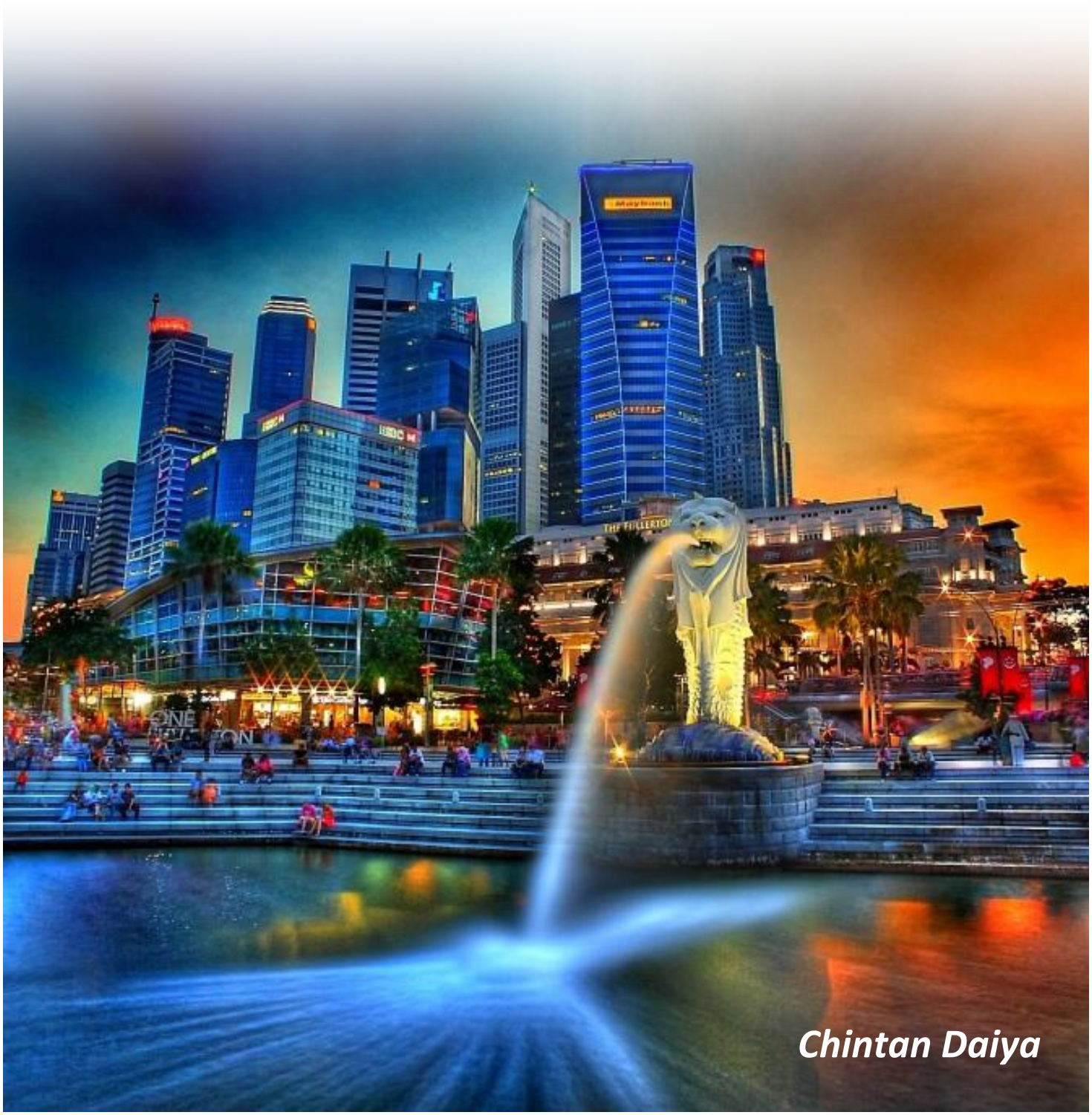
SINGAPORE

World Plumbing Council

Education & Training Scholarship 2011



Chintan Daiya

Contents

Introduction

Singapore gets its name from the Sanskrit combination, “Singha” meaning lion and “Pura” a city. Indeed one of Asia’s four lions has been a turning point in my knowledge of plumbing. In the pages which follow, I will try to re-live and take you along on this wonderful experience of mine.

Why Singapore for India?

India, presently is seeing a huge spurt in real estate development and satellite townships, in most of the cases, the townships are being developed in areas which do not have an existing basic infrastructure. The country faces mandatory impositions of “zero-discharge”; it practically becomes a difficult situation to implement technics which may face difficulties in maintenance later.

My visit to Singapore was purely intended to learn how they manage such a small country with a large population so precisely. The water resources of Singapore are especially precious given the small amount of land and territory in Singapore's geography while having a large urban population in the city-state. How they manage 24-hour water supply, while places in India go without supply for up to a week.

Singapore relies on four water sources: Rainfall, collected in reservoirs or water catchments, reclaimed water (producing NEWater, a brand which is treated sewage purified using dual-membrane via microfiltration and RO with ultraviolet technologies, in addition to conventional water treatment processes. This is potable grade and also used in industries requiring high quality water), and seawater desalination. Gradually, water is replacing oil in political motives, globally. Singapore is also strategizing to reduce reliance on supply from Malaysia (which is presently up to 40%) by increasing the volume supplied from these three sources.

Storm run-off or rainwater harvesting has been implemented in India since many long years; I wanted to learn what innovations Singapore has attained in this technology.

India, at the same time, via the Ministry of Environment and Forests (MoEF) is compelling new developments to install sewage treatment plants, but the lack of knowledge for handling sewage poses a very high potential risk to public health and environment at the same time. Singapore implements the same; it was of interest to learn their management process for such a hazardous process being so well executed.

India wants to venture in to seawater desalination, but long term effects, it seems, have disastrous consequences from brines, which are led back into the sea after the desalination process is completed. The payoff is an increase in ocean salinity as well as the warming of coastal areas. I wanted to learn as to how Singapore manages to run desalination while managing these hurdles.

Further, if any cultural habits or geographical effects forced Singapore to work out the systems they presently use, I wanted to learn how their existing codes and practices were, and are being implemented. How the code-makers got them accepted by the local jurisdictions and their enforcements? What mistakes they did in the past, where they had to rebuke things which they had enforced?

The Singapore Plumbing Society

The warm support extended by Singapore Plumbing Society is beyond words, for me, to express. The Singapore Plumbing Society, which was founded in 1956, having a base of more than 400 registered plumbers, is located in an old Victorian shop-house on the Jalan Besar Road in the vicinity of "Little India" neighbourhood. Just like many changes Singapore has seen in its regime before gaining its independence in 1965, Singapore Plumbing Society has come a long way from being "Singapore Sanitary Contractors" to "Singapore Institute of Plumbing" in 1971. It was again renamed as "Singapore Plumbing & Sanitary Association" before it took its present name.

With its aim to uplift the standards of plumbing services & to ensure quality plumbing works are maintained, Singapore Plumbing Society has been very actively involved with Public Utilities Board (PUB) and has been instrumental in getting many standards laid down for the city-state of Singapore. Though the original standards laid down were as per British Standards, but the collaboration between SPS and PUB has made it very dynamic and adept for local conditions.

They have been involved in offering insight to the PUB on water conservation techniques right from 2006 when the PUB introduced "Voluntary Efficiency Labelling Scheme". At the same time they have highlighted the perils and hazards of lowering pipe sizing and flow-rates, and signified skill-sets required for plumbers (especially foreign workers), and safety management. At the same time SPS, works hand in hand with industrial (ITE) and educational bodies (BCA) in pursuit of its aim.

Its members are committed to the Society Code of Practices & Ethics. SPS very well understands that mere presence of the code can create a false sense of security unless the documents are not fully understood, enforced and made a meaningful part of daily professional activities.

To eliminate the appalling health risks coupled with shoddy works and unscrupulous methods carried out by many unauthorised fly-by-the-night unqualified plumbers, SPS operates a free referral service known as "SPS Home Plumbing Service" for the general public. Anyone in need to engage a qualified plumber can call SPS and the call will be immediately directed to the nearest plumber. The call is usually attended to within 3 hours and a guarantee of 3 months is offered on the repairs carried out.

The activities of SPS involve conducting dialogues with government/semi-government bodies, seminars, social and networking gatherings and publications in industry newsletters and newspapers. As a matter of fact the print media is more than happy to always carry articles from SPS. During my visit, the society had conducted a song-writing

Figure 1 – The Heritage Building that houses Singapore Plumbing Society

contest. Of course, the song had to be related to plumbing and the members (including PUB officials) enthusiastically participated. The media coverage of the contest was astounding (see *fig.2*)

The Society is also the authority in conducting examinations for "Registered Plumbers" in Singapore. To prepare such candidates, short-term refresher courses are also conducted on a regular basis. I have covered more on the formal education and training for plumbing trade in a section featured ahead.

SPS boasts of a very active committee, which meets in the first week of every month (See *fig.3*). The members comprise of some renowned contractors and plumbing professionals of the country.

I owe huge gratitude to Mr. Chia Wai Chon, the Operations Manager of SPS, who right from before my arrival into Singapore helped me with the travels, transit, accommodation, setting up the meetings and site-visits with relevant authorities, members of SPS and individuals and offering guidance of Plumbing practices in Singapore. The enthusiasm of this 70-year-old retired gentleman could give a teenager a run for his money. Still wanting to learn more in plumbing, he is very active when it comes to public awareness and liaison with PUB and BCA for his members.

16 Thursday, February 23 2012 · THE NEW PAPER

News

"After two days, I didn't even have one line! But I kept humming the tunes in my head and thinking of possible lyrics to describe what plumbers do."

– Mr Chia Wai Chon (left)

ENTHUSIASTIC: Mr Chia Wai Chon, 70, operations manager for the Singapore Plumbing Society. THE PICTURE: KUA CHEE SIONG

All pumped up to bump up interest

Plumbing society member holds songwriting contest to push profession

REPORT: TEH JEN LEE
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YOU could say he is using his pipes to plumb for support.

Mr Chia Wai Chon, 70, operations manager for the Singapore Plumbing Society (SPS), feels too few Singaporeans are qualified plumbers, so he decided to use music to promote the image of the profession.

SPS is a recognised establishment that represents trained and qualified plumbers here.

Mr Chia decided against giving career talks because they would have been "one ear in, one ear out".

Instead, he organised a songwriting competition last October to publicise the profession.

The winner has yet to be picked.

It was open to SPS members and staff of national water agency PUB. SPS works with the PUB on the licensing process of plumbers.

Out of the six song entries, two are from Mr Chia, who rewrote the lyrics of existing songs to convey how a plumber's work and expertise benefit consumers.

He decided to try his hand at songwriting in the middle of the competition to encourage more members to join.

"It was hard. After two days, I didn't even have one line! But I kept humming the tunes in my head and thinking of possible lyrics to describe what plumbers do," said Mr Chia, who eventually finished rewriting the songs in two weeks.

One of his songs has this opening verse: "Guardian living a healthy lifestyle!// Clean water for drinking our nation needs!// Safe sanitation the assurance we give!// The best quality works that all may receive."

Another SPS member joined the competition after he e-mailed his songs.

And while Mr Chia did not receive as many entries and contestants as he would have liked, he remains dedicated to improving the image of plumbers.

He is actually not a plumber as he started working for SPS only after he retired from the oil rig construction industry about nine years ago.

When he e-mailed one of his songs to other plumbing associations overseas, it was warmly received.

Mr Peter Placidus Petrus, the Asia Pacific representative of the International Association of Plumbing and Mechanical Officials who is based in Jakarta, told The New Paper that Mr Chia's song is "excellent".

He aims to propose the song to be "the hymn" of the World Plumbing Council, of which SPS is a member.

Recognition

Dr Tan Pei Sik, an SPS member involved in building management, said the plumbing profession needs greater recognition here.

He gave the example of how plumbers in the UK have their own chartered institute, similar to the Association of Chartered Certified Accountants.

"Plumbers are highly valued in other countries and given extensive proper training before licensing," said Dr Tan, who has a doctorate in engineering from University of Bradford in the UK.

Mr Chia said plumbers are paid by the hour in Australia, "just like lawyers".

"They charge A$45 ($$60) an hour, from the moment they start travelling to your home for the job. In Singapore, a plumbing supervisor earns only about $3,000 a month, and the average plumber probably less than that," he said.

To get licensed here, plumbers first go through a one-year basic course. After two years of practical experience, they can take a PUB licensing exam, said Mr Chia.

Mr Tony Goh, who has more than 40 years of experience in the construction industry, says that while many out there may profess to be plumbers, there are only five per cent who are Singaporean and qualified.

"Plumbing is a core trade in construction but very few locals want to do it, so we rely on foreigners," he said.

Director of PUB's water supply network, Mr Chong Hou Chian, said that the plumbing industry provides diverse career paths.

"Many plumbers progress to design, consultancy and management, making the plumbing industry a career with a future.

"The skills acquired will never become obsolete, keeping one employable. Plumbing is never boring, as plumbers face different situations and challenges daily," he said.

Figure 2 – Media Coverage for Song Contest.

Figure 3 - An SPS Committee Meeting [Myself standing; L to R, Mr. Richard Tock (Hon. Secretary), Mr. Dickrose Masalamani (Vice President), Mr. William Tang Kok Khiong (President), Mr. Chan Ah Leong Robert (Member), Mr. Richard Tan Poh Huat (Hon. Treasurer), Mr. Ricky Tan Choo Heng (Asst. Secretary), Mr.Johnny NG Tow Hock (Asst. Treasurer), Mr. Chia Wai Chon (Operations Manager), Mr. Amos Phua C.T. (Member)]

Training & Registration of Plumbers

As we all know that Plumbing is a very skilful job, but at the same carries a social taboo and is most often neglected globally (yes, in Singapore too). A formal training is a must which unfortunately lacks in a country like India. In this section, I have tried to learn the process in which an unskilled individual can go on to become a skilled plumber authorised to carry out works in Singapore.

Timeline

Here, I would like to take you down by about 50 years in evolution of the plumbing trade.

1958 – 1964

Formal structured training courses begin in Singapore Polytechnic in 1958.

a. Fulltime Craft Diploma in Plumbing.
b. Part-time Advanced Craft Diploma in Plumbing.

The course programmes with duration of two years, ensured both theoretical and practical skills in all aspects of plumbing were fully covered. The course curriculum also equipped students for the "Full City & Guilds (Plumbing) Technology Certificate Examination" and many also benefited by obtaining this certificate by the time they graduated.

1965 – 1971

After Singapore gained independence in 1965, plumbing courses were transferred to the "Singapore Vocational Institute" under the umbrella of Ministry of Education. Here again, two courses were offered:

a. Ordinary Craft Certificate in Plumbing. (2-years fulltime).
b. Advanced Craft Certificate in Plumbing. (3-years part time).

1972 – 1985

Plumbing courses saw some migration again, this time it was transferred to the "Vocational & Industrial Training Board" (VITB), though still under the umbrella of Ministry of Education. The course continued to stay at two levels with two years of full time.

a. National Trade Certificate Grade 3 in Plumbing & Pipe Fitting.
b. National Trade Certificate Grade 2 in Plumbing & Pipe Fitting.

1986 – 2006

From 1986, training of plumbers was started at Construction Industry Training Institute (CITI) (Now known as the BCA Academy, *fig.4*). Again, the training format remains at 2 levels.

Figure 4 - The Building & Construction Authority Academy

Level 1: A 2-years, part-time, 396-hours course. The trainee has to obtain a "Builders Certificate in Pipe & Pipefittings. Holders of "Builders Certificate" with 2 years of relevant working experience become eligible to sit for the "Licensed Water Service Plumber" Examination conducted by the PUB's water department.

Level 2: 2-years part-time, 480-hours course.

Advanced Builders Certificate in Pipe & Pipefittings (ABC). This was an step-up route for the holders of "Builders Certificate" or "National Trade Certificate Grade 3 (NTC-3)" who wished to upgrade their knowledge and skills in the plumbing trade. The "Advanced Builders Certificate" or simply called ABC, coupled with 2 years of relevant sanitary works experience was a pre-requisite to appear for the Sewerage Department Registered Plumber Examination.

Hence only a registered plumber or RP was allowed to carry out sanitary / sewerage works installations prior to the deregulation of Sanitary Plumbers in August 2002. Also noteworthy is the fact that it took a minimum of 6 years (which included 4 years of part-time study and 2 years of gaining experience) just to be eligible to appear for the "Sanitary License Examination" conducted by the sewerage department. But after the deregulation in 2002, any Tom, Dick or Harry could carry out sanitary plumbing works, although qualified plumbers or professionals are held accountable for the sanitary/ sewerage installations. This could be alarming and a matter of concern, if the supervision was not up to the mark.

2007 – Present

In an attempt to arrest the dwindling enrolment for Plumbing, and perhaps realizing the vitality of a Plumbers' role in public health safety, the BCA now offer a new revised "Trade Diploma in Plumbing Technology" (See *fig.5* for a sample course brochure).

Course Code: 74041

BCA ACADEMY
of the built environment

Trade Diploma in
Plumbing Technology

With the mission of shaping our built environment, supporting Singapore's economic growth and enhancing the quality and productivity levels for the construction industry, BCA Academy has offer the Trade Diploma with the revised course structure to align with the Construction Registration for Tradesmen (CoreTrade) scheme. The trainees will undergo 651 hours of training which comprises Part A (Foundation Skills), Part B (Technical Knowledge Skills) and Part C (Craft Skills and Knowledge).

