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Water Resources Management and Governance as Part of an Overall Framework for Growth and Development

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Singapore has recognized the importance of universal principles and paradigms in the management of water resources whilst also acknowledging that they do not automatically lead to improvement unless there is a strong emphasis on policy and programme implementation. As a result, the city-state has developed a comprehensive, holistic vision for the overall management of its water resources, making them essential elements for overall development, economic growth and national security. This paper discusses the city-state's long-term, comprehensive water resources strategies including their policy-making, planning, management, governance and development. It also argues that Singapore is one of the very few countries, if not the only one, that has developed its water policies as part of the overall development goals of the city-state.

Keywords: Singapore, water resources, governance, management, development.

1. Introduction

Water is, and has always been, a multi-dimensional resource that crosses all other social and economic sectors, with its management, policy making, development and governance, increasingly depending on policies on the other sectors. In addition, since water quantity and quality aspects are multi-sectoral, multi-dimensional and multi-disciplinary, so are their associated trends, drivers and challenges and should be considered as such (Söderbaum and Tortajada, 2011).

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Equally, at the global and local levels, there are increasing numbers of drivers of change that have important impacts on water resources and on their governance[1]. These driving forces include population and urbanization, economic growth, energy generation and agricultural production, as well as far more complex issues like globalization, free trade, migration, advances in technology (biotechnology and desalination, for example), changing management paradigms, and evolving social attitudes and perceptions. In addition, water is increasingly becoming a central consideration for food, energy and environmental security and thus is having significant implications for future human development at the global, regional, national and sub-national levels. As such, it is surprising that policies and strategies for the water sector continue being developed in isolation, as it is the case in most parts of the world. It would be more logical that they were viewed in a broader and systematic manner so that their impacts on other sectors were considered as part of an overall framework for development (Tortajada, 2010a).

Ideally, progress and innovation in water management and governance policy and implementation[2] should move forward so that they were able to match the constant evolution of the other sectors. Nonetheless, the required reforms in the governance of the water sector are taking place very slowly in most countries of the world, partly due to lack of administrative capacity, but also partly due to lack of incentives or interests for actors and institutions to change, issues that may be economic in nature but that also may be related to leadership capabilities. Therefore, the slow pace of formulating a much needed vision for the overall governance and management of water, which can actually be implemented, is an increasing constraint.

The situation is such that water governance is considered to be in a state of confusion in most of the world, with both developed and developing countries facing challenges which are common in nature (OECD, 2011). These include issues that go from short-term planning, shortage and inappropriate use of financial resources, to lack of institutional and human capacities. A main lacuna is the lack of vision to develop strategies that go beyond short-term political and economic considerations and that should focus instead on the long-term needs of the water sector for alleviating poverty, improving quality of life, and protecting the environment. Other concerns are legislation and regulations that lack the necessary implementing instruments, inefficiency inherit in public expenditure on water services, subsidy regimes that do not promote innovative ideas, and water organizations that do not attract or retain staff with the skills required for efficient service delivery (Tortajada, 2010b).

[1] Literature that focuses on the meaning and implementation of water governance under different situations is vast. See, for example, Araral, 2008, Araral and Yu, 2010; Bakker and Cook, 2011; Biswas and Tortajada, 2010a; Biswas and Tortajada, 2010b; Guidi-Gutiérrez et al., 2012; Hering and Ingold, 2012; Kooiman, 2003; Molden et al., 2010; OECD, 2011; Rogers and Hall, 2003; Sokhem and Sunada, 2006; Tiihonen, 2004; Tortajada, 2010a; Tortajada, 2010b; Tropp, 2007.

[2] Water governance and water management are interdependent in the sense that effective governance systems are meant to enable practical management tools to be applied properly as situations require.

One of the very few countries that has developed holistic water management and governance policies and has enabled practical management tools to be implemented efficiently and effectively as situations have required is Singapore. Most importantly, water resources policies and programmes have been developed and implemented in coordination with institutions of other sectors. This as part of the city-state's systems's for vertical and horizontal coordination, cooperation, and communication among institutions that have been set and sustained along the years in spite of their complexity. The overall objective of this system has been to pursue a single set of national goals, rather than sectoral ones, to propel the city-state into the path towards sustainable development.

This paper discusses water resources management, policy-making, development and governance in Singapore from the time of the independence in 1965. It presents numerous examples of how policies and management practices for water resources have been developed, tailored and implemented along the years within a broader framework for development where they have responded to the development goals of the city-state, not of the water sector.

One could say that innovative water resources planning and management have resulted out of necessity due to the naturally limited availability of water resources of the city-state. Nevertheless, these policies have clearly emerged from a clear national vision and a long-term planning exercise where the city-state' goals have prevailed over those of individual sectors. There is always room for improvement, but so far, Singapore has developed one of the best public policy laboratories in the world in terms of water resources management where leadership has played a very important role. Both developed and developing countries can certainly learn from its lessons learned and emulate those that prove relevant.

2. Water resources management and governance

At present, Singapore is a city-state of 714 km^2 and a population of 5.1 million inhabitants. It is one of the most prosperous countries in the world, with strong international trading links and a per capita gross domestic product (GDP) of S$63,050.0 in 2011 (see Singapore Department of Statistics, http://www.singstat.gov.sg/stats/keyind.html#econind, accessed on 28 August 2012).

In order to sustain its growth, Singapore has elaborated and implemented long-term development policies that are mindful of the country's limited water resources. One of the best examples is the series of water supply strategies that have been refined over the last 48 years. In 1965, the city-state was heavily dependent on water imports from Johor, Malaysia. Since then, strategies, policies and programmes have focused on the diversification of water resources. These measures have included the expansion of catchment areas, infrastructure development and the implementation of water supply and demand mechanisms. Moreover, large investments in research and development (R&D) have been undertaken on technology for recycling wastewater—used water or NEWater—and desalination as unconventional sources of water.

