

ASEAN IWRM PERFORMANCE REPORTS & MONITORING INDICATORS

Singapore 2010 Report (Water Supply Management)

Outcome Indicators

IWRM Issue 1 - Water Supply Management (34 indicators)			
Indicator Types	Indicators	Progress	Description
Outcome Indicators	1. Percentage of population having access to piped drinking water	100 %	See Note 1
	2. Percentage of water delivered to customer meeting WHO guidelines for drinking water quality	100 %	See Note 1
	3. Average hour of water supplied/day	24 hr/day	See Note 1
	4. Per capita domestic water consumption	154 l/c/day	See Note 2
	5. Percentage of water supply metered	100 %	
	6. Percentage of UFW/NRW	5.2 %	See Note 3

Outcome Indicators Notes

1. Singapore is a small island country with a total land area of about 700 km² and a population of some 5 million in 2010. This high population density has led to competition for land that is needed to provide infrastructure for housing, transport, industry as well as water supply. Receiving some 2400mm of rain each year, Singapore does not lack rainfall for water supply. What it lacks is the limited land resources (i.e. catchment) for storage of water. Bound by this unique circumstance, innovative solutions are needed to ensure an adequate water supply to the population for both domestic use and economic growth.

As part of the strategy to diversify our water resources, the Public Utilities Board (PUB) of Singapore has put in place what we call our 4 National Taps, comprising:

- Local Catchment Water;
- Imported Water from our Neighbour (Johor in Malaysia);
- NEWater (high-grade reclaimed water) and
- Desalinated Water.

With the 4 Taps, PUB is able to close the water loop as illustrated in Figure 1 below.

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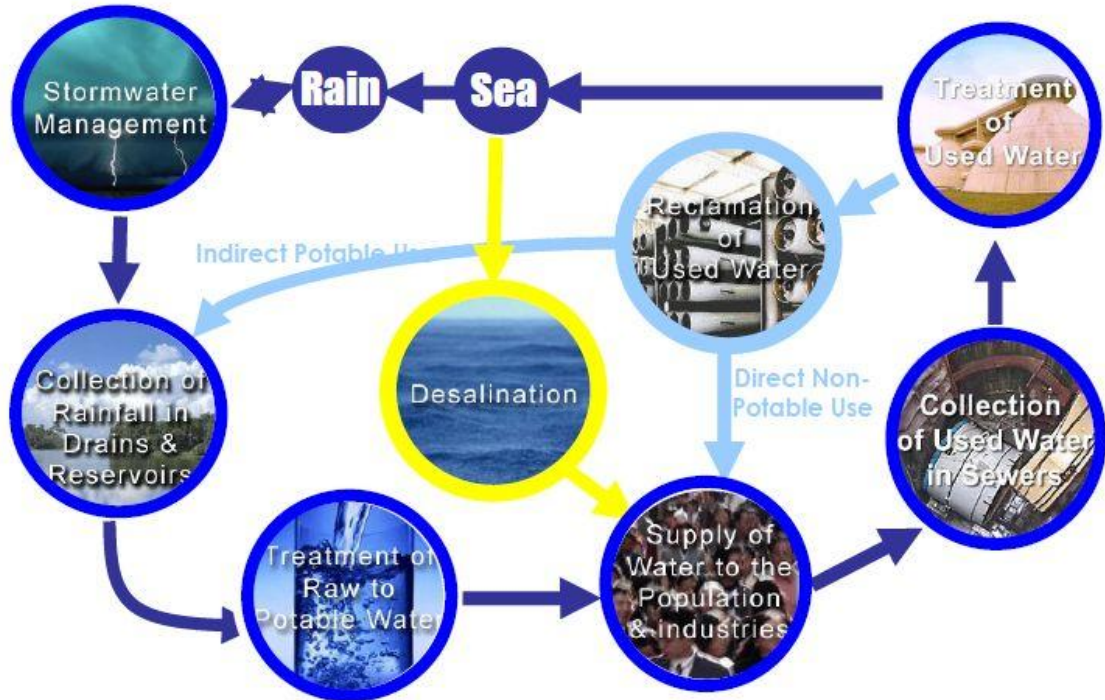


Figure 1 - Closing the Water Loop

The supply of water to the population and industries is done through an extensive 5400km of water supply pipelines 24 hours per day. The quality of our drinking water is regulated by the Environmental Public Health (EPH) (Quality of Piped Drinking Water) Regulations 2008. The drinking water standards set out under the EPH Regulations were based on the WHO Guidelines for Drinking-water Quality. PUB will make continuous effort to maintain drinking water quality at the highest possible level.

