

Bolla aqueduct: a two-thousand-year lasting service

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Abstract

This study aims to show the importance that Bolla aqueduct has held for over two millenniums for the city of Naples, its present role and the uses for which it could still be destined.

Bolla has been the first aqueduct for Naples, built in ancient times (Hellenistic or Roman, the dating problem has not been solved yet), and it has provided Naples with drinkable water for most of the city's millennial life, being for most of its history its main water resource.

In fact in Romans times Serino aqueduct (known as Claudius', as it was restored by Claudius emperor) brought a little contribution to it, but it was dismissed in High Middle age.

Moreover the water of Bolla's source, which originally fed the aqueduct and which has mainly kept feeding it for centuries, was considered of a quality certainly superior than the other local water sources and than the waters of the next Carmignano aqueduct.

To satisfy Naples' chronic need of water, in fact, in 1629 Carmignano aqueduct was added to Bolla, but they were both open-channelled aqueducts, which produced a lot of defiling of the waters and epidemics. Only in latest '800, as many other European cities and due to the new technologies, it was possible to construct the first pressure aqueduct for Naples, the new Serino aqueduct of 1882, which replaced the two previous ones.

It seemed that the long Bolla service had ended, but in the '30s some Neapolitan industries recovered its waters, and lately, thank to the restoration of one of its channels, it has been destined to some industrial uses for Neapolitan hinterland.

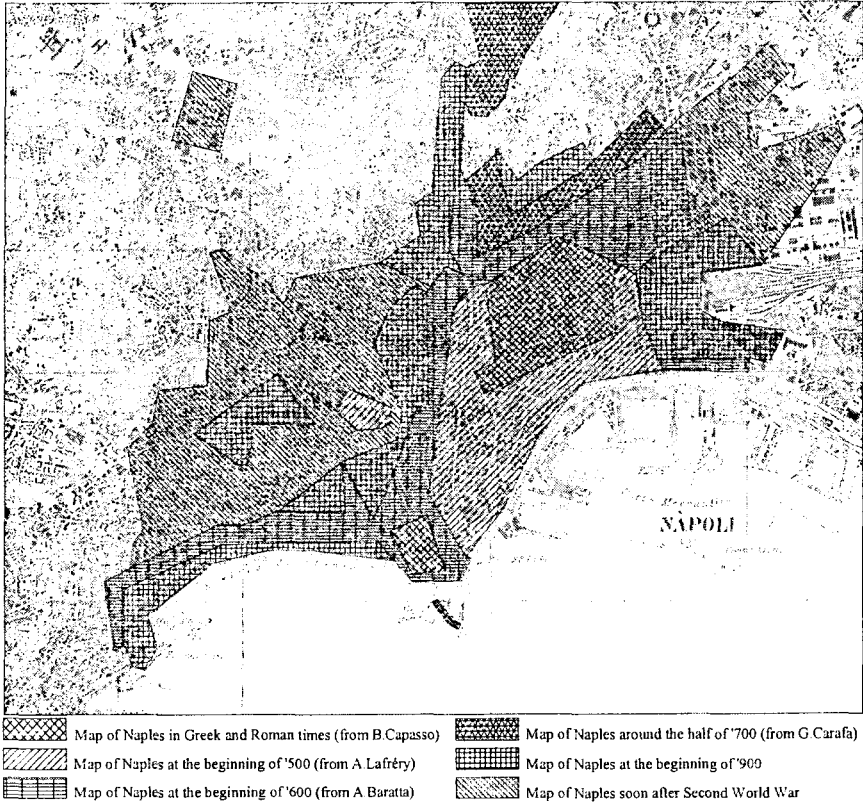


Figure 1: The development of Naples during the centuries.