The content of each of the 651-hour trade diploma programme as follows:

PART A: 153 HOURS OF FOUNDATION SKILLS COMMON FOR ALL TRADE DIPLOMAS WILL CONSIST OF:
- Construction Technology
- Technical Drawings & CAD
- Communication Skills
- Supervisory Skills

PART B: 198 HOURS OF TECHNICAL KNOWLEDGE WILL CONSIST OF INDUSTRY AND TRADE KNOWLEDGE FOR THE SPECIFIC TRADES:
- Levelling and Setting Out
- Module 1 - Plumbing Principles
- Module 2 - Plumbing Technology

PART C: 300 HOURS OF CRAFT SKILLS AND KNOWLEDGE WILL CONSIST OF:
- Module 3 - Code of Practices & Drawings
- Module 4 - Basic Pipework & Pipefitting Practice
- Module 5 - Applied Practices I
- Module 6 - Plumbing System Design Principles
- Module 7 - Applied Practices II

Enquiries
For enquiries, please call 6248-9999 or email us at bca_academy@bca.gov.sg
For details of other seminars and courses, please visit our website @ www.bcaa.edu.sg

DATE: June/July 2011
DURATION: 651 hours
VENUE: BCA Academy
FEE (inclusive of GST):
Part A: S$1,819
Part B: S$2,461
Part C: S$5,350
Total Fee: S$9,630
(SDF/WTU funding available)

ENTRY REQUIREMENT
i) possess one of the following academic qualifications/experience:
- *2 GCE 'O' level passes, or
- *2 GCE 'N' level passes, or
- WDA's Statement of Attainment in Workplace Literacy & Numeracy (Level 8)
- CITI's Construction Trade Foremen Certificate with minimum 1 year of supervisory experience after completing certificate, or

ii) For existing site foremen, (industry grandfathers) a minimum of 6 years of relevant experience; or
iii) Holders of NTC 2 or NTC 3 awarded by ITE; or
iv) Other qualifications will be evaluated on a case-by-case basis.

** Those who have attempted the GCE 'O' level and 'N' level but do not meet this course's specified two level passes, may take an English or Mathematics test conducted by BCAA to decide their enrol.*

Holders of relevant SEC(K) certificates will be considered for exemptions on a case-by-case basis.

Figure 5 - A Brochure of 2011 Diploma in Plumbing Tech.

The Building and Construction Authority Academy now offers the revised course structure to align with the Construction Registration for Tradesmen (CoreTrade) scheme.

The trainees have to undergo a total of 651 hours of training which comprises of Part A (Foundation Skills), Part B (Technical Knowledge Skills) and Part C (Craft Skills and Knowledge).

1. Part A: 153 hours of foundation skills common for all trade diplomas consisting of:
   - Construction Technology
   - Technical Drawings & CAD
   - Communication Skills
   - Supervisory Skills

2. Part B: 198 hours of technical knowledge which consists of industry and trade knowledge for the specific trades:
   - Levelling and Setting Out
   - Module 1 - Plumbing Principles
   - Module 2 - Plumbing Technology

3. Part C: 300 hours of craft skills and knowledge consisting of:

    - Module 3 - Code of Practices & Drawings
    - Module 4 - Basic Pipework & Pipefitting Practice
    - Module 5 - Applied Practices I
    - Module 6 - Plumbing System Design Principles
    - Module 7 - Applied Practices II

Figure 6 - Workshop for live hands-on training at BCA Academy.

The eligibility criteria are:

The candidate must possess one of the following academic qualifications/experience:

1. 2 GCE 'O' level passes (General Certificate of Education, Ordinary Level at School), or
2. 2 GCE 'N' level passes(General Certificate of Education, Normal Level at School), or
3. Workforce Development Agency's (WDA, Singapore Government) "Statement of Attainment in Workplace Literacy & Numeracy" (Level 8)

The candidate possessing CITI's Construction Trade Foremen Certificate with minimum 1 year of supervisory experience after completing certificate is also eligible, or

For existing site foremen, a minimum of 6 years of relevant experience; or

Holders of National Trade Certificate Grade 2 or National Trade Certificate Grade 3 awarded by ITE.

Compared to Training in India.

1950: Craftsman Training Scheme

A few years after India gained its independence in 1947, the Craftsman Training Scheme (CTS) was introduced by the government of India in 1950 to ensure a steady flow of skill workers in different trades for the domestic Industries, to raise quantitatively and qualitatively the industrial production by systematic training, to reduce unemployment among the educated youth by providing them employable training, to cultivate and nurture a technical and industrial attitude in the minds of younger generation. The scheme, most important in the field of vocational training, has been shaping craftsmen to meet the existing as well as future manpower need, through the vast network of ITIs' the day-to-day administration of ITIs' under the craftsman Training Scheme was transferred to State Government with effect from the year 1956.

Thus forming Industrial Training Institutes (ITIs) throughout the country under the umbrella of "Directorate of Vocational Education & Training"

Under the CTS, two sub-categories exist for plumbing works:

a. Engineering courses of 6 months.
    i. Sanitary hardware fitter.
    ii. Building maintenance.

Figure 7 - The Plumbing Workshop at BCA Academy.

b. Engineering course of 1 year duration to be an ITI-certified Plumber (See *fig. 8*).

1961: Apprenticeship Training Scheme

Acute shortage of manpower in the skilled categories is felt in many Industries in India. With this objective, the Apprentices Act 1961 was enacted in the Parliament in 1961. The Act came into force from 1st March 1962 and is applicable to the whole of India.

Under the Act, it is a statutory obligation on Employers in the specified industries to engage apprentices as per ratio prescribed in the designated trades.

In this case, a certain amount of stipend stipulated by the government is paid by the employer to the apprentice.

For a plumber, this programme lasts for a duration of 3 years.

The efficacy of the programme is yet to be gauged, since India still faces the deficit of trained plumbers.

Advanced Vocational Training Scheme

Though, plumbing as a subject does not directly exist in this scheme. A course on "Hydraulics and Pneumatics" is also available.

Figure 8 - A CTS Plumbers Training in ITI, Maharashtra

The PUB of Singapore

No, I am not talking about a pub or a club in Singapore. Though in a way this PUB plays a vital role in drinking . . . but the most essential commodity, Water.

PUB

Water for All : Conserve, Value, Enjoy

Figure 9 - The PUB Logo. (Source; PUB)

PUB is the "Public Utilities Board" of Singapore. The Board, which was created in 1963 from the Singapore Municipality, is a statutory board under the Ministry of Environment and Water Resources. It is the national water agency that manages Singapore's water supply, water catchment and used water in an integrated way. PUB won the 2007 Stockholm Industry Water Award and was named Water Agency of the Year at the Global Water Awards 2006.

Located at 40 Scotts Road in the Environment Building (*fig. 11*), PUB shares the 27-storey building with Ministry of Environment and Water Resources and National Environment Agency (NEA).

Figure 11 - The Environment Building with PUB Offices.

PUB's Tagline

Water for All: Conserve, Value, Enjoy.

PUB has ensured a diversified and sustainable supply of water for Singapore with the Four National Taps (next section).

"Water for All" represents the commitment to ensure the robustness, reliability and sustainability of water supply.

"Conserve, Value, Enjoy" projects PUB's 3P approach in reaching out to their stakeholders and involving the community in their work.

Underpinning the above are the 3Cs (*fig. 10*), which drive how PUB formulates policies and programmes to fulfil their mission and vision:

Figure 10 - The 3Cs Strategy of PUB.

Competence - is about getting the people to be technically competent. It is about investing strongly in people -- in training, technology and creating an environment where the staff can be innovative, highly committed, responsible and always daring to try new ideas. PUB's ability to remain a leading water agency depends on them making sure they keep on developing their competence as an integrated water resource agency with excellent people at all levels of the organisation.

Connections - is about connecting with their customers, with the community, with the industry, and with other countries in order that people understand them, and work with them. Connecting with Singapore residents is the key part of their mission, but increasingly, they also have to connect with the world to help bring about more business for their water companies, and to keep abreast with technology and best practices.

Creating Value - is the essence of price-minus that PUB embarked on since 2004. It is not about cost cutting to save money for the short term. It is about making sure they give value and ensure the sustainability of their water resources in the most cost-effective way. PUB's work is very capital intensive, so a key challenge of Creating Value is to find better ways to manage the assets, especially in their plants and networks.

Figure 12 - PUB's Customer C.A.R.E. model

Customer C.A.R.E. Philosophy

PUB is customer-focused; their customer-centric culture is illustrated through their C.A.R.E model (*fig. 12*).

Key Performance Indicators

Part 1: General Feedback:

Feedback Mechanism	Response Time
Customer Service Feedback Form	5 working days
Quality Service Helpline	Immediate
Email	3 working days
Mail and Fax	5 working days

Part 2: Feedback via PUB 24 hours call centre.

A call to 1-800-284600 assures a response within two hours to feedback on water leakage, poor pressure, sewer chokes, choked or damaged drain and flood.

Part 3: Service Quality Indicators.

Applications	Response Time
Processing of Notification of Water Service Work	12 working days
Completing new water connections after receiving approval for road opening and upon availability of site for laying of connection	6 working days
Turning on water supply after completion of piping works	1 working day
Processing Drainage Development Control Plans	12 working days
Processing architect's application for Drainage Interpretation Plans	7 working days
Processing of Certificate of Statutory Completion	7 working days

Codes and Standards of Singapore

The codes and standards pertaining to Plumbing works in Singapore are laid down only by the PUB.

Code of Practice on Sewerage and Sanitary Works: The code of practice contains information on the basic planning, design and procedural requirements for surface water drainage, and specifies the minimum engineering requirements for the provision of functional facilities for surface water drainage. General amendments and revisions are expected from time to time. The currently used code is 1st Edition – March 2000 with amendments under addendum No.1 – February 2001 and addendum No.2 – November 2004. The code is available as a free download on the PUB website or can also be viewed directly online at the following link http://www.pub.gov.sg/general/code/Pages/ViewOnlineSewandSan.aspx.

Code of Practice on Surface Water Drainage: The code of practice contains information on the basic planning, design and procedural requirements for surface water drainage, and specifies the minimum engineering requirements for the provision of functional facilities for surface water drainage. General amendments and revisions are expected from time to time. Currently in its sixth edition it was recently published in December 2011. The code is available as a free download on the PUB website or can also be viewed online.

Singapore Standard CP 48 – Code of Practice for Water Services: This 56-page code deals with services for the supply of potable water to all residential, commercial and industrial buildings/premises. The scope extends from the Authority's water supply to the point where the water is drawn off for use, including storage. It does not cover all aspects of services for the supply of water for fire fighting (which has a separate code, The Singapore Standard CP 52). The current code was formed in 2005 and underwent amendments in October 2006 and June 2009.

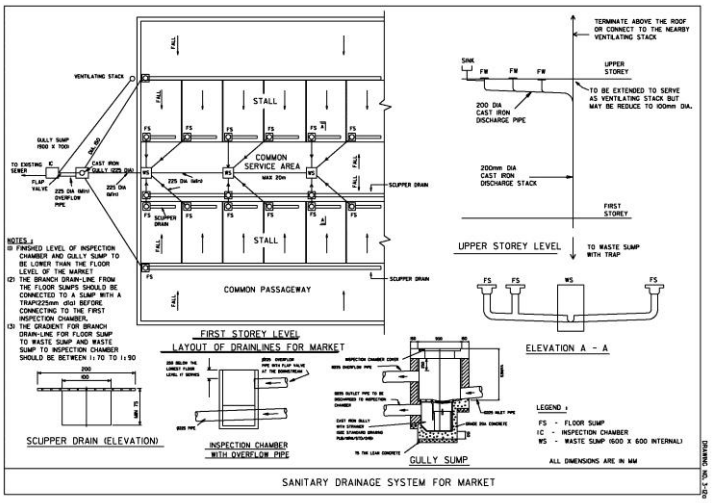


Figure 13 - A Drawing illustrating the drainage system in a Market.

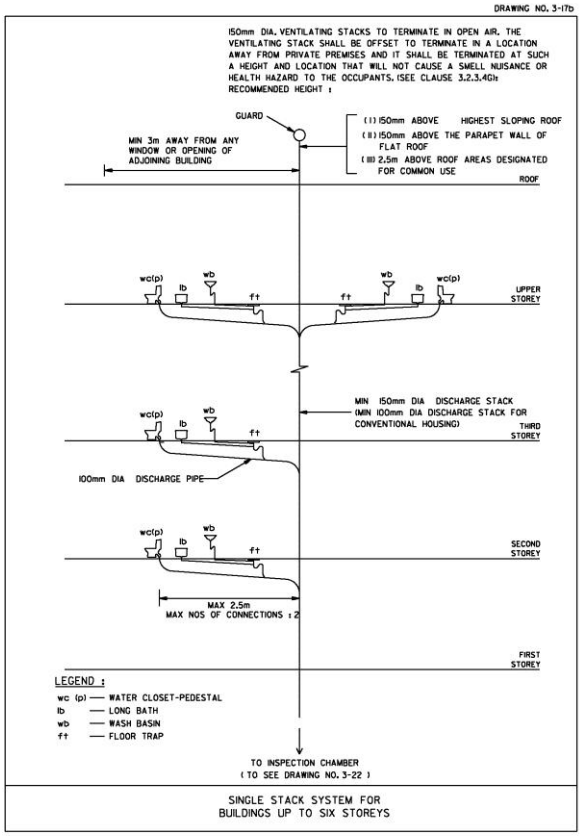


Figure 14 - Single stack arrangement for Buildings up to six storeys. (Separate system above six storeys)

Licensing of Plumbers for Water Service

Licensing for Plumbing works was enforced by PUB in 1981. Since then over 800 licensed plumbers have registered throughout Singapore of which only about 35% are active.

A plumbing license is essential to carry out water service works in Singapore. Though, a plumbing license is not essential to carry out works related to sanitary works.

As mentioned on the PUB's website:

***"Water service plumbing work** refers to the laying, installation, alteration, repair or replacement of water pipes, tanks, taps and fittings in the drinking water supply system, for the conveyance of drinking water.*

***Sanitary plumbing work**, on the other hand, deals with sanitary discharge pipes and sanitary appliances (water closet or WC, urinal, sink, etc), such as installing, changing or relocating toilet bowls and sanitary piping system, for carrying used water from the premise/building to the used water system."*

Elaborating further, all water service plumbing work shall only be carried out by a water service plumber licensed by PUB. Where the work involves the design of a pumping system or storage tank, a professional engineer registered by the Professional Engineers Board, Singapore must also be engaged for the design and supervision before the licensed water service plumber can proceed with the work. The professional engineers and licensed water service plumbers shall comply with the requirements in the Singapore Standard CP48 - Code of Practice for Water Services, the Public Utilities (Water Supply) Regulations and the Public Utilities Act when carrying out water service design and installation works.

Water service plumbers are licensed by PUB to ensure that the safety and water conservation aspects of drinking water supply are not compromised and good standard of water service plumbing work is maintained in customers' premises. Licences are issued to water service plumbers who possess the necessary qualifications (see section "*Training & Registration of Plumbers*") and experience to maintain quality service and standards in water service plumbing work and to ensure that their work does not cause water wastage or contaminate the water supply to customers.

Under the Public Utilities Act, it is an offence for anyone to engage a plumber who is not licensed by PUB to carry out water service plumbing work. It is also an offence for anyone to carry out water service plumbing work or advertise or otherwise hold himself out as a licensed water service plumber without a valid PUB Water Service Plumber Licence. The penalty for such offences is a fine not exceeding $10,000 or imprisonment for a term not exceeding 3 years or both.

Till Jan 1, 2011 the Plumbing License had to be renewed every 3 years, but the policy was changed to make the license lifetime, though a refresher course has to be attended at an interval of every 3 years, says Mr. Rajendram, Manager, Water Supply Department. He further elaborates that being a Licensed Plumber is not too easy in Singapore. A work reflecting bad workmanship or not adhering to the codes would attract demerit points. Anything above three demerit points in a year would attract warnings and eventual suspension of the license for a period of 2 years.

It is also a necessity to hold a valid license to be a member of the Singapore Plumbing Society.

Water Conservation: A Top Priority

Teach the Children

That's exactly the strategy the PUB has adopted to involve children in the fight to curb wastage of water. Some of the initiatives include:

- Water Wally.
- Water Detective Programme.
- Water Conservation School Outreach Programme.
- Student Audit Water Exercise.
- Water Conservation Video Competition.
- Water Play Areas.

Figure 15 - Water Wally, The Official Mascot of PUB

Water Wally is the official mascot of PUB. The whole idea of the mascot is to create a set of characters that children can associate with.

Water Wally, as the official website claims, "*is friendly, helpful and kind. His mission is to protect all water sources so that they can be clean, sparkling and free-flowing. A water droplet, he turns brown when he is sick, that is, when water gets polluted. An expert on everything about water, Water Wally is always on the lookout to stop any abuse of our precious water resources.*"

The complete array of characters other than Water Wally, includes "Runny Hose", "Barry", "Sludge", "The Oil Boys", "Fiona the Fish", "Lindsay Lizard", "Iggy and Biggy", "Fred the Toad", etc. to name some.

