Environmental Protection Department

Marine Water Quality in Hong Kong in 2003

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Results for 2003 from the
Marine Monitoring Programme
of the Environmental Protection Department

Monitoring Section
Water Policy and Planning Group
Environmental Protection Department
Government of the Hong Kong Special Administrative Region
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Marine Water Quality in Hong Kong in 2003

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  for providing information on the geography, major activities and uses of marine water.

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Summary of Marine Water Quality in Hong Kong in 2003

In 2003, the marine water quality of Hong Kong was largely similar to that in 2002. The overall compliance with the Water Quality Objectives (WQOs) at 87% was among the best ever recorded.

The water quality of Port Shelter and Mirs Bay continued to be excellent, with low sewage bacteria, nutrients and high dissolved oxygen (DO). On the other hand, the water quality in Inner Deep Bay was poor with lower DO and elevated levels of nitrogen and phosphorus, showing signs of further deterioration.

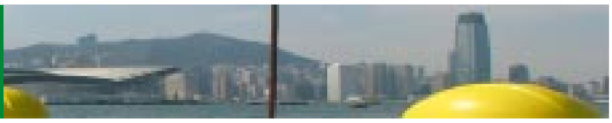
The water quality in Tolo Harbour continued to improve with declines in organic and inorganic pollutants and a decrease in hypoxia. The Southern water experienced a marked reduction in total inorganic nitrogen (TIN) in 2003, which resulted in an improvement in the compliance with the WQOs.

The commissioning of the Harbour Area Treatment Scheme (HATS) Stage I in 2002 has resulted in a significant improvement in the eastern and central parts of Victoria Harbour, including an increase in DO, decreases in TIN and *E.coli* bacteria. These water quality improvements were sustained in 2003.

There was a widespread reduction of DO of around 10% in Hong Kong waters in 2003. This might be related to the unusually warm, dry and calm weather during the year.

CHAPTER 1

INTRODUCTION



Chapter 1 - Introduction

Introduction

1.1 The Hong Kong Special Administrative Region (HKSAR) has a land area of 1,103km^2 and 1,651km^2 area of marine waters. It has long coastlines, including 458km in Kowloon Peninsula and New Territories and 724km in Hong Kong Island, Lantau Island and other small islands. There are more than 260 islands in the territory, each with an area greater than 500m^2.

1.2 With a population approaching 7 million, Hong Kong relies heavily on its coastal water for a variety of uses such as recreation, fish culture, cooling, toilet flushing, transport and effluent disposal. There is also a rich array of marine life in Hong Kong ranging from microscopic planktons, corals to dolphins and porpoises.

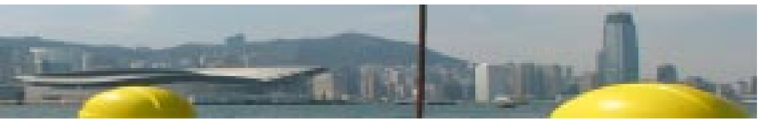
1.3 To protect the ecology and beneficial uses of Hong Kong marine waters, a set of Water Quality Objectives (WQOs) (Table 1.1) was established for each of the 10 Water Control Zones (WCZs) (Figure 1.1). The HKSAR Government aims to achieve the WQOs by implementing pollution abatement measures to reduce pollution and improve water quality. In order to assess the state of health of the marine environment and its long-term changes, and to measure the compliance with the WQOs, the Environmental Protection Department (EPD) implements a comprehensive marine monitoring programme.

Marine Monitoring Programme

1.4 The current marine monitoring programme was set up in 1986. Monitoring is mostly conducted onboard a 26-metre monitoring vessel *Dr. Catherine Lam*. The vessel is equipped with an advanced Differential Global Positioning System (DGPS) and an electronic navigation chart system for precise location of monitoring stations in the sea.

1.5 A conductivity-temperature-depth (CTD) profiler linked to a computer -controlled rosette water sampler, is used for *in situ* measurement of a number of physical and chemical parameters and for collecting water samples. Bottom sediment samples are collected using a sediment grab. The water and sediment samples are analysed by EPD's laboratories and Government Laboratory (http://www.info.gov.hk/govlab) for over 80 physical, chemical and biological parameters (see Tables 1.2 and 1.3 for analytical methods).

1.6 In 2003, a total of 94 water quality stations were monitored (Table 1.4): 76 in open



waters (Figure 1.2) sampled once a month; and 18 in typhoon shelters (Figure 1.4) sampled once every two months. Sea bottom sediments were monitored twice a year at 60 stations: 45 in open waters (Figure 1.3) and 15 in typhoon shelters (Figure 1.4).

Uses and Characteristics of Marine Water

1.7 Human activities affect the quality of the receiving water body. Similarly, water quality also determines the suitability of water for specific uses. Areas of Hong Kong marine waters with major activities and uses include:

- Bathing beaches, secondary contact recreation areas, and seawater abstraction points (Figure 1.5)
- Fish culture zones and marine conservation areas (Figure 1.6)
- Disposal areas for dredged materials, public filling areas and major reclamation sites (Figure 1.7)
- Disposal of treated effluent from major public sewage treatment works and outfalls (Figure 1.8)

Annual Report on Marine Water Quality

1.8 This is EPD's 18th annual Marine Water Quality Report. It reports on the state of Hong Kong marine waters in 2003 and their compliance with the key Water Quality Objectives (WQOs) (Figures 15.5 and 15.6). The Seasonal Kendall statistical test was applied to detect long-term water quality trends, and the increase or decrease of pollutants in the last 18 years (1986–2003). In addition, the Wilcoxon-Mann-Whitney test was also used to reveal significant variations of water quality parameters between 2003 and 2002.

1.9 The 2003 Marine Water Quality Report (CD-ROM version) is found in many public libraries (http://www.hkpl.gov.hk) and EPD's Environmental Resource Centres. The report and monitoring data are also available on EPD's website (http://www.epd.gov.hk) for public's viewing and free download.

Figure 1.1 Water Control Zones in Hong Kong

(Sources: Environmental Protection Department and Environment, Transport and Works Bureau - Plan No. WP/WP4/75, Nov 1999)

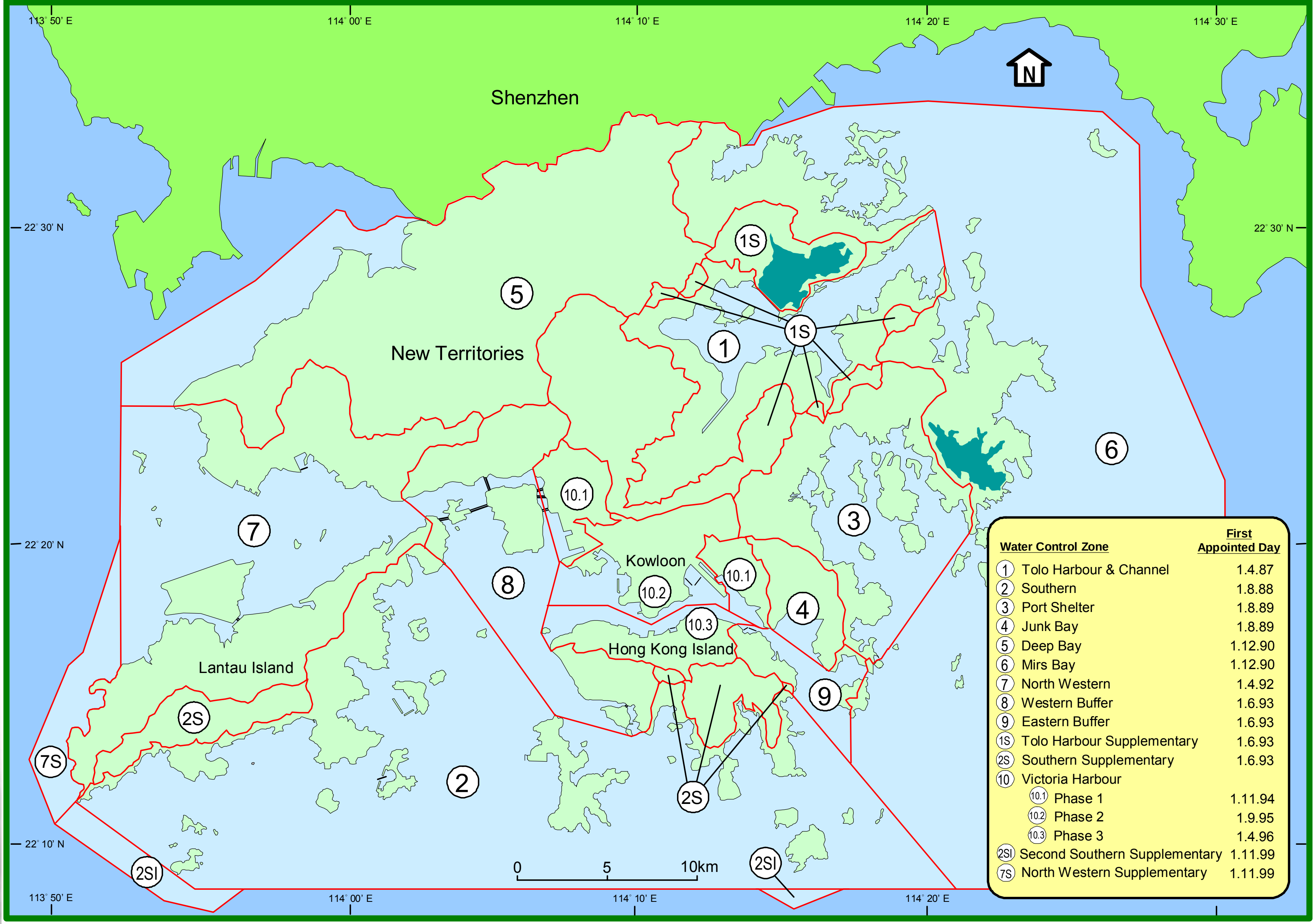


Figure 1.2 76 water quality monitoring stations in open waters of Hong Kong in 2003

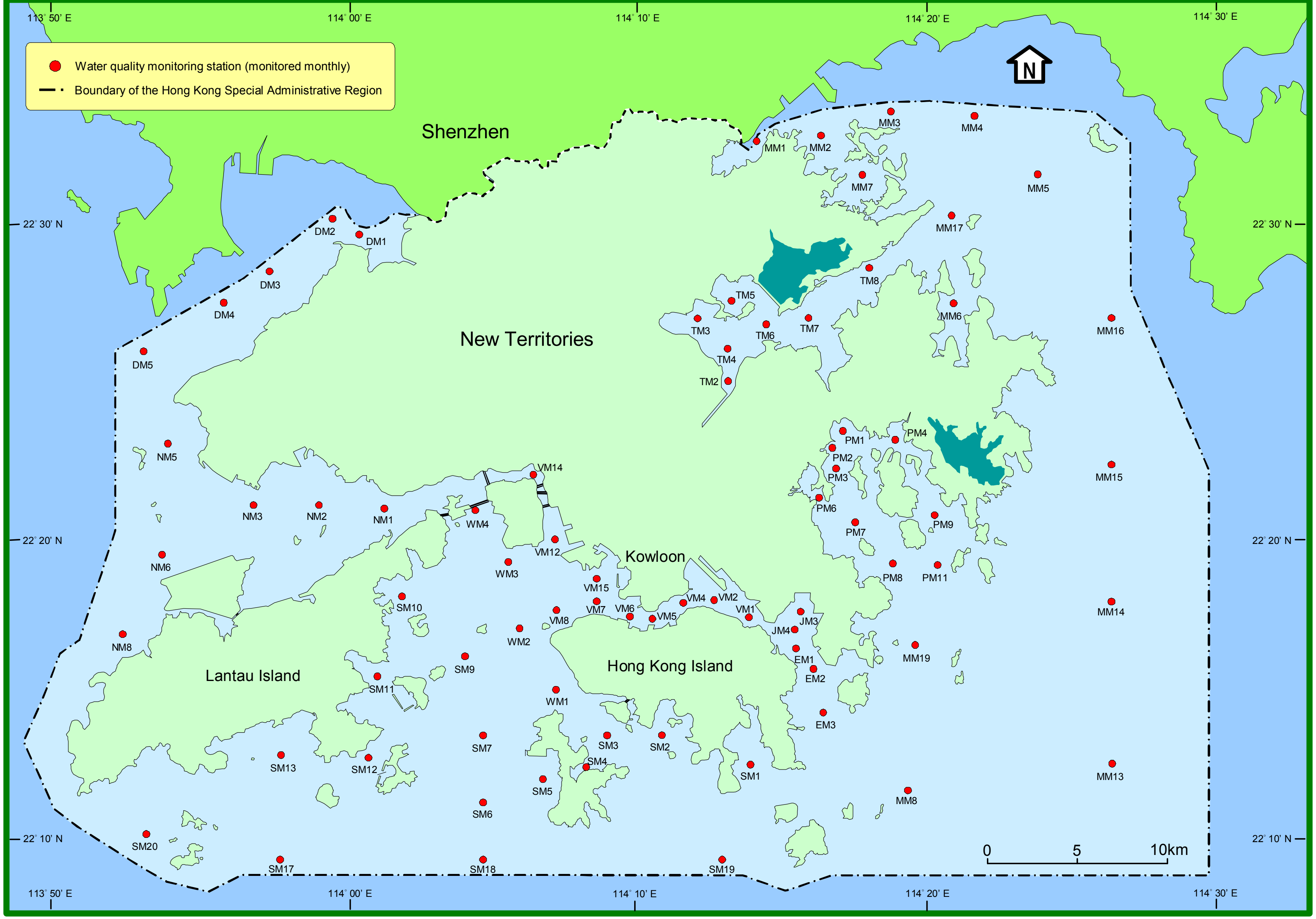
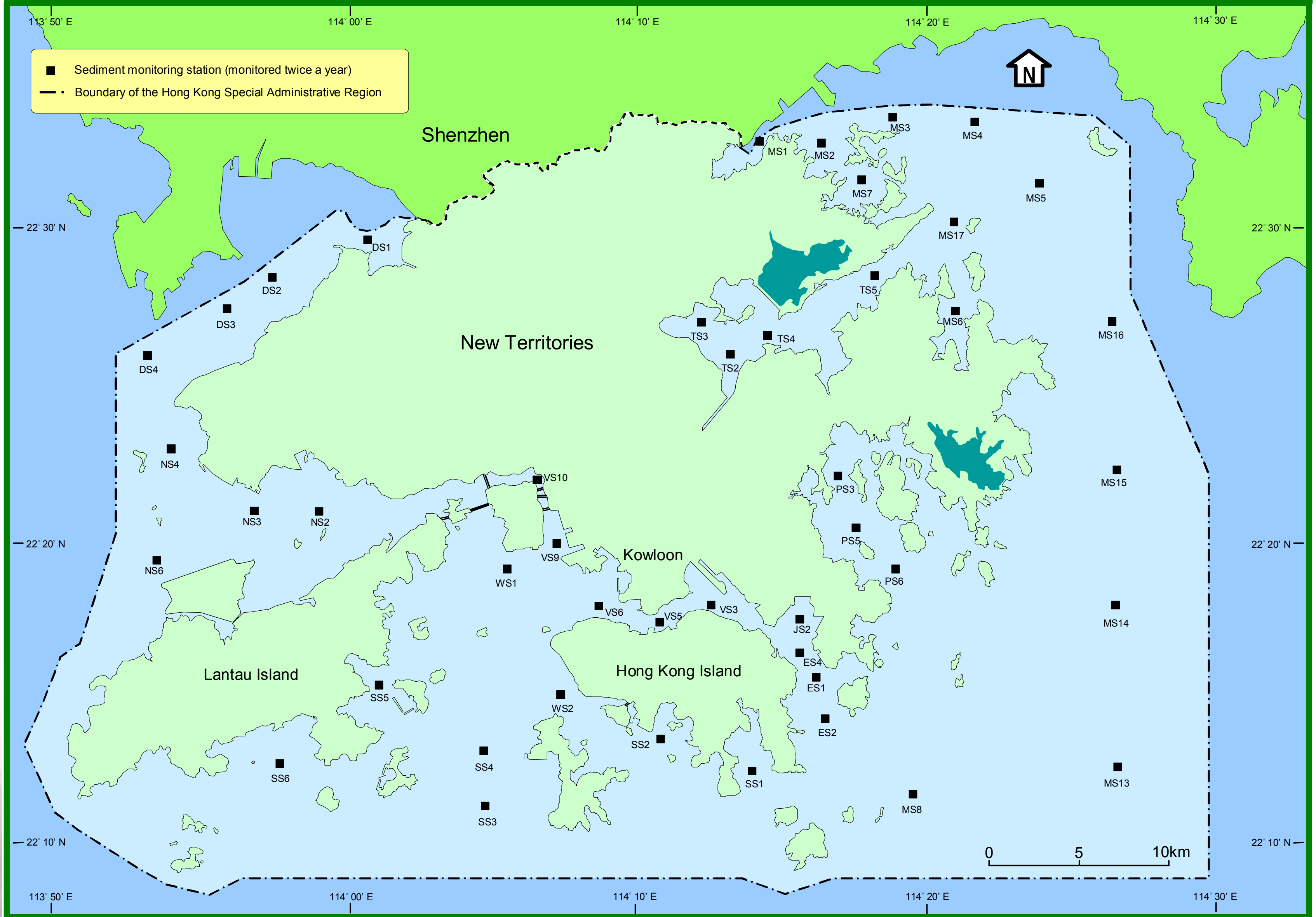


Figure 1.3 45 sediment monitoring stations in open waters of Hong Kong in 2003



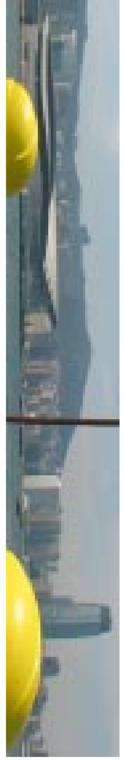
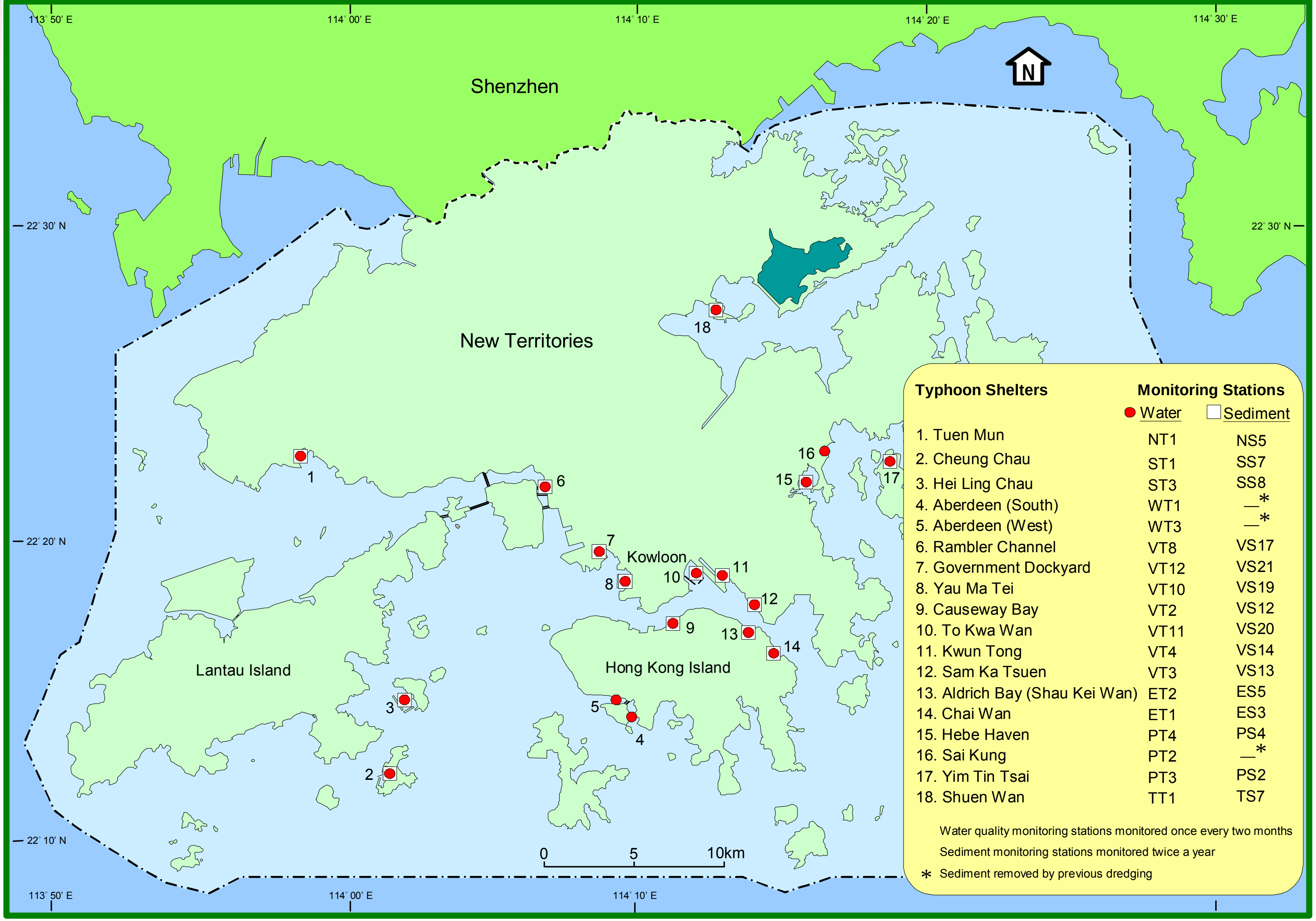


Figure 1.4 18 water quality monitoring stations and 15 sediment monitoring stations in typhoon shelters of Hong Kong in 2003



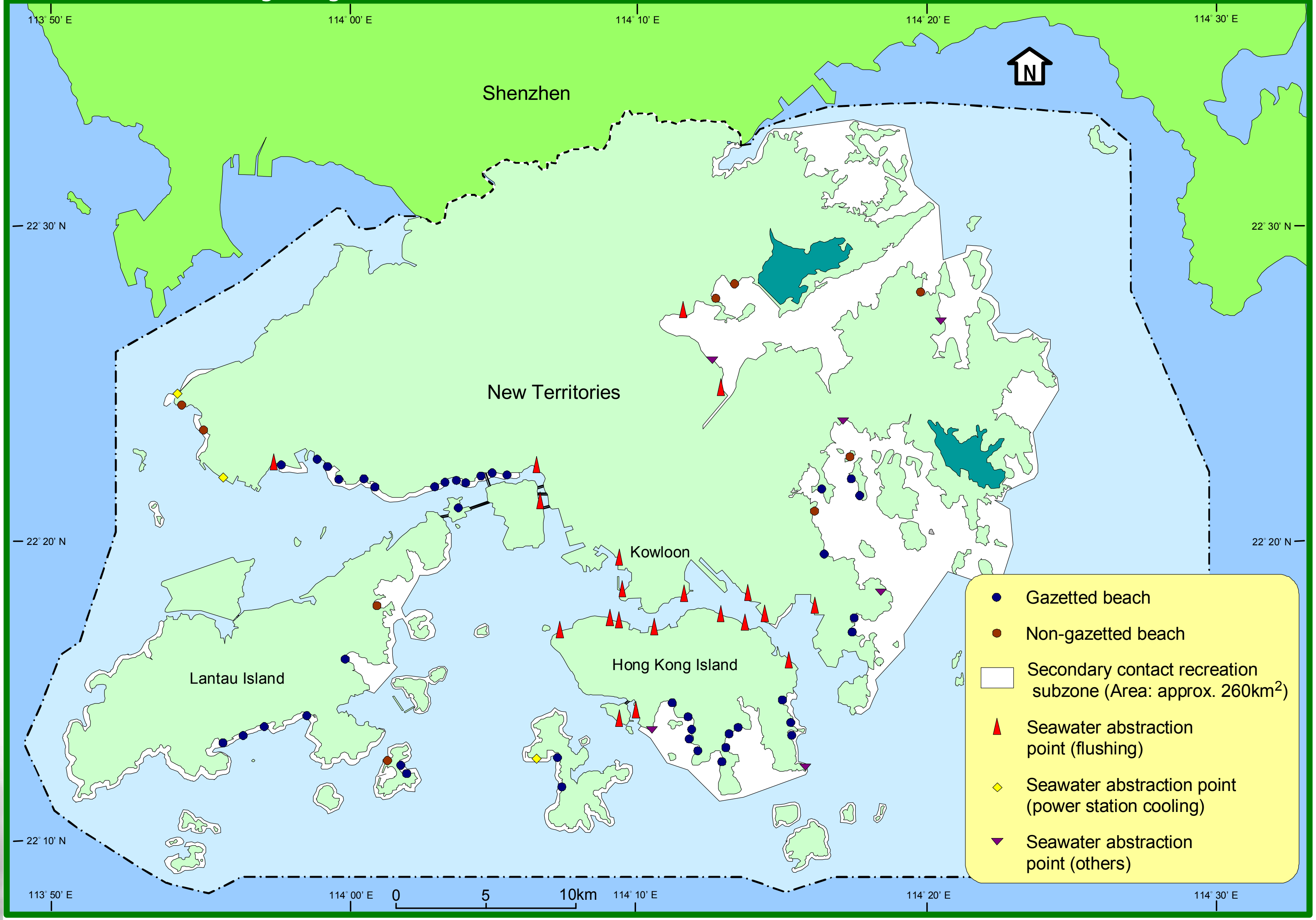
Typhoon Shelters	Monitoring Stations: Water	Monitoring Stations: Sediment
1. Tuen Mun	NT1	NS5
2. Cheung Chau	ST1	SS7
3. Hei Ling Chau	ST3	SS8
4. Aberdeen (South)	WT1	—*
5. Aberdeen (West)	WT3	—*
6. Rambler Channel	VT8	VS17
7. Government Dockyard	VT12	VS21
8. Yau Ma Tei	VT10	VS19
9. Causeway Bay	VT2	VS12
10. To Kwa Wan	VT11	VS20
11. Kwun Tong	VT4	VS14
12. Sam Ka Tsuen	VT3	VS13
13. Aldrich Bay (Shau Kei Wan)	ET2	ES5
14. Chai Wan	ET1	ES3
15. Hebe Haven	PT4	PS4
16. Sai Kung	PT2	—*
17. Yim Tin Tsai	PT3	PS2
18. Shuen Wan	TT1	TS7

Water quality monitoring stations monitored once every two months

Sediment monitoring stations monitored twice a year

* Sediment removed by previous dredging

Figure 1.5 Bathing beaches, secondary contact recreational areas, and seawater abstraction points in Hong Kong in 2003 (Sources: Environmental Protection Department and Water Services Department)



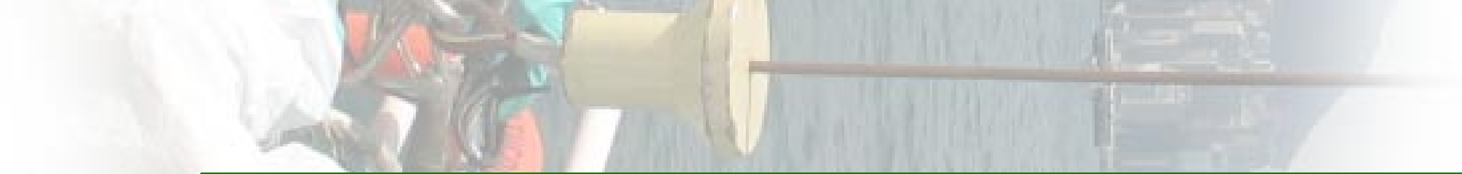
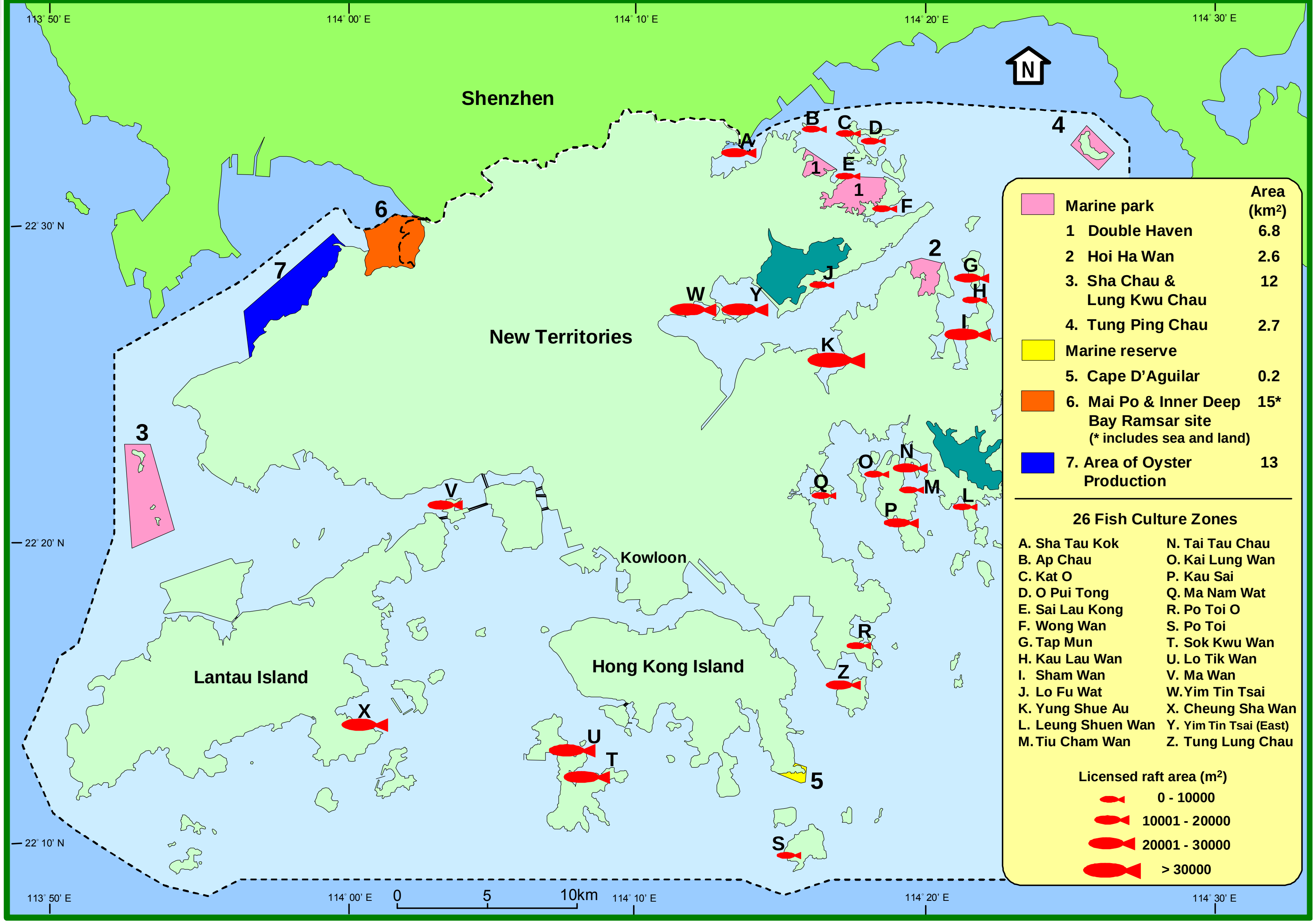


Figure 1.6 Fish culture zones and marine conservation sites in Hong Kong in 2003

(Sources: Agriculture, Fisheries and Conservation Department)



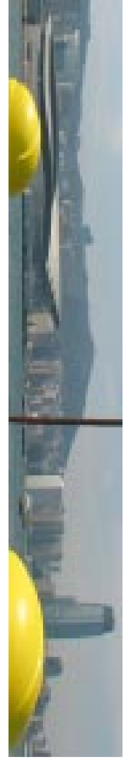
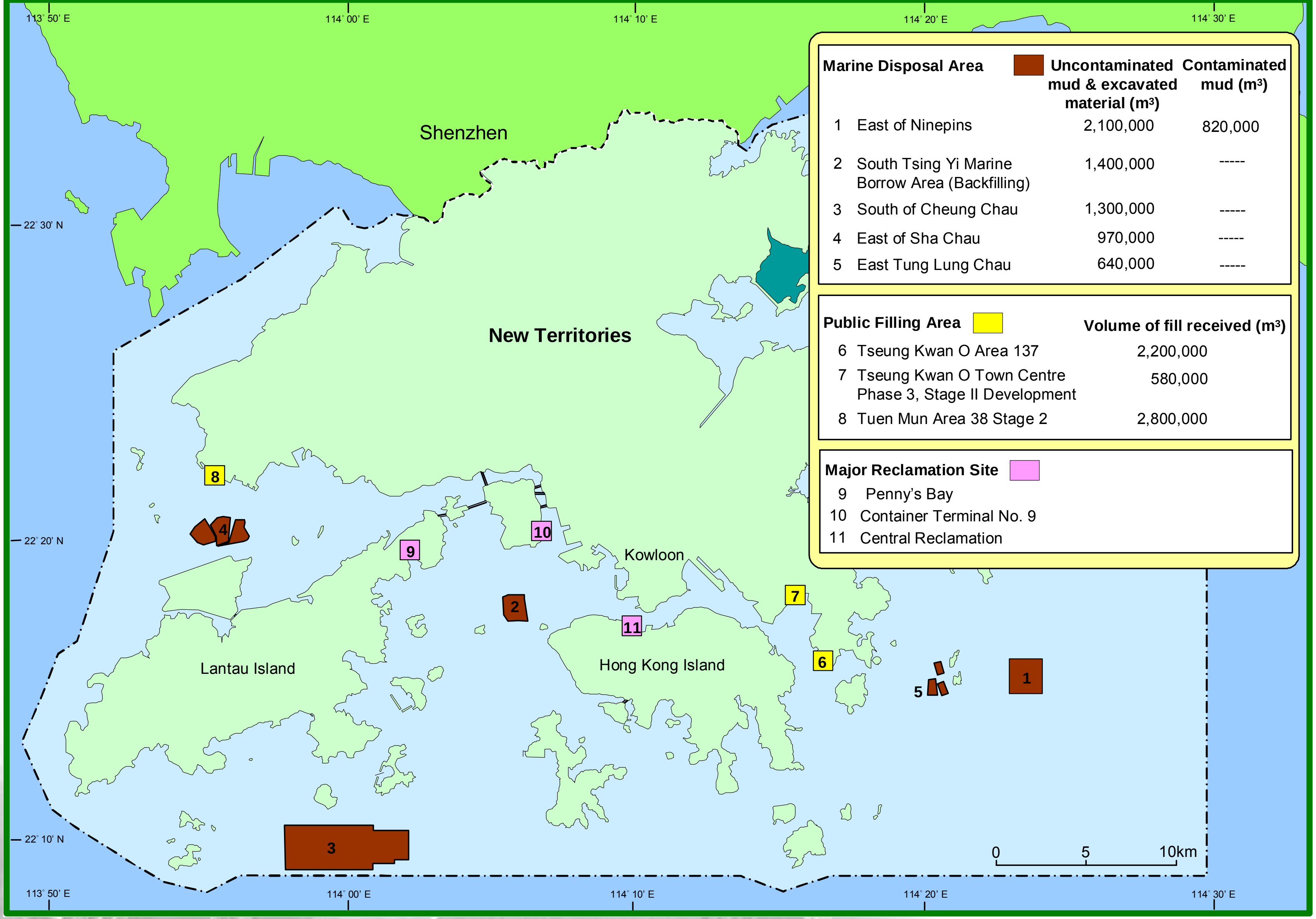


Figure 1.7 Marine disposal, public filling areas and major reclamation sites in Hong Kong in 2003
(Sources: Civil Engineering Department and Environmental Protection Department)

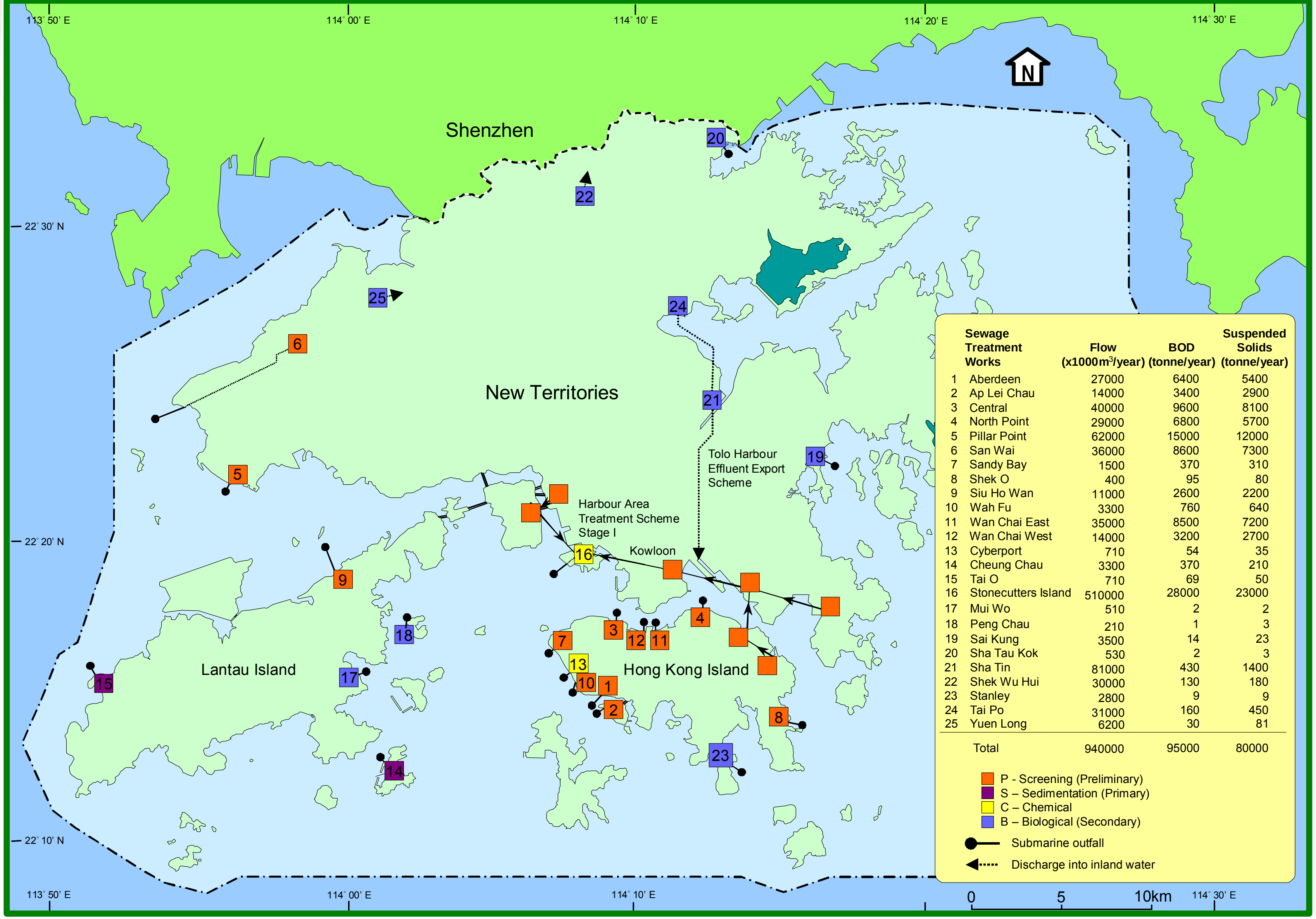


Marine Disposal Area		Uncontaminated mud & excavated material (m³)	Contaminated mud (m³)
1	East of Ninepins	2,100,000	820,000
2	South Tsing Yi Marine Borrow Area (Backfilling)	1,400,000	-----
3	South of Cheung Chau	1,300,000	-----
4	East of Sha Chau	970,000	-----
5	East Tung Lung Chau	640,000	-----

Public Filling Area		Volume of fill received (m³)
6	Tseung Kwan O Area 137	2,200,000
7	Tseung Kwan O Town Centre Phase 3, Stage II Development	580,000
8	Tuen Mun Area 38 Stage 2	2,800,000

Major Reclamation Site	
9	Penny's Bay
10	Container Terminal No. 9
11	Central Reclamation

Figure 1.8 Major public sewage treatment works, outfalls and pollution loads in Hong Kong in 2003
(Sources: Drainage Services Department and Evironmental Protection Department)



Sewage Treatment Works		Flow (x1000m^3/year)	BOD (tonne/year)	Suspended Solids (tonne/year)
1	Aberdeen	27000	6400	5400
2	Ap Lei Chau	14000	3400	2900
3	Central	40000	9600	8100
4	North Point	29000	6800	5700
5	Pillar Point	62000	15000	12000
6	San Wai	36000	8600	7300
7	Sandy Bay	1500	370	310
8	Shek O	400	95	80
9	Siu Ho Wan	11000	2600	2200
10	Wah Fu	3300	760	640
11	Wan Chai East	35000	8500	7200
12	Wan Chai West	14000	3200	2700
13	Cyberport	710	54	35
14	Cheung Chau	3300	370	210
15	Tai O	710	69	50
16	Stonecutters Island	510000	28000	23000
17	Mui Wo	510	2	2
18	Peng Chau	210	1	3
19	Sai Kung	3500	14	23
20	Sha Tau Kok	530	2	3
21	Sha Tin	81000	430	1400
22	Shek Wu Hui	30000	130	180
23	Stanley	2800	9	9
24	Tai Po	31000	160	450
25	Yuen Long	6200	30	81
	Total	940000	95000	80000

P - Screening (Preliminary)
S – Sedimentation (Primary)
C – Chemical
B – Biological (Secondary)
Submarine outfall
Discharge into inland water

Table 1.1

Summary of Water Quality Objectives (WQOs) for marine waters of Hong Kong

Parameter	Water Quality Objective	Water Control Zone (WCZ) / Part(s) of zone / Subzone to which the WQO applies
Dissolved Oxygen (bottom)	Not less than 2 mg/L for 90% samples ;	Marine waters of all WCZs except Tolo Harbour & Channel WCZ
Dissolved Oxygen (Depth-averaged)	Not less than 4 mg/L for 90% samples ;	Marine waters of all WCZs except Tolo Harbour & Channel WCZ
Dissolved Oxygen (bottom)	Not less than 2mg/L	Harbour Subzone in Tolo Harbour & Channel WCZ
	Not less than 3mg/L	Buffer Subzone in Tolo Harbour & Channel WCZ
	Not less than 4mg/L	Channel Subzone in Tolo Harbour & Channel WCZ
Dissolved Oxygen (surface to 2m above bottom)	Not less than 4mg/L	Harbour Subzone and Buffer Subzone in Tolo Harbour & Channel WCZ
Dissolved Oxygen (all depths)	Not less than 4mg/L	Channel Subzone in Tolo Harbour & Channel WCZ
Nutrients	Annual mean depth-averaged inorganic nitrogen not to exceed 0.1 mg/L	Marine waters of Southern WCZ and Port Shelter WCZ
	Annual mean depth-averaged inorganic nitrogen not to exceed 0.3 mg/L	Marine waters of Mirs Bay WCZ, Junk Bay WCZ, North Western WCZ (Castle Peak Subzone)
	Annual mean depth-averaged inorganic nitrogen not to exceed 0.4 mg/L	Marine waters of Eastern Buffer WCZ, Western Buffer WCZ, Victoria Harbour WCZ.
	Annual mean depth-averaged inorganic nitrogen not to exceed 0.5 mg/L	Marine waters of Deep Bay WCZ (Outer Subzone) and North Western WCZ (Whole zone except Castle Peak Subzone).
	Annual mean depth-averaged inorganic nitrogen not to exceed 0.7 mg/L	Marine waters of Deep Bay WCZ (Inner Subzone)
Unionised ammonia	Annual mean not to exceed 0.021 mg/L	All WCZs (whole zone) except Tolo Harbour & Channel WCZ
E. coli	Annual geometric mean not to exceed 610cfu/100mL	Secondary contact recreation subzones in Tolo Habour & Channel WCZ, Southern WCZ, Port Shelter WCZ, Mirs Bay WCZ, Deep Bay WCZ, North Western WCZ, Western Buffer WCZ.
	Annual geometric mean not to exceed 610cfu/100mL	Fish culture subzones in Tolo Habour & Channel WCZ, Southern WCZ, Port Shelter WCZ, Junk Bay, Mirs Bay WCZ, Deep Bay WCZ, Eastern Buffer WCZ, Western Buffer WCZ.
pH	To be in the range 6.5 - 8.5, change due to waste discharge not to exceed 0.2	Marine waters of all WCZs except Tolo Harbour & Channel WCZ
	Change due to waste discharge not to be greater than ±0.5	Harbour Subzone in Tolo Harbour & Channel WCZ
	Change due to waste discharge not to be greater than ±0.3	Buffer Subzone in Tolo Harbour & Channel WCZ
	Change due to waste discharge not to be greater than ±0.1	Channel Subzone in Tolo Harbour & Channel WCZ
Salinity	Change due to waste discharge not to exceed 10% of natural ambient level	All WCZs (Whole zone) except Tolo Harbour & Channel WCZ
	Change due to waste discharge not to be greater than ±3‰	Tolo Harbour & Channel WCZ
Temperature	Change due to waste discharge not to exceed 2℃	All WCZs (Whole zone) except Tolo Harbour & Channel WCZ
	Change due to waste discharge not to exceed 1℃	Tolo Harbour & Channel WCZ
Suspended solids	Waste discharge not to raise the natural ambient level by 30% nor cause the accumulation of suspended solids which may adversely affect aquatic communities	Marine waters of all WCZs except Tolo Harbour & Channel WCZ
Toxicants	Not to be present at levels producing significant toxic effect	All WCZs (Whole zone)
Chlorophyll-*a*	Not to exceed 20mg/m^3 (μg/L) calculated as running arithmetic mean of 5 daily measurements for any location and depth	Harbour Subzone in Tolo Harbour & Channel WCZ
	Not to exceed 10mg/m^3 (μg/L) calculated as running arithmetic mean of 5 daily measurements for any location and depth	Buffer Subzone in Tolo Harbour & Channel WCZ
	Not to exceed 6mg/m^3 (μg/L) calculated as running arithmetic mean of 5 daily measurements for any location and depth	Channel Subzone in Tolo Harbour & Channel WCZ

Table 1.2
Summary of marine water quality parameters

Parameter		Reporting Limit	Unit	Sampling Depth	Standard Method / Techniques used [20]	Analysed by
Physical and Aggregate Properties	Temperature[1]	0.1	°C	Depth Profiling[10]	Instrumental (thermistor), SEACAT19+ CTD and Water Quality Profiler	MMT/EPD[15]
	Salinity [1,8]	0.1	-	Depth Profiling	Instrumental (electrical conductivity), SEACAT19+ CTD and Water Quality Profiler	MMT/EPD
	Dissolved Oxygen[1]	0.1 1	mg/L % saturation [9]	Depth Profiling	Instrumental (membrane elelectrode), SBE23Y dissolved oxygen sensor linked to SEACAT19+ CTD and Water Quality Profiler	MMT/EPD
	Turbidity [2]	0.1	NTU	Depth Profiling	Instrumental (nephelometric / infrared back scattering), OBS-3 turbidity sensor linked to SEACAT 19+ CTD and Water Quality Profiler	MMT/EPD
	pH[1]	0.1	-	Depth Profiling	Instrumental (electrodemetric) SBE18 pH sensor linked to SEACAT19 + CTD and Water Quality Profiler	MMT/EPD
	Secchi Disc Depth[2]	0.1	m	---	Manual	MMT/EPD
	Suspended Solids[2]	0.5	mg/L	S,M,B[11]	In house method GL-PH-23, based on APHA 20ed. 2540D (weighing)	GL[18]
	Volatile Suspended	0.5	mg/L	S,M,B	In house method GL-PH-23, based on APHA 20ed. 2540E (weighing)	GL
Aggregate Organic Constituents	5-day Biochemical Oxygen Demand (BOD5)[4]	0.1	mg/L	S,M,B	In house method based on APHA 18ed. 5210B	EML/EPD[16]
Nutrients and Inorganic Constituents	Ammonia Nitrogen[5]	0.005	mg/L	S,M,B	In house method GL-IN-15, based on ASTM D3590-89 B (FIA)	GL
	Unionised Ammonia[5]	0.001	mg/L	S,M,B	By calculation[12]	MMT/EPD
	Nitrite Nitrogen[5]	0.002	mg/L	S,M,B	In house method GL-IN-18, based on APHA 20ed. 4500-NO2- B (FIA)	GL
	Nitrate Nitrogen[5]	0.002	mg/L	S,M,B	In house method GL-IN-18, based on APHA 20ed. 4500-NO3- F & I (FIA)	GL
	Total Inorganic Nitrogen[5]	0.01	mg/L	S,M,B	By calculation[13]	MMT/EPD
	Total Kjeldahl Nitrogen[5] (soluble; soluble & particulate)	0.05	mg/L	S,M,B	In house method GL-IN-14 & GL-IN-15, based on ASTM D3590-89 B (FIA) & APHA 20ed 4500-N A&D (FIA)	GL
	Total Nitrogen[5]	0.05	mg/L	S,M,B	By calculation[13]	MMT/EPD
	Orthophosphate	0.002	mg/L	S,M,B	In house method GL-IN-16, based on ASTM D515-88 A (FIA)	GL
	Total Phosphorus[5] (soluble; soluble & particulate)	0.02	mg/L	S,M,B	In house method GL-IN-14 & GL-IN-16, based on ASTM D515-88 B (FIA) & APHA 20ed 4500-P G (FIA)	GL
	Silica (as SiO_2) (soluble) [5]	0.05	mg/L	S,M,B	In house method GL-IN-17, based on APHA 20ed. 4500-SiO2 C&E (FIA)	GL
Biological and Microbiological Examination	Chlorophyll-a [6]	0.2	µg/L	S,M,B	In house method GL-OR-34, based on APHA 20ed. 10200H 2 (spectrophotometric)	GL
	Escherichia coli (*E. coli*)[7]	1	cfu/100mL	S,M,B	In house method, membrane filtration with CHROMagar Liquid *E. coli* - coliform culture[14]	EML/EPD
	Faecal Coliforms[7]	1	cfu/100mL	S,M,B	In house method, membrane filtration with CHROMagar Liquid *E. coli* - coliform culture[14]	EML/EPD
	Phytoplankton	1	cell/ml	S	In house method, 10 ml settled sub-sample using plankton chamber and inverted microscope[19]	WSL/EPD[17]

Note: 1. Indicate general oceanographic conditions of marine water
2. Low transparency and light penetration would affect aesthetic value and photosynthesis in marine water
3. Indicate the amount of particulate organic matters in marine water
4. Indicate the amount of organic pollutants in marine water
5. Major nutrients (nitrogen, phosphorus, silica) promoting algal growth in marine water
6. Indicate the amount of algal biomass in marine water
7. Sewage bacteria indicate the extent of faecal pollution in marine water
8. Measuring and reporting of Salinity (S) is based on the Practical Salinity Scale and International Equation of State of Seawater (UNESCO Technical Papers in Marine Science No. 30 (1981) ; No. 36 (1981) and No. 45 (1985))
9. Percent saturation of dissolved oxygen is calculated from dissolved oxygen in mg/L based on Weiss R.F. (1970); The solubility of nitrogen, oxygen ad argon in water and seawater. Deep Sea Res. Vol. 17, pp.721-735
10. Depth profiling - continuous measurements at downcast are processed and presented at 1m intervals from 1m below the surface to 1m above the seabed
11. If water depth is 6m or above, sampling is taken at three depths during upcast: S - 1m below water surface; M - mid-depth of water column; B - 1m above seabed. If water depth is 4 to 5 m, 'M' is skipped; If water depth is 3m or less, 'M' and 'B' are skipped.
12. i) Bower C.E. and Bidwell J.P. (1978), Ionization of ammonia in seawater: Effect of temperature, pH and salinity. J. Fish. Res. Board Can. Vol.35, pp.1012-1016;
ii) K., Russo R.C. & et. al. (1975), Aqueous ammonia equilibrium calculations: effect of pH and temperature. J. Fish. Res. Board Can. Vol.32, pp.2379-2383
13. Total Inorganic Nitrogen = Ammonia Nitrogen + Nitrite Nitrogen + Nitrate Nitrogen ; Total Nitrogen = Total Kjeldahl Nitrogen (soluble & particulate) + Nitrite Nitrogen + Nitrate Nitrogen
14. i) DoE, DHSS & PHLS (1983); The Bacteriological Examination of Drinking Water Supplies 1982, Sec.7.8 & 7.9;
ii) B.S.W. Ho and T.Y. Tam (1997), Enumeration of *E. coli* in environmental waters and wastewater using a chromogenic medium. Wat. Sci. Tech.Vol.35, No.11-12, pp.409-413; method adopted in 1997.
15. MMT/EPD - Marine Monitoring Team, Water Policy & Planning Group, Environmental Protection Department.
16. EML/EPD - Environmental Microbiology Laboratory, Waste Policy & Services Group, Environmental Protection Department.
17. WSL/EPD - Water Sciences Laboratory, Water Policy & Planning Group, Environmental Protection Department
18. GL - Environmental Chemistry B Section, Environmental Chemistry & Other Scientific Services Group, Government Laboratory.
19. i) Lund, J.H., Kipling, C. and Le Cren, E.D. 1958. The inverted microscope method of estimating algal numbers, and the statistical basis of estimations by counting. Hydrobiologia Vol. 11, pp. 143-170.
ii) Utermohl, H. 1958. Zur Vervollkommung der Quantitativen Phytoplankton-Methodik. Mitt. Inter. Verein. Lim. Vol. 9, pp. 1-38.
20. Mention of brand names and commercial products does not constitute or imply endorsement or recommendation by the Environmental Protection Department.

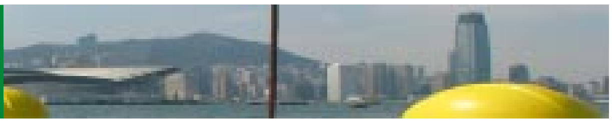


Table 1.3

Summary of marine sediment[1] parameters

	Parameter	Reporting Limit	Unit [2]	Standard Method / Techniques used [8]	Analysed by
Physical and Aggregate Properties	Particle Size Fractionation	1	% w/w	In house method, sieving and weighing ; 8 fractions : >4000µm, <4000µm, <2000µm, <1000µm, <500µm, <250µm, <125µm and <63µm	MMT/EPD [6]
	Electrochemical Potential [4]	1	mV	Instrumental, Orion Model 250A pH/Redox Meter (electrodemetric)	MMT/EPD
	Total Solids (TS) [3]	0.1	% w/w	In house method GL-PH-22, based on APHA 20ed 2540G (weighing)	GL [7]
	Total Volatile Solids (TVS) [3]	0.1	% TS	In house method GL-PH-22, based on APHA 20ed 2540G (weighing)	GL
	Dry Wet Ratio	0.01	-	In house method GL-PH-22, based on APHA 20ed 2540G (weighing)	GL
Aggregate Organic Constituents [3]	Chemical Oxygen Demand (COD)	2	mg/kg	In house method GL-OR-38, based on ASTM D1252-00 A (open reflux)	GL
	Total Carbon (TC)	0.1	% w/w	In house method GL-OR-33, based on APHA 20ed 5310 B (FIA)	GL
Nutrients and Inorganic Constituents [3]	Ammonia Nitrogen (NH_4-N)	0.05	mg/kg	In house method GL-IN-15, based on ASTM D3590-89 B (FIA)	GL
	Total Kjeldahl Nitrogen (TKN)	0.5	mg/kg	In house method GL-IN-14 & GL-IN-15, based on ASTM D3590-89 B (FIA) & APHA 20ed 4500-N A&D (FIA)	GL
	Total Phosphorus	0.2	mg/kg	In house method GL-IN-14 & GL-IN-16, based on ASTM D515-88 B (FIA) & APHA 20ed 4500-P G (FIA)	GL
	Total Sulphide	0.2	mg/kg	In house method GL-IN-45, based on APHA 20ed 4500-S^{2-} D (FIA)	GL
	Total Cyanide	0.1	mg/kg	In house method GL-IN-44, based on APHA, 20ed., 4500 CN -A&E (distillation and colorimetric)	GL
Metals & Metalloids [5]	Aluminium (Al)	1	mg/kg	In house method GL-TE-60, based on USEPA method 6010B (ICP-AES)	GL
	Arsenic (As)	0.1	mg/kg	In house method GL-TE-64 & GL-TE-66, based on USEPA method 6020 (ICP-MS)	GL
	Barium (Ba)	0.2	mg/kg	In house method GL-TE-60 & GL-TE-64, based on USEPA method 6010B (ICP-AES) and USEPA method 6020	GL
	Boron (B)	5	mg/kg	In house method GL-TE-60, based on USEPA method 6010B (ICP-AES)	GL
	Cadmium (Cd)	0.1	mg/kg	In house method GL-TE-64, based on USEPA method 6020 (ICP-MS)	GL
	Chromium (Cr)	0.2	mg/kg	In house method GL-TE-60 & GL-TE-64, based on USEPA method 6010B (ICP-AES) and USEPA method 6020	GL
	Copper (Cu)	0.2	mg/kg	In house method GL-TE-60 & GL-TE-64, based on USEPA method 6010B (ICP-AES) and USEPA method 6020	GL
	Iron (Fe)	5	mg/kg	In house method GL-TE-60, based on USEPA method 6010B (ICP-AES)	GL
	Lead (Pb)	0.2	mg/kg	In house method GL-TE-60 & GL-TE-64, based on USEPA method 6010B (ICP-AES) and USEPA method 6020	GL
	Manganese (Mn)	1	mg/kg	In house method GL-TE-60, based on USEPA method 6010B (ICP-AES)	GL
	Mercury (Hg)	0.05	mg/kg	In house method GL-TE-64 & GL-TE-66, based on USEPA method 6020 (ICP-MS)	GL
	Nickel (Ni)	0.2	mg/kg	In house method GL-TE-60 & GL-TE-64, based on USEPA method 6010B (ICP-AES) and USEPA method 6020	GL
	Silver (Ag)	0.2	mg/kg	In house method GL-TE-64, based on USEPA method 6020 (ICP-MS)	GL
	Vanadium (V)	0.1	mg/kg	In house method GL-TE-60 & GL-TE-64, based on USEPA method 6010B (ICP-AES) and USEPA method 6020	GL
	Zinc (Zn)	0.2	mg/kg	In house method GL-TE-60 & GL-TE-64, based on USEPA method 6010B (ICP-AES) and USEPA method 6020	GL
Trace Organic Compounds	Polychlorinated Biphenyls (PCBs)				
	18 PCB congeners : PCB 8, 18, 28, 44, 52, 66, 77, 101, 105, 118, 126, 128, 138, 153, 169, 170, 180, 187	2	µg/kg	In house method GL-OR-25, based on Reference Method for the Analysis of Polychlorinated Biphenyls, Environmental Protection Series: Report EPS 1/RM/31, March 1997, Environment Canada (GC-MS)	GL
	Polyaromatic Hydrocarbons (PAHs)				
	- Acenaphthene	50	µg/kg	In house method, GL-OR-15, based on USEPA method 610, 1984 (UV-FLUO)	GL
	- Acenaphthylene	50	µg/kg	In house method, GL-OR-15, based on USEPA method 610, 1984 (UV-FLUO)	GL
	- Naphthalene	60	µg/kg	In house method, GL-OR-15, based on USEPA method 610, 1984 (UV-FLUO)	GL
	- Fluorene	10	µg/kg	In house method, GL-OR-15, based on USEPA method 610, 1984 (UV-FLUO)	GL
	- Phenanthrene	5	µg/kg	In house method, GL-OR-15, based on USEPA method 610, 1984 (UV-FLUO)	GL
	- Anthracene	5	µg/kg	In house method, GL-OR-15, based on USEPA method 610, 1984 (UV-FLUO)	GL
	- Fluoranthene	5	µg/kg	In house method, GL-OR-15, based on USEPA method 610, 1984 (UV-FLUO)	GL
	- Pyrene	5	µg/kg	In house method, GL-OR-15, based on USEPA method 610, 1984 (UV-FLUO)	GL
	- Benzo(*a*)anthracene	3	µg/kg	In house method, GL-OR-15, based on USEPA method 610, 1984 (UV-FLUO)	GL
	- Chrysene	5	µg/kg	In house method, GL-OR-15, based on USEPA method 610, 1984 (UV-FLUO)	GL
	- Benzo(*b*)fluoranthene	1	µg/kg	In house method, GL-OR-15, based on USEPA method 610, 1984 (UV-FLUO)	GL
	- Benzo(*k*)fluoranthene	1	µg/kg	In house method, GL-OR-15, based on USEPA method 610, 1984 (UV-FLUO)	GL
	- Benzo(*a*)pyrene	1	µg/kg	In house method, GL-OR-15, based on USEPA method 610, 1984 (UV-FLUO)	GL
	- Dibenzo(*a,h*)anthracene	5	µg/kg	In house method, GL-OR-15, based on USEPA method 610, 1984 (UV-FLUO)	GL
	- Benzo(*ghi*)perylene	1	µg/kg	In house method, GL-OR-15, based on USEPA method 610, 1984 (UV-FLUO)	GL
	- Indeno(*1,2,3-cd*)pyrene	5	µg/kg	In house method, GL-OR-15, based on USEPA method 610, 1984 (UV-FLUO)	GL

Note : 1. Birge-Ekman (0.023m^2) grab / Van Veen (0.1m^2) grab / Smith-McIntyre (0.1m^2) grab is employed to collect sediment samples from the top 10cm of seabed.
2. All parameters are reported on a dry weight basis unless otherwise stated.
3. Determinants are reported on a wet weight basis.
4. Electrochemical potential (Eh) is measured 'on-site' at 3cm below the surface of freshly collected sediment samples (Reference : Handbook of Techniques for Aquatic Sediment Sampling. By A. Mudrock & S.D. MacKnight, 1994, CRC Press).
5. Digestion procedure for metals and metalloids in sediment follows In house method, WC-ME-2 (3.5 hours digestion in conc. HCl/conc. HNO_3 ; 3:1 v/v)
6. MMT/EPD - Marine Monitoring Team, Water Policy & Planning Group, Environmental Protection Department.
7. GL - Environmental Chemistry B Section, Environmental Chemistry & Other Scientific Services Group, Government Laboratory.
8. Mention of brand names and commercial products does not constitute or imply endorsement or recommendation by the Environmental Protection Department.

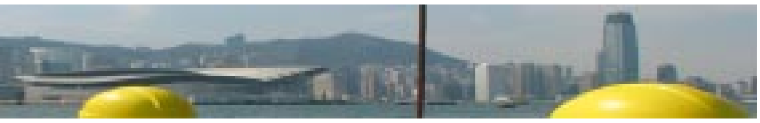


Table 1.4
Location of marine water and sediment monitoring stations

Water Control Zone	Station		Location		Depth (m)
	Water	Sediment	Latitude	Longitude	approx.
Tolo Harbour and Channel	TM2		22° 24.744' N	114° 13.085' E	4
	TM3	TS3	22° 26.857' N	114° 12.181' E	7
	TM4	TS2	22° 25.964' N	114° 13.176' E	8
	TM5		22° 27.426' N	114° 13.456' E	4
	TM6	TS4	22° 26.631' N	114° 14.506' E	12
	TM7		22° 26.907' N	114° 16.057' E	11
	TM8	TS5	22° 28.392' N	114° 18.003' E	22
	*TT1	*TS7	22° 27.270' N	114° 12.717' E	6
Southern Water	SM1	SS1	22° 12.738' N	114° 13.885' E	14
	SM2	SS2	22° 13.447' N	114° 10.691' E	14
	SM3		22° 13.527' N	114° 8.980' E	33
	SM4		22° 12.758' N	114° 8.315' E	11
	SM5		22° 12.141' N	114° 6.728' E	8
	SM6	SS3	22° 11.500' N	114° 4.743' E	14
	SM7	SS4	22° 13.740' N	114° 4.743' E	8
	SM9		22° 16.420' N	114° 4.024' E	8
	SM10		22° 18.125' N	114° 1.919' E	5
	SM11	SS5	22° 15.443' N	114° 1.078' E	8
	SM12		22° 12.861' N	114° 0.869' E	7
	SM13	SS6	22° 12.957' N	113° 57.724' E	6
	SM17		22° 9.211' N	113° 57.727' E	12
	SM18		22° 9.211' N	114° 4.746' E	21
	SM19		22° 9.211' N	114° 13.077' E	24
	SM20		22° 10.448' N	113° 52.932' E	7
	*ST1	*SS7	22° 12.607' N	114° 1.345' E	5
	*ST3	*SS8	22° 14.734' N	114° 1.928' E	6
Port Shelter	PM1		22° 23.242' N	114° 17.145' E	6
	PM2		22° 22.643' N	114° 16.687' E	8
	PM3	PS3	22° 22.156' N	114° 16.910' E	13
	PM4		22° 22.940' N	114° 18.819' E	6
	PM6		22° 21.102' N	114° 16.213' E	11
	PM7	PS5	22° 20.453' N	114° 17.703' E	17
	PM8	PS6	22° 19.168' N	114° 18.745' E	20
	PM9		22° 20.529' N	114° 20.196' E	15
	PM11		22° 19.240' N	114° 20.163' E	21
	*PT2		22° 22.798' N	114° 16.540' E	3
	*PT3	*PS2	22° 22.790' N	114° 18.400' E	6
	*PT4	*PS4	22° 21.728' N	114° 15.879' E	5
Junk Bay	JM3	JS2	22° 17.490' N	114° 15.657' E	10
	JM4		22° 16.873' N	114° 15.378' E	16
Deep Bay	DM1	DS1	22° 29.769' N	114° 0.644' E	2
	DM2		22° 30.454' N	113° 59.549' E	2
	DM3	DS2	22° 28.680' N	113° 57.551' E	3
	DM4	DS3	22° 27.335' N	113° 55.937' E	4
	DM5	DS4	22° 25.561' N	113° 53.388' E	8
North Western	NM1		22° 20.877' N	114° 1.286' E	34
	NM2	NS2	22° 21.130' N	113° 58.815' E	11
	NM3	NS3	22° 21.324' N	113° 56.783' E	14
	NM5	NS4	22° 23.051' N	113° 53.972' E	20
	NM6	NS6	22° 19.281' N	113° 53.908' E	5
	NM8		22° 16.695' N	113° 51.886' E	8
	*NT1	*NS5	22° 22.475' N	114° 58.353' E	4
Mirs Bay	MM1	MS1	22° 32.984' N	114° 14.271' E	6
	MM2	MS2	22° 32.626' N	114° 16.648' E	11
	MM3	MS3	22° 33.714' N	114° 18.615' E	16
	MM4	MS4	22° 33.817' N	114° 21.483' E	18
	MM5	MS5	22° 31.233' N	114° 23.633' E	20
	MM6	MS6	22° 27.334' N	114° 20.997' E	12
	MM7	MS7	22° 31.409' N	114° 17.824' E	13
	MM8	MS8	22° 12.021' N	114° 19.345' E	31
	MM13	MS13	22° 13.000' N	114° 26.920' E	28
	MM14	MS14	22° 17.560' N	114° 26.920' E	25
	MM15	MS15	22° 22.120' N	114° 26.920' E	24
	MM16	MS16	22° 26.670' N	114° 26.920' E	22
	MM17	MS17	22° 30.192' N	114° 20.960' E	17
	MM19		22° 15.921' N	114° 19.411' E	28
Western Buffer	WM1	WS2	22° 15.044' N	114° 7.363' E	35
	WM2		22° 17.074' N	114° 5.730' E	13
	WM3	WS1	22° 19.203' N	114° 5.826' E	20
	WM4		22° 20.940' N	114° 4.256' E	26
	*WT1		22° 14.584' N	114° 9.588' E	7
	*WT3		22° 14.900' N	114° 8.770' E	10
Eastern Buffer	EM1	ES4	22° 16.506' N	114° 15.335' E	16
	EM2	ES1	22° 15.732' N	114° 15.971' E	21
	EM3	ES2	22° 14.237' N	114° 16.144' E	21
	*ET1	*ES3	22° 16.203' N	114° 14.624' E	6
	*ET2	*ES5	22° 17.078' N	114° 13.783' E	12
Victoria Harbour	VM1		22° 17.280' N	114° 13.839' E	38
	VM2		22° 17.862' N	114° 12.619' E	12
		VS3	22° 17.631' N	114° 12.526' E	8
	VM4		22° 17.860' N	114° 11.654' E	12
	VM5		22° 17.266' N	114° 10.510' E	11
		VS5	22° 17.077' N	114° 10.600' E	8
	VM6		22° 17.371' N	114° 9.665' E	14
	VM7	VS6	22° 17.771' N	114° 8.416' E	10
	VM8		22° 17.564' N	114° 7.175' E	11
	VM12	VS9	22° 19.757' N	114° 7.278' E	14
	VM14	VS10	22° 21.935' N	114° 6.527' E	11
	VM15		22° 18.579' N	114° 8.539' E	13
	*VT2	*VS12	22° 17.194' N	114° 11.304' E	5
	*VT3	*VS13	22° 17.448' N	114° 14.250' E	5
	*VT4	*VS14	22° 18.734' N	114° 12.814' E	6
	*VT8	*VS17	22° 21.360' N	114° 6.867' E	5
	*VT10	*VS19	22° 18.590' N	114° 9.430' E	5
	*VT11	*VS20	22° 18.981' N	114° 11.814' E	6
	*VT12	*VS21	22° 19.429' N	114° 8.587' E	5

Note : 1. All locations are based on WGS84 datum
2. Water quality and sediment monitoring stations in typhoon shelters are marked with an asterisk *

CHAPTER 2

TOLO HARBOUR & CHANNEL WATER CONTROL ZONE

Chapter 2 – Tolo Harbour and Channel Water Control Zone

Water Quality in 2003

2.1 The Tolo Harbour and Channel Water Control Zone (WCZ) is a semi-enclosed bay with a gradient of water quality from the more enclosed and densely populated inner Harbour Subzone to the outer Channel Subzone opening to Mirs Bay. A summary of the 2003 water quality data for the Tolo Harbour and Channel WCZ is shown in Table 2.1.

2.2 In 2003, the gradual decline in nitrogen in Tolo Harbour occurred over the past few years has continued. The annual mean *E. coli*, ammonia nitrogen (NH_4-N), total inorganic nitrogen (TIN), total nitrogen and orthophosphate phosphorus in the Tolo Harbour and Channel WCZ have reached their minimum levels in 10 years.

2.3 After a widespread and significant decrease in chlorophyll-*a* in Tolo Harbour in 2002, the levels at various stations increased by 1.0-3.4mg/L (23-89%) in 2003. Overall, the chlorophyll-*a* level in the Harbour remained largely stable in the past decade, despite the changes in nitrogen and phosphorus nutrients in the water.

2.4 In 2003, the depth-averaged and the bottom dissolved oxygen (DO) in Tolo Harbour have decreased by 0.8mg/L (12%) and 0.6mg/L (10%) respectively. This was, however, within the range of natural fluctuation. The frequency of bottom hypoxia (i.e. DO<2mg/L) was maintained at a low level (3.7%). In 2003, the mean bottom DO in the harbour was maintained at 4.7-6.3 mg/L, above the level needed to sustain fish and other forms of marine life. Lower bottom DO levels occurred more often in Tolo Channel than in the Inner Harbour under stratification conditions.

2.6 Temperature and salinity stratification is commonly observed in Tolo Channel (TM6-TM8) during the warm months (May-September) under stable weather conditions. The phenomenon generally reduces vertical mixing of the water column and prevents replenishment of DO in the bottom layer. Figure 2.4 shows the vertical temperature, salinity and DO profiles of a typical stratification occurring during the summer of 2003.

2.5 In 2003, the *E. coli* bacterial levels in the Inner Harbour (TM2 & TM3) were low (15-18 cfu/100mL) showing a further improvement of bacteriological water quality. The *E. coli* level at TM2 (near Shatin) was the lowest ever recorded.

Compliance with Water Quality Objectives (WQOs)

2.7 Figure 2.1 shows the compliance with Water Quality Objectives (WQOs) in the Tolo Harbour and Channel WCZ in 2003 and the previous nine years. Due to the reduction of DO, there was a decrease in the compliance rate for the DO objective from 81% in 2002 to 63% in 2003. Only two stations (TM 3 & TM5) fully met the DO objective.

2.8 As in the previous years, all sampling stations in the WCZ achieved 100% compliance with the *E. coli* WQO indicating that the harbour was of good bacteriological quality, suitable for secondary contact recreational uses.

2.9 Being a semi-enclosed bay with weak tidal flushing, Tolo Harbour is generally susceptible to algal blooms. In 2003, 92% of the samples complied with the chlorophyll-*a* WQO, comparable to that in 2002 (Figure 2.2).

2.10 Figure 2.3 shows the annual means total inorganic nitrogen (TIN) and unionised ammonia (NH_3-N). The annual mean TIN and NH_3-N levels in 2003 were low, in the ranges of 0.05-0.07 mg/L and 0.002-0.004mg/L respectively. Both parameters exhibited a decreasing gradient from the inner part of the harbour to the outer channel.

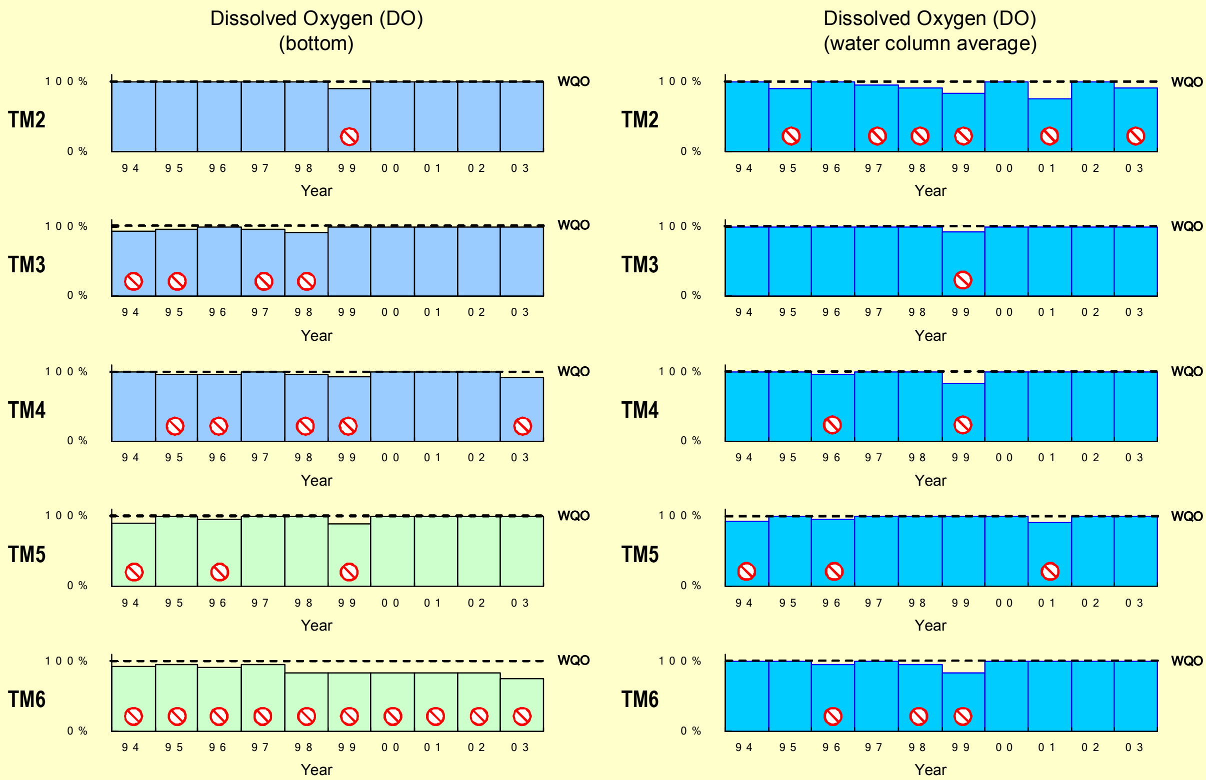
Long-term Water Quality Trends

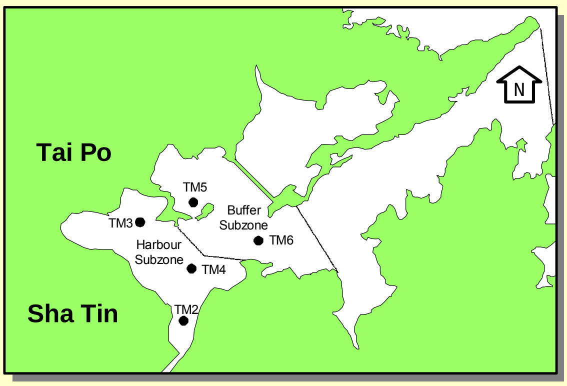
2.11 Due to eutrophication and frequent occurrence of red tides in Tolo Harbour in the 1980s, the Government implemented a Tolo Harbour Action Plan (THAP) to reduce pollution and nutrient loading in the harbour. The abatement measures included: eliminating livestock pollution; restoring old landfill; enforcing the Water Pollution Control Ordinance; exported effluents out of the harbour and extending sewer networks to rural villages.

2.12 As a result of the implementation of the THAP, the nutrient enrichment problem in Tolo Harbour has been effectively controlled. Significant long-term decreases in organic pollutants (BOD_5), Kjeldahl nitrogen, total nitrogen and total phosphate have been observed (Table 2.2).

2.13 To further control pollution sources in the harbour catchment, the Government has constructed public sewers for 26 villages in 2003 and another 10 villages will be provided with sewerage by 2005. These measures would help further improve water quality and restore the ecological health of Tolo Harbour.

Figure 2.1 Level of compliance with key Water Quality Objectives in the Tolo Harbour and Channel WCZ





Dissolved Oxygen (DO)

Harbour Subzone (TM2 - TM4)

1. Bottom

WQO : 100% sample with bottom DO ≥ 2 mg/L

% sample with bottom DO ≥ 2 mg/L

2. Water column average (surface to 2m above bottom)

WQO : 100% sample with water column average DO ≥ 4 mg/L

% sample with water column average DO ≥ 4 mg/L

Buffer Subzone (TM5 - TM6)

1. Bottom

WQO : 100% sample with bottom DO ≥ 3 mg/L

% sample with bottom DO ≥ 3 mg/L

2. Water column average (surface to 2m above bottom)

WQO : 100% sample with water column average DO ≥ 4 mg/L

% sample with water column average DO ≥ 4 mg/L

Non-compliance

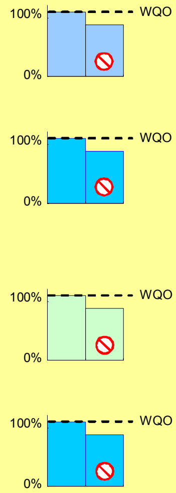
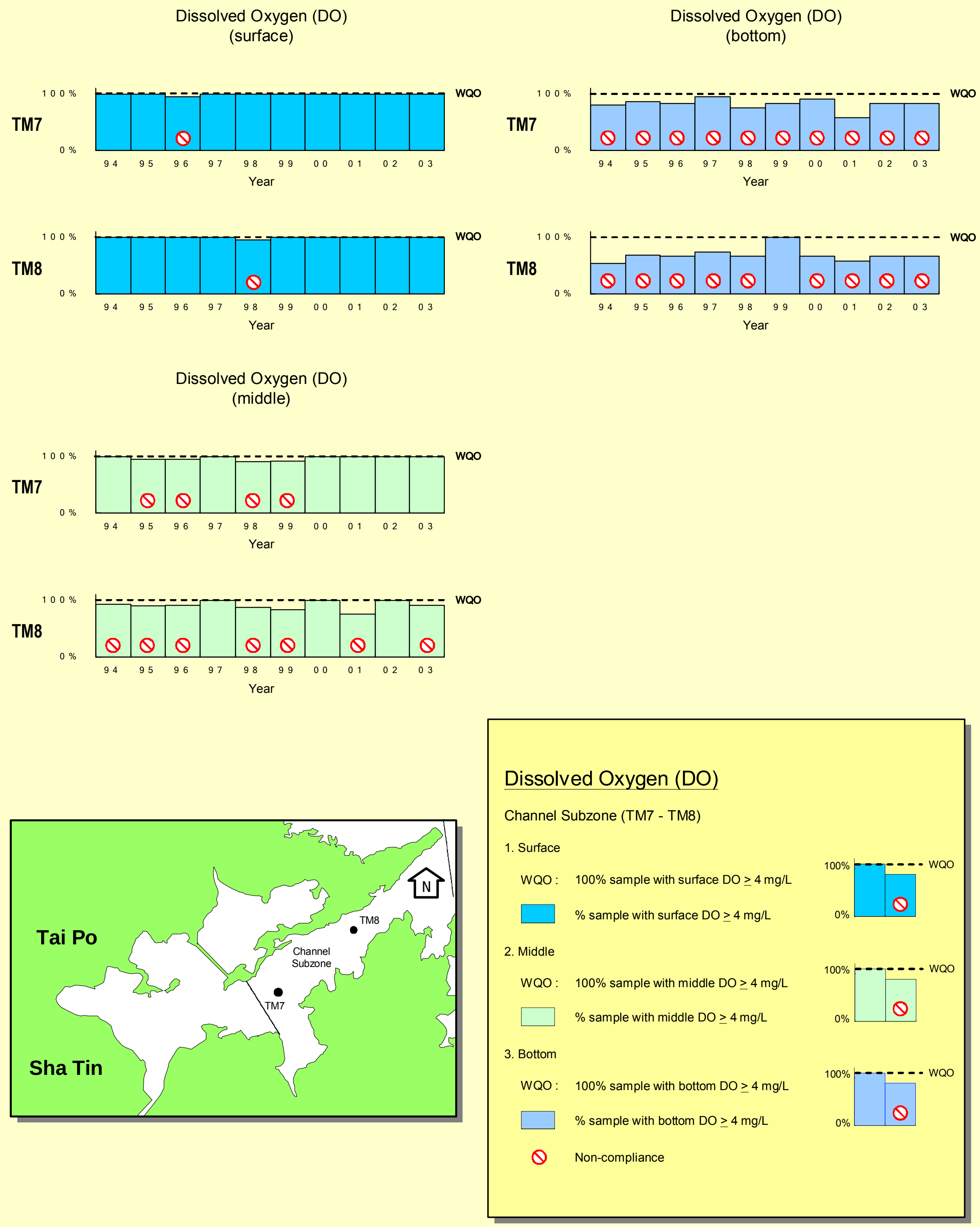


Figure 2.1 (continued) Level of compliance with key Water Quality Objectives in the Tolo Harbour and Channel WCZ



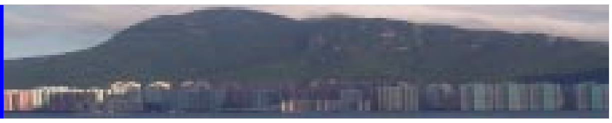
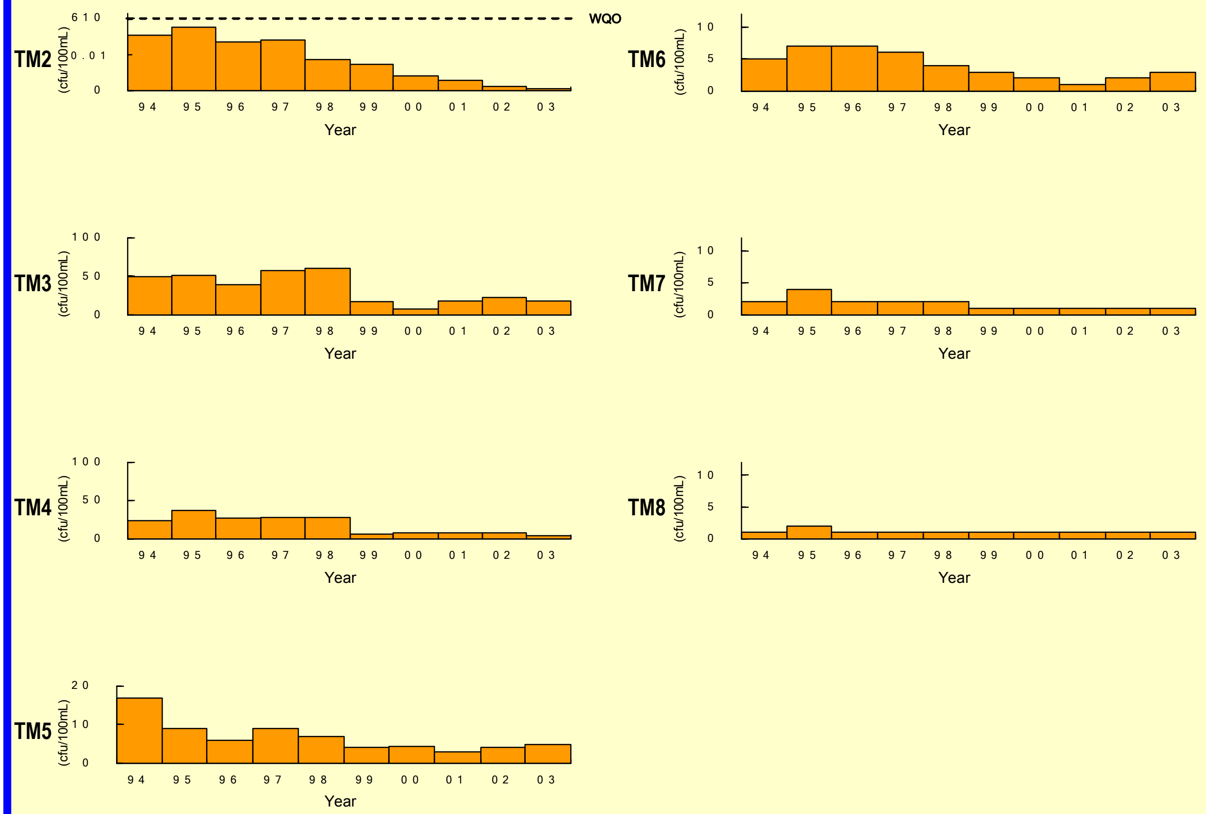
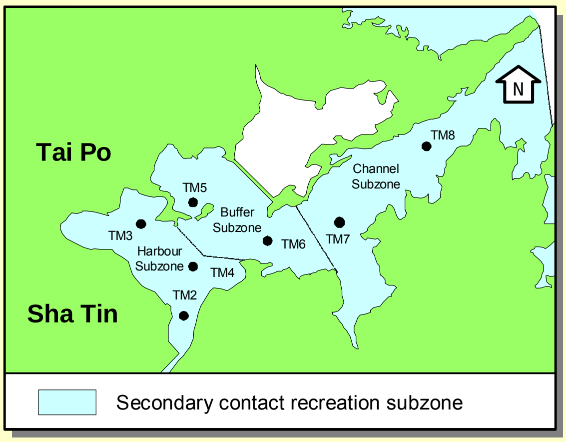


Figure 2.1 (continued) Level of compliance with key Water Quality Objectives in the Tolo Harbour and Channel WCZ

E. coli
(annual geometric mean)





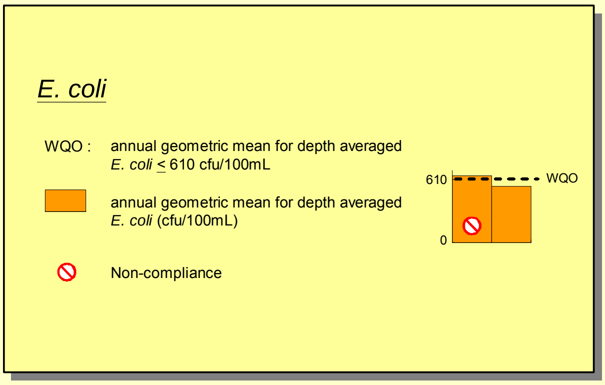
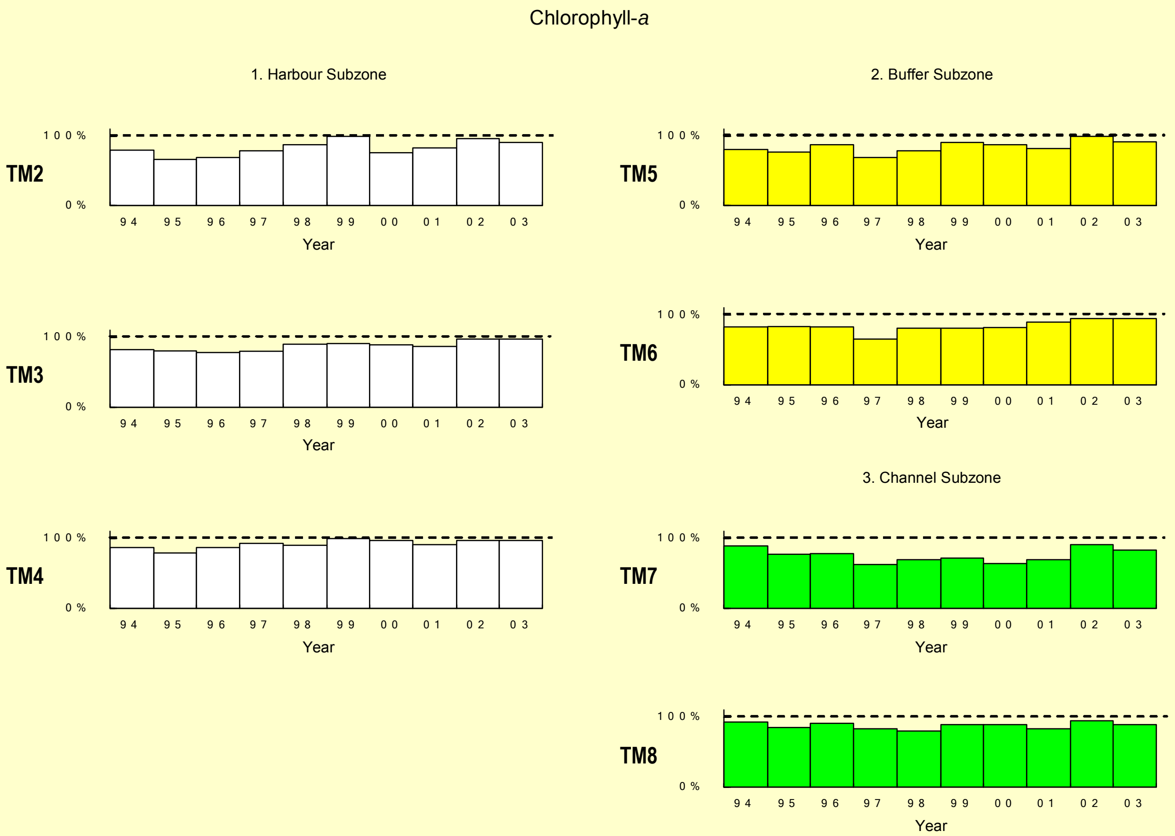
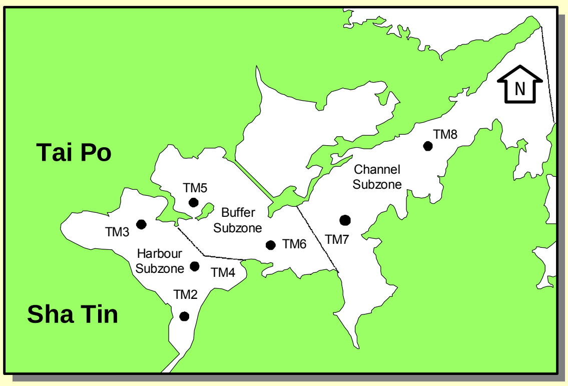


Figure 2.2 Level of chlorophyll-*a* in the Tolo Harbour and Channel WCZ





Chlorophyll-*a*

1. Harbour Subzone

   % sample (S, M, B) with Chlorophyll-*a* ≤ 20 μg/L

   WQO : Chlorophyll-*a* ≤ 20 μg/L

2. Buffer Subzone

   % sample (S, M, B) with Chlorophyll-*a* ≤ 10 μg/L

   WQO : Chlorophyll-*a* ≤ 10 μg/L

3. Channel Subzone

   % sample (S, M, B) with Chlorophyll-*a* ≤ 6 μg/L

   WQO : Chlorophyll-*a* ≤ 6 μg/L

Figure 2.3 Levels of total inorganic nitrogen and unionised ammonia in the Tolo Harbour and Channel WCZ

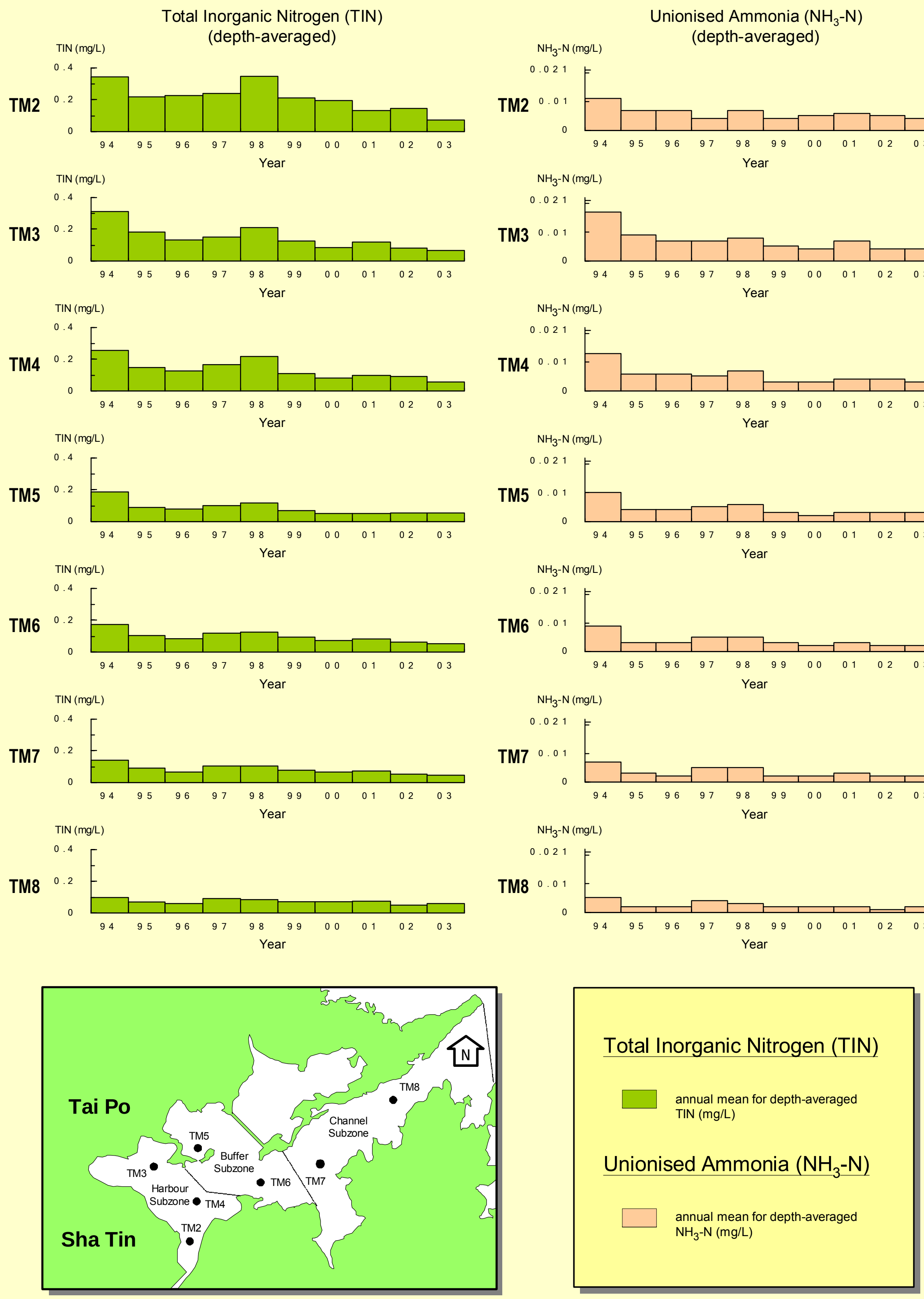


Figure 2.4 Dissolved oxygen, salinity and temperature profiles in the Tolo Harbour and Channel WCZ illustrating water stratification in the summer of 2003

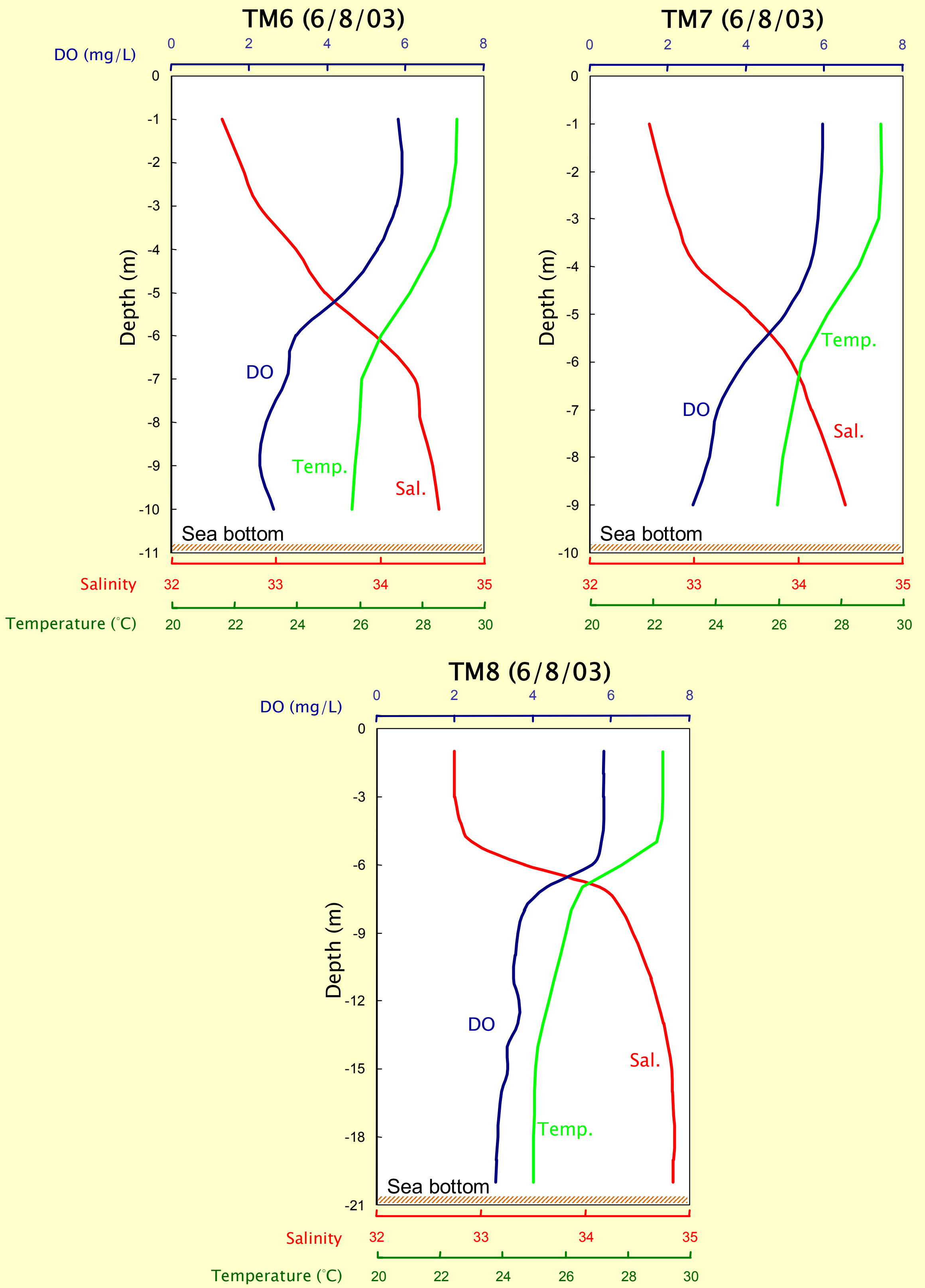


Table 2.1

Summary water quality statistics of the Tolo Harbour and Channel WCZ in 2003

Parameter	Harbour Subzone TM2	Harbour Subzone TM3	Harbour Subzone TM4	Buffer Subzone TM5	Buffer Subzone TM6	Channel Subzone TM7	Channel Subzone TM8
Number of samples	12	12	12	12	12	12	12
Temperature (°C)	24.3 (16.7 - 29.0)	24.3 (16.6 - 28.9)	24.1 (16.6 - 28.7)	24.5 (16.5 - 29.6)	23.7 (16.6 - 28.3)	23.8 (16.6 - 28.5)	23.4 (16.6 - 28.3)
Salinity	31.3 (28.5 - 33.5)	31.8 (28.7 - 33.4)	31.7 (29.3 - 33.5)	31.3 (27.3 - 33.3)	32.4 (30.8 - 34.3)	32.3 (29.9 - 34.1)	32.7 (30.5 - 34.4)
Dissolved Oxygen (mg/L)	6.3 (3.4 - 8.9)	6.3 (4.4 - 8.2)	6.3 (4.7 - 8.3)	6.1 (4.7 - 7.6)	5.5 (3.7 - 7.5)	5.7 (4.1 - 7.1)	5.3 (3.9 - 7.3)
Bottom	6.3 (3.2 - 8.1)	5.8 (2.2 - 8.1)	5.7 (1.8 - 8.3)	6.1 (4.8 - 7.8)	4.7 (1.9 - 7.5)	5.4 (3.1 - 7.2)	4.7 (1.9 - 7.3)
Dissolved Oxygen (% Saturation)	89 (51 - 120)	90 (67 - 111)	90 (70 - 107)	87 (74 - 116)	78 (56 - 95)	81 (63 - 96)	75 (58 - 92)
Bottom	90 (47 - 125)	81 (34 - 109)	79 (27 - 104)	87 (72 - 120)	65 (28 - 95)	75 (46 - 98)	65 (28 - 92)
pH	8.2 (8.0 - 8.4)	8.3 (8.1 - 8.4)	8.3 (8.1 - 8.4)	8.2 (8.0 - 8.6)	8.2 (8.1 - 8.4)	8.2 (8.1 - 8.5)	8.2 (8.0 - 8.4)
Secchi Disc Depth (m)	2.0 (0.4 - 3.0)	2.1 (1.1 - 2.9)	2.4 (1.5 - 3.3)	2.3 (1.0 - 3.4)	2.9 (1.5 - 5.4)	3.1 (1.0 - 5.0)	3.3 (1.5 - 4.8)
Turbidity (NTU)	7.1 (2.3 - 10.2)	6.6 (2.2 - 9.3)	6.2 (2.1 - 8.0)	9.1 (5.1 - 16.8)	6.4 (1.9 - 10.9)	6.1 (0.9 - 8.9)	7.1 (4.4 - 8.6)
Suspended Solids (mg/L)	4.1 (2.4 - 8.4)	5.5 (1.1 - 34.3)	2.3 (1.4 - 4.2)	11.8 (1.3 - 86.9)	2.6 (1.2 - 6.8)	2.2 (1.2 - 4.6)	3.2 (2.0 - 4.8)
5-day Biochemical Oxygen Demand (mg/L)	2.5 (1.6 - 4.7)	2.4 (1.5 - 4.2)	2.0 (1.4 - 3.0)	2.2 (1.3 - 5.3)	1.4 (1.0 - 2.7)	1.1 (0.4 - 1.5)	0.9 (0.3 - 1.5)
Ammonia Nitrogen (mg/L)	0.05 (0.03 - 0.10)	0.05 (0.01 - 0.15)	0.04 (0.01 - 0.10)	0.04 (0.01 - 0.10)	0.03 (0.01 - 0.06)	0.03 (0.01 - 0.05)	0.03 (0.01 - 0.06)
Unionised Ammonia (mg/L)	0.004 (0.002 - 0.007)	0.004 (<0.001 - 0.012)	0.003 (<0.001 - 0.007)	0.003 (<0.001 - 0.012)	0.002 (0.001 - 0.004)	0.002 (<0.001 - 0.004)	0.002 (<0.001 - 0.004)
Nitrite Nitrogen (mg/L)	<0.01 (<0.01 - 0.02)	0.01 (<0.01 - 0.02)	0.01 (<0.01 - 0.03)	<0.01 (<0.01 - 0.01)	0.01 (<0.01 - 0.05)	0.01 (<0.01 - 0.04)	0.01 (<0.01 - 0.07)
Nitrate Nitrogen (mg/L)	0.01 (<0.01 - 0.04)	0.01 (<0.01 - 0.03)	0.01 (<0.01 - 0.02)	0.01 (<0.01 - 0.06)	0.01 (<0.01 - 0.03)	0.01 (<0.01 - 0.02)	0.02 (<0.01 - 0.04)
Total Inorganic Nitrogen (mg/L)	0.07 (0.03 - 0.14)	0.07 (0.01 - 0.19)	0.05 (0.01 - 0.12)	0.05 (0.01 - 0.12)	0.05 (0.01 - 0.10)	0.05 (0.01 - 0.09)	0.06 (0.02 - 0.15)
Total Kjeldahl Nitrogen (mg/L)	0.29 (0.23 - 0.36)	0.27 (0.19 - 0.43)	0.23 (0.19 - 0.30)	0.25 (0.18 - 0.38)	0.18 (0.15 - 0.22)	0.17 (0.12 - 0.24)	0.15 (0.11 - 0.25)
Total Nitrogen (mg/L)	0.30 (0.23 - 0.37)	0.28 (0.19 - 0.47)	0.24 (0.19 - 0.32)	0.26 (0.18 - 0.40)	0.20 (0.15 - 0.25)	0.19 (0.13 - 0.25)	0.18 (0.12 - 0.36)
Orthophosphate Phosphorus (mg/L)	<0.01 (<0.01 - 0.01)	<0.01 (<0.01 - 0.02)	<0.01 (<0.01 - 0.01)	<0.01 (<0.01 - 0.02)	<0.01 (<0.01 - 0.01)	<0.01 (<0.01 - 0.01)	0.010 (0.01 - 0.02)
Total Phosphorus (mg/L)	0.03 (0.02 - 0.05)	0.03 (0.02 - 0.05)	0.03 (0.02 - 0.04)	0.04 (0.02 - 0.07)	0.03 (0.02 - 0.04)	0.03 (0.02 - 0.04)	0.02 (0.02 - 0.04)
Silica (as SiO_2) (mg/L)	0.8 (0.1 - 1.4)	0.6 (0.1 - 1.2)	0.7 (0.3 - 1.1)	0.7 (0.1 - 1.2)	0.7 (0.2 - 1.3)	0.6 (0.1 - 1.2)	0.7 (0.2 - 1.7)
Chlorophyll-*a* (µg/L)	11.2 (1.0 - 30.5)	9.7 (2.4 - 32.2)	6.5 (2.9 - 10.3)	7.2 (1.6 - 25.0)	4.6 (1.5 - 8.2)	4.3 (1.9 - 6.8)	3.7 (1.2 - 13.7)
E. coli (cfu/100mL)	15 (5 - 110)	18 (1 - 780)	4 (1 - 60)	5 (1 - 380)	3 (1 - 65)	1 (1 - 25)	1 (1 - 6)
Faecal Coliforms (cfu/100mL)	110 (35 - 1200)	92 (2 - 9800)	17 (2 - 430)	26 (1 - 2400)	10 (1 - 600)	3 (1 - 230)	2 (1 - 30)

Note :
1. Unless otherwise specified, data presented are depth-averaged (A) values calculated by taking the means of three depths: Surface (S), Mid-depth (M), Bottom (B).
2. Data presented are annual arithmetic means of the depth-averaged results except for *E. coli* and faecal coliforms which are annual geometric means.
3. Data in brackets indicate the ranges.

