Deep Bay Water Quality in 1996

Introduction

A member of the Council has raised concerns about a possible decline in the numbers of bottom-dwelling animals in Deep Bay. He requested a review of the Deep Bay water quality data and data obtained from the Shenzhen River Regulation Office so as to ascertain whether there was a decline in water quality in inner Deep Bay in 1996 which might account for the decline in the biota. This paper presents the results of the analysis requested.

Water Quality Data for Deep Bay

2. Deep Bay water quality data is available from the long-term marine monitoring programme conducted by the Environmental Protection Department (EPD) since 1986. A large number of physico-chemical parameters are measured at four sampling stations in Deep Bay (Figure 1) and the results are published yearly by the EPD. Data prior to 1986 are also available but the sampling frequency for those years was only quarterly or 2-monthly and it was only since 1988 that a monthly sampling regime was adopted which provides sufficient data for a year-on-year assessment of the change in water quality. It is these which have been used for analysis of marine water quality.

3. We have also examined our river water quality data to determine whether the quality of water entering the bay from the Hong Kong side of the catchment has deteriorated recently. Data from the Shenzhen River Regulation Office collected during 1996 have been examined to determine whether the river regulation works have had any impact on the quality of the Shenzhen river.

Data Analysis and Results

4. The first objective of the data analysis was to determine whether the Deep Bay water quality in 1996 was particularly poor when compared with previous years, i.e. from 1988 to 1995. The second objective was to determine whether the deterioration in water quality in

1996, if real, constitutes part of a long-term deteriorating trend. The details of the statistical procedures used in the analysis are described in the footnote below.[1]

5. Ten water quality parameters were used in the analysis. They cover different indicators of water pollution by nutrients (nitrogen and phosphorus), organic pollution (5-day biochemical oxygen demand (BOD)), sewage input (the bacterium *E. coli*), eutrophication (dissolved oxygen and chlorophyll-a) and other human activities (suspended solids and salinity).

Water Quality in 1996

6. Table 1 shows how water quality in 1996 compared with the previous 8 years. It is clear from the analysis that at the innermost stations (DM1 and DM2) 1996 was a particularly bad year compared with preceding years whereas for DM3 and DM4 there was no widespread or systematic difference. Focussing on DM1 and DM2, the most obvious differences were in biochemical oxygen demand, and ammonia nitrogen (measures of organic pollution and nutrient enrichment), *E. coli* bacteria (a measure of sewage pollution) and chlorophyll (a measure of populations of microscopic algae) (see Figure 2). The latter indicates there was an algal bloom in the inner bay over the summer months in 1996.

7. Over the whole year, there was no statistically significant difference in 1996 compared with 1995 for dissolved oxygen and suspended solids but, importantly, there was a period from June to August at DM1 when dissolved oxygen remained below 1 mg/L for a period of three months (Figure 3). Possibly this could have been connected with the algal bloom, with large quantities of algae dying and depleting the water of oxygen. The maintenance of such a low level for such a long time may well have had an impact on the fauna.

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[1]To determine whether 1996 was a particular bad year in terms of water quality, the monthly water quality data for a variety of parameters were compared to the data from the same month in other years, i.e. 1988 to 1995. The non-parametric Wilcoxon Matched-Pair Signed-Ranks Test was used to test the statistical difference of the matched comparison between 1996 and other years. The comparison is judged to be statistically significant if $p < 0.05$.

To determine whether or not there have been gradual changes in water quality from 1988 to 1996 in Deep Bay, the non-parametric Seasonal Kendall Test was applied. It should be noted that the Kendall Test provides the dominant trend in the data and could be insensitive to short-term changes or reversals. For example, if 1996 water quality is unique and different from the trend established for the other years (1988 to 1995), it would probably have no effect on the long term trend (for example, see Figure 9 on total phosphorus).

Long-term Water Quality Trends

8. Table 2 summarizes the long-term water quality trends at the four sampling stations. In the inner Bay at DM1 and DM2, long-term increasing trends were found for the sewage bacterium *E. coli*, total nitrogen and total inorganic nitrogen. Salinity is decreasing in the inner Bay and dissolved oxygen is decreasing at DM1. In the middle and outer Bay, *E. coli* exhibits an increasing trend while ammoniacal nitrogen shows an increase at DM4. To illustrate the long-term changes in graphical form, the significant trends at DM1 in the inner Bay are plotted out in Figures 4 to 9.

River water quality

9. An analysis of river water quality data for the Hong Kong side of the catchment shows (Table 3) that for the key pollution parameters of BOD and ammoniacal nitrogen there were few differences between 1995 and 1996, and where there were differences they were in the nature of improvements. This is consistent with the slow but steady removal of polluting loads from the Hong Kong catchment under the livestock waste control scheme and other improvement programmes.

10. Data from the Shenzhen River Regulation Office are plotted in Figures 10 to 12. They confirm that the river is very heavily polluted but do not indicate any obvious deterioration which may have accounted for a marked change in the water quality of Deep Bay.

Effect of Shenzhen River Regulation Project Stage I

11. Figures 10 to 12 show that commencement of the dredging under the Shenzhen River Regulation project produced a temporary increase in suspended solids levels but had no obvious impact on other important measures of water quality.

Conclusions

12. There is clearly a long-term trend of deteriorating water quality in inner Deep Bay. In 1996 water quality was in broad terms worse than at any time in the preceding eight years. There was an unprecedented period of low dissolved oxygen in the inner bay over the height of

summer. None of these changes are likely to have been caused by Stage I of the Shenzhen River Regulation, but they could have had an impact on mudflat fauna.

13. The cause of the long-term deteriorating trend is unlikely to be due to increasing pollution from the Hong Kong side of the catchment, given that loads to Hong Kong rivers continue to be reduced, and water quality in the rivers continues to improve slowly.