Using the "Water Wally" set of cartoon characters, the PUB has made it straight to the minds of young and older children alike with comics, activity books, games and animations series (*fig. 16*).

Water Detective Programme focuses on the importance of conserving, valuing and enjoying water. Using theatrical skits and stage presentation, the show features memorable characters like "Herman" and "Screech", with a special appearance by Water Wally.

Designed to excite and engage the students in the water cause, the show helps to educate the kids (target audience is upper primary students within the age of 9-12 years) on the importance of water and how they can do their part to protect the precious resource.

Water Conservation School Outreach Programme is to educate students to carry out a water audit and in turn encourage their friends and family members to do the same and achieve water savings. The overall

Figure 16 - A screenshot from the episode, "Bin There, Dump That"

programme and highlights are as follows:

- Talk on water management / scarcity issues in the world, Singapore's Water Supply – 4 National Taps and Water Conservation.
- Teach students how to carry out 5-step water audits at homes using the Water Audit website or Facebook Game.

Student Audit Water Exercise encourages the students to conduct a water audit at their homes in a 5-step method using the water audit website or Facebook Game. On completion of a successful audit, children are entitled to get a mystery gift from PUB.

Figure 17 - Snapshot of the "Water Audit" game for children of PUB's website.

Water Conservation Video Competition which was last conducted in 2011 demanded for inclusion of the following points on water conservation at home in a fun and interactive manner.

- What does water mean to me?
- What can I do to use water wisely?
- Good examples of water conservation at home.

The video is required to be of 45 seconds duration and necessarily in MP4 format. This video competition is open to all public and private primary schools in Singapore. It is mandatory for each team to be led by a teacher facilitator with a minimum of 4 and a maximum of 6 students (10-12 years old). The teacher facilitator can lead up to two teams and act as a point of contact between the school and organiser. However, he/she cannot work directly on the team's entry. This also includes two free workshops on movie making by the PUB.

Prizes included a group trophy with S$1000, S$800, S$500 and S$300 cash prize for 1st, 2nd, 3rd & Merit positions respectively.

Water Play Areas are a very common sight throughout Singapore. Be it the Singapore Zoo, Jurong Bird Park, Science Center, the famous Sentosa Island, Malls or even smaller community parks. Children are encouraged to enter the play areas (often free of charge) and cool down in the hot and humid climate of Singapore. Fountains are easily accessible and in most cases have no restrictions for entry. Not only children but adults too can be seen enjoying splashing fun in some of these features.

The idea is not to waste water here, but to bring people closer to water and realize the importance of keeping it clean to enjoy the splurge it offers.

Figure 18 - Top L to R: The "Birds of Play" Area at Jurong Bird Park, Another area of "Birds of Play"; A Child has splashing fun at "Marina Barrage"; Fiddling with the flow at Sentosa Island; The Water Play Park at Science Center

Household Conservation (10-Litre Challenge)

Figure 19 - The Save 10-Litres of Water a Day Campaign.

The 10-Litre Challenge aims to get every individual to reduce daily water consumption by 10 litres. PUB and the Singapore Environment Council (SEC) are urging everyone to take the 10-Litre Challenge.

To assess one's individual water usage, to learn about the various water saving measures and devices to achieve a saving of 10 litres per person per day, a user can log on the web application (see *fig. 21*). A water saving kit (*fig. 20*) too is available free of cost from the PUB for Singaporeans to use.

Figure 20 - The Water Conservation Kit available from PUB.

Figure 21 - A Snapshot of the Web Application for Save 10 Litres a day.

Water Efficient Homes

Water Efficient Homes (WEH) is a programme to help residents save water at home and cut down on their water bills. The programme encourages residents to install water saving devices and practice good water conservation habits. As part of the programme, PUB officers visit households in Singapore to install free-of-charge water saving devices such as thimbles. A set of thimbles (part of the water saving kit) with three and four holes allows residents to have greater flexibility in regulating their tap's and showerhead's flow rates. "Water Wally" stickers with specific messages are also included in the kit to act as reminders of good water saving habits in homes.

The WEH programme was launched in Feb 2003 and all the 84 constituencies of Singapore had launched the WEH programme by 2006.

Figure 24 - Consumers awareness of the WELS programme.

40% of households installed water saving households saved up to 5% of their monthly water consumption. Starting from 2007, the programme was enhanced by re-visiting HDB (Housing Development Board's mass housing) blocks including private housing with higher water consumption.

commercial buildings and industrial establishments in 1997.

Moving forward, dual flush LCFCs which offer the option of a half flush (not more than 3 litres of water) when a full flush (not more than 4.5 litres of water) is not necessary, was made mandatory in all new domestic developments and existing domestic premises undergoing renovation from July 2009. (Though the PUB faced line-carry issues and approached the Singapore Plumbing Society, the outcome of the research and debate is unknown).

All flush valves must be adjusted to give a flush of not more than 1.5 litres, 1 litre and 0.5 litre of water per flush for large, medium and small size urinals respectively or not more than 4.5 litres of water per flush for water closets.

Water Efficient Labelling Scheme (WELS)

Background

Since 1983, the installation of water-saving devices such as constant flow regulators and self-closing delayed action taps has been made mandatory in all non-domestic premises and common amenities areas of all private residential apartments and condominiums.

Bathtubs and Jacuzzis larger than 250 litres in capacity also require a water recirculation system. Low capacity flushing cisterns (LCFCs) that use not more than 4.5 litres of water per flush have been installed in all new public housing units since 1992. This was later made mandatory for all new and on-going building projects, including all residential premises, hotels,

Fitting or appliance	Maximum allowable flow rate (litres/min)	Water Efficient flow rate (litres/min)
Wash basin tap	6	2 (public / staff toilets) 4 (other areas)
Shower (Hotel)	12	7
Shower (Others)	9	7
Sink / Kitchen and other taps (except bathtub taps)	8	6
Bib tap	8	6

Figure 22 - Flow rates at various fittings or appliances.

Usage	Maximum allowable flow rate (litres/min)	Timing (seconds)
i) Basin	6	2 – 3
ii) Shower (Hotel)	12	13-15
iii) Shower (Others)	9	13-15

Sensor-equipped self-closing delayed action basin taps with a flow rate of 2 litres/min are allowed at a maximum preset timing of not more than 60 seconds provided water supply from the tap is automatically cut off when the hand is moved away from beneath the tap.

Figure 23 - Flow rates and timing for self-closing delayed action taps.

To prevent excessive flow rates at water fittings, PUB limits the maximum allowable flow rates at water fittings. A review was conducted in 2003 and the maximum allowable flow rates at various water fittings were reduced by between 25% and 33% to prevent water wastage (*fig 22 and 23*). The requirement on limiting maximum allowable flow rates at water fittings was also extended to all domestic premises. These requirements are also found in the Singapore Standard CP 48 - Code of Practice for Water Services and the Public Utilities Regulations.

WELS was started in 2006 on a voluntary basis, which offers 0-3 ticks rating to reflect the water efficiency level of a product. Since 2009, WELS is mandatory and currently, taps and mixers, dual-flush low capacity cisterns, urinal flush valves and waterless urinals are labelled under this Scheme. As per the mandate, taps, urinals and urinal flush valves

Products/ Fittings	Flow Rate/ Flush Capacity Requirements			
Under Mandatory WELS	Zero Tick ○	Good ✓	Very Good ✓✓	Excellent ✓✓✓
Shower Taps & Mixers (Pressure Range from 0.5 to 5.5 bars)	> 9 litres/min	> 7 to 9 litres/min	> 5 to 7 litres/min	5 litres/min or less
Basin Taps & Mixers (Pressure Range from 0.5 to 5.5 bars)	> 6 litres/min	> 4 to 6 litres/min	> 2 to 4 litres/min	2 litres/min or less
Sink/Bip Taps & Mixers (Pressure Range from 0.5 to 5.5 bars)	> 8 litres/min	> 6 to 8 litres/min	> 4 to 6 litres/min	4 litres/min or less
Flushing Cisterns (Per Flush)	NA	Dual Flush > 4 to 4.5 litres (full flush) > 2.5 to 3 litres (reduced flush)	Dual Flush > 3.5 to 4.0 litres (full flush) > 2.5 to 3 litres (reduced flush)	Dual Flush 3.5 litres or less (++) (full flush) 2.5 litres or less (reduced flush)
Urinals & Urinal Flush Valve (Per Flush)	NA	> 1 to 1.5 litres	> 0.5 to 1 litres	0.5 litres or less (++) or waterless urinals

NOTE: ++ PUB to prescribe additional test(s) to be carried out for the Dual-Flush Low Capacity Flushing Cisterns and Urinal Flush Valves with flush volumes below 3.5 litres (full flush) and 0.5 litre respectively.

Figure 25 - The WELS rating scheme eliciting the "Ticks" as per flow rates.

Products/ Fittings	Flow Rate/ Flush Capacity Requirements			
Under Voluntary WELS	Zero Tick ○	Good ✓	Very Good ✓✓	Excellent ✓✓✓
Showerheads (Pressure Range from 0.5 to 5.5 bars)	NA	> 7 to 9 litres/min	> 5 to 7 litres/min	5 litres/min or less
Clothes Washing Machines (Per Washload)	NA	> 12 to 15 litres/kg	> 9 to 12 litres/kg	9 litres/kg or less

Taps and mixers with zero tick are to be installed with constant flow regulators to meet the mandatory maximum allowable flow rates listed in Table 1.

and dual flush cisterns installed in all new premises and existing premises undergoing renovations, must have at least a "one-tick" water efficiency rating.

Since October 1, 2011, even washing machines sold in Singapore have to carry a mandatory Water Efficiency label, though showerheads still remain under the voluntary efficiency scheme.

Industrial / Commercial / Hotel Level Conservation

The PUB strongly encourages water efficient designs for Industries, Commercial complexes and Hotels. With NEWater, such installations are encouraged to use the same for allied purposes like cooling towers and landscaping.

Success Story: Hotel Regent, Singapore

The Regent Singapore offers 439 rooms, houses 7 dining outlets, 14 function rooms and a ballroom and has a gross floor area of 42,483m^2. Awarded Gold Plus under the BCA's Green Mark Scheme in May 2008, the Hotel was also certified by PUB as a Water Efficient Building in October 2008.

The Regent Singapore enjoys water saving of up to about 16%, reflecting the success of implementing various water conservation measures in 2008.

The Regent Singapore is committed actively conserve natural resources including water and energy in the Hotel without compromising on the Hotel's safety and operational standards.

Environmental Management Committee

Senior management is very supportive of environmental issues. An environmental committee comprising of different representatives from different departments is tasked to look into water conservation matters in addition to other environmental issues. Monthly meetings are held and talks and briefings are organised to create awareness among employees to conserve water at all times. Articles concerning water and environmental issues are also posted on a notice board for the staff to read (*fig. 26*).

Figure 26 - Notice board eliciting environmental articles.

Regular Monitoring

Private water meters are installed at essential areas such as cooling towers, production kitchen, laundry and swimming pool for monitoring purposes. Meter readings are taken regularly to observe any abnormal increase of water consumption. This promptly detects and effectively tackles unsatisfactory water consumption in any of these areas.

Figure 27 - Regular monitoring of water consumption.

The Building Management System (BMS) also monitors the water level of the water tanks, chiller pumps, etc.

The 3Rs Approach - Reduce, Replace and Reuse

The approach to water conservation and sustainability ensured by the environmental committee can be classified into 3Rs - reduce, replace and reuse.

Reduce

Apart from installing pressure reducing valves (PRVs) to reduce the pressure at the water reticulation system, the flow rates of all the basin taps in the guest and staff rooms are reduced to a water efficient rates of 4 litres / min and 2 litres/min respectively. The flow rate of showerheads in all the guest rooms is also reduced to 9 litres / min. In addition, vegetables are washed in a sink filled with water in the Hotel's kitchens.

A rain sensor system is installed to turn off the irrigation system during rainy days.

Variable Speed Drive (VSD) system is installed for secondary chilled water pumps at the cooling towers, which enables savings of energy and water.

Figure 29 - NEWater used for landscaping & features.

Replace

NEWater instead of potable water is used for cooling towers, irrigation use, as well as the water feature.

Reuse

Chilled water from the chiller plant is reused to cool the refrigeration units of cold rooms in the production kitchens.

Site Visit: Meter Testing Workshop.

Figure 28 - The Woodleigh Complex which houses the meter workshop.

PUB uses water meters imported mainly from UK and France with sizes varying from 15mm to 150mm in diameter. For domestic consumption accounting, PUB uses 15mm meters complying with ISO 4064/1C standard which are able to register more accurately a low flow rates, these household meters are volumetric type. The meters thus used can be mounted both, horizontally or vertically. For factories and commercial complexes with a huge variance in consumption, compound meters are used. These compound meters have a main meter to measure large flows and a by-pass meter to register low flows. Although, more costly, the use of compound meters has ensured that consumptions are registered accurately.

PUB operates a workshop for maintaining and testing water meter. Every meter installed in any complex is only sourced by the PUB who in turn does random checks on all new meters

acquired. Since 1985, in-service testing of meters is carried out periodically to check for their accuracy. A random selection of meters according to model, size, period in service and location are returned to the meter workshop for accuracy testing.

In addition, a dynamic meter replacement programme ensures that meters in domestic premises are replaced with when the meters register above 4000 cu.m. or are more than 15 years old, whichever criterion is met first. For non-domestic meters, they are replaced every 2-7 years; for customers that have high water consumption such a refineries and water fabrication plants, the meters are replaced annually. It has been experienced by the PUB that having good water quality, strict supervision during laying of water mains, use of good water mains material, coupled with well-maintained network and customers' reticulation system help in ensuring the accuracy and extending the lifespan of meters.

A computerised billing system incorporating a check programme called "Investigation & Report System" (I&R) is used to verify readings taken off meters. Any abnormally high or low consumption is automatically flagged by the computer during the billing process for further investigation. This enables defective meters and leaks in the customers' reticulation systems to be identified and rectified early.

The testing bench is an innovative brainchild of a top PUB management officer, employing a hydraulic press along with couplings, the bench can test 20 meters at a time on a bench. This not only ensures faster workflow but also an accurate system capable of measuring minute errors.

At the entrance of the workshop, one is welcomed with a wide range of meter types, right from the ones used during the British era to today, even testing and measuring equipment preserved since then are to be seen, almost giving you a feeling of walking down in history at a museum.

Figure 30 - Meters being tested on the indigenously designed hydraulic bench.

The ABC Programme

"*By linking up our water bodies and waterways, we will create new community spaces that are clean, pleasant, and bustling with life and activities. We will integrate our water bodies with our parks and green spaces and turn Singapore into a "City of Gardens and Water'.*" – Prime Minister Lee Hsien Loong at the Launch of ABC Waters Programme

One of the PUB's prime initiatives, ABC, "Active, Beautiful, and Clean Waters" was initiated in 2006. It is a strategic initiative to improve the quality of water and life by harnessing the full potential of the water-bodies.

By integrating the drains, canals and reservoirs with the surrounding environment in a holistic way, the ABC Waters Programme aims to create beautiful and clean streams, rivers, and lakes with postcard-pretty community spaces for all to enjoy. By virtue of the master plan, the major water sheds are developed to bring people closer to the waters.

There are 18 successful ABC Waters projects around the island as of 2012. In the next 10 to 15 years, over 100 ABC Waters proposals have been identified for implementation. These are guided by an island-wide ABC Waters Master Plan unveiled in 2007.

The ABC Waters Programme aims to achieve the following objectives:

- To develop the water bodies beyond their functional use as resources for water collection, storage and drainage into vibrant, clean and aesthetically pleasing lifestyle attractions where recreational and communal bonding activities can take place;
- To tap ideas, expertise and resources from the People-Public-Private (3P) in developing and managing the catchments and water bodies as new community spaces, while continuing to safeguard the water quality and safety to the community;
- To act as an umbrella programme for integrating and holistically managing all initiatives involving catchments and water bodies; and
- To get community closer to the water and instil stewardship.

Site Visit: Kallang River Bishan Park

Figure 31 - Visit to Bishan Park with Mr.Chia Wai Chon and Mr.Dickrose Masalamani.

Inaugurated by the Prime Minister on March 17, 2012, a joint collaboration between national water agency PUB and the National Parks Board, the Kallang River @ Bishan - Ang Mo Kio Park ABC Waters Project was designed with a holistic sustainable approach in mind, and with the concept of integrating the park with the river.

One of the main features of the redevelopment is the restoration of the concrete canal into a naturalized river with bio-engineered river edges (*fig. 33*) using a variety of plants and bedding materials. This project is the first of its kind in Singapore, and the integration of the river with the park aims to make the waterway more accessible to the public while creating more spaces for the public to enjoy.

Figure 32 - An Artist's impression of the redeveloped Bishan Park.

The naturalized river meanders through the park and brings park users closer to the water, so they can enjoy it while appreciating the importance of clean water. The river is designed based on a flood plain concept whereby during dry weather, the river flow is confined to a narrow stream in the middle of the river. The gently sloped river banks form part of the park features, and park users are able to walk along the water's edge. In the event of a storm, the water level in the river rises and the area adjacent to the river is used as a flood plain to contain the rainwater.

