Hydrol. Earth Syst. Sci., 12, 1153–1164, 2008
www.hydrol-earth-syst-sci.net/12/1153/2008/

Hydrology and Earth System Sciences

The development of water services and their interaction with water resources in European and Brazilian cities

B. Barraqué[1], **R. M. Formiga Johnsson**[2], **and A. L. Nogueira de Paiva Britto**[3]

[1]Centre International de Recherches sur l'Environnement et le Développement, Paris, France
[2]State University of Rio de Janeiro/Environment and Sanitation Department (UERJ/DESMA), Rio de Janeiro, Brazil
[3]Federal University of Rio de Janeiro/Faculty of Architecture and Urbanism (UFRJ/FAU), Rio de Janeiro, Brazil

Received: 18 July 2007 – Published in Hydrol. Earth Syst. Sci. Discuss.: 14 September 2007
Revised: 22 April 2008 – Accepted: 12 July 2008 – Published: 26 August 2008

Abstract. The extension and complexity of large cities creates "urban water" and a related issue: public water services, including public water supply, sewage collection and treatment, and storm water control, had previously become a policy sector separate from water resource allocation issues thanks to water transport and treatment technologies. Large metropolitan areas today cannot take nature for granted anymore, and they need to protect water resources, if only to reduce the long term cost of transporting and treating water. In this paper, we compare the historical development of water services in European and Brazilian metropolitan areas, placing the technological developments in their geographic, socio-economic and political contexts. Our frame is to follow the successive contributions of civil engineering, sanitary engineering, and environmental engineering: the "quantity of water" and civil engineering paradigm allowed to mobilise water in and out of the city, and up the hills or the floors; in the "water quality" and chemical/sanitary engineering paradigm, water treatment gave more freedom to cities to take water from rivers closer to them, but also to reduce sewer discharge impacts; lastly, the environmental engineering paradigm proposes to overcome the supply side perspective, by introducing demand side management, water conservation, water allocation flexibilisation, and an integrated approach to water services, water resources management, and land use policies.

Correspondence to: B. Barraqué
(barraque@engref.fr)

1 Introduction

Paris is now a world size metropolis, but unfortunately, the Seine has not grown with it! And this is no isolated case: many large cities in Europe have to re-consider the separation between water management and land use planning. Increasing interaction with nature gives rise to a reflection on "urban water": water resources and water services, which had become two separate issues thanks to the development of water transport and treatment technologies, are now increasingly interfering. Protecting the resource allows to reduce transportation and water treatment costs. In Brazil, at least in the large metropolitan areas around Sao Paulo and Rio de Janeiro, there is a growing competition for water resources between water and waste water services, and electricity, while the three systems are interdependent. This paper builds upon the similarities and differences which developed over a century between a few European and Brazilian metropolitan areas.

Piped water systems spread on both sides of the Atlantic at the same time; until the 1930s there was no significant difference in terms of connection rates to both systems, and only central city and privileged areas had domestic connections. And of course sewerage was embryonic, often limited to drainage, with most houses still on cesspools or privies. But, along the 20th century, the richest western European States managed to universalise the services, while in Brazil governments at different territorial levels are still striving to do it, in particular concerning sewerage. What made the difference? Is it the wealth of industrialized countries, the technical development conditions, differences in demography or in financing systems, or the difference in engineering cultures and in the allocation of competences between local, regional

Published by Copernicus Publications on behalf of the European Geosciences Union.

and national levels? In this paper we can only sketch how these various factors combined. Over the last century and a half, we can identify three socio-technical systems which successively developed under civil engineering (Sect. 2), sanitary engineering (Sect. 3), and environmental engineering (Sect. 4) perspectives. Indeed, these three approaches developed in Europe partly as answers to sustainability crises. In Brazil, relative abundance of water but also dramatic urban in-migration of poor people made it more difficult. However, in Europe, there are now signs of a new crisis, which might make water services unsustainable: a "spiralling down" evolution could take place, partly due to the low acceptability of the full cost recovery doctrine and of the subsequent prices increase. Europe might then face similar water services issues as emerging countries. We then imagine that territory could resolve what technology cannot any more, and this is why the above mentioned separation between water services and water resources is increasingly blurred. From the comparison, we draw some conclusions on the role of capacity building at local level, but also on the need for multi-level governance of both resources and services together.

This paper is also the product of several years of research devoted to a presentation and comparison of water policies in each of the member Sates of the European Union, elaborated in partnership with many European colleagues, in particular those of the Eurowater network. 5 member States were analysed in detail and their policies presented in a 2 volumes book (Correia et al., 1998). A quicker synthesis covering the 15 EU member States (Barraqué, 1995) presents in each case the global geographical situation (water availability, abstractions pollutions, issues in water allocation), the organisation of water services delivery, and the regulations and institutions for water resources allocation. No systematic historical account could be provided, but the distinctive evolution in the contemporaneous period was sketched for several countries. Resources allocation and services provision constitute two distinct sectors in legal, political and institutional terms, the environmental sanitation sector being a water user. In many cases, analyses of both sectors were developed separately. Only part of the analyzed material is referenced here (see bibliography for Europe in Barraqué, 1995, for more documents). In 1999, the World Bank and the Brazilian Water Resources Association (Associação Brasileira de Recursos Hidricos) invited the Eurowater network to present the European situation to Brazilian water academics and engineers, and this gave the opportunity to develop a comparative analysis, again encompassing the management of both water resources and environmental sanitation. This partnership has long been supported by the Franco-Brazilian cooperation, and an ongoing funding by French CNRS and Brazilian CNPq focuses on sustainability of urban water management[1]. The ambition here is to present the evolution of water services as socio-technical systems overlapping with water resources issues in varying degrees with the three successive engineering paradigms (Barraqué, 1993).

