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Coevolution in water resource development The vicious cycle of water supply and demand in Athens, Greece

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ABSTRACT

This paper adopts a coevolutionary perspective to criticize the dominant narratives of water resource development. Such narratives of progress portray a sequence of improving water technologies that overcame environmental constraints, supplying more water to satisfy the demands of growing populations for better living. Water supply appears as the response to an insatiable demand, exogenous to the water system. Instead, as the history of water in Athens, Greece illustrates water supply and demand in fact coevolve, new supply generating higher demands, and in turn, higher demands favouring supply expansion over other alternatives. This vicious cycle expands the water footprint of cities degrading environments and communities in the countryside. Far from being predetermined and inevitable, as progressive narratives wants it, water resource development has been contingent on geographical and environmental conditions, institutional struggles, accidents, experiments and external geo-political and technological forces. In the last part of this paper, I discuss the policy implications of this coevolutionary reframing with respect to a the transition to a "soft water path".

1. Introduction

You are in Athens. It is the year 1830. Greece's liberation war has just ended and 12 thousand Athenians have returned home. You are standing on top of the Acropolis watching the city below. Nothing remains but 'piles of scattered ruins … stones and parts of walls'.[1] You see people around water fountains waiting to fill their buckets, others pulling water from wells. At the time no one could have predicted the drastic transformations the city was to face.

Fast forward. The year is 2004. You are again standing on top of the Acropolis. Everywhere you look now there are multi-storey apartments, thousands of them. Four million people now inhabit the city. There are no longer fountains or wells, but 4 reservoirs, far from the city, with a capacity of 1.5 billion cubic meters (cu.m). Water passes through 500 km of canals, 4 treatment plants, 7000 km of underground pipes and flows out to 1.7 million taps. This spectacular evolution of a city and its water system is the subject of this paper.

The dominant narrative in studies of water resource development is one of progress. Heroic politicians and engineers built new waterworks that secured water, satisfying popular demands for growth and more comfortable living (e.g. Kupel, 2003). Athens' histories for example celebrate the technological feats that "watered the thirst" of a growing population (Skouzes and Gerontas, 1963). These narratives link supply, demand[2] and the environment in a particular way. Demand is assumed exogenous and insatiable, the causal driver of change. Supply, transforms a malleable environment to satisfy water demand.

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[1] French traveler Michaud cited in Kaika (2005, 89).

[2] The term "demand" is used in this paper in the water engineering sense of water use or consumption and, not in its strict economic sense.

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As technologies progress, more and more water is supplied and society is getting better.

The narrative of progress has been challenged by many (Norgaard, 1994). Environmentally minded works have highlighted the ecological impacts of water supply and the resource limitations of ever-growing demands (Pearce, 2006; Reisner, 1996; Postel, 1992). Political economists have reversed causality between supply and demand showing how powerful interests coalesce to see that water availability and related costs do not stand in the way of regional growth and profits. From this perspective, waterworks are built to create demand and growth, not to satisfy it (Walker and Williams, 1981; Worster, 1985). Institutional economists, historians and political scientists have documented the fierce institutional battles over new values and technologies that condition change in water systems (Righter, 2005; Paavola, 2002; Elkind, 1998; Platt, 1995). More recently, Marxian political ecologists have described cities and water systems as "hybrid" metabolisms that interweave flows of water, money, technology and ideology. Uneven socio-natures are produced, where some benefit and many loose (Swyngedouw, 2004; Kaika, 2005).

From these and other works, a distinction of three periods in the history of modern urban water supply emerges:

i) an early period of private control and limited domestic access to water, with low-scale, local technological solutions (roughly till mid/end-19th century),
ii) a period of State or municipal control, large engineering works and universalization of domestic water access, that has been called by Sauri and Del Moral (2001) the "hydraulic paradigm" and linked by Gandy (1997) to the "Fordist period" (roughly mid/end-19th century to 1970s),
iii) a contemporary shift to market instruments and integrated management (Gandy, 1997; Bakker, 2003; Elkind, 1998).

The present work is positioned within this rich intellectual context. It seeks to problematize the progressive narrative of water resource development and explore the complex interactions between technologies, institutions and nature, supply and demand, power and distribution through which urban water systems gradually evolve.

A time sequence of events, such as those that mark Athens' water history (Fig. 1), lacks a narrative. A narrative needs theory to select important from un-important events and link them causally (Cronon, 1992). The theory of coevolution (Norgaard, 1994) is used here as the glue to bind an alternative narrative. Coevolution "provides a sophisticated explanatory framework which can incorporate a multi-dimensional and cross-disciplinary approach to dealing with complex … change" (Kerr, 2004, 331). Others too have referred before to coevolution in relation to water management but did not develop it beyond a metaphor for interaction between multiple variables (Aguilera-Klink, 2000) or for social adaptation to climate variability (Adger, 1999).

The building blocks of a coevolutionary narrative are interconnectedness and variation. Norgaard (1994) argued that technologies, institutions and values change interdependently and in connection to the bio-physical environment. Beyond "co", Norgaard also argued that this change is "evolutionary", i.e. that its constituents parts exhibit variation and that this variation changes over time, increasing by *innovation*, and decreasing by systematic *selection* (Nelson, 1995). In social systems, the contextual environment in which various actions (practices, habits) occur sets constraining and enabling principles that exert selective bias in favour of some actions and against others (Kerr, 2004).

For example, policy change may be represented in terms of an evolving population of policy ideas that express ideological preferences and are differentially materialized into actions. Selection takes place in political arenas influenced by the relative power of the social interests that support competing ideas (Kerr, 2004). Culture also evolves as the frequency of different ideas or practices in a population changes through mimicry, persuasion or coercion (Runciman, 2005). Norgaard's model is in effect a meta-framework whereby evolution in each of the policy, cultural and environmental spheres is affecting evolution in the others.

In the next section I work with these ideas to construct a coevolutionary narrative of water resource development in cities. Section 3 discusses the methods used for this research and Section 4 narrates the case study. Section 5 concludes with the implications of the coevolutionary narrative.

2. A coevolutionary perspective of urban water resource development

Let us think of a city in terms of two evolutionary systems, the output of which roughly corresponds to water demand and water supply (Fig. 2). The first system consists of a population of households with different behavioural and physical attributes, in our case a variety of water-use practices and appliances.[3] Variation increases as new ways of using water are invented, or introduced from abroad. These are differentially adopted through intra-household selection in the context of inter-household imitation, persuasion (advertising, education) and coercion (laws). The multi-dimensional contextual environment of the city – economic, ideological, cultural, built, and biophysical – exerts selective pressure upon household variants. Over time the frequency of different attributes in the population changes. Compare for example water uses and appliances in a population of an early 19th century city with those of today. Change did not happen overnight. Some households introduced new appliances. They coexisted with households with older ones. New designs and uses gradually spread to dominate the population, only to be replaced by other ones (Goubert, 1989).

The second evolutionary system consists of a population of competing water supply policies (Kerr, 2004). Policy evolution is punctuated by crises, such as water shortages. Social actors struggle for selection of the solutions they support in – visible and hidden – political arenas. A key selection attribute is the costs – and benefits – of each solution, including monetary and non-monetary values, and their distribution. These in turn are

[3] The same conception could apply to producing units consuming water, e.g. industries, farms. For simplicity these are not discussed here.

