WATER RECYCLING AND REUSE

for WaterHarmony+

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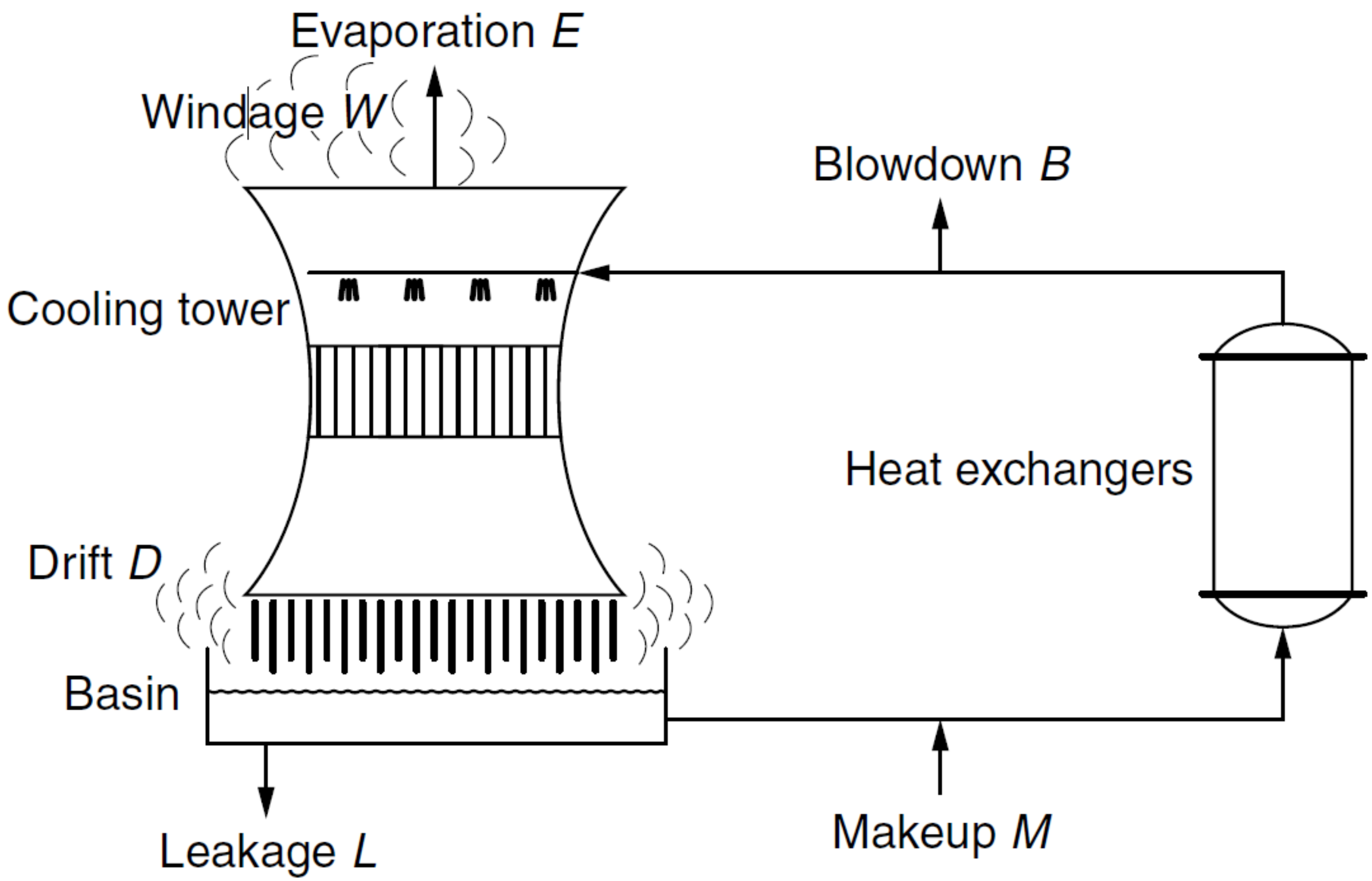
Basic sources for this presentation

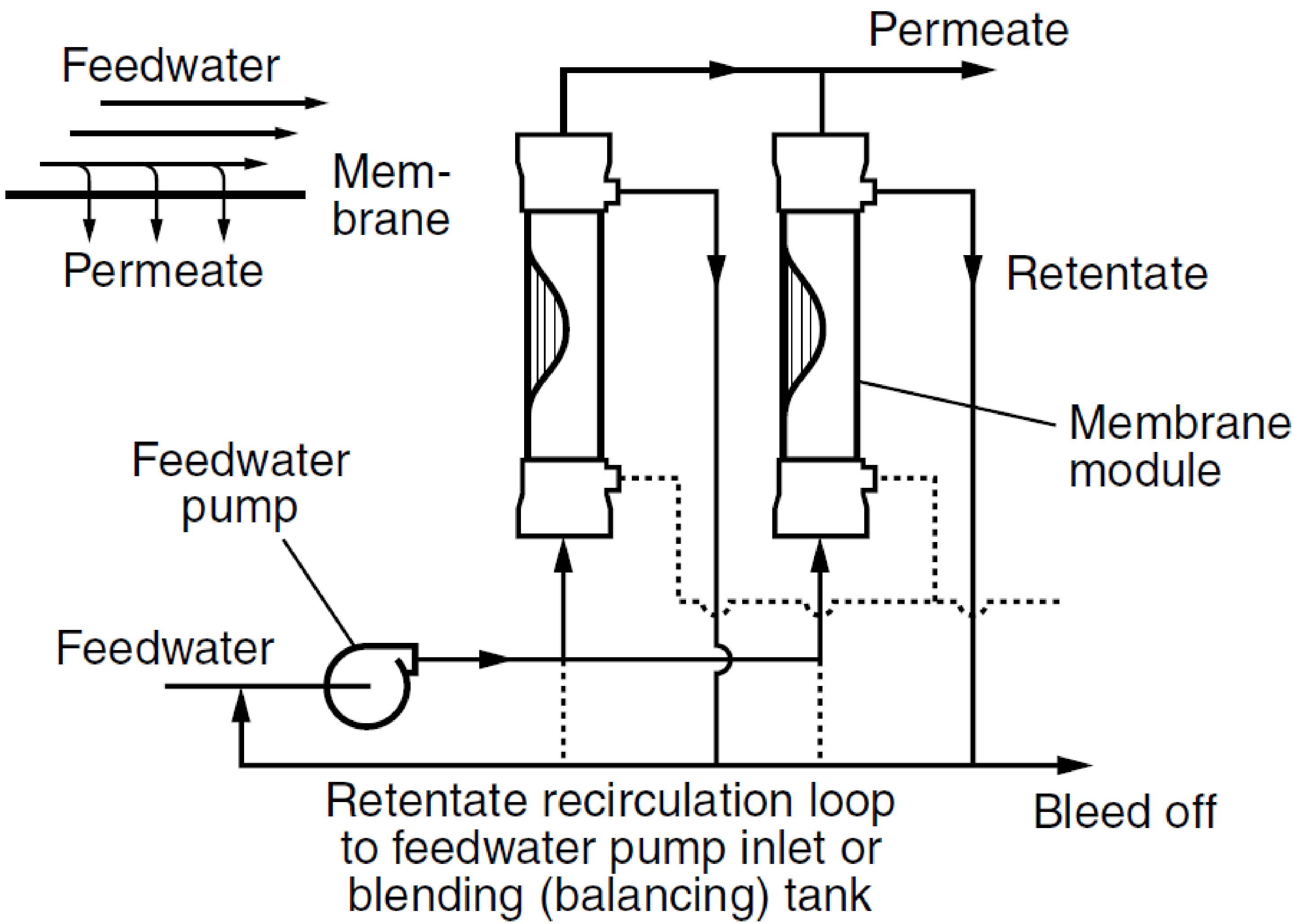
- Water Encyclopedia, Volume 1, Domestic, Municipal, and Industrial Water Supply and Waste Disposal. Jay H. Lehr (Editor-in-Chief), Jack Keeley (Editor), Janet Lehr (Associate Editor). ISBN: 978-0-471-73687-5. 952 pages, 2005
- Water reuse : issues, technologies, and applications / written by Takashi Asano … [et al.]. ISBN-13:978-0-07-145927-3. 1503 pages, 2007
- PUB, Singapore's National Water Agency: https://www.pub.gov.sg