Water Policy & Planning Group
Environmental Protection Department
March 1997

Table 1 Comparison of water quality in 1996 with those of 1988 to 1995 at the four sampling stations (DM1, DM2, DM3 and DM4) in Deep Bay, using the Wilcoxon Matched-Pair Signed-Ranks Test ($p < 0.05$).

(A "∧" indicates a significant increase of the parameter in 1996 and a "∨" means a significant decrease. A "--" means no significant difference.)

Deep Bay sampling station	Year compared with 1996	Biochemical Oxygen Demand	*E. coli*	Dissolved Oxygen	Salinity	Ammoniacal Nitrogen	Total Nitrogen	Total Inorganic Nitrogen	Chloro-phyll-a	Suspended Solids	Total Phosphorus
DM1	1988	∧	∧	∨	∨	∧	∧	∧	--	--	--
	1989	∧	∧	--	--	∧	∧	∧	--	--	∧
	1990	∧	∧	∨	∨	∧	∧	∧	--	--	--
	1991	--	∧	--	∨	∧	∧	∧	--	--	--
	1992	∧	∧	--	--	∧	∧	∧	∧	∧	∧
	1993	∧	∧	--	--	∧	∧	∧	--	∧	∧
	1994	∧	∧	--	--	∧	∧	∧	∧	--	∧
	1995	∧	∧	--	--	∧	∧	∧	∧	--	∧
DM2	1988	--	∧	--	--	∧	∧	∧	--	--	--
	1989	--	∧	--	--	∧	∧	∧	--	--	∧
	1990	--	∧	--	--	∧	--	∧	--	∧	--
	1991	--	∧	--	--	∧	∧	∧	--	--	--
	1992	∧	∧	--	--	∧	∧	∧	∧	∧	∧
	1993	--	∧	--	--	∧	∧	∧	--	∧	∧
	1994	∧	∧	--	--	∧	∧	∧	--	--	∧
	1995	∧	∧	--	--	∧	∧	∧	∧	--	∧

Deep Bay sampling station	Year compared with 1996	Biochemical Oxygen Demand	*E. coli*	Dissolved Oxygen	Salinity	Ammoniacal Nitrogen	Total Nitrogen	Total Inorganic Nitrogen	Chloro-phyll-a	Suspended Solids	Total Phosphorus
DM3	1988	--	--	--	--	--	--	--	--	--	--
	1989	--	--	--	--	--	--	--	--	--	Λ
	1990	Λ	--	--	--	--	--	--	Λ	--	--
	1991	--	--	--	--	Λ	--	Λ	--	--	Λ
	1992	--	--	--	--	Λ	--	--	Λ	--	--
	1993	--	--	--	--	Λ	--	--	--	--	Λ
	1994	--	--	--	--	--	--	--	Λ	--	Λ
	1995	Λ	--	--	--	--	--	--	--	--	Λ
DM4	1988	--	--	--	--	--	--	Λ	--	--	--
	1989	--	Λ	--	--	--	--	--	--	--	Λ
	1990	--	--	--	--	Λ	--	--	--	--	Λ
	1991	--	Λ	--	--	--	--	--	--	--	--
	1992	V	Λ	--	--	--	--	--	Λ	--	--
	1993	--	--	--	--	--	--	--	--	--	Λ
	1994	--	--	--	--	--	--	--	--	--	--
	1995	--	--	--	--	--	--	Λ	--	--	--

Table 2 Long-term water quality trends at the four sampling stations (DM1, DM2, DM3 and DM4) in Deep Bay from 1988 to 1996. Trend detection is by the Seasonal Kendall Test at $p < 0.05$.

(A "∧ indicates a significant increasing trend and a "∨ means a significant decreasing trend. A - means no trend.)

Sampling Station	Water Depth	Biochemical Oxygen Demand	*E. coli*	Dissolved Oxygen	Salinity	Ammoniacal Nitrogen	Total Nitrogen	Total Inorganic Nitrogen	Chlorophyll-a	Suspended Solids	Total Phosphorus
DM1	Surface	--	∧	∨	∨	--	∧	∧	--	--	∨
DM2	Surface	--	∧	--	∨	--	∧	∧	--	--	--
DM3	Depth average	--	∧	--	--	--	--	--	--	--	--
DM4	Depth average	--	∧	--	--	∧	--	--	--	--	--

Table 3   A comparison of the 1995 and 1996 river water quality data, using the Wilcoxon's Matched-Pairs Signed-Ranks test

River	Sampling Station	5-day biochemical oxygen demand	Ammoniacal nitrogen
River Indus	IN1	---	---
	IN2	---	V
	IN3	V	V
River Beas	RB1	---	---
	RB2	---	---
	RB3	V	---
River Ganges	GR1	V	---
	GR2	V	V
	GR3	---	---
Yuen Long Greek	YL1	---	---
	YL2	---	---
	YL3	---	---
	YL4	---	---
Kam Tin River	KT1	---	---
	KT2	---	---

Note

1. A "V" indicates that the results between 1995 and 1996 are significantly different at $p < 0.05$ and a decrease in the level of the variable in 1996 was observed.
2. "---" indicate the results between 1995 and 1996 are not significant different at $p < 0.05$.

