Managing Water Beyond Limits
- Singapore Strategies

By

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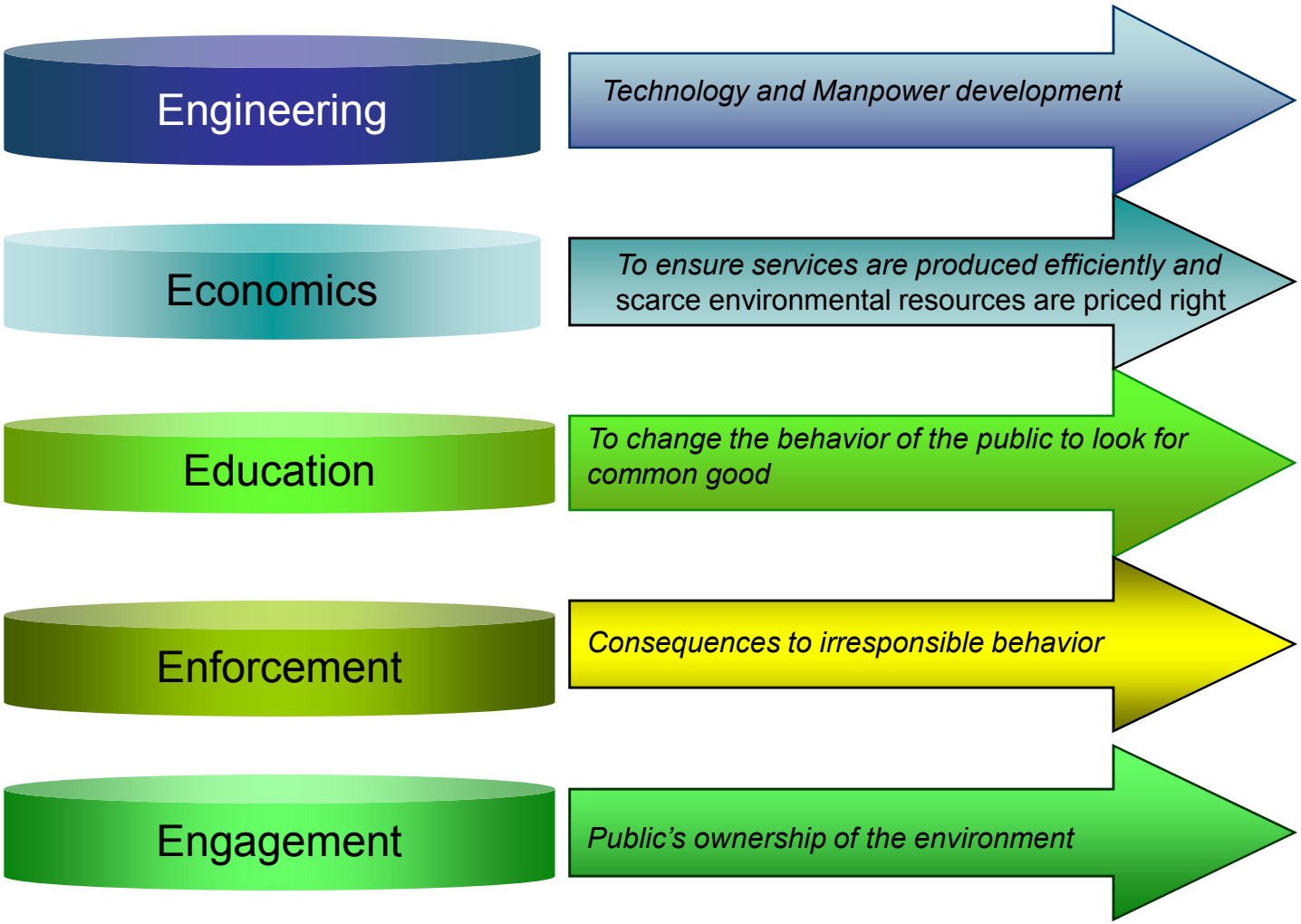
Singapore

Source: http://www.worldatlas.com/webimage/countrys/asia/asiaall.htm

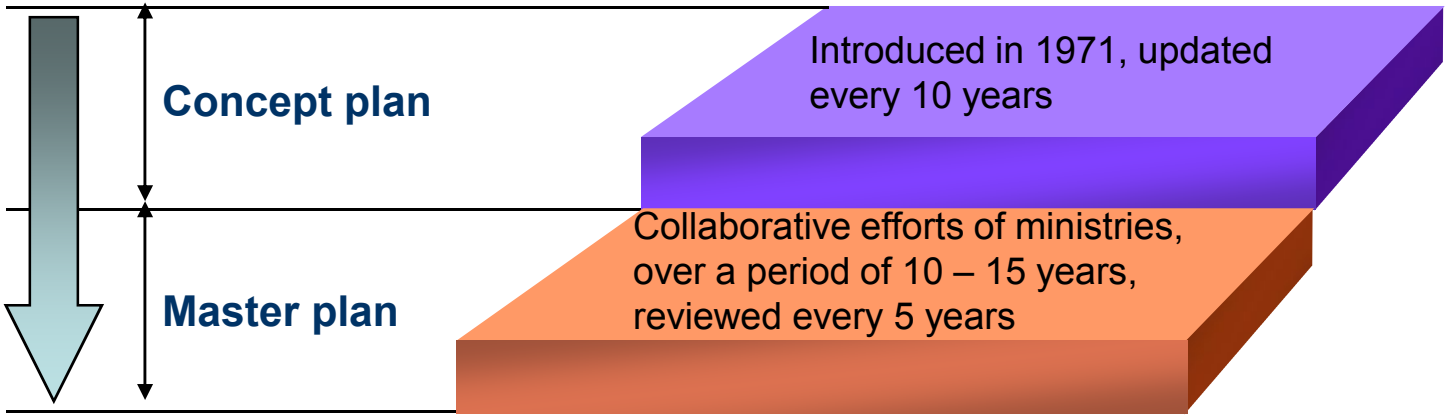
Singapore's 5 Es Approach



to better Environment Management

Source: Tan S.Y., Lee T.J. and Tan K. (2008) Clean, Green and Blue. Institute of Southeast Asian Studies, Singapore

Integrated Plan for Successful Implementation of Water Management Strategies



Examples:

- Land use planning
  - need to protect Singapore's water catchment

- Water Catchment Policy enforced in 1983 to control developments within unprotected catchment area
  - Urbanized cap at 31.4% and population density limit of 198 dwelling units per hectare up to 2005
  - 1999 the cap was lifted, PUB upgraded treatment plants with advanced water treatment technology to cater for water from increasingly urbanized and protected areas.

Water Scarcity

– Singapore's experience in the early years

Reservoirs not sufficient to supply water to population of 1 million

Water has to be imported from Johor Malaysia

1950s

Rivers were open sewers & were extremely polluted

Drought led to severe water rationing being imposed - 1963

1960s

More local reservoirs and cleanliness of water supply at all costs

1970s – 1980s

Master plan for Singapore River and Kallang Basin clean up (1977 – 1987)

Save water campaign

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Managing Supply and Demand

Supply management:

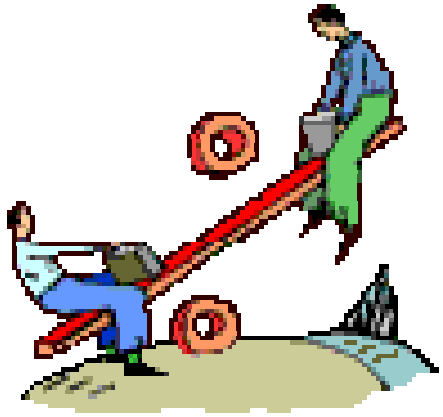
→ Catchment management

→ Imported water supply

→ Water from unconventional water resource

→ NEWater

→ Desalinated water



Demand management:

Through Water Conservation Plan

→ Water pricing

→ Mandatory requirements

→ Public Education

Singapore's Water Supply

Overview

Imported water (Johor)
Singapore will continue to import water. The 1961 and 1962 agreements will expire in 2011 and 2061 respectively.

Local catchment

Currently Singapore has 14 reserviors. The new Marina Reservoir will add to the local water supply and increase the water catchment from half to two-thirds of Singapore.

NEWater
At least 55 mgd of NEWater will be supplied directly to industries -and 10 mgd will be blended with freshwater in reservoirs by 2011.

Desalinated water
30 mgd of desalinated water is being produced starting from 2005.