2 The Paradigm of water quantity and water systems

In the 19th century, or rather until the Koch and Pasteur discoveries were popularised, hygienists and engineers imposed the idea of abundant running water to clean the city. The progressive mastering of pipes, taps and welding led to the development of water systems and multiplication of public fountains (Goubert, 1986). Some imagined a development of private services up the buildings; many thought that water should be drawn from flowing water, or better, from natural environments far from the cities. Even small cities developed gravity systems with water from upstream catchments. With the financial and institutional support of governments, a few large cities in particular built long distance aqueducts. Typically, in Paris, engineer Belgrand supplemented the pumping stations close to or within the city with water from several distant sources, which were all at higher level than the city itself. Thanks to clever hydraulic works including siphons, Paris would get clean water at low energy costs (Cebron de Lisle, 1991). Glasgow also obtained water from a Highlands lake 55 km away (Maver, 2000). Yet obtaining a water right or a concession on distant water sources requested at least the legal intervention of national governments, who had sovereignty on water resources and their allocation. This led to a de facto centralisation, and remained limited in Northern Europe. Most cities went on taking water from local wells and from nearby rivers (Guillerme, 1988), and in Britain, this was supported by the development of slow filtration. Conversely, in Mediterranean Europe, Central governments intervened more in the economy through large hydraulic projects, in particular during authoritarian periods before or after World War II. In any case, distribution systems initially served mostly public fountains, supporting the traditional vision that people should have free access to water resources for their domestic needs. Thus paying for water was a limited, albeit ancient practice, and this vision was supported by the quasi-absence of operation costs[2]. All the expenses were with the installation of the infrastructure, which was paid for by public money or by aristocrats.

2.1 The failure of private concessions in Europe ...

Yet, in the 19th century private companies multiplied with the purpose of bringing water to private residences, including in condominiums, against payment of a bill. In many cities of the time, authorities would consider this as a luxury, and they did not want to get involved. In France they granted

[1]CNRS-CNPq, Projet no. 19336: Gestion durable de l'eau et de l'assainissement dans les régions urbaines françaises et brésiliennes, 2006–2008

[2]But of course, people would pay water vendors carrying water to their homes.

concessions to the companies, which often had to deliver water at a cheap price to fountains and public needs, most of the profit coming from subscribers to "private" water (Pezon, 2000). Companies were left by themselves to produce and distribute water, having to solve several technological problems (leak control, metering etc.). These initial ventures usually lacked both enough capital and political support to be able to generalise the service. The initial model of the concession in turn suffered distrust between companies and the population. Conflicts grew at the end of 19th century when municipalities became convinced that water supply was not a luxury, but a fundamental public health issue. If operators took water from nearby rivers, it was of bad quality, but they had even fewer financial and legal possibilities to get it from a distance. In most cases, it is the municipalities which achieved to complete water supply systems, taking over the role of operators.

As concerns waste water, heavy investments were made too on urban drainage, which led to the adoption of combined sewers, people being forced to connect. This usually implied public procurement, with private companies' role limited to construction phases.

2.2 ... and in Brazil: the emergence of municipal management

In Brazil, municipal councils and government took on responsibility for developing water and sanitation services starting in the middle of 19th century in response to a catastrophic health situation which struck various towns (Britto, 2006). Yet the embryonic character of the Brazilian state at this time and the limited technical development led to call foreign companies, mainly English ones, to build harbours, railways, sewerage, electricity, tramways and telephones throughout Brazil.

In 1857 in Rio de Janeiro, water distribution remained under public administration, but a company, set up with English capital, took over the construction and operation of waste water, thus making the city one of the firsts in the world to have a system of separate sewers. In São Paulo, water and sanitation services were provided by the Companhia Cantareira, created in 1877 from Brazilian and British capital. Public offices and religious buildings were connected, but residential water supply was still the privilege of an elite. There were no regulatory instruments helping the state control the concessions which lost credibility with the rising concern for public health. By the 1890s, sanitation services were no longer provided satisfactorily by the Companhia Cantareira. When its contract ended, the state water and sanitation service took over. The same occurred a few years later in Rio de Janeiro, Brazil's capital (until 1960), when the federal district government took over sanitation services from a private concession (water services were under public administration since the beginning of the systems installation).

The idea that water should be paid for as a service was still unthinkable, in part because operation costs were almost nil. All investments were devoted to the infrastructure, especially for water supply, paid for by government revenues. As in Europe, medical thought assumed that cleaner water should be drawn from sources far from the cities. The limited availability of good-quality water was associated with annual epidemics of yellow fever and of other diseases resulting in a significant number of deaths (Rezende and Heller, 2002). This situation worsened in the first decades of the 20th century, as sanitation infrastructure failed to expand at the same rate as population, in particular after 1930.

A new notion of sanitation formulated by civil engineers became hegemonic. It was concerned with preparing space for urban expansion through landfills, river channels, flood control, and the elimination of risk areas, where networks of water supply and sewerage were to be installed as well. Saturnino de Brito's plans for Sao Paulo are an example of this idea of integrated urban water management, including the protection of strategic water sources for public supply. However, the largest Brazilian cities – and São Paulo itself – failed to put those plans in practice. This integrated concept of sanitation planning would later be replaced by the new concept of "saneamento básico" (Britto, 2006; see Sect. 3.2).

Like in Mediterranean Europe, between 1930 and 1940 (a period known as the "Estado Novo"), the Brazilian welfare state developed under a mixture of authoritarianism and populism. Expansion of infrastructure took place in a new regulatory climate which eventually evolved into a highly centralized system of electric energy regulation and large scale water resources management at federal level. Urban sanitation services partly escaped that model, and from 1940 to 1960, water supply and sewerage stayed with municipal departments; but a "public service" logic dominated and tariff issues were kept on the backstage. Costs were covered by taxes and unit costs decreased as consumption increased, fostering waste and losses. In turn, water engineers imagined meeting the demand with quantitative supply side solutions, and they remained influenced by the civil engineering paradigm more than in Europe (Britto, 2001; Costa, 1994).

Our hypothesis is that civil engineering remained more dominant in the New World, and was extended to the Third world after World War II, due to the co-occurrence of International Financing Institutions offering cheap money, and of various forms of support for National Governments' intervention in infrastructure provision (Keynesian or socialist). The American federal government's involvement in large multipurpose hydraulics during the first half of the 20th century (TVA, Mississipi, Colorado) showed the way, and additionally many Anglo-Saxon experts were convinced of the uselessness of local governments in public services (e.g. for Britain, Saunders, 1983).