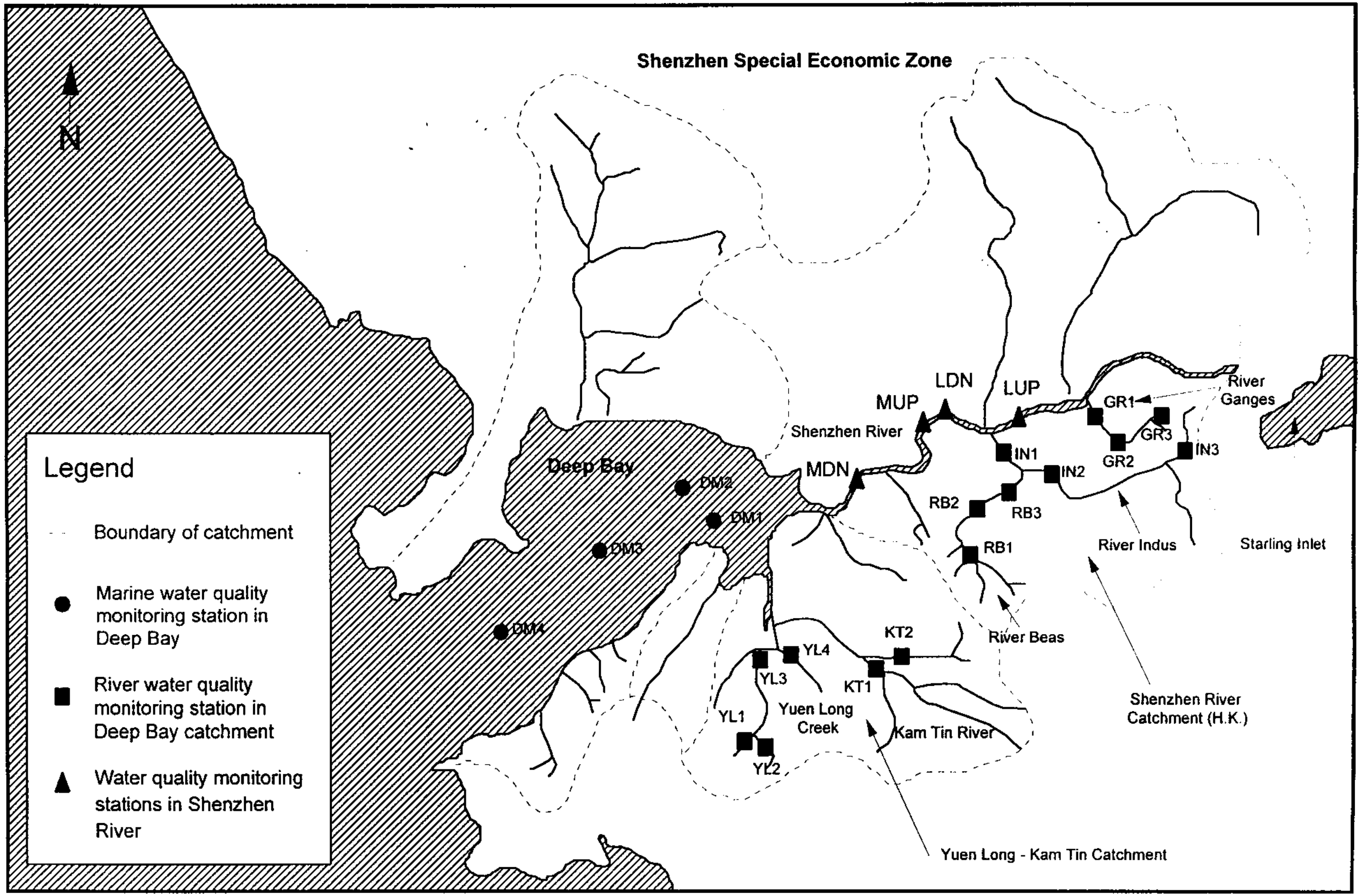


Figure 1. Locations of marine and river water quality monitoring stations in Deep Bay and its catchments (including the monitoring stations for the Shenzhen River Regulation Project, Stage I)

Figure 2. The following graphs show statistically significant($p<0.05$) changes in 5-day biochemical oxygen demand (BOD_5), *E.coli*, ammoniacal nitrogen(NH_4) and chlorophyll-*a* (CHY) in the two sampling stations, DM1 and DM2, in inner Deep Bay for 1995 and 1996.