Water supply diversification has led to the so-called Four National Taps: water from local catchment areas, imports from Malaysia, reclaimed resources known as NEWater and desalinated water. (For more information, see Tan, 2011; Ching, 2010; Lee, 2010; Lee, 2005; PUB, http://www.pub.gov.sg/water/Pages/default.aspx, accessed on 28 August 2012). Furthermore, in addition to education, information and communication campaigns, partnerships between the public, private and 'people' sectors, have also been core elements of Singapore's water resources management strategies (Tan, 2011; Tan et al., 2009; Tortajada, 2006; Tortajada et al., 2013).

Table 1 presents the situation in Singapore in 1965 and 2011 regarding land and water resources. During this time, land area increased by 134 km^2, population grew by 3.2 million people, and water consumption per capita per day and total water consumption increased from 75 liters and 70 Mgal/day to 153 litres and 380 Mgal/day. Water catchment land area increased to 67%; desalination capacity reached 30Mgal/day and NEWater (treated wastewater or used water) capacity went to 117 Mgal/day from none in 1965 (see Singapore Department of Statistics, http://www.singstat.gov.sg/stats/keyind .html#econind, accessed on 15 May 2012).

In Singapore, one of the main premises in the planning and management of water resources has been that water can be a finite resource if not naturally available. Nevertheless, this only holds up to the point where technology is developed, although with the related high expenses, mostly in terms of energy. Therefore, aware of the potential of high-quality

Table 1
Key Statistics on Singapore, 1965 and 2011.

	1965	2011	Change
Land Area (km^2)	580 km^2	714 km^2	+134 km^2
Population	1,887,000	5,184,000	3,297,000
GDP per capita[1]	S $ 1,580	S $ 63,050	S $ 61,470
Water Consumption per capita	75 l/person-day	153 l/person-day	+78 l/person-day
Total Water Consumption	70 Mgal/day	380 Mgal/day	310 Mgal/day
No. of Reservoirs	3	17	+14
Land Area as Water Catchment	11 %	67 %	+56 %
Desalination Capacity	0	30 Mgal/day	+30 Mgal/day
NEWater Capacity	0	117 Mgal/day	+117 Mgal/day
Industrial Water Capacity[2]	0	15 Mgal/day (2010)	+15 Mgal/day
Water Availability	24 hours/day	24 hours/day	–
Service Coverage	~80%	100%	
Unaccounted-for-Water	8.9 %	5.0 % (2010)	–3.9 %

Sources: Ministry of the Environment and Water Resources, "Key Environment Statistics—Water Resource Management", Singapore. Available at http://app.mewr.gov.sg/web/Contents/contents.aspx?ContId=682 (accessed 22 August 2012); Department of Statistics "Key Annual Indicators." Singapore; Available at http://www.singstat.gov.sg/stats/keyind.html (accessed 22 August 2012); PUB Annual Reports.
Notes:
[1] At 2011 market prices.
[2] Assume industrial water capacity is equal to sales of industrial water. Information extracted from http://app.mewr.gov.sg/web/Contents/Contents.aspx?ContId=682, accessed on 9 March 2012.

reclaimed water as a resource for non-direct and non-potable uses, the city-state has invested very heavily on research and development to build up the necessary know-how and technology for its mass production mostly for industrial use. The most stringent regulations and monitoring have also been developed, with water quality standards that comply, and even exceed, those set by the World Health Organization (Khoo, 2011; Luan, 2010; Tan et al., 2009; Tortajada et al., 2013).

3. Early planning

Before independence, water demand was met from the then three existing reservoirs in the protected central catchment area (MacRitchie, Seletar and Peirce) and from water imports from Malaysia's Gunong Pulai and Pontian reservoirs. Between the 1960s and 1970s, the implemented water supply development scheme was the continuation of earlier plans set out by the British. Singapore started by expanding two of the three existing reservoirs in the central catchment area: Seletar Reservoir was expanded 35 times to create Upper Seletar Reservoir in 1969 and Peirce Reservoir was expanded 10 times to create Upper Peirce Reservoir in 1975. To import water from Malaysia, the Scudai River Scheme and Johor River Scheme were also developed and set out under the 1961 and 1962 Water Agreements respectively.

Subsequently, unprotected water catchments were created with the formation of barrages to form estuarine reservoirs. They were formed by damming the mouths of the western rivers and brackish water was pumped out so that the rivers could be used to store fresh water. The Kranji-Pandan scheme was finalized in 1975 with the completion of the works in the Kranji and Pandan reservoirs. The Western Catchment scheme—comprising Murai, Poyan, Sarimbun and Tengeh reservoirs—was completed in 1981. Singapore then turned to unprotected water catchments in urban areas to collect water from densely populated new towns. The first of these urban water catchments was the Sungei Seletar-Bedok scheme, finalized in 1985, along with the creation of Bedok and Lower Seletar reservoirs and waterworks at Bedok to treat the water (PUB, 2002). Figure 1 shows the development of water resources in the city-state from 1965 and until 2011.

Shortly after independence, the government was particularly keen on developing effective and efficient drainage and sewage management systems to improve the quality of life of the population and sustain Singapore's economic growth. In 1969, approximate 6,900 ha (about 12.75% of main land area at that time) were flood prone (Lim, 1997). The Government started providing drainage in flood prone areas as well as implementing flood prevention measures in low-lying areas. During the early post-independence years, financial constraints limited the planning and construction of water projects. However, by early 1970s, rapid industrialization and economic growth made Singapore's per capita income second in Asia only after Japan. With more resources, it became easier to plan and implement new flood alleviation measures.