Water Supply - Imported Water

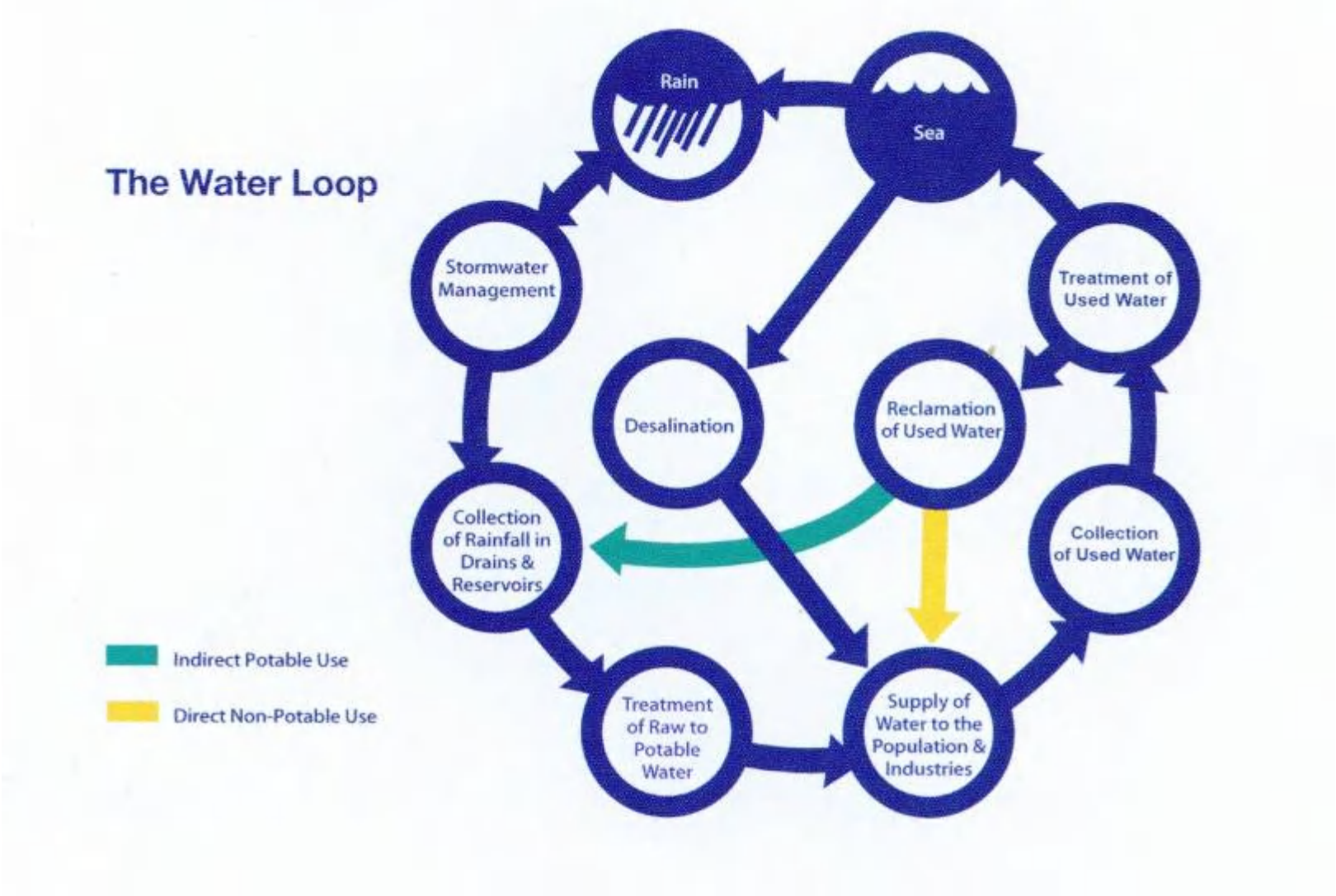
- 1961 – 2011 : State of Johor in Malaysia for the supply of water to Singapore from Gunong Pulai and Pontain catchments and Tebrau and Skudai Rivers

- 1962 – 2061: Drawing up to 260 million gallons of water per day from Johor river.

- Under the Water Agreement, the raw water price was fixed at 3 sen per 1,000 gallons of water. Singapore pays for the water infrastructure including construction of dams, pipelines, plants and equipment, operational and maintenance costs

- Singapore supplied treated water to Johor at a price of 50 sen per 1000 gallons of water (costs at RM2.50 to treat every gallon).

Singapore's Water loop



Source: PUB, 2006

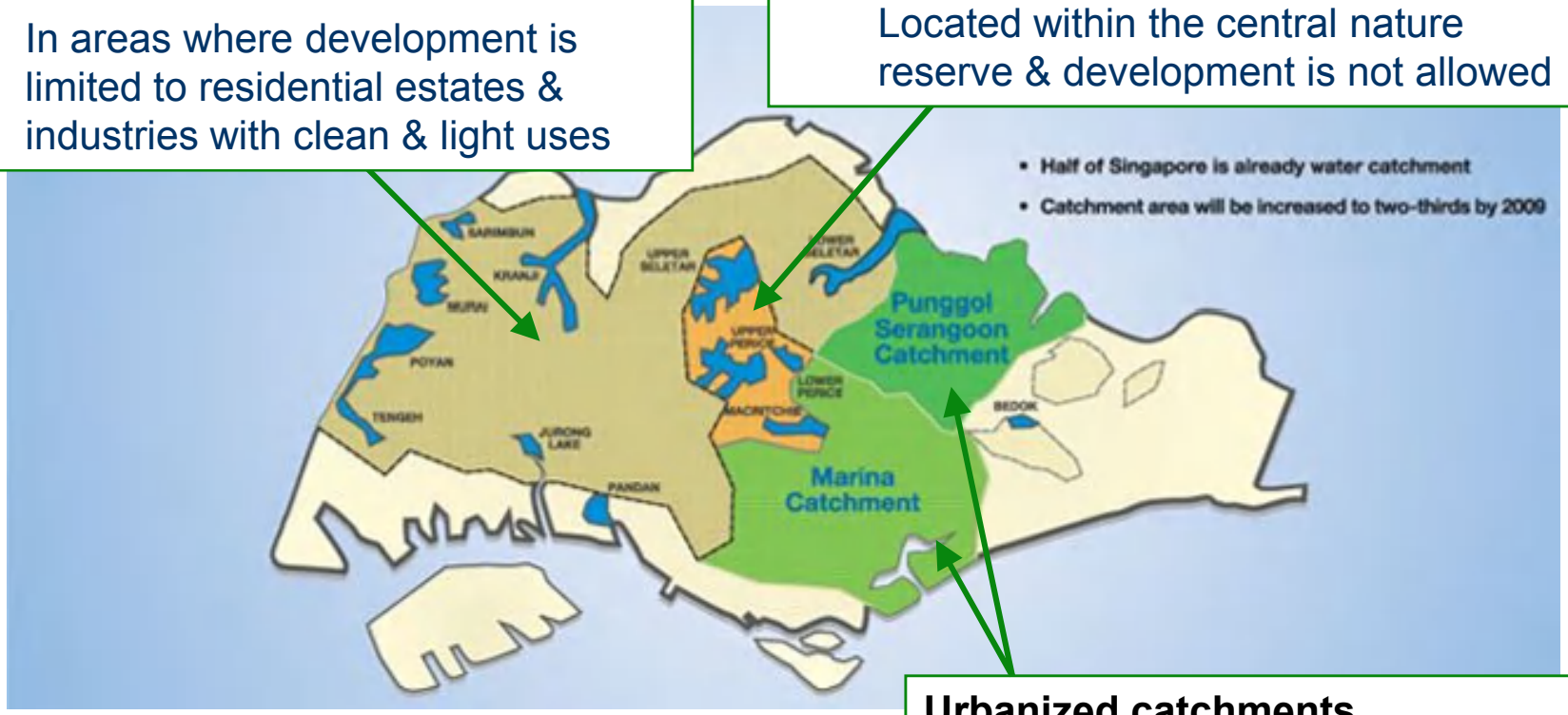
Water supply – Catchment management

Unprotected catchments

In areas where development is limited to residential estates & industries with clean & light uses

Protected catchments

Located within the central nature reserve & development is not allowed



Catchment area – 2/3 of Singapore's land

Urbanized catchments

In areas with multiple uses of land, i.e for housing, industry, commerce & transport

http://www.pub.gov.sg/privatesewer/index1.html

The Great River Clean-Up

A revitalised Boat Quay now with its vibrant night-life. A popular dining stretch offering al fresco dining by the River for locals and tourists.