2. Besides expanding and diversifying our water resources, the other key pillar of managing water resources is demand management and engaging the public to conserve value and enjoy our water. To manage water demand effectively, a 2-pronged approach was adopted - by way of implementation of water conservation measures to keep potable water consumption in check and the other through the efficient management of the transmission and distribution system from water source to the customer tap to minimize the unaccounted-for water (UFW).

PUB's water conservation strategy in curbing water demand growth takes a multi-pronged approach. This comprehensive approach targeting both domestic and non-domestic customers encompasses pricing, mandatory water conservation requirements and promoting and encouraging ownership and voluntarism through 3P (People, Private, Public) partnership in water conservation.

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The above deliberate efforts in water conservation and UFW control has enabled Singapore to reduce its per capita domestic water consumption from 176 litres/day in 1994 to 154 litres/day in 2010 and 151 litres/day in 2013. This per capita domestic water consumption is targeted to be reduced even further in the years ahead (please refer to Figure 2).

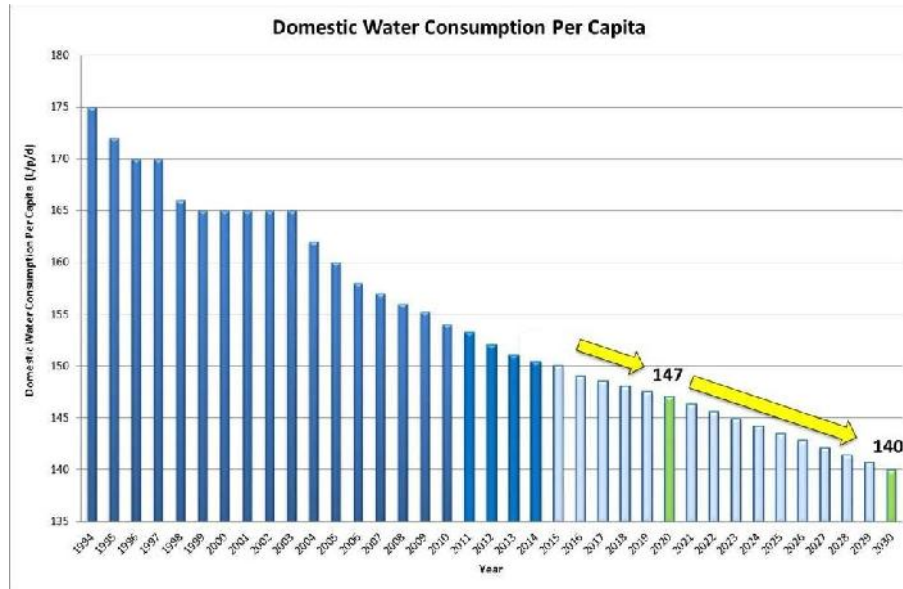


Figure 2: Domestic Water Consumption Per Capita (1994 to 2013)

3. Since the early 1980s, PUB has been conscious of the need to manage the water supply network efficiently and to account for the amount of water distributed through the network. This concern is primarily motivated by PUB's goal to provide a high level of service to customers with reliable supply of water at affordable cost. With the strong support of the top management and the active participation of everyone in PUB, an Integrated Water Network Management System has been adopted to ensure that leakage in new networks is kept to a minimum through proper planning, design and the use of good quality materials that are installed with good workmanship. Losses in existing network are reduced through network management and leakage controls as well as accounting for water distributed with full and accurate metering.

PUB adopts a holistic approach to Integrated Water Network Management. This comprises both the hardware and the software necessary to ensure the integrity of the water supply network. Hardware refers to the technical and legislative aspects of network management; software refers to our approach of partnering the public to ensure that any deficiencies in the network can be tackled quickly. The key components of the Integrated Water Network Management System are broadly categorized as:

- Good quality network and efficient management
- Active leakage controls

Source: ASEAN Working Group for Water Resources Management (AWGWRM) – July 2015
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- Accurate metering practices
- Strict legislation on illegal draw-offs
- Customer relationship management

The above efforts in UFW control has enabled Singapore to reduce its UFW from 10.6% in 1989 to maintain at about 5% from 2010 onwards (please see Figure 3).