2.3 Water supply, hydropower and large water transfers in Brazil

The first major water transfers in Brazil were to produce electric energy for the metropolitan regions of São Paulo and Rio de Janeiro, but they later conflicted with urban water supply. The expansion of drinking water needs in Greater São Paulo entered into conflict with the hydropower sector (Formiga-Johnsson and Kemper, 2005). The Guarapiranga and Billings reservoirs were built for power generation purposes in the 1920s and 1930s, respectively. For decades, the Alto-Tietê – Cubatão Complex diverted a large volume of water from the Tietê and Pinheiro rivers into the Billings reservoir (with a capacity of 1 km^3) for use by the Henry Borden hydropower plant, located in the state's coastal area, in another river basin. As had occurred in the late 1940s with the Guarapiranga reservoir, in the 1970s, the water in the Billings reservoir was re-allocated to supply Greater São Paulo. But sanitation infrastructure in São Paulo had failed to expand at the same rate as the population, resulting in severe pollution of these rivers and, consequently, of the Billings reservoir. Although engineers and politicians have repeatedly recognized the precariousness of both drinking water supply systems, priority for this complex was always given to hydropower generation (Keck, 2002). Pressures from environmental groups increased, however, and the 1989 state constitution changed the priority for use of the Billings Reservoir to urban supply. Since 1992, pumping into Billings has been suspended altogether, except when required for severe flood control. However, tensions continue since plans to increase energy production by pumping water from the Tietê and Pinheiros Rivers have always been on the electricity company's agenda. After a major drought in 2000 which culminated in a national level energy crisis the following year, a special license was granted to transfer an outflow of up to 4 m^3/s to meet an emergency power demand; there are also projects for cleaning up the Pinheiros river so that it would be possible to use it as in the past, while meeting environmental regulations. Today, the main function of the Guarapiranga reservoir is to supply São Paulo city. One isolated part of the Billings reservoir supplies some municipalities of Greater São Paulo, including São Paulo city itself (Formiga-Johnsson and Kemper, 2005).

Conversely, the dominance of large water transfers for hydropower purposes was beneficial for Greater Rio de Janeiro's water supply needs (Formiga-Johnsson and al., 2007). After World War II, the largest transfer in the country in terms of water volume was designed to generate electricity for the Rio de Janeiro Metropolitan area. Located in the middle stretch of the Paraiba do Sul river[3], immediately downstream from the main industrial area of the basin, this transfer diverts two-thirds of the average flow of the river (up to 160 m^3/s) and the entire flow of one of its tributaries, the Piraí River (about 20 m^3/s), into a system of hydropower reservoirs known as the Sistema LIGHT. The outflow provides over six times more water to the Guandu River than that river's natural average flow, eventually turning it into the main water source for domestic users in the metropolitan region of Rio de Janeiro (RMRJ) and many important industrial users. Indeed, although Light's hydroelectric plants remain in operation today, electricity production plays a minor role, while water supply is crucial for 8 million inhabitants of RMRJ.

Large water transfers have been widely used for more than 50 years, and continue to be common practice in Brazil. But the mobilizations against the Alto-Tietê diversion in São Paulo and recently against the contentious São Francisco project have demonstrated that centralized supply sided solutions for water based development are getting more difficult to carry out in Brazil.

[3]The Paraíba do Sul river basin is federal, since shared by the states of São Paulo, Minas Gerais and Rio de Janeiro.

3 The paradigm of water treatment

In North West Europe, industrialisation and urbanisation led to a quicker crisis of the "civil engineering paradigm": as cities grew in population, water needs would increase, and taking more from further would generate conflicts with communities deprived from their resources. In addition, for reasons of political conflicts related to the centralisation versus decentralisation issue, cities would eventually become reluctant to depend on central governments' legal and financial support: following the trend set in England, local public services developed in the context of decentralisation and rise of what should be termed municipalism (rather than municipal socialism as depicted in France, or as water and gas socialism as derided in the UK itself). Indeed, "welfare state" and central governments' involvement in the economy were anticipated by at least two generations of municipal welfare policy in England, followed by other cities in Europe.

With the emergence of a middle class and a qualified working class, also came the savings banks, which would eventually loan at cheap rates for local welfare achievements. Municipal bonds were found attractive by the public, and on top of this the Government would subsidise projects. Direct management and cheap money together allowed generalising water supply and sewerage. Operational costs being still limited, in that early phase in Britain, the idea prevailed that water services should be covered by local taxation, i.e. by rates proportional to the renting value of the house. This not only provided funds for the initial installation, but eventually had important redistributive effects and played a significant role in the acceptance of domestic supply.

However in Britain, there was not so much water available, and many cities had to take it from rivers; so they had to invent some form of purification, and first filtration; then, the overall problematique of water quantity could be supplemented by a quality one, thanks to sanitary engineering innovations. This would eventually support local water management.

3.1 Drinking water plants and sewage treatment plants in Europe[4]

Once Pasteur and Koch found water contamination was a major cause of diseases in the 1880s, even distant and pure water would eventually need to be treated. This is how sanitary engineering developed to supplement civil engineering and solve the first crisis of water services. Because direct medical action upon waterborne diseases was uneasy, it was decided that water should be filtered (end of 19th century), and later disinfected or chemically treated (chlorination, ozone, UV or activated carbon, around World War I). But then, taking surface water just upstream from cities would induce economies of scale, and would save a lot of investments. Typically, in Paris a 30 years' debate started in1890 about an aqueduct from Lake Geneva which would solve all the City's water quantity problems forever (Duvillard and Badois, 1900). The project was discarded after the First World War for geostrategic reasons, but indeed it had become useless after the inauguration, in 1902, of the slow filtration plant in Ivry, operating with Seine water just upstream from Paris; filtration gained support after a typhoid epidemics in 1899, which was found to be due to the contamination of the Loing springs; yet these were the furthest and supposedly cleanest water sources for the city.

However, treating water would induce a serious rise in operation costs, which are usually more visible to the public and to city councils. Then the idea spread that services could be at least partly covered by bills. It meant an important change for the public, and charges were initially limited to cover operation and maintenance. Slowly however, delivery of pressure water within the homes changed status, from a luxury good to a commodity, and made water billing normal. In Europe, only Britain (and the Republic of Ireland) have kept until now the ancient charging system based on rateable housing values.

Covering an ever larger fraction of the costs by bills increased the self financing capacity of water services, which improved their sustainability; later in many continental countries, it was decided to pass on the sewerage charges in the drinking water bills, despite the compulsory character of sewer connection, which would normally imply coverage of the costs by local taxes. Sewage treatment (and even collection) also became a commercial service. Eventually, increased self financing capacity reinforced the legitimacy of local authorities as providers, or at least organisers of the services. But, in order to achieve economies of scale, it was often needed to develop the joint efforts of neighbouring communes. Usually, central governments allowed and supported the creation of joint boards of municipalities, to bring the institutional, technical and management scales closer to each other.

In turn, this innovation in both plants (water and waste water) supported the development of new territories and of new relationships between politics and expertise, between elected representatives and engineers. In several countries, citizens pay a water bill to a private company which is owned by a joint board of municipalities, sometimes involving a regional level institution (Barraqué, 1995). The counterpart is that the relationship between water services and urban planning and environmental management is usually very small: this would lead to a new crisis at the end of the 20th century.