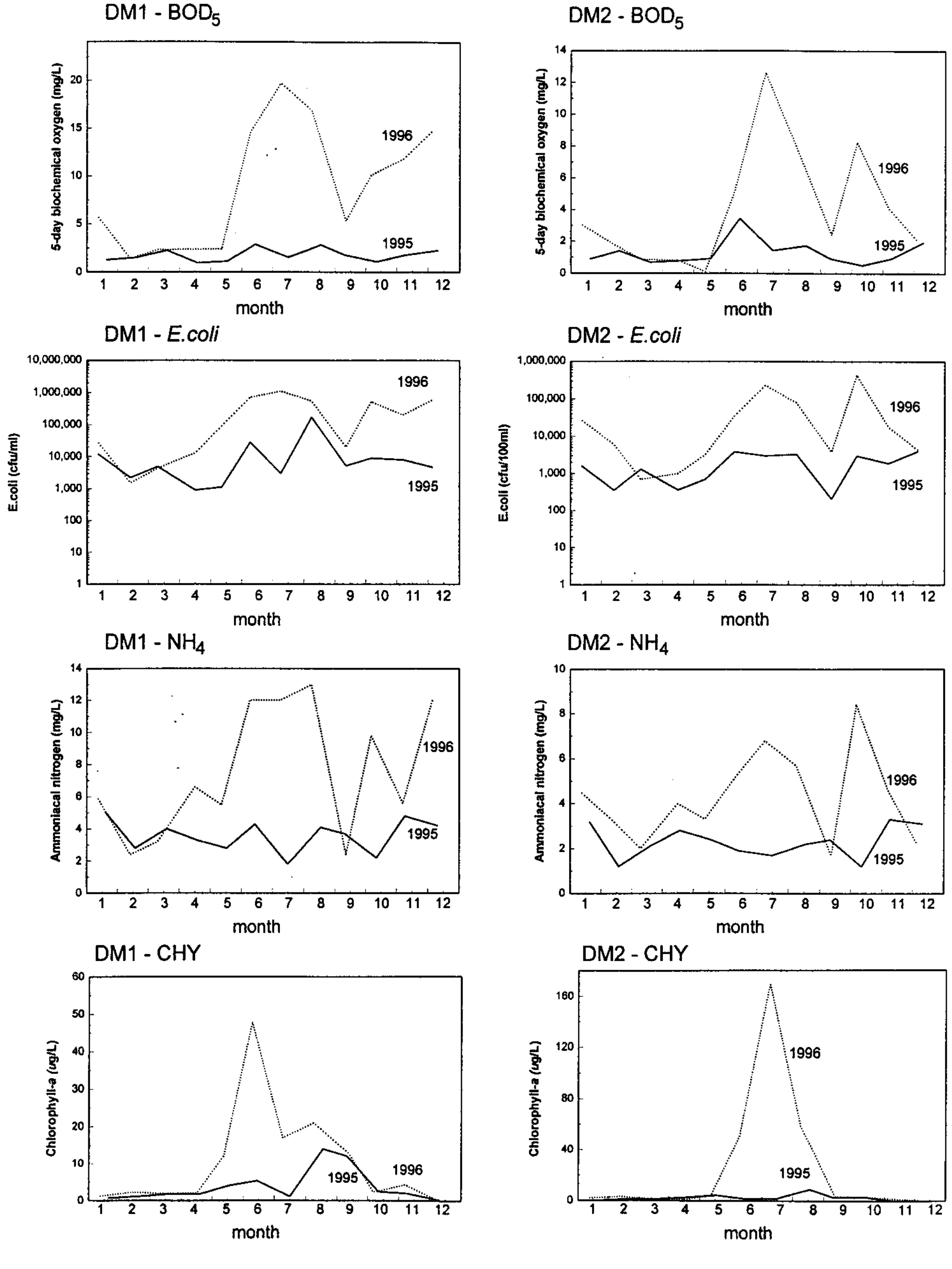
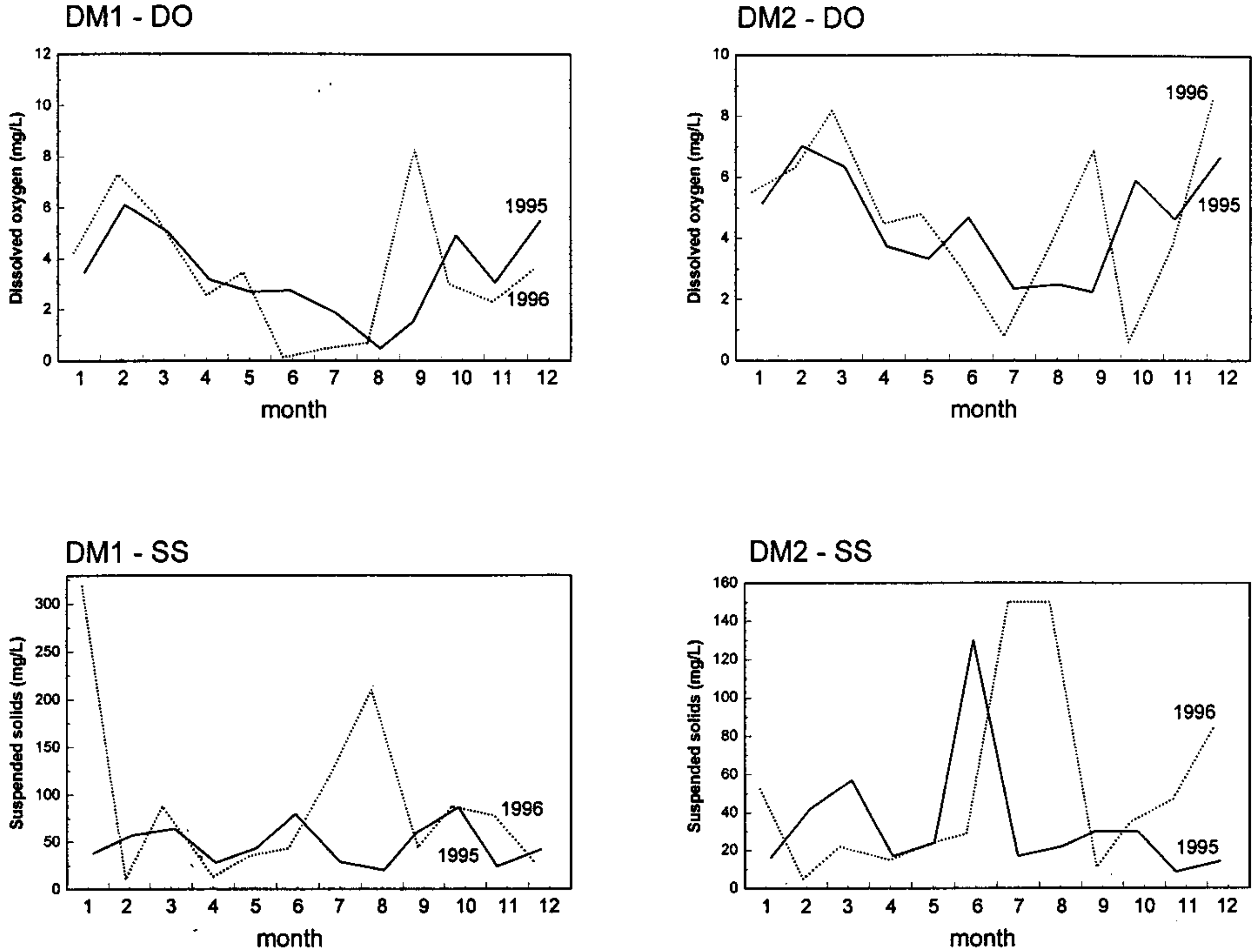


Figure 3. The following graphs show no changes in dissolved oxygen (DO), and suspended solids (SS) in the two sampling stations, DM1 and DM2, in inner Deep Bay for 1995 and 1996.