Clarke Quay today, offering the river taxi service, plying between Clarke Quay and Boat Quay.

A River Reborn

In 1977, the government embarked on a massive task to clean up the river. The "Great River Clean-up" campaign was mooted. The works included resiting the lighterage activities to Pasir Panjang, removal of flotsam and rubbish along the river and its banks, and reconstructing and strengthening the riverwall.

With the Singapore River cleaned up, URA undertook the key task of planning for the river and working with other public agencies to breathe new life to the river - outdoor refreshment areas were introduced along the river banks, buildings conserved, tree-lined promenades designed, etc. It was envisioned that the river could be transformed into a waterway providing waterfront housing, entertainment and dining facilities to all Singaporeans. It will be a river sparkling with life and exuberance for all to enjoy.

http://www.ura.gov.sg/skyline/skyline02/skyline02-04/text/changingfaces2.html

Clean Rivers Education Programme and Clean River Commemoration

The Clean Rivers Education Programme was started by the government in 1987. The main aim of the programme was to raise awareness of the negative effects of dumping waste into our waterways, and to encourage that all our waterways be kept pollution free. In 1987, the Ministry of Environment, along with other government ministries and statutory boards, concluded a decade-long project which transformed the polluted Singapore River and Kallang River Basin into vibrant rivers. Through the Clean Rivers Commemoration, this massive effort is remembered.

Background

The Clean Rivers Education Programme has its origins in the Singapore River and Kallang River Basin clean-up project. The project to clean up both the rivers took a decade to complete, starting in October 1977 with the cleaning up of Kallang River and smaller rivers in the Kallang Basin. At the opening of the Upper Pierce Reservoir on 27 February 1977, Prime Minister Lee Kuan Yew had remarked how keeping the waterways of Singapore clean need to be a priority. There he set the target of a decade for the Ministry of Environment to clean up both the Singapore River and the Kallang River.

The rivers' pollution had grown as for decades, the river residents had lived in unsewered premises and disposed their farm wastes into the river. These included families living on bum boats, hawkers, squatters, pig farms and duck farms. At least 26,000 families and 2,800 cottage industries had to be relocated during this massive clean-up.

Various agencies besides the Ministry of Environment were brought together for the project. They included the Primary Production Department, Housing Development Board, Jurong Town Corporation, Urban Development Authority, Sewerage Department, Hawkers Department, Drainage Department, Environmental Health and Parks and Recreation Department. It cost the government nearly S$300 million for the clean-up project excluding resettlement compensation. Several engineering measures were used to prevent the entry of further pollution such as covering drains in litter-prone areas with slabs, installing vertical gratings at selected outlet drains leading to main canals and rivers and installing floatbooms across rivers and canals. A system of stiff fines was also imposed on littering offenders in order to continue keeping the rivers and its waterways clean. Today, both rivers have a living ecosystem and serves as a water playground for residents.

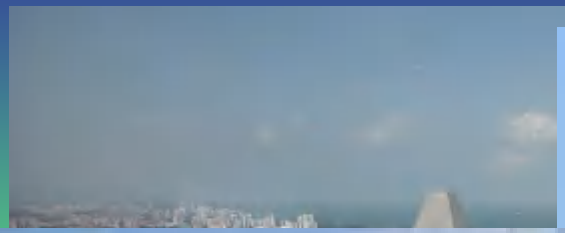
http://infopedia.nlb.gov.sg/articles/SIP_398_2004-12-23.html

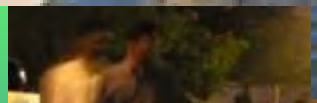
About Marina Barrage

- The Marina Barrage is a dam built across the Marina Channel. It acts as a tidal barrier that prevents high tides from causing flooding of inland low-lying areas at the same time creates a fresh water reservoir behind it.
- It provides three main benefits: Water Supply, Flood Control and a New Lifestyle Attraction.
- It is therefore a unique 3-in-1 project.

Singapore's Water Supply

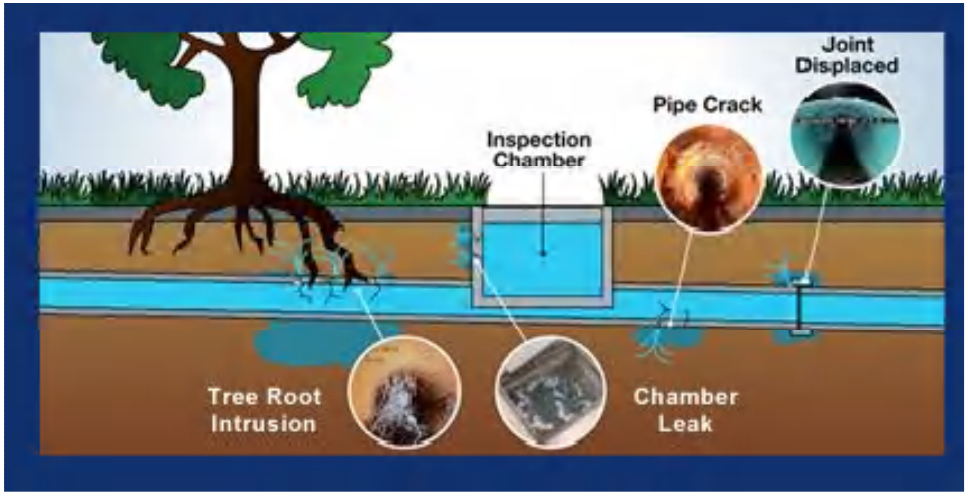
http://www.pub.gov.sg/Marina/IndexMarina.htm





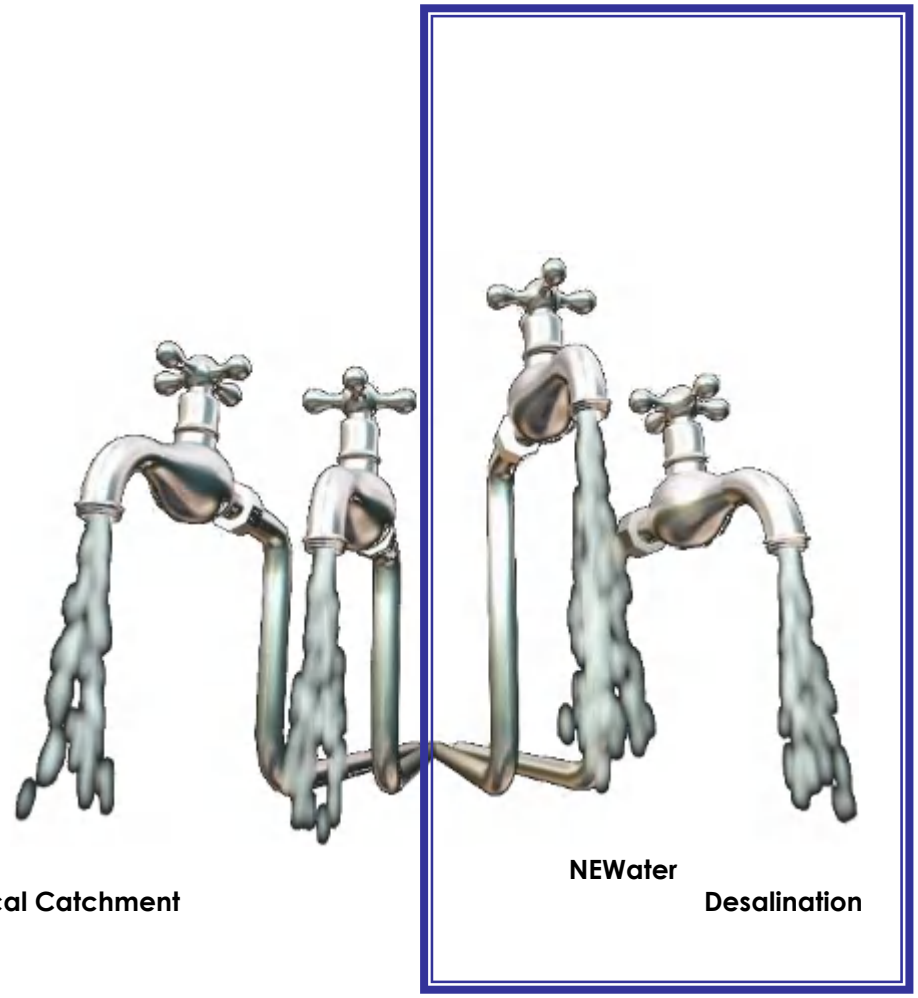
Sewer Rehabilitation Program

- ***Private Sewer Rehabilitation Program at Marina Catchment (2006 – 2012)*** was implemented to improve ***Urban Catchment*** water quality
  - Restoration of structural integrity, and
  - To ensure a leak-free used water network to minimize pollution to the reservoirs and waterways
- Rehabilitation of 300 km public sewer ***by 2009***
- Rehabilitation of 300 km sanitary drain-lines (private sewers) that connect more than 10,000 premises to public used water network ***by 2012***



http://www.pub.gov.sg/privatesewer/index1.html

Harnessing Water from Non-conventional Water Resources



Tapping into Non-conventional Water Resources

NEWater Supply

Kranji NEWater Factory (9 mgd)
Launched in Feb 2003
Supply to Woodlands
Wafer Fab Park,
Senoko & Yishun