3.2 "Saneamento básico" and centralisation of services in Brazil

By the mid-1950s, a new concept, "basic sanitation" ("saneamento básico"), began to guide service management in Brazil. This concept refers exclusively to water supply services and to the collection and treatment of waste water, unlike the broader concept of the previous period, when sanitation was associated with wider sanitary conditions for urban development and the integration of urban infrastructure (Rezende and Heller, 2002).

Under the new perspective, water supply and sewer services were both considered essential services within the urban sanitation sector. They should be under the control of public administration but autonomously managed by specific agencies which would run the two systems together. Planning and management were expected to rely on modern engineering techniques and entrepreneurial models. System maintenance and expansion would be financed by user fees which would vary according to consumption levels. The idea of self-sufficiency, alongside the creation of municipal autarchies, i.e. of autonomous companies owned by the government, began to spread. These ideas fundamentally differentiated the "saneamento básico" approach from other services such as garbage collection and flood control, which continued to be financed by taxes and stayed under the purview of ordinary municipal agencies.

Municipal management itself gained autonomy through the development of independent agencies and self-financing mechanisms. Services began to expand into the suburbs. However, since the health situation had improved, federal and state levels of government preferred to devote public resources to productive infrastructure (energy, transport) than to local sanitation. Under-funding and rapid urban growth finally resulted in a pattern of centre-periphery fragmentation: most of the suburbs, distant from the centre, and inhabited predominantly by low income groups, were poorly served. In addition, in these areas the urbanisation process often took place without planning or public control; the infrastructure

[4] The history of drinking water treatment technologies largely remains to be written: for Paris see Gaiilard-Butruille (nd); for sewage works see Boutin, 1986.

layout was not thought out in advance, leading to a growing deficit. Conditions were made worse by irregular urban land occupation. For example, squatts, or "favelas" located in areas improper for settlement (wetlands, flood risk areas, and agriculture or environmental conservation areas) were not allowed to receive public infrastructure which, indeed, was often technically unfeasible (Britto, 2001).

The "water treatment paradigm" really developed only in the 1970s, with the implementation of the "saneamento básico" concept and, above all, the generalization of urban water supply. In those years, the country underwent a period of great transformations, with intense industrial development, demographic explosion and accelerated urbanization. The political situation also underwent deep changes after a military coup in 1964.

The military regime decided to set up a new operation and regulation structure for the water and sanitation sector based on the concept of "basic sanitation" ("saneamento básico"). PLANASA – the National Plan of Basic Sanitation or "Plano Nacional de Saneamento Básico" – was launched in 1971 with the goal of making investments more rational and of significantly developing the system within 10 years. To achieve these objectives, administrative centralisation at the state level was considered to be of utmost importance. Centralisation would also allow for cross subsidization. In each state, a Sate Water Basic Sanitation Company (CESB) was set up. In the state of Rio de Janeiro, a new State Water Company created in 1975, CEDAE, would become responsible for almost all municipalities of Rio de Janeiro state. In São Paulo state, SABESP was created in 1973, absorbing various regional companies. Despite the emphasis on expanding the network, however, the new companies were pushed to operate as if they were private companies, leading them to give priority to higher profits and rapid returns. And, after a few years of initial success in improving services coverage, CESBs were bound to meet financial difficulties.

Even though the 1967 Federal Constitution continued to give municipalities the responsibility for providing water services, the new policy reduced the role of local government to signing concession contracts with the state companies. Handing over the concession to state companies was the only way to be gain access to the new financing structure. Most municipal governments did not question the new model for many years. Indeed, the predominance of CESBs became a justification for denying that they had responsibility for matters related to water supply and sanitary sewers, in particular in the northern and poorer states (Braga et al., 1995; Fabriani and Pereira, 1987).

In terms of the quality of the infrastructure systems and of the urban environment itself, the consequences of this new approach were disastrous. As argued by Silva, infrastructure networks must be planned in accordance with vectors of city growth (Silva, 2004). However, the State Companies of Sanitation rarely considered local plans, unless, of course, they coincide with their own. On the other hand, the way "saneamento básico" was defined – giving priority to evidently essential systems, such as water and sewerage, but excluding drainage and solid residue collection, and delaying sewage treatment – generated critical situations in terms of flooding and water resources pollution.

In this period, the need to integrate water resources management and water and sewerage services became apparent. Environmental agencies were created to control pollution and local integrated water management initiatives were adopted in Greater São Paulo, though with few practical results. These experiences, however, were important precursors to the emergence of a new water services paradigm, in which water resources' protection and quality improvement become unavoidable.

In 1986, a profound institutional crisis led to PLANASA's termination. Its initial success in increasing water access coverage was largely a result of the vitality of the Brazilian economy between 1967 and 1980: high growth rates allowed social security and retirement funds to finance ever larger housing and urban infrastructure. However, investments concentrated on water supply, while sewerage was left aside, especially waste water treatment. Water supply is cheaper and can easily be charged for, producing better returns on investment than waste water collection and treatment, which must be done collectively and at high cost. In addition, the portion of the population able to pay for the real price of services was too small to guarantee self-sustainability, as originally planned. As a result, PLANASA invested more in wealthy urban areas while connection deficits in poor municipalities and, in particular, in areas of irregular land use did not decrease (Britto and Barraque, 2006).

The management model of the state companies was dominated by a supply side logic, based on the belief in the inexhaustibility both of resources and of the technical capacity to expand water supply systems and infrastructure. Indeed, water transfers continue to be necessary in Greater São Paulo, since most water bodies there have been heavily polluted. This so-called "relative water scarcity" – caused by inadequate water quality – led the Alto-Tietê basin to import water from neighbouring basins in the 1970s (Formiga-Johnsson and Kemper, 2005). Water diverted from the Piracicaba and Capivari basins to the Cantareira System currently supplies half of the total water in Greater São Paulo. A new major conflict has risen recently: rapid population and economic growth in the Piracicaba basin increased significantly local water demand as well as the level of pollution of its rivers. After an intense and lengthy mobilization that started in the 1980s, the Piracicaba basin only recently obtained more flexible operating rules for the Cantareira system, which now must ensure minimum water quality conditions in the Piracicaba basin. This conflict and the movement around it also greatly influenced the state reform of water resources management that occurred during the 1990s, which in turn strongly influenced the adoption and implementation of national level integrated water management policies in the

1990s (Formiga-Johnsson and Kemper, 2005). In the end, drinking water quality is not very good, and sewage treatment is lagging behind: Brazil has to meet the third paradigm issues, while it has not yet met those of the second one: in large metropolitan areas, there is an increasing shortage of water, both in quantity and in quality.