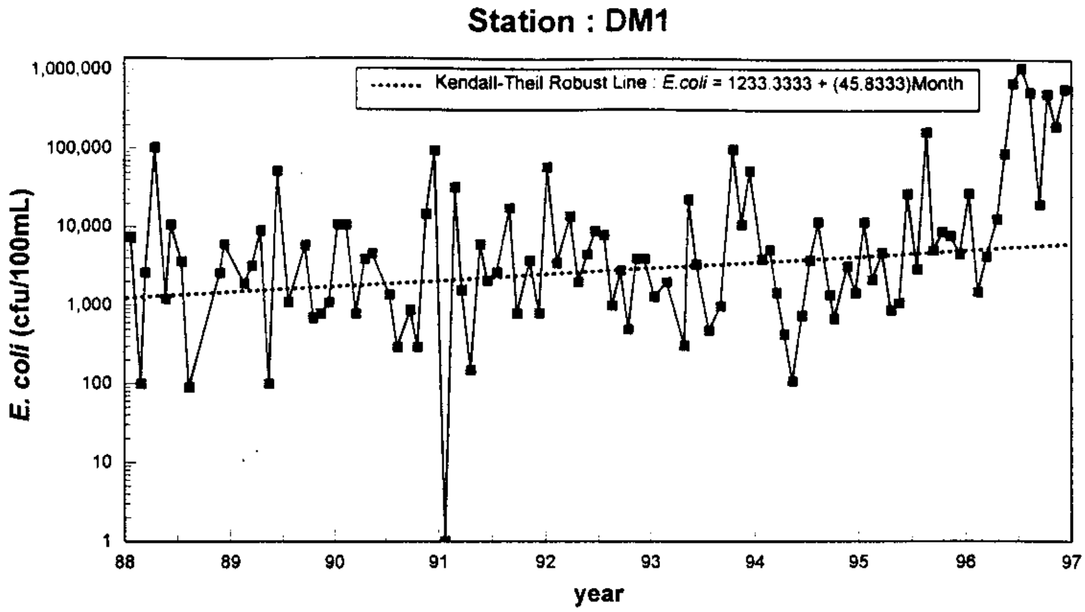


Figure 4. Increasing trend in depth-averaged *E.coli* level for station DM1 during 1988-1996

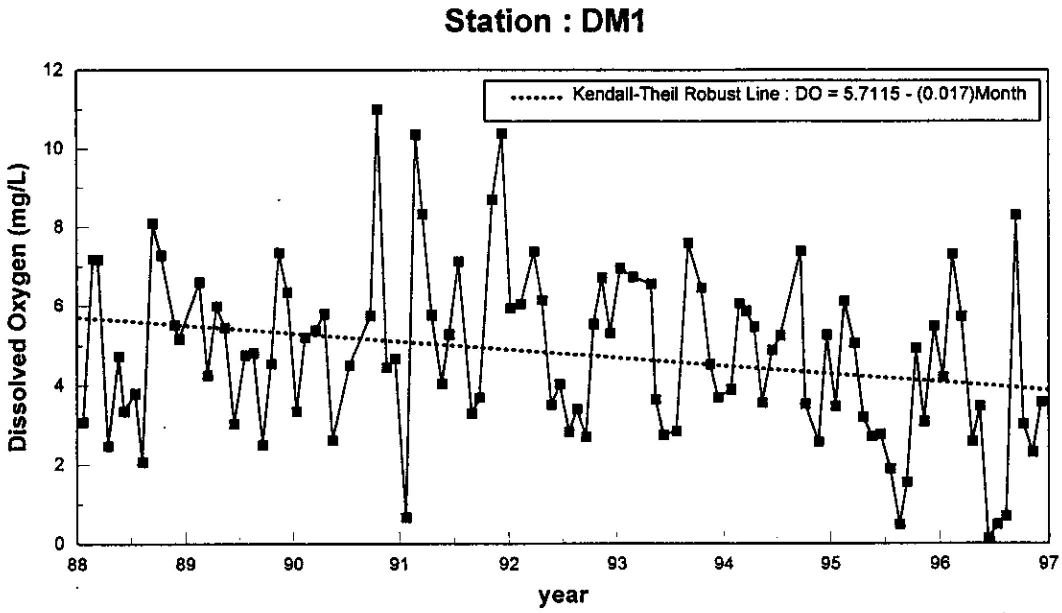


Figure 5. Decreasing trend in depth-averaged dissolved oxygen concentrate for station DM1 during 1988-1996

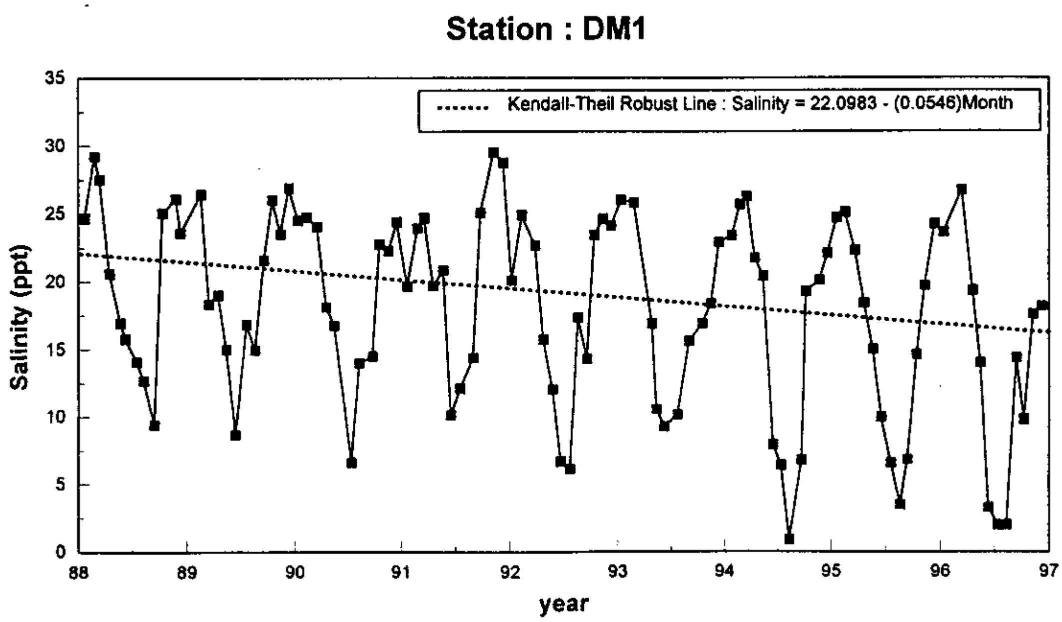


Figure 6. Decreasing trend in depth-averaged salinity concentration for station DM1 during 1988-1996