Introduction. Naples and its ancient aqueducts

Naples was founded in ancient times (by Greeks around 470 B.C.) and during the centuries it has been continuously inhabited, progressively growing in extension and in its population density. In fact it can be said that Naples' urban growth has been uninterrupted ever since its foundation because, apart from some crisis period in which its population suddenly decreased, mainly its growth has been tumultuous and uncontrolled during all its long history. Nevertheless, instead of expanding, for centuries the town has been growing on itself, occupying more and more all the areas left free inside the town walls by the former civilizations, reaching a very high inhabitation density ever since a very ancient time.

Until the beginning of 19th century, the northward and westward city's expansion was hindered by the steep slopes of the hills and of the glens that surrounded the inhabited centre, while its eastward expansion was hindered by

the swamps, whose reclaiming has lasted for eight centuries, being concluded only in 1917. Only afterwards the city began to expand beyond its original border, to end with the deflagrating expansion succeeded to the Second World War.

Naples is seated on a bank of volcanic materials originated by the Flegrean volcanic system and constituted by yellow Neapolitan tufa, puteolan powder, pumices and lapillus; it has always been provided with a few local water sources and so it has never been self-sufficient for what concerns water, but it has always been forced to trace water, and in an ever-growing quantity, somewhere else. It can be said that the problem of water supply to satisfy the ever more numerous and ever more pressing demands of the city has always existed, and so the city was furnished with aqueducts ever since the ancient times.

The first aqueduct for Naples, Bolla aqueduct, was constructed in Hellenistic or Roman times and has provided Naples with drinkable water for more than two millenniums. It was furnished by several water sources, the main of which was the Bolla one, and they were sited to the east of the town (about 8 kilometres), just in that swampy, rich of natural water sources area, which constituted the natural boundary for the eastward town's expansion.

Around the second half of the 1st century a.D, in Augustan age, also another aqueduct was constructed for Naples: its name later on became "Claudius" because of a memorial tablet that there was found which testified how the aqueduct had been restored in the 4th century thanks to several princes, among which there was Claudius Constantine. It picked up its waters much farther than the Bolla, from the Apennines in Serino locality, about 80 kilometres away from Naples, and it even had a longer route (around 100 kilometres) as it ended in Bacoli, in the grand Roman military fleet's cistern known as "Piscina Mirabilis". Anyway Claudius aqueduct always had a very troubled life, probably because of the Vesuvius' eruptions and of the subsequent earthquakes, as it had first to be restored, as said, in the 4th century, and afterwards it was definitively dismissed probably in the 5th century [1].

Hydrogeological origins of Bolla's waters

Bolla aqueduct was fed by the water sources sited in that Naples' eastern area known as "Volla plain"; it is constituted by an about 2100-hectares-wide strip of plain land facing the sea in the shape of a fan and having a very low slope (the higher point measures about 24 meters above the sea level).

Originally (around 30.000 years ago) it was constituted by a deep ditch that by the years was filled with volcanic materials (belonging to the Flegrean volcanic system and most of all by the Vesuvius-Somma complex), which were constituted mainly by Campania "ignimbrite" and yellow Neapolitan tufa, but also by alluvial materials such as peat. The site's morphology and the presence along the seaside of sandy dunes which stopped the water flowing, favoured the stagnation of the area, which has always been presenting swampy characteristics and a great water richness, both as water sources and as subterranean flows [2],

which has been exploited ever since very ancient times with wells and the construction of aqueducts.



Figure 2: Volva plain.

However with the passing of the time Volva plain has lost all its water richness mainly because of anthrop causes. In fact the area has been interested at different times during the centuries by reclaiming operations which favoured both the external waters diverting and the local subterranean flow draining. The development of ever wider and ever denser human settlements, mainly in the last fifty years with the wild urbanization and industrialization phenomena in this area and with a very deep water pumping from the subterranean flow both for domestic, irrigating and industrial uses, produced its drying up and the lowering of the soil.

Today in Volva plain exist a complex system of subterranean water flows: a superficial one above the Campania ignimbrite layer, and several ones deep below it; they are connected both by interruption among the less permeable rocks and by vertical draining flows. The thousands of abusive wells, not less than 70-

80 per square kilometre, deeply alter the balance between the flows, with the risk of defiling them [3].