Table 2.2

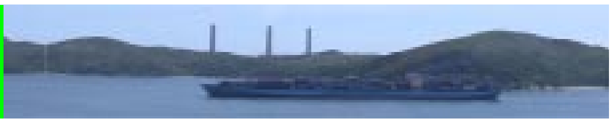
Results of the Seasonal Kendall Test for trends in water quality parameters measured in the Tolo Harbour and Channel WCZ, 1986 - 2003

Monitoring Station		TM2	TM3	TM4	TM5	TM6	TM7	TM8
Monitoring Period		1986 - 2003	1986 - 2003	1986 - 2003	1986 - 2003	1986 - 2003	1986 - 2003	1986 - 2003
Parameter	Water Depth							
Temperature (°C)	Surface	↗	↗	↗	↗	↗	↗	↗
	Middle	NA	↗	↗	NA	↗	↗	↗
	Bottom	↗	↗	↗	↗	↗	↗	↗
	Average	↗	↗	↗	↗	↗	↗	↗
Salinity	Surface	-	-	-	-	-	-	-
	Middle	NA	-	-	NA	-	-	-
	Bottom	-	-	-	-	-	-	-
	Average	-	-	-	-	-	-	-
Dissolved Oxygen (mg/L)	Surface	↘	↘	↘	↘	↘	↘	↘
	Middle	NA	↗	-	NA	↗	-	-
	Bottom	↗	↗	↗	-	↗	↗	-
	Average	-	-	-	-	-	-	-
Dissolved Oxygen (%)	Surface	-	↘	↘	↘	↘	↘	↘
	Middle	NA	↗	↗	NA	↗	-	-
	Bottom	↗	↗	↗	↗	↗	↗	↗
	Average	-	↗	-	-	-	-	-
pH	Surface	-	-	↘	↘	↘	↘	-
	Middle	NA	-	-	NA	-	-	-
	Bottom	-	-	-	↘	-	-	-
	Average	-	-	-	↘	-	-	-
Secchi disc depth (m)		-	-	-	-	↗	-	-
Turbidity (NTU)	Surface	-	-	↗	↗	↗	↗	↗
	Middle	NA	↗	↗	NA	↗	↗	↗
	Bottom	-	↗	↗	↗	↗	↗	↗
	Average	-	-	↗	↗	↗	↗	↗
Suspended Solids (mg/L)	Surface	-	-	-	-	-	-	↘
	Middle	NA	-	-	NA	-	-	-
	Bottom	-	-	-	-	-	-	-
	Average	-	-	-	-	-	-	-
Total volatile solids (mg/L)	Surface	-	-	-	-	-	-	↘
	Middle	NA	-	-	NA	-	-	↘
	Bottom	-	-	↘	-	↘	-	-
	Average	-	-	-	-	↘	-	↘
5-day Biochemical Oxygen Demand (mg/L)	Surface	↘	↘	↘	↘	↘	↘	↘
	Middle	NA	↘	↘	NA	-	-	↘
	Bottom	-	-	-	-	-	-	↘
	Average	↘	↘	↘	↘	↘	↘	↘
Ammonia nitrogen (mg/L)	Surface	↘	-	-	-	-	-	-
	Middle	NA	-	-	NA	-	-	-
	Bottom	-	↘	-	-	-	-	-
	Average	↘	↘	-	-	-	-	-
Nitrite nitrogen (mg/L)	Surface	↘	↘	-	-	-	-	-
	Middle	NA	↘	↘	NA	↘	↘	-
	Bottom	-	↘	↘	-	↘	↘	-
	Average	↘	↘	-	↘	↘	↘	-
Nitrate nitrogen (mg/L)	Surface	↘	↘	↘	↘	↘	↘	↘
	Middle	NA	↘	↘	NA	↘	↘	-
	Bottom	↘	↘	↘	↘	↘	-	-
	Average	↘	↘	↘	↘	↘	-	-
Total inorganic nitrogen (mg/L)	Surface	↘	↘	-	-	-	-	-
	Middle	NA	↘	-	NA	-	↘	-
	Bottom	↘	↘	-	-	-	-	-
	Average	↘	↘	-	-	-	-	-
Total Kjeldahl nitrogen (mg/L)	Surface	↘	↘	↘	↘	↘	↘	↘
	Middle	NA	↘	↘	NA	↘	↘	↘
	Bottom	-	↘	↘	↘	↘	↘	-
	Average	↘	↘	↘	↘	↘	↘	↘
Total nitrogen (mg/L)	Surface	↘	↘	↘	↘	↘	↘	↘
	Middle	NA	↘	↘	NA	↘	↘	↘
	Bottom	↘	↘	↘	↘	↘	↘	-
	Average	↘	↘	↘	↘	↘	↘	↘
Orthophosphate phosphorus (mg/L)	Surface	↘	↘	↘	↘	↘	↘	-
	Middle	NA	↘	↘	NA	-	-	-
	Bottom	↘	↘	-	↘	-	-	-
	Average	↘	↘	↘	↘	↘	↘	-
Total phosphorus (mg/L)	Surface	↘	↘	↘	↘	↘	↘	↘
	Middle	NA	↘	↘	NA	-	↘	-
	Bottom	↘	↘	↘	↘	-	↘	-
	Average	↘	↘	↘	↘	↘	↘	↘
Silica (mg/L)	Surface	-	-	-	↗	-	-	-
	Middle	NA	-	-	NA	-	-	-
	Bottom	-	-	-	-	-	-	-
	Average	-	-	-	↗	-	-	-
Chlorophyll-*a* (µg/L)	Surface	-	-	-	-	-	-	-
	Middle	NA	-	-	NA	-	-	-
	Bottom	-	-	-	-	-	-	-
	Average	-	-	-	-	-	-	-
E. coli (cfu/100mL)	Surface	↘	-	-	-	-	-	-
	Middle	NA	-	↘	NA	-	-	-
	Bottom	↘	-	↘	-	-	-	-
	Average	↘	-	↘	-	↘	↘	-
Faecal coliforms (cfu/100mL)	Surface	-	↗	-	↗	-	-	-
	Middle	NA	-	-	NA	-	-	-
	Bottom	-	-	-	↗	-	-	-
	Average	-	-	-	↗	-	-	-

Note
1. Results of the Seasonal Kendall Test shown are statistically significant at $p < 0.05$
2. - indicates no significant trend is detected
3. NA (Not Applicable) indicates the measurement was not made due to shallow water
4. ↗ represents a significant increase over time
5. ↘ represents a significant decrease over time

CHAPTER 3

SOUTHERN WATER CONTROL ZONE



Chapter 3 – Southern Water Control Zone

Water Quality in 2003

3.1 The Southern Water Control Zone (WCZ) is largely an open water affected by Pearl River flow, local discharges and marine works in the southern part of Hong Kong Island (Figure 1.8). The effect of the Pearl River is generally stronger in the northern and western parts of the WCZ and gradually diminishes towards the eastern end. A summary of the 2003 water quality data from 15 monitoring stations in the Southern WCZ is shown in Table 3.1.

3.2 There was a widespread decrease of nitrogen in the Southern WCZ in 2003. The mean levels of ammonia nitrogen, total inorganic nitrogen (TIN) and total nitrogen in the WCZ were lowered by 0.009 mg/L (18%), 0.068 mg/L (33%) and 0.075 mg/L (22%) respectively. Silica has also decreased by about 16%. At the same time, a general reduction of chlorophyll-*a* concentration was seen in the WCZ with the exception of SM9-SM12 along the eastern coast of Lantau Island.

3.3 The levels of orthophosphate phosphorus (PO_4-P) and total phosphorus (TP) in the WCZ in 2003 were largely similar to those in 2002. As in other parts of Hong Kong, there was a decrease in dissolved oxygen (DO) in the whole WCZ by around 0.7mg/L (10%) in 2003. A widespread increase in salinity (by 1.0-5.6%) was also observed during the year.

3.4 A significant rise of sewage bacteria was found at the northern station SM9 near the Stonecutters Island Sewage Treatment Works (SCISTW) outfall in 2002. This, however, was not observed in 2003: the annual mean *E.coli* at SM9 dropped from the record high level of 290 cfu/100mL in 2002 to 190 cfu/100mL in 2003. Similar reduction was also found in the neighbouring area, at SM7 and SM10.

Compliance with Water Quality Objectives

3.5 The compliance of the Southern WCZ with the key Water Quality Objectives i.e. dissolved oxygen, unionised ammonia, TIN and *E. coli* between 1994 and 2003 is illustrated in Figure 3.1. Similar to 2002, full compliance (100%) with the WQOs for DO and unionised ammonia was achieved at all stations in 2003.

3.6 As there was a widespread decrease of nitrogen in the Southern WCZ, the overall compliance rate for the TIN WQO in the Southern WCZ has increased from 13% in 2002 to 44% in 2003. The majority of stations which complied with the TIN WQO were located in the eastern

part of the WCZ where influence from the Pearl River flow was minimal.

3.7 All the monitoring stations located within the secondary contact recreation subzones in the Southern water (i.e. SM1, SM2, SM10 and SM11) have achieved full compliance (100%) with the *E. coli* objective in 2003, indicating that the water was suitable for wind surfing, boating and other recreational activities.

Long-term Water Quality Trends

3.8 Between 1986 and 2003, significant increases in inorganic nitrogen, notably NO_2-N, NO_3-N and TIN, were found at the eastern coast of Lantau Island (SM10-13) (Table 3.2 and Figure 3.2). On the other hand, decreasing trends in total Kjeldahl nitrogen and total nitrogen were detected in two areas: a) South coast of Hong Kong Island (SM1-3) and b) Southern edge of the WCZ (SM17-19). The ammonia levels in Southern water remained largely stable during the same period.

3.9 Together with the long-term increases in nitrogenous nutrients, the Southern WCZ has also experienced a decline in total phosphorus, mainly in two areas: a) south of Hong Kong Island (SM1-4) and b) along the southern edge of the Southern WCZ (SM17-19) (Figure 3.2). Despite the changes in nitrogen and phosphorus nutrients, the silica and chlorophyll-*a* levels in the WCZ remained relatively stable in the past 18 years.

3.10 The level of *E. coli* bacteria in the Southern WCZ has remained largely low and stable with a few exceptions including the stations SM2, SM4, SM7 and SM9 showed increasing trends (Table 3.2 and Figure 3.2). While the increase of *E. coli* at SM9 may be related to the SCISTW outfall discharges, the increase of *E. coli* at SM4 could indicate increasing pollution from Sok Kwu Wan in Lamma Island. Under the Outlying Island Sewerage Master Plan, the Government has plans to provide public sewage infrastructure to prevent any deterioration of water quality in the area.

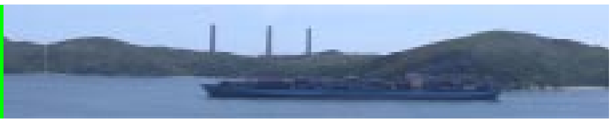


Figure 3.1 Level of compliance with key Water Quality Objectives in the Southern WCZ

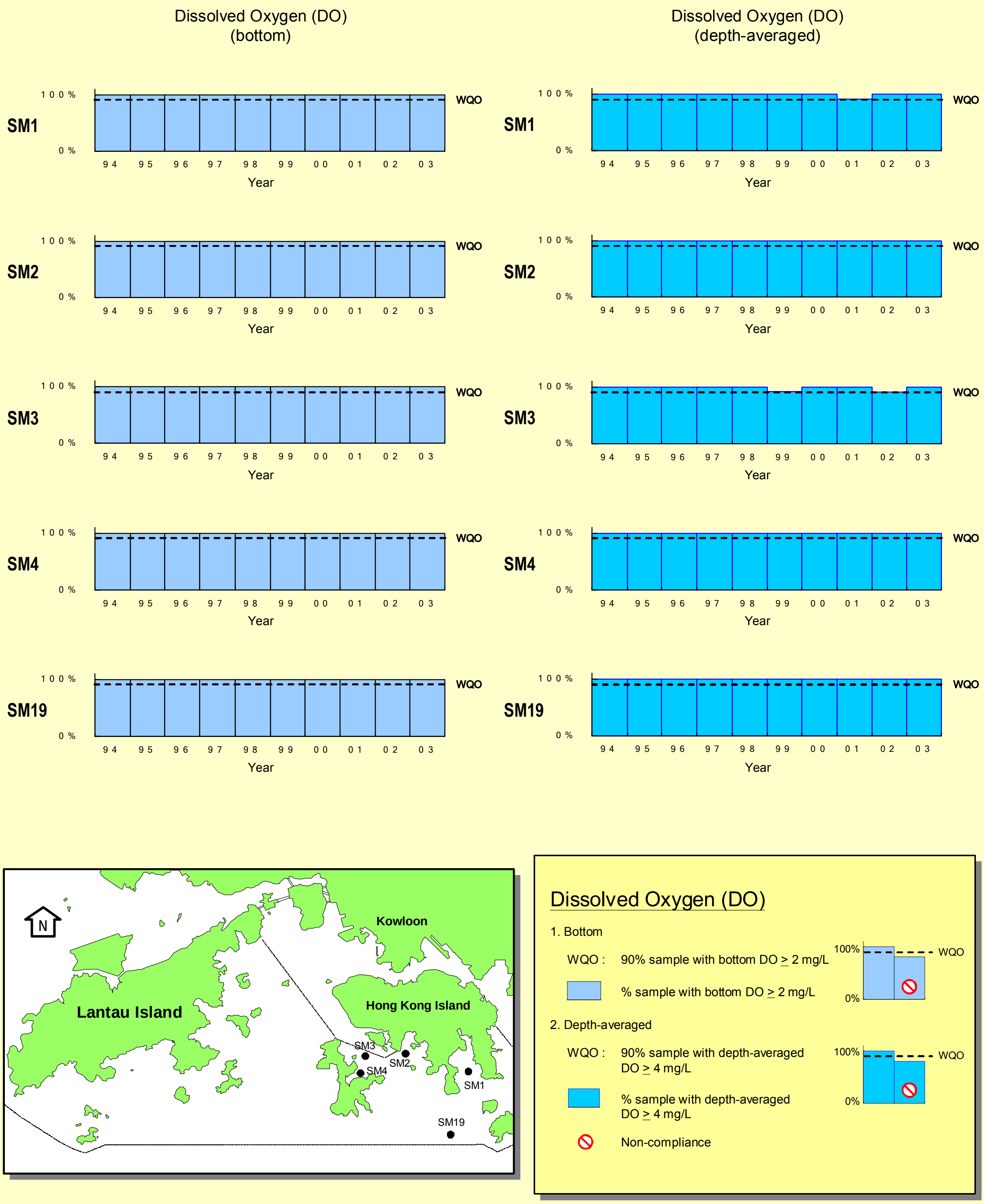
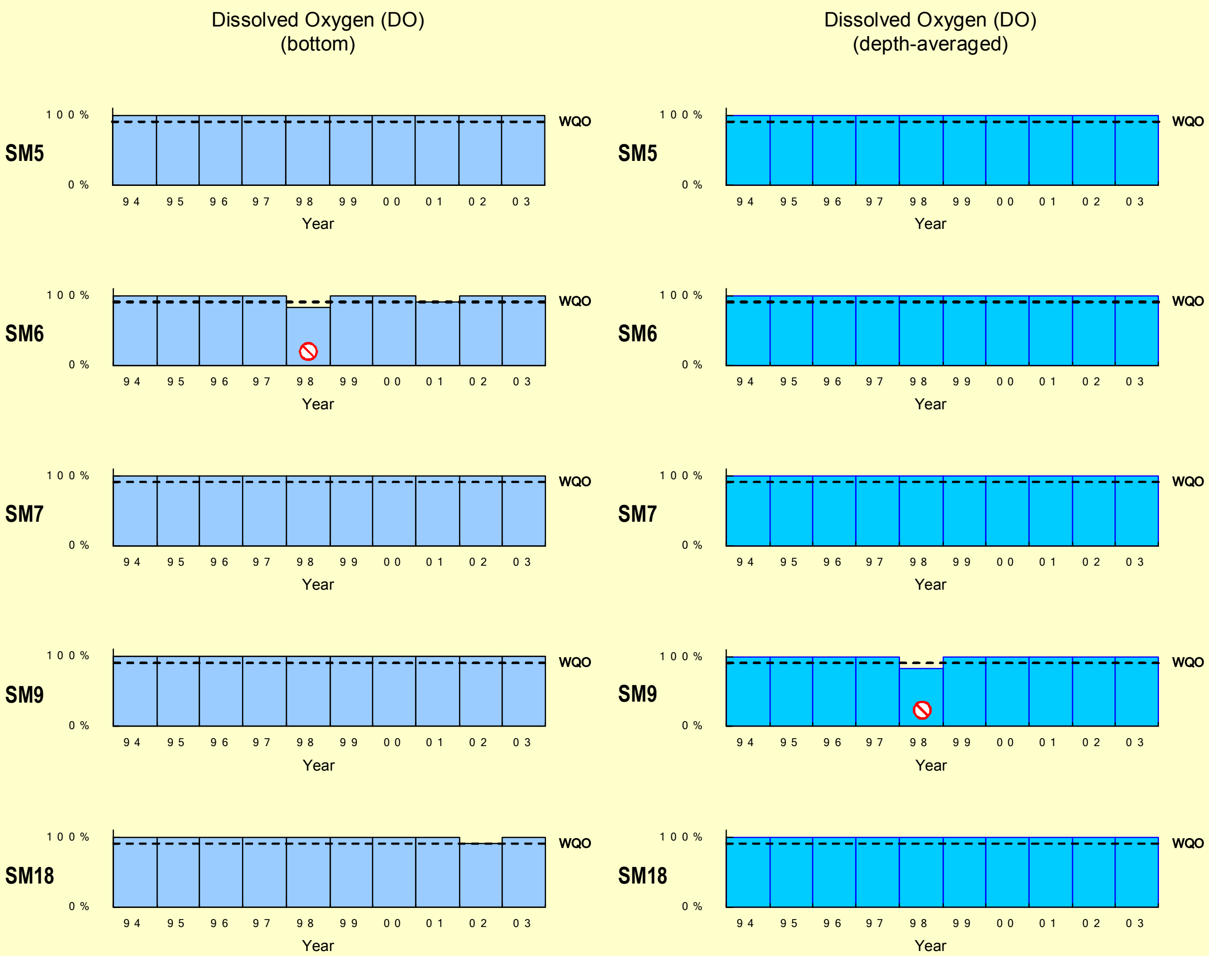
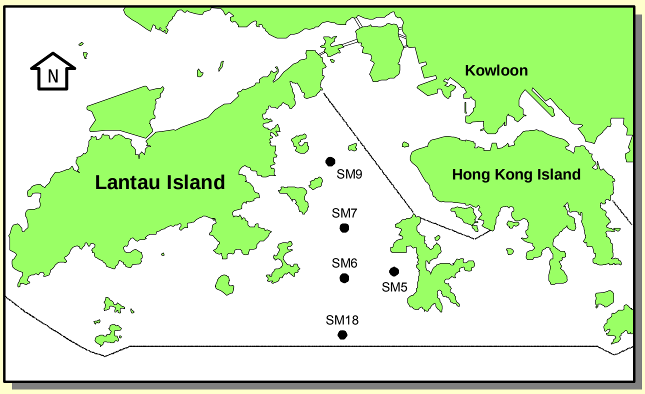


Figure 3.1 (continued) Level of compliance with key Water Quality Objectives in the Southern WCZ





Dissolved Oxygen (DO)

1. Bottom

WQO : 90% sample with bottom DO $\geq$ 2 mg/L

% sample with bottom DO $\geq$ 2 mg/L

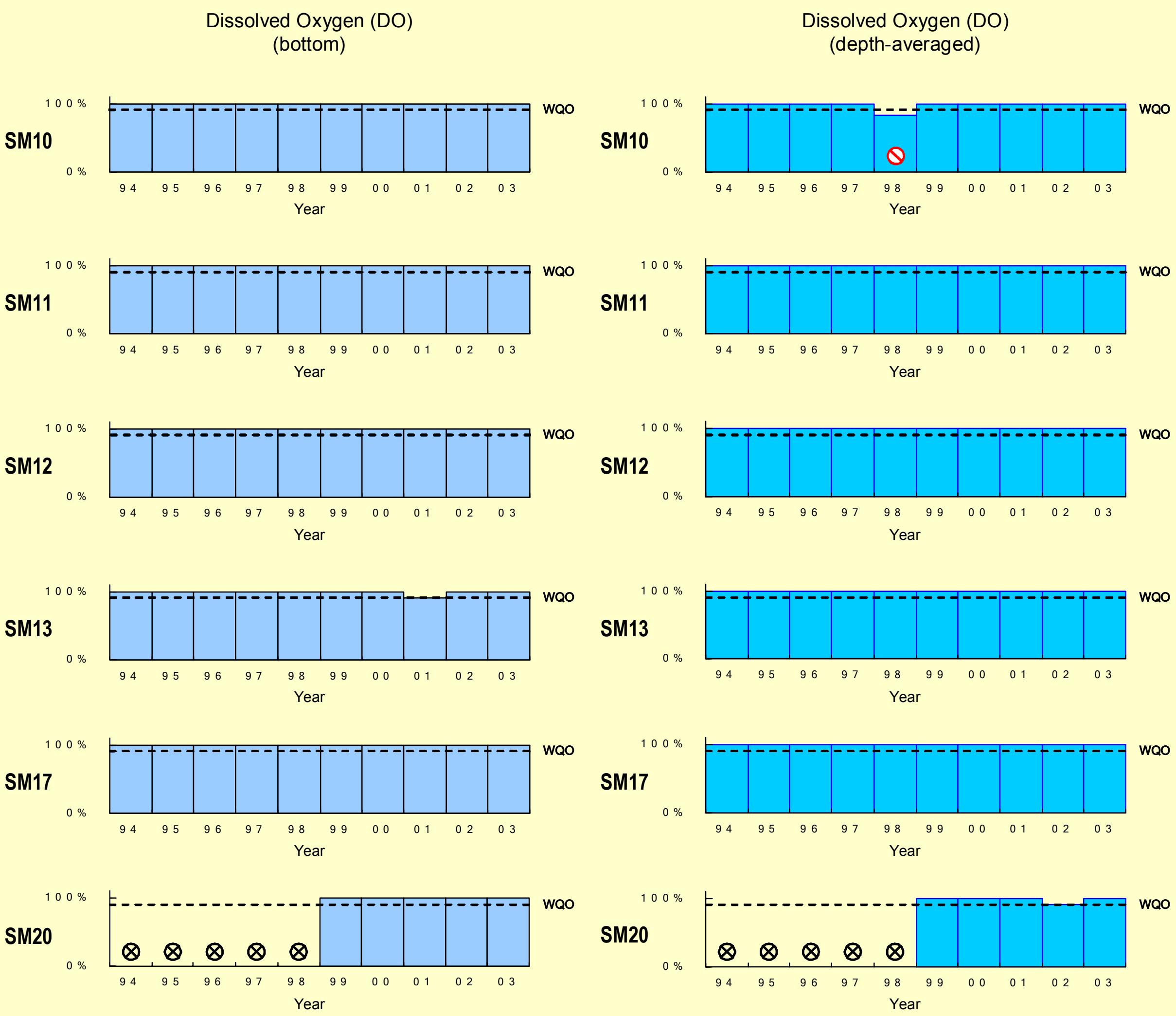
2. Depth-averaged

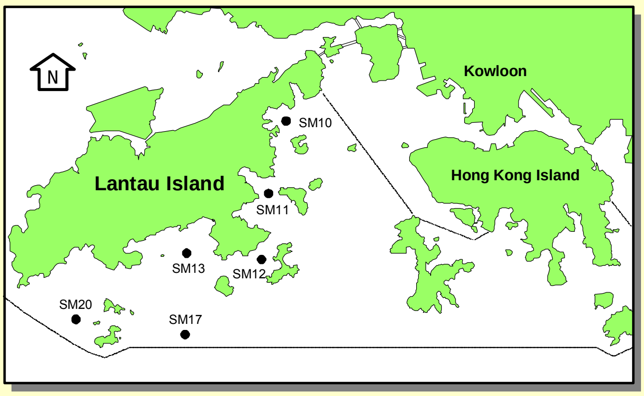
WQO : 90% sample with depth-averaged DO $\geq$ 4 mg/L

% sample with depth-averaged DO $\geq$ 4 mg/L

Non-compliance

Figure 3.1 (continued) Level of compliance with key Water Quality Objectives in the Southern WCZ





Dissolved Oxygen (DO)

1. Bottom

WQO : 90% sample with bottom DO ≥ 2 mg/L

% sample with bottom DO ≥ 2 mg/L

2. Depth-averaged

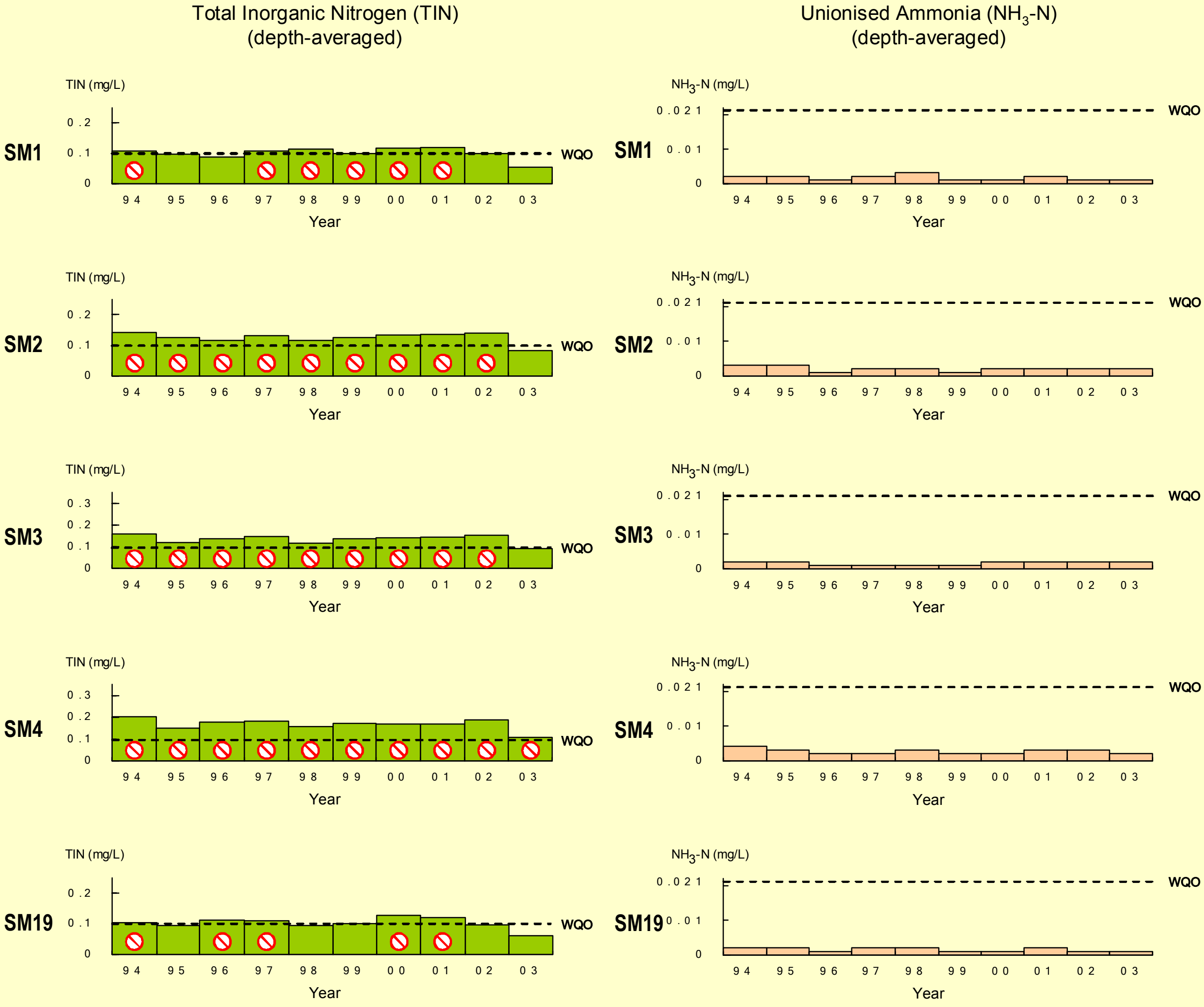
WQO : 90% sample with depth-averaged DO ≥ 4 mg/L

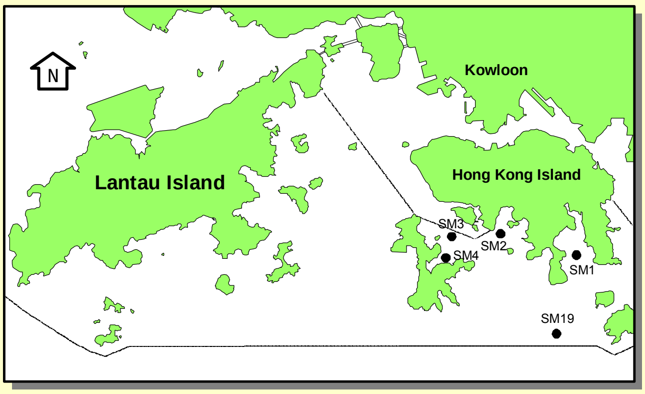
% sample with depth-averaged DO ≥ 4 mg/L

Non-compliance

No data ; monitoring of SM20 started in 1999

Figure 3.1 (continued) Level of compliance with key Water Quality Objectives in the Southern WCZ





Total Inorganic Nitrogen (TIN)

WQO : annual mean for depth-averaged TIN $\leq$ 0.1 mg/L

annual mean for depth-averaged TIN

Unionised Ammonia (NH_3-N)

WQO : annual mean for depth-averaged NH_3-N $\leq$ 0.021 mg/L

annual mean for depth-averaged NH_3-N

Non-compliance

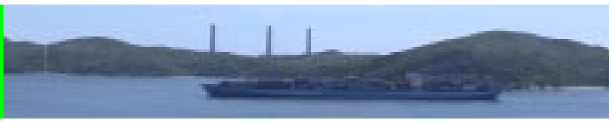
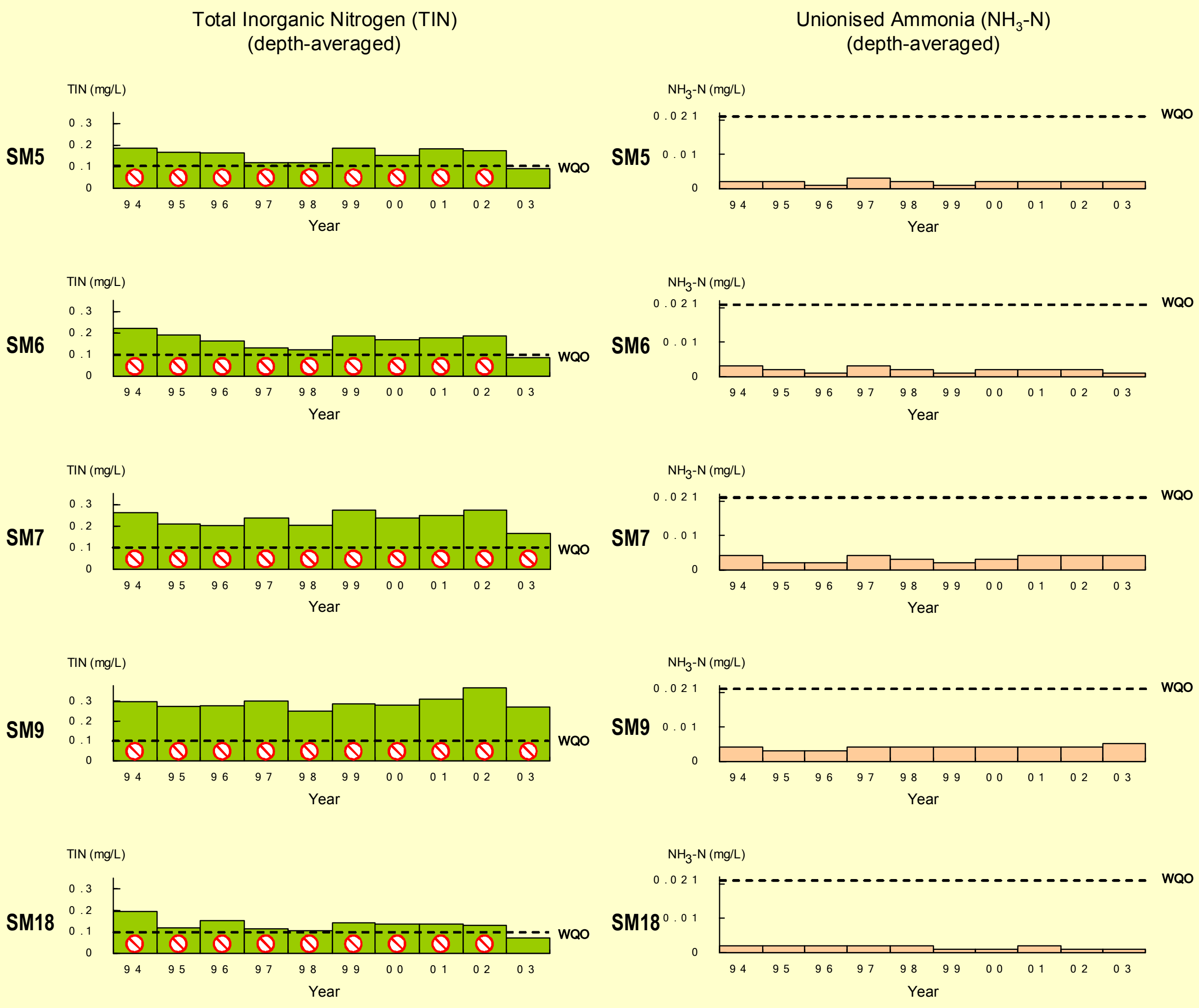
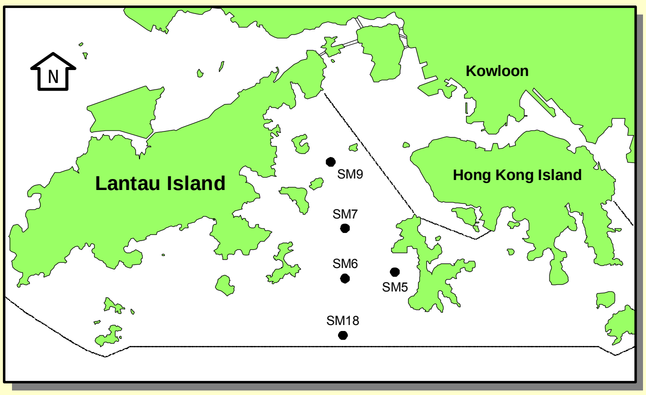


Figure 3.1 (continued) Level of compliance with key Water Quality Objectives in the Southern WCZ





Total Inorganic Nitrogen (TIN)

WQO : annual mean for depth-averaged TIN ≤ 0.1 mg/L

annual mean for depth-averaged TIN

TIN (mg/L) 0.1 WQO 0

Unionised Ammonia (NH_3-N)

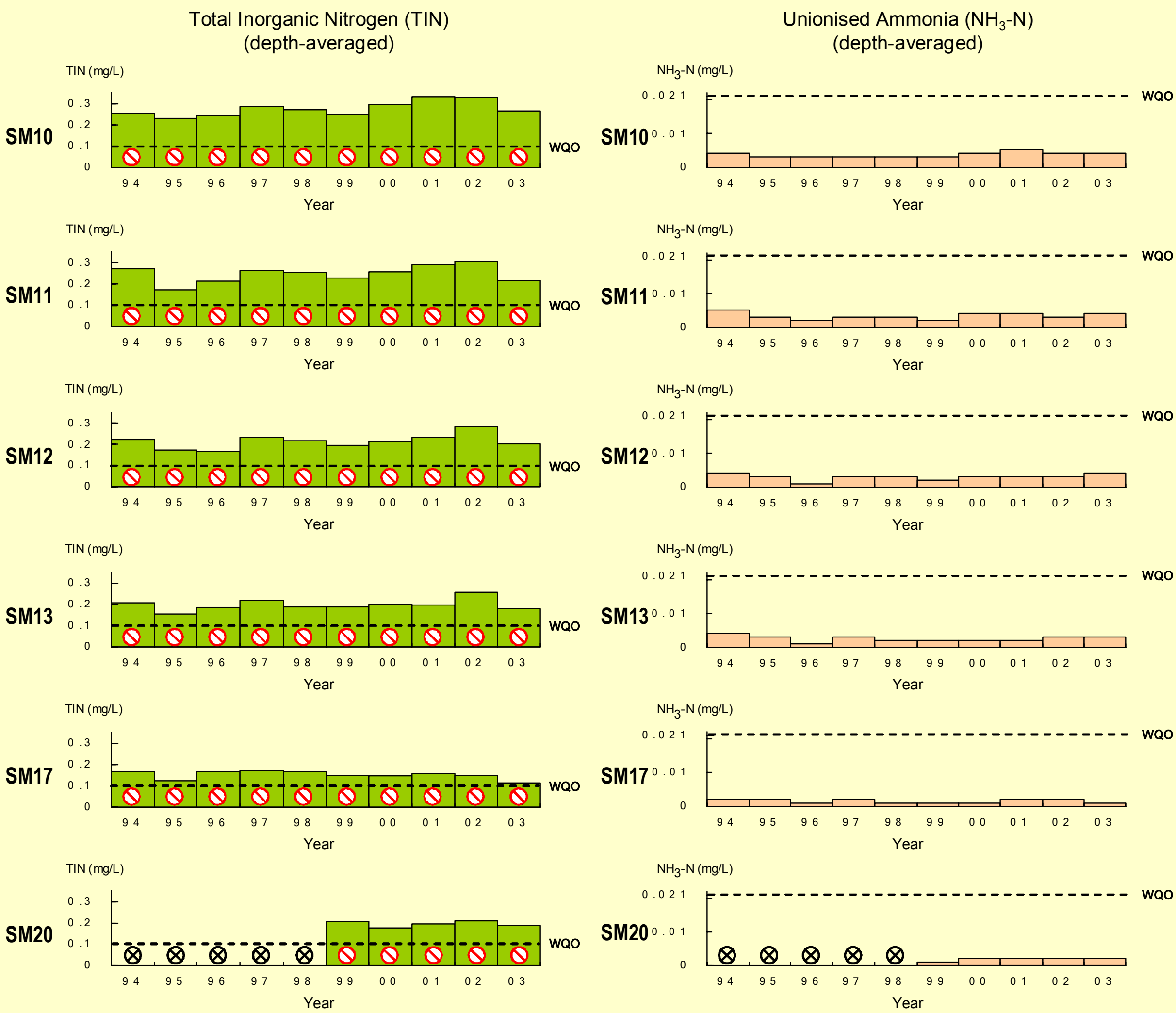
WQO : annual mean for depth-averaged NH_3-N ≤ 0.021 mg/L

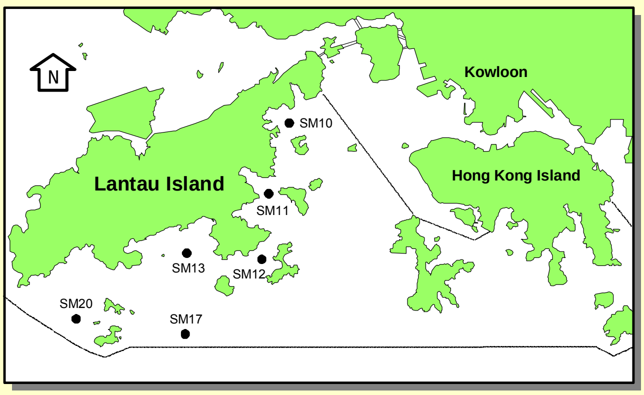
annual mean for depth-averaged NH_3-N

NH_3-N (mg/L) 0.021 WQO 0

Non-compliance

Figure 3.1 (continued) Level of compliance with key Water Quality Objectives in the Southern WCZ





Total Inorganic Nitrogen (TIN)

WQO : annual mean for depth-averaged TIN $\leq$ 0.1 mg/L

annual mean for depth-averaged TIN

Unionised Ammonia (NH_3-N)

WQO : annual mean for depth-averaged NH_3-N $\leq$ 0.021 mg/L

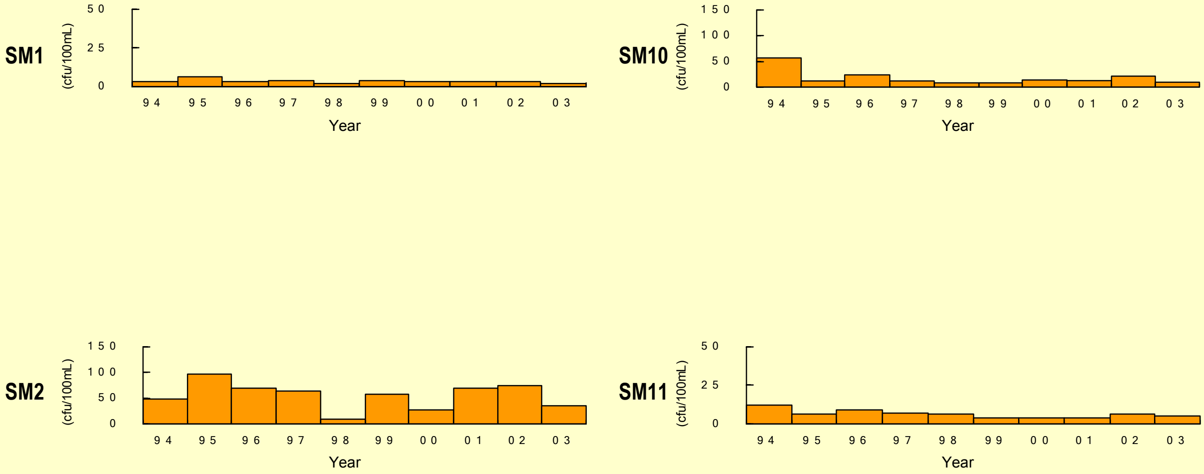
annual mean for depth-averaged NH_3-N

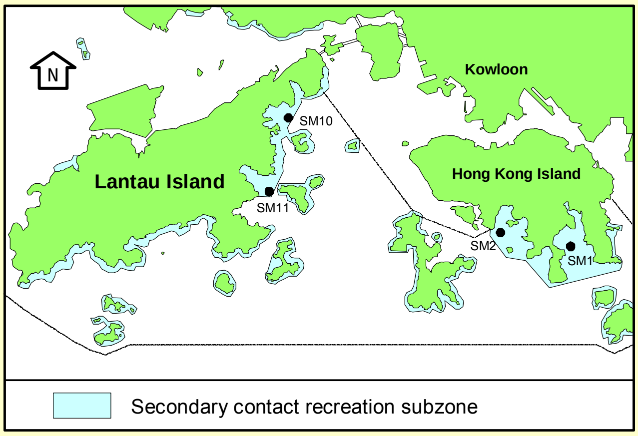
Non-compliance

No data ; monitoring of SM20 started in 1999

Figure 3.1 (continued) Level of compliance with key Water Quality Objectives in the Southern WCZ

E. coli
(annual geometric mean)





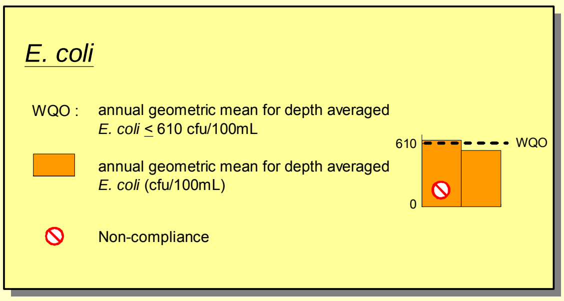
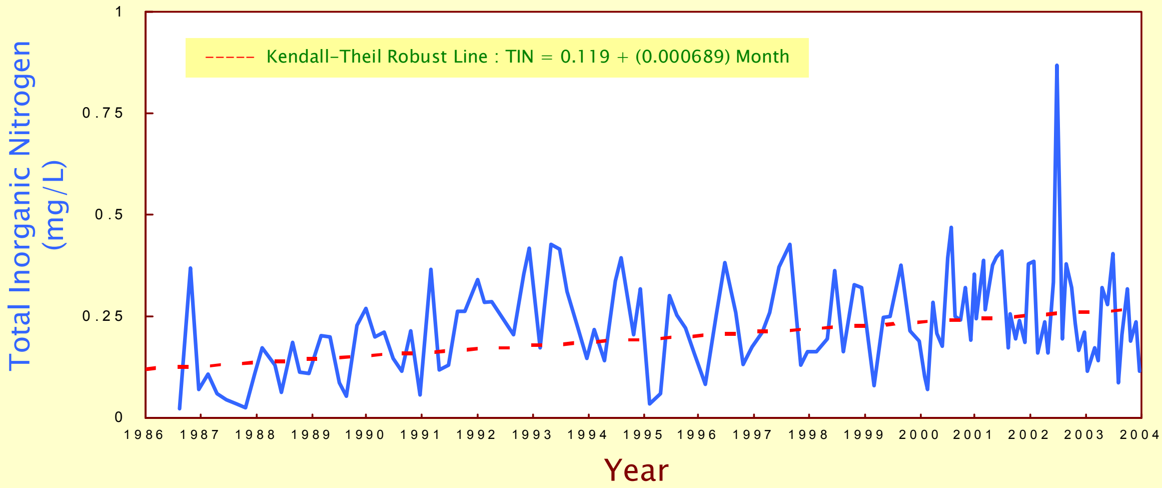
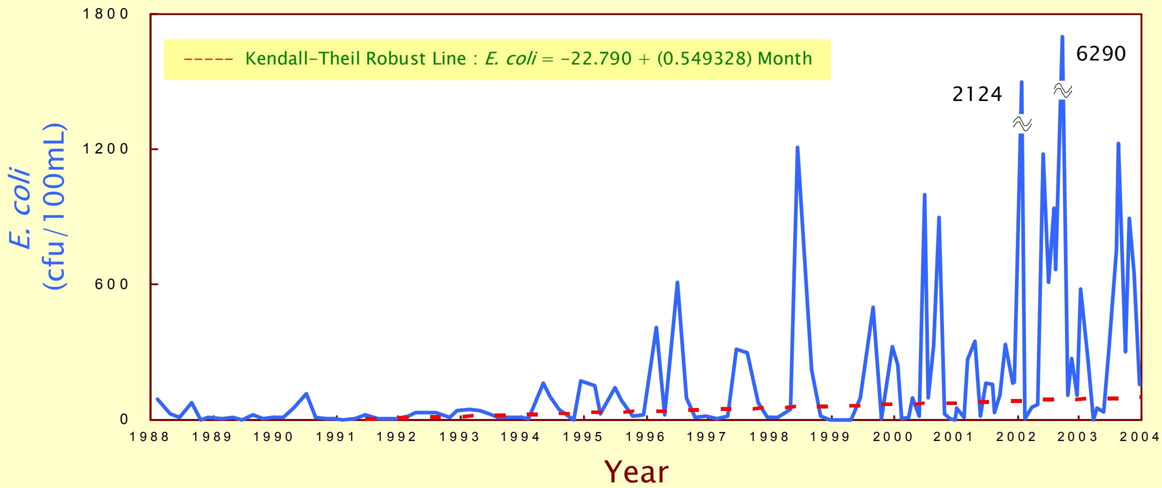


Figure 3.2 Marine water quality trends in the Southern WCZ
(based on the Seasonal Kendall Test significant at $p<0.05$)

Increasing trend in depth-averaged Total Inorganic Nitrogen at SM11, 1986 – 2003



Increasing trend in depth-averaged *E. coli* at SM9, 1988 – 2003



Decreasing trend in depth-averaged Total Phosphorus at SM17, 1986 – 2003

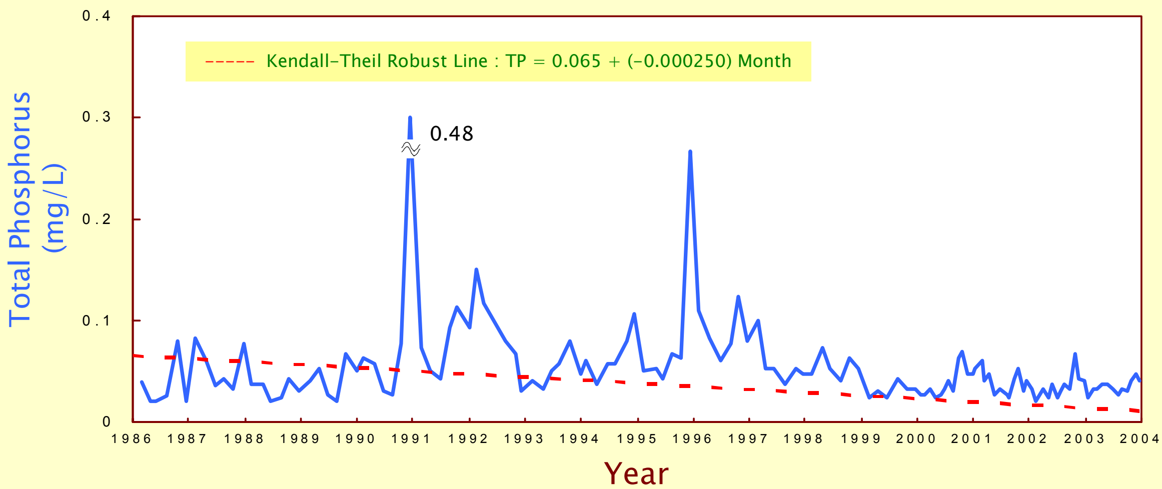


Table 3.1

Summary water quality statistics of the Southern WCZ in 2003

Parameter	Hong Kong Island (South)			East Lamma Channel	
	SM1	SM2	SM19	SM3	SM4
Number of samples	12	12	12	12	12
Temperature (°C)	23.2 (16.5 - 27.8)	23.4 (16.8 - 27.9)	23.1 (16.2 - 27.8)	23.4 (16.9 - 27.9)	23.5 (17.0 - 27.9)
Salinity	33.0 (31.4 - 34.0)	32.8 (31.4 - 34.0)	33.0 (32.1 - 34.0)	32.9 (31.5 - 33.9)	32.6 (30.5 - 33.8)
Dissolved Oxygen (mg/L)	6.0 (4.9 - 7.3)	5.8 (4.1 - 7.6)	5.9 (4.7 - 7.4)	5.8 (4.5 - 7.7)	5.8 (4.3 - 7.5)
Bottom	5.9 (3.8 - 7.6)	5.6 (3.6 - 7.6)	5.7 (3.7 - 7.4)	5.6 (3.0 - 7.7)	5.7 (3.7 - 7.4)
Dissolved Oxygen (% Saturation)	85 (75 - 93)	81 (62 - 95)	83 (69 - 99)	82 (67 - 97)	82 (65 - 94)
Bottom	82 (56 - 94)	79 (53 - 95)	79 (54 - 92)	78 (45 - 96)	81 (54 - 93)
pH	8.2 (8.0 - 8.4)	8.2 (8.0 - 8.4)	8.2 (8.0 - 8.4)	8.2 (8.0 - 8.3)	8.2 (8.0 - 8.4)
Secchi Disc Depth (m)	3.0 (1.8 - 5.9)	2.4 (1.8 - 4.5)	2.8 (1.4 - 6.0)	2.7 (1.8 - 5.0)	2.4 (1.8 - 4.0)
Turbidity (NTU)	8.8 (3.6 - 16.7)	9.0 (5.2 - 15.7)	9.1 (5.9 - 12.5)	9.6 (5.6 - 18.9)	8.2 (5.3 - 12.0)
Suspended Solids (mg/L)	5.3 (1.2 - 15.3)	5.5 (1.7 - 13.5)	4.9 (1.1 - 9.6)	6.0 (1.3 - 18.8)	4.5 (1.0 - 7.6)
5-day Biochemical Oxygen Demand (mg/L)	0.7 (0.1 - 1.7)	0.8 (0.4 - 1.4)	0.7 (0.4 - 1.2)	0.9 (0.4 - 2.2)	0.9 (0.4 - 1.8)
Ammonia Nitrogen (mg/L)	0.02 (0.01 - 0.03)	0.02 (0.01 - 0.04)	0.02 (0.01 - 0.04)	0.03 (0.01 - 0.05)	0.04 (0.01 - 0.08)
Unionised Ammonia (mg/L)	0.001 (<0.001 - 0.004)	0.002 (<0.001 - 0.005)	0.001 (<0.001 - 0.004)	0.002 (<0.001 - 0.004)	0.002 (0.001 - 0.006)
Nitrite Nitrogen (mg/L)	0.01 (<0.01 - 0.05)	0.01 (<0.01 - 0.07)	0.01 (<0.01 - 0.06)	0.01 (<0.01 - 0.08)	0.02 (<0.01 - 0.09)
Nitrate Nitrogen (mg/L)	0.03 (<0.01 - 0.09)	0.04 (<0.01 - 0.13)	0.03 (<0.01 - 0.10)	0.05 (<0.01 - 0.15)	0.05 (<0.01 - 0.20)
Total Inorganic Nitrogen (mg/L)	0.05 (0.01 - 0.15)	0.08 (0.01 - 0.21)	0.06 (0.01 - 0.15)	0.09 (0.02 - 0.24)	0.11 (0.03 - 0.31)
Total Kjeldahl Nitrogen (mg/L)	0.11 (0.07 - 0.17)	0.13 (0.09 - 0.21)	0.10 (0.07 - 0.15)	0.13 (0.10 - 0.17)	0.14 (0.10 - 0.22)
Total Nitrogen (mg/L)	0.14 (0.08 - 0.26)	0.19 (0.10 - 0.32)	0.15 (0.07 - 0.25)	0.19 (0.12 - 0.37)	0.21 (0.11 - 0.41)
Orthophosphate Phosphorus (mg/L)	<0.01 (<0.01 - 0.01)	<0.01 (<0.01 - 0.01)	<0.01 (<0.01 - 0.02)	<0.01 (0.01 - 0.02)	0.010 (<0.01 - 0.02)
Total Phosphorus (mg/L)	0.02 (0.02 - 0.03)	0.02 (0.02 - 0.02)	0.02 (0.02 - 0.03)	0.02 (0.02 - 0.03)	0.02 (0.02 - 0.03)
Silica (as SiO_2) (mg/L)	0.5 (0.2 - 1.1)	0.6 (0.2 - 1.3)	0.6 (0.2 - 1.2)	0.6 (0.2 - 1.4)	0.6 (0.2 - 1.6)
Chlorophyll-*a* (µg/L)	1.7 (0.8 - 6.2)	2.1 (0.9 - 9.4)	1.6 (0.8 - 3.5)	2.0 (0.8 - 7.3)	2.6 (1.0 - 12.7)
E. coli (cfu/100mL)	2 (1 - 4)	35 (2 - 350)	1 (1 - 2)	15 (1 - 110)	21 (1 - 58)
Faecal Coliforms (cfu/100mL)	3 (1 - 11)	72 (6 - 590)	1 (1 - 3)	30 (2 - 130)	49 (3 - 170)

Note :
1. Unless otherwise specified, data presented are depth-averaged (A) values calculated by taking the means of three depths: Surface (S), Mid-depth (M), Bottom (B).
2. Data presented are annual arithmetic means of the depth-averaged results except for *E. coli* and faecal coliforms which are annual geometric means.
3. Data in brackets indicate the ranges.

Table 3.1 (continued)

Summary water quality statistics of the Southern WCZ in 2003

Parameter		West Lamma Channel				
		SM5	SM6	SM7	SM9	SM18
Number of samples		12	12	12	12	12
Temperature (°C)		23.7 (16.8 - 28.2)	23.5 (16.9 - 28.1)	23.6 (17.0 - 28.2)	23.7 (17.9 - 27.8)	23.4 (16.4 - 28.0)
Salinity		32.1 (28.1 - 34.0)	32.4 (30.1 - 34.0)	31.8 (27.5 - 34.0)	31.4 (26.9 - 33.8)	32.8 (31.2 - 34.1)
Dissolved Oxygen (mg/L)		6.3 (5.2 - 8.4)	6.2 (5.4 - 7.2)	6.0 (4.7 - 7.8)	5.7 (4.0 - 7.3)	5.9 (4.6 - 7.4)
	Bottom	6.2 (5.1 - 7.9)	5.8 (2.7 - 7.3)	6.0 (4.7 - 7.6)	5.5 (3.8 - 7.3)	5.6 (2.9 - 7.4)
Dissolved Oxygen (% Saturation)		90 (73 - 125)	88 (75 - 106)	85 (70 - 117)	81 (60 - 105)	84 (69 - 103)
	Bottom	88 (69 - 118)	81 (40 - 94)	85 (70 - 114)	77 (55 - 99)	78 (43 - 93)
pH		8.3 (8.0 - 8.6)	8.2 (8.0 - 8.5)	8.2 (8.0 - 8.5)	8.2 (7.9 - 8.3)	8.2 (8.0 - 8.5)
Secchi Disc Depth (m)		2.1 (0.5 - 3.1)	2.3 (1.3 - 3.0)	1.9 (1.0 - 2.7)	1.9 (1.0 - 2.9)	2.5 (1.5 - 6.7)
Turbidity (NTU)		9.9 (3.6 - 17.2)	9.0 (4.0 - 14.3)	10.5 (4.8 - 15.5)	10.8 (7.1 - 14.0)	9.6 (5.0 - 17.0)
Suspended Solids (mg/L)		6.6 (2.2 - 14.7)	5.7 (1.9 - 12.0)	8.2 (4.7 - 13.9)	9.7 (4.8 - 25.3)	5.6 (1.1 - 15.0)
5-day Biochemical Oxygen Demand (mg/L)		0.9 (0.4 - 2.6)	0.9 (0.5 - 2.0)	1.1 (0.6 - 3.0)	0.8 (0.4 - 1.2)	0.7 (0.3 - 1.5)
Ammonia Nitrogen (mg/L)		0.02 (0.01 - 0.05)	0.02 (0.01 - 0.04)	0.05 (0.01 - 0.15)	0.09 (0.03 - 0.19)	0.02 (0.01 - 0.04)
Unionised Ammonia (mg/L)		0.002 (<0.001 - 0.006)	0.001 (<0.001 - 0.005)	0.004 (0.001 - 0.009)	0.005 (0.002 - 0.010)	0.001 (<0.001 - 0.006)
Nitrite Nitrogen (mg/L)		0.01 (<0.01 - 0.06)	0.01 (<0.01 - 0.06)	0.02 (<0.01 - 0.11)	0.04 (0.01 - 0.14)	0.01 (<0.01 - 0.06)
Nitrate Nitrogen (mg/L)		0.06 (<0.01 - 0.23)	0.05 (<0.01 - 0.14)	0.09 (<0.01 - 0.24)	0.15 (0.02 - 0.46)	0.04 (<0.01 - 0.14)
Total Inorganic Nitrogen (mg/L)		0.09 (0.02 - 0.28)	0.09 (0.01 - 0.21)	0.16 (0.03 - 0.36)	0.27 (0.12 - 0.64)	0.07 (0.02 - 0.19)
Total Kjeldahl Nitrogen (mg/L)		0.14 (0.08 - 0.32)	0.13 (0.08 - 0.21)	0.20 (0.10 - 0.34)	0.22 (0.17 - 0.29)	0.11 (0.06 - 0.18)
Total Nitrogen (mg/L)		0.21 (0.08 - 0.45)	0.19 (0.10 - 0.36)	0.31 (0.11 - 0.49)	0.40 (0.25 - 0.80)	0.17 (0.06 - 0.33)
Orthophosphate Phosphorus (mg/L)		<0.01 (<0.01 - 0.01)	<0.01 (<0.01 - 0.01)	0.012 (<0.01 - 0.02)	0.020 (0.01 - 0.03)	<0.01 (<0.01 - 0.01)
Total Phosphorus (mg/L)		0.02 (0.02 - 0.03)	0.02 (0.02 - 0.03)	0.03 (0.02 - 0.04)	0.04 (0.03 - 0.06)	0.02 (0.02 - 0.03)
Silica (as SiO_2) (mg/L)		0.5 (0.2 - 1.3)	0.6 (0.2 - 1.2)	0.6 (0.1 - 1.8)	1.0 (0.4 - 2.7)	0.6 (0.2 - 1.3)
Chlorophyll-*a* (µg/L)		3.3 (0.8 - 12.8)	3.8 (0.8 - 13.0)	5.2 (1.1 - 23.0)	4.1 (0.6 - 10.3)	2.2 (1.0 - 6.9)
E. coli (cfu/100mL)		1 (1 - 7)	2 (1 - 25)	20 (1 - 2100)	190 (1 - 1200)	1 (1 - 6)
Faecal Coliforms (cfu/100mL)		3 (1 - 43)	4 (1 - 43)	42 (2 - 3300)	380 (5 - 2700)	2 (1 - 8)

Note :
1. Unless otherwise specified, data presented are depth-averaged (A) values calculated by taking the means of three depths: Surface (S), Mid-depth (M), Bottom (B).
2. Data presented are annual arithmetic means of the depth-averaged results except for *E. coli* and faecal coliforms which are annual geometric means.
3. Data in brackets indicate the ranges.

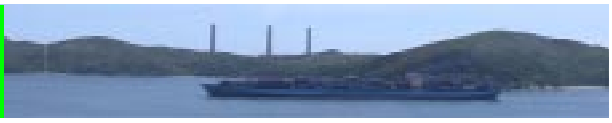


Table 3.1 (continued)

Summary water quality statistics of the Southern WCZ in 2003

Parameter		Lantau Island (East)		Lantau Island (South)			Soko Islands
		SM10	SM11	SM12	SM13	SM17	SM20
Number of samples		12	12	12	12	12	12
Temperature (°C)		23.7 (17.1 - 28.4)	23.8 (17.3 - 28.5)	23.7 (17.6 - 28.4)	23.7 (17.7 - 28.4)	23.4 (17.7 - 28.1)	23.7 (17.8 - 28.2)
Salinity		30.7 (26.0 - 33.7)	31.1 (27.7 - 33.8)	31.4 (29.0 - 33.8)	31.4 (28.1 - 33.8)	32.5 (30.4 - 34.1)	31.3 (27.1 - 33.8)
Dissolved Oxygen (mg/L)		6.6 (5.2 - 9.4)	7.0 (5.6 - 9.3)	6.2 (5.4 - 7.8)	6.6 (5.5 - 7.9)	6.2 (4.7 - 8.2)	6.2 (4.5 - 7.8)
	Bottom	6.7 (5.3 - 9.5)	6.7 (5.4 - 9.2)	6.0 (5.3 - 7.7)	6.5 (5.4 - 7.7)	5.5 (3.4 - 8.1)	5.9 (3.9 - 7.4)
Dissolved Oxygen (% Saturation)		93 (75 - 142)	100 (79 - 140)	88 (73 - 119)	94 (82 - 121)	87 (70 - 105)	88 (66 - 117)
	Bottom	94 (77 - 142)	95 (79 - 140)	86 (72 - 117)	92 (79 - 106)	77 (50 - 103)	84 (58 - 95)
pH		8.2 (8.0 - 8.3)	8.2 (7.9 - 8.4)	8.2 (8.0 - 8.4)	8.2 (8.0 - 8.4)	8.2 (8.0 - 8.4)	8.2 (8.0 - 8.4)
Secchi Disc Depth (m)		1.5 (0.5 - 2.4)	1.6 (0.5 - 3.0)	1.8 (1.0 - 2.9)	1.9 (0.5 - 2.8)	1.8 (0.5 - 3.0)	1.7 (0.5 - 3.0)
Turbidity (NTU)		12.3 (4.5 - 17.7)	12.2 (3.6 - 36.9)	11.9 (3.9 - 19.9)	11.8 (5.3 - 24.5)	13.2 (5.3 - 32.6)	12.7 (3.9 - 24.8)
Suspended Solids (mg/L)		18.7 (5.9 - 107.8)	10.0 (5.2 - 41.7)	10.0 (5.0 - 20.0)	10.8 (2.5 - 27.3)	10.8 (3.1 - 36.0)	9.7 (3.5 - 24.3)
5-day Biochemical Oxygen Demand (mg/L)		1.2 (0.5 - 2.7)	1.3 (0.4 - 2.7)	1.0 (0.3 - 2.2)	0.9 (0.3 - 1.8)	0.7 (0.2 - 1.5)	0.8 (0.2 - 1.8)
Ammonia Nitrogen (mg/L)		0.08 (0.02 - 0.17)	0.07 (0.02 - 0.17)	0.06 (0.02 - 0.14)	0.05 (0.01 - 0.12)	0.02 (0.01 - 0.05)	0.04 (0.01 - 0.10)
Unionised Ammonia (mg/L)		0.004 (0.001 - 0.007)	0.004 (0.001 - 0.007)	0.004 (0.001 - 0.006)	0.003 (0.001 - 0.006)	0.001 (<0.001 - 0.003)	0.002 (<0.001 - 0.004)
Nitrite Nitrogen (mg/L)		0.04 (<0.01 - 0.14)	0.03 (0.01 - 0.11)	0.03 (<0.01 - 0.10)	0.03 (<0.01 - 0.11)	0.02 (<0.01 - 0.07)	0.03 (<0.01 - 0.10)
Nitrate Nitrogen (mg/L)		0.15 (0.03 - 0.45)	0.11 (0.03 - 0.27)	0.11 (0.02 - 0.24)	0.10 (0.01 - 0.31)	0.07 (<0.01 - 0.21)	0.12 (0.01 - 0.41)
Total Inorganic Nitrogen (mg/L)		0.26 (0.10 - 0.61)	0.21 (0.09 - 0.40)	0.20 (0.09 - 0.34)	0.18 (0.07 - 0.43)	0.11 (0.01 - 0.29)	0.19 (0.04 - 0.52)
Total Kjeldahl Nitrogen (mg/L)		0.25 (0.15 - 0.36)	0.25 (0.16 - 0.30)	0.21 (0.17 - 0.27)	0.20 (0.14 - 0.26)	0.13 (0.08 - 0.20)	0.17 (0.12 - 0.26)
Total Nitrogen (mg/L)		0.44 (0.19 - 0.95)	0.39 (0.25 - 0.61)	0.35 (0.21 - 0.51)	0.33 (0.17 - 0.59)	0.22 (0.09 - 0.41)	0.32 (0.13 - 0.66)
Orthophosphate Phosphorus (mg/L)		0.016 (<0.01 - 0.03)	0.015 (<0.01 - 0.03)	0.014 (<0.01 - 0.02)	0.011 (<0.01 - 0.02)	<0.01 (0.01 - 0.02)	0.010 (<0.01 - 0.02)
Total Phosphorus (mg/L)		0.04 (0.02 - 0.11)	0.04 (0.02 - 0.05)	0.03 (0.02 - 0.05)	0.03 (0.02 - 0.05)	0.03 (0.02 - 0.04)	0.03 (0.02 - 0.04)
Silica (as SiO_2) (mg/L)		0.9 (0.3 - 2.7)	0.8 (0.3 - 2.2)	0.8 (0.4 - 1.9)	0.8 (0.4 - 2.2)	0.7 (0.2 - 1.7)	0.9 (0.3 - 2.5)
Chlorophyll-*a* (μg/L)		8.7 (0.7 - 20.0)	9.9 (0.9 - 26.3)	6.7 (1.1 - 18.7)	5.8 (0.9 - 18.0)	3.5 (0.8 - 10.2)	4.4 (0.9 - 14.4)
E. coli (cfu/100mL)		9 (1 - 140)	5 (1 - 450)	16 (1 - 320)	5 (1 - 120)	1 (1 - 3)	2 (1 - 43)
Faecal Coliforms (cfu/100mL)		16 (1 - 170)	11 (2 - 710)	32 (1 - 660)	7 (1 - 220)	2 (1 - 11)	3 (1 - 72)

Note :
1. Unless otherwise specified, data presented are depth-averaged (A) values calculated by taking the means of three depths: Surface (S), Mid-depth (M), Bottom (B).
2. Data presented are annual arithmetic means of the depth-averaged results except for *E. coli* and faecal coliforms which are annual geometric means.
3. Data in brackets indicate the ranges.

Table 3.2

Results of the Seasonal Kendall Test for trends in water quality parameters measured in the Southern WCZ, 1986 – 2003

Monitoring Station		SM1	SM2	SM3	SM4	SM5	SM6	SM7	SM9
Monitoring Period		1986 – 2003	1986 – 2003	1986 – 2003	1986 – 2003	1986 – 2003	1986 – 2003	1986 – 2003	1988 – 2003
Parameter	Water Depth								
Temperature (°C)	Surface	-	-	↗	-	↗	↗	↗	↗
	Middle	-	-	↗	↗	↗	↗	↗	↗
	Bottom	-	↗	↗	↗	↗	-	↗	↗
	Average	-	-	-	-	↗	↗	↗	↗
Salinity	Surface	-	-	-	-	-	-	-	-
	Middle	-	-	-	-	-	-	-	-
	Bottom	-	-	-	-	-	-	-	-
	Average	-	-	-	-	-	-	-	-
Dissolved Oxygen (mg/L)	Surface	↘	-	↘	↘	↘	-	-	-
	Middle	-	-	-	-	-	-	-	-
	Bottom	-	-	-	-	-	↘	-	-
	Average	-	-	-	↘	-	↘	-	-
Dissolved Oxygen (%)	Surface	↘	-	↘	↘	-	-	-	-
	Middle	-	-	-	-	-	-	-	-
	Bottom	-	-	-	-	-	-	-	-
	Average	-	-	-	-	-	-	-	-
pH	Surface	-	-	-	-	-	-	-	-
	Middle	-	-	-	-	-	-	-	-
	Bottom	-	-	-	-	-	-	-	-
	Average	-	-	-	-	-	-	-	-
Secchi disc depth (m)		-	-	-	-	-	-	-	-
Turbidity (NTU)	Surface	↗	↗	↗	↗	↗	↗	↗	↗
	Middle	↗	↗	↗	↗	↗	↗	↗	↗
	Bottom	↗	↗	↗	↗	↗	↗	↗	↗
	Average	↗	↗	↗	↗	↗	↗	↗	↗
Suspended Solids (mg/L)	Surface	-	-	-	-	-	-	-	-
	Middle	-	-	-	-	-	-	-	-
	Bottom	-	-	-	-	-	↗	-	-
	Average	-	-	-	-	-	-	-	-
Total volatile solids (mg/L)	Surface	-	-	↘	↘	-	-	-	-
	Middle	-	↘	-	-	-	-	-	-
	Bottom	-	-	-	-	-	-	-	-
	Average	↘	↘	-	↘	-	-	-	-
5-day Biochemical Oxygen Demand (mg/L)	Surface	-	-	↘	-	-	-	-	-
	Middle	-	-	-	-	-	-	-	-
	Bottom	-	-	-	-	-	-	-	-
	Average	-	-	-	-	-	-	-	-
Ammonia nitrogen (mg/L)	Surface	-	-	-	-	-	-	-	-
	Middle	-	-	-	-	-	-	-	-
	Bottom	-	-	-	-	-	-	-	-
	Average	-	-	-	-	-	-	-	-
Nitrite nitrogen (mg/L)	Surface	↗	-	-	-	-	-	-	-
	Middle	↗	-	-	-	-	-	-	-
	Bottom	-	-	-	-	-	-	-	-
	Average	-	-	-	-	-	-	-	-
Nitrate nitrogen (mg/L)	Surface	-	-	-	-	-	-	-	-
	Middle	↗	-	-	-	-	-	-	-
	Bottom	-	-	-	-	-	-	-	-
	Average	-	-	-	-	-	-	-	-
Total inorganic nitrogen (mg/L)	Surface	-	-	-	-	-	-	-	-
	Middle	-	-	-	-	-	-	-	-
	Bottom	-	-	-	-	-	-	-	-
	Average	-	-	-	-	-	-	-	-
Total Kjeldahl nitrogen (mg/L)	Surface	-	↘	↘	↘	-	-	-	-
	Middle	↘	↘	↘	↘	-	-	-	-
	Bottom	↘	↘	↘	↘	-	-	-	-
	Average	↘	↘	↘	↘	-	-	-	-
Total nitrogen (mg/L)	Surface	-	-	-	-	-	-	-	-
	Middle	↘	↘	-	-	-	-	-	-
	Bottom	↘	↘	↘	-	-	-	-	-
	Average	↘	↘	-	-	-	-	-	-
Orthophosphate phosphorus (mg/L)	Surface	-	-	-	-	-	-	-	-
	Middle	-	-	-	-	-	-	-	-
	Bottom	-	-	-	-	-	-	-	-
	Average	-	-	-	-	-	-	-	-
Total phosphorus (mg/L)	Surface	↘	↘	↘	-	-	-	-	↘
	Middle	-	-	↘	↘	-	-	-	-
	Bottom	↘	↘	-	-	-	-	-	↘
	Average	↘	↘	↘	↘	-	-	-	↘
Silica (mg/L)	Surface	-	-	-	-	-	-	-	-
	Middle	-	-	-	-	-	-	-	-
	Bottom	-	-	-	-	-	-	-	-
	Average	-	-	-	-	-	-	-	-
Chlorophyll-*a* (μg/L)	Surface	↗	-	-	-	-	-	-	-
	Middle	-	-	-	-	↗	-	-	-
	Bottom	-	-	-	-	-	-	-	-
	Average	-	-	-	-	-	-	-	-
E. coli (cfu/100mL)	Surface	-	↗	-	↗	-	-	↗	↗
	Middle	-	↗	-	↗	-	-	-	↗
	Bottom	-	-	-	↗	-	-	↗	↗
	Average	-	↗	-	↗	-	-	↗	↗
Faecal coliforms (cfu/100mL)	Surface	-	↗	↗	↗	-	-	↗	↗
	Middle	-	↗	-	↗	-	-	↗	↗
	Bottom	-	-	-	↗	↗	-	↗	↗
	Average	-	↗	↗	↗	↗	-	↗	↗

Note
1. Results of the Seasonal Kendall Test shown are statistically significant at $p < 0.05$
2. – indicates no significant trend is detected
3. NA (Not Applicable) indicates the measurement was not made due to shallow water
4. Test applied to past 18 years' data from each monitoring station unless stated otherwise
5. SM20 has five years' data only, which is insufficient to perform Seasonal Kendall Test
6. ↗ represents a significant increase over time
7. ↘ represents a significant decrease over time

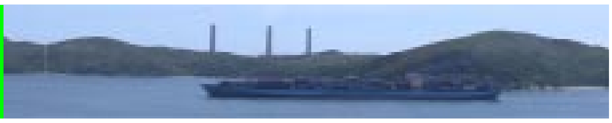


Table 3.2 (continued)

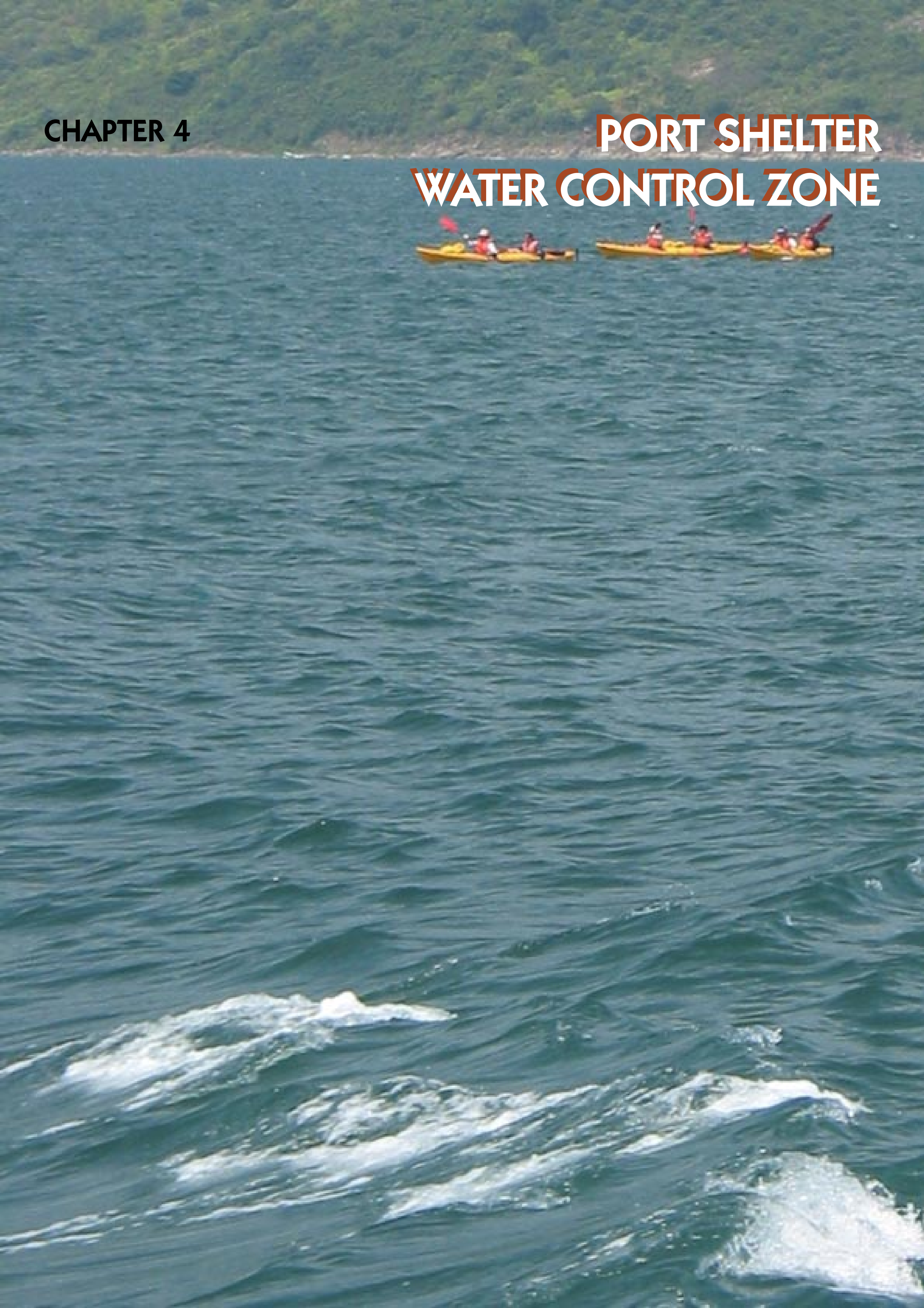
Results of the Seasonal Kendall Test for trends in water quality parameters measured in the Southern WCZ, 1986 - 2003

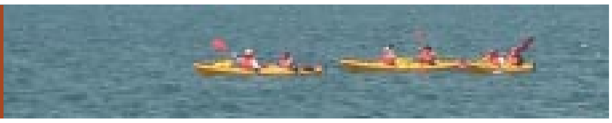
Monitoring Station		SM10	SM11	SM12	SM13	SM17	SM18	SM19
Monitoring Period		1986 - 2003	1986 - 2003	1986 - 2003	1986 - 2003	1989 - 2003	1989 - 2003	1989 - 2003
Parameter	Water Depth							
Temperature (°C)	Surface	↗	↗	-	-	↗	↗	-
	Middle	NA	↗	-	↗	-	↗	-
	Bottom	↗	↗	↗	↗	↗	↗	↗
	Average	↗	↗	↗	-	↗	↗	-
Salinity	Surface	-	-	-	-	-	-	-
	Middle	NA	-	-	-	-	-	-
	Bottom	-	-	-	-	-	-	-
	Average	-	-	-	-	-	-	-
Dissolved Oxygen (mg/L)	Surface	↘	↘	↘	↘	↘	-	↘
	Middle	NA	-	↘	-	↘	-	↘
	Bottom	-	-	-	↘	-	↘	-
	Average	-	-	↘	↘	↘	↘	↘
Dissolved Oxygen (%)	Surface	-	-	↘	↘	-	-	-
	Middle	NA	-	-	-	-	-	-
	Bottom	-	-	-	-	-	-	-
	Average	-	-	-	-	-	-	-
pH	Surface	-	-	↘	-	-	-	-
	Middle	NA	-	↘	↘	-	-	-
	Bottom	-	-	↘	↘	-	-	-
	Average	-	-	↘	-	-	-	-
Secchi disc depth (m)		-	-	-	-	-	-	-
Turbidity (NTU)	Surface	↗	↗	↗	↗	↗	↗	↗
	Middle	NA	↗	↗	↗	↗	↗	↗
	Bottom	↗	↗	↗	↗	↗	↗	↗
	Average	↗	↗	↗	↗	↗	↗	↗
Suspended Solids (mg/L)	Surface	↗	-	↗	↗	-	-	-
	Middle	NA	↗	↗	↗	-	-	-
	Bottom	-	↗	↗	↗	↗	↗	↗
	Average	↗	-	↗	↗	↗	-	↗
Total volatile solids (mg/L)	Surface	-	-	-	-	-	-	-
	Middle	NA	-	-	-	-	-	-
	Bottom	-	-	-	-	-	-	-
	Average	-	-	-	-	-	-	-
5-day Biochemical Oxygen Demand (mg/L)	Surface	-	-	-	-	-	-	-
	Middle	NA	-	-	-	-	↘	-
	Bottom	-	↘	-	↘	-	-	-
	Average	-	-	-	-	-	-	-
Ammonia nitrogen (mg/L)	Surface	-	-	-	-	-	-	-
	Middle	NA	-	-	-	-	-	-
	Bottom	-	-	-	-	↘	-	-
	Average	-	-	-	-	-	-	-
Nitrite nitrogen (mg/L)	Surface	↗	↗	↗	↗	↗	-	-
	Middle	NA	↗	↗	↗	-	-	-
	Bottom	↗	↗	↗	↗	-	-	-
	Average	↗	↗	↗	↗	-	-	-
Nitrate nitrogen (mg/L)	Surface	↗	↗	↗	↗	-	-	-
	Middle	NA	↗	↗	↗	-	-	-
	Bottom	↗	↗	↗	↗	-	-	-
	Average	↗	↗	↗	↗	-	-	-
Total inorganic nitrogen (mg/L)	Surface	↗	↗	↗	↗	-	-	-
	Middle	NA	↗	↗	↗	-	-	-
	Bottom	↗	↗	↗	↗	-	↘	-
	Average	↗	↗	↗	↗	-	-	-
Total Kjeldahl nitrogen (mg/L)	Surface	↘	-	-	-	-	↘	↘
	Middle	NA	-	-	-	↘	↘	↘
	Bottom	-	-	-	-	↘	↘	↘
	Average	↘	-	-	-	↘	↘	↘
Total nitrogen (mg/L)	Surface	-	-	-	-	-	↘	-
	Middle	NA	-	-	-	↘	↘	↘
	Bottom	-	-	-	-	↘	↘	↘
	Average	-	-	-	-	↘	↘	↘
Orthophosphate phosphorus (mg/L)	Surface	-	-	-	-	↘	↘	-
	Middle	NA	-	-	-	↘	-	-
	Bottom	-	-	-	-	-	-	-
	Average	-	-	-	-	↘	-	-
Total phosphorus (mg/L)	Surface	↘	↘	-	-	↘	↘	↘
	Middle	NA	-	-	-	↘	↘	↘
	Bottom	-	-	-	-	↘	↘	↘
	Average	↘	-	-	-	↘	↘	↘
Silica (mg/L)	Surface	-	-	-	-	-	-	-
	Middle	NA	-	-	-	-	↘	-
	Bottom	-	-	-	-	-	-	-
	Average	-	-	-	-	-	-	-
Chlorophyll-*a* (µg/L)	Surface	-	-	-	-	↗	↗	↗
	Middle	NA	-	-	-	-	-	-
	Bottom	-	-	-	-	-	-	-
	Average	-	-	-	-	-	-	-
E. coli (cfu/100mL)	Surface	↘	↘	-	-	-	-	-
	Middle	NA	-	-	-	-	-	-
	Bottom	-	-	-	↗	-	-	-
	Average	-	-	-	-	-	-	-
Faecal coliforms (cfu/100mL)	Surface	-	-	-	-	-	-	-
	Middle	NA	-	-	↗	-	-	-
	Bottom	-	-	-	↗	-	-	-
	Average	-	-	-	↗	-	-	-

Note
1. Results of the Seasonal Kendall Test shown are statistically significant at $p < 0.05$
2. – indicates no significant trend is detected
3. NA (Not Applicable) indicates the measurement was not made due to shallow water
4. Test applied to past 18 years' data from each monitoring station unless stated otherwise
5. SM20 has five years' data only, which is insufficient to perform Seasonal Kendall Test
6. ↗ represents a significant increase over time
7. ↘ represents a significant decrease over time

CHAPTER 4

PORT SHELTER WATER CONTROL ZONE





Chapter 4 – Port Shelter Water Control Zone

Water Quality in 2003

4.1 The water quality in the Port Shelter Water Control Zone (WCZ) is amongst the best in the territory with high dissolved oxygen (DO), low turbidity, nutrients and *E. coli* bacteria. The water quality at different monitoring stations in the Port Shelter WCZ is fairly uniform, slightly better in the outer part of the bay. The whole of Mirs Bay is a gazetted secondary recreational water. A summary of the 2003 water quality data is shown in Tables 4.1.

4.2 Similar to other Hong Kong waters, the Port Shelter WCZ experienced a moderate decrease of DO by 0.6 mg/L (10%) in 2003. The annual mean DO levels at nine monitoring stations ranged from 5.8 mg/L to 6.0 mg/L which were the lowest in ten years. Of all the stations, only the decrease of DO at the inner most PM1 was statistically significant.

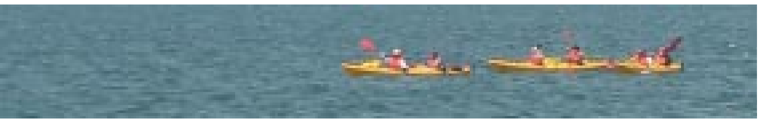
4.3 The levels of pollutants in the Port Shelter WCZ were largely similar to those 2002, however, a notable decrease in nitrogen (NH_4-N, TKN, TN) was observed at all stations in the bay. The annual mean total nitrogen (TN), total inorganic nitrogen (TIN), total phosphorus (TP) and orthophosphate phosphorus (PO_4-P) mostly reached their lowest levels in the past decade. Despite the reduction in nutrients, the averaged chlorophyll-*a* content (indicating algal biomass) in the Port Shelter WCZ has increased by around 0.3 µg/L (17%) in 2003. The increases at PM1 (by 50%) and PM4 (by 34%), located in the inner parts of the bay, were higher than other stations in the WCZ (Figure 4.2).

