



Introduction

About Singapore: City of Gardens and Water

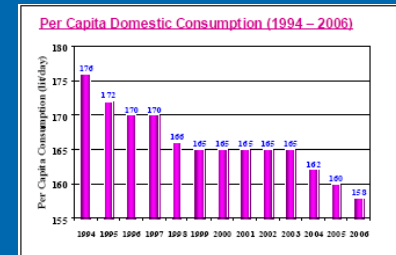
Land Area	697 km ²
Population	4.5 mil
Average Annual Rainfall	2,400 mm
Average Water Demand	1.3 mil m ³ /day

- Singapore has a tropical rainforest climate with no distinctive seasons
- Temperatures range from 22 °C to 34 °C (72°–93°F), June and July are the hottest months, while November and December make up the wetter monsoon season
- Forest and nature reserves occupies about 23 percent of Singapore's land area
- Most of the people in Singapore live in high raised apartments (know as HDBs)

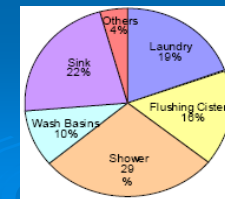
- ## Water Sources/Water Management
1. Local catchment
 2. Imported water
 3. NEWater (water re-use)
 4. Desalinated water
- PUB of Singapore calls these four sources as 'Four National Taps'
 - Public Utilities Board (PUB) manages the entire water cycle of Singapore
 - There are no natural freshwater rivers and lakes in Singapore

- The primary domestic source of water supply is rainfall, collected in reservoirs or catchment areas
- The remainder is imported from neighboring countries or obtained from recycled water facilities and desalination plants
- Singapore uses recycled water as portable water (Payson city in AZ, USA uses recycled water as portable water, Orange County Water District, Southern California, high quality water reclaimed from treated used water has been injected into ground water since 1976)
- 2007 Stockholm Industry Water Award Recipient is PUB Singapore

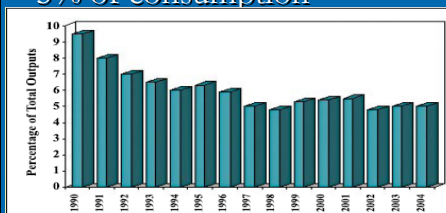
- Water consumption trends (Source: PUB)



- Domestic sector break down (Source: PUB)



- Over the years Singapore has lower unaccounted for water (UFW) (leaks, inaccurate measurements etc) to 5% of consumption



Unaccounted for Water, Singapore, 1990-2004
(Ref: Tortajada, Asian Water APRIL 2006)

ITEM	1995	2000	2004
Average monthly consumption, m ³	21.7	20.5	19.3
Average monthly bill, inclusive of all taxes	S\$14.50	S\$31.00	S\$29.40

Average monthly consumption and bills per household (Ref: Tortajada, Asian Water APRIL 2006)

3P Approach



"Conserve Water"

"Value Our Water"

"Enjoy Our Waters"

"Conserve, Value, Enjoy"

PUB advertisement

Local catchment



- Protected catchment areas are well demarcated and gazetted, and no pollution-causing activities are allowed in such protected areas

- Protected catchment classification covers less than 5% of the area
- Half of the total area is protected or partly protected (effluent will have acceptable water quality), This ratio is expected to increase to two-thirds by 2009



Seletar Reservoir



Jurong Bird Park, Wetland



Sungai Serangoon

Water Imports

- The Water from Johor (Malaysia) is imported through pipelines across the 2-km causeway that separates the two countries
- Under the 1961 and 1962, the Johor River Water Agreement which will expire in 2011 and 2061, Singapore can draw from the Johor 0.4 million m³ and 1.15 million m³ a day respectively
- Water deliveries to Singapore at three Malaysian cents (US 0.85 cents) for every 1000 gallons of raw water
- Exploring use of tankers to transport fresh water from water rich countries such as Laos and Papua New Guinea. Singapore can be a trading hub for water like oil
- Singapore relies on its neighbor for about half of the 300 million gallons of water it consumes every day

NEWater

- Uses three step process of microfiltration, reverse osmosis and UV disinfection in the order to treat used water
- Microfiltration:
 - Removes particles up to 0.2 μm,
 - Reducing turbidity from 3 – 6 NTU to < 0.1 NTU
 - Also can remove bacteria and protozoa

NEWater

- Reverse Osmosis (RO):
 - Effective in reducing 95% Total Dissolved Solids (TDS)
 - Can remove inorganics such as heavy metals, nitrate, chloride, etc, and organics such as disinfection by products, pesticides, etc.
- UV disinfection:
 - Used to remove left out bacteria and viruses from RO process



([Reference and video](#))

NEWater

- The quality of NEWater exceed water quality standards of the Environmental Protection Agency of the United States and the World Health Organization, and also better than the water supplied by PUB
- The country is fully seweraged to collect all wastewater, and the separate drainage and sewerage systems have facilitated wastewater reuse on an extensive scale
- It is expected that, by 2011, Singapore will produce 65 mgd of NEWater annually, (for 2.5% of portable water consumption and it is about 15% of total water consumption)
- Singapore plans to increase the amount of reclaimed water in their reservoirs from 1% to 2.5% by 2011
- There are at present three plants producing NEWater (at Seletar, Bedok and Kranji)

NEWater quality comparison (Ref: http://www.pub.gov.sg/NEWater_files/newater_quality/index.html)