Kranji

Seletar NEWater Factory (5 mgd)
Launched in Jun 2004
Supply to Ang Mo Kio
Industrial Park &
Serangoon

Seletar

Ulu Pandan

Ulu Pandan NEWater Factory
(Initial capacity 25 mgd)
To be commissioned by end 2006
Supply to Central & Western
parts of Singapore

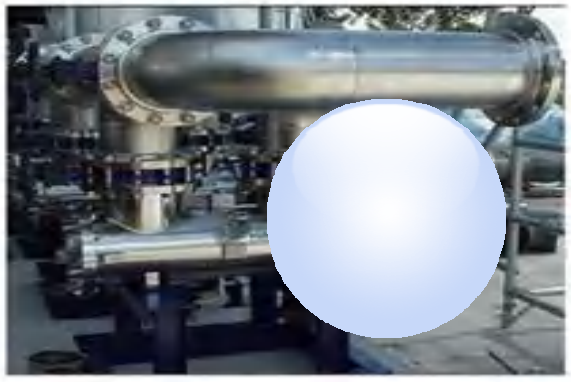
Bedok

Bedok NEWater Factory (6 mgd)
Launched in Feb 2003
Supply to Tampines/Pasir Ris
Wafer Fab Park, Bedok,
Chai Chee & Loyang

Microfiltration

Reverse Osmosis

NEWater



Ultra-Violet

Singapore's Water Supply

Water Quality Comparisons

Water Quality Parameters	Local Reservoir Water	PUB Tap water	NEWater	USEPA / WHO Standards
Turbidity [NTU]	0.5 - 11	< 0.1	< 0.1	5
Total Dissolved Solids [mg/l]	117 - 154	149.5	48.5	500
Lead [mg/l]	< 0.013	0.002	< 0.0005 to 0.002	0.01
Mercury [mg/l]	<0.00003	<0.00003	<0.00003	0.001
Hormones (Synthetic & Natural) [µg/l]	ND	ND	ND	Not Specified
PCBs [µg/l]	ND	ND	ND	0.5
Dioxin [pg/l]	ND	ND	ND	30
Total Organic Carbon [mg/l]	2.6 – 6.2	1.9 – 3.5	<0.1	Not Specified
Total Coliform [cfu/100 ml]	3 - 967	ND	ND	ND
Enterovirus	ND	ND	ND	ND

ND – Not Detected

TOXIC CONTAMINANTS

Don't fret, treated water here is fine

AZIZ HUSSIN

Water here is filtered, passed through a semi-permeable membrane, then exposed to ultraviolet light.

Harmful compound was found in treated water in US but Singapore's reclaimed water is safe as it is exposed to sunlight which kills germs

By **CHANG AI-LIEN**
SCIENCE CORRESPONDENT

CONTAMINANTS discovered in recent years in treated water are potent cancer-causing agents and may pose a problem in many areas of the United States and around the world, said researchers in the US.

However, these by-products of processes used to kill pathogens are unlikely to be found in treated water consumed here, because it is exposed to sunlight that destroys the contaminants.

The addition of chlorine and trace amounts of ammonia to treated water is an effective way to kill pathogens, explained Professor Lisa Alvarez-Cohen, an expert in the field, who was here on a four-day visit.

However, this leads to the production of contaminants.

Researchers are still trying to understand the mechanism by which the harmful compound, called N-nitrosodimethylamine (NDMA), is produced via the disinfection process.

"It's an expensive and labour-intensive process to test for NDMA," said Prof Alvarez-Cohen.

"And the contaminant is a potent human carcinogen even at very low levels."

In Singapore, reclaimed water goes through a three-stage process, unlike in many other countries where only one or two stages are involved. The process involves filtering out elements — bacteria, viruses and solids — passing the water through a semi-permeable membrane, then exposing it to ultraviolet light.

This removes particles smaller than one-thousandth the thickness of a human hair.

The result is ultra-pure water that far surpasses world standards for drinking water.

Prof Alvarez-Cohen, who visited the Newater treatment plants here, said she was impressed with Singapore's water re-use technology, which was on a bigger scale than in most other countries.

"With Newater, there's a wonderful safeguard because on top of the other precautions, it's placed in reservoirs and exposed to large quantities of sunlight — a good way to destroy trace contaminants."

Ultraviolet light, as well as exposure to UV sunlight, and beneficial bacteria and oxygen in the reservoirs, all help to eradicate the chemical, said researchers here.

The trace contaminants were discovered relatively recently, and some older treatment facilities in the US were affected.

For instance, NDMA was discovered at a treatment facility in Southern California.

The facility takes highly treated waste water from the Orange County Sanitation District and purifies it to drinking water standards before it injects it into the groundwater basin on the coast.

Two of its wells had to be closed in 2000, and the water treated with ultraviolet light to destroy the contaminants before the centre could be reopened, Prof Alvarez-Cohen said.

NUS National University of Singapore

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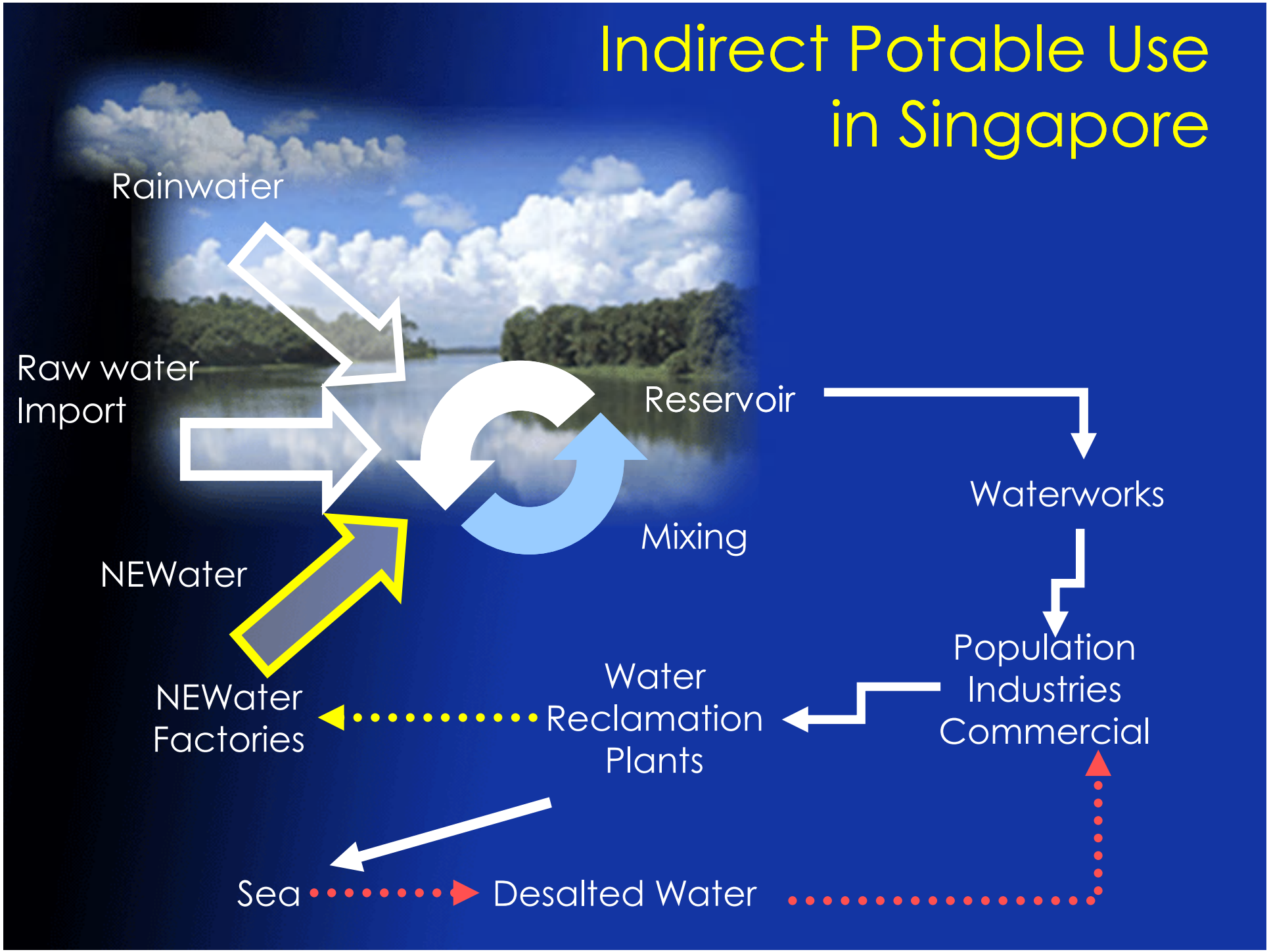