Compliance with Water Quality Objectives

4.4 The Port Shelter WCZ has the best WQO compliance record amongst all the WCZs. Figure 4.1 shows that the Port Shelter WCZ has fully achieved its Water Quality Objectives (WQOs) in 2003. With the exception of 1998 (an El Niño year), the WCZ has complied with all the WQOs in the past decade.

Long-term Water Quality Trends

4.5 Despite the increase of population in the catchment, the water quality of Port Shelter has shown pleasing improvement since the mid-1980s, with decreasing trends in total nitrogen, total phosphorus, *E. coli* bacteria at the inner bay (stations PM2 and PM5) (Table 4.2 and Figure 4.3). This could be attributed to the pollution control measures implemented, including enforcement



of Water Pollution Control Ordinance, upgrading of the Sai Kung Sewage Treatment Works and provision of sewerage to villages. These efforts would need to be continued in order to preserve the precious water environment of Port Shelter.

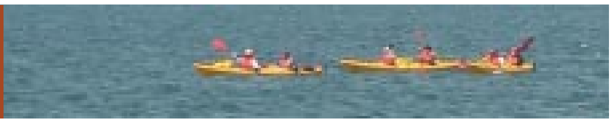
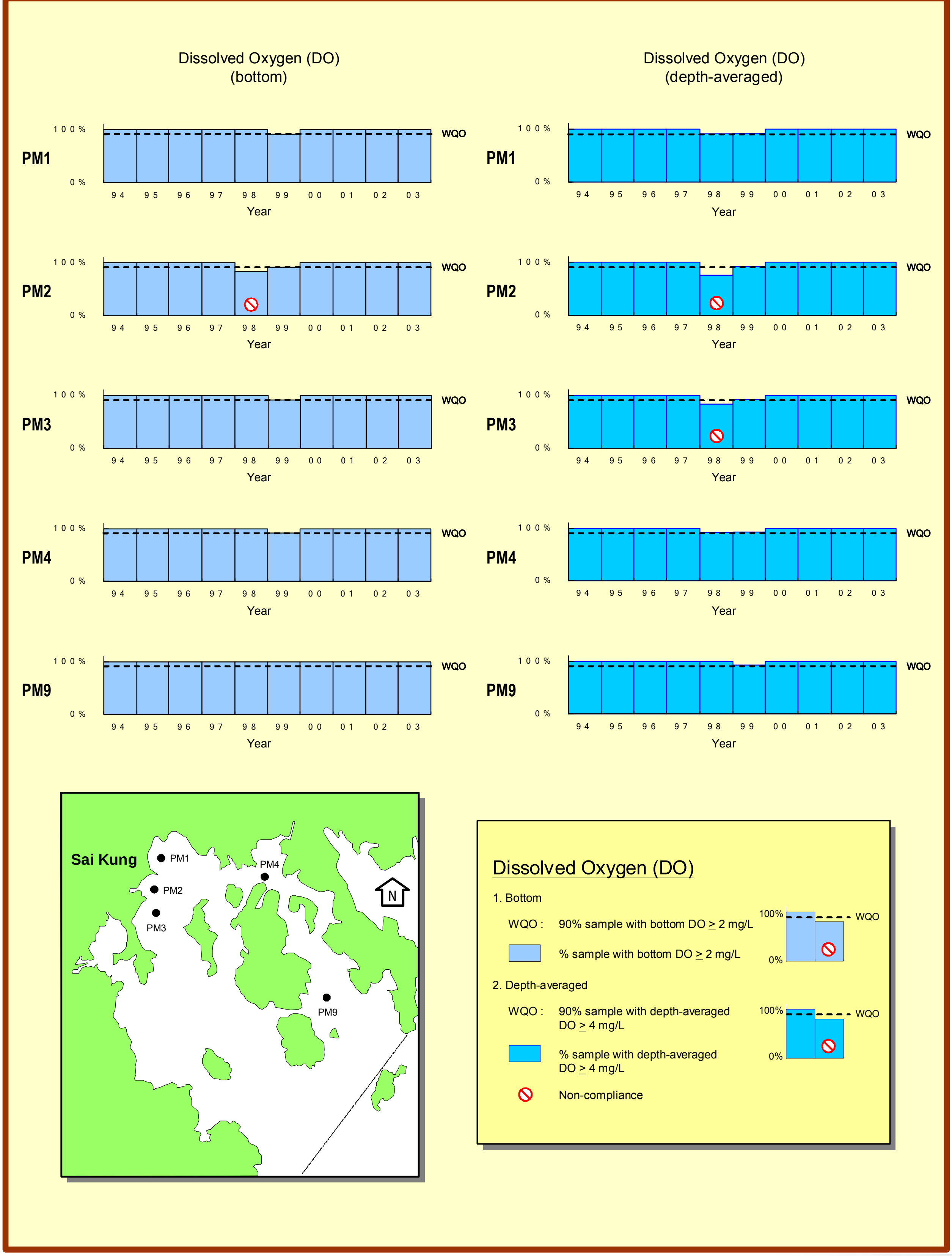


Figure 4.1 Level of compliance with key Water Quality Objectives in the Port Shelter WCZ



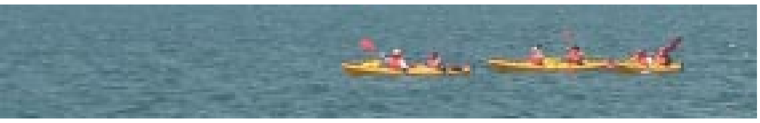
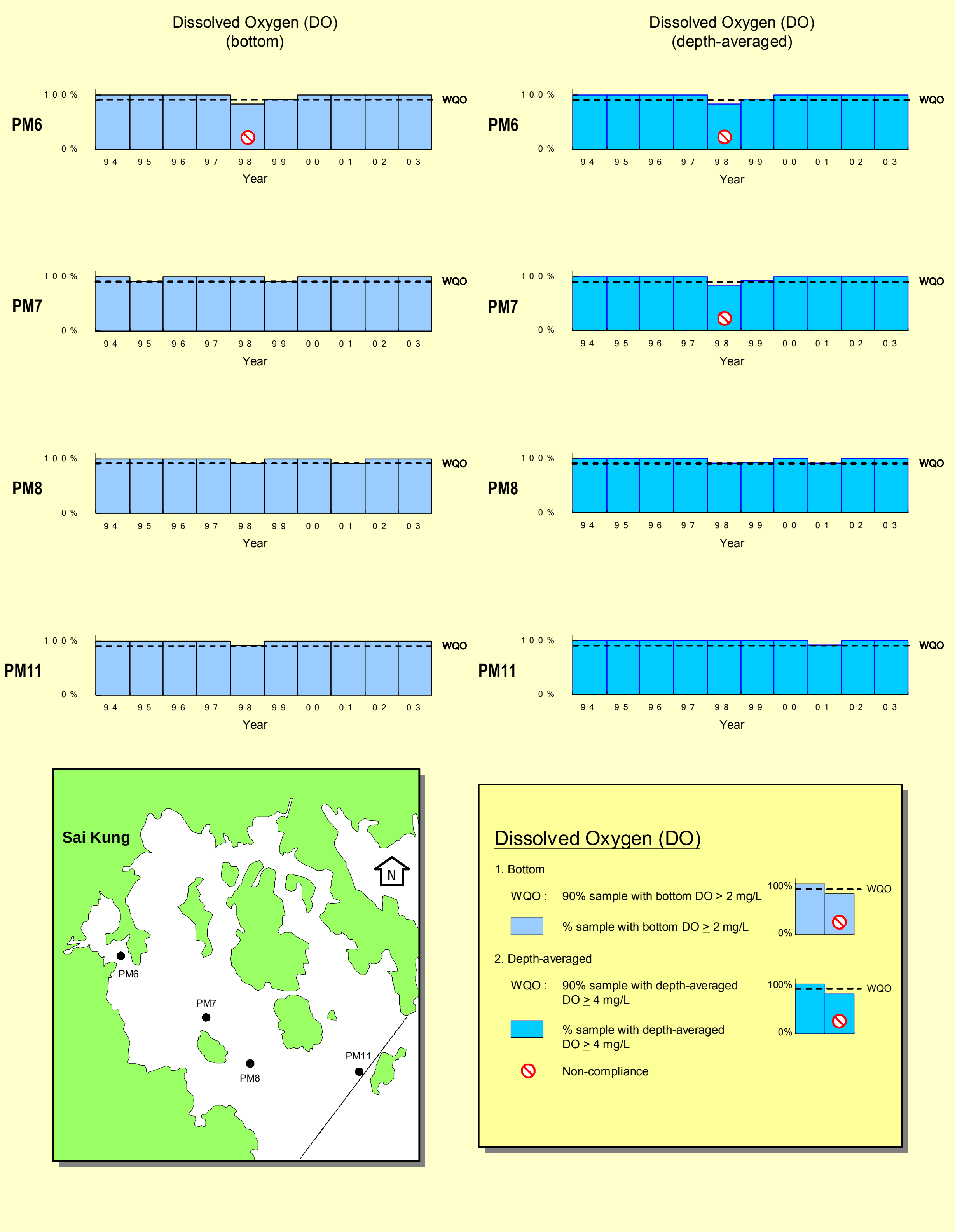


Figure 4.1 (continued) Level of compliance with key Water Quality Objectives in the Port Shelter WCZ



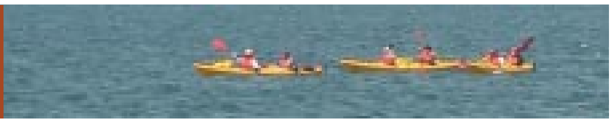
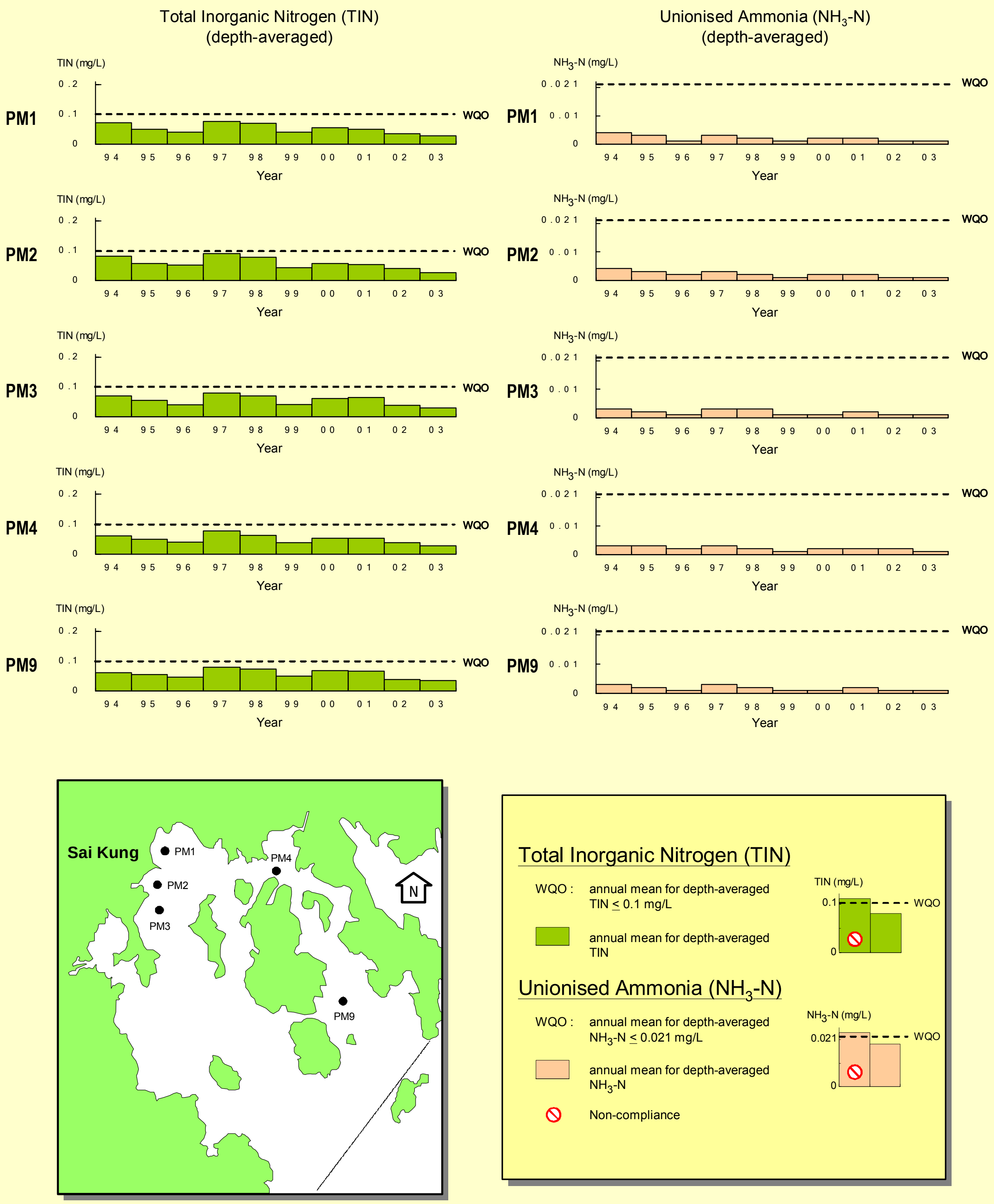


Figure 4.1 (continued) Level of compliance with key Water Quality Objectives in the Port Shelter WCZ



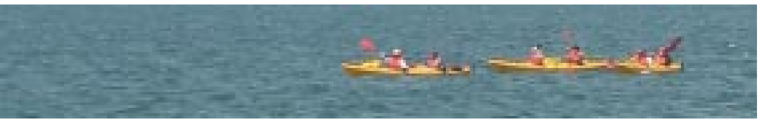
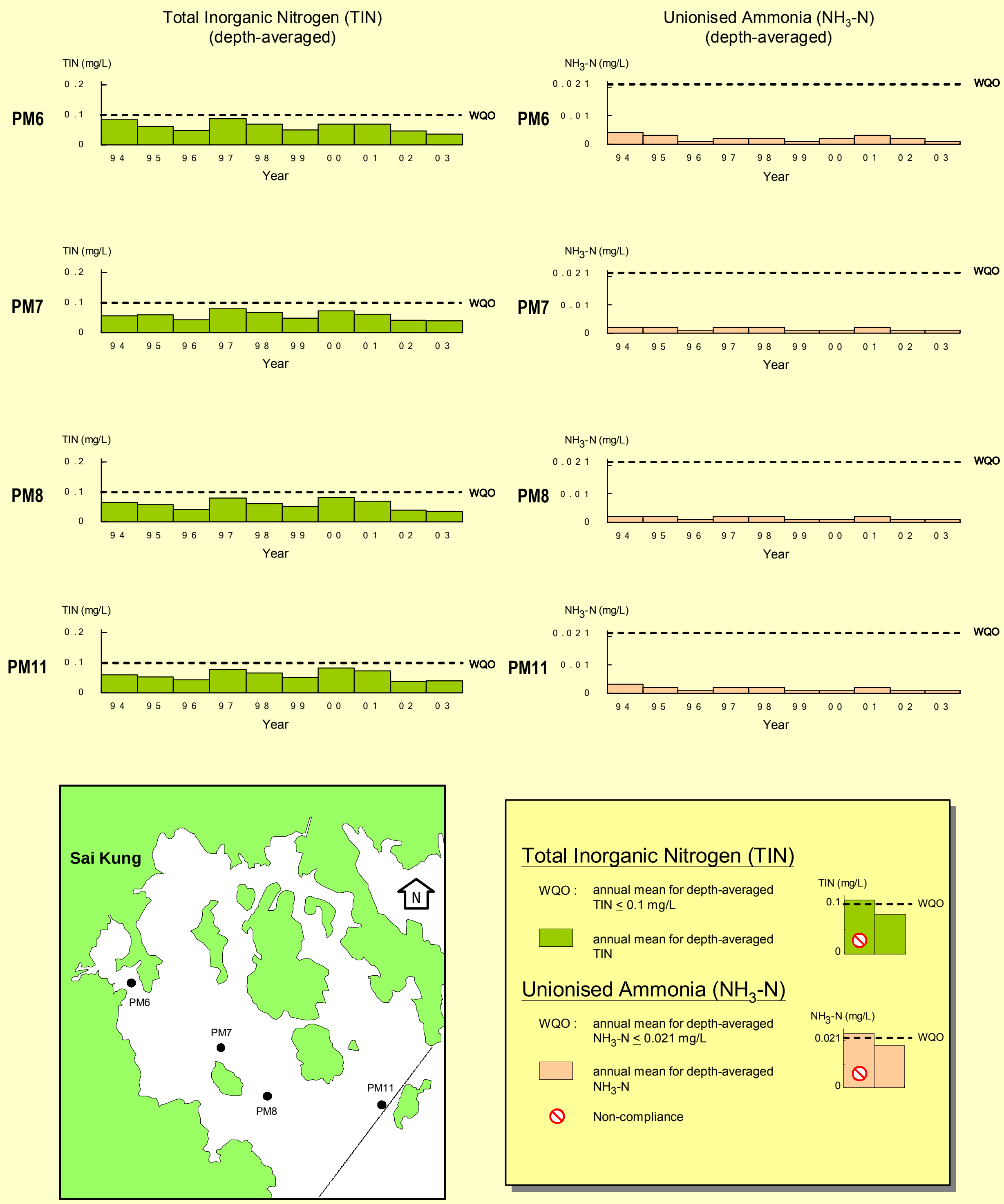


Figure 4.1 (continued) Level of compliance with key Water Quality Objectives in the Port Shelter WCZ



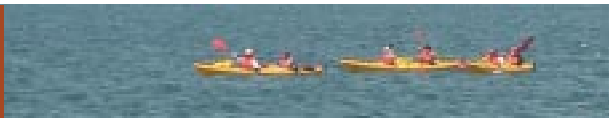
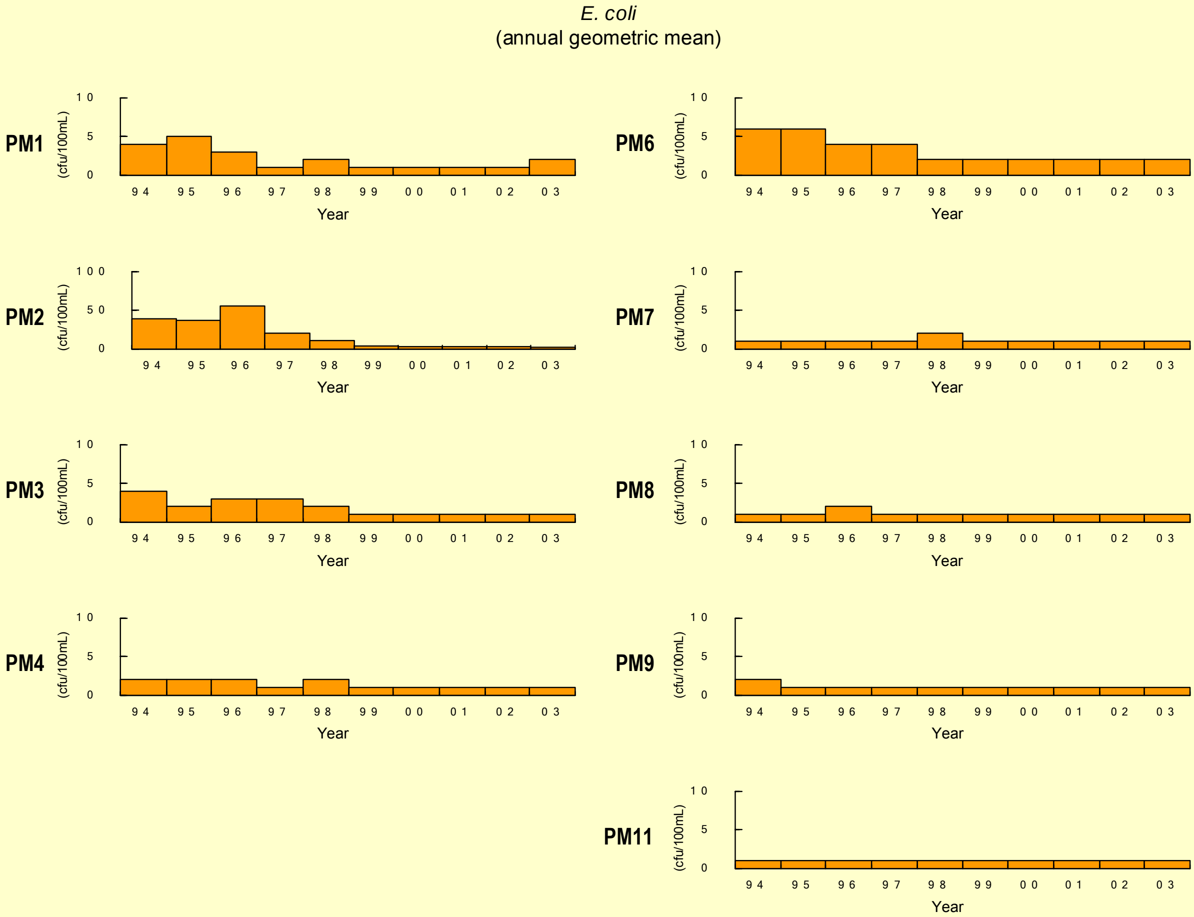
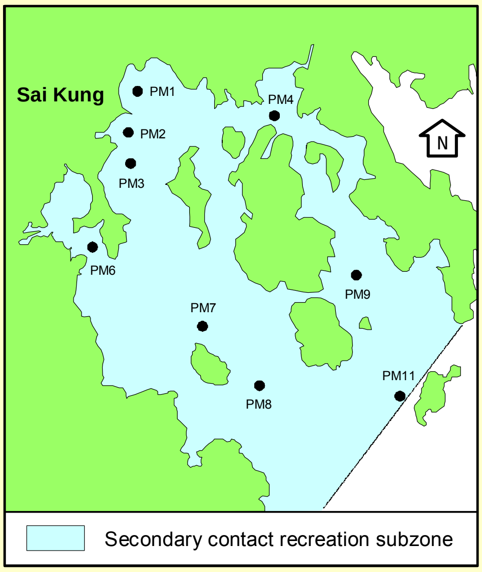


Figure 4.1 (continued) Level of compliance with key Water Quality Objectives in the Port Shelter WCZ





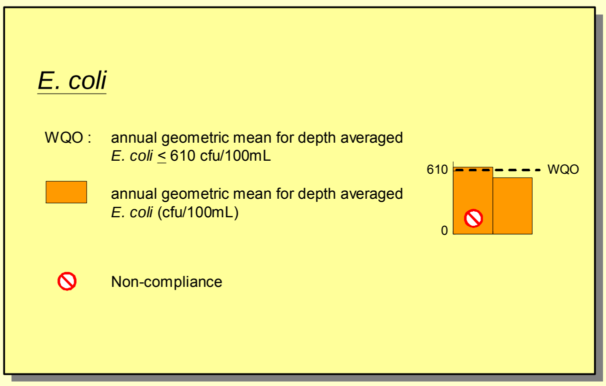


Figure 4.2 Levels of chlorophyll-*a* at PM4, 1986 - 2003

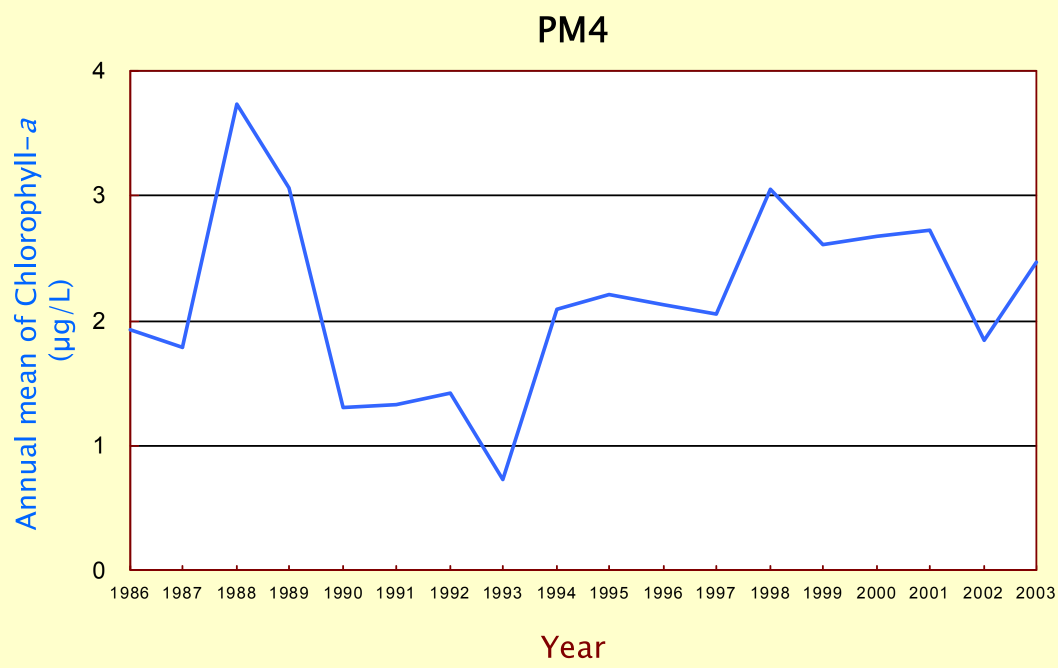


Figure 4.3 Levels of *E. coli* at PM2, 1986 - 2003

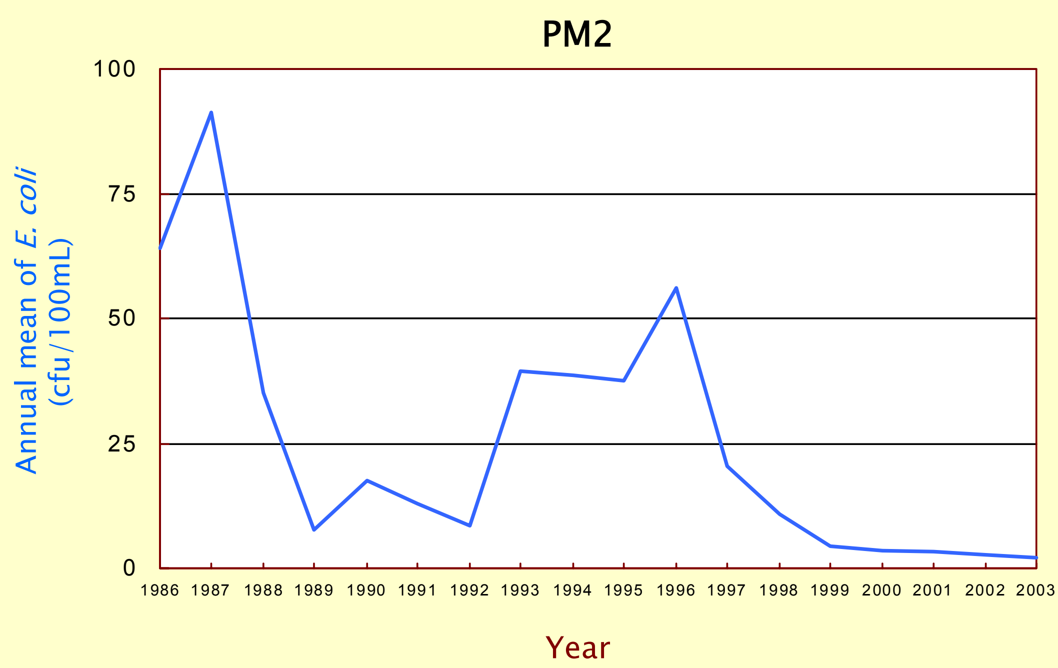


Table 4.1

Summary water quality statistics of the Port Shelter WCZ in 2003

Parameter		Inner Port Shelter				Hebe Haven
		PM1	PM2	PM3	PM4	PM6
Number of samples		12	12	12	12	12
Temperature (°C)		23.4 (16.8 - 28.6)	23.5 (16.7 - 29.5)	23.3 (16.6 - 28.5)	23.3 (16.6 - 28.8)	23.4 (16.8 - 28.5)
Salinity		32.8 (30.1 - 34.4)	32.8 (30.6 - 34.4)	33.0 (31.0 - 34.0)	32.9 (30.3 - 34.2)	32.9 (30.9 - 34.3)
Dissolved Oxygen (mg/L)		5.8 (4.7 - 6.9)	6.0 (4.8 - 7.6)	6.0 (4.7 - 7.6)	5.8 (4.4 - 6.7)	5.8 (4.6 - 7.3)
	Bottom	5.7 (3.3 - 7.2)	6.0 (3.8 - 7.8)	5.7 (3.1 - 7.5)	5.8 (3.4 - 6.9)	5.4 (3.1 - 7.4)
Dissolved Oxygen (% Saturation)		83 (72 - 91)	85 (72 - 96)	85 (70 - 96)	83 (68 - 93)	81 (70 - 93)
	Bottom	80 (47 - 93)	85 (55 - 98)	79 (44 - 94)	81 (51 - 97)	76 (44 - 93)
pH		8.2 (8.1 - 8.4)	8.2 (8.0 - 8.4)	8.2 (8.1 - 8.4)	8.2 (8.0 - 8.3)	8.2 (8.0 - 8.4)
Secchi Disc Depth (m)		3.3 (2.0 - 5.0)	4.0 (1.7 - 6.5)	4.3 (2.3 - 7.0)	3.0 (2.0 - 3.6)	3.8 (2.2 - 6.0)
Turbidity (NTU)		6.2 (2.1 - 9.2)	5.8 (2.1 - 10.3)	5.8 (1.1 - 10.6)	6.6 (2.9 - 10.0)	6.4 (2.6 - 12.4)
Suspended Solids (mg/L)		2.2 (1.2 - 4.1)	1.6 (0.6 - 4.5)	1.6 (0.6 - 4.6)	3.4 (0.8 - 7.9)	2.5 (0.8 - 4.9)
5-day Biochemical Oxygen Demand (mg/L)		0.8 (0.3 - 1.2)	0.8 (0.2 - 1.2)	0.7 (0.1 - 1.2)	0.8 (0.3 - 1.4)	0.8 (0.2 - 1.4)
Ammonia Nitrogen (mg/L)		0.02 (0.01 - 0.05)	0.02 (0.01 - 0.06)	0.02 (0.01 - 0.06)	0.01 (0.01 - 0.04)	0.02 (0.01 - 0.03)
Unionised Ammonia (mg/L)		0.001 (<0.001 - 0.003)	0.001 (<0.001 - 0.003)	0.001 (<0.001 - 0.003)	0.001 (<0.001 - 0.002)	0.001 (<0.001 - 0.003)
Nitrite Nitrogen (mg/L)		0.01 (<0.01 - 0.03)	<0.01 (<0.01 - 0.01)	0.01 (<0.01 - 0.02)	0.01 (<0.01 - 0.02)	0.01 (<0.01 - 0.03)
Nitrate Nitrogen (mg/L)		0.01 (<0.01 - 0.02)	0.01 (<0.01 - 0.02)	0.01 (<0.01 - 0.02)	0.01 (<0.01 - 0.03)	0.01 (<0.01 - 0.03)
Total Inorganic Nitrogen (mg/L)		0.03 (0.01 - 0.07)	0.03 (0.01 - 0.07)	0.03 (0.01 - 0.07)	0.03 (0.01 - 0.06)	0.04 (0.01 - 0.10)
Total Kjeldahl Nitrogen (mg/L)		0.12 (0.09 - 0.16)	0.11 (0.08 - 0.21)	0.11 (0.07 - 0.20)	0.12 (0.09 - 0.16)	0.11 (0.07 - 0.14)
Total Nitrogen (mg/L)		0.13 (0.09 - 0.19)	0.12 (0.08 - 0.22)	0.13 (0.09 - 0.21)	0.13 (0.09 - 0.19)	0.13 (0.08 - 0.21)
Orthophosphate Phosphorus (mg/L)		<0.01 (<0.01 - 0.02)	<0.01 (<0.01 - 0.01)	<0.01 (<0.01 - 0.01)	<0.01 (<0.01 - 0.01)	<0.01 (<0.01 - 0.01)
Total Phosphorus (mg/L)		0.02 (0.02 - 0.03)	0.02 (0.02 - 0.03)	0.02 (0.02 - 0.03)	0.02 (0.02 - 0.03)	0.02 (0.02 - 0.03)
Silica (as SiO_2) (mg/L)		0.6 (0.1 - 1.1)	0.6 (0.1 - 1.1)	0.6 (0.1 - 1.1)	0.6 (0.1 - 1.1)	0.6 (0.2 - 1.2)
Chlorophyll-*a* (μg/L)		2.6 (1.0 - 5.4)	2.1 (1.1 - 3.3)	1.9 (0.7 - 3.9)	2.5 (0.7 - 5.5)	2.0 (0.8 - 3.6)
E. coli (cfu/100mL)		2 (1 - 9)	2 (1 - 15)	1 (1 - 3)	1 (1 - 2)	2 (1 - 5)
Faecal Coliforms (cfu/100mL)		3 (1 - 39)	6 (1 - 250)	2 (1 - 8)	2 (1 - 5)	4 (1 - 37)

Note : 1. Unless otherwise specified, data presented are depth-averaged (A) values calculated by taking the means of three depths: Surface (S), Mid-depth (M), Bottom (B).
2. Data presented are annual arithmetic means of the depth-averaged results except for *E. coli* and faecal coliforms which are annual geometric means.
3. Data in brackets indicate the ranges.

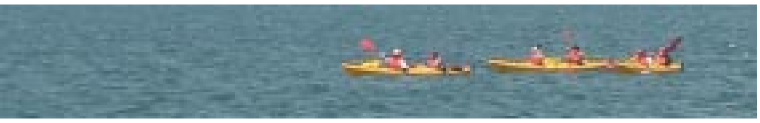


Table 4.1 (continued)

Summary water quality statistics of the Port Shelter WCZ in 2003

	Outer Port Shelter		Rocky Harbour	Bluff Island
Parameter	**PM7**	**PM8**	**PM9**	**PM11**
Number of samples	12	12	12	12
Temperature (°C)	23.2 (16.4 - 28.4)	23.1 (16.5 - 27.9)	22.9 (16.5 - 28.5)	22.9 (16.4 - 27.8)
Salinity	33.1 (31.9 - 34.3)	33.3 (32.4 - 34.4)	33.2 (32.0 - 34.7)	33.3 (32.5 - 34.5)
Dissolved Oxygen (mg/L)	5.8 (4.3 - 7.2)	6.0 (4.4 - 7.4)	5.9 (4.6 - 7.1)	5.8 (4.6 - 7.3)
Bottom	5.6 (2.6 - 7.5)	5.7 (3.4 - 7.8)	5.8 (3.5 - 7.2)	5.6 (3.7 - 7.2)
Dissolved Oxygen (% Saturation)	82 (63 - 93)	84 (65 - 95)	83 (67 - 93)	82 (67 - 90)
Bottom	78 (36 - 94)	80 (48 - 98)	80 (50 - 93)	78 (52 - 91)
pH	8.2 (8.1 - 8.4)	8.2 (8.1 - 8.4)	8.2 (8.1 - 8.4)	8.2 (8.1 - 8.4)
Secchi Disc Depth (m)	5.2 (3.0 - 7.3)	6.0 (3.0 - 9.3)	4.7 (2.8 - 7.3)	5.3 (2.7 - 8.0)
Turbidity (NTU)	6.5 (2.8 - 11.4)	6.7 (3.5 - 11.9)	6.5 (3.6 - 10.6)	6.5 (3.5 - 9.7)
Suspended Solids (mg/L)	1.9 (0.5 - 4.1)	2.3 (0.8 - 6.9)	2.3 (0.7 - 4.9)	2.3 (1.2 - 4.4)
5-day Biochemical Oxygen Demand (mg/L)	0.6 (0.1 - 1.2)	0.5 (0.1 - 1.0)	0.7 (0.3 - 1.1)	0.6 (0.3 - 1.1)
Ammonia Nitrogen (mg/L)	0.01 (0.01 - 0.03)	0.01 (0.01 - 0.02)	0.02 (0.01 - 0.03)	0.01 (0.01 - 0.02)
Unionised Ammonia (mg/L)	0.001 (<0.001 - 0.003)	0.001 (<0.001 - 0.001)	0.001 (<0.001 - 0.002)	0.001 (<0.001 - 0.002)
Nitrite Nitrogen (mg/L)	0.01 (<0.01 - 0.03)	0.01 (<0.01 - 0.03)	0.01 (<0.01 - 0.03)	0.01 (<0.01 - 0.03)
Nitrate Nitrogen (mg/L)	0.02 (<0.01 - 0.05)	0.01 (<0.01 - 0.04)	0.01 (<0.01 - 0.04)	0.02 (<0.01 - 0.05)
Total Inorganic Nitrogen (mg/L)	0.04 (0.01 - 0.08)	0.03 (0.01 - 0.06)	0.04 (0.01 - 0.08)	0.04 (0.01 - 0.08)
Total Kjeldahl Nitrogen (mg/L)	0.10 (0.07 - 0.15)	0.09 (0.06 - 0.12)	0.10 (0.07 - 0.13)	0.09 (0.07 - 0.13)
Total Nitrogen (mg/L)	0.13 (0.09 - 0.19)	0.11 (0.08 - 0.16)	0.12 (0.07 - 0.20)	0.11 (0.07 - 0.18)
Orthophosphate Phosphorus (mg/L)	<0.01 (0.01 - 0.01)	<0.01 (0.01 - 0.01)	<0.01 (0.01 - 0.01)	<0.01 (0.01 - 0.01)
Total Phosphorus (mg/L)	0.02 (0.02 - 0.02)	0.02 (0.02 - 0.02)	0.02 (0.02 - 0.02)	0.02 (0.02 - 0.02)
Silica (as SiO_2) (mg/L)	0.6 (0.1 - 1.1)	0.6 (0.2 - 0.9)	0.6 (0.2 - 1.0)	0.6 (0.2 - 1.0)
Chlorophyll-a (µg/L)	1.5 (0.7 - 3.1)	1.4 (0.7 - 2.3)	1.7 (0.7 - 4.0)	1.5 (0.8 - 2.7)
E. coli (cfu/100mL)	1 (1 - 1)	1 (1 - 1)	1 (1 - 1)	1 (1 - 1)
Faecal Coliforms (cfu/100mL)	1 (1 - 3)	1 (1 - 2)	1 (1 - 8)	1 (1 - 1)

Note : 1. Unless otherwise specified, data presented are depth-averaged (A) values calculated by taking the means of three depths: Surface (S), Mid-depth (M), Bottom (B).
2. Data presented are annual arithmetic means of the depth-averaged results except for *E. coli* and faecal coliforms which are annual geometric means.
3. Data in brackets indicate the ranges.

Table 4.2

Results of the Seasonal Kendall Test for trends in water quality parameters measured in the Port Shelter WCZ, 1986 – 2003

Monitoring Station		PM1	PM2	PM3	PM4	PM6	PM7	PM8	PM9	PM11
Monitoring Period		1986 – 2003	1986 – 2003	1986 – 2003	1986 – 2003	1986 – 2003	1988 – 2003	1986 – 2003	1986 – 2003	1986 – 2003
Parameter	Water Depth									
Temperature (°C)	Surface	↗	↗	↗	↗	↗	↗	↗	↗	-
	Middle	↗	↗	↗	↗	↗	↗	↗	↗	-
	Bottom	↗	↗	↗	↗	↗	↗	↗	↗	-
	Average	↗	↗	↗	↗	↗	↗	↗	↗	-
Salinity	Surface	-	-	-	-	-	-	-	-	-
	Middle	-	-	-	-	-	-	-	-	-
	Bottom	-	-	-	-	-	-	-	-	-
	Average	-	-	-	-	-	-	-	-	-
Dissolved Oxygen (mg/L)	Surface	↘	↘	↘	↘	↘	↘	↘	↘	↘
	Middle	-	-	-	-	-	-	-	-	-
	Bottom	-	-	-	-	-	-	-	-	-
	Average	-	-	-	-	-	-	-	-	-
Dissolved Oxygen (%)	Surface	↘	↘	↘	↘	↘	↘	↘	↘	↘
	Middle	-	-	-	-	-	-	-	-	-
	Bottom	↗	↗	↗	↗	-	↗	-	-	-
	Average	-	-	-	-	-	-	-	-	-
pH	Surface	↘	-	-	-	↘	-	-	-	-
	Middle	-	-	-	-	↘	-	-	-	-
	Bottom	-	-	-	-	-	-	-	-	-
	Average	-	-	-	-	↘	-	-	-	-
Secchi disc depth (m)		-	-	-	-	↗	-	-	-	-
Turbidity (NTU)	Surface	↗	↗	↗	↗	↗	↗	↗	↗	↗
	Middle	↗	↗	↗	↗	↗	↗	↗	↗	↗
	Bottom	↗	↗	↗	↗	↗	↗	↗	↗	↗
	Average	↗	↗	↗	↗	↗	↗	↗	↗	↗
Suspended Solids (mg/L)	Surface	-	-	↘	-	↘	-	↘	-	-
	Middle	-	-	↘	-	↘	-	-	-	-
	Bottom	-	-	-	-	-	-	-	↗	↗
	Average	-	-	↘	-	↘	-	-	-	-
Total volatile solids (mg/L)	Surface	-	↘	-	↘	↘	-	-	-	-
	Middle	↘	↘	↘	↘	↘	-	-	-	-
	Bottom	-	↘	-	↘	-	-	-	-	-
	Average	↘	↘	↘	↘	↘	↘	↘	↘	-
5-day Biochemical Oxygen Demand (mg/L)	Surface	-	↘	-	-	↘	-	-	-	-
	Middle	-	-	-	-	-	-	-	-	-
	Bottom	-	-	-	-	-	-	-	-	-
	Average	-	-	-	-	↘	-	-	-	-
Ammonia nitrogen (mg/L)	Surface	-	-	-	-	-	-	-	-	-
	Middle	-	-	-	-	-	-	-	-	-
	Bottom	-	-	-	-	-	-	-	-	↘
	Average	-	-	-	-	-	-	-	-	-
Nitrite nitrogen (mg/L)	Surface	-	-	-	-	-	-	-	-	-
	Middle	-	-	-	-	-	-	-	-	-
	Bottom	-	-	-	-	-	-	-	-	-
	Average	-	-	-	-	-	-	-	-	-
Nitrate nitrogen (mg/L)	Surface	-	-	-	-	-	-	-	-	-
	Middle	-	-	-	-	-	-	-	-	-
	Bottom	-	-	-	-	-	-	-	-	-
	Average	-	-	-	-	-	-	-	-	-
Total inorganic nitrogen (mg/L)	Surface	-	-	-	-	-	-	-	-	-
	Middle	-	-	-	-	-	-	-	-	-
	Bottom	-	-	-	-	-	-	-	-	-
	Average	-	-	-	-	-	-	-	-	-
Total Kjeldahl nitrogen (mg/L)	Surface	↘	↘	↘	↘	↘	-	-	↘	-
	Middle	↘	-	↘	-	↘	↘	↘	↘	-
	Bottom	↘	↘	-	↘	↘	↘	↘	↘	-
	Average	↘	↘	↘	↘	↘	↘	↘	↘	-
Total nitrogen (mg/L)	Surface	↘	↘	↘	↘	↘	-	-	↘	-
	Middle	↘	-	-	-	↘	↘	↘	↘	-
	Bottom	↘	↘	-	↘	↘	-	↘	↘	-
	Average	↘	↘	↘	↘	↘	↘	↘	↘	-
Orthophosphate phosphorus (mg/L)	Surface	-	-	-	-	-	-	-	-	↘
	Middle	-	-	-	-	-	-	-	-	↘
	Bottom	-	-	-	-	-	-	-	-	↘
	Average	-	-	-	-	-	-	-	-	↘
Total phosphorus (mg/L)	Surface	↘	-	-	-	↘	-	-	-	↘
	Middle	-	-	-	-	↘	-	-	-	↘
	Bottom	↘	-	-	-	↘	-	-	-	↘
	Average	↘	↘	↘	-	↘	-	-	-	↘
Silica (mg/L)	Surface	-	-	-	-	-	-	-	-	-
	Middle	-	-	-	-	-	-	-	-	-
	Bottom	↘	-	-	-	-	-	-	-	-
	Average	-	-	-	-	-	-	-	-	-
Chlorophyll-*a* (μg/L)	Surface	-	-	-	-	-	-	-	-	-
	Middle	-	-	↗	-	-	-	-	-	-
	Bottom	-	↗	↗	↗	-	-	↗	↗	-
	Average	-	-	-	-	-	-	-	-	-
E. coli (cfu/100mL)	Surface	-	↘	-	-	↘	-	-	-	-
	Middle	-	↘	-	-	↘	-	-	-	-
	Bottom	-	↘	-	-	-	-	-	-	-
	Average	↘	↘	↘	-	↘	-	-	-	-
Faecal coliforms (cfu/100mL)	Surface	-	-	-	-	-	-	-	-	-
	Middle	-	-	-	-	↘	-	-	-	-
	Bottom	-	-	-	-	-	-	-	-	-
	Average	-	-	-	-	-	-	-	-	-

Note
1. Results of the Seasonal Kendall Test shown are statistically significant at $p < 0.05$
2. - indicates no significant trend is detected
3. Test applied to past 18 years' data from each monitoring station unless stated otherwise
4. ↗ represents a significant increase over time
5. ↘ represents a significant decrease over time

CHAPTER 5

JUNK BAY WATER CONTROL ZONE

Chapter 5 - Junk Bay Water Control Zone

Water Quality in 2003

5.1 The water quality in the Junk Bay Water Control Zone (WCZ) is influenced by the flow from Victoria Harbour. Since the commissioning of the Harbour Area Treatment Scheme (HATS) Stage I in 2002, major pollution sources (outfalls of Tseung Kwan O and Chai Wan Sewage Treatment Works) have been removed and the water quality of Junk Bay has experienced a marked improvement. In 2003, this improvement was sustained. A summary of water quality data is shown in Table 5.1.

5.2 In 2003, the levels of *E. coli*, ammonia nitrogen (NH_4-N), total inorganic nitrogen (TIN), total nitrogen and total phosphorus in Junk Bay fell to their lowest levels in 10 years. A remarkable decrease of *E. coli* was found at the two monitoring stations, JM3 (by 54%) and JM4 (by 64%), as compared to that in the previous year. This could be attributed to the reduction of sewage pollution in the area due to HATS Stage I improvement.

5.3 The depth-averaged and bottom dissolved oxygen (DO) in Junk Bay have decreased by 0.4mg/L (6%) and 0.7mg/L (11%) respectively in 2003. This might be largely due to natural fluctuation which was observed widely in other parts of Hong Kong waters.

Compliance with Water Quality Objectives (WQOs)

5.4 Figure 5.1 shows that the stations JM3 and JM4 in Junk Bay fully (100%) complied with the key WQOs: dissolved oxygen, unionised ammonia and total inorganic nitrogen in 2003.

Long-term Water Quality Trends

5.5 Similar to 2002, the increasing trends of *E. coli* and nitrate nitrogen in the outer Junk Bay (JM4) which was evident in previous years, have been arrested (Table 5.2). In addition, long-term decreases in nutrients such as total Kjeldahl nitrogen started to emerge in 2003.

5.6 Notable decline in two sewage-related parameters: ammonia nitrogen and *E. coli* were also observed in Junk Bay over the last 10 years (Figure 5.2).

Figure 5.1 Level of compliance with key Water Quality Objectives in the Junk Bay WCZ

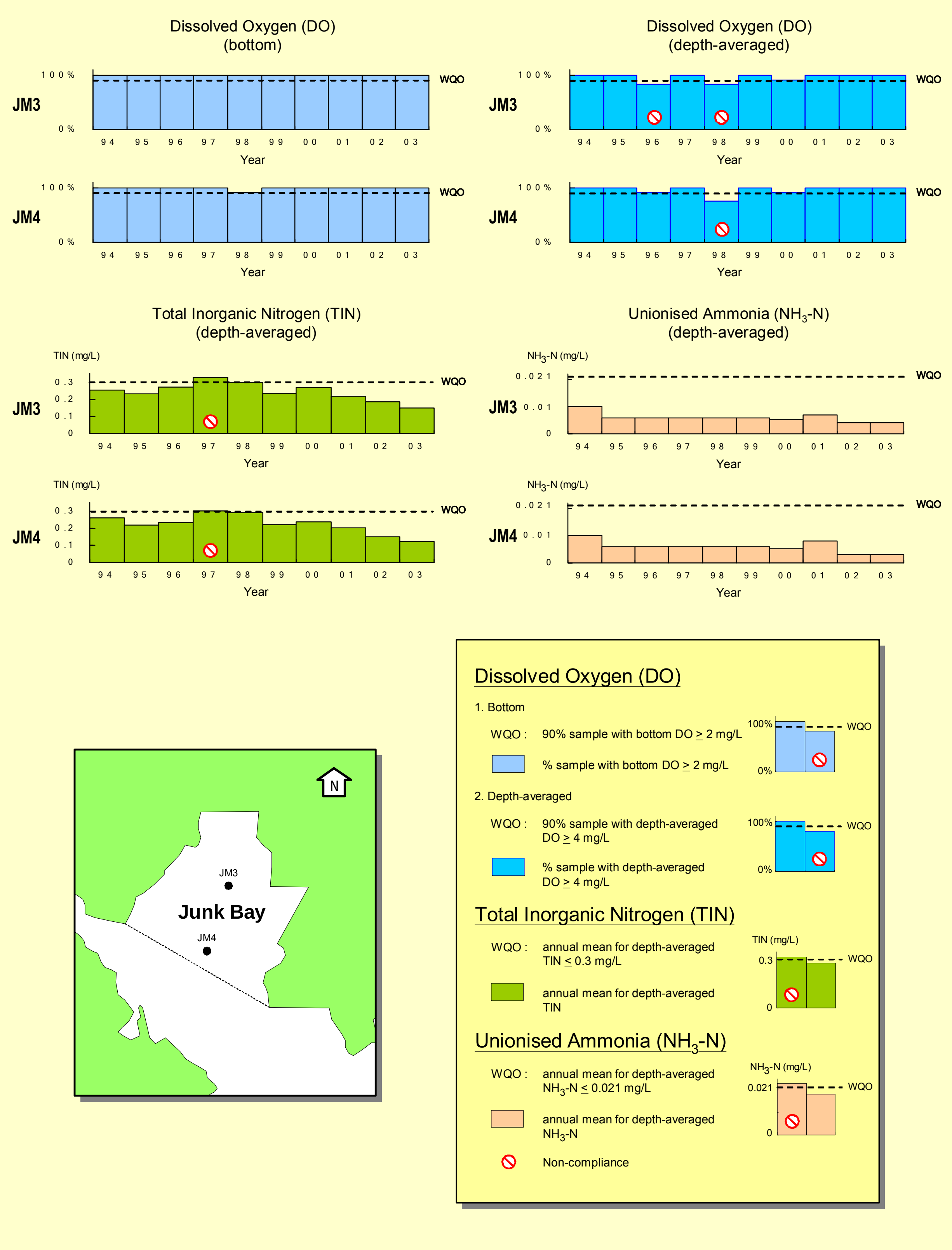
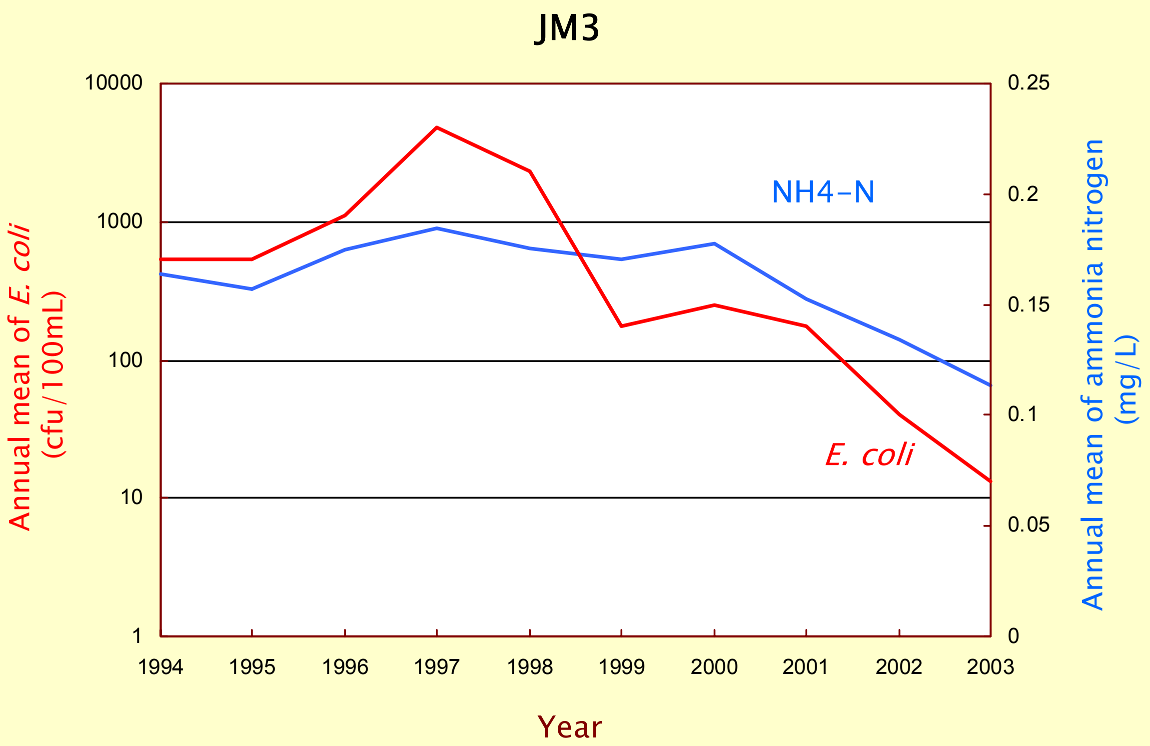
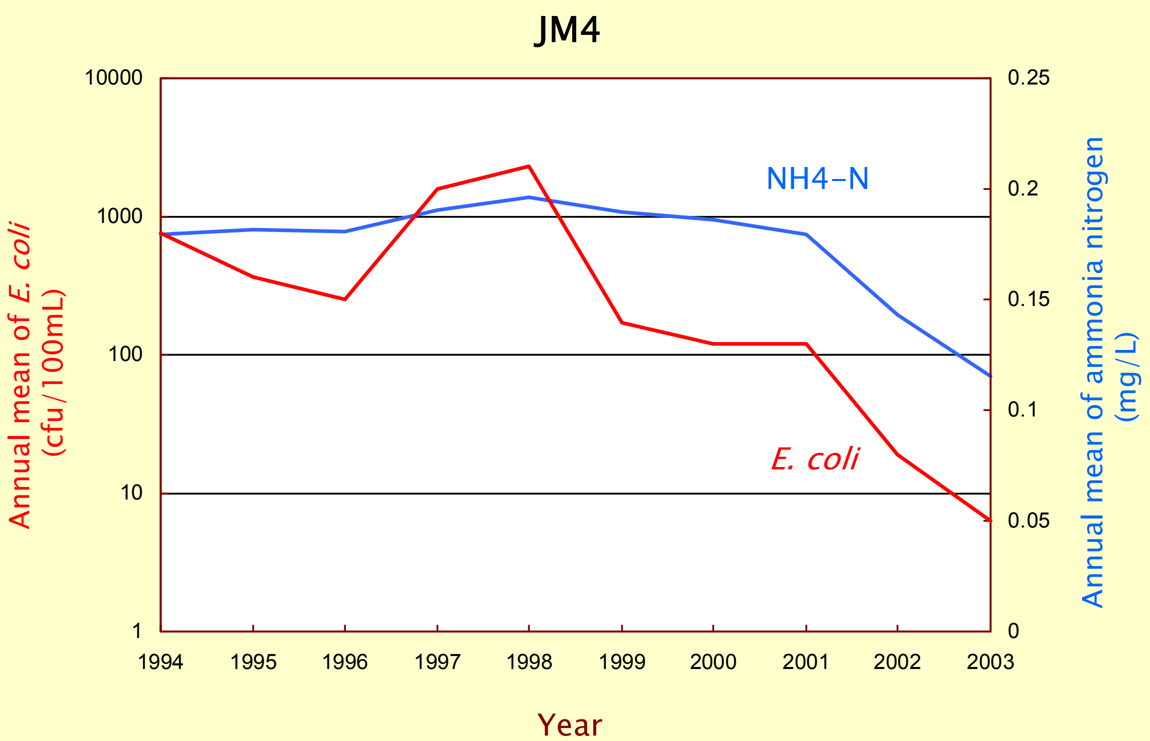


Figure 5.2 Levels of ammonia nitrogen and *E. coli* at JM3 and JM4, 1994 – 2003





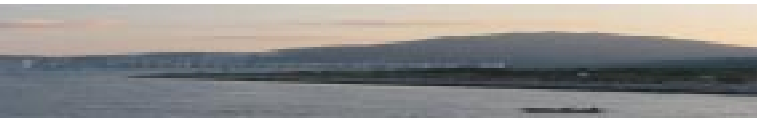


Table 5.1

Summary water quality statistics of the Junk Bay WCZ in 2003

Parameter		Junk Bay JM3	Junk Bay JM4
Number of samples		12	12
Temperature (°C)		23.1 (17.2 - 27.2)	22.9 (17.1 - 27.0)
Salinity		32.9 (30.9 - 33.9)	33.1 (32.2 - 33.8)
Dissolved Oxygen (mg/L)		6.1 (4.9 - 7.8)	5.9 (4.4 - 8.1)
	Bottom	5.7 (3.9 - 7.9)	5.6 (3.2 - 7.9)
Dissolved Oxygen (% Saturation)		86 (72 - 115)	83 (66 - 102)
	Bottom	80 (55 - 101)	78 (46 - 100)
pH		8.1 (7.9 - 8.3)	8.1 (7.9 - 8.3)
Secchi Disc Depth (m)		2.7 (1.5 - 4.0)	2.8 (1.6 - 3.7)
Turbidity (NTU)		7.3 (3.2 - 11.5)	8.1 (5.4 - 11.0)
Suspended Solids (mg/L)		3.6 (1.7 - 5.8)	7.3 (1.7 - 38.7)
5-day Biochemical Oxygen Demand (mg/L)		1.1 (0.4 - 3.1)	1.1 (0.4 - 3.1)
Ammonia Nitrogen (mg/L)		0.07 (0.01 - 0.19)	0.05 (0.01 - 0.12)
Unionised Ammonia (mg/L)		0.004 (0.001 - 0.006)	0.003 (0.001 - 0.005)
Nitrite Nitrogen (mg/L)		0.02 (<0.01 - 0.06)	0.02 (<0.01 - 0.06)
Nitrate Nitrogen (mg/L)		0.06 (0.02 - 0.12)	0.05 (0.01 - 0.10)
Total Inorganic Nitrogen (mg/L)		0.15 (0.09 - 0.27)	0.12 (0.05 - 0.20)
Total Kjeldahl Nitrogen (mg/L)		0.20 (0.13 - 0.30)	0.17 (0.12 - 0.22)
Total Nitrogen (mg/L)		0.28 (0.17 - 0.41)	0.24 (0.14 - 0.36)
Orthophosphate Phosphorus (mg/L)		0.017 (0.01 - 0.03)	0.015 (0.01 - 0.02)
Total Phosphorus (mg/L)		0.03 (0.02 - 0.04)	0.03 (0.02 - 0.04)
Silica (as SiO_2) (mg/L)		0.6 (0.1 - 1.0)	0.6 (0.2 - 1.0)
Chlorophyll-a (μg/L)		3.9 (0.6 - 11.5)	3.4 (0.6 - 11.4)
E. coli (cfu/100mL)		65 (2 - 640)	71 (12 - 730)
Faecal Coliforms (cfu/100mL)		140 (3 - 1600)	170 (51 - 1700)

Note : 1. Unless otherwise specified, data presented are depth-averaged (A) values calculated by taking the means of three depths: Surface (S), Mid-depth (M), Bottom (B).
2. Data presented are annual arithmetic means of the depth-averaged results except for *E. coli* and faecal coliforms which are annual geometric means.
3. Data in brackets indicate the ranges.

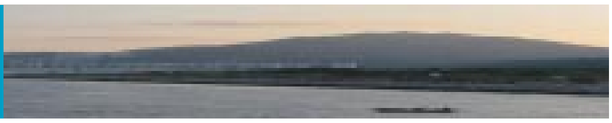


Table 5.2

Results of the Seasonal Kendall Test for trends in water quality parameters measured in the Junk Bay WCZ, 1986 - 2003

Monitoring Station		JM3	JM4
Monitoring Period		1986 - 2003	1986 - 2003
Parameter	Water Depth		
Temperature (°C)	Surface	↗	↗
	Middle	↗	↗
	Bottom	↗	↗
	Average	↗	↗
Salinity	Surface	-	-
	Middle	-	-
	Bottom	-	-
	Average	-	-
Dissolved Oxygen (mg/L)	Surface	↘	↘
	Middle	-	-
	Bottom	-	-
	Average	-	-
Dissolved Oxygen (%)	Surface	-	-
	Middle	-	-
	Bottom	-	-
	Average	-	-
pH	Surface	-	-
	Middle	-	-
	Bottom	-	-
	Average	-	-
Secchi disc depth (m)		-	-
Turbidity (NTU)	Surface	↗	↗
	Middle	↗	↗
	Bottom	↗	↗
	Average	↗	↗
Suspended Solids (mg/L)	Surface	-	-
	Middle	-	-
	Bottom	-	-
	Average	-	-
Total volatile solids (mg/L)	Surface	↘	↘
	Middle	↘	↘
	Bottom	↘	-
	Average	↘	↘
5-day Biochemical Oxygen Demand (mg/L)	Surface	-	-
	Middle	-	-
	Bottom	-	-
	Average	-	-
Ammonia nitrogen (mg/L)	Surface	-	-
	Middle	-	-
	Bottom	-	-
	Average	-	-
Nitrite nitrogen (mg/L)	Surface	-	-
	Middle	-	-
	Bottom	-	-
	Average	-	-
Nitrate nitrogen (mg/L)	Surface	-	-
	Middle	-	-
	Bottom	-	-
	Average	-	-
Total inorganic nitrogen (mg/L)	Surface	-	-
	Middle	-	-
	Bottom	-	-
	Average	-	-
Total Kjeldahl nitrogen (mg/L)	Surface	-	-
	Middle	-	-
	Bottom	↘	-
	Average	↘	↘
Total nitrogen (mg/L)	Surface	-	-
	Middle	-	-
	Bottom	-	-
	Average	↘	-
Orthophosphate phosphorus (mg/L)	Surface	-	-
	Middle	-	-
	Bottom	-	-
	Average	-	-
Total phosphorus (mg/L)	Surface	-	-
	Middle	-	↘
	Bottom	-	-
	Average	-	-
Silica (mg/L)	Surface	-	-
	Middle	-	-
	Bottom	-	-
	Average	-	-
Chlorophyll-*a* (µg/L)	Surface	-	-
	Middle	-	-
	Bottom	-	-
	Average	-	-
E. coli (cfu/100mL)	Surface	-	-
	Middle	-	-
	Bottom	-	-
	Average	-	-
Faecal coliforms (cfu/100mL)	Surface	↗	↗
	Middle	-	-
	Bottom	-	-
	Average	-	-

Note 1. Results of the Seasonal Kendall Test shown are statistically significant at $p < 0.05$
2. - indicates no significant trend is detected
3. ↗ represents a significant increase over time
4. ↘ represents a significant decrease over time

CHAPTER 6

DEEP BAY
WATER CONTROL ZONE

Chapter 6 – Deep Bay Water Control Zone

Water Quality in 2003

6.1 Deep Bay is a shallow and sediment-laden water body in the north western part of New Territories bordering Shenzhen. On the Hong Kong side, seven major rivers, tributaries and nullahs (River Indus, River Ganges, River Beas, Kam Tin River, Yuen Long Creek, Fairview Park Nullah and Tin Shui Wai Nullah) drain into inner part of the bay, whereas a number of minor streams flow into the outer bay.

6.2 The data from EPD's river monitoring programme indicate that the water quality of the major rivers and nullahs in the Inner Deep Bay catchment is generally poor mainly due to pollution by unsewered villages and livestock farms. The minor streams, on the other hand, are largely pristine and free from anthropogenic impact.

6.3 The Inner Deep Bay has the poorest water quality in open marine waters, characterised by high ammonia and low dissolved oxygen (DO). The pollution-related parameters e.g. 5-day Biochemical Oxygen Demand (BOD_5), suspended solids and nitrogenous nutrients show a distinct increasing gradient from the outer part towards the inner part of the bay.

6.4 A summary of the 2003 marine water quality data is shown in Table 6.1. The levels of nitrogenous compounds in Deep Bay were the highest in the territory. The averaged ammonia nitrogen (NH_4-N) and total inorganic nitrogen (TIN) concentrations in Inner Deep Bay (DM1, 2 and 3) were 2.9 mg/L and 3.8 mg/L respectively, which were 13-19% higher than those in 2002. Lower levels of NH_4-N and TIN (0.26 mg/L and 0.89 mg/L respectively) were found in Outer Deep Bay (DM4 and 5), farther away from the pollution sources.

6.5 Similar to other marine waters in Hong Kong, the mean DO at different stations in Deep Bay has decreased by 0.5-0.8 mg/L (8-15%) in 2003, reaching their lowest levels in 10 years. The BOD_5 concentration in the Deep Bay WCZ (averaged 2.6 mg/L) was the highest in the territory, signifying the extent of organic pollution in the bay. In 2003, ortho-phosphate phosphorus has increased by 22% (0.04 mg/L) and *E. coli* bacteria by 43% as compared with those in 2002.

Compliance with Water Quality Objectives

6.6 In 2003, the Inner Bay stations DM1 and DM2 and the outer bay station DM5 failed to comply with the Water Quality Objective (WQO) for DO (Figure 6.1). The overall WQO compliance at DM1 and DM2 were 17% and 25% respectively.

6.7 The Deep Bay WCZ has not met the WQO for total inorganic nitrogen (TIN) since 1996 (Figure 6.1). The TIN at various stations exceeded the WQO level by a very large margin (41%-655%). The persistent high level of TIN and non-compliance with the WQO highlight the seriousness of the nutrient pollution problem in Deep Bay.

6.8 All the Inner Deep Bay stations (DM1, DM2 and DM3) failed to comply with the WQO for unionised ammonia in 2003. It is noted that Inner Deep Bay was the only marine water in the territory which could not meet the objective. This is an environmental concern as high level of unionized ammonia is known to be toxic to aquatic life.

Long-term Water Quality Trends

6.9 Long-term monitoring data indicate that all monitoring stations in Deep Bay have shown significant increases in ammonia nitrogen and total inorganic nitrogen since the mid 80s (Table 6.2). In 2003, the station DM2 also experienced a rise in BOD_5, indicating increased organic matter in the water (Figure 6.2).

6.10 The whole of Deep Bay experienced a significant decline in the DO level, and with the exception of DM1, there has also been a rise in *E. coli*, signifying increasing faecal pollution from human and animal sources (Table 6.2 and Figures 6.2).

6.11 In summary, Deep Bay is facing serious pollution problems including nutrient and organic enrichment, hypoxia, ammonia toxicity and bacterial contamination. They are threatening the sensitive ecosystem in the bay.

6.12 To tackle pollution problems in Deep Bay, the Hong Kong Special Administrative Region (HKSAR) and Shenzhen have taken actions to reduce pollution loadings under the Deep Bay Water Pollution Control Joint Implementation Programme. On the Hong Kong side, EPD enforces the relevant pollution control legislation and implements the Livestock Waste Control Scheme and various Sewerage Master Plans (SMPs).

6.13 Under the Yuen Long and Kam Tin SMP, sewerage has been planned for 41 unsewered villages in the Yuen Long areas. New sewerage for another 38 villages in the North District under the North District SMP was being planned for 2010. In addition, a consultancy study would start at the end of 2004 to formulate a sewerage strategy for the remaining unsewered villages/areas in the northwestern New Territories. The study was scheduled to be completed in 2006.

Figure 6.1 Level of compliance with key Water Quality Objectives in the Deep Bay WCZ

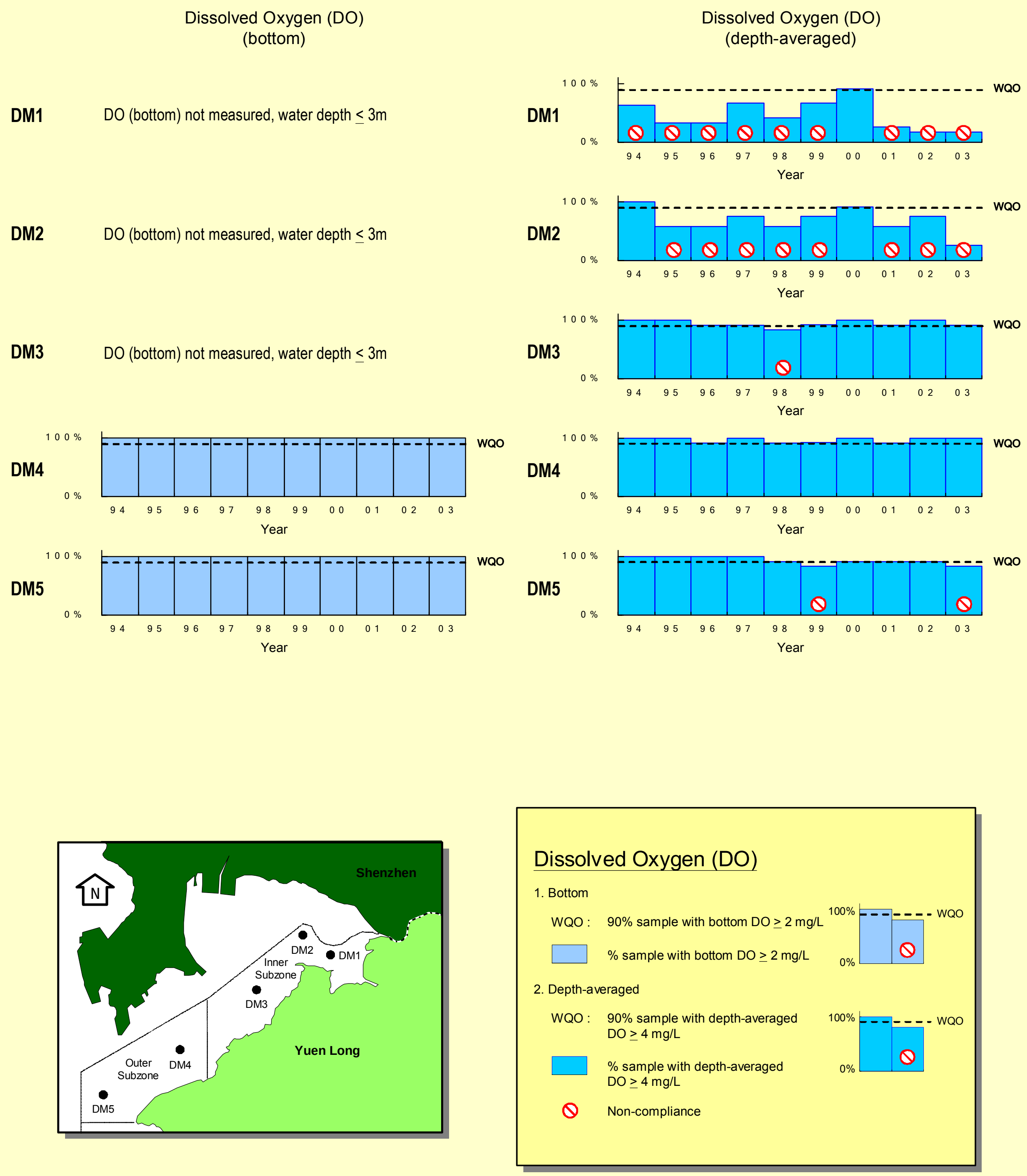
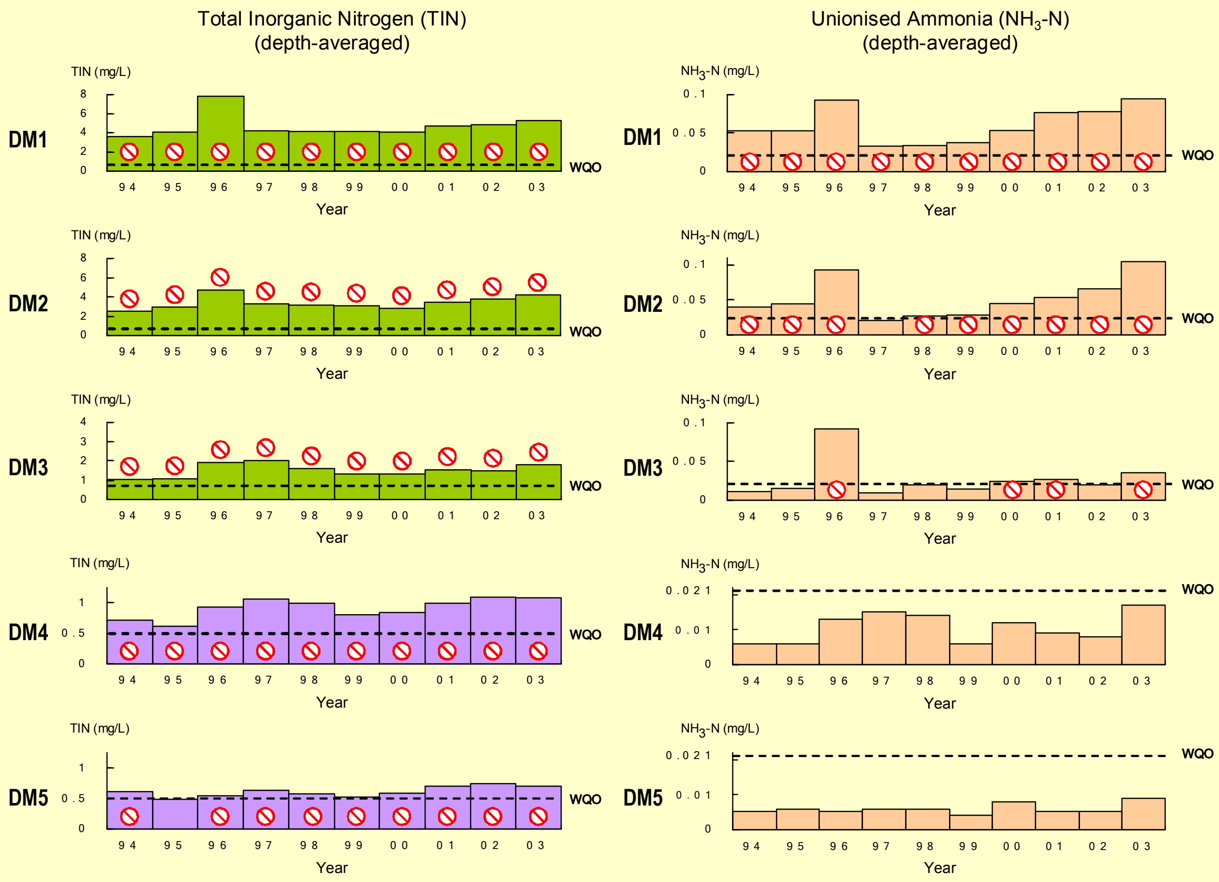
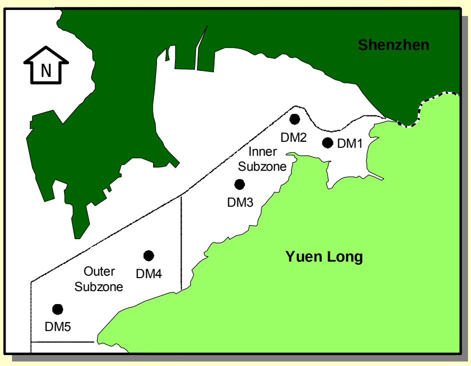


Figure 6.1 (continued) Level of compliance with key Water Quality Objectives in the Deep Bay WCZ





Total Inorganic Nitrogen (TIN)

Inner Subzone (DM1 - DM3)

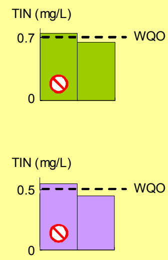
WQO : annual mean for depth-averaged TIN ≤ 0.7 mg/L

annual mean for depth-averaged TIN

Outer Subzone (DM4 - DM5)

WQO : annual mean for depth-averaged TIN ≤ 0.5 mg/L

annual mean for depth-averaged TIN



Unionised Ammonia (NH_3-N)

WQO : annual mean for depth-averaged NH_3-N ≤ 0.021 mg/L

annual mean for depth-averaged NH_3-N

Non-compliance

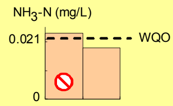


Figure 6.2 Marine water quality trends in the Deep Bay WCZ
(based on the Seasonal Kendall Test significant at $p<0.05$)

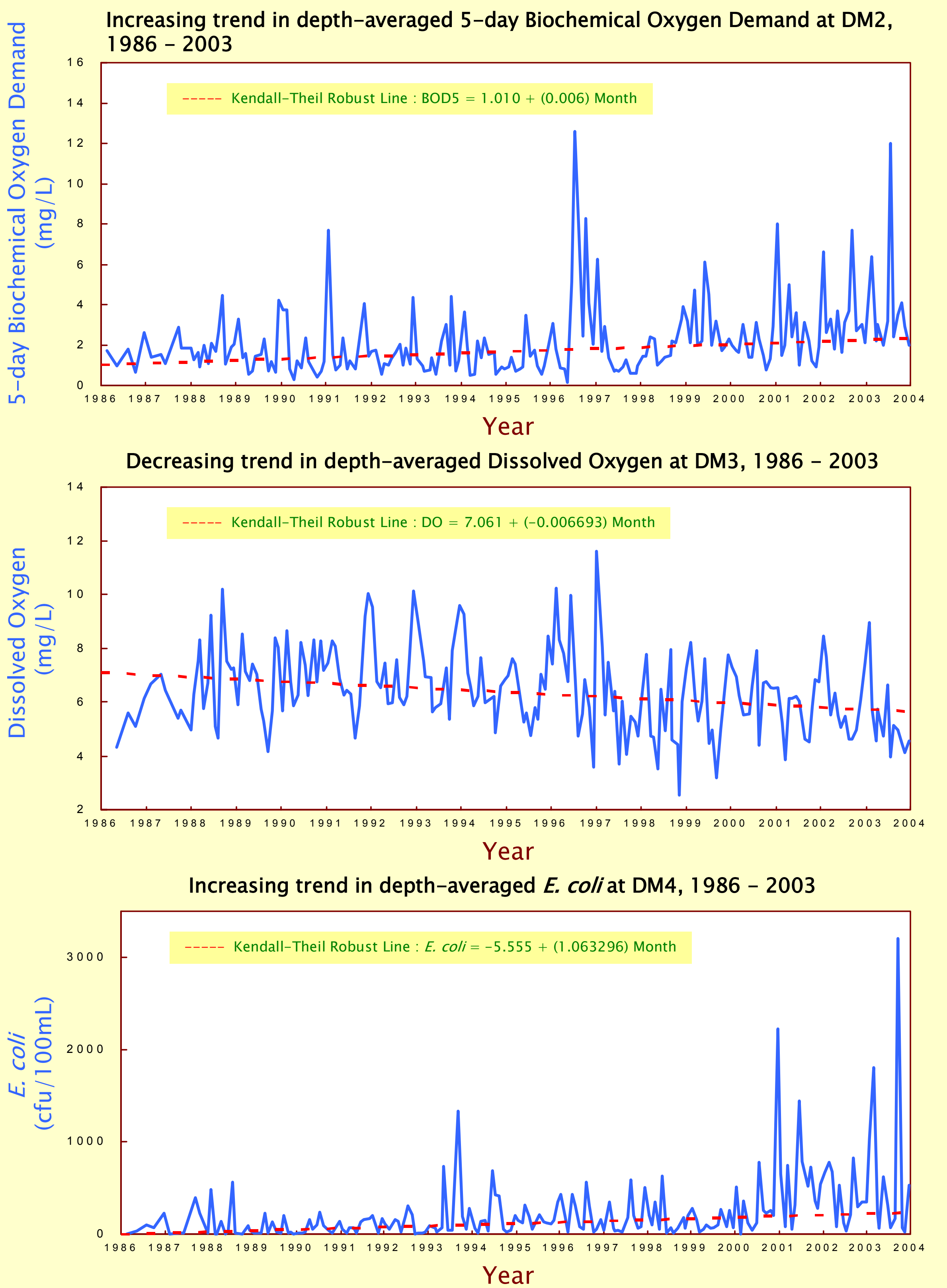


Table 6.1

Summary water quality statistics of the Deep Bay WCZ in 2003

Parameter		Inner Deep Bay			Outer Deep Bay
	DM1	DM2	DM3	DM4	DM5
Number of samples	12	12	12	12	12
Temperature (°C)	24.1 (17.6 - 31.8)	24.2 (17.6 - 31.6)	24.3 (17.0 - 30.6)	24.3 (16.5 - 30.1)	24.4 (16.7 - 29.0)
Salinity	16.4 (6.8 - 23.7)	18.2 (7.6 - 25.6)	21.0 (10.3 - 29.3)	23.4 (14.0 - 32.4)	27.1 (20.4 - 33.2)
Dissolved Oxygen (mg/L)	2.9 (2.1 - 5.2)	3.6 (2.7 - 5.2)	5.3 (4.0 - 9.0)	5.5 (4.2 - 9.9)	5.3 (3.3 - 9.8)
Bottom	NM	NM	NM	5.5 (3.4 - 10.0)	5.1 (2.7 - 10.0)
Dissolved Oxygen (% Saturation)	38 (26 - 65)	48 (35 - 65)	71 (55 - 108)	75 (59 - 117)	72 (47 - 120)
Bottom	NM	NM	NM	74 (49 - 118)	71 (40 - 122)
pH	7.6 (7.1 - 7.9)	7.8 (7.5 - 8.4)	8.0 (7.6 - 8.2)	8.0 (7.6 - 8.4)	8.1 (7.5 - 8.6)
Secchi Disc Depth (m)	0.3 (0.1 - 0.5)	0.4 (0.1 - 0.8)	0.8 (0.5 - 1.5)	1.0 (0.5 - 1.8)	1.4 (0.5 - 2.1)
Turbidity (NTU)	51.8 (24.2 - 143)	42.1 (17.1 - 158.7)	27.7 (8.4 - 74.9)	23.6 (12.2 - 46.6)	18.6 (10.9 - 29.4)
Suspended Solids (mg/L)	59.8 (23.0 - 220)	42.8 (14.0 - 190)	26.1 (4.2 - 90.0)	21.2 (5.9 - 36.1)	11.0 (2.8 - 20.0)
5-day Biochemical Oxygen Demand (mg/L)	4.7 (2.0 - 13.0)	4.0 (2.0 - 12.0)	1.8 (0.8 - 2.9)	1.3 (0.7 - 2.5)	1.1 (0.6 - 2.4)
Ammonia Nitrogen (mg/L)	4.51 (0.71 - 7.90)	3.42 (0.97 - 5.40)	0.91 (0.04 - 2.30)	0.33 (0.07 - 0.69)	0.18 (0.03 - 0.45)
Unionised Ammonia (mg/L)	0.095 (0.028 - 0.239)	0.105 (0.037 - 0.257)	0.035 (0.002 - 0.098)	0.017 (0.004 - 0.050)	0.009 (0.001 - 0.017)
Nitrite Nitrogen (mg/L)	0.33 (0.17 - 0.73)	0.33 (0.21 - 0.67)	0.22 (0.07 - 0.33)	0.15 (0.06 - 0.32)	0.10 (0.04 - 0.23)
Nitrate Nitrogen (mg/L)	0.44 (0.12 - 1.10)	0.48 (0.20 - 1.10)	0.67 (0.19 - 1.20)	0.60 (0.17 - 1.15)	0.43 (0.12 - 0.87)
Total Inorganic Nitrogen (mg/L)	5.29 (2.00 - 8.35)	4.23 (2.28 - 5.91)	1.79 (0.86 - 2.88)	1.08 (0.56 - 1.61)	0.70 (0.31 - 1.15)
Total Kjeldahl Nitrogen (mg/L)	5.54 (1.00 - 9.50)	4.20 (1.30 - 6.50)	1.19 (0.26 - 2.70)	0.53 (0.28 - 0.86)	0.33 (0.17 - 0.56)
Total Nitrogen (mg/L)	6.32 (2.29 - 9.95)	5.01 (2.61 - 7.09)	2.07 (1.19 - 3.28)	1.28 (0.67 - 1.91)	0.85 (0.48 - 1.34)
Orthophosphate Phosphorus (mg/L)	0.443 (0.14 - 0.67)	0.373 (0.14 - 0.51)	0.139 (0.05 - 0.29)	0.064 (0.01 - 0.11)	0.040 (0.02 - 0.05)
Total Phosphorus (mg/L)	0.61 (0.21 - 0.92)	0.48 (0.21 - 0.69)	0.18 (0.07 - 0.36)	0.10 (0.07 - 0.14)	0.06 (0.05 - 0.08)
Silica (as SiO_2) (mg/L)	6.2 (3.1 - 9.2)	5.4 (2.1 - 8.1)	3.9 (1.8 - 6.2)	3.2 (1.5 - 5.7)	2.2 (0.9 - 4.2)
Chlorophyll-a (µg/L)	7.1 (0.8 - 36.0)	5.0 (0.7 - 25.0)	3.5 (0.4 - 17.0)	2.4 (0.5 - 10.2)	2.0 (0.5 - 4.8)
E. coli (cfu/100mL)	3800 (170 - 220000)	2200 (77 - 200000)	100 (11 - 520)	260 (17 - 3200)	540 (150 - 2600)
Faecal Coliforms (cfu/100mL)	8300 (380 - 420000)	4400 (370 - 360000)	190 (49 - 790)	490 (39 - 5300)	1100 (470 - 5400)

Note :
1. Unless otherwise specified, data presented are depth-averaged (A) values calculated by taking the means of three depths: Surface (S), Mid-depth (M), Bottom (B).
2. Data presented are annual arithmetic means of the depth-averaged results except for *E. coli* and faecal coliforms which are annual geometric means.
3. Data in brackets indicate the ranges.
4. NM - not measured

Table 6.2

Results of the Seasonal Kendall Test for trends in water quality parameters measured in the Deep Bay WCZ, 1986 - 2003

Monitoring Station		DM1	DM2	DM3	DM4	DM5
Monitoring Period		1986 - 2003	1986 - 2003	1986 - 2003	1986 - 2003	1991 - 2003
Parameter	Water Depth					
Temperature (°C)	Surface	-	-	-	-	-
	Middle	NA	NA	NA	NA	-
	Bottom	NA	NA	NA	↗	-
	Average	-	-	-	-	-
Salinity	Surface	↘	↘	-	-	-
	Middle	NA	NA	NA	NA	-
	Bottom	NA	NA	NA	-	-
	Average	↘	↘	-	-	-
Dissolved Oxygen (mg/L)	Surface	↘	↘	↘	↘	↘
	Middle	NA	NA	NA	NA	↘
	Bottom	NA	NA	NA	↘	↘
	Average	↘	↘	↘	↘	↘
Dissolved Oxygen (%)	Surface	↘	↘	↘	↘	↘
	Middle	NA	NA	NA	NA	↘
	Bottom	NA	NA	NA	-	-
	Average	↘	↘	↘	↘	↘
pH	Surface	↘	↘	↘	↘	↘
	Middle	NA	NA	NA	NA	-
	Bottom	NA	NA	NA	↘	-
	Average	↘	↘	↘	↘	-
Secchi disc depth (m)		-	-	-	-	-
Turbidity (NTU)	Surface	-	↗	↗	-	↗
	Middle	NA	NA	NA	NA	↗
	Bottom	NA	NA	NA	-	↗
	Average	-	↗	-	-	↗
Suspended Solids (mg/L)	Surface	↗	↗	-	-	-
	Middle	NA	NA	NA	NA	-
	Bottom	NA	NA	NA	-	-
	Average	↗	↗	-	-	-
Total volatile solids (mg/L)	Surface	-	-	-	-	-
	Middle	NA	NA	NA	NA	-
	Bottom	NA	NA	NA	-	-
	Average	-	-	-	-	-
5-day Biochemical Oxygen Demand (mg/L)	Surface	-	↗	-	-	-
	Middle	NA	NA	NA	NA	-
	Bottom	NA	NA	NA	↗	-
	Average	-	↗	-	-	-
Ammonia nitrogen (mg/L)	Surface	↗	↗	↗	↗	↗
	Middle	NA	NA	NA	NA	↗
	Bottom	NA	NA	NA	↗	↗
	Average	↗	↗	↗	↗	↗
Nitrite nitrogen (mg/L)	Surface	-	↗	↗	↗	↗
	Middle	NA	NA	NA	NA	↗
	Bottom	NA	NA	NA	↗	↗
	Average	-	↗	↗	↗	↗
Nitrate nitrogen (mg/L)	Surface	-	-	↗	↗	↗
	Middle	NA	NA	NA	NA	-
	Bottom	NA	NA	NA	↗	-
	Average	-	-	↗	↗	-
Total inorganic nitrogen (mg/L)	Surface	↗	↗	↗	↗	↗
	Middle	NA	NA	NA	NA	-
	Bottom	NA	NA	NA	↗	-
	Average	↗	↗	↗	↗	↗
Total Kjeldahl nitrogen (mg/L)	Surface	↗	↗	-	-	-
	Middle	NA	NA	NA	NA	-
	Bottom	NA	NA	NA	-	-
	Average	↗	↗	-	-	-
Total nitrogen (mg/L)	Surface	↗	↗	↗	↗	-
	Middle	NA	NA	NA	NA	-
	Bottom	NA	NA	NA	-	-
	Average	↗	↗	↗	-	-
Orthophosphate phosphorus (mg/L)	Surface	-	-	-	-	-
	Middle	NA	NA	NA	NA	-
	Bottom	NA	NA	NA	↗	-
	Average	-	-	-	-	-
Total phosphorus (mg/L)	Surface	↘	-	-	-	↘
	Middle	NA	NA	NA	NA	↘
	Bottom	NA	NA	NA	-	↘
	Average	↘	-	-	-	↘
Silica (mg/L)	Surface	-	↗	-	-	-
	Middle	NA	NA	NA	NA	-
	Bottom	NA	NA	NA	-	-
	Average	-	↗	-	-	-
Chlorophyll-*a* (µg/L)	Surface	-	-	-	-	↗
	Middle	NA	NA	NA	NA	↗
	Bottom	NA	NA	NA	-	↗
	Average	-	-	-	-	↗
E. coli (cfu/100mL)	Surface	-	↗	↗	↗	↗
	Middle	NA	NA	NA	NA	↗
	Bottom	NA	NA	NA	↗	↗
	Average	-	↗	↗	↗	↗
Faecal coliforms (cfu/100mL)	Surface	-	↗	↗	↗	↗
	Middle	NA	NA	NA	NA	↗
	Bottom	NA	NA	NA	↗	↗
	Average	-	↗	↗	↗	↗

Note
1. Results of the Seasonal Kendall Test shown are statistically significant at $p < 0.05$
2. - indicates no significant trend is detected
3. NA (Not Applicable) indicates the measurement was not made due to shallow water
4. Test applied to past 18 years' data from each monitoring station unless stated otherwise
5. ↗ represents a significant increase over time
6. ↘ represents a significant decrease over time

CHAPTER 7

MIRS BAY
WATER CONTROL ZONE

Chapter 7 – Mirs Bay Water Control Zone

Water Quality in 2003

7.1 The Mirs Bay Water Control Zone (WCZ) is located in the eastern part of the Hong Kong under substantial oceanic influence. It has a very good and stable water quality, with high dissolved oxygen (DO), low turbidity, *E. coli* and nutrients. The water in the semi-enclosed Starling Inlet is subjected to impact of the Sha Tau Kok town and has slightly higher levels of pollutants than the rest of the WCZ. A total of 14 marine stations were monitored in 2003, and a summary of the water quality data of the Mirs Bay WCZ is shown in Table 7.1.

7.2 Similar to other marine waters in the territory, the DO in Mirs Bay has experienced a general decrease (an average of 0.7 mg/L (11%)) in 2003. The reduction of DO in the southern part of the bay (MM8, MM13-16 and MM19) was less (by 0.4-0.6 mg/L) than in the northern part and within Starling Inlet (by 0.8-1.2 mg/L) where the water circulation was more restricted.

7.3 The levels of inorganic nutrients in the Mirs Bay WCZ in 2003 were largely similar to those in 2002. Total inorganic nitrogen (TIN), ammonia nitrogen and *E. coli* in Starlet Inlet (MM1) continued to decrease indicating a further reduction of domestic sewage pollution in the area and an improvement of water quality. On the other hand, the level of chlorophyll-*a* at MM1 was found to have increased by 4.4µg/L (68%) and an elevation of BOD_5 (by 24%) and SS (by 72%) was also observed.

Compliance with Water Quality Objectives

7.4 Similar to Port Shelter, the Mirs Bay WCZ has an excellent record of Water Quality Objective (WQO) compliance. Full (100%) compliance with the key WQOs was achieved in the WCZ for the fifth consecutive year since 1999 (Figure 7.1).

7.5 The secondary contact recreation subzones within Mirs Bay include Crooked Harbour (MM2), Long Harbour (MM6) and Double Haven (MM7). These waters have very low *E. coli* counts (≤ 2 *E. coli*/100mL) and fully complied with the bacterial objective in 2003 (Figure 7.1).

Long-term Water Quality Trends

7.6 The water quality in the Mirs Bay WCZ has remained largely pristine in the past decade with significant reductions in many nutrient-related parameters (Table 7.2). Significant long-term decreases of total phosphorus (including orthophosphate phosphorus) and total nitrogen (including ammonia nitrogen) were detected at many stations in the WCZ between 1986 and 2003 (Figure 7.2). Some reduction in silica was also noted but it was less widespread than that for phosphorus and nitrogen (Figure 7.2). On the other hand, the chlorophyll-*a* levels in the northern (MM1-5 and MM7) and southern parts (MM8 and MM13) of the bay showed a significant long-term increase, indicating enhanced algal productivity despite the reduced availability of inorganic nutrients in the water.

7.7 To preserve the good water quality and ecology of Mirs Bay, the Government would continue to provide sewerage to unsewered populated areas in the catchment. Under the North District Sewerage Master Plan (SMP), there was a plan to construct the Pak Hok Lam trunk sewer to serve 10 villages in the Sha Tau Kok area. The implementation programme of this SMP was currently under review.