https://www.youtube.com/user/pubwebadmin

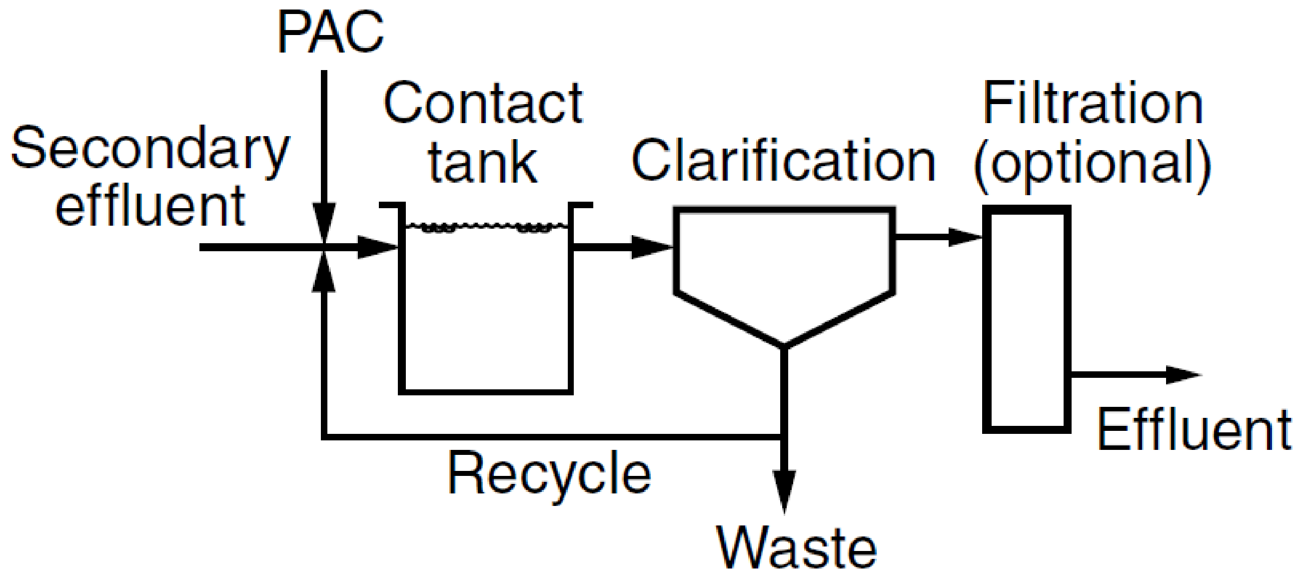
Cooling water system



Pressurized cross-flow membrane system



Mixed PAC contactor with gravity separation

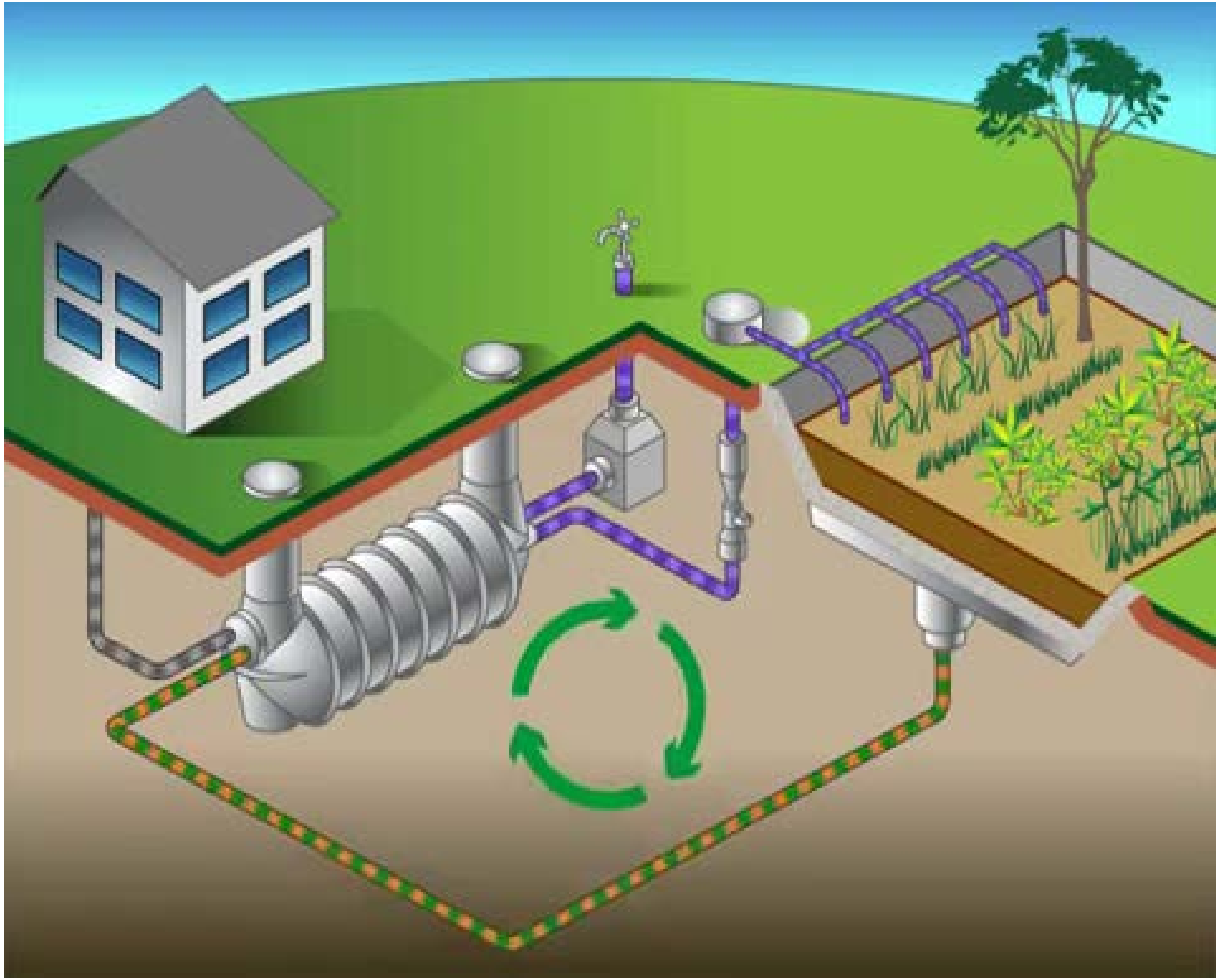


Powdered activated carbon (PAC)

Greywater recycling

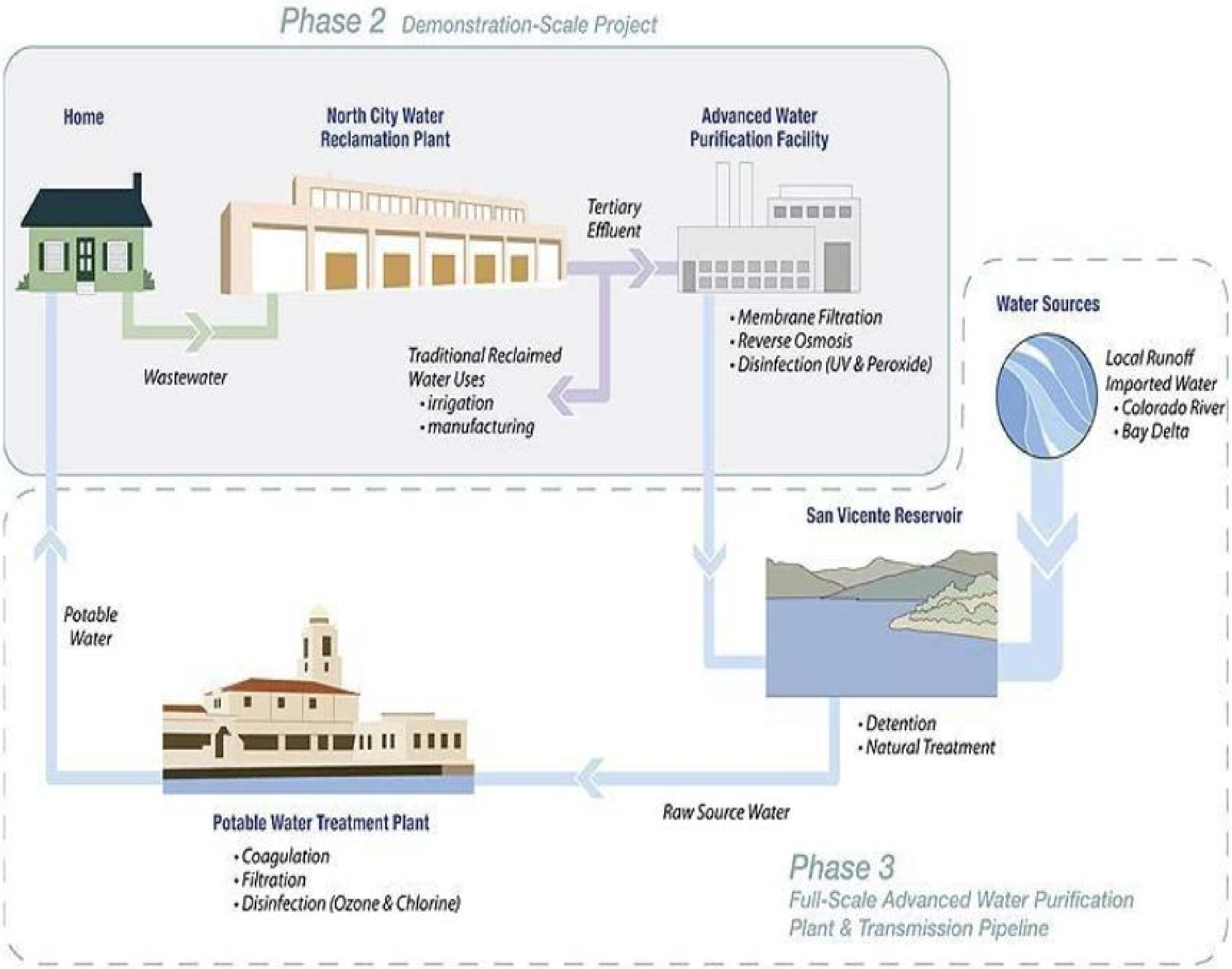
https://www.youtube.com/watch?v=y8kipgTJDUw

Ecocyclet Water Reuse System



https://www.youtube.com/watch?v=fDcQxX77cU0

Demonstration Project, City of San Diego



BASIC WORKING TERMINOLOGY

Potable water	Water suitable for human consumption without deleterious health risks. The term drinking water is a preferable term better understood by the community at large.
Potable reuse, indirect	The planned incorporation of reclaimed water into a raw water supply such as in potable water storage reservoirs or a groundwater aquifer, resulting in mixing and assimilation, thus providing an environmental buffer
Potable reuse, direct	The introduction of highly treated reclaimed water either directly into the potable water supply distribution system downstream of a water treatment plant, or into the raw water supply immediately upstream of a water treatment plant
Water reclamation	Treatment or processing of wastewater to make it reusable with definable treatment reliability and water quality criteria
Water recycling	The use of wastewater that is captured and redirected back into the same water use scheme such as in industry. However, the term water recycling is often used synonymously with water reclamation
Water reuse	The use of treated wastewater for a beneficial use, such as agricultural irrigation and industrial cooling.

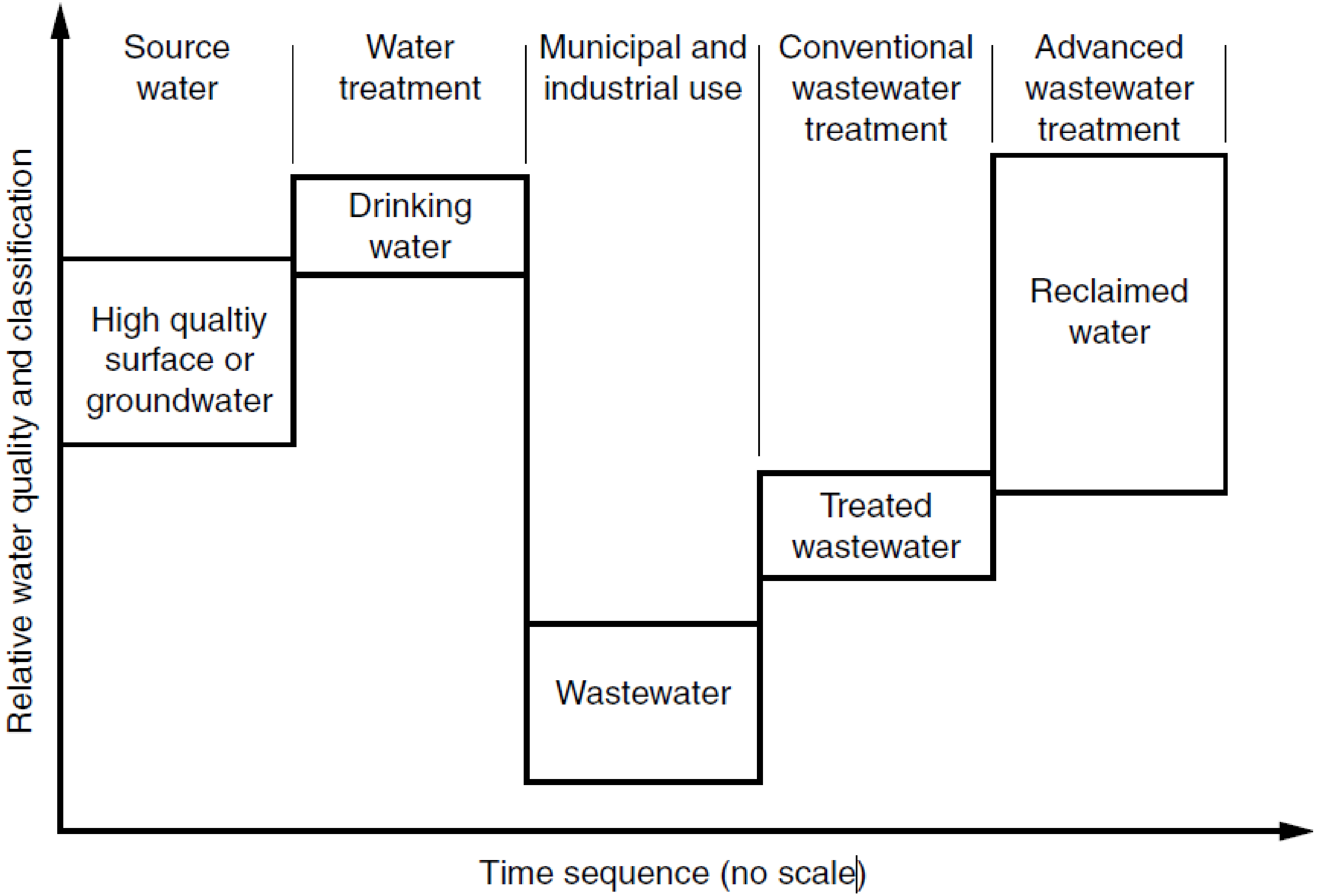
BENEFITS OF USING RECLAIMED WATER

- It saves millions of gallons of drinking water each day.
- Its use for nonpotable (nondrinking) purposes is less expensive for the vast majority of of customers.
- It delays the need for developing costly new water sources and building very expensive treatment plants.
- There is no odor or staining fromits use.
- It allows a city to comply with permits relating to its water supply and wastewater treatment.

Water reuse categories and typical applications

Category	Typical application
Agricultural irrigation	Crop irrigation Commercial nurseries
Landscape irrigation	Parks School yards Freeway medians Golf courses Cemeteries Greenbelts Residential
Industrial recycling and reuse	Cooling water Boiler feed Process water Heavy construction
Groundwater recharge	Groundwater replenishment Salt water intrusion control Subsidence control
Recreational/environmental uses	Lakes and ponds Marsh enhancement Streamflow augmentation Fisheries Snowmaking
Nonpotable urban uses	Fire protection Air conditioning Toilet flushing
Potable reuse	Blending in water supply reservoirs Blending in groundwater Direct pipe to pipe water supply

Water quality changes during municipal uses of water in a time sequence and the concept of water reclamation and reuse



Constituents of Reclaimed Water

Classification	Constituent
Conventional	Total suspended solids
	Colloidal solids
	Biochemical oxygen demand
	Chemical oxygen demand
	Total organic carbon
	Ammonia
	Nitrate
	Nitrite
	Total nitrogen
	Phosphorus
	Bacteria
	Protozoan cysts and oocysts[a]
	Viruses[b]
Nonconventional	Refractory organics
	Volatile organic compounds
	Surfactants
	Metals
	Total dissolved solids
Emerging	Prescription and nonprescription drugs[c]
	Home care products
	Veterinary and human antibiotics
	Industrial and household products
	Sex and steroidal hormones
	Other endocrine disrupters

[a]Value per 100 mL.
[b]Plaque-forming units/100 mL.
[c]Pharmaceutically active substances.