Indirect Potable Use in Singapore
Rainwater
Raw water Import
Reservoir
Waterworks
Mixing
NEWater
Population Industries Commercial
Water Reclamation Plants
NEWater Factories
Sea
Desalted Water

Indirect Potable Use for Singapore

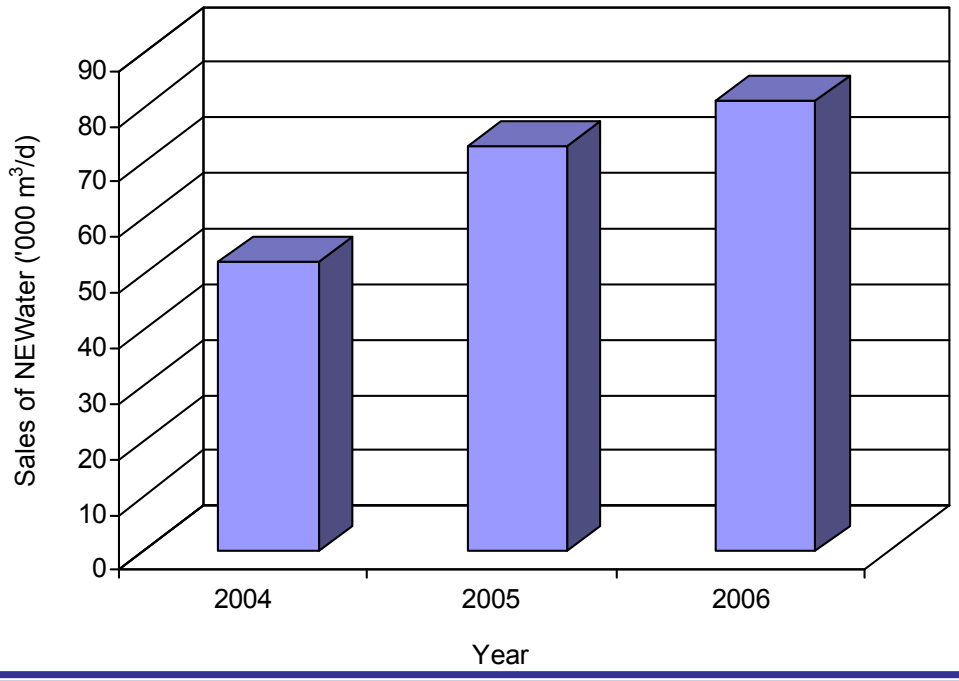
- 2 mgd was injected into reservoirs from Feb 2003
  - Less than 1% of total water consumption
- To increase progressively to 2.5% by 2011

NEWater for Non-Potable Use

- Wafer Fab Industry
  - Supply to wafer fab industry at Woodlands & Tampines / Pasir Ris
  - 4,000 to 5,000 m^3/day per plant
- Air-con cooling in commercial buildings
  - 30% of building water consumption
- Cooling and Boiler Feed
- Other Non-Potable Uses such as landscaping & general washing

NEWater for Non-potable reuse

Sales of NEWater



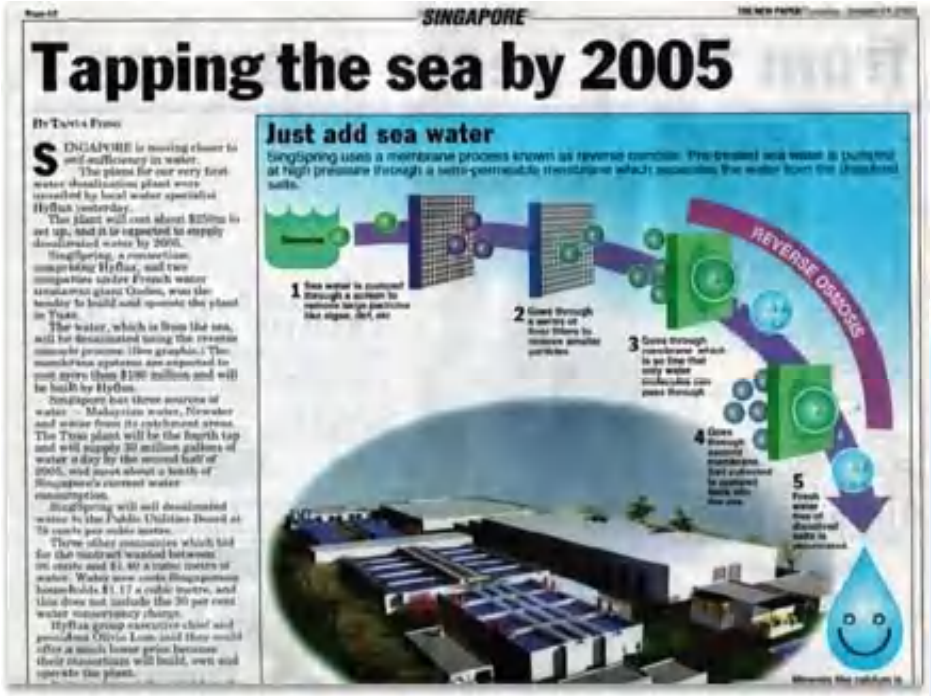
Price of NEWater (includes production, transmission & distribution):

S$1.30/m^3 — 2003

S$1.15/m^3 — 2005

S$1.00/m^3 — 2007

Fourth “national tap” - Desalinated water



SINGAPORE

Tapping the sea by 2005

By Tania Fong

SINGAPORE is moving closer to self-sufficiency in water.

The plans for our very first water desalination plant were unveiled by local water specialist Hyflux yesterday.

The plant will cost about $250m to set up, and it is expected to supply desalinated water by 2005.

SingSpring, a consortium comprising Hyflux, and two companies under French water multinational giant Ondeo, won the tender to build and operate the plant in Tuas.

The water, which is from the sea, will be desalinated using the reverse osmosis process (See graphic.) The membrane systems are expected to cost more than $100 million and will be built by Hyflux.

Singapore has three sources of water — Malaysian water, Newater and water from its catchment areas. The Tuas plant will be the fourth tap and will supply 30 million gallons of water a day by the second half of 2005, and meet about a tenth of Singapore's current water consumption.

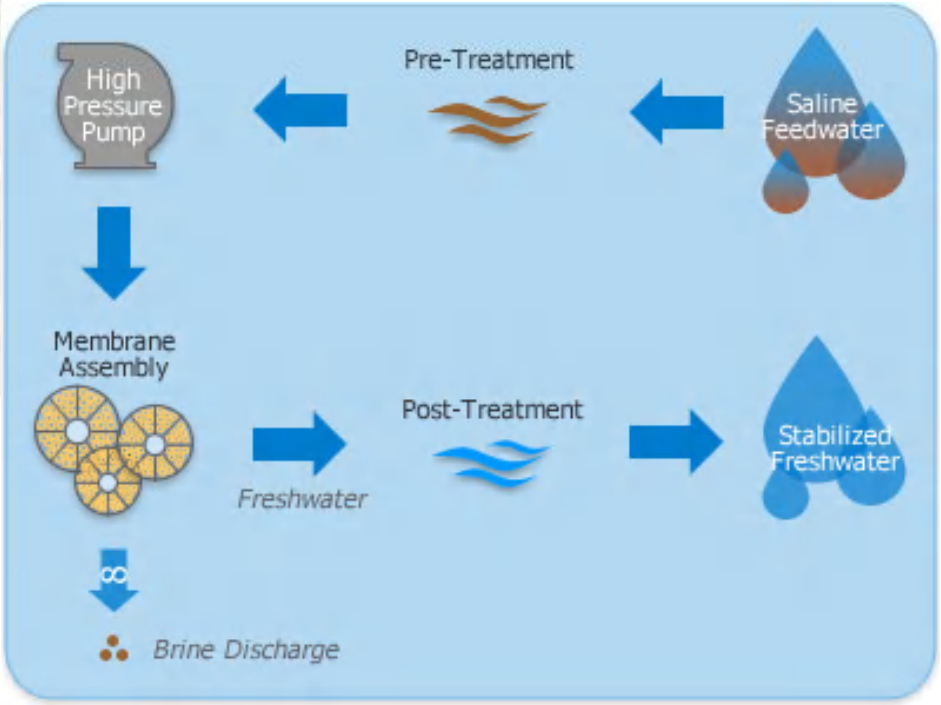
SingSpring will sell desalinated water to the Public Utilities Board at 78 cents per cubic metre.