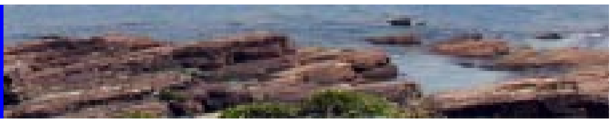
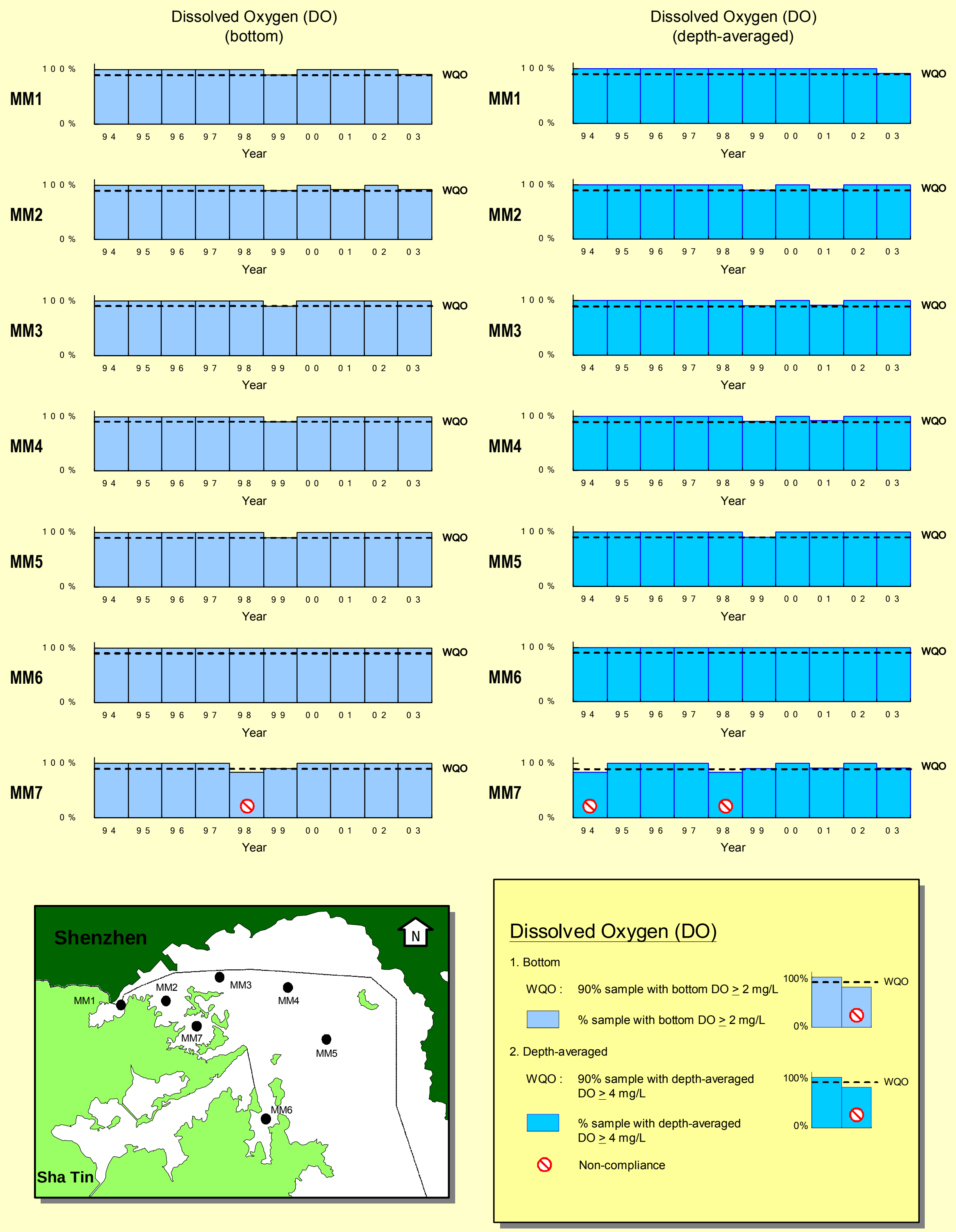


Figure 7.1 Level of compliance with key Water Quality Objectives in the Mirs Bay WCZ



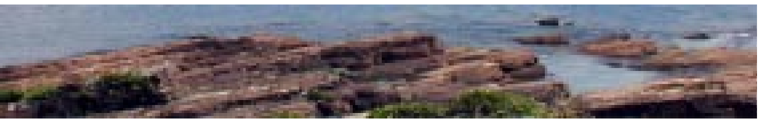
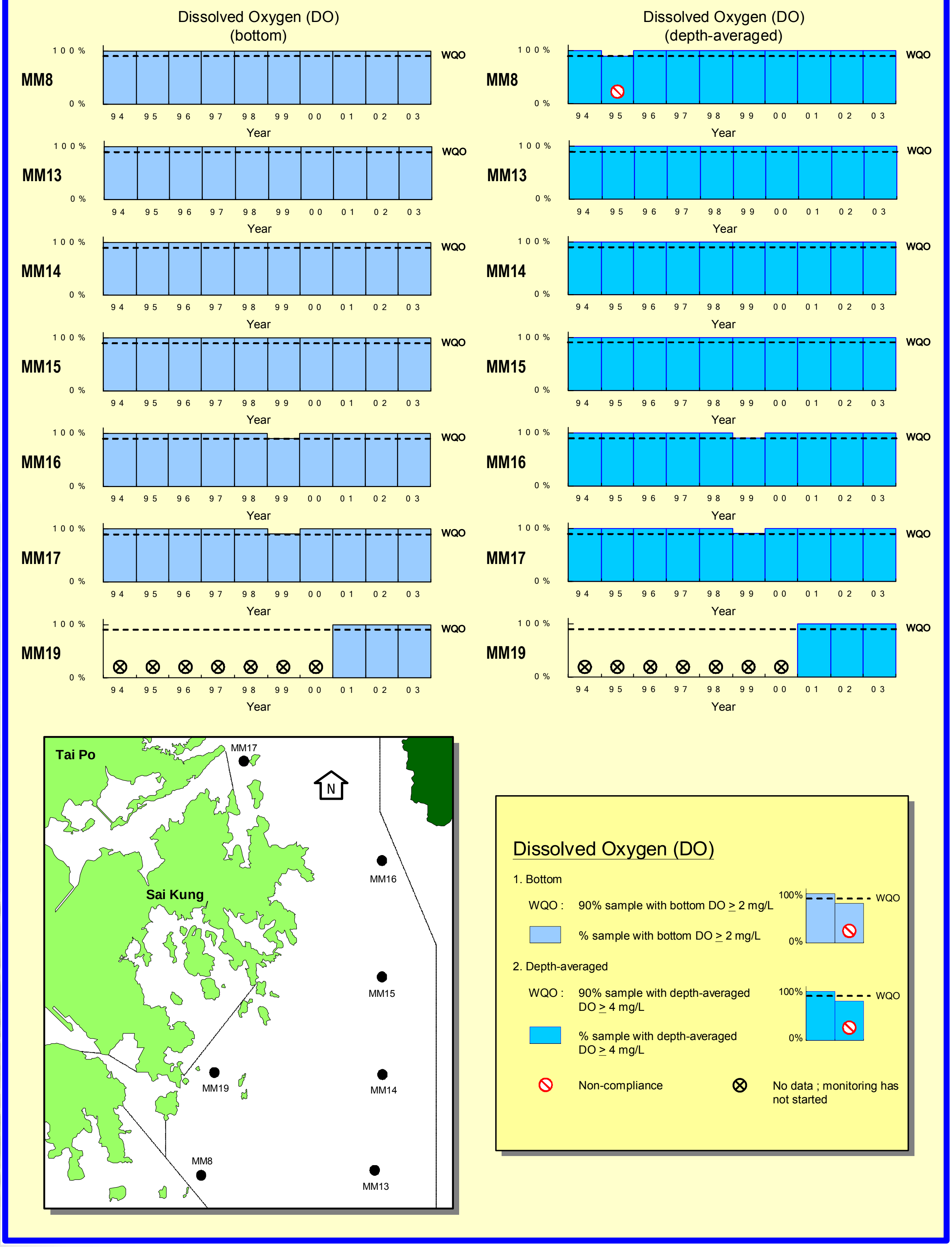


Figure 7.1 (continued) Level of compliance with key Water Quality Objectives in the Mirs Bay WCZ



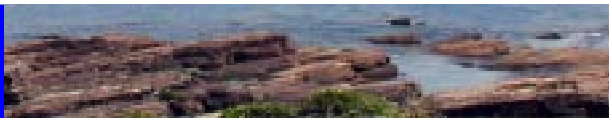


Figure 7.1 (continued) Level of compliance with key Water Quality Objectives in the Mirs Bay WCZ

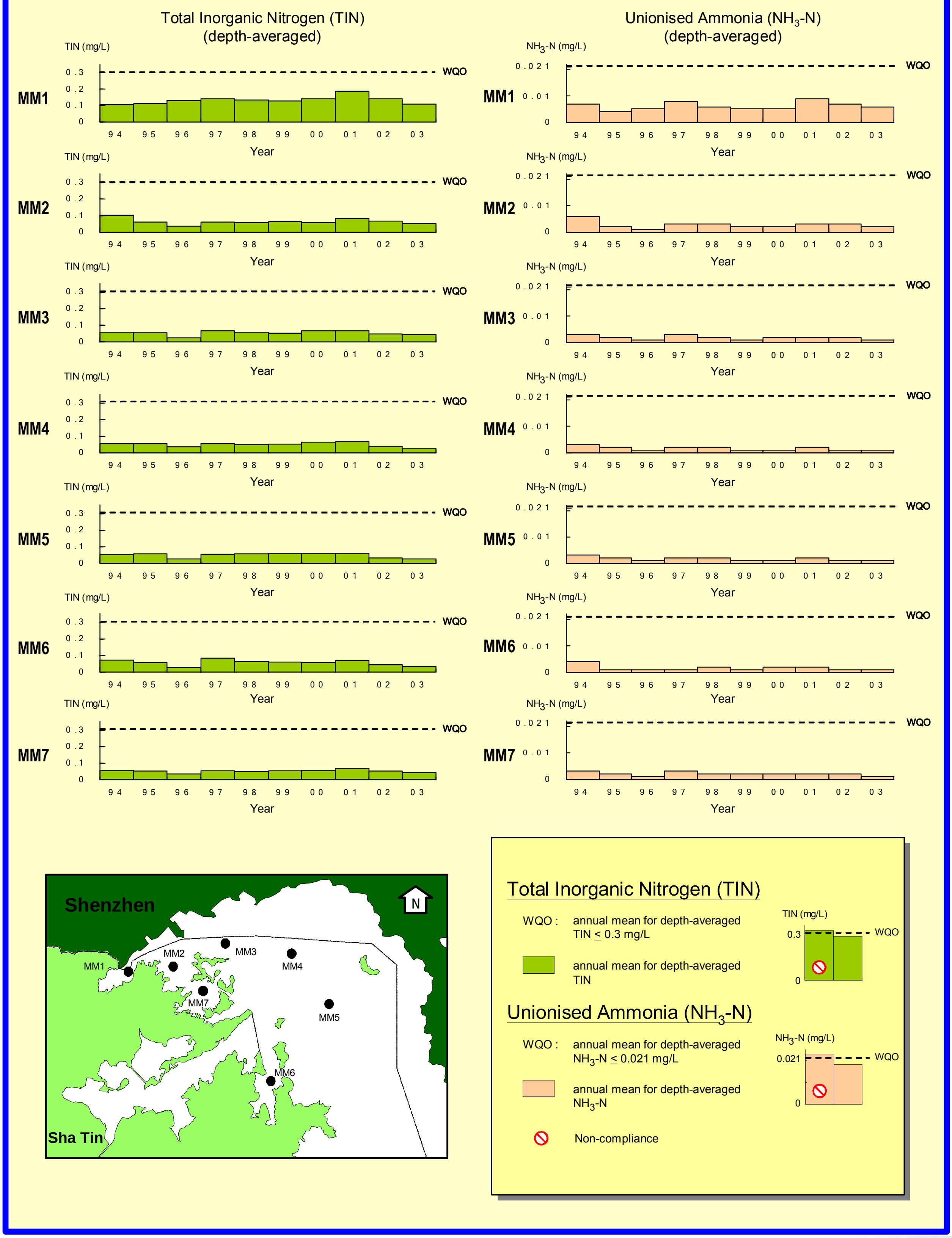


Figure 7.1 (continued) Level of compliance with key Water Quality Objectives in the Mirs Bay WCZ

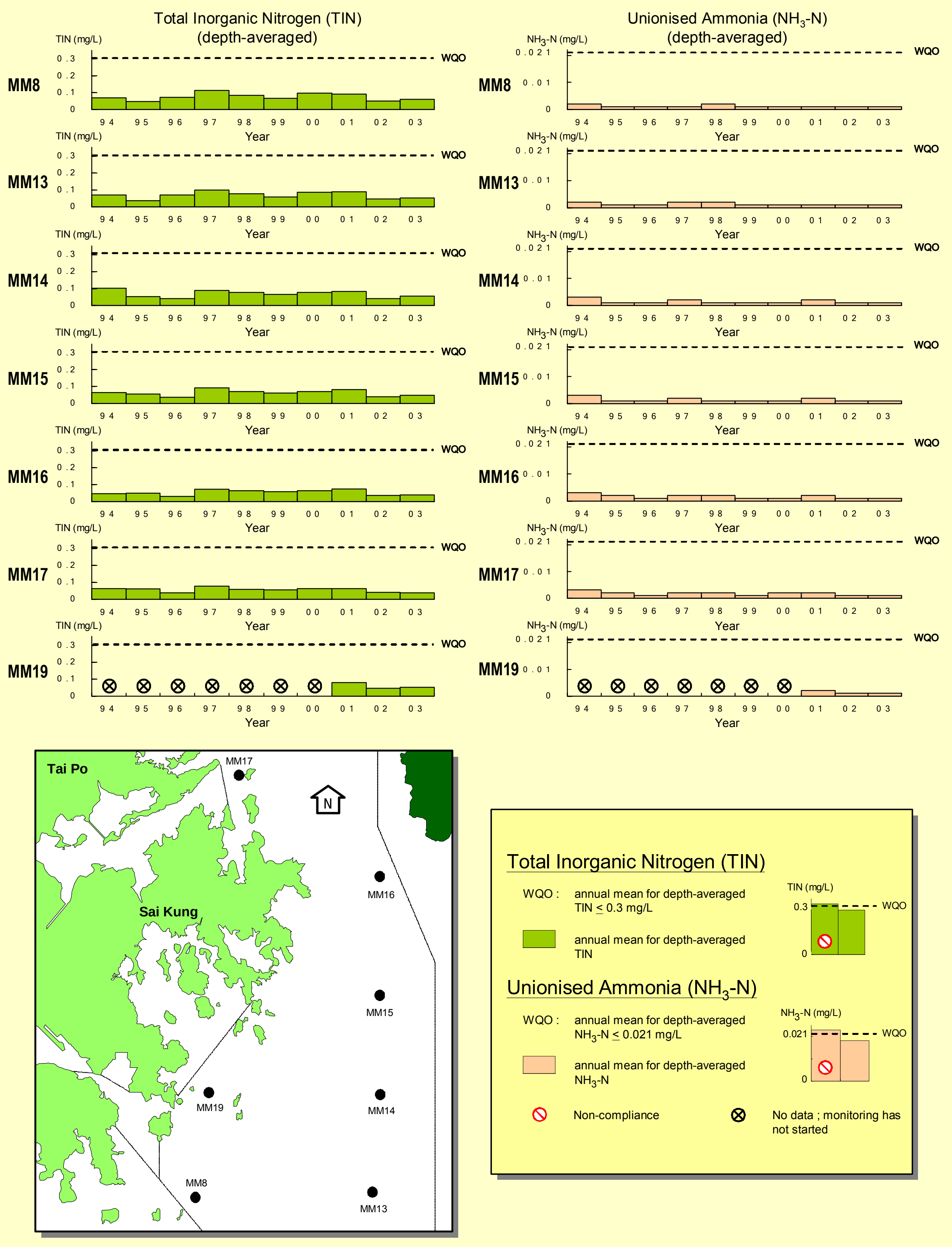
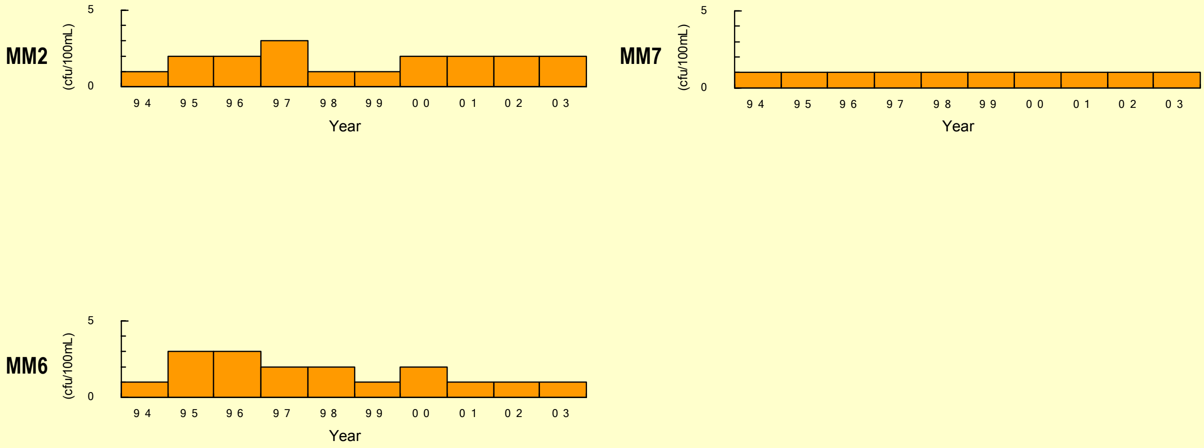
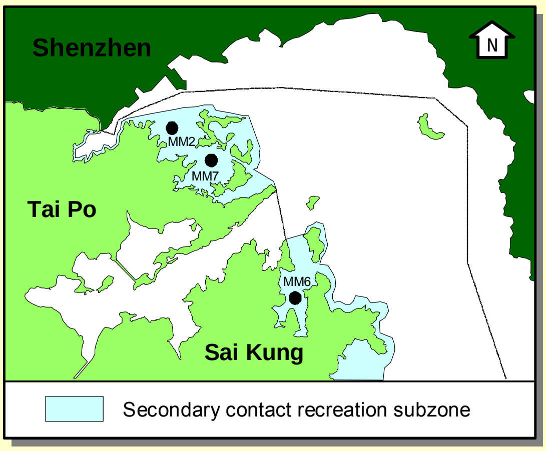


Figure 7.1 (continued) Level of compliance with key Water Quality Objectives in the Mirs Bay WCZ

E. coli
(annual geometric mean)





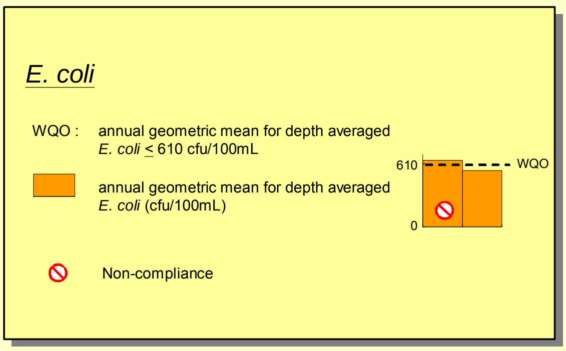


Figure 7.2 Marine water quality trends in the Mirs Bay WCZ (based on the Seasonal Kendall Test significant at $p<0.05$)

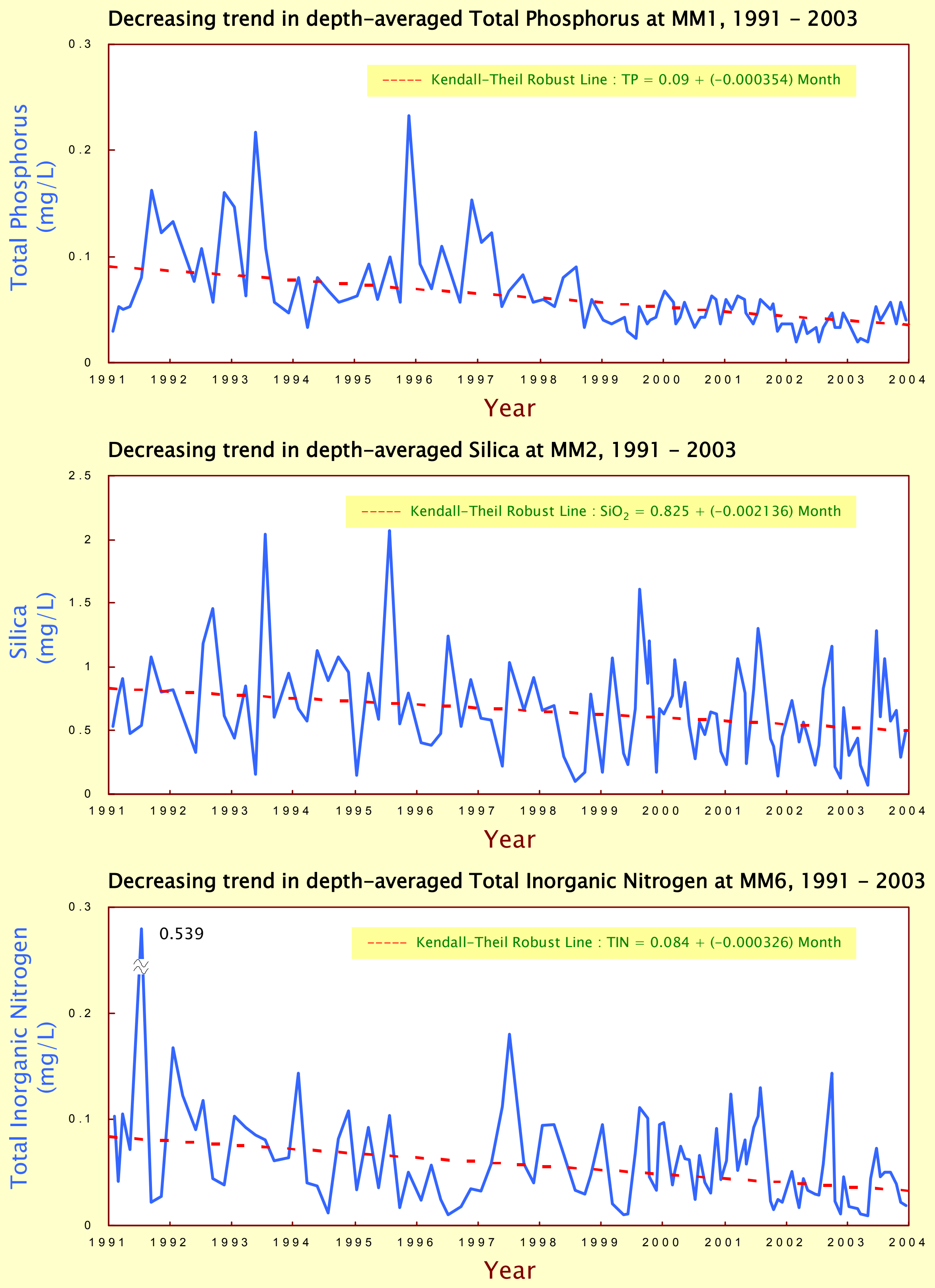


Table 7.1

Summary water quality statistics of the Mirs Bay WCZ in 2003

Parameter		Starling Inlet	Crooked Island		Port Island	Mirs Bay North		
		MM1	MM2	MM7	MM17	MM3	MM4	MM5
Number of samples		12	12	12	12	12	12	12
Temperature (°C)		24.6 (16.6 - 28.9)	24.1 (16.5 - 28.3)	23.9 (16.5 - 28.2)	23.6 (16.6 - 27.8)	23.7 (16.4 - 27.8)	23.6 (16.6 - 27.9)	23.5 (16.6 - 27.9)
Salinity		31.9 (28.5 - 33.1)	32.7 (31.1 - 33.6)	32.8 (31.5 - 34.0)	33.1 (32.0 - 34.4)	33.0 (31.9 - 34.2)	33.2 (32.2 - 34.5)	33.2 (32.5 - 34.5)
Dissolved Oxygen (mg/L)		6.1 (4.0 - 7.7)	5.8 (4.2 - 7.2)	5.6 (3.8 - 7.3)	5.9 (4.7 - 7.6)	5.7 (4.5 - 7.0)	5.8 (4.6 - 7.0)	5.9 (4.8 - 7.0)
	Bottom	5.7 (1.7 - 7.1)	5.2 (1.9 - 7.5)	5.1 (2.3 - 7.2)	5.5 (3.0 - 7.8)	5.5 (3.4 - 7.2)	5.7 (3.8 - 7.1)	5.7 (4.0 - 7.2)
Dissolved Oxygen (% Saturation)		88 (59 - 114)	82 (56 - 102)	81 (58 - 105)	83 (70 - 98)	81 (67 - 95)	83 (69 - 96)	84 (66 - 95)
	Bottom	81 (25 - 105)	73 (27 - 96)	72 (34 - 102)	76 (42 - 99)	78 (50 - 93)	80 (55 - 97)	79 (56 - 92)
pH		8.3 (8.0 - 8.6)	8.3 (8.0 - 8.6)	8.3 (8.0 - 8.6)	8.2 (8.0 - 8.5)	8.3 (8.0 - 8.5)	8.2 (8.0 - 8.5)	8.2 (8.0 - 8.5)
Secchi Disc Depth (m)		2.1 (1.3 - 3.5)	3.5 (2.6 - 5.0)	4.1 (2.7 - 6.5)	5.3 (2.3 - 11.0)	3.3 (2.3 - 4.5)	4.8 (3.0 - 6.5)	5.5 (2.8 - 9.0)
Turbidity (NTU)		9.7 (3.0 - 19.3)	6.5 (1.7 - 9.8)	5.7 (1.5 - 7.9)	6.0 (2.8 - 9.6)	7.1 (2.2 - 11.0)	6.2 (1.8 - 9.1)	6.3 (2.9 - 8.8)
Suspended Solids (mg/L)		8.1 (1.9 - 28.3)	2.9 (1.0 - 7.6)	2.7 (0.8 - 13.3)	2.0 (0.9 - 4.7)	3.3 (0.9 - 10.5)	2.1 (0.8 - 4.5)	2.3 (0.7 - 5.4)
5-day Biochemical Oxygen Demand (mg/L)		2.0 (0.5 - 3.3)	1.1 (0.4 - 1.9)	1.2 (0.6 - 3.2)	0.9 (0.2 - 2.9)	0.9 (0.3 - 1.6)	0.8 (0.4 - 1.3)	0.9 (0.5 - 2.2)
Ammonia Nitrogen (mg/L)		0.08 (0.01 - 0.20)	0.03 (0.01 - 0.04)	0.02 (0.01 - 0.08)	0.02 (0.01 - 0.05)	0.02 (0.01 - 0.03)	0.01 (0.01 - 0.03)	0.01 (0.01 - 0.02)
Unionised Ammonia (mg/L)		0.006 (0.002 - 0.013)	0.002 (0.001 - 0.003)	0.001 (<0.001 - 0.004)	0.001 (<0.001 - 0.002)	0.001 (0.001 - 0.002)	0.001 (<0.001 - 0.002)	0.001 (<0.001 - 0.002)
Nitrite Nitrogen (mg/L)		0.01 (<0.01 - 0.04)	0.01 (<0.01 - 0.08)	0.01 (<0.01 - 0.10)	0.01 (<0.01 - 0.05)	0.01 (<0.01 - 0.09)	0.01 (<0.01 - 0.02)	0.01 (<0.01 - 0.02)
Nitrate Nitrogen (mg/L)		0.02 (<0.01 - 0.04)	0.01 (<0.01 - 0.04)	0.01 (<0.01 - 0.04)	0.01 (<0.01 - 0.03)	0.01 (<0.01 - 0.06)	0.01 (<0.01 - 0.03)	0.01 (<0.01 - 0.02)
Total Inorganic Nitrogen (mg/L)		0.11 (0.02 - 0.28)	0.05 (0.02 - 0.15)	0.04 (0.01 - 0.14)	0.04 (0.01 - 0.08)	0.04 (0.01 - 0.16)	0.03 (0.01 - 0.06)	0.03 (0.01 - 0.05)
Total Kjeldahl Nitrogen (mg/L)		0.28 (0.14 - 0.43)	0.14 (0.11 - 0.18)	0.15 (0.09 - 0.36)	0.11 (0.06 - 0.17)	0.12 (0.08 - 0.19)	0.11 (0.08 - 0.14)	0.10 (0.07 - 0.15)
Total Nitrogen (mg/L)		0.31 (0.16 - 0.51)	0.17 (0.11 - 0.26)	0.17 (0.10 - 0.40)	0.13 (0.06 - 0.21)	0.15 (0.08 - 0.33)	0.12 (0.08 - 0.17)	0.12 (0.07 - 0.19)
Orthophosphate Phosphorus (mg/L)		0.012 (<0.01 - 0.03)	<0.01 (<0.01 - 0.02)	<0.01 (<0.01 - 0.02)	<0.01 (<0.01 - 0.01)	<0.01 (<0.01 - 0.02)	<0.01 (0.01 - 0.01)	<0.01 (<0.01 - 0.01)
Total Phosphorus (mg/L)		0.04 (0.02 - 0.06)	0.02 (0.02 - 0.03)	0.03 (0.02 - 0.09)	0.02 (0.02 - 0.03)	0.02 (0.02 - 0.03)	0.02 (0.02 - 0.03)	0.02 (0.02 - 0.03)
Silica (as SiO_2) (mg/L)		0.6 (0.1 - 1.5)	0.5 (0.1 - 1.3)	0.6 (0.1 - 1.2)	0.6 (0.1 - 1.1)	0.6 (0.1 - 1.7)	0.5 (0.1 - 0.8)	0.5 (0.1 - 1.0)
Chlorophyll-*a* (μg/L)		11.0 (1.2 - 28.4)	3.4 (1.3 - 7.1)	2.8 (1.0 - 7.1)	1.9 (1.0 - 5.0)	2.8 (1.1 - 6.2)	2.1 (1.0 - 5.0)	2.0 (1.2 - 4.6)
E. coli (cfu/100mL)		48 (3 - 470)	2 (1 - 48)	1 (1 - 1)	1 (1 - 2)	2 (1 - 29)	1 (1 - 2)	1 (1 - 2)
Faecal Coliforms (cfu/100mL)		110 (9 - 920)	3 (1 - 100)	1 (1 - 2)	1 (1 - 3)	3 (1 - 83)	1 (1 - 3)	1 (1 - 12)

Note :
1. Unless otherwise specified, data presented are depth-averaged (A) values calculated by taking the means of three depths: Surface (S), Mid-depth (M), Bottom (B).
2. Data presented are annual arithmetic means of the depth-averaged results except for *E. coli* and faecal coliforms which are annual geometric means.
3. Data in brackets indicate the ranges.

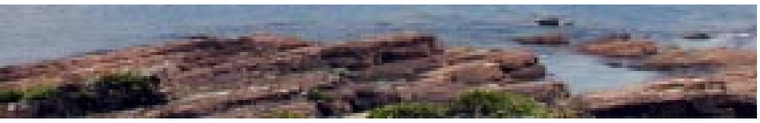


Table 7.1 (continued)

Summary water quality statistics of the Mirs Bay WCZ in 2003

Parameter	Ninepin Group MM19	Waglan Isalnd MM8	Mirs Bay (South) MM13	Mirs Bay (Central) MM14	Mirs Bay (Central) MM15	Mirs Bay (Central) MM16	Long Harbour MM6
Number of samples	12	12	12	12	12	12	12
Temperature (°C)	23.1 (16.7 - 27.9)	23.3 (16.7 - 28.0)	23.5 (16.3 - 28.1)	23.2 (16.3 - 27.6)	23.1 (16.4 - 27.7)	23.1 (16.4 - 27.8)	23.6 (16.2 - 28.0)
Salinity	33.5 (32.8 - 34.4)	33.4 (32.2 - 34.1)	33.4 (31.5 - 34.4)	33.4 (32.3 - 34.3)	33.4 (32.6 - 34.5)	33.4 (32.7 - 34.7)	32.9 (31.8 - 34.2)
Dissolved Oxygen (mg/L)	5.9 (4.4 - 7.0)	5.9 (4.4 - 7.0)	6.0 (5.0 - 7.2)	6.0 (4.7 - 7.4)	6.0 (4.8 - 7.1)	6.2 (4.9 - 7.8)	5.8 (4.6 - 7.1)
Bottom	5.6 (3.6 - 7.0)	5.5 (4.1 - 6.9)	5.7 (4.1 - 7.0)	5.8 (4.4 - 7.2)	5.8 (4.2 - 7.3)	5.8 (3.5 - 7.8)	5.8 (4.0 - 8.7)
Dissolved Oxygen (% Saturation)	84 (63 - 91)	83 (63 - 99)	86 (72 - 93)	85 (68 - 94)	85 (70 - 93)	87 (72 - 99)	82 (68 - 100)
Bottom	78 (51 - 92)	78 (58 - 90)	80 (61 - 94)	81 (62 - 91)	81 (59 - 97)	81 (49 - 103)	81 (60 - 112)
pH	8.2 (8.0 - 8.4)	8.2 (8.0 - 8.4)	8.2 (8.0 - 8.4)	8.2 (8.0 - 8.4)	8.2 (8.0 - 8.4)	8.2 (8.0 - 8.3)	8.2 (8.0 - 8.4)
Secchi Disc Depth (m)	3.1 (2.1 - 4.0)	3.5 (2.0 - 6.0)	4.8 (1.5 - 13.0)	4.6 (2.0 - 10.0)	4.7 (2.5 - 8.0)	5.0 (3.0 - 10.0)	5.3 (3.2 - 8.0)
Turbidity (NTU)	8.1 (5.8 - 10.6)	9.6 (6.0 - 16.4)	8.5 (4.2 - 12.7)	9.0 (5.3 - 14.9)	8.5 (5.0 - 13.9)	7.1 (4.2 - 9.7)	5.7 (2.7 - 7.7)
Suspended Solids (mg/L)	4.0 (1.3 - 8.1)	4.9 (1.9 - 7.0)	4.4 (2.0 - 9.3)	4.8 (1.4 - 9.0)	4.1 (1.2 - 7.0)	2.8 (1.0 - 4.7)	1.4 (0.9 - 2.6)
5-day Biochemical Oxygen Demand (mg/L)	0.6 (0.3 - 1.2)	0.6 (0.3 - 1.0)	0.5 (0.2 - 1.1)	0.6 (0.1 - 1.3)	0.6 (0.1 - 1.3)	0.7 (0.3 - 1.1)	1.1 (0.5 - 3.0)
Ammonia Nitrogen (mg/L)	0.01 (0.01 - 0.02)	0.01 (0.01 - 0.02)	0.01 (0.01 - 0.02)	0.01 (0.01 - 0.02)	0.01 (0.01 - 0.02)	0.01 (0.01 - 0.02)	0.02 (0.01 - 0.04)
Unionised Ammonia (mg/L)	0.001 (<0.001 - 0.002)	0.001 (<0.001 - 0.002)	0.001 (<0.001 - 0.002)	0.001 (<0.001 - 0.001)	0.001 (<0.001 - 0.002)	0.001 (<0.001 - 0.001)	0.001 (<0.001 - 0.002)
Nitrite Nitrogen (mg/L)	0.01 (<0.01 - 0.03)	0.01 (<0.01 - 0.03)	0.01 (<0.01 - 0.02)	0.01 (<0.01 - 0.03)	0.01 (<0.01 - 0.02)	0.01 (<0.01 - 0.02)	0.01 (<0.01 - 0.04)
Nitrate Nitrogen (mg/L)	0.03 (<0.01 - 0.12)	0.04 (<0.01 - 0.11)	0.03 (<0.01 - 0.10)	0.03 (<0.01 - 0.11)	0.03 (<0.01 - 0.12)	0.02 (<0.01 - 0.05)	0.01 (<0.01 - 0.02)
Total Inorganic Nitrogen (mg/L)	0.05 (0.01 - 0.14)	0.06 (0.02 - 0.13)	0.05 (0.01 - 0.13)	0.05 (0.01 - 0.14)	0.05 (0.01 - 0.14)	0.04 (0.01 - 0.07)	0.03 (0.01 - 0.07)
Total Kjeldahl Nitrogen (mg/L)	0.10 (0.08 - 0.13)	0.10 (0.07 - 0.13)	0.09 (0.07 - 0.11)	0.09 (0.07 - 0.11)	0.09 (0.08 - 0.11)	0.10 (0.07 - 0.14)	0.12 (0.08 - 0.14)
Total Nitrogen (mg/L)	0.14 (0.09 - 0.21)	0.15 (0.09 - 0.22)	0.13 (0.08 - 0.21)	0.13 (0.08 - 0.22)	0.13 (0.08 - 0.21)	0.12 (0.09 - 0.16)	0.13 (0.08 - 0.20)
Orthophosphate Phosphorus (mg/L)	<0.01 (<0.01 - 0.02)	<0.01 (<0.01 - 0.01)	<0.01 (0.01 - 0.01)	<0.01 (<0.01 - 0.02)	<0.01 (<0.01 - 0.02)	<0.01 (0.01 - 0.01)	<0.01 (<0.01 - 0.01)
Total Phosphorus (mg/L)	0.02 (0.02 - 0.03)	0.02 (0.02 - 0.03)	0.02 (0.02 - 0.02)	0.02 (0.02 - 0.03)	0.02 (0.02 - 0.03)	0.02 (0.02 - 0.03)	0.02 (0.02 - 0.03)
Silica (as SiO_2) (mg/L)	0.6 (0.3 - 1.3)	0.6 (0.3 - 1.1)	0.5 (0.2 - 1.0)	0.6 (0.3 - 1.2)	0.6 (0.2 - 1.3)	0.6 (0.2 - 0.9)	0.6 (0.1 - 1.2)
Chlorophyll-*a* (µg/L)	2.0 (0.8 - 4.8)	1.8 (0.9 - 4.9)	1.5 (0.6 - 3.7)	1.5 (0.6 - 3.5)	1.3 (0.6 - 2.3)	1.6 (0.7 - 2.7)	2.2 (1.0 - 7.2)
E. coli (cfu/100mL)	1 (1 - 3)	1 (1 - 2)	1 (1 - 1)	1 (1 - 1)	1 (1 - 1)	1 (1 - 1)	1 (1 - 1)
Faecal Coliforms (cfu/100mL)	2 (1 - 10)	1 (1 - 3)	1 (1 - 3)	1 (1 - 2)	1 (1 - 2)	1 (1 - 2)	1 (1 - 6)

Note : 1. Unless otherwise specified, data presented are depth-averaged (A) values calculated by taking the means of three depths: Surface (S), Mid-depth (M), Bottom (B).
2. Data presented are annual arithmetic means of the depth-averaged results except for *E. coli* and faecal coliforms which are annual geometric means.
3. Data in brackets indicate the ranges.

Table 7.2

Results of the Seasonal Kendall Test for trends in water quality parameters measured in the Mirs Bay WCZ, 1986 - 2003

Monitoring Station		MM1	MM2	MM3	MM4	MM5	MM6	MM7
Monitoring Period		1991 - 2003	1991 - 2003	1991 - 2003	1991 - 2003	1991 - 2003	1991 - 2003	1991 - 2003
Parameter	Water Depth							
Temperature (°C)	Surface	-	-	-	-	-	-	-
	Middle	↗	-	-	↗	↗	↗	-
	Bottom	-	↗	↗	↗	↗	↗	↗
	Average	↗	-	-	↗	-	↗	-
Salinity	Surface	-	-	-	-	-	-	-
	Middle	-	-	-	-	-	-	-
	Bottom	-	-	-	-	-	-	-
	Average	-	-	-	-	-	-	-
Dissolved Oxygen (mg/L)	Surface	↘	↘	↘	↘	↘	↘	↘
	Middle	-	↘	-	↘	-	↘	-
	Bottom	-	-	-	-	-	-	-
	Average	-	↘	-	-	-	↘	-
Dissolved Oxygen (%)	Surface	↘	↘	↘	↘	↘	↘	↘
	Middle	-	-	-	-	-	-	-
	Bottom	-	-	-	-	-	-	-
	Average	-	-	-	-	-	↘	-
pH	Surface	-	-	-	-	-	-	-
	Middle	-	-	-	-	-	-	-
	Bottom	-	-	-	-	-	-	-
	Average	-	-	-	-	-	-	-
Secchi disc depth (m)		-	-	-	-	-	↗	-
Turbidity (NTU)	Surface	↗	↗	↗	↗	↗	↗	↗
	Middle	↗	↗	↗	↗	↗	↗	↗
	Bottom	↗	↗	↗	↗	↗	↗	↗
	Average	↗	↗	↗	↗	↗	↗	↗
Suspended Solids (mg/L)	Surface	-	-	-	-	-	-	-
	Middle	-	-	-	-	-	-	-
	Bottom	-	-	-	-	-	-	-
	Average	-	-	-	-	-	-	-
Total volatile solids (mg/L)	Surface	-	-	-	-	-	-	-
	Middle	-	-	-	-	-	-	-
	Bottom	-	-	-	-	-	-	-
	Average	-	-	-	↘	-	↘	-
5-day Biochemical Oxygen Demand (mg/L)	Surface	-	-	-	-	-	-	-
	Middle	-	-	-	-	-	-	-
	Bottom	-	-	-	-	-	-	-
	Average	-	-	-	-	-	-	-
Ammonia nitrogen (mg/L)	Surface	-	↘	↘	↘	↘	↘	↘
	Middle	-	-	↘	↘	↘	↘	↘
	Bottom	-	-	-	-	-	-	-
	Average	-	-	↘	-	↘	↘	-
Nitrite nitrogen (mg/L)	Surface	-	-	-	-	-	-	-
	Middle	-	-	-	-	-	-	-
	Bottom	-	-	-	-	-	-	-
	Average	-	-	-	-	-	-	-
Nitrate nitrogen (mg/L)	Surface	-	-	-	-	-	-	↘
	Middle	-	-	-	-	-	-	-
	Bottom	-	-	-	-	-	-	-
	Average	-	-	-	-	-	-	-
Total inorganic nitrogen (mg/L)	Surface	-	↘	↘	-	↘	↘	↘
	Middle	-	-	↘	↘	↘	↘	↘
	Bottom	-	-	-	↘	-	↘	-
	Average	-	-	↘	-	↘	↘	↘
Total Kjeldahl nitrogen (mg/L)	Surface	-	↘	-	-	-	↘	-
	Middle	-	↘	↘	-	↘	-	-
	Bottom	-	-	-	-	-	↘	-
	Average	-	↘	↘	↘	↘	↘	↘
Total nitrogen (mg/L)	Surface	-	↘	-	-	-	↘	-
	Middle	-	-	↘	-	↘	↘	-
	Bottom	-	-	-	↘	↘	-	-
	Average	-	↘	-	↘	↘	↘	↘
Orthophosphate phosphorus (mg/L)	Surface	↘	↘	↘	-	-	↘	↘
	Middle	-	-	↘	↘	↘	↘	↘
	Bottom	-	-	-	↘	↘	↘	-
	Average	↘	↘	↘	↘	↘	↘	↘
Total phosphorus (mg/L)	Surface	↘	↘	↘	↘	↘	↘	↘
	Middle	↘	↘	↘	↘	↘	↘	↘
	Bottom	↘	↘	↘	↘	↘	↘	↘
	Average	↘	↘	↘	↘	↘	↘	↘
Silica (mg/L)	Surface	↘	↘	-	-	-	-	↘
	Middle	↘	↘	-	-	↘	-	↘
	Bottom	-	↘	-	↘	-	-	-
	Average	-	↘	-	↘	-	-	↘
Chlorophyll-*a* (μg/L)	Surface	↗	↗	↗	↗	-	-	↗
	Middle	↗	↗	↗	↗	↗	-	↗
	Bottom	-	↗	↗	↗	↗	-	↗
	Average	↗	↗	↗	↗	↗	-	↗
E. coli (cfu/100mL)	Surface	-	-	-	-	-	-	-
	Middle	-	-	-	-	-	-	-
	Bottom	-	-	-	-	-	-	-
	Average	-	-	-	-	-	-	-
Faecal coliforms (cfu/100mL)	Surface	-	-	-	-	-	-	-
	Middle	-	↗	-	-	-	-	-
	Bottom	-	-	-	-	-	-	-
	Average	-	↗	-	-	-	-	-

Note
1. Results of the Seasonal Kendall Test shown are statistically significant at $p < 0.05$
2. - indicates no significant trend is detected
3. Test applied to past 18 years' data from each monitoring station unless stated otherwise
4. ↗ represents a significant increase over time
5. ↘ represents a significant decrease over time

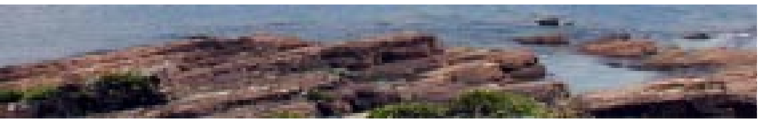


Table 7.2 (continued)

Results of the Seasonal Kendall Test for trends in water quality parameters measured in the Mirs Bay WCZ, 1986 – 2003

Monitoring Station		MM8	MM13	MM14	MM15	MM16	MM17
Monitoring Period		1991 – 2003	1991 – 2003	1994 – 2003	1994 – 2003	1994 – 2003	1986 – 2003
Parameter	Water Depth						
Temperature (°C)	Surface	-	-	-	-	-	↗
	Middle	↗	↗	-	-	-	↗
	Bottom	↗	-	-	-	-	↗
	Average	↗	↗	-	-	-	↗
Salinity	Surface	-	-	-	-	-	-
	Middle	-	-	-	-	-	-
	Bottom	-	-	-	-	-	-
	Average	-	-	-	-	-	-
Dissolved Oxygen (mg/L)	Surface	-	↘	-	-	-	↘
	Middle	↘	↘	-	-	-	-
	Bottom	↘	-	↘	-	-	-
	Average	↘	-	↘	-	-	-
Dissolved Oxygen (%)	Surface	-	-	-	-	-	-
	Middle	-	-	-	-	-	-
	Bottom	-	-	↘	-	-	↗
	Average	-	-	-	-	-	-
pH	Surface	-	-	-	-	-	-
	Middle	-	-	-	-	-	-
	Bottom	-	-	-	-	-	-
	Average	-	-	-	-	-	-
Secchi disc depth (m)		-	-	-	-	-	-
Turbidity (NTU)	Surface	↗	↗	↗	↗	↗	↗
	Middle	↗	↗	↗	↗	↗	↗
	Bottom	↗	↗	↗	↗	↗	↗
	Average	↗	↗	↗	↗	↗	↗
Suspended Solids (mg/L)	Surface	-	-	↘	-	-	↘
	Middle	-	-	-	-	-	↘
	Bottom	-	-	-	-	-	-
	Average	-	-	-	-	-	↘
Total volatile solids (mg/L)	Surface	-	-	-	-	-	↘
	Middle	-	-	-	-	-	↘
	Bottom	-	-	-	-	-	↘
	Average	-	-	-	-	-	↘
5-day Biochemical Oxygen Demand (mg/L)	Surface	-	-	-	-	-	-
	Middle	-	-	-	-	-	-
	Bottom	-	-	-	-	-	-
	Average	-	-	-	-	-	-
Ammonia nitrogen (mg/L)	Surface	↘	↘	↘	-	-	-
	Middle	↘	↘	↘	-	-	-
	Bottom	↘	↘	-	-	-	-
	Average	↘	↘	↘	-	-	-
Nitrite nitrogen (mg/L)	Surface	-	-	-	-	-	-
	Middle	-	-	-	-	-	-
	Bottom	-	-	-	-	-	-
	Average	-	-	-	-	-	-
Nitrate nitrogen (mg/L)	Surface	-	-	-	-	-	↘
	Middle	-	-	-	-	-	-
	Bottom	-	-	-	-	-	-
	Average	-	-	-	-	-	-
Total inorganic nitrogen (mg/L)	Surface	↘	-	-	-	-	-
	Middle	-	-	-	-	-	-
	Bottom	-	-	-	-	-	-
	Average	-	-	-	-	-	-
Total Kjeldahl nitrogen (mg/L)	Surface	↘	↘	-	-	↘	↘
	Middle	↘	↘	-	-	-	↘
	Bottom	↘	↘	-	-	-	↘
	Average	↘	↘	-	-	↘	↘
Total nitrogen (mg/L)	Surface	↘	↘	-	-	-	↘
	Middle	↘	↘	-	-	-	↘
	Bottom	↘	↘	-	-	-	↘
	Average	↘	↘	-	-	↘	↘
Orthophosphate phosphorus (mg/L)	Surface	↘	-	↘	↘	↘	-
	Middle	-	-	↘	↘	↘	-
	Bottom	↘	-	↘	↘	↘	-
	Average	↘	-	↘	↘	↘	-
Total phosphorus (mg/L)	Surface	↘	↘	↘	↘	↘	↘
	Middle	↘	↘	↘	↘	↘	-
	Bottom	↘	↘	↘	↘	↘	-
	Average	↘	↘	↘	↘	↘	↘
Silica (mg/L)	Surface	-	-	-	-	-	↘
	Middle	-	-	-	-	-	↘
	Bottom	-	-	-	-	-	-
	Average	-	-	-	-	-	-
Chlorophyll-*a* (μg/L)	Surface	↗	↗	-	-	-	-
	Middle	↗	↗	-	-	-	-
	Bottom	↗	↗	-	-	-	-
	Average	↗	↗	-	-	-	-
E. coli (cfu/100mL)	Surface	-	-	-	-	-	-
	Middle	-	-	-	-	-	-
	Bottom	-	-	-	-	-	-
	Average	-	-	-	-	-	-
Faecal coliforms (cfu/100mL)	Surface	-	-	-	-	-	-
	Middle	-	-	-	-	-	-
	Bottom	-	-	-	-	-	-
	Average	-	-	-	-	-	-

Note
1. Results of the Seasonal Kendall Test shown are statistically significant at $p < 0.05$
2. – indicates no significant trend is detected
3. Test applied to past 18 years' data from each monitoring station unless stated otherwise
4. MM19 has three years' data only, which is insufficient to perform Seasonal Kendall Test
5. ↗ represents a significant increase over time
6. ↘ represents a significant decrease over time

CHAPTER 8

NORTH WESTERN WATER CONTROL ZONE

Chapter 8 – North Western Water Control Zone

Water Quality in 2003

8.1 The water quality in the North Western Water Control Zone (WCZ) is influenced by local effluent discharges and the Pearl River flow. There are three major sewage outfalls in the WCZ: Pillar Point, Northwest New Territories (from San Wai Sewage Treatment Works (STW)) and Siu Ho Wan which discharged a total of 0.3 million m^3/day of treated effluent into the North Western water in 2003 (Figure 1.8). The levels of *E. coli* and ammonia nitrogen (NH_4-N) at the stations NM1, NM2, NM3 and NM5 located near the outfalls were generally higher compared with other stations. A summary of the 2003 water quality data is shown in Table 8.1.

8.2 The increase of *E. coli* bacteria at NM1 noted in 2002 was again observed in 2003, reaching a maximum of 810 cfu/100mL in 10 years. This may be related to the increased volume of effluent from the Stonecutters Island Sewage Outfall to 1.4 million m^3/day. On the other hand, there was a 40% decrease of *E. coli* at NM5 located near the discharge point of San Wan STW which had a slight reduction in effluent discharge in 2003.

8.3 As in other parts of territorial waters, there has been a moderate decrease of dissolved oxygen (DO) in the North Western WCZ by around 0.7mg/L (11%) in 2003. In addition, the levels of total inorganic nitrogen (TIN) and total phosphorus increased by 0.04 mg/L (9%) and 0.005 mg/L (13%) respectively in 2003.

Compliance with Water Quality Objectives

8.4 Among the six monitoring stations in the North Western WCZ, two eastern stations (NM1 and NM3) failed to comply with the DO objective in 2003 (Figure 8.1). These stations have experienced periods of water stratification in the summer when high salinity and low DO (below 4mg/L) prevailed in the middle and bottom layers (Figure 8.2). Water column stratification (i.e. salinity difference between surface and bottom water exceeds 5 unit) occurred in 39% of the sampling events in 2003 as compared with 25% in 2002. Increased water stratification may contribute to lower compliance of the DO objective in 2003.

8.5 For TIN, four of the six monitoring stations in the North Western WCZ complied with the WQO in 2003. The two non-compliance stations (i.e. NM5 and NM6) were nearer to the Pearl River flow and had a lower track record of WQO compliance in the past. As in previous years, all stations in the WCZ fully complied with the WQO for unionised ammonia in 2003.

Long-term Water Quality Trends

8.6 Significant long-term increases of *E. coli* were detected at NM1 and NM5 during 1988–2003 (Table 8.2). The former may be related to pollution in Victoria Harbour and other local discharges around Castle Peak Road, while the latter to effluents discharged from the San Wai and Pillar Point STWs.

8.7 Long-term increases in ammonia nitrogen (NH_4-N), nitrite, nitrate and TIN were detected at the stations NM2, NM3 and NM5. These increasing trends may undermine the compliance with the TIN objective at the stations NM2 and NM3 in the future as NM5 had already exceeded the WQO level.

8.8 To reduce pollution and arrest the trend of water quality deterioration in the North Western WCZ, the Government has plans to upgrade the Siu Ho Wan, Pillar Point and San Wai Sewage Treatment Works from preliminary to chemical treatment with disinfection. The upgrading of the Siu Ho Wan Sewage Treatment Works (from preliminary to chemical treatment) which started in 2001 would be commissioned around the end of 2004.

Figure 8.1 Level of compliance with key Water Quality Objectives in the North Western WCZ

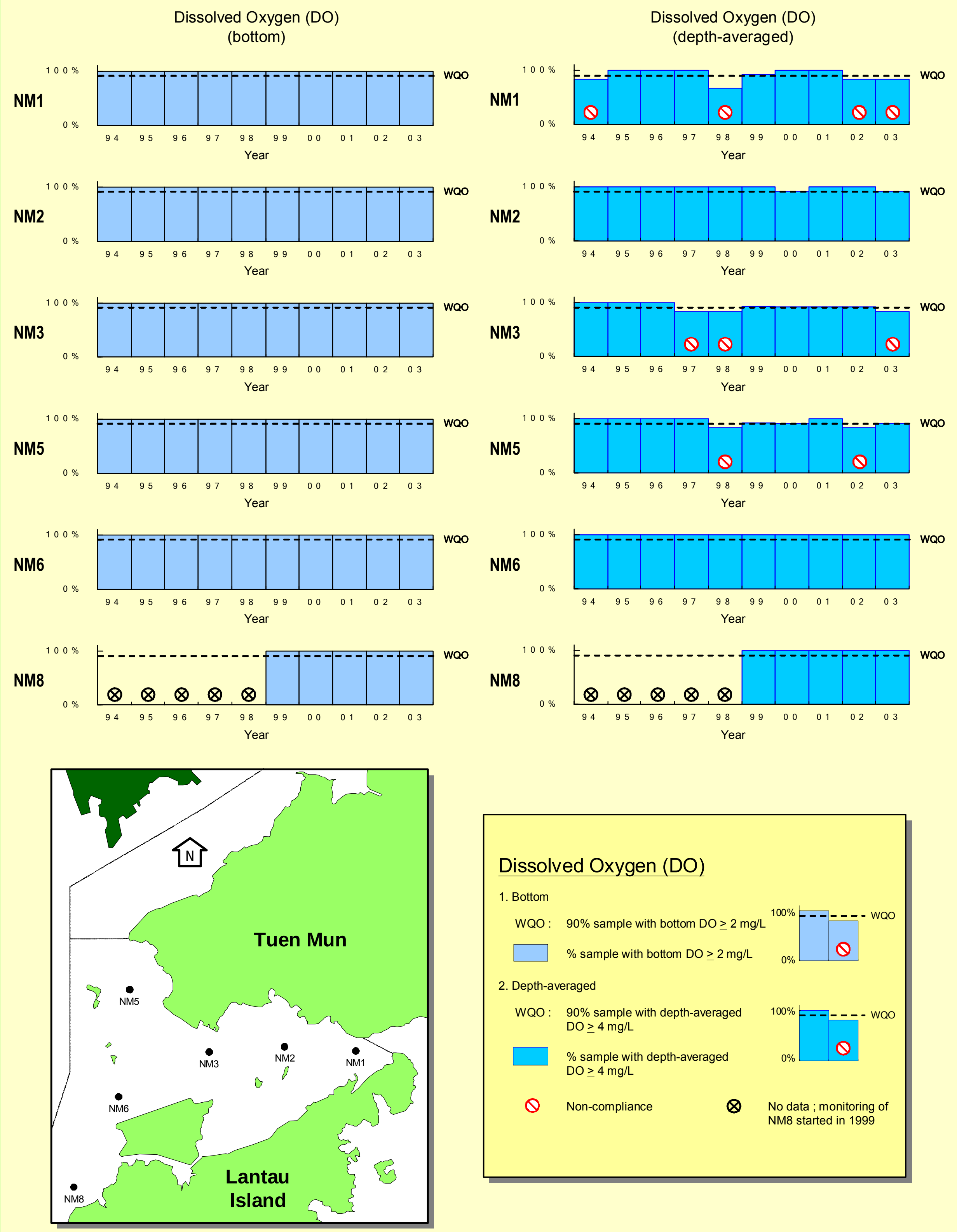


Figure 8.1 (continued) Level of compliance with key Water Quality Objectives in the North Western WCZ

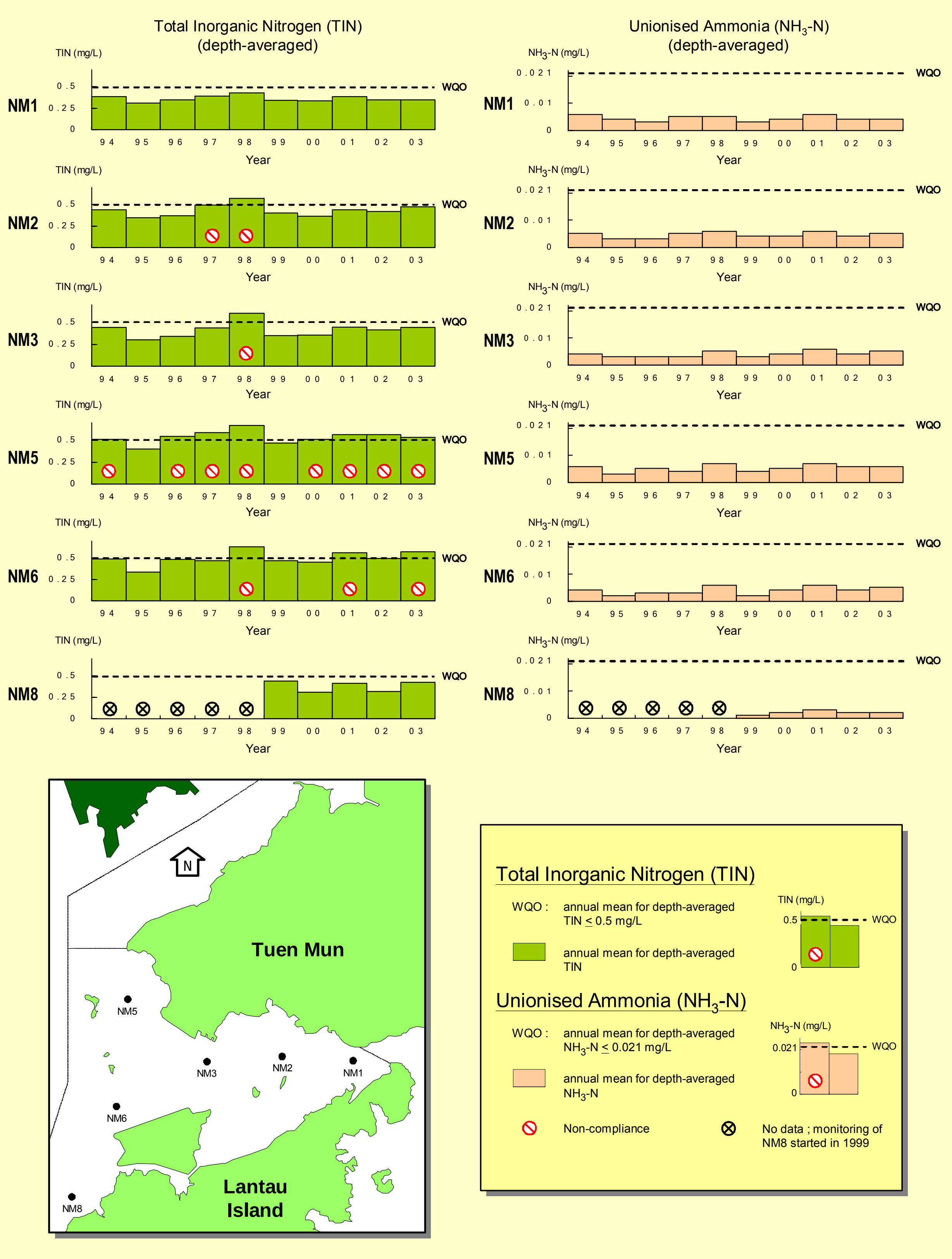
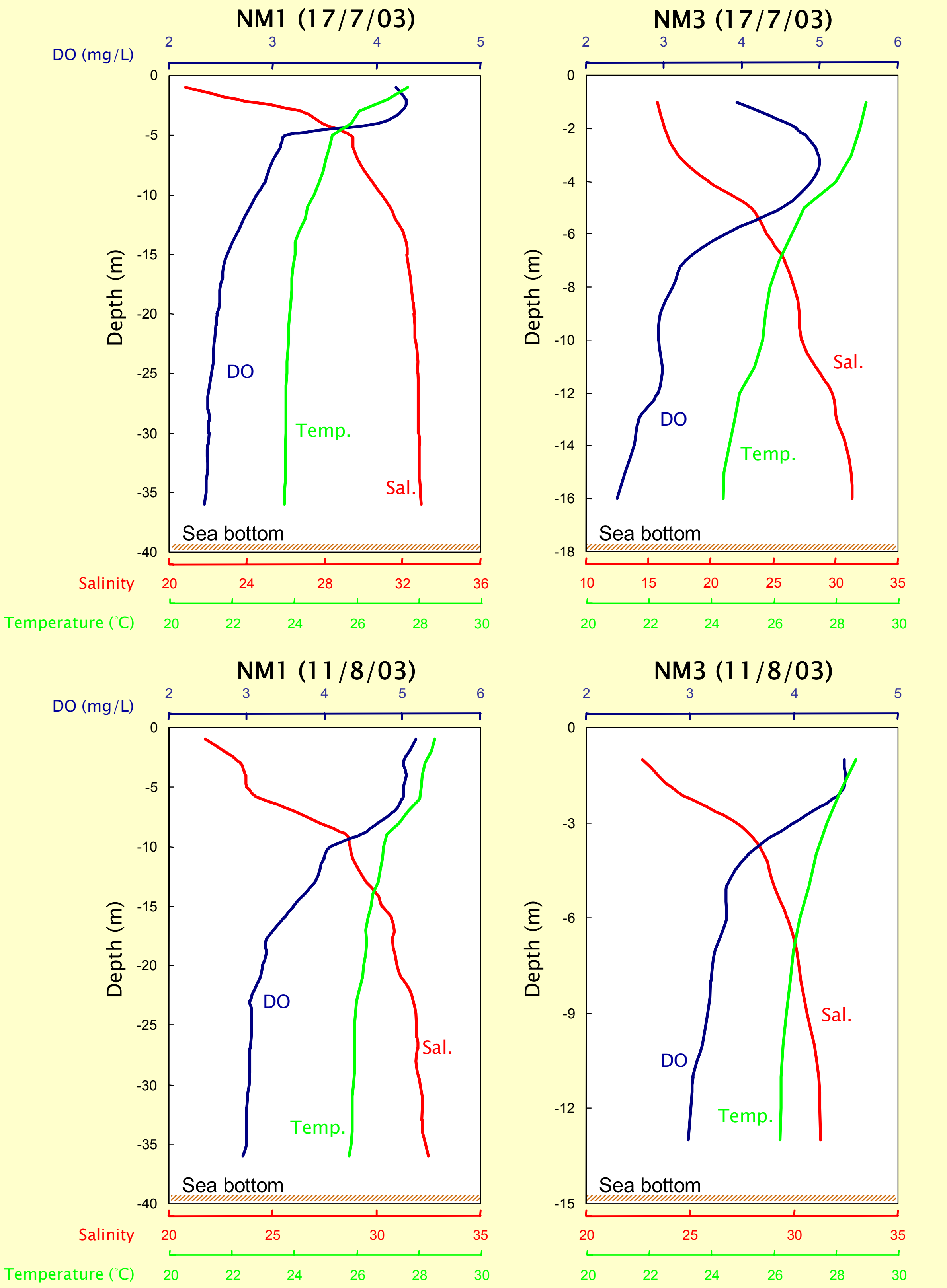


Figure 8.2 Dissolved oxygen, salinity and temperature profiles in the North Western WCZ illustrating water stratification in the summer of 2003



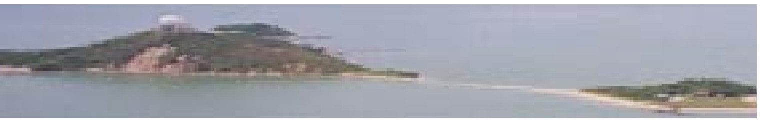


Table 8.1

Summary water quality statistics of the North Western WCZ in 2003

Parameter	Lantau Island (North) NM1	Pearl Island NM2	Pillar Point NM3	Urmston Road NM5	Chek Lap Kok (North) NM6	Chek Lap Kok (West) NM8
Number of samples	12	12	12	12	12	12
Temperature (°C)	23.2 (17.1 - 28.3)	23.5 (17.1 - 28.6)	23.4 (17.0 - 28.4)	23.5 (17.1 - 28.5)	23.6 (16.8 - 29.1)	23.4 (16.9 - 28.8)
Salinity	30.3 (22.9 - 33.5)	28.4 (14.3 - 33.5)	29.0 (20.2 - 33.6)	28.0 (19.5 - 33.5)	26.7 (11.4 - 33.7)	27.7 (10.1 - 33.7)
Dissolved Oxygen (mg/L)	5.5 (3.0 - 8.4)	5.8 (3.8 - 8.5)	5.6 (3.2 - 8.4)	5.6 (3.4 - 8.4)	5.7 (4.3 - 7.7)	5.9 (4.5 - 7.3)
Bottom	5.2 (2.4 - 8.5)	5.6 (2.7 - 8.4)	5.4 (2.5 - 8.4)	5.2 (2.4 - 8.3)	5.6 (3.3 - 7.7)	5.6 (2.7 - 7.2)
Dissolved Oxygen (% Saturation)	76 (43 - 106)	79 (55 - 107)	77 (46 - 106)	77 (49 - 105)	78 (62 - 97)	81 (66 - 95)
Bottom	72 (34 - 107)	77 (38 - 106)	74 (36 - 105)	71 (35 - 104)	77 (47 - 96)	77 (40 - 91)
pH	8.1 (7.9 - 8.3)	8.1 (7.9 - 8.4)	8.1 (7.9 - 8.4)	8.1 (7.8 - 8.4)	8.1 (7.8 - 8.4)	8.2 (8.0 - 8.4)
Secchi Disc Depth (m)	1.8 (0.5 - 3.1)	1.9 (1.0 - 3.5)	1.5 (0.4 - 2.4)	1.3 (0.2 - 2.1)	1.4 (0.5 - 2.4)	1.4 (0.5 - 2.0)
Turbidity (NTU)	12.3 (5.6 - 28.0)	10.9 (6.1 - 19.7)	13.5 (8.0 - 22.0)	17.6 (9.7 - 30.4)	15.0 (7.8 - 21.6)	18.4 (5.5 - 46.3)
Suspended Solids (mg/L)	9.7 (2.2 - 32.7)	7.4 (2.1 - 19.3)	10.0 (3.4 - 23.3)	17.2 (6.7 - 37.7)	11.4 (2.0 - 25.8)	17.0 (5.5 - 51.3)
5-day Biochemical Oxygen Demand (mg/L)	0.9 (0.4 - 1.6)	1.0 (0.3 - 2.1)	1.0 (0.3 - 2.4)	1.1 (0.5 - 2.5)	1.2 (0.6 - 3.1)	1.0 (0.4 - 2.1)
Ammonia Nitrogen (mg/L)	0.09 (0.02 - 0.23)	0.10 (0.03 - 0.25)	0.10 (0.03 - 0.26)	0.13 (0.03 - 0.31)	0.10 (0.01 - 0.25)	0.04 (0.01 - 0.14)
Unionised Ammonia (mg/L)	0.004 (0.001 - 0.008)	0.005 (0.002 - 0.008)	0.005 (0.001 - 0.009)	0.006 (0.002 - 0.014)	0.005 (0.001 - 0.017)	0.002 (<0.001 - 0.006)
Nitrite Nitrogen (mg/L)	0.05 (<0.01 - 0.16)	0.07 (<0.01 - 0.23)	0.07 (<0.01 - 0.19)	0.08 (<0.01 - 0.20)	0.08 (<0.01 - 0.24)	0.06 (<0.01 - 0.22)
Nitrate Nitrogen (mg/L)	0.20 (0.01 - 0.58)	0.31 (<0.01 - 0.95)	0.27 (<0.01 - 0.70)	0.33 (<0.01 - 0.74)	0.39 (<0.01 - 1.13)	0.33 (<0.01 - 1.13)
Total Inorganic Nitrogen (mg/L)	0.35 (0.07 - 0.75)	0.48 (0.06 - 1.19)	0.44 (0.03 - 0.92)	0.53 (0.05 - 1.00)	0.57 (0.02 - 1.61)	0.42 (0.01 - 1.38)
Total Kjeldahl Nitrogen (mg/L)	0.23 (0.15 - 0.34)	0.23 (0.16 - 0.35)	0.25 (0.16 - 0.37)	0.29 (0.16 - 0.43)	0.26 (0.14 - 0.41)	0.19 (0.11 - 0.27)
Total Nitrogen (mg/L)	0.48 (0.23 - 0.92)	0.61 (0.25 - 1.37)	0.59 (0.22 - 1.13)	0.69 (0.19 - 1.19)	0.73 (0.16 - 1.78)	0.57 (0.14 - 1.62)
Orthophosphate Phosphorus (mg/L)	0.023 (0.01 - 0.04)	0.026 (0.01 - 0.04)	0.026 (0.01 - 0.04)	0.030 (0.01 - 0.05)	0.027 (0.01 - 0.06)	0.017 (<0.01 - 0.04)
Total Phosphorus (mg/L)	0.04 (0.02 - 0.06)	0.04 (0.02 - 0.06)	0.04 (0.02 - 0.06)	0.05 (0.02 - 0.08)	0.05 (0.02 - 0.08)	0.04 (0.02 - 0.07)
Silica (as SiO_2) (mg/L)	1.3 (0.2 - 3.3)	1.7 (0.2 - 4.8)	1.6 (0.2 - 3.9)	1.9 (0.3 - 4.3)	2.2 (0.3 - 6.3)	1.9 (0.2 - 5.8)
Chlorophyll-*a* (µg/L)	2.2 (0.5 - 5.2)	2.3 (0.5 - 8.4)	2.6 (0.6 - 11.5)	2.7 (0.6 - 11.7)	2.6 (0.7 - 5.9)	3.2 (0.7 - 7.4)
E. coli (cfu/100mL)	810 (180 - 3600)	380 (84 - 2500)	440 (92 - 4600)	470 (7 - 1800)	44 (4 - 1200)	5 (1 - 110)
Faecal Coliforms (cfu/100mL)	1900 (460 - 7900)	920 (230 - 8900)	1000 (210 - 7800)	1000 (17 - 3800)	110 (18 - 2700)	11 (2 - 270)

Note :
1. Unless otherwise specified, data presented are depth-averaged (A) values calculated by taking the means of three depths: Surface (S), Mid-depth (M), Bottom (B).
2. Data presented are annual arithmetic means of the depth-averaged results except for *E. coli* and faecal coliforms which are annual geometric means.
3. Data in brackets indicate the ranges.

Table 8.2

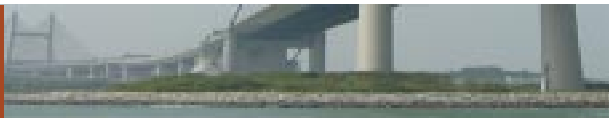
Results of the Seasonal Kendall Test for trends in water quality parameters measured in the North Western WCZ, 1986 - 2003

Monitoring Station		NM1	NM2	NM3	NM5	NM6
Monitoring Period		1988 - 2003	1986 - 2003	1986 - 2003	1988 - 2003	1991 - 2003
Parameter	Water Depth					
Temperature (°C)	Surface	-	-	-	-	-
	Middle	-	-	-	↗	-
	Bottom	-	-	-	-	-
	Average	-	-	-	↗	-
Salinity	Surface	-	-	-	-	-
	Middle	-	-	-	-	-
	Bottom	-	-	-	-	-
	Average	-	-	-	-	-
Dissolved Oxygen (mg/L)	Surface	-	-	-	↘	↘
	Middle	-	-	-	-	-
	Bottom	-	-	-	↘	-
	Average	-	-	-	-	↘
Dissolved Oxygen (%)	Surface	-	-	-	-	↘
	Middle	-	-	-	-	-
	Bottom	-	-	-	-	-
	Average	-	-	-	-	↘
pH	Surface	↘	-	-	-	-
	Middle	-	-	-	↘	-
	Bottom	-	-	-	↘	-
	Average	-	-	-	-	-
Secchi disc depth (m)		-	-	-	-	-
Turbidity (NTU)	Surface	-	-	-	-	↗
	Middle	-	↗	-	-	↗
	Bottom	-	-	-	-	↗
	Average	-	-	-	-	↗
Suspended Solids (mg/L)	Surface	-	-	-	-	-
	Middle	-	-	-	-	-
	Bottom	-	-	-	-	-
	Average	-	-	-	-	-
Total volatile solids (mg/L)	Surface	-	-	-	-	-
	Middle	-	-	-	-	-
	Bottom	-	-	-	-	-
	Average	-	↘	-	-	-
5-day Biochemical Oxygen Demand (mg/L)	Surface	-	-	-	-	-
	Middle	-	-	-	-	-
	Bottom	-	-	-	-	-
	Average	-	-	-	-	-
Ammonia nitrogen (mg/L)	Surface	-	↗	↗	↗	-
	Middle	-	↗	↗	↗	-
	Bottom	-	-	↗	↗	-
	Average	-	↗	↗	↗	-
Nitrite nitrogen (mg/L)	Surface	-	↗	↗	↗	-
	Middle	-	↗	↗	-	-
	Bottom	-	-	-	-	-
	Average	-	↗	↗	↗	-
Nitrate nitrogen (mg/L)	Surface	-	↗	↗	↗	-
	Middle	-	↗	↗	-	-
	Bottom	-	-	-	-	-
	Average	-	-	↗	-	-
Total inorganic nitrogen (mg/L)	Surface	-	↗	↗	↗	-
	Middle	-	-	↗	-	-
	Bottom	-	-	↗	-	-
	Average	-	-	↗	↗	-
Total Kjeldahl nitrogen (mg/L)	Surface	↘	↘	↘	-	-
	Middle	↘	↘	↘	↘	-
	Bottom	↘	↘	↘	-	-
	Average	↘	↘	↘	-	↘
Total nitrogen (mg/L)	Surface	-	-	-	-	-
	Middle	-	-	-	-	-
	Bottom	-	↘	-	-	-
	Average	-	-	-	-	-
Orthophosphate phosphorus (mg/L)	Surface	-	-	-	-	-
	Middle	-	-	-	-	↘
	Bottom	-	-	-	-	↘
	Average	-	-	-	-	↘
Total phosphorus (mg/L)	Surface	-	-	-	-	↘
	Middle	-	-	-	-	↘
	Bottom	↘	-	-	-	↘
	Average	-	-	-	-	↘
Silica (mg/L)	Surface	-	-	-	-	-
	Middle	-	-	-	-	-
	Bottom	-	-	-	-	-
	Average	-	-	-	-	-
Chlorophyll-*a* (μg/L)	Surface	-	-	-	↗	↗
	Middle	-	-	-	-	-
	Bottom	-	-	-	-	↗
	Average	-	-	-	-	↗
E. coli (cfu/100mL)	Surface	↗	-	-	↗	-
	Middle	↗	-	-	↗	-
	Bottom	↗	-	-	↗	-
	Average	↗	-	-	↗	-
Faecal coliforms (cfu/100mLl)	Surface	↗	-	-	↗	↗
	Middle	↗	↗	-	↗	-
	Bottom	↗	↗	↗	↗	-
	Average	↗	↗	-	↗	-

Note
1. Results of the Seasonal Kendall Test shown are statistically significant at $p < 0.05$
2. - indicates no significant trend is detected
3. Test applied to past 18 years' data from each monitoring station unless stated otherwise
4. NM8 has five years' data only, which is insufficient to perform Seasonal Kendall Test
5. ↗ represents a significant increase over time
6. ↘ represents a significant decrease over time

CHAPTER 9

WESTERN BUFFER WATER CONTROL ZONE



Chapter 9 – Western Buffer Water Control Zone

Water Quality in 2003

9.1 The Western Buffer Water Control Zone (WCZ) covers the Ma Wan Channel, Kap Shui Mun Channel and other major navigation channels and anchorages in the Western Harbour. It has a strong tidal flushing capacity and is used for disposal of effluent from the Stonecutters Island Sewage Treatment Works (SCISTW). A summary of the 2003 water quality data for the Western Buffer WCZ is shown in Table 9.1.

9.2 Since the commissioning of the Harbour Area Treatment Scheme (HATS) Stage I in 2002, the water near the SCISTW Outfall has experienced a marked increase of faecal bacteria. In 2003, the *E. coli* levels at the stations WM2, WM3 and WM4 have risen further by 40% (to 280 cfu/100mL), 79% (to 2000 cfu/100mL) and 27% (to 300 cfu/100mL) respectively, reaching their maximum levels since the mid 80s (Figure 9.2). The amount of effluent discharged from the SCISTW Outfall has increased from 1.3 million m^3/day in 2002 to 1.4 million m^3/day in 2003. Local pollution around Tsuen Wan also contributed to the pollution in the area.

9.3 The higher bacterial levels in the Western Buffer WCZ have resulted in the closure of beaches along the Tsuen Wan coast during bathing season in 2003. EPD's beach monitoring results showed that the annual rankings of Approach, Lido, Casam and Gemini Beaches in Tsuen Wan were 'Very Poor' and Hoi Mei Wan Beach was "Poor".

9.4 Like the rest of Hong Kong waters, the Western Buffer WCZ has experienced a 6-11% decrease of dissolved oxygen (DO) in 2003 which may be due to natural fluctuations in the sea water. The levels of orthophosphate phosphorus at all stations (WM1-WM4) showed significant increases (41-64%) but no elevation of algal biomass (i.e. chlorophyll-*a*) was observed.

9.5 The levels of suspended solids (SS) and turbidity in the WCZ showed a reduction of 25-70% in 2003, in particular at WM3 which could be related to the decrease of marine works around South Tsing Yi Island. In 2002, the marine sand abstracted from the South Tsing Yi Marine Borrow Area amounted to 14 million m^3. The sand dredging activity was ceased in 2003 (Figure 1.7). In addition, the amount of materials dumped at the two marine disposal sites in South Tsing Yi has been reduced from 10 million m^3 in 2002 to 1.4 million m^3 in 2003 (Figure 1.7).

Compliance with Water Quality Objectives

9.6 Figure 9.1 shows the levels of compliance with the key Water Quality Objectives (WQOs) between 1994 and 2003. All four stations in the WCZ fully complied with the key WQOs in 2003, similar to that in 2002.

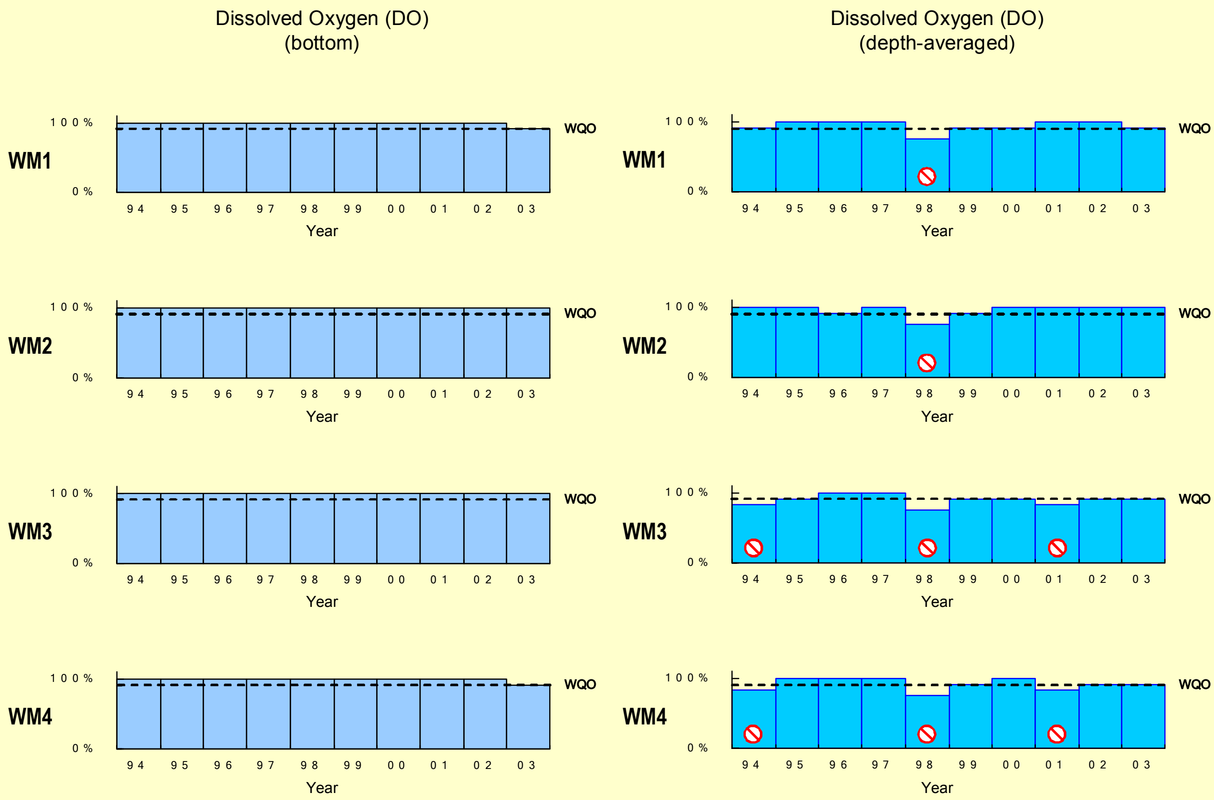
Long-term Water Quality Trends

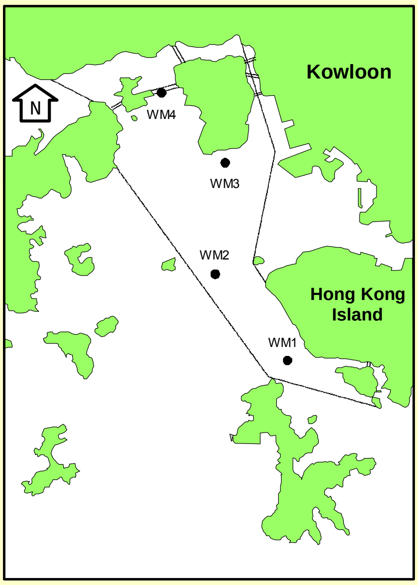
9.7 Long-term increasing trends in sewage bacteria were observed in the central and northern parts of the Western Buffer WCZ (i.e. at WM2, WM3 and WM4) (Table 9.2 and Figure 9.2) in the last 18 years (1986-2003). On the other hand, the water quality at WM1 in the East Lamma Channel has remained relatively stable with some decreases in total nitrogen and total phosphorus.

9.8 To reduce local pollution in the Western Buffer WCZ, the Government has built a new sewage treatment plant in Sham Tseng, the Sham Tseng Sewage Treatment Works, which was commissioned in December 2003. Sewage undergoes chemically enhanced primary treatment with disinfection prior to discharge. In addition, the Government has plans to provide sewerage along the Castle Peak Road to serve unsewered villages and properties around Ting Kau, Sham Tseng and Tsing Lung Tau.

9.9 The current chemically enhanced primary treatment at the SCISTW under the HATS Stage I development was mainly targeting towards the removal of organic pollutants (BOD) and SS. The long term solution of the pollution problem in Victoria Harbour has been investigated and the study findings have been put forward for consultation in 2004 (http://www.cleanharbour.gov.hk).

Figure 9.1 Level of compliance with key Water Quality Objectives in the Western Buffer WCZ





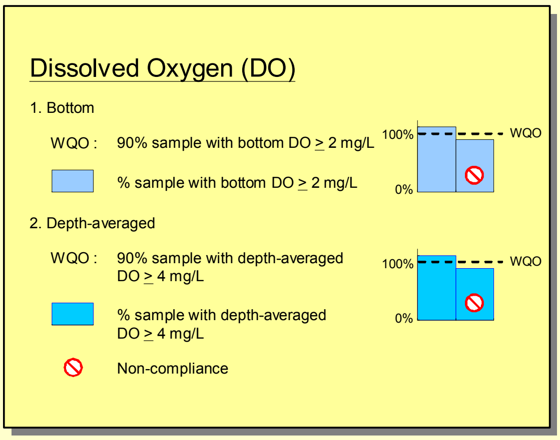
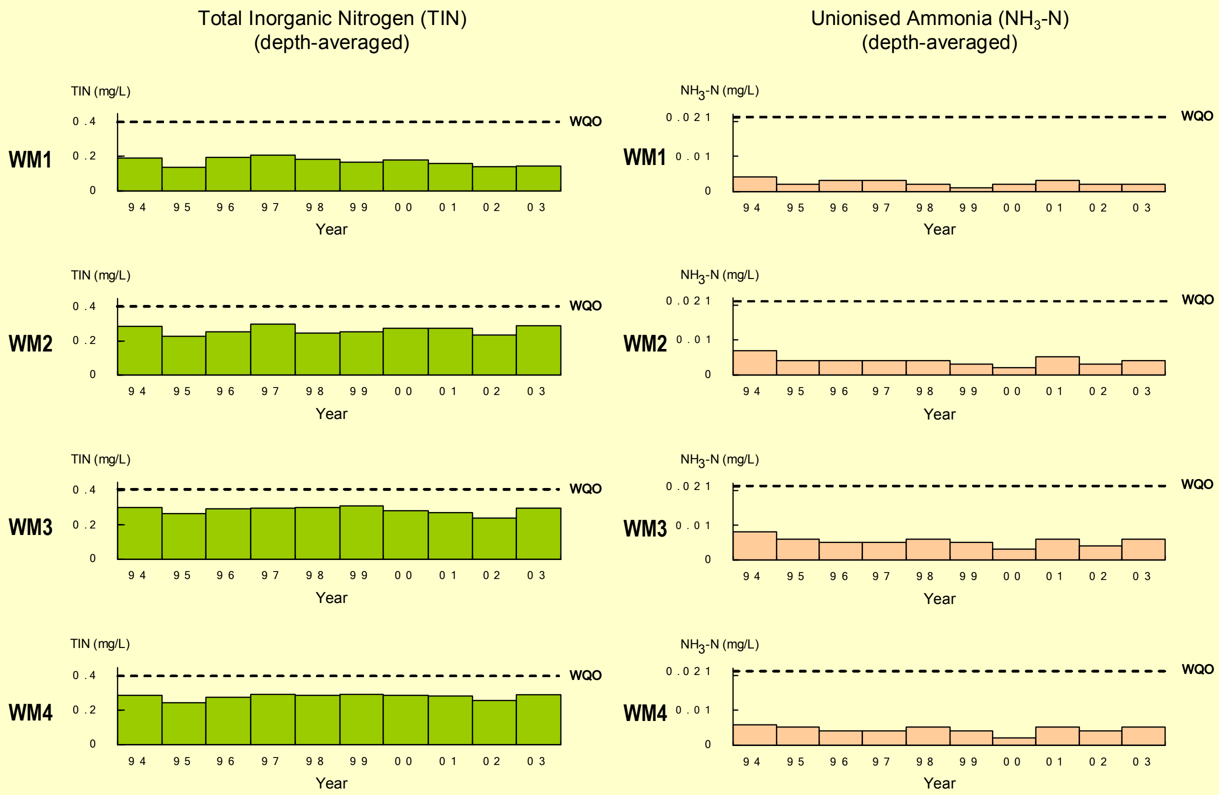
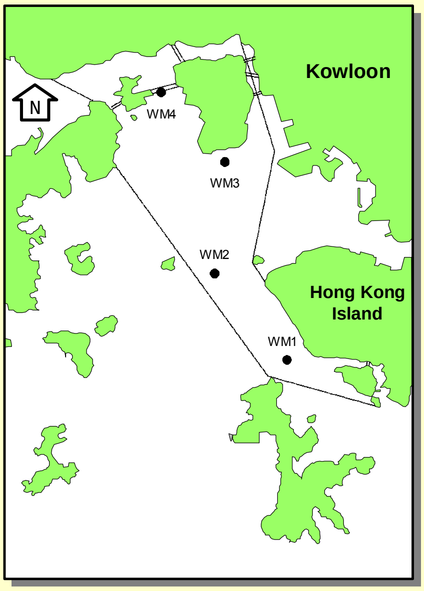


Figure 9.1 (continued) Level of compliance with key Water Quality Objectives in the Western Buffer WCZ





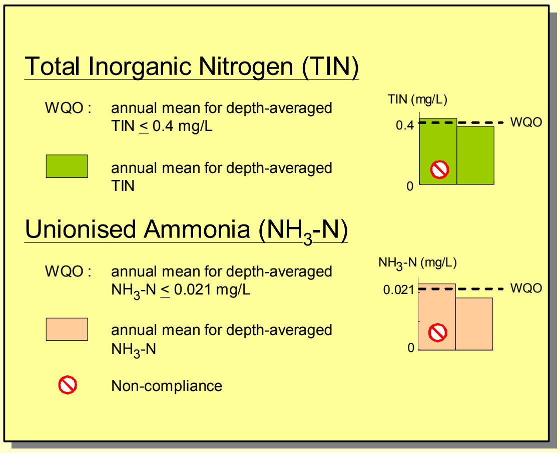


Figure 9.2 Levels of *E. coli* at WM2, WM3 and WM4, 1986 – 2003

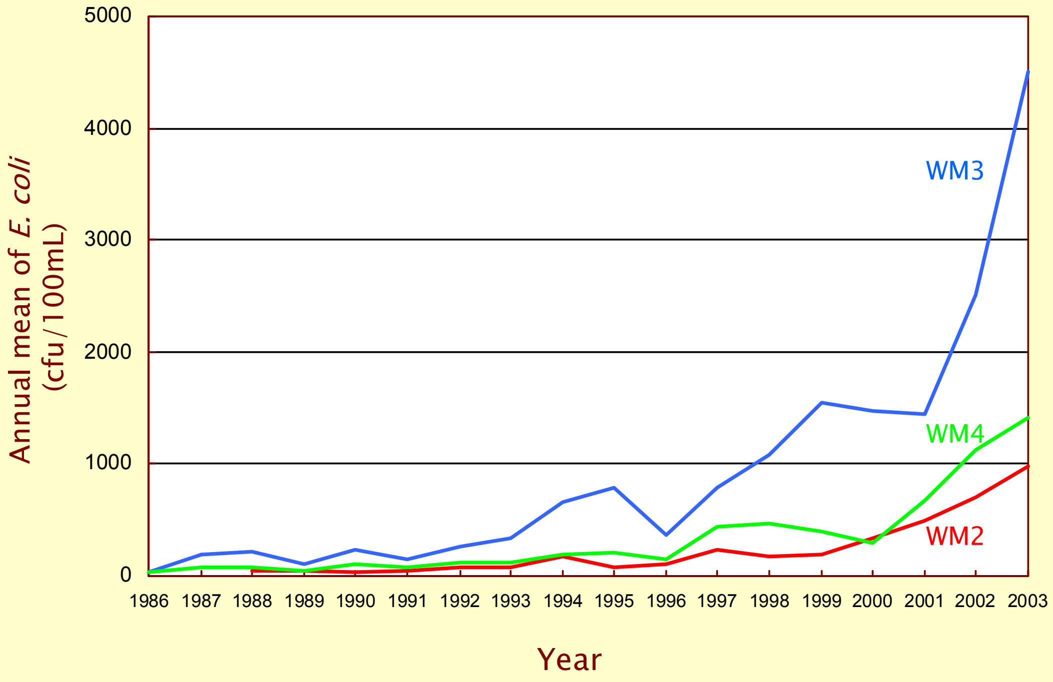


Table 9.1

Summary water quality statistics of the Western Buffer WCZ in 2003

Parameter		Hong Kong Island (West) WM1	Hong Kong Island (West) WM2	Tsing Yi (South) WM3	Tsing Yi (West) WM4
Number of samples		**12**	**12**	**12**	**12**
Temperature (°C)		23.3 (17.3 - 26.9)	23.6 (17.5 - 28.0)	23.5 (17.3 - 27.8)	23.5 (17.4 - 28.0)
Salinity		32.6 (29.2 - 33.8)	31.1 (23.7 - 33.5)	31.6 (26.6 - 33.5)	31.4 (27.6 - 33.5)
Dissolved Oxygen (mg/L)		5.6 (3.7 - 7.5)	5.5 (4.2 - 7.1)	5.4 (3.7 - 7.0)	5.2 (3.1 - 6.9)
	Bottom	5.1 (1.7 - 7.4)	5.2 (2.4 - 7.1)	5.0 (2.0 - 7.4)	4.9 (1.9 - 7.0)
Dissolved Oxygen (% Saturation)		78 (53 - 95)	77 (60 - 91)	75 (54 - 89)	73 (45 - 88)
	Bottom	71 (26 - 94)	73 (34 - 91)	70 (30 - 93)	69 (29 - 88)
pH		8.1 (7.9 - 8.3)	8.1 (7.9 - 8.3)	8.1 (7.9 - 8.3)	8.1 (7.9 - 8.3)
Secchi Disc Depth (m)		2.7 (2.0 - 3.7)	2.2 (1.0 - 3.9)	2.2 (1.6 - 2.8)	2.2 (1.4 - 4.1)
Turbidity (NTU)		10.0 (7.3 - 14.8)	9.7 (5.7 - 14.7)	11.6 (5.7 - 25.3)	11.9 (6.6 - 19.2)
Suspended Solids (mg/L)		6.7 (2.3 - 9.9)	6.5 (2.2 - 12.8)	8.0 (2.6 - 14.5)	9.6 (2.7 - 18.5)
5-day Biochemical Oxygen Demand (mg/L)		0.8 (0.4 - 1.2)	0.9 (0.4 - 1.5)	0.9 (0.5 - 1.4)	0.7 (0.4 - 1.0)
Ammonia Nitrogen (mg/L)		0.04 (0.01 - 0.08)	0.08 (0.03 - 0.15)	0.12 (0.04 - 0.21)	0.10 (0.01 - 0.23)
Unionised Ammonia (mg/L)		0.002 (<0.001 - 0.003)	0.004 (0.002 - 0.009)	0.006 (0.002 - 0.009)	0.005 (<0.001 - 0.008)
Nitrite Nitrogen (mg/L)		0.02 (<0.01 - 0.05)	0.04 (<0.01 - 0.14)	0.04 (<0.01 - 0.10)	0.04 (<0.01 - 0.11)
Nitrate Nitrogen (mg/L)		0.09 (0.01 - 0.32)	0.16 (0.01 - 0.59)	0.14 (0.02 - 0.44)	0.16 (0.02 - 0.40)
Total Inorganic Nitrogen (mg/L)		0.14 (0.03 - 0.39)	0.29 (0.10 - 0.77)	0.30 (0.11 - 0.60)	0.29 (0.13 - 0.50)
Total Kjeldahl Nitrogen (mg/L)		0.13 (0.07 - 0.19)	0.20 (0.15 - 0.27)	0.24 (0.18 - 0.33)	0.21 (0.15 - 0.31)
Total Nitrogen (mg/L)		0.24 (0.09 - 0.52)	0.41 (0.17 - 0.93)	0.41 (0.20 - 0.76)	0.40 (0.19 - 0.64)
Orthophosphate Phosphorus (mg/L)		0.012 (0.01 - 0.02)	0.019 (0.01 - 0.03)	0.023 (0.01 - 0.03)	0.022 (0.02 - 0.03)
Total Phosphorus (mg/L)		0.03 (0.02 - 0.03)	0.04 (0.02 - 0.05)	0.04 (0.03 - 0.06)	0.04 (0.03 - 0.06)
Silica (as SiO_2) (mg/L)		0.8 (0.4 - 1.9)	1.1 (0.4 - 3.2)	1.0 (0.4 - 2.8)	1.1 (0.5 - 2.7)
Chlorophyll-*a* (µg/L)		2.8 (0.7 - 10.7)	3.4 (0.7 - 12.5)	2.9 (0.6 - 10.9)	2.6 (0.4 - 8.9)
E. coli (cfu/100mL)		84 (36 - 440)	970 (110 - 9000)	4500 (1400 - 14000)	1400 (200 - 7700)
Faecal Coliforms (cfu/100mL)		160 (65 - 800)	1700 (160 - 16000)	10000 (2600 - 31000)	2900 (420 - 17000)

Note :
1. Unless otherwise specified, data presented are depth-averaged (A) values calculated by taking the means of three depths: Surface (S), Mid-depth (M), Bottom (B).
2. Data presented are annual arithmetic means of the depth-averaged results except for *E. coli* and faecal coliforms which are annual geometric means.
3. Data in brackets indicate the ranges.