The Bishan - Ang Mo Kio Park is already home to diverse ecology, with existing water bodies in the park playing an important role in promoting growth. These ponds are developed into water features with soft, gradual edges, and integrated seamlessly with the river.

In addition, a water playground is constructed as part of the redevelopment, allowing children to have fun with water and appreciate its qualities and value. Through these interactions with water, it is envisioned that the redevelopment of the park will both engage the public and foster a sense of communal ownership and appreciation for our water resources.

The redevelopment also includes innovations like cleansing biotopes (*fig. 33*) which will offer effective water treatment while maintaining natural and beautiful environment and water cascades which will help to improve the water circulation of the existing ponds.

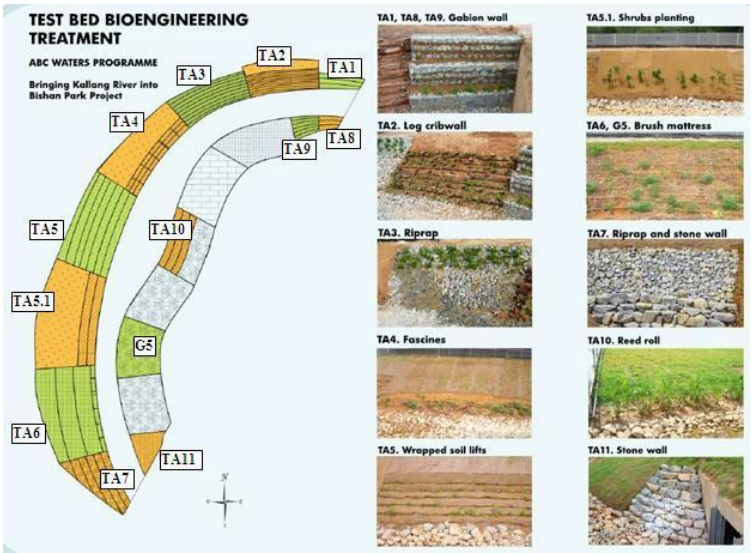


Figure 33 - The Bio-engineered riverbed (up) and Biotope system for treatment using natural materials. (right)

Site Visit: Singapore Zoo

The Singapore Zoo / Night Safari is the only public complex in the whole of Singapore utilizing its own sewage treatment plant.

All other sewage through the island is collected via the *DTSS* and delivered to *NEWater* plants (*see NEWater section*) for recycling.

The Singapore Zoo which is home to some of the finest reptiles and animals, has the reputation of breeding the most animals in captivity, also requires huge amounts of water for the cleanliness and hygiene of the creatures.

The design of the Zoo employs a unique strategy, the recycled water from the treatment plant is used for supply to the fire suppression system with fire hydrants at every 70 meters, but the same supply is also used for cleanliness purposes of the animals.

In case of a fire and inadequacy of treated water (chances are the tanks could be emptied or mid-way due to washing routines), it is believed that the adjoining Seletar reservoir can be tapped into. The interesting fact is that the tanks used are to two types: Galvanised Iron and Stainless Steel (*fig. 35*). The actual design intended pumping potable water supply from the same location, but due to inadequacy pointed out the contractor, Mr. Dickrose Masalamani of DJJ Engineering Pte. Ltd. both the tanks were converted to fire and wash supply.

Figure 37 - A Fire Hydrant in the Zoo premises, the tag on the side states "Not for Drinking, Raw Water Supply"

Figure 36 - The Sewage Treatment Plant of the Zoo.

Figure 34 - The Pump Room and water tanks for fire and washing supply.

Figure 35 - The GI Tank of left and Stainless Steel Tank on Right.

Innovations in sensing water distribution problems.

A prototype network of 25 sensor packages that report in real time on water pressure, flow rate and disinfectant levels has been installed in Singapore's central business district (*fig. 39*). Encouraging results on the long-term accuracy of the sensors and the ability of the network to locate pipe bursts have been obtained during the trial. Enhancements to the system are underway and, once fully developed, will automate monitoring of water quality deviations and leaks in Singapore's entire water distribution system.

Figure 39 - A Sensor panel in the CBD area of Singapore.

PUB and the Massachusetts Institute of Technology (MIT) are developing, testing and implementing the low-cost system in collaboration with the Center for Environmental Sensing and Modeling as part of the Singapore–MIT Alliance for Research and Technology programme. Solar panels or the street lighting system can be used to power the packages directly.

The idea, according to Harry Seah, director of PUB Singapore's Technology and Water Quality Office, is to develop a more efficient and reliable detection system that will serve as an early-warning, event-locating and water-demand prediction system. Successful development of the full system will make it of great commercial value.

The packages of sensors, which include acoustic hydrophones, extend about 10 cm into distribution pipes of least 20 cm in diameter. The sensors measure water pressure, water flow, conductivity, pH and oxidation–reduction potential (ORP). Transient changes in pressure for example, caused by a leak or burst pipe, arrive at and are sent from different sensors at different times depending on sensor location. A central computer receives the automatic reports from the sensors via the 3G mobile phone system. The computer then integrates all the real-time hydraulic data into a model of the water distribution system that was established using EPAnet simulation software from the US Environmental Protection Agency.

The model can localise the problem to within an average of about 40 m and send out an alarm. Last year, the development team tested the system using fire hydrants to simulate burst water mains (*fig.38*). A new round of experimentation integrating both acoustics and pressure is already underway.

Figure 38 - Emulation of a burst water main was quickly detected by a neighbouring sensor node of Singapore's prototype monitoring network.

Deviations in the quality of the water supply are detected by the ORP and pH sensors that provide a measure of disinfectant levels, such as the concentration of chlorine. Water quality issues can be localised in the same way as leakages.

As the wireless sensor network is developed and tested further, it will gradually be implemented throughout the water distribution network in Singapore.

Site Visit: Plumbing Retrofitting and Tank Sterilization.

Mr. Steven Tang, the General Manager of M/s Stace Integrated Building Service Pte. Ltd. in coordination with the Singapore Plumbing Society was kind enough to arrange a site visit in the "Jalan Sultan" area of Singapore.

The complex is a condominium building where existing mild steel water supply headers and risers were being replaced with modern PP-R (polypropylene-random) pipes; the work also included enhancement of the pumping system and cleaning of the water storage tanks. In usual cases, smaller houses (most of the pre-war houses and shop houses) up to 3 storeys do not require storage tanks, due to the availability of 24/7 supply and 4 bars pressure in the PUB supplied lines, as informed by Mr.Tang. Also it may be noted that PUB has very strict guidelines for cleaning of tanks.

Figure 41 - The Domestic Water Storage being cleaned.

As mentioned in the Public Utilities (Water Supply) Regulations and Singapore Standard CP48 – Code of Practice for Water Services "*any person responsible for the maintenance of any part of a water service installation having a water storage tank shall engage, at least once every 12 months, a licensed water service plumber to inspect, and where necessary to clean and disinfect, and certify the water storage tank*."

This ensures that:

Figure 40 - In the Pump Room during a retrofit installation.

- the water storage tank is fit and safe for the storage of water for human consumption;
- the water contained in the water storage tank is free from contamination or pollution and that there is no likelihood of the same;
- the water storage tank is properly maintained; and
- there is no leakage and no likelihood of leakage in the water service installation, including the water tank.

Water samples taken from the water storage tanks have to be sent to a *Singapore Accreditation Council-SINGLAS* accredited laboratory for testing of potable water quality to pass the appropriate chemical and

bacteriological examinations. The minimum parameters to be tested and the corresponding typical values they must comply with are shown in the table alongside. The complete procedure (which can involve 24 hours of stoppage of supply) to be followed is available on the PUB website at http://www.pub.gov.sg/general/Documents/ProcedureForInspectionAndSterilisationOfWaterStorageTanks.pdf

The supply piping was of the similar nature being carried out in India, where a central main is looped at the roof level with down-comers. Though the down-comers were installed with pressure-reducer valves a telescopic arrangement for pipe sizing is not usually practised.

Figure 42 - (Up) Tapping for down-comers in PP-R (Down) New lines laid alongside old lines to facilitate uninteruppted supply during replacement.

Physical, Chemical & Bacteriological Characteristics	Typical Water Quality Values to be complied with
Physical Analysis Parameters	
Colour (Hazen Unit)	<5
Turbidity (NTU)	<5
pH Value	7.0 – 9.0
Conductivity (umhos/cm)	80 – 550
Chemical Analysis Parameters	
Residual Chlorine (as mg/l CL_2)	<2.0
Iron (as mg/l Fe)	<0.04
Bacteriological Characteristics	
Total Colony Count (cfu/ml, 35°C, 48 hrs)	<500
E.Coli (cfu/100ml, 35°C, 24 hrs)	<1

The Four Taps of Singapore

Singapore gets its water from four primary sources, what they fondly call as “The Four Taps of Singapore”;

- **Local Catchment.**
- **Imported Water** (from Malaysia).
- **NEWater**.
- **Desalinated Water**.

The first 'tap' refers to the supply from the local water catchments and reservoirs (*fig.43*).

The second 'tap' refers to the import of water from Malaysia under the 1961- 1962 water agreement.

The third 'tap' NEWater, leverages on a 3-stage process of ultra-filtration / micro filtration, reverse osmosis and ultra violet radiation to reclaim water from the used water effluent.

The fourth 'tap' is desalination through which freshwater is obtained by desalting seawater through the reverse osmosis process.

Tap 1 - Local Catchment

Two-thirds of Singapore land area is covered by local catchments. Currently, Singapore has 17 reservoirs operational of which Punggol and Serangoon are recently added in 2011.

Most of the reservoirs in Singapore are created by damming the rivers or estuaries flowing into the sea. Almost all the unprotected reservoirs have been beautified around and created into wonderful recreational grounds with play parks, theme gardens, public performance areas and allow activities like canoeing, rafting and some water sports. Though most of the

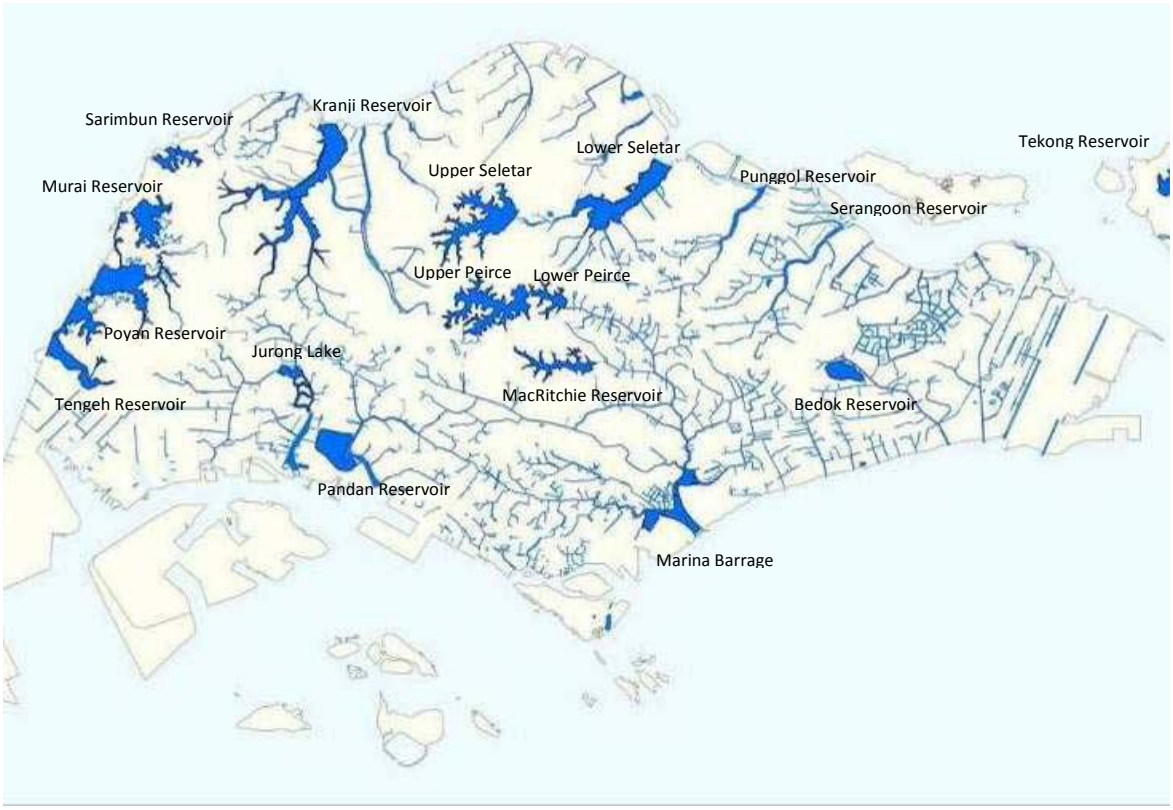


Figure 43: The Blue Map of Singapore (Reservoirs, Rivers and Drains)

reservoirs do not allow fishing, some do with only artificial baits, swimming is an absolute no-no in these reservoirs. Some of the places even make it to the top in tourist spots. Though it wasn't always like this.

History

The Singapore & Kallang River:

Figure 44 - The Boat Quay on Singapore River c.1800s (Source; PUB)

The Singapore River has been the life-blood of the island for more than 600 years. Standing at the confluence of various civilisations, Singapore has been a hub for trade and culture throughout history, its waters and banks filled with vessels, visitors, traders, labourers and craftsmen from China, India, West Asia and surrounding region.

The Singapore River and the adjacent harbour became the centre of great expansion in trade and business during Singapore colonial period.

Starting in the 1880s, there was heavy traffic on the Singapore River due to rapid urbanization and expanding trade. At the same time, it brought in water pollution caused by the disposal of garbage, sewage and other by-products of industries located along the river's banks. The sources of water pollution into the Singapore River and Kallang Basin (see *fig. 44 & 46*) included pig wastes from pig and duck farms, unsewered premises, street hawkers and vegetable wholesaling. Riverine activities such as transport, boat building and repairs were also found along the Singapore River. Some 750 lighters plied along the Singapore River and Kallang Basin in 1977. Waste, oil spills and wastewater from these boats and lighters added to the pollution of the rivers.

In 1977, Lee Kuan Yew, then the Prime Minister put forth an ambitious goal for the government to clean up the Singapore River and Kallang Basin: and in ten years allow fishing in the Singapore River and Kallang River. By October 1977, an action plan on "The Clean-up of the Singapore River and Kallang Basin" was submitted to the Prime Minister. By late October 1977, the government was starting to take action to clean up the river. The plan involved the development of infrastructure such as housing, industrial workshops and sewage; massive resettlement of squatters, backyard trades and industries and farmers; re-siting of street hawkers to food centres; and phasing out of pollutive activities. Industries located by the river were removed and squatters were resettled into flats. Refuse was collected daily for

Figure 45- The Boat Quay today (clicked on a water taxi)

Figure 46 - The Kallang River c. 1800s (Source; PUB)

incineration, while hawkers were issued licenses and provided specified areas with proper sewerage amenities. The dredging of the river bed and the removal of hundreds of tons of debris which had been piled up over the years helped marine life to return to the tidal river.

Ten years later in 1987, the clean-up of the Singapore River and Kallang Basin was completed. In September 1987, the Ministry of the Environment together with other government ministries and statutory boards celebrated the success of the clean-up with an event called the "Clean Rivers Commemoration". After the massive clean-up, people can now engage in activities such as “wayang” performances on a bumboat, variety shows staged on pontoons anchored in the river, and boat races. Today, speedboats, dragon boats, pedal-boats and sampans can be seen plying on the clean waterways of the Singapore River. The Boat Quay, today, hosts some of the finest eateries and restaurants.

Figure 47 – Clockwise from Top: Hawkers along the Singapore River created unsanitary conditions in 1970 | Polluted condition of Singapore river in 1950 | People queue up to get water in pails for homes from the rural board's supply wagon in 1959| PM Lee Kuan Yew pesents at Gold Medal to PUB Chairman, Mr. Lee Ek Tieng on completion of the 10-year river cleanup in 1987. (Sources; PUB, ACM, Strait Times)

The Seventeen Reservoirs

***Bedok Reservoir*:** is a reservoir located in the eastern part of Singapore, to the north of Bedok New Town. Bedok Reservoir was constructed under the Sungei Seletar/Bedok Water Scheme, completed in 1986. The scheme involved the damming of Sungei Seletar to form a reservoir (Lower Seletar Reservoir), the creation of Bedok Reservoir from a former sand quarry between 1966 and 1972 and the construction of Bedok Waterworks. Its unique feature was the construction of nine storm-water collection stations to tap the storm runoffs of the surrounding urbanised catchments.

Jurong Lake: is a fresh-water lake and reservoir located in the western region of Singapore formed with the damming of Sungei Jurong further downstream. In addition to a number of artificial islands such as the Chinese (*fig.49*) and Japanese Gardens, the lake is planned to be a future recreational hub for the western side of the island.

Figure 49: The Chinese Garden on Jurong Lake.

Kranji Reservoir: is a reservoir in the northern part of Singapore; near the Straits of Johor was a former freshwater river that flowed out into the sea that dammed at its mouth to form a freshwater reservoir. It can also be classified as an estuary. The dam has a road bridging the two banks, and now prevents the sea from coming in, and is home to a marsh. The former Kranji River has three main tributaries - Sungei Peng Siang, Sungei Kangkar and Sungei Tengah.