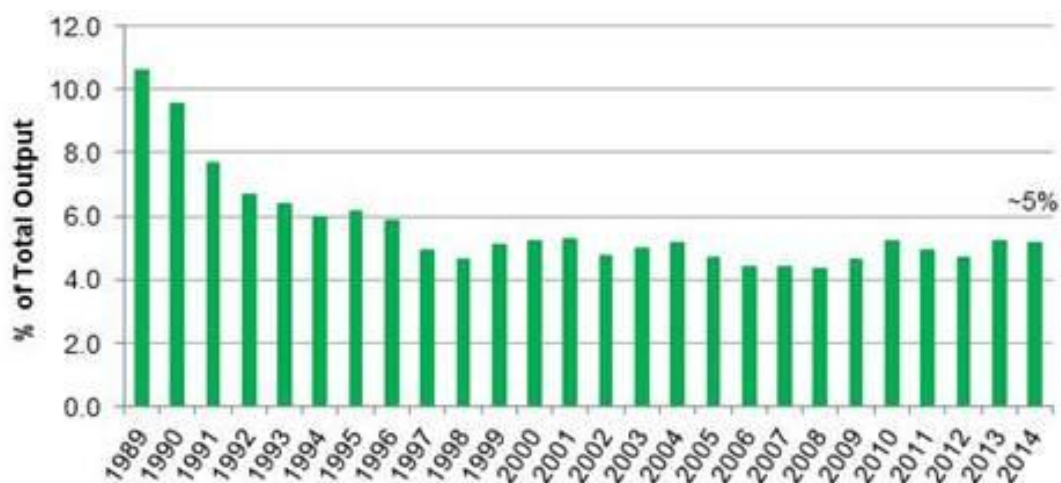


Figure 3: Singapore's Unaccounted-For-Water (1989 – 2014)

Enabling Environment Indicators

EE Indicators	1. Any "Policy" on water supply management	8	
	2. Any "Legislation/Regulations" on water supply distribution management	8	
	3. Any "Legislation/Regulations" on water supply quality management	8	See Note 1
	4. Any "Legislation/Regulations" on water conservation management	8	See Note 2
	5. Any "Financial framework and Financing plans" for development of water supply	8	See Note 3
	6. Any "Operator business plan" (Annual Budget, Manpower resource plan, etc.)	8	

Enabling Environment Indicators Notes

1. Due to sound watershed management, effective water treatment processes and continued investments in R&D, Singaporeans have been enjoying good quality water for the last five decades. Raw water from various sources is conveyed by pipelines to the

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waterworks where it is chemically treated, filtered and disinfected. Finally, the water goes through a series of water quality tests before it is piped to the customers.

Singapore's tap water is well within the World Health Organization drinking water guidelines, and is suitable for drinking without any further filtration. To ensure that the water supply is clean and safe, water samples are regularly collected and analyzed chemically and bacteriologically at the Water Testing Laboratory. Samples of water at various stages of treatment at all waterworks, raw water from all sources, treated water from all service reservoirs and selected points in the distribution network are also collected for daily or periodic analysis.

2. Legislative measures have been put in place to deter water wastage. Punitive measures for non-compliance include fines and/or court prosecution. These legislative measures are constantly reviewed to keep abreast of the latest developments in the area of water conservation to ensure that they continue to remain relevant. Since 1983, installation of water saving devices such as constant flow regulators and self-closing delayed action taps was made mandatory in all non-domestic premises and common amenities areas of all private high-rise residential apartments and condominiums. Since 1992, low capacity flushing cisterns (LCFCs) that use not more than 4.5 litres of water per flush were installed in all new public housing units. The installation of LCFCs, in place of the conventional 9-litres cistern for all new and ongoing building projects, including all residential premises, hotels, commercial buildings and industrial establishments, was made mandatory in 1997. PUB will also be mandating the installation of dual-flush LCFCs from July 2009 for all new domestic premises and existing domestic premises undergoing renovations. Compared with single flush LCFCs, the use of dual-flush LCFCs is expected to result in further water savings.