In the late 1960s, a Sewerage Master Plan was conceived as a detailed guide for the development of wastewater infrastructure. The plan included macro level wastewater

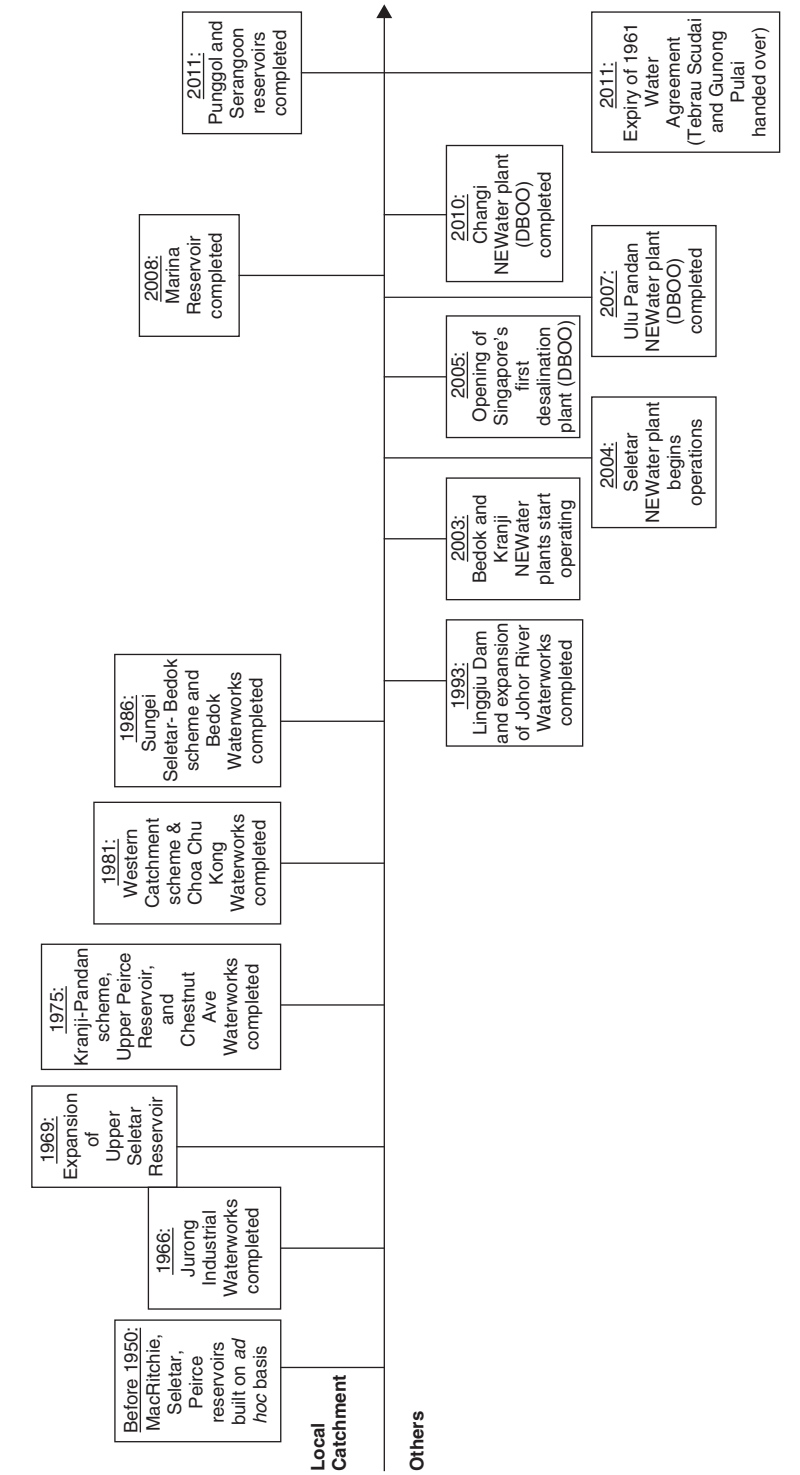

Figure 1. Development of Singapore Water Resources. (Source: Public Utilities Board, 2012.)

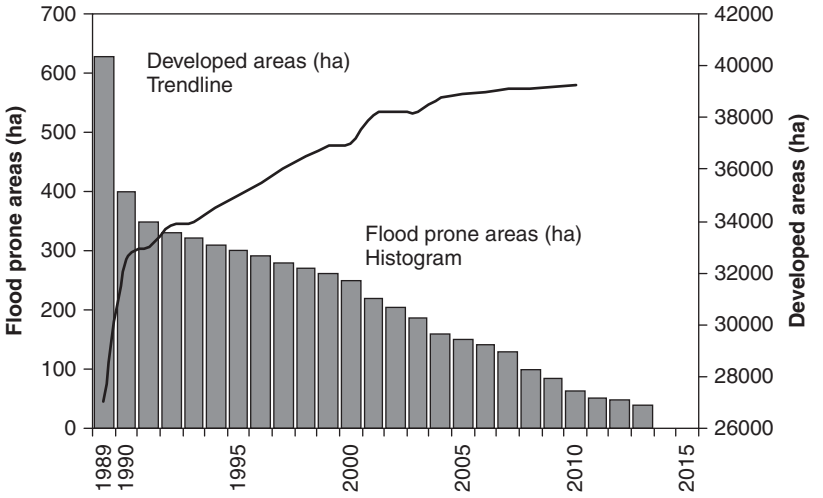

Figure 2. Reduction in flood-prone areas despite urbanization. (Source: Public Utilities Board, 2012)

projections, micro level sewer design considerations and the layout of the sewerage network (Tan et al., 2009). In 1970, the government came up with a Local Government Integration (Amendment) Bill, and revised sewerage charges based on the amount of water used to meet the foreign exchange component of the cost of sewerage expansion projects (Hansard, 1970). This was the end of the country's flat rate era for sanitation services and paved the way for modern sanitation.

The multiple drainage projects have helped reduce flood prone areas by more than 95% over the last few decades, even as urbanization has intensified over the same period of time. From the 3,178 ha of flood prone areas in 1970s, only 56 ha remained vulnerable in March 2011 (PUB, 2011) (Figure 2).

4. Industrialization, Environment and Legislation

The immediate years after independence have been perhaps the most dynamic in the history of Singapore (Turnbull, 2009). Internally, much of the growth accrued from heightened industrial activities and government expenditure on overall infrastructure, housing and development. At the same time, the city-state focused on export-oriented industrialization, encouraged foreign and local investment and grew rapidly as a financial centre and capital market. Singapore's economic development project was unique: while newly independent states around the world were looking for a domestic market for their pioneer industries, the vision of the city-state was to link with global markets (Goldblum, 2008).