Figure 48 - Expansion works at Lower Selatar

The Upper and Lower Peirce Reservoirs: Lower Peirce is one of the oldest reservoirs in Singapore. It is located near the MacRitchie Reservoir and the Upper Peirce Reservoir. It was originally created as the Peirce Reservoir but was designated as lower upon the creation of the Upper Peirce Reservoir. The reservoir is the source of the Kallang River, the longest river in Singapore.

Originally known as the Kallang River Reservoir, Singapore's second reservoir was impounded across the lower reaches of the Kallang River in 1910. In 1922, it was renamed Peirce Reservoir in commendation of the services of Robert Peirce, who was the municipal engineer of Singapore from 1901 to 1916.

In 1975, a major water supply project to develop new water resources was undertaken to support Singapore's rapid housing and industrialisation programmes. A dam was constructed at the

Figure 50 - The Selatar Reservoir (now Upper Selatar, as seen from Singapore Zoo)

upper reaches of the Peirce Reservoir, forming the Upper and Lower Peirce Reservoirs.

The Upper Peirce Reservoir was officially opened by then Prime Minister Lee Kuan Yew in 1977 (he was the one who initiated the River Cleaning campaign in Singapore). This second and largest reservoir of Singapore has a capacity of 27.8 million of water over 304 hectares of water surface.

***Upper & Lower Seletar Reservoirs*:** Seletar Reservoir (see *fig.50*) is Singapore's third reservoir (after MacRitchie and Peirce reservoirs). Upon construction of the Lower Seletar and Bedok reservoirs under the Sungei Seletar / Bedok Water Scheme, as mentioned earlier, with the damming of the mouth of Seletar river, the original Seletar Reservoir was renamed to Upper Seletar.

Originally, Seletar Reservoir was built to meet the surge in water demand after World War I. It was completed in 1940 and opened in August 1969.

The world-renowned Singapore Zoo and Night Safari are located on the banks of Upper Seletar Reservoir. The fire prevention system installed for these facilities acquires water from the Upper Seletar Reservoir and localized Sewage Treatment Plant (the one and only STP other than Newater Plants in Singapore). I have elicited more on the Singapore Zoo water supply more in a case-study further.

Presently, PUB is constructing a 60MGD water works installation at Lower Selatar Reservoir for supply to the island nation. (see *fig.48*)

***MacRitchie Reservoir*:** is the oldest reservoir of Singapore. The reservoir was completed in 1868 by impounding water from an earth embankment, and was then known as the Impounding Reservoir or Thomson Reservoir.

In 1823, British Resident John Crawfurd proposed the building of a reservoir and waterworks, setting aside $1,000 for these plans but nothing came of them. Another plan that ended up in smoke was the idea to tap the headwaters of Singapore Creek.

Finally, in 1857, a Chinese merchant Tan Kim Seng donated $13,000 for the improvement of the town's waterworks but delays, poor planning and use of the wrong building materials ate into the budget. New plans were drawn up for an impounding reservoir in Thomson. Tan's money was insufficient – the cost of the new reservoir was $100,000 – but colonial headquarters in Calcutta, India, refused to make up the rest of the cost. When Tan died in 1864, the reservoir was nowhere nearer completion.

Construction was eventually completed in 1868 but the pumps and distributing network were not finished until 1877. By this time, public confidence in the government's ability was dented.

In 1882, in a move to salvage its reputation, the Municipal Council erected a fountain in Fullerton Square in honour of Tan Kim Seng.

Figure 51 - The MacRitchie Reservoir as seen today.

The fountain was later moved to Queen Elizabeth Walk, where it stands today.

In 1891, the holding capacity of the Impounding Reservoir or Thomson Reservoir, after its designer John Turnbull Thomson, was expanded to over 465 million imperial gallons (2,110,000 m3). Municipal Engineer James MacRitchie oversaw this $32,000 expansion and the reservoir was named after him in 1922. In the 1890s, he had urged the government to buy the Chasseriau Estate for use as a reservoir but it was not until much later that the purchase was made.

However, the reservoir's 4 million imperial gallons (18,000 m^3) a day was still insufficient to meet demand. Water was pumped into the reservoir from the upper section of Kallang River, one of the island's bigger sources of fresh water. Other fresh water supplies – Lower Peirce Reservoir and Seletar Reservoir – were completed in 1912 and 1920 respectively. However, the government realised that Singapore would not be able to meet its own fresh water needs. In 1927, a water treaty was signed with the Sultan of Johor. Singapore received its first supply of water from Johor in 1932 (*more has been elicited under "Imported Water" section of this report*).

The development of the MacRitchie Reservoir brought the forest devastation around the area to a halt. The forest surrounding the reservoir has been protected as a water catchment reserve. The forested areas surrounding the other two reservoirs, Peirce Reservoir and Upper Seletar Reservoir (formerly Seletar Reservoir) were also protected when these reservoirs were developed.

Marina Reservoir*:** Formed after completion of ***Marina Barrage, a dam spanning the Marina Channel. Singapore's 15th reservoir is located in the Central Business District. It has the largest and most urbanised catchment at 10,000 hectares, one-sixth the size of Singapore.

Figure 52 – An aerial view of the Marina Barrage.

The Marina Barrage offers three benefits to the denizens of Singapore, to Recharge, Regulate and Relax.

a. *Recharge (Water Supply)*: The Marina Barrage is a dam built across the 350-metre wide Marina Channel to keep out seawater, forming Singapore's first reservoir within the city.

   On 20 November 2010, the Marina Reservoir was commissioned by former Minister Mentor Lee Kuan Yew as a freshwater reservoir, augmenting Singapore's water supply for generations to come. Desalting had begun in April 2009 through natural replacement by rainwater. As a pillar of local water supply, Marina Reservoir can meet about 10% of Singapore's current water demand.

b. *Regulate (Flood Control)*: The Marina Barrage is part of a comprehensive flood control scheme to alleviate flooding in the low-lying areas in the city such as Chinatown, Boat Quay, Jalan Besar and Geylang.

   During heavy rain, the series of nine crest

Figure 53 - A typical weekend at The Marina Barrage.

gates (*fig. 55*) at the dam will be activated to release excess storm water into the sea when the tide is low. In the case of high tide, seven giant pumps which are capable of pumping $40m^3$ per second will drain excess storm water into the sea. The pumps leverage on the siphon effect that occurs shortly after the pumps' activation, so less energy is consumed, compared to a centrifugal pump of similar pumping capacity. This results in energy savings of 105 MWh per year. These pumps are housed in a naturally cooled green-roofed complex.

c. *Relax (Lifestyle Attraction)*: As the water in the Marina Basin is unaffected by the tides, its water level is kept constant all year round. This is ideal for all kinds of recreational activities such as boating, windsurfing, kayaking, etc. Colourful performances, thrilling water sports and pleasure craft plying between waterfront attractions bring an attractive new lifestyle experience for all to enjoy.

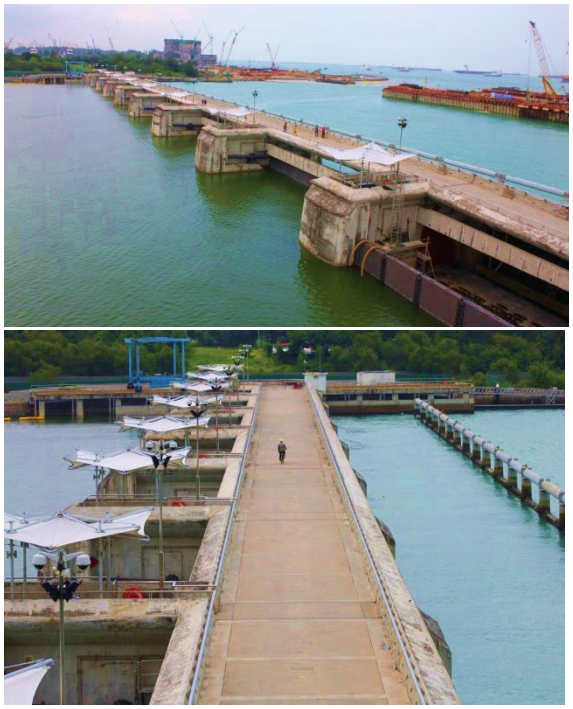


Figure 55 - The nine crest gates separating seawater from fresh water at Marina Barrage.

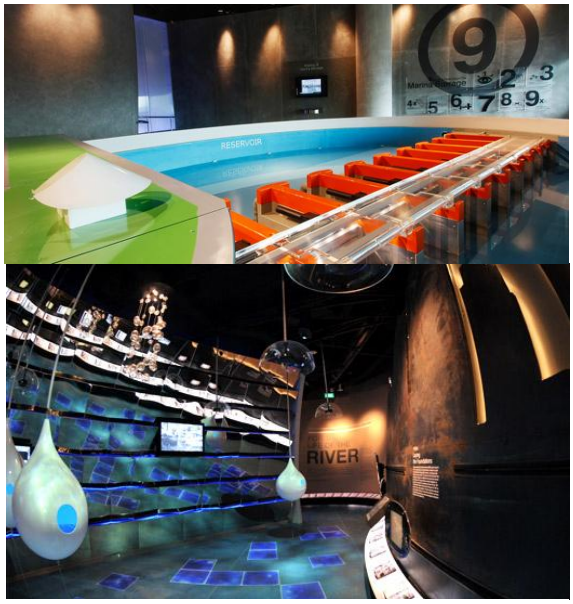


Figure 54 - Sustainable Singapore Gallery at the Barrage.

The green roof of the pump station also doubles up as a recreation ground (see *fig. 53*).

The Marina Barrage also houses a "Sustainable Singapore Gallery" (see *fig.54*) which consists of six galleries showcasing environmental challenges, clean-up of its rivers, the ABC program of PUB, the working of the Marina Barrage, Singapore's sustainable town planning and the commitment from the 3Ps (People, Private and Public) sectors of Singapore.

Murai Reservoir: is one of the four reservoirs in the Western Water Catchment of Singapore. It was formerly Sungei Murai, which was dammed in early 1980s, to create a reservoir. It is now part of SAFTI Military Institute's Live Firing Area, of which is restricted to civilian military.

Pandan Reservoir: is also located in the West Region of Singapore. Formed by damming the mouth of Sungei Pandan, it is the largest service reservoir in Singapore providing non-potable water to the surrounding industrial areas and in particular, the Jurong Industrial Estate.

The Pandan Reservoir houses the Singapore Amateur Rowing Association and is popular for fishing catfishes and peacock bass at two of its designated spots. Though the PUB is very strict about using live or organic baits and only allows artificial baits.

***Poyan & Tengeh Reservoirs*:** Just like Pandan, are reservoirs in the Western Water Catchment of Singapore. Formed by damming Sungei Poyan and Sungei Tengeh respectively, before emptying in to the Straits of Johor, these reservoirs too are a part of the restricted SAFTI firing area.

***Pulau Tekong Reservoir*:** Pulau Tekong is the largest island of Singapore which is mainly used as a training base for military installations. The reservoir serves the military installations on this island.

***Sarimbun Reservoir*:** Again a part of the SAFTI Firing Area, Sungei Sarimbum too was dammed to form the reservoir and become a part of the Western Water Catchment. The interesting fact about this reservoir is that the first Japanese troops landed near here in 1942 to leave a mark in the history of Singapore.

***Punggol & Serangoon Reservoirs*:** are the very recent additions to the island nation of Singapore. The opening ceremony was held on July 03, 2011, though the plans were chalked out as early as March 9, 2008. Together these two reservoirs will add up 5500 ha to the catchment areas.

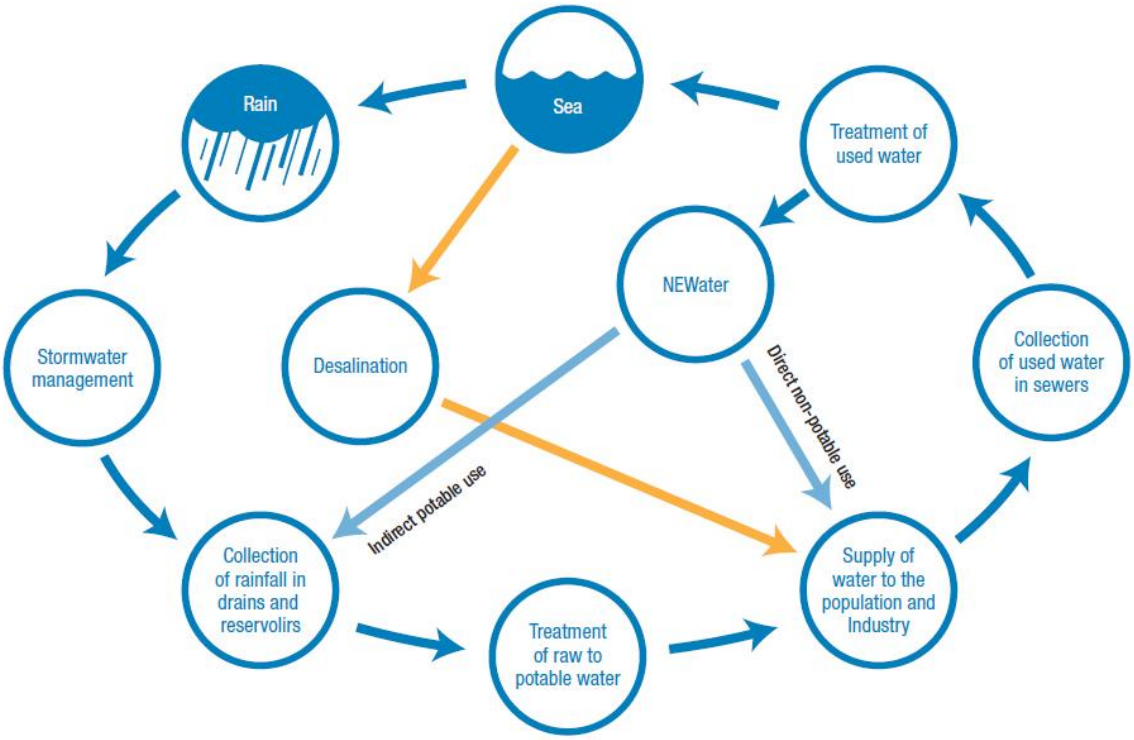
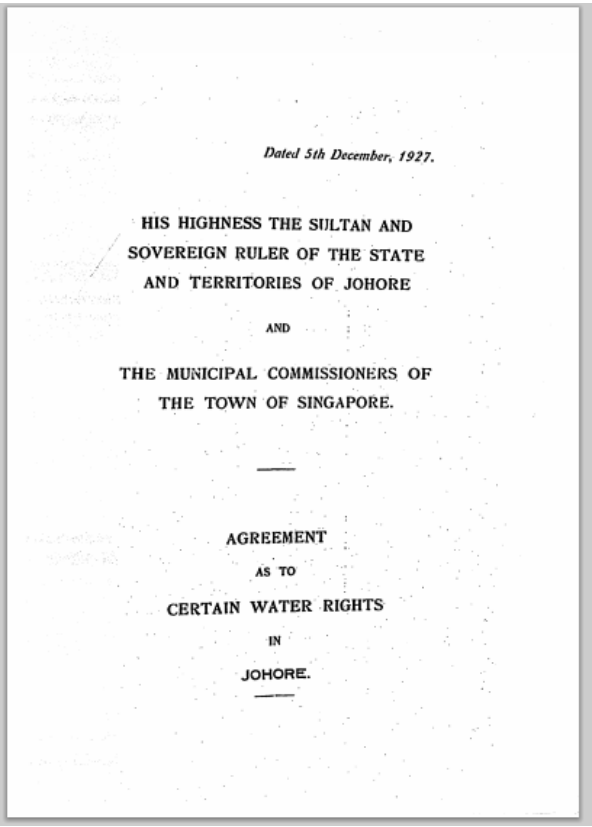


Figure 56 - Singapore's Water Loop (Source; PUB)

Tap 2 - Imported Water



Dated 5th December, 1927.

HIS HIGHNESS THE SULTAN AND
SOVEREIGN RULER OF THE STATE
AND TERRITORIES OF JOHORE

AND

THE MUNICIPAL COMMISSIONERS OF
THE TOWN OF SINGAPORE.

AGREEMENT
AS TO
CERTAIN WATER RIGHTS
IN
JOHORE.

Figure 57- The Agreement dated Dec 5, 1927.

Subsequent to the completion of MacRitchie, Seletar and Peirce Reservoirs, Singapore government realised it was not able to meet the water demands of Singapore and signed an agreement with the Sultan of Johore in 1927 (*fig. 57*) and has relied on import from Johor state in Malaysia to supply half of its water consumption.

As of today, imported water had been reduced to 40% of total consumption. Two water supply agreements between Malaysia and the British crown colony Singapore were signed in 1961 and 1962 respectively. The first agreement expired in 2011, the second will expire in 2061. Under these agreements the price of water is set at a very low level of less than 1 cent per 1,000 imperial gallons (4,500 L). The two countries are in disagreement about the future price of water. In the absence of a resolution, the government of Singapore decided to increase self-sufficiency in its water supply.

