5. WATER QUALITY

5.1 Introduction

Development of the Tai O sheltered boat anchorage has the potential to adversely impact upon water quality during both the construction and operational phases. In order to assess the significance of potential impacts upon water quality, this chapter includes details as followings:

- identification of water sensitive receivers;
- identification of applicable legislation and standards;
- review of available water quality data;
- definition of baseline conditions;
- identification of water pollution sources and impacts during the sheltered boat anchorage construction phase;
- identification of water pollution sources and impacts during the sheltered boat anchorage operation; and
- identification of appropriate mitigation measures.

5.2 Water Sensitive Receivers and Beneficial Uses

Water sensitive receivers are defined as those users/occupants of the aquatic/marine environment whose use of the environment could be impaired as a result of the proposed development. According to the EIA TM, existing or potential beneficial uses that are sensitive to water pollution include, but are not limited to, the following:

- areas of ecological or conservation value, including marine conservation areas, existing or gazetted proposed marine parks and marine reserves, Sites of Special Scientific Interest (SSSIs), existing or gazetted proposed Country Parks and Special Areas, wetlands, mangroves and important freshwater habitats;
- areas for abstraction of water for potable water supply;
- water abstraction for irrigation and aquaculture;
- fish spawning grounds, fish culture zones, shellfish harvesting/culture site and brackish/freshwater fish ponds;
- beaches and other recreational areas;
- water abstraction for cooling, flushing and other industrial purposes;
- areas for navigation/shipping including typhoon shelters, marinas and boat parks.

Given the above definitions, the main water sensitive receivers in the vicinity of Tai O Bay are the existing mangrove stands along Tai O Creek and within the existing salt pans (refer to **Figure 5.1**) and the brackish ponds and wetland area behind the salt pans. In addition, it is noted that sensitive ecological habitats such as the Sha Chau and Lung Kwu Chau Marine Park and the potential South Lantau Marine Park may also be considered to be water sensitive receivers during the construction phase.

There are no cooling water intakes or Water Services Department (WSD) seawater pumping stations in the Study Area.

Following sheltered boat anchorage development, the created salt pan mangrove habitat will be the principal water sensitive receiver, although in accordance with the EIA TM, the sheltered boat anchorage and its associated navigational access routes will also be deemed to be water sensitive receivers. It is noted that EPD is proposing to gazette the shoreline along both sides of outer Tai O Bay as secondary recreational subzones (refer to **Figure 5.1**). These secondary recreational subzones are likely to be gazetted following anchorage development and are thus considered to be potential future sensitive receivers.

5.3 Legislation and Applicable Standards

The acceptability of water quality impacts during sheltered boat anchorage construction and operation can be determined through reference to relevant Hong Kong water quality related legislation. Key legislative water quality control documents include the following:

- the Shipping and Port Control Ordinance;
- the Water Pollution Control Ordinance (Cap. 358);
- the Water Pollution Control (General) Regulations;
- the Water Pollution Control (Sewerage) Regulations;
- the Statement of Water Quality Objectives (North Western Water Control Zone); and
- Annex 6 and Annex 14 of the EIA TM.

Hong Kong's water quality legislative framework is built around the Water Pollution Control Ordinance (WPCO 1981(Cap. 358)), from which over 20 other Regulations and Orders stem. Under the WPCO, Hong Kong waters are divided into 10 Water Control Zones (WCZs). Each WCZ has a designated set of statutory Water Quality Objectives (WQOs).

The WCZ closest to Tai O is the North Western WCZ which was declared on 1 April 1992 and covers the water body between north Lantau and coast-line of the north west New Territories and adjacent waters. **Table 5.1** presents the WQOs for the North Western WCZ.

Table 5.1: Water Quality Objectives (WQOs) for the North Western Water Control Zone.

	Water Quality Objective	Part of Parts of Zone
A.	AESTHETIC APPEARANCE	
	(a) Waste discharges shall cause no objectionable odours or discoloration of the water.	Whole zone
	(b) Tarry residues, floating wood, articles made of glass, plastic, rubber or of any other substances should be absent.	Whole zone
	(c) Mineral oil should not be visible on the surface. Surfactants should not give rise to a lasting foam.	Whole zone
	(d) There should be no recognisable sewage-derived debris.	Whole zone
	(e) Floating, submerged and semi-submerged objects of a size likely to interfere with the free movement of vessels, or cause damage to vessels, should be absent.	Whole zone
	(f) Waste discharges shall not cause the water to contain substances which settle to form objectionable deposits.	Whole zone
B.	BACTERIA	
	(a) The level of *Escherichia coli* should not exceed 610 per 100 mL, calculated as the geometric mean of all samples collected in a calendar year.	Secondary Contact Recreation Subzones
	(b) The level of *Escherichia coli* should be less than 1 per 100 mL, calculated as the running median of the most recent 5 consecutive samples taken at intervals of between 7 and 21 days.	Tuen Mun (A) and Tuen Mun (B) Subzones and Water Gathering Ground Subzones
	(c) The level of *Escherichia coli* should not exceed 1 000 per 100 mL, calculated as the running median of the most recent 5 consecutive samples taken at intervals of between 7 and 21 days.	Tuen Mun (C) Subzone and other inland waters
C.	COLOUR	
	(a) Waste discharges shall not cause the colour of water to exceed 30 Hazen units.	Tuen Mun (A) and Tuen Mun (B) Subzones and Water Gathering Ground Subzones
	(b) Waste discharges shall not cause the colour of water to exceed 50 Hazen units.	Tuen Mun (C) Subzone and other inland waters
D.	DISSOLVED OXYGEN	
	(a) Waste discharges shall not cause the level of dissolved oxygen to fall below 4mg/L for 90% of the sampling occasions during the whole year; values should be calculated as water column average (arithmetic mean of at least 3 measurements at 1m below surface, mid-depth and 1m above seabed). In addition, the concentration of dissolved oxygen should not be less than 2mg/L for 90% of bottom samples during the whole year.	Marine waters
	(b) Waste discharges shall not cause the level of dissolved oxygen to be less than 4 mg per litre.	Tuen Mun (A), Tuen Mun (B) and Tuen Mun (C) Subzones, Water Gathering Ground Subzones and other inland waters
E.	pH	
	(a) The pH of the water should be within the range of 6.5-8.5 units. In addition, waste discharges shall not cause the natural pH range to be extended by more than 0.2 unit.	Marine waters excepting Bathing Beach Subzones
	(b) Waste discharges shall not cause the pH of the water to exceed the range of 6.5-8.5 units.	Tuen Mun (A), Tuen Mun (B) and Tuen Mun (C) Subzones and Water Gathering Ground Subzones
	(c) The pH of the water should be within the range of 6.0-9.0 units.	Other inland waters
F.	TEMPERATURE	
	Waste discharges shall not cause the natural daily temperature range to change by more than 2.0ºC.	Whole zone
G.	SALINITY	
	Waste discharges shall not cause the natural ambient salinity level to change by more than 10%.	Whole zone
H.	SUSPENDED SOLIDS	

	Water Quality Objective	Part of Parts of Zone
	(a) Waste discharges shall neither cause the natural ambient level to be raised by more than 30% nor give rise to accumulation of suspended solids which may adversely affect aquatic communities.	Marine waters
	(b) Waste discharges shall not cause the annual median of suspended solid to exceed 20 mg per litre.	Tuen Mun (A), Tuen Mun (B) and Tuen Mun (C) Subzones and Water Gathering Ground Subzones
	(c) Waste discharges shall not cause the annual median of suspended solids to exceed 25 mg per litre.	Other inland waters
I.	AMMONIA	
	The un-ionised ammoniacal nitrogen level should not be more than 0.021 mg per litre, calculated as the annual average (arithmetic mean).	Whole zone
J.	NUTRIENTS	
	(a) Nutrients should not be present in quantities sufficient to cause excessive or nuisance growth of algae or other aquatic plants.	Marine waters
	(c) Without limiting the generality of objective (a) above, the level of inorganic nitrogen should not exceed 0.5 mg per litre, expressed as annual water column average (arithmetic mean of at least 3 measurements at 1m below surface, mid-depth and 1m above seabed).	Marine waters excepting Castle Peak Bay Subzone
K.	5-DAY BIOCHEMICAL OXYGEN DEMAND	
	(a) Waste discharges shall not cause the 5-day biochemical oxygen demand to exceed 3 mg per litre.	Tuen Mun (A), Tuen Mun (B) and Tuen Mun (C) Subzones and Water Gathering Ground Subzones
	(b) Waste discharges shall not cause the 5-day biochemical oxygen demand to exceed 5 mg per litre	Other inland waters
L.	CHEMICAL OXYGEN DEMAND	
	(a) Waste discharges shall not cause the chemical oxygen demand to exceed 5 mg per litre.	Tuen Mun (A), Tuen Mun (B) and Tuen Mun (C) Subzones and Water Gathering Ground Subzones
	(b) Waste discharges shall not cause the chemical oxygen demand to exceed 30 mg per litre.	Other inland waters
M.	TOXIC SUBSTANCES	
	(a) Waste discharges shall not cause the toxins in water to attain such levels as to produce significant toxic, carcinogenic, mutagenic or teratogenic effects in humans, fish or any other aquatic organisms, with due regard to biologically cumulative effects in food chains and to toxicant interaction with each other.	Whole zone
	(b) Waste discharges shall not cause a risk to any beneficial use of the aquatic environment.	Whole zone

In addition to the standards specified above, any discharges into the inland waters of the North Western WCZ are required to comply with the standards provided in **Table 5.2**, as taken from the Technical Memorandum on Standards for Effluents Discharged into Drainage and Sewerage Systems, Inland and Coastal Waters (1991) (TMES) as issued under the provisions of the WPCO.

Table 5.2: Water Quality Standards for Effluent Discharges into the Inshore Waters of North Western Water Control Zone.

Flow rate (m^3/day) **Determinant**	**≤ 10**	**> 10 and ≤ 200**	**> 200 and ≤ 400**	**> 400 and ≤ 600**	**> 600 and ≤ 800**	**> 800 and ≤ 1000**	**> 1000 and ≤ 1500**	**> 1500 and ≤ 2000**	**> 2000 and ≤ 3000**	**> 3000 and ≤ 4000**	**> 4000 and ≤ 5000**	**> 5000 and ≤ 6000**
pH (pH units)	6-9	6-9	6-9	6-9	6-9	6-9	6-9	6-9	6-9	6-9	6-9	6-9
Temperature (ºC)	40	40	40	40	40	40	40	40	40	40	40	40
Colour (lovibond units) (25mm cell length)	1	1	1	1	1	1	1	1	1	1	1	1
Suspended solids	50	30	30	30	30	30	30	30	30	30	30	30
BOD	50	20	20	20	20	20	20	20	20	20	20	20
COD	100	80	80	80	80	80	80	80	80	80	80	80
Oil and grease	30	20	20	20	20	20	20	20	20	20	20	20
Iron	15	10	10	7	5	4	3	2	1	1	0.8	0.6
Boron	5	4	3	2	2	1.5	1.1	0.8	0.5	0.4	0.3	0.2
Barium	5	4	3	2	2	1.5	1.1	0.8	0.5	0.4	0.3	0.2
Mercury	0.1	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Cadmium	0.1	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Other toxic metals individually	1	1	0.8	0.7	0.5	0.4	0.3	0.2	0.15	0.1	0.1	0.1
Total toxic metals	2	2	1.6	1.4	1	0.8	0.6	0.4	0.3	0.2	0.1	0.1
Cyanide	0.2	0.1	0.1	0.1	0.1	0.1	0.05	0.05	0.03	0.02	0.02	0.01
Phenols	0.5	0.5	0.5	0.3	0.25	0.2	0.1	0.1	0.1	0.1	0.1	0.1
Sulphide	5	5	5	5	5	5	2.5	2.5	1.5	1	1	0.5
Total residual chlorine	1	1	1	1	1	1	1	1	1	1	1	1
Total nitrogen	100	100	80	80	80	80	50	50	50	50	50	30
Total phosphorus	10	10	8	8	8	8	5	5	5	5	5	5
Surfactants (total)	20	15	15	15	15	15	10	10	10	10	10	10
E. coli (count/100 mL)	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000

Notes:
All units in mg/L unless otherwise stated; all figures are upper limits unless otherwise indicated

Table 5.3 presents standards applicable to effluent discharges to foul sewers leading into Government sewage treatment plants as defined in the TMES. These guidelines are applicable during both construction and operation of the Tai O sheltered boat anchorage for all discharges that are categorised as effluents.

Table 5.3: Water Quality Standards for Effluent Discharges into Foul Sewers Leading into Government Sewage Treatment Plants.