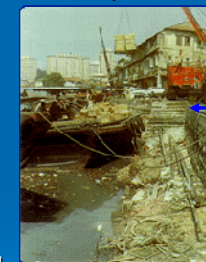
Water Quality Parameters	NEWater	USEPA /WHO Standards
Turbidity (NTU)	<5	5 - May
Colour (Hazen units)	<5	15 / 15
Conductivity (µS/cm)	<250	Not Specified(- / -)
pH Value	7.0 - 8.5	6.5-8.5 / -
Total Dissolved Solids (mg/L)	<150	500 / 1000
Total Organic Carbon (mg/L)	<0.5	- / -
Total Hardness (CaCO ₃) (mg/L)	<50	Not available
Ammoniacal nitrogen (as N)	<1.0	- / 1.5
Chloride (Cl)	<20	250 / 250
Fluoride (F)	<0.5	4 / 1.5
Nitrate (NO ₃)	<15	- / -
Silica (SiO ₂)	<3	- / -
Sulphate (SO ₄)	<5	250 / 250
Residual Chlorine (Cl, Total)	<2	- / 5
Total Trihalomethanes (as mg/l)	<0.08	0.08 / -
Total Coliform Bacteria (Counts/100 ml)	Not detectable	Not detectable
Enterovirus	Not detectable	Not detectable
Heterotrophic Plate Count (CFU/ml, 35°C, 48 h)	<300	

Desalinated water

- First desalination plant in Singapore was opened in September 2005
- Sea water is forced through plastic membranes with microscopic pores to extract dissolved salts
- Silt is removed by dousing the seawater with chemicals that coagulate the particles
- Singapore is desalinating water for 49 cents per cubic meter (Israel spends about 53 cents/m³)
- This plant supplies 10% of water needs of the Singapore
- One of the largest RO desalination plant and can supply 20mgd for 20 years

Drainage

- Singapore has a sophisticated and well-planned drainage system
- Singapore is divided into 3 waterways management catchments
- The extent of flood-prone areas in Singapore has been reduced from 3178 hectares in the 1970s to about 124
- Since 1982, the Public Utilities Board has completed \$1.5 billion worth of drainage projects



Singapore River past and present

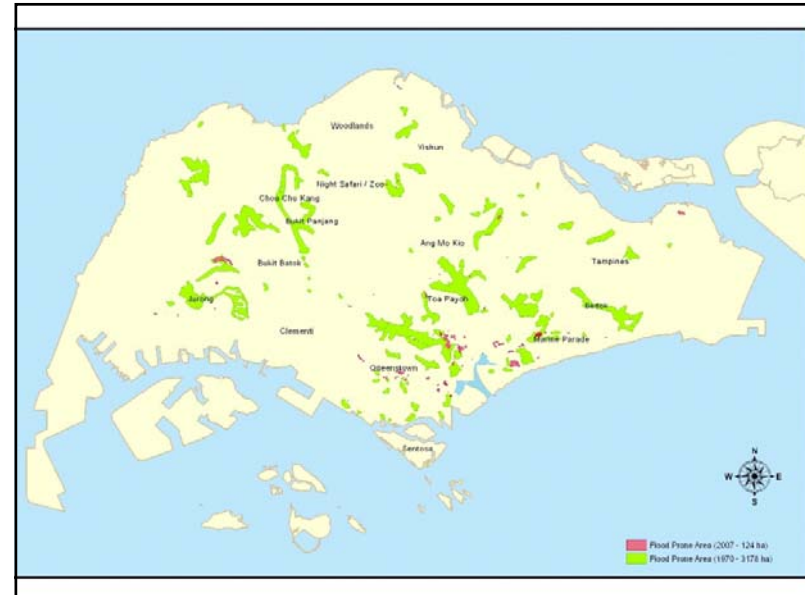


Drainage

- On 19th December 2006, the third highest rainfall (366 mm in 24hrs) in past 75years caused huge flooding across the lower areas of Singapore
- The highest rainfall was in 1978 (512 mm over 24hrs)



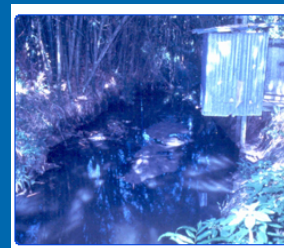
Flooding on 19th Dec'2006, Source: Channel NewsAsia



Used water/Wastewater

- Managing wastewater was started in 1890 when municipals engineer Mr. James MacRitchie proposed the collection of nightsoil and dumping in the sea
- In 1898 they started a plant to boil of the liquid portion of the nightsoil and solids part reduced to a powder called poudrette, but this plant was expensive and smelled bad
- From 1915 they divided the Singapore into three areas with each served by a trunk sewer which drained into a pumping station. The used water sent to trickling filter treatment and humus tank then discharged into the Singapore River

Used water/Wastewater



Overhanging Latrine



The last nightsoil bucket being phased out in 1987

- In 1930s the trickling filter treated nightsoil was pumped to a activated sludge process plant and digested with sludge which was then dried

Used water/Wastewater

- Post World War - II population has increased and demanded for new waste treatment facilities
- In 1960s constructed new treatment plant with trickling filter and activated sludge process together
- Today, Singapore's world class sewage system serving 100% of its population with six modern treatment plants



Ulu Pandan Sewage Treatment Works

Conclusions

- Water supply and wastewater management practices in recent years in Singapore have been excellent
- Singapore has successfully managed to find the right balance water supply and water demand management
- Ensuring efficient use of its limited water resources through
 - Adopting the latest technological development
 - Enhancing storage capacities by proper catchment management,
 - Practicing water conservation measures
- Singapore has reached a level of holistic water management which can be a good role model for other urban centers

- Most of the material used in this presentation is based on web search
- Thank you