The Malaysian government has stated that the agreements were signed during a different time and that the price should increase. They cite the example of water sold by China to Hong Kong in the past, which was approximately $8 per 1,000 imperial gallons (4,500 L). However, this price comparison is not directly applicable because while China has borne the cost of constructing and maintaining the infrastructure to provide water to Hong Kong, Singapore paid for all the costs of the reservoirs in Johore, the dams, pipelines, plant, equipment, etc. and Singapore continues to pay all the costs of operating and maintaining this infrastructure.

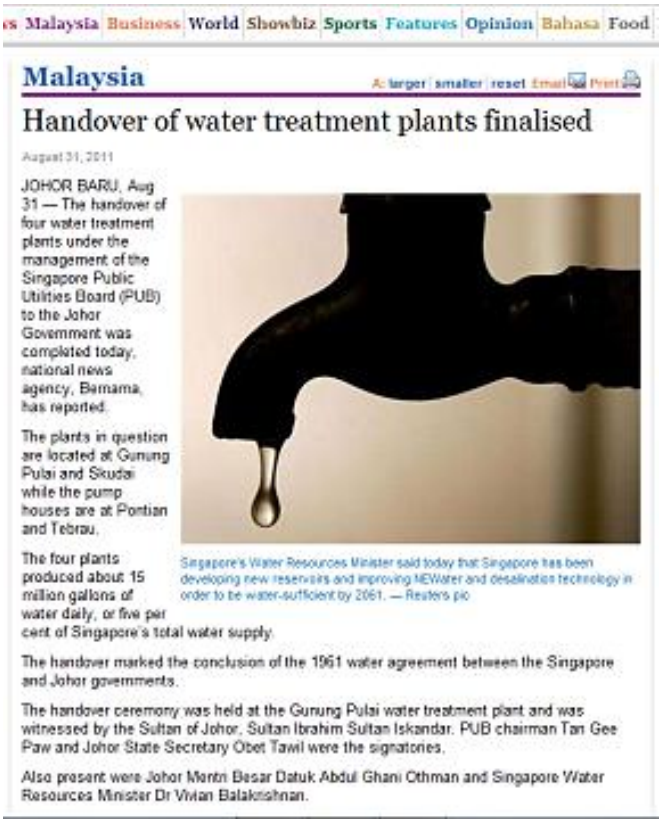
Malaysia has always been a reliable provider of water to Singapore, but Malaysia has often used threats of cutting off the water supply to pressure Singapore politically. Seeking greater political independence and freedom from such pressures, Singapore has pursued a strategy of developing self-sufficiency of water sources.

Singapore's water needs are anticipated to double in the next 50 years. Planned Newater (*see "Newater" section*) output will triple to

Figure 58 - Water pipeline from Malaysia at Johor-Woodlands causeway.

meet 50% of needs by year 2060 whilst desalination (*see "Desalination" section*) investment will raise output to meet 30% of needs. By the expiry of the 1962 water agreement in 2061, the necessity for Malaysia water import is expected to be eliminated.

In August 2011, the 1961 water agreement expired and the waterworks and facilities were handed over to the Johor state government. The handover included the Skudai and Gunung Pulai water treatment plants and two pump houses in Pontian and Tebrau, which were built and managed by PUB for 50 years (*fig. 59*).



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Handover of water treatment plants finalised

August 31, 2011

JOHOR BARU, Aug 31 — The handover of four water treatment plants under the management of the Singapore Public Utilities Board (PUB) to the Johor Government was completed today, national news agency, Bernama, has reported.

The plants in question are located at Gunung Pulai and Skudai while the pump houses are at Pontian and Tebrau.

The four plants produced about 15 million gallons of water daily, or five per cent of Singapore's total water supply.

Singapore's Water Resources Minister said today that Singapore has been developing new reservoirs and improving NEWater and desalination technology in order to be water-sufficient by 2061. — Reuters pic

The handover marked the conclusion of the 1961 water agreement between the Singapore and Johor governments.

The handover ceremony was held at the Gunung Pulai water treatment plant and was witnessed by the Sultan of Johor, Sultan Ibrahim Sultan Iskandar. PUB chairman Tan Gee Paw and Johor State Secretary Obet Tawil were the signatories.

Also present were Johor Menteri Besar Datuk Abdul Ghani Othman and Singapore Water Resources Minister Dr Vivian Balakrishnan.

Figure 59 - A News article on the handover of treatments plants and pump house by Singapore to Malaysia.

Tap 3 - NEWater

Figure 60 - My visit to the NEWater Visitor's Centre

On my arrival at the Newater Visitor's Center, initially, I confused it to be a tourist place. Considering a weekday and the visitor's which included school children and families, the confusion was quite legitimate.

Under the PUB's ABC water program (see *PUB - ABC Program*) they have ensured to bring people to the waters. Impressively, people have taken to it like fish to water (pun intended).

On the reception, I was greeted by a cheerful pretty guide, whose name I cannot recollect, but she knew my name very well (of course had to since I had registered earlier online for the visit). She started the tour by seating me in a theatre, almost the size of a small multiplex hall, where a short film on the importance of water and recycling was played, followed by a tour around the premises and a few more audio-visual experiences. The tour, contrary to my belief, was pretty non-technical and simplified for a lay man to understand, terms like "the size of a football field" and "quantity of a swimming pool" are commonly used instead of saying "x square meters" or "y cubic meters or litres", but I have to admit the guide was equally knowledgeable enough to answer every technical question raised by me too.

Many multimedia consoles were laid out as if in some gaming arcade (*fig. 61*). The visual impact created is not only astounding to young children but also leaves a deep impact on adult minds alike.

Figure 61 - Informative multimedia consoles at the NEWater Centre

NEWater, not really NEW!?!

The term "NEWater" was coined to re-brand the concept of recyled water and do away the pschyche attached to the fact that it was sewage treated water. Even the term "Sewage Treatment Plant" is re-branded as "Water Reclamation Plant". But it wasn't always like this. NEWater may sound like an overnight success for Singapore. But its evolution is a journey that spanned 3 decades.

Singapore's first water masterplan was drawn up in 1972. In 1974, PUB built a pilot plant to turn used water into potable water (*fig. 62*). This was the precursor of today's NEWater factories. But it was ahead of its time. The costs were astronomical and the membranes were unreliable, so the idea was shelved to await further technological advancement.

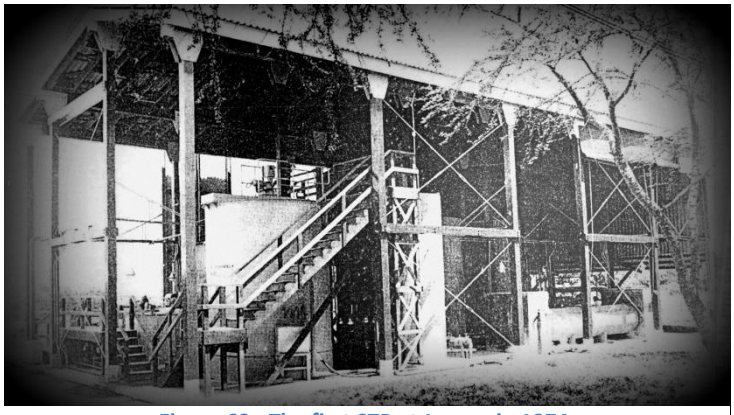


Figure 62 - The first STP at Jurong in 1974.

In 1998, the necessary technology had matured and driven production costs down. In May 2000, the first NEWater plant was completed at Bedok (where the NEWater visitor centre presently stands) followed by Kranji in 2003.

The Present

Currently, there are four NEWater plants in Singapore. The latest and the largest NEWater plant at Changi with a capacity of 50mgd was opened in May 2010. The plant at Changi is on a DBOO (Design Build Own Operate) basis with Sembcorp Utilities Pte. Ltd., a firm dealing in solid and liquid waste management extensively. With this addition, coupled with the expansion of the existing plants, NEWater now meets 30% of Singapore's total water demand. By 2060, NEWater is projected to meet 50% of Singapore's future water demand.

NEWater is primarily for non-potable industrial uses. Supplied to wafer fabrication, electronics and power generation industries for process use, it is also piped to commercial and institutional buildings for air conditioning cooling purposes. This frees up potable water for domestic consumption. It is delivered via a separate distribution network to industrial and commercial customers (separate purple coloured pipelines).

The demand for NEWater has grown 15-fold from 4 mgd (18,200 cubic metres a day) in 2003 to some 60 mgd (273,000 cubic metres a day) today.

A small percentage of NEWater is also blended with raw water in the reservoirs. The raw water from the reservoir then goes through treatment at the waterworks before it is supplied to consumers as tap water.

Twice a year, NEWater undergoes rigorous audit processes by an external audit panel comprising international experts in engineering, water chemistry, toxicology and microbiology.

This high-grade reclaimed water has consistently been awarded top marks for its high quality, safety and for exceeding international standards.

DTSS (Deep Tunnel Sewerage System)

If NEWater is considered the heart of the sewerage system of Singapore, the DTSS would definitely be the vascular system.

As quoted by the PUB Chief Executive, Mr. Khoo Teng Chye, "The DTSS is an integral part

of Singapore's water management as it allows every drop of used water to be collected, transported, treated and further purified into NEWater."

Figure 64 - The huge DTSS pipes from inside.

To prevent contamination to its enriched seventeen reservoirs, two separate systems are in place to collect rainwater and sewage. Sewage is collected, from modern sanitation which is available throughout the nation, through a network of sewerage pipes, which leads directly to the water reclamation plants. This is essential to avoid cross-contamination especially for reservoirs like the Marina Reservoir that runs through some of the oldest and densely built-up areas of Singapore.

However, as Singapore continues to rapidly grow and urbanise like all cities globally, more pumping stations and water reclamation plants will be needed to collect and treat used water. This takes up the scarcest commodity in Singapore, land and also requires huge invests in costly equipment.

The PUB thus conceived the DTSS as Singapore's long-term answer to its used water needs for the next 100 years.

The mammoth DTSS (Phase 1 & 2) consists of two large (up to 6 meters diameter), deep tunnels crisscrossing the island, two centralised WRPs, deep sea outfalls, a link sewer network (see *fig. 63*).

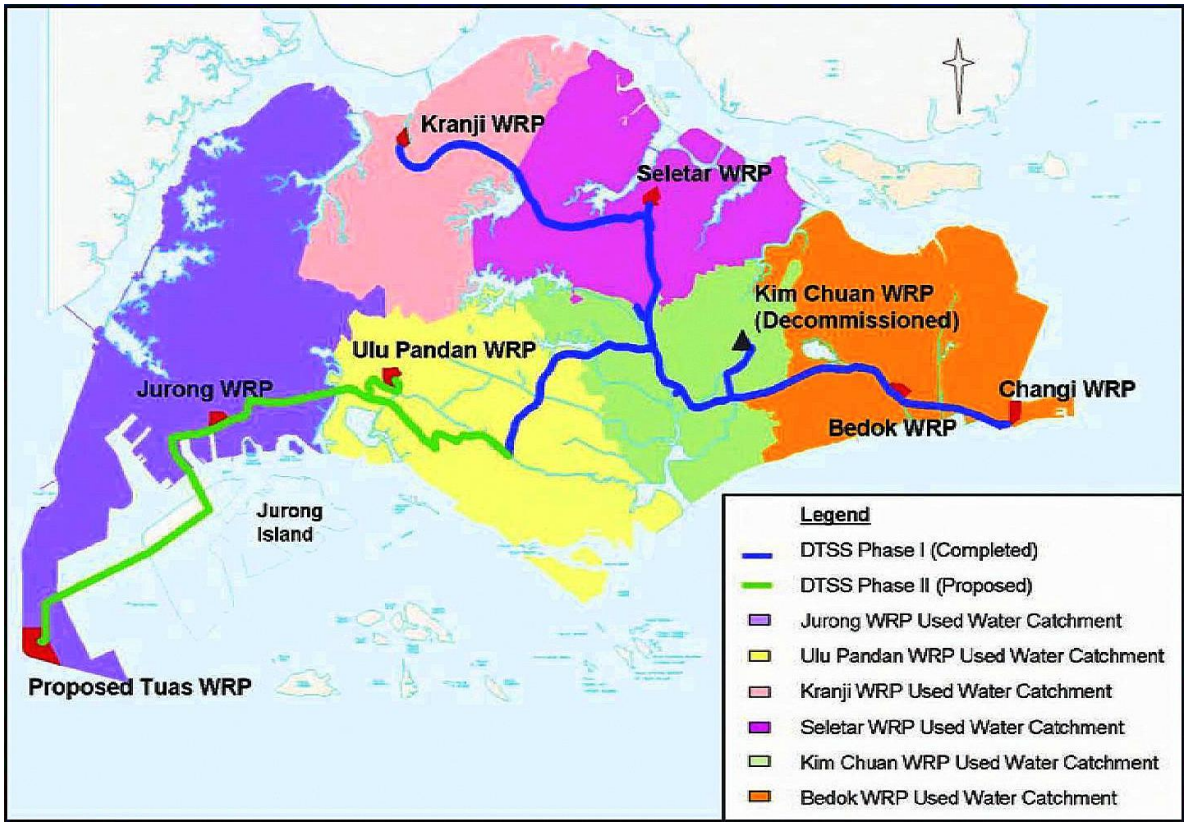


Figure 63 - The DTSS Map of Singapore.

Completed in 2008, Phase 1 of the DTSS comprises of 48km long deep tunnel sewer running from Kranji to Changi, the WRP at Changi, a 5km long deep sea outfall, and over 60km of link sewers.

Phase 2 of the DTSS will consist of the South Tunnel and its network of link sewers, leading to a WRP in the south-western part at Tuas and another deep sea outfall. This is expected to be developed before 2030.

The Multiplier Effect of NEWater

Apart from freeing up large amounts of potable water for other purposes, NEWater has a role in "multiplying" the water supply achieved through recycling.

What this means is that if 50% of water is recycled, the water supply could theoretically be doubled. From recycling 100 litres of water, 50 litres of water can be obtained. This 50 litres can in turn be recycled to get 25 litres, and then 12.5 litres, and so on. Theoretically, recycling, say a 100 litres of water results in another 100 litres (50 + 25 + 12.5 +… =100) produced. This is a multiplier of two. At a higher recycling rate, a higher multiplier effect, mathematically equal to 1/(1-R) where R is the recycling rate, can be achieved.

This means that instead of building new capacity of 100 million gallons per day (mgd) through catchment expansion, which is quite difficult in land-scarce Singapore, only half the required new capacity needs to be built and the rest made up through the multiplier effect of recycling.