Flow rate (m^3/day) Determinant	≤ 10	> 10 and ≤ 100	> 100 and ≤ 200	> 200 and ≤ 400	> 400 and ≤ 600	> 600 and ≤ 800	> 800 and ≤ 1000	> 1000 and ≤ 1500	> 1500 and ≤ 2000	> 2000 and ≤ 3000	> 3000 and ≤ 4000	> 4000 and ≤ 5000	> 5000 and ≤ 6000
pH (pH units)	6-10	6-10	6-10	6-10	6-10	6-10	6-10	6-10	6-10	6-10	6-10	6-10	6-10
Temperature (ºC)	43	43	43	43	43	43	43	43	43	43	43	43	43
Suspended solids	1200	1000	900	800	800	800	800	800	800	800	800	800	800
Settleable solids	100	100	100	100	100	100	100	100	100	100	100	100	100
BOD	1200	1000	900	800	800	800	800	800	800	800	800	800	800
COD	3000	2500	2200	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000
Oil and grease	100	100	50	50	50	40	30	20	20	20	20	20	20
Iron	30	25	25	25	15	12.5	10	7.5	5	3.5	2.5	2	1.5
Boron	8	7	6	5	4	3	2.4	1.6	1.2	0.8	0.6	0.5	0.4
Barium	8	7	6	5	4	3	2.4	1.6	1.2	0.8	0.6	0.5	0.4
Mercury	0.2	0.15	0.1	0.1	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Cadmium	0.2	0.15	0.1	0.1	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Copper	4	4	4	3	1.5	1.5	1	1	1	1	1	1	1
Nickel	4	3	3	2	1.5	1	1	0.8	0.7	0.7	0.6	0.6	0.6
Chromium	2	2	2	2	1	0.7	0.6	0.4	0.3	0.2	0.1	0.1	0.1
Zinc	5	5	4	3	1.5	1.5	1	0.8	0.7	0.7	0.6	0.6	0.6
Silver	4	3	3	2	1.5	1.5	1	0.8	0.7	0.7	0.6	0.6	0.6
Other toxic metals individually	2.5	2.2	2	1.5	1	0.7	0.6	0.4	0.3	0.2	0.15	0.12	0.1
Total toxic metals	10	10	8	7	3	2	2	1.6	1.4	1.2	1.2	1.2	1
Cyanide	2	2	2	1	0.7	0.5	0.4	0.27	0.2	0.13	0.1	0.08	0.06
Phenols	1	1	1	1	0.7	0.5	0.4	0.27	0.2	0.13	0.1	0.1	0.1
Sulphide	10	10	10	10	5	5	4	2	2	2	1	1	1
Sulphate	1000	1000	1000	1000	1000	1000	1000	900	800	600	600	600	600
Total nitrogen	200	200	200	200	200	200	200	100	100	100	100	100	100
Total phosphorus	50	50	50	50	50	50	50	25	25	25	25	25	25
Surfactants (total)	200	150	50	40	30	25	25	25	25	25	25	25	25

Notes:
All units in mg/L unless otherwise stated; all figures are upper limits unless otherwise indicated

The WQOs for the North Western WCZ as detailed above in **Table 5.1** are the governing reference standards for this Study through which the significance of any identified impacts on water quality during anchorage construction/operation will be defined. However, it is of interest to compare existing and predicted water quality with other world-wide standards, especially for parameters such as heavy metals for which there are no specified WQOs. Standards for selected heavy metals which may be referenced during the impact assessment are presented in **Table 5.4**.

Table 5.4: Water Quality Standards for General Ecosystem Conservation (μg/L).

Parameter	Standards for General Ecosystem Conservation.		
	UK (HMIP 1994)[1]	USEPA[2]	Environment Canada[3]
Chromium	15	100	50
Copper	5	50	5
Inorganic lead	25	50	30
Nickel	30	100	25
Zinc	40	100	30

Notes:

1 HMIP (1994) Environmental Economic and BPEO Assessment Principals for Integrated Pollution Control

2 US Environmental Protection Agency 440/a-76-023

3 Environment Canada "References sur la qualite des eaux guide des parameters de la qualite des eaux", Eaux Interieures, Ottawa

5.4 Data Review

Tai O lies on the western edge of Lantau Island in the Pearl River Estuary (Lingdingyang). Local marine waters are strongly influenced by Pearl River flows which raise oxygen demand and nitrate levels, particularly during the summer monsoon.

EPD routinely monitors water quality at five stations within the North Western WCZ, namely NM1, NM2, NM3, NM5, NM6. The nearest routine monitoring station to Tai O is NM6 which is located in open marine waters about 2km to the north of Chek Lap Kok and approximately 12km from Tai O Bay. It is considered that the water quality data obtained for this monitoring station is representative of the regional water quality conditions in vicinity of Tai O, but not of Tai O Bay and its immediate surrounds. A summary of EPD routine water quality data for station NM6 is presented in **Table 5.5**.

Table 5.5: Summary of Marine Water Quality at NM6 EPD Routine Water Quality Monitoring Station (EPD 1998).

Determinant	Depth	Concentration
Temperature (°C)		23.2 (17.8- 28.5)
Salinity (ppt)		24.3 (14.1 - 31.4)
Dissolved oxygen	Surface	6.1 (4.6 - 8.2)
	Bottom	5.8 (4.6 - 8.2)
Dissolved oxygen (% Saturation)	Surface	83 (59 - 106)
	Bottom	78 (58 - 106)
pH		7.9 (718 - 8.4)
Secchi disc depth (m)		1.8 (1.0 - 2.5)
Turbidity (NTU)		5.2 (2.6 - 7.7)
Suspended solids (mg/L)		8.3 (4.8 - 12.5)
5-day Biochemical oxygen demand (mg/L)		0.6 (0.2 - 1.5)
Ammoniacal nitrogen (mg/L)		0.08 (0.02 - 0.12)
Unionised ammoniacal nitrogen (mg/L)		0.002 (< 0.001 - 0.005)
Nitrite nitrogen (mg/L)		0.02 (< 0.01 - 0.09)
Nitrate nitrogen (mg/L)		0.35 (0.01 - 0.61)
Total inorganic nitrogen (mg/L)		0.47 (0.03 - 0.80)
Total Kjeldahl nitrogen (mg/L)		0.63 (0.29 - 1.03)
Total nitrogen (mg/L)		1.02 (0.51 - 1.35)
Ortho-phosphate (mg/L)		0.03 (0.01 - 0.05)
Total phosphorus (mg/L)		0.07 (0.05 - 0.09)
Silica (as SiO_2) (mg/L)		2.9 (0.4 - 6.3)
Chlorophyll-a (μg/L)		2.8 (0.3 - 8.5)
Phaeo-pigment (μg/L)		1.5 (0.8 - 3.1)
E.coli (cfu/100mL)		59 (15 - 960)
Faecal coliforms (cfu/100mL)		105 (24 - 1810)

Notes:

1. Data presented are depth-averaged data, except as specified
2. Data presented are annual arithmetic means except for *E.coli* and faecal coliform data which are geometric means
3. Data enclosed in brackets indicate the ranges

Water quality data for NM6 presented in **Table 5.5** indicates that there was full compliance with the North Western WCZ WQOs for bottom/depth average dissolved oxygen (DO) (≥2mg/L for 90% of bottom samples and ≥4mg/L for 90% depth-averaged samples), total inorganic nitrogen (≤0.5mg/L annual mean depth-average) and unionised ammonia (≤0.021mg/L annual mean depth-average).

In addition to the EPD data presented above, water quality surveys have also been undertaken during the Study on Tonggu Waterway (Agreement No 32/96 by Scott Wilson (Hong Kong) Ltd). Such surveys have entailed detailed water quality monitoring in the near vicinity of Tai O Bay. **Tables 5.6a** and **5.6b** provide a summary of the water quality data obtained during the Tonggu Waterway Study (refer to **Figure 5.2** for monitoring locations). **Table 5.6a** presents a summary of the dry season spring and neap survey water quality data for monitoring stations closest to Tai O, whilst **Table 5.6b** presents the wet season spring and neap water quality data.

Table 5.6a: Summary of Marine Water Quality Data Collected During the Tonggu Waterway Study (Wet Season) (Scott Wilson (Hong Kong) Ltd 1998).

Station 5

	TOC	DOC	COD_{Mn}	BOD_5	*E.coli*	Chl.*a*	TN	TDN	TKN	TDKN	NH_3-N	NO_2-N	NO_3-N	TIN	TP	TDP	PO_4-P	SiO_3-Si	SS	pH	S	T (°C)
Neap																						
Av	2.63	1.53	1.04	0.95	242	1.75	1.136	0.980	0.218	0.152	0.080	0.083	0.655	0.818	0.037	0.020	0.015	3.620	16.48	7.84	8.18	26.62
Min	1.78	1.16	0.81	0.50	45	0.64	0.903	0.780	0.109	0.078	0.056	0.070	0.447	0.594	0.028	0.014	0.010	2.695	7.65	7.64	0.80	25.53
Max	4.46	2.62	1.48	1.48	740	4.83	1.525	1.410	0.360	0.286	0.107	0.091	0.787	0.950	0.062	0.028	0.019	4.853	45.60	8.02	27.07	27.15
Spring																						
Av	2.22	1.49	1.44	1.23	272	4.22	1.029	0.918	0.199	0.137	0.057	0.087	0.642	0.785	0.041	0.024	0.018	3.609	18.04	7.89	12.82	27.07
Min	1.85	1.28	0.84	0.82	5	1.86	0.901	0.622	0.114	0.077	0.010	0.034	0.407	0.458	0.023	0.015	0.005	2.176	5.15	7.69	3.10	25.86
Max	2.86	2.65	2.36	1.62	565	11.92	1.697	1.107	0.276	0.211	0.094	0.106	0.819	0.992	0.094	0.034	0.024	4.342	51.50	8.06	28.71	27.77

Station 7

	TOC	DOC	COD_{Mn}	BOD_5	*E.coli*	Chl.*a*	TN	TDN	TKN	TDKN	NH_3-N	NO_2-N	NO_3-N	TIN	TP	TDP	PO_4-P	SiO_3-Si	SS	pH	DO	S	T (°C)
Neap																						
Av	5.91	4.63	1.19	0.47	31	0.50	0.801	0.717	0.184	0.138	0.046	0.052	0.489	0.587	0.069	0.041	0.017	2.670	11.03	7.97	4.21	16.87	26.04
Min	3.54	3.24	0.37	0.18	0	0.09	0.388	0.356	0.032	0.031	0.022	0.007	0.230	0.266	0.041	0.020	0.006	1.177	1.80	7.86	2.39	1.20	24.74
Max	8.64	7.83	2.30	1.23	284	1.42	1.260	1.139	0.520	0.494	0.118	0.084	0.649	0.741	0.178	0.083	0.025	3.686	93.20	8.08	5.96	33.13	27.20
Spring																						
Av	6.45	4.54	1.15	0.51	21	1.89	0.719	0.668	0.144	0.083	0.051	0.047	0.519	0.617	0.053	0.029	0.026	2.431	24.57	7.95	4.87	19.36	26.73
Min	4.12	3.09	0.43	0.17	0	0.62	0.258	0.254	0.037	0.022	0.014	0.007	0.180	0.211	0.014	0.013	0.011	0.881	1.80	7.83	3.13	5.34	25.54
Max	9.37	6.97	1.79	0.99	91	6.96	1.023	0.932	0.287	0.185	0.094	0.084	0.750	0.820	0.098	0.045	0.039	3.666	165.40	8.04	6.98	32.17	28.63

Station 8

	TOC	DOC	COD_{Mn}	BOD_5	*E.coli*	Chl.*a*	TN	TDN	TKN	TDKN	NH_3-N	NO_2-N	NO_3-N	TIN	TP	TDP	PO_4-P	SiO_3-Si	SS	pH	DO	S	T (°C)
Neap																						
Av	5.62	4.44	0.81	0.34	11	1.32	0.686	0.600	0.251	0.210	0.050	0.026	0.315	0.391	0.070	0.035	0.015	1.648	9.59	7.98	3.63	24.37	25.53
Min	3.65	2.45	0.26	0.13	0	0.32	0.342	0.308	0.142	0.093	0.015	0.002	0.105	0.176	0.037	0.021	0.008	0.795	3.60	7.86	2.56	1.15	24.52
Max	8.00	7.53	1.66	0.65	133	4.90	1.125	1.023	0.420	0.388	0.103	0.077	0.648	0.781	0.129	0.048	0.025	3.379	24.00	8.12	6.24	33.75	27.01
Spring																						
Av	6.36	4.23	0.87	0.45	12	1.52	0.505	0.429	0.132	0.078	0.041	0.023	0.307	0.372	0.043	0.027	0.019	1.532	-	7.95	3.88	25.21	26.43
Min	3.91	2.64	0.35	0.25	0	0.39	0.258	0.172	0.013	0.031	0.012	0.001	0.111	0.149	0.019	0.012	0.006	0.744	-	7.82	2.61	3.50	25.21
Max	9.51	7.94	1.63	0.94	108	4.74	1.119	0.949	0.374	0.200	0.075	0.075	0.643	0.751	0.096	0.073	0.031	3.283	-	8.12	6.83	33.14	29.36

Date: July 4-5, 1998 (Neap Tide) **Date: July 9-10, 1998 (Spring Tide)**

Table 5.6b: Summary of Marine Water Quality Data Collected During the Tonggu Waterway Study (Dry Season) (Scott Wilson (Hong Kong) Ltd 1998).