Three other companies which bid for the contract wanted between 90 cents and $1.40 a cubic metre of water. Water now costs Singaporean households $1.17 a cubic metre, and this does not include the 30 per cent water conservancy charge.

Hyflux group executive chief and president Olivia Lum said they could offer a much lower price because their consortium will build, own and operate the plant.

Just add sea water

SingSpring uses a membrane process known as reverse osmosis. Pre-treated sea water is pumped at high pressure through a semi-permeable membrane which separates the water from the dissolved salts.

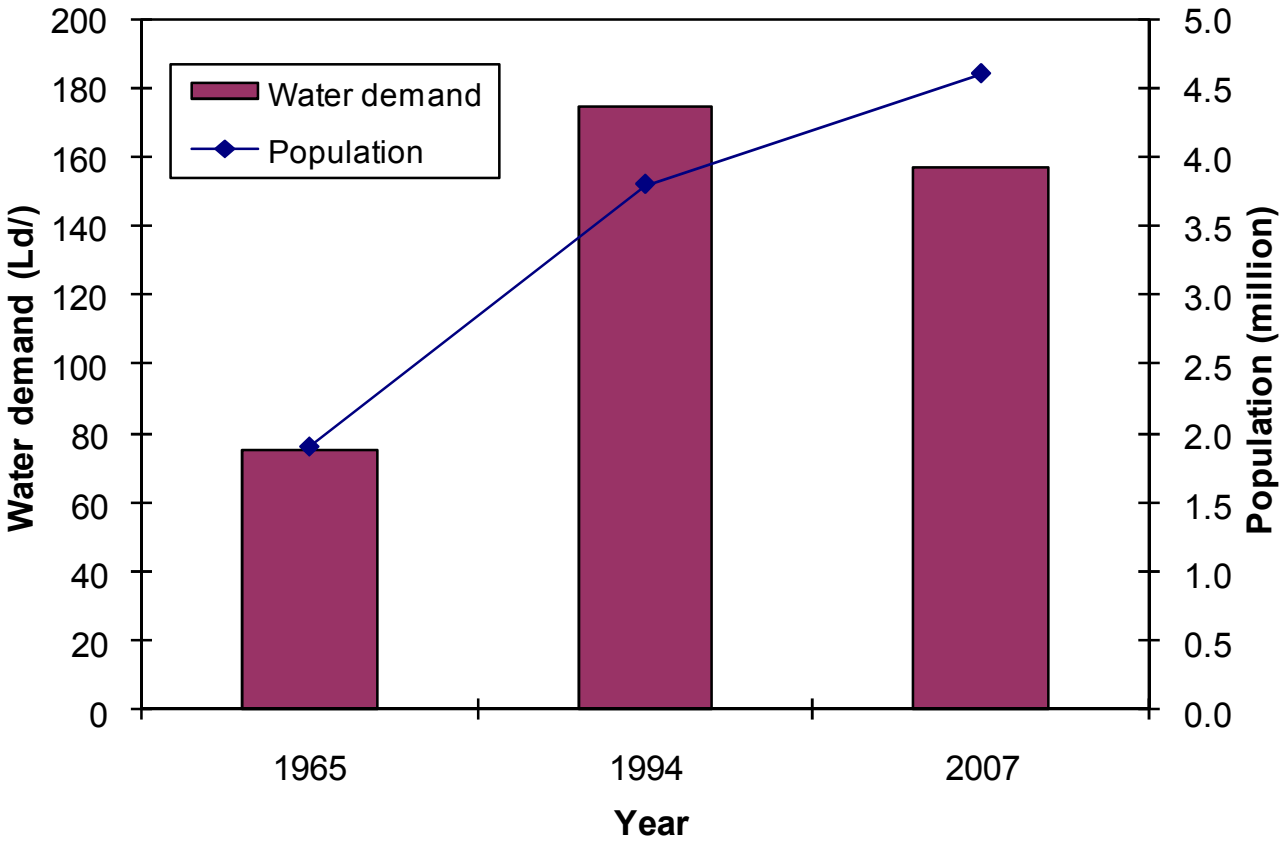


Seawater desalination plant at Tuas

- Plant cost: S$200 M (US120M)
- Capacity: 136,000 m^3/d
- Supply: 10% of Singapore's water demand
- Technology: RO membrane
- Cost: S$0.78/$m^3$

http://www.hyflux.com/singapore.htm

Water Demand Management



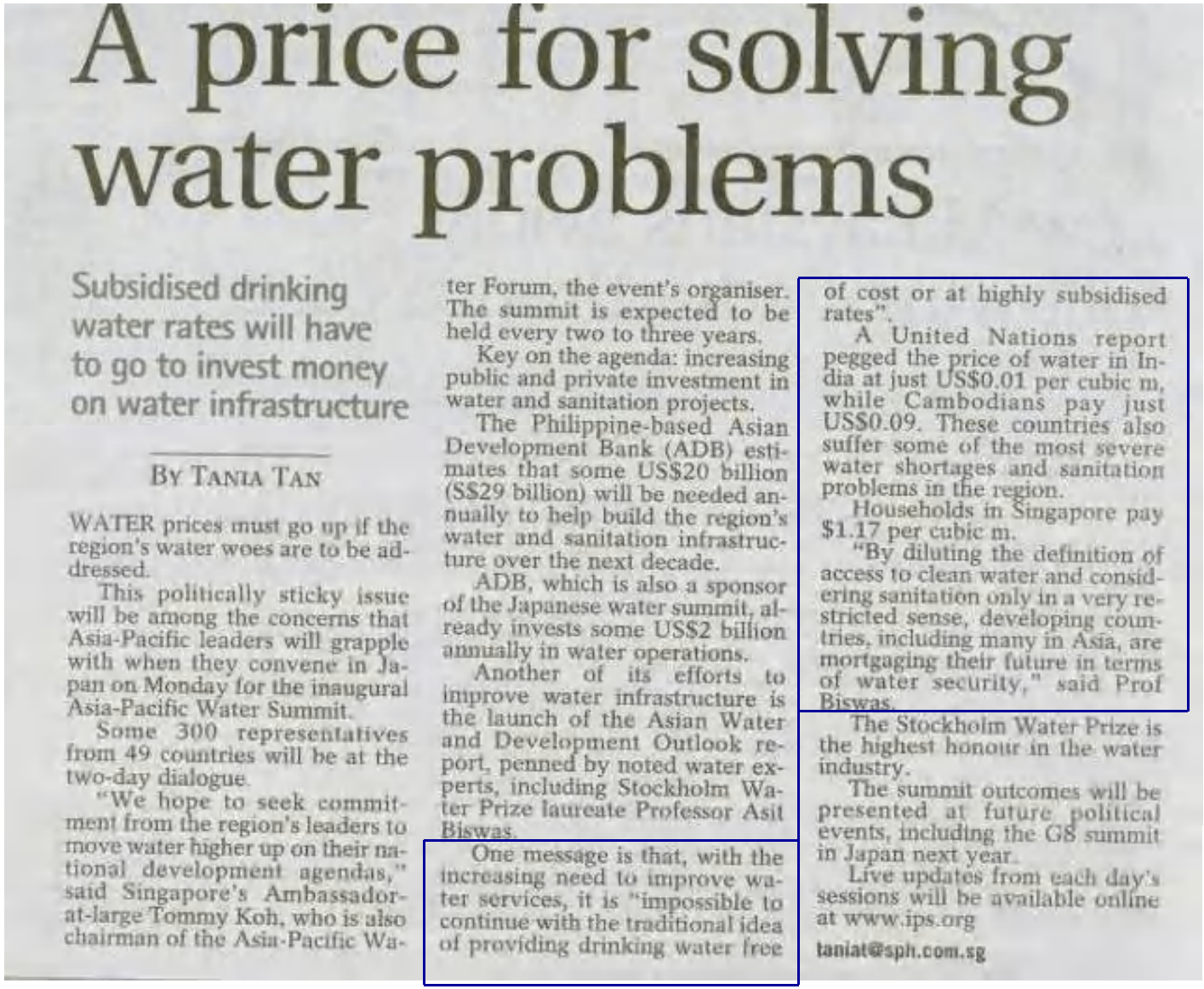
Target to achieve

155 L/d in 2012

Solution through Water Conservation Plan (1981)

- *Water pricing*
- *Mandatory requirements*
- *Public Education*

Managing Demand with Price



A price for solving water problems

Subsidised drinking water rates will have to go to invest money on water infrastructure

BY TANIA TAN

WATER prices must go up if the region's water woes are to be addressed.