- The term conventional is used to define those constituents measured in mg/L that are the basis for designing most conventional wastewater treatment plants.
- Nonconventional applies to those constituents that may have to be removed or reduced using advanced wastewater treatment processes before the tank can be used beneficially.
- The term emerging is applied to those classes of compounds measured in the micro- or nanogram/L range that may pose long-term health concerns and environmental problems as more is known about the compounds. In some cases, these compounds cannot be removed effectively, even by advanced treatment processes.

Typical Analysis Of Municipal Wastewater

Constituent, mg/L	Concentration		
	Strong	Medium	Weak
Solids, total	1200	720	350
Dissolved, total	850	500	250
Fixed	525	300	145
Volatile	325	200	105
Suspended, total	350	220	100
Fixed	75	55	20
Volatile	275	165	80
Settleable solids, mL/L	20	10	5
Biochemical oxygen demand, 5-day, 20 °C (BOD_5)	400	220	110
Total organic carbon (TOC)	290	160	80
Chemical oxygen demand (COD)	1000	500	250
Nitrogen, total as N	85	40	20
Organic	35	15	8
Free ammonia	50	25	12
Nitrites	0	0	0
Nitrates	0	0	0
Phosphorus, total as P	15	8	4
Organic	5	3	1
Inorganic	10	5	3
Chlorides	100	50	30
Alkalinity, as CaCO3	200	100	50
Grease	150	100	50

Contaminant	Source
Suspended solids	Domestic use, industrial wastes, erosion by infiltration/inflow
Biodegradable organics	Domestic waste
Pathogens	Domestic waste
Nutrients	Domestic and industrial waste
Refractory organics	Industrial waste
Heavy metals	Industrial waste, mining etc.,
Dissolved inorganic solids	Increase above level in water supply by domestic and/or industrial use

Important Wastewater Contaminants

Suggested Treatment

Type of Use	Recommended Degree of Treatment
Urban	
Landscape irrigation, fire protection	Secondary, filtration, disinfection
Restricted access irrigation	Secondary, disinfection
Construction	Secondary, disinfection
Industrial Reuse	
Industrial cooling, once-through	Secondary
Industrial cooling, recirculated	Secondary, disinfection
Agricultural Irrigation	
Food products, not commercially processed	Secondary, filtration, disinfection
Food products, commercially processed	Secondary, disinfection
Nonfood products	Secondary, disinfection
Habitat Restoration / Recreational	
Recreational impoundments	Secondary, filtration, disinfection
Landscape impoundments	Secondary, disinfection
Environmental (wetlands, stream augmentation)	Secondary, disinfection
Groundwater Recharge	
Surface irrigation	Primary
Subsurface injection	Secondary
Augmentation of Potable Supplies	
Indirect reuse, aquifer spreading	Secondary, disinfection
Indirect reuse, aquifer injection	Secondary, filtration, disinfection, advanced
Indirect reuse, surface augmentation	Secondary, filtration, disinfection, advanced

Preliminary Treatment Processes: Screening. Grit Removal. Comminution. Equalization.
Primary Treatment Processes: Sedimentation.
Secondary Treatment Processes: Activated Sludge Processes. Plug Flow. Step Feed. Tapered Aeration. Complete Mix. Contact Stabilization. Sequencing Batch Reactor. Extended Aeration. Fixed Film Processes. Stabilization Ponds.
Advanced Treatment Processes: Nitrification. Biological Phosphorus Removal. Denitrification. Biological Dual-Nutrient Removal. Air Stripping. Coagulation / Sedimentation. Filtration. Activated Carbon Adsorption. Membrane Systems.
Disinfection Processes: Chlorination/Dechlorination. Ozonation. Ultraviolet Light Disinfection.

Treatment Levels Achievable from Various Combinations of Unit Operations and Processes Used for Water Reclamation

	Typical Effluent Quality, mg/L, Except Turbidity, NTU						
	TSS	BOD_5	COD	Total N	NH_3-N	PO_4-P	Turbidity
Activated sludge + granular medium filtration	4–6	<5–10	30–70	15–35	15–25	4–10	0.3–5
Activated sludge + granular medium filtration + carbon adsorption	<5	<5	5–20	15–30	15–25	4–10	0.3–3
Activated sludge/nitrification single stage	10–25	5–15	20–45	20–30	1–5	6–10	5–15
Activated sludge/nitrification denitrification separate stages	10–25	5–15	20–35	5–10	1–2	6–10	5–15
Metal salt addition to activated sludge +nitrification/ denitrification separate stages	≤5–10	≤5–10	20–30	3–5	1–2	≤1	0.3–2
Biological phosphorus removal[a]	10–20	5–15	20–35	15–25	5–10	≤2	5–10
Biological nitrogen and phosphorus removal + filtration	≤10	<5	20–30	≤5	≤2	≤2	0.3–2
Activated sludge + granular medium filtration + carbon adsorption +reverse osmosis	≤1	≤1	5–10	<2	<2	≤1	0.01–1
Activated sludge/nitrification-denitrification +granular medium filtration + carbon adsorption + reverse osmosis	≤1	≤1	2–8	≤1	≤0.1	≤0.5	0.01–1
Activated sludge/nitrification-denitrification and phosphorus removal + microfiltration +reverse osmosis	≤1	≤1	2–8	≤0.1	≤0.1	≤0.5	0.01–1

[a] Removal process occurs in the main flowstream as opposed to sidestream process.

Summary of EPA Suggested Guidelines for Water Reuse

Levels of Treatment	Types of Reuse	Reclaimed Water Quality	Reclaimed Water Monitoring	Setback Distances
1. Disinfected tertiary[b]	Urban reuse[c]	pH = 6–9	pH = weekly	15 m (50 ft) to potable water supply wells[d]
	Food crop irrigation	$BOD_5 \leq 10$ mg/L Turb. ≤ 2 NTU	BOD = weekly Turb. = cont.	
	Recreational impoundments	*E. coli* = none Res. $Cl_2 \geq 1$ mg/L	*E. coli* = daily Res. Cl_2 = cont.	
2. Disinfected secondary	Restricted-access-area irrigation	pH = 6–9	pH = weekly	30 m (100 ft) to areas accessible to the public (if spray irrigation)
	Food crop irrigation (commercially processed)	$BOD_5 = 30$ mg/L TSS = 30 mg/L *E. coli* = 200/100 mL	BOD = weekly TSS = cont. *E. coli* = daily Res. Cl_2 = cont.	90 m (300 ft) to potable water supply well
	Nonfood crop irrigation Landscape impoundments (restricted access) Construction Wetlands habitat	Res. $Cl_2 \geq 1$ mg/L		

[a] From Reference 1.
[b] Filtration of secondary effluent.
[c] Uses include landscape irrigation, vehicle washing, toilet flushing, fire protection, and commercial air conditioners.
[d] Setback increases to 150 m (500 ft) if impoundment is not sealed.

EPA - the U.S. Environmental Protection Agency

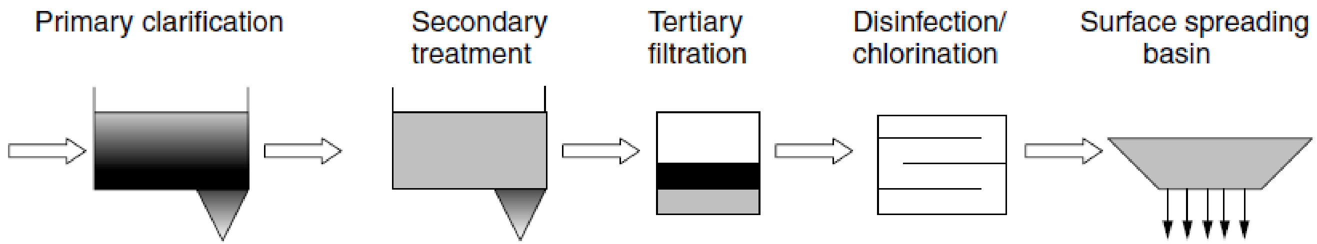
A Comparison of Wastewater Treatment and Recycling Technologies

Wastewater Technologies	Applicability[a]	Suitability[b]	Cost (US$ per Million Liters of Treated Water)
	A. Physical technologies		
Screening, filtration, and centrifugal separation	Ss & Sl IOB	RSrT	20–450
Micro- and ultra-filtration	Sl IOB	RSrT	10–400
Reverse osmosis	Sl IOB	RSrT	10–450
Crystallization[c]	Sl IO	RSrT	50–150
Sedimentation and gravity separation	Ss IOB	RSrT	2–10
Flotation	Ss IOB	RT	5–25
Adsorption	Ss & Sl IOB	RSrT	50–150
	B. Chemical technologies		
Precipitation[c]	Sl IO	RT	15–500
Coagulation	Ss & Sl I	RT	20–500
Oxidation	Sl IO	RSrT	100–2000
Ion exchange	Sl IO	RSrT	50–200
Solvent extraction	Sl OV	RSrT	250–2500
	C. Electrical technologies		
Electrodialysis	Sl IO	RSrT	10–400
Electrolysis	Sl IO	RSrT	—
	D. Thermal technologies		
Evaporation[c]	Sl & Ss IOB	RSrT	10–200
Distillation	Sl IOB	RT	10–2000
	E. Biological technologies		
Aerobic	Sl & Ss O	RT	10–200
Anaerobic	Sl & Ss O	RT	10–200

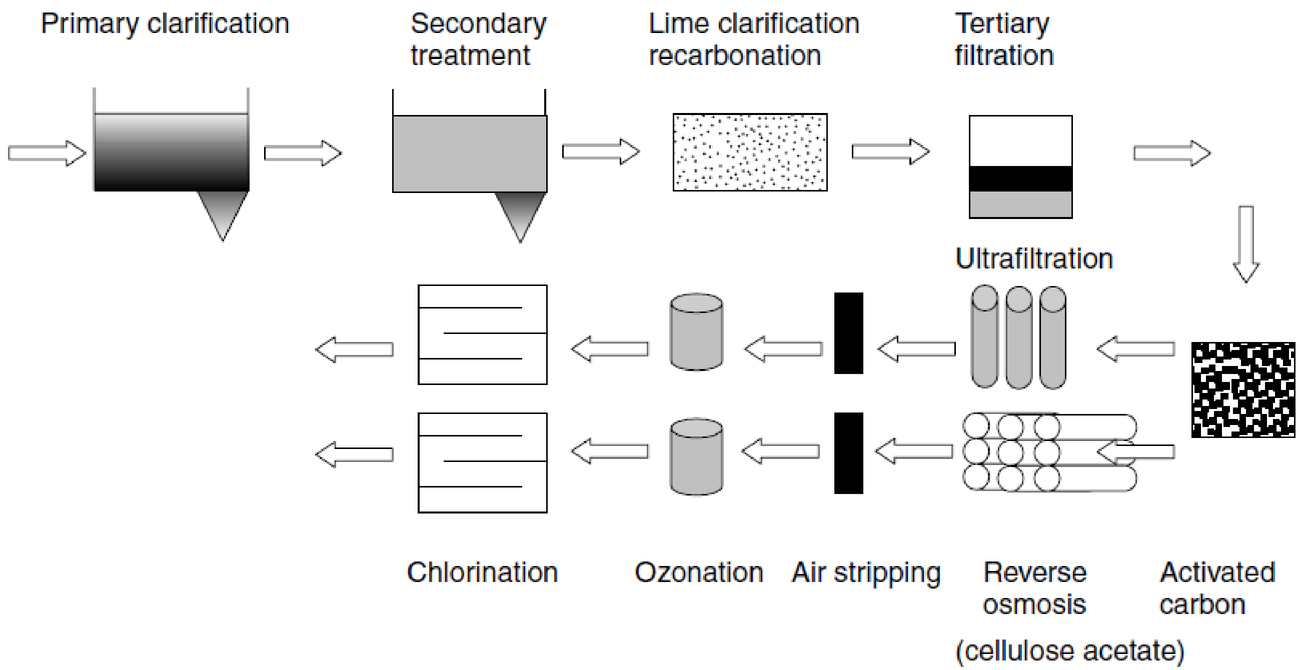
[a]Sl: soluble; Ss: suspended; I: inorganics; O: organics; V: volatiles; B: biologicals.
[b]R: reclamation; T: treatment; and Sr: source reduction.
[c]Rarely Used.