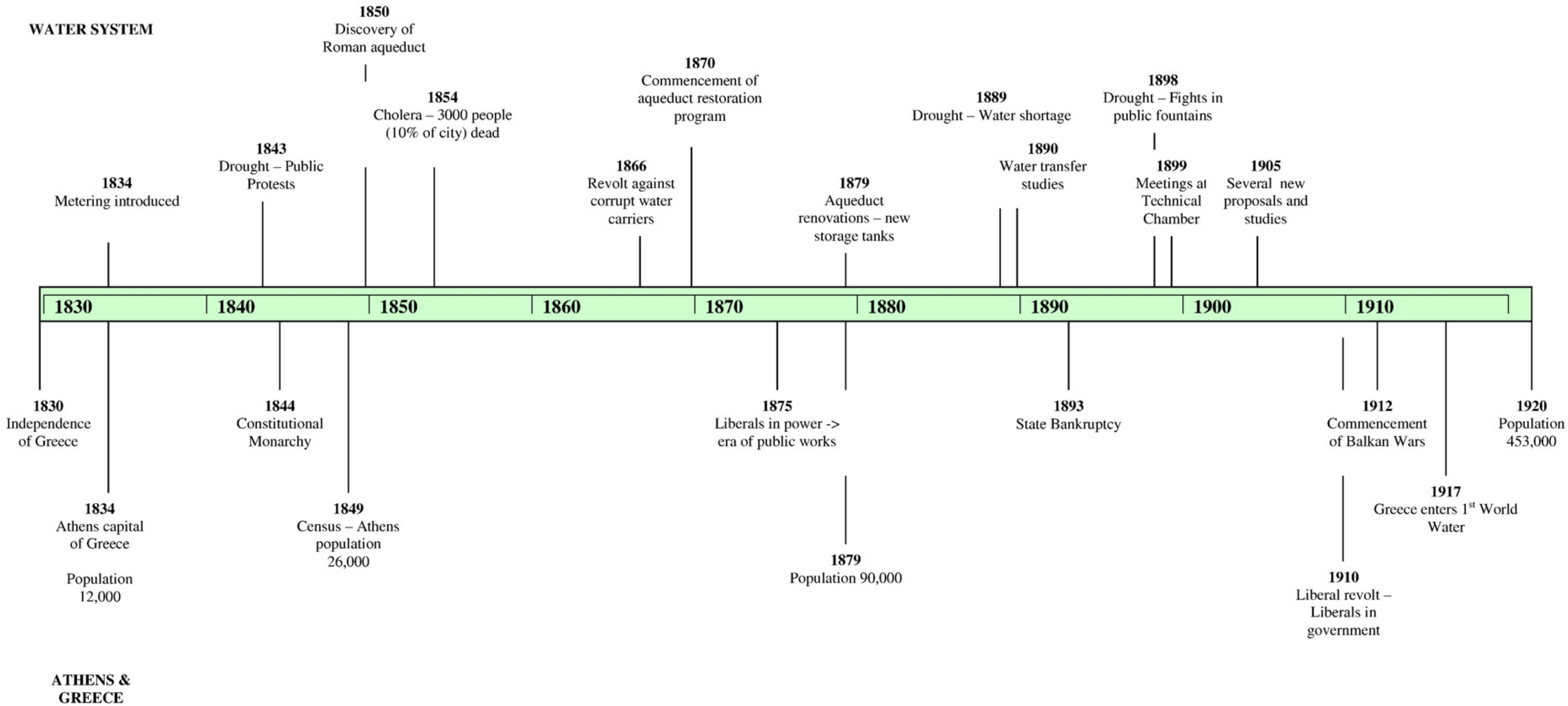


Fig. 1 – A chronology of Athens and its water history (1830–1920). A chronology of Athens and its water history (1920–2004).

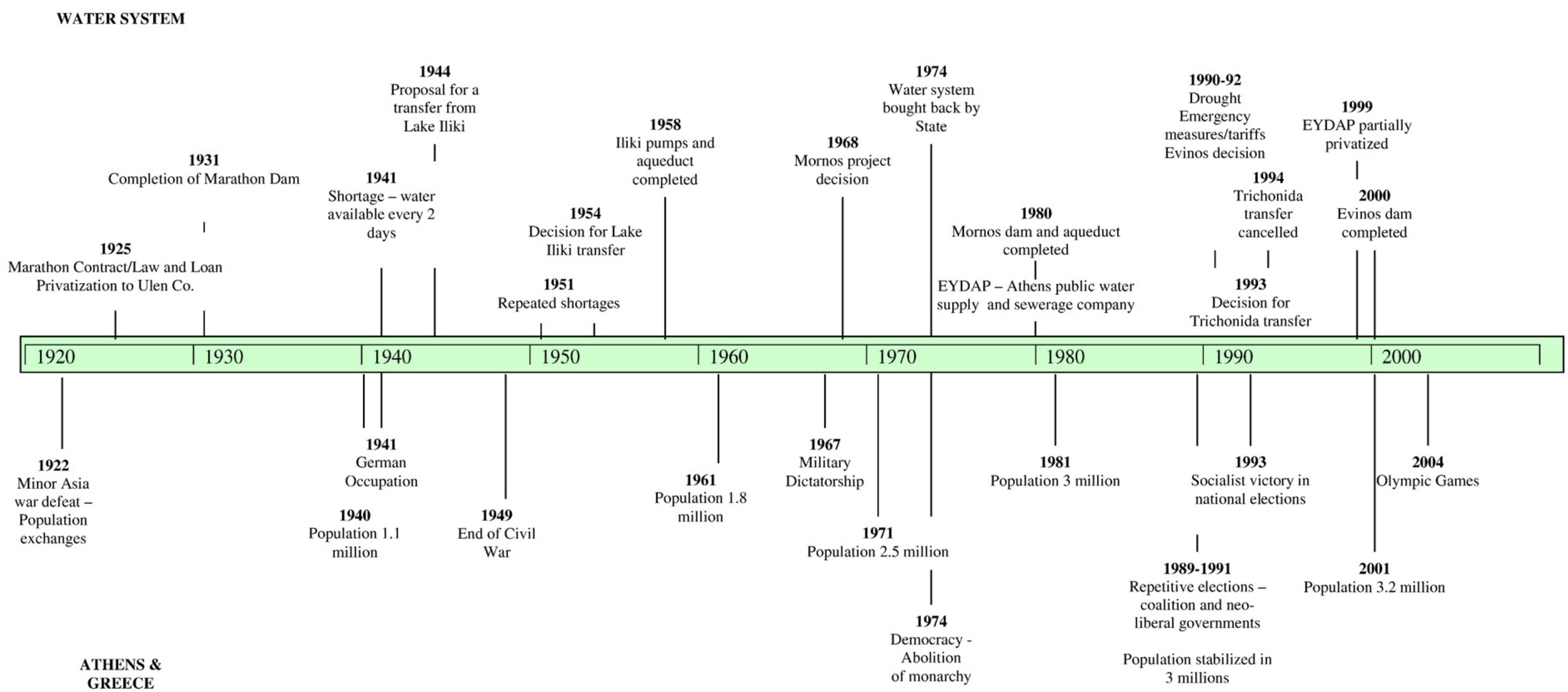


Fig. 1 (*continued*).

a function of technology, the hydrological environment and its geography. Multi-dimensional contextual conditions (political, economic and ideological) and power relations exert selective bias in favour of some solutions but not others. I distinguish here between two levels of selection operating in tandem. A strategic level, at which the broad contours of responses are selected (e.g. a new supply vs. doing nothing vs. conservation) and an implementation level, where there is competition for how to realize the strategy (e.g., 'a dam here' vs. 'a dam there').

The policy system produces supply and the household system produces demand. Policies affect the selection environment of household practices. Vice versa, the structure of household population and its demands affect the multi-dimensional selection environment of competing policies. Demand and supply are also inter-related through positive feedbacks. In particular, the high fixed costs of waterworks historically led utilities to set prices to cover past, rather than future, costs. After a major surface water project is completed, supply capacity exceeds demand and there is a strong economic incentive to utilities to set price to cover only the short-run operating cost, which is relatively minuscule (Hanemann, 2006). Low water prices instigate consumption. But as consumption increases and reaches the limits of supply, there is a positive-feedback to the policy system to expand supply.

The household and policy systems are in coevolutionary interaction with a bio-physical environment in and out of the city. They transform this environment and evolutionary adapt to their transformations (Fig. 2). The environment includes both "first" (pristine) and "second" (transformed) nature such as dams. Biophysical conditions – together with socioeconomic and cultural conditions – constitute part of the selection environment for alternative household practices or policy actions. From a coevolutionary perspective biophysical constraints are not absolute or constant. Their effect is seen as conditioning, rather than limiting, social change. New technologies are invented that overcome constraints and reduce costs making possible new environmental transformations. Then again, new technologies and transformations produce new environments and different structures of socioeconomic and biophysical selective conditions and constraints (Benton, 1992). Technological transformations are often imperfect and have unforeseen secondary effects (e.g. pollution, degradation of resource) that also change subsequent selection conditions.