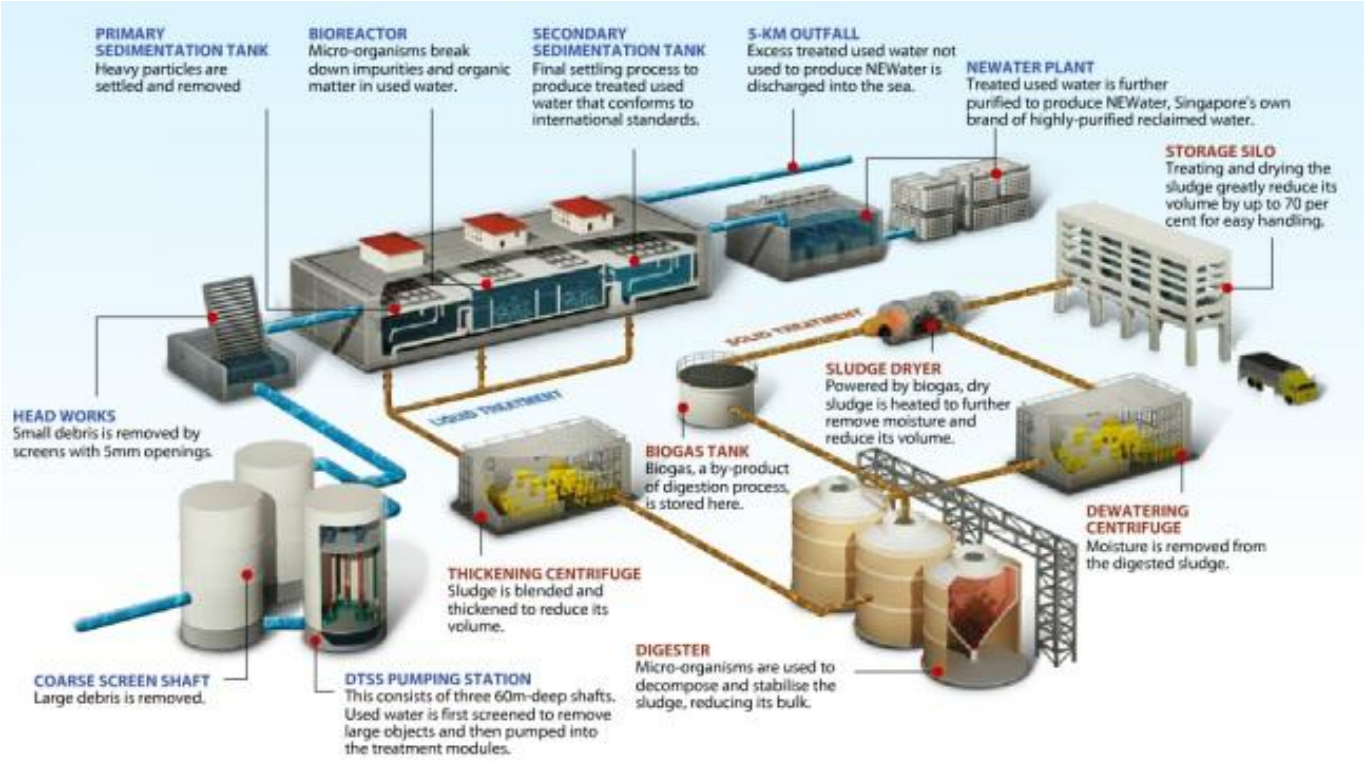
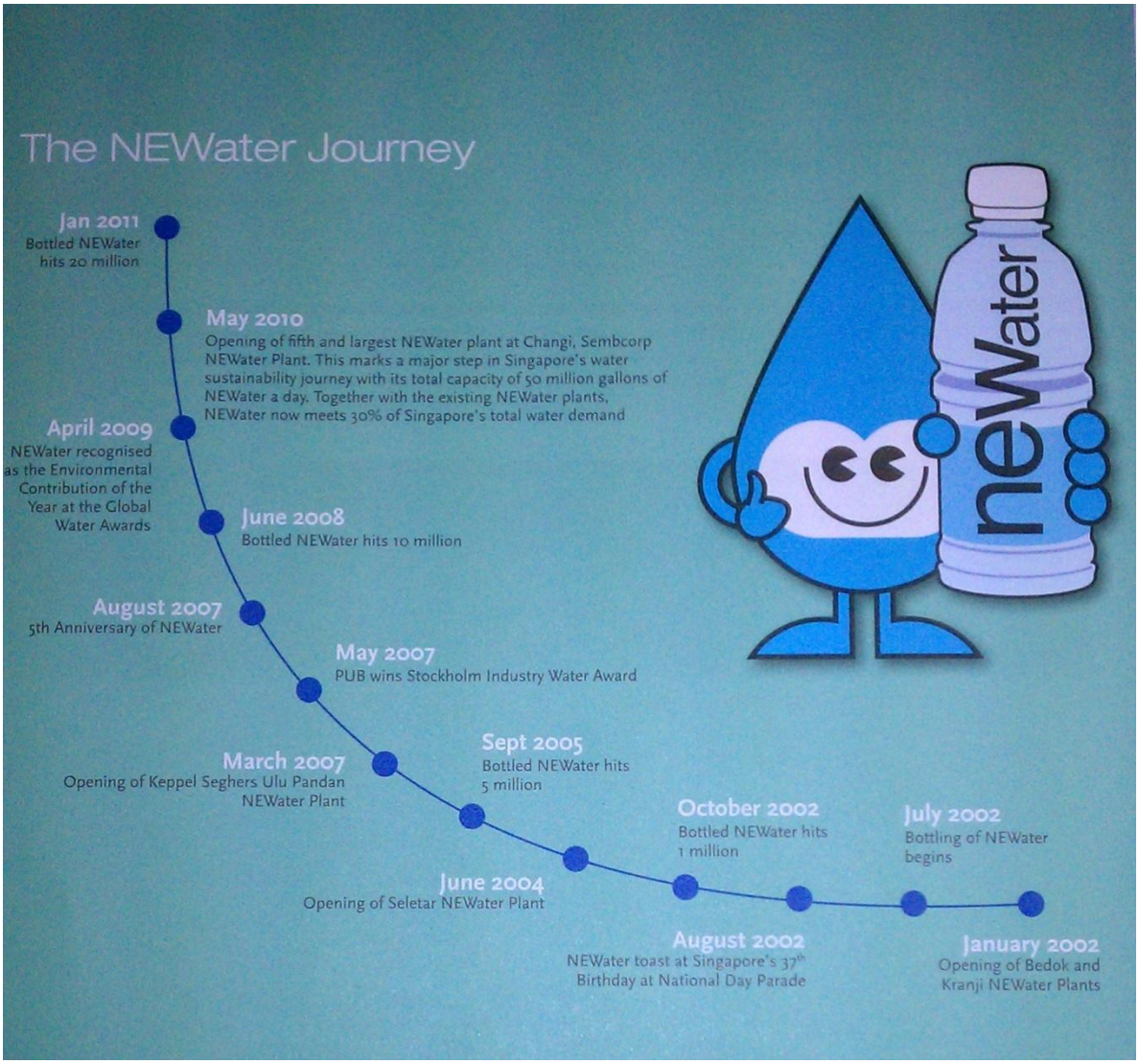


Figure 65 - The Schematic Flow-Chart of DTSS & NEWater


The NEWater Journey
Jan 2011
Bottled NEWater hits 20 million
May 2010
Opening of fifth and largest NEWater plant at Changi, Sembcorp NEWater Plant. This marks a major step in Singapore's water sustainability journey with its total capacity of 50 million gallons of NEWater a day. Together with the existing NEWater plants, NEWater now meets 30% of Singapore's total water demand
April 2009
NEWater recognised as the Environmental Contribution of the Year at the Global Water Awards
June 2008
Bottled NEWater hits 10 million
August 2007
5th Anniversary of NEWater
May 2007
PUB wins Stockholm Industry Water Award
March 2007
Opening of Keppel Seghers Ulu Pandan NEWater Plant
Sept 2005
Bottled NEWater hits 5 million
October 2002
Bottled NEWater hits 1 million
July 2002
Bottling of NEWater begins
June 2004
Opening of Seletar NEWater Plant
August 2002
NEWater toast at Singapore's 37th Birthday at National Day Parade
January 2002
Opening of Bedok and Kranji NEWater Plants
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The Process

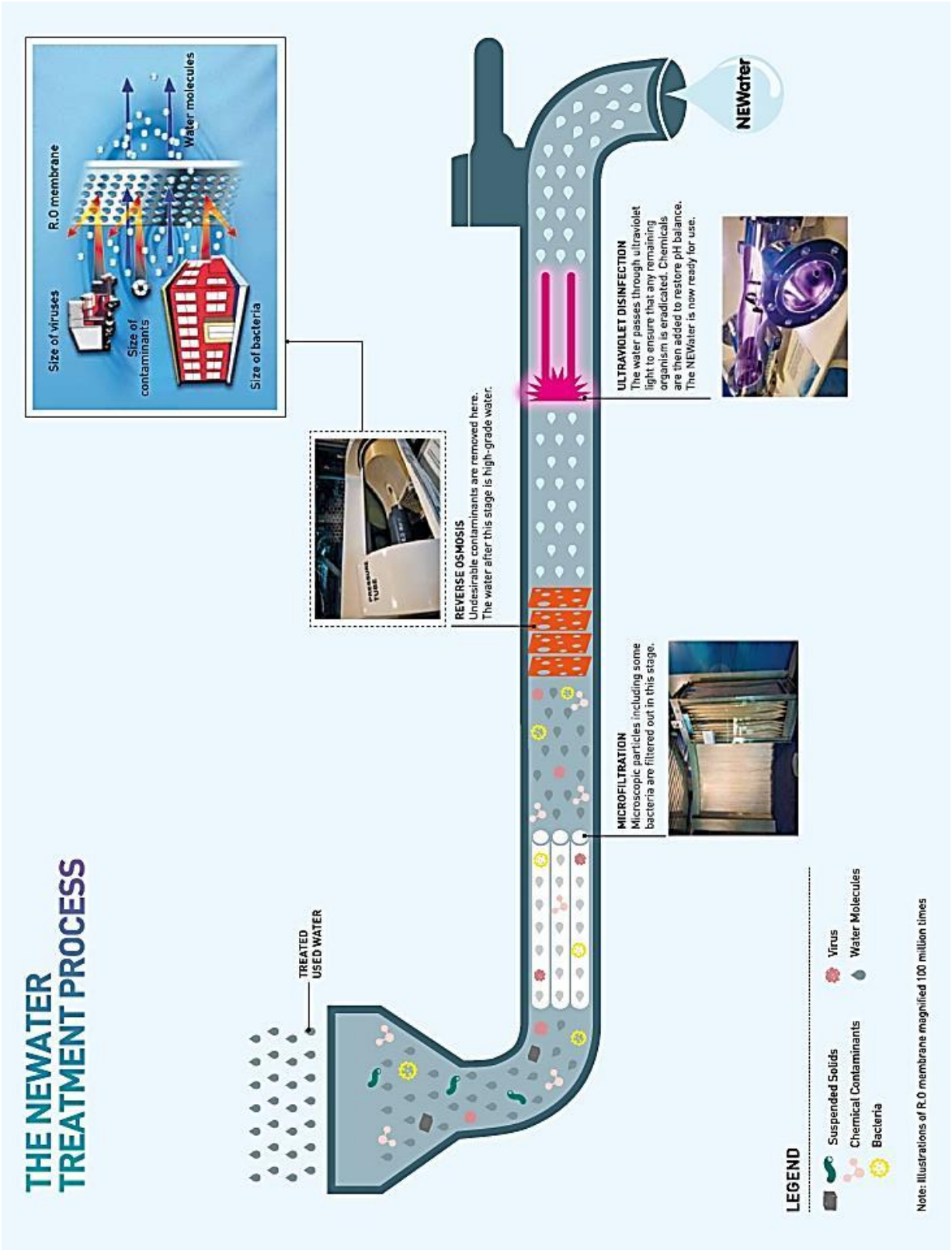

Figure 66 - The NEWater Treatment Process.

Mircofiltration: After screening for floating and suspended matter and removal of sediments, the first stage of the NEWater production process is Microfiltration (MF). In this process, the treated used water is passed through membranes (*fig.68*) to filter out and retained on the membrane surface suspended solids, colloidal particles, disease-causing bacteria, some viruses and protozoan cysts. The filtered water that goes through the membrane contains only dissolved salts and organic molecules.

Figure 68 - The Microfilration Membrane.

Reverse Osmosis: The second stage of the NEWater production process is Reverse Osmosis (RO). In RO, a semi-permeable membrane is used. The semi-permeable membrane has very small pores which only allow very small molecules like water molecules to pass through. The processes explained at visitor centre are explained with reference to size like ping-pong balls, footballs, trucks, buildings sizes (see *fig.66*). Consequently, undesirable contaminants such as bacteria, viruses, heavy metals, nitrate, chloride, sulphate, disinfection by-products, aromatic hydrocarbons, pesticides etc, cannot pass through the membrane. Hence, NEWater is RO water and is free from viruses, bacteria and contains negligible amount of salts and organic matters.

Figure 67 - The cut-section of the RO Module

Figure 70 – A Sample UV Module.

UV Disinfection: After this stage, the water is already of a high grade quality. The third stage of the NEWater production process really acts as a further safety back-up to the RO. In this stage, ultraviolet or UV disinfection (*fig.67*) is used to ensure that all organisms are inactivated and the purity of the product water guaranteed.

Figure 69 - The NEWater Control Room deploying SCADA assures round the clock monitoring.

With the addition of some alkaline chemicals to restore the acid-alkali or pH balance, the NEWater is now ready to be piped off to its wide range of applications.

The Indian Scenario

Unfortunately in India, no such centralized treatment system yet exists. Though there is a huge demand for individual plants as imposed by statutory bodies, but that yields diversified results with a wide array of treatment technologies all claiming to be the best in the market (considering proper maintenance). In most case, the developers may with all good intent install the best treatment option, but on transfer to the end user, especially in residential complexes, the occupants are ignorant of the maintenance regime required for such a system, on a longer-term making this a highly hazardous system which could result in raw sewage being circulated and causing a large-scale epidemic.

The vital aspect about NEWater is that since PUB is the only authority supplying water in Singapore the standard is uniform throughout.

But when I posed the question to the PUB officials on a one-on-one interaction as to why separate water lines do not exist as is the case in many cities in India (domestic water supply and flushing water supply) and why is treated potable quality water used for flushing when they have NEWater. I was informed that the infrastructure of Singapore had always used a single pipe system and replacing the whole infrastructure would have substantial financial implications. Though with the NEWater network progressively growing through the island and many new commercial and industrial developments opting for the alternate sources for allied purposes, it may be possible in the near future that the load on potable water may be reduced substantially.

NEWater Quality Parameters

Water Quality Parameters	NEWater	USEPA / WHO Standards
Physical		
Turbidity (NTU)	<5	5 / 5
Colour (Hazen Units)	<5	15 / 15
Conductivity (µS/cm)	<250	NA
pH Value	7.0 – 8.5	6.5-8.5 / -
TDS* (mg/L)	<150	500 / 1000
TOC# (mg/L)	<0.5	- / -
Tot hardness^ (mg/L)	<50	NA
Chemical (mg/L)		
Ammoniac Nitrogen (N)	<1.0	- / 1.2
Chloride (Cl)	<20	250 / 250
Fluoride (F)	<0.5	4 / 1.5
Nitrate (NO_3)	<15	10 / 11
Silica (SiO_2)	<3	- / -
Sulphate (SO_4)	<5	250 / 250
Residual Chlorine (Cl)	<2	4 / 5
Total Trihalomethane	<0.08	0.08 / -
Metals (mg/L)		
Aluminium	<0.1	0.05-2 / 0.2
Barium (Ba)	<0.1	2 / 0.7
Boron (B)	<0.5	- / 0.5
Calcium (Ca)	4 - 20	- / -
Copper (Cu)	<0.05	1.3 / 2
Iron (Fe)	<0.04	0.3 / 0.3
Manganese (Mn)	<0.05	0.05 / 0.4
Sodium (Na)	<20	- / 200
Strontium (Sr)	<0.1	- / -
Zinc (Zn)	<0.1	5 / 3
Bacteriological		
Total Coliform Bacteria (Counts/100ml)	Not Detectable	Not Detectable
Enterovirus	Not Detectable	Not Detectable
Heterotrophic Plate Count (CFU/ml, 35°C, 48 hrs)	<300	<500 / -

* Total Dissolved Solids

Total Organic Carbon

^ Total Hardness ($CaCO_3$)

Tap 4 - Desalination

Completed three months ahead of schedule, on September 13, 2005, Singapore turned on its fourth National Tap, with the opening of the SingSpring Desalination Plant in Tuas. The SingSpring desalination plant was PUB's first public-private partnership (PPP) project. This plant can produce 30 million gallons of water a day (136, 000 cubic meters) and is one of the Asia's largest seawater reverse-osmosis plants.

Figure 71 - Visit to Tuas SingSpring Desal Plant; L to R - Mr. Chia Wai Chon, SPS; Mr. Rajiv Dixit, Head of Municipal Sales, Hyflux; Mr. Johnny NG Tow Hock, SPS; Myself; Mr. Kishor Dobariya, GM Tech & Business Development, Hyflux.

At the SingSpring plant which is on a DBOO (Design, Build, Own, Operate) term with Hyflux, sea water goes through a pre-treatment process where suspended particles are removed. In the second stage, the water undergoes reverse osmosis (RO), the same technology used in the production of NEWater. The water produced is very pure and is re-mineralised in the third stage. After treatment, desalinated water is blended with treated water before it is supplied to homes and industries in the western part of Singapore.

The General Manager of Technology and Business Development, Mr. Kishor Dobariya alongwith the Head of Municipal Sales, Mr. Rajiv Dixit were kind enough to arrange a visit to this otherwise restricted facility. Though the facility has photography / videography restrictions, certain images used in this section have been sourced from Hyflux and PUB or have been clicked in areas permitting photography.

The work for a second desalination plant with a capacity of 70 million gallons of water a day is in progress in full swing and will be completed in 2013. This agreement too has been signed between PUB and Hyflux.

The desalination plant, to be located in Tuas, very next to the present plant, will be constructed under a Design, Build, Own and Operate (DBOO) model. It is expected to commence operations in 2013 and will add another 70 imperial million gallons (mgd) or 318,500 cubic metres of desalinated water per day to Singapore's water supply. The first-year price for the desalinated water is expected to be S$0.45 per cubic metre (1000 litres).

The Plant Process

The plant process primarily comprises of three elements:

- Pre-Treatment
- Reverse Osmosis
- Post-Treatment

Pre-Treatment: The plant design uses an open seawater intake structure, with two separate inlet channels each equipped with mechanical rake coarse screens. Growth inhibitors are added to the intake to reduce the potential for marine growth to accumulate around the screens, pipes and other structures. Further chemical dosing systems

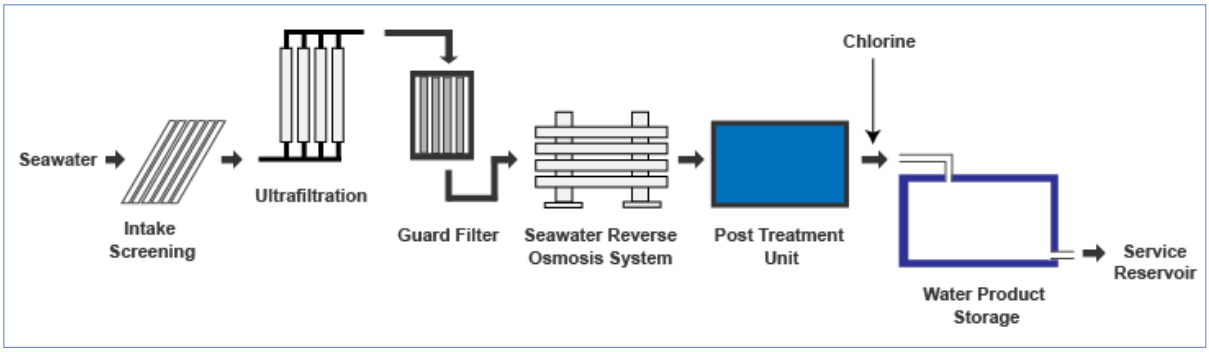

Figure 72 - Schematic flow of Desalination Process (Source: Hyflux)

ensure adequate pH correction and enable the addition of polymer coagulants.