Station : DM1

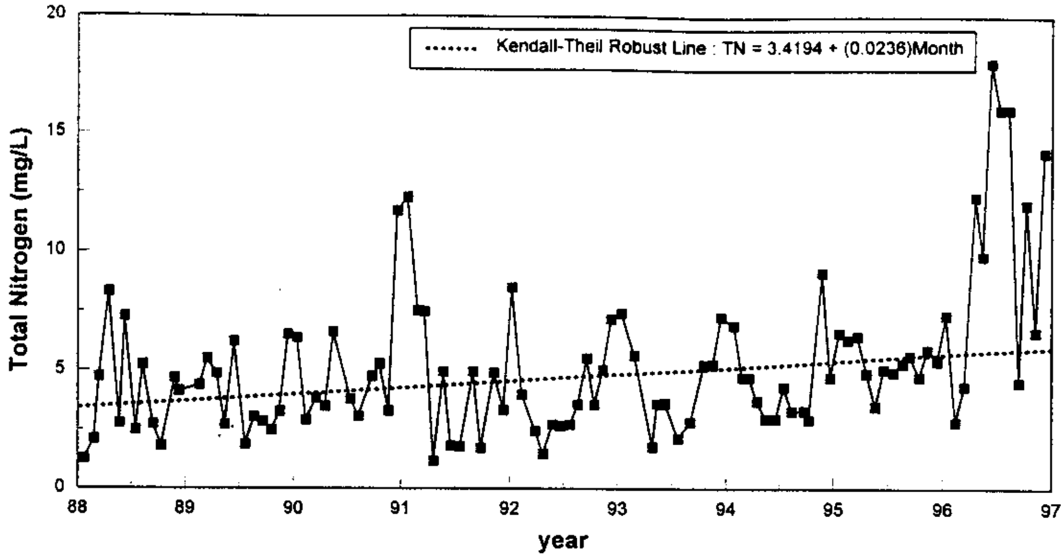


Figure 7. Increasing trend in depth-averaged total nitrogen concentration for station DM1 during 1988-1996

Station : DM1

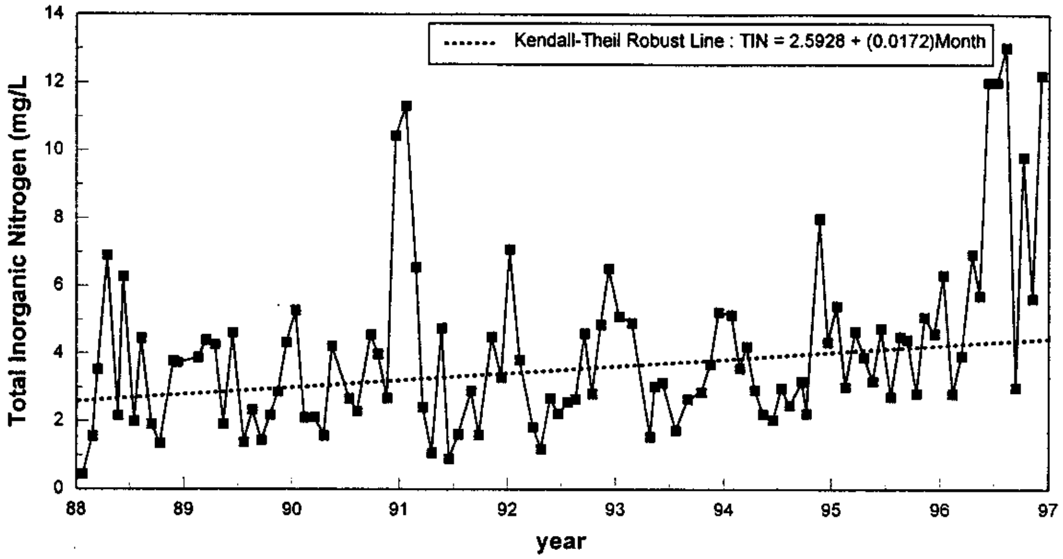


Figure 8. Increasing trend in depth-averaged total inorganic nitrogen concentration for station DM1 during 1988-1996

Station : DM1

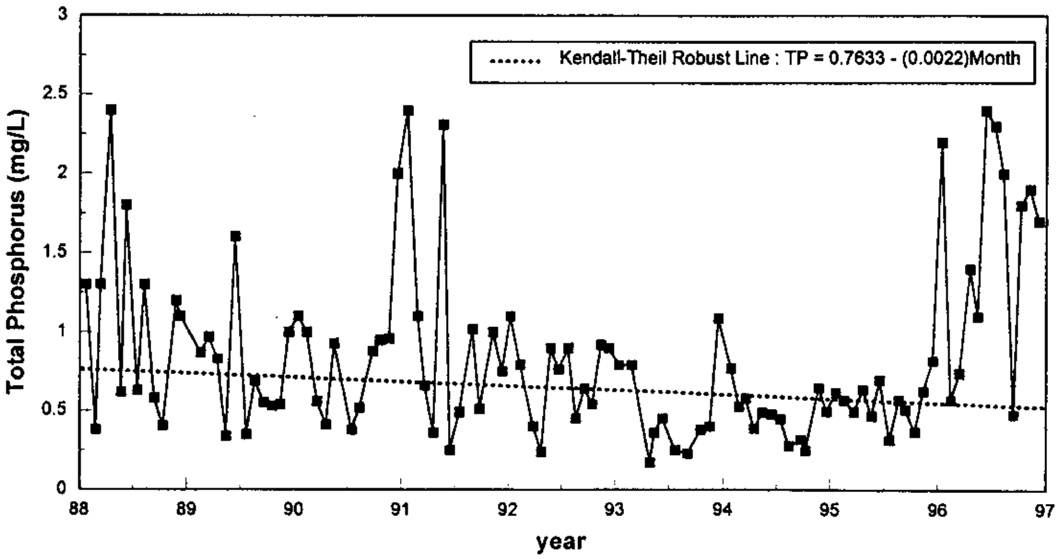


Figure 9. Decreasing trend in depth-averaged total phosphorus concentration for station DM1 during 1988-1996