Presently Volla plain covers several municipalities' territories under the jurisdiction of the "Naples and Volla Reclaiming Consortium" which collects a tax and mainly attends the hydraulic and environmental restoring of the plain, of the western slopes of Somma mountain and of the plain ploughed by the external waters which once flowed in Volla plain.

Bolla aqueduct

At present it doesn't exist a complete cartographic mapping of the immense channels net which subterraneous crosses the city and which constitutes the ancient Bolla aqueduct. Moreover the uncertainty about the knowledge of the subterranean cavities produced not a few problems by an engineering and constructive point of view, because the presence of many unknown empty spaces more than once caused, in the past, the collapsing of the above buildings and installations. From a functional point of view, Bolla aqueduct is essentially divided in three sections: the first is constituted by the draining tunnels admitted directly in the subterranean water flow; the second by the main channel to the city, from the Water House to the Capuan gate, partially covered and partially open; the third by the distribution channels' net, bored in the tufa bank. These three sections do not present the same characteristics for all the wideness of the aqueduct, because some were subterranean and some were open, some were simply bored and some were paved, with variable sections and variable heights along the net.

The lack of documents does not certify the aqueduct branches dating, but it can approximately be ascribed to the periods of urban expansion in the city's various areas. Not even estimating the water carriage of the Bolla, changing during the times and along its route, is simple. Verneau at the end of the 19th century estimated Bolla's flow at its arrival to town being 14.000 m³ per day; Firrao, instead, in 1966 estimated its arrival to the Capuan gate being 5.198 m³ per day; Ruocco in 1969 estimated Bolla's flow at its beginning being 500 litres per second, equal to around 43.000 m³ per day [1]. Surely Bolla's water supply became ever more insufficient to satisfy the city's water demands.

Naples tumultuous and uncontrolled growth, as said quite constant during the centuries, not a few problems did historically produced for the city's water supply: it was constantly necessary to find out new sources with which increasing the water carriage of the aqueduct, to bore new channels and distribution branches to the city's new expansion areas and to the new users, and moreover to fight the abuses towards the aqueduct that were continuously perpetrated by clandestine picking ups and deviations.

However, even if there is not a complete and up-dated cartography of Bolla aqueduct, there are many description of it, as during the centuries several technicians and engineers were periodically charged by the city's governments with drawing its state of conservation and of usage.

The first known report was written in 1574 by the town lawyer Gaetano Lettieri, sent together with two deputies to inspection the hygienic conditions of the “Royal channel”: not only does he give precious information about that time’s channels’ conservation state, but he gives also information about the aqueduct’s increasing enterprises; another report was given in 1626 by the engineer Alessandro Ciminelli, with the very charge of increasing the aqueduct water carriage; this report was followed in 1667 by a report with 17 maps by the architect Antonio Galluccio, charged of verifying the aqueduct’s deliveries. The knowledge of the aqueduct’s legal and abusive deliveries was fundamental for the city government, and so with their census were periodically charged the technicians who carried on the aqueduct’s maintenance (there are description of the aqueduct written at several times between 1668 and 1797) [4]; these technicians were called “wellers” and were the only real expert about the water net, where they moved with familiarity. As much fundamental it was the knowledge of the sources where the aqueduct picked up its waters, and so several studies were published about it, among which stand out the one by Teodoro Monticelli [5] and the ones by Luigi Cangiano [6, 7, 8]. But the most accurate description of Bolla aqueduct net beyond Naples is due to Guglielmo Melisurgo [9].