Evolution of water reclamation process trains leading to indirect potable reuse / 1

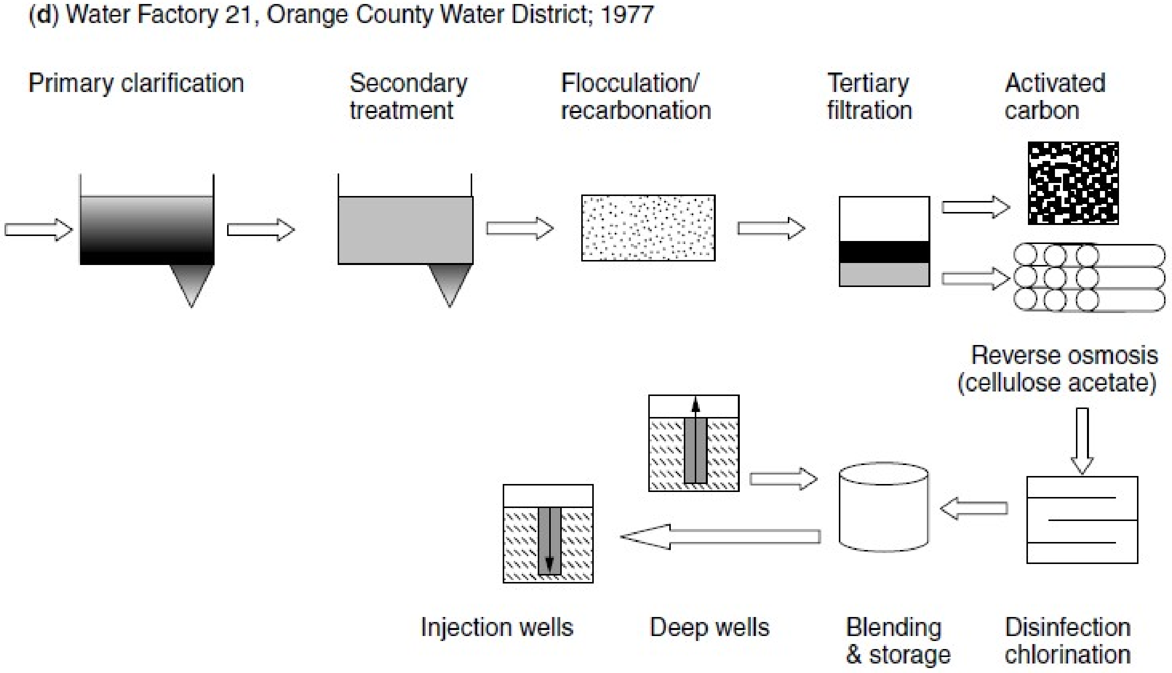
(**a**) Montebello Forebay surface spreading grounds, County Sanitation Districts of Los Angeles County, California; continuous, started in 1962

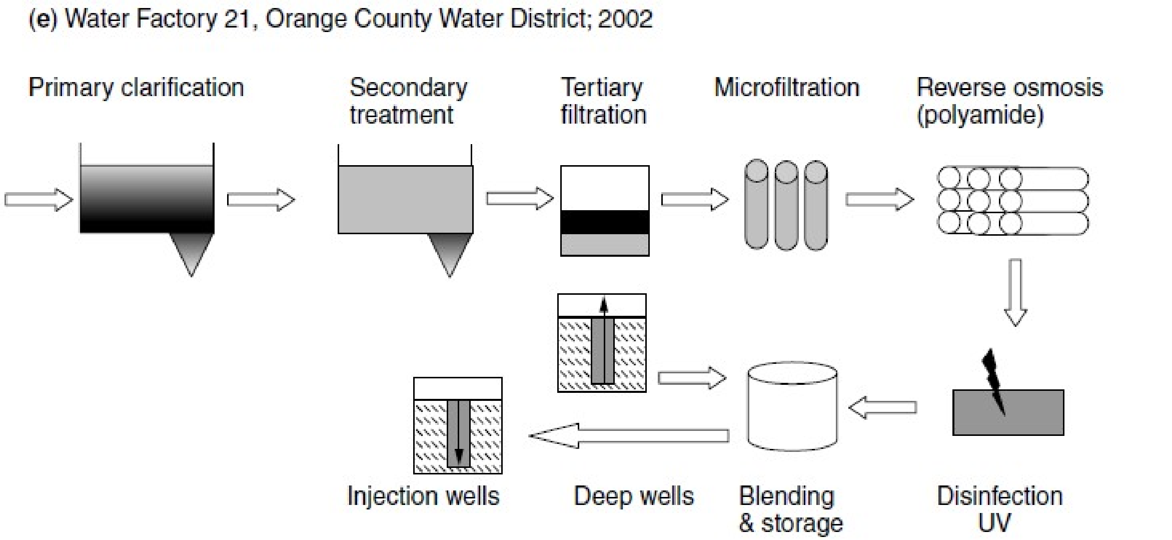


(**b**) Denver potable water demonstration project, City of Denver, Colorado; initiated in 1974, completed in 1990



Evolution of water reclamation process trains leading to indirect potable reuse / 2





WATER REUSE IN CALIFORNIA

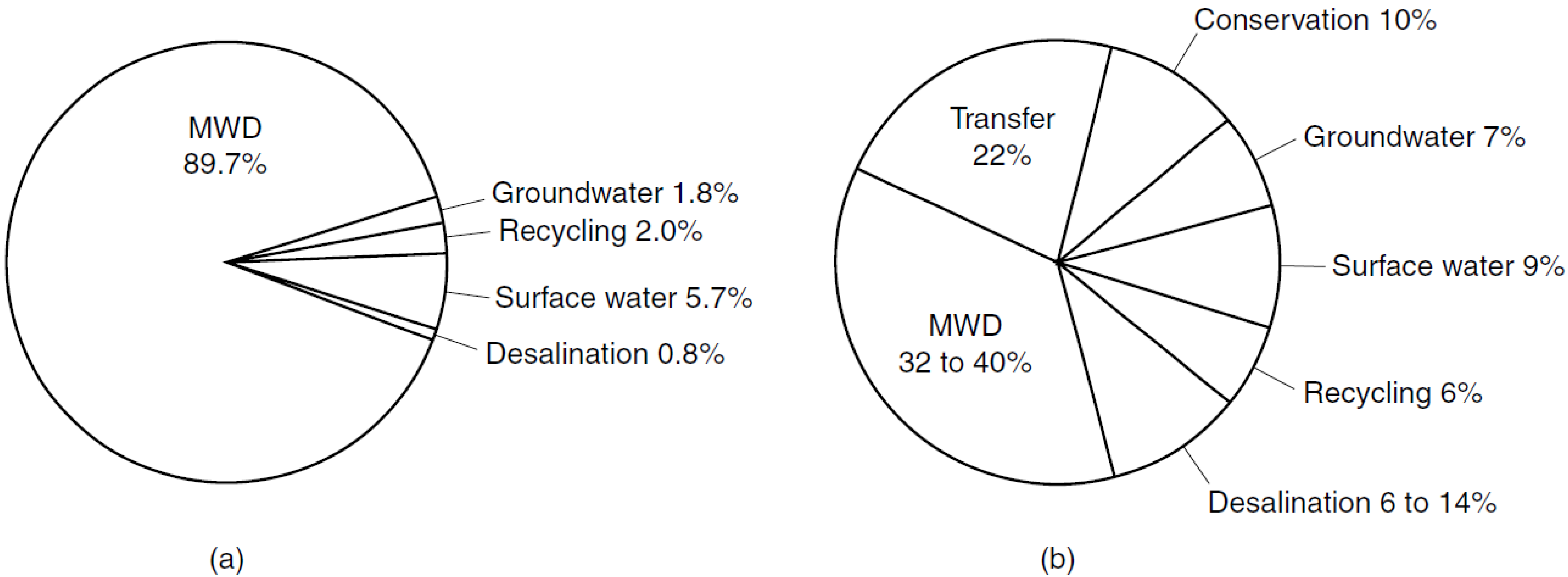
- California, the most populous state (2004 population: 35.9 million) in the union, is a state where two-thirds of the population live in a semiarid and desert climate.

- In many ways, California has been in the vanguard of water reclamation and reuse since its early days as a state. Water reclamation has been practiced in California as early as 1890 for agriculture.

- By 1910 at least 35 communities were using wastewater for farm irrigation, 11 without wastewater treatment, and 24 after septic tank treatment.

Type of water reuse	10^6 m^3/yr	% of total
Agricultural irrigation	297	46
Landscape irrigation	137	21
Industrial use	34	5
Groundwater recharge	60	9
Seawater intrusion barrier	32	5
Recreational impoundment	41	6
Wildlife habitat	25	4
Geysers/energy production	3	1
Other uses or mixed type	19	3
Total	648	100

Comparison of regional water supply sources for San Diego County, CA the years 2002 (a) and 2020 (b)



The principal source of water is from the Metropolitan WaterDistrict (MWD) of Southern Californa (Adapted from San Diego County Water Authority, 2002)

The 15 largest reclaimed water producing agencies in California[a]

Rank	Agency	Number of plants	Reclaimed water deliveries, 10^6 m^3/yr 1987	2001
1	County Sanitation Districts of Los Angeles County	8	66	103
2	City of Los Angeles	2	4	50
3	City of Bakersfield	2	30	39
4	Eastern Municipal Water District	4	12	35
5	West Basin Municipal Water District	1	0	32
6	Irvine Ranch Water District	1	10	24
7	City of Santa Rosa	2	11	15
8	Monterey Regional Water Pollution Control Agency	1	0	15
9	Orange County Water District	1	3	14
10	City of Modesto	1	18	13
11	Inland Empire Utilities Agency	4	2	12
12	Las Virgenes Municipal Water District	1	5	8
13	East Bay Municipal Utility Distict	1	0	7
14	City of San Jose	1	0	7
15	South Tahoe Public Utility District	1	6	6
	Total	31	167	380

[a]Adapted from State of California (1990) and (2002).
Note: There were over 200 water reclamation plants in California delivering reclaimed water statewide in 2001, but 59 percent (380/648) of the reclaimed water came from the 15 largest water reclamation and reuse agencies as listed in this table.

Water Reuse Policies and Recycling Regulations

- The California Department of Health Services (DHS) has the authority and responsibility to establish statewide health-related regulations for water reclamation and reuse.
- The Wastewater Reclamation Criteria (State of California, 1978) were widely used for over 20 years, the formative years of water reclamation and reuse, and were commonly known as Title 22 regulations because they were listed in Title 22, Division 4 of the California Code of Regulations.
- The current Water Recycling Criteria were adopted by DHS in 2000 (State of California, 2000). The water recycling criteria include water quality standards, treatment process requirements, operational requirements, and treatment reliability requirements.

Projections for reclaimed water use in California[a] ($\times 10^6$ m^3/yr)

	Year			
Application	2002	2007	2010	2030
Planned nonpotable use	494–629	642–913	950–1234	1875–2283
Planned indirect potable use[b]	61–86	99–148	148–210	407–494
Total	555–715	741–1061	1098–1444	2282–2777

[a]Adapted from State of California (2003b).

[b]Planned indirect potable use includes groundwater recharge, a portion of recharged groundwater in seawater intrusion barriers, and surface water reservoir augmentation for domestic water supply.

However, technology is becoming more effective in removing pathogens and trace chemical constituents of concern.

Evolving technology will make water reclamation and reuse, and alternative treatment methods such as membrane processes, more reliable and economical in the future.

It is anticipated that the next areas for expanded reclaimed water use will be landscape irrigation, industrial reuse, groundwater recharge, and surface water augmentation.

SOLAIRE BUILDING, NEW YORK

The Solaire is a residential highrise building in New York that has an onsite wastewater system for treating wastewater for toilet flushing and cooling water (coordinates: 40.717 N,74.016 W).

The Solaire is the first building designed in accordance with environmental guidelines instituted in 2000 by the BPCA (Battery Park City Authority).

The building received a LEED (Leadership in Energy and Environmental Design) Gold Certification from the U.S. Green Building Council.