4 The third paradigm of water services

In the third paradigm, technology is not sufficient to solve all water problems, and both demand management and territorial policies are needed. Then, the sustainability of the European model (strong local legitimacy and high quality standards, allowing for a high rate of cost recovery despite heavy investments) might be challenged in the near future: how is it possible to maintain a good service quality on the long run, even once everybody is connected, if full cost recovery is imposed while investments are not subsidised anymore? This is indeed the challenge with the Water Framework Directive of the European Union (2000/60/EC of 23 October 2000): water users should pay for the services rendered by water, and should support the cost of recovering a clean aquatic environment.

In France like in other northern European countries, it was decided back in the 1960s to have sewerage paid within the water bills. But in the same period, water supply itself became a mature business, i.e. it had to face the issue of renewing ageing infrastructure without any more subsidies. We hypothesize that European municipalism had to adapt in various ways, but chiefly through returning to legal private status, so as to be able to depreciate the assets and to make renewal provisions, which was difficult under public accounting. In turn, adopting depreciation and provisions meant another rise in water bills. As a result, today an increasing number of large water users (industry, services) either quit or change their processes or fight their leaks. This explains the recent stagnation and even decrease in volumes sold (Barbier, 2000). In some countries, even domestic consumers have reduced their demand, through changing fixtures, different garden design, and also with rainfall storage or other alternative sources of water for non drinking uses. Yet this demand reduction ultimately worsens the already fragile financial balance of collective services.

In addition, water suppliers have a harder time to permanently comply with the drinking water standards (DWS) at reasonable costs. Drinking water criteria tend to privilege a traditional "no-risk" strategy at the expense of economic considerations. But the multiplication of criteria is slowly bringing the situation into over-complexification: chlorination by-products give cancer (Okun, 1996). There are many other examples: eventually the media can report a growing proportion of people receiving non-complying water, even though the treatment is improving on the long run. To lower the risk of being unable to make it, along with local, national and European authorities, water supplies turn to a new strategy: water resources protection. That is part of environmental engineering.

4.1 Environmental engineering as part of the third paradigm

Originated in sanitary engineering in the US, environmental engineering aims at protecting not only populations from negative environmental factors, but also global and local environments from potentially dangerous human activities. Of course, understanding natural processes was an important issue, but programs also focussed on urban issues and technical systems (Barraqué, 1993). The common characteristic of the two first paradigms is to focus on supply-side solutions, while environmental approaches have to consider "demand side". While economists would equate this term with market prices, environmental engineering considers that demand and supply are not independent like in a market, but inter-related. Thanks to the concept of environment, we have learnt that sometimes causes interact with consequences with feed-back loops, eventually provoking exponential outcomes; in other words supply and demand are not really independent, but interacting. This is what we call the "network effects".

Until recently, however, systems called "infrastructure" were hidden from the people, while offering more freedom, as time and space saving devices. In addition, it was not the infrastructure, but the plot of built or buildable land, which provided political legitimacy. City aldermen and elected representatives were competent on issues like valorisation (or devalorisation) of urban land, and they did not know much about the systems. Symmetrically, early sanitary engineers were convinced that public health needed an urgent development of water systems, in particular waste water collection and drainage, to evacuate the growing flows of potable water (Barles, 1995); and they preferred to locate them under the streets, i.e. in public space. The choice of the tout-à-l'égout in Paris is typical (Dupuy and Knaebel, 1982). In turn, people later became ignorant of the importance of systems: "out of sight, out of mind" and NIMBYism characterise the public's attitude and is at odds with a conservation attitude (Melosi, 1981). Operators had no interaction with the public and with demand side problems: they just had to match the demand with more or less invisible infrastructure and that was it.

With our "systemic" eyes of today, we can see how the municipalist model comes to a crisis. Sewer systems were designed bigger and bigger to accommodate increasing volumes of stormwater, because planning regulations seldom include limitations on soil imperviousness. Now stormwater storage and on-site reinfiltration are developed to reduce the size of interceptors conveying stormwater to some treatment plant. Since urban services are finally meeting diseconomies of scale, demand side is at last considered as a potential rationalisation. And so is land-based water control. Increasingly, in Germany, the Netherlands, and to a lesser degree in Denmark and France, utilities or their organising authorities develop contracts with farmers, to obtain raw water of better quality from a reduction of fertilizers and pesticides' use, through appropriate compensation for the corresponding loss in revenues (Brouwer et al., 2003). This policy is criticised by some economists and ecologists together, who argue that the polluters and not the victims should be the payers. Other economists just acknowledge that it is an efficient policy, and probably the only one, at least during a phase of "social learning" (Salzman, 2005).

This leads to redefine the very notion of "operator"; if supply and demand interact permanently, the traditional separation between supply-side and engineers, and demand-side and elected representatives, is blurred. A direct contact with the public is necessary, so as to get away from coarse linear and overoptimistic projections for the demand. Beyond the understanding of what people do with water, one can incite users of the system to use it more efficiently, and alleviate the negative network effects. This implies a significant change in governance: in the end the new grid-based systems operator is a complex mix of people and institutions who can only master the networks effects when they interact. Sharing information becomes crucial to succeed when a growing number of institutions interact to provide the water services and manage water resources together.

4.2 The case of Paris region

As any large metropolis, Paris offers a very complex institutional situation: communes are responsible for water services, but they cannot anymore do it alone: for historical reasons, Paris city has its own water services, and relies for half of its needs upon distant springs and aquifers, but the other half comes from rivers. Suburban communes are almost all part of large joint boards (the largest one, SEDIF, serves 4 million inhabitants in 144 communes), to rationalise their services (large plants treating surface water) and to build a better balance of power with the private operators; only one commune has a direct municipal water supply, Saint-Maur.

Since water supply in Paris suburbs heavily relies on rivers, it was decided to build 3 upstream reservoirs with more than 100 million m^3 capacity to sustain the low flow in the summer[5]. The first one (now called Lac de la forêt d'Orient) was built through central government funding, taking advantage of an important winter flooding in 1952. But the two next ones were funded by Agence de l'eau Seine Normandie, i.e. in the end by levies paid by water abstractors. This new responsibility of water users in funding dams led them to discard a project for a fourth reservoir[6]. And it turned out to be a good choice, since drinking water demand is now on a slight but steady decline. Clearly, the major issue remains drinking water quality, and since the treatment plants are now within the urbanised area, the big metropolis is dependent on better protection of both surface water resources (from upstream cities, agriculture and industry) and groundwater (from agriculture).