Table 9.2

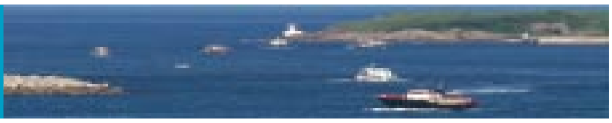
Results of the Seasonal Kendall Test for trends in water quality parameters measured in the Western Buffer WCZ, 1986 – 2003

Monitoring Station / Monitoring Period		WM1 1988 – 2003	WM2 1988 – 2003	WM3 1986 – 2003	WM4 1986 – 2003
Parameter	Water Depth				
Temperature (°C)	Surface	↗	↗	↗	↗
	Middle	↗	↗	↗	↗
	Bottom	↗	↗	↗	↗
	Average	↗	↗	↗	↗
Salinity	Surface	-	-	-	-
	Middle	-	-	-	-
	Bottom	-	-	-	-
	Average	-	-	-	-
Dissolved Oxygen (mg/L)	Surface	-	↘	-	-
	Middle	-	-	-	-
	Bottom	-	-	-	-
	Average	-	↘	-	-
Dissolved Oxygen (%)	Surface	-	-	-	-
	Middle	-	-	-	-
	Bottom	-	-	-	-
	Average	-	-	-	-
pH	Surface	-	-	-	-
	Middle	-	↘	-	-
	Bottom	-	↘	-	-
	Average	-	↘	-	-
Secchi disc depth (m)		-	-	-	-
Turbidity (NTU)	Surface	↗	↗	↗	-
	Middle	↗	-	-	-
	Bottom	↗	↗	↗	↗
	Average	↗	-	-	-
Suspended Solids (mg/L)	Surface	-	-	-	-
	Middle	-	-	-	-
	Bottom	↗	-	-	-
	Average	↗	-	-	-
Total volatile solids (mg/L)	Surface	-	-	↘	-
	Middle	-	-	-	-
	Bottom	-	-	-	-
	Average	-	-	-	-
5-day Biochemical Oxygen Demand (mg/L)	Surface	-	-	-	-
	Middle	-	-	-	-
	Bottom	-	-	-	-
	Average	-	-	-	-
Ammonia nitrogen (mg/L)	Surface	-	-	-	-
	Middle	-	-	-	-
	Bottom	↘	-	-	-
	Average	-	-	-	-
Nitrite nitrogen (mg/L)	Surface	-	↗	-	-
	Middle	-	-	-	-
	Bottom	-	-	-	-
	Average	-	-	-	-
Nitrate nitrogen (mg/L)	Surface	-	-	↗	↗
	Middle	-	-	-	↗
	Bottom	-	-	-	-
	Average	-	-	↗	↗
Total inorganic nitrogen (mg/L)	Surface	-	↗	↗	↗
	Middle	-	-	-	-
	Bottom	-	-	-	-
	Average	-	-	-	↗
Total Kjeldahl nitrogen (mg/L)	Surface	↘	↘	-	↘
	Middle	↘	-	-	-
	Bottom	↘	↘	↘	↘
	Average	↘	↘	↘	↘
Total nitrogen (mg/L)	Surface	-	-	-	-
	Middle	↘	-	-	-
	Bottom	↘	-	↘	-
	Average	↘	-	-	-
Orthophosphate phosphorus (mg/L)	Surface	-	-	-	-
	Middle	-	-	-	-
	Bottom	-	-	-	-
	Average	-	-	-	-
Total phosphorus (mg/L)	Surface	↘	-	-	-
	Middle	↘	-	-	-
	Bottom	-	-	↘	-
	Average	↘	-	-	-
Silica (mg/L)	Surface	-	-	-	-
	Middle	-	-	-	-
	Bottom	-	-	-	-
	Average	-	-	-	-
Chlorophyll-*a* (μg/L)	Surface	↗	↗	↗	↗
	Middle	-	-	↗	-
	Bottom	↗	↗	-	-
	Average	↗	↗	-	-
E. coli (cfu/100mL)	Surface	-	↗	↗	↗
	Middle	-	↗	↗	↗
	Bottom	↘	↗	↗	↗
	Average	-	↗	↗	↗
Faecal coliforms (cfu/100mL)	Surface	-	↗	↗	↗
	Middle	-	↗	↗	↗
	Bottom	-	↗	↗	↗
	Average	-	↗	↗	↗

Note
1. Results of the Seasonal Kendall Test shown are statistically significant at $p < 0.05$
2. - indicates no significant trend is detected
3. Test applied to past 18 years' data from each monitoring station unless stated otherwise
4. ↗ represents a significant increase over time
5. ↘ represents a significant decrease over time

CHAPTER 10

EASTERN BUFFER WATER CONTROL ZONE



Chapter 10 – Eastern Buffer Water Control Zone

Water Quality in 2003

10.1 The Eastern Buffer Water Control Zone (WCZ) is situated east of the Victoria Harbour WCZ covering Lei Yue Mun and Tathong Channel. There is a general descend of major pollutants (such as *E. coli*, ammonia nitrogen (NH_4-N), total inorganic nitrogen (TIN) and total phosphorus) from north to south of the WCZ (i.e. from EM1 to EM3). Due to the influence of oceanic inflow, the water quality in the southern end of the WCZ was better with lower bacterial and nutrient levels. A summary of the 2003 water quality data for the Eastern Buffer WCZ is shown in Table 10.1.

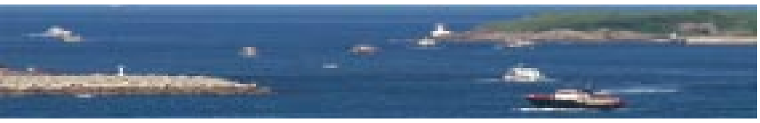
10.2 Since 2002, the major pollution discharges from the Tseung Kwan O and Chai Wan Outfalls have been diverted to the Stonecutters Island Sewage Treatment Works following the commissioning of the Harbour Area Treatment Scheme (HATS) Stage I, the Eastern Buffer WCZ has experienced a very substantial improvement in water quality e.g. notable decreases in *E. coli* and nutrients (nitrogen and phosphorus). In 2003, the improvement was sustained and the concentrations of pollutants, such as *E. coli,* NH_4-N, TIN and total phosphorus showed further reductions.

10.3 In 2003, the mean *E. coli* and ammonia nitrogen (NH_4-N) levels in the Eastern Buffer WCZ were 35 cfu/100mL and 0.042 mg/L respectively. These, together with other nutrient parameters e.g. total inorganic nitrogen (TIN), total nitrogen and total phosphorus, have reached their lowest levels since the mid-80s.

10.4 Like in other marine waters in Hong Kong, there has been a general decrease of dissolved oxygen (DO) concentrations in the Eastern Buffer WCZ in 2003. The depth-averaged and the bottom DO have decreased by 0.5mg/L (8%) and 0.8mg/L (12%) respectively, within the range of natural fluctuations.

Compliance with Water Quality Objectives

10.5 As in previous years, the Eastern Buffer WCZ has fully achieved compliance with the Water Quality Objectives for dissolved oxygen, total inorganic nitrogen and unionised ammonia in 2003 (Figure 10.1).



Long-term Water Quality Trends

10.6 Up until 2001, there have been significant long-term deteriorating water quality trends (i.e. increases in *E. coli*, NH_4-N, TIN and decrease in DO) in the Eastern Buffer WCZ. With the commissioning of HATS Stage I in 2002, these trends were halted. In 2003, improving trends (e.g. decreases in nitrogen and phosphorous) started to appear (Table 10.2). The reduction of sewage-related bacteria and ammonia nitrogen in the last few years was evident at all sampling stations (Figure 10.2).

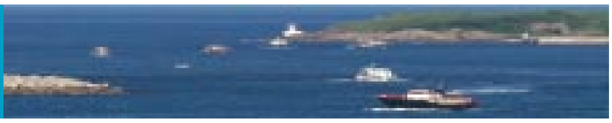
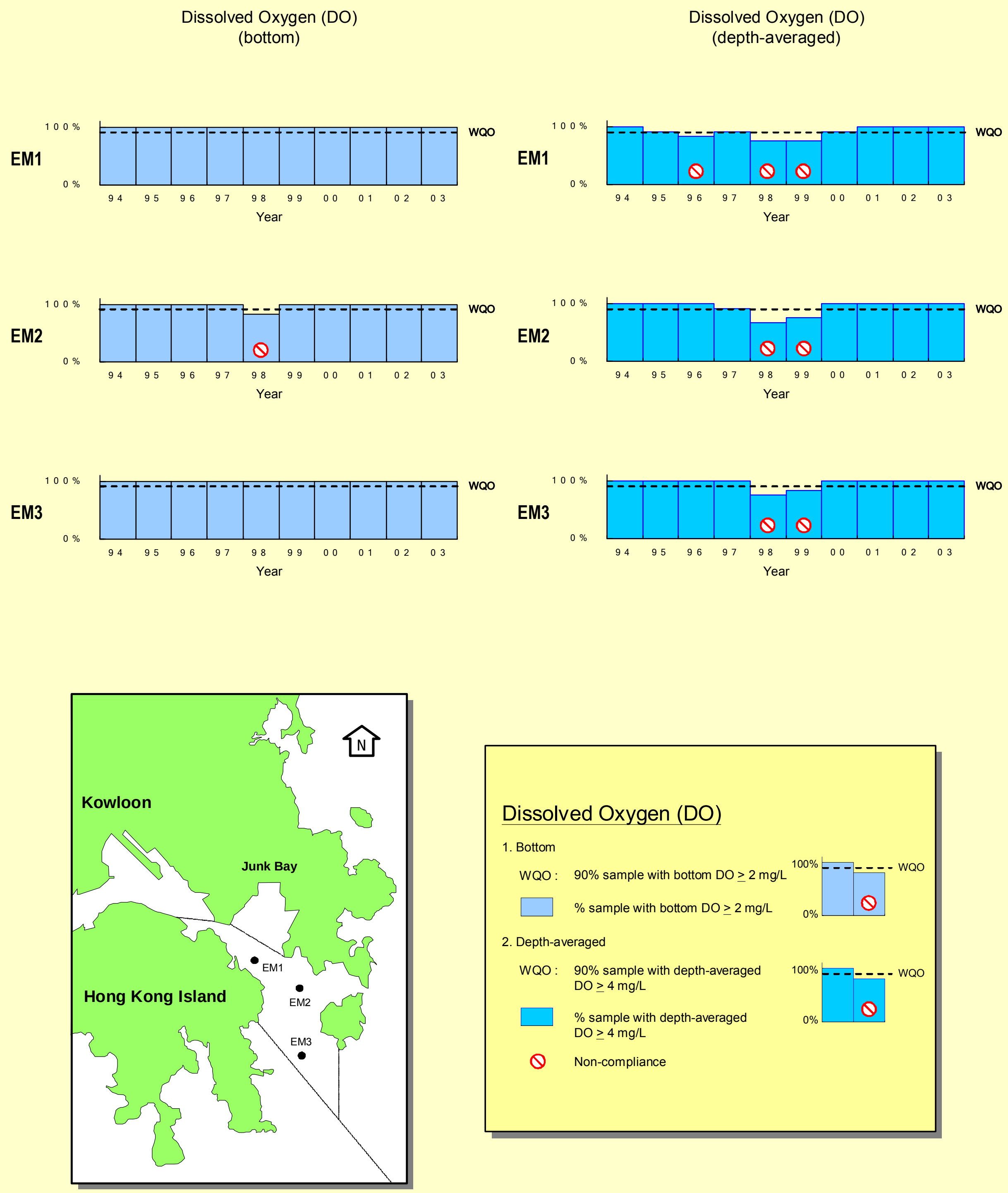


Figure 10.1 Level of compliance with key Water Quality Objectives in the Eastern Buffer WCZ



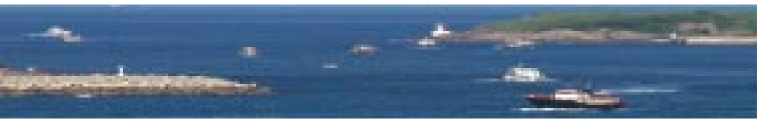
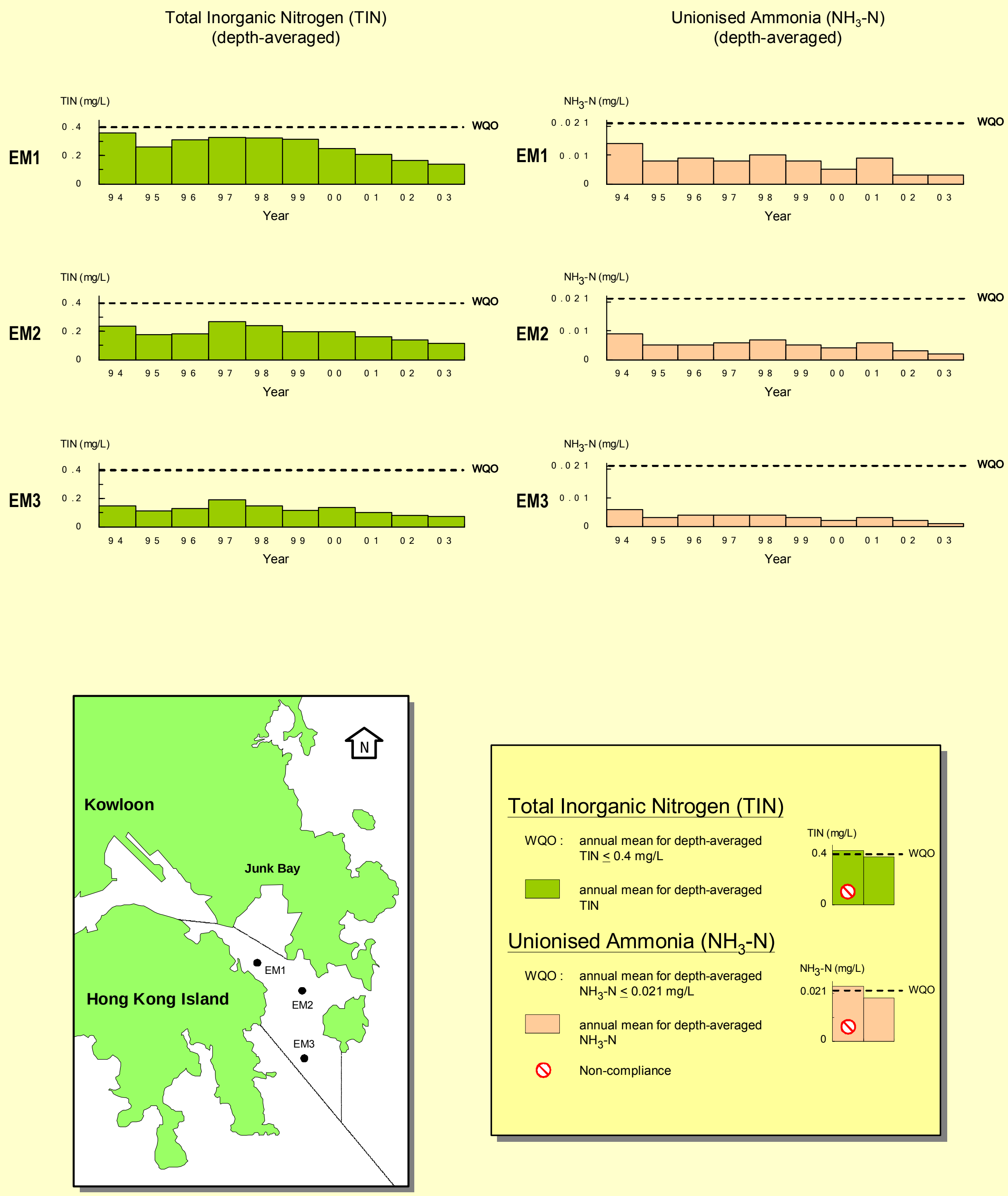


Figure 10.1 (continued) Level of compliance with key Water Quality Objectives in the Eastern Buffer WCZ



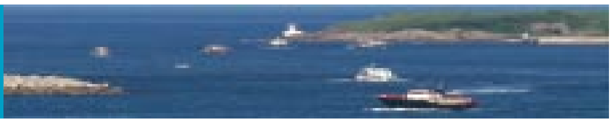
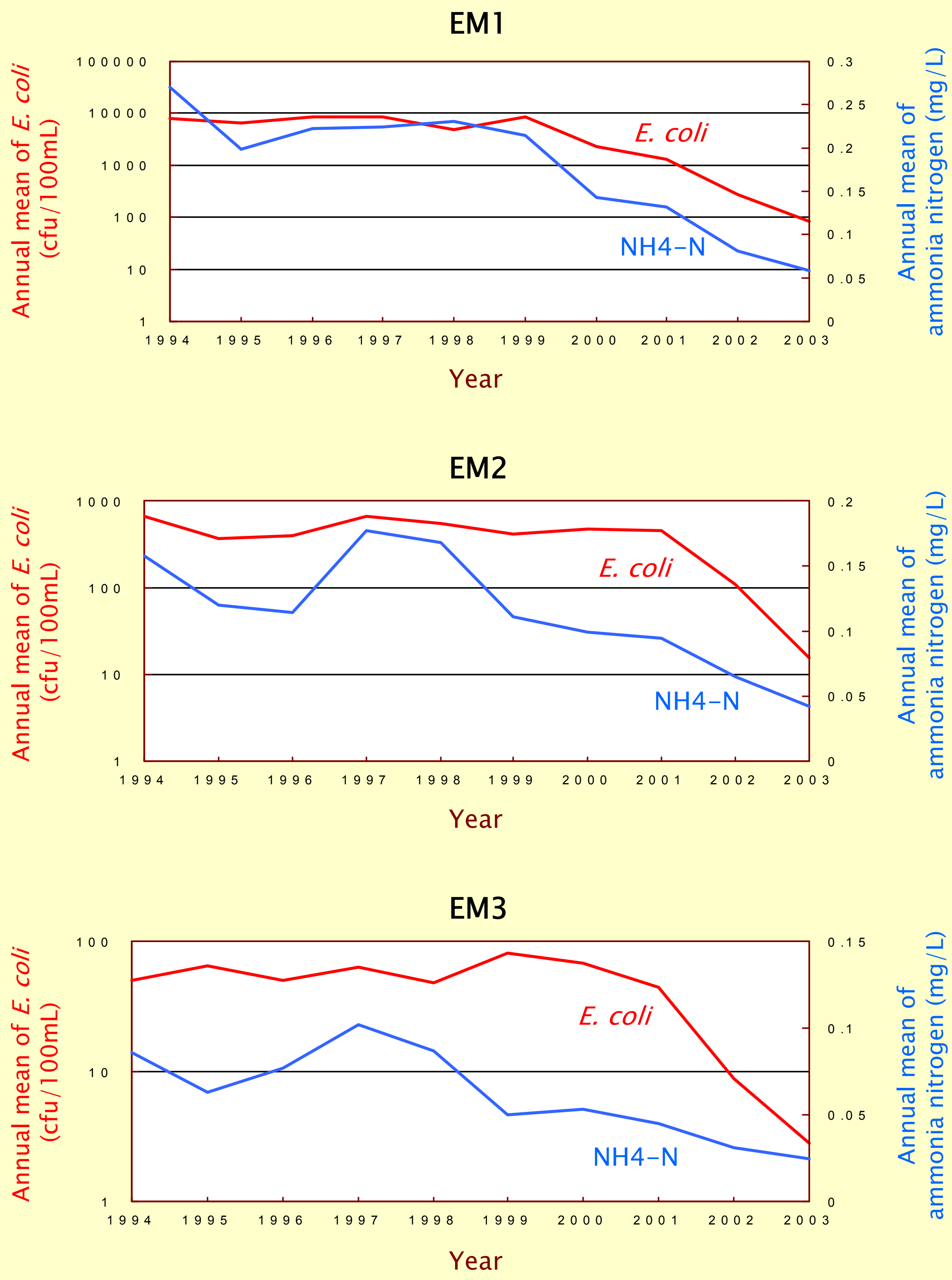


Figure 10.2 Levels of ammonia nitrogen and *E. coli* at EM1, EM2 and EM3, 1994 – 2003



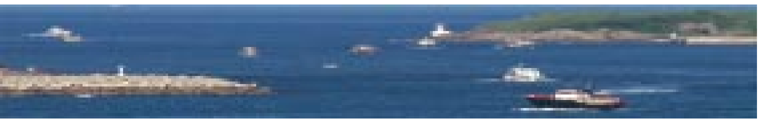


Table 10.1

Summary water quality statistics of the Eastern Buffer WCZ in 2003

Parameter		Chai Wan EM1	Tathong Channel EM2	Tathong Channel EM3
Number of samples		12	12	12
Temperature (°C)		23.0 (17.1 - 26.8)	22.9 (16.9 - 26.9)	22.9 (16.9 - 27.0)
Salinity		32.9 (31.2 - 33.8)	33.0 (30.4 - 34.2)	33.3 (32.3 - 34.3)
Dissolved Oxygen (mg/L)		5.9 (4.5 - 8.2)	5.9 (4.0 - 8.2)	6.0 (4.1 - 7.7)
	Bottom	5.5 (3.2 - 8.3)	5.6 (3.0 - 8.3)	5.7 (3.4 - 7.8)
Dissolved Oxygen (% Saturation)		83 (67 - 103)	83 (59 - 104)	83 (59 - 97)
	Bottom	77 (45 - 106)	78 (43 - 105)	79 (48 - 99)
pH		8.1 (7.9 - 8.3)	8.2 (7.9 - 8.3)	8.2 (7.9 - 8.3)
Secchi Disc Depth (m)		2.9 (1.5 - 4.5)	2.7 (1.3 - 5.0)	3.1 (1.5 - 5.8)
Turbidity (NTU)		7.4 (4.4 - 10.6)	7.5 (3.9 - 10.0)	10.6 (5.4 - 37.5)
Suspended Solids (mg/L)		3.9 (1.3 - 7.1)	3.6 (0.9 - 5.6)	4.0 (1.1 - 8.7)
5-day Biochemical Oxygen Demand (mg/L)		0.9 (0.3 - 1.4)	0.7 (0.3 - 1.2)	0.8 (0.3 - 1.3)
Ammonia Nitrogen (mg/L)		0.06 (0.01 - 0.16)	0.04 (0.01 - 0.09)	0.02 (0.01 - 0.07)
Unionised Ammonia (mg/L)		0.003 (<0.001 - 0.006)	0.002 (<0.001 - 0.005)	0.001 (<0.001 - 0.003)
Nitrite Nitrogen (mg/L)		0.03 (<0.01 - 0.12)	0.02 (<0.01 - 0.08)	0.02 (<0.01 - 0.05)
Nitrate Nitrogen (mg/L)		0.05 (0.01 - 0.16)	0.06 (0.01 - 0.25)	0.03 (0.01 - 0.12)
Total Inorganic Nitrogen (mg/L)		0.14 (0.04 - 0.33)	0.12 (0.03 - 0.36)	0.07 (0.02 - 0.19)
Total Kjeldahl Nitrogen (mg/L)		0.17 (0.11 - 0.25)	0.14 (0.09 - 0.21)	0.12 (0.08 - 0.16)
Total Nitrogen (mg/L)		0.25 (0.13 - 0.43)	0.22 (0.11 - 0.51)	0.17 (0.10 - 0.33)
Orthophosphate Phosphorus (mg/L)		0.016 (0.01 - 0.03)	0.013 (0.01 - 0.02)	0.010 (<0.01 - 0.01)
Total Phosphorus (mg/L)		0.03 (0.02 - 0.04)	0.03 (0.02 - 0.04)	0.02 (0.02 - 0.04)
Silica (as SiO_2) (mg/L)		0.6 (0.2 - 1.1)	0.7 (0.3 - 1.7)	0.6 (0.3 - 1.0)
Chlorophyll-a (µg/L)		3.2 (0.6 - 8.5)	2.6 (0.5 - 10.9)	2.9 (0.6 - 9.4)
E. coli (cfu/100mL)		86 (11 - 1300)	16 (1 - 510)	3 (1 - 13)
Faecal Coliforms (cfu/100mL)		200 (22 - 2900)	38 (3 - 1200)	7 (1 - 46)

Note :
1. Unless otherwise specified, data presented are depth-averaged (A) values calculated by taking the means of three depths: Surface (S), Mid-depth (M), Bottom (B).
2. Data presented are annual arithmetic means of the depth-averaged results except for *E. coli* and faecal coliforms which are annual geometric means.
3. Data in brackets indicate the ranges.

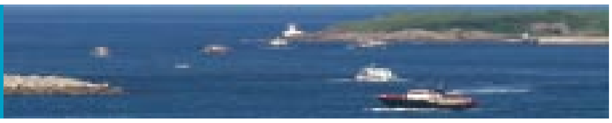


Table 10.2

Results of the Seasonal Kendall Test for trends in water quality parameters measured in the Eastern Buffer WCZ, 1986 – 2003

Monitoring Station		EM1	EM2	EM3
Monitoring Period		1986 – 2003	1986 – 2003	1986 – 2003
Parameter	Water Depth			
Temperature (°C)	Surface	↗	↗	↗
	Middle	↗	↗	↗
	Bottom	↗	↗	↗
	Average	↗	↗	↗
Salinity	Surface	-	-	-
	Middle	-	-	-
	Bottom	-	-	-
	Average	-	-	-
Dissolved Oxygen (mg/L)	Surface	-	-	↘
	Middle	-	-	-
	Bottom	-	-	-
	Average	-	-	-
Dissolved Oxygen (%)	Surface	-	-	-
	Middle	-	-	-
	Bottom	-	-	-
	Average	-	-	-
pH	Surface	-	-	-
	Middle	-	-	-
	Bottom	-	-	-
	Average	-	-	-
Secchi disc depth (m)		-	-	-
Turbidity (NTU)	Surface	↗	↗	↗
	Middle	↗	↗	↗
	Bottom	↗	↗	↗
	Average	↗	↗	↗
Suspended Solids (mg/L)	Surface	-	-	-
	Middle	-	-	-
	Bottom	-	-	-
	Average	-	-	-
Total volatile solids (mg/L)	Surface	↘	↘	↘
	Middle	↘	↘	↘
	Bottom	↘	↘	-
	Average	↘	↘	↘
5-day Biochemical Oxygen Demand (mg/L)	Surface	-	-	-
	Middle	-	-	-
	Bottom	-	-	-
	Average	-	-	-
Ammonia nitrogen (mg/L)	Surface	-	-	-
	Middle	-	-	-
	Bottom	-	-	-
	Average	-	-	-
Nitrite nitrogen (mg/L)	Surface	-	-	-
	Middle	-	-	-
	Bottom	↘	-	-
	Average	-	↘	-
Nitrate nitrogen (mg/L)	Surface	-	-	-
	Middle	-	-	-
	Bottom	-	-	-
	Average	-	-	-
Total inorganic nitrogen (mg/L)	Surface	-	-	-
	Middle	-	-	-
	Bottom	-	-	-
	Average	-	-	-
Total Kjeldahl nitrogen (mg/L)	Surface	-	-	-
	Middle	-	-	↘
	Bottom	-	↘	↘
	Average	-	↘	↘
Total nitrogen (mg/L)	Surface	-	-	-
	Middle	-	-	-
	Bottom	-	-	↘
	Average	-	-	↘
Orthophosphate phosphorus (mg/L)	Surface	-	-	-
	Middle	-	-	-
	Bottom	-	-	-
	Average	-	-	-
Total phosphorus (mg/L)	Surface	-	-	-
	Middle	-	-	-
	Bottom	-	-	↘
	Average	-	-	↘
Silica (mg/L)	Surface	-	-	-
	Middle	-	-	-
	Bottom	-	-	-
	Average	-	-	-
Chlorophyll-*a* (µg/L)	Surface	-	-	-
	Middle	-	-	-
	Bottom	-	-	-
	Average	-	-	-
E. coli (cfu/100mL)	Surface	-	-	-
	Middle	-	-	-
	Bottom	-	-	-
	Average	-	-	-
Faecal coliforms (cfu/100mL)	Surface	-	-	-
	Middle	-	-	-
	Bottom	-	-	-
	Average	-	-	-

Note 1. Results of the Seasonal Kendall Test shown are statistically significant at $p < 0.05$
2. - indicates no significant trend is detected
3. ↗ represents a significant increase over time
4. ↘ represents a significant decrease over time

CHAPTER 11

VICTORIA HARBOUR WATER CONTROL ZONE

Chapter 11 – Victoria Harbour Water Control Zone

Water Quality in 2003

11.1 Victoria Harbour is a major tidal channel with strong current flushing and has long been utilised for disposal of sewage effluent. In the past, wastewater was discharged into the harbour after simple screening process. To improve the water quality of the harbour, the Stonecutters Island Sewage Treatment Works (SCISTW) under the Harbour Area Treatment Scheme (HATS) Stage I was commissioned in 2002. It received wastewater from Kowloon and eastern part of Hong Kong Island for Chemically Enhanced Primary Treatment and disposal into the Western Harbour area. In 2003, the effluent flow from the SCISTW has slightly increased from 1.3 million m^3/day to 1.4 million m^3/day which accounted for 75% of the total sewage flow of HATS (Figure 1.8). A summary of the 2003 water quality data is shown in Tables 11.1.

11.2 In 2002, the implementation of HATS Stage I has resulted in a very substantial water quality improvement at the eastern end of the harbour (VM1 and VM2) and moderate improvement in the mid harbour stations (VM4 and VM5) and northern part of Rambler Channel (VM14). These improvements were generally sustained in 2003.

11.3 The level of *E. coli* in the Victoria Harbour Water Control Zone (WCZ) in 2003 was largely comparable to that in 2002. The pattern of bacterial distribution was also similar; the zone of peak *E. coli* concentration shifted from the central part of the harbour (VM1, 2, 4 and 5) to the western side (VM5, 6, 7, 8 and 12).

11.4 The general decrease of ammonia nitrogen (NH_4-N) as a result of HATS Stage I was also observed in 2003. Similar to 2002, higher levels of NH_4-N (0.14–0.23 mg/L), compared with those in other areas (e.g. 0.09-0.16mg/L at VM1, 2 and 4), were found in the western part of the harbour near Stonecutters Island (i.e. VM 6, 7, 8, 12 and 15). The depth-averaged and bottom DO at various monitoring stations ranged 5.1-5.6 mg/L and 4.8-5.4 mg/L respectively and no bottom layer hypoxia (i.e. DO<2 mg/L) was observed.

11.5 In 2003, the level of orthophosphate phosphorus (PO_4-P) in Victoria Harbour showed a significant increase of 39-86% at nearly all stations in the WCZ. However, no marked increase in algal activity (chlorophyll-*a*) was observed during the year.

11.6 The monitoring data also showed a general decline in suspended solids (SS) in 2003, in particular at the station VM12 in the southern end of Rambler Channel which was heavily impacted by the Container 9 reclamation works in 2002. The decrease of SS at VM12 was 45% as compared to 3-27% in other parts of the WCZ.

Compliance with Water Quality Objectives

11.7 In 2003, all the monitoring stations in the Victoria Harbour WCZ fully complied (100%) with the WQOs for DO and unionized ammonia (Figure 11.1). The compliance for the TIN WQO was 80%. Two stations (VM7 and VM14) which failed to comply with the WQO were located in the western part of the harbour.

Long-term Water Quality Trends

11.8 The long-term water quality changes (1986-2003) in the Victoria Harbour WCZ are summarised in Table 11.2. The increasing trends in *E. coli* at the eastern harbour stations (VM1 and VM2) were arrested in 2002 immediately after the implementation of HATS Stage I. In 2003, the increasing trends formerly observed at the mid harbour stations (VM4 and VM6) also ceased.

11.9 A significant decline in Kjeldahl nitrogen was found at eight of the ten stations in Victoria Harbour. This was probably related to a reduction in organic nitrogen as the ammonia nitrogen level remained relatively stable in the last 18 years (1986-2003). On the other hand, there was a rise in nitrate nitrogen (NO_3-N) at six stations (VM5-8, 12 and 14) (Table 11.2) in the western and central parts of the harbour, possibly related to the influence of Pearl River flow. Decreasing trend in suspended solids was found at the station VM2 (Figure 11.2) which may be related to the diversion of sewage from the East Kowloon to the west under HATS Stage I.

11.10 Signs of water quality improvement: increase in DO, decreases in nutrients (i.e. nitrogen and phosphorus) and organic pollutants (i.e. 5-day Biochemical Oxygen Demand) were found at VM14, in the northern part of Rambler Channel in the past 18 years (Figure 11.2).

11.11 A significant long-term increase in water temperature was detected at most stations in Victoria Harbour (Table 11.2 and Figure 11.2). This may be related to factors such as surface run off and increases in discharges of spent cooling water from the air conditioning systems in the harbour area.

11.12 As part of the HATS development, various studies and trials were conducted to help identify long-term sewage options for Victoria Harbour and these were near completion at the end of 2003. The findings would be put forward for consultation in 2004, and subject to outcome of the consultation, an option would be selected for future implementation. More details on these studies and trials can be found on the Government's Cleanharbour website (http://www.cleanharbour.gov.hk).

Figure 11.1 Level of compliance with key Water Quality Objectives in the Victoria Harbour WCZ

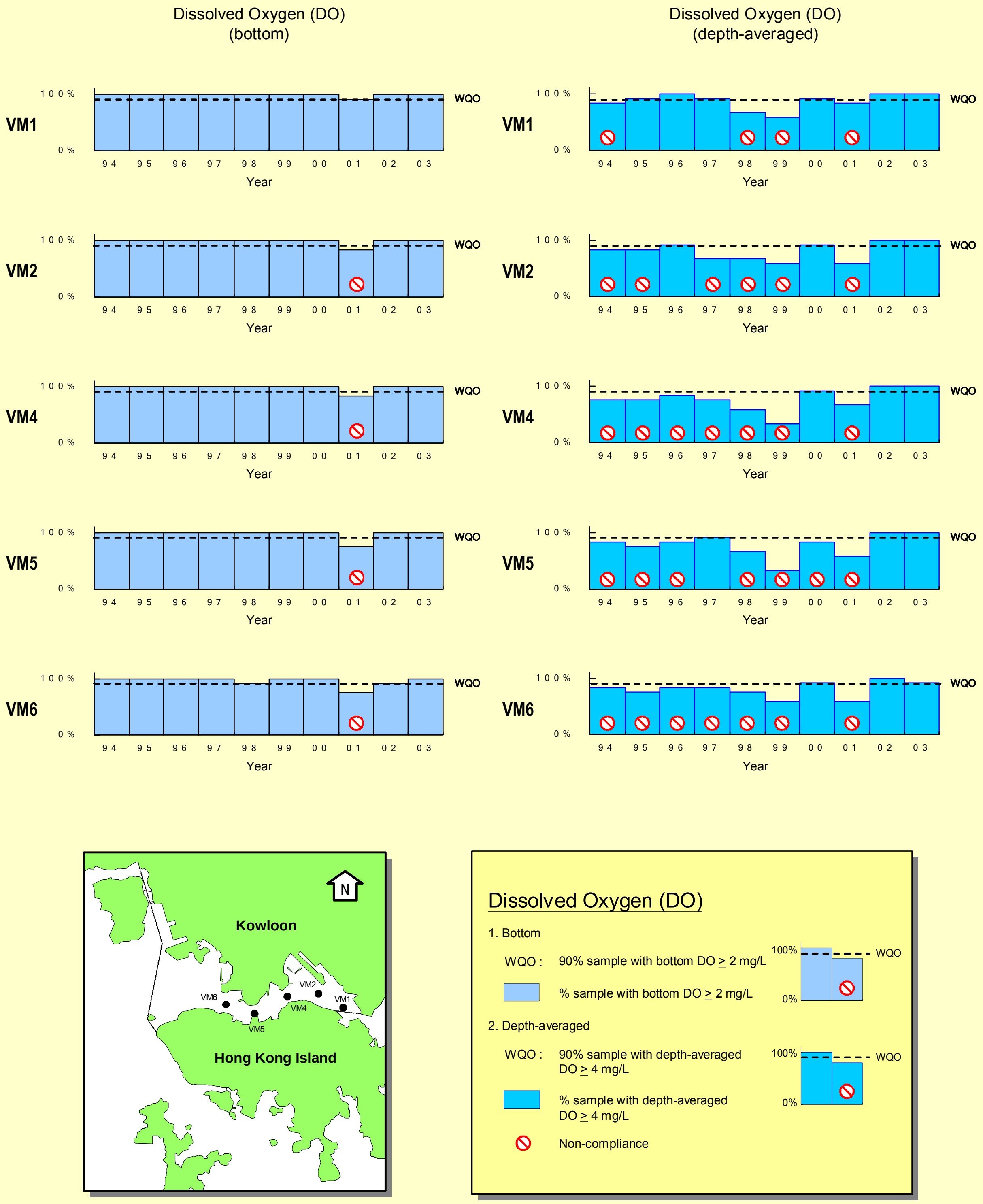


Figure 11.1 (continued) Level of compliance with key Water Quality Objectives in the Victoria Harbour WCZ

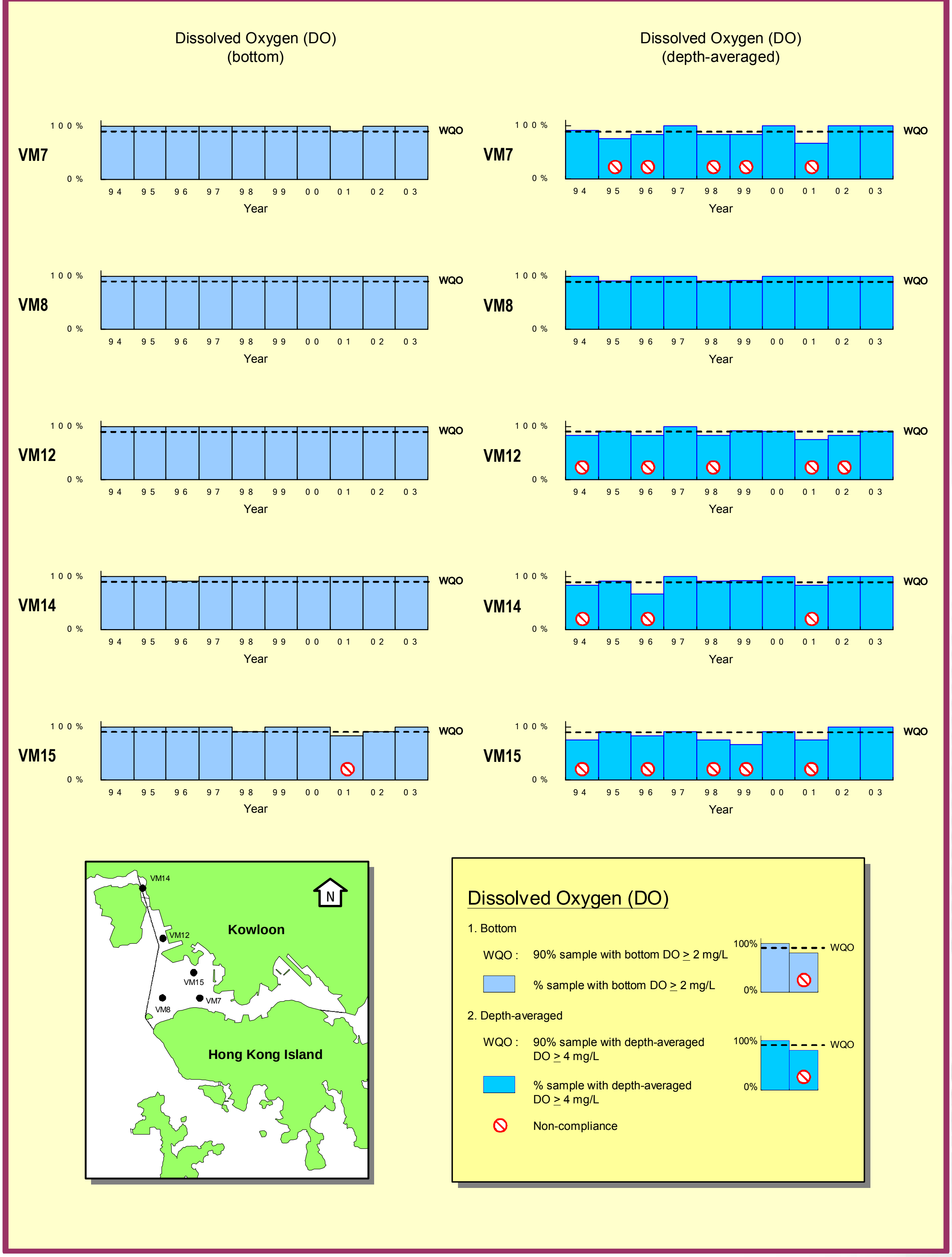


Figure 11.1 (continued) Level of compliance with key Water Quality Objectives in the Victoria Harbour WCZ

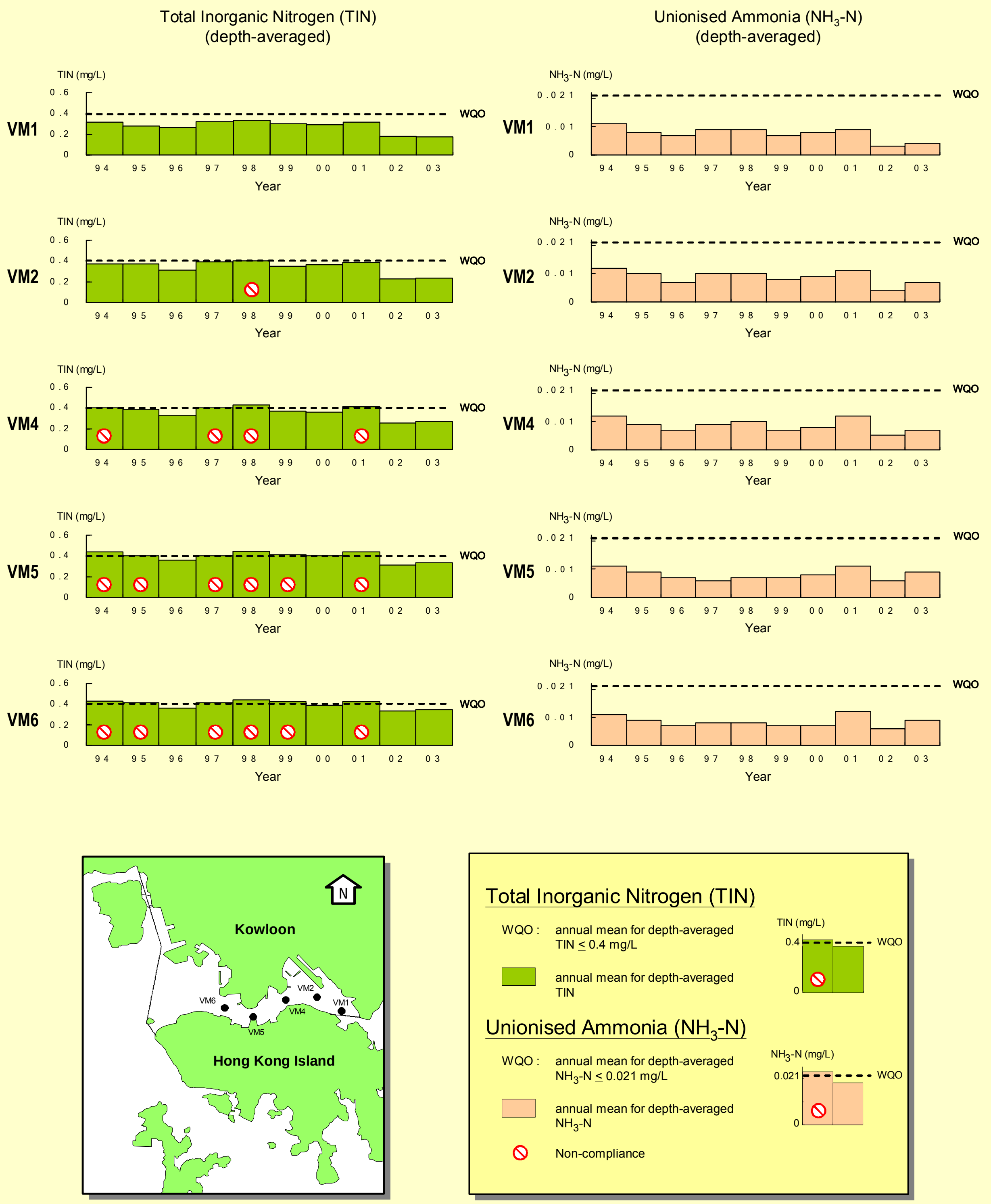


Figure 11.1 (continued) Level of compliance with key Water Quality Objectives in the Victoria Harbour WCZ

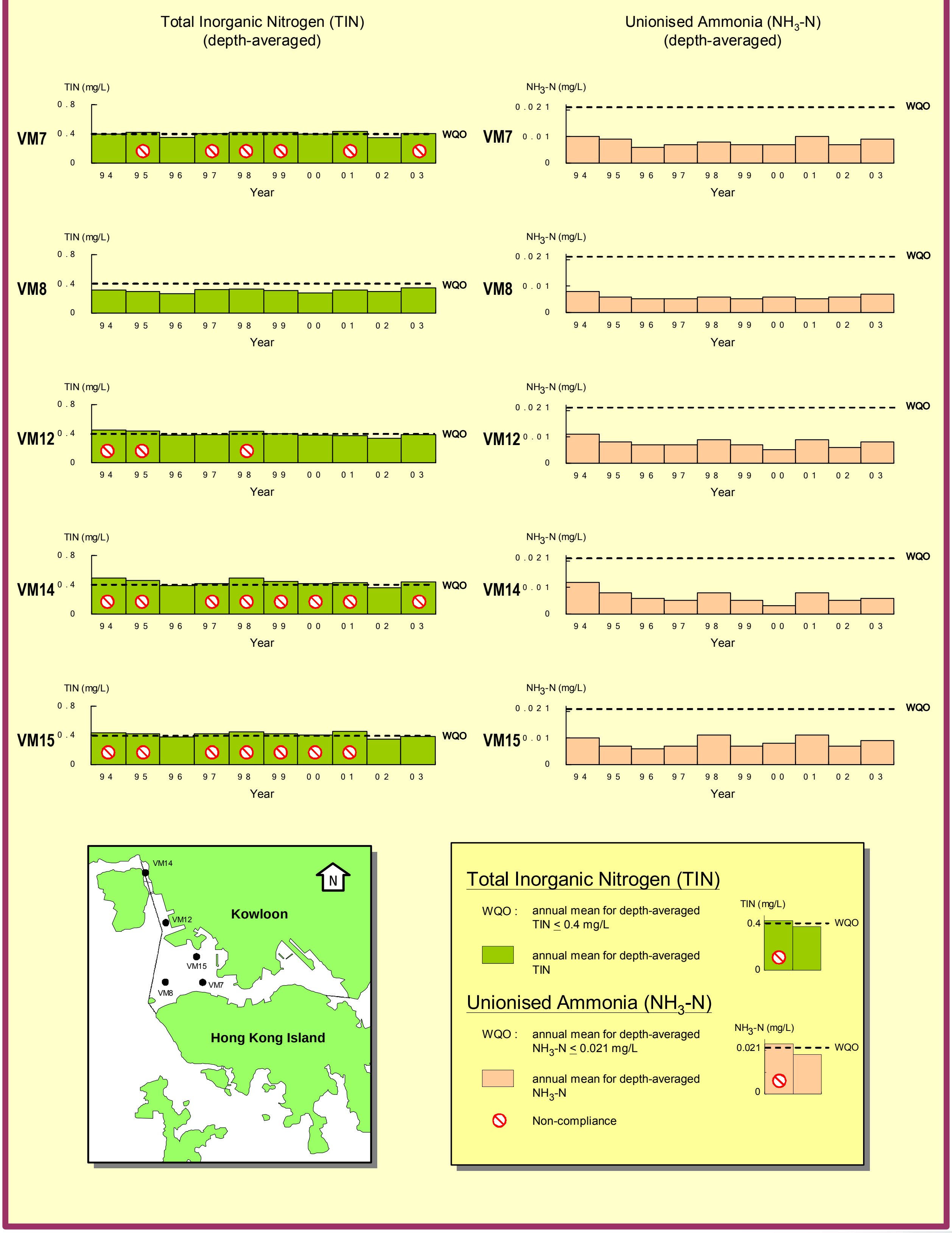


Figure 11.2 Marine water quality trends in the Victoria Harbour WCZ (based on the Seasonal Kendall Test significant at $p<0.05$)

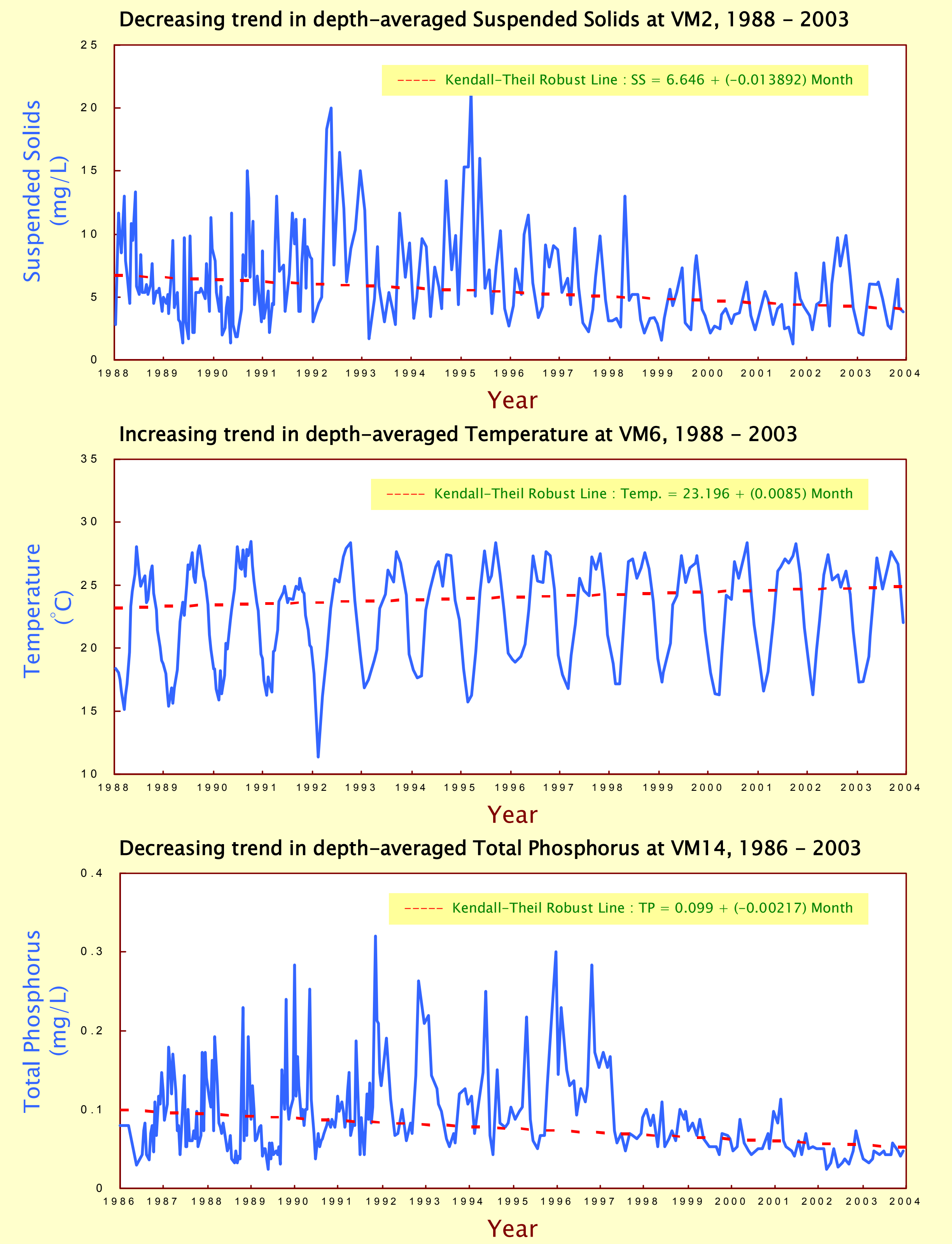


Table 11.1

Summary water quality statistics of the Victoria Harbour WCZ in 2003

Parameter	Victoria Harbour (East) VM1	Victoria Harbour (East) VM2	Victoria Harbour (Central) VM4	Victoria Harbour (Central) VM5	Victoria Harbour (Central) VM6
Number of samples	12	12	12	12	12
Temperature (°C)	23.0 (17.0 - 26.6)	23.2 (16.9 - 27.1)	23.3 (17.0 - 27.2)	23.4 (17.1 - 27.5)	23.5 (17.3 - 27.6)
Salinity	33.0 (32.5 - 33.6)	32.6 (31.6 - 33.7)	32.4 (31.0 - 33.5)	32.1 (29.4 - 33.4)	32.0 (29.8 - 33.3)
Dissolved Oxygen (mg/L)	5.5 (4.3 - 7.5)	5.5 (4.1 - 7.4)	5.4 (4.2 - 6.8)	5.3 (4.1 - 6.9)	5.3 (3.9 - 6.7)
Bottom	5.4 (3.1 - 7.6)	5.3 (3.9 - 7.4)	5.4 (3.6 - 7.2)	5.0 (3.7 - 6.9)	4.9 (3.1 - 6.7)
Dissolved Oxygen (% Saturation)	77 (63 - 95)	78 (61 - 93)	76 (61 - 85)	75 (61 - 88)	74 (58 - 85)
Bottom	75 (46 - 95)	74 (54 - 93)	75 (51 - 90)	71 (53 - 88)	69 (44 - 85)
pH	8.1 (8.0 - 8.3)	8.1 (8.0 - 8.3)	8.1 (8.0 - 8.2)	8.1 (8.0 - 8.2)	8.0 (7.9 - 8.2)
Secchi Disc Depth (m)	2.8 (1.7 - 3.9)	2.5 (1.5 - 3.5)	2.3 (1.5 - 3.2)	2.3 (1.5 - 4.1)	2.3 (1.5 - 4.0)
Turbidity (NTU)	8.7 (5.9 - 11.8)	8.1 (5.4 - 10.8)	8.5 (6.3 - 13.1)	8.6 (5.4 - 11.0)	8.8 (5.4 - 12.2)
Suspended Solids (mg/L)	5.2 (2.3 - 9.2)	4.3 (1.9 - 6.4)	4.9 (2.5 - 11.3)	4.7 (2.5 - 7.5)	5.1 (2.4 - 9.8)
5-day Biochemical Oxygen Demand (mg/L)	0.9 (0.4 - 1.6)	1.1 (0.5 - 1.8)	1.1 (0.6 - 1.8)	1.4 (0.7 - 2.2)	1.1 (0.5 - 2.0)
Ammonia Nitrogen (mg/L)	0.09 (0.02 - 0.22)	0.13 (0.04 - 0.26)	0.16 (0.05 - 0.28)	0.20 (0.07 - 0.34)	0.20 (0.09 - 0.34)
Unionised Ammonia (mg/L)	0.004 (0.002 - 0.008)	0.007 (0.002 - 0.012)	0.007 (0.003 - 0.014)	0.009 (0.005 - 0.014)	0.009 (0.005 - 0.015)
Nitrite Nitrogen (mg/L)	0.02 (<0.01 - 0.05)	0.02 (<0.01 - 0.05)	0.02 (0.01 - 0.05)	0.03 (0.01 - 0.05)	0.03 (0.01 - 0.05)
Nitrate Nitrogen (mg/L)	0.06 (0.02 - 0.11)	0.08 (0.02 - 0.14)	0.09 (0.03 - 0.15)	0.11 (0.04 - 0.21)	0.11 (0.04 - 0.19)
Total Inorganic Nitrogen (mg/L)	0.18 (0.11 - 0.31)	0.24 (0.11 - 0.38)	0.27 (0.18 - 0.42)	0.33 (0.22 - 0.50)	0.34 (0.25 - 0.50)
Total Kjeldahl Nitrogen (mg/L)	0.22 (0.17 - 0.32)	0.29 (0.17 - 0.42)	0.32 (0.23 - 0.47)	0.39 (0.29 - 0.51)	0.38 (0.30 - 0.48)
Total Nitrogen (mg/L)	0.30 (0.20 - 0.45)	0.39 (0.19 - 0.57)	0.44 (0.28 - 0.61)	0.52 (0.33 - 0.65)	0.52 (0.35 - 0.64)
Orthophosphate Phosphorus (mg/L)	0.021 (0.01 - 0.04)	0.027 (0.02 - 0.05)	0.030 (0.02 - 0.05)	0.036 (0.02 - 0.05)	0.037 (0.02 - 0.05)
Total Phosphorus (mg/L)	0.04 (0.02 - 0.06)	0.04 (0.02 - 0.06)	0.05 (0.03 - 0.07)	0.06 (0.03 - 0.08)	0.06 (0.04 - 0.07)
Silica (as SiO_2) (mg/L)	0.7 (0.4 - 1.1)	0.7 (0.2 - 1.2)	0.7 (0.1 - 1.2)	0.8 (0.3 - 1.4)	0.9 (0.2 - 1.4)
Chlorophyll-*a* (μg/L)	2.9 (0.4 - 12.5)	4.0 (0.2 - 19.0)	3.9 (0.4 - 18.2)	4.0 (0.3 - 22.7)	3.5 (0.4 - 16.7)
E. coli (cfu/100mL)	200 (48 - 2400)	1100 (130 - 6600)	2700 (580 - 23000)	5200 (640 - 42000)	3000 (250 - 14000)
Faecal Coliforms (cfu/100mL)	390 (70 - 3800)	2100 (160 - 13000)	4800 (1100 - 42000)	12000 (2500 - 100000)	7000 (1100 - 26000)

Note : 1. Unless otherwise specified, data presented are depth-averaged (A) values calculated by taking the means of three depths: Surface (S), Mid-depth (M), Bottom (B).
2. Data presented are annual arithmetic means of the depth-averaged results except for *E. coli* and faecal coliforms which are annual geometric means.

Table 11.1 (continued)

Summary water quality statistics of the Victoria Harbour WCZ in 2003

Parameter		Victoria Harbour (West)		Stonecutters Island	Rambler Channel	
		VM7	VM8	VM15	VM12	VM14
Number of samples		12	12	12	12	12
Temperature (°C)		23.5 (17.2 - 27.8)	23.5 (17.2 - 27.8)	23.7 (17.3 - 27.7)	23.6 (17.5 - 28.0)	24.0 (17.6 - 28.3)
Salinity		31.0 (21.7 - 33.3)	31.1 (24.0 - 33.4)	31.7 (28.3 - 33.2)	31.1 (25.3 - 33.3)	29.3 (15.4 - 33.3)
Dissolved Oxygen (mg/L)		5.4 (4.1 - 6.9)	5.6 (4.3 - 6.8)	5.5 (4.2 - 6.6)	5.1 (3.8 - 6.3)	5.5 (4.6 - 6.5)
	Bottom	5.1 (3.8 - 6.8)	5.3 (2.1 - 7.0)	5.1 (3.6 - 6.6)	4.8 (2.2 - 6.4)	5.2 (3.3 - 6.6)
Dissolved Oxygen (% Saturation)		76 (62 - 91)	79 (61 - 90)	78 (63 - 88)	71 (54 - 86)	78 (69 - 85)
	Bottom	72 (55 - 91)	74 (31 - 93)	72 (51 - 84)	67 (32 - 87)	73 (47 - 87)
pH		8.1 (7.9 - 8.2)	8.1 (8.0 - 8.2)	8.0 (7.9 - 8.2)	8.1 (7.8 - 8.2)	8.1 (7.9 - 8.3)
Secchi Disc Depth (m)		2.1 (1.3 - 3.2)	2.1 (1.4 - 3.7)	2.1 (1.4 - 4.5)	2.0 (1.2 - 3.5)	1.9 (0.9 - 3.9)
Turbidity (NTU)		8.9 (4.7 - 14.2)	9.9 (5.0 - 14.9)	9.3 (3.8 - 13.1)	11.6 (5.8 - 15.9)	11.4 (5.4 - 20.7)
Suspended Solids (mg/L)		5.8 (2.8 - 13.3)	7.9 (3.1 - 14.6)	6.3 (2.9 - 9.9)	10.5 (4.8 - 16.2)	7.1 (3.4 - 10.0)
5-day Biochemical Oxygen Demand (mg/L)		1.2 (0.6 - 2.4)	1.0 (0.4 - 1.9)	1.1 (0.5 - 1.9)	0.8 (0.7 - 1.1)	0.9 (0.6 - 1.3)
Ammonia Nitrogen (mg/L)		0.21 (0.11 - 0.31)	0.14 (0.03 - 0.26)	0.23 (0.07 - 0.34)	0.17 (0.04 - 0.29)	0.14 (0.03 - 0.27)
Unionised Ammonia (mg/L)		0.009 (0.005 - 0.016)	0.007 (0.002 - 0.016)	0.009 (0.005 - 0.016)	0.008 (0.002 - 0.013)	0.006 (0.002 - 0.010)
Nitrite Nitrogen (mg/L)		0.04 (0.01 - 0.14)	0.04 (0.01 - 0.12)	0.03 (0.01 - 0.06)	0.04 (0.01 - 0.12)	0.06 (0.01 - 0.18)
Nitrate Nitrogen (mg/L)		0.16 (0.05 - 0.58)	0.16 (0.03 - 0.49)	0.12 (0.05 - 0.24)	0.17 (0.03 - 0.53)	0.25 (0.03 - 0.83)
Total Inorganic Nitrogen (mg/L)		0.40 (0.28 - 0.93)	0.34 (0.21 - 0.75)	0.38 (0.30 - 0.49)	0.39 (0.25 - 0.68)	0.44 (0.20 - 1.04)
Total Kjeldahl Nitrogen (mg/L)		0.39 (0.31 - 0.50)	0.30 (0.20 - 0.41)	0.41 (0.34 - 0.56)	0.31 (0.20 - 0.40)	0.28 (0.23 - 0.35)
Total Nitrogen (mg/L)		0.58 (0.44 - 1.15)	0.49 (0.32 - 0.93)	0.57 (0.46 - 0.63)	0.53 (0.35 - 0.84)	0.58 (0.31 - 1.27)
Orthophosphate Phosphorus (mg/L)		0.037 (0.02 - 0.05)	0.027 (0.01 - 0.04)	0.037 (0.02 - 0.05)	0.032 (0.02 - 0.04)	0.029 (0.02 - 0.04)
Total Phosphorus (mg/L)		0.06 (0.04 - 0.08)	0.04 (0.03 - 0.07)	0.06 (0.04 - 0.07)	0.05 (0.04 - 0.06)	0.04 (0.03 - 0.06)
Silica (as SiO_2) (mg/L)		1.0 (0.5 - 3.2)	1.1 (0.5 - 2.9)	0.9 (0.2 - 1.4)	1.2 (0.5 - 3.1)	1.5 (0.5 - 4.7)
Chlorophyll-a (µg/L)		3.3 (0.3 - 15.6)	3.4 (0.5 - 16.7)	4.7 (0.4 - 24.9)	2.4 (0.3 - 7.8)	3.9 (0.4 - 15.0)
E. coli (cfu/100mL)		5900 (500 - 22000)	3700 (390 - 22000)	1700 (220 - 14000)	5400 (2400 - 14000)	1700 (470 - 12000)
Faecal Coliforms (cfu/100mL)		14000 (1200 - 60000)	7600 (660 - 37000)	4500 (780 - 37000)	12000 (4600 - 33000)	3400 (770 - 25000)

Note : 1. Unless otherwise specified, data presented are depth-averaged (A) values calculated by taking the means of three depths: Surface (S), Mid-depth (M), Bottom (B).
2. Data presented are annual arithmetic means of the depth-averaged results except for *E. coli* and faecal coliforms which are annual geometric means.

Table 11.2
Results of the Seasonal Kendall Test for trends in water quality parameters measured in the Victoria Harbour WCZ, 1986 - 2003

Monitoring Station		VM1	VM2	VM4	VM5	VM6
Monitoring Period		1988 – 2003	1988 – 2003	1988 – 2003	1986 – 2003	1988 – 2003
Parameter	Water Depth					
Temperature (°C)	Surface	↗	↗	↗	↗	↗
	Middle	↗	↗	↗	↗	↗
	Bottom	↗	↗	↗	↗	↗
	Average	↗	↗	↗	↗	↗
Salinity	Surface	-	-	-	-	-
	Middle	-	-	-	-	-
	Bottom	-	-	-	-	-
	Average	-	-	-	-	-
Dissolved Oxygen (mg/L)	Surface	-	-	-	-	-
	Middle	-	-	-	↗	↗
	Bottom	-	-	-	-	↗
	Average	-	-	-	-	-
Dissolved Oxygen (%)	Surface	-	-	-	-	-
	Middle	↗	-	↗	↗	↗
	Bottom	↗	↗	↗	↗	↗
	Average	↗	-	↗	↗	↗
pH	Surface	-	-	-	-	↘
	Middle	-	↘	-	-	↘
	Bottom	-	-	-	-	↘
	Average	-	-	-	-	↘
Secchi disc depth (m)		↗	↗	↗	↗	↗
Turbidity (NTU)	Surface	-	-	-	↗	↗
	Middle	↗	-	-	↗	↗
	Bottom	↗	-	-	↗	↗
	Average	↗	-	-	↗	↗
Suspended Solids (mg/L)	Surface	↘	↘	-	-	-
	Middle	-	↘	-	-	-
	Bottom	-	↘	-	-	-
	Average	-	↘	↘	-	-
Total volatile solids (mg/L)	Surface	↘	↘	↘	↘	↘
	Middle	↘	↘	↘	↘	↘
	Bottom	↘	↘	↘	↘	↘
	Average	↘	↘	↘	↘	↘
5-day Biochemical Oxygen Demand (mg/L)	Surface	-	-	-	-	-
	Middle	-	-	-	-	-
	Bottom	-	-	-	-	-
	Average	-	-	-	-	-
Ammonia nitrogen (mg/L)	Surface	-	-	-	-	-
	Middle	-	-	-	-	-
	Bottom	↘	-	-	-	-
	Average	-	-	-	-	-
Nitrite nitrogen (mg/L)	Surface	-	-	-	-	-
	Middle	-	-	-	-	-
	Bottom	-	-	-	-	-
	Average	-	-	-	-	-
Nitrate nitrogen (mg/L)	Surface	-	-	-	↗	↗
	Middle	-	-	-	↗	↗
	Bottom	-	-	-	↗	-
	Average	-	-	-	↗	↗
Total inorganic nitrogen (mg/L)	Surface	-	-	-	-	-
	Middle	-	-	-	-	-
	Bottom	↘	-	-	-	-
	Average	-	-	-	-	-
Total Kjeldahl nitrogen (mg/L)	Surface	↘	↘	↘	↘	↘
	Middle	↘	↘	↘	-	↘
	Bottom	↘	↘	↘	-	↘
	Average	↘	↘	↘	-	↘
Total nitrogen (mg/L)	Surface	↘	↘	↘	-	-
	Middle	↘	↘	↘	-	↘
	Bottom	↘	-	↘	-	↘
	Average	↘	↘	↘	-	↘
Orthophosphate phosphorus (mg/L)	Surface	-	-	-	-	-
	Middle	-	-	-	-	-
	Bottom	↘	-	-	-	-
	Average	-	-	-	-	-
Total phosphorus (mg/L)	Surface	↘	↘	↘	-	-
	Middle	-	↘	-	-	-
	Bottom	↘	-	-	-	-
	Average	↘	↘	-	-	-
Silica (mg/L)	Surface	-	-	-	-	-
	Middle	-	-	-	-	-
	Bottom	-	-	-	-	-
	Average	-	-	-	-	-
Chlorophyll-*a* (µg/L)	Surface	-	-	-	-	-
	Middle	-	-	-	-	-
	Bottom	-	-	-	-	-
	Average	-	-	-	-	-
E. coli (cfu/100mL)	Surface	-	-	-	↗	-
	Middle	-	-	-	↗	-
	Bottom	-	-	-	↗	-
	Average	-	-	-	↗	-
Faecal coliforms (cfu/100mL)	Surface	-	-	-	↗	-
	Middle	-	-	↗	↗	↗
	Bottom	-	-	↗	↗	↗
	Average	-	-	↗	↗	↗

Note 1. Results of the Seasonal Kendall Test shown are statistically significant at $p < 0.05$
2. - indicates no significant trend is detected
3. Test applied to past 18 years' data from each monitoring station unless stated otherwise
4. ↗ represents a significant increase over time
5. ↘ represents a significant decrease over time

Table 11.2 (continued)

Results of the Seasonal Kendall Test for trends in water quality parameters measured in the Victoria Harbour WCZ, 1986 - 2003

Monitoring Station		VM7	VM8	VM12	VM14	VM15
Monitoring Period		1986 – 2003	1986 – 2003	1986 – 2003	1986 – 2003	1993 – 2003
Parameter	Water Depth					
Temperature (°C)	Surface	↗	↗	↗	↗	-
	Middle	↗	↗	↗	↗	-
	Bottom	↗	↗	↗	↗	-
	Average	↗	↗	↗	↗	-
Salinity	Surface	-	-	-	-	-
	Middle	-	-	-	-	-
	Bottom	-	-	-	-	-
	Average	-	-	-	-	-
Dissolved Oxygen (mg/L)	Surface	-	-	-	-	-
	Middle	↗	-	↗	↗	-
	Bottom	-	-	-	↗	-
	Average	-	-	-	↗	-
Dissolved Oxygen (%)	Surface	-	-	↗	-	-
	Middle	↗	-	↗	↗	-
	Bottom	↗	-	↗	↗	-
	Average	↗	-	↗	↗	-
pH	Surface	-	↘	-	↘	-
	Middle	-	↘	-	↘	-
	Bottom	-	↘	-	↘	-
	Average	-	↘	-	↘	-
Secchi disc depth (m)		-	-	-	↗	↗
Turbidity (NTU)	Surface	↗	-	-	-	↗
	Middle	-	-	-	-	↗
	Bottom	↗	↗	↗	↗	-
	Average	↗	↗	-	↗	-
Suspended Solids (mg/L)	Surface	-	-	-	-	↘
	Middle	-	-	-	-	↘
	Bottom	-	-	-	-	↘
	Average	-	-	-	-	↘
Total volatile solids (mg/L)	Surface	↘	↘	-	↘	↘
	Middle	↘	↘	-	↘	-
	Bottom	↘	↘	-	↘	↘
	Average	↘	↘	-	↘	↘
5-day Biochemical Oxygen Demand (mg/L)	Surface	-	-	-	↘	-
	Middle	-	-	-	↘	-
	Bottom	-	-	-	↘	-
	Average	-	-	-	↘	-
Ammonia nitrogen (mg/L)	Surface	-	-	↘	↘	-
	Middle	-	-	-	-	-
	Bottom	-	-	-	-	-
	Average	-	-	-	-	-
Nitrite nitrogen (mg/L)	Surface	-	-	-	-	-
	Middle	-	-	-	-	-
	Bottom	-	-	-	-	-
	Average	-	-	-	-	-
Nitrate nitrogen (mg/L)	Surface	↗	↗	↗	↗	-
	Middle	↗	↗	↗	↗	-
	Bottom	↗	-	↗	↗	-
	Average	↗	↗	↗	↗	-
Total inorganic nitrogen (mg/L)	Surface	-	↗	-	-	-
	Middle	-	↗	-	-	-
	Bottom	-	-	-	↗	↘
	Average	-	↗	-	-	-
Total Kjeldahl nitrogen (mg/L)	Surface	↘	-	↘	↘	-
	Middle	↘	-	↘	↘	-
	Bottom	↘	↘	↘	↘	-
	Average	↘	-	↘	↘	↘
Total nitrogen (mg/L)	Surface	-	-	-	↘	-
	Middle	-	-	-	-	↘
	Bottom	-	↘	↘	-	↘
	Average	-	-	↘	↘	↘
Orthophosphate phosphorus (mg/L)	Surface	-	-	↘	↘	↘
	Middle	-	-	-	↘	↘
	Bottom	-	-	-	-	↘
	Average	-	-	↘	↘	↘
Total phosphorus (mg/L)	Surface	-	-	-	↘	↘
	Middle	-	-	-	↘	↘
	Bottom	-	-	-	↘	↘
	Average	-	-	-	↘	↘
Silica (mg/L)	Surface	-	-	-	-	↘
	Middle	-	-	-	-	↘
	Bottom	-	-	-	-	↘
	Average	-	-	-	-	↘
Chlorophyll-*a* (µg/L)	Surface	-	-	-	-	↗
	Middle	-	-	-	-	↗
	Bottom	-	-	-	-	↗
	Average	-	-	-	-	↗
E. coli (cfu/100mL)	Surface	↗	↗	↗	-	-
	Middle	↗	↗	↗	↗	-
	Bottom	↗	↗	↗	↗	-
	Average	↗	↗	↗	-	-
Faecal coliforms (cfu/100mL)	Surface	↗	↗	↗	-	-
	Middle	↗	↗	↗	↗	-
	Bottom	↗	↗	↗	↗	-
	Average	↗	↗	↗	↗	-

Note
1. Results of the Seasonal Kendall Test shown are statistically significant at $p < 0.05$
2. - indicates no significant trend is detected
3. Test applied to past 18 years' data from each monitoring station unless stated otherwise
4. ↗ represents a significant increase over time
5. ↘ represents a significant decrease over time

CHAPTER 12

SEDIMENT QUALITY

Chapter 12 – Sediment

Introduction

12.1 Many inorganic and organic contaminants in the marine water are associated with particulate matters which settle to form part of the sediments on the sea bed. Sediments are often regarded as the ultimate sink for persistent contaminants in the marine environment. Bottom sediments are an important habitat for marine life, including many commercially important food species. Toxic contaminants can accumulate in sediments and may pose a potential threat to marine organisms and human health.

12.2 Sediment monitoring is an integral part of EPD's marine monitoring programme. In 2003, sediments were sampled twice at 45 stations in open waters (Figure 1.3) and 15 stations in typhoons shelters (Figure 1.4). Sediment samples were collected using grab samplers and analysed for over 60 physical and chemical parameters (Table 1.3). A summary of the bottom sediment quality in different Water Control Zones in the last 5 years (1999–2003) is shown in Tables 12.1–12.6.

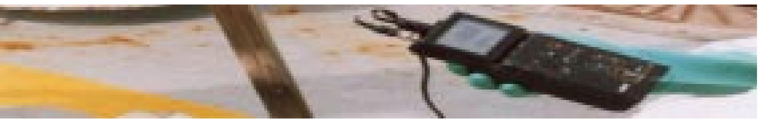
12.3 This report applies the Lower Chemical Exceedance Levels (LCELs) and Upper Chemical Exceedance Levels (UCELs) set out in the '*Environment, Transport and Work Bureau Technical Circular ETWB(W) No. 34/2002 - Management of Dredged / Excavated Sediment*' as a benchmark to assess the extent of contamination of marine sediments in the territory. The LCELs and UCELs cover 12 individual or groups of chemicals found in the sediments (Table 12.7).

Metals and Metalloid

12.4 Figures 12.1 to 12.8 summarise the mean concentrations of eight heavy metals (cadmium, chromium, copper, lead, mercury, nickel, silver and zinc) in marine sediments in 1999-2003. The mean concentrations of arsenic are presented in Figure 12.9.

12.5 In general, sediments in Victoria Harbour (from Junk Bay to Tsuen Wan) had higher levels of heavy metals, especially copper and silver (Figures 12.3 and 12.7). The contamination by copper was mainly due to discharges from printed circuit board, electroplating, metal and textile industries between the 60s and 80s. Elevated concentration of silver in sediments was likely to be related to pollution from electroplating industries, photo-developing business and dental clinics.

12.6 Tsuen Wan Bay (VS10), near the old industrial area, was a "hot-spot" of heavy metal



contamination with copper, nickel and silver all exceeding the UCELs. The levels of lead and zinc in the Tolo Harbour Subzone (TS2 and TS3) were relatively high (above LCELs). On the other hand, arsenic was higher in Deep Bay (DS1-DS4) than the rest of the territory, probably related to the higher natural arsenic levels in the soil of northern New Territories.

Trace Organics

12.7 Trace organic pollutants refer to organic contaminants such as polychlorinated biphenyls (PCBs), polycyclic aromatic hydrocarbons (PAHs) which persist in the environment and generally present at low concentrations. Some of these compounds are bioaccumulative, potentially carcinogenic, mutagenic or teratogenic.

12.8 Overall, the levels of total PCBs in the sediments of Hong Kong were very low and none of the stations exceeded LCEL (Figure 12.10). For most of the sediments sampled (about 95%), all 18 PCB congeners tested were below the reporting limits (<2μg/kg dry weight).

12.9 Similar to total PCBs, the average levels of low and high molecular weight PAHs in the marine sediments of Hong Kong were also very low and quite evenly distributed. All stations, with the exception of VS6 (near Sai Ying Pun), were below the LCELs (Figures 12.11 and 12.12). High molecular weight PAHs, notably Fluoranthene, Pyrene, Benzo(a)pyrene and Benzo(g,h,i)perylene were the dominant congeners found at VS6.

Electrochemical Potential

12.10 The marine sediments in Hong Kong were generally anoxic (i.e. with negative electrochemical potential). Highly anoxic sediments were mainly found in three areas: a) Victoria Harbour WCZ (VS3, VS5 & VS6); b) Double Haven and Crooked Harbour (MS1, MS2 & MS7) in Mirs Bay; and c) Tolo Harbour (TS2 & TS4) (Figure 12.13). The low electrochemical potential in Victoria Harbour was mainly due to organic deposition from sewage discharges which exerted a high oxygen demand on the seabed. Double Haven & Crooked Harbour in Mirs Bay and Tolo Harbour were largely enclosed embayments with fish culture zones (Figure 1.6). The sediments of these waters were subject to organic pollution from fish excreta and excessive fishfeed which contributed to the anoxic condition.

Figure 12.1 Cadmium in marine sediments in Hong Kong, 1999 – 2003

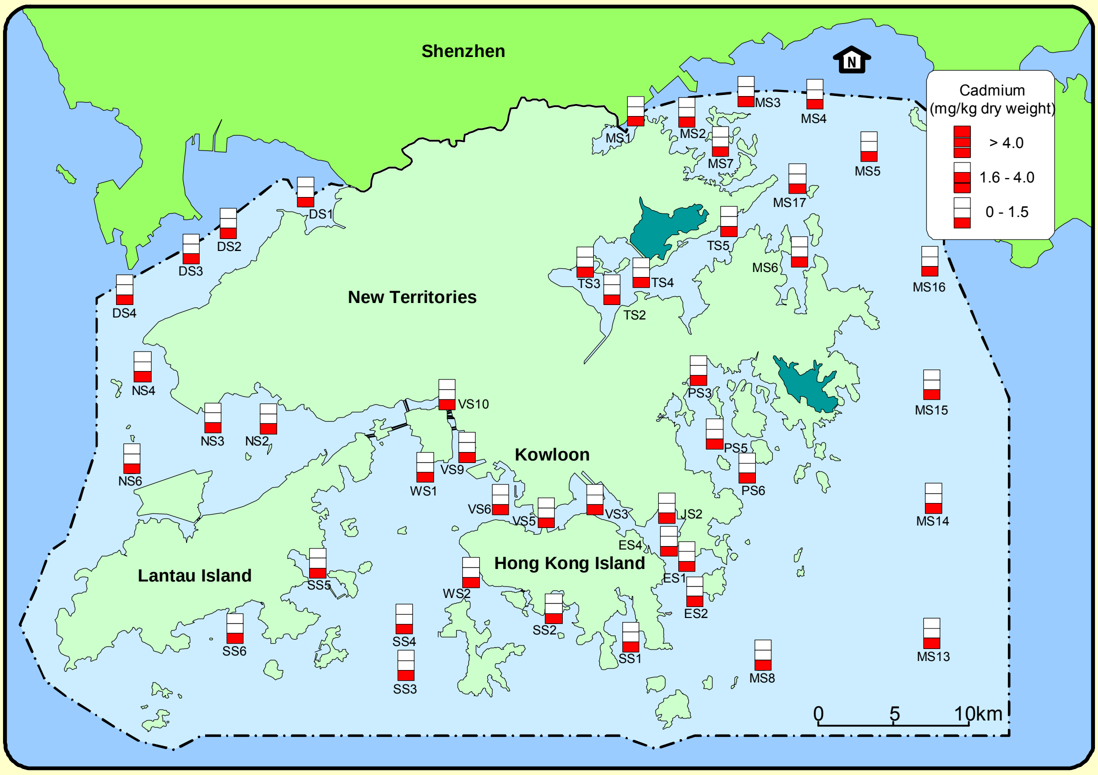


Figure 12.2 Chromium in marine sediments in Hong Kong, 1999 – 2003

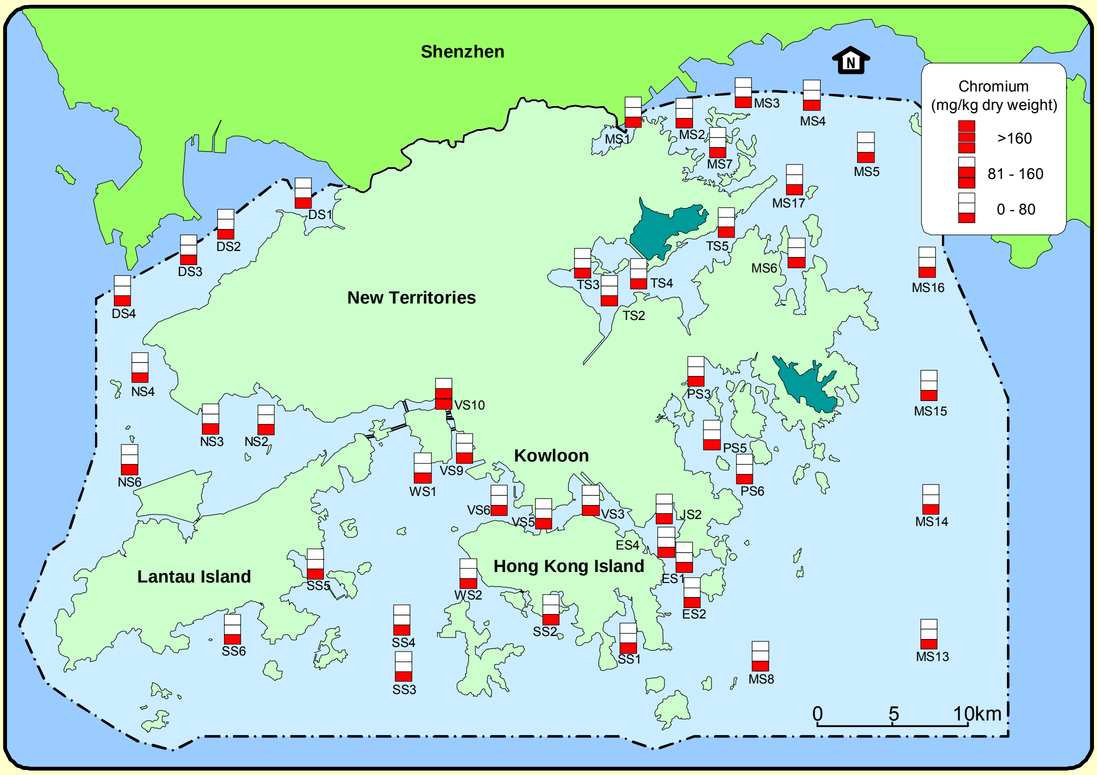


Figure 12.3 Copper in marine sediments in Hong Kong, 1999 - 2003

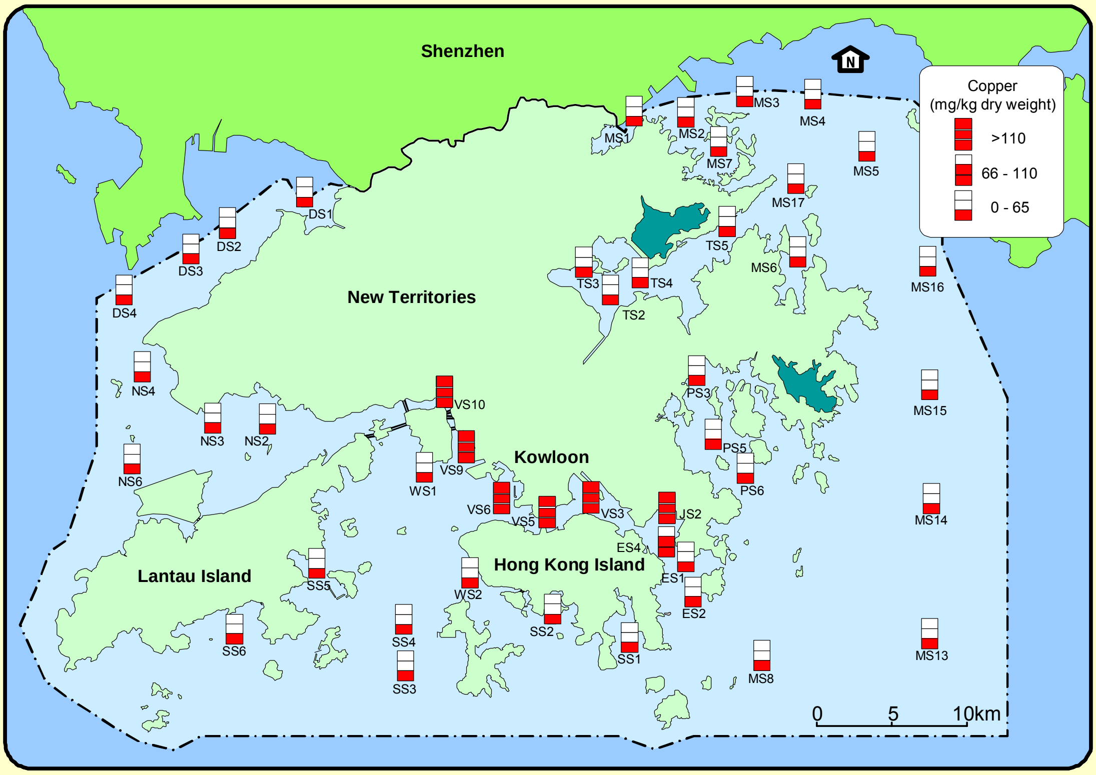


Figure 12.4 Mercury in marine sediments in Hong Kong, 1999 - 2003

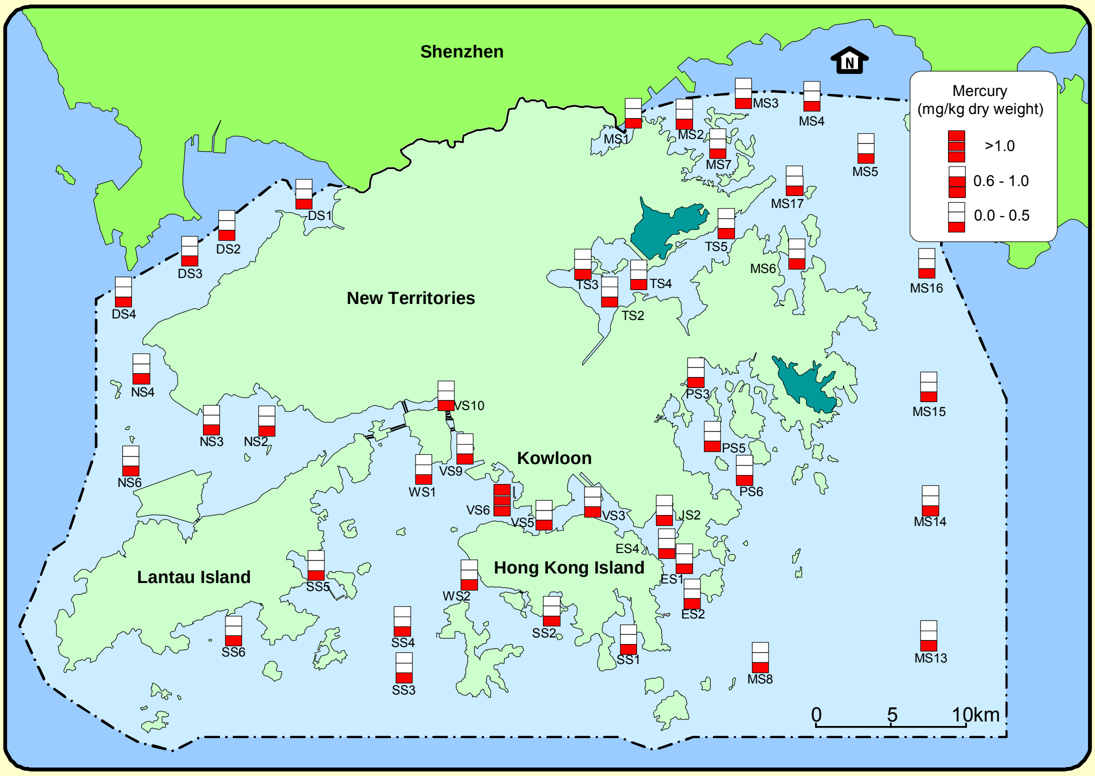


Figure 12.5 Nickel in marine sediments in Hong Kong, 1999 – 2003

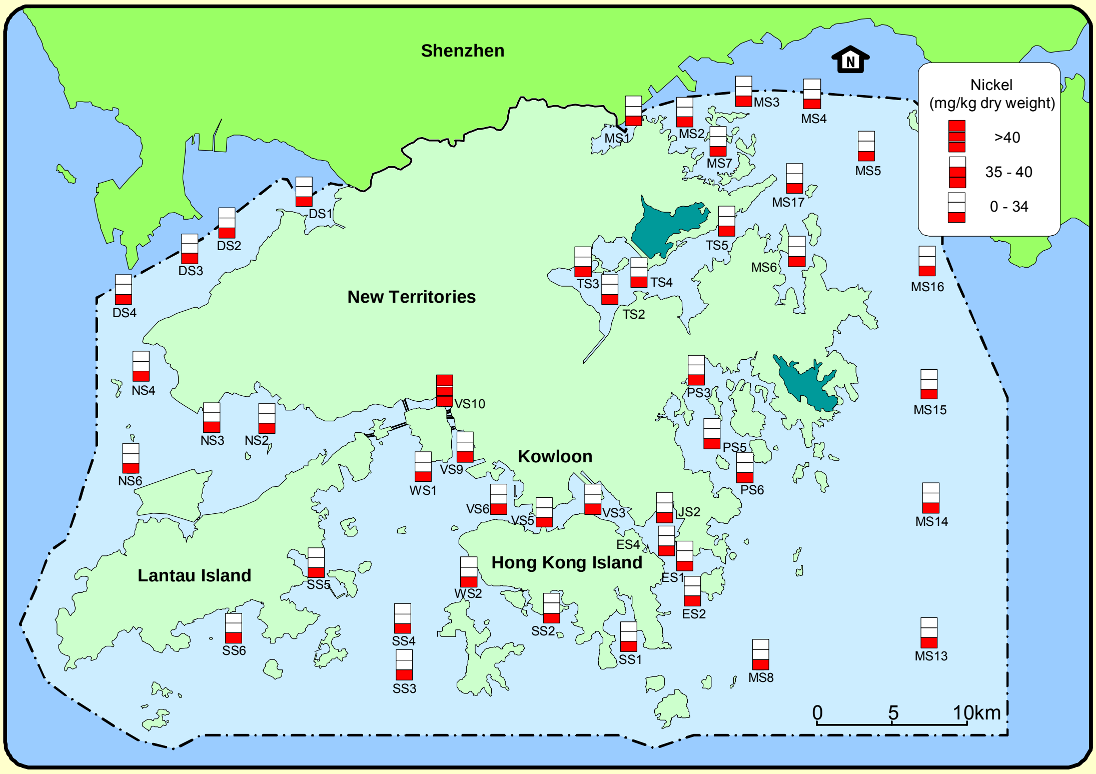
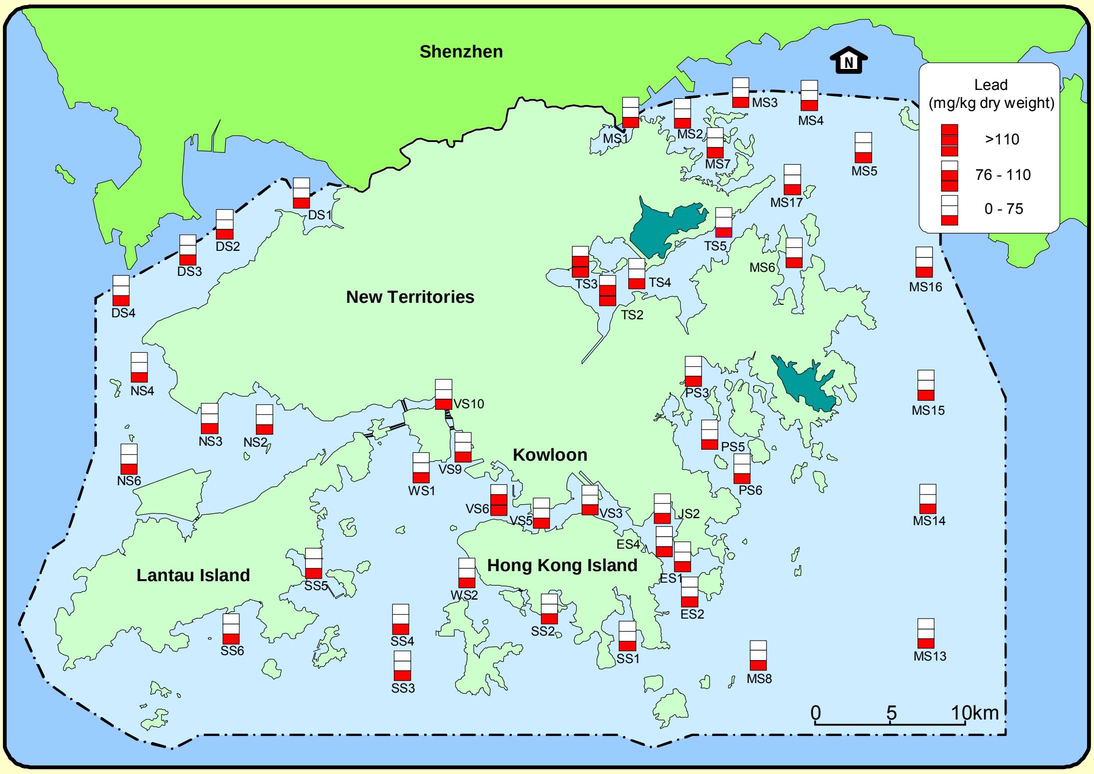