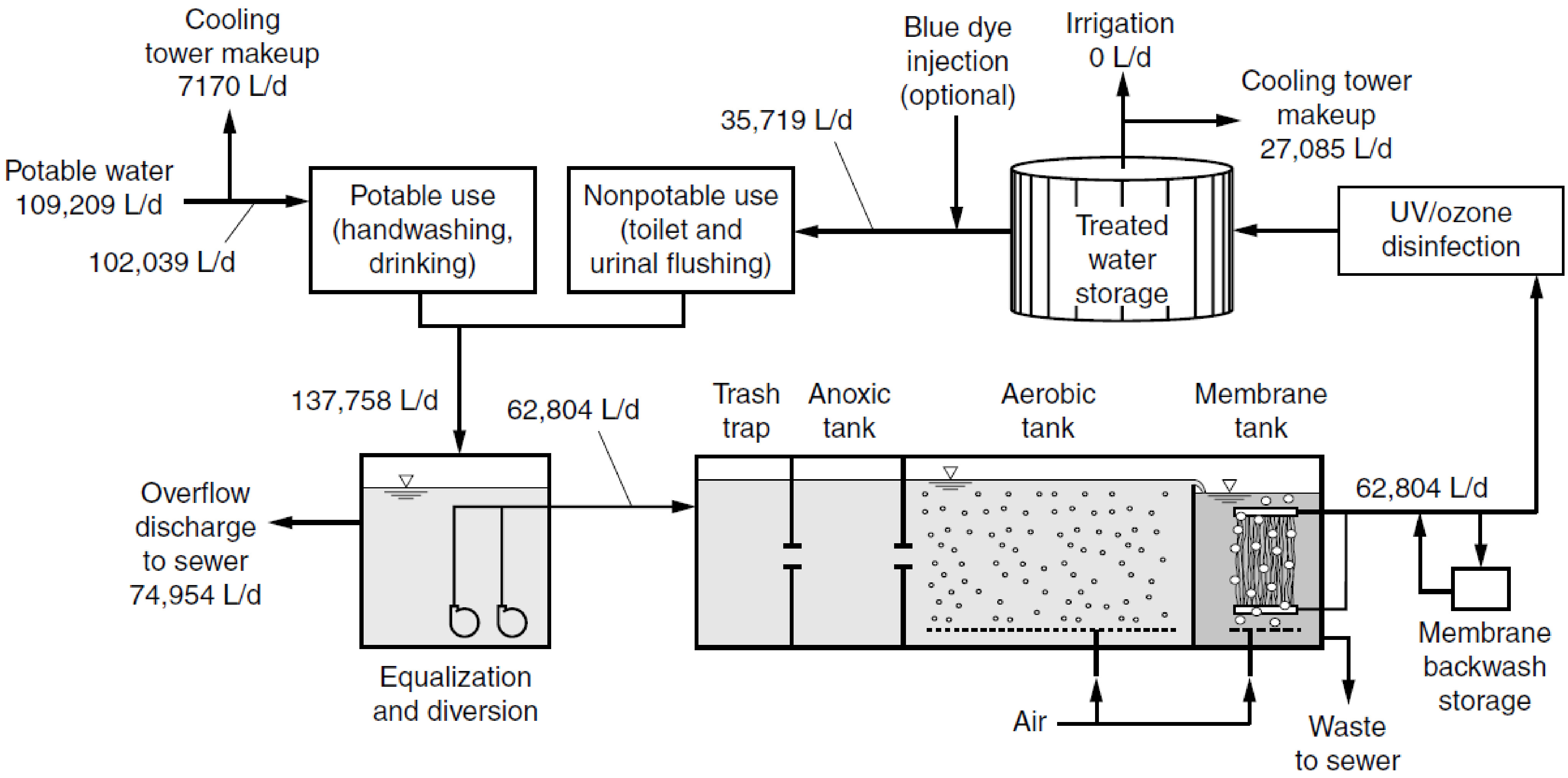
The Solaire, the first building to be designed for the LEED program, was designed to require 50 percent less potable water than a conventional residential high-rise building.

The building included a wastewater treatment and recycling system to supply reclaimed water for toilet flushing and cooling tower makeup.

The Solaire water reclamation system

- Aerated influent feed tank
- Trash trap to intercept nonbiodegradable solids
- Three-stage membrane bioreactor (MBR) consisting of an anoxic mix tank, aerobic digestion tank, filter tank containing ultrafiltration membrane units, and recirculation of the mixed liquor to the anoxic tank
- Ozone oxidation for color removal
- Ultraviolet (UV) disinfection
- Finished water storage tanks
- Booster pumping system and reclaimed water distribution piping

Schematic flow diagram of the Solaire water reclamation and reuse system showing average daily flows for the first 12 months of operation



Reclaimed water quality monitoring data from the water reclamation process in the Solaire

Constituents	Unit	Sample date			
		2/5/04	4/13/04	8/25/04	2/16/05
Electrical conductivity	dS/m			0.898	0.405
TDS	mg/L	448	994		242
Calcium	mg/L	11.5		48.9	11.3
Magnesium	mg/L	3.62		33.4	
Total phosphorous	mg/L	6.74			8.0
Orthophosphate	mg/L			21.8	
Sodium	mg/L	124			48.5
Potassium	mg/L	17.4			8.5
Iron	mg/L	0.033		0.051	
Copper	mg/L	0.046		0.031	
Silica	mg/L	10.1		20.07	
Zinc	mg/L			0.045	
Sulfate	mg/L	34			40
Chloride	mg/L	48		158.7	43
Nitrate-N	mg/L	21.3			11.4
Ammonia-N	mg/L	0.16			
Bicarbonate	mg/L as $CaCO_3$	120			
M-Alkalinity	mg/L as $CaCO_3$			97.6	
Total alkalinity	mg/L as $CaCO_3$		290		24
Calcium hardness	mg/L as $CaCO_3$		50		
Langlier index			−0.73		
TOC	mg/L	6.62			
COD	mg/L	22			

Significant events related to water reclamation and reuse in the world[a]

Period	Location	Event
1962	La Soukra, Tunisia	Irrigation with reclaimed water for citrus plants and groundwater recharge to reduce saltwater intrusion into coastal groundwater.
1965	Israel	Use of secondary effluent for crop irrigation.
1969	Wagga Wagga, Australia	Landscape irrigation of sporting fields, lawns, and cemeteries.
1968	Windhoek, Namibia	Research on direct potable reuse and subsequent implementation.
1977	Tel-Aviv, Israel	Dan Region Project—Groundwater recharge via basins. Pumped groundwater is transferred via a 100-km-long conveyance system to southern Israel for unrestricted crop irrigation.
1984	Tokyo, Japan	Toilet flushing water for commercial buildings in the Shinjuku District using reclaimed water from the Ochiai Wastewater Treatment Plant operated by the Tokyo Metropolitan Sewerage Bureau.
1988	Brighton, UK	Inauguration of the Specialist Group on Wastewater Reclamation, Recycling and Reuse at the 14th Biennial Conference of the International Association on Water Pollution Research and Control (currently, the International Water Association, headquartered in London, UK).
1989	Girona, Spain	Golf course irrigation using reclaimed water from the Consorci de la Costa Brava wastewater treatment facility.
1999	Adelaide, South Australia	The Virginia Pipeline Project, the largest water reclamation project in Australia—irrigating vegetable crops using reclaimed water from the Bolivar Wastewater Treatment Plant (120,000 m^3/d).
2002	Singapore	NEWater-reclaimed water that has undergone significant purification using microfiltration, reverse osmosis, and ultraviolet disinfection. NEWater is used as a raw water source to supplement Singapore's water supply.

[a]Compiled from various sources including Metcalf and Eddy (1928); AWWA (1981); Ongerth and Ongerth (1982); Asano and Levine (1996); Baird and Smith (2002).

The water reclamation and reuse activities in the countries belonging to the European Union (EU) are guided by the EU Water Framework Directives promulgated in 2000. In the European Communities Commission Directive (91/271/EEC), "Treated wastewater shall be reused whenever appropriate . . . ," and that ". . . disposal routes shall minimize the adverse effects on the environment . . ." (EEC, 1991).

Unique to the prevailing water reuse applications which are mostly in irrigation uses, Japan's water reclamation and reuse has focused on urban water applications such as in building water reuse for toilet flushing in commercial and office buildings, urban landscapes, stream flow augmentation, and even snow melting and heating and air conditioning using heat content of the reclaimed water (Japan Sewage Works Association, 2005; UNEP and GEC, 2005).

WATER RECLAMATION AND REUSE IN TOKYO, JAPAN

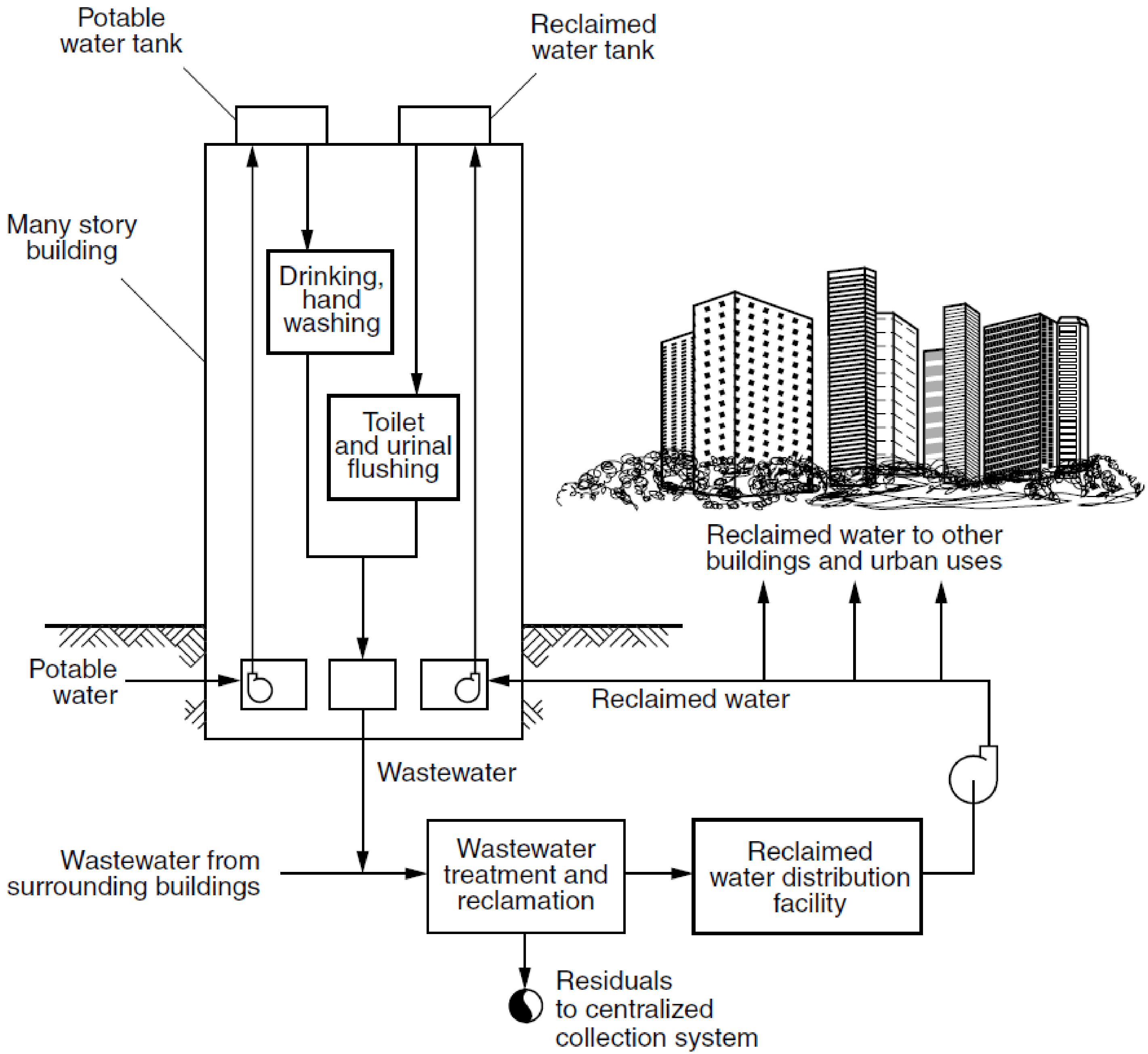
- Tokyo is one of the largest cities in the world, with a population of over 12 million, or about 10 percent of Japan's total population, and a population density of over 5500 inhabitants/km^2
- To maximize the use of limited water resource, the Tokyo Metropolitan Government (TMG) established an ordinance in 1984 to require all newly constructed large buildings, generally within area greater than 3000 to 5000 m^2 and/or buildings with installed water supply pipe diameters of greater than 50 mm, be equipped with dual plumbing systems and use reclaimed water for toilet and urinal flushing
- Reclaimed water quality criteria evolved through several revisions. The original criterion for total coliform was 1000 organisms per 100 mL, much higher than the requirements set forth by California and most other states in the United States (Asano et al., 1996). The most recent revision of Japanese

Reclaimed water quality guidelines for urban uses in Japan[a]

	Unit	Toilet/urinal flushing	Spraying on street and ground	Recreational uses and water features
Total coliform	No./100mL	no detect	no detect	no detect
Turbidity	NTU	2	2	2
pH	pH unit	5.8–8.6	5.8–8.6	5.8–8.6
Appearance	—	not unpleasant	not unpleasant	not unpleasant
Color[b]	CU			<10
Odor[b]	—	not unpleasant	not unpleasant	not unpleasant
Chlorine residual	mg/L	0.1 (free), 0.4 (combined)	0.1 (free), 0.4 (combined)	0.1 (free), 0.4 (combined)
Treatment requirements		Sand filtration or equivalent	Sand filtration or equivalent	Coagulation, sedimentation, and filtration, or equivalent

[a]Adapted from MLIT (2005).
[b]To be adjusted on a case-by-case basis to meet the user's demand.
Note: Water quality is measured at the outflow of the water reclamation plant.