The Singapore Government was aware of the environmental consequences of industrialization. Therefore, it developed its own integrated approach to environmental protection aimed at ensuring that industrial development was not at the environment's expense.

As such, infrastructure was built in designated areas to mitigate environmental impacts and, as a rule, pollution control measures were incorporated from the design stages. For any development activity, provisions to control air, water and noise pollution; management of hazardous substances; and treatment and disposal of toxic waste had to be clearly indicated in the proposal. Once projects were to be built, the Anti Pollution Unit and the Sewerage Department were both in charge of ensuring compliance for sewerage, drainage, environmental public health and pollution control (Chia and Chionh, 1987).

Overall, the centralized command-and-control measures of prevention, law and regulation enforcement and monitoring (Lee, 2008) became the key strategies adopted to mitigate the adverse environmental impacts of infrastructural development. Singapore adopted an integrated approach to land use planning where planning was done in consultation and coordination with concerned government agencies who shared not only the allocated resources, but also took part in mitigating adverse impacts of developments on environment and specially, on water resources. Initially, all types of industries were allowed. Nevertheless, with time, high technology, high value-added and low-polluting industries were preferred over low technology, low value added, labour intensive and polluting activities.

Since its independence, Singapore's water vulnerability challenged the government to adopt strategies in maintaining, reinforcing, enhancing and reusing water resources. From very early on, the impacts on water of land use, industrial development, air and soil pollution as well as solid waste were acknowledged. Stringent laws were thus passed and strictly implemented trying to protect the scarce water resources.

In 1975, the Water Pollution Control and Drainage Act (Chapter 348) was enacted to control water pollution. Its overriding principle was that, wherever possible, effluents were to be discharged into sewers and their quality monitored and regulated. Part IV of this Act primarily addressed water pollution control for inland waters (rivers, streams, lakes or ponds) and made it a punishable offence to discharge "any toxic substance into any inland water so as to be likely to give rise to an environmental hazard". In addition, Section 4(1) of the 1976 Trade Effluent Regulation enabled the Director of the Water Pollution Control and Drainage to ensure that trade effluents were discharged into sewers only.

5. The Concept Plan of 1971

In 1962, 1963 and 1965, United Nations consultant groups visited Singapore answering to a technical assistance request to deal with redevelopment problems in the city's central area. In general, the different groups recommended replacing the previous 1958 development plan (Dix, 1959) with the objective to organize and direct the resources available to the government so that it could achieve a progressive development (Crooks, Michell, Peacock and Stewart Pty Ltd, 1971).

In 1971, a long-term, comprehensive Concept Plan was elaborated for Singapore's physical development, mapping the country's vision for a period of 40 to 50 years. It articulated the strategic directions for land use and transportation and prescribed reviews

every ten years. It took into account changing economic and population trends as well as land use needed in the course of physical growth (Crooks, Michell, Peacock and Stewart Pty Ltd, 1971). The Concept Plan, which ensured that land resources were used efficiently and effectively, was implemented with the help of a Master Plan through detailed land use plans.

While at the macro level Concept Plans guide Singapore's development, a level below, the Master Plan translates its broad, long-term strategies into medium-term development details. Both Plans are the result of collaborative effort of various ministries and statutory boards. In the Master Plan, proper land-use planning plays a major role in protecting water bodies and the environment. For example, it sets land aside for sewerage, waste disposal and incineration facilities; similarly, polluting industries are grouped together and located away from residential areas. Thus, by clustering industries in one place, economies of scale assist in the implementation of the environmental protection measures considered in the Master Plan. Furthermore, when designing for infrastructural development, environmental pollution control requirements are incorporated, particularly with regard to health, drainage, sewerage and pollution control (Tan et al., 2009).

The Concept Plan of 1971 provided a flexible framework within which detailed programmes could be prepared by the different government agencies. The main advantages of this plan were its flexibility and practicability since it could be adapted to future changing circumstances and implemented within known and predicted constraints imposed by governmental objectives, policies and resources, and market forces influencing private investment.

What is more, one of the fundamental aspects of this Concept Plan was the 'ring concept' integrative approach (Development Ring around the Central Catchment Area). According to this notion, major industrial areas were to be located on the periphery of corridors and major recreational areas were to be developed from the Central Catchment Area through the coast (Crooks, Michell, Peacock and Stewart Pty Ltd, 1971). The new towns were to be built around the Central Catchment Area covering 18 square miles, where the protected catchments of that time (MacRitchie, Peirce and Seletar) were located. This served the definite purpose of protecting water bodies from pollution. It also eased population concentration from the Central Area. The protected catchments were left in their natural state as far as possible except for recreational activities and no development work was authorized.

The 1974–1989 Central Area Plans focused on the redevelopment of the Central Area, where population, commercial, banking and business activities were concentrated. This was implemented by different government agencies: the Urban Development Authority (URA) was responsible for resettlement and relocation, clearing, assembling and selling land and developing necessary projects; the Housing & Development Board (HDB) constructed massive housing infrastructure; and an action plan was implemented by the Public Utilities Board (PUB) to clean waterways such as the Singapore River (historically the most important trade artery) and the Kallang Basin (Joshi et al., 2012a; Tortajada et al., 2013).

6. Water Supply Strategies

After independence, rapid industrialization and population growth, in addition to dependence on foreign sources of water, put enormous pressure on utilities as well as on scarce land and domestic water resources. Institutionally, the responsibility to supply water, electrical power, and gas fell under the Public Utilities Board (PUB, 1963). PUB's Water Department was responsible for raw water collection and storage, its treatment to drinking water, operation and maintenance of the water supply pipe network, water delivery to the consumer and water supply through standpipes and trucks. In the 1980s, PUB took over the Sewerage and Drainage Departments of the Ministry of the Environment (ENV) so that all functions related to the water cycle were under one organization. In 2001, PUB become a statutory board under ENV, which was renamed as the Ministry of the Environment and Water Resources (MEWR) in 2004 (Tan et al., 2009).