Figure 12.6 Lead in marine sediments in Hong Kong, 1999 – 2003



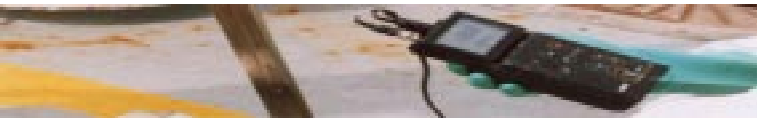


Figure 12.7 Silver in marine sediments in Hong Kong, 1999 – 2003

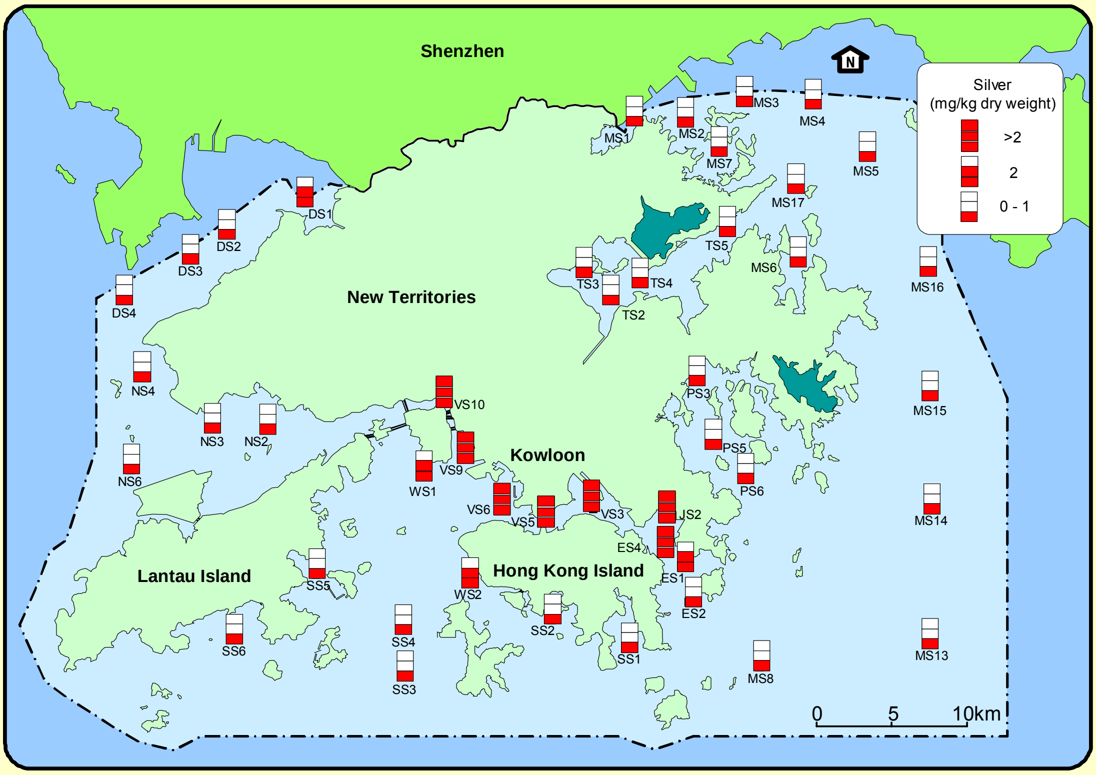


Figure 12.8 Zinc in marine sediments in Hong Kong, 1999 – 2003

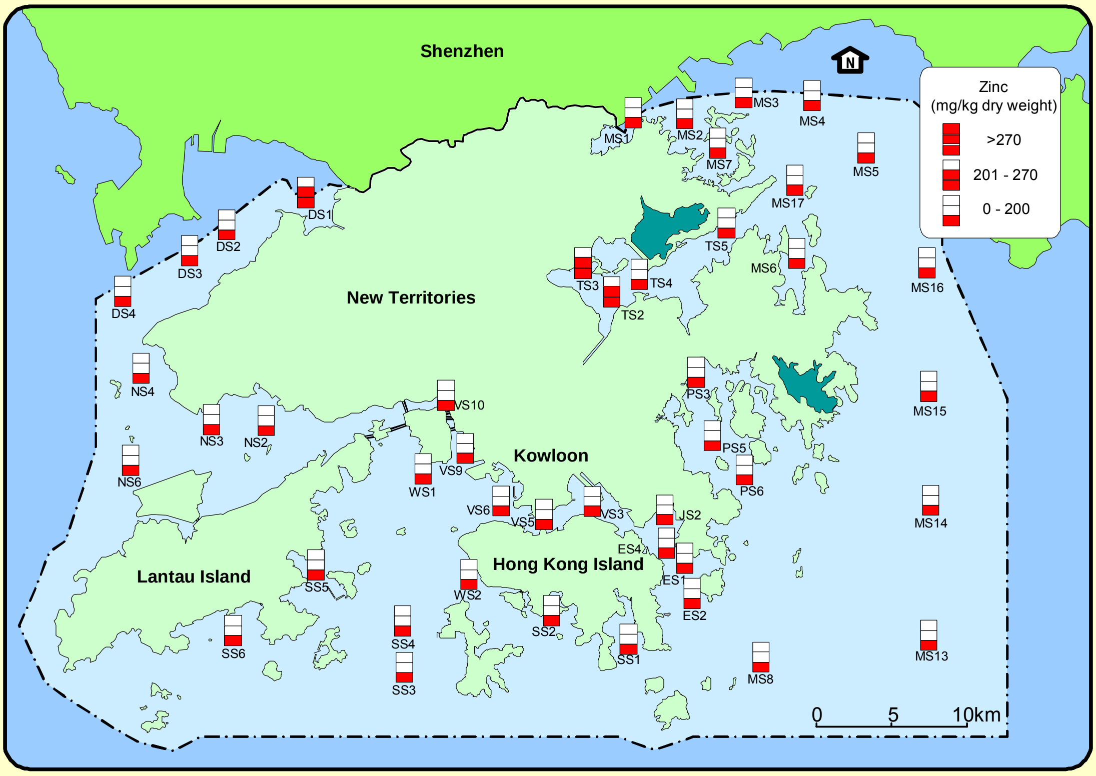


Figure 12.9 Arsenic in marine sediments in Hong Kong, 1999 – 2003

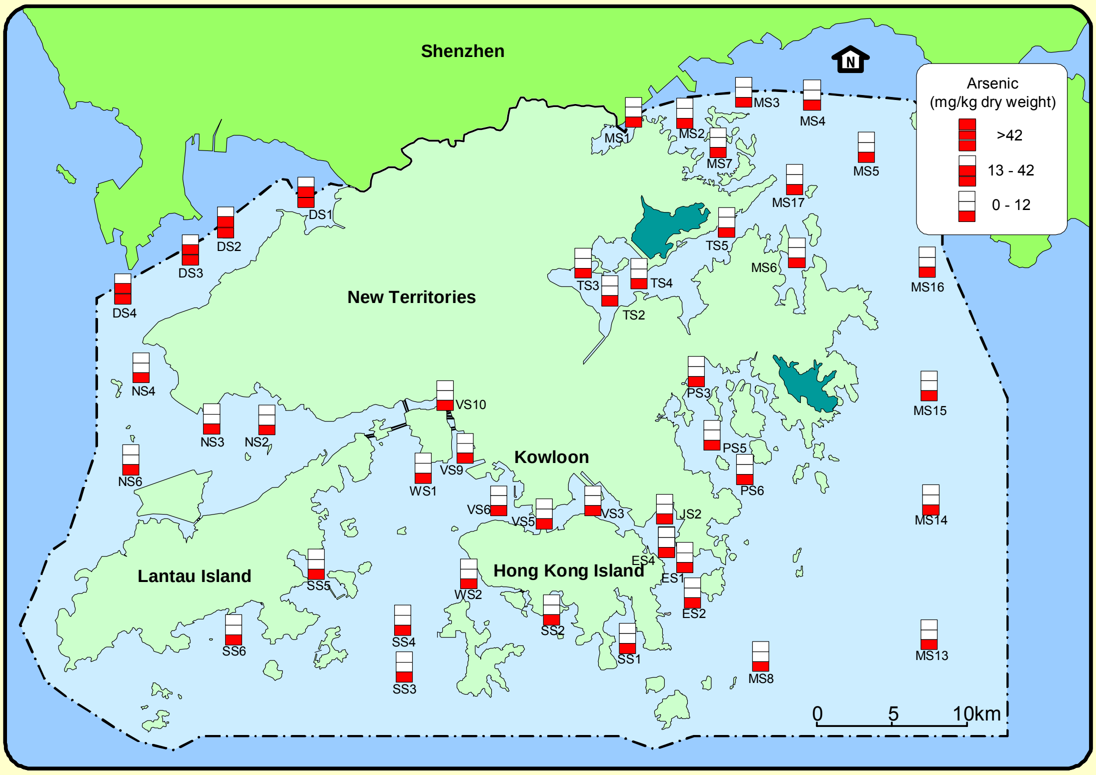


Figure 12.10 Total polychlorinated biphenyls (PCBs) in marine sediments in Hong Kong, 2002 – 2003

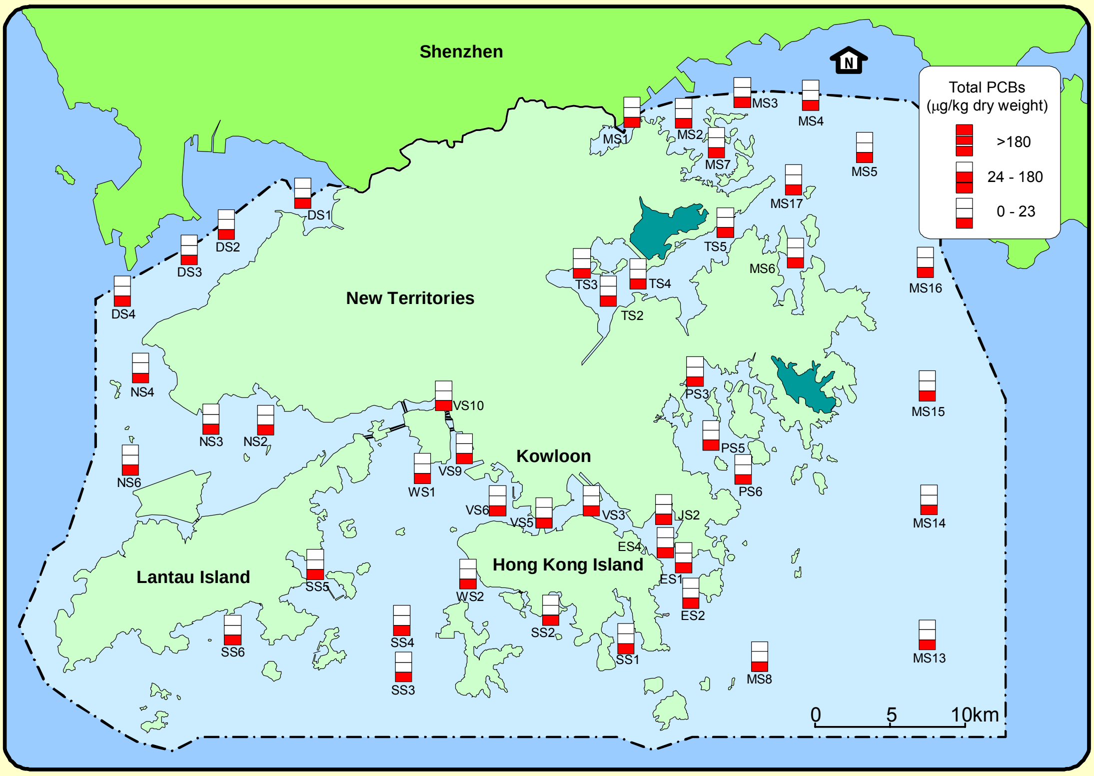


Figure 12.11 Low molecular weight polycyclic aromatic hydrocarbons (PAHs) in marine sediments in Hong Kong, 2002 – 2003

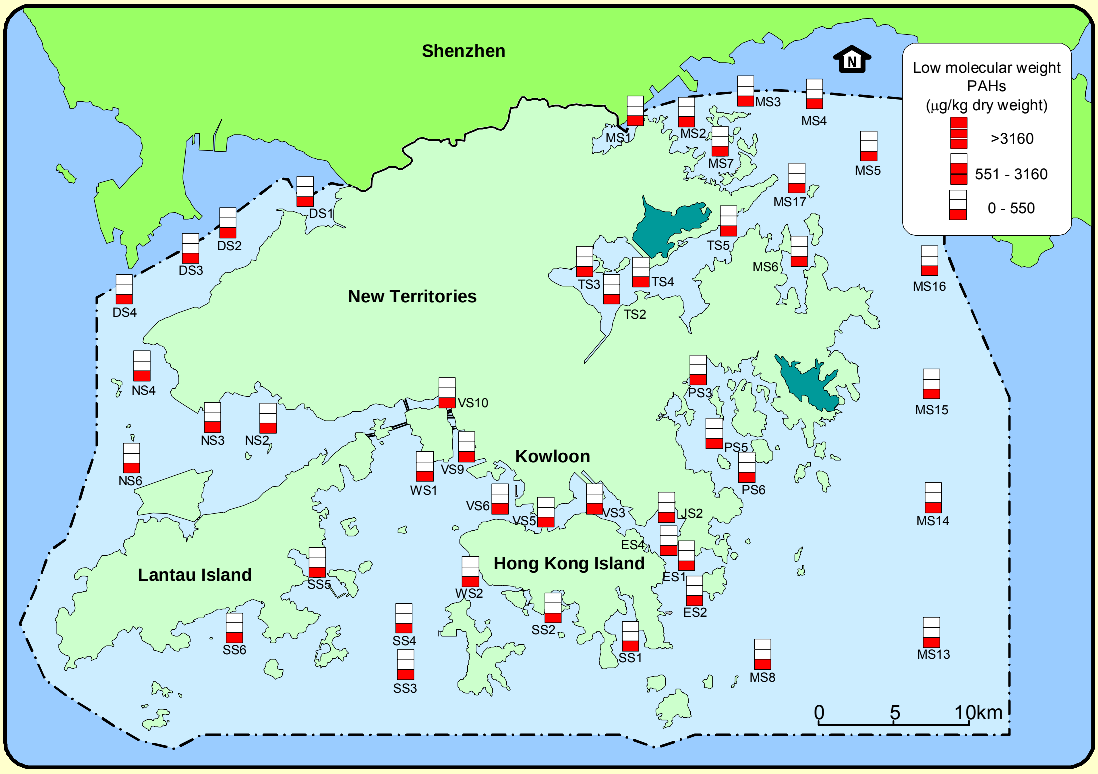


Figure 12.12 High molecular weight polycyclic aromatic hydrocarbons (PAHs) in marine sediments in Hong Kong, 1999 – 2003

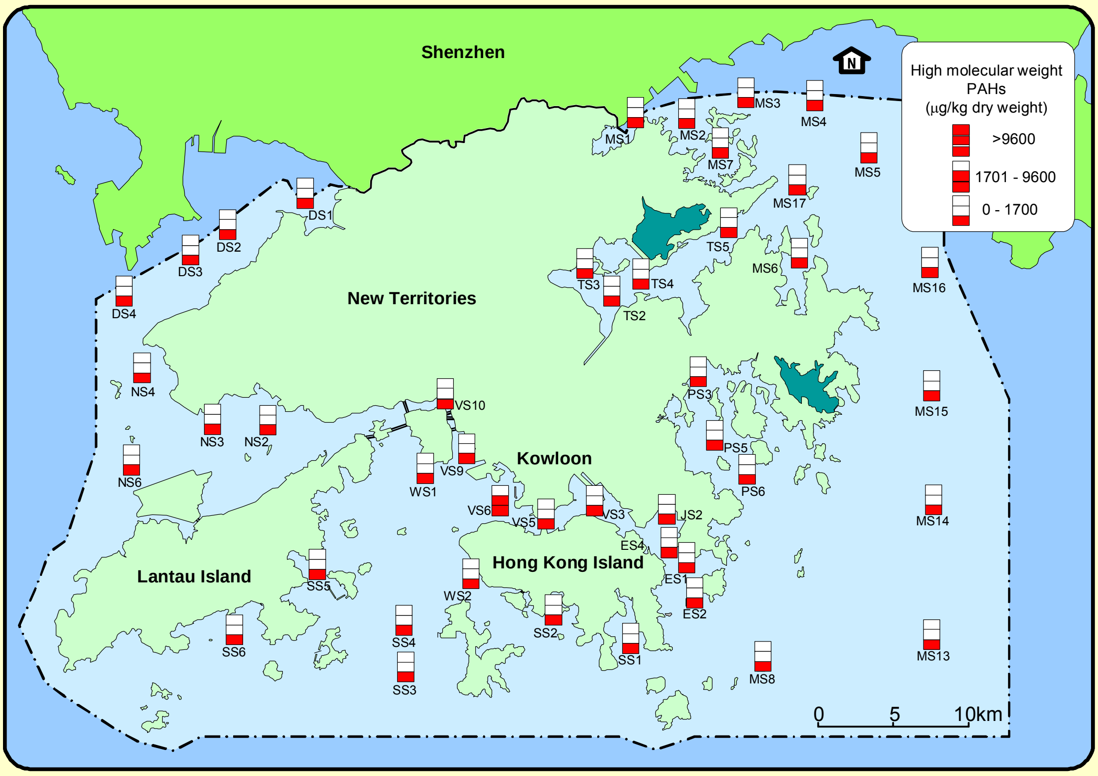
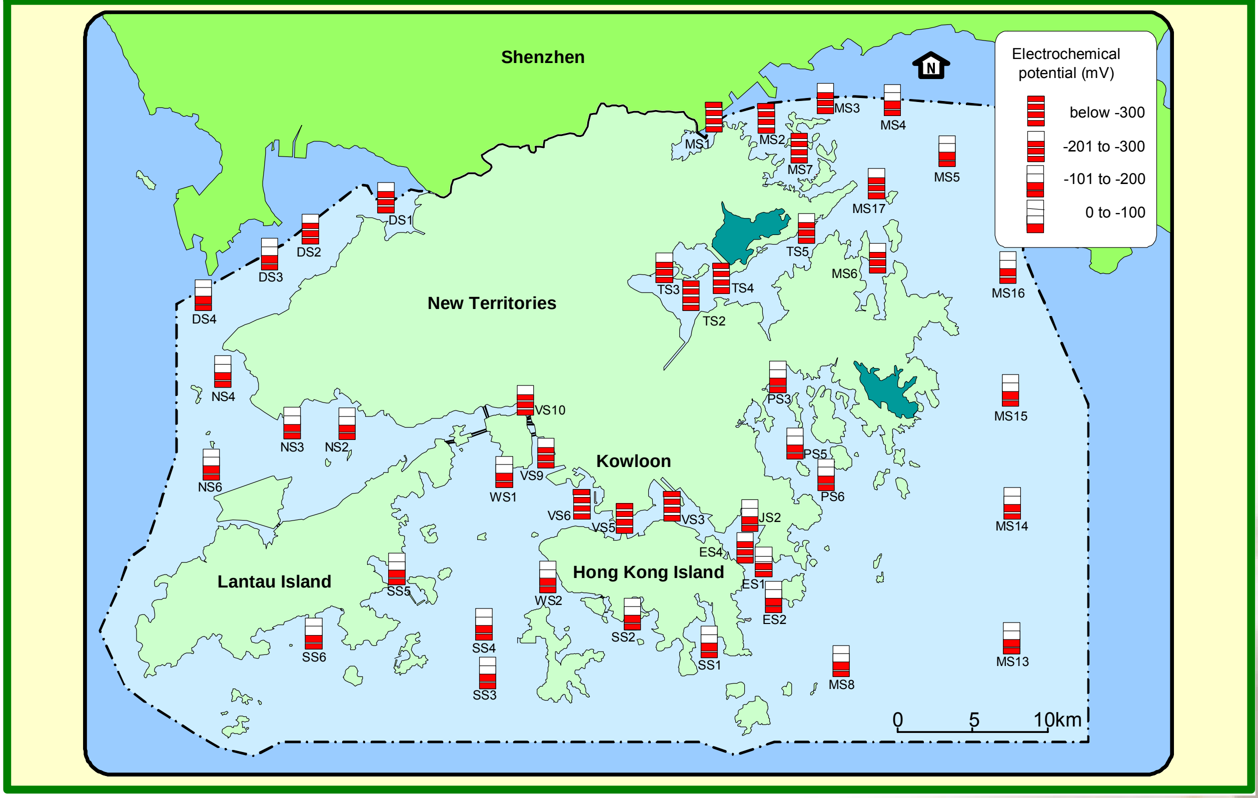


Figure 12.13 Electrochemical potential in marine sediments in Hong Kong, 1999 - 2003



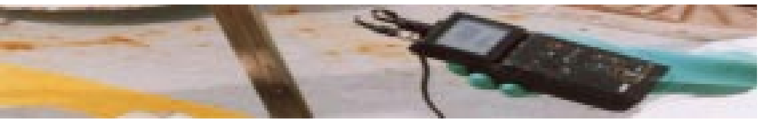


Table 12.1

Summary statistics of bottom sediment quality of the Tolo Harbour and Channel and Southern WCZs, 1999 – 2003

Parameter	Tolo Harbour and Channel: Harbour Subzone TS2	Tolo Harbour and Channel: Harbour Subzone TS3	Tolo Harbour and Channel: Buffer Subzone TS4	Tolo Harbour and Channel: Channel Subzone TS5	Hong Kong Island (South) SS1	Hong Kong Island (South) SS2	West Lamma Channel SS3	West Lamma Channel SS4
Number of samples	10	10	10	10	10	10	10	10
Particle Size Fractionation <63µm (%w/w)	74 (14 - 98)	77 (49 - 100)	70 (34 - 99)	90 (65 - 100)	71 (47 - 92)	90 (88 - 93)	78 (65 - 93)	90 (68 - 100)
Electrochemical Potential (mV)	-308 ((-365) - (-178))	-284 ((-364) - (-95))	-302 ((-368) - (-190))	-290 ((-351) - (-130))	-123 ((-205) - 61)	-139 ((-338) - 24)	-168 ((-280) - (-30))	-148 ((-208) - (-81))
Total Solids (%w/w)	35 (30 - 40)	35 (28 - 45)	38 (32 - 51)	32 (28 - 44)	55 (49 - 59)	47 (41 - 51)	51 (45 - 59)	45 (42 - 51)
Total Volatile Soilds (%w/w)	10.2 (8.6 - 12.0)	9.8 (7.4 - 12.0)	10.1 (7.5 - 12.0)	11.2 (9.5 - 13.0)	6.4 (5.9 - 7.2)	7.4 (6.7 - 7.8)	6.9 (6 - 7.6)	7.4 (7 - 7.9)
Chemical Oxygen Demand (mg/kg)	24000 (21000 - 28000)	22000 (15000 - 25000)	21000 (17000 - 24000)	19000 (16000 - 21000)	11000 (10000 - 13000)	15000 (13000 - 16000)	19000 (14000 - 25000)	16000 (14000 - 18000)
Total Carbon (%w/w)	0.8 (0.7 - 0.9)	0.7 (0.5 - 0.8)	0.8 (0.7 - 0.9)	0.8 (0.7 - 0.9)	0.8 (0.6 - 1.0)	0.7 (0.6 - 0.7)	0.9 (0.7 - 1.4)	0.6 (0.5 - 0.7)
Ammonical Nitrogen (mg/kg)	11 (2 - 32)	6 (3 - 14)	12 (2 - 24)	18 (5 - 25)	6 (0 - 11)	7 (0 - 14)	6 (1 - 16)	5 (0 - 10)
Total Kjeldahl Nitrogen (mg/kg)	608 (470 - 720)	529 (350 - 640)	638 (460 - 820)	730 (540 - 890)	372 (260 - 450)	384 (230 - 520)	350 (240 - 430)	356 (240 - 420)
Total Phosphorus (mg/kg)	177 (160 - 200)	168 (140 - 200)	195 (140 - 230)	207 (180 - 240)	213 (160 - 250)	193 (150 - 240)	234 (190 - 270)	192 (160 - 240)
Total Sulphide (mg/kg)	193 (13 - 400)	170 (15 - 320)	144 (10 - 230)	155 (15 - 240)	34 (7 - 70)	46 (8 - 74)	26 (11 - 55)	48 (15 - 140)
Total Cyanide (mg/kg)	0.2 (0.1 - 0.3)	0.1 (0.1 - 0.2)	0.1 (0.1 - 0.3)	0.1 (0.1 - 0.2)	0.1 (0.1 - 0.1)	0.1 (0.1 - 0.2)	0.1 (0.1 - 0.2)	0.1 (0.1 - 0.1)
Arsenic (mg/kg)	9.6 (7.8 - 11.0)	10.1 (8.2 - 13.0)	8.5 (6.6 - 9.8)	7.2 (6.3 - 8.6)	6.9 (4.6 - 8.2)	9.3 (7.9 - 12.0)	7.6 (6.0 - 8.8)	9.1 (6.2 - 11.0)
Cadmium (mg/kg)	0.6 (0.4 - 0.6)	0.5 (0.2 - 0.7)	0.4 (0.2 - 0.5)	0.2 (0.1 - 0.3)	0.1 (0.1 - 0.1)	0.1 (0.1 - 0.1)	0.1 (0.1 - 0.1)	0.1 (0.1 - 0.1)
Chromium (mg/kg)	29 (23 - 34)	24 (18 - 35)	26 (19 - 32)	35 (25 - 40)	27 (17 - 34)	35 (28 - 38)	32 (25 - 38)	38 (26 - 44)
Copper (mg/kg)	50 (37 - 60)	43 (22 - 60)	27 (15 - 38)	23 (12 - 26)	13 (8 - 17)	24 (19 - 30)	21 (15 - 29)	38 (20 - 48)
Lead (mg/kg)	89 (76 - 100)	99 (76 - 130)	68 (55 - 81)	54 (40 - 62)	29 (21 - 40)	38 (28 - 44)	34 (23 - 42)	44 (25 - 50)
Mercury (mg/kg)	0.08 (<0.05 - 0.17)	0.07 (<0.05 - 0.10)	0.06 (<0.05 - 0.09)	0.06 (<0.05 - 0.12)	0.07 (<0.05 - 0.16)	0.09 (<0.05 - 0.14)	0.08 (0.06 - 0.11)	0.14 (0.08 - 0.21)
Nickel (mg/kg)	18 (15 - 22)	15 (10 - 22)	17 (13 - 20)	24 (17 - 28)	18 (12 - 21)	23 (20 - 26)	21 (17 - 26)	22 (16 - 27)
Silver (mg/kg)	<1.0 (<1.0 - <1.0)	<1.0 (<1.0 - <1.0)	<1.0 (<1.0 - <1.0)	<1.0 (<1.0 - <1.0)	<1.0 (<1.0 - <1.0)	<1.0 (<1.0 - <1.0)	<1.0 (<1.0 - <1.0)	<1.0 (<1.0 - 1.0)
Zinc (mg/kg)	212 (140 - 270)	211 (180 - 270)	142 (75 - 190)	123 (87 - 140)	73 (56 - 91)	103 (93 - 120)	87 (68 - 110)	112 (75 - 130)
Total Polychlorinated Biphenyls (PCBs) (µg/kg) [3] [4]	18 (18 - 18)	18 (18 - 18)	18 (18 - 18)	18 (18 - 18)	18 (18 - 18)	18 (18 - 18)	18 (18 - 18)	18 (18 - 18)
Low Molecular Weight Polycylic Aromatic Hydrocarbons (PAHs) (µg/kg) [5] [6] [9]	92 (90 - 98)	91 (90 - 94)	90 (90 - 90)	91 (90 - 93)	90 (90 - 90)	91 (90 - 93)	91 (90 - 95)	92 (90 - 98)
High Molecular Weight Polycylic Aromatic Hydrocarbons (PAHs) (µg/kg) [7] [8] [9]	63 (35 - 120)	50 (21 - 100)	62 (20 - 137)	70 (45 - 115)	47 (28 - 98)	75 (30 - 133)	101 (23 - 354)	124 (41 - 189)

Note :
1. Data presented are arithmetic means ; data in brackets indicate ranges.
2. All data are based on the analyses of bulk (unsieved) sediment and are reported on a dry weight basis unless stated otherwise.
3. The Technical Circular 'ETWB (W) No. 34/2002 Management of Dredged / Excavated Sediment' issued in 2002 has revised the definition of 'Total PCBs' as the summation of 18 specific PCB congeners. Following the new definition, the monitoring of these 18 PCB congeners started in 2002 and the Total PCBs results only refer to 2002 and 2003.
4. Total PCBs results are derived from the summation of 18 congeners. If the concentration of a congener is below report limit (RL), the result will be taken as 0.5xRL in the calculation.
5. Low molecular weight polyaromatic hydrocarbons (PAHs) include 6 congeners of molecular weight below 200, namely : Acenaphthene, Acenaphthylene, Anthracene, Fluorene, Naphthalene and Phenanthrene.
6. As the monitoring of Naphthalene only started in 2002, the Low Molecular Weight PAHs results are based on sediments samples collected in 2002 and 2003.
7. High molecular weight polyaromatic hydrocarbons (PAHs) include 10 congeners of molecular weight above 200, namely : Fluoranthene, Pyrene, Benzo(a) anthracene, Chrysene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Benzo(a)pyrene, Dibenzo(a,h)anthracene, Benzo(g,h,i)perylene and Indeno(1,2,3-cd) pyrene.
8. High Molecular Weight PAHs results are based on sediment samples collected in five years (1999-2003).
9. Low and high molecular weight PAHs results are derived from the summation of the corresponding congeners. If the concentration of a congener is below report limit (RL), the result will be taken as 0.5xRL in the calculation.

Table 12.2

Summary statistics of bottom sediment quality of the Southern, Junk Bay and Deep Bay WCZs, 1999 – 2003

	Lantau Island		Junk Bay	Inner Deep Bay		Outer Deep Bay	
	(East)	(South)					
Parameter	SS5	SS6	JS2	DS1	DS2	DS3	DS4
Number of samples	10	10	10	10	10	10	10
Particle Size Fractionation <63µm (%w/w)	98 (93 - 100)	72 (38 - 100)	85 (56 - 99)	83 (41 - 99)	85 (63 - 99)	83 (38 - 100)	71 (13 - 99)
Electrochemical Potential (mV)	-155 ((-289) - (-60))	-135 ((-226) - (-41))	-173 ((-239) - (-70))	-258 ((-368) - (-94))	-202 ((-310) - (-98))	-161 ((-291) - (-9))	-114 ((-204) - (-29))
Total Solids (%w/w)	37 (35 - 39)	61 (57 - 64)	45 (41 - 54)	46 (34 - 53)	46 (42 - 50)	49 (43 - 69)	54 (41 - 71)
Total Volatile Soilds (%w/w)	8.5 (8 - 8.8)	4.6 (4.2 - 5.2)	7.3 (5.8 - 8.2)	6.8 (4.7 - 9.2)	7.1 (6 - 7.9)	6.7 (4.3 - 7.6)	6.1 (4.6 - 7.7)
Chemical Oxygen Demand (mg/kg)	15000 (13000 - 17000)	10000 (9400 - 12000)	16000 (11000 - 18000)	20000 (15000 - 24000)	16000 (12000 - 18000)	15000 (12000 - 18000)	14000 (8800 - 19000)
Total Carbon (%w/w)	0.6 (0.5 - 0.6)	0.5 (0.5 - 0.6)	0.7 (0.6 - 0.8)	0.6 (0.3 - 0.7)	0.5 (0.4 - 0.6)	0.5 (0.4 - 0.6)	0.5 (0.3 - 0.6)
Ammonical Nitrogen (mg/kg)	15 (1 - 34)	10 (2 - 21)	8 (5 - 14)	17 (2 - 39)	8 (2 - 32)	3 (0 - 7)	5 (0 - 11)
Total Kjeldahl Nitrogen (mg/kg)	446 (350 - 580)	309 (260 - 370)	440 (340 - 520)	412 (210 - 800)	407 (300 - 510)	349 (210 - 470)	272 (160 - 490)
Total Phosphorus (mg/kg)	194 (150 - 230)	190 (170 - 220)	197 (170 - 240)	330 (140 - 620)	302 (220 - 380)	238 (130 - 320)	174 (120 - 270)
Total Sulphide (mg/kg)	58 (9 - 110)	28 (5 - 59)	101 (29 - 230)	439 (12 - 1200)	134 (30 - 320)	59 (3 - 160)	24 (0 - 76)
Total Cyanide (mg/kg)	0.1 (0.1 - 0.2)	0.1 (0.1 - 0.2)	0.1 (0.1 - 0.2)	0.2 (0.1 - 0.4)	0.2 (0.1 - 0.2)	0.1 (0.1 - 0.2)	0.1 (0.1 - 0.3)
Arsenic (mg/kg)	9 (7.8 - 9.9)	6.3 (5.4 - 7.6)	7.9 (5.8 - 9.6)	12.9 (8.5 - 20.0)	14.8 (11.0 - 18.0)	15.6 (13.0 - 17.0)	14.8 (7.6 - 19.0)
Cadmium (mg/kg)	0.1 (0.1 - 0.1)	0.1 (0.1 - 0.1)	0.2 (0.2 - 0.2)	0.3 (0.1 - 0.6)	0.3 (0.2 - 0.4)	0.2 (0.1 - 0.4)	0.1 (0.1 - 0.2)
Chromium (mg/kg)	42 (34 - 47)	25 (20 - 32)	54 (41 - 78)	42 (28 - 57)	43 (36 - 49)	45 (39 - 53)	35 (27 - 50)
Copper (mg/kg)	42 (30 - 49)	14 (11 - 17)	137 (98 - 190)	62 (14 - 100)	59 (51 - 70)	53 (38 - 77)	29 (15 - 57)
Lead (mg/kg)	54 (41 - 64)	27 (22 - 32)	47 (35 - 55)	63 (39 - 87)	61 (46 - 87)	56 (49 - 62)	45 (29 - 68)
Mercury (mg/kg)	0.17 (0.12 - 0.27)	0.06 (<0.05 - 0.09)	0.25 (0.14 - 0.35)	0.12 (<0.05 - 0.29)	0.14 (0.11 - 0.16)	0.14 (0.09 - 0.16)	0.08 (<0.05 - 0.15)
Nickel (mg/kg)	25 (18 - 30)	16 (11 - 22)	24 (17 - 38)	24 (14 - 33)	26 (23 - 29)	29 (23 - 37)	21 (15 - 30)
Silver (mg/kg)	<1.0 (<1.0 - 1.0)	<1.0 (<1.0 - <1.0)	2.2 (1.0 - 3.0)	<1.0 (<1.0 - 2.0)	<1.0 (<1.0 - 1.0)	<1.0 (<1.0 - <1.0)	<1.0 (<1.0 - <1.0)
Zinc (mg/kg)	137 (110 - 160)	69 (61 - 86)	142 (100 - 180)	226 (86 - 380)	191 (140 - 240)	157 (130 - 230)	108 (60 - 180)
Total Polychlorinated Biphenyls (PCBs) (µg/kg) (3) (4)	18 (18 - 18)	18 (18 - 18)	18 (18 - 18)	18 (18 - 18)	18 (18 - 18)	18 (18 - 18)	18 (18 - 18)
Low Molecular Weight Polycyclic Aromatic Hydrocarbons (PAHs) (µg/kg) (5) (6) (9)	90 (90 - 90)	90 (90 - 90)	91 (90 - 95)	94 (90 - 104)	92 (90 - 94)	93 (90 - 96)	90 (90 - 90)
High Molecular Weight Polycyclic Aromatic Hydrocarbons (PAHs) (µg/kg) (7) (8) (9)	92 (44 - 155)	29 (19 - 47)	183 (121 - 273)	119 (18 - 355)	101 (42 - 190)	86 (37 - 120)	71 (16 - 254)

Note :
1. Data presented are arithmetic means ; data in brackets indicate ranges.
2. All data are based on the analyses of bulk (unsieved) sediment and are reported on a dry weight basis unless stated otherwise.
3. The Technical Circular 'ETWB (W) No. 34/2002 Management of Dredged / Excavated Sediment' issued in 2002 has revised the definition of 'Total PCBs' as the summation of 18 specific PCB congeners. Following the new definition, the monitoring of these 18 PCB congeners started in 2002 and the Total PCBs results only refer to 2002 and 2003.
4. Total PCBs results are derived from the summation of 18 congeners. If the concentration of a congener is below report limit (RL), the result will be taken as 0.5xRL in the calculation.
5. Low molecular weight polyaromatic hydrocarbons (PAHs) include 6 congeners of molecular weight below 200, namely : Acenaphthene, Acenaphthylene, Anthracene, Fluorene, Naphthalene and Phenanthrene.
6. As the monitoring of Naphthalene only started in 2002, the Low Molecular Weight PAHs results are based on sediments samples collected in 2002 and 2003.
7. High molecular weight polyaromatic hydrocarbons (PAHs) include 10 congeners of molecular weight above 200, namely : Fluoranthene, Pyrene, Benzo(a) anthracene, Chrysene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Benzo(a)pyrene, Dibenzo(a,h)anthracene, Benzo(g,h,i)perylene and Indeno(1,2,3-cd) pyrene.
8. High Molecular Weight PAHs results are based on sediment samples collected in five years (1999-2003).
9. Low and high molecular weight PAHs results are derived from the summation of the corresponding congeners. If the concentration of a congener is below report limit (RL), the result will be taken as 0.5xRL in the calculation.

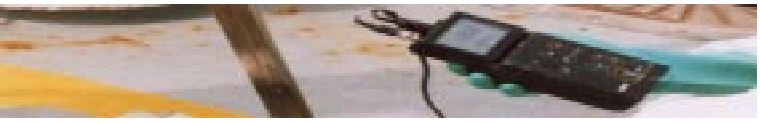


Table 12.3

Summary statistics of bottom sediment quality of the Port Shelter and Mirs Bay WCZs, 1999 – 2003

Parameter	Inner Port Shelter PS3	Outer Port Shelter PS5	Outer Port Shelter PS6	Starling Inlet MS1	Crooked Island MS2	Crooked Island MS7	Port Island MS17	Mirs Bay (North) MS3
Number of samples	10	10	10	10	10	10	10	10
Particle Size Fractionation <63μm (%w/w)	90 (55 - 99)	57 (19 - 97)	87 (82 - 97)	90 (82 - 100)	97 (93 - 100)	97 (90 - 100)	96 (91 - 100)	95 (89 - 100)
Electrochemical Potential (mV)	-198 ((-324) - (-34))	-108 ((-249) - (-15))	-164 ((-281) - (-33))	-302 ((-379) - (-106))	-323 ((-390) - (-71))	-339 ((-395) - (-152))	-232 ((-342) - (-61))	-238 ((-346) - (-6))
Total Solids (%w/w)	37 (32 - 53)	54 (38 - 63)	46 (43 - 51)	40 (32 - 46)	32 (30 - 35)	30 (27 - 34)	36 (34 - 42)	39 (35 - 44)
Total Volatile Soilds (%w/w)	12 (8.2 - 14.0)	8.1 (5.5 - 11.0)	9.5 (8.8 - 11.0)	8.3 (7.4 - 10.0)	10.6 (9.8 - 12.0)	11.3 (11 - 12.0)	10.1 (9 - 11.0)	9.5 (7.8 - 11.0)
Chemical Oxygen Demand (mg/kg)	19000 (15000 - 21000)	12000 (7200 - 17000)	14000 (10000 - 15000)	19000 (14000 - 22000)	19000 (16000 - 20000)	19000 (17000 - 21000)	18000 (14000 - 19000)	18000 (14000 - 20000)
Total Carbon (%w/w)	1 (0.5 - 1.2)	1 (0.3 - 1.8)	0.9 (0.4 - 1.3)	0.7 (0.6 - 0.8)	0.7 (0.6 - 0.9)	0.8 (0.7 - 0.9)	0.8 (0.7 - 1.2)	0.7 (0.6 - 0.9)
Ammonical Nitrogen (mg/kg)	9 (4 - 15)	8 (4 - 15)	8 (2 - 15)	19 (3 - 50)	18 (13 - 25)	12 (1 - 18)	9 (1 - 16)	7 (2 - 13)
Total Kjeldahl Nitrogen (mg/kg)	638 (420 - 780)	389 (300 - 600)	485 (270 - 600)	554 (270 - 760)	648 (510 - 720)	666 (570 - 760)	606 (390 - 760)	565 (380 - 670)
Total Phosphorus (mg/kg)	211 (170 - 240)	165 (120 - 210)	198 (110 - 250)	190 (150 - 230)	206 (180 - 240)	202 (170 - 240)	213 (150 - 270)	198 (170 - 230)
Total Sulphide (mg/kg)	72 (7 - 200)	13 (0 - 36)	32 (1 - 59)	198 (34 - 350)	150 (43 - 340)	98 (2 - 190)	50 (2 - 77)	36 (10 - 100)
Total Cyanide (mg/kg)	0.1 (0.1 - 0.1)	0.1 (0.1 - 0.1)	0.1 (0.1 - 0.2)	0.1 (0.1 - 0.2)	0.1 (0.1 - 0.2)	0.1 (0.1 - 0.2)	0.1 (0.1 - 0.2)	0.1 (0.1 - 0.2)
Arsenic (mg/kg)	7 (5.4 - 9.7)	5.1 (3.1 - 8.2)	6.5 (5.2 - 9.3)	9.8 (7.5 - 12.0)	7.9 (5.8 - 9.4)	7.6 (5.7 - 10.0)	7.3 (5.3 - 10.0)	7.6 (5.1 - 9.6)
Cadmium (mg/kg)	0.1 (0.1 - 0.1)	0.1 (0.1 - 0.1)	0.1 (0.1 - 0.1)	0.2 (0.2 - 0.3)	0.2 (0.1 - 0.2)	0.2 (0.1 - 0.2)	0.1 (0.1 - 0.2)	0.1 (0.1 - 0.2)
Chromium (mg/kg)	28 (20 - 35)	23 (16 - 35)	29 (26 - 34)	28 (26 - 31)	35 (28 - 40)	36 (32 - 38)	36 (28 - 40)	33 (27 - 39)
Copper (mg/kg)	25 (19 - 31)	11 (5 - 19)	14 (12 - 21)	40 (32 - 45)	21 (19 - 26)	20 (16 - 25)	17 (13 - 19)	15 (12 - 19)
Lead (mg/kg)	40 (34 - 44)	27 (18 - 43)	34 (32 - 38)	51 (38 - 57)	47 (39 - 50)	44 (36 - 51)	45 (34 - 52)	40 (32 - 49)
Mercury (mg/kg)	0.1 (0.06 - 0.18)	<0.05 (<0.05 - 0.07)	0.05 (<0.05 - 0.09)	0.1 (0.07 - 0.15)	0.07 (<0.05 - 0.1)	0.08 (0.06 - 0.11)	0.06 (<0.05 - 0.09)	<0.05 (<0.05 - 0.07)
Nickel (mg/kg)	17 (9 - 22)	16 (9 - 26)	20 (18 - 23)	17 (15 - 20)	23 (20 - 28)	24 (21 - 26)	26 (21 - 30)	23 (19 - 28)
Silver (mg/kg)	<1.0 (<1.0 - <1.0)	<1.0 (<1.0 - <1.0)	<1.0 (<1.0 - <1.0)	<1.0 (<1.0 - 1.0)	<1.0 (<1.0 - 1.0)	<1.0 (<1.0 - <1.0)	<1.0 (<1.0 - <1.0)	<1.0 (<1.0 - <1.0)
Zinc (mg/kg)	102 (77 - 130)	68 (36 - 120)	83 (67 - 100)	107 (80 - 130)	101 (77 - 120)	97 (78 - 120)	95 (66 - 120)	85 (60 - 99)
Total Polychlorinated Biphenyls (PCBs) (μg/kg) (3) (4)	18 (18 - 18)	18 (18 - 18)	18 (18 - 18)	18 (18 - 18)	18 (18 - 18)	18 (18 - 18)	18 (18 - 18)	18 (18 - 18)
Low Molecular Weight Polycyclic Aromatic Hydrocarbons (PAHs) (μg/kg) (5) (6) (9)	90 (90 - 90)	90 (90 - 90)	90 (90 - 90)	90 (90 - 90)	91 (90 - 95)	90 (90 - 90)	90 (90 - 90)	90 (90 - 90)
High Molecular Weight Polycyclic Aromatic Hydrocarbons (PAHs) (μg/kg) (7) (8) (9)	74 (57 - 107)	38 (20 - 92)	50 (24 - 89)	60 (34 - 93)	72 (44 - 109)	89 (36 - 200)	60 (30 - 101)	52 (33 - 94)

Note : 1. Data presented are arithmetic means ; data in brackets indicate ranges.

2. All data are based on the analyses of bulk (unsieved) sediment and are reported on a dry weight basis unless stated otherwise.
3. The Technical Circular 'ETWB (W) No. 34/2002 Management of Dredged / Excavated Sediment' issued in 2002 has revised the definition of 'Total PCBs' as the summation of 18 specific PCB congeners. Following the new definition, the monitoring of these 18 PCB congeners started in 2002 and the Total PCBs results only refer to 2002 and 2003.
4. Total PCBs results are derived from the summation of 18 congeners. If the concentration of a congener is below report limit (RL), the result will be taken as 0.5xRL in the calculation.
5. Low molecular weight polyaromatic hydrocarbons (PAHs) include 6 congeners of molecular weight below 200, namely : Acenaphthene, Acenaphthylene, Anthracene, Fluorene, Naphthalene and Phenanthrene.
6. As the monitoring of Naphthalene only started in 2002, the Low Molecular Weight PAHs results are based on sediments samples collected in 2002 and 2003.
7. High molecular weight polyaromatic hydrocarbons (PAHs) include 10 congeners of molecular weight above 200, namely : Fluoranthene, Pyrene, Benzo(a) anthracene, Chrysene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Benzo(a)pyrene, Dibenzo(a,h)anthracene, Benzo(g,h,i)perylene and Indeno(1,2,3-cd) pyrene.
8. High Molecular Weight PAHs results are based on sediment samples collected in five years (1999-2003).
9. Low and high molecular weight PAHs results are derived from the summation of the corresponding congeners. If the concentration of a congener is below report limit (RL), the result will be taken as 0.5xRL in the calculation.

Table 12.4

Summary statistics of bottom sediment quality of the Mirs Bay WCZ, 1999 – 2003

Parameter	Mirs Bay (North)		Long Harbour	Waglan Island	Mirs Bay (South)	Mirs Bay (Central)		
	MS4	MS5	MS6	MS8	MS13	MS14	MS15	MS16
Number of samples	10	10	10	10	10	10	10	10
Particle Size Fractionation <63µm (%w/w)	65 (65)	91 (85 - 96)	97 (95 - 100)	96 (91 - 98)	94 (91 - 100)	92 (88 - 95)	90 (81 - 96)	85 (76 - 94)
Electrochemical Potential (mV)	-182 ((-291) - 10)	-175 ((-256) - (-27))	-211 ((-300) - (-8))	-124 ((-237) - (-4))	-111 ((-195) - (-19))	-119 ((-189) - (-18))	-118 ((-209) - (-29))	-131 ((-274) - (-10))
Total Solids (%w/w)	35 (33 - 36)	39 (36 - 44)	35 (32 - 40)	46 (44 - 51)	49 (47 - 51)	49 (46 - 53)	51 (49 - 54)	52 (46 - 56)
Total Volatile Soilds (%w/w)	9.6 (8.9 - 10.0)	8.7 (7.8 - 10.0)	11 (8 - 12.0)	7.2 (6.6 - 7.6)	6.7 (6.1 - 7.5)	6.8 (5.7 - 7.4)	6.4 (5.3 - 7.0)	6.4 (5.5 - 7.1)
Chemical Oxygen Demand (mg/kg)	15000 (12000 - 17000)	15000 (13000 - 16000)	19000 (15000 - 21000)	13000 (10000 - 20000)	11000 (9700 - 12000)	11000 (9600 - 12000)	11000 (9500 - 12000)	11000 (8200 - 12000)
Total Carbon (%w/w)	0.6 (0.6 - 0.7)	0.7 (0.6 - 0.9)	0.9 (0.7 - 1.0)	0.6 (0.5 - 0.6)	0.6 (0.5 - 0.6)	0.6 (0.5 - 0.7)	0.6 (0.5 - 0.8)	0.6 (0.5 - 0.8)
Ammonical Nitrogen (mg/kg)	8 (1 - 20)	10 (1 - 16)	12 (1 - 21)	6 (0 - 20)	8 (0 - 48)	10 (0 - 69)	4 (0 - 10)	10 (2 - 37)
Total Kjeldahl Nitrogen (mg/kg)	622 (550 - 680)	592 (530 - 650)	698 (480 - 840)	390 (320 - 480)	406 (350 - 520)	389 (280 - 560)	370 (270 - 470)	386 (260 - 450)
Total Phosphorus (mg/kg)	210 (190 - 230)	214 (180 - 240)	239 (180 - 290)	206 (180 - 220)	229 (210 - 250)	217 (190 - 250)	211 (180 - 230)	216 (160 - 260)
Total Sulphide (mg/kg)	45 (1 - 86)	59 (13 - 180)	84 (15 - 210)	42 (1 - 180)	26 (8 - 130)	23 (8 - 89)	16 (8 - 27)	39 (2 - 210)
Total Cyanide (mg/kg)	0.1 (0.1 - 0.2)	0.1 (0.1 - 0.1)	0.1 (0.1 - 0.2)	0.1 (0.1 - 0.2)	0.1 (0.1 - 0.1)	0.1 (0.1 - 0.1)	0.1 (0.1 - 0.1)	0.1 (0.1 - 0.1)
Arsenic (mg/kg)	7.1 (4.9 - 9.0)	7.7 (5.7 - 9.7)	6.8 (5.0 - 8.8)	7.9 (6.6 - 9.4)	8.2 (6.4 - 9.3)	8.1 (6.9 - 9.1)	7.3 (5.6 - 8.6)	6.8 (5.0 - 8.0)
Cadmium (mg/kg)	0.1 (0.1 - 0.2)	0.1 (0.1 - 0.2)	0.1 (0.1 - 0.2)	0.1 (0.1 - 0.1)	0.1 (0.1 - 0.1)	0.1 (0.1 - 0.1)	0.1 (0.1 - 0.1)	0.1 (0.1 - 0.1)
Chromium (mg/kg)	37 (30 - 43)	37 (26 - 62)	32 (27 - 35)	34 (26 - 41)	31 (29 - 34)	32 (28 - 36)	30 (25 - 35)	28 (24 - 34)
Copper (mg/kg)	16 (13 - 18)	15 (11 - 19)	18 (15 - 23)	14 (11 - 20)	13 (11 - 14)	13 (10 - 16)	11 (9 - 13)	10 (8 - 14)
Lead (mg/kg)	41 (33 - 48)	43 (33 - 49)	42 (36 - 48)	34 (27 - 40)	31 (26 - 34)	32 (26 - 36)	31 (25 - 36)	32 (26 - 39)
Mercury (mg/kg)	<0.05 (<0.05 - 0.07)	<0.05 (<0.05 - 0.08)	0.08 (0.06 - 0.12)	<0.05 (<0.05 - 0.09)	<0.05 (<0.05 - 0.06)	<0.05 (<0.05 - 0.07)	<0.05 (<0.05 - 0.09)	<0.05 (<0.05 - 0.06)
Nickel (mg/kg)	28 (23 - 33)	27 (20 - 39)	24 (21 - 28)	25 (20 - 31)	24 (21 - 27)	23 (20 - 27)	22 (18 - 26)	21 (17 - 26)
Silver (mg/kg)	<1.0 (<1.0 - <1.0)	<1.0 (<1.0 - <1.0)	<1.0 (<1.0 - <1.0)	<1.0 (<1.0 - <1.0)	<1.0 (<1.0 - <1.0)	<1.0 (<1.0 - <1.0)	<1.0 (<1.0 - <1.0)	<1.0 (<1.0 - <1.0)
Zinc (mg/kg)	94 (66 - 120)	92 (62 - 110)	100 (78 - 120)	83 (59 - 100)	78 (56 - 95)	78 (58 - 92)	71 (53 - 85)	71 (54 - 82)
Total Polychlorinated Biphenyls (PCBs) (µg/kg) (3) (4)	18 (18 - 18)	18 (18 - 18)	18 (18 - 18)	18 (18 - 18)	18 (18 - 18)	18 (18 - 18)	18 (18 - 18)	18 (18 - 18)
Low Molecular Weight Polycyclic Aromatic Hydrocarbons (PAHs) (µg/kg) (5) (6) (9)	90 (90 - 90)	90 (90 - 90)	90 (90 - 90)	90 (90 - 90)	90 (90 - 90)	90 (90 - 90)	90 (90 - 90)	90 (90 - 90)
High Molecular Weight Polycyclic Aromatic Hydrocarbons (PAHs) (µg/kg) (7) (8) (9)	57 (30 - 89)	47 (28 - 75)	76 (38 - 123)	57 (22 - 101)	40 (26 - 82)	37 (23 - 67)	34 (19 - 54)	30 (19 - 47)

Note : 1. Data presented are arithmetic means ; data in brackets indicate ranges.
2. All data are based on the analyses of bulk (unsieved) sediment and are reported on a dry weight basis unless stated otherwise.
3. The Technical Circular 'ETWB (W) No. 34/2002 Management of Dredged / Excavated Sediment' issued in 2002 has revised the definition of 'Total PCBs' as the summation of 18 specific PCB congeners. Following the new definition, the monitoring of these 18 PCB congeners started in 2002 and the Total PCBs results only refer to 2002 and 2003.
4. Total PCBs results are derived from the summation of 18 congeners. If the concentration of a congener is below report limit (RL), the result will be taken as 0.5xRL in the calculation.
5. Low molecular weight polyaromatic hydrocarbons (PAHs) include 6 congeners of molecular weight below 200, namely : Acenaphthene, Acenaphthylene, Anthracene, Fluorene, Naphthalene and Phenanthrene.
6. As the monitoring of Naphthalene only started in 2002, the Low Molecular Weight PAHs results are based on sediments samples collected in 2002 and 2003.
7. High molecular weight polyaromatic hydrocarbons (PAHs) include 10 congeners of molecular weight above 200, namely : Fluoranthene, Pyrene, Benzo(a) anthracene, Chrysene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Benzo(a)pyrene, Dibenzo(a,h)anthracene, Benzo(g,h,i)perylene and Indeno(1,2,3-cd) pyrene.
8. High Molecular Weight PAHs results are based on sediment samples collected in five years (1999-2003).
9. Low and high molecular weight PAHs results are derived from the summation of the corresponding congeners. If the concentration of a congener is below report limit (RL), the result will be taken as 0.5xRL in the calculation.

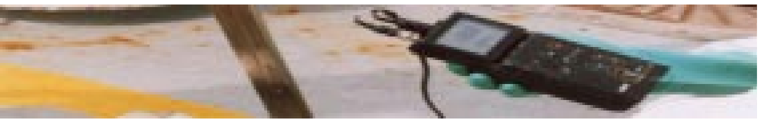


Table 12.5

Summary statistics of bottom sediment quality of the North Western and Western Buffer WCZs, 1999 – 2003

Parameter	Pearl Island NS2	Pillar Point NS3	Urmston Road NS4	Chek Lap Kok (North) NS6	Tsing Yi (South) WS1	Hong Kong Island (West) WS2
Number of samples	10	10	10	10	10	10
Particle Size Fractionation <63µm (%w/w)	74 (46 - 90)	58 (5 - 86)	54 (26 - 86)	63 (26 - 92)	84 (27 - 97)	87 (71 - 97)
Electrochemical Potential (mV)	-129 ((-186) - (-33))	-149 ((-236) - (-18))	-152 ((-230) - (-19))	-143 ((-205) - (-20))	-163 ((-263) - (-31))	-121 ((-166) - 43)
Total Solids (%w/w)	52 (50 - 58)	58 (51 - 69)	63 (50 - 68)	62 (47 - 73)	45 (38 - 64)	46 (41 - 54)
Total Volatile Soilds (%w/w)	6.3 (5 - 7.0)	5.9 (3.1 - 7.4)	5.3 (4.5 - 6.7)	4.8 (2.9 - 8.3)	7 (4 - 9.0)	7.1 (5.6 - 8.4)
Chemical Oxygen Demand (mg/kg)	14000 (10000 - 16000)	16000 (8400 - 19000)	13000 (11000 - 14000)	12000 (8300 - 17000)	16000 (11000 - 19000)	14000 (9800 - 20000)
Total Carbon (%w/w)	0.6 (0.5 - 0.7)	0.6 (0.4 - 0.8)	0.5 (0.3 - 0.7)	0.5 (0.4 - 0.7)	0.6 (0.5 - 0.7)	0.6 (0.5 - 0.7)
Ammonical Nitrogen (mg/kg)	3 (1 - 8)	5 (1 - 12)	17 (2 - 39)	5 (1 - 16)	16 (6 - 38)	7 (2 - 11)
Total Kjeldahl Nitrogen (mg/kg)	298 (220 - 360)	280 (120 - 340)	254 (200 - 340)	239 (140 - 370)	417 (200 - 570)	381 (260 - 460)
Total Phosphorus (mg/kg)	181 (130 - 210)	181 (86 - 240)	156 (110 - 220)	156 (100 - 260)	189 (110 - 240)	193 (140 - 220)
Total Sulphide (mg/kg)	24 (2 - 64)	17 (5 - 32)	20 (1 - 54)	6 (1 - 15)	101 (13 - 210)	48 (15 - 87)
Total Cyanide (mg/kg)	0.1 (0.1 - 0.1)	0.2 (0.1 - 0.5)	0.1 (0.1 - 0.1)	0.1 (0.1 - 0.1)	0.1 (0.1 - 0.3)	0.1 (0.1 - 0.2)
Arsenic (mg/kg)	9.9 (8.3 - 11.0)	10.8 (6.3 - 14.0)	11.1 (9.1 - 15.0)	10.9 (6.1 - 22.0)	9.9 (5.6 - 13.0)	11.8 (9.5 - 16.0)
Cadmium (mg/kg)	0.1 (0.1 - 0.1)	0.1 (0.1 - 0.3)	0.1 (0.1 - 0.2)	0.1 (0.1 - 0.2)	0.2 (0.1 - 0.3)	0.1 (0.1 - 0.3)
Chromium (mg/kg)	33 (30 - 35)	31 (16 - 41)	27 (20 - 36)	26 (15 - 45)	41 (13 - 52)	40 (32 - 51)
Copper (mg/kg)	32 (27 - 45)	34 (17 - 47)	23 (18 - 37)	17 (8 - 34)	52 (9 - 94)	38 (18 - 120)
Lead (mg/kg)	36 (32 - 44)	36 (20 - 45)	38 (29 - 47)	29 (17 - 49)	41 (15 - 49)	42 (34 - 54)
Mercury (mg/kg)	0.08 (0.06 - 0.15)	0.12 (0.06 - 0.19)	0.08 (0.06 - 0.11)	0.06 (<0.05 - 0.15)	0.17 (<0.05 - 0.49)	0.13 (<0.05 - 0.26)
Nickel (mg/kg)	19 (16 - 22)	19 (10 - 25)	17 (14 - 20)	16 (9 - 27)	23 (8 - 27)	24 (21 - 27)
Silver (mg/kg)	<1.0 (<1.0 - <1.0)	<1.0 (<1.0 - <1.0)	<1.0 (<1.0 - <1.0)	<1.0 (<1.0 - <1.0)	1 (<1.0 - 2.0)	<1.0 (<1.0 - 3.0)
Zinc (mg/kg)	93 (73 - 110)	87 (48 - 120)	99 (67 - 110)	72 (34 - 120)	110 (31 - 150)	107 (82 - 160)
Total Polychlorinated Biphenyls (PCBs) (µg/kg) (3) (4)	18 (18 - 18)	18 (18 - 18)	18 (18 - 18)	18 (18 - 18)	18 (18 - 18)	18 (18 - 18)
Low Molecular Weight Polycylic Aromatic Hydrocarbons (PAHs) (µg/kg) (5) (6) (9)	90 (90 - 90)	91 (90 - 94)	90 (90 - 90)	90 (90 - 90)	90 (90 - 90)	90 (90 - 90)
High Molecular Weight Polycylic Aromatic Hydrocarbons (PAHs) (µg/kg) (7) (8) (9)	53 (27 - 92)	87 (31 - 296)	58 (22 - 139)	31 (16 - 84)	112 (22 - 197)	81 (22 - 185)

Note : 1. Data presented are arithmetic means ; data in brackets indicate ranges.
2. All data are based on the analyses of bulk (unsieved) sediment and are reported on a dry weight basis unless stated otherwise.
3. The Technical Circular 'ETWB (W) No. 34/2002 Management of Dredged / Excavated Sediment' issued in 2002 has revised the definition of 'Total PCBs' as the summation of 18 specific PCB congeners. Following the new definition, the monitoring of these 18 PCB congeners started in 2002 and the Total PCBs results only refer to 2002 and 2003.
4. Total PCBs results are derived from the summation of 18 congeners. If the concentration of a congener is below report limit (RL), the result will be taken as 0.5xRL in the calculation.
5. Low molecular weight polyaromatic hydrocarbons (PAHs) include 6 congeners of molecular weight below 200, namely : Acenaphthene, Acenaphthylene, Anthracene, Fluorene, Naphthalene and Phenanthrene.
6. As the monitoring of Naphthalene only started in 2002, the Low Molecular Weight PAHs results are based on sediments samples collected in 2002 and 2003.
7. High molecular weight polyaromatic hydrocarbons (PAHs) include 10 congeners of molecular weight above 200, namely : Fluoranthene, Pyrene, Benzo(a) anthracene, Chrysene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Benzo(a)pyrene, Dibenzo(a,h)anthracene, Benzo(g,h,i)perylene and Indeno(1,2,3-cd) pyrene.
8. High Molecular Weight PAHs results are based on sediment samples collected in five years (1999-2003).
9. Low and high molecular weight PAHs results are derived from the summation of the corresponding congeners. If the concentration of a congener is below report limit (RL), the result will be taken as 0.5xRL in the calculation.

Table 12.6

Summary statistics of bottom sediment quality of the Eastern Buffer and Victoria Harbour WCZs, 1999 – 2003

Parameter	Eastern Buffer			Victoria Harbour			Rambler Channel	
	Chai Wan ES1	Tathong Channel ES2	ES4	(East) VS3	(Central) VS5	(West) VS6	VS9	VS10
Number of samples	10	10	10	8	8	8	10	10
Particle Size Fractionation <63μm (%w/w)	54 (31 - 94)	70 (37 - 92)	59 (29 - 87)	54 (8 - 91)	69 (28 - 100)	68 (45 - 86)	86 (67 - 99)	84 (29 - 99)
Electrochemical Potential (mV)	-175 ((-246) - (-34))	-145 ((-202) - (-26))	-245 ((-349) - (-64))	-313 ((-421) - (-66))	-339 ((-408) - (-213))	-338 ((-410) - (-218))	-243 ((-365) - (-100))	-247 ((-365) - (-148))
Total Solids (%w/w)	64 (51 - 69)	56 (44 - 70)	54 (45 - 64)	52 (39 - 73)	46 (31 - 66)	48 (41 - 59)	47 (42 - 53)	42 (35 - 60)
Total Volatile Soilds (%w/w)	5 (4 - 6.6)	5.7 (4 - 7.6)	6.3 (4.9 - 8.1)	6.4 (3.2 - 8.8)	8.5 (5.2 - 12.0)	7.9 (6.3 - 9.4)	7 (6 - 7.8)	7.9 (4.8 - 9.6)
Chemical Oxygen Demand (mg/kg)	11000 (9400 - 13000)	11000 (8000 - 15000)	15000 (11000 - 18000)	18000 (7300 - 24000)	24000 (15000 - 29000)	24000 (13000 - 29000)	18000 (12000 - 25000)	20000 (13000 - 27000)
Total Carbon (%w/w)	1 (0.3 - 1.8)	0.7 (0.5 - 1.1)	0.7 (0.3 - 1.0)	0.7 (0.5 - 0.8)	0.7 (0.5 - 0.9)	0.9 (0.7 - 1.3)	0.7 (0.6 - 0.8)	0.6 (0.4 - 0.8)
Ammonical Nitrogen (mg/kg)	10 (2 - 22)	6 (2 - 10)	11 (4 - 34)	38 (1 - 240)	34 (2 - 86)	16 (1 - 42)	14 (1 - 47)	17 (3 - 34)
Total Kjeldahl Nitrogen (mg/kg)	323 (190 - 430)	361 (230 - 520)	428 (290 - 620)	493 (220 - 640)	558 (360 - 670)	457 (360 - 580)	320 (160 - 460)	457 (270 - 630)
Total Phosphorus (mg/kg)	161 (100 - 210)	181 (130 - 230)	181 (120 - 240)	179 (120 - 240)	191 (130 - 240)	230 (200 - 280)	162 (120 - 200)	217 (150 - 260)
Total Sulphide (mg/kg)	71 (10 - 140)	51 (2 - 150)	212 (13 - 360)	358 (78 - 690)	686 (170 - 1700)	256 (100 - 490)	92 (0 - 300)	357 (120 - 1100)
Total Cyanide (mg/kg)	0.1 (0.1 - 0.2)	0.1 (0.1 - 0.2)	0.2 (0.1 - 0.4)	0.2 (0.1 - 0.4)	0.3 (0.1 - 0.8)	0.2 (0.1 - 0.3)	0.1 (0.1 - 0.3)	0.3 (0.1 - 0.5)
Arsenic (mg/kg)	5.4 (3.5 - 7.0)	6.4 (4.9 - 8.3)	6.3 (4.9 - 8.1)	6.2 (0.9 - 9.4)	7.5 (5.4 - 8.5)	8.6 (6.6 - 10.0)	7 (4.0 - 9.7)	9.5 (4.6 - 11.0)
Cadmium (mg/kg)	0.1 (0.1 - 0.2)	0.1 (0.1 - 0.1)	0.2 (0.1 - 0.3)	0.4 (0.1 - 0.9)	0.7 (0.3 - 1.0)	0.5 (0.4 - 0.6)	0.5 (0.1 - 1.3)	0.9 (0.3 - 2.4)
Chromium (mg/kg)	24 (15 - 36)	29 (20 - 41)	35 (23 - 54)	44 (12 - 100)	50 (28 - 70)	48 (34 - 60)	58 (33 - 88)	109 (48 - 190)
Copper (mg/kg)	44 (17 - 87)	29 (16 - 48)	84 (54 - 140)	136 (27 - 330)	163 (84 - 250)	141 (95 - 210)	147 (11 - 320)	309 (110 - 760)
Lead (mg/kg)	25 (20 - 32)	29 (21 - 46)	40 (24 - 69)	41 (21 - 68)	55 (41 - 75)	88 (51 - 130)	62 (25 - 260)	62 (42 - 76)
Mercury (mg/kg)	0.19 (0.06 - 1)	0.07 (<0.05 - 0.13)	0.18 (0.09 - 0.3)	0.31 (<0.05 - 0.72)	0.36 (0.20 - 0.50)	1.62 (0.29 - 8.00)	0.21 (<0.05 - 0.40)	0.2 (0.09 - 0.34)
Nickel (mg/kg)	13 (10 - 18)	18 (13 - 23)	17 (8 - 22)	17 (6 - 30)	21 (12 - 31)	20 (16 - 24)	30 (19 - 38)	46 (16 - 110)
Silver (mg/kg)	<1.0 (<1.0 - 2.0)	<1.0 (<1.0 - 1.0)	2.1 (1.0 - 3.0)	3.6 (<1.0 - 6.0)	6.7 (3.0 - 11.0)	4.1 (3.0 - 6.0)	3.7 (<1.0 - 10.0)	9.3 (3.0 - 19.0)
Zinc (mg/kg)	67 (46 - 100)	74 (54 - 110)	102 (63 - 140)	137 (17 - 240)	200 (110 - 300)	192 (120 - 250)	128 (62 - 200)	192 (94 - 270)
Total Polychlorinated Biphenyls (PCBs) (μg/kg) (3) (4)	18 (18 - 18)	18 (18 - 18)	18 (18 - 18)	18 (18 - 19)	19 (18 - 19)	21 (18 - 25)	18 (18 - 19)	21 (18 - 30)
Low Molecular Weight Polycylic Aromatic Hydrocarbons (PAHs) (μg/kg) (5) (6) (9)	90 (90 - 90)	90 (90 - 90)	96 (93 - 101)	106 (90 - 124)	107 (90 - 118)	140 (113 - 169)	90 (90 - 90)	93 (90 - 99)
High Molecular Weight Polycylic Aromatic Hydrocarbons (PAHs) (μg/kg) (7) (8) (9)	83 (21 - 160)	52 (30 - 143)	141 (74 - 265)	337 (66 - 689)	476 (278 - 712)	1997 (357 - 5780)	153 (16 - 433)	194 (89 - 339)

Note :
1. Data presented are arithmetic means ; data in brackets indicate ranges.
2. All data are based on the analyses of bulk (unsieved) sediment and are reported on a dry weight basis unless stated otherwise.
3. The Technical Circular 'ETWB (W) No. 34/2002 Management of Dredged / Excavated Sediment' issued in 2002 has revised the definition of 'Total PCBs' as the summation of 18 specific PCB congeners. Following the new definition, the monitoring of these 18 PCB congeners started in 2002 and the Total PCBs results only refer to 2002 and 2003.
4. Total PCBs results are derived from the summation of 18 congeners. If the concentration of a congener is below report limit (RL), the result will be taken as 0.5xRL in the calculation.
5. Low molecular weight polyaromatic hydrocarbons (PAHs) include 6 congeners of molecular weight below 200, namely : Acenaphthene, Acenaphthylene, Anthracene, Fluorene, Naphthalene and Phenanthrene.
6. As the monitoring of Naphthalene only started in 2002, the Low Molecular Weight PAHs results are based on sediments samples collected in 2002 and 2003.
7. High molecular weight polyaromatic hydrocarbons (PAHs) include 10 congeners of molecular weight above 200, namely : Fluoranthene, Pyrene, Benzo(a) anthracene, Chrysene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Benzo(a)pyrene, Dibenzo(a,h)anthracene, Benzo(g,h,i)perylene and Indeno(1,2,3-cd) pyrene.
8. High Molecular Weight PAHs results are based on sediment samples collected in five years (1999-2003).
9. Low and high molecular weight PAHs results are derived from the summation of the corresponding congeners. If the concentration of a congener is below report limit (RL), the result will be taken as 0.5xRL in the calculation.

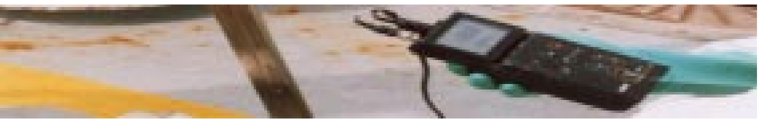


Table 12.7

Sediment Quality Criteria for the Classification of Sediments[1]

Contaminants	Lower Chemical Exceedance Level (LCEL)	Upper Chemical Exceedance Level (UCEL)
Metals *(mg/kg dry weight)*		
Cadmium (Cd)	1.5	4
Chromium (Cr)	80	160
Copper (Cu)	65	110
Mercury (Hg)	0.5	1
Nickel (Ni) [2]	40	40
Lead (Pb)	75	110
Silver (Ag)	1	2
Zinc (Zn)	200	270
Metalloid *(mg/kg dry weight)*		
Arsenic (As)	12	42
Organic-PAHs *(mg/kg dry weight)*		
Low Molecular Weight PAHs [3]	550	3160
High Molecular Weight PAHs [4]	1700	9600
Organic-non-PAHs *(mg/kg dry weight)*		
Total PCBs	23	180
Organometallics *(mg TBT/L in Interstitial water)*		
Tributyltin [2]	0.15	0.15

Footnote : 1. The table is extracted from Appendix A of ETWB (W) No. 34/2002 Management of Dredged / Excavated Sediment (http://www.etwb.gov.hk).

2. When the LCEL and UCEL for a contaminant are the same, the contaminant level is considered to have exceeded UCEL if it is greater than the value shown.
3. Low molecular weight PAHs include acenaphthene, acenaphthylene, anthracene, fluorene, naphthalene, and phenanthrene.
4. High molecular weight PAHs include benzo[a]anthracene, benzo[a]pyrene, chrysene, dibenzo[a,h]anthracene, fluoranthene, pyrene, benzo[b]fluoranthene, benzo[k]fluoranthene, indeno[1,2,3-c,d]pyrene and benzo[g,h,i] perylene.
5. Total PCBs include 18 congeners: PCB 8, 18, 28, 44, 52, 66, 77, 101, 105, 118, 126, 128, 138, 153, 169, 170, 180, 187.

CHAPTER 13

TYPHOON SHELTER

Chapter 13 – Typhoon Shelters

Water Quality in 2003

13.1 Typhoon shelters are port facilities which provide refuge for vessels during the advent of typhoons. These embayments are largely enclosed with low water exchange with open waters and are highly vulnerable to pollution from storm-drains, surface-runoff and vessels. In 2003, monitoring was carried out at 18 water and 15 sediment stations in 17 typhoon shelters and sheltered anchorages in the territory (Figure 1.4). A summary of the water quality data is shown in Table 13.1, while the key results are presented in Figure 13.1.

13.2 Like other port facilities, typhoon shelters are managed by the Marine Department (http://www.mardep.gov.hk). The Marine Department is responsible for controlling pollution from ships by enforcing environmental legislation such as the 'Merchant Shipping (Prevention and Control of Pollution) Ordinance' and the 'Shipping and Port Control Ordinance'. In addition, it also cleans up floating refuse in typhoon shelters and other marine waters.

13.3 The older typhoon shelters used to receive discharges from storm-drains and contaminated by wastewater from expedient connections. Many such connections have been rectified during the implementation of Sewerage Master Plans and the enforcement of Water Pollution Control Ordinance (WPCO).

Water Quality in 2003

13.4 In 2003, an increase of dissolved oxygen (DO) was observed in many typhoon shelters in the Victoria Harbour area, including Chai Wan, Causeway Bay, Kwun Tong and Yau Ma Tei. The increases ranged 13-106%, highest at Kwun Tong Typhoon Shelter.

13.5 In the eastern Victoria Harbour, notable decreases in *E. coli* and ammonia nitrogen (NH_4-N) in Chai Wan, Aldrich Bay (Shau Kei Wan), Sam Ka Tsuen and To Kwa Wan Typhoon Shelters were observed in 2002 after the commissioning of the Harbour Area Treatment Scheme (HATS) Stage I. These improvements were sustained in 2003.

13.6 The two typhoon shelters in Sai Kung, Yim Tin Tsai and Hebe Haven, continued to have the best water quality in the territory, while Kwun Tong Typhoon Shelter the poorest, with highest *E. coli*, NH_4-N and total inorganic nitrogen (TIN) (Figure 3.1). In addition, Causeway Bay, Rambler Channel and Yau Ma Tei Typhoon Shelters also had high levels of *E. coli* content (5,000 –

8,000 cfu/100mL) indicating faecal contamination.

Long-term Water Quality Trends

13.7 Except Hei Ling Chau Typhoon Shelter and Government Dockyard which had less than 10 years of monitoring data which were insufficient to perform statistical analysis, the long-term water quality trends in other 15 typhoon shelters (16 monitoring stations) are shown in Table 13.3. Long-term improvement trends (i.e. increase in DO and decreases in BOD_5, *E. coli* and NH_4-N) were observed in Causeway Bay, Kwun Tong, Sam Ka Tsuen and Sai Kung Typhoon Shelters.

Sediment Quality

13.8 Results of sediment monitoring in typhoon shelters between 1999 and 2003 are summarised in Table 13.2. The mean concentrations of contaminants as compared to those listed in the document '*ETWB(W) No. 34/2002 - Management of Dredged / Excavated Sediment*' (Table 12.7) are presented in Figures 13.2 – 13.13.

13.9 Contamination of sediments by copper and silver was commonly observed in the typhoon shelter sediments in the Victoria Harbour and Eastern Buffer WCZs. Kwun Tong Typhoon Shelter had the highest level of metals, with cadmium, chromium, copper, mercury, nickel, lead, silver and zinc, all exceeded the 'Upper Chemical Exceedance Levels (UCELs)'. Rambler Channel Typhoon Shelter was also heavily contaminated with chromium, copper, nickel, silver and zinc, exceeded the UCELs.

13.10 Among the trace organics, the level of total Polychlorinated Biphenyls (PCBs) in the sediment of Kwun Tong Typhoon Shelter was the highest, above the UCEL value. The high concentrations of metals and PCBs in Kwun Tong Typhoon Shelter were related to discharges from printed circuit board, electroplating and electronic industries in the Kwun Tong industrial area between the 60s and 80s.

13.11 The levels of Total PCBs in sediments in most other typhoon shelters were below the 'Lower Chemical Exceedance Levels (LCELs)' (Figure 13.11). Elevated levels (i.e. between LCEL and UCEL) were found in Sam Ka Tsuen, To Kwa Wan, Rambler Channel and Chai Wan Typhoon Shelters.

13.12 The levels of high and low molecular weight Polycyclic Aromatic Hydrocarbons (PAHs) in the typhoon shelter sediments were also all below the LCELs with the exception of To Kwa Wan

Typhoon Shelter (Figures 13.12 and 13.13), where the concentrations exceeded the UCELs. The contamination of PAHs in To Kwa Wan Typhoon Shelter was likely to be related to contamination by aviation fuel from the former Kai Tak Airport.

Electrochemical Potential

13.13 Organic-enriched and highly anoxic (i.e. with negative electrochemical potentials) sediments were found in the typhoon shelters of the Victoria Harbour and Eastern Buffer WCZs (Figure 13.14). High levels of sulphide (above 1,000mg/kg dry weight) were found in the sediments of Kwun Tong, Sam Ka Tsuen and Aldrich Bay Typhoon Shelters.

Figure 13.1 Water quality of typhoon shelters in Hong Kong in 2003

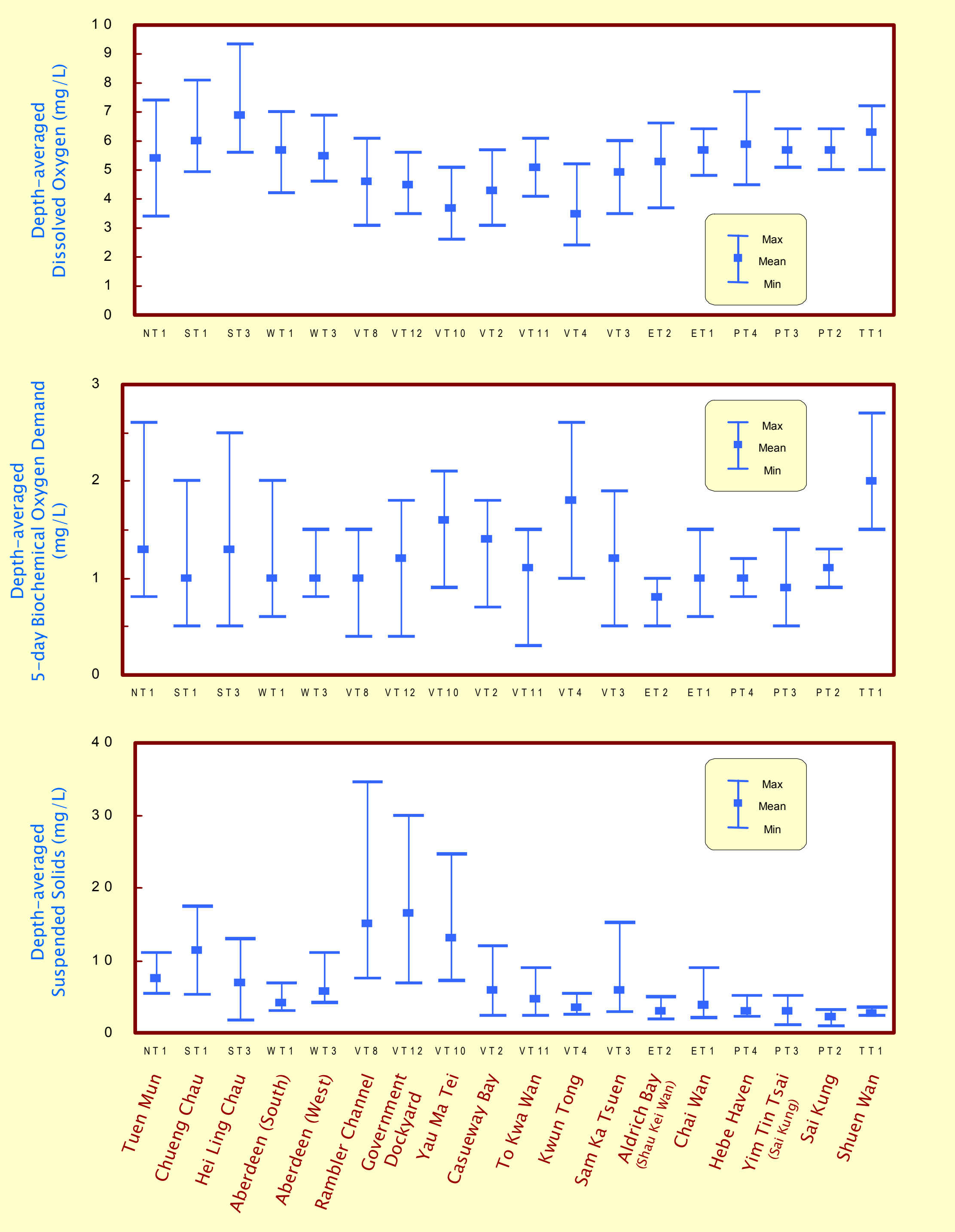


Figure 13.1 Water quality of typhoon shelters in Hong Kong in 2003 (continued)

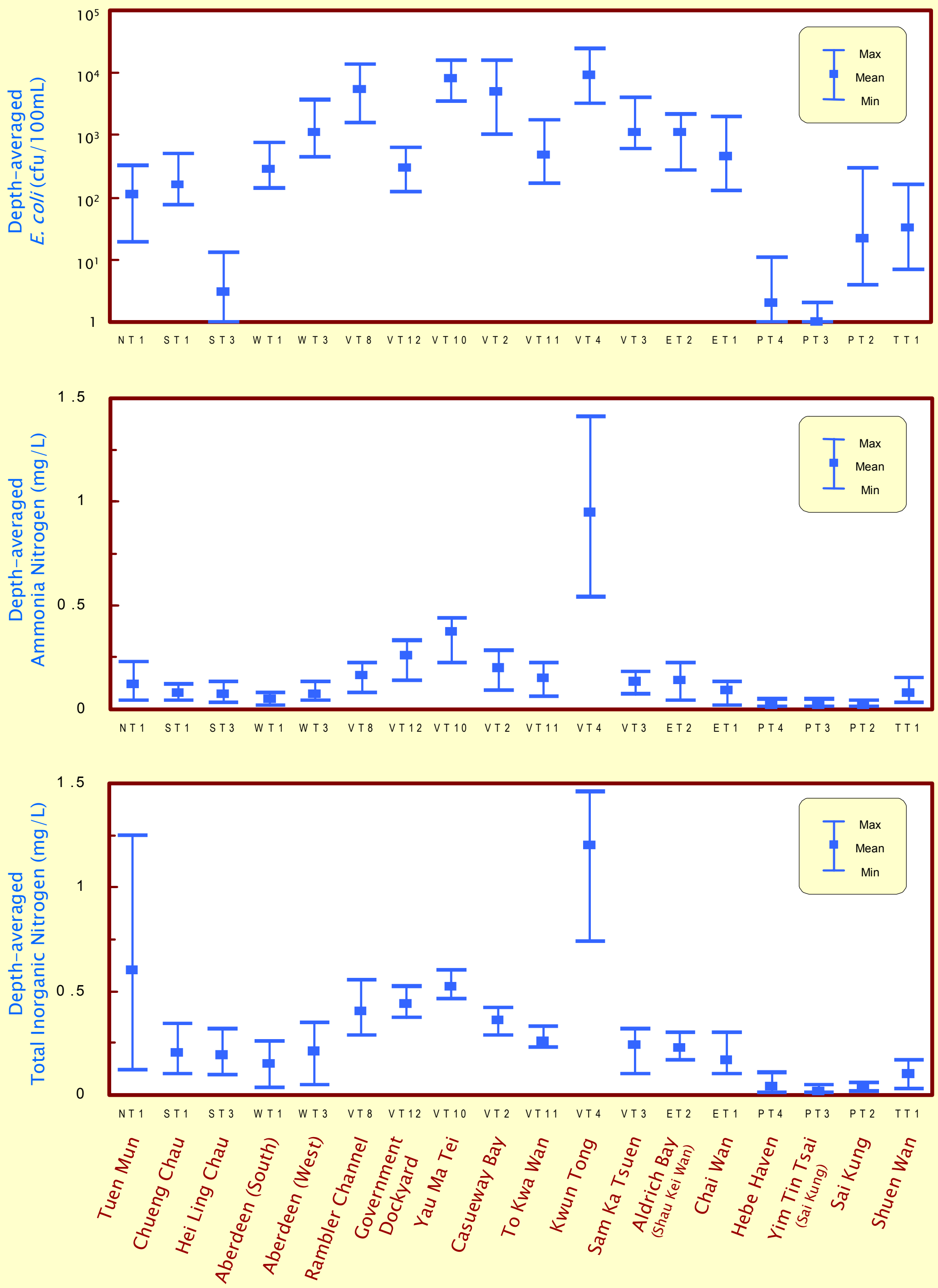


Figure 13.2 Cadmium in typhoon shelter sediments in Hong Kong, 1999 – 2003

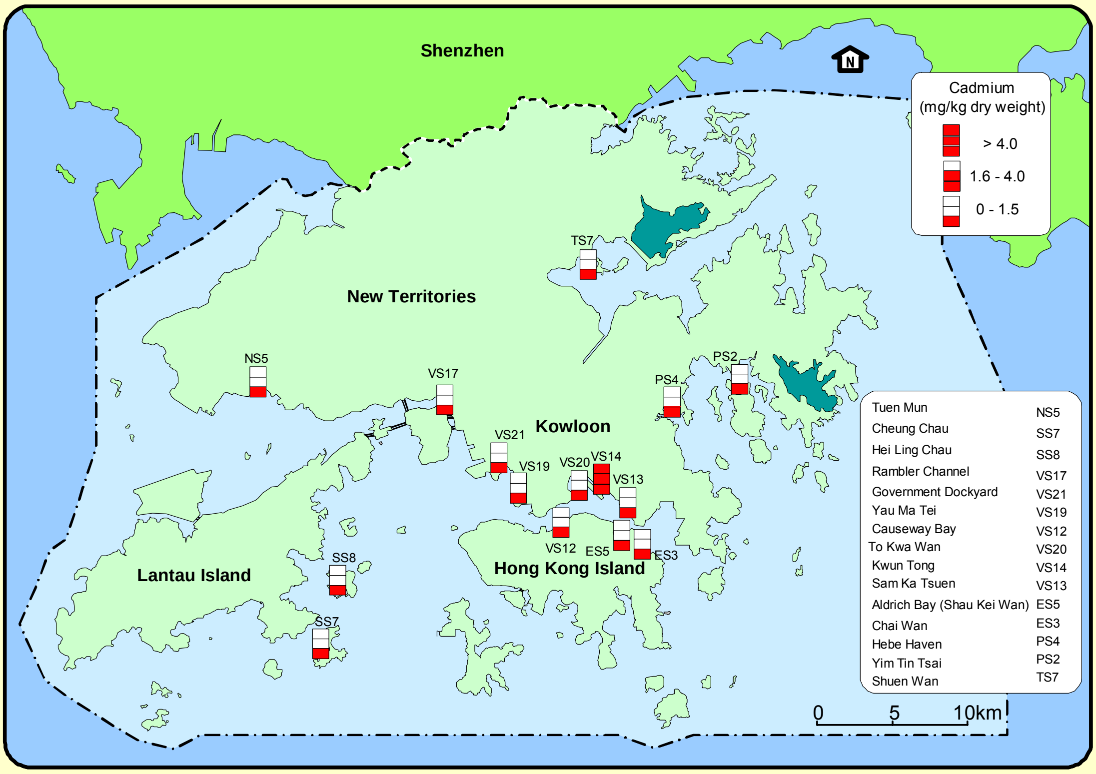


Figure 13.3 Chromium in typhoon shelter sediments in Hong Kong, 1999 – 2003

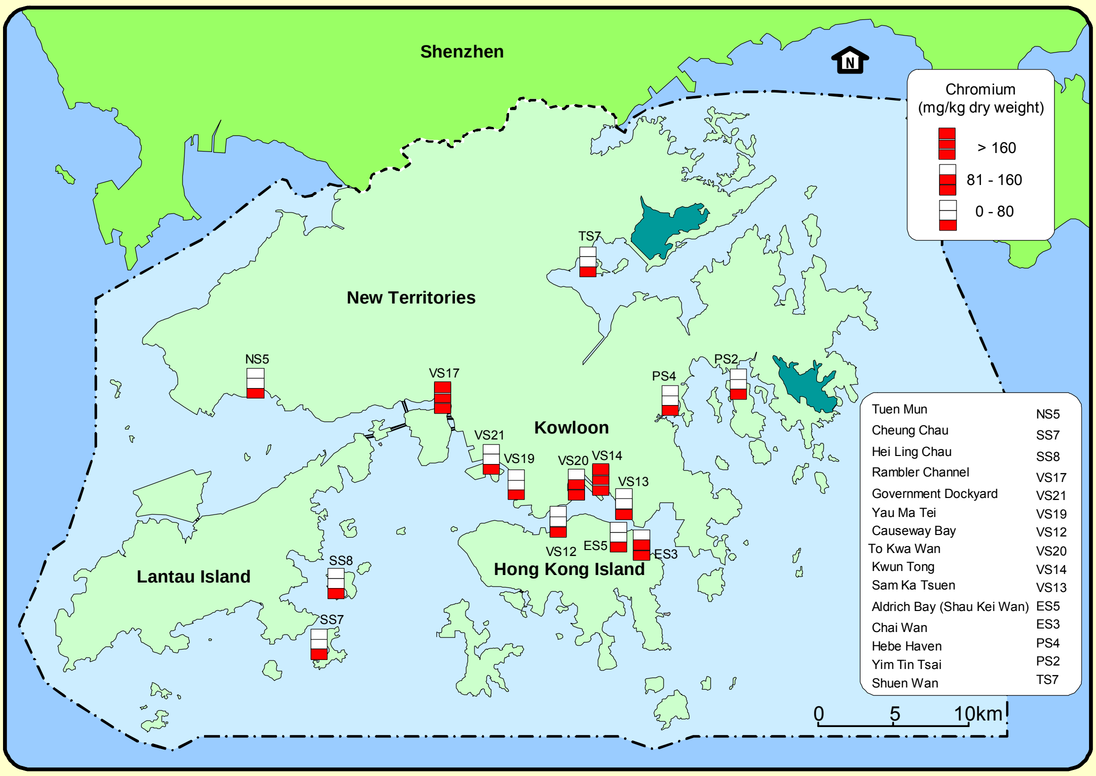


Figure 13.4 Copper in typhoon shelter sediments in Hong Kong, 1999 – 2003

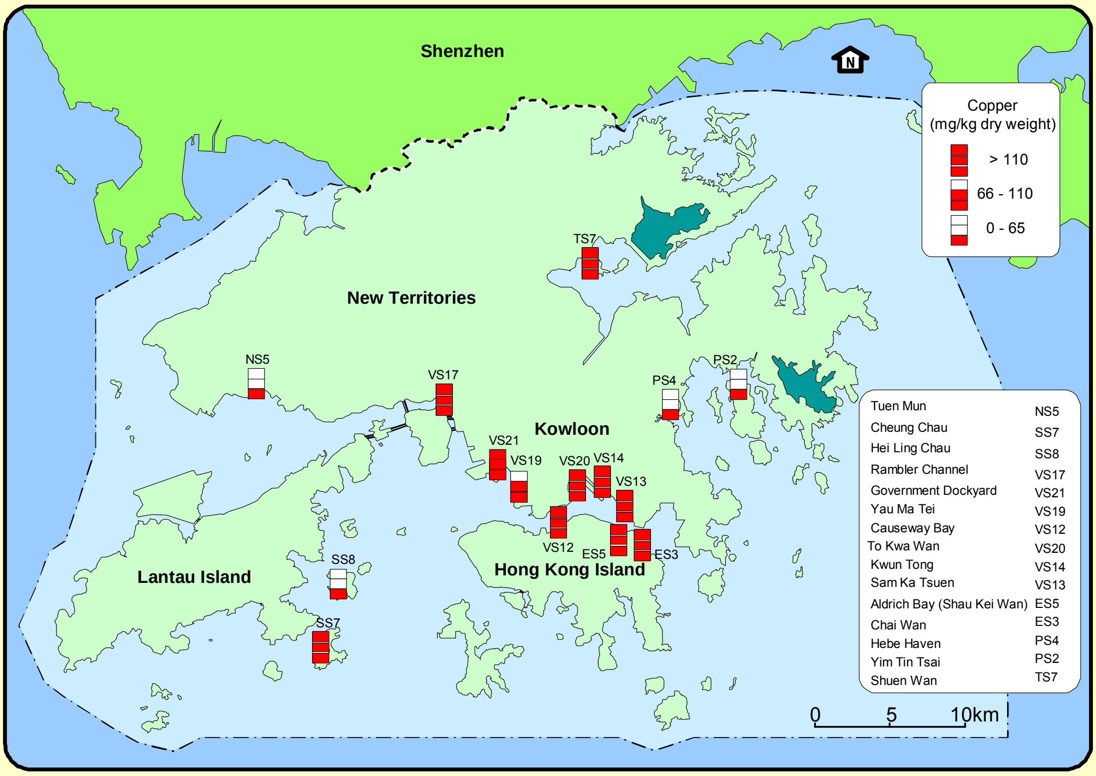


Figure 13.5 Mercury in typhoon shelter sediments in Hong Kong, 1999 – 2003

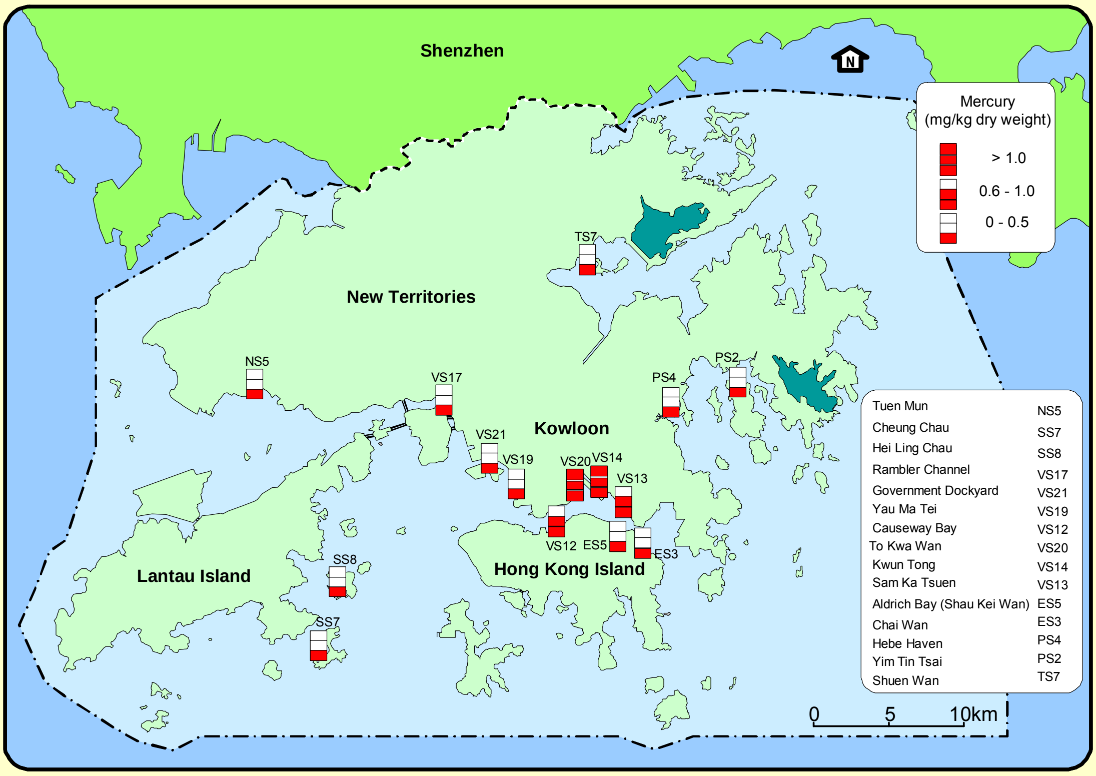


Figure 13.6 Nickel in typhoon shelter sediments in Hong Kong, 1999 – 2003

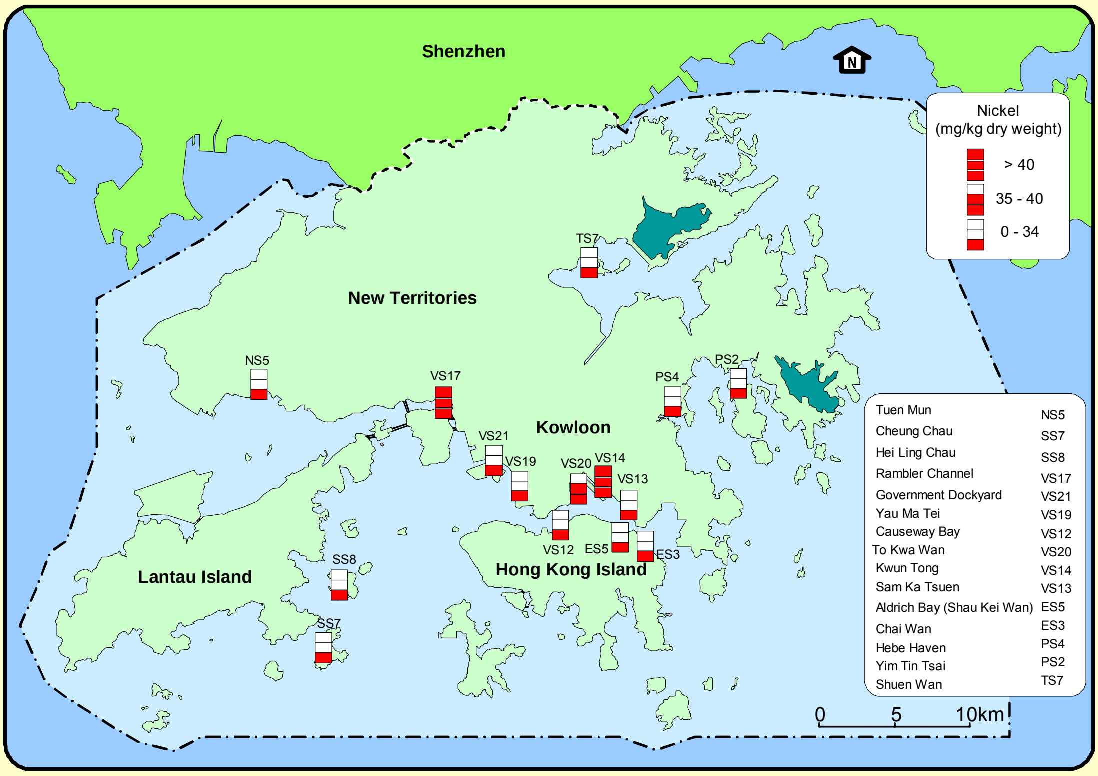


Figure 13.7 Lead in typhoon shelter sediments in Hong Kong, 1999 – 2003

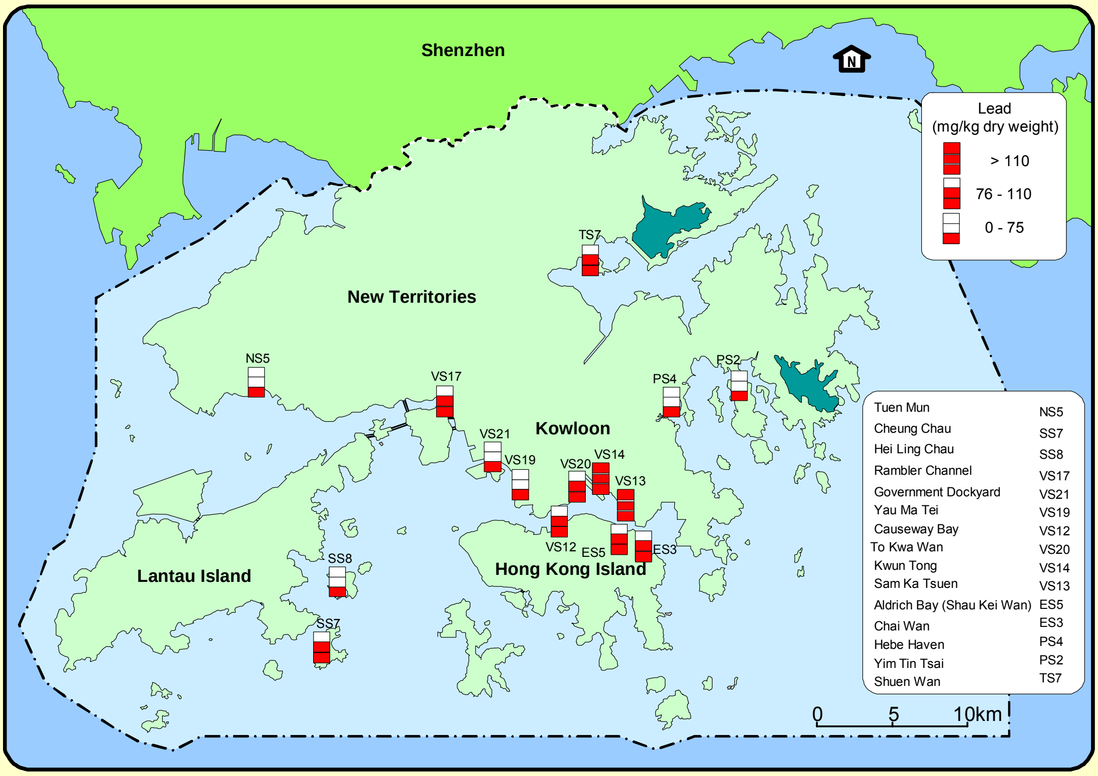


Figure 13.8 Silver in typhoon shelter sediments in Hong Kong, 1999 – 2003

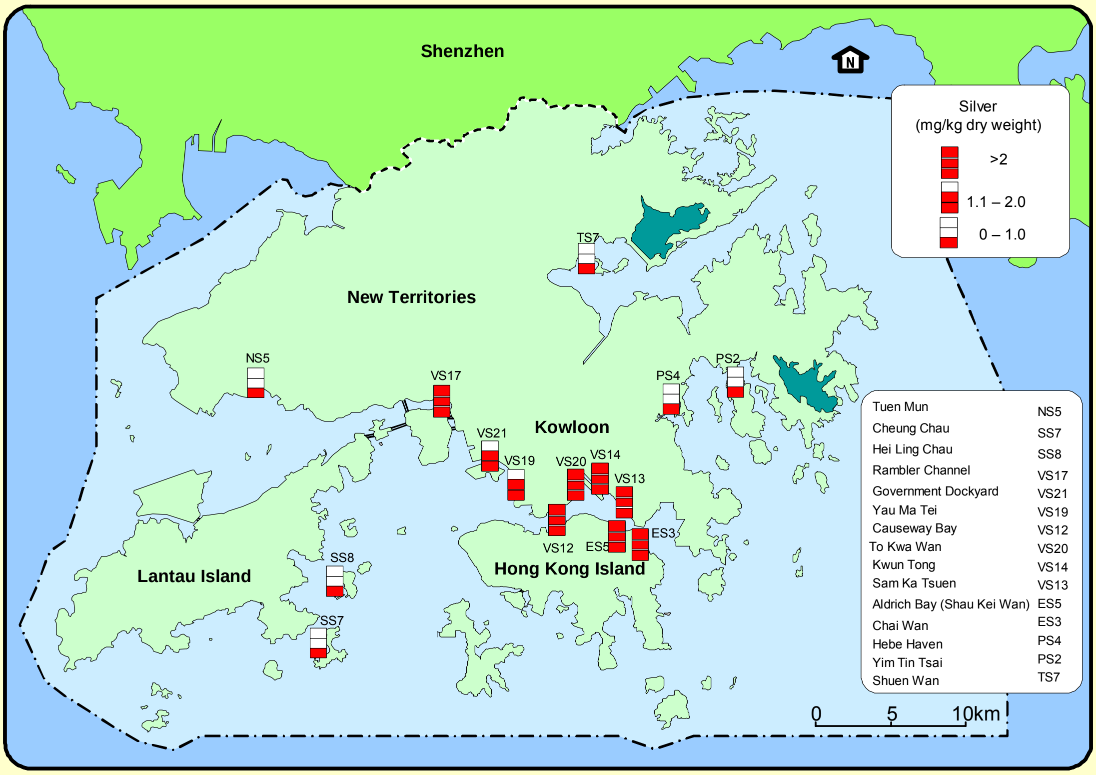


Figure 13.9 Zinc in typhoon shelter sediments in Hong Kong, 1999 – 2003

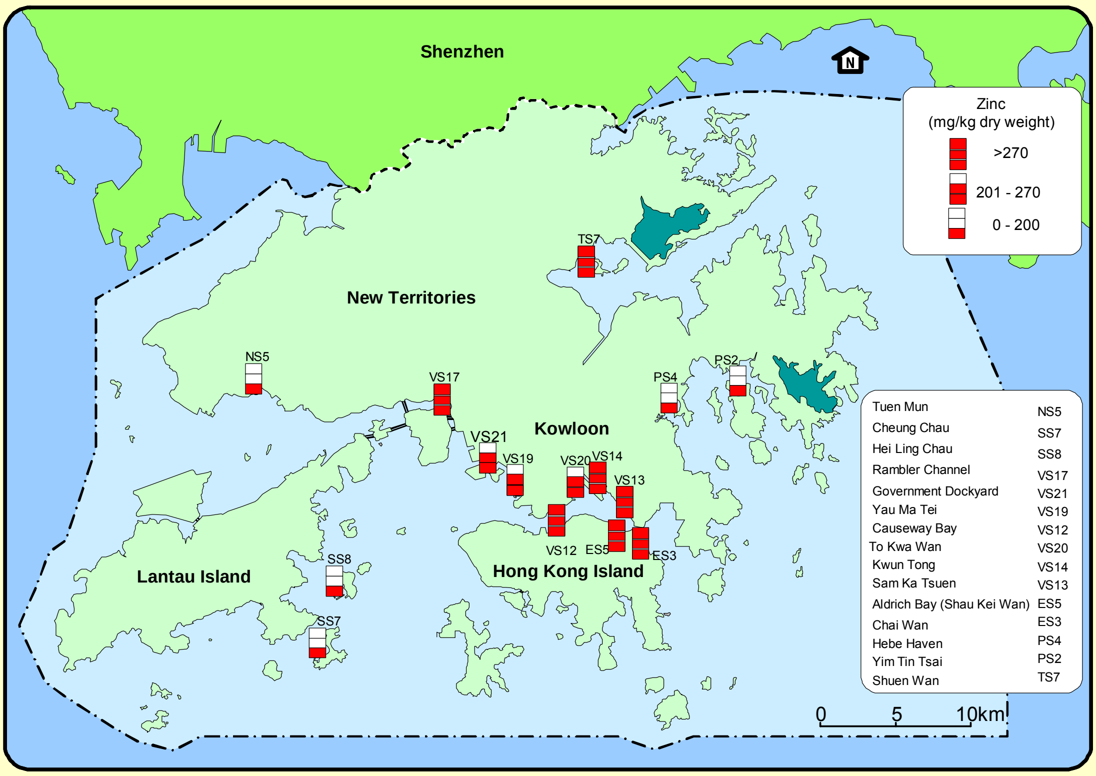


Figure 13.10 Arsenic in typhoon shelter sediments in Hong Kong, 1999 – 2003

Figure 13.11 Total polychlorinated biphenyls (PCBs) in typhoon shelter sediments in Hong Kong, 2002 – 2003