Schematic diagram of an area-wide recycling system in Shinjuku, Tokyo



Reclaimed water quality between April 1994 and January 1995 at Shinjuku, Tokyo[a]

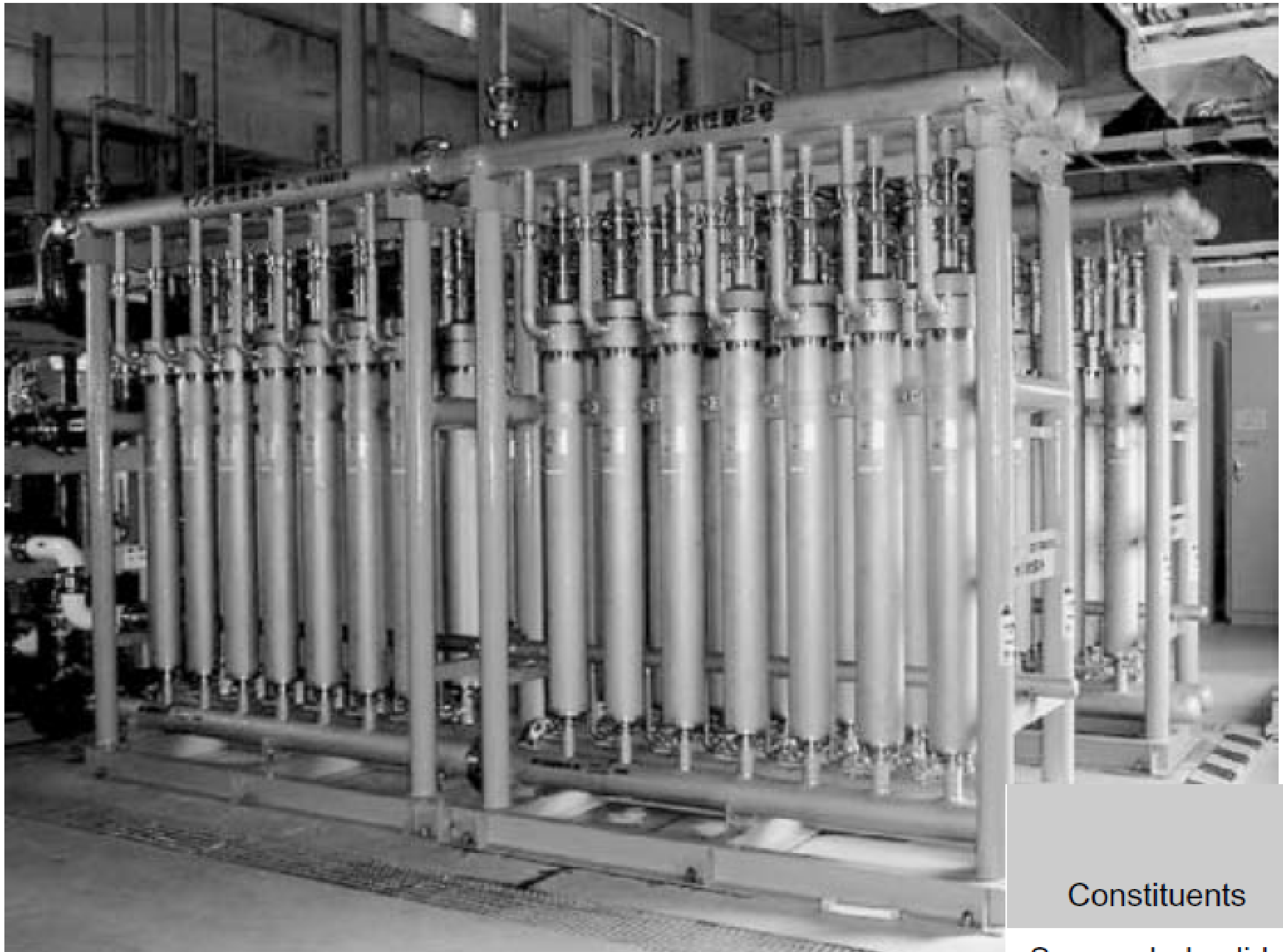
Constituent	Unit	Month									
		4	5	6	7	8	9	10	11	12	1
pH	—	7.2	7.2	7.2	7.0	7.3	7.2	7.1	6.8	7.1	7.5
Total coliform	no./mL	0	0	0	0	0	0	0	0	0	0
Combined chlorine residual	mg/L	0.2	1.5	1.0	0.8	0.2	0.2	0.3	0.2	0.4	1.5
Appearance[b]	—	SY	C	C	C	C	C	C	SY	C	C
Odor[c]	—	WM	WM	WS	WS	WM	WS	SS	MS	MS	SS
BOD	mg/L	2.8	2.5	1.0	2.3	2.0	1.4	1.5	3.0	1.9	4.3
Turbidity	NTU	1	1	1	1	1	0	1	0	1	1
Suspended solids	mg/L	0	—	—	0	—	—	0	—	—	0
Total nitrogen	mg/L	13.0	—	—	9.7	—	—	9.6	—	—	16.0
Total phosphorous	mg/L	0.48	—	—	0.70	—	—	1.00	—	—	0.65

[a]Adapted from Maeda et al. (1996).

[b]SY = slightly yellow; C = clear.

[c]WM = weak mold odor; WS = weak sewage odor; MS = moderate sewage odor; SS = strong sewage odor.

Ozone resistant membranes used for color removal from reclaimed water for toilet and urinal flushing in a high-rise building



Comparison of water quality at the Shibaura wastewater treatment plant before and after the installation of an ozone-resistant microfiltration membrane treatment system

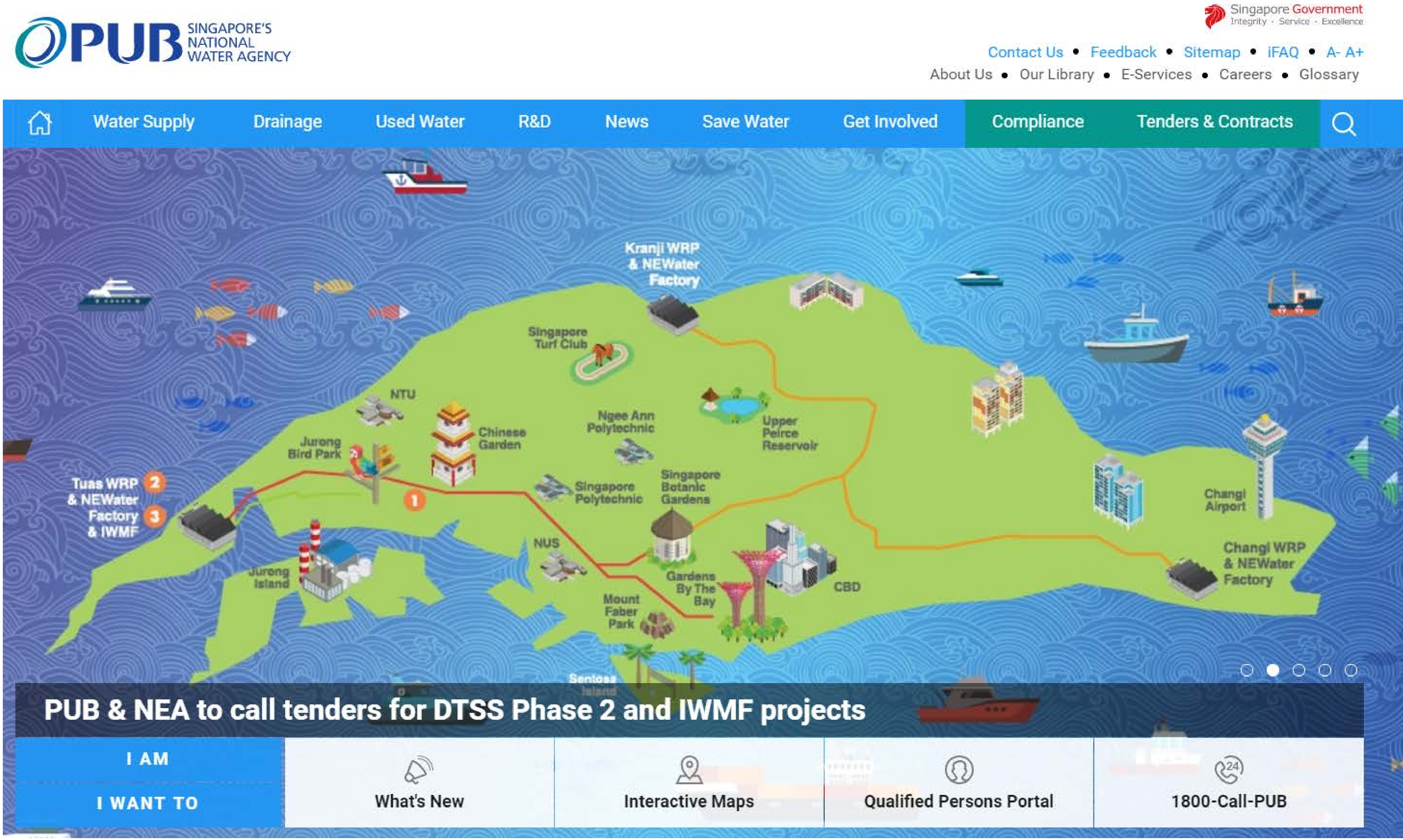
Constituents	Unit	Secondary effluent	Reclaimed water after membrane treatment
Suspended solids	mg/L	10.3	0.0
Turbidity	NTU	9.4	<0.1
Color	CU	40	3
Odor	—	slight moldy smell	no smell detected

NEWater

- NEWater, a pillar of Singapore's water sustainability strategy, is high-grade reclaimed water. Produced from treated used water that is further purified using advanced membrane technologies and ultra-violet disinfection, it is ultra-clean and safe to drink.
- NEWater has passed more than 130,000 scientific tests and is well within World Health Organisation requirements.

Use Each Drop of Water More Than Once

- NEWater was first mooted by PUB in the 1970s. We *(PUB)* were ahead of our time as the membranes then were costly and unreliable. In 1998, a NEWater study was successfully conducted to determine the suitability of using NEWater as a source of raw water to supplement Singapore’s water supply. In May 2000, the first NEWater plant was completed and by 2001, we had embarked on this new initiative that would increase water supply from unconventional sources for no-potable use.
- Presently Singapore's four NEWater plants can meet up to 30% of the nation’s current water needs. By 2060, NEWater is expected to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Tenders & Contracts
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Singapore Turf Club
NTU
Jurong Bird Park
Chinese Garden
Ngee Ann Polytechnic
Upper Peirce Reservoir
Tuas WRP & NEWater Factory & IWMF
Singapore Polytechnic
Singapore Botanic Gardens
Changi Airport
NUS
Jurong Island
Gardens By The Bay
CBD
Changi WRP & NEWater Factory
Mount Faber Park
Sentosa Island
PUB & NEA to call tenders for DTSS Phase 2 and IWMF projects
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I WANT TO
What's New
Interactive Maps
Qualified Persons Portal
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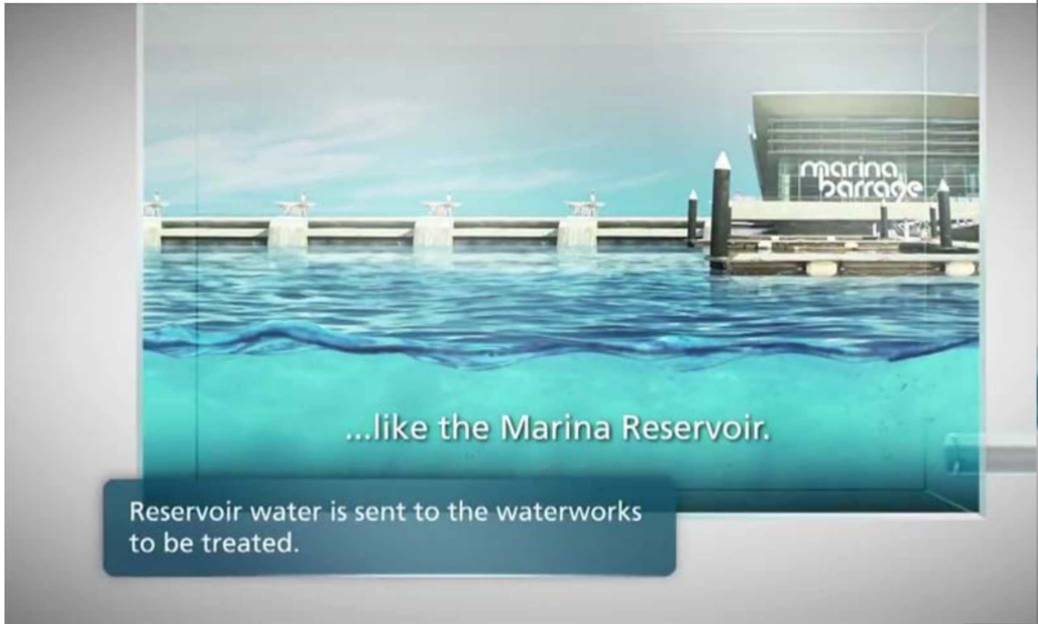
Site of PUB