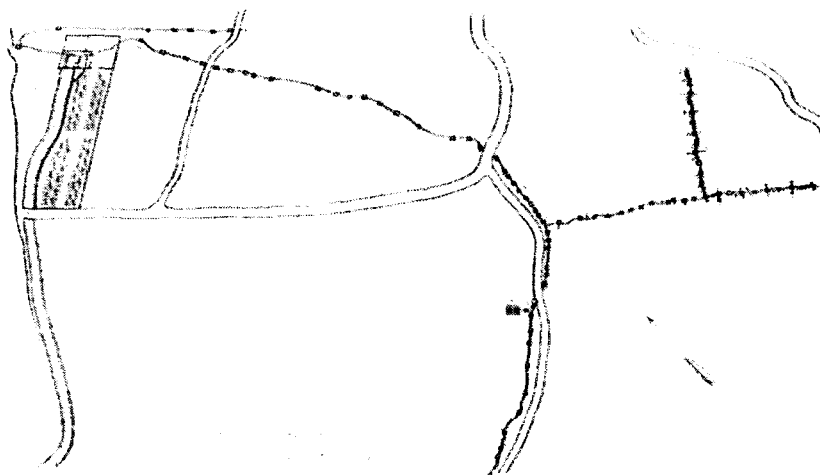


Figure 3: Map of the Water House and of Bolla aqueduct’s draining channels from its sources drawn by T.Monticelli [5].

By this description has been drawn the map presented in this study.

As said the question about Bolla aqueduct’s dating is still unsolved. Surely it is of ancient origins, but it has not been cleared up yet if Greek or Roman. The ancient aqueduct picked up its waters from Bolla’s source, from which its name was originated; this was the main water source among the numerous ones which vivified Volla plain and it sprang high quality drinkable water, much better than the water supplied by Carmignano aqueduct, built much later (in 1629).

Actually Bolla source was double, as it had two outlets not far from one another, as it's clearly evident for the first time also in the cartographic representation "*Campania felix*" made by Paolo Petrini at the beginning of 18th century [10]. The ancient aqueduct collected its waters through draining channels and flowed them into the *Benincasa branch* sited at a quote of about 19 metres above the sea level, to deliver them after a track of about 8 kilometres to the town, that it entered near Formiello fountain, a bit to the north of the Capuan gate, at a quote of about 13 metres above the sea level. Inside the town the ancient branches are surely constituted by the *Main branch* and the *Arch branch* with their main secondary branches.

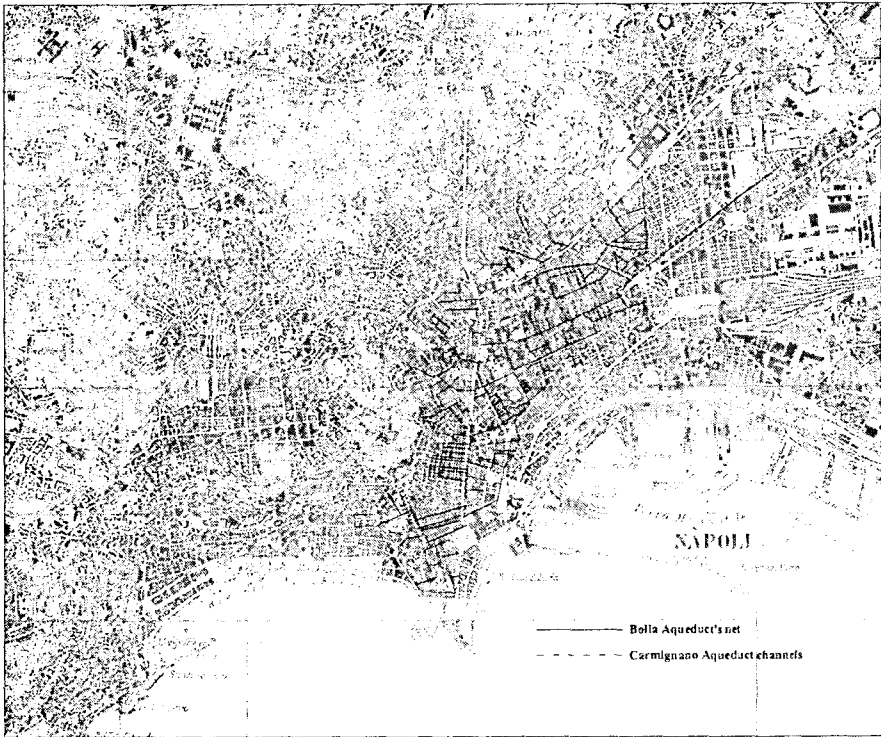


Figure 4: Map of Bolla aqueduct drawn on the base of the description made by G. Melisurgo [11].