Figure 10. The following graphs show the change of suspended solids (SS) and dissolved oxygen (DO) at four monitoring stations along the Shenzhen River. The arrow in each graphs indicate the commencement of dredging work. (LUP: 500m upstream of Liu Pok site, MUP: 500m upstream of Lok Ma Chau site, LDN: 1000m downstream of Liu Pok site, MDN: 1000m downstream of Lok Ma Chau site)

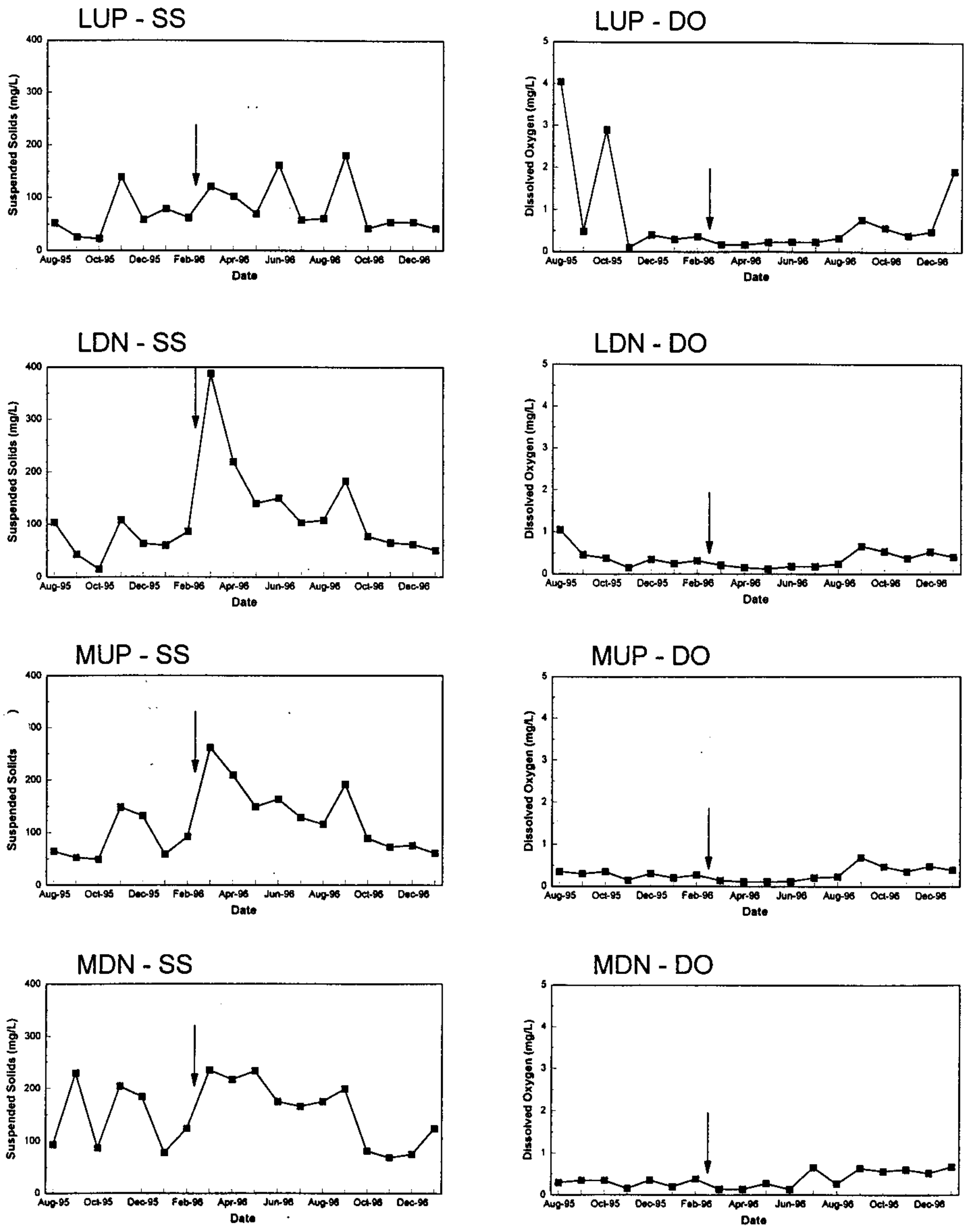


Figure 11. The following graphs show the change of total nitrogen (TN) and total phosphorus (TP) at four monitoring stations along the Shenzhen River. The arrow in each graphs indicate the commencement of dredging work. (LUP: 500m upstream of Liu Pok site, MUP: 500m upstream of Lok Ma Chau site, LDN: 1000m downstream of Liu Pok site, MDN: 1000m downstream of Lok Ma Chau site)