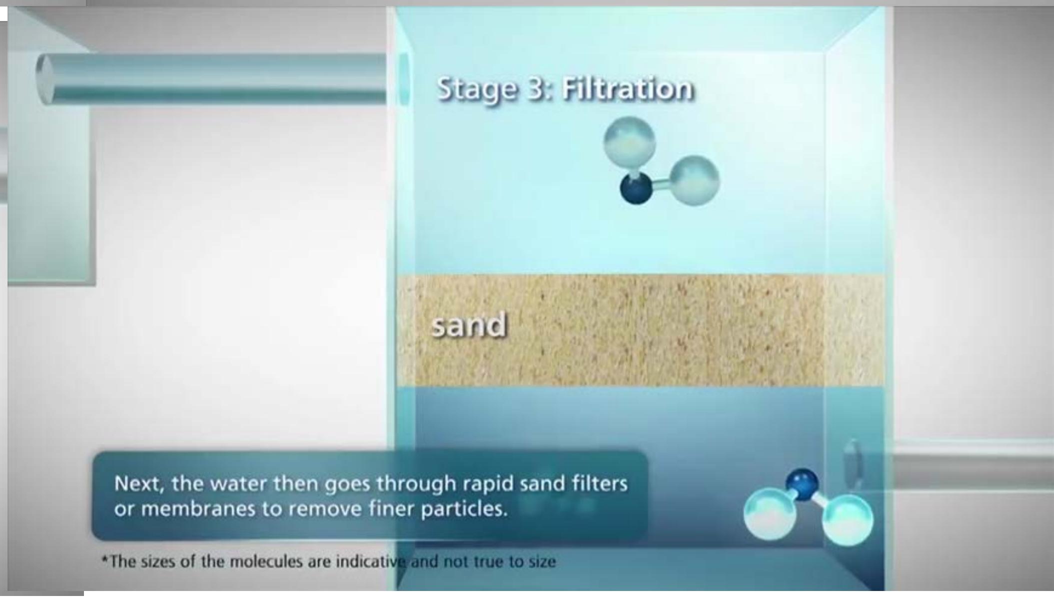
Imported Water

Under two bilateral agreements, Singapore has been importing water from Johor, Malaysia. The first agreement expired in August 2011. The second agreement will expire in 2061.

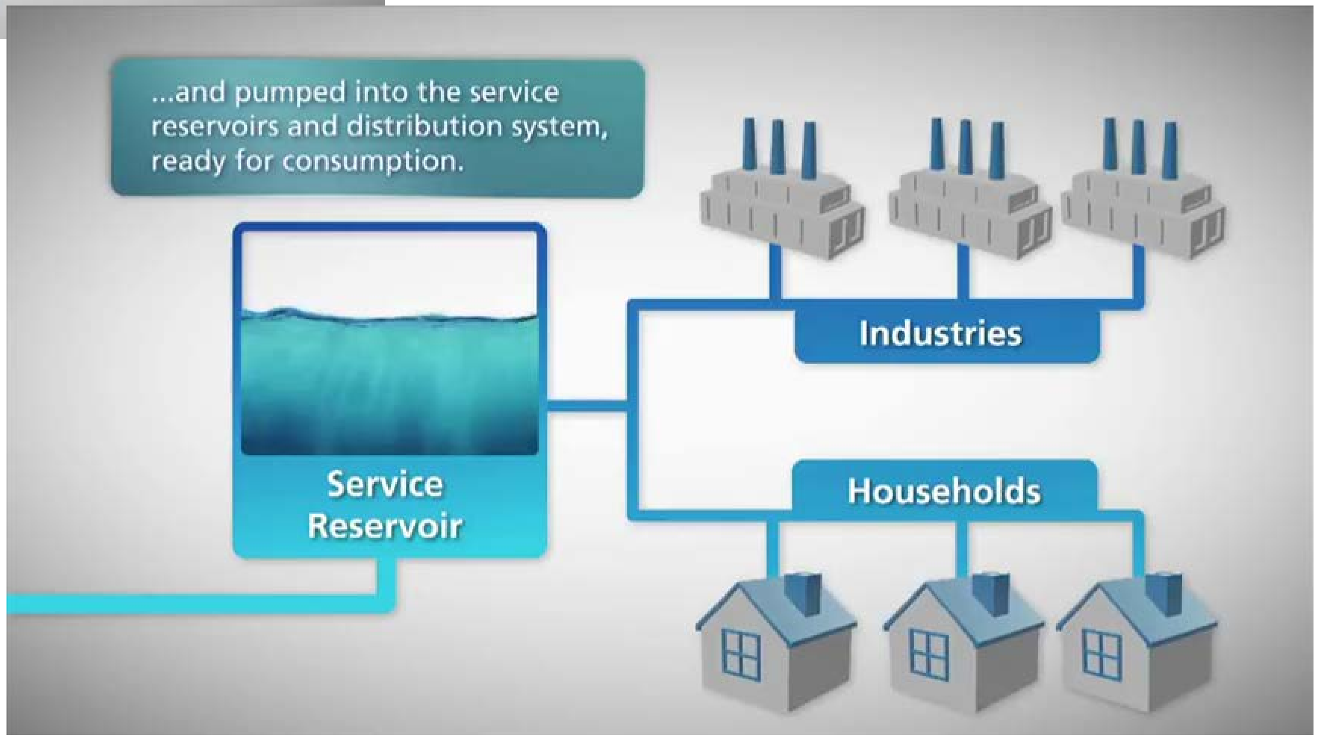
How tap water is treated in Singapore / 1

How tap water is treated in Singapore / 2

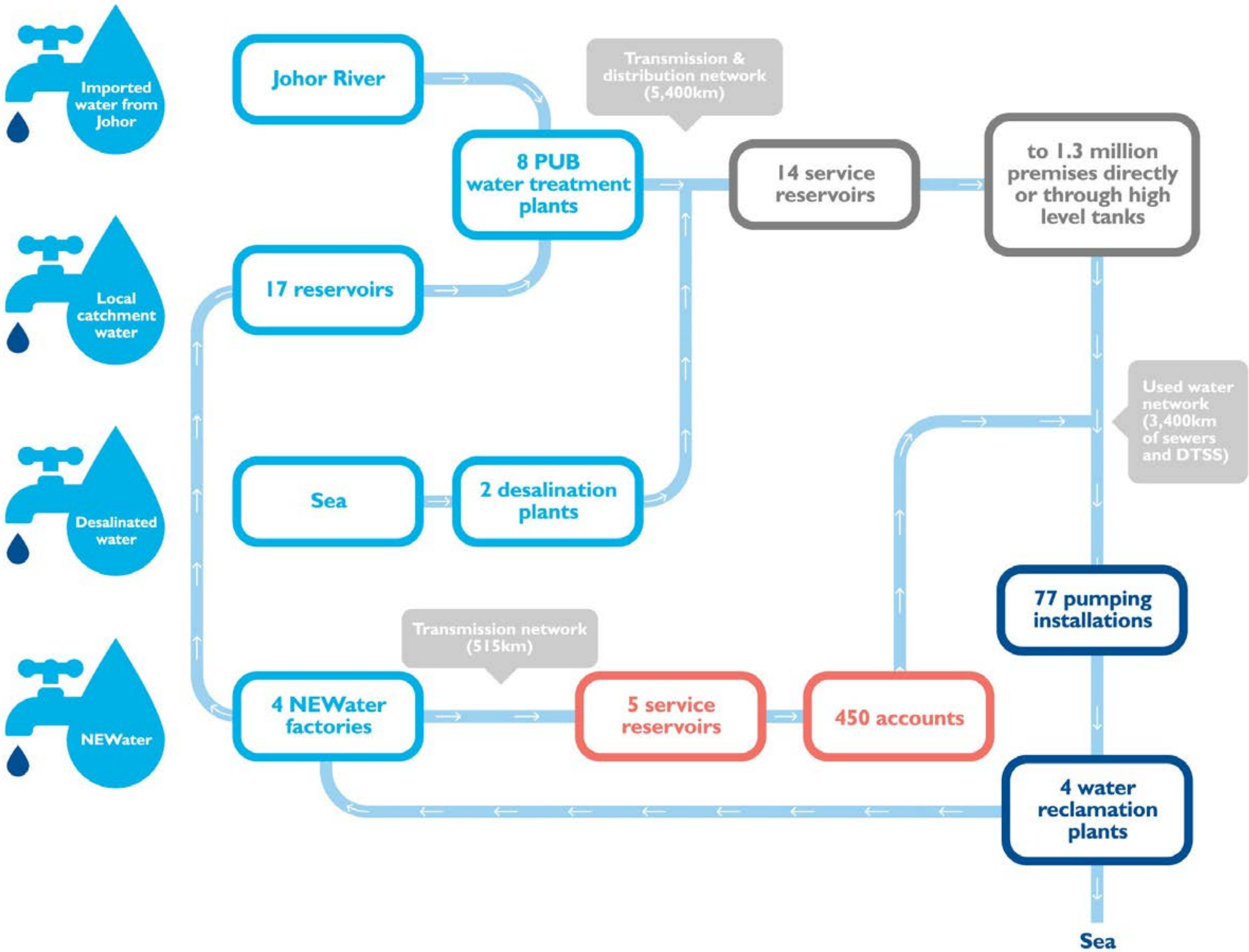




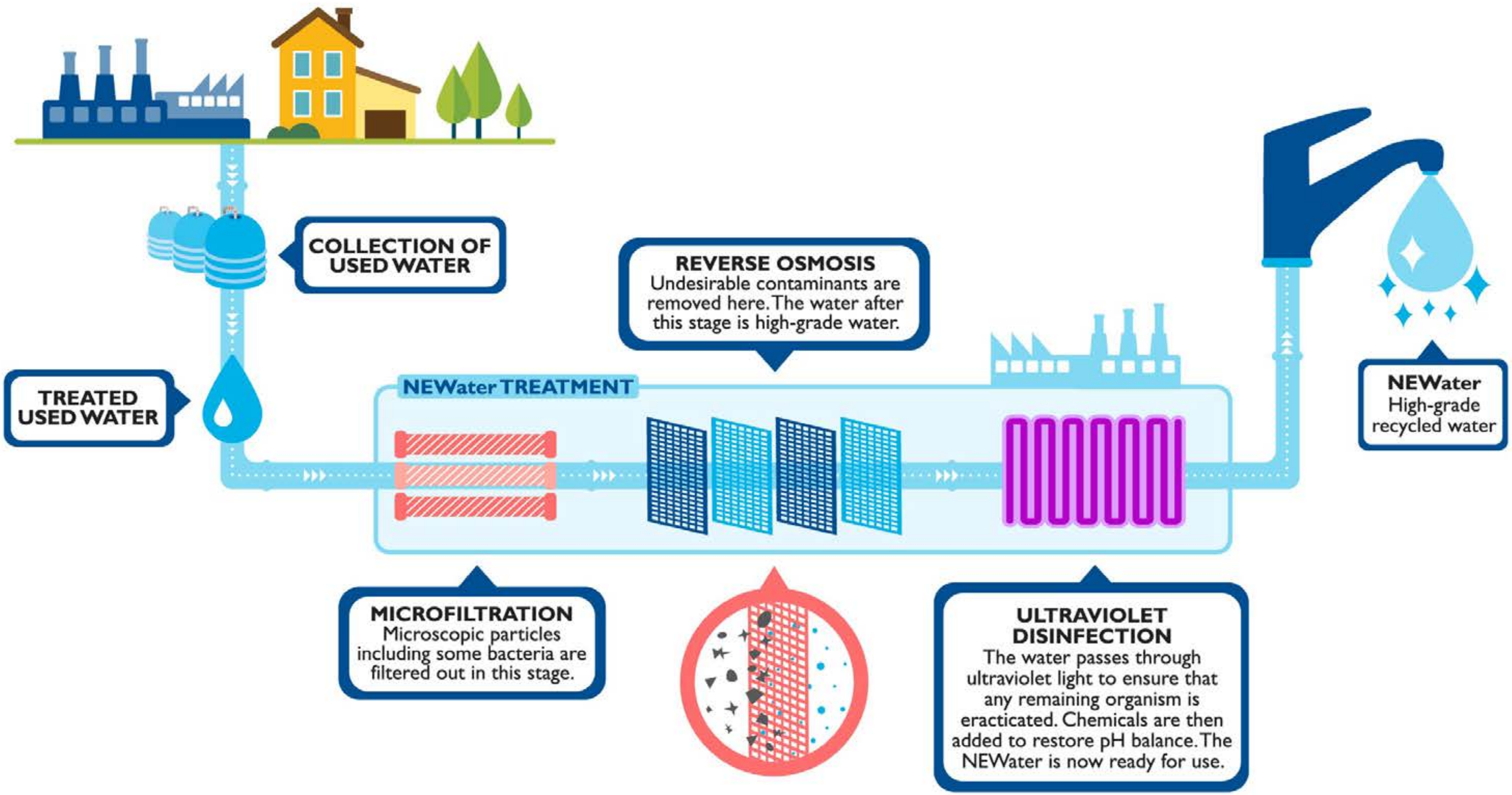
How tap water is treated in Singapore / 3