Station 5

	TOC	DOC	COD_{Mn}	BOD_5	*E.coli*	Chl.*a*	Cu	Pb	Zn	Cr	Cd	Ni	Hg	TN	TDN	TKN	TDKN	NH_3-N	NO_2-N	NO_3-N	TIN	TP	TDP	PO_4-P	SiO_3-Si	SS	pH
Neap																											
Av	2.14	1.50	0.87	0.79	46	2.50	1.00	0.18	5.43	0.69	0.046	1.14	0.005	1.119	1.046	0.493	0.424	0.245	0.477	0.052	0.774	0.037	0.024	0.017	1.577	7.78	8.08
Min	1.93	1.37	0.49	0.43	3	0.48	0.80	0.05	3.53	0.50	0.017	0.79	0.005	0.863	0.775	0.338	0.312	0.162	0.323	0.037	0.523	0.027	0.014	0.009	0.917	4.90	8.01
Max	2.35	1.71	1.44	1.63	200	10.32	1.40	0.52	7.30	0.90	0.075	1.31	0.005	1.423	1.325	0.614	0.520	0.343	0.599	0.063	0.915	0.052	0.033	0.024	2.220	24.30	8.19
Spring																											
Av	2.13	1.56	0.45	0.64	107	1.00	0.60	0.13	5.08	0.70	0.026	1.18	0.005	1.248	1.063	0.528	0.452	0.270	0.305	0.045	0.620	0.056	0.033	0.025	1.188	17.00	8.07
Min	1.89	1.32	0.20	0.31	5	0.16	0.40	0.05	3.77	0.50	0.016	0.92	0.005	0.825	0.672	0.335	0.268	0.135	0.149	0.029	0.315	0.035	0.023	0.015	0.557	5.50	8.00
Max	2.60	1.84	0.71	1.21	338	1.84	0.80	0.34	7.18	1.31	0.058	1.73	0.005	1.811	1.479	0.798	0.653	0.391	0.469	0.063	0.868	0.133	0.049	0.035	1.760	48.60	8.14

Station 7

	TOC	DOC	COD_{Mn}	BOD_5	*E.coli*	Chl.*a*	Cu	Pb	Zn	Cr	Cd	Ni	Hg	TN	TDN	TKN	TDKN	NH_3-N	NO_2-N	NO_3-N	TIN	TP	TDP	PO_4-P	SiO_3-Si	SS	pH
Neap																											
Av	5.04	4.08	0.38	0.49	2	1.48	0.59	0.62	9.51	0.33	0.054	0.83	0.016	0.677	0.533	0.293	0.251	0.108	0.206	0.027	0.341	0.055	0.037	0.014	1.405	5.67	8.13
Min	2.13	2.16	0.20	0.31	1	0.24	0.41	0.43	6.50	0.14	0.039	0.14	0.004	0.342	0.286	0.101	0.103	0.027	0.065	0.014	0.105	0.039	0.021	0.009	0.605	1.90	8.05
Max	8.13	7.59	0.54	0.87	12	2.72	1.03	0.88	13.00	0.65	0.097	1.34	0.043	1.468	1.046	0.535	0.443	0.212	0.482	0.048	0.720	0.070	0.053	0.019	2.698	15.00	8.19
Spring																											
Av	4.85	3.10	0.44	0.50	8	0.77	0.47	0.62	7.64	0.34	0.042	1.03	0.007	0.547	0.431	0.211	0.166	0.086	0.140	0.021	0.247	0.061	0.024	0.013	0.958	9.29	8.16
Min	1.18	1.87	0.19	0.24	1	0.28	0.20	0.32	4.90	0.10	0.014	0.69	0.004	0.305	0.194	0.061	0.045	0.044	0.054	0.011	0.118	0.037	0.017	0.008	0.515	2.20	8.12
Max	8.96	5.96	0.83	1.03	21	1.24	0.68	1.07	9.60	0.70	0.069	1.47	0.013	1.010	0.964	0.503	0.405	0.225	0.402	0.051	0.677	0.091	0.033	0.020	2.530	32.00	8.21

Station 8

	TOC	DOC	COD_{Mn}	BOD_5	*E.coli*	Chl.*a*	Cu	Pb	Zn	Cr	Cd	Ni	Hg	TN	TDN	TKN	TDKN	NH_3-N	NO_2-N	NO_3-N	TIN	TP	TDP	PO_4-P	SiO_3-Si	SS	pH
Neap																											
Av	4.78	3.05	0.49	0.84	1	2.57	0.52	0.59	9.71	0.35	0.043	0.94	0.007	0.507	0.420	0.252	0.221	0.060	0.111	0.019	0.190	0.053	0.027	0.009	0.919	6.93	8.09
Min	1.43	1.44	0.26	0.51	1	0.75	0.36	0.28	7.50	0.19	0.034	0.17	0.004	0.283	0.194	0.137	0.096	0.013	0.005	0.008	0.063	0.031	0.015	0.003	0.480	3.10	7.96
Max	8.43	6.29	0.86	1.35	2	5.43	0.71	0.78	12.60	0.58	0.050	1.53	0.024	1.015	0.917	0.367	0.361	0.188	0.392	0.039	0.541	0.081	0.051	0.030	1.972	22.00	8.16
Spring																											
Av	4.76	3.07	0.39	0.64	6	1.06	0.44	0.61	11.45	0.34	0.067	0.60	0.023	0.428	0.331	0.185	0.162	0.067	0.095	0.021	0.182	0.058	0.025	0.012	0.923	8.68	8.05
Min	1.74	0.98	0.24	0.26	1	0.34	0.27	0.50	8.60	0.23	0.050	0.17	0.004	0.237	0.135	0.104	0.086	0.024	0.011	0.013	0.076	0.030	0.016	0.008	0.503	1.00	7.87
Max	9.23	9.31	0.68	1.97	36	1.83	0.64	0.70	14.70	0.42	0.107	0.99	0.051	0.880	0.751	0.300	0.301	0.193	0.363	0.050	0.591	0.097	0.038	0.020	2.300	55.00	8.16

Date: March 12-13, 1998 (Spring Tide) **Date: March 19-20, 1998 (Neap Tide)**

The water quality data presented in **Tables 5.5** and **5.6a/b** are considered to be indicative of the water quality conditions in the open waters of the North Western WCZ, but not of conditions within Tai O Bay.

Prior to this Assignment, the only known water quality monitoring data available for Tai O Bay was that collected by Tam and Wong (1997 pers. comm.). Between March 1995 and April 1996 salinity testing was carried out at three sampling sites; one within the salt pans and the other two to the immediate north and south of the existing outer seawall. Mean salinity in the salt pans ranged from 2 - 37 ppt from March 1995 through to April 1996, with a range of 5 - 12 ppt from 21 June 1995 through to 6 September 1995. These data illustrate that in general, salinity levels drop between the months of June and September and peak within the months of December - March. This probably reflects the wet and dry season rainfall typically experienced in this region. Salinity levels were generally slightly higher within the salt pans than outside the salt pans, probably as a result of reduced circulation and tidal exchange, shallow water depths and higher temperatures.

Based upon the assessment of the water quality data given above, it was considered necessary to undertake a focused water quality monitoring programme in order to adequately define baseline conditions within Tai O Bay. The monitoring programme designed and completed is described in **Appendix 3**, whilst the results obtained are presented in Section 5.5 below.

5.5 Site Investigation Results

5.5.1 Introduction

The water quality monitoring programme described in **Appendix 3** involved both *in situ* and laboratory chemical analysis of water samples collected from within Tai O Bay - water quality sampling locations are illustrated in **Figure 5.3**. Continuous *in situ* monitoring over a 24 hour period was carried out at three locations (stations 5, 6, and 8), as well as sampling and testing at each monitoring location at high high (HHW) and low low (LLW) water. Water samples were also collected at stations 1 - 7 at HHW and LLW.

Results obtained from the monitoring programme are illustrated in **Tables 5.7a/5.7b** and **Figures 5.3, 5.4a** to **5.4c**. Results from the continuous *in situ* water quality monitoring are presented in **Appendix 4**. It is noted that there were no active construction activities occurring during the water quality monitoring event.

Table 5.7a: Marine Water Quality Data Collected During the Tai O Bay Water Quality Monitoring Programme (EGS 1999).

Station	Tide	Suspended Solids (mg/L)	*E. coli* (cfu/100ml)	Total Volatile Solids (mg/L)	Cd (µg/L)	Cr (µg/L)	Cu (µg/L)	Ni (µg/L)	Pb (µg/L)	Zn (µg/L)	Hg (µg/L)	Ammonia as N (mg/L)	Nitrite as N (mg/L)	Nitrate as N (mg/L)	Total Kjeldahl Nitrogen as N (mg/L)	Total Nitrogen (mg/L)	Total Inorganic Nitrogen (mg/L)	Total Phosphorus (mg/L)	Total Organic Carbon (mg/L)	Total Inorganic Carbon (mg/L)	Total Carbon (mg/L)	Oil and Grease (mg/L)	COD (mg/L)	BOD (mg/L)
1	HHW	18	410	38,000	< 1	< 5	10	< 5	< 5	5	< 0.5	< 0.01	< 0.01	0.01	0.3	0.3	0.01	< 0.1	< 1	8	8	< 5	< 10	< 1
	LLW	16	390	31,000	< 1	< 5	10	< 5	< 5	10	< 0.5	0.03	< 0.01	0.02	0.4	0.5	0.05	< 0.1	1	8	9	< 5	12	< 1
2	HHW	13	16	33,000	< 1	< 5	10	< 5	< 5	5	< 0.5	< 0.01	< 0.01	< 0.01	0.3	0.3	< 0.01	< 0.1	2	3	5	< 5	15	1
	LLW	10	3,400	25,000	< 1	< 5	10	< 5	< 5	10	< 0.5	0.02	< 0.01	0.02	0.4	0.4	0.04	< 0.1	< 1	9	9	< 5	< 10	< 1
3	HHW	8	9	29,000	< 1	< 5	10	< 5	< 5	5	< 0.5	0.01	< 0.01	0.01	0.3	0.3	0.02	< 0.1	< 1	7	7	< 5	< 10	< 1
	LLW	8	14	23,000	< 1	< 5	55	< 5	10	30	< 0.5	0.06	< 0.01	< 0.01	0.3	0.4	0.06	< 0.1	1	4	4	< 5	10	< 1
4	HHW	10	22	22,000	< 1	< 5	10	< 5	< 5	5	< 0.5	0.02	< 0.01	0.01	0.3	0.3	0.03	< 0.1	1	6	6	< 5	12	< 1
	LLW	6	19	16,000	< 1	< 5	10	< 5	< 5	5	< 0.5	0.02	< 0.01	< 0.01	0.3	0.3	0.02	< 0.1	1	8	8	< 5	< 10	< 1
5	HHW	6	13	24,000	< 1	< 5	10	< 5	< 5	10	< 0.5	0.06	< 0.01	< 0.01	0.4	0.5	0.06	< 0.1	< 1	6	6	< 5	< 10	< 1
	LLW	10	7	30,000	< 1	< 5	10	< 5	< 5	5	< 0.5	0.02	< 0.01	< 0.01	0.4	0.4	0.02	< 0.1	1	8	9	5	14	< 1
6	HHW	6	2	26,000	< 1	< 5	10	< 5	< 5	< 5	< 0.5	< 0.01	< 0.01	0.02	0.3	0.6	0.02	< 0.1	1	4	5	< 5	16	< 1
	LLW	9	1,900	28,000	< 1	< 5	10	< 5	< 5	5	< 0.5	0.03	< 0.01	0.02	0.5	0.5	0.05	< 0.1	< 1	10	10	< 5	12	< 1
7	HHW	10	25	26,000	< 1	< 5	10	< 5	< 5	5	< 0.5	0.01	< 0.01	0.01	0.3	0.3	0.02	< 0.1	2	4	6	< 5	13	< 1
	LLW	78	1,600	26,000	< 1	< 5	10	< 5	< 5	5	< 0.5	0.06	< 0.01	0.02	0.4	0.5	0.08	< 0.1	2	3	5	< 5	< 10	< 1

Table 5.7b: *In Situ* Water Quality Data Obtained During Water Sampling Events - Tai O Bay Water Quality Monitoring Programme (EGS 1999).

Position	Water Depth (m)	Speed (cm/s)	Direction (°)	Temperature (°C)	Salinity (pt)	D.O. (% sat)	D.O. (mg/L)	pH (pH units)	Silt (NTU)
HHW									
1	1.0	6.3	60.0	19.35	32.04	120.19	8.73	8.16	13.53
2	3.5	6.3	58.9	18.79	32.04	124.94	8.85	8.12	14.74
3	4.5	10.5	90.0	18.30	32.23	117.19	8.52	8.09	3.99
4	3.6	9.4	72.0	18.52	32.23	123.13	8.80	8.10	6.20
5	4.6	9.0	260.0	18.56	32.13	118.53	8.16	8.10	3.18
6	2.3	14.0	79.0	18.60	32.13	119.32	8.67	8.09	2.78
7	2.0	5.0	100.0	18.92	32.04	113.00	8.22	8.17	4.69
8	-	-	-	20.72	32.46	-	-	-	-
10	0.8	< 1	-	19.02	31.86	97.40	7.64	8.22	15.21
LLW									
1	2.6	6.0	330.0	18.09	31.09	81.18	5.60	7.75	5.90
2	1.9	7.5	25.0	18.06	31.76	101.56	7.01	7.87	11.92
3	3.1	7.5	125.0	17.79	32.23	103.72	7.36	7.93	6.80
4	1.4	6.3	160.0	17.90	32.23	105.87	7.30	7.94	6.30
5	2.6	2.5	20.0	17.50	32.23	103.18	7.29	7.92	8.61
6	0.5	3.5	105.0	18.10	31.76	99.23	6.87	7.90	10.82
7	0.3	5.5	150.0	17.94	31.85	95.08	6.75	7.92	17.05
8	-	-	-	17.84	31.94	-	-	-	-
10	0.0	-	-	-	-	-	-	-	-

5.5.2 Discussion of Results

The water quality monitoring programme undertaken as part of this Assignment illustrates that water quality in Tai O Bay varies according to tidal conditions, with a slight deterioration during low tide. Spatial and temporal patterns/characteristics of water quality are discussed below:

pH: pH values were generally uniform throughout Tai O Bay, ranging between approximately 7.75 and 8.4. The highest pH values were recorded at all monitoring stations at HHW;

Salinity: Salinity varied between approximately 31ppt and 32.25ppt. Lowest salinity levels were recorded at LLW when freshwater inputs from Tai O Creek are at their relative highest - the lowest salinity reading was found at Station 1 located at the mouth of Tai O Creek. Salinity readings within the salt pan (position A/B) were roughly equivalent to levels recorded in Tai O Bay. Station 8 was located within the marsh area behind the salt pans and was also found to have a salinity similar to that found in Tai O Bay;

Dissolved Oxygen: DO levels varied between approximately 5.5mg/L to over 9.0mg/L. The DO WQO for marine waters in the North Western WCZ is set at ≥4mg/L for 90% depth-averaged samples. DO levels were highest at HHW and declined through to LLW when water depths were at their lowest and when freshwater inputs from Tai O Creek were at their relative maximum. Nevertheless, throughout the tidal cycle at all locations monitored, DO levels were high;