The Concept Plan of 1971 also included the construction of new reservoirs. In 1971, a Water Planning Unit was set up under the Prime Minister's Office to study water's scope and feasibility through conventional and unconventional sources. Based on the Unit's studies, the First Water Master Plan of 1972 was drafted. This document outlined plans for Singapore's local water resources to ensure diversified and adequate water supplies to meet projected future water demands. Similarly to the Concept Plan for the island's entire development, this Water Master Plan was to serve as a blue print to guide the long-term development of water resources (Tan et al., 2009). The objective was to first create urbanized catchments whilst following up on developments in water reuse and desalination (Tan et al., 2009).

The Concept Plan of 1971 recognized the importance of water scarcity and considered that water supply was the most critical among the public utility services (Crooks Michell Peacock Stewart Pty Ltd, 1971). That same year, the 1971 UN Project Report on Urban Renewal and Development noted that domestic water was available over almost the whole of the island, including all the rural villages. It also noted that "there were no special difficulties in providing for large scale urban development" (Crooks Midhell Peacock Stewart Pty Ltd, 1971:28). Moreover, the government was reluctant to continue depending so heavily on external supplies and thus planned to develop additional catchments. It was expected that after completion, internal sources would meet 50% of the total water needs.

Yet, infrastructure developments and water imports were not enough to cover Singapore's fresh water demands. Therefore, there was an urgent need to clean up highly polluted rivers and water bodies. Cleaning and pollution control became even more urgent due to the growing need to develop unprotected catchments especially in the urban areas.

To reduce the possibility of polluting water sources, pigs, duck and other forms of animal husbandry activities near catchment areas were relocated, sanitation systems were extended over the entire island and anti pollution legislations were introduced and effectively implemented. Tan et al. (2009) mentions that with rapidly growing demand, it was

required to capture every economically viable drop of water. PUB then started its ambitious project of creating urbanized water catchments.

For such an unconventional project, the polluted water run-off from urbanized areas was too big of a risk. In those days, there were many potential pollution sources including household waste; industrial discharges; sewage from leaking sewers; waste from hawkers (food sellers), slums and squatters, pig and duck farmers; and litter. Singapore's rivers were full of rubbish perennially floating on dirty water. Thus, with the beginning of the implementation of the Concept Plan of 1971, it seemed ironic that in the midst of all the talk of refurbishing the city centre, there were more than 46,000 squatters still living in unsanitary conditions in the vicinity of the rivers (Dobbs, 2003).

In 1977, at the opening ceremony of the Upper Peirce Reservoir, Prime Minister Lee Kuan Yew challenged officials to clean the rivers within ten years time. In that period, the ongoing redevelopment of the Singapore and Kallang River catchments would see the entire area properly sewered and drained. Clearance and relocation programmes were based on census surveys of the affected squatters. Eviction notices were given by the Land Office, Resettlement Department, Housing & Development Board (HDB), and Jurong Town Corporation (JTC), depending on who owned the land. Squatters were given eviction notices several times, including repeated warnings to convince them to relocate, and severe actions were taken against non-compliant inhabitants as well as against those persons who delayed their departure without valid reasons (Joshi et al., 2012b).

In general, all persons and business establishments affected by the resettlement were offered compensation as well as housing units that were of much better quality than the ones they had before. They also benefited from rent concessions or down payments waivers to buy their properties. Squatters were paid compensation on fixed government approved rates, which was ex-gratia in nature. For example, farmers were paid compensation at approximately S$205 per square meter for their house, while squatters were compensated at a rate of S$105 per square meter of housing. Grants in cash were given to farmers in lieu of alternative farm lands, and residential families and business establishments living in the central urban areas that preferred to arrange for their own accommodation, were also paid cash compensations (Tan, 1986).

More than 46,000 unsewered squatters were resettled from the Singapore River and Kallang Basin area to other places (Tan, 1986). More than 4,900 street hawkers and 2,800 backyard trades and industries were relocated and 11,847 night soil bucket latrines, 3,259 pig farms from the catchment area and 7,290 duck farms were phased out. Within ten years, the rivers became clean, with the waterways thriving with marine lives, a legacy Prime Minister Lee wished future generations could enjoy. The river's banks, once cluttered with boatyards, backyard trades and squatters, were transformed into attractive riverside walkways and landscaped parks (Joshi et al., 2002a). The direct and indirect benefits Singapore got from the river cleaning exercise and the resulting value added to the city-state in general and the Central City in particular, by far justified the approximately $300 million it cost to do the clean up (Tan et al., 2009).

7. Developing the Drainage Master Plan

In 1972, the Drainage Department was set up under the newly formed Ministry of Environment. Its main objective was to ensure an effective land drainage system to protect national assets, improve public health and achieve flood alleviation and prevention. That same year, a comprehensive Drainage Master Plan was drawn up and immediately implemented (Lim, 1997). During the next 25 years, the Drainage Department constructed some S$2 billion worth of projects (PUB, personal communication, 2012). In view of rapid urbanization, many waterways were upgraded to facilitate increased storm water run-off. This work was done in tandem with massive Housing & Development Board (HDB) housing and Jurong Town Corporation (JTC) industrial developments.

The Drainage Department was entrusted with the enforcement of the Water Pollution Control and Drainage Act (1975), the Surface Water Drainage Regulations (2007) and the Trade Effluent Regulations (1976). It was also entrusted with the authority to recommend the Certificate of Statutory Completion on development works carried out under approved building plans. This body was also to monitor construction sites to ensure that construction works did not affect existing drains and that new drains were constructed according to approved building plans.

8. Developing the Used Water (or Wastewater) Master Plan

In early years after independence, the solution to Singapore's sanitation problem was the night soil bucket collection service. This system remained in vogue till late 1980s when it was replaced by alternative on-site sanitation systems. Growing pollution made necessary a more effective and expanded sanitation system, especially to minimize pollution of waterways and coastal waters. Satellite towns were developed under the new development plans and there was an immediate need to invest in sewerage. Consequently, a Sewerage Master Plan was formulated in the late 1960s.