The situation is even more complex concerning sewage collection and treatment. The initial scheme at the end of 19th century was to collect all waste water and some of the rainfall and to convey this water downstream (combined sewers at the time), where it would be spread on sewage farms. The large interceptors were built and operated by central government staff at the département (county) level. But with the growth of the city, there was not enough space, and sewage works with biological treatment were built in Achères just before World War II. Stormwater would overflow directly in the river. With the rise of environmental policy though, it was found that Achères, the second largest sewage works in the world, had a severe impact on the Seine down to the estuary: there was not enough space to fully stabilise pollution. In addition, stormwater was increasingly found to be heavily polluted: the post war choice of separate sewers forced engineers to admit it. After several years of intense debate between the many stakeholders involved, it was finally decided to break the linear scheme of engineer Belgrand: taking water upstream and discharging it all downstream. The construction of modern and innovative sewage works upstream from Paris in Valenton, and the enlargement of smaller sewage works, will reduce waste water arriving in Achères by 30%, which would allow treating it better. Stormwater is increasingly collected and stored before reaching the sewers, in reservoirs or artificial ponds. After the peak flow, water is sent for treatment either to the sewage works, or to a couple of special treatment plants.

The resulting institutional set up is quite complex: suburban communes are in charge of street sewers, the three départements of the inner ring around Paris city are in charge of larger interceptors and of the stormwater control policy. Together with Paris city, they formed the SIAAP (Syndicat Interdépartemental d'Assainissement de l'Agglomération Parisienne), an inter-county board for running the largest interceptors and the sewage treatment plants. In the outer ring, there are some inter-communal joint boards which operate at the level of catchments of small tributaries, and which combine sewage collection and treatment and protection of the

[5] Four reservoirs were built before: Crescent (1931), Chaumençon (1934), Champaubert-aux-Bois (1938), and Pannecière-Chaumard (1950). But they were not sufficient to mitigate Seine floods and droughts: Pannecière-Chaumard is the largest but only stores 80 million m^3.

[6] This fourth reservoir was planned by mayor J. Chirac's experts, but it was abandoned for the same reasons (we must and can purify the water anyway, said the giant water supply companies, and the probability to have a dramatic scarcity is very low); plus the fact that Paris water demand went down by 16% between 1990 and 1998 (Cambon-Grau, 2000); after a pause, demand is now reducing again.

aquatic environment. Projects benefit from the financial support of the Agence de l'eau. This implies an unprecedented need for multilevel governance, and it is a very sensitive issue in the region and in the country: the Agences de l'eau cannot fund stormwater control projects, unless one can prove that quantity management has a positive impact on water quality. And symmetrically, communes are not sufficiently encouraged to reduce runoff from their territory, e.g. by subjecting building permits to detention constraints.

Now it is clear that the new water services policy needs to turn towards demand management, and we argue that this indeed means to develop citizens' participation. Indeed, several institutions like the SIAAP, the city of Paris and some suburban départemental councils have recently set up consultative bodies to share information with citizens and NGOs.

4.3 Towards the third paradigm in Brazil

In Brazil, the environmental engineering paradigm develops basically because problems related to water supply and, above all, sewage collection and treatment developed into major challenges. Intense urban and industrial growth during the second half of the last century means that the chief water issue in the Alto-Tietê Basin – where Greater São Paulo is located – is the struggle to balance water demand and availability. Ultimately, it is a tremendous challenge to provide water for nearly 18 million people in a highly urbanized area. Rapid urbanization has had intense impacts on water sources and water quality and has developed a complex web of interests and issues around water, involving sectoral policies, inter-basin transfers, and others (Formiga-Johnsson and Kemper, 2005). The same problem can be observed in the Rio de Janeiro Metropolitan Region, although less intensely: that city's main source of drinking water – the Guandu river, which receives waters diverted from the Paraíba do Sul river basin – has become severely polluted in recent decades, requiring the Guandu water treatment station to use enormous quantities of chemical products to make the water collected potable. Water services universalisation remains a challenge, especially with respect to sewage treatment and collection: investments increased substantially in the 1990s, but deficits remain important.

Indeed, São Paulo and Rio de Janeiro and their metropolitan areas illustrate a generalized problem in Brazil's large cities, the resolution of which will require the integration of the two main dimensions of water management in metropolitan areas: water resources management and environmental sanitation management. This is what the new policy starting in the early 1990s develops: it is based on intrinsic concepts of the environmental engineering paradigm such as demand side management, water conservation, water allocation flexibilisation, and an integrated approach of water services, water resources management, and land use policies. In Greater São Paulo, the water resources policy has gone even further, addressing the issue of headwaters protection from urban sprawl, one of the most serious water-related problems of the basin (and the most difficult to resolve). Initiated in the mid-1970s and revised in 1997 (State Headwaters Law 9.866/97), this new approach also represents a remarkable departure from São Paulo's traditional sectoral approach to water quantity and quality, which separated the management of water from its environmental aspects, especially water pollution and land use. However, the implementation of such policies will likely face significant difficulties, since reaching the proposed goals depends on the capacity and will of municipal authorities to improve their urban regulations so as to guarantee the control and monitoring of land use in the sub-basins (Formiga-Johnsson and Kemper, 2005).

But this also implies to develop new forms of multi-level governance: the predominant management model is still based on the delegation of services to state-owned sanitation companies, unlike other Latin American countries that have recently undergone major privatization in the area. By the year 2000, 71% of the 5.507 Brazilian municipalities had delegated their responsibility for water and sewage services to state leveled companies; 28% had their own municipal agency, and only 1% had handed over services to private companies (63 concessions in all) (SNIS, 2004). However, in 2006, a new regulatory framework law passed in congress, defining new operating rules for sanitation services; and in 2007 additional legislation creates participatory management bodies at municipal level, encourages new territorial scales of service management (see below) and gives municipalities more control over services ("program contracts"). The law returns to and broadens the integrated sanitation vision of the early 20th century, now called "saneamento ambiental" and including water supply, sewage collection and treatment, solid waste and urban drainage.