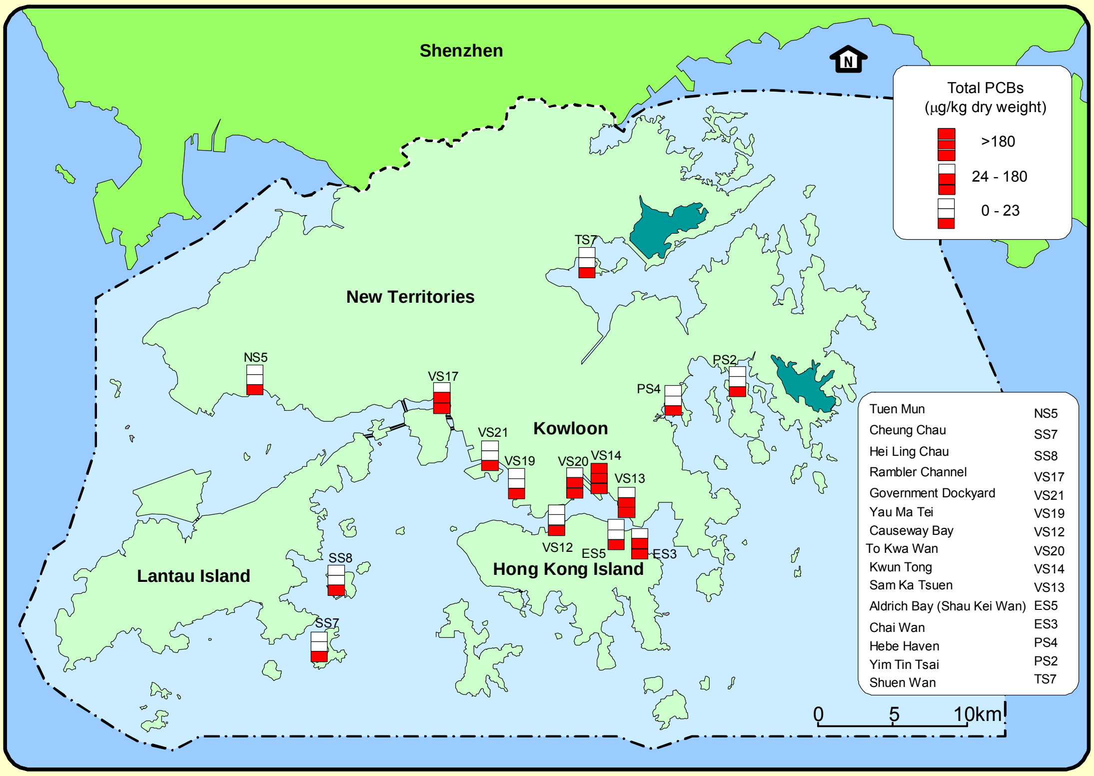


Figure 13.12 Low molecular weight polycyclic aromatic hydrocarbons (PAHs) in typhoon shelter sediments in Hong Kong, 2002 – 2003

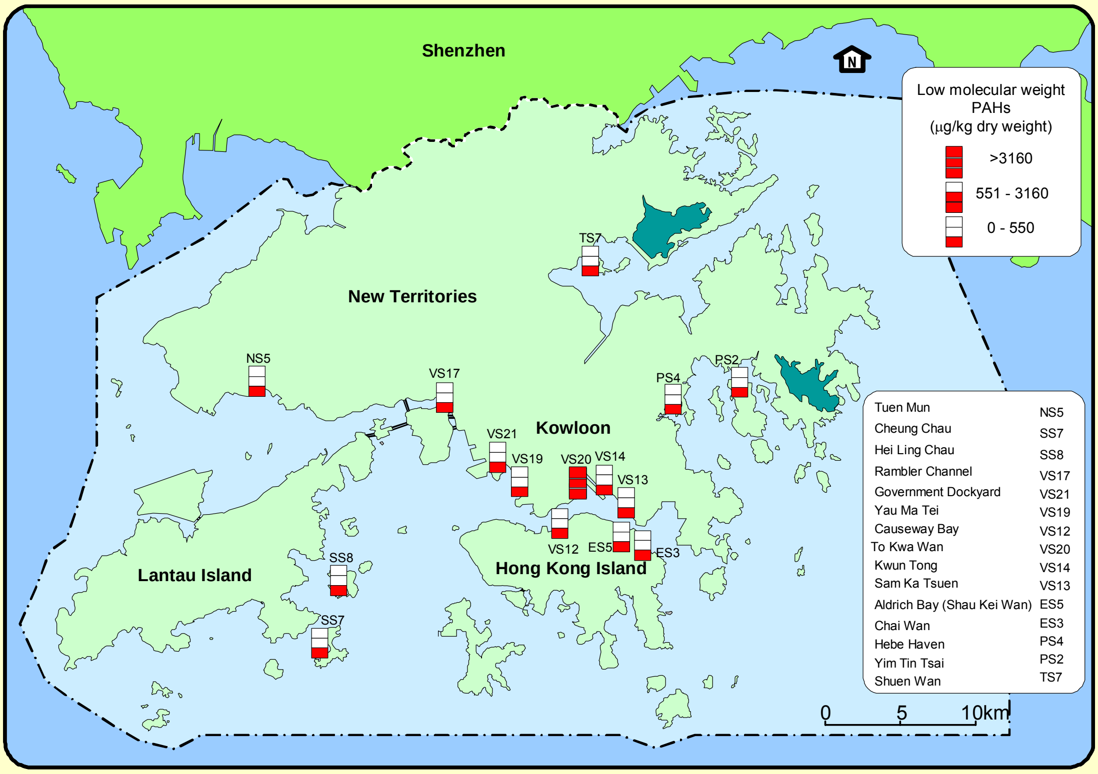


Figure 13.13 High molecular weight polycyclic aromatic hydrocarbons (PAHs) in typhoon shelter sediments in Hong Kong, 1999 – 2003

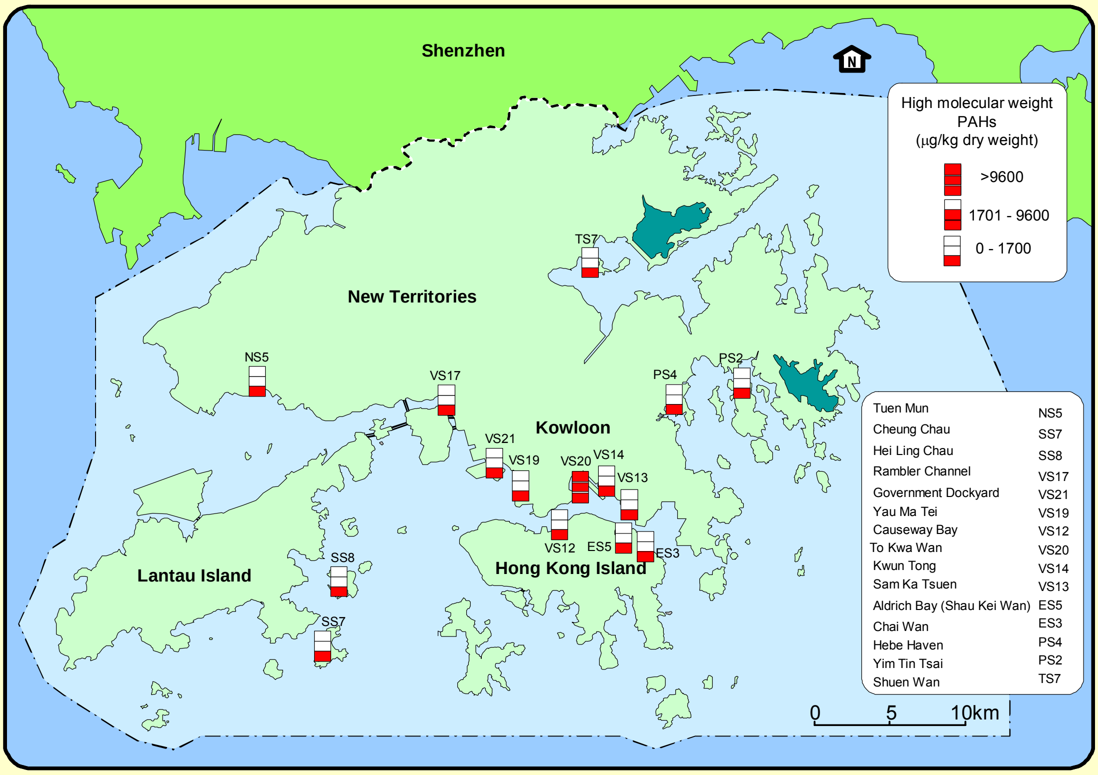


Figure 13.14 Electrochemical potential in typhoon shelter sediments in Hong Kong, 1999 – 2003

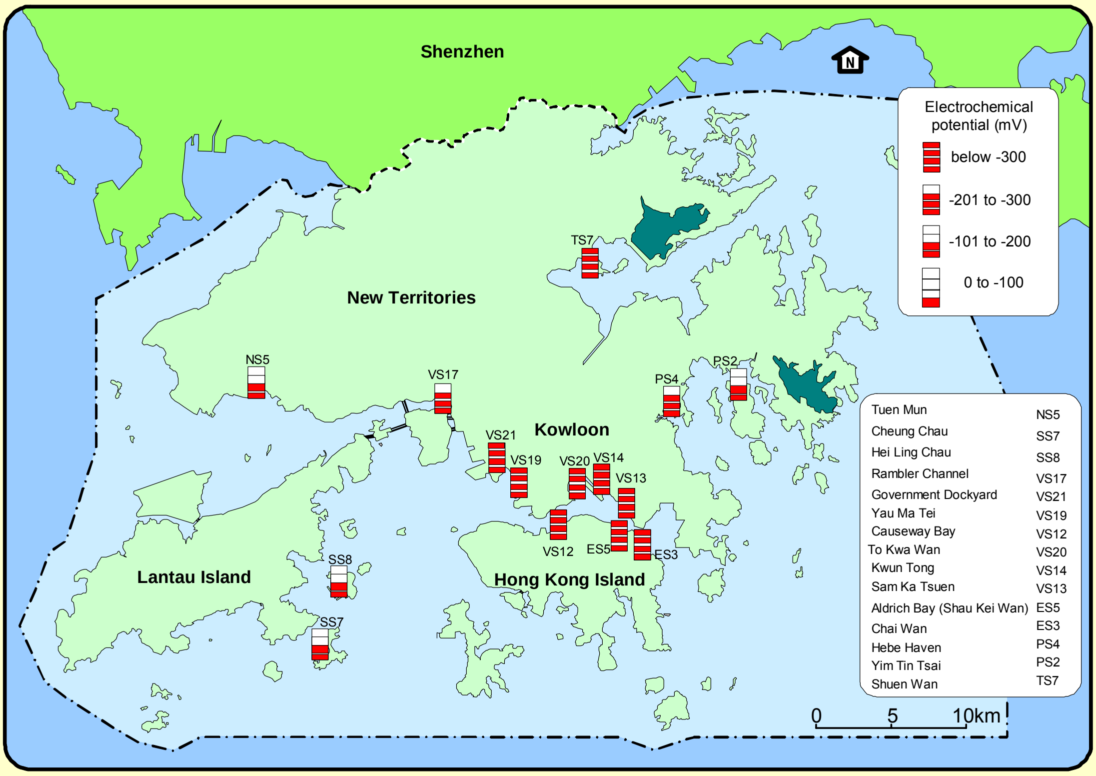


Table 13.1

Summary water quality statistics of the typhoon shelters in 2003

Parameter	Tuen Mun NT1	Cheung Chau ST1	Hei Ling Chau ST3	Aberdeen (South) WT1	Aberdeen (West) WT3	Rambler Channel VT8
Number of samples	6	6	6	6	6	6
Temperature (°C)	24.2 (17.3 - 29.4)	24.2 (17.2 - 28.7)	24.2 (17.5 - 28.6)	24.1 (18.6 - 27.6)	24.0 (18.6 - 27.7)	23.8 (17.5 - 27.7)
Salinity	26.3 (17.7 - 32.2)	31.5 (29.3 - 33.4)	31.1 (28.8 - 33.1)	31.3 (26.5 - 33.7)	31.3 (27.1 - 33.6)	30.0 (26.4 - 32.7)
Dissolved Oxygen (mg/L)	5.4 (3.4 - 7.4)	6.0 (4.9 - 8.1)	6.9 (5.6 - 9.3)	5.7 (4.2 - 7.0)	5.5 (4.6 - 6.9)	4.6 (3.1 - 6.1)
Bottom	N.M.	6.0 (5.0 - 7.9)	6.9 (5.6 - 9.4)	5.7 (4.4 - 6.7)	5.2 (3.3 - 6.8)	4.8 (3.1 - 6.0)
Dissolved Oxygen (% Saturation)	74 (49 - 93)	86 (71 - 124)	99 (81 - 142)	82 (63 - 104)	78 (68 - 91)	65 (45 - 78)
Bottom	N.M.	86 (72 - 121)	99 (78 - 142)	81 (67 - 87)	73 (47 - 90)	67 (45 - 85)
pH	8.1 (7.9 - 8.3)	8.2 (7.9 - 8.4)	8.2 (7.9 - 8.4)	8.0 (7.5 - 8.3)	8.0 (7.8 - 8.3)	8.1 (8.0 - 8.3)
Secchi Disc Depth (m)	1.6 (0.6 - 2.3)	1.3 (0.5 - 2.2)	1.7 (1.0 - 3.1)	2.6 (2.1 - 3.7)	2.1 (1.3 - 2.5)	1.4 (0.5 - 2.3)
Turbidity (NTU)	11.1 (6.3 - 14.5)	12.0 (5.3 - 16.1)	9.5 (2.6 - 14.5)	7.5 (3.9 - 9.1)	8.9 (4.3 - 14.0)	12.9 (7.4 - 20.4)
Suspended Solids (mg/L)	7.6 (5.4 - 11.0)	11.4 (5.3 - 17.5)	6.9 (1.8 - 13.0)	4.2 (3.0 - 6.9)	5.8 (4.2 - 11.0)	15.1 (7.5 - 34.5)
5-day Biochemical Oxygen Demand (mg/L)	1.3 (0.8 - 2.6)	1.0 (0.5 - 2.0)	1.3 (0.5 - 2.5)	1.0 (0.6 - 2.0)	1.0 (0.8 - 1.5)	1.0 (0.4 - 1.5)
Ammonia Nitrogen (mg/L)	0.12 (0.04 - 0.23)	0.08 (0.04 - 0.12)	0.07 (0.03 - 0.13)	0.05 (0.02 - 0.08)	0.07 (0.04 - 0.13)	0.16 (0.08 - 0.22)
Unionised Ammonia (mg/L)	0.006 (0.003 - 0.010)	0.005 (0.002 - 0.006)	0.004 (0.001 - 0.007)	0.002 (0.001 - 0.005)	0.003 (0.001 - 0.007)	0.009 (0.004 - 0.017)
Nitrite Nitrogen (mg/L)	0.07 (0.01 - 0.22)	0.02 (<0.01 - 0.05)	0.02 (0.01 - 0.06)	0.01 (<0.01 - 0.05)	0.02 (<0.01 - 0.07)	0.04 (0.02 - 0.12)
Nitrate Nitrogen (mg/L)	0.41 (0.03 - 0.94)	0.11 (0.04 - 0.24)	0.10 (0.04 - 0.23)	0.09 (0.01 - 0.19)	0.11 (0.01 - 0.26)	0.21 (0.09 - 0.44)
Total Inorganic Nitrogen (mg/L)	0.60 (0.12 - 1.25)	0.21 (0.10 - 0.35)	0.19 (0.10 - 0.32)	0.15 (0.04 - 0.26)	0.21 (0.05 - 0.35)	0.40 (0.29 - 0.55)
Total Kjeldahl Nitrogen (mg/L)	0.28 (0.22 - 0.41)	0.24 (0.20 - 0.27)	0.23 (0.15 - 0.29)	0.18 (0.10 - 0.33)	0.21 (0.11 - 0.31)	0.33 (0.25 - 0.41)
Total Nitrogen (mg/L)	0.76 (0.31 - 1.45)	0.37 (0.27 - 0.53)	0.35 (0.19 - 0.54)	0.28 (0.11 - 0.54)	0.34 (0.13 - 0.60)	0.58 (0.50 - 0.73)
Orthophosphate Phosphorus (mg/L)	0.029 (0.01 - 0.05)	0.015 (<0.01 - 0.03)	0.012 (<0.01 - 0.03)	0.011 (0.01 - 0.02)	0.015 (0.01 - 0.03)	0.029 (0.02 - 0.04)
Total Phosphorus (mg/L)	0.06 (0.03 - 0.10)	0.04 (0.03 - 0.05)	0.03 (0.02 - 0.04)	0.03 (0.02 - 0.04)	0.03 (0.02 - 0.05)	0.06 (0.05 - 0.08)
Silica (as SiO_2) (mg/L)	2.1 (0.1 - 5.0)	0.7 (0.4 - 1.1)	0.6 (0.4 - 1.0)	0.6 (0.3 - 1.2)	0.8 (0.4 - 1.4)	1.2 (0.4 - 2.1)
Chlorophyll-*a* (μg/L)	3.1 (1.8 - 4.9)	6.3 (0.9 - 18.3)	7.9 (1.0 - 19.0)	3.9 (0.8 - 15.4)	3.9 (0.7 - 16.8)	2.1 (0.8 - 3.7)
E.coli (cfu/100mL)	110 (19 - 330)	160 (76 - 510)	3 (1 - 13)	280 (140 - 750)	1100 (450 - 3700)	5400 (1600 - 14000)
Faecal Coliforms (cfu/100mL)	750 (140 - 4100)	440 (150 - 1100)	5 (2 - 31)	820 (210 - 2600)	2100 (1100 - 5700)	13000 (3700 - 32000)

Note :
1. Unless otherwise specified, data presented are depth-averaged (A) values calculated by taking the means of three depths: Surface (S), Mid-depth (M), Bottom (B).
2. Data presented are annual arithmetic means of the depth-averaged results except for *E.coli* and faecal coliforms which are annual geometric means.
3. Data in brackets indicate the ranges.
4. NM - not measured

Table 13.1 (continued)

Summary water quality statistics of the typhoon shelters in 2003

Parameter	Government Dockyard VT12	Yau Ma Tei VT10	Causeway Bay VT2	To Kwa Wan VT11	Kwun Tong VT4	Sam Ka Tsuen VT3
Number of samples	6	6	6	6	6	6
Temperature (°C)	24.1 (18.0 - 27.7)	23.9 (17.6 - 27.5)	23.7 (17.4 - 27.1)	23.2 (17.3 - 27.0)	23.5 (17.5 - 27.1)	23.3 (17.2 - 27.1)
Salinity	30.4 (27.3 - 32.2)	30.6 (27.0 - 32.1)	31.1 (28.2 - 32.2)	32.1 (31.4 - 32.7)	30.9 (30.0 - 32.4)	31.9 (29.9 - 32.8)
Dissolved Oxygen (mg/L)	4.5 (3.5 - 5.6)	3.7 (2.6 - 5.1)	4.3 (3.1 - 5.7)	5.1 (4.1 - 6.1)	3.5 (2.4 - 5.2)	4.9 (3.5 - 6.0)
Bottom	4.5 (3.6 - 5.6)	3.8 (3.1 - 5.1)	4.4 (3.1 - 5.8)	5.0 (3.7 - 6.4)	4.0 (2.6 - 5.4)	5.1 (3.6 - 6.5)
Dissolved Oxygen (% Saturation)	65 (53 - 72)	53 (39 - 65)	61 (45 - 72)	71 (59 - 80)	50 (34 - 65)	69 (50 - 79)
Bottom	64 (54 - 72)	55 (45 - 65)	62 (44 - 73)	71 (54 - 84)	57 (37 - 70)	71 (52 - 86)
pH	8.0 (7.9 - 8.2)	8.0 (7.8 - 8.1)	8.1 (7.9 - 8.3)	8.2 (8.0 - 8.4)	7.9 (7.4 - 8.1)	8.1 (7.9 - 8.4)
Secchi Disc Depth (m)	1.6 (1.0 - 2.4)	1.3 (0.5 - 1.8)	2.2 (1.3 - 2.8)	2.3 (1.5 - 3.1)	1.3 (0.2 - 2.1)	2.1 (1.5 - 2.7)
Turbidity (NTU)	16.9 (7.8 - 33.1)	14.8 (6.6 - 22.2)	7.6 (3.7 - 8.8)	8.3 (5.0 - 11.8)	7.9 (2.8 - 10.8)	8.1 (3.2 - 10.3)
Suspended Solids (mg/L)	16.5 (6.9 - 30.0)	13.2 (7.2 - 24.7)	6.0 (2.4 - 12.0)	4.6 (2.4 - 9.0)	3.6 (2.5 - 5.5)	5.9 (2.9 - 15.2)
5-day Biochemical Oxygen Demand (mg/L)	1.2 (0.4 - 1.8)	1.6 (0.9 - 2.1)	1.4 (0.7 - 1.8)	1.1 (0.3 - 1.5)	1.8 (1.0 - 2.6)	1.2 (0.5 - 1.9)
Ammonia Nitrogen (mg/L)	0.26 (0.14 - 0.33)	0.37 (0.22 - 0.44)	0.20 (0.09 - 0.28)	0.15 (0.06 - 0.22)	0.95 (0.54 - 1.41)	0.13 (0.07 - 0.18)
Unionised Ammonia (mg/L)	0.012 (0.006 - 0.022)	0.015 (0.008 - 0.028)	0.010 (0.005 - 0.021)	0.008 (0.004 - 0.018)	0.025 (0.008 - 0.041)	0.007 (0.003 - 0.012)
Nitrite Nitrogen (mg/L)	0.03 (0.02 - 0.05)	0.03 (0.02 - 0.04)	0.03 (0.01 - 0.05)	0.02 (0.01 - 0.03)	0.09 (0.01 - 0.20)	0.02 (<0.01 - 0.03)
Nitrate Nitrogen (mg/L)	0.16 (0.11 - 0.22)	0.13 (0.09 - 0.21)	0.13 (0.09 - 0.22)	0.09 (0.05 - 0.15)	0.16 (0.04 - 0.54)	0.09 (0.03 - 0.16)
Total Inorganic Nitrogen (mg/L)	0.44 (0.37 - 0.52)	0.52 (0.46 - 0.60)	0.36 (0.29 - 0.42)	0.26 (0.23 - 0.33)	1.20 (0.74 - 1.46)	0.24 (0.10 - 0.32)
Total Kjeldahl Nitrogen (mg/L)	0.47 (0.42 - 0.58)	0.63 (0.55 - 0.76)	0.43 (0.33 - 0.60)	0.33 (0.24 - 0.47)	1.24 (0.89 - 1.77)	0.29 (0.17 - 0.40)
Total Nitrogen (mg/L)	0.66 (0.62 - 0.71)	0.78 (0.71 - 0.88)	0.59 (0.45 - 0.71)	0.44 (0.36 - 0.56)	1.50 (1.09 - 1.82)	0.40 (0.20 - 0.58)
Orthophosphate Phosphorus (mg/L)	0.043 (0.03 - 0.06)	0.051 (0.03 - 0.06)	0.038 (0.02 - 0.05)	0.029 (0.02 - 0.05)	0.195 (0.05 - 0.32)	0.025 (0.01 - 0.04)
Total Phosphorus (mg/L)	0.08 (0.06 - 0.09)	0.09 (0.08 - 0.11)	0.06 (0.05 - 0.09)	0.05 (0.04 - 0.07)	0.26 (0.16 - 0.35)	0.05 (0.02 - 0.07)
Silica (as SiO_2) (mg/L)	1.1 (0.6 - 1.9)	0.9 (0.6 - 1.6)	0.8 (0.3 - 1.6)	0.7 (0.1 - 1.1)	1.7 (0.9 - 2.9)	0.6 (0.2 - 1.2)
Chlorophyll-*a* (µg/L)	4.6 (1.0 - 15.7)	3.9 (0.6 - 13.7)	4.2 (0.7 - 14.5)	4.0 (0.6 - 9.6)	5.3 (0.7 - 18.4)	4.3 (0.7 - 14.7)
E.coli (cfu/100mL)	290 (120 - 630)	8200 (3500 - 16000)	5000 (1000 - 16000)	490 (170 - 1700)	9400 (3200 - 24000)	1100 (600 - 4000)
Faecal Coliforms (cfu/100mL)	1100 (220 - 2800)	21000 (5300 - 42000)	15000 (3300 - 27000)	1300 (280 - 6500)	19000 (8700 - 47000)	2500 (1200 - 13000)

Note :
1. Unless otherwise specified, data presented are depth-averaged (A) values calculated by taking the means of three depths: Surface (S), Mid-depth (M), Bottom (B).
2. Data presented are annual arithmetic means of the depth-averaged results except for *E.coli* and faecal coliforms which are annual geometric means.
3. Data in brackets indicate the ranges.
4. NM - not measured

Table 13.1 (continued)

Summary water quality statistics of the typhoon shelters in 2003

Parameter		Aldrich Bay (Shau Kei Wan) ET2	Chai Wan ET1	Hebe Haven PT4	Yim Tin Tsai PT3	Sai Kung PT2	Shuen Wan TT1
Number of samples		6	6	6	6	6	6
Temperature (°C)		23.2 (18.7 - 26.9)	23.3 (18.5 - 27.6)	24.0 (17.2 - 28.6)	23.7 (16.6 - 28.8)	23.8 (16.9 - 28.7)	24.0 (16.5 - 28.6)
Salinity		32.7 (32.0 - 33.4)	32.3 (31.0 - 33.4)	32.3 (28.4 - 33.9)	32.9 (31.2 - 34.0)	32.5 (29.6 - 33.8)	31.4 (28.8 - 33.8)
Dissolved Oxygen (mg/L)		5.3 (3.7 - 6.6)	5.7 (4.8 - 6.4)	5.9 (4.5 - 7.7)	5.7 (5.1 - 6.4)	5.7 (5.0 - 6.4)	6.3 (5.0 - 7.2)
	Bottom	4.9 (2.8 - 6.6)	5.6 (4.6 - 6.6)	6.1 (4.9 - 7.8)	5.6 (4.2 - 6.4)	5.7 (4.5 - 6.4)	5.8 (0.6 - 7.8)
Dissolved Oxygen (% Saturation)		74 (56 - 87)	81 (72 - 96)	84 (66 - 97)	81 (76 - 86)	81 (75 - 89)	89 (76 - 106)
	Bottom	68 (41 - 87)	79 (65 - 100)	87 (72 - 99)	79 (61 - 86)	79 (65 - 85)	80 (9 - 114)
pH		8.0 (7.8 - 8.1)	8.1 (7.9 - 8.2)	8.1 (7.8 - 8.3)	8.2 (8.0 - 8.3)	8.2 (8.0 - 8.4)	8.2 (8.1 - 8.3)
Secchi Disc Depth (m)		3.0 (1.8 - 4.0)	2.6 (1.3 - 3.7)	2.7 (1.6 - 3.5)	3.4 (2.3 - 4.3)	3.0 (2.2 - 3.5)	2.2 (1.5 - 2.5)
Turbidity (NTU)		6.9 (5.2 - 7.7)	6.9 (5.3 - 8.7)	6.9 (2.4 - 12.0)	6.7 (2.5 - 10.1)	6.1 (2.0 - 8.3)	6.3 (2.1 - 8.9)
Suspended Solids (mg/L)		3.1 (1.9 - 4.9)	3.9 (2.1 - 8.9)	3.0 (2.2 - 5.1)	3.0 (1.1 - 5.2)	2.2 (0.9 - 3.2)	2.8 (2.4 - 3.5)
5-day Biochemical Oxygen Demand (mg/L)		0.8 (0.5 - 1.0)	1.0 (0.6 - 1.5)	1.0 (0.8 - 1.2)	0.9 (0.5 - 1.5)	1.1 (0.9 - 1.3)	2.0 (1.5 - 2.7)
Ammonia Nitrogen (mg/L)		0.14 (0.04 - 0.22)	0.09 (0.02 - 0.13)	0.02 (0.01 - 0.05)	0.02 (0.01 - 0.05)	0.02 (0.01 - 0.04)	0.08 (0.03 - 0.15)
Unionised Ammonia (mg/L)		0.006 (0.002 - 0.010)	0.004 (0.001 - 0.008)	0.001 (<0.001 - 0.003)	0.001 (<0.001 - 0.003)	0.001 (0.001 - 0.003)	0.006 (0.002 - 0.014)
Nitrite Nitrogen (mg/L)		0.01 (0.01 - 0.02)	0.01 (0.01 - 0.03)	<0.01 (<0.01 - <0.01)	<0.01 (<0.01 - <0.01)	<0.01 (<0.01 - <0.01)	<0.01 (<0.01 - <0.01)
Nitrate Nitrogen (mg/L)		0.07 (0.04 - 0.12)	0.07 (0.04 - 0.14)	0.01 (<0.01 - 0.06)	<0.01 (<0.01 - 0.01)	0.01 (<0.01 - 0.03)	0.01 (<0.01 - 0.05)
Total Inorganic Nitrogen (mg/L)		0.23 (0.17 - 0.30)	0.17 (0.10 - 0.30)	0.04 (0.01 - 0.11)	0.02 (0.01 - 0.05)	0.04 (0.02 - 0.06)	0.10 (0.03 - 0.17)
Total Kjeldahl Nitrogen (mg/L)		0.26 (0.20 - 0.37)	0.23 (0.18 - 0.29)	0.13 (0.11 - 0.18)	0.11 (0.08 - 0.14)	0.13 (0.09 - 0.20)	0.29 (0.23 - 0.37)
Total Nitrogen (mg/L)		0.35 (0.31 - 0.46)	0.32 (0.23 - 0.40)	0.14 (0.11 - 0.24)	0.12 (0.08 - 0.14)	0.15 (0.09 - 0.21)	0.31 (0.23 - 0.38)
Orthophosphate Phosphorus (mg/L)		0.027 (0.02 - 0.04)	0.018 (0.01 - 0.03)	<0.01 (<0.01 - 0.01)	<0.01 (0.01 - 0.01)	<0.01 (<0.01 - 0.01)	0.013 (0.01 - 0.02)
Total Phosphorus (mg/L)		0.04 (0.03 - 0.05)	0.03 (0.02 - 0.04)	0.03 (0.02 - 0.04)	0.02 (0.02 - 0.03)	0.02 (0.02 - 0.03)	0.04 (0.03 - 0.06)
Silica (as SiO_2) (mg/L)		0.7 (0.5 - 1.2)	0.6 (0.1 - 1.2)	0.7 (0.1 - 1.5)	0.5 (0.2 - 0.7)	0.6 (0.2 - 1.0)	0.8 (0.5 - 1.5)
Chlorophyll-*a* (µg/L)		2.7 (0.4 - 10.7)	5.4 (0.6 - 17.8)	3.4 (1.6 - 8.0)	2.4 (1.0 - 3.3)	2.8 (1.1 - 4.8)	8.8 (2.7 - 13.6)
E.coli (cfu/100mL)		1100 (270 - 2200)	460 (130 - 2000)	2 (1 - 11)	1 (1 - 2)	22 (4 - 290)	32 (7 - 160)
Faecal Coliforms (cfu/100mL)		3900 (1800 - 9700)	1200 (420 - 7900)	9 (1 - 120)	2 (1 - 3)	120 (7 - 1900)	120 (28 - 650)

Note :
1. Unless otherwise specified, data presented are depth-averaged (A) values calculated by taking the means of three depths: Surface (S), Mid-depth (M), Bottom (B).
2. Data presented are annual arithmetic means of the depth-averaged results except for *E.coli* and faecal coliforms which are annual geometric means.
3. Data in brackets indicate the ranges.
4. NM - not measured

Table 13.2

Summary statistics of bottom sediment quality of the typhoon shelters, 1999 – 2003

Parameter	Tuen Mun NS5	Cheung Chau SS7	Hei Ling Chau SS8 [10]	Rambler Channel VS17	Government Dockyard VS21 [10]	Yau Ma Tei VS19	Causeway Bay VS12
Number of samples	10	10	6	10	6	10	10
Particle Size Fractionation <63μm (%w/w)	75 (59 - 92)	69 (22 - 98)	95 (84 - 100)	79 (56 - 98)	99 (98 - 100)	77 (48 - 97)	86 (48 - 99)
Electrochemical Potential (mV)	-181 ((-286) - (-69))	-190 ((-300) - (90))	-161 ((-232) - (-25))	-295 ((-404) - (-90))	-307 ((-388) - (-97))	-346 ((-407) - (-190))	-328 ((-407) - (-173))
Total Solids (%w/w)	48 (39 - 57)	48 (34 - 68)	38 (34 - 41)	45 (39 - 53)	37 (31 - 44)	51 (43 - 59)	44 (33 - 68)
Total Volatile Soilds (%w/w)	6.9 (6.2 - 8.4)	7.1 (3.8 - 8.5)	8.2 (7.4 - 8.8)	8.3 (7 - 8.9)	8.4 (7.4 - 9.3)	7 (6 - 8.1)	8.6 (3.9 - 11.0)
Chemical Oxygen Demand (mg/kg)	19000 (15000 - 23000)	21000 (10000 - 28000)	14000 (13000 - 15000)	30000 (21000 - 41000)	16000 (9900 - 21000)	22000 (13000 - 26000)	30000 (26000 - 32000)
Total Carbon (%w/w)	0.6 (0.4 - 0.9)	0.8 (0.5 - 1.7)	0.5 (0.5 - 0.6)	0.9 (0.8 - 1.1)	0.6 (0.5 - 0.8)	0.8 (0.5 - 0.9)	0.9 (0.7 - 1.0)
Ammonical Nitrogen (mg/kg)	10 (1 - 28)	10 (2 - 20)	12 (4 - 22)	21 (4 - 37)	14 (4 - 29)	31 (11 - 48)	31 (4 - 67)
Total Kjeldahl Nitrogen (mg/kg)	334 (170 - 580)	412 (180 - 550)	430 (290 - 540)	503 (320 - 640)	350 (310 - 410)	415 (300 - 520)	586 (290 - 780)
Total Phosphorus (mg/kg)	191 (86 - 330)	401 (230 - 1100)	186 (160 - 220)	227 (160 - 300)	204 (180 - 230)	205 (160 - 230)	227 (150 - 300)
Total Sulphide (mg/kg)	131 (0 - 370)	197 (18 - 520)	111 (68 - 200)	865 (110 - 2500)	205 (8 - 630)	365 (26 - 1200)	368 (180 - 630)
Total Cyanide (mg/kg)	0.2 (0.1 - 0.3)	0.2 (0.1 - 0.3)	0.1 (0.1 - 0.1)	0.4 (0.1 - 0.8)	0.2 (0.1 - 0.3)	0.1 (0.1 - 0.2)	0.2 (0.1 - 0.3)
Arsenic (mg/kg)	8.9 (7.0 - 11.0)	8.7 (4.4 - 11.0)	8.6 (7.4 - 12.0)	8.4 (5.2 - 10.0)	8.8 (7.3 - 9.7)	6.4 (4.0 - 8.8)	8.3 (2.9 - 12.0)
Cadmium (mg/kg)	0.2 (0.1 - 0.4)	0.2 (0.1 - 0.3)	0.1 (0.1 - 0.1)	1.2 (0.5 - 2.0)	0.3 (0.1 - 0.5)	0.5 (0.1 - 0.9)	0.9 (0.2 - 1.2)
Chromium (mg/kg)	34 (24 - 49)	56 (14 - 73)	43 (34 - 58)	229 (85 - 470)	53 (50 - 56)	42 (26 - 54)	71 (15 - 95)
Copper (mg/kg)	47 (14 - 83)	156 (41 - 250)	41 (34 - 55)	395 (130 - 850)	119 (29 - 180)	97 (33 - 170)	272 (48 - 410)
Lead (mg/kg)	45 (27 - 60)	75 (27 - 190)	54 (41 - 78)	83 (54 - 110)	49 (34 - 65)	55 (24 - 82)	85 (24 - 120)
Mercury (mg/kg)	<0.05 (<0.05 - 0.12)	0.32 (0.1 - 0.6)	0.18 (0.12 - 0.39)	0.42 (0.14 - 1.5)	0.14 (<0.05 - 0.20)	0.31 (0.1 - 0.74)	0.84 (0.18 - 1.7)
Nickel (mg/kg)	19 (14 - 22)	17 (6 - 23)	27 (22 - 33)	99 (39 - 210)	32 (28 - 36)	23 (18 - 30)	27 (7 - 39)
Silver (mg/kg)	<1.0 (<1.0 - <1.0)	<1.0 (<1.0 - <1.0)	<1.0 (<1.0 - <1.0)	10.3 (3.0 - 18.0)	1.6 (<1.0 - 2.4)	1.9 (<1.0 - 3.7)	6.8 (<1.0 - 9.0)
Zinc (mg/kg)	136 (74 - 200)	188 (65 - 400)	143 (120 - 160)	323 (170 - 530)	204 (110 - 270)	202 (99 - 340)	298 (66 - 380)
Total Polychlorinated Biphenyls (PCBs) (μg/kg) [3] [4]	18 (18 - 18)	18 (18 - 19)	18 (18 - 18)	30 (18 - 48)	21 (18 - 25)	21 (18 - 26)	22 (18 - 32)
Low Molecular Weight Polycylic Aromatic Hydrocarbons (PAHs) (μg/kg) [5] [6] [9]	90 (90 - 90)	99 (90 - 108)	90 (90 - 90)	124 (96 - 142)	99 (90 - 117)	119 (110 - 132)	118 (90 - 150)
High Molecular Weight Polycylic Aromatic Hydrocarbons (PAHs) (μg/kg) [7] [8] [9]	143 (20 - 292)	491 (0 - 1427)	85 (38 - 151)	983 (366 - 2141)	197 (49 - 285)	1026 (65 - 3185)	590 (169 - 999)

Note :
1. Data presented are arithmetic means ; data in brackets indicate ranges.
2. All data are based on the analyses of bulk (unsieved) sediment and are reported on a dry weight basis unless stated otherwise.
3. The Technical Circular 'ETWB (W) No. 34/2002 Management of Dredged / Excavated Sediment' issued in 2002 has revised the definition of 'Total PCBs' as the summation of 18 specific PCB congeners. Following the new definition, the monitoring of these 18 PCB congeners started in 2002 and the Total PCBs results only refer to 2002 and 2003.
4. Total PCBs results are derived from the summation of 18 congeners. If the concentration of a congener is below report limit (RL), the result will be taken as 0.5xRL in the calculation.
5. Low molecular weight polyaromatic hydrocarbons (PAHs) include 6 congeners of molecular weight below 200, namely : Acenaphthene, Acenaphthylene, Anthracene, Fluorene, Naphthalene and Phenanthrene.
6. As the monitoring of Naphthalene only started in 2002, the Low Molecular Weight PAHs results are based on sediments samples collected in 2002 and 2003.
7. High molecular weight polyaromatic hydrocarbons (PAHs) include 10 congeners of molecular weight above 200, namely : Fluoranthene, Pyrene, Benzo(a) anthracene, Chrysene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Benzo(a)pyrene, Dibenzo(a,h)anthracene, Benzo(g,h,i)perylene and Indeno(1,2,3-cd) pyrene.
8. High Molecular Weight PAHs results are based on sediment samples collected in five years (1999-2003).
9. Low and high molecular weight PAHs results are derived from the summation of the corresponding congeners. If the concentration of a congener is below report limit (RL), the result will be taken as 0.5xRL in the calculation.
10. Monitoring of Hei Ling Chau Typhoon Shelter (SS8) and Government Dockyard (VS21) commenced in 2000.

Table 13.2 (continued)

Summary statistics of bottom sediment quality of the typhoon shelters, 1999 - 2003

Parameter	To Kwa Wan VS20	Kwun Tong VS14	Sam Ka Tsuen VS13	Aldrich Bay (Shau Kei Wan) ES5 [11]	Chai Wan ES3	Hebe Haven PS4	Yim Tin Tsai PS2	Shuen Wan TS7
Number of samples	10	10	10	10	10	10	9	10
Particle Size Fractionation <63µm (%w/w)	75 (53 - 94)	71 (36 - 85)	90 (70 - 97)	90 (74 - 99)	84 (69 - 90)	92 (80 - 98)	74 (13 - 98)	64 (45 - 81)
Electrochemical Potential (mV)	-363 ((-433) - (-182))	-388 ((-437) - (-309))	-370 ((-417) - (-276))	-378 ((-422) - (-324))	-311 ((-394) - (-133))	-249 ((-354) - (-13))	-196 ((-286) - (-75))	-324 ((-392) - (-113))
Total Solids (%w/w)	46 (34 - 63)	39 (33 - 43)	41 (39 - 44)	34 (30 - 36)	43 (40 - 48)	37 (34 - 46)	49 (40 - 75)	41 (29 - 54)
Total Volatile Soilds (%w/w)	7.9 (5.3 - 10.0)	10.3 (8.9 - 11.0)	10 (8.7 - 11.0)	10.9 (9.7 - 12.0)	8.2 (7.4 - 9.2)	9.8 (8.2 - 11.0)	10.2 (4.3 - 12.0)	8.5 (5.6 - 12.0)
Chemical Oxygen Demand (mg/kg)	31000 (29000 - 36000)	40000 (29000 - 45000)	27000 (22000 - 32000)	26000 (18000 - 31000)	24000 (18000 - 29000)	23000 (19000 - 26000)	17000 (7100 - 24000)	27000 (20000 - 32000)
Total Carbon (%w/w)	1 (0.8 - 1.5)	1.3 (1.1 - 1.5)	0.8 (0.7 - 0.9)	0.9 (0.7 - 1.0)	0.8 (0.7 - 1.0)	0.7 (0.5 - 0.9)	1.4 (0.6 - 4.4)	0.8 (0.5 - 1.0)
Ammonical Nitrogen (mg/kg)	25 (1 - 53)	47 (17 - 66)	24 (9 - 49)	36 (14 - 61)	10 (4 - 15)	7 (2 - 14)	13 (6 - 28)	12 (1 - 25)
Total Kjeldahl Nitrogen (mg/kg)	564 (390 - 740)	779 (680 - 950)	494 (420 - 600)	551 (470 - 640)	479 (400 - 540)	544 (450 - 620)	482 (180 - 630)	584 (310 - 780)
Total Phosphorus (mg/kg)	222 (170 - 260)	300 (260 - 360)	238 (180 - 370)	240 (190 - 390)	240 (200 - 270)	194 (160 - 240)	154 (48 - 200)	203 (140 - 270)
Total Sulphide (mg/kg)	360 (100 - 1300)	1281 (220 - 2500)	1173 (510 - 2300)	1173 (690 - 2800)	232 (21 - 420)	100 (8 - 210)	54 (15 - 110)	242 (15 - 460)
Total Cyanide (mg/kg)	0.2 (0.1 - 0.3)	0.3 (0.1 - 0.7)	0.3 (0.1 - 0.6)	0.2 (0.1 - 0.4)	0.2 (0.1 - 0.3)	0.2 (0.1 - 0.2)	0.1 (0.1 - 0.2)	0.2 (0.1 - 0.4)
Arsenic (mg/kg)	7.7 (6.3 - 9.0)	8.1 (5.9 - 10.0)	7.1 (5.8 - 8.9)	8.5 (6.9 - 11.0)	10.2 (8.4 - 11.0)	10.3 (8.6 - 12.0)	5.2 (0.6 - 9.1)	10 (7.0 - 13.0)
Cadmium (mg/kg)	1 (0.4 - 1.6)	4.2 (3.0 - 5.3)	0.7 (0.5 - 1.1)	0.7 (0.5 - 1.6)	0.6 (0.4 - 0.7)	0.2 (0.1 - 0.3)	0.1 (0.1 - 0.1)	0.5 (0.2 - 0.9)
Chromium (mg/kg)	100 (64 - 130)	405 (250 - 560)	73 (36 - 200)	72 (63 - 89)	110 (83 - 180)	37 (25 - 51)	17 (<5 - 24)	24 (15 - 33)
Copper (mg/kg)	629 (410 - 810)	2640 (1700 - 4000)	196 (97 - 450)	312 (250 - 370)	320 (240 - 400)	49 (31 - 58)	15 (1 - 20)	134 (37 - 310)
Lead (mg/kg)	99 (77 - 130)	154 (100 - 230)	118 (84 - 150)	92 (68 - 130)	85 (64 - 140)	45 (39 - 52)	30 (9 - 39)	104 (77 - 140)
Mercury (mg/kg)	1.12 (0.65 - 1.4)	1.03 (0.77 - 1.4)	0.57 (0.34 - 1.3)	0.37 (0.29 - 0.54)	0.48 (0.42 - 0.58)	0.16 (0.09 - 0.22)	0.05 (<0.05 - 0.09)	0.13 (0.07 - 0.21)
Nickel (mg/kg)	36 (29 - 40)	113 (68 - 170)	21 (11 - 48)	26 (21 - 36)	29 (20 - 37)	9 (7 - 15)	11 (<5 - 14)	12 (6 - 19)
Silver (mg/kg)	5.7 (3.0 - 9.0)	11.9 (8.0 - 16.0)	3.3 (2.0 - 6.0)	5.7 (5.0 - 7.0)	9.9 (6.0 - 18.0)	<1.0 (<1.0 - <1.0)	<1.0 (<1.0 - <1.0)	<1.0 (<1.0 - 1.0)
Zinc (mg/kg)	264 (180 - 320)	526 (420 - 670)	280 (210 - 360)	355 (280 - 480)	283 (220 - 340)	158 (120 - 170)	70 (24 - 91)	272 (170 - 400)
Total Polychlorinated Biphenyls (PCBs) (µg/kg) [(3) (4)]	78 (18 - 120)	186 (35 - 293)	32 (22 - 41)	19 (18 - 20)	41 (34 - 54)	19 (18 - 20)	18 (18 - 18)	18 (18 - 19)
Low Molecular Weight Polycyclic Aromatic Hydrocarbons (PAHs) (µg/kg) [(5) (6) (9)]	8544 (2974 - 17405)	164 (145 - 191)	96 (94 - 98)	101 (94 - 113)	118 (108 - 127)	91 (90 - 93)	90 (90 - 90)	92 (90 - 98)
High Molecular Weight Polycyclic Aromatic Hydrocarbons (PAHs) (µg/kg) [(7) (8) (9)]	62412 (2137 - 132600)	1429 (1052 - 2058)	420 (231 - 535)	714 (515 - 993)	613 (341 - 776)	100 (74 - 190)	67 (22 - 116)	107 (46 - 193)

Note : 1. Data presented are arithmetic means ; data in brackets indicate ranges.
2. All data are based on the analyses of bulk (unsieved) sediment and are reported on a dry weight basis unless stated otherwise.
3. The Technical Circular 'ETWB (W) No. 34/2002 Management of Dredged / Excavated Sediment' issued in 2002 has revised the definition of 'Total PCBs' as the summation of 18 specific PCB congeners. Following the new definition, the monitoring of these 18 PCB congeners started in 2002 and the Total PCBs results only refer to 2002 and 2003.
4. Total PCBs results are derived from the summation of 18 congeners. If the concentration of a congener is below report limit (RL), the result will be taken as 0.5xRL in the calculation.
5. Low molecular weight polyaromatic hydrocarbons (PAHs) include 6 congeners of molecular weight below 200, namely : Acenaphthene, Acenaphthylene, Anthracene, Fluorene, Naphthalene and Phenanthrene.
6. As the monitoring of Naphthalene only started in 2002, the Low Molecular Weight PAHs results are based on sediments samples collected in 2002 and 2003.
7. High molecular weight polyaromatic hydrocarbons (PAHs) include 10 congeners of molecular weight above 200, namely : Fluoranthene, Pyrene, Benzo(a) anthracene, Chrysene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Benzo(a)pyrene, Dibenzo(a,h)anthracene, Benzo(g,h,i)perylene and Indeno(1,2,3-cd) pyrene.
8. High Molecular Weight PAHs results are based on sediment samples collected in five years (1999-2003).
9. Low and high molecular weight PAHs results are derived from the summation of the corresponding congeners. If the concentration of a congener is below report limit (RL), the result will be taken as 0.5xRL in the calculation.
10. Monitoring of Hei Ling Chau Typhoon Shelter (SS8) and Government Dockyard (VS21) commenced in 2000.
11. The monitoring station in Alsrich Bay Typhoon Shelter (ES5) was renamed from VS18 to ES5 in 2000.

Table 13.3

Results of the Seasonal Kendall Test for trends in water quality parameters measured in the typhoon shelters, 1986 – 2003

Monitoring Station		NT1	ST1	WT3	WT1	VT8	VT10	VT2	VT11
Monitoring Period		1986 – 2003	1986 – 2003	1986 – 2003	1986 – 2003	1986 – 2003	1993 – 2003	1986 – 2003	1994 – 2003
Parameter	Water Depth								
Temperature (°C)	Surface	-	↗	-	↗	-	-	-	-
	Middle	-	-	-	-	-	-	-	-
	Bottom	-	↗	-	-	-	-	-	-
	Average	-	↗	-	-	-	-	-	-
Salinity	Surface	-	-	-	-	-	-	-	-
	Middle	-	-	-	-	-	-	-	-
	Bottom	-	-	-	-	-	-	-	-
	Average	-	-	-	-	-	-	-	-
Dissolved Oxygen (mg/L)	Surface	↗	-	-	-	-	-	↗	-
	Middle	-	-	-	-	-	-	-	↗
	Bottom	↗	-	-	↗	↗	-	↗	↗
	Average	↗	-	-	-	↗	-	↗	-
Dissolved Oxygen (%)	Surface	↗	-	-	-	-	-	↗	-
	Middle	-	-	-	↗	-	-	-	-
	Bottom	↗	-	-	↗	↗	-	↗	↗
	Average	↗	-	-	↗	↗	-	↗	↗
pH	Surface	-	↘	↘	↘	↘	-	-	-
	Middle	-	-	↘	↘	-	-	-	-
	Bottom	-	↘	↘	↘	↘	-	-	-
	Average	-	↘	↘	↘	↘	-	-	-
Secchi disc depth (m)		↗	-	↗	↗	-	↗	↗	-
Turbidity (NTU)	Surface	-	-	-	-	↗	-	↗	↗
	Middle	-	-	-	-	↗	-	-	↗
	Bottom	-	-	-	-	↗	-	↗	↗
	Average	-	-	-	-	↗	-	↗	↗
Suspended Solids (mg/L)	Surface	-	↗	-	-	-	-	-	-
	Middle	-	-	-	-	-	-	-	-
	Bottom	-	↗	-	-	-	-	-	-
	Average	-	↗	-	-	-	-	-	-
Total volatile solids (mg/L)	Surface	↘	-	↘	↘	-	-	↘	-
	Middle	-	-	↘	↘	-	-	-	-
	Bottom	-	-	↘	↘	-	-	-	-
	Average	↘	-	↘	↘	-	-	↘	-
5-day Biochemical Oxygen Demand (mg/L)	Surface	-	↘	-	-	↘	-	↘	-
	Middle	-	-	-	-	↘	-	↘	-
	Bottom	-	↘	-	-	↘	-	↘	-
	Average	-	↘	-	-	↘	-	↘	-
Ammonia nitrogen (mg/L)	Surface	↘	-	-	↘	-	-	↘	↘
	Middle	-	-	-	-	↘	-	-	↘
	Bottom	-	-	-	-	-	-	↘	-
	Average	↘	-	-	-	-	-	↘	-
Nitrite nitrogen (mg/L)	Surface	↗	-	-	-	-	-	-	-
	Middle	-	-	-	-	-	-	-	-
	Bottom	-	-	-	-	-	-	-	-
	Average	↗	-	-	-	-	-	-	-
Nitrate nitrogen (mg/L)	Surface	↗	↗	-	-	-	-	↗	-
	Middle	-	-	-	-	↗	-	↗	-
	Bottom	↗	-	-	-	-	-	↗	-
	Average	↗	-	-	-	-	-	↗	-
Total inorganic nitrogen (mg/L)	Surface	-	-	-	-	-	-	-	-
	Middle	-	-	-	-	-	-	-	-
	Bottom	↗	-	-	-	-	↘	-	-
	Average	-	-	-	-	-	↘	-	-
Total Kjeldahl nitrogen (mg/L)	Surface	↘	-	-	-	↘	-	↘	-
	Middle	-	-	-	-	↘	-	-	↘
	Bottom	-	-	-	-	↘	-	↘	-
	Average	↘	-	-	-	↘	-	↘	-
Total nitrogen (mg/L)	Surface	-	-	-	-	↘	-	↘	-
	Middle	-	-	-	-	-	-	-	-
	Bottom	-	-	-	-	-	-	↘	-
	Average	-	-	-	-	↘	-	↘	-
Orthophosphate phosphorus (mg/L)	Surface	↘	-	-	-	↘	-	↘	↘
	Middle	-	-	-	-	↘	↘	-	-
	Bottom	-	-	-	-	↘	-	↘	↘
	Average	↘	-	-	-	↘	-	↘	↘
Total phosphorus (mg/L)	Surface	↘	-	-	-	↘	↘	↘	↘
	Middle	-	-	-	-	↘	↘	-	↘
	Bottom	-	-	-	-	↘	↘	↘	↘
	Average	↘	-	-	-	↘	↘	↘	↘
Silica (mg/L)	Surface	-	-	-	-	-	↘	-	-
	Middle	-	-	-	-	-	-	-	-
	Bottom	-	-	-	-	-	↘	-	-
	Average	-	-	-	-	-	↘	-	-
Chlorophyll-*a* (µg/L)	Surface	↗	-	-	↗	-	-	-	-
	Middle	-	-	-	-	-	-	-	-
	Bottom	-	-	↗	↗	-	-	-	-
	Average	↗	-	-	↗	-	-	-	-
E. coli (cfu/100mL)	Surface	↘	-	-	↘	↗	-	↘	-
	Middle	-	-	-	↘	-	-	-	-
	Bottom	-	-	-	-	↗	-	↘	-
	Average	↘	-	-	↘	↗	-	↘	-
Faecal coliforms (cfu/100mL)	Surface	-	-	-	-	↗	-	-	-
	Middle	-	-	-	-	↗	-	-	-
	Bottom	-	↗	-	-	↗	-	-	-
	Average	-	↗	-	-	↗	-	-	-

Note
1. Results of the Seasonal Kendall Test shown are statistically significant at $p < 0.05$
2. - indicates no significant trend is detected
3. NA (Not Applicable) indicates the measurement was not made due to shallow water
4. Test applied to past 18 years' data from each monitoring station unless stated otherwise
5. ST3 has four years' data only, which is insufficient to perform Seasonal Kendall Test
6. ↗ represents a significant increase over time
7. ↘ represents a significant decrease over time

Table 13.3 (continued)

Results of the Seasonal Kendall Test for trends in water quality parameters measured in the typhoon shelters, 1986 - 2003

Monitoring Station		VT4	VT3	ET2	ET1	PT4	PT2	PT3	TT1
Monitoring Period		1987 - 2003	1986 - 2003	1993 - 2003	1986 - 2003	1986 - 2003	1986 - 2003	1986 - 2003	1986 - 2003
Parameter	Water Depth								
Temperature (°C)	Surface	-	-	-	↗	↗	↗	↗	↗
	Middle	-	-	-	↗	-	-	↗	↗
	Bottom	-	↗	-	↗	↗	↗	↗	-
	Average	-	↗	-	↗	↗	↗	↗	↗
Salinity	Surface	-	-	-	-	-	-	-	-
	Middle	-	-	-	-	-	-	-	-
	Bottom	-	-	-	-	-	-	-	-
	Average	-	-	-	-	-	-	-	-
Dissolved Oxygen (mg/L)	Surface	↗	↗	-	-	↘	↗	-	↘
	Middle	↗	↗	-	-	-	-	-	-
	Bottom	↗	↗	-	-	-	-	-	-
	Average	↗	↗	↗	-	-	↗	-	-
Dissolved Oxygen (%)	Surface	↗	↗	-	-	↘	↗	-	↘
	Middle	↗	↗	↗	-	-	-	-	-
	Bottom	↗	↗	↗	-	-	-	-	-
	Average	↗	↗	↗	-	-	↗	-	-
pH	Surface	-	-	-	-	↘	-	↘	↘
	Middle	↗	-	-	-	-	-	↘	↘
	Bottom	-	-	-	-	↘	-	-	↘
	Average	-	-	-	-	↘	-	-	↘
Secchi disc depth (m)		-	-	↗	-	-	↗	-	-
Turbidity (NTU)	Surface	-	↗	↗	-	↗	-	-	-
	Middle	-	↗	↗	-	-	-	↗	↗
	Bottom	↗	↗	↗	-	↗	-	-	↗
	Average	-	↗	↗	-	↗	-	-	-
Suspended Solids (mg/L)	Surface	↘	-	↘	-	-	-	-	-
	Middle	↘	-	-	-	-	-	↗	-
	Bottom	↘	-	-	-	-	↘	-	-
	Average	↘	-	-	-	-	-	-	-
Total volatile solids (mg/L)	Surface	↘	-	-	↘	↘	↘	↘	-
	Middle	↘	↘	↘	↘	-	-	-	-
	Bottom	↘	↘	-	↘	-	-	-	-
	Average	↘	↘	-	↘	↘	-	-	-
5-day Biochemical Oxygen Demand (mg/L)	Surface	↘	↘	-	↘	↘	↘	-	↘
	Middle	↘	↘	-	-	-	-	-	-
	Bottom	↘	↘	-	-	↘	-	-	↘
	Average	↘	↘	-	-	↘	↘	-	↘
Ammonia nitrogen (mg/L)	Surface	-	↘	↘	-	-	↘	-	-
	Middle	↘	↘	↘	-	-	-	-	-
	Bottom	↘	↘	-	-	-	-	-	-
	Average	↘	↘	-	-	-	↘	-	-
Nitrite nitrogen (mg/L)	Surface	↗	-	-	-	-	↘	-	-
	Middle	↗	-	-	-	-	-	-	-
	Bottom	-	-	↘	-	-	-	-	-
	Average	↗	-	-	-	-	↘	-	-
Nitrate nitrogen (mg/L)	Surface	↗	-	-	-	-	↘	-	-
	Middle	↗	-	-	-	-	-	-	-
	Bottom	↗	-	↘	-	-	↘	↘	-
	Average	↗	-	-	-	-	↘	-	-
Total inorganic nitrogen (mg/L)	Surface	-	↘	↘	↗	-	↘	-	-
	Middle	↘	-	↘	↗	-	-	-	-
	Bottom	↘	-	↘	-	-	↘	-	-
	Average	↘	↘	↘	↗	-	↘	-	-
Total Kjeldahl nitrogen (mg/L)	Surface	-	↘	-	-	↘	-	-	-
	Middle	↘	↘	-	-	-	-	-	-
	Bottom	↘	↘	-	-	-	-	-	-
	Average	↘	↘	-	-	↘	-	-	-
Total nitrogen (mg/L)	Surface	-	↘	↘	-	↘	-	-	-
	Middle	↘	↘	↘	-	-	-	-	-
	Bottom	↘	↘	↘	-	-	-	-	-
	Average	↘	↘	↘	-	↘	-	-	-
Orthophosphate phosphorus (mg/L)	Surface	-	↘	↘	-	-	-	-	-
	Middle	↘	↘	↘	-	-	-	-	↘
	Bottom	↘	-	↘	-	-	-	-	-
	Average	-	↘	↘	-	-	-	↘	-
Total phosphorus (mg/L)	Surface	-	↘	↘	-	↘	-	-	-
	Middle	↘	↘	↘	↘	-	-	-	-
	Bottom	↘	↘	↘	-	-	-	-	-
	Average	↘	↘	↘	-	-	-	-	-
Silica (mg/L)	Surface	-	-	↘	↗	-	-	-	-
	Middle	↘	-	↘	-	-	-	-	-
	Bottom	↘	-	-	↗	-	-	-	-
	Average	-	-	↘	↗	-	-	-	-
Chlorophyll-*a* (µg/L)	Surface	↗	↗	-	-	-	-	-	-
	Middle	↗	-	-	-	-	-	-	-
	Bottom	↗	↗	-	-	-	-	-	-
	Average	↗	↗	-	-	-	-	-	-
E. coli (cfu/100mL)	Surface	-	↘	-	-	↘	↘	-	-
	Middle	↘	↘	-	-	-	-	-	-
	Bottom	↘	↘	-	-	↘	↘	-	↘
	Average	↘	↘	-	-	↘	↘	-	↘
Faecal coliforms (cfu/100mL)	Surface	-	-	-	↗	↘	-	-	-
	Middle	↘	-	-	↗	-	-	-	-
	Bottom	↘	-	-	↗	-	↘	-	-
	Average	↘	-	-	↗	↘	↘	-	-

Note
1. Results of the Seasonal Kendall Test shown are statistically significant at $p < 0.05$
2. - indicates no significant trend is detected
3. NA (Not Applicable) indicates the measurement was not made due to shallow water
4. Test applied to past 18 years' data from each monitoring station unless stated otherwise
5. VT12 has four years' data only, which is insufficient to perform Seasonal Kendall Test
6. ↗ represents a significant increase over time
7. ↘ represents a significant decrease over time

CHAPTER 14

PHYTOPLANKTON AND RED TIDES

Chapter 14 - Phytoplankton & Red Tides

Introduction

14.1 Eutrophication is a condition in the water body where high concentrations of nutrients (mainly nitrogen and phosphorus) stimulate blooms of algae (e.g. phytoplankton). Increased eutrophication from nutrient enrichment due to human activities is one of the leading environmental problems in many coastal waters as it can have adverse effects on the ecosystem. Phytoplankton is a critical component of coastal ecosystems and represents the first biological response to nutrient enrichment. Phytoplankton monitoring can track the biological consequences of nutrient enrichment over time and therefore forms an essential part of coastal eutrophication management.

14.2 The Environmental Protection Department (EPD) conducts long-term monitoring of phytoplankton at 25 stations covering nine Water Control Zones (WCZs) in the territory (Figure 14.1). Monthly phytoplankton samples are collected from 1m below water surface. Detailed identification and enumeration of phytoplankton taxa are carried out using light and electron microscopes.

Composition of phytoplankton

14.3 A total of 89 phytoplankton species was recorded in Hong Kong waters in 2003. Of these, 54 were diatoms (61%), 24 were dinoflagellates (27%), 11 were from other minor algal groups (12%) including Cyanophyta, Chrysophyta and Prozotoa. The most dominant diatom species were *Skeletonema costatum* and *Chaetoceros* spp. which constituted 52-70% of the diatom population in the North Western, Western Buffer, Victoria Harbour and Eastern Buffer WCZs (Table 14.1). The most abundant dinoflagellate species were *Scrippsiella* spp. and *Gymnodinium vestifici*, comprising more than 50% of the dinoflagellate populations in 7 out of the 9 WCZs (i.e. Eastern Buffer, Port Shelter, Victoria Harbour, Southern, North Western, Western Buffer and Deep Bay) (Table 14.1). The majority of the other phytoplankton groups were made up of small flagellates (54-85%) in all the WCZs (Table 14.1).

14.4 Of the samples examined in 2003, diatoms constituted the largest component of phytoplankton in term of species number (i.e. 53-66%) followed by dinoflagellates (23-31%) and other phytoplanktons (10-20%) (Figure 14.2). In terms of cell density, diatom was also the largest phytoplankton group in eight WCZs, i.e. Southern (70%), Tolo Harbour and Channel (67%), Eastern Buffer (63%), Victoria Harbour (56%), Mirs Bay (56%), North Western (51%), Western Buffer (50%) and Port Shelter (49%) (Figure 14.3). Other minor phytoplankton groups formed the majority only in the Deep Bay (57%) WCZ.

Abundance of phytoplankton groups

14.5 Figure 14.4 shows the annual mean densities of total phytoplankton at 25 sampling stations in 2003. In general, the total phytoplankton densities were 2-6 times higher at stations in Tolo Harbour and Channel than those in other WCZs. Diatom densities were found to be higher at stations in Tolo Harbour and Channel and parts of Southern water (Figure 14.5); whereas dinoflagellate densities were higher in Tolo Harbour and Channel and some stations in inner Mirs Bay and North Western waters (Figure 14.6). The other minor phytoplankton groups were more abundant in Tolo Harbour and some stations in Victoria Harbour and Southern waters (Figure 14.7).

Red tides and harmful algal blooms

14.6 Red tides and algal blooms are natural phenomena which occur in both polluted and unpolluted waters. Red tides are common in semi-enclosed bays with low tidal flushing and under favourable environmental conditions. Red tides and harmful algal blooms (HABs) can cause oxygen depletion in the water body resulting in fish kills and mass mortalities of other organisms. Algal toxins can contaminate seafood as well. Some phytoplankton species may cause eye, nose, skin irritations or respiratory distress in humans.

14.7 The Government has implemented effective measures to protect swimmers at bathing beaches from possible harmful effects of red tides/algal blooms. When a red tide (or a toxic algal bloom) is detected near a gazetted beach, warning flag will be raised and the beach will be closed. Water samples will be collected immediately and analysed in the laboratory. The beach will be reopened to the public when the bloom has dissipated and the water is free of harmful algae.

Occurrence of red tides

14.8 Red tides generally occur more frequently in the eastern waters and Southern waters (Figure 14.8). From 1980 to 2003, some 289 of 675 red tides (43%) occurred in the Tolo Harbour and Channel WCZ, and 122 (18%) in the Mirs Bay WCZ, 89 (13%) in the Port Shelter WCZ and 108 (16%) in the Southern WCZ respectively.

14.9 Red tides increased significantly in the 80s and reached a peak in 1988, when a total of 88 incidents were reported (Figure 14.9). Since the mid 90s, red tides fluctuated between 20 and

45 incidents per year. A total of 20 red tides was recorded in 2003, of these 9 occurred in Tolo Harbour, 4 occurred in Southern waters and 4 in Mirs Bay.

14.10 Red tides generally peak during the spring months. From 1980 to 2003, 276 of 675 red tides (41%) occurred between March and May. In 2003, only 6 of the 20 red tides (30%) occurred in spring.

14.11 About 15% of the red tides affected bathing beaches between 1980 and 2003 (i.e. 102 of 675 incidents) (Figure 14.10). During the bathing season between March and October, 77 out of the 445 red tides (17%) affected bathing beaches. Of the 20 reported red tide incidents in 2003, only one occurred at bathing beaches.

14.12 Among all red tide cases recorded between 1980 and 2003 (Figure 14.9), 439 were caused by dinoflagellates (65%); 115 were by diatoms (17%) and 96 were by other minor phytoplankton groups (14%) (Figure 14.11) (Note: The causative species of some red tides were unknown). Dinoflagelates caused red tides formed a peak in the spring, i.e. between March and May (208 out of 439 cases); whereas those caused by diatoms occurred more frequently in summer, i.e. between May and August (65 out of 115 cases). Red tides formed by other minor phytoplankton groups mostly occurred in winter and spring months (Figure 14.11).

Red tide causative species

14.13 A total 77 red tide species has been identified from Hong Kong waters since 1980 (Table 14.2). The most common species was the dinoflagellate *Noctiluca scintillans,* which accounted for a third of the reported red tides (210 out of 675). The diatom *Skeletonema costatum* and dinoflagellate *Gonyaulax polygramma* were also frequently encountered. The number of red tide species varied considerably between different WCZs: ranging from 52 species in Tolo Harbour and Channel to four species in Deep Bay.

14.14 The red tide species recorded from different WCZs in 2003 are listed below. Of the 17 species recorded, *Noctiluca scintillans, Mesodinium rubrum* and *Thalassiosira nordenskioeldii* were more widely distributed than others. Red tide species compositions in the Tolo Harbour and Channel WCZ were more diverse than in other WCZs. It is noted that there were considerable year-to-year variations in species composition in different WCZs. There was no red tide related fish kill in 2003.

Tolo Harbour and Channel WCZ:

Chattonella marina

Chattonella sp.

Cyclotella caspia

Karenia mikimotoi

Noctiluca scintillans

Prorocentrum balticum

Prorocentrum minimum

Thalassiosira proschkinae

Mirs Bay WCZ:

Karlodinium micrum

Mesodinium rubrum

Scrippsiella trochoidea

Thalassiosira nordenskioeldii

Port Shelter WCZ:

Prorocentrum dentatum

Southern WCZ:

Noctiluca scintillans

Thalassiosira nordenskioeldii

Trichodesmium erythraeum

Trichodesmium thiebautii

Deep Bay WCZ:

Mesodinium rubrum

Junk Bay WCZ:

Chaetoceros curvisetus

Skeletonema costatum

Figure 14.1 Phytoplankton monitoring stations in Hong Kong waters in 2003

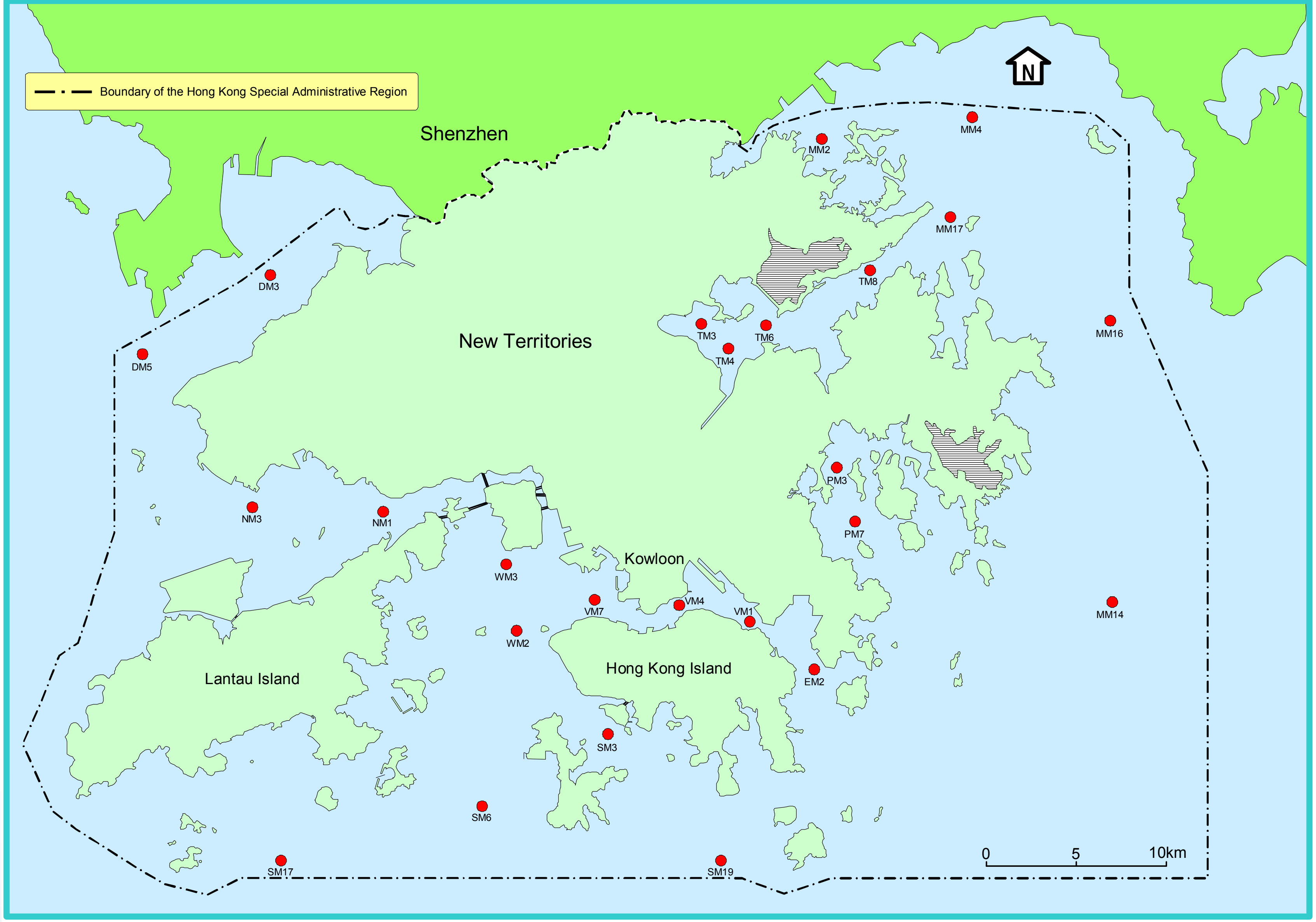


Figure 14.2 Percentage contribution of phytoplankton groups to the total number of species in the nine WCZs (2003)

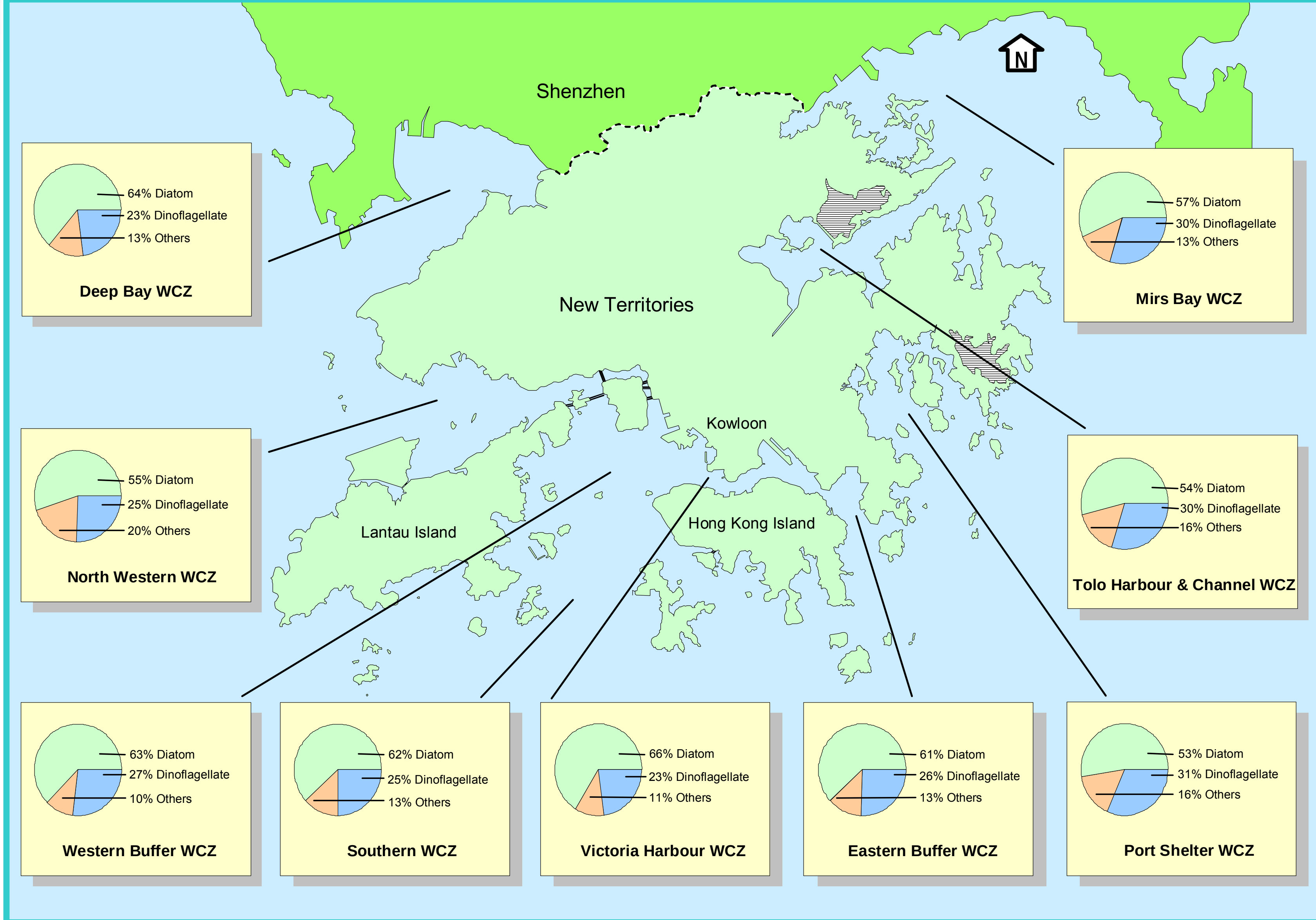


Figure 14.3 Percentage contribution of phytoplankton groups to the total density in the nine WCZs (2003)

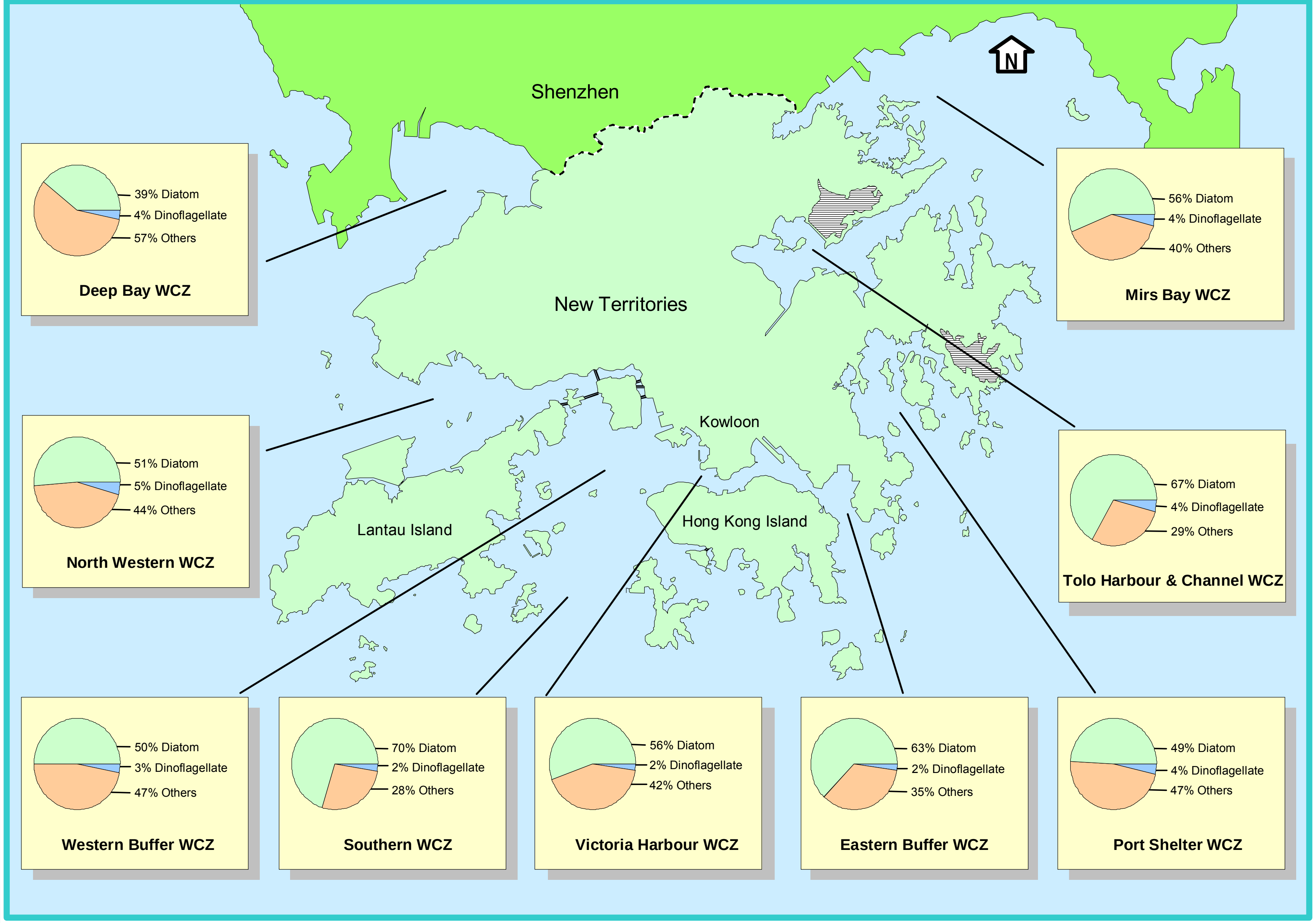


Figure 14.4 Annual mean densities (cell/mL) of total phytoplankton at 25 monitoring stations in Hong Kong waters in 2003

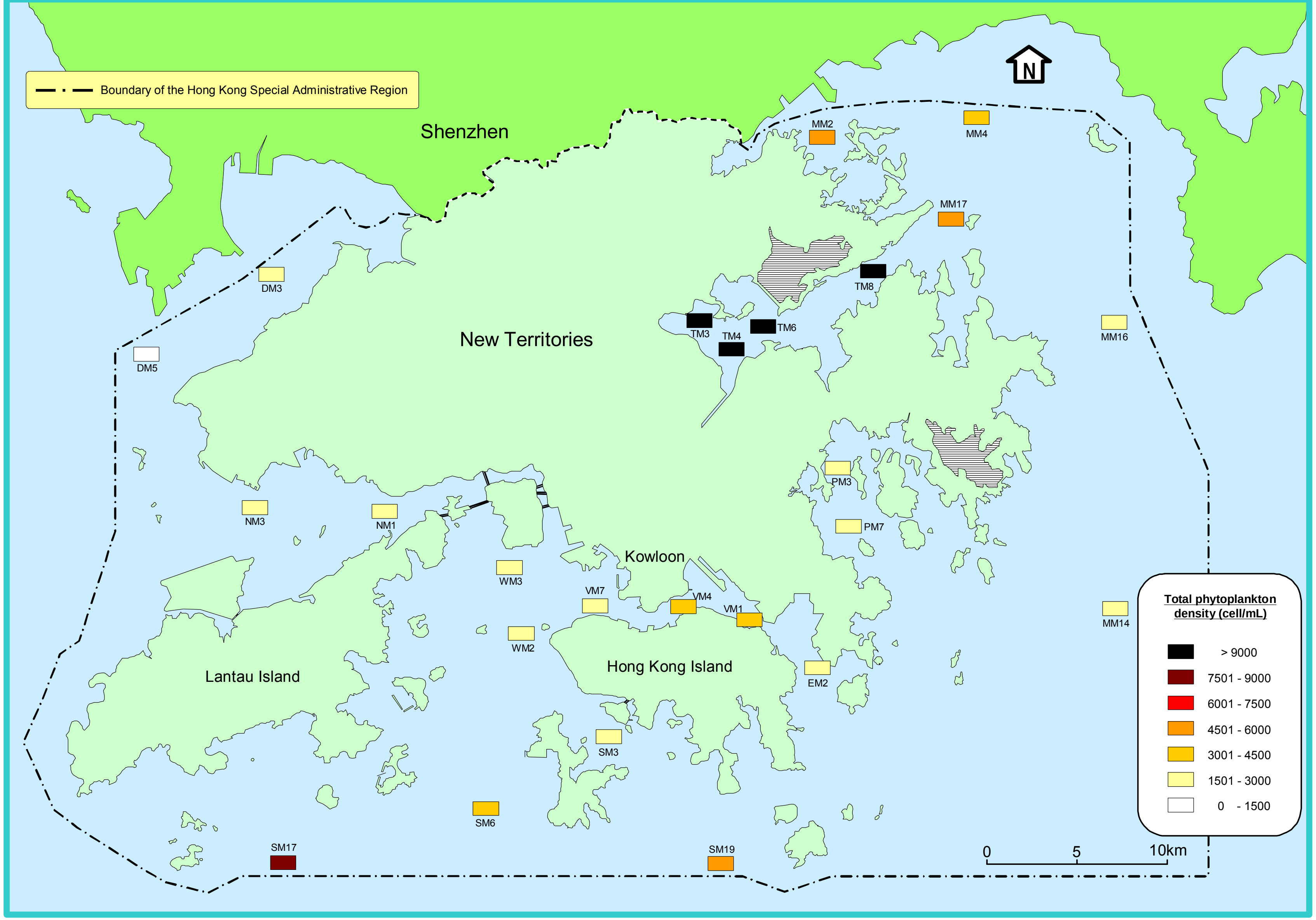


Figure 14.5 Annual mean densities (cell/mL) of diatoms at 25 monitoring stations in Hong Kong waters in 2003

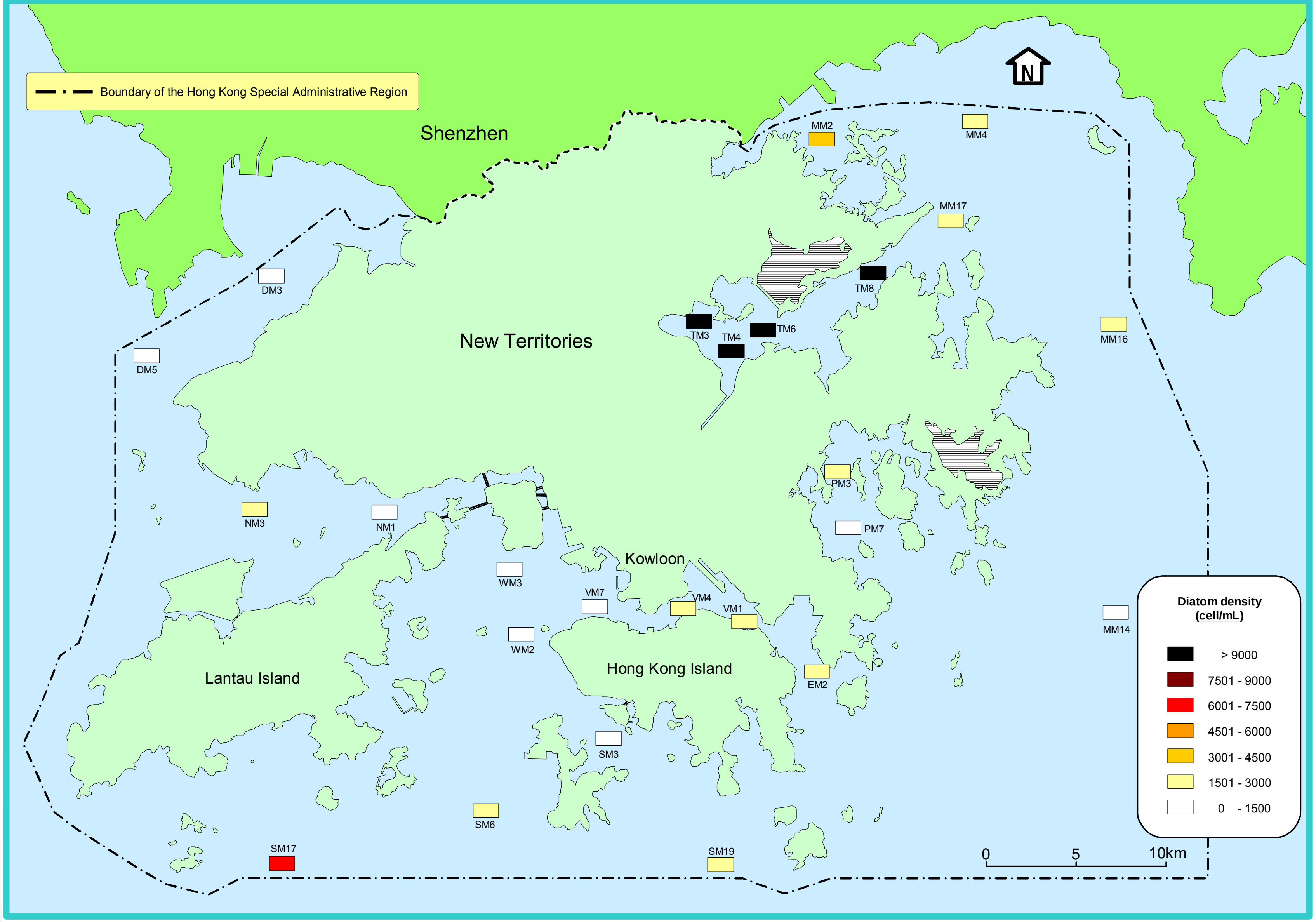


Figure 14.6 Annual mean densities (cell/mL) of dinoflagellates at 25 monitoring stations in Hong Kong waters in 2003