3. Methods

There has been a methodological debate in this journal concerning coevolutionary studies. Winder et al. (2005) argued that empirical research should verify evolving populations, distribution changes and interactive selection forces. Norgaard (2005) and Kallis (2007) argued for a more open approach, and an eclectic combination of coevolutionary and other concepts (e.g. positive feedbacks) used for interpretative social science. This project is rooted in this latter, grounded research epistemology (Pryke et al., 2003). The goal is not theoretical prediction and empirical verification, but a dialectic development of theory and empirical material. The Athens case study is not meant to prove that coevolution did take place. It is a narrative that uses theoretical concepts from coevolutionary theory to connect events and interpret changes. The focus is on population changes, policy competition, positive feedbacks between supply and demand and the conditioning effects and transformations of the biophysical environment.

The historical material (1834–1979) was collected from the archives of the National Library of Greece. Secondary histories of Athens' water (Skouzes and Gerontas, 1963; Kalantzopoulos, 1964; Koromilas, 1977; Koumbarellis, 1989) were reinterpreted under the light of coevolution. For contemporary affairs (1980–2004) I examined publications from Athens' water company (EYDAP), the Ministry of Public Works and the National Technical University, articles in the daily press (1989–2004) and proceedings of the Hellenic Parliament in matters related to Athens' water supply. I also interviewed twenty four policy-makers, managers and NGO representatives involved in Athens' water policy.

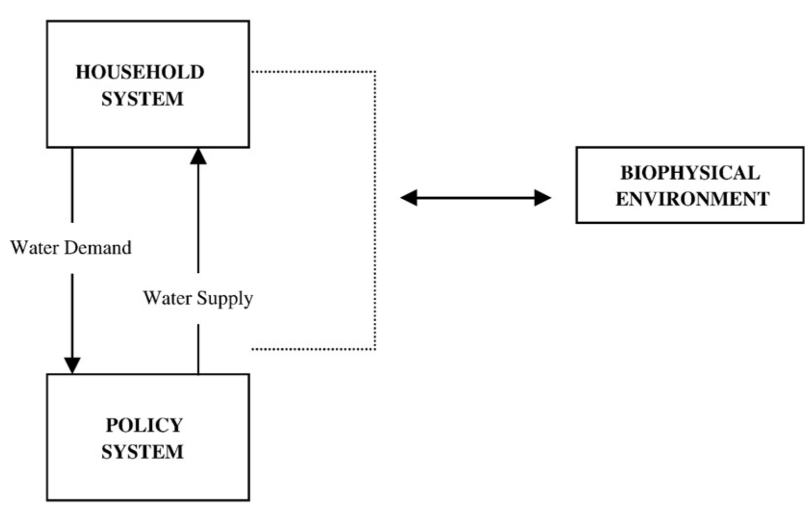


Fig. 2 – A coevolutionary scheme of water resource development.

4. Water resources development in Athens: a coevolutionary history

4.1. The early period (1834–circa 1890)

> "We forget how recent the conquest of water is and to what extent it ran counter to the sensibilities of our recent forebears" (Goubert, 1989, p. 12).

In the 1840s and 1850s, the population of Athenian households looked like this: most families lived in small, one or two floor homes with a single space. Some had wells in their yard. Others got water from public fountains fed by local springs and rivers. There were also a few wealthy households receiving water from the municipality with stone canals, lined straight from the fountains (Skouzes and Gerontas, 1963). Present day notions of running water, faucets or bathrooms in every dwelling were inconceivable.[4] The only water "appliances" were the jugs and bowls used to wash hands in the dining table or the wooden or metal tubs used for bathing. Common people washed rarely, with water from wells, in rivers or at Ottoman baths. They washed clothes few times a year, in the city's rivers (Skouzes and Gerontas, 1963).

New variety was introduced around the mid-19th century. Rich Athenians, many of them resettling from western capitals, brought with them the innovation of the compartmentalized house with functional rooms and specialized appliances using running water (introduced earlier by Royals and aristocrats in Western Europe, Goubert, 1989). Washbasins and water closets were introduced replacing bowls and receptacles. But only a privileged few had enough land or money to get domestic access to running water. Cleanliness and proper sanitary behaviour became class delineators (Goubert, 1989, Kaika, 2005).

Lack of water and a network dilapidated from the war limited the number of households that could access running water. Droughts and increasing demand caused frequent shortages and epidemics in the 1840s and 1850s. The imitating desires of middle and high classes for domestic water and the health advantages of water and sanitation documented in other cities (Goubert, 1989), selected for strategies of increasing supply, instead of inaction. But there was a competition of ideas about how precisely to supply water. This variety in the policy system was related to a competition between the State, the municipality, private entrepreneurs and water carriers concerning who will control – and benefit from – water. For the municipality maintaining its Ottoman-inherited responsibility for water distribution was a last bastion of defence against a centralistic State taking over its other taxing and service responsibilities. But water rights were linked to land property; consortia of private investors and engineers engaged in a frenzy of finding a water source, which they could sell for profit to the city. The State tacitly supported such plans; privatizing water supply (with a concession) provided an indirect away of taking control away from the municipality.

The hydro-environmental geography of Athens conditioned which solutions failed and which worked. Private consortia invested in the dominant water supply technology in Europe at the time: artesian wells (Goubert, 1989). These failed miserably (Koromilas, 1977). Only 400 mm/yr of rain fall on average in Athens. Today we know, what engineers in 19th century could not know: the aquifer beneath the city is small (about 50 Mcu.m/yr), and although it can supply individual wells, it is not enough for a big supply. But larger aquifers, springs and torrents are found in the mountain outskirts of Athens (Karavitis, 1998). Indeed, the Romans built in 2nd century A.D. a 25 km aqueduct that transferred water from mountain springs to the centre of the city, replenishing local springs and fountains. Knowledge about the aqueduct's route had vanished over the centuries. But in 1850, municipal engineers searching for groundwater discovered accidentally the remains of the dilapidated aqueduct (Koromilas, 1977). Restoring ancient aqueducts was common at that time in arid cities that lacked local sources (Goubert, 1989). Athens' municipality jumped on the restoration solution seeing an opportunity to retain control of the system (Skouzes and Gerontas, 1963). Aqueduct and groundwater became the two main competing policy options. Symbolically, aqueduct restoration fitted the national imaginary of modernization through linkage to a "glorious" past (Kaika, 2005). But the aqueduct had also clear hydro-economic benefits: low capital costs (when Greece lacked capital), and good yields, replenishing directly the city's existing fountains, which previously were thought to be fed by groundwater. As a result restoration dominated groundwater in terms of public investments after 1870. The State financed restoration with loans and the municipality recovered loans and operational expenses by metering and charging in-house supply.[5] Water was provided free-of-charge to the public fountains, used by the poor.

Within this hydrological and socioeconomic setting water carriers found a niche. They got (or bought) water from springs in the mountains/outskirts, carried it with horses to the city and sold it for profit to areas not reached by the network, especially in periods of drought. Exploitative prices and carrier's abuse of power to return favours to political patrons caused the resentment of the public. Occasional revolts were followed by State regulation of carriers' activity (Skouzes and Gerontas, 1963; Koromilas, 1977).

The restoration of the aqueduct increased water supply six-fold between 1860 and 1879, to 1.1 million cubic meters a year (Mcu.m/yr) (Skouzes and Gerontas, 1963). New iron fountains and storage reservoirs secured cleaner water and buffered against drought. In turn, in a positive-feedback cycle, the increase of running water from the network created a new selective environment for household practices. Rich Greeks

[4] Indicatively, an icon of wealth and luxury as the Buckingham Palace in London, did not have a bathroom in the 1830s (Goubert, 1989).

[5] In reality, water revenues were used for other municipal expenditures and the municipality was often unable to repay debts to the State. Vice versa, the State often refrained paying the water bills of public buildings accumulating substantial debts to the municipality (Skouzes and Gerontas, 1963; Paraskevopoulos, 1907).

relocating to Athens from European and Ottoman urban centres could install the appliances they were habituated to, such as washbasins and lavatories. Bureaucrats and professionals who could afford water fees mimicked elites (Koromilas, 1977). The State used education mechanisms to persuade the poor on the importance of hygiene and regular use of water (Goubert, 1989). By 1874, about 15% of Athenians using municipal water received it in-house, presumably having specialized running-water appliances and about 15% brought water from fountains, utilizing it in more rudimentary ways.[6] Water demand reached an all-time high of 44 lt/cap/day in 1874 (Skouzes and Gerontas, 1963). But aqueduct restoration had diminishing returns Rural landowners also claimed aqueduct water passing through their territory as theirs. Shortages reappeared and in the Summer of 1889 public fountains and private supplies ran dry.