This politically sticky issue will be among the concerns that Asia-Pacific leaders will grapple with when they convene in Japan on Monday for the inaugural Asia-Pacific Water Summit.

Some 300 representatives from 49 countries will be at the two-day dialogue.

"We hope to seek commitment from the region's leaders to move water higher up on their national development agendas," said Singapore's Ambassador-at-large Tommy Koh, who is also chairman of the Asia-Pacific Water Forum, the event's organiser. The summit is expected to be held every two to three years.

Key on the agenda: increasing public and private investment in water and sanitation projects.

The Philippine-based Asian Development Bank (ADB) estimates that some US$20 billion (S$29 billion) will be needed annually to help build the region's water and sanitation infrastructure over the next decade.

ADB, which is also a sponsor of the Japanese water summit, already invests some US$2 billion annually in water operations.

Another of its efforts to improve water infrastructure is the launch of the Asian Water and Development Outlook report, penned by noted water experts, including Stockholm Water Prize laureate Professor Asit Biswas.

One message is that, with the increasing need to improve water services, it is "impossible to continue with the traditional idea of providing drinking water free of cost or at highly subsidised rates".

A United Nations report pegged the price of water in India at just US$0.01 per cubic m, while Cambodians pay just US$0.09. These countries also suffer some of the most severe water shortages and sanitation problems in the region.

Households in Singapore pay $1.17 per cubic m.

"By diluting the definition of access to clean water and considering sanitation only in a very restricted sense, developing countries, including many in Asia, are mortgaging their future in terms of water security," said Prof Biswas.

The Stockholm Water Prize is the highest honour in the water industry.

The summit outcomes will be presented at future political events, including the G8 summit in Japan next year.

Live updates from each day's sessions will be available online at www.ips.org

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The Straits Times
Dec 1, 2007

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Water Tariff in Singapore

Table 2. Water Tariffs, 1997–2006

Tariff category	Consumption block (m^3 per month)	Before 1 July 1997 Tariff (¢/m^3)	WCT (%)	WBF (¢/m^3)	Effective 1 July 1997 Tariff (¢/m^3)	WCT (%)	WBF (¢/m^3)
Domestic	1 to 20	56	0	10	73	10	15
	20 to 40	80	15	10	90	20	15
	Above 40	117	15	10	121	25	15
Non-domestic	All units	117	20	22	117	25	32
Shipping	All units	207	20	–	199	25	–

Tariff category	Consumption block (m^3 per month)	Effective 1 July 1998 Tariff (¢/m^3)	WCT (%)	WBF (¢/m^3)	Effective 1 July 1999 Tariff (¢/m^3)	WCT (%)	WBF (¢/m^3)	Effective 1 July 2000 Tariff (¢/m^3)	WCT(%)	WBF (¢/m^3)
Domestic	1 to 20	87	20	20	103	25	25	117	30	30
	20 to 40	98	25	20	106	30	25	117	30	30
	Above 40	124	35	20	133	40	25	140	45	30
Non-domestic	All units	117	25	42	117	30	51	117	30	60
Shipping	All units	199	25	–	192	30	–	192	30	–

Notes: Water Conservation Tax (WCT) levied by the government to reinforce the water conservation message. Water Borne Fee (WBF) and Sanitary Appliance Fee (SAF); Statutory charges prescribed under the Statutory Appliances and Water Charges Regulations to offset the cost of treating used water and for the maintenance and extension of the public sewerage system. SAF is S$3 per sanitary fitting per month. WBF and SAF charges are inclusive of goods and services tax. *Source:* PUB (2005) personal communication.

Source: Tortajada, 2006

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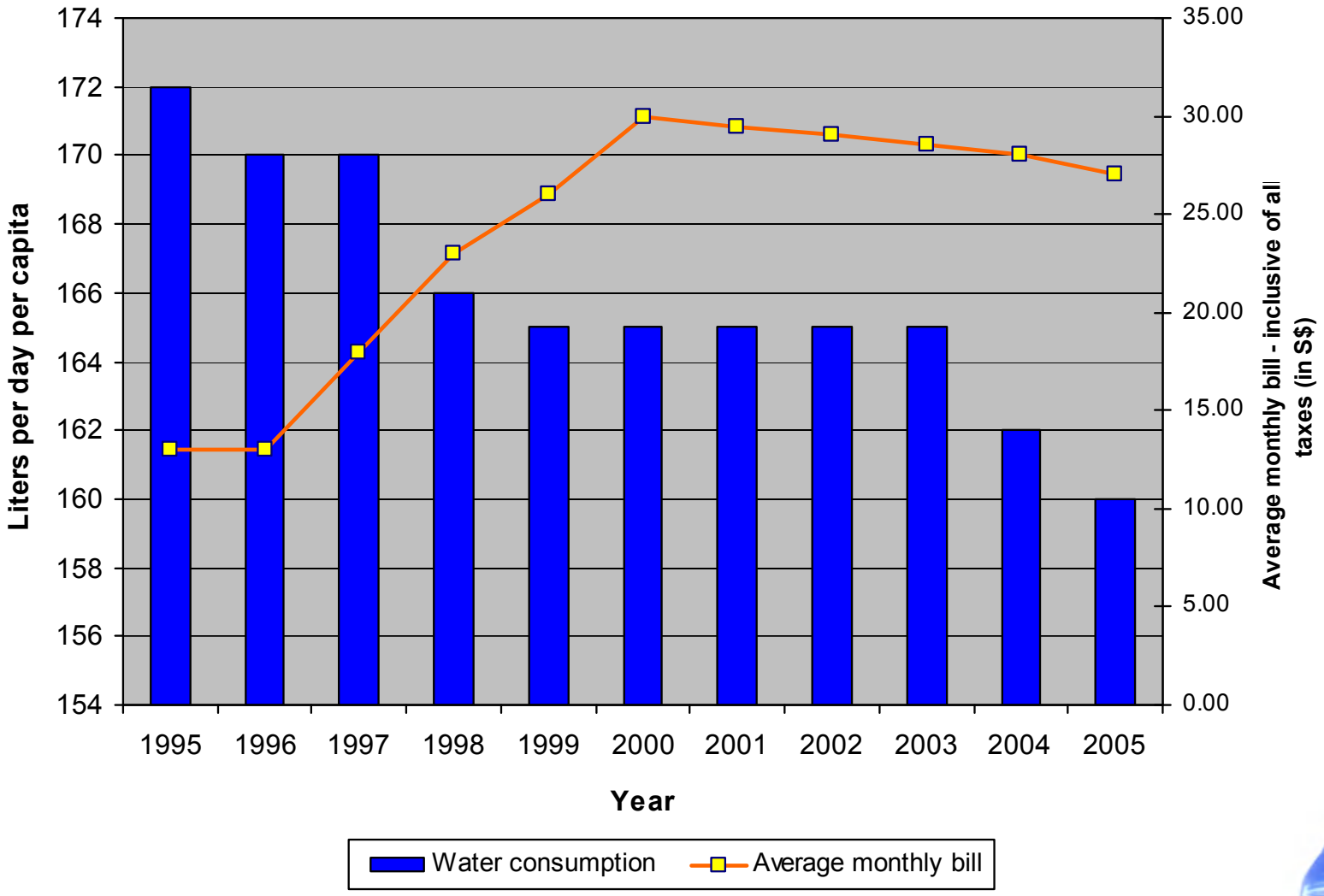
Increase Water Tariff – Reduced Water Consumption



Source: Tortajada, 2006

Programs for water conservation

- *Water Audit for Household*
- *Water Efficient Homes*
- *Water Efficient Buildings*
- *Water Efficient Construction Sites*

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Water Efficient Home

- 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.