As it seems from historical sources [11] Belisario, Byzantine emperor Giustinianus' general, managed to conquer the city from Goths just because of the Bolla: in fact, after having uselessly cut it to leave the city without water (but the population continued to be provided with water probably thanks to the wells fed from the local sources), in 537 penetrated inside the city with 600 soldiers through its branches. In the same way in 1442 Alfonso of Aragon could conquer

the city to Renato the Angevin after a long siege penetrating inside the city with 200 soldiers through the branch called *King Robert*, afterwards named *S. Giovanni a Carbonara*, that is dated to the Angevin period.

In vice royal times (16th and 17th centuries) Naples knew an extraordinary growth, and the water deliveries and picking ups along the aqueduct became innumerable, both inside and outside the urban territory, both legal and abusive: they were used by the fountains or by the mills, or they were used by merchants, religious orders, noble families and rich bourgeoisie; anyway for the most of the population the most common water form of supply were the public wells sited in several points of the city (at the end of the 19th century Melisurgo [9] counted about 3.700 wells inside the city, while Fiengo [4] estimates their number being about 9.000): today they are very difficult to be identified because almost all of them have been dismissed and obstructed.

Therefore in vice royal times also the problem of the Bolla's insufficient water carriage became more and more drastic, and this problem was even more pressing as not all the waters of Bolla's source were flowed into the aqueduct, but some of them were let to flow through the reclaiming channels on which the mills were settled. Indeed the milling activity in the plain has always been contending with the city for Bolla water, often to its profit and making the fortune of the mighty feudatories and of the rich religious orders, which historically owned the lucrative mills.

Under the government of viceroy Duke of Alcalà (1559–1571), the regent Albertino, responsible for Bolla aqueduct, inspected the water sources area and discovered two new little water sources nearby the two farmhouses "*La Preziosa*" and "*Tavernanova*". Nevertheless it was only between 1612 and 1617, under the government of viceroy Pietro Fernando di Castro count of Lemos (1610–1613), that the engineer Alessandro Ciminelli constructed the new branches to collect their waters; at the beginning these two new branches were used to feed four mills sited along the ancient town walls moat, from the Capuan gate to the Carmine gate, but already in 1629 they proved insufficient and were relieved by the new *Fogliette channel* coming from the Carmignano aqueduct that had been completed just that year; only in 1765, then, for municipal will, as the Neapolitan population had considerably increased, the two new channels were finally connected to the main course of the Bolla with the *Bardassini (or Mills channel)*. Another draining tunnel was built in the same year 1765 connecting to the aqueduct a few to the south of the Water House [4, 9].

Also around the half of 19th century other two pipes were installed by Luigi Cangiano to pour more water inside one of the aqueduct's draining channels to increase its water carriage [9]. Anyway by this time Neapolitan water necessity had become chronic. Already in 1629 the Carmignano aqueduct had been added to the Bolla, but by this time it was clear enough that these waters were not sufficient anymore. Ever more water was needed, and many projects were drawn in 19th century to provide for it: some of them still planned to pick up more waters from Volla plain, but finally in 1885 the new Serino aqueduct was constructed, taking the waters from the same area as the ancient Claudius.