PUB also limits the maximum allowable flow rates at water fittings to prevent excessive flow rates and hence water wastage at these fittings. PUB will also be mandating the water efficiency labeling of water fittings and products such as taps, urinals and dual flush LCFCs from July 2009. Under the Mandatory Water Efficiency Labelling Scheme, the water fittings and products will be labeled with ticks to indicate its water efficiency. The more ticks, the more water efficient the fitting or product. In addition, from July 2009, all new developments and existing premises undergoing renovations which involve replacement of taps, urinals or water closets shall incorporate only "1-tick" and above taps, urinals and dual flush LCFCs.

Starting 1 October 2011, washing machines sold in Singapore have to also carry a mandatory Water Efficiency label. A one-tick washing machine can help consumers save 81 litres of water per wash, while indication of two-ticks and three-ticks can save them 102 litres and 1112 litres of water respectively.

3. Water Tariff - Pricing of water is an important and effective mechanism in encouraging customers to conserve water. Water should be treated as an economic good. The water in Singapore is priced not only to recover the full cost of its production and supply, but also to reflect the scarcity of this precious resource and the high cost of water from developing additional sources. To further encourage water conservation, a water

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conservation tax is also imposed. The tax was first introduced in 1991. Water tariffs and the water conservation tax were restructured over a 4-year period, starting in 1997 (See Table 1 below), to reflect the strategic importance and scarcity value of water. The restructuring also brought the water tariffs and water conservation tax to a single rate for both domestic and non-domestic customers to emphasize the strategic and equal importance of water to all categories of users. Domestic customers using more than 40 m³/month incur higher tariffs and water conservation tax.

Table 1: Water Tariff Table- Tariff since 1 Jul 2000

Tariff Category	Consumption Block (m ³ per month)	Before 1 July 1997			From 1 July 2000		
		Tariff (¢/m ³)	Water Conservation Tax (%)	Total (¢/m ³)	Tariff (¢/m ³)	Water Conservation Tax (%)	Total (¢/m ³)
Domestic	1 to 20	56	0	56.0	117	30	152.1
	20 to 40	80	15	92.0	117	30	152.1
	Above 40	117	15	134.6	140	45	203.0
Non-Domestic	All Units	117	20	140.4	117	30	152.1

Institutional Set-up Indicators

IS Indicators			
	1. Any water supply planning and policy department	8	See Note 1
	2. Any water supply quality office, water testing lab, water sampling team	8	See Note 2
	3. Any water supply operation centre	8	See Note 2
	4. Any water conservation unit	8	See Note 2
	5. Any water meter management unit	8	See Note 2
	6. Any customer account/meter reading/billing unit	8	See Note 2
	7. Any water meter workshop	8	See Note 2
	8. Any water leak detection unit	8	See Note 2
	9. Any 24-hr water supply call centre	8	See Note 2
	10. Any water supply network maintenance unit	8	See Note 2
	11. Any water supply meter management unit	8	See Note 2
	12. Any water supply EMI unit	8	See Note 2

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Institutional Setup Indicators Notes

1. PUB was formed on 1 May 1963 as a statutory authority to take over the production and supply of electricity, water and piped gas from the then City Council. On 1 Oct 1995, PUB's electricity and piped gas undertakings were corporatized to Singapore Power Ltd with the intent of liberalizing the electricity market. PUB remained the water authority and was also reconstituted to take on the new role of regulating the electricity and piped gas industries.

PUB's role changed again on 1 April 2001 with the transfer of the electricity regulatory functions to the newly formed Energy Market Authority and became the national water agency of Singapore with sewerage and drainage departments which were originally under the Ministry of the Environment (ENV) transferred to PUB. This transfer allowed PUB to oversee the management of the entire water loop, from the sourcing of water by rainwater collection in reservoirs, desalination or import; to treatment and distribution of drinking water; and the collection of used water which is then treated and discharged or reclaimed to produce NEWater. In this way, Singapore has integrated the management of water resources by vesting operational and decision-making responsibilities under one agency. This allows holistic planning and management of water resources to meet both social and economic outcomes as well as ensuring long term water and environmental sustainability.