Under this Master Plan (later renamed as the Used Water Master Plan), Singapore was divided into six used-water catchment zones, each one served by a centralized water reclamation plant (or wastewater treatment plant) that complied with international standards (Lawrence and Aziz, 1995). These plans were implemented through the 1968–1973 and 1973–1978 investment programmes. A charging mechanism was adopted to recover the cost from consumers (Tan et al., 2009). The sewerage system was designed based on a 'separate system' where used water was collected separately in a network of underground sewers that led to a treatment plant, while storm water and surface runoffs were collected in open drains and channelled to rivers and reservoirs (see http://www.pub.gov.sg/about/historyfuture/pages/usedwater.aspx, accessed on 29 August 2012).

With the development of the first urban centres, an old open trench method of sewer rehabilitation was not only time consuming but inconvenient to the public as well. Therefore, from the early 1980s, PUB explored the use of 'trenchless' technologies, which saved enormous amounts of time and costs, and proved less irritating to the public. When

the plans for urban catchments began in 1980, leaks were considered a major threat to the aesthetic and recreational quality of water bodies, leading PUB to explore newer technologies and better sewer rehabilitation programmes (Tan et al., 2009).

Within 20 years, Singapore eradicated bucket latrines and open defecation. Robust sewerage infrastructure helped the government to provide nearly universal coverage of modern sanitation services. With time, on-site sanitation became a service provided to all population.

9. Urban Development post-1980

By 1991, basic infrastructure required for a prosperous urban city had already been developed. Waterways became clean, and the 1985 Singapore River Development Plan was in progress. In safeguarding the environmental norms, Housing & Development Board (HDB) collaborated with the Parks and Recreation Department, to provide landscaped open-space greenery by planting and maintaining tropical trees. With the majority of the population residing in high-rise HDB flats, 100% of the population had access to piped water and modern sanitation by the end of 1990s. As water was properly managed, it was easy to implement the State and City Planning project where business and residential districts were visualized in the Development Plan of the Central Area. Land acquisition and a wide range of infrastructure development such as roads, sewerage, drainage, telecommunications, etc., helped transform residential areas into efficient businesses cities.

After the successful clean-up of urban water pollution sources, it was also possible to develop urban water catchments outside protected catchment zones in highly urbanized areas with residential, commercial and industrial developments. The Sungei Seletar-Bedok water scheme, a technically complex stormwater collection system, was developed in 1986 as the first urban catchment. Sungei Seletar was dammed to form Lower Seletar Reservoir. From here, raw water is conveyed through pipelines to the Bedok Reservoir, which was constructed out of a sand quarry. This reservoir also receives water from storm water abstraction ponds in highly urbanized towns. In all these projects, integrated planning played an important role.

In the development of the Bedok catchment, Urban Redevelopment Authority (URA) planned land use in such a way that polluting developments were kept away from water sources 10 to 15 years prior to the construction of any reservoir scheme. This area was reserved for light industries and residential purposes only and it has an extensive sewerage network planned by Public Utilities Board (PUB) in cooperation with Urban Redevelopment Authority (URA) and Housing & Development Board (HDB) (Tan et al., 2009).

By this time, the International Monetary Fund had declared Singapore a First World Country. Its economy, which was caught in slight downturn in 1985, recorded very high annual growth rates from 1987 onwards. It was hardly affected by the first Gulf War, which drove the country's main trading partner, the United States, into recession. Before the end of the 1980s, Singapore had consistent budget surpluses, accumulated substantial foreign exchange reserves and was ready to take its economy in a new direction (Turnbull, 2009).

10. The 1991 Concept Plan

By 1989, much of Singapore's infrastructure had been developed as planned in the 1971 Concept Plan. That same year, URA merged with the Planning Department and Research & Strategic Unit of the Ministry of National Development. The new body became the national planning and conservation authority with many more resources to lead the island's physical development into the year 2000 and beyond (URA, see http://www.ura.gov.sg/about/ura-history.htm, accessed on 29 August 2012).

In 1989, Liu Thai Ker, then the new URA Chief Executive, was asked to review the 1971 Concept Plan to the point when Singapore would reach four million people. This review resulted in new policies and directions for the future environment of the city-state. It acknowledged, for example, that many social and economic changes had occurred since the previous Concept Plan had been developed in 1971: population had increased, industrial developments had new requirements and extra land was required to make possible a better life style for more recreation-conscious citizens (Waller, 2001). In fact, between 1979 and 1989, spending on recreation and education increased three-fold. Singapore thus needed new development strategies to meet new expectations (URA, 1999).

In 1991, URA came with the revised Concept Plan and associated national policies, a document that included three staging plans for the years 2000, 2010 and the year 'X' (an unknown date when population would touch a four million mark) (URA, 1991). These staging plans would then be used as a reference to help in the preparation of 55 detailed Development Guide Plans (DGPs) for the entire city-state. These 55 DGPs would gradually replace the 1985 Master Plan.

The names 'Concept Plans' and 'Guide Plans' indicate a considerable degree of flexibility in terms of decision-making, even though the 1991 Concept Plans are more detailed than the one from 1971. The 1991 Plan also had a framework for the physical development of the island according to Singapore's vision of its future (Waller, 2001). By that time, Singapore was the first developed country in the equatorial belt, so it initiated the task of creating an international investment hub and a vast tropical resort named 'A Tropical City of Excellence' (Liu, 1997). This plan analyzed in detail a variety of issues like economic infrastructure, transportation networks, housing, green network and waterways, social and cultural facilities, and environmental control measures. URA felt that is was necessary to develop housing, commercial and leisure activities at waterfront locations such as the sea, rivers and even canals.

The 1991 Concept Plan emphatically addressed how judicious planning would turn water vulnerability into a strength; for this, both URA and PUB started to work closely together and utilize canals and inland reservoirs to create landscaped lakes and streams that were integrated to developments. Water was thus used as an instrument to create Singapore's new vision, its utilization and impact to be universal in the development of new areas in the main island and the underdeveloped smaller islands alike.

Singapore also understood the importance of water in enhancing the value of real estate and creating business opportunities. New prospects were created for the private

sector to invest and transform dilapidated areas or virgin land into highly valuable assets. The government supported the private sector with timely land release and infrastructural development. At present, areas developed next to the Singapore River, Tanjong Rhu and Marina Bay areas are examples of this public-private sector collaboration (Cheong, 2008).