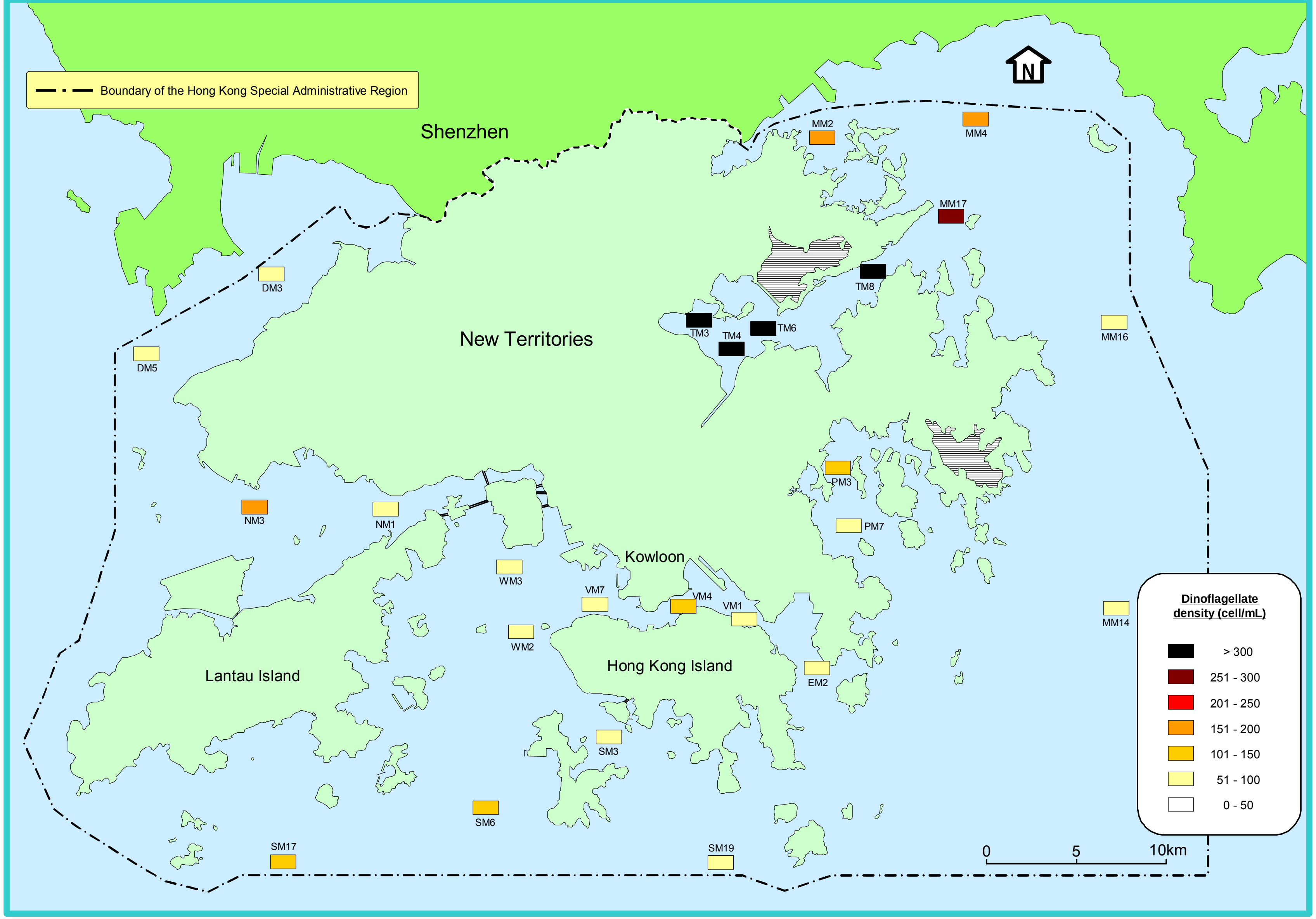


Figure 14.7 Annual mean densities (cell/mL) of other phytoplankton groups at 25 monitoring stations in Hong Kong waters in 2003

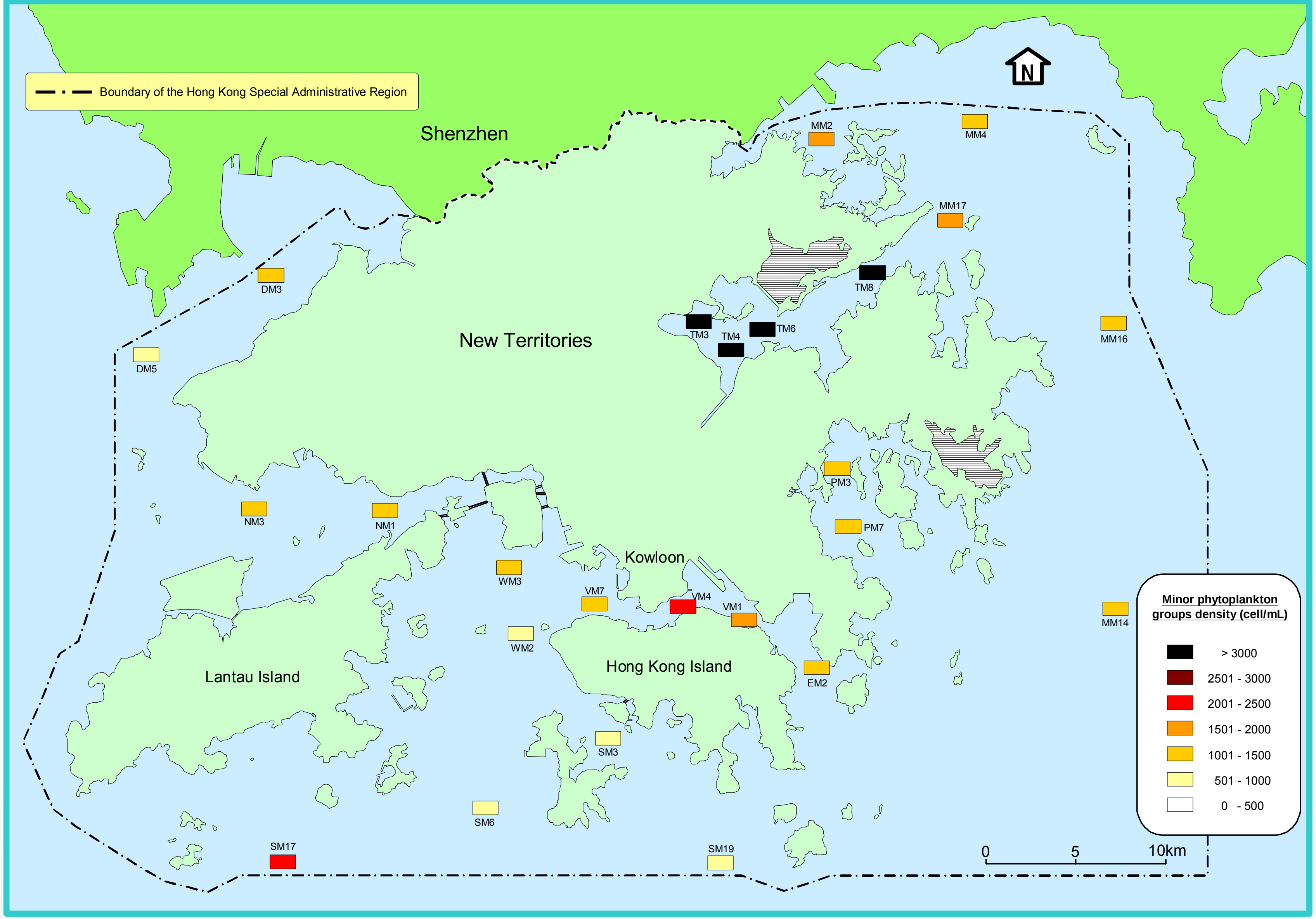


Figure 14.8 Frequency of red tides in 10 WCZs in Hong Kong, 1980 - 2003

(Sources: Agriculture, Fisheries and Conservation Department and Environmental Protection Department

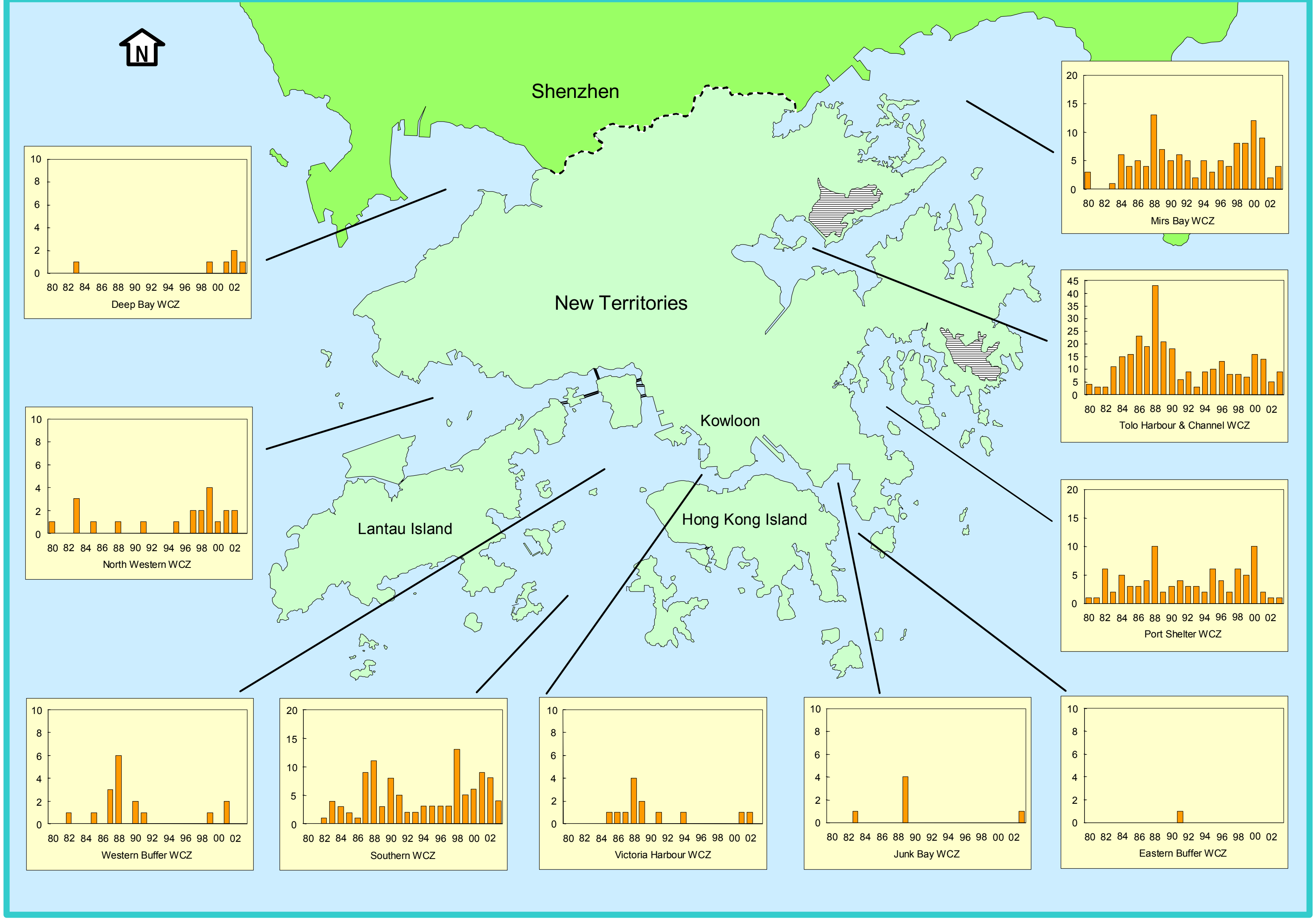
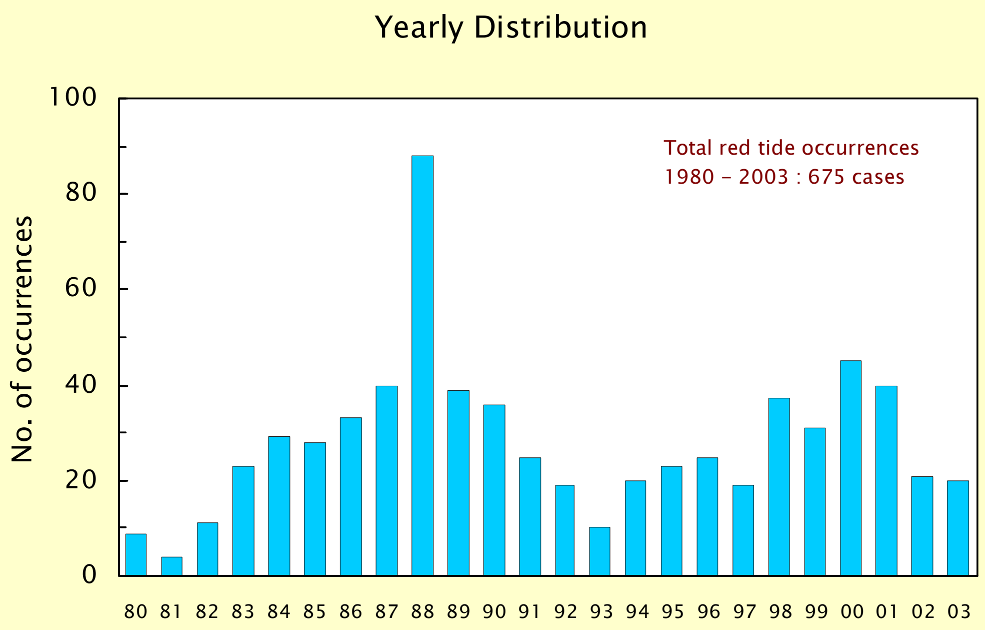


Figure 14.9 Occurrence of red tides in Hong Kong waters, 1980 – 2003
(Sources: Agriculture, Fisheries and Conservation Department and Environmental Protection Department)



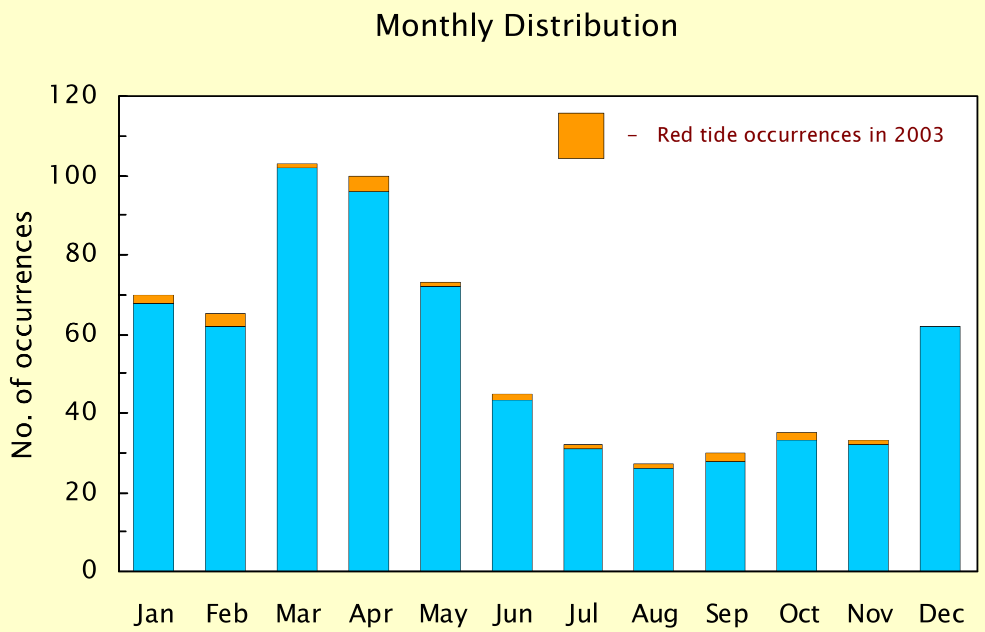
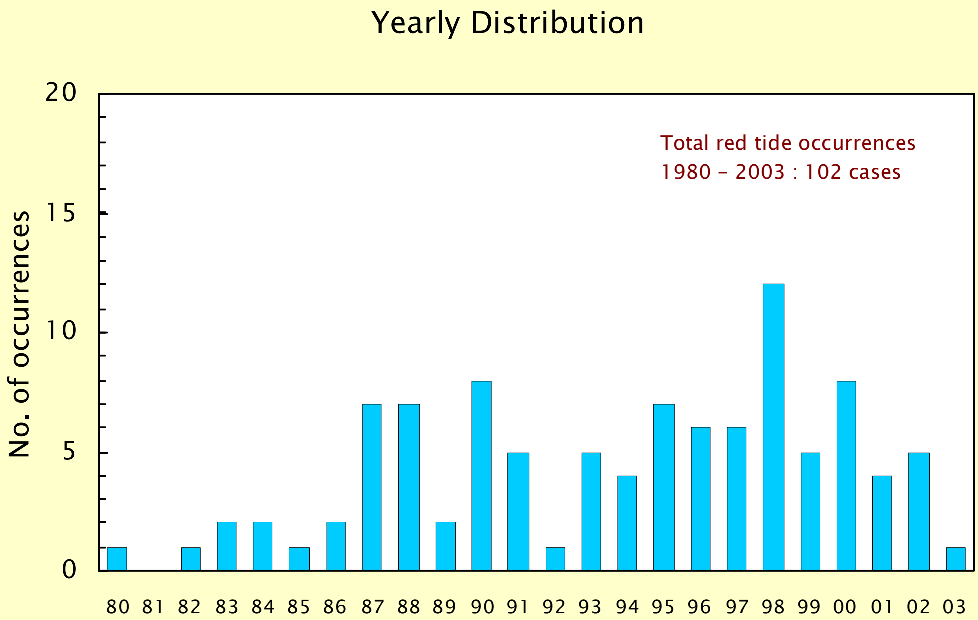


Figure 14.10 Occurrence of red tides at bathing beaches in Hong Kong waters, 1980 – 2003

(Sources: Agriculture, Fisheries and Conservation Department and Environmental Protection Department)



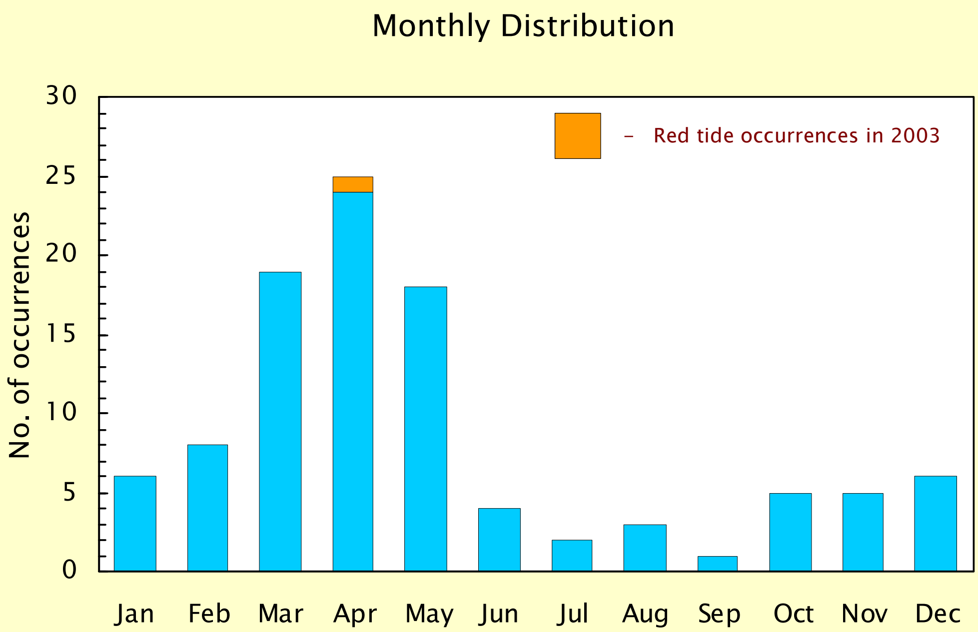


Figure 14.11 Seasonal occurrence of red tides caused by different phytoplankton groups in Hong Kong, 1980 – 2003

(Sources: Agriculture, Fisheries and Conservation Department and Environmental Protection Department)

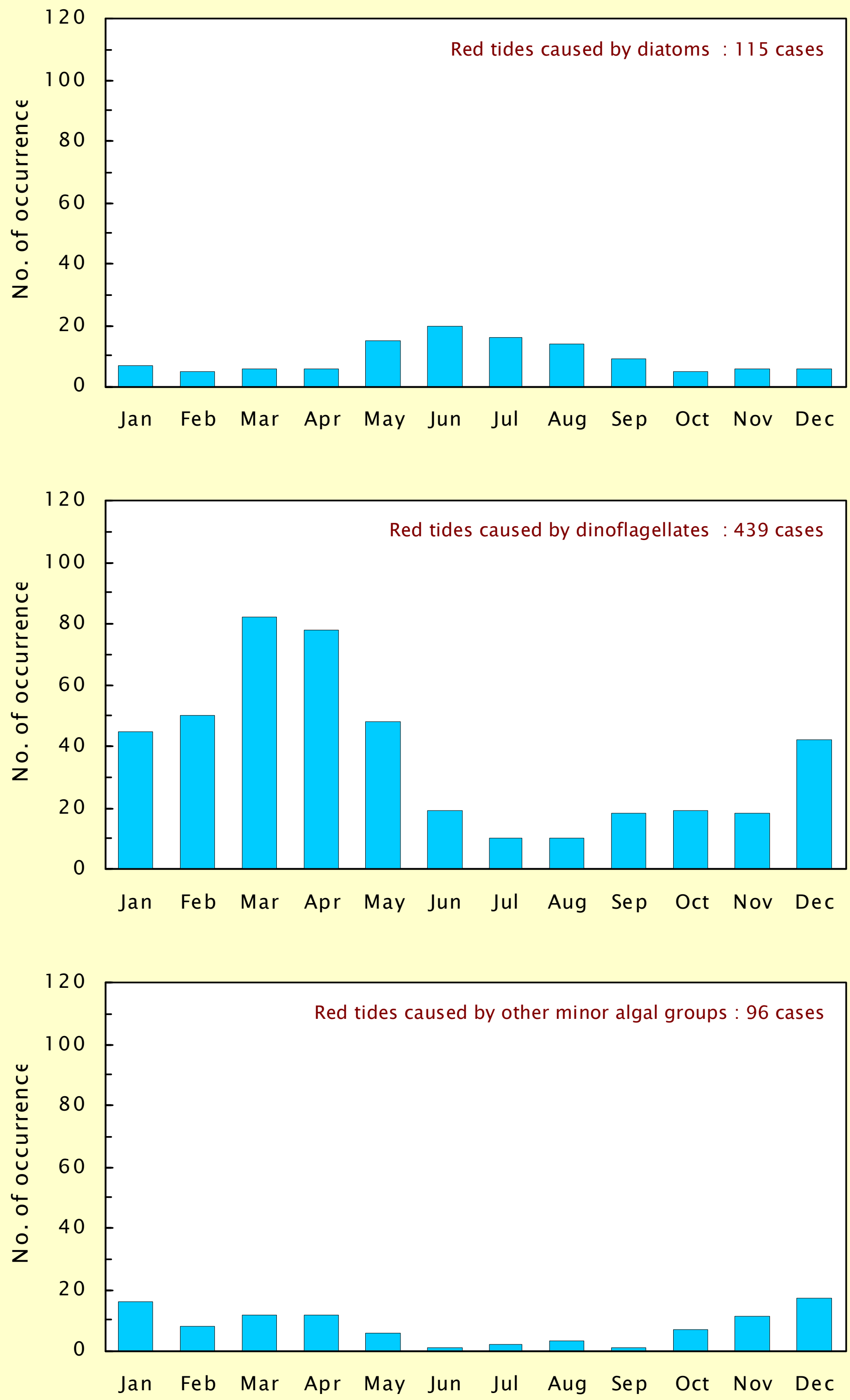


Table 14.1
Abundance and frequency of the dominant phytoplankton species in different WCZs in 2003

Species	% Abundance[1]	Frequency[2]
Tolo Harbour & Channel		
Diatoms		
Leptocylindrus danicus	32	9
Dactyliosolen fragilissimus	13.4	11
Chaetoceros spp.	13	12
Dinoflagellates		
Karenia mikimotoi	29.4	6
Prorocentrum minimum	28.7	8
Scrippsiella spp.	10.8	12
Others		
small flagellates	78.1	12
Plagioselmis prolonga	13	12
Teleaulax acuta	7.8	10
Mirs Bay		
Diatoms		
Pseudo-nitzschia delicatissima	23	12
Skeletonema costatum	20.8	12
Leptocylindrus danicus	16	9
Dinoflagellates		
Karenia mikimotoi	35.7	6
Gymnodinium vestifici	20.6	12
Scrippsiella spp.	18.4	12
Others		
small flagellates	84.7	12
Plagioselmis prolonga	11.8	12
Teleaulax acuta	3.1	12
Eastern Buffer		
Diatoms		
Skeletonema costatum	51.2	10
Chaetoceros spp.	18.5	9
Pseudo-nitzschia delicatissima	8.5	9
Dinoflagellates		
Gymnodinium vestifici	36.9	12
Scrippsiella spp.	25.8	8
Gymnodinium spp.	11.9	7
Others		
small flagellates	76.9	12
Plagioselmis prolonga	15.7	12
Teleaulax acuta	7.3	10
Port Shelter		
Diatoms		
Dactyliosolen fragilissimus	33	5
Chaetoceros spp.	14.4	12
Leptocylindrus danicus	13.9	6
Dinoflagellates		
Scrippsiella spp.	30.2	12
Gymnodinium vestifici	23.9	12
Gymnodinium spp.	19.7	11
Others		
small flagellates	83	12
Plagioselmis prolonga	13	12
Teleaulax acuta	3.1	11
Victoria Harbour		
Diatoms		
Skeletonema costatum	45.7	12
Chaetoceros spp.	18	12
Pseudo-nitzschia delicatissima	14.7	9
Dinoflagellates		
Scrippsiella spp.	31.8	12
Gymnodinium vestifici	30.1	12
Gymnodinium spp.	16.1	11
Others		
small flagellates	77.3	12
Plagioselmis prolonga	16.5	12
Teleaulax acuta	6	12
Southern		
Diatoms		
Pseudo-nitzschia delicatissima	49.3	12
Skeletonema costatum	16	12
Chaetoceros spp.	14.5	12
Dinoflagellates		
Gymnodinium vestifici	42.6	12
Scrippsiella spp.	27.2	12
Gymnodinium spp.	17	12
Others		
small flagellates	82.8	12
Plagioselmis prolonga	13	12
Teleaulax acuta	3.7	12
North Western		
Diatoms		
Skeletonema costatum	52.4	11
Thalassiosira spp.	22.9	12
Pseudo-nitzschia delicatissima	8.7	8
Dinoflagellates		
Scrippsiella spp.	54.4	12
Gymnodinium vestifici	21.7	11
Amphidinium spp.	7.8	6
Others		
small flagellates	64.9	12
Plagioselmis prolonga	21.1	12
Teleaulax acuta	12.1	12
Western Buffer		
Diatoms		
Skeletonema costatum	38.2	11
Chaetoceros spp.	19.6	12
Thalassiosira spp.	17	12
Dinoflagellates		
Scrippsiella spp.	36.5	12
Gymnodinium vestifici	28.6	12
Gymnodinium spp.	18.8	8
Others		
small flagellates	75.8	12
Plagioselmis prolonga	15.4	12
Teleaulax acuta	8	12
Deep Bay		
Diatoms		
Thalassiosira spp.	42.7	10
Skeletonema costatum	41.4	8
Chaetoceros spp.	5.6	12
Dinoflagellates		
Scrippsiella spp.	67.8	12
Gymnodinium spp.	11.3	11
Gymnodinium vestifici	9.3	7
Others		
small flagellates	54	12
Teleaulax acuta	26.5	12
Plagioselmis prolonga	17.1	12

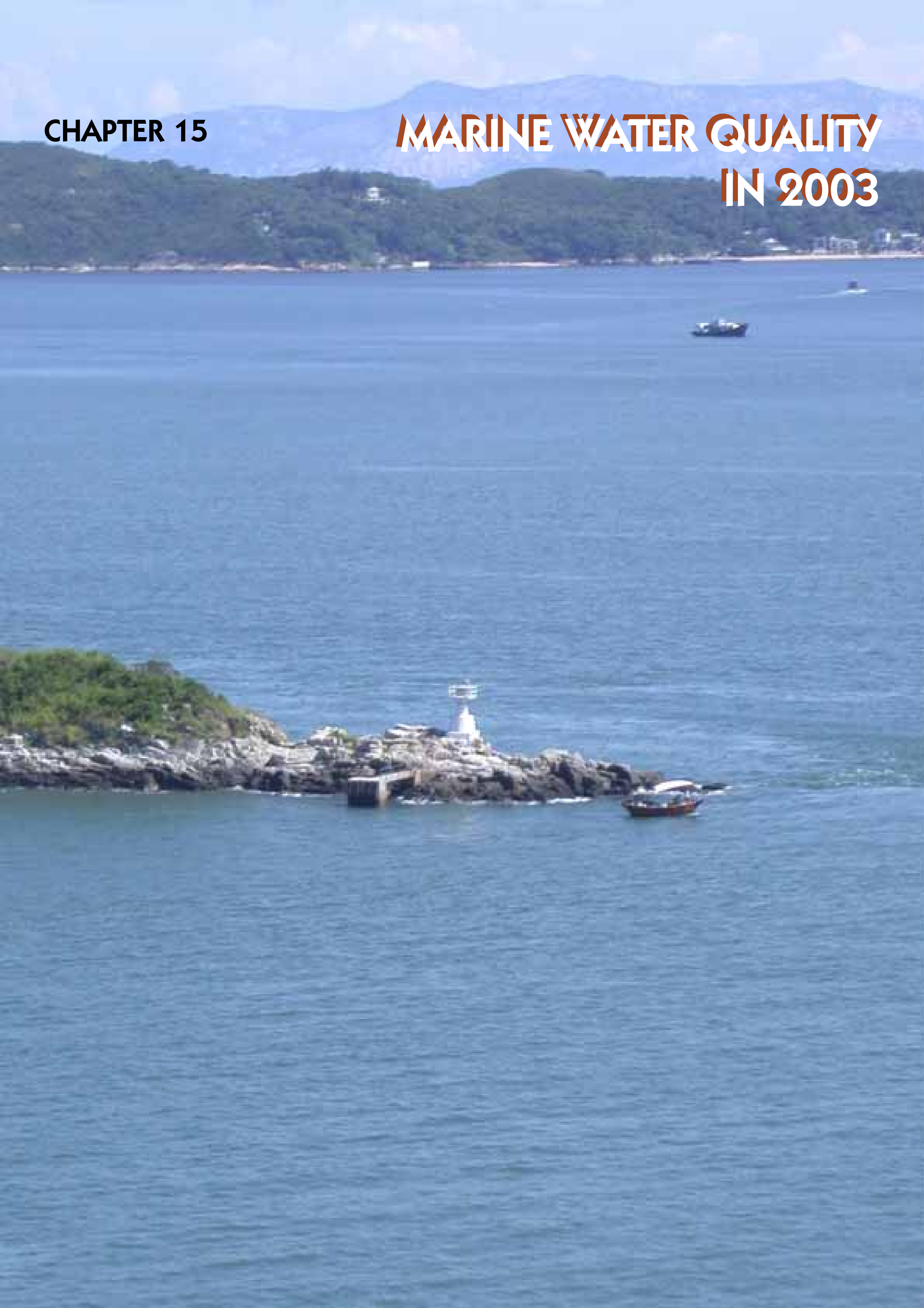
1 % of species/group in diatoms, dinoflagellates and other phytoplankton

2 Number of occurrences out of 12 sampling occasions

Table 14.2
Occurrence and distribution of red tide species in different WCZs, 1980 - 2003

Species	Number of occurrences Tolo Harbour & Channel WCZ	Mirs Bay WCZ	Eastern Buffer WCZ	Port Shelter WCZ	Junk Bay WCZ	Victoria Harbour WCZ	Southern Waters WCZ	North Western WCZ	Western Buffer WCZ	Deep Bay WCZ	Total
Noctiluca scintillans	54	57		39			50	4	6		210
Skeletonema costatum	23	2		1	3	8	7	3	7		54
Gonyaulax polygramma	21	8		12			6	1			48
Mesodinium rubrum	8	8		7	1		13	5		2	44
Prorocentrum minimum	42	1									43
Prorocentrum triestinum	33										33
Ceratium furca	10	6		10							26
Scrippsiella trochoidea	14	4		2			1				21
Prorocentrum sigmoides	14	1		1							16
Heterosigma akashiwo	10	2						3			15
Heterocapsa circularisquama	13	2									15
Prorocentrum dentatum	7	3		1							11
Karenia mikimotoi	6	1		3							10
Leptocylindrus minimus	10										10
Thalassiosira nordenskioeldii	2	3				1	2		1		9
Cryptomonas sp.	8										8
Dactyliosolen fragilissimus	6	1		1							8
Chaetoceros spp.	6			1							7
Karenia digitata	1	3		2			1				7
Thalassiosira mala	6						1				7
Thalassiosira proschkinae	6	1									7
Akashiwo sanguinea	2	2						1		1	6
Gyrodinium instriatum						1		2	1	1	5
Thalassiosira spp.	2				1		2				5
Dictyocha speculum		2		1			1				4
Eutreptiella spp.	4										4
Leptocylindrus danicus	3	1									4
Plagioselmis prolonga	4										4
Prorocentrum micans	3	1									4
Pseudo-nitzschia pseudodelicatissima	1						2		1		4
Chaetoceros curvisetus			1		1		1				3
Chattonella ovata		2		1							3
Gymnodinium simplex	3										3
Karenia longicanalis	1	1					1				3
Pseudo-nitzschia seriata	1					2					3
Trichodesmium erythraeum		2					1				3
Trichodesmium sp.		1		1			1				3
Alexandrium tamarense				2							2
Cerataulina pelagica	2										2
Chattonella marina	1	1									2
Chattonella sp.	1						1				2
Cochlodinium polykrikoides							2				2
Cochlodinium sp.	2										2
Eucampia zodiacus							1	1			2
Gymnodinium sp. X				2							2
Nitzschia longissima	1						1				2
Prorocentrum balticum	1	1									2
Prorocentrum spp.	1	1									2
Teleaulax acuta	2										2
Alexandrium catenella					1						1
Chaetoceros pseudocrinitus	1										1
Chaetoceros pseudocurvisetus							1				1
Chaetoceros socialis							1				1
Chaetoceros sp.0105	1										1
Chaetoceros tenuissimus		1									1
Chlamydomonas sp.	1										1
Cyclotella caspia	1										1
Cyclotella spp.	1										1
Cyttarocylis sp.				1							1
Guinardia delicatula	1										1
Guinardia striata	1										1
Gymnodinium sp.		1									1
Gyrodinium spirale							1				1
Haematococcus pluvialis	1										1
Hermesinum adriaticum		1									1
Karlodinium micrum		1									1
Katodinium rotundatum								1			1
Leptocylindrus spp.							1				1
Odontella mobiliensis	1										1
Odontella sinensis	1										1
Pedinomonadaceae species	1										1
Phaeocystis globosa							1				1
Protoperidinium quinquecorne	1										1
Pseudo-nitzschia spp.							1				1
Thalassiosira weissflogii										1	1
Thalassomonas sp.	1										1
Trichodesmium thiebautii							1				1
Total : 77 species	348	122	1	88	7	12	102	21	16	5	722

Note: a red tide incident may involve more than one causative species.
Source: Agriculture, Fisheries and Conservation Department and Environmental Protection Department



CHAPTER 15

MARINE WATER QUALITY IN 2003

Chapter 15 – Marine Water Quality in 2003

Water Quality in 2003

15.1 In 2003, the water quality of Hong Kong waters was generally similar to that in 2002. The water quality of the Port Shelter and Mirs Bay Water Control Zones (WCZs) continued to be excellent, with low sewage bacteria and nutrients and high dissolved oxygen (DO) content. Under the influence of the Pearl River flow and local pollution sources such as effluent from sewage treatment works and screening plants in the western part of Hong Kong Island and northwestern New Territories, the North Western and Southern WCZs had moderate water quality. The water quality in Deep Bay remained poor, with relatively low DO and high levels of nutrients (nitrogen and phosphorus) and showing signs of further deterioration.

15.2 After the full commissioning of the Harbour Area Treatment Scheme (HATS) Stage I in 2002, a substantial water quality improvement (i.e. an increase in DO and reductions in *E. coli*, ammonia nitrogen and total inorganic nitrogen) was observed in central and eastern Victoria Harbour, Junk Bay and the Eastern Buffer WCZ. These improvements were sustained in 2003. On the other hand, the elevation of *E. coli* bacteria in the western harbour particularly in the vicinity of the Stonecutters Island Outfall has remained and slightly worsened. It has resulted in the closure of the beaches in Tsuen Wan during the 2003 bathing season.

15.3 In connection with HATS development, the Government has completed several studies and trials in 2003 in order to identify long-term options for solving sewage pollution problem in Victoria Harbour. The findings have been put forward for public consultation in mid 2004. Subject to the outcome of the consultation, a scheme would be selected for future implementation.

15.4 There was a slight but widespread decrease of DO in Hong Kong marine waters in 2003. All WCZs showed DO reduction of around 10%. The decrease may be related to the unusually warm and dry weather with rainfall being 12% below normal. The decrease of DO was more evident in the southern part of Hong Kong and parts of Mirs Bay during the summer, when there were fewer tropical cyclones than usual.

Spatial and Temporal Distributions

15.5 Figures 15.1-15.3 illustrate the spatial and temporal distributions of three key water quality parameters: DO (bottom), suspended solids (SS) and chlorophyll-*a* (1 m below sea surface) in marine waters in the colder dry season (January – March) and warmer wet season (July –

September) in 2003.

15.6 Figure 15.1 shows that during the colder months (January – March), the bottom DO in Hong Kong waters was maintained well above 3.5 mg/L. However bottom DO fell considerably in the summer especially in July and August and it was also more unevenly distributed. This was likely to be related to the higher temperature, water column stratification and greater terrestrial discharges during these months. Hypoxia (i.e. DO<2mg/L) of bottom water occurred mainly in Deep Bay and North Western waters as well as parts of Tolo Harbour, Mirs Bay, Port Shelter and Western Buffer during summer.

15.7 Suspended solids (SS) were generally higher in the western side of Hong Kong due to the influence of the highly turbid Pearl River flow, local discharges and marine works (Figure 15.2). The SS levels were lower in Mirs Bay and Port Shelter in particular during the dry months.

15.8 Figure 15.3 shows that the concentration of chlorophyll-*a* (surface) was generally higher in the summer (June and July), especially in Southern waters and Victoria Harbour, indicating elevated algal productivity. Tolo Harbour generally has a higher chlorophyll-*a* level compared with other WCZs, and was vulnerable to algal blooms and red tides.

Compliance with Water Quality Objectives

15.9 In 2003, the overall compliance with the four key marine WQOs in the territory was 87%, the same as in 2002, and amongst the highest recorded (Figure 15.6).

15.10 Statistics on WQOs compliance for individual WCZs are summarised in Figure 15.4. In 2003, a full (100%) WQO compliance was obtained in five of the ten WCZs: Junk Bay, Port Shelter, Eastern Buffer, Mirs Bay and Western Buffer. The Deep Bay WCZ has the poorest compliance, at 27%, which was also the lowest recorded in 10 years. The North Western WCZ experienced a continued decline due to a lower compliance with the TIN and DO objectives. On the other hand, the compliance rate for the Southern WCZ has increased from 71% to 83% in 2003 relating to a marked reduction of TIN during the year.

15.11 The overall compliance of Hong Kong marine waters with the WQO for DO was 87% in 2003, slightly lower than the 89% in 2002 (Figure 15.5). It was mainly due to a widespread decrease of DO of around 10%. On the other hand, the compliance with the TIN objective was 74%, highest in 10 years. Full (100%) compliance with the unionised ammonia objective was achieved in all WCZs, with the exception of Deep Bay. As before, Tolo Harbour, Port Shelter, Mirs Bay and the secondary contact recreation subzones in the Southern Water have fully achieved the WQO for *E. coli* bacteria.

Long-term Water Quality Trends

15.12 Figures 15.7 to 15.16 summarise the significant changes in the major water quality parameters (DO, 5-day Biochemical Oxygen Demand (BOD_5), *E. coli*, NH_4-N, nitrate nitrogen (NO_3-N), TIN, PO_4-P, chlorophyll-*a*, temperature and pH) in the territory over the last 18 years (1986-2003).

15.13 Long-term decreases in depth-averaged DO were found in Deep Bay (Figure 15.17) and a large part of the Southern WCZ. On the other hand, there were decreasing trends in BOD_5 in Tolo Harbour indicating a reduction in organic pollution. Bacterial pollution has worsened in the western part of Victoria Harbour and Western Buffer as well as in the Deep Bay area.

15.14 While Deep Bay has experienced significant increases in NH_4-N and TIN, a decrease in TIN was observed at many stations in the Mirs Bay WCZ. In the Southern WCZ, the increasing trends in nitrate nitrogen and TIN were mainly confined to the coastal area of Lantau Island.

15.15 Tolo Harbour and northern Mirs Bay showed a decline in orthophosphate phosphorus (PO_4-P) and the number of monitoring stations showing decreasing trends in the territory has increased from 12 in 2002 to 23 in 2003 (Figure 15.18). The level of chlorophyll-*a* in Hong Kong water was largely stable since the mid 80s with increasing trends found mainly in the inner (northern) part of Mirs Bay.

15.16 Long-term increases in seawater temperature were observed in Tolo Harbour, Port Shelter, Victoria Harbour, Eastern and Western Buffer and the more confined area of Southern waters. Some parts of Mirs Bay started to show increase in water temperature as well in 2003. The mean seawater temperature in Hong Kong has risen by about 1°C in the last 18 years (1986-2003).

Figure 15.1 Bottom Dissolved Oxygen (DO) in marine waters of Hong Kong in the colder dry season and warmer wet season in 2003

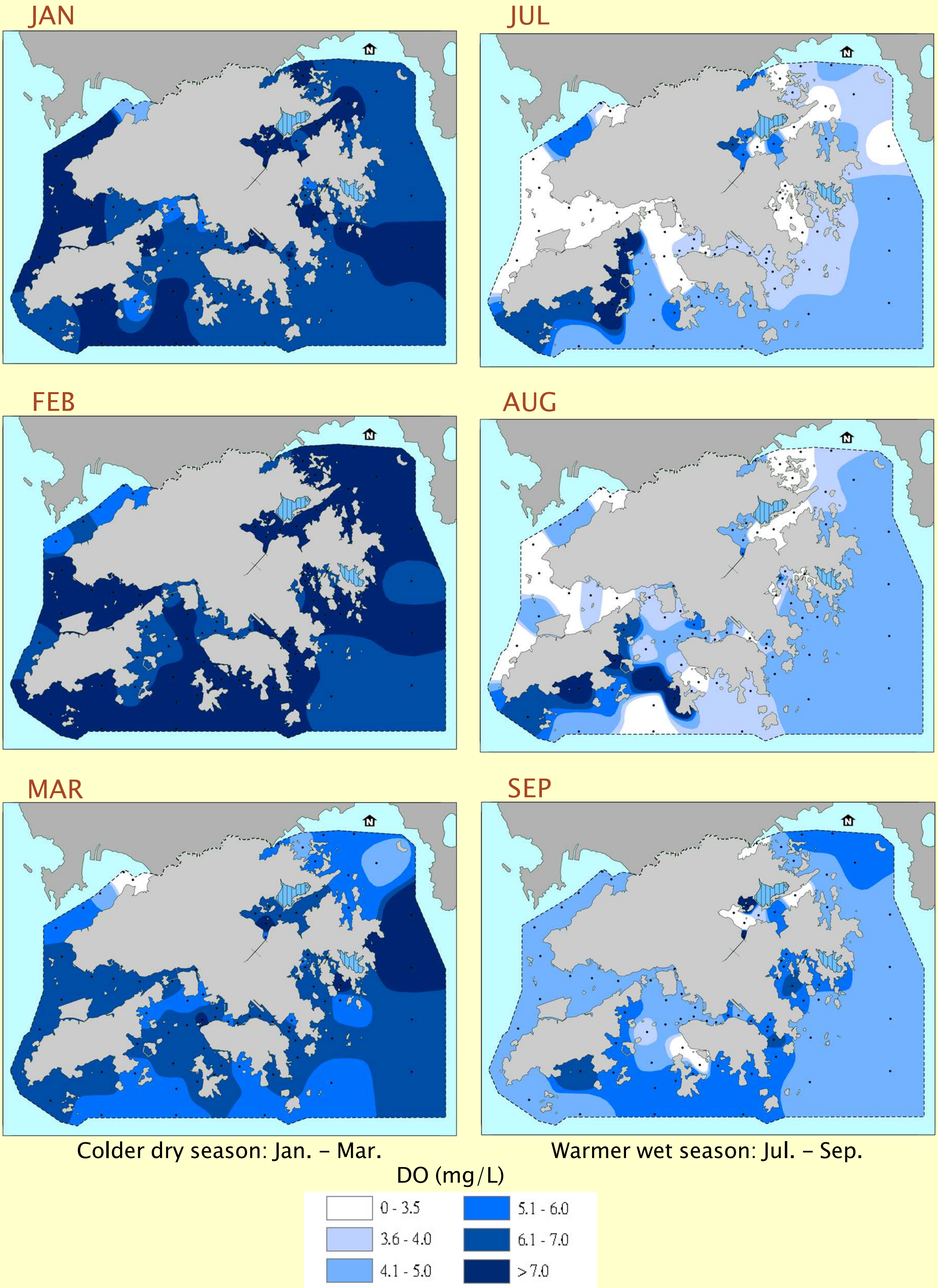


Figure 15.2 Depth-averaged Suspended Solids (SS) in marine waters of Hong Kong in the colder dry season and warmer wet season in 2003

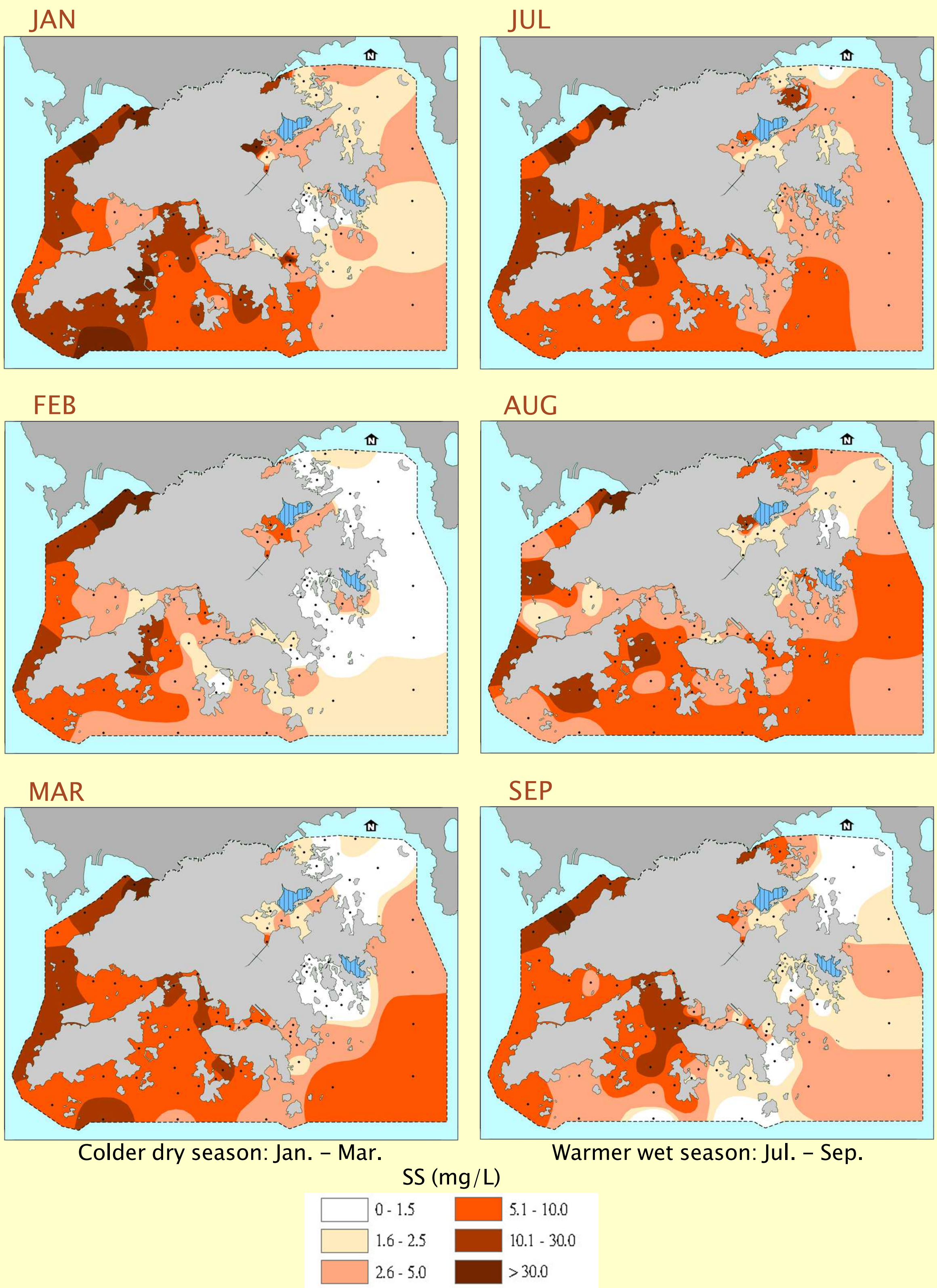
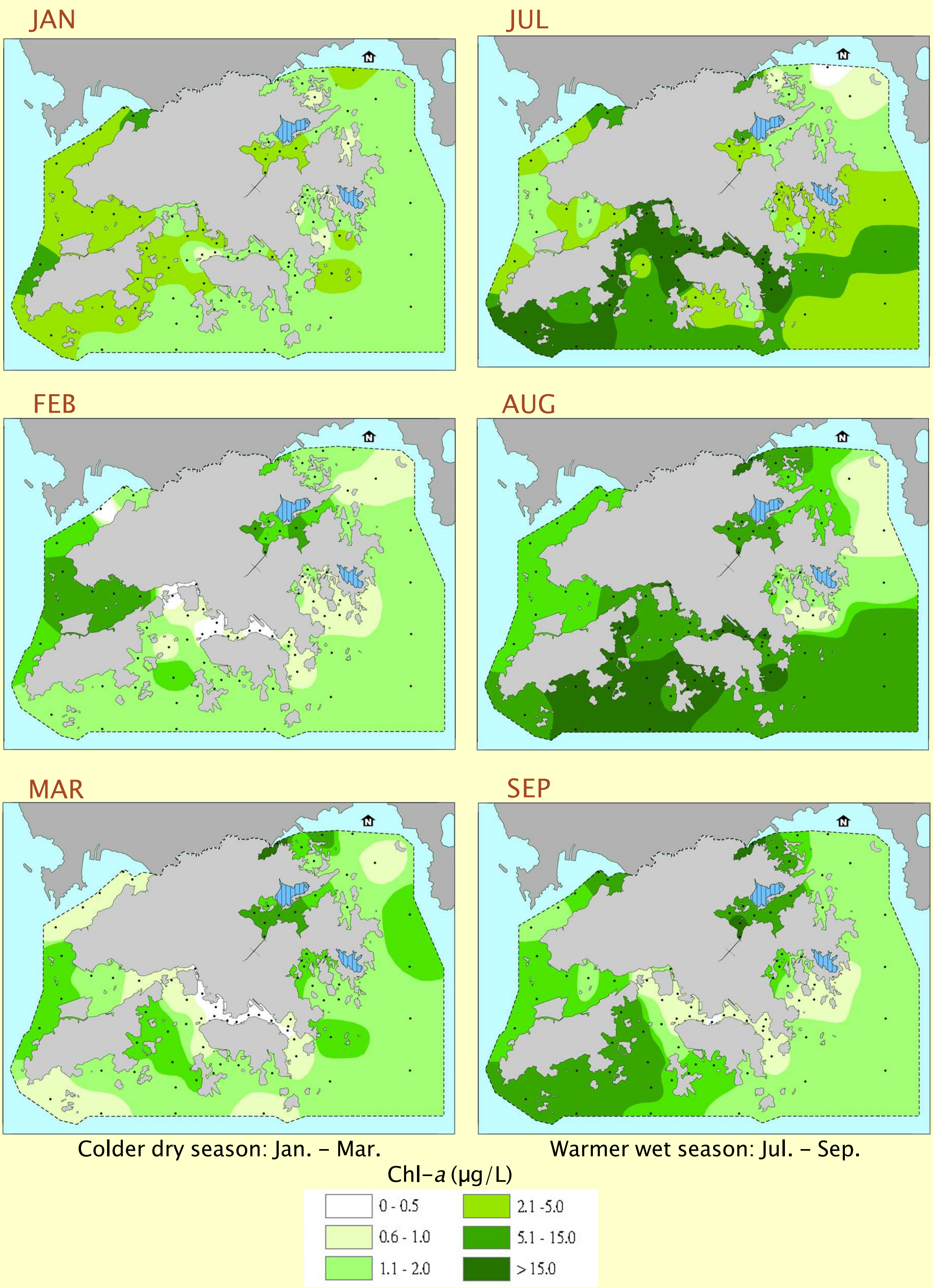


Figure 15.3 Surface Chlorophyll-*a* in marine waters of Hong Kong in the colder dry season and warmer wet season in 2003



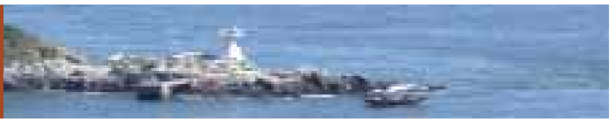
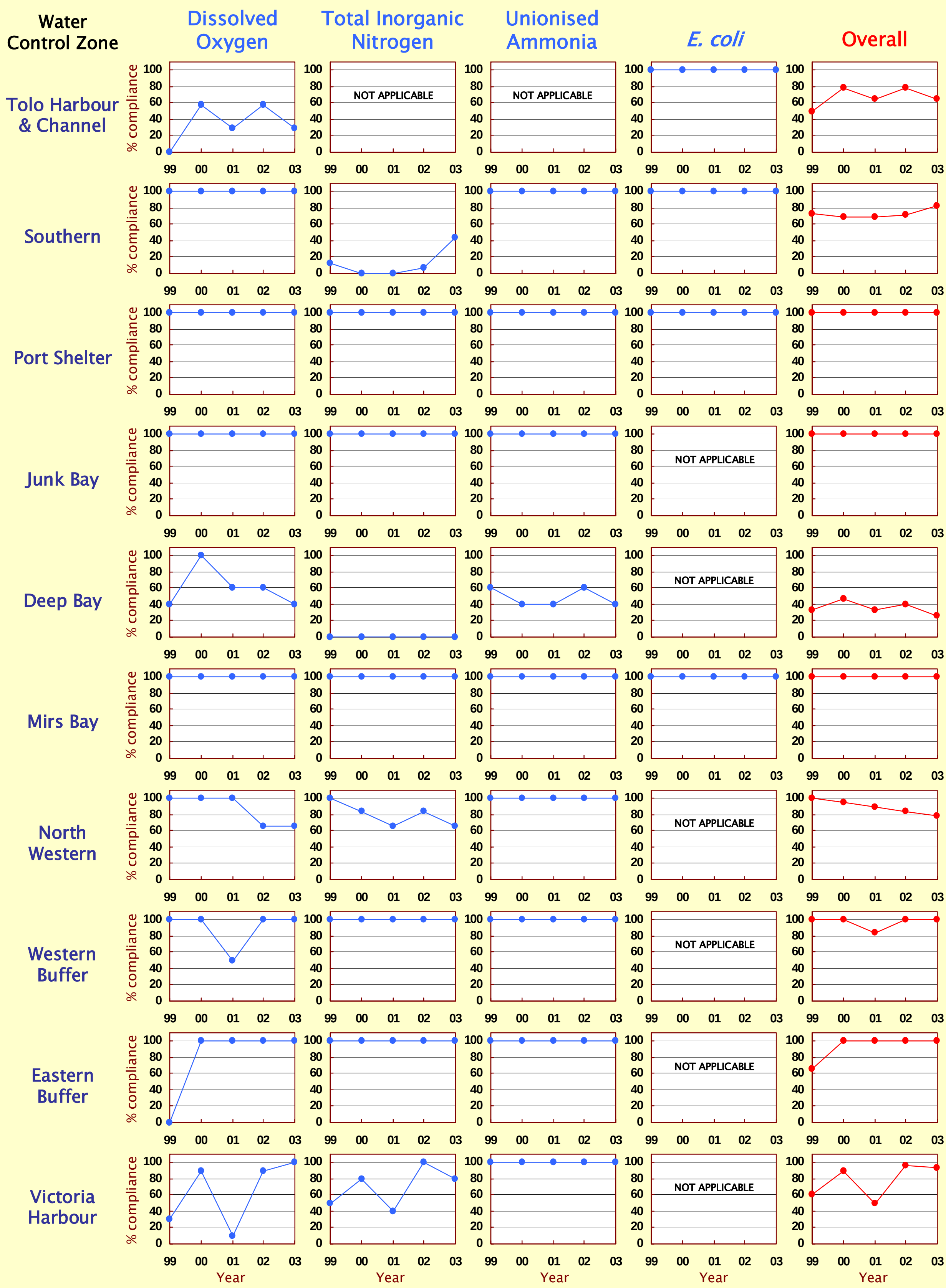


Figure 15.4 Level of compliance with key marine Water Quality Objectives for 10 Water Control Zones in Hong Kong, 1999 – 2003



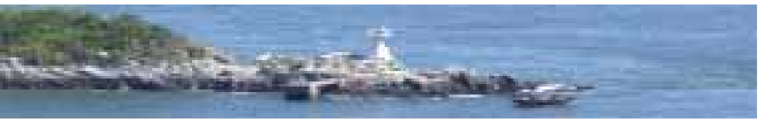


Figure 15.5 Level of compliance with key marine Water Quality Objectives in Hong Kong, 1994 – 2003

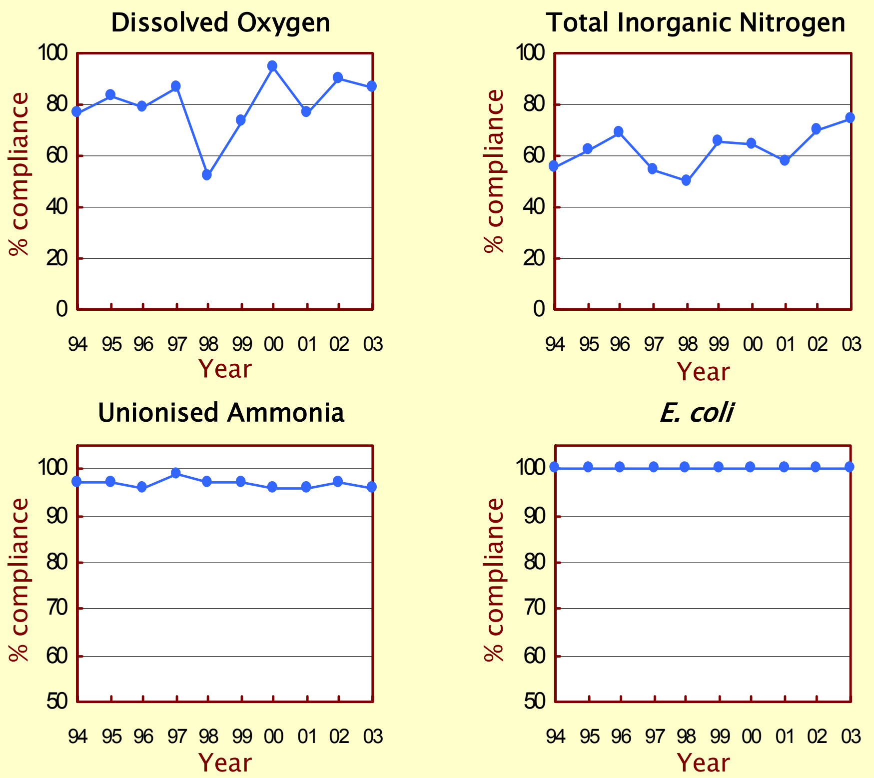


Figure 15.6 Overall level of compliance with key marine Water Quality Objectives in Hong Kong, 1986 – 2003

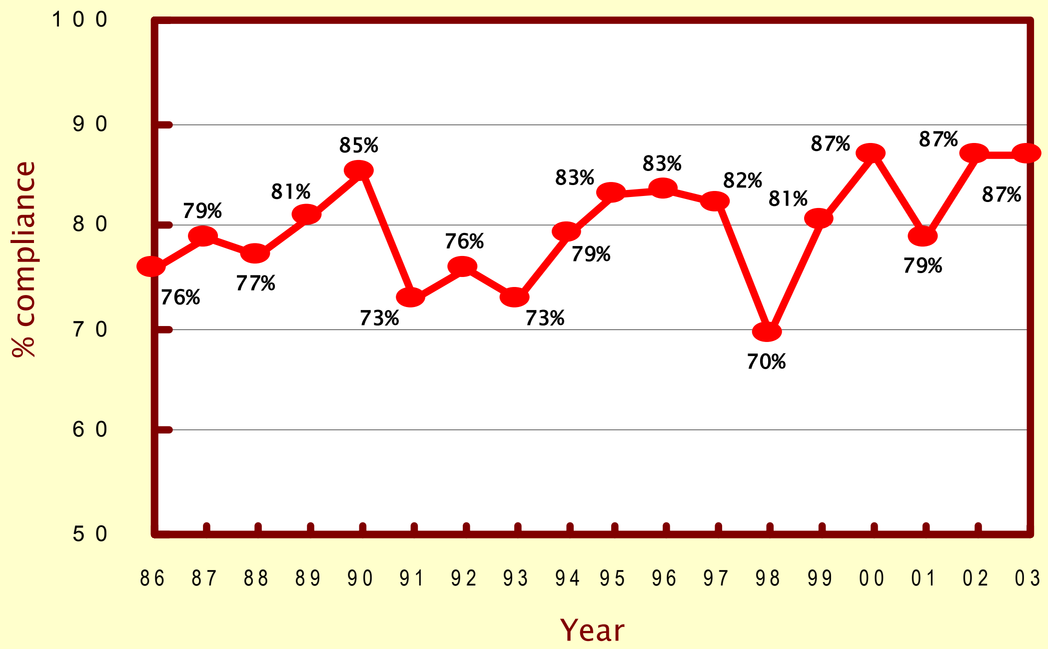


Figure 15.7 Long-term changes in dissolved oxygen in marine waters of Hong Kong, 1986 - 2003

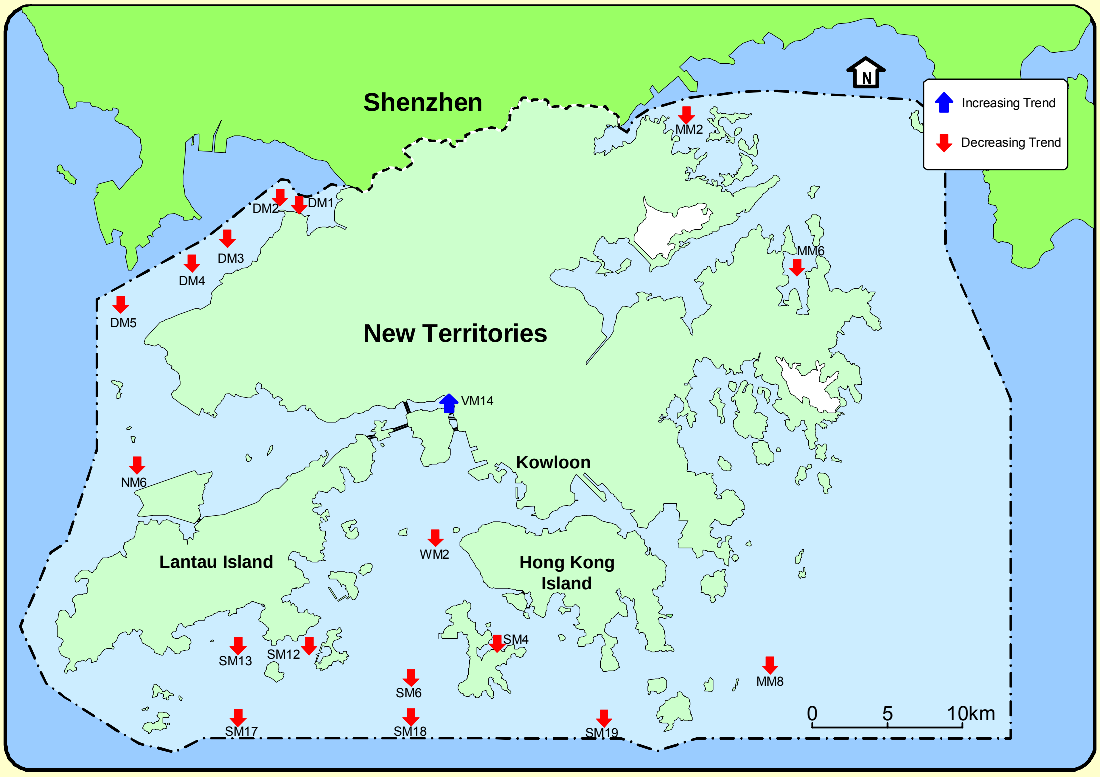


Figure 15.8 Long-term changes in 5-day Biochemical Oxygen Demand in marine waters of Hong Kong, 1986 - 2003

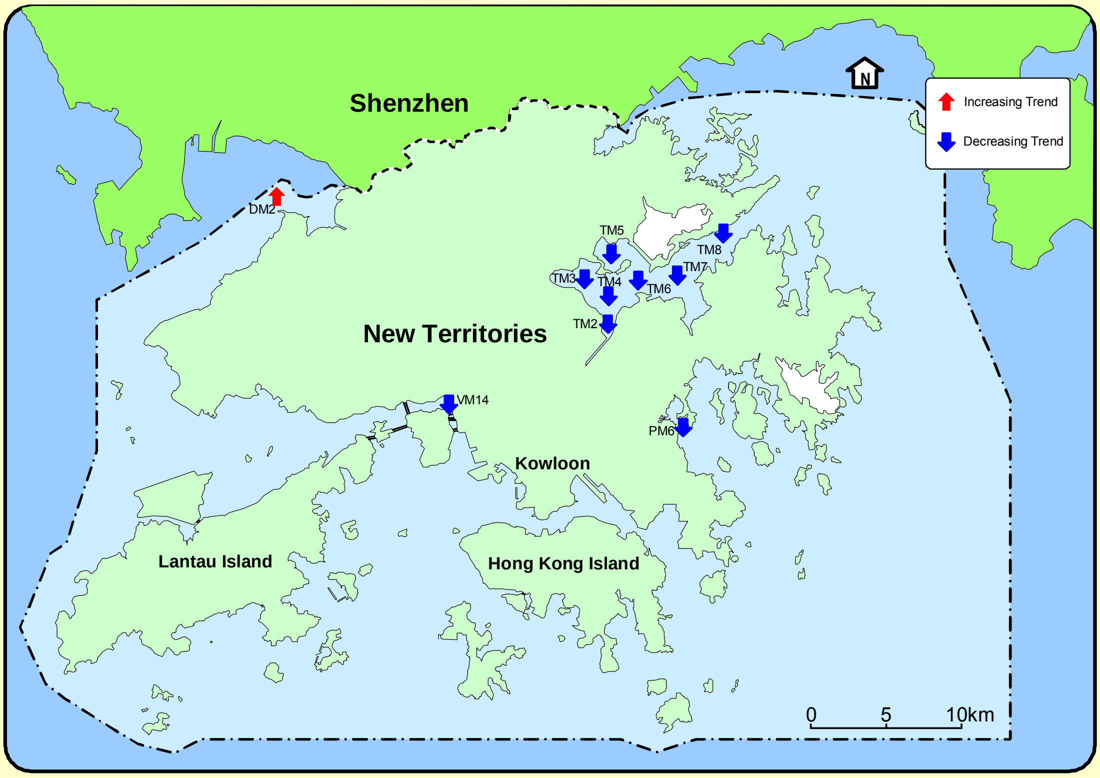


Figure 15.9 Long-term changes in *E. coli* in marine waters of Hong Kong, 1986 – 2003

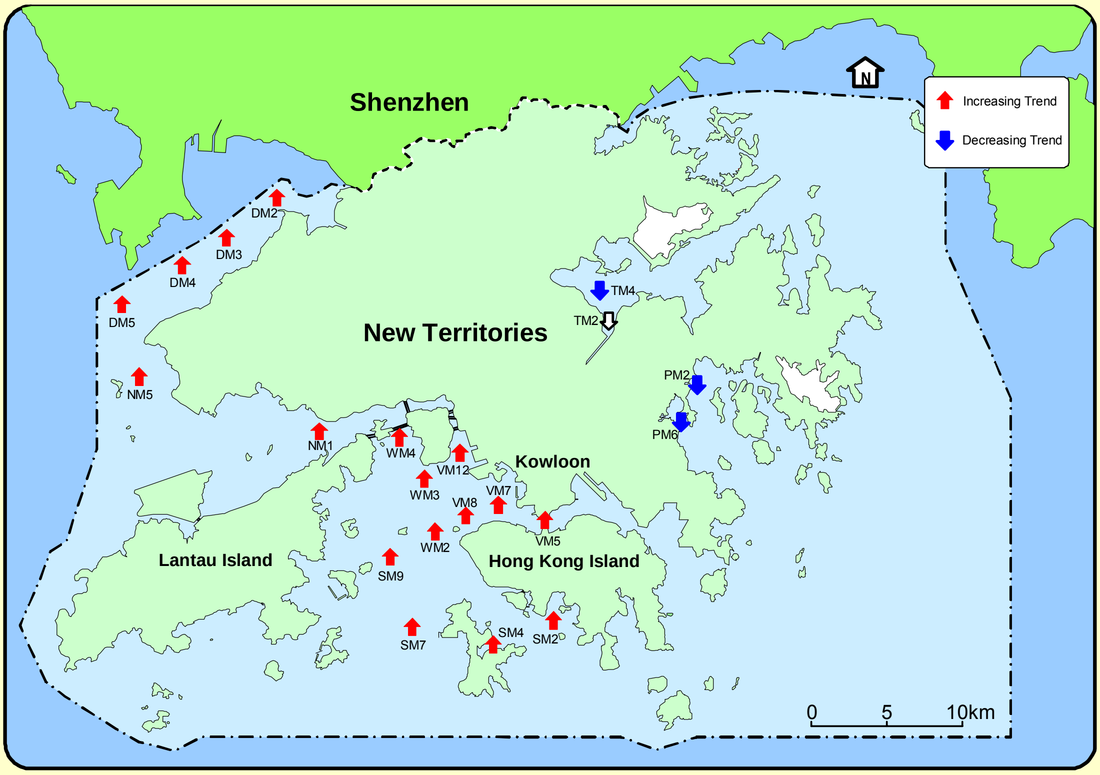


Figure 15.10 Long-term changes in ammonia nitrogen in marine waters of Hong Kong, 1986 – 2003

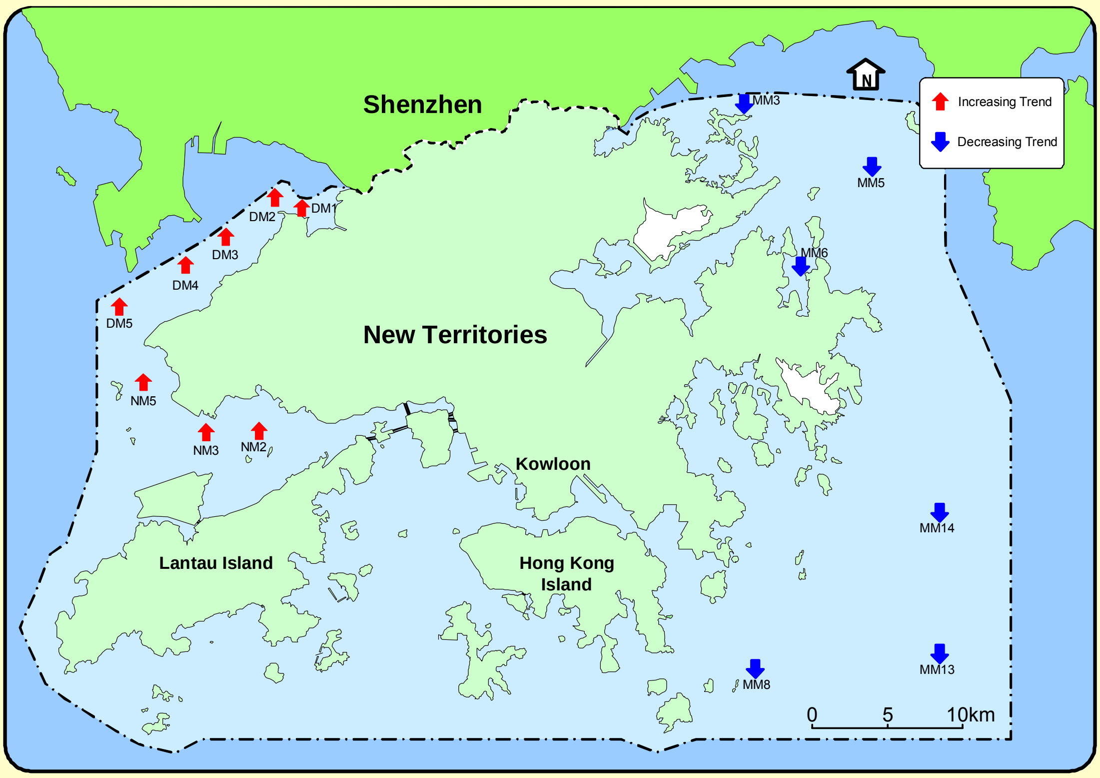


Figure 15.11 Long-term changes in nitrate nitrogen in marine waters of Hong Kong, 1986 – 2003

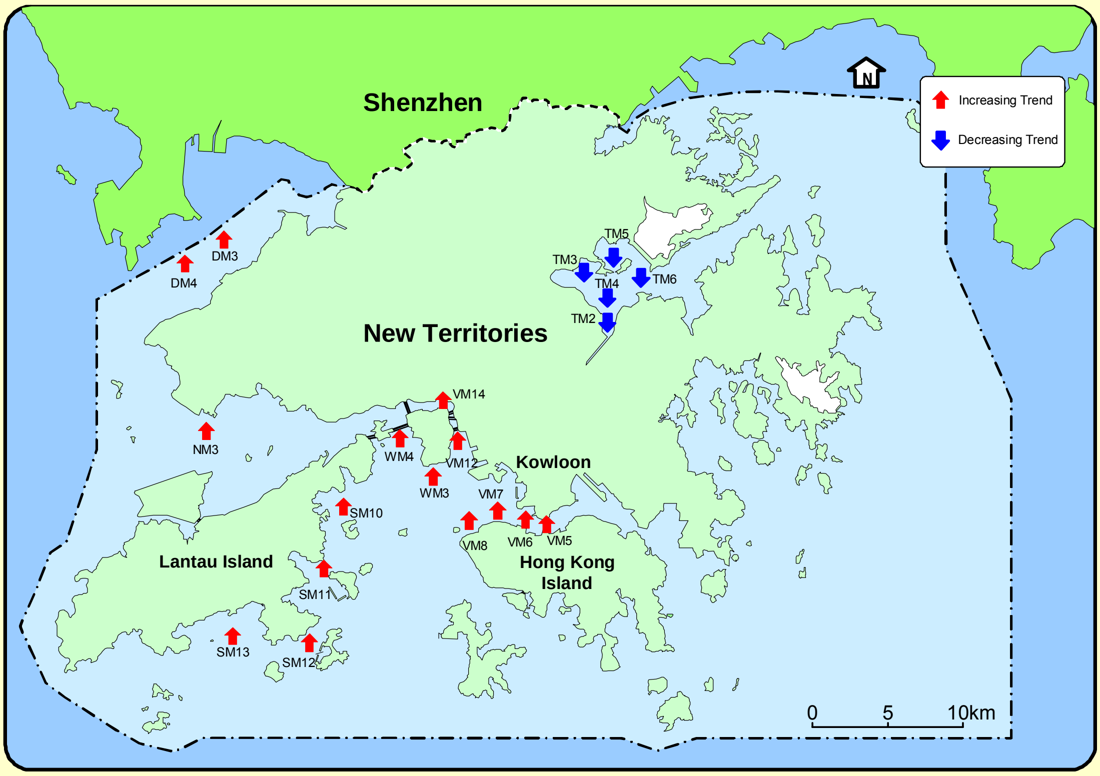


Figure 15.12 Long-term changes in total inorganic nitrogen in marine waters of Hong Kong, 1986 – 2003

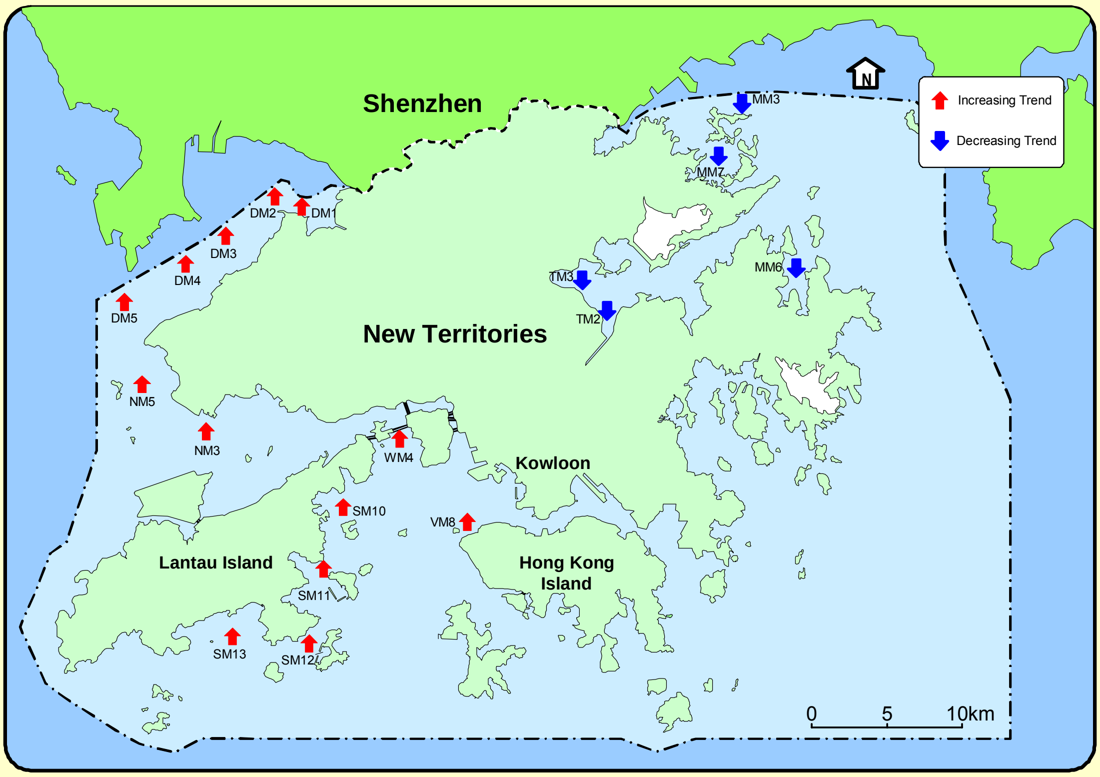


Figure 15.13 Long-term changes in orthophosphate phosphorus in marine waters of Hong Kong, 1986 - 2003

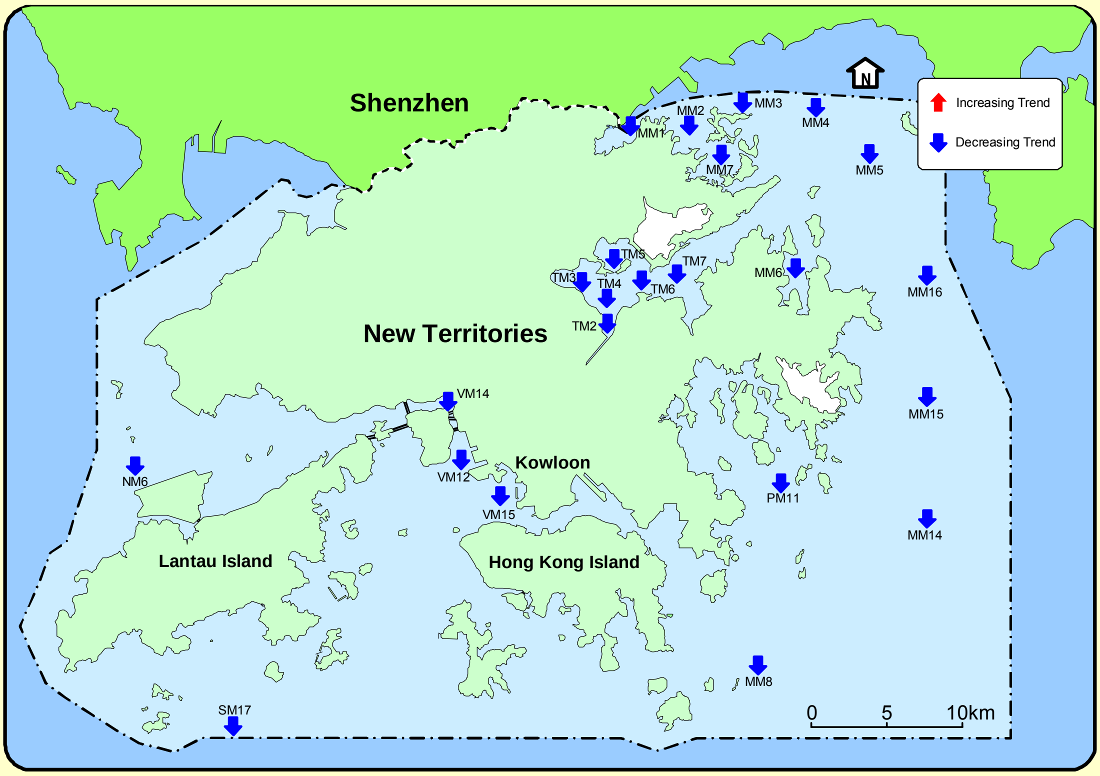


Figure 15.14 Long-term changes in chlorophyll-a in marine waters of Hong Kong, 1986 - 2003

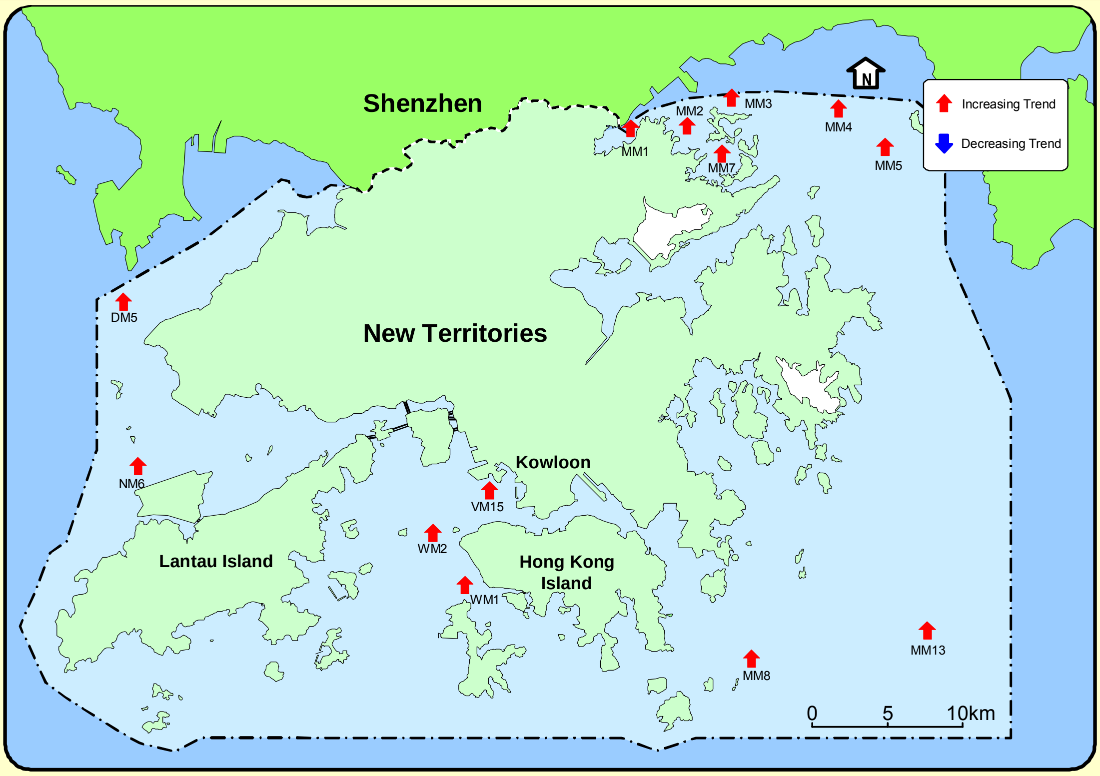


Figure 15.15 Long-term changes in temperature in marine waters of Hong Kong, 1986 – 2003

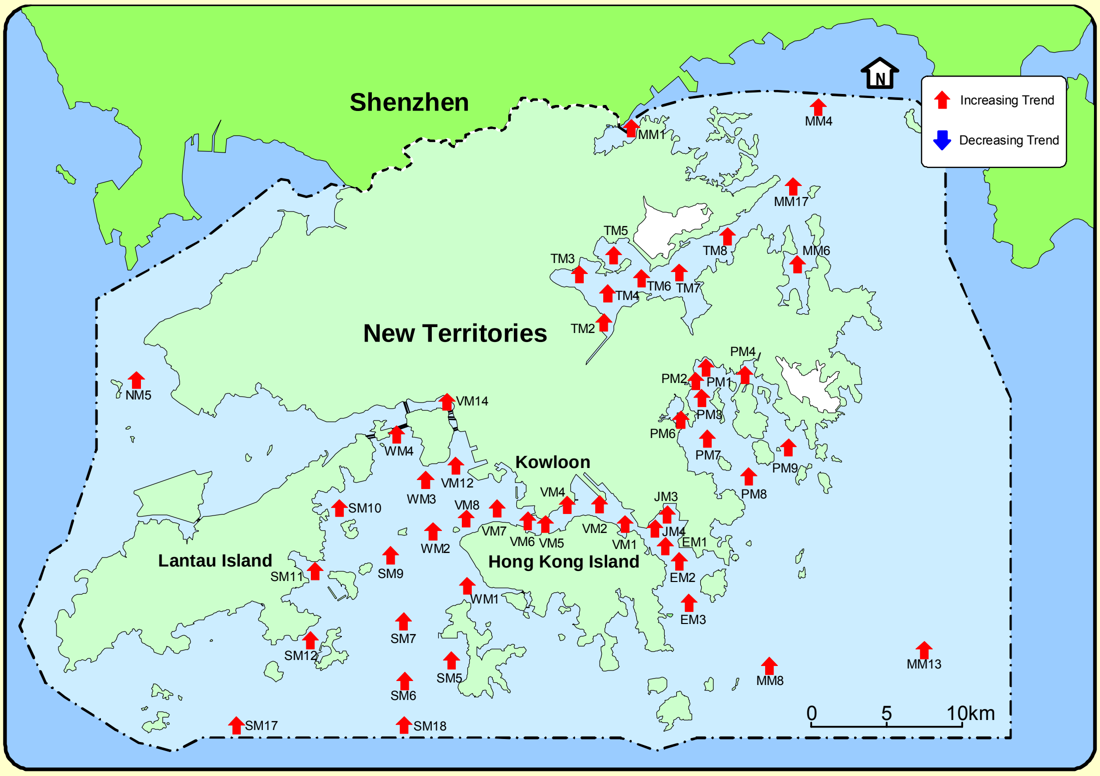


Figure 15.16 Long-term changes in pH in marine waters of Hong Kong, 1986 – 2003

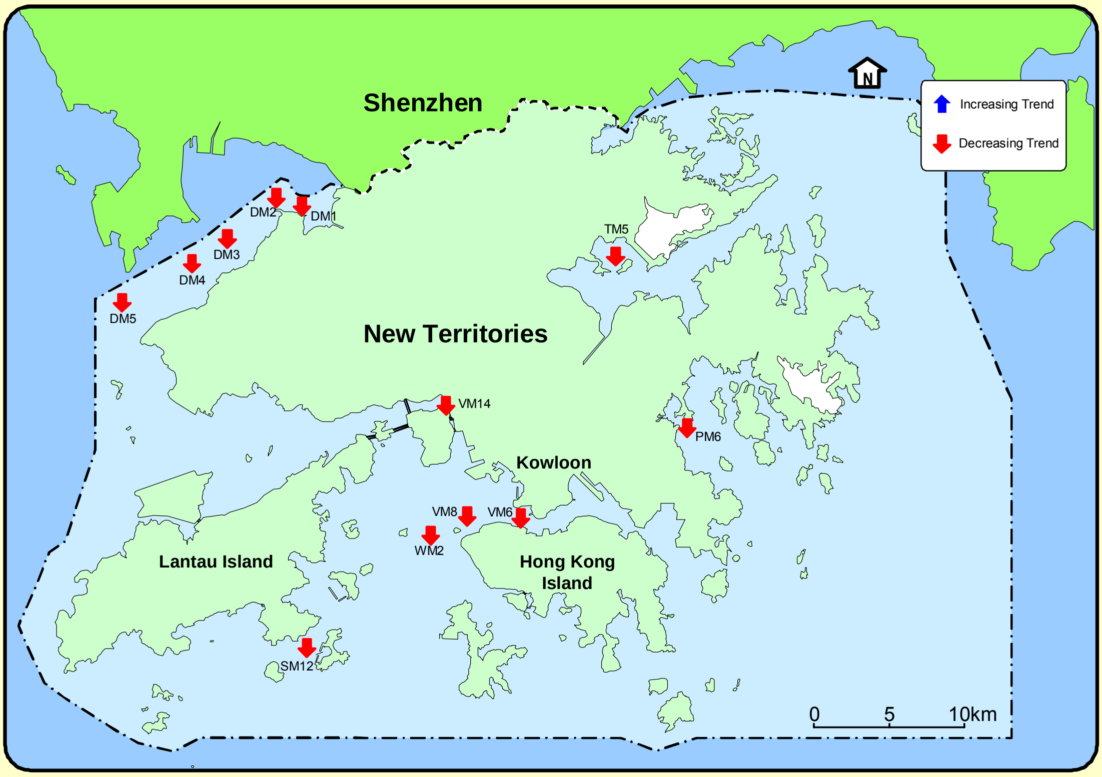
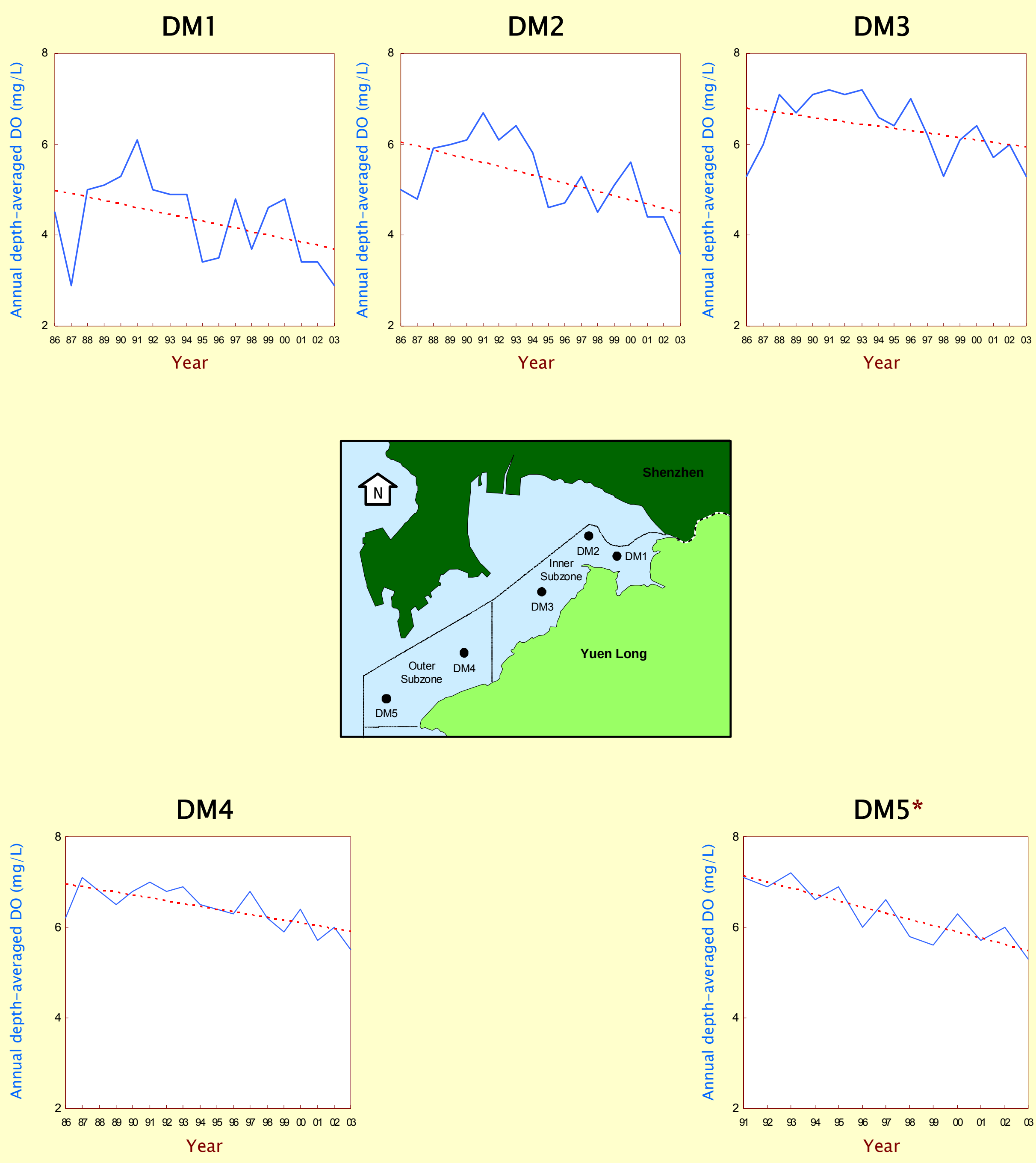
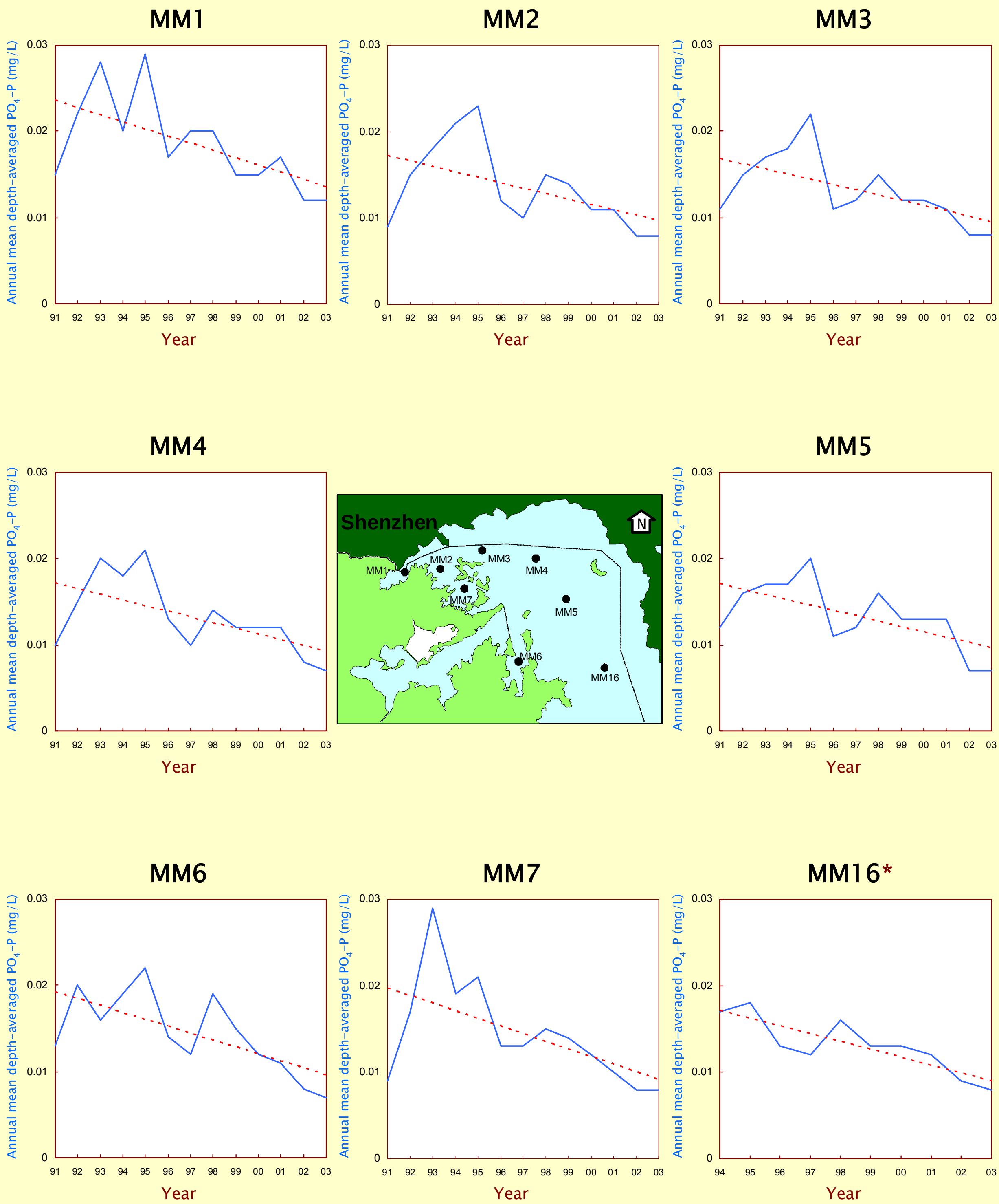


Figure 15.17 Decreasing trends in depth-averaged DO in the Deep Bay WCZ, 1986 - 2003



(* Monitoring of DM5 commenced in 1991)

Figure 15.18 Decreasing trends in depth-averaged PO_4-P in the northern part of Mirs Bay, 1991 – 2003



(* Monitoring of MM16 commenced in 1994)