Unfortunately the water net system Bolla-Carmignano had often been a means for the spreading of cholera's epidemics which many times plagued the population, among which the 1884 one which devastated mainly the low slums of Naples (Porto, Pendino, Vicaria); in fact the aqueduct in the lower part of the city flowed at the same quote, or even at a lower quote than the scarce sewer infrastructures and of the many cesspools, being bored in the fissured tufa bank and moreover lacking of the normal lime protecting layer, with the consequent water defiling: already at the half of the 16th century Lettieri had remarked that, and later on in the 19th century Melisurgo had confirmed it. Because of the sanitary problems produced by the two previous open-channelled aqueducts, the Serino, whose waters were delivered in pression, excluding hygienic problems, replaced them both. The fact of being an open-channelled aqueduct produced also relevant problems for the distribution of the waters: in fact the original quote to the Water House was of 18,52 metres above the sea level and the quote at the city's entrance was of 13 metres above the sea level, so that the channel net didn't allow the expansion of the city on the hills that surrounded the inhabited centre.

Serino completely replaced both the Bolla and the Carmignano, relegating them to the uses of the industrial Neapolitan hinterland. The subterranean cavities below the city have been long used as waste material deposits, and during the Second World War Bolla's subterranean net was used as an air-raid shelter; most of the wells were eliminated or used as dirty dumpers. It seemed that the millenary service of the aqueduct was over, but soon after the Second World War Neapolitan Aqueduct company restored its old channel adapting it to modern standards: the water was lifted from the sources by deep wells and taken in the quantity of about 500 litres per second to the city, where they were let in the modern aqueduct net by a lifting installation. The channel was finally dismissed in 1989, but is still considered for reserve.

So it can be said that the Bolla has been serving Naples almost interruptedly for about two millenniums. Presently a little stretch of the ancient aqueduct below the ancient centre of Naples has been cleaned and lighted up by a private association and can be visited to show such a great piece of our history.

References

- [1] A.M.A.N. Azienda Municipalizzata Acquedotto di Napoli, *Gli acquedotti di Napoli*. Napoli, 1994
- [2] Francesca Bellucci (Dipartimento di geofisica e vulcanologia), *Nuove conoscenze stratigrafiche sui depositi vulcanici del sottosuolo del settore meridionale della piana campana*. Bollettino della società geologica italiana n° 113, 1994
- [3] Michele Viparelli, *Le acque sotterranee ad oriente di Napoli*. Napoli, 1978
- [4] Giuseppe Fiengo: *L'acquedotto di Carmignano e lo sviluppo di Napoli in età barocca*. Leo S. Olschki Editore, Firenze, 1990
- [5] Teodoro Monticelli, *Memoria sulla origine delle acque del Sebeto*. Napoli, Tipografia Cataneo, Fernandes e comp., 1830

- [6] Luigi Cangiano, *Sulle acque potabili pubbliche della città di Napoli*. Napoli, 1843
- [7] Luigi Cangiano, *Sull' attuale conduzione delle acque pubbliche potabili*. Napoli, 1859
- [8] Luigi Cangiano, *Relazioni intorno alle acque potabili della città di Napoli*. Napoli, 1865
- [9] Guglielmo Melisurgo: *Napoli sotterranea*. Colonnese editore, Napoli, 1979 (first edition: *Napoli sotterranea. Topografia della rete di canali di acqua profonda. Contributo allo studio del sottosuolo di Napoli*. Napoli, Real tipografia Francesco Giannini & figli, 1889)
- [10] Paolo Petrini, *Campagna felice o terra di lavoro meridionale*. Napoli, 1700 circa
- [11] Procopio, *Guerra Gotica*. Newton Compton, 1974

Cartographical sources

- Bartolomeo Capasso, *Topografia della città di Napoli nell'XI secolo*. Napoli, 1895
- Antonio Lafréry e Stéphan Du Perac, *Quale e di quanta importanza e bellezza sia la nobile città di Napoli...* Roma, 1566
- Alessandro Baratta, *Napoli*. Napoli, 1629
- Bastien Stopendael, *Napoli*. Amsterdam, 1653-1663
- Paolo Petrini, *Campagna felice o terra di lavoro meridionale*. Napoli, 1700 circa
- Giovanni Carafa duca di Noja e Niccolò Carletti. *Mapa topografica della città di Napoli e dei suoi contorni*. Napoli, 1750-1775