11. Water Management from 1991

Urban development and its emphasis on recreation and better quality of life could give the impression that there has been a shift from immediate water issues to more aesthetic ones. Nevertheless, in practice, core water issues have not been overlooked. On the contrary, PUB has continued working towards a more efficient provision of water services, and better planned and managed water resources whilst trying to keep a balance between the life style expected in a developed country and the need for water conservation. Water has consistently been recognized as a strategic resource and its conservation has always been considered as a vital national security aspect (Hansard, 1989).

Concurrently with the rapid development of the city-state, appropriate control strategies continued being adopted, outdated legislation and regulations were amended and new ones were drafted such as the Surface Water Drainage Regulations. Pollution control legislation also provided for waste management and safe disposal. Even though by 1980 a basic legal framework was already in place to meet Singapore's environmental needs, new issues coming up as a result of development activities demanded more suitable laws.

Throughout the years, strong emphasis was put on water conservation campaigns. Nonetheless, after 25 years of awareness raising, it was clear that such initiatives were not enough to conserve water. It was then decided to make use of every possible sources and technology to achieve this goal. In 1997, water pricing was revised not only to cover the full cost of production and supply, but also to reflect the higher cost of alternative water supply sources. This sent a strong signal to the population and it encouraged technical solutions for water fittings and its economic use (Tan et al., 2009; Tortajada et al., 2013). All non-domestic premises were required to install water saving devices such as self closing delayed action taps and constant flow regulators. Since 1992, low capacity flushing cisterns of 3.5 to 4.5 litres per discharge were installed in all new public housing apartments. From April 1997, the installation of these cisterns was made mandatory for all new premises.

In 1983 and for ten years, PUB started a S$55 million pipe replacement programme. It involved changing all unlined water mains with cement-lined ductile iron and galvanized iron pipes with corrosion (resistant stainless steel and copper pipes). Some 182 km of old unlined cast iron water mains and 75,000 of old galvanized iron connecting pipes were removed. This project ensured that water supply remained at its best and that leakage losses were kept at minimum. This also made it possible for PUB to have one of the lowest unaccounted-for water levels in the world averaging 5% in 2011 compared to 10.6% in 1989 (Figure 3).

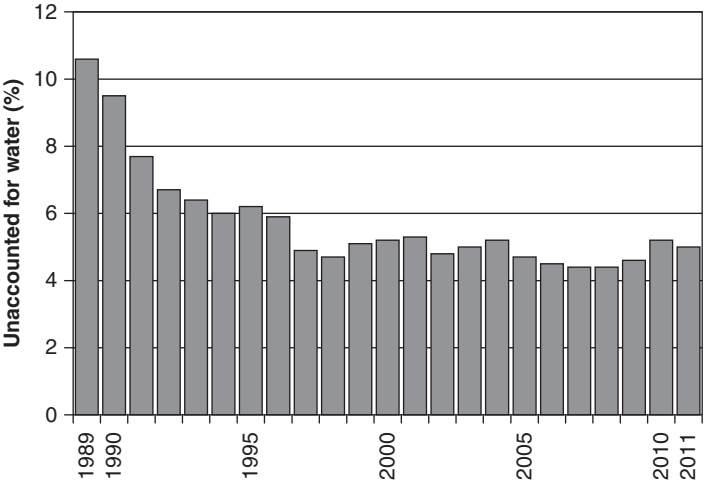

Figure 3. Unaccounted for water. (Source: Public Utilities Board, 2012.)

Land competing uses in a fast growing Singapore made land a premium commodity and thus its efficient use became a priority. Innovations and technological advancement for the efficient use of land were thus vigorously pursued. For example, conventional water reclamation plants with open tanks had one km buffer zone where very limited development was allowed. In 1990, the majority of them were covered, odour treatment facilities were added and the buffer zone was reduced to 500 m. Later on, all water reclamation plans were covered and made even more compact.

More recently and in terms of water supply, there are two initiatives that have proved to be extraordinarily innovative: Marina Barrage and the production of NEWater. Marina Barrage is the largest urban reservoir in the city-state. It has a catchment area of 10,000 ha (or one-six the size of Singapore) and is able to cover 10% of total water demand. Constructed for water supply, flood control and recreation purposes, together with two more reservoirs, it has increased the water catchment land area in the island from half of its landmass to two-thirds (PUB, see http://www.pub.gov.sg/Marina/Pages/3-in-1-benefits.aspx). Marina Barrage is one of the best examples of how water solutions are integrated with the growing needs and expectations of a modern city (Khoo, 2007).

NEWater, or high-grade reclaimed water, is one of the Four National Taps. The result of three decades of R&D, it is primarily used for industrial purposes and non-direct potable use. It is supplied for wafer fabrication, electronics and power generation industries for process use and delivered to commercial and institutional buildings for air conditioning cooling purposes via a separate distribution network. Its demand has increased by 15 times from 4 mgd (18,200 cubic metres per day) in 2003 to some 60 mgd (273,000 cubic metres per day) in 2011. A certain percentage of NEWater is also mixed with raw water in the reservoir, which is then treated before being supplied to consumers as tap water. At present,

NEWater covers 30% of water needs, a figure which is expected to rise to 50% by 2060. Its importance lies in the fact that, together with desalination, it offers the city-state the possibility to become water self-sufficient within the next decades (see http://www.pub.gov.sg/ABOUT/HISTORYFUTURE/Pages/NEWater.aspx, accessed on 28 August 2012).

12. Adding Blue to Green

The importance of greenery for a quality living environment has been stressed in Singapore's Master Plan 2003. Under this plan, efforts are being made to bring people closer to nature and, where possible, to integrate nature areas within parks and to plan for an island-wide network of green links to connect parks and water bodies with residential areas.