Turbidity: Turbidity in Tai O Bay was low to moderately low with values varying between 3 NTU and 20 NTU. Turbidity did not appear to be related to either location within the bay or tidal conditions. It is noted that the relatively higher turbidity reading found at Station 7 during LLW is considered to be due to sediment disturbance caused by the sampling boat touching the seabed;

Suspended Solids: Suspended solids concentrations varied between 6 - 78 mg/L. The WQO applicable to suspended solids for marine waters in the North Western WCZ states that waste discharges should not cause the natural ambient levels to be raised by more than 30% nor give rise to the accumulation of suspended solids which may adversely affect aquatic communities. As indicated above, the relatively higher suspended solids reading obtained for Station 7 at low tide may be due to sample boat disturbance of the seabed. In other locations, suspended solids concentrations appear to be relatively similar at HHW and LLW throughout the bay - however, it is noted that relatively higher suspended solids levels were found at Station 1 located at the mouth of Tai O Creek;

E.coli: *E.coli* levels varied between 2 - 3,400 cfu/100mL. It is noted that the *E.coli* WQO for secondary contact recreation subzones in the North Western WCZ is set at 610 cfu/100mL (geometric mean of all samples collected in a calendar year). Low *E.coli* levels were found at most locations at HHW. At Station 1 located at the mouth of Tai O Creek, *E.coli* levels were 410 and 390 cfu/100mL at HHW and LLW respectively. At Stations 2, 6 and 7 which are all in the inner part of Tai O Bay, relatively higher *E.coli* levels were found at LLW, presumably as a response to the lower dilution of effluent inputs from Tai O Creek and Nam Chung Tsuen. It is noted, however, that even at low tide, *E.coli* levels remained low in locations in the mid and outer parts of Tai O Bay;

Heavy Metals: Concentrations of metals Cd, Cr, Ni, Pb, Zn and Hg were low throughout the tidal cycle in Tai O Bay and lower than water quality standards for general ecosystem conservation (as detailed in **Table 5.4**). However, copper concentrations at Station 3 at HHW were relatively elevated (55µg/L) - the reason for this is uncertain, although it is not considered to be related to inputs from Tai O Creek given that Station 3 is located near to the Tai O ferry jetty;

Nutrients: Nutrient levels in Tai O Bay were low. Nitrite was not detected (detection limit of <0.01mg/L), whilst the levels of nitrate varied between <0.01 - 0.02 mg/L. Ammonia concentrations varied between <0.001 - 0.06 mg/L - given the temperature, salinity and pH characteristics of the water in Tai O Bay, it can be derived that the approximately 3.23% of the ammonia present within the water column may be present in an unionised state. Therefore, unionised ammonia levels are considered to vary between <0.0003 - 0.0019 mg/L. These concentrations are below the WQO for unionised ammonia of 0.021mg/L (annual average) for the North Western WCZ. Total inorganic nitrogen levels varied between <0.01 - 0.08 mg/L. The total inorganic nitrogen WQO for marine waters in the North Western WCZ is set at ≤0.5mg/L for marine waters (annual water column average). Overall total nitrogen levels varied between 0.3 - 0.6 mg/L. Total phosphorus was not detected during the monitoring programme (detection limit of <0.1mg/L). These nutrient levels are perhaps surprising given the known pollution input from Tai O Creek. In this regard, ammonia and phosphate concentrations were not found to be elevated at Station 1 located at the mouth of Tai O Creek, although slightly higher nutrient levels were found at LLW when dilution of effluent discharges is expected to be low;

Carbon: Total carbon levels varied between 5 - 10 mg/L, with the vast majority of the carbon present being in the inorganic form;

COD/BOD: COD levels varied between <10 - 16 mg/L and did not appear to be related to tidal conditions or location within Tai O Bay. BOD levels recorded were all ≤1mg/L;

Oil and Grease: Oil and grease was not detected during the monitoring programme (detection limit of 5mg/L).

5.5.3 Overview of Monitoring Results

The results of the water quality monitoring programme undertaken during this Assignment illustrate that water in Tai O Bay has relatively low levels of carbon, ammonia, nitrogen species, phosphate, BOD and heavy metals. However, it is illustrated that Tai O Creek and Nam Chung Tsuen are key sources of *E.coli* which results is relatively high levels within the inner part of Tai O Bay during LLW – nevertheless, dilution at HHW means that such levels are drastically reduced. Tidal influx also reduces the bay’s salinity and pH, whilst elevating DO levels.

5.6 Existing Water Pollution Sources to Tai O Bay

5.6.1 Pollution Sources

The principal pollution sources to Tai O Bay include the following:

- discharges from the surface water drainage system/runoff;
- effluent inputs from the drainage channel adjacent to Nam Chung Tsuen and Leung Uk Tsuen;
- treated wastewater discharges from the Kau San Tei sewage treatment facility;
- sewage effluents from unsewered Tai O residences that discharge directly into Tai O Bay or Tai O Creek;

- on-going sewage infrastructure works;
- vessels using Tai O Bay;
- erosion of Tai O headland; and
- regional water currents from the Pearl River Estuary.

The sections below present estimates of the pollution load currently delivered to Tai O Bay from local sources. Impacts related to on-going works associated with the sewage infrastructure works are not assessed given that these works will be completed by the time of the sheltered boat anchorage construction and operation.

5.6.2 Estimation of Existing Pollution Loadings

Untreated Sewage Inputs

According to the 1996 Population By-Census, the existing population of Tai O is 2,223 (Planning Department 1998 pers. com.). According to Planning Department knowledge, many of the local fishermen reside in the stilted structures along Tai O Creek and are thus included in these population figures. A total of 129 fishing vessels are known to use Tai O as a home port (AFD 1998), 109 of these vessels are below 15m in length, with 20 being greater than 15m in length.

The amount of sewage generated by the land-based Tai O population can be estimated from sewage generation rates given in EPD's Guidelines for the Design of Small Sewage Treatment Plants (GDSSTP), Solid Waste Control Group, March 1990 (and Amendment ProPECC PN5/93). The daily volume of sewage currently generated by the Tai O population is estimated to be in the region of 410m^3 (assuming a flow rate of 185L $head^{-1}$ day^{-1} as detailed in Appendix 3 of the GDSSTP for traditional type village housing). The pollution load of this sewage is illustrated in **Table 5.8 -** the loading data has been generated using untreated domestic wastewater (medium strength) figures as cited by Metcalf and Eddy (1991).

Table 5.8: Estimation of Total Pollution Load Generated by the Tai O Community and Pollution Load Delivered to Tai O Bay from the Unsewered Areas.

Contaminant	Untreated Sewage Contamination Concentration (mg/L unless indicated)[1]	Contaminant Load Generated per Person (kg/day)	Contaminant Load Generated by Total Tai O Community (kg/day)	Contaminant Load Generated by Tai O Community Not Connected to Trunk Sewer (kg/day)
Suspended solids	220	0.04	90	68
BOD	220	0.04	90	68
Nitrogen (as total N)	40	0.01	16	12
Nitrogen (organic)	15	0.003	6	4.6
Nitrogen (ammonia)	25	0.005	10	7.7
Phosphorus (as total P)	8	0.001	3	2.5
Phosphorus (organic)	3	0.001	1	0.9
Phosphorus (inorganic)	5	0.001	2	1.5
Total coliform (no/100ml)	1.00E+08	1.85E+11	4.11255E+14	3.08E+14

Notes:
[1] raw untreated wastewater concentrations (medium strength) quoted by Metcalf and Eddy (1991)
Volume of sewage generated per person - 185L per person per day (refer to EPD GDSSTP)
Total population of Tai O - 2223
Tai O population connected to trunk sewer - 556
Tai O population unconnected to trunk sewer - 1667

The proportion of sewage generated by Tai O's population which is delivered to the existing sewage treatment works (STW) at Kau San Tei is difficult to define. The existing sewerage network comprises a trunk sewer from Lung Tin Estate Phase I, which passes through the old town area, crosses the river channel and runs along the east of the Tai O Island to Kau San Tei. The sewers pick up discharges from the public housing areas, but there are few connections from the Tai O village area. Wilbur Smith (1987) estimated that of the 1,330 living quarters in Tai O, no more than one quarter are served by the trunk sewer - the rest either discharge directly into Tai O Creek, Tai O Bay or they have septic tanks. If it is assumed that this connection rate is still applicable, it can be estimated that approximately 555 people in Tai O are connected to the existing trunk sewer. Therefore, it is estimated that approximately 310m^3 of sewage currently enters Tai O Creek and Bay each day with a potential BOD load of approximately 68kg/day (refer to **Table 5.8** for pollution loading data).

Treated Sewage Inputs

It is noted that the Kau San Tei STW to the north of Tai O is also a source of pollutants to the local environment. The STW provides primary treatment of the sewage received - sewage is passed through a coarse screen (30mm bar spacing), through a pista grit trap and into an Imhoff Tank. The Imhoff tank comprises two compartments, one for sedimentation (2 hour retention period in tanks of combined 100m^3 capacity), the other for sludge digestion and storage (45 day retention period and combined capacity of 110m^3) (Montgomery Watson 1994). The system receives on average 400m^3 of effluent per day (includes a significant proportion of groundwater inflow/influx) and removes approximately 34% of BOD, 47% of the suspended solids and 23% of the ammonia, with the treated effluent being discharged to the marine environment via a 440m submarine outfall (Montgomery Watson 1994). The 440m outfall comprises twin 225mm diameter pipes with two 150mm diameter port diffusers that discharge treated effluent to the north-west of the treatment works (outfall co-ordinates 813798.71 Northing, 803409.04 Easting - DSD pers. comm. 1999). The outfall design was based upon achieving an initial dilution of 1:50 plus a minimum time delay of 3 hours before the sewage field reaches bathing beaches (ERM 1999).

The estimated existing pollutant loadings to the marine environment from the Kau San Tei STW are as presented in **Table 5.9** and are calculated based upon average discharge rates and wastewater discharge quality concentrations.

Table 5.9: Estimated Pollution Loading from the Kau San Tei Sewage Treatment Works to the Marine Environment via Sea Outfall.

Parameter	Treated Sewage Contaminant Conc. (mg/L)	Sewage Load (kg/day)[1]
BOD	76	30.4
Suspended solids	48	19.2
Ammonia	20	8.0

Notes:
[1] Assumes an average sewage flow of 400m^3/day

Urban Runoff

Tai O Bay currently receives run-off from the surrounding catchment. The volume of run-off discharged to Tai O Bay is dependent on numerous factors such as land use, rainfall intensity/volume etc. It is known that surface runoff collects contaminants from sources such as atmospheric wet and dry deposition, vegetation and leaf litter, land surface erosion, oil and chemical spills, pavement wear and degradation, building erosion, car and truck emissions, rubber particles from vehicle tyres, asbestos fibres from brake linings, animal and bird droppings, pesticides and fertilisers. Indicative pollutant levels found in storm water run-off from residential and commercial areas are shown in **Table 5.10** (data from the USA and Tin Shui Wai).

Table 5.10 Typical Water Quality Characteristics of Run-off from Residential and Commercial Areas of the US as Compared to those Measured in Tin Shui Wai (Binnie 1997) (mg/L unless indicated).

Parameter	Average[1] Concentration for Residential or Commercial Site	Weighted Mean[1] Concentration for Residential or Commercial Site	NURP[1] Recommendations for Load Estimate	Weighted[4] Average Measured at Tin Shui Wai
TSS	239	180	180 – 548	148 - 1200
BOD	12	12	12 – 19	7 - 103
COD	94	82	82 – 178	-
Total P	0.5	0.42	0.42 - 0.88	0.5
Sol. P	0.15	0.15	0.15 - 0.28	-
TKN	2.3	1.9	1.80 - 4.18	2.0
NO_2 + 3-N	1.4	0.86	0.86 - 2.2	-
Cu (μg/L)	53	43	43 - 118	4 (20[2])
Pb (μg/L)	238	53	182 - 443	2 (14[2])
Zn (μg/L)	353	202	202 - 633	42 (46[2])
E. coli (per 100mL)	27,000[3]	-	-	42,000

Notes:
1 Results of nationwide urban run-off program, NURP, Vol, NTIS PB 84-185552, USEPA 1983
2 Highest value from 4 points
3 Faecal coliforms
4 Only limited sampling and testing of urban stormwater was undertaken during the study during one rainfall incident only (Binnie 1997)

Based upon the NURP recommended loading factors, the load of pollutants delivered to Tai O Bay associated with Tai O urban run off has been calculated - refer to **Table 5.11**.

Table 5.11: Estimated Pollution Loading from Tai O Urban Runoff[1].

Parameter	Concentration		Unit	Load per Year (kg)		Load per Day (kg)		Average Load per Day
	Low	High		Low	High	Low	High	(kg)
TSS	180	548	mg/L	62,775	191,116	172.0	523.6	347.8
BOD	12	19	mg/L	4,185	6,626	11.5	18.2	14.8
COD	82	178	mg/L	28,598	62,078	78.3	170.1	124.2
Total P	0.42	0.88	mg/L	146	307	0.40	0.84	0.62
Sol. P	0.15	0.28	mg/L	52	98	0.14	0.27	0.21
TKN	1.8	4.18	mg/L	628	1,458	1.72	3.99	2.86
NO_3 + NO_2	0.86	2.2	mg/L	300	767	0.82	2.10	1.46
Cu	43	118	μg/L	15	41	0.04	0.11	0.08
Pb	182	443	μg/L	63	154	0.17	0.42	0.30
Zn	202	633	μg/L	70	221	0.19	0.60	0.40

Notes:
[1] Assumes Tai O urban area of 15.75ha which receives annual rainfall of 2.2143m. Total runoff flow equivalent to 955.5m^3 per day.

