuvius in the late 5th/early 6th century buried much of its channel. A Roman aqueduct at Abella (Fig. 3), long out of commission, was repaired around AD 406 at the instigation of Paulinus of Nola.⁹⁵ The upheavals in the area during the 5th and 6th centuries probably prevented any further repairs. The construction of a new aqueduct at Salerno during the 9th century was unusual. Almost all aqueduct construction at this time was repair of Roman systems and the Salerno aqueduct was probably the last wholly new aqueduct built in Italy for several hundred years.⁹⁶ At Rome, the last ancient aqueducts had been maintained, intermittently, until the 11th century due to Papal repairs.⁹⁷

For a long time after the final breakdown of the Roman aqueducts, generally only very low-level aqueducts seem to have been maintained or constructed. The Acquedotto della Bolla probably supplied Naples during this time,⁹⁸ but the Neapolitans accessed its water through wells, rendering it vulnerable to contamination. At Romavecchia, where the Aqua Claudia and Anio Novus had soared up to 32 m above ground in superimposed, covered stone channels, the Acqua Marrana Mariana, constructed to supply Rome in 1122,⁹⁹ was an uncovered canal running at ground level.

The remains of the Roman aqueducts were sometimes reused in later ones. An early initiative was the reuse of a 1 km section of the Aqua Claudia and of parts of the Aqua Alexandrina at Rome in the construction of the Acqua Marrana Mariana.¹⁰⁰ A further step was taken with the repair of

⁹⁴ Hughes 1994, 69. These include the widespread 'metallic ages' mythological motif found in Hesiod, the Book of Daniel and Ovid.

⁹⁵ Paulinus of Nola, *Carmen* 21.706–750.

⁹⁶ Squatriti 2002, 17.

⁹⁷ Coates-Stephens 2003, 169; Hostetter et al. forthcoming.

⁹⁸ Rasulo 2002; Riccio 2002.

⁹⁹ Motta 1986b, 203–204.

¹⁰⁰ Ashby 1935, 222–223.

the Aqua Virgo at Rome by a succession of Popes between 1453 and 1570.¹⁰¹ Subsequent Papal projects at Rome were the reuse of several ancient aqueducts in order to build the Acqua Felice (completed in 1589) and of the Aqua Traiana to build the Acqua Paola (completed in 1613).¹⁰² Sufficient centralized authority to undertake such large-scale repairs and constructions seems to have reappeared at Naples rather later. The Spanish viceroy of Naples commissioned a four-year study (completed in 1560)¹⁰³ of the feasibility of repairing the Aqua Augusta, but the repair was never undertaken. The same viceroy had, however, repaired the ancient aqueduct supplying Puteoli known as the Acquedotto Campano in 1540.¹⁰⁴ Further repairs to this aqueduct are attested in 1640, 1695 and 1863.¹⁰⁵ Outside Central-Southern Italy, the reunification of Italy seems to have given impetus to such projects, with the reactivation, or investigations to do so, of Roman aqueducts at Bologna and Forlì (1880) and Corfinium (1888–1900).¹⁰⁶

Pietrantonio Abate was an engineer in the Kingdom of Naples in the mid-19th century and a leading proponent of the repair of the Aqua Augusta. After more than two decades of research into the feasibility of the project, he introduced his final report in this way:

The art under consideration (water supply), the origin of which goes back to furthest antiquity, has two hey-days: classical Rome and the present. A protracted period of decline and misery, which extends into the early years of the current century, separates these two outstanding epochs.¹⁰⁷

Abate's proposal of the repair of the Aqua Augusta was also not taken up. Instead an entirely new aqueduct, the Acquedotto di Serino (completed in 1885)¹⁰⁸ was built, which was symptomatic of the increasing technical confidence and capability in Central-Southern Italy (with British assistance in this case). The springs used for the Aqua Augusta were again transferred out of their drainage basin to supply Naples in 1938 when they were added to Acquedotto di Serino.¹⁰⁹ The ancient Romans had been surpassed but

¹⁰¹ Ashby 1935, 170; Evans 2002, 72.

¹⁰² Cancellieri 1986; Motta 1986a.

¹⁰³ Lettieri 1560.

¹⁰⁴ Scherillo 1844, 101–103.

¹⁰⁵ De Criscio 1881, 58–69.

¹⁰⁶ Bologna and Forlì (Santarelli 1882), Corfinium (De Nino 1900, 642). Evidence outside Italy also comes from Nîmes in the 19th Century (Espérandieu 1926; Fabre et al. 1991).

¹⁰⁷ Abate 1864, 2.

¹⁰⁸ Naples Water Works Company Ltd 1885.

¹⁰⁹ Lettieri 1560; Sgobbo 1938.

not forgotten: a new water system inaugurated in 1923 was commemorated by the addition of another Latin inscription in the already crowded Porta Maggiore.¹¹⁰

The diversion of the Clanis (Chiana) from the Tiber into the Arno, planned in AD 15, was actually carried out piecemeal between about 1500 and the eighteenth century. By that time, the purpose was not flood-control, but land reclamation.¹¹¹ Land reclamation on the Roman scale had to wait until the mid-19th century and it continued under Mussolini. The partial draining of Lake Fucino in the 1st century AD, mentioned above, was carried out again (and completed) between 1861 and 1875.¹¹² Lake Mezzano was similarly drained during the Roman period and then partially drained again at some point after the 17th century.¹¹³

Thus the history of water management in Central-Southern Italy shows the persistent influence of Roman technical achievements and thought right through to the early 20th century.

¹¹⁰ Aicher 1995, 168.

¹¹¹ Alexander 1984, 547.

¹¹² Giraudi 1998, 2.

¹¹³ Giraudi 2004.