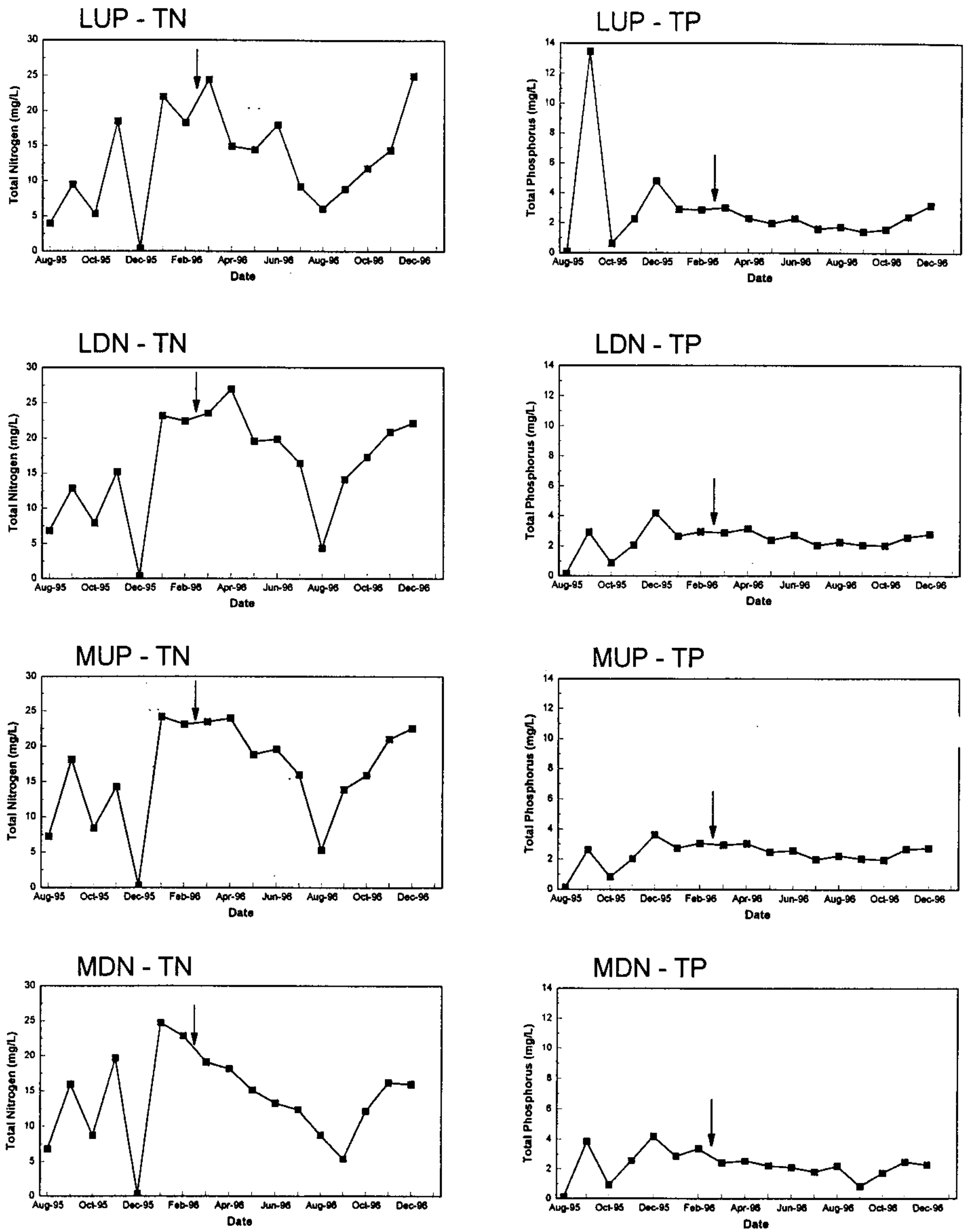
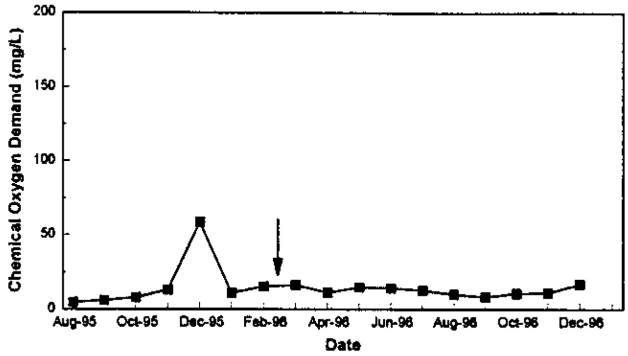
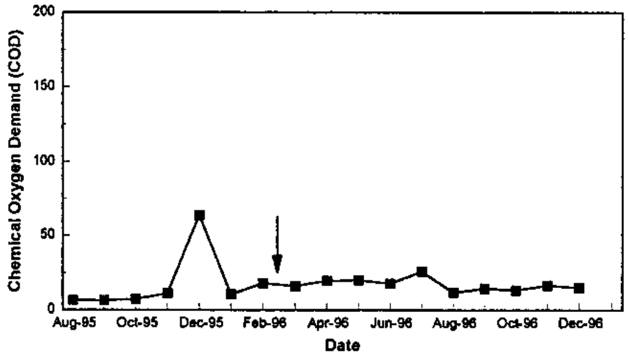


Figure 12. The following graphs show the change of chemical oxygen demand (COD) at four monitoring stations along the Shenzhen River.
The arrow in each graphs indicate the commencement of dredging work.
(LUP: 500m upstream of Liu Pok site, MUP: 500m upstream of Lok Ma Chau site, LDN: 1000m downstream of Liu Pok site, MDN: 1000m downstream of Lok Ma Chau site)

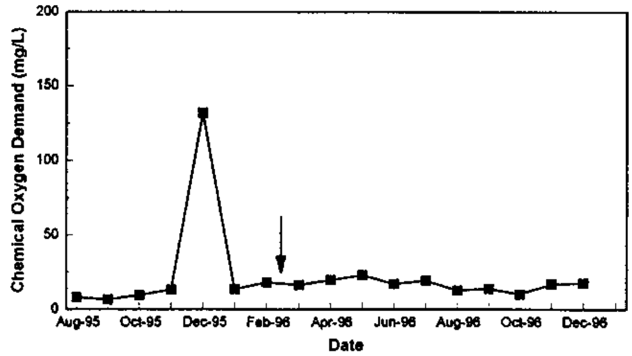
LUP - COD



LDN - COD



MUP - COD



MDN - COD