Summary

Based upon the loading analysis as presented above, **Table 5.12** illustrates the total calculated pollution loadings to Tai O Bay for suspended solids and BOD from the identified pollution sources.

Table 5.12: Estimated Daily Pollution Loading to the Marine Waters of Tai O (kg/day).

Pollution Source	Untreated Sewage Inputs	Treated Sewage Inputs	Urban Runoff	Total
BOD	68	30.4	14.8	113.2
Suspended solids	68	19.2	347.8	435

5.7 Modelling of Existing Tai O Bay Hydrodynamics and Water Quality Conditions

5.7.1 Introduction

Prior to the assessment construction and operation activities upon water quality, it is necessary to establish the hydrodynamics of the marine environment in the vicinity of Tai O and baseline water quality conditions. This has been achieved through the development of a water quality model. Details of the water quality model developed are provide below

5.7.2 Model Details

Model Set-up

The Tai O model is configured as a three level dynamically nested grid system (refer to **Figure 5.5**) with a 135m grid, a 45m intermediate grid and a 15m local grid covering Tai O Bay. The 135m grid serves to resolve currents through the South Lantau Channel and along the west coast of Lantau Island. The 45m grid was used only as a link to couple the 135m grid to the 15m grid. The small-scale 15m grid was used to define flows within Tai O Bay, including resolution of flows in Tai O Creek, the salt pans and the pond area behind the salt pans.

A two dimensional model was used for dry season simulations, where the effect of stratification is weak and baroclinic forcing can be neglected. A three dimensional model was used for wet season simulations, as the waters off Tai O are affected by stratification in the summer months due to the influence of fresh water inputs from the Pearl River. Although the waters within Tai O Bay itself are shallow and well mixed throughout the year, it was important to consider the 3 dimensional characteristics immediately out of the bay during the wet season.

Model Forcing

The main forcing of the dry season model consists of the tide, which was generated by the Tonggu Waterway model (Agreement No. CE 32/96) and transferred to the boundaries of the Tai O model. In the wet season, Tai O Bay falls under the influence of the Pearl River, introducing a stratified flow field outside of the bay. In this case, baroclinic forcing at the open lateral model boundaries is obtained through prescribed temporal salinity distributions that were also extracted from the Tonggu Waterway wet season model.

Tidal range inside Tai O Bay is significant, especially when compared to the average water depth. For example, during a typical spring tide with a range of about 2m, the tidal exchange is approximately 100% of the volume contained by the bay at mean sea level. Nevertheless, tidal currents within the bay are notably small, typically less than 0.2m/sec (refer to **Figures A1** to **A16** as presented in **Annex A** of the Water Quality Modelling Annex – **Figures A1** to **A4** are reproduced as **Figures 5.6** to **5.9**). Immediately outside the bay currents are stronger, up to 1m/sec during a spring tide, which tends to cause tidal flow to shear across the entrance of the bay, inducing slower secondary currents within the bay. It is noted that on **Figures 5.8** and **5.9** that there areas of apparent high velocity within Tai O Creek and in the area behind the salt pans - these high velocities are mathematical model artifacts that occur within flooding and drying cells of shallow depth which are located near a cell defined as land. Thus these high velocities do not exist in reality and are of no significance to the modelling results.

The tidal hydrodynamics of Tai O Creek and the backwater ponds was found to be an important element of the model. The tidal prism upstream of the creek entrance acts as a hydraulic diaphragm, delivering periodic discharges from the creek to the bay. For this reason, the inclusion of the tidal prism upstream of the creek entrance was critical in the calibration of both the hydrodynamic and water quality models for the bay area.

Wind forcing was found to be a significant forcing mechanism in the bay area. Wind forcing is particularly important in shallow waters, where a significant proportion of the water volume is exposed to wind induced shear stress. Analysis off the field data collected within Tai O Bay in February 1999 showed that current speed and directions within the bay tended to fluctuate at a rate greater than periodic tidal variation. It was found that strong monsoonal wind was apparent during the field survey period, and that application of a wind field to the model adequately reproduced the wind driven currents within the model. Wind data were drawn from the Hong Kong Observatory wind records for Chek Lap Kok airport, which were scaled down to allow for the effect of topographical shielding and surface roughness. A linear scale factor was selected using professional judgement based on data provided in the Shore Protection Manual, Volume 1, CERC 1984, Figure 3.15 as a guide.

Model Calibration

The model used was set up based upon the Mike 2D/3D model suit set up for the Study on Tonggu Waterway - this model has been calibrated with data from the following sources:

- the 1990/92 WAHMO data set;
- the 1991/92 Chinese hydrographic survey data set; and
- the 1996/97 SSDS EIA field survey data set.

The Tonggu Waterway model has been calibrated and was subsequently validated with data generated by 1998 water quality and hydrographic surveys. This model provided calibrated boundary conditions to the Tai O nested model used for this Study. Further calibration of the Tai O nested model was undertaken utilising the 1996/97 SSDS EIA field survey data set, as well as calibration of the hydrodynamics and water quality models using field data collected in Tai O Bay in February 12-13, 1999 as a part of this Study. Details of the model calibration are provided in **Annex J** of the Water Quality Modelling Annex. It is noted that the model simulation period used was 15 days, whilst the model was warmed up for a simulation period of approximately 1 day until it reached a dynamic equilibrium.

5.7.3 Water Quality

Figures B1 to **B36** (as presented in **Annex B** of the Water Quality Modelling Annex) illustrate dry and wet season ebb and flood concentrations of BOD, DO, suspended solids, ammonia, nitrate, phosphate and faecal coliform for neap and spring tides (**Figures B31** and **B32** are reproduced as **Figures 5.10** and **5.11** which show faecal coliform levels in Tai O Bay during ebb and flood during a neap tide in the dry season).

The baseline water quality modelling exercise has indicated the following key points with respect to existing water quality conditions:

- there appears to be little difference between contaminant dispersion and concentration patterns in Tai O Bay between neap and spring tides (as such only spring tide figures are presented for the wet season in **Annex B**);

- during the ebb tide, contaminants are brought from Tai O village and the drainage channel near Nam Chung Tsuen into the inner part of Tai O Bay. Whilst Tai O Creek and in the inner part of Tai O Bay is impacted by the identified pollution sources, the area outside Tai O Bay is not (including the secondary contact recreation subzones along both sides of outer Tai O Bay), indicating the localised impact of the Tai O pollution sources as identified in Section 5.6;

- during the flood tide, contaminants from Tai O village are flushed into the inner part of Tai O Creek. This draws water into Tai O Bay from the open sea areas which may lead to either the improvement or deterioration in water quality depending upon the characteristics of the water being drawn into the bay;

- treated effluent discharges from the Tai O sewage treatment works can be seen to locally impact upon ammonia and faecal coliform levels in the marine environment to the north of Tai O outside of the proposed anchorage area;

- the baseline water quality modelling exercise illustrates that the pollution load delivered to Tai O Creek and the drainage channel at Nam Chung Tsuen have an impact upon the water quality of Tai O Bay (i.e. BOD, DO, faecal coliforms and ammonia levels). This contaminant pattern is in full corroboration with the findings of the water quality monitoring programme as described in Section 5.5;

- the baseline modelling results indicate that water quality in Tai O Creek is significantly poorer than in the inner part of Tai O Bay. As such, the mangrove habitats located in the upper intertidal reaches of Tai O Creek (sensitive receiver No 3 – refer to **Figure 5.1**) and the marsh area behind the salt pans (water sensitive receiver No 2) are periodically exposed to relatively higher BOD, ammonia and faecal coliform levels and lower DO levels, especially during the flood tide which drives pollutants discharged into Tai O Creek upstream.

The water quality conditions as characterised above define the baseline model to which water quality characteristics following sheltered boat anchorage development will be compared.

5.8 Potential Water Quality Impacts During the Works Phase

5.8.1 Introduction

During the construction phase there are numerous methods by which water quality can be adversely impacted. Impact sources include the following:

- dredging of marine sediments;
- reclamation and general construction activities; and
- sediment placement in the salt pan area.

Impacts resulting from these activities are considered in the sections below.

5.8.2 Dredging Impacts Upon Water Quality

Sources of Impact and Sediment Release

The significance impacts caused by dredging are dependent upon the following:

- the occurrence of sensitive receivers;
- sediment release rates; and
- the physico-chemical characteristics of the dredged sediment.

Dredging activities inevitably result in the release of sediment into suspension. Grab dredgers, which have been recommended of use (refer to Section 2.7) may release sediment into suspension by the following mechanisms:

- impact of the grab on the sea bed as it is lowered;
- disturbance of the bed as the closed grab is removed, which may be exacerbated by the release of gas from the disturbed sediments;
- sediment washing off the outside of the grab as it is raised through the water column and when it is lowered again after being emptied;
- leakage of water from the grab as it is hauled above the water surface;
- spillage of sediment from over-full grabs; and

- loss from grabs which cannot be fully closed due to the presence of debris.

In addition, sediments may be released by splashing when loading barges and by careless, inaccurate barge loading. The release of suspended solids into the water column during dredging has the potential to generate the following water quality impacts:

- physical effects such as the smothering of marine organisms as well as reductions in light penetration;
- release of sediment bound pollutants to the receiving water column. (As illustrated in Chapter 4, the vast majority of sediment to be dredged in Tai O Bay is uncontaminated and as such significant effects of contaminant release are not anticipated);
- release of suspended solids into the water column and the formation, and off-site migration, of sediment plumes; and
- potential depletion of dissolved oxygen in the vicinity of the dredgers as a result of the sediment perturbation.

As detailed in Section 5.7.1, the effects of dredging and the resultant sediment plumes have been modelled. The results obtained from the modelling exercise are discussed below.

It is considered that sediment release rates during grab dredging operations are likely to be in the region of 1.0kg/sec for a 8m^3 grab dredger, although in order to allow for worst-case conditions, a sediment release rate of 1.44kg/sec has been used during the modelling scenarios (release rate defined from maximum rate of production of 22,000m^3 per week for an 8m^3 grab dredger working for 12 hours a day for 6 days and assuming a sediment release rate of 17kg/m^3 dredged – refer to **Table 2.2**).

It is noted that sediment may also be lost through leakage from barges and trailers during the transport of the dredged material to the defined disposal site. The amount of sediment which may be lost can vary considerably, depending upon the condition of the vessel. However, dredging projects in Hong Kong include a requirement that all barges and trailers used for the transport of dredged materials should have bottom-doors or discharge valves which are properly maintained and have tight-fitting seals in order to avoid leakage. Given this requirement, sediment release during material transport has not been considered during this Study.

Assessing the Significance of Dredging Impacts

The significance of dredging impacts have been assessed through comparison to the defined WQOs for the North Western WCZ. The WQO for suspended solids states that discharges shall not cause the natural ambient level of suspended solids to be raised by more than 30% nor cause the accumulation of suspended solids which may adversely affect aquatic communities.

According to the suspended solids data collected during the water quality monitoring programme, the average concentration recorded in Tai O Bay was 10mg/L (refer to Section 5.5) (note that this excludes the figure of 78mg/L recorded at Station 7 during low tide as this anomalously high figure is considered to be due to boat interference during sampling). As for previous EIAs investigating the impact of dredging activities, ambient conditions have been assumed to be represented by the 90th percentile of reported concentrations as this avoids bias if the database is skewed. From the dataset available for Tai O Bay, the 90th percentile is calculated as being 15.4mg/L - as such the suspended solids WQO can be calculated as follows:

- suspended solids concentration elevation - 4.62mg/L (i.e. 30% of 15.4mg/L)
- suspended solids concentration absolute - 20.02mg/L (i.e. 4.62mg/L plus 15.4mg/L)

In addition to the above, given the limited size and temporal coverage of the suspended solids dataset, in accordance with other EIAs investigating the impact of dredging activities on water quality, under certain circumstances the maximum permissible impact upon water quality at sensitive receivers can be defined as being 10mg/L above existing concentrations - this assessment criterion has also been considered during the assessment detailed herein, although it is noted that this figure is not a blanket allowable limit for suspended solids elevation.

It is also worthy of note that there are specific criteria for the level of suspended solids at fish culture zones and fisheries. Water quality protection guidelines set by AFD, which are applicable to both fisheries and fish culture zones, require that suspended solids levels remain below 50mg/L and do not exceed the highest level recorded in the area during the five years before the commencement of the works – this criteria is applicable to the fisheries impact assessment as presented in Chapter 7.

Dredging Modelling Results

In order to assess the impact of dredging events upon water quality during construction of the Tai O sheltered boat anchorage, a modelling exercise has been undertaken. A total of three main modelling scenarios have been investigated (refer to **Table 5.13** and **Figure 5.12**).

Table 5.13: Construction Phase Dredging Modelling Scenarios.

Scenario No	Dredger Type	Location	Hydrodynamic Conditions
1	Two 8m^3 grab dredgers	A and B	Baseline
2	Two 8m^3 grab dredgers	C and D	Baseline
3	One 8m^3 grab dredger	C	Baseline

Scenario 1 assumes the use of two grab dredgers working in areas close to the entrance of the Tai O Bay (refer to **Figure 5.12**). Dredging is assumed to take place continuously during normal working hours, i.e. 07:00 hrs - 19:00 hrs per day, six days per week. The sediment release rate from each dredger is taken to be 1.44kg/sec (refer to section above) and that the sediment is assumed to be evenly distributed throughout the water column. The fines content of the sediment is assumed to be 98% (refer to **Table 4.2**). It is noted that this is the maximum sediment fines content as found during the site investigation as described in Section 4.3.1.

Scenario 2 considers the effects of sediment release from two grab dredgers, each with a 8m^3 capacity, one working at the mouth of Tai O Creek and the other working in the breakwater foundation trench (refer to **Figure 5.12**). The sediment release rates are the same as those adopted for scenario 1.