4.2. *The hydraulic period (1890–1979)*

Frequent shortages exerted pressure on the policy side to solve the problem. Water shortages were seen as a sign of national backwardness (Kaika, 2005).[7] After 1875, Greece experienced a period of liberal reforms and modernization pursued through engineering and new infrastructures (Kaika, 2005). There was political consensus about the need to develop a new water supply to meet significantly higher demands in the future (Tympas et al., 2005). But the rivalry between the State and the municipality over who will control water continued. The State favoured a southern transfer from Peloponnesus; the municipality a northern, from the springs of river B. Kifissos (Fig. 4). Native and foreign engineers debated studies and counter-studies by State or municipality-favoured consortiums during fierce meetings at the National Technological Chamber (Tympas et al., 2005, Kalantzopoulos, 1964). But the hydro-geography of Athens – for the level of technological and economic development of the time – limited the feasibility of any solution. The sources that could supply the required quantities of water (200–300 Mcu.m/yr) were too far, requiring 150–200 km canals, longer than anywhere in Europe at the time (Tympas et al., 2005). Estimated capital costs were 600 times the annual municipal water budget.[8] The sites were at lower altitude than Athens and water had to be pumped from areas without electricity yet. Water policies completed for scarce financial resources with other infrastructure projects and lost. Western capital's preference for investments in transportation that would open peripheral markets, instead of productive infrastructures, was important (Svoronos, 1976; Kaika, 2005). Nonetheless public–private partnerships did finance other productive and domestic infrastructures.[9] Cost was the limiting factor against a water transfer to Athens.

Water policy debates paused during the economic crisis of the 1890s and the Balkan and 1st world wars. But exogenous changes in the household system started exerting strong pressures in the policy system. Athens' population doubled in a few years. Industrialization, facilitated by transportation infrastructure which turned Athens into a national hub, attracted rural labour to the city. And in 1922, literally overnight some 200,000 war refugees arrived in Athens from Minor Asia (Burgel, 1981). The great majority of the population lived now in dire conditions. Lack of water became a source of social tension and perceived by political elites an impediment to both industrialization and the smooth settlement of refugees and workers (Leontidou, 1989). Water became a strategic priority compared to other public projects.

Even so, Athens water supply would remain prohibitively expensive, save for technological developments in the water sector which reduced the costs of access to new sources. In the 1890s the Belgian ambassador had threw a solution in the policy mix that at its time was ridiculed as impossible but which thirty years would be by far the best option: a dam to collect seasonal torrents in the outskirts of Athens (Marathon; Fig. 3). The scientific community rejected it because of quality concerns and collapses of dams elsewhere (Kalantzopoulos, 1964). But new dam designs in the early 1900s in the U.S. survived floods and earthquakes. And in 1923 a prominent professor introduced to Athens' medical community the – counterintuitive till then – idea that stagnation of water in reservoirs improves quality (Kitariolos, 1923). The Marathon dam and transfer offered water at 4–6 times the cost of a northern or southern transfer, with the added advantage of costless gravity conveyance (Ministry of Transport, 1923). New financial instruments, such as bonds and the shift of international capital to peripheral domestic infrastructures (Kaika, 2005) made also financing such a project easier. Vice versa, the demographic and economic dynamism of cities like Athens attracted foreign investors (Burgel, 1981).

This change in the cost and benefits of policy options coincided with shifts in the distribution of political power. The refugee crisis gave Liberals, back in control of the national government, an opportunity to settle scores with the landed elites that dominated the municipality. The water system was removed permanently on the occasion of outsourcing financing and construction of the new water supply. The government also institutionalized with a law the right of eminent domain for public works of national importance, in effect asserting ultimate State control over water resources in private land (Svoronos, 1976; Kaika, 2005).

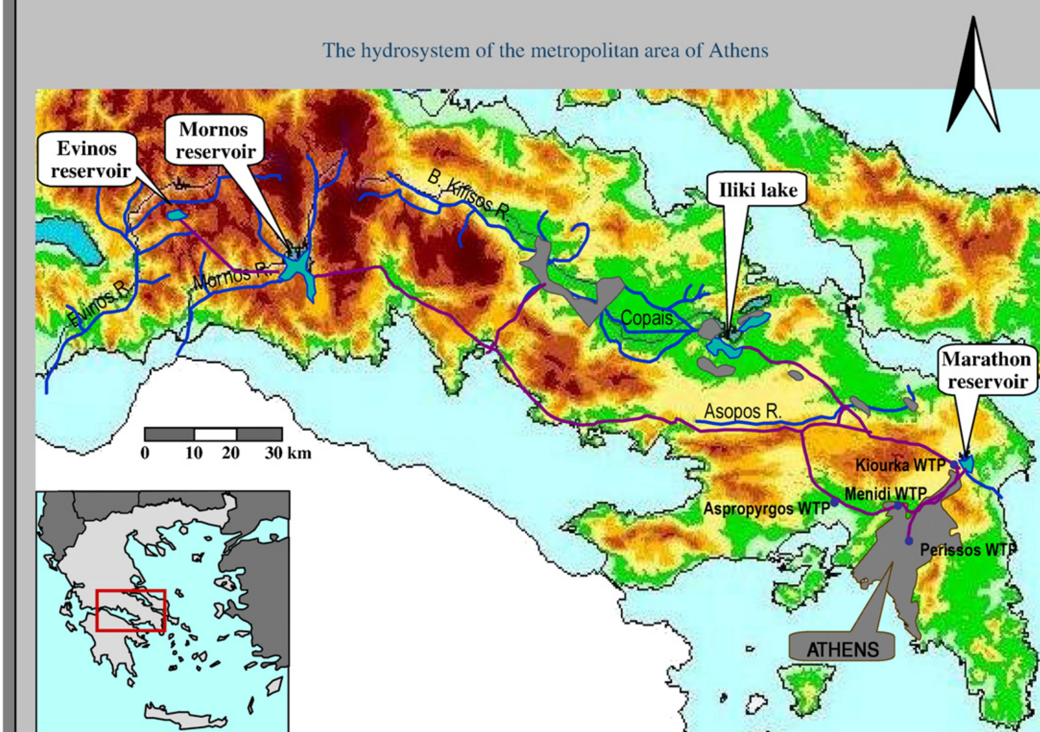
In 1925 the Parliament ratified a "Build-Operate and Transfer" agreement with New York-based Ulen Co. By 1932, Athens had a brand new dam, treatment plant and network. Marathon's water relegated the aqueduct to a relic. Water carriers were also

[6] My estimation based on municipal records at Paraskevopoulos (1907) showing that in 1879 42% of water was distributed individually and metered and 32% supplied free in fountains. I assumed a consumption of 80 lt/cap/day for those that had in-house supply and 10 lt/cap/day for those that brought water from fountains.

[7] Per capita spending on waterworks in 1878 was 5–10 times less in Athens than in other European capitals. Water supply was 45 lt/cap/day, when other European cities had 100–200 lt/cap/day (Kordellas, 1879).

[8] My calculations based on costs of projects (Kalantzopoulos, 1964) and annual municipal water expenditures (Paraskevopoulos, 1907).

[9] Foreign investors financed in 1886 the irrigation of the Kifissos basin north of Athens, and also Athens' electrification in 1903 (Burgel, 1981).