In addition, the creation of river basin committees has created a new multisectoral articulation that has challenged the sectoral logic of sanitation management that reigned until the 1990s. Even a river whose waters are limited to a single municipality will normally flow into another river, probably in another municipality. A waste water treatment problem becomes a water resources one, just like in France when the Agences de l'eau were invented.

The "ideal scale" for sanitation services management is currently in debate in Brazil, opposing defenders of the municipalista option and those who support regionalized management at the level of state governments. A third option is now emerging: intermunicipal articulation through consortia formed at the river basin or sub-river basin level and the formulation of an inter-sectoral management model (Britto and Formiga-Johnsson, 2008). Such integration is necessary to deal with the fundamental questions related to water management that Brazilian cities are confronting. The consortia, whose structure has been recently regulated by federal law, have been conducting service management planning and regulation and interacting in an integrated manner with the Basin Committees, the most important bodies for mediating conflicts among public actors and civil society. They may be a viable alternative for building the intersectorality that is so necessary. However, since they are a form of voluntary and cooperative intermunicipal organization, creating consortia requires breaking with the fragmented vision that characterizes city management today, typically ridden with party politics and competition among cities (Britto and Formiga-Johnsson, 2008). In this respect, the ABC Consortium and the Alto Tietê Committee, both in the Metropolitan Region of São Paulo, point to new, alternative paths and deserve further study.

5 Conclusion

In Europe, urban water services were increasingly run separately from the issues of water resources allocation, thanks to the innovation of water works and sewage treatment plants. Today it becomes preferable to combine technology and land use based solutions for a better sustainability of water services, rather than just rely upon technological solutions. A new intelligence of the limits of urban technology, also means extending the services to new areas, but with alternative technologies, e.g. decentralised sewerage systems: in most rural areas, and in low density suburbs, it is economically unreasonable to connect everybody to a sewer. Advances in soil biology make septic tanks better than small treatment plants, if properly operated. What we need to invent then is a service in-between the costly and heavy traditional centralised sewerage system, and the full self reliance of rural people. Even in water supply, there are a lot of flexible alternative technologies which could be used safely if under an appropriate institutional set up. The biggest technological challenge is then to better define the limits of centralised and decentralised water service technologies. In Brazil like in some European countries, historical centralisation and governments' support of large hydraulic projects made it more difficult to separate water services provision and water resources mobilization, resulting today in a crisis due to water resources contamination and even shortage.

In the early 20th century in both Europe and Brazil, water services were under the responsibility of local authorities. In Western Europe, they were part of local welfare through what is termed municipalism (including other public services). Even though upper levels of government would intervene in support of local policies, there was little centralisation, but frequent concentration (joint boards). Conversely in Brazil, water policy was long dominated by the over-powerful hydro-energy sector. In addition, agricultural conversion starting in the 1960s, with no land reform, led to an intense rural to urban migration of very poor people, while local authorities were weak and unprepared. During the military period starting 1964, water services were centralised at States' level: the program named PLANASA met an initial success in extending water services, but it failed to modernise services up to the standards reached in Europe. Quantities of water used are higher per capita, but quality of services is lower, and is maintained low by lack of self funding capacity: the price of water services is low, because the poorer cannot afford to pay higher prices, and then service remains deficient.

Some European countries are still in an intermediate position between the two models. Portugal and Spain had authoritarian governments until 1974–1975, and they ended up with water services lagging behind, but large hydraulic projects developed for the sake of hydroelectricity and irrigated agriculture (Pato, 2008). Joining the EU allowed for some decentralisation, and more recently, they develop the cooperation between central, regional and local governments. In Brazil there is a debate on decentralisation, but it reveals more confrontation than co-operation. Our analysis leads to consider that the centralisation/decentralisation issue is more important than the public/private debate. Indeed, a striking institutional evolution in continental Europe is voluntary concentration of services at an upper than local level of government. In Great Britain regionalisation and removal of local authorities' control took place 15 years before privatisation (Saunders, 1983), but remains very controversial (Bakker, 2003). Many fewer people know that in the Netherlands there remain only 10 water supply companies, and less than 30 water boards (in charge of large sewers and sewage works). In Belgium a strong concentration process leads to some sort of water services regionalisation. In Italy, communal water services are merged into new integrated boards (water and sewer) organised at the level of ATOs (optimal territories) which usually correspond to the provinces. In Portugal, the Government pushes communes to join large mixed boards where the National water company holds half of the shares and they have the other half. In a way, Brazil is undergoing reverse processes: since former centralization was associated with a non democratic regime, a lot of people, and in particular left wing parties, advocate for a re-municipalization of water services. Some even mix up decentralisation and privatisation, because many State water companies are held in distrust. But the real challenge is to develop intergovernmental cooperation.

The picture is then largely blurred: in developed countries there is good tap water, but people have been brought to ignore quasi everything about their services, so they cannot make a difference between water resources and water from the tap. Conversely, in developing countries part of the population has to rely on untreated water resources. Unfortunately, in the global debate about privatization, there is a tendency to amalgamate water resources and water services, and also developed countries and developing ones, for the sake of fighting globalisation and related privatisations: people advocate that water should be public and free for the poor. This will not help finding sustainable financial management! In addition, in large metropolitan areas in the whole world, water as a resource, water services and other services like electricity have to be integrated and request intergovernmental solutions plus public participation.

The expression "three engineering paradigms for water industry" should not be understood as replacing each other in a sequence: each one brings innovations which cumulate and bring more degrees of freedom to the services, but also new technology/territory articulations. Some projected dams and water transfers are still quite necessary and sustainable. And cities will go on needing water and sewage works. But new land use based solutions will help; they request new and interdisciplinary approaches. A comparative analysis helps developing a good vision of what is at stake in water services provision today: a need for social sciences in what we call "hybrid forums", where stakeholders are confronted to scientific or technical issues within the scientific community, and can eventually build up alternative and innovative "advocacy coalitions" to lead more sustainable water policies (Sabatier, 1993). We should therefore mobilize enlarged interdisciplinarity in environmental engineering. May be the most important is to give engineers a socio-economic and institutional culture of their action, to help them accept the consequences of the new motto: integrated and participatory water management.

Edited by: S. Barles

References

Bakker, K.: An uncooperative commodity: privatizing water in England and Wales, Oxford University Press, Oxford, 260 pp., 2003.

Barbier, J. M. (Ed.): Dossier: Evolution des consommations d'eau, Techniques Sciences Méthodes: Génie Urbain Génie Rural, 2, 14–59, 2000.