2. Under the treatment and distribution management of the water loop, PUB has a Water Quality Office (which has been designated as a World Health Organization (WHO) Collaborating Centre for safe drinking-water management and integrated urban water management) and also Water Supply Network Department to manage the water safety planning for the distribution process. The Water Supply Network Department also takes care of the distribution of clean water to the taps of customers. The Water Supply Network Department operates and manages about 5400km of potable water supply pipelines and its functions include water supply and pipeline asset management, leak detection and pipe maintenance, 24 hour customer call service and water demand management and more. Together, they ensure a reliable and clean supply of water for Singapore.

Management Tools Indicators

MT Indicators	1. Any short and long term water demand projection and infrastructure development plan	8	See Note 1
	2. Any water safety plan – e.g. water sampling programme, water testing lab, real time monitoring of water quality at water treatment plants and service reservoirs	8	See Note 2

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3. Any water supply pressure monitoring system – e.g. pressure sensor/ monitoring in network, flow and level monitoring at service reservoirs, waterworks outputs	8	See Note 3
4. Any water conservation plan – e.g. water saving measures, public education programme	8	See Note 4
5. Any water supply meter installation plan – e.g. all new premises must be metered	8	See Note 5
6. Any monitoring of water treatment plant output meters – e.g. all are metered and the meters are checked periodically	8	See Note 5
7. Any water meter management system – e.g. comply with ISO/EU standard, error check system, meter replacement programme, meter repair and testing facilities	8	See Note 5
8. Any water supply network record /mapping system, network asset management and pipeline replacement/ renewal programme	8	See Note 6
9. Any water supply leak detection programme	8	See Note 7
10. Any 24-hour Call Centre and Operation Centre for feedback on leak and deployment of crew for repair	8	See Note 8

Management Tools Indicators Notes

1. Adequacy, Resilience and Sustainability- PUB's Water Supply Network Department uses these 3 principles to guide in the planning of infrastructure development plans. Adequacy is to have the capacity to meet projected water demands. Resilience is to ensure the readiness of infrastructure to meet contingency scenarios. Sustainability is the managing of demand and ensuring of affordability. In order to develop infrastructure plans, some major activities and tools used include the following:

- Using of Singapore's Land Use Plans to plan for future needs of Singapore
- Calculation of the demand projections based on actual and projected water consumption indices
- Run hydraulic simulations and analysis on new development plans to ensure that the supply and pressure is sufficient
- Conduct site investigations in the area of the planned infrastructure
- Work closely with other agencies to firm up the these plans

Source: ASEAN Working Group for Water Resources Management (AWGWRM) – July 2015
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2. Singapore's water is moderately soft and is safe to drink straight from the tap. To ensure safe drinking water, water samples are regularly collected and analyzed. Some methods in which PUB ensures the quality of Singapore's water includes:
 - Water Safety Plan- Water Safety Plan describes the risk assessment and risk management measures that are used or to be used to minimize the likelihood of any piped drinking water failing to comply with the water quality standards specified in the Schedule of the Environmental Public Health (Quality of Piped Drinking Water) Regulations.
 - Operations and monitoring- At different stages of the water treatment and distribution operations, water samples are taken to monitor the quality of the water through online sensors and manual sampling. Parameters like the pH, conductivity are monitored closely.
 - Fish Activity Monitoring System- Fishes are traditionally used to monitor the quality of water at the waterworks and service reservoirs and observed dead fish would indicate possible variation in water quality. Video analytics is used for round the clock monitoring and automated alert generation.

3. Leveraging on various technological advancements, PUB is able to have online monitoring systems for real-time monitoring of pressure, flow and water quality in the water distribution network. Some of these technologies used are:
 - Wireless sensor network that was developed to measure hydraulics (pressure and flow) and surrogate water quality parameters in the network.
 - Sensor network platform also offers tools to perform functions such as leak detection, valve operation simulation, short-term demand prediction and other related assistive tools
 - SCADA - Supervisory Control and Data Acquisition combines a number of technologies to provide secure data and control over various communications mediums. The emerging trends of integrating SCADA and IT system are able to help the stakeholders to gain visibilities on better operational efficiency and knowledge transfer by creating alarm response management techniques which allow the operators to monitor and handle numerous alerts such as an automated knowledge base system that could give them quick responses and accurate information for control purposes.