	Distance from Athens (km)	Size: Surface (km^2)	Size: Volume (million m^3)	Catchment (km^2)	Average renewable run-off (Million m^3/yr)
Mornos Reservoir	192	18.5	780	560	235
Evinos Reservoir	221.5	3.5	140	350	200
Marathon Reservoir	21.5	2.4	41	130	7-10
Iliki Lake	85	24.5	600	422	100 – 120

Fig. 3 – The water system of Athens (courtesy of Dr. Dimitris Koutsogiannis, National Technical University, Athens).

driven out of the market as network water was 4–5 times cheaper. In turn, the Marathon project set in motion a cycle of supply and demand growth. The economics of water supply and Ulen's profit incentives favoured an expansion of the distribution network to new areas and customers. Indicatively, Ulen was guaranteed an annual fee, a premium of 7.5% on gross water sales and a 10% return on water supply and network investments (Hellenic Democracy, 1925). And although water charges were intended to repay in 22 years Ulen's loan to the Greek State, the State soon lowered tariffs below cost, as many Athenians protested that they could not afford them and stopped paying bills putting in question the financial viability of Ulen's operation (Stefanidis, 1930).[10]

Water use tripled between 1928 and 1940 (Fig. 4). As a result, the Marathon reservoir, supposed to serve supply well into the 1960s, was depleted by the 1940s. A policy search for new supplies commenced culminating in a transfer from Lake Iliki (Fig. 4). This idea was introduced to the policy mix in 1944 by a state engineer. It is indicative of the degree of randomness in Athens' water policy that Lake Iliki, a huge stock of water close to the city, was not considered in previous policy debates (Kalantzopoulos, 1964).[11] The reduction in fuel prices and the electrification of Greece made more affordable to pump and transfer water from lower-altitude areas, such as Lake Iliki. Policy proposals competing with the lake option included various other northern transfers, most notably a transfer from B. Kifissos that Ulen promoted. Policy variation was sorted out as Greek engineers, challenging Ulen's monopolization of waterworks, supported the lake solution (Kalantzopoulos, 1964). Reasserting national control over strategic resources, the State confined Ulen to operations and went ahead to construct the new waterwork with Greek firms. Still, native engineers disagreed intensely concerning alternative designs of the project. One issue was whether the lake should

[10] Actually the interests from Ulen's loan are still being paid today (EYDAP, 1999).

[11] Kalantzopoulos (1964) discards. He is right to point that the northern and southern transfers that were considered also required electricity.

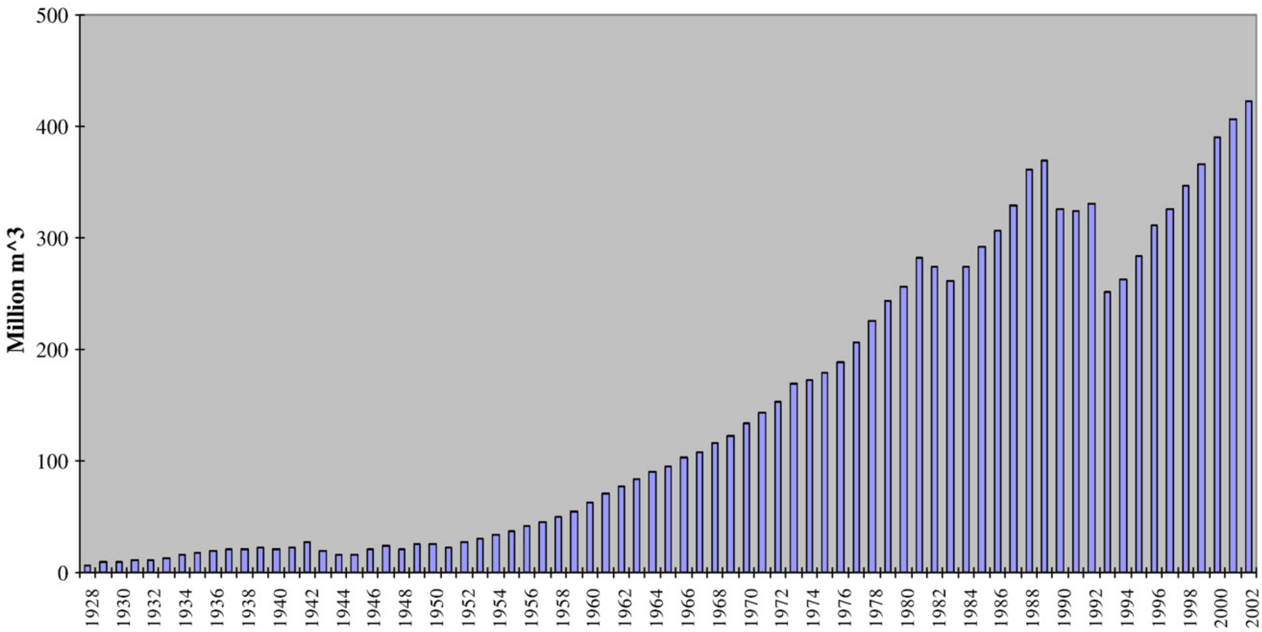


Fig. 4 – Total water use (million cubic metres) at the exit of the treatment plants (source: EYDAP).

be emptied and its holes refilled.[12] A second issue was the location of the water intake and the route of the canal to Athens (Kalantzopoulos, 1964). The government ignored engineers' concerns and decisively proceeded with a minimum cost design.[13] More water was needed, no matter how. The consequences of this decision were to be felt in later droughts.[14]

Marathon and Iliki watered the subsequent spectacular urbanization of Athens. Greece's Civil War had devastated the countryside. Athens attracted impoverished rural immigrants offering conveniences unknown to the rest of Greece, including electricity and potable water. Peasants marvelled to the water uses of the urban bourgeois; domestic water was a symbol of comfortable, modern living (Goubert, 1989). Construction of cheap private housing in Athens by – and for – the rural immigrants, boosted the urban economy, providing employment opportunities and quick investment returns (Burgel, 1981). Cheap, high-pressure water was part of an infrastructure selective environment that favoured the spreading of apartment-block housing over the traditional single-storey, single-family homes. In fact, Athens' Planning Committee was a strong advocate for the Marathon project recognizing that low water pressure was a "constraint to the desired increase of density in the city" (quoted in Polizos, 1985). Together with this new form of housing came a new type of household and associated water practices: apartment households had one or more rooms, a kitchen with running tap water, a bathroom with a WC, a bidet, a bath and a shower, a boiler and later a washing-machine for clothes and a balcony, typically with watered plants. As newcomers entered new apartments and adopted new water practices, the change in water demand was not gradual but saltational. While population doubled from 1951 to 1971, water use increased 7-fold (Fig. 4).

Cheaper energy and advances in hydraulic engineering rendered accessible for Athens the plentiful, undeveloped rivers of Western Greece. Sky-rocketing water demands and the increasing returns of investments in Athens created a favourable environment for new policies of water expansion. The decision in 1968 to build a new dam at river Mornos (Fig. 3) and a 190 km canal to Athens was the least debated in Athens' water history and the only one well-planned ahead of a shortage. It is not coincidental that this was the product of a Military Junta which stifled political debate and built its symbolic image around grand engineering. The Junta contracted a consortium consisting of all 10 major Greek construction firms to build the dam, spreading benefits among the powerful economic interests they represented. The Mornos dam and canal were the biggest of their kind in Europe (Koromilas, 1977) and the highest public infrastructure investments till then in Greece. River Mornos had hydro-economic advantages over revived proposals for a transfer from river Kifissos, which was heavily utilized and polluted by farmers. But the project had huge social and environmental costs. The Mornos dam drained the river's Delta, a unique

[12] Iliki received water diverted upstream from lake Kopais drained in 1886 for agriculture. The lake's natural formation was not capable of holding this water (especially at high elevations) and water seeped to the aquifer, more so when the lake was full. The initial proposal was to drain the lake, fix its holes and then refill it as a semi-artificial reservoir.

[13] Post-war public finances were not good: American reconstruction aid had been exhausted to defeat communists (Svoronos, 1976). The decision was not to fix the lake's holes. Pumps were installed at the closest point to Athens to minimize the canal's length. An open, instead of a closed, canal was built (Kalantzopoulos, 1964; Koromilas, 1977).

[14] Water would seep through holes in abundant years and not be available in droughts. The location of the intake at high elevation limited accessibility to water when the reserves of the lake were low. The water company devised expensive floating pumps for drought periods.

wetland host to migratory birds (Hatzibiros and Papagrigoriou, 1994). The dam drowned two villages. It separated physically remaining towns and increased their distance from – and transportation costs to – Athens. Agriculture was prohibited in the catchment to protect water quality. Displaced or devoid of economic opportunities, villagers of the Mornos communities massively immigrated to Athens (Kallis, 2003). Locals opposing the dam, if any, were silent in this period of military oppression. The Mornos dam fit well the institutional distribution of powers, but it was far from being a socially optimal solution.