It is noted that these dredging scenarios have been proposed as they are likely to represent worst-case conditions. Reference to Section 2.10 indicates that the dredging campaign could be achieved using a single $8m^3$ grab dredger, therefore, the modelling scenarios which consider two grab dredgers are inherently conservative. In addition, the sediment release rate adopted is very conservative, as is the sediment fines content and the adopted sediment settlement rate (0.1 mm/sec). As such, scenario 3 considers the use of a single $8m^3$ grab dredger working at the entrance of Tai O Creek.

The dredging scenarios have been modelled at two different scales. In order to assess the impact of dredging on areas outside Tai O Bay, scenario 1 has been run using the 135m grid model which covers the whole of west Lantau. This scenario has been run for both wet and dry season conditions. Scenarios 2 and 3 have been run using the 15m grid model which only covers Tai O Bay and Creek - the aim of these model runs is to determine the impact of dredging in the inner bay area and possible impacts upon the identified sensitive receivers in the upper tidal parts of Tai O Creek. Model runs have been undertaken for the dry season only, given that this is when the dredging is scheduled to take place in the berthing area (refer to **Figure 2.7**) and that this represents the worst case season. The dry season is considered to be the worst case given that during the wet season there will be a greater base flow into the bay from Tai O Creek, thus significantly reducing the potential for dredging to impact upon the sensitive receivers in the upstream areas of the creek.

Key findings of the dredging scenario model runs are presented below.

Scenario 1 Results

Suspended Solids

Scenario 1 considers two $8m^3$ dredgers working at the mouth of Tai O Bay and aims to define impacts on regional water quality. The modelling results indicate that dredging at the mouth of Tai O Bay will generate a suspended solids plume that extends northward during the flood tide and southwards during the ebb (refer to **Figures C1** to **C4** in **Annex C** of the Water Quality Modelling Technical Annex).

Figures C6/C7 (reproduced as **Figures 5.13** and **5.14**) and **C10/C11** (reproduced as **Figures 5.15** and **5.16**) illustrate the predicted percent frequency in which the suspended solids concentration elevations of 4.6mg/L and 10mg/L (refer to previous section) would be exceeded during scenario 1 dredging in the dry and wet seasons. These figures illustrate that the 4.6mg/L and 10mg/L suspended solids assessment criteria would only be exceeded for very brief periods outside of Tai O Bay, generally for less than 5% of the time (< 1.2 hours), especially during the wet season.

Figure C5 (reproduced as **Figures 5.17)** and **C9** show the mean suspended solids concentration occurring during the scenario 1 dredging event for the dry and wet seasons, respectively. These figures indicate that mean suspended solids concentration elevations outside of Tai O Bay during scenario 1 dredging are exclusively less than 4.6mg/L, indicating that during the dredging works the suspended solids WQO should not be compromised in areas outside Tai O

Bay.

The water quality modelling results indicate that dredging at the mouth of Tai O Bay has a low potential impact on water quality and that significant environmental impacts are not anticipated given that outside Tai O Bay average suspended solids concentrations are <4.6mg/L and given the general lack of sensitive receivers. This is especially the case given that the scenario 1 dredging event is considered to represent worst case conditions. It is noted that scenario 1 dredging is illustrated to have no impact upon the Sha Chau and Lung Kwu Chau Marine Parks or the potential South Lantau Marine Park/Reserve.

Sediment Deposition

For scenario 1, sediment deposition elevations (refer to **Figure C8/C12**) greater than 10g/m^2 only occur in the immediate vicinity of the dredgers. Outside Tai O Bay, sediment deposition rates are typically <3.5g/m^2, although very slightly higher sediment deposition rates may occur in the outer Yam O Bay area.

Scenario 2 and 3 Results

Suspended Solids

Scenario 2 considers two 8m^3 dredgers, one working at the mouth of Tai O Creek, the other working in the breakwater foundation trench. This modelling scenario aims to define impacts upon local water quality in Tai O Bay and especially to identified sensitive receivers in Tai O Creek.

Figures D2 and **D3** (refer to the Water Quality Technical Annex) (reproduced as **Figures 5.18** and **5.19**) illustrate the percent frequency in which the suspended solids concentration elevation of 4.6mg/L and 10mg/L would be anticipated to be exceeded during scenario 2 dredging. These figures illustrate that the 4.6mg/L and 10mg/L suspended solids assessment criteria are only exceeded for very brief periods of time outside of Tai O Bay, generally for less than 5% of the time (<1.2 hours). Within Tai O Bay, the 4.6mg/L assessment criteria is exceeded with increasing frequency moving closer to the dredgers.

Figure D1 (reproduced as **Figure 5.20**) shows the mean suspended solids concentration occurring during the scenario 2 dredging event and indicates that mean suspended solids concentration elevation outside of Tai O Bay is below 4.6mg/L. Therefore, the suspended solids WQO in areas outside the bay should be complied with during dredging works. Within Tai O Bay, mean suspended solids concentration elevations are only in excess of the 4.6mg/L criteria in the inner most part of the bay closest to the dredgers and in the lower part of Tai O Creek.

Figure D1 (refer to **Figure 5.20**) illustrates that elevated suspended solids concentrations may occur within the existing salt pan area where there are mangrove stands defined as water sensitive receivers. Whilst these salt pan mangroves are defined as water sensitive receivers, they are not considered to be sensitive with respect to the exposure to elevated suspended solids levels and are thus not anticipated to be adversely impacted by dredging activities (refer to Chapter 6). It is noted that the mangrove habitat created will also lead to the unavoidable exposure of existing mangroves to elevated suspended solids concentrations. Whilst the mangroves in the salt pans may be exposed to elevated suspended solids levels, the modelling results indicate that dredging is not anticipated to impact upon the mangroves in the upper reaches of Tai O Creek or the marsh area behind the salt pans – mean suspended solids concentrations are indicated to be below 10mg/L and are generally below 4.6mg/L.

It is stressed that the modelling results as presented above represent worst-case conditions and potentially over-estimate potential impacts during the works. This is the case given that the scenario considers the use of two dredgers working in close proximity, with a high sediment release rate and a low sediment settling velocity. In order to model more realistic conditions, scenario 3 considers a single dredger operating at the mouth of Tai O Creek. For this scenario the same sediment release rate has been used, but with a higher sediment settling velocity (0.4mm/sec). Results from this scenario are presented in **Figures E1** to **E4** (**Figures E1** to **E3** reproduced as **Figures 5.21** to **5.23**) and show that under these conditions the degree of suspended solids elevation is significantly lower than as predicted under scenario 2. Here, mean suspended solids concentration elevations greater than 4.6mg/L (refer to **Figure E1**/**Figure 5.21**) only occur in the immediate vicinity of dredger and the inner bay area – thus the suspended solids WQO should be complied with in much of Tai O Bay during dredging with a single grab dredger. Under these conditions, mean suspended solids concentrations in the area of mangrove in the upper parts of Tai O Creek are indicated to be 4.6mg/L.

Nutrient Release and BOD

It is known the ammonia can be readily released during sediment disturbance. Therefore, the potential impacts resulting from nitrogen release during dredging activities has been assessed through water quality modelling. Sediment quality data as collected during this Assignment (refer to Section 4.3.1 and **Table 4.3**) have been used as input data for this modelling exercise. **Figures D5** to **D8** (**Figures D5** and **D6** reproduced as **Figures 5.24** and **5.25**) illustrate total inorganic nitrogen (TIN) levels during scenario 2 dredging events – these figures illustrate actual TIN concentrations and not TIN concentration elevations. These figures illustrate that scenario 2 dredging has very little impact upon water column TIN concentrations and that in Tai O Bay the TIN WQO of 0.5mg/L should be complied with throughout the tidal cycle.

During dredging, the release of contaminants into the water column has the potential to exert an oxygen demand. In order to assess the potential impacts of contaminant release during dredging, BOD levels during dredging events have been modelled. **Figure D9** to **D12** illustrate absolute BOD concentrations during scenario 2 dredging. These figures illustrate that scenario 2 dredging has the potential to lead to a very slight increase in BOD concentrations in the vicinity of the dredgers. However, typical BOD concentration elevations are $<$0.1mg/L, whilst all BOD concentrations within Tai O Bay and Creek are below 0.3mg/L. As such, the dredging works will not impact upon the oxygen status of the water column or impact upon identified sensitive receivers.

Sediment Deposition

For scenario 2, sediment deposition elevations (refer to **Figure D4**) greater than 10g/m^2 occur within the bay area, and includes the lower part of Tai O Creek and parts of the salt pans. Outside Tai O Bay sediment deposition rates are typically $<$3.5g/m^2. If only one dredger is used (refer to **Figure E4**), the area where sediment deposition rates are $>$10g/m^2 is significantly reduced and in much of the bay deposition rates are typically $<$3.5g/m^2.

Overview

Construction phase dredging activities have the ability to generate sediment plumes, however, even during worst-case dredging scenarios plumes are generally confined to within the bay. The modelling results illustrate that the mean suspended solids concentration elevations in areas outside Tai O Bay will not be in excess of the defined WQO elevation criteria. Therefore, sensitive receivers outside the bay, such as the Sha Chau and Lung Kwu Chau Marine Parks or the potential South Lantau Marine Park/Reserve, will not be adversely impacted by the dredging works.

Within the inner parts of the bay, the suspended solids WQO should be complied with in most parts of the bay. Whilst dredging in the inner bay area has the potential to expose mangroves in the existing salt pan area to elevated suspended solids concentrations, they are not considered to be sensitive with respect to exposure to elevated suspended solids concentrations. Other sensitive receivers in the upstream tidal parts of Tai O Creek such as mangroves and the marsh area are not anticipated to be significantly impacted by the dredging works.

5.8.3 Reclamation Impacts

The sheltered boat anchorage development includes the reclamation of approximately 1ha of land (refer to **Figure 2.1**). Both the proposed reclamations are located within the confines of the existing salt pan area. These reclamations are to be formed largely on ground which is already above sea level, whilst the eastern reclamation area is not exposed to open water. The western reclamation is expected to be formed following substantial completion of the berthing face and containment bunds and will, therefore, not be exposed to open water. It is expected that sand filling materials, with a low or negligible fines content, will be delivered to site in small barges and mechanically offloaded into the reclamation area for placement using trucks and bulldozers. On this basis, it is expected that sediment release during placement will be negligible and thus not impact upon water quality during the works phase.

5.8.4 Salt Pan Reworking

As detailed on Section 2.8, the salt pan area would be reworked during the construction phase in order to form the site for subsequent mangrove planting - this will involve the mechanical placement of approximately 20,000m^3 of dredged mud. Given that under the proposed construction programme there are some 65 weeks available for mangrove area formation, it has been estimated that a bulldozer could re-shape the existing bunds and spread the added mud at a combined rate of about 230m^3 per working day. The mud would be mixed with the relatively coarse salt pan bed materials and will thus be more resistant than ‘normal’ marine mud to erosion during the flood and ebb tides between each working period. Material would be likely to consolidate very quickly. Given the above, it is estimated that the potential for sediment release during salt pan area reworking will be very low.

In order to minimise sediment loss further, the proposed salt pan area layout involves the creation of wide breaches in the existing seawall. This will substantially reduce the velocity of water entering and leaving the salt pans and thus reduce the risk of erosion of newly placed or moved materials. Losses can be further minimised, if necessary, by working at as slow a rate as is practical and by ensuring that all mud delivered to the pans during each working day (approximately 100m^3/day) is spread and mixed with existing bed material before completion of the day's work i.e. mud should not be stockpiled in the salt pans. It is also noted that some material brought into resuspension may settle in the shallow parts of the salt pan, particularly at slack high water. In addition, the impact of such material release is considered to be insignificant in comparison to the release of material during dredging events as detailed above. Whilst it is considered that material loss from the salt pans during construction activities is anticipated to be very low, opportunities for further reducing sediment loss through blocking of the outer seawall have been considered. However, it is not considered practical to deploy silt curtains in the breaches of the existing seawall, whilst temporarily sealing the seawall breaches during filling and removing the sealing material following completion of the works will almost certainly give rise to much greater sediment losses. This technique could only be justified if the mud were to be placed using hydraulic methods which is not considered to be practical.

The only sensitive receivers likely to be affected by salt pan reworking will be the existing mangroves within the salt pan area. Such mangroves are not considered to be sensitive with respect to exposure to elevated suspended solids concentrations.

5.8.5 Worker Impacts

Construction workers will generate wastes that have the potential to impact upon the water environment. Site workers should use either the existing public toilets in Tai O village or be provided with separate portable toilet facilities. If such sewage control measures are practised, there should be no adverse impacts upon the water environment.

5.9 Potential Water Quality Impacts During Anchorage Operation

5.9.1 Pollutant Sources and Impacts

Following completion of the works, the anchorage, its navigational approaches and the new mangrove habitat will be defined as water sensitive receivers (refer to Section 5.2). During anchorage operation there are a number of pollution sources that may impact upon these sensitive receivers. The pollution sources as identified in Section 5.6 will still be apparent, although sewage improvement works will have been completed thereby reducing the amount of sewage effluent being discharging directly into Tai O Creek and Bay. There will also be additional pollution sources as follows:

- controlled, discrete discharges from the land uses associated with the western and eastern reclamation areas (including any proposed boat maintenance and repair facilities);
- surface run-off from the new reclamation areas; and
- discharges from additional vessels using the sheltered boat anchorage.

During anchorage operation, the key water quality concern relates to the accumulation of pollutants within the anchorage area. In addition, sheltered boat anchorage development will affect the hydrodynamics of Tai O Bay. These impacts are considered in the sections below, following definition of pollution loadings.

5.9.2 Pollutant Sources and Loadings During Anchorage Operation

By definition, development of the sheltered boat anchorage will result in the creation of a sheltered body of water which will be used relatively intensely by boats. Discharges from the surrounding land uses as well as from the boats may have an adverse effect on the water quality within the anchorage, affecting water quality in the bay as well as in the salt pan mangrove habitat.