Installation of Thimble

Installation of cistern water saving bag

http://www.pub.gov.sg/conserve/Home/Pages/WaterEfficientHomesProgram.aspx

Water Demand Management - Public Education

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Public Education in Managing Water Demand

Conserve Water

Water is a scarce and precious resource. To reinforce the message that water conservation is vital to Singapore, PUB has put in place the water conservation programmes. Click here to find out.

http://he.ecitizen.gov.sg/env_help_individual_conserve.htm

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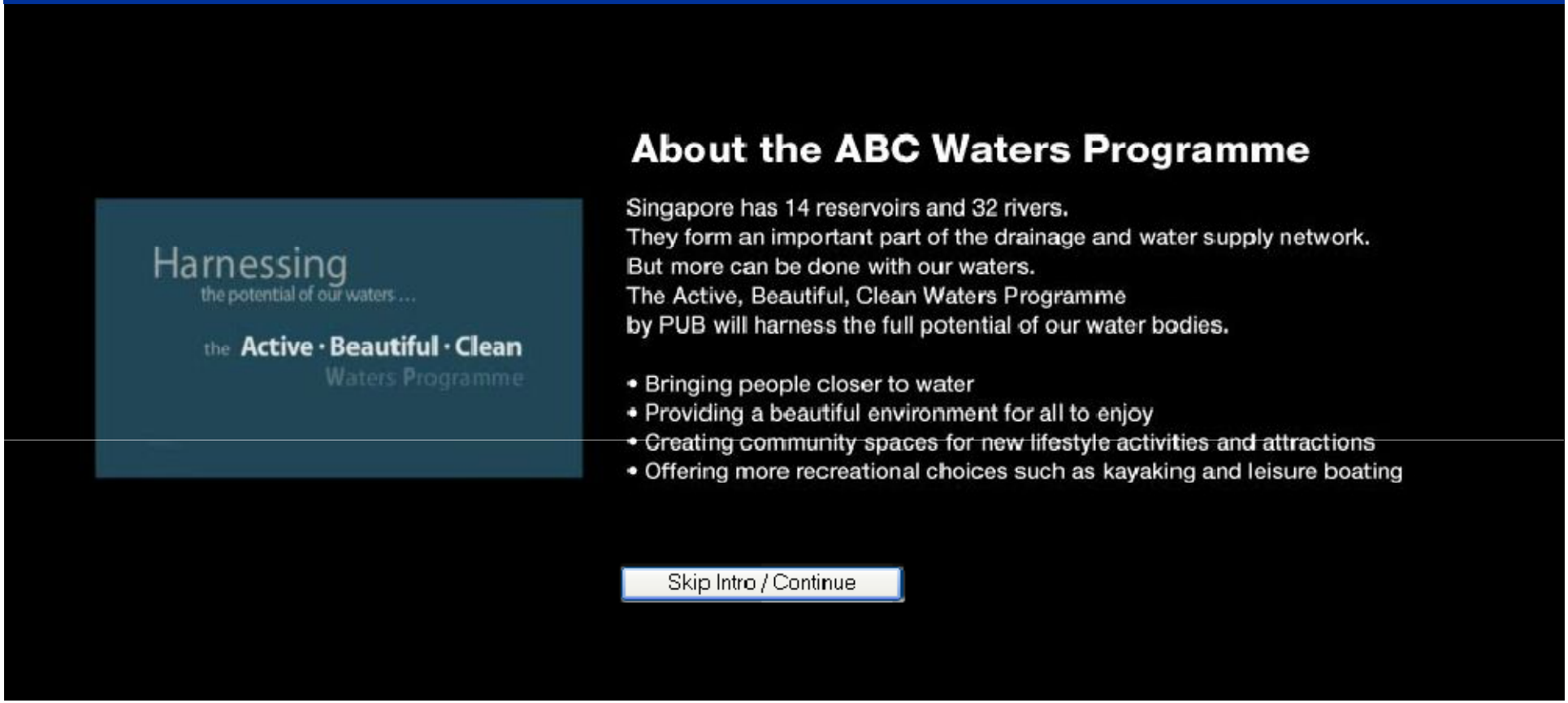
Partnership in Water Management



http://www.pub-abc.com.sg/

The ABCs of Water

With over 30 rivers and canals, connecting with water should be as elementary as ABC, reports Tan Kheng Im.

http://www.pub.gov.sg/annualreport2005/Feature_abcs_of_water.html

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Proposals for the ABC Waters Programme

Re-circulation of Waters for Flowing Waters

Upstream of our rivers and canals has little flow during dry weather. Water quality can also deteriorate due to stagnation. Re-circulating water from downstream to the upstream of some major rivers can help create flowing water and improve water quality. This will help to enhance the æsthetics of the waterscapes and increase recreational values of the waterways.

Rain Gardens - Rain Gardens are landscaping features that may be designed for stormwater quality treatment without foregoing æsthetic of ornamental values.

http://www.pub-abc.com.sg/clean.html

Asia's water report card

To help governments pinpoint leaks in their water policies, the Asian Development Bank proposed an index of drinking water adequacy (IDWA). Taking into account five key areas of drinking water management, the IDWA provides an estimate of each country's success. The index uses data from 2004 – when the most reliable information was available – but is nonetheless a good reflection of the current water situation. Tania Tan looks at how the countries measure up.

INDIA: Up to 500,000 children under five years of age die annually from diarrhoea, as a result of drinking unclean water. Less than half of the country's waste water is treated before being discharged into freshwater bodies, creating a vicious circle of pollution and disease.

SINGAPORE: The city state has done well in providing good-quality drinking water for its population, despite insufficient natural water resources. Newater has been a key factor in helping the country alleviate its water scarcity.

The Straits Times, 1 Dec 07

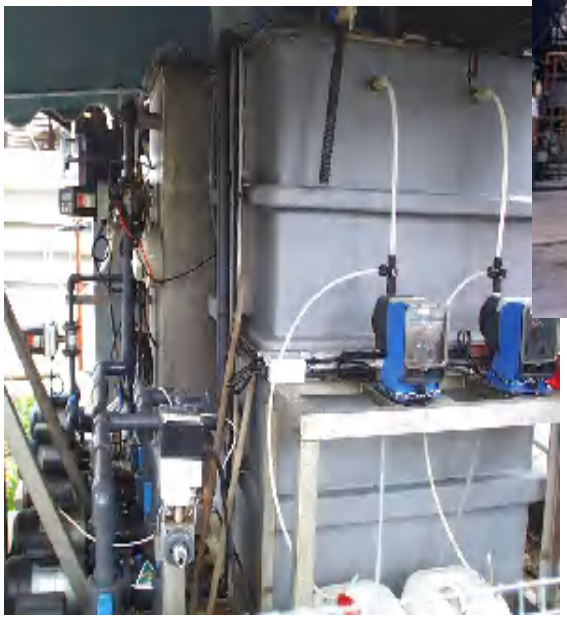
Investments in *R & D*

- Compact treatment systems
  - *Sequencing Batch Reactors (SBRs)*
  - *Membrane Bioreactors (MBRs)*

- Energy efficient and recovery systems
  - *Upflow anaerobic sludge blankets (UASBs)*
  - *Microbial Fuel Cells (MFCs)*

Acidogenic AnSBR

Full scale SBR for industrial wastewater treatment



Pilot scale anSBR

- **Sequencing Batch Reactor (SBR)**
  - *Reaction and settling occurred within the reaction compartment,*
  - *Ability to change the operating process to accommodate changes in the wastewater characteristics without the need to alter the physical design,*
  - *Can be operated either as an aerobic or anaerobic SBR,*
  - *Ability to retain high MLSS concentration of up to 4000 mg/L and with granulation up to 10 g/L,*
  - *Nutrient removal and energy recovery could be achieved*

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Membrane Bioreactor (MBR)

Anaerobic MBR

Aerobic MBR

- *Biological reaction and sludge separation within the same compartment*
- *Able to achieve high MLSS concentration*
- *Produces permeate of high quality, free from suspended solids, ability to remove bigger water pathogens such as Cryptosporidium and Giardia.*

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- Upflow Anaerobic Sludge Blanket (UASB)
  - *Compact with small footprint,*
  - *Low energy consumption as it does not require aeration for degradation,*
  - *Stable towards shock loadings and ability to treat toxicants in the wastewater,*
  - *Biogas production for energy recovery*

Alternative Energy - Microbial Fuel Cell

- To generate electricity & treat wastewater simultaneously using electrodes and electrophilic bacteria.

- Emerging technology that can potentially change the way domestic and industrial wastewater treatment is being carried out.

- Challenges: Finding a sustainable and affordable type of MFC achieving high wastewater treatment efficiency and high power generation; Characterization of the microbial community in MFC.

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Thank you