4.3. The contemporary period (1980 to today)

Water from Mornos produced a new cycle of demand growth. Water managers failed to anticipate it accustomed, as they are accustomed to treat supply and demand as independent variables. Mornos and Iliki had secured in theory enough supply to satisfy demand for 30–50 years (CPER, 1990).[15] Yet although Athens' population did not grow in the 1980s by 1990, the city's water reserves were nearly exhausted (Karavitis, 1998). EYDAP, the state utility that bought the system back from Ulen in 1980, inherited huge debts (Interview #2). This explains why instead of optimizing yield by balancing supplies between Mornos and Iliki, EYDAP used only Mornos whose gravity-driven supply was cheaper. Unfortunately Iliki was anyways loosing unused water through its holes (NTU, 1994). EYDAP expanded also water supply to new areas and customers in the periphery of Athens while keeping prices low to instigate consumption. This made sense given the huge scale economies and low operational costs of Mornos (Interview #7). In a positive-feedback fashion Mornos' water supply form part of a regulatory and infrastructure selection environment that favoured the proliferation of suburban houses in Athens' periphery and the adoption of increasingly intensive domestic appliances in inner-city apartments. The household population changed. Low water prices made it easy to install cloth and dish washers, high-powered showers, new baths, gardens and hoses. Showering, watering the plants or cloth-washing became daily uses. Apartment blocks and suburban villas with lush lawns replaced fields and rural houses in Athens' periphery (Delladetsimas and Leontidou, 1995). Water demand continued to grow in the 1980s (Fig. 4), per household water use increasing some 20% (Kallis, 2003).

Like Marathon and Iliki in the past, Mornos delivered only half the water engineers promised (the yield of the system has been re-estimated since from 600 to about 400 Mcu.m/yr; EYDAP, 1996). Lots of water was lost in the poorly constructed leaky Mornos and Iliki canals (NTU, 1994). The unusual drought in 1989–1990 found the city's reserves already low. The government responded to the shortage in the short-term rationing water and instituting punitive tariffs (Karavitis, 1998). The crisis spurred also a policy search for longer-term responses. At a strategic level there were two rival options. On the one side were the government, engineering institutions (the National Technical University and the Technical Chamber) and prominent construction firms, determined to develop new supplies (MPWE, 1990). Against them stood the political parties of the opposition and environmental groups; for them the shortage was temporary and water conservation (leakage reduction and demand-side management) was a better longer-term strategy.

Supply proposals included new dams in adjacent rivers to replenish Mornos, a 60 km transfer from Lake Trichonida to Mornos, a revival of the old proposal to refill Iliki's holes, and several proposals for groundwater drills. In terms of hydro-economic attributes, the superior solution was a dam at river Evinos (Fig. 3). Compared to Iliki whose water was polluted from farming and required pumping, Evinos had clean mountain water that could flow to Athens by gravity. Groundwater drills around Iliki could capture the lake's seepage and were more affordable and feasible than fixing the lake (MPWE, 1990). Evinos had also socio-political advantages: there was no strong constituency to claim the river's water, in contrast to other catchments heavily utilized by farmers.

Based on a study by construction firms and academics (MPWE, 1990), the Government decided in favour of the construction of the Evinos dam, the transfer from Lake Trichonida to Mornos and the drills in Iliki and other basins. The study recognized conservation as a short-term drought response that should be maintained also after, but which alone could not satisfy the dynamic growth of the capital (Germanopoulos and collaborators, 1990). The government's decision was approved by the Parliament despite reactions from opposition parties. Environmentalists argued that water conservation was cheaper and would avoid the environmental impacts of the Evinos dam. These included reduced flows to sensitive lagoons with endangered species and reduced water tables in aquifers used by downstream communities (Hatzibiros and Papagrigoriou, 1994). Even if conservation was overall less expensive, a crucial difference was that waterworks were eligible for an 85% EU subsidy (Kaika, 2005). Conservation threatened EYDAP revenues and would tax urban growth. Evinos instead provided water at 85% discount and promised lucrative contracts to construction firms owned by powerful economic actors. The household system also exerted selective pressures that favoured supply expansion over demand management. Accustomed now to an uncompromised domestic water supply, and scared by the media who sensationalized the crisis (Kaika, 2005), public opinion favoured the tested solution of a dam over new ideas of conservation, or living with drought, that hinted to material sacrifices. Sensing public mood, environmentalists decided not to waste political capital in an unpopular battle. They did not challenge the environmental impact study of the Evinos transfer at the Supreme Court as they had done with other transfers in the past (Interview # 24).

Since 2000 river Evinos supplies Athens with water. After the end of the drought, tariffs were never increased again (save for adjustments to inflation, without much publicity). Awareness campaigns that successfully reduced demand during the drought quietly stopped. Scale economies and profit incentives once again favoured growth. Indicatively, EYDAP, partially privatized in 1999, boasted to investors about the prospects of a "growing metropolis" with "rising consumption" (EYDAP, 1999). Although EYDAP's (1996) Strategic

[15] On the basis of project designs the average combined yield from the two reservoirs was estimated around 600 Mcu.m/yr. Water demand was estimated 250 Mcu.m in 1982 (Kallis, 2003).

plan included also commitments to leakage control and demand management, they were never materialized as the investments were expensive compared to the cheap, abundant supplies from Mornos and Evinos (Kallis, 2003). Demand, which was temporarily controlled during the drought, rebounded to all-time highs (Fig. 4). The Olympic games boosted once again the growth of the city, with new peri-urban areas annexed into the water network and new water practices (lush gardens and swimming pools) spreading in the suburbs. Once more, new supply seems to be generating new demand, which sooner rather than later will be asking for more supply.

But this vicious cycle of expansion might be reaching its limits due to a combination of environmental and social factors that produce new selection conditions and opportunities for the evolution of alternative paths. Unlike Evinos, the policy decision for an additional transfer from Lake Trichonida, was eventually sorted out. The bio-physical, economic and socio-political features of the Lake project offer a cluse of why this happened. Compared to Evinos, the lake transfer produced fewer, narrowly spread benefits. Its water, polluted from agricultural and urban run-off could contaminate Mornos irreversibly (Interview #4). Pumping water from the lake, which was located lower than Mornos, would cost in 2 years the equivalent capital cost of Evinos (Hellenic Parliament, 1993). The EU would not fund a second transfer. The State would subsidize electricity costs and EYDAP would pay the construction contractor a fixed fee for 420 Mcu.m/yr of water for 2 years and buy the canal after (Hellenic Parliament, 1993). The socialist party then in opposition accused the conservative government of favouritism for giving the contract to the construction firm of a media magnate (Hellenic Parliament, 1993). Soon after there was a change of ruling parties, yet the project remained alive.[16] But citizens in the – much more populated than Evinos – area around the lake opposed what they saw as “the latest grab” of the region’s water by Athens (Hellenic Parliament, 1993). They coalesced with environmentalists in Athens and organized protests. Regional MPs passed angry community petitions to the Parliament referring to the impacts of the Mornos dam in the region (Hellenic Parliament, 1993). Locals and environmentalists had some unusual allies: pressured by employees and its Union, EYDAP’s politically appointed directorate rebelled and asked the government to cancel the project because it would pollute its sources and indebt the company.[17] The National Technical Chamber, usually in favour of waterworks, questioned the costs and usefulness of the transfer in light of the end of the drought. Under this changed field of powers, the government bowed and cancelled the unpopular transfer.

The Trichonida case may be pointing to a new stage in the evolution of Athens’ water system. Untapped sources of good quality are fewer, farther away and increasingly expensive (EYDAP, 1996). Funds to finance costly supplies are in shortage. Social groups emerge that struggle at policy arenas to institutionalize environmental and local interests. These new hydro-economical and socio-political forces create new selective conditions in the policy system and may favour conservation alternatives, against supply expansion. This in turn, might change selective pressures on the household system, and favour new, more efficient household types and practices.