In order to evaluate such water quality impacts, it is necessary to define the pollution loadings that will be delivered to Tai O Bay during anchorage operation.

Untreated Sewage Inputs

Section 5.6 illustrated that approximately 310m^3 of sewage currently enters Tai O Creek and Bay each day with a potential BOD load of approximately 68kg/day.

Based upon an assessment of the exiting sewerage facilities, Wilbur Smith (1987) recommended the provision of an intercepting sewer pipe to connect other permanent structures to the existing trunk sewer. On the basis of these recommendations, there are at least three sewer upgrading works which are either being planned or are currently being constructed - these are as follows:

- sewer connecting a population of approximately 500 along Shek Tsai Po Street to the existing trunk sewer (Tai O Development Package 4 Stage 1);
- sewer connecting premises along Tai O Market Street, Kat Hing Back Street and Kat Hing Street (Tai O Development Package 4 Stage 1) ; and
- sewer connecting the planned Tai O Development Package 3 Stage II Northeast Riverwall Works area.

There is no official estimate as to the total number of people who will be connected to the trunk sewer following completion of these sewerage connection programmes. However, it is conservatively estimated that a total population of at least 800 people will be connected to the trunk sewer under these programmes.

According to Planning Department in-house estimates, the planned population capacity of Tai O may be 5,600 - this assumes full development assuming all living quarters in the area are fully occupied. It is assumed that any sewage load produced by these additional villagers will be delivered to the sewage network and not discharged direct to sea without treatment.

Based on these figures it is estimated that the sewage from approximately 870 people will be discharged into Tai O Creek and Bay at the time of anchorage operation. This figure is calculated by assuming that 800 people out of the 1,667 people which are not currently connected to the trunk sewer, will become connected as part of the sewer connection programmes detailed above. The pollution load derived to Tai O Creek and Bay from this unsewered population (total effluent flow of 160m^3) is estimated in **Table 5.14**.

Table 5.14: Estimated Pollution Load Delivered to Tai O Bay from the Unsewered Population of Tai O during Sheltered Boat Anchorage Operation.

Contaminant	Untreated Sewage Contamination Concentration (mg/L unless indicated)[1]	Contaminant Load Generated per Person (kg/day)	Contaminant Load Generated by Tai O Community Not Connected to Trunk Sewer during Anchorage Operation (kg/day)
Suspended solids	220	0.04	35
BOD	220	0.04	35
Nitrogen (as total N)	40	0.01	6.4
Nitrogen (organic)	15	0.003	2.4
Nitrogen (free ammonia)	25	0.005	4.0
Phosphorus (as total P)	8	0.001	1.3
Phosphorus (organic)	3	0.001	0.5
Phosphorus (inorganic)	5	0.001	0.8
Total coliform (no/100ml)	1.00E+08	1.85E+11	1.61E+14

Notes:
[1] raw untreated wastewater concentrations (medium strength) quoted by Metcalf and Eddy (1991)
Volume of sewage generated per person - 185L per person per day
Tai O population not connected to trunk sewer- 870

It is noted that the estimated pollution load defined above it considered to be a worst-case scenario. This is the case given there are proposals to reduce or remove the stilted housing areas in Tai O Creek - these areas are considered to be the principal source of the pollution load as defined above. In addition, future sewer connection programmes may be implemented to reduce further sewage effluent discharges.

Discharges from Boats

During sheltered boat anchorage operation, there may be direct discharge of pollutants into the anchorage from the boats therein. Whilst the anchorage is planned to accommodate 220 boats owned by Tai O residents and for the storage of small P4 fishing vessels, the increased water depths in the anchorage could attract larger vessels and thus increase the potential for people to live onboard berthed vessels. Given that there are a number of uncertainties regarding the occurrence and number of people that may reside in the anchorage, a number of pollutant input scenarios have been considered - these are defined below:

Scenario 1 - that none of the vessels are used for residential purposes;

Scenario 2 - that there are a limited number of vessels (10% - 22 boats) large enough to be used for residential purposes;

Scenario 3 - that there are a medium number of vessels (20% - 44 boats) large enough to be used for residential purposes; and

Scenario 4 - that there are a large number of vessels (40% - 88 boats) large enough to be used for residential purposes.

For all the above scenarios, it is assumed that all the boats will be within the anchorage for 12 hours a day. It is also assumed that the number of people on the boats suitable for residential purposes is equivalent to 4 people. Under these scenarios the pollutant loads detailed in **Table 5.15** have been calculated.

Table 5.15: Pollution Load Delivered to Tai O Sheltered Boat Anchorage Directly from Vessels under Various Pollution Scenarios.

Contaminant	Conc. (mg/L unless indicated)	Load per person (kg/day)	Pollution Load Under Scenario 1 (kg/day)	Pollution Load Under Scenario 2 (kg/day)	Pollution Load Under Scenario 3 (kg/day)	Pollution Load Under Scenario 4 (kg/day)
Suspended solids	220	0.02	0.00	1.79	3.58	7.16
BOD	220	0.02	0.00	1.79	3.58	7.16
Nitrogen (as total N)	40	0.0037	0.00	0.33	0.65	1.30
Nitrogen (organic)	15	0.0014	0.00	0.12	0.24	0.49
Nitrogen (free ammonia)	25	0.0023	0.00	0.20	0.41	0.81
Phosphorus (as total P)	8	0.0007	0.00	0.07	0.13	0.26
Phosphorus (organic)	3	0.0003	0.00	0.02	0.05	0.10
Phosphorus (inorganic)	5	0.0005	0.00	0.04	0.08	0.16
Total coliform (no/100ml)	1.00E+08	9.25E+10	0.00E+00	8.14E+12	1.63E+13	3.26E+13

The figures provided in **Table 5.15** ignore the fact that discharges from some fishers living in the unsewered village area are included in the calculated pollution load as detailed in **Table 5.14**.

It is noted that boat bilge is recognised as a potential source of marine pollution given that bilges tend to collect engine oil, fuel and transmission fluids. When bilge is pumped overboard, usually by automatic bilge pumps, such oily discharges can spread over the water surface and impact upon marine life. Of particular concern at Tai O is the deliberate/accidental discharge of oil contaminated bilge within the sheltered boat anchorage and subsequent oil entry into the mangrove planting habitat.

Under the provisions of the WPCO it is illegal to discharge wastewater containing oil or tar into inland and coastal waters. The only allowable discharge of any oily mixture is where the discharge contains less than 30mg/L (where discharges are of a volume $\leq 10m^3$ per day). In addition, under Section 46 of the Shipping and Port Control Ordinance it is an offence to discharge oil or a mixture containing oil and any person who commits an offence under this section is liable to a fine (currently HK$200,000). Whilst it is illegal to discharge such material, it is considered that other measures need to introduced to minimise the potential occurrence of bilge pollution - as such Section 5.10 presents methods that aim to minimise the potential occurrence of bilge pollution. Potential impacts of boat bilge upon marine ecology is considered in Chapter 6. However, it is noted here that Marine Department (1999 pers. comm.) records show that P4's use highly volatile gasoline and that the potential for oil pollution from such vessels is very low. Fishing vessels are subjected to Marine Department safety surveys before the issuance and subsequent renewal of licenses. In addition, given that pumping of boat bilge in confined waters is easy to spot by Marine Department patrols, such activities rarely occur.

Treated Sewage Inputs

The planned sewer connection programmes will result in lower volumes of sewage being discharged into Tai O Creek and Bay during anchorage operation. However, it is apparent that the sewer connection programme will increase the amount of effluent delivered to the Kau San Tei STW. In order for the modelling studies to define the water quality impacts during anchorage operation, an estimate of pollution loading from the Kau San Tei STW is required - such an estimate is provided in **Table 5.16**.

Table 5.16: Estimated Pollution Loading from the Kau San Tei Sewage Treatment Works to the Marine Environment via a Sea Outfall During Operation of the Sheltered Boat Anchorage.

Parameter	Treated Sewage Contaminant Conc. (mg/L)	Existing Sewage Load (kg/day)[1]	Sewage Load during Anchorage Operation (kg/day)[2]
BOD	76	30.4	41.6
Suspended solids	48	19.2	26.3
Ammonia	20	8.0	11.0

Notes:

1 Assumes an average sewage flow of 400m^3/day

2 Assumes that an additional 800 people are connected to the sewerage system by the time of anchorage operation resulting in the discharge of an additional sewage volume of 148m^3 per day

Urban Runoff

Section 5.6 identified the existing potential for run-off to deliver pollutants from the urban environment to Tai O Bay. Development of the sheltered boat anchorage will entail increasing the urban area of Tai O by approximately 1ha due to the construction of the reclamation areas. The pollution load delivered to Tai O Bay from urban runoff due to this increase in urban areal coverage is presented in **Table 5.17**.

Table 5.17: Estimated Pollution Loading from Tai O Urban Runoff during Sheltered Boat Anchorage Operation.

Parameter	Concentration		Unit	Load per Year (kg)		Load per Day (kg)		Average Load per Day (kg)
	Low	High		Low	High	Low	High	
TSS	180	548	mg/L	66,761	203,251	182.9	556.9	369.9
BOD	12	19	mg/L	4,451	7,047	12.2	19.3	15.8
COD	82	178	mg/L	30,413	66,019	83.3	180.9	132.1
Total P	0.42	0.88	mg/L	156	326	0.43	0.89	0.66
Sol. P	0.15	0.28	mg/L	56	104	0.15	0.28	0.22
TKN	1.8	4.18	mg/L	668	1,550	1.83	4.25	3.04
NO_3 + NO_2	0.86	2.2	mg/L	319	816	0.87	2.24	1.55
Cu	43	118	µg/L	16	44	0.04	0.12	0.08
Pb	182	443	µg/L	68	164	0.18	0.45	0.32
Zn	202	633	µg/L	75	235	0.21	0.64	0.42

Notes:
Assumes Tai O urban area of 16.75ha which receives annual rainfall of 2.2143m. Total runoff flow equivalent to 1,016m^3 per day.

Table 5.17 illustrates the new reclamation areas will increase the pollution load from urban runoff by approximately 6%.

It is recommended that surface runoff generated from the eastern reclamation area is directed towards the mangrove habitat in order to provide a source of uncontaminated freshwater - this assumes that the eastern reclamation is used for non-polluting land use such as a visitor centre. Surface runoff from the western reclamation should be directed towards Tai O Bay.

Surface runoff from the road behind the salt pan area will continue to discharge into the salt pan area - this is considered to be beneficial to the mangrove habitat due to the supply of freshwater, whilst also reducing the pollution potential of non-point pollution sources.

Process Wastes from the Reclamation Areas

It is proposed that the western reclamation be used for boat maintenance facilities. Such facilities have the potential to generate process wastewaters, which if discharged directly into Tai O Bay have the potential to impact upon water quality. Process wastes are not anticipated from the eastern reclamation area given that this area may be developed as a visitor centre. Whilst the boat maintenance facilities are not anticipated to be able to undertake major boat repair activities, such facilities may generate wastewaters associated with the following activities:

- limited boat paint stripping;
- limited boat hull painting/varnishing;
- boat part washing;
- storage and use of chemical/paint/fuel/oils.

It is also recommended that a waste collection point be sited here to serve boat users (refer to Section 9.). Wastewaters generated from such activities need to be prevented from discharging directly into Tai O Bay without treatment. All these wastes will be subject to compliance with the standards specified in the TMES and require a license from EPD (refer to **Tables 5.2/5.3**). If the western reclamation is to be developed for boat maintenance facilities undertaking the types of operations detailed above, it is recommended that a centralised wastewater collection and treatment system be considered. This could take the form of a collection system in order to deliver wastewaters to an appropriately sized underground sand filtration system to remove the suspended solids load, including any paint particulates. Thereafter, the filtrate could be discharged to sea, if compliant with the terms specified in the TMES. If this were to be undertaken there would be minimal pollution loading to Tai O Bay, and no impact upon the sewerage system. In addition, during the Outlying Islands SMP Stage Review, the feasibility of connecting the boat maintenance facilities to the public sewer should be considered taking into account wastewater flow volumes and chemical characteristics.

It is noted that the proposed boat maintenance facilities at Tai O are not expected to use tributyltin (TBT) - based paints given that it is illegal to use such paints on vessels less than 25m in length, unless they are aluminium hulled. Vessels using Tai O are typically less than 15m in length and made from wood, whilst the boat maintenance facilities may not have slipway facilities, thus preventing boats from being dry-docked. As such, no specific mitigation measures are considered necessary to specifically control potential TBT contamination, although the measures defined above for the control of process wastewaters are also applicable for the control of pollution from TBT-based paints.

The use of the western reclamation area for boat yard facilities, whilst proposed, has yet to be confirmed. The DIA Report prepared as part of this Study (Scott Wilson 1999) has illustrated that the proposed reclamation areas are at elevations below the 1 in 10 year return period flood protection level. Given that the western reclamation area may be susceptible to flooding indicates that whilst routine operation of boat maintenance facilities is not anticipated to represent an environmental pollution hazard, periodic flooding may give rise to environmental contamination. As such, the DIA has recommended that the elevation of the western reclamation areas be raised, unless a non-polluting land use is proposed for which a 1 in 10 year return period flood protection level is considered to be adequate.

Sewage from Reclamation Areas

Sewage effluents will be generated on the reclamation areas by site workers. Such sewage effluents will need to be conveyed towards the sewerage system thus preventing any adverse impacts upon water quality. As detailed in Section 5.13, it is currently estimated that approximately 1.2m^3 of sewage a day will be generated by workers on the reclamation areas.

Summary

The sections above estimate pollution loadings to Tai O Bay during the time of the sheltered boat anchorage operation. **Table 5.18** summarises the loadings for BOD and suspended solids.