4. Ownership Through 3P Initiatives - We engaged the 3P (i.e. Public, Private and People) Initiative to encourage the public to use water wisely, keep our water clean and enjoy our waters. PUB has an on-going public education and publicity programme to educate the public in the management of our water resources, emphasizing on the importance of water conservation. The main objective of the programme is to effect behavioral change in the way water is being used so that saving water becomes an ingrained habit. The various activities are targeted at both the domestic and non-domestic sectors. Some of the major activities carried out include the following:
 - Save Water Campaigns and Sustained Publicity Programmes

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- educating our young by incorporating water conservation topics in school textbooks and conducting water conservation talks at schools,
- the Water Efficient Homes and Water Volunteer Group programmes that encourage the installation of water saving devices in domestic premises and educates people on good water saving habits the 10-Litre Challenge encourages the public to play a part in reducing the domestic water consumption by striving to reduce their consumption by 10 litres per person per day.
- The Water Efficient Building and 10% Challenge programmes encourage non-domestic users to work towards making their buildings water efficient and saving 10% or more of their monthly water consumption
- Water recycling and substitution with NEWater, Industrial Water and Sea Water for non-potable use
- Water Efficiency Fund to support and co-fund water conservation projects that yield at least 10% savings in water consumption

In addition, we also encourage organizations and individuals to adopt our waterbodies and become Friends of Waters. Their efforts and contributions of outstanding Friends of Water are recognized at an annual Watermark Award Ceremony.

5. 100% of Singapore's water supply is metered with approximately 1.33 million meters installed island wide. Meters are used for functions like billing of customers, accounting for water use (Unaccounted-for-water) and also water conservation measures. PUB has guidelines for the installation of meters. One of which is the guidelines on water meter positions. For instance, big meters serving apartments or high rise buildings shall be hosed in proper chamber/enclosed. This is for aesthetics purposes and easy access for meter reading and maintenance.

Meters in Singapore are regularly serviced, reconditioned and tested at the meter workshop to ensure that the meters have an accuracy of within 3%. Additionally, these meters are tracked for replacement under the replacement program once they reach their life spans of 15 years (small meters) and 2 to 7 years (larger meters).

6. Over the years, PUB has built up an extensive water supply network with some 5400km of pipelines in length. In order to keep track and manage this network well, PUB uses a Geographical Information System (GIS) for its network mapping system, recording all important information of the network within the GIS. These records are used for network asset management and pipeline replacement/renewal programs. These records can help determine the health of pipelines through analytics and assist management to make sound decisions when it comes to pipeline replacement/ renewal.
7. Water is a precious resource and it is important to conserve our waters. With this in mind, PUB has been engaging in dynamic leak detection with a 24/7 contact center. Water leaks can occur due to various reasons which include pressure surges, soil conditions, pipe material and corrosion and workmanship of fittings. When a pipe leaks, there will be tell-tale signs such as sudden increase in water

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consumption, water flowing into drains, damp walls, cracking of driveways, damp ground or even fresh green grass or moss.

As such, PUB has a systematic approach in leak detection. The entire network is divided into sub regions for leak detection surveillance. During the surveillance, visual inspections and deployment of Acoustic Leak Noise Localisers in leak prone areas are carried out. If a possible leak is detected, correlators are used to pinpoint possible leak spots and other devices like listening sticks, electronic ground microphones are used to confirm the leak spot. PUB also keeps up with the latest technologies on leak detection equipment and methods.

Additionally, PUB does dry weather flow monitoring whereby drains and waterways are monitored for abnormal flow during dry seasons as these flows may indicate a leak upstream.

8. PUB has a 24 hour Call Centre called PUBOne that was formed in Aug 2002. When a customer calls in to report an issue such as poor water quality, poor pressure or pipe leak suspected, PUBOne will first try to resolve the case over the phone through simple measures that can be taken. Should these measures be unable to solve the issue, PUBOne will request for site investigation by the relevant operations crew. The operations crew responds promptly to assist in providing temporary water supply to affected customers and solve the issues reported.

Tools such as a Call Centre System (CCS), Digital Trunked Radio System (DTRS), waterproof Computer Tablets, GIS, Incident Response Vehicle (IRV), Mobile Water Boosting System, Water Wagons and wireless CCTVs are used to support PUB's prompt services and response. Once the case/ issue are resolved, PUBOne will inform the customers and bring up any non-routine cases to management for evaluation and review for a more seamless operation.