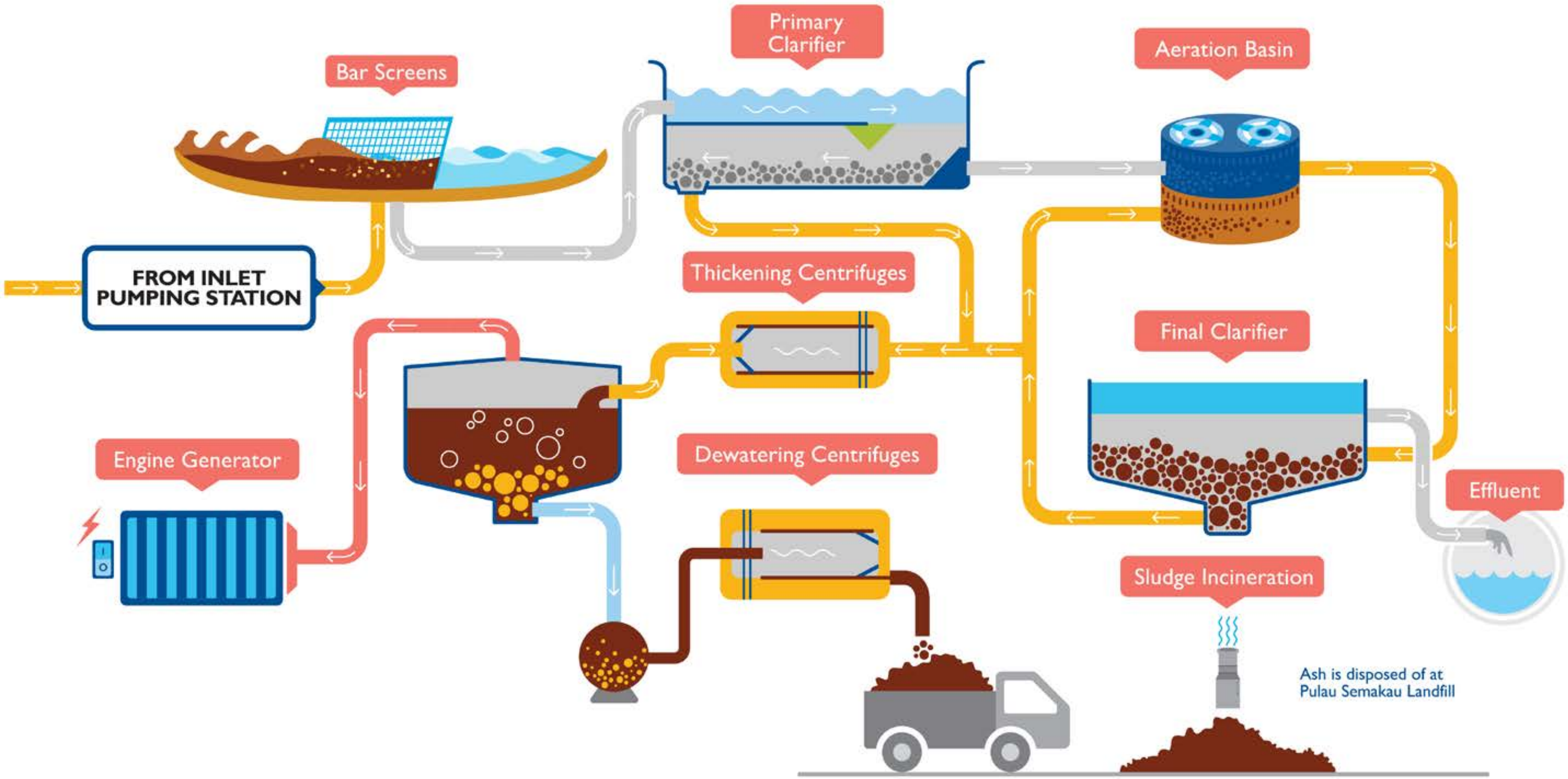
Diversifying Water Supply



NEWater Technology

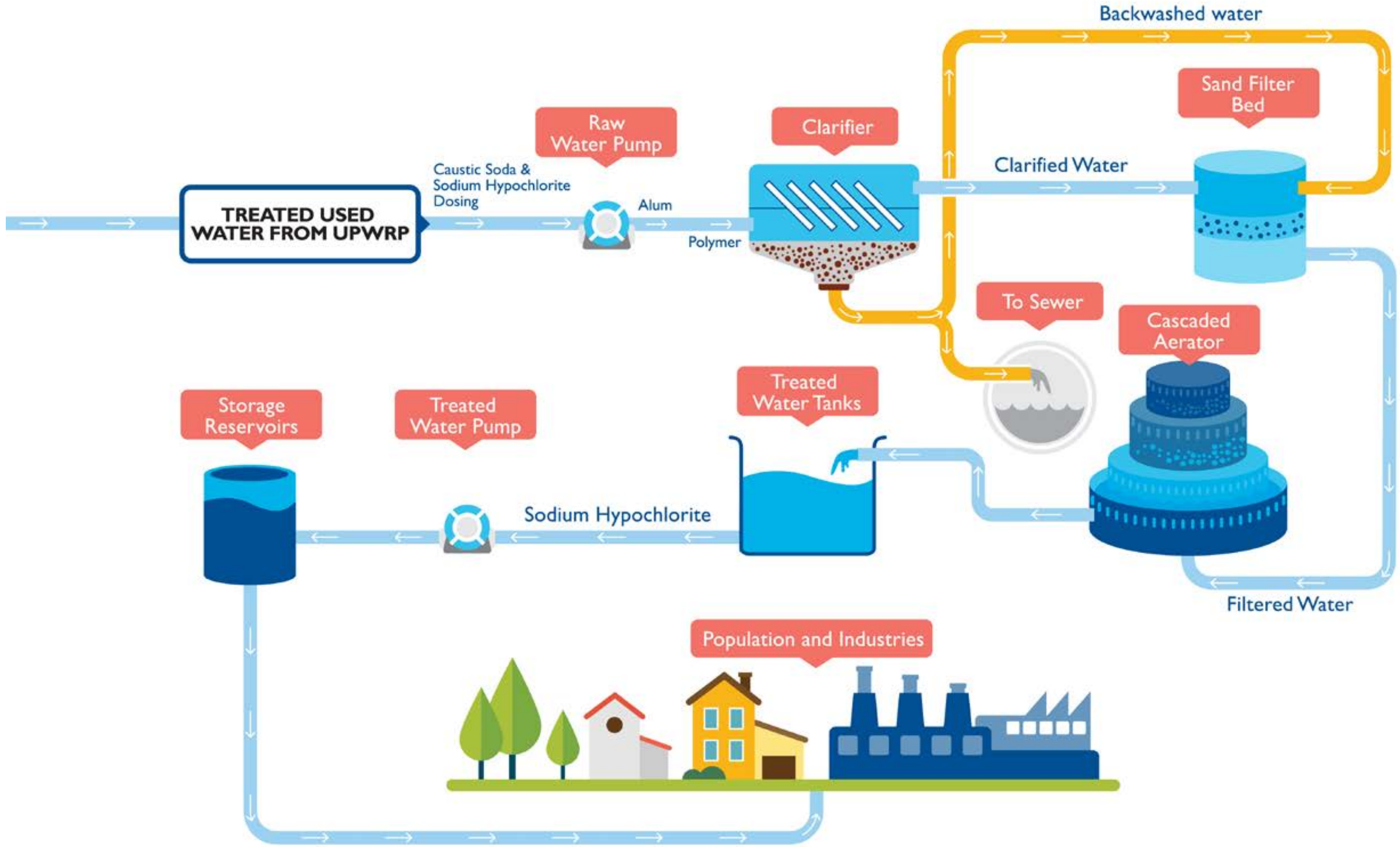


Used Water Treatment Process - 1



Used water from both domestic and non-domestic sources is collected through a comprehensive network of underground public sewers. Used water from trade sources and industries are required to meet certain standards before it can be discharged into public sewers. The collected used water is treated at five water reclamation plants to render it clean for reuse or discharge into watercourses.

Used Water Treatment Process - 2



Jurong Industrial Water Works (JIWW) was set up to reclaim wastewater effluent of the Ulu Pandan Water Reclamation Plant (UPWRP). The purpose of wastewater effluent reclamation is to provide an alternative source of water for industries in the Jurong and Tuas Industrial Estate.

From an original capacity of 45,000 m^3 per day, the current capacity is increased to 125,000 m^3 per day over the years to cater for industries set up on Jurong Island and Tuas South.

The Treatment Process / 1

Screening (1):
The raw water enters the Works from UPWRP through the intake chamber into the bandscreen chamber. Large suspended solids and debris of sizes greater than 4mm are removed with the help of bandscreen equipment.

Pre-Clorination and pH Correction (2)
The water then flows into the raw water pump sump where it is dosed with sodium hypochlorite solution. This process, known as pre-chlorination, helps to suppress algae and bacterial growth on the surfaces of downstream units thereby reducing the amount of maintenance work required to keep these units clean. Caustic soda is also dosed when necessary to maintain the desired pH level as acidic raw water will cause erosion problems to the downstream units.

The Treatment Process / 2

After pre-chlorination and pH correction, the raw water is pumped to the **clarifiers (3)** via the raw water pumps. At the clarifiers, the raw water is dosed with chemicals called aluminium sulphate (Alum) to bring about the coagulation, flocculation and sedimentation of the suspended solids in the raw water. The primary purpose of chemical clarification is for the removal of suspended solids and reduction of phosphates.

The clarified water from the clarifier flows by gravity into the **sand filters (4)** where the remaining fine suspended solids are removed. Filter beds are regenerated regularly by means of backwashing using industrial water. The suspended solids that are trapped on the sand filters are then desludged into the sewer.

The Treatment Process / 3

The filtered water is then sent by gravity to the **cascade aerator (5)** to increase dissolved oxygen in the water.

plus **post-chlorination (6)**:
This is the final stage of the treatment process. The filtered water is channelled to the treated water tank where sodium hypochlorite is dosed to disinfect the treated water.

After the post-chlorination process, the treated water is ready to be supplied to the industrial consumers. The treated water is pumped to the 3 **industrial water reservoirs (7)** (total capacity: 35,000 m^3) situated on Jurong Island via the high-lift pumps and along the underground pumping mains.

Effective water reclamation and reuse facilities should include the following elements:

- assessment of wastewater treatment and disposal needs
- assessment of water supply and demand
- assessment of water supply benefits based on water reuse potential
- analysis of reclaimed water market

Integrated water resources planning	A process that promotes the coordinated development and management of water, land, and related resources to maximize the resultant economic and social welfare in an equitable sustainable manner.

- a public information program

and finally:

Thank you!