It is planned that in line with Prime Minister's vision of Singapore as a City of Gardens and Water, waterways will be integrated with parks to create new community spaces and bring waterfront to the heartlands. To make these plans a reality, Public Utilities Board (PUB) developed its Active, Beautiful and Clean (ABC) Waters programme with more than 20 projects carried out in the city-state. An example include the creation of a waterfront town at Punggol by damming up the mouths of Sungei Punggol and Sungei Serangoon to form freshwater lakes and then joining these two lakes by a man-made river running through the estate and town centre, thus creating opportunities for waterside activities. This ambitious programme aims at transforming Singapore into a 'City of Gardens and Water' as envisioned by the Concept Plan 2001 review (PUB, 2006).

The matrix of park connectors as green links and recreational corridors among parks are planned as ways to expand green space in the city. The park connector network is a series of seven connecting bikeways or green paths. The target is to build 200 km of park connectors by the year 2015. Properly integrated with their surrounding areas, the park connectors are expected to enhance the sense of green space throughout the city. The first 42 km-series, which was completed in December 2007, is known as the Eastern Coastal Park Connector Network (Ng, 2008).

The Singapore Green Plan 2012 charts Singapore's approach to achieve environmental sustainability over the next ten years and sets out the broad directions and the strategic thrusts that will help ensure the city-state's long-term environmental sustainability. The Singapore Green Plan was reviewed in 2005 and an updated edition was published in February 2006 (Lee, 2008).

The importance of planning for the long-term has also been understood and reflected in the blueprint presented by the Inter-Ministerial Committee on Sustainable Development (IMCSD), which has established key goals for 2030 to guide Singapore towards a more lively and liveable city. This 20-year timeframe vision has also set intermediate goals to be reviewed in 2020; thereby assessing the progress attained and correct the undertaken course if needed. As part of this scheme, water's important role has been expressed as an aim towards self-sufficiency and greater efficiency. The targets seek to reduce total

domestic water consumption from 153 litres per capita per day in 2011 to 147 litres per capita per day by 2020 and to 140 litres per capita per day by 2030. Additionally, it looks to open 820 ha of reservoirs and 90 km of waterways for recreational activities by 2020, reaching 900 ha of reservoirs and 100 km of recreational waterways by 2030 (MEWR and MND 2009).

13. Final Thoughts

At independence in 1965, Singapore's environmental problems and constraints made it no different from any other developing nation. It was almost completely dependent on Malaysia for its water supplies, dilapidated buildings and squatter sheds in its business hub or 'city centre' were basically slum colonies and riverways and canals resembled open sewers. Apart from the downtown core, other areas remained villages, with animal husbandry being the main profession and most of the population living in slums, huts and kampongs without proper sanitation, water supply or adequate public transportation. Population was growing rapidly and the city centre housed more than 40,000 persons per square miles. The waste disposal system in place was in disarray and depended on daily-wages cleaners. Street vendors and hawkers were a source of pollution, and threat of possible epidemics loomed over the small city-state. Public service agencies were inefficient and archaic. Moreover, political history and association with the Malay Federation restricted trade to the repackaging of imported goods and was largely reliant on Malay hinterland and on the British Military base that was about to be vacated.

Singapore had only two resources: its people and strategic location. It thus decided to capitalize on them to develop the foundations for economic development by attracting foreign investment as well as implementing sound, pragmatic and long-term management, business, administrative and environmental policies. The results of these policies are best reflected in the country's overall development, one that outstands among few examples of sustainable development in the world.

Regarding natural resources, water has remained a very sensitive issue for land-constrained Singapore. Its search for self-sufficiency has been strenuous because of its dramatic separation from the Malaysian Federation in 1965 as well as due to the 'vulnerability' that results from relying on Malaysian water imports. Nonetheless, Singapore's policy-makers have moved impressively towards reducing its reliance on outside sources and strengthening its own internal capacities based on managerial, governance-related and technological approaches.

A most important factor in Singapore's success has been its pragmatic approach to public policy, including those extended to water management and development. Even when decision-making has been heavily centralized, measures have remained matter-of-fact, sensible and looking out for the best long-term benefits for the city-state and its people as time and needs have changed.

There is no doubt that pragmatic economic policies and strategies attracting foreign companies based on providing quality and efficient infrastructure has led to the great

economic development of the city-state. This material prosperity has been the backbone of Singapore's nation-building programme, where Public Utilities Board (PUB) has played a very important part by making sure that services were and are efficiently delivered. With rising affluence, high living standards, and heightened urbanization and industrialization, the demand for water has grown rapidly. Population has increased to more than 5 million and both domestic and industrial demands for water have showed steady increases. The built environment has also been transformed during the last decades. From 1950 to 1993, the percentage of developed area rose from 18.5% to 48.6%. Intensive utilization of limited land endowments and high opportunity costs have reduced the share of land farms, forests, and marsh and tidal wastes occupy (Low, 1997).

In such a scenario, it has been fundamental to find different ways to make the city as green as possible with more water everywhere. After the consolidation of the economy and the first cycle of urban development, planners were considering the second round of urban improvement aiming at quality, variety, excellence in architecture and design of urban spaces. Improved use was sought for natural assets such as water bodies, tropical weather and lush vegetation. For the island, it was deemed imperative to identify manners of turning water a key element for and part of urban development. Since its independence, it has been clear that Singapore has not pursued any specific water paradigm, but rather a multiplicity of inter-related goals that have been implemented as and when needed according to the city-state's development stage. It has been clear that, while the world is only recently discovering the essential role of water resources in terms of growth and development, the city-state has been aware of it for decades. Its long-term, comprehensive strategy of water resources (policy-making, planning, management, governance and development) has been thoughtfully elaborated keeping in mind that it should respond to national priorities rather than sectoral ones. As a multi-dimensional and cross-sectoral resource, water resources have been clearly an integral part of the overall development strategies of the city-state.

Finally, national holistic planning processes have been the city-state's most powerful management tools. Long-term vision and pragmatic policies have allowed Singapore to find the right balance between strategic national interests and economic efficiency. Looking at the country's journey towards development through water lenses, one can conclude that the holistic management of water resources has allowed its progress towards its ambitious development goals. It is clear that water resources have been crucial in Singapore's sustainable development and the improved quality of life of its population, a key role that will only be heightened in the future to come.

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