Chemical de-chlorination takes place both upstream and downstream of the cartridge filters leading to the RO plant and any further adjustment of the pH can also be made downstream of the cartridge filters, as required.

Oil, grease and suspended solids are removed from the flow by dissolved air flotation filtration (DAFF), prior to the primary gravity sand filters (GSF) and the flow subsequently passes through secondary pressure sand filtration (PSF) before entering the reverse osmosis section of the plant.

The Tuas Seawater Reverse Osmosis (SWRO) also has the benefit of being constructed on reclaimed land and hence does not have to intake seawater from an otherwise distance of 8km but can achieve the same from 5km.

Figure 73 - An Aerial view of SingSpring Plant at Tuas. (Source – Hyflux)

Reverse Osmosis: The RO treatment process itself consists of two passes through the installed membrane batteries. On the first pass, dissolved solids are removed from the flow; the purpose of the second is to enable the RO units to reduce the boron level in the treated water.

One of the key factors in the economics of the SWRO is the energy usage, since the monthly variable purchase price is predicated on fuel costs. The energy recovery system (ERS) at this facility, which has been designed with the specific intention of minimising operating costs, consists of a "pelton-wheel" type system and pressure exchange energy recovery. As explained and understood by me, the high pressure used to permeate the membranes is re-used by the return liquid by just adding only the additional pressure required for the second pass. The success of this approach is clear. At 4.1kWh/m3, the plant is one the most energy efficient ever built; the first year selling price of S$0.48/m3 is the world's lowest for desalinated seawater.

Figure 74 - The Seawater Reverse Osmosis Building at Tuas (Source; Hyflux)

Post-Treatment: Downstream of the RO process, dosing facilities introduce lime to the product water to control the pH and improve the taste, together with the chlorine and ammonia used for disinfection. Fluoride is also added. A series of treated water tanks hold the product prior to entering the main transmission line.

As is the case with NEWater, the administration and control building houses state-of-art SCADA systems in place, which constantly monitor and can manually control the equipment in case of failures or overloads and the display parameters of treated water live even to PUB.

A pumping system is provided to connect the supply to a PUB main existing eight kilometres away.

The brine stream discharges into the sea through a submerged outfall 4 km away. The positioning and capacity of the outfall was the subject of extensive assessment to mitigate its environmental impact.

Environmental Concerns

On a personal level, I always bore concerns when it comes to desalination, having had nightmares of seeing raw brine being pumped in to an ocean with its Nat-Geo-style picture-perfect flora and fauna. This had made me very keen on actually visiting a desalination plant.


Figure 75 - The Outfall Sump at SingSpring.

The question that always bothered me was, of course, the brine disposal and also the impact that that it made on the surrounding ecology. My concern also extended to long-term global impacts such as the change of sea-water density (though it sounds funny because the water withdrawn from the sea is of negligible quantity hence the impact wouldn't be high, right?), but looking at a bigger picture, one theory states that the melting glaciers which are adding millions of litres of fresh water in the sea can impact the density and in turn the ocean temperature and eventually ocean currents leading to volatile weather patterns.

Now picture a country like India having a coastline of above 6000km with some of the largest cities dotted along it craving for water pumping in all the seawater and discharging the brine back, quite a scary picture!

On asking this question to Mr. Kishor Daboriya, the GM of Hyflux, he mentioned that indeed desalination does have a certain amount of environmental impact, especially if the location is not assessed properly. While in case of the SingSpring plant which was visited and the upcoming adjoining TuasSpring have a benefit of the location and the extensive study conducted has assured that the surrounding ecology and environment in not harmed in any way.

Innovations in Desalination.

Desalination is the solution to coastal water-scarce cities but the process is inherently energy intensive. With ever increasing energy prices and the need to mitigate the impact on global climate, there is an added urgency to intensify the search for more energy-efficient desalination processes to solve these problems. Singapore is pioneering these efforts by investing in R&D activities to achieve sustainable development in desalination and water reuse (NEWater).

Membrane Distillation

Membrane distillation offers the potential to desalt seawater at one-third the current energy demands of RO desalination. It combines evaporation and membrane technology to produce near distilled water through a process of vaporisation and condensation. Besides serving as a micro-filter, the membrane also acts as a barrier between the liquid and vapour phases.

Savings in energy arise from not having to use an RO membrane. Also to vaporise water, low-grade heat and steam from incineration plants and power stations can be exploited. This heat and steam would otherwise have been wasted. Currently, a 2 cubic metre per day pilot plant is being tested using waste heat from an incineration plant.

Variable Salinity Plants

In the Variable Salinity Plant (VSP) Project, the plant is designed to automatically adjust its treatment regime to suit the salinity of the incoming feed water. Water is first pre-treated with an MF (microfiltration) or UF (ultrafiltration), and depending on its salinity, the filtrate will be subjected to either one pass or two passes of RO.

Not only can a VSP effectively process collected brackish rainwater, but it can also adapt to changes in precipitation by switching over to seawater desalination during dry spells. As a proof of concept, the PUB team designed and constructed a prototype VSP at the Bedok NEWater facility in 2004. "Raw water was extracted from the Bedok Canal, which leads to the sea," explains Sarah Hiong, an engineer at PUB and part of the VSP team. "This pilot plant had a capacity of 24 cubic metres per hour in brackish water mode and 10 cubic metres per hour in seawater mode." The Bedok plant proved a remarkable success, so in 2007, PUB decided to scale up and construct a dedicated demonstration-scale variable salinity plant.

The fundamental design of a VSP is relatively simple. Each facility receives source water via two inputs. During the wet season, rainwater accumulates in a nearby canal where it remains trapped via an inflatable rubber weir (*fig.76*); the water retained within this canal is transferred to the plant and purified via the VSP's 'brackish water' process. When the canal runs dry, the VSP can shift to a seawater processing workflow, using source water obtained from an intake feed positioned a few hundred metres offshore.

Given the potentially dramatic variability in the quality of the water that may be processed, this system requires considerable robustness and flexibility. "The raw water is of varying salinity, a factor that is dependent on tide and surface runoff," explains Hiong.

The initial stages of processing are the same for both feeds. The source water is first screened and strained to remove large solids; then it is passed through a series of microfiltration membranes that remove finer particulate matter. The two paths subsequently diverge, with water from each source undergoing a different reverse-osmosis (RO) purification process to remove organic matter and dissolved salts. Seawater is

Figure 76- Inflatable rubber weir traps rainwater, which is processed via the VSP's brackish water workflow.

subjected to two rounds of RO (*fig.77*), first with a specialised membrane element designed for seawater (SWRO) and then with a pair of membrane elements suitable for use with brackish water (BWRO). The use of the SWRO membranes is important because they are specifically designed to reduce the elevated concentrations of boron that are typically found in seawater. Brackish water, on the other hand, requires only one round of processing, through either a single SWRO or a pair of BWROs. Finally, the output from both reverse-osmosis processes is subjected to a standard post-treatment protocol by adding sodium hydroxide for pH adjustment and sodium hypochlorite for disinfection.

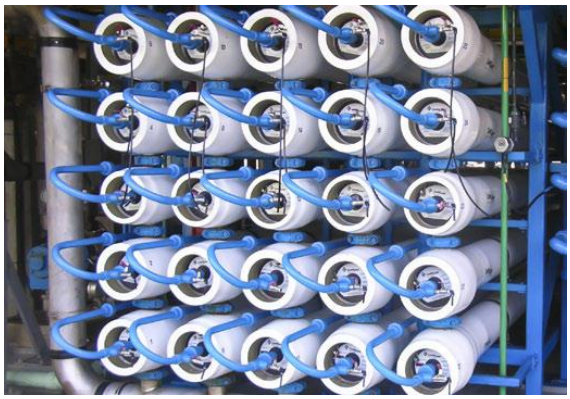

Figure 77 - Water processing at the VSP entails the passage of microfiltered water through a series of RO Membranes.

PUB's demonstration-scale VSP, which was constructed in Pasir Ris town and received water from the nearby Tampines Canal, was considerably larger than the prototype tested at Bedok. It has the capacity to handle some 7,570 cubic metres (two million gallons) of brackish water per day and 3,785 cubic metres (one million gallons) of seawater per day. This gave the PUB team the opportunity to identify and resolve many of the issues associated with the operation of a full-scale water processing facility at normal throughput continuously.

One of the issues facing the team was the high density of microorganisms in the seawater feed that resulted in unforeseen consequences when the plant was running continuously in that mode (*fig.78*). "It led to uncontrolled biological growth in the seawater pipeline," says Hiong, "to the extent that 20 bags full of mussels were collected!" The team resolved this problem by pumping brackish water from the canal into the system, thereby creating an environment that was unsuitable for the growth of seawater microorganisms.

Figure 78 - VPS Pipelines overgrown with barnacles and mussels.

The canal water, however, brought complications of its own. In the aftermath of heavy rains, this water routinely contained large quantities of silt and debris, and considerable optimisation of the first-stage filtration process proved necessary. The PUB team was also cognisant of the risk of mosquito populations becoming established in the canal if the trapped water was allowed to grow stagnant. To prevent this from happening, the team compromised on brackish-water production by deflating the weir on a weekly basis.

In general, the Tampines facility saw far greater use for brackish-water processing; although the system was originally projected to handle a 50:50 ratio, the breakdown was closer to 60% brackish water and 40% seawater over the course of 2008. As the former mode of operation is energetically more efficient, this also resulted in considerable savings, with an average energy usage of 1.9 kilowatt-hours per cubic metre (kWh/m3) of water rather than the predicted 2.99 kWh/m3. Notably, the VSP also proved more efficient than a typical seawater desalination plant, with approximately 50% lower energy consumption. To optimise overall plant operation, the PUB team found it best to alternate three days of brackish-water operation with a single day of seawater operation when possible.

This demonstration-scale VSP also outperformed expectations in terms of reduced mineral scaling on RO membranes. This problem is commonly observed at seawater desalination plants that modulate the pH of source water as a means to remove excess boron. Such facilities are typically forced to add additional chemicals to the water that prevent scaling from occurring.

However, the RO membranes used at Tampines were designed to remove the boron adequately without the need for pH adjustment; this essentially minimised the scaling problem, and eliminated the need for dosing with anti-scaling agents.

The findings from this pilot effort have given PUB the momentum to develop additional facilities that employ the same technology; and Tampines remains a working laboratory for the further refinement of VSP implementation. “The demonstration plant has been operating continuously since June 2007 while undergoing process optimisation,” says Hiong.

In January 2011, PUB was awarded a patent for its VSP technology — the first patent to be granted to the water utility. PUB’s innovative approaches are garnering interest worldwide. “PUB has been sharing its know-how with other countries including China and the United States,” says Hiong.

The agency has also made charitable use of this technology. The 2004 tsunami that wreaked havoc throughout the Indian Ocean had a particularly devastating impact on the island republic of the Maldives, situated off the south-western coast of India. The resulting damage severely affected roughly a third of the Maldives’ 300,000 inhabitants3. Many of these individuals also faced a shortage of fresh water in the weeks and months following the disaster. Singapore stepped in by providing them with VSP infrastructure. “The Bedok pilot plant was relocated to the Maldives as part of the reconstruction efforts,” says Hiong.

The 1.5 kWh per 1000 litres challenge

A Request-for-Proposal (RFP) in the area of seawater desalination was launched in July 2007 to come up with innovative desalination

solutions that consume 1.5 kilowatt-hour (kWh) energy or less per cubic metre of potable water produced from seawater. This is at least 50% more energy-efficient than the most energy-efficient advanced seawater desalination technology currently available.

The Challenge RFP attracted the attention of local and overseas research institutions and companies. Siemens Water Technologies, through its Singapore Global R&D Center, will receive funding support amounting to some S$4 million worth of research funds to carry out R&D on a seawater desalination technology. Siemens believes that the future of desalination lies with electrically-driven processes which do not have the same inherent energy demand limitations as thermal or pressure-driven processes. The project awarded under this Challenge RFP will investigate a novel process that includes electro-dialysis and ion exchange.

Concluding Afterthoughts

Technology has been key to Singapore's success in diversifying its water resources. Through it, desalinated water has become a viable source of water to augment the supply from local catchments and imported water.

Also through it, closing the water loop by large scale reclamation of NEWater from treated used water has become a reality and enabled the multiplying effect of water reclamation to increase Singapore's water supply substantially to meet the increasing demand for water to support the population and economic growth at an affordable cost.

The strategy to involve the public in its initiatives has gathered huge response and implanted a positive sense of belonging amongst the masses.

Singapore will continue to invest in technology and R &D activities to find even more energy-efficient solutions to develop its water resources in an environmentally and economically sustainable manner and to achieve its aim to be a **GLOBAL HYDRO-HUB**.

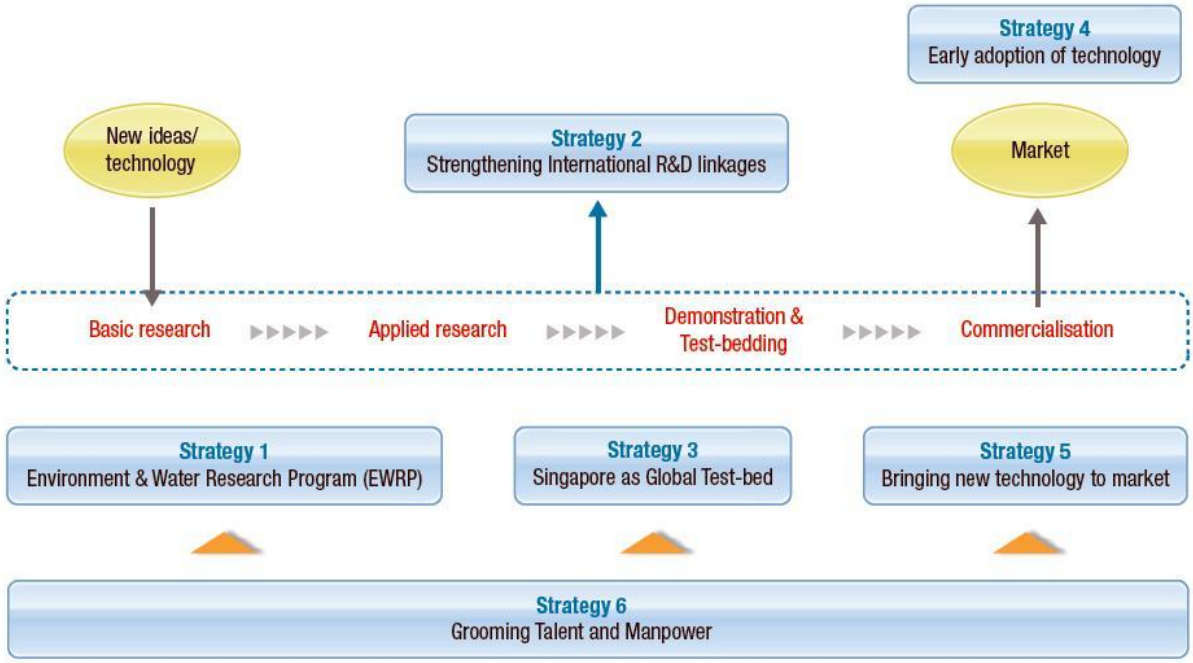

Figure 79- Singapore's strategies to catalyse growth of water industry from idea conceptualisation to commercialisation.

Acknowledgements

Mr. William Tang Kok Khiong, President *Singapore Plumbing Society (SPS).*

Mr. Chia Wai Chon of *Singapore Plumbing Society(SPS).*

Mr. Johnny NG Tow Hock of *NKH Building Services Pte Ltd.*

Mr. Dickrose Masalamani of *DJJ Engineering Services (S) Pte Ltd.*

Mr. Steven Tang of *Stace Integrated Building Services Pte Ltd*.

Mr. Richard Tock of *Nan Wah Engineering Pte Ltd.*

Mr. Christopher Chua Wee Hong, Executive Engineer, Water Supply (Network) Department, *Public Utilities Board.*

Mr. R. Rajendram, Executive Engineer, Water Supply (Network) Department, *Public Utilities Board.*

Ms. Tan Giin Bo, Head, Training, Human Resources Department, *Public Utilities Board.*

Mr. Kishor Dobariya, General Manager, Technology & Business Development, *Hyflux Ltd.*

Mr. Rajiv Dixit, Head of Municipal Sales, India, *Hyflux Ltd.*

Mr. V. Devaraja of *One Asia Consult*

Executive Committee of Singapore Plumbing Society

President & Executive Committee of World Plumbing Council.

President & National Executive Committee of Indian Plumbing Association.

PUB Officials at Marina Barrage

PUB Officials at Meter Testing Workshop.

Administrative and Training Staff at BCA Academy

Management of Singapore Zoo

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一人将进行两桶水，供自己使用
两名男子将携带他们的一个共同使用，
三名男子将携带没有任何人使用。

One man will carry two buckets of water for his own use,
Two men will carry one for their joint use,
Three men will carry none for anybody's use.
- *Chinese Proverb*