Barles, S.: La ville délétère: médecins et ingénieurs dans l'espace urbain, XVIIIe-XIXe siècle, Champ Vallon, Seyssel, Paris, 373 pp., 1995.

Barraqué, B. (Ed.): La ville et le génie de l'environnement, Presses de l'ENPC, Paris, 249 pp., 1993.

Barraqué, B. (Ed.): Les politiques de l'eau en Europe, La Découverte, coll. Recherches, Paris, 304 pp., 1995.

Barraqué, B. and Britto, A. L. N.: Urban water services: a sustainability issue at both ends?, Annual International Conference of Royal Geographical Society, London, England, 30 August 2006–1 September 2006.

Boutin P.: Eléments pour une histoire des procédés de traitement des eaux résiduaires, Tribune du Cebedeau, Liège, Cebedoc, 511–517, 1986.

Braga, J. C., Medici, A. C., and Arretche, M.: Novos Horizontes para a Regulação do Sistema de Saneamento no Brasil, Revista de Administração Pública, 29, 115–148, 1995.

Britto, A. L. N. and Formiga-Johnsson, R. M.: Gouvernance de l'eau dans les métropoles brésiliennes : une nouvelle perspective pour la coopération inter-institutionnelle, Colloque Nord-Sud: regards croisés sur le développement urbain durable, Paris, 23–25 January 2008.

Britto, A. L. N.: A regulação dos serviços de saneamento no Brasil: perspectiva histórica, contexto atual e novas exigências de uma regulação pública, Anais do IX Encontro Nacional da ANPUR, Rio de Janeiro, Brazil, 28 May–1 June 2001, 1080–1093, 2001.

Britto, A. L. N.: Redes de infra-estrutura na cidade: uma revisão dos conceitos e concepções de saneamento, IX Seminário de História da Cidade e do Urbanismo, São Paulo, 4–6 September 2006.

Brouwer, F., Heinz, I., and Zabel, T. (Eds.): Governance of water related conflicts in agriculture, New Directions in Agri-environmental & Water Policies in the EU, Kluwer, coll. Environment & Policy, 37, 236 pp., 2003.

Cambon-Grau, S.: Baisse des consommations d'eau à Paris: enquête auprès de 51 gros consommateurs, Techniques Sciences Méthodes: Génie Urbain Génie Rural, 2, 37–46, 2000.

Cebron de Lisle, P.: L'eau à Paris au XIXe siècle. Ph.D. thesis, University Paris I, 691 pp., 1991.

Correia, F. N. (Ed.): Eurowater, Institutions for Water Resources Management in Europe, 2 vol., Balkema, Rotterdam, 1112 pp., 1998.

Costa, A. M.: Análise histórica do saneamento no Brasil, M.Sc. thesis, ENSP, FIOCRUZ, Rio de Janeiro, Brazil, 1994.

Dupuy, G. and Knaebel, G.: Assainir la ville hier et aujourd'hui, Dunod, Paris, 92 pp., 1982.

Duvillard, P. and Badois, E.: L'adduction des eaux françaises du Lac Léman à Paris et dans la banlieue (projet P. Duvillard – résumé des études – projet définitif), Librairie Polytechnique Ch. Béranger, Paris, 191 pp.+7 planches hors texte, 1900.

Fabriani, C. B. and Pereira, V. M.: Tendências e Divergências sobre o Modelo de Intervenção Pública no Saneamento Básico, Texto pra Discussão no. 124, UFRJ/IEI, Brazil, 1987.

Formiga-Johnsson, R. M., Kumler, L., and Lemos, M. C.: The politics of bulk water pricing in Brazil: lessons from the Paraíba do Sul basin, Water Policy, 9, 87–104, 2007.

Formiga-Johnsson, R. M. and Kemper, K. E.: Institutional and policy analysis of river basin management in the Alto-Tiete river basin, São Paulo, Brazil, The World Bank, Policy Research Working Paper 3650, Washington, 53 pp., 2005.

Gaillard-Butruille, S.: Evolution des traitements de potabilisation jusqu'en 1940, l'exemple de Paris, published by SAGEP, Société Anonyme de Gestion des Eaux de Paris, no date.

Goubert, J. P.: La Conquête de l'eau. L'avènement de la santé à l'âge industriel, Hachette, Pluriel, Paris, 302 pp., 1986.

Guillerme, A.: The genesis of water supply, distribution and sewerage systems in France, in: Technology and the rise of the networked city in Europe and America, edited by: Tarr, J. and Dupuy, G., Temple University Press, Philadelphia, 1800–1850, 1988.

Keck, M. E.: Water, water everywhere, nor any drop to drink: land use and water policy in São Paulo, Brazil, in: Livable Cities? Urban Struggles for Livelihood and Sustainability, edited by: Evans, P., University of California Press, Berkeley, 161–194, 2002.

Maver, I.: Glasgow: Town and city histories, Edinburgh University Press, 256 pp., 2000.

Melosi, M.: Garbage in the cities, refuse, reform and the environment, Texas U.P., 268 pp., 1981.

Okun, D. A.: From cholera to Cancer to cryptosporidiosis, J. Environ. Eng. Div, ASCE, 122, 453–458, 1996.

Pato, J. H.: O valor da água como bem público, PhD Thesis, Instituto de Ciências Sociais, Universidade de Lisboa, 353 pp.+anexos, 2008.

Pezon C.: Le service d'eau potable en France de 1850 à 1995, Presses du C.E.R.E.M., Paris, 450 pp., 2000.

Rezende, S. C. and Heller, L.: O saneamento no Brasil: políticas e interfaces, Editora UFMG, Belo Horizonte, Brazil, 2002.

Sabatier, P. and Jenkins-Smith, H.: Policy change and learning, an advocacy coalitions approach, Westview press, coll. Theoretical lenses on public policy, Boulder, Colorado, 290 pp., 1993.

Salzman, J.: Creating markets for ecosystem services: notes from the field, in: New York University Law Review, 80, 870–961, 2005.

Saunders, P.: The regional state, a review of literature and agenda for research, Sussex University Papers, Sussex, 82 pp., 1983.

Silva, R. T.: Infra-estrutura urbana, necessidades sociais e regulação pública: avanços institucionais e metodológicos a partir da gestão integrada de bacias, in: Metrópoles. Entre a coesão, a fragmentação, a coesão e o conflito, edited by: Ribeiro, L. C. Q., Fundação Perseu Abramo, Rio de Janeiro, 2004.

SNIS – Sistema Nacional de Informações em Saneamento, 2004, available at: http://www.snis.gov.br/, 2004.