5. Conclusions and political implications

In progressive narratives of Athens’ water resource development, new supplies, such as Marathon or Mornos, are the means to a predetermined historical end: urbanization and increasing consumption (Skouzes and Gerontas, 1963; Koumbarellis, 1989). Coevolution tells a different story. In 19th century only some households could – or wanted to – live in the city and use water frequently. Health and symbolic benefits and inter-social imitation, coupled with state policies of persuasion and coercion, spread the desire for water in the population and pressed for more supply. Supply expansion entrained then Athens in a path of perpetual urbanization and growth of water consumption. The economic features of water infrastructure favoured network expansion and low water prices. The abundance of running water at a low cost gave a competitive advantage to Athens over other rural and urban areas, facilitated settlement in the arid city, and made easier the adoption of increasingly intensive water appliances. Demand increased and stressed water supplies. Acculturated to water amenities, the majority of households favoured further supply expansion. New supplies accrued also important benefits to those political and economic interests that wielded more power in the policy arena. Through positive feedbacks and mutual selection, supply bred demand and demand asked for more supply. But if early supply works facilitated the attainment of basic health needs, the vicious supply–demand cycle they set in motion facilitates today (sub)urbanization and the spread of pleasure, status-oriented water uses while degrading the social and natural environment of the countryside.

Although not explicitly put in these terms, this vicious cycle of water resource development has been documented elsewhere: Seville (Del Moral and Giansante, 2000), Barcelona (Sauri, 2003) and Tenerife (Aguilera-Klink, 2000) in Spain, southern California (Gottlieb and Fitzsimmons, 1991), Boston and New York (Platt and Morill, 1997) in the U.S., London (Castro et al., 2003), France (Barraqué, 2003) and Mexico city (IAURIF, 1997). There are claims that the cycle may be coming to an end, urban water demand no longer increasing. In many cases this is because of wrong accounting: where water use may be stable or decreasing within the strict administative boundaries of a city, it typically keeps increasing at the metropolitan/regional level (Kallis and Coccossis, 2002).

Policy discourse is increasingly talking of a transition to a “soft water path”, i.e. managing water through conservation rather than new supply (Gleick, 2003). This has given rise to so-called integrated, twin-track policies of supply and conservation (Arnell et al., 2001). But the underlying narrative remains one in which water policies and technologies are a response to exogenously determined demands. Assuming that a transition to a soft path

[16] Coming in power in 1993, socialists revived the contract, although conservatives were planning to cancel it. The media magnate had shifted alliances in the elections, his newspapers siding now for the socialists. See articles in “Eleftherotipia”, 22/9/1993, p. 47 and “Eleftheros Tipos”, 20/11/93, p. 10.

[17] Interviews of General Manager of EYDAP in *EYDAP Source of Information*, a bi-monthly magazine of EYDAP’s office of public relations, 7: p. 9 and 10: p. 6.

is desired, then balanced twin-track policies may not be the way forward. The coevolutionary perspective suggests that new supplies create economic and political conditions that work against conservation. Furthermore, change is not gradual and continuous: once a new supply work is in place, restraining use from it becomes difficult. Similarly, once abundant water supply permits households to move to new type of homes or buy new appliances, temporary reductions during shortages may be possible but the new appliances and life-styles lock-in households at higher levels of consumption (Unruh, 2000). In so far as twin-track policies promote new supplies, even if smaller or with more attention to the remediation of environmental impacts, the vicious cycle will likely be sustained.

Instead there is a need for political determination to:

i) Stop supply expansion.

For example, Boston, U.S. is an internationally acclaimed example of transition to the soft path (Postel, 1992; Platt and Morill, 1997). It was in fact a moratorium on new water supplies that triggered effective experimentation with demand management policies and in turn, significant reductions in household water use.

Supply constraints are not advocated here because we are running out of water, nor because of any ethical supremacy of pristine rivers. Water is a renewable resource and has always been used and transformed by humans and other beings. The point is not to save an "environment which in any case, does not exist… Rather, we must decide what kind of world we want to live in and then try to manage the process of change as best as we can approximate it" (Lewontin, cited in Swyngedouw, 2004). Sustainable water management is not about staying within limits but about distributing equitably the costs and benefits of water use within and between city and countryside and among humans and non-humans.

ii) Experiment with large-scale, "supplier-driven conservation".

Similar investments to those of 19th and early 20th century are needed today in Western cities to change the infrastructure of water production and consumption to a 'soft' path. States and utilities should take the lead in promoting conservation; their role should not end up with providing economic incentives to consumers. Experiments may include – among others – investments on wastewater reuse projects, large-scale programmes to retrofit or replace domestic appliances or installation of household rainwater collection cisterns. Uncertainty about the results of conservation is not a reason to delay action. The supply solutions that were tried in the 20th century were rarely studied in detail or proven to be better beyond doubt. Early dams collapsed. The yields from Athens' dams turned out much lower and the canals leaked. Huge costs were externalized to non-urban populations. Yet, within the strategic consensus that water supply had to be expanded, large-scale 'experiments' were performed, which in turn created wholly new selective conditions on the demand side. The evolutionary perspective lets us see this mixture of intention/determination and experimentation/chance through which social change takes place (Norgaard, 1994; Aldrich, 1999).

But politics and policy are not external, but internal to the coevolutionary scheme. The struggle over alternative ways of producing water will be fought at political arenas. To the extent that these arenas remain dominated by the same growth interests that profit from supply-side solutions, there is little hope for a transition to a soft path. As Platt (1995) shows for the case of Boston, it was a successful coalition of environmental activists, citizens from the source regions, academics and politicians which, managed to fight and win the judicial battle against a new water transfer, in turn creating favourable conditions for water conservation. Stopping effectively new water supplies may be the most effective way to force Athens and other cities to a soft water path.

A coevolutionary perspective reframes nature from an unlimited source of wealth or an absolute limit, to an active agent conditioning and co-producing change (Norgaard, 1994). The geography, hydrology, quality, ecology and biology of water resources exert selective pressure by influencing which interventions are feasible, at what cost and to whom this cost falls upon. Other water histories, too, have recognized the hybrid, interdependent character of socio-environmental change, but ended up subsuming nature into society by suggesting that the former determines the later "in the last instance" (Swyngedouw, 2004; Kaika, 2005). The coevolutionary perspective goes one step further suggesting that environmental changes, such as climate change or fossil fuel exhaustion, can change dramatically the selection conditions for supply and demand alternatives and reshuffle the social balance of powers. Coevolution therefore allows for some optimism in the face of strong structural forces of lock-in (Norgaard, 1994). Environmental changes, social and technical experiments, social movements and coalitions and innovations may alter the balance of the status quo.

An Athenian staring at the city from the Acropolis in 1830 could not contemplate how it would look today. Somehow the city and its water system evolved to what they are today. More than likely they will evolve to something very different in 180 years time. Alternative futures are possible and the institutional struggles through which these are determined are fought now.

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REFERENCES

Adger, W.N., 1999. Evolution of economy and environment: an application to land-use in lowland Vietnam. Ecological Economics 31, 365–379.

Aguilera-Klink, F.A., 2000. The social construction of scarcity. The case of water in Tenerife (Canary Islands). Ecological Economics 34, 233–245.

Aldrich, H., 1999. Organizations Evolving. Sage, London.
Arnell, N., Liu, C., Compagnucci, R., Da Cunha, L., Hanaki, K., et al., 2001. Hydrology and water resources. In: McCarthy, J.J., Canziani, O.F., Leary, N.A., Dokken, D.J., White, K.S. (Eds.), Climate Change 2001: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change (IPCC). Cambridge University Press, Cambridge.
Bakker, K., 2003. An Uncooperative Commodity. Oxford University Press, Oxford.
Barraqué, B., 2003. Past and future sustainability of water policies in Europe. Natural Resources Forum 27 (3), 200–211.
Benton, T., 1992. Ecology, socialism and the mastery of nature: a reply to Reiner Grundmann. New Left Review 192, 55–74.
Burgel, G., 1981. Athens. The Growth of a Mediterranean Capital. Exantas, Athens.
Castro, J.E., Kaika, M., Swyngeouw, E., 2003. London: structural continuities and institutional change in water management. European Planning Studies 11 (3), 283.
CPER, 1990. Report on Water Supply and Sewerage for the 1988–1992 Programme (in Greek). Centre for Programmes and Economic Research, Athens.
Cronon, W., 1992. A place for stories: nature, history and narrative. Journal of American History 78 (4), 1347–1376.
Del Moral, L., Giansante, C., 2000. Constraints to drought contingency planning in Spain: the hydraulic paradigm and the case of Seville. Journal of Contingencies and Crisis Management 8 (2), 93–102.
Delladetsimas, P., Leontidou, L., 1995. Athens. In: Berry, J., McGreal, S. (Eds.), Urban Planning and Property Markets in Europe. E. & F. N. Spon, London.
Elkind, S.S., 1998. Bay Cities and Water Politics: The Battle for Resources in Boston and Oakland. University Press of Kansas, Lawrence.
EYDAP, 1996. Water Supply Master Plan. EYDAP, Athens.
EYDAP, 1999. Information Report Following the Offer of New Stocks and Introduction of the Company in the Stock Exchange Market. Hellenic Investment Bank, Athens.
Gandy, M., 1997. The making of a regulatory crisis: restructuring New York city's water supply. Transactions of the Institute of British Geographers 22, 338–358.
Germanopoulos, G., collaborators, 1990. The Evolution of Athens' Water Demand (in Greek). National Technical University, Athens.
Gleick, P.H., 2003. Global freshwater resources: soft-path solutions for the 21st century. Science 302, 1524–1528.
Gottlieb, R., Fitzsimmons, M., 1991. Thirst for Growth. The University of Arizona Press, Tucson.
Goubert, J.P., 1989. The Conquest of water. Polity Press, Cambridge.
Hanemann, W.M., 2006. The economic conception of water. In: Rogers, P., Llamas, R. (Eds.), Water Crisis: Myth or Reality? Taylor & Francis.
Hatzibiros, K. and Papagrigoriou, S., 1994. Environmental impacts from Athens water supply works and the need for management solutions (in Greek), in NTUA (Ed), The water supply problem of Athens. National Technical University, Athens.
Hellenic Democracy, 1925. Ratification of the contract for the water supply of Athens, Piraeus and Suburbs and issue of State Bond for financing of the works. Official Government Journal 100, 569–597.
Hellenic Parliament, 1993. Proceedings of the Assembly, May 21, 1993.
IAURIF, 1997. Integrating the Management of Water into Town Planning. Les Cahiers De l'IAURIF, Paris.
Kaika, M., 2005. City of Flows. Modernity, Nature and the City. Routledge.
Kalantzopoulos, T., 1964. The History of Water Supply of Athens (in Greek). Palamari Kathrogianni and Co, Athens.
Kallis, G., 2007. When is it coevolution? Ecological Economics 62, 1–6.
Kallis, G. 2003. Institutions and sustainable management of water supply sources: the case of Athens (unpublished PhD thesis). Lesvos, University of the Aegean.
Kallis, G., Coccossis, H., 2002. Water for the city: lessons from tendencies and critical issues in five advanced urban areas. Built Environment 28 (2), 96–110.
Karavitis, C.A., 1998. Drought and urban water supplies: the case of metropolitan Athens. Water Policy 1, 505–524.
Kerr, P., 2004. Saved from extinction: evolutionary theorising, politics and the state. British Journal of Politics and International Relations 4 (2), 330–358.
Kitariolos, L., 1923. On Athens and Piraeus Supply with Water from an Artificial Lake at Marathon (in Greek). Academy of Athens, Athens. Lecture 5-5-1923.
Kordellas, A., 1879. Athens Examined from a Hydraulic Perspective (in Greek). Athens.
Koromilas, L.G., 1977. The Athenian Roll (in Greek). Hellenic Water Supply Company, Athens.
Koumbarellis, S.G., 1989. The History of the Water/Sewerage Works of the Capital (in Greek). EYDAP, Athens.
Kupel, D.E., 2003. Fuel for Growth. Water and Arizona's Urban Environment. University of Arizona Press, Tucson.
Leontidou, L., 1989. Cities of Silence. Working-Class Colonization of Urban Space, Athens and Piraeus 1909–1940 (in Greek). ETBA, Athens.
Ministry of Transport, 1923. Water Supply of Athens-Piraeus (in Greek). Ministry of Transport, Athens.
MPWE, 1990. Study for the Augmentation of Athens' Water Supply to Satisfy Needs till 2030 (in Greek). Ministry of Public Works and Environment, Athens.
Nelson, R.R., 1995. Recent evolutionary theorising about economic change. Economic Journal XXXIII, 48–90.
Norgaard, R.B., 2005. Bubbles in a back eddy: a commentary on "The origin, diagnostic attributes and practical application of coevolutionary theory". Ecology and Economics 54, 362–365.
Norgaard, R.B., 1994. Development Betrayed: the End of Progress and a Coevolutionary Revisioning of the Future. Routledge.
NTU, 1994. The water supply problem of Athens, Conference Proceedings. National Technical University, Athens.
Paavola, J., 2002. Water quality as property: industrial water pollution and common law in the nineteenth century United States. Environment and History 8, 295–318.
Paraskevopoulos, G., 1907. The Mayors of Athens (1835–1907). Municipality of Athens Publications, Athens.
Pearce, F., 2006. When the Rivers Run Dry. Key Porter Books.
Platt, R.H., 1995. The 2020 Water Supply Study for Metropolitan Boston. Journal of the American Planning Association 61 (2), 185–199.
Platt, R.H., Morill, V.L., 1997. Sustainable water supply in the United States: experience in metropolitan Boston, New York, and Denver. In: Shrubsole, D., Mitchell, B. (Eds.), Practicing Sustainable Water Management: Canadian and International Experiences. Canadian Water Resources Association.
Polizos, G., 1985. Reformist dreams and urban planning reforms (in Greek), In Ministry of Culture (Ed) Athens in the 20th century. Athens, Ministry of Culture.
Postel, S., 1992. Last Oasis: Facing Water Scarcity. W.W. Norton, New York and London.
Pryke, M., Rose, G., Whatmore, S. (Eds.), 2003. Using Social Theory. Thinking Through Research. Sage, London.
Reisner, M., 1996. Cadillac Dessert: The American West and its Disappearing Water. Penguin.
Righter, R.W., 2005. The Battle over Hetch-Hetchy: America's most Controversial Dam and the Birth of Modern Environmentalism. Oxford University Press, Oxford.
Runciman, W.G., 2005. Culture does evolve. History and Theory 44, 1–13.

Sauri, D., 2003. Lights and shadows of urban water demand management: the case of the metropolitan region of Barcelona. European Planning Studies 11 (3), 229–243.
Sauri, D., Del Moral, L., 2001. Recent developments in Spanish water policy. Alternatives and conflicts at the end of the hydraulic age. Geoforum 32, 351–362.
Skouzes, D.G., Gerontas, D.A., 1963. The Chronicle of Watering Athens (in Greek). Athens.
Stefanidis, D.S., 1930. Foreign Capital Inflows and their Economic and Political Consequences (in Greek). Thessaloniki.
Svoronos, N., 1976. A Review of Modern Greek History (in Greek). Themelio, Athens.
Swyngedouw, E., 2004. Social Power and the Urbanization of Water. Oxford University Press, Oxford.
Tympas, T., Tzokas, S., Garifallos, G., 2005. The greatest aqueduct in Europe: contrasting estimations of engineers for Athens and its water supply (in Greek). In: Sapounaki-Drakaki, L. (Ed.), The Greek City in Historical Perspective. Dionikos, Athens.
Unruh, G.C., 2000. Understanding carbon lock-in. Energy Policy 28, 817–830.
Walker, R.A., Williams, M.J., 1981. Water from power: water supply and regional growth in the Santa Clara valley. Economic Geography 58 (2), 95–119.
Winder, N., McIntosh, B.S., Jeffrey, P., 2005. The origin, diagnostic attributes and practical application of co-evolutionary theory. Ecol. Econ. 54 (4), 347–361.
Worster, D., 1985. Rivers of Empire. Water, Aridity and the Growth of the American West. Oxford University Press, New York, Oxford.