Table 5.18: Estimated Daily Pollution Loading to the Marine Waters of Tai O During Sheltered Boat Anchorage Operation (kg/day).

Pollution Source	BOD	Suspended Solids
Untreated Sewage Inputs	35	35
Sewage from Boats in Anchorage Scenario 1	-	-
Scenario 2	1.79	1.79
Scenario 3	3.58	3.58
Scenario 4	7.16	7.16
Treated Sewage Inputs	41.6	26.3
Urban Runoff	15.8	369.9
Total Projected Load	**92.4 to 104.93**	**431.2 to 438.36**
Load in 1999	113.2	435
Load Change	-18.4% to -7.3%	-0.9% to +0.77%

Table 5.18 illustrates that during anchorage operation, depending upon the number of vessels used as residential premises within the anchorage, BOD inputs will fall by 7.3% to 18.4% as compared to existing loads due to the implementation of sewerage connection programmes. Inputs of suspended solids during sheltered boat anchorage operation will be similar to loads currently experienced given that the principal source of suspended solids is urban runoff.

5.9.3 Operational Impact Assessment

Water quality and hydrodynamic impacts during anchorage operation have been investigated through the use of a water quality modelling exercise (refer to Section 5.7.1 for model details) - the results obtained are presented below.

Hydrodynamics

The impact of the breakwater on the hydrodynamics of Tai O Bay (neap and spring tides) is illustrated in **Figures A17 – A20** (as presented in the Water Quality Modelling Annex – **Figures A17** and **A18** reproduced as **Figures 5.26** and **5.27**). These figures illustrate that, as expected, anchorage development will alter the natural circulation of water within Tai O Bay resulting in the creation of a relative sheltered body of water behind the breakwater for boat anchorage. However, it is apparent that currents still pass through the anchorage offering a degree of tidal flushing.

Wave Impacts

Tai O Bay is offered a degree of natural protection against waves by virtue of its shallow waters, which causes larger waves to break in the bay prior to reaching the shore. The largest waves during a typhoon will break several hundred meters from the shoreline and energy dissipates in the breaking process. The old seawall in the bay is testimony to the relatively low wave energy climate at the shoreline - despite its age and low strength, it has survived countless storms and typhoons.

The proposed sheltered boat anchorage will involve dredging works and increase the water depth of parts of the bay. Dredging has the potential to create adverse effects due to a subsequent increase in wave energy that could reach the shoreline due to a reduction in wave breaking. However, the proposed dredging arrangements involve a diagonal channel across the bay which means that waves from the west will still be subject to shoaling prior to reaching the shoreline/breakwater. Provided that dredging is conducted as indicated, the current mechanism for wave breaking and energy dissipation will remain and as such the impact on the wave climate of the bay will be minimal.

Water Quality Impacts

Water quality modelling using the pollution loading rates defined above (refer to **Table 5.18**) has been undertaken for a total of four model run scenarios - these equate to scenarios 1 to 4 as detailed in Section 5.9.2, namely:

Scenario 1 - pollution loadings assuming that no vessels in the anchorage are used for residential purposes;

Scenario 2 - pollution loadings assuming that there are a limited number of vessels (22 boats) large enough to be used for residential purposes;

Scenario 3 - pollution loadings assuming that there are a medium number of vessels (44 boats) large enough to be used for residential purposes; and

Scenario 4 - pollution loadings assuming that there are a large number of vessels (88 boats) large enough to be used for residential purposes.

For each of the modelling scenarios detailed above, the following water quality parameters have been considered:

- biochemical oxygen demand (BOD)
- dissolved oxygen
- ammonia
- nitrate
- phosphate
- faecal coliforms

These parameters have been selected as they either have a specified WQO or they are of ecological importance. The pollution loadings of these water quality parameters from local sources to Tai O Bay are as detailed in Section 5.9.2 and as summarised in **Table 5.18**. It is noted that the background values for these parameters were based upon the water quality monitoring programme as detailed in Section 5.5 given the absence of other relevant monitoring data.

Results of the water quality modelling exercise are provided in **Annexes F**, **G**, **H** and **I** of the Water Quality Modelling Annex. Key findings of the anchorage operation water quality modelling exercise are as follows (for illustrative purposes **Figures 5.28/29** and **5.30/31** show faecal coliform levels in Tai O Bay during the ebb and flood for a neap tide in the dry season for operational scenarios 1 (no anchorage discharge) and 4 (maximum anchorage discharge) respectively):

- whilst pollution loads from Tai O impact upon the water quality within Tai O Bay, impacts are generally wholly restricted to within the bay area and as such are not of regional significance. As such anchorage operation will not impact upon the water quality of the secondary contact recreation subzones along both sides of outer Tai O Bay (refer to **Figure 5.1**);

- the pollutant load delivered by Tai O village and Nam Chung Tsuen is dominant with respect to water quality within Tai O Bay. However, figures presented in **Annexes F**, **G**, **H** and **I** illustrate that with increasing discharge of sewage effluents from vessels moored in the anchorage, there is an incremental increase in levels of BOD, ammonia and faecal coliforms (refer to **Figures 5.28** to **5.31**) behind the breakwater. These contaminants are associated with sewage effluent discharges. Worst-case elevations in the anchorage occur during the ebb tide as this tide draws pollutants from Tai O village and Nam Chung Tsuen into the inner parts of the bay and anchorage. Under these conditions, BOD levels within the anchorage area under scenario 4 may be increased by 0.15mg/L, DO levels may fall by 0.3mg/L, while ammonia levels may increase by $<$0.1mg/L and faecal coliform counts can increase by over 800/100mL;

- whilst the breakwater and the identified pollution sources appear to impact upon water quality in the anchorage area, it is also apparent that the presence of the breakwater can improve water quality in the outer parts of Tai O Bay. This is due to a combination of reduced pollution load inputs (refer to Section 5.9.2) and restricted dispersion of contaminants from Tai O village during the ebb tide;

- development of the anchorage does not affect water quality within the upper tidal reaches of Tai O Creek. As such, the marsh area defined as water sensitive receiver No 2 and the mangrove habitat defined as water sensitive receiver No 3 (refer to **Figure 5.1**) will not be adversely impacted by the development of the sheltered boat anchorage;

- whilst water quality in the anchorage area will be impacted by breakwater construction, the actual pollutant concentrations attained are generally restricted. Pollutant concentrations within the anchorage are anticipated to comply with the WQOs for DO, ammonia and BOD during all tidal and seasonal conditions. WQOs for *E-coli* apply only to the Secondary Contact Recreation Sub-Zone located outside of Tai O Bay, (see Figure 5.1). Pollution concentrations of *E-coli* are expected to comply with the WQO in this area. Whilst not a breach of WQOs, it is possible that there may be localised elevations of *E.coli* in the northern and southern parts of the anchorage, principally during ebb tidal conditions (this assumes that a high percentage of faecal coliforms are *E.coli*). This is considered to be due to effluent discharges from Tai O village and Nam Chung Tsuen as well as sewage discharges from boats moored in the anchorage. It is noted elevated levels of *E.coli* are currently experienced.

- the salt pan area will be developed into a mangrove habitat as described in Section 2.5, and will thus be defined as a water sensitive receiver. As a worst-case, it can be assumed that that water quality in the mangrove habitat will be equivalent to that observed within the anchorage. As such, the salt pan area may be exposed to elevated *E.coli* levels, especially in the northern and southern parts. It is considered that mangroves are not sensitive with respect to *E.coli* and as such are not anticipated to be adversely impacted by the anchorage development. It is noted that the mangrove stands in the upper parts of Tai O Creek are routinely exposed without apparent adverse effect to significantly higher concentrations of BOD, ammonia and faecal coliforms and lower DO levels than will be experienced by the mangroves to be planted in the salt pans. Therefore, the mangroves to be planted in the salt pans are not expected to be adversely affected by the predicted water quality characteristics during anchorage operation.

Overall, the water quality modelling results indicate that whilst the sheltered boat anchorage has the ability to impact upon water quality, the identified sensitive receivers within and outside Tai O Bay are not expected to be adversely impacted even under maximum estimated pollutant loading (i.e. scenario 4). In fact, based on the modelling results, it is anticipated that water quality both within and outside of the anchorage will comply with defined WQOs. Whilst not subject to specified WQOs, there may be periodic elevations of *E.coli* during ebb tidal conditions in the northern and southern parts of the anchorage due to effluent discharges from Tai O village, Nam Chung Tsuen and moored vessels. It is noted that the planned sewerage connection programme will reduce the pollution delivered to Tai O Bay and thus improve water quality, whilst in future there may be further water quality improvements due to additional sewer connection programmes, and possible clearance of some of the stilted structures in Tai O village.

Table 5.19 which shows faecal coliform levels at the mouth of Tai O Creek (position C as illustrated in **Figure 5.12**), within the anchorage (position D in **Figure 5.12**) and at the entrance to Tai O Bay (position A/B in **Figure 5.12**). **Table 5.19** illustrates the key water quality patterns as discussed above, namely the improved water quality in Tai O Bay due to the planned sewerage connection programme, the high levels of faecal coliform at the mouth of Tai O Creek, low faecal coliform levels in areas outside Tai O Bay and the relative increase in faecal coliform levels within the anchorage with increasing pollution loading (i.e. boat occupation).

Table 5.19: Faecal Coliform Levels in Tai O Bay as Determined by the Water Quality Modelling Exercise (No per 100mL).

Pollution Scenario	Mouth of Tai O Creek	Within the Anchorage	Mouth of Tai O Bay
Existing Conditions	5,737	80	9
Pollution Loading 1	2,082	21	6
Pollution Loading 2	2,083	30	6
Pollution Loading 3	2,084	39	6
Pollution Loading 4	2,100	57	6

In addition to the above, as illustrated in Section 5.9.2, runoff from the reclamation areas and process wastes are not anticipated to have an adverse impact upon water quality if appropriately managed. Potential ecological impacts resulting from the discharge of boat bilge are considered in Chapter 6.

Section 5.9.2 illustrated that the DIA undertaken during this Assignment indicated that the elevation of the proposed reclamation areas is below the 1 in 10 year return period flood protection level. On the basis of the existing proposed land use, it has been recommended that the western reclamation level be raised given the pollution potential of boat maintenance facilities, alternatively the land use could be changed to one that has less potential to pollute the marine environment during flood events.

5.10 Mitigation Requirements – Construction Phase

Section 5.7 illustrated that there are potential impacts upon water quality during the proposed construction phase. The sections below define the applicable mitigation techniques which may be employed.

5.10.1 Dredging Best Practice

Mitigation measures that should be implemented to ensure that unacceptable environmental impacts are avoided during dredging (including any future maintenance dredging) are defined below:

- minimisation of unnecessary disturbance to the sediments by exerting care when lowering and lifting the grab;
- all vessels used should be sized such that adequate clearance of the seabed is maintained at all stages of the tidal cycle and ensure that undue turbidity is not generated by turbulence from vessel movement or propeller wash;
- the Contractor should use barges that are fitted with tight fitting seals to their bottom openings to prevent leakage of material;
- the Contractor should ensure accurate barge loading to avoid splashing of dredged material to the surrounding water;
- the Contractor should ensure that grabs close tightly and that hoist speeds are suitably low;
- barges or hoppers should not be filled to a level which will cause the overflow of materials or polluted water during loading or transportation. Adequate freeboard should be maintained to ensure that the decks are not washed by wave action;
- the Contractor should manually remove large objects and debris prior to mechanical dredging to minimise losses from partially closed grabs;
- dredging should be undertaken taking into account tidal conditions;
- construction works should cause no visible foam, oil, grease, scum, litter or other objectionable matter to be present in the water within the site or dumping grounds;
- appropriate monitoring of water quality during dredging works should be undertaken to allow the implementation of appropriate action plans to prevent any unacceptable water quality impacts(refer to Section 5.12). Through this approach, water quality impacts

during dredging can be controlled and limited.

Additional mitigation measures are required during the dredging of the small volume of contaminated sediments (refer to Section 4.5). The location and depth of areas of contaminated sediment should be indicated in the construction contract. The Contractor should be required to ensure that contaminated sediments are dredged, transported and placed in approved special dumping grounds in accordance with EPD Technical Circular 1-1-92, WB Technical Circulars 22/92 and 6/92. Typical mitigation measures to minimise the loss of contaminated material to the water column are provided below:

- contaminated sediments should be dredging using grabs of no more than $8m^3$;
- use of specialised water tight grabs to control sediment loss;
- transport of contaminated mud to marine disposal sites should, wherever possible, be by split barges of not less than $750m^3$ capacity, well maintained and capable of rapid opening and discharge at the disposal site;
- monitoring of the barge loading to ensure that loss of material does not take place during transportation; and
- on-site auditing of the equipment and plant is essential to ensure that it is used in the appropriate manner.

It is recommended that in order to ensure that adverse water quality impacts do not arise, the number of grab dredgers operating simultaneously in Tai O Bay should be restricted to two. In addition, if during the works additional water quality mitigation measures are indicated to be required by the EM&A programme, silt curtains may need to be employed to prevent the sediment plume spreading into Tai O Creek and outer Tai O Bay. In particular, whilst adverse water quality impacts upon the mangrove and marsh habitats in the upper parts of Tai O Creek are not anticipated to occur, it is recommended that silt curtains are used at the mouth of Tai O Creek during dredging activities to restrict potential sedimentation within the lower reaches of the creek given the already low water depths.

5.10.2 Reclamation

Formation of the two reclamation areas have the potential to generate silt-laden run-off that could feasibly impact upon the water quality of Tai O Bay. As detailed in Section 5.8.3, reclamation activities are not anticipated to generate suspended sediment plumes given that these reclamations are to be formed largely on ground which is already above sea level and are not exposed to open water.

Following formation, these reclamation areas may be used as works sites. In order to ensure that silt-laden runoff from these areas does not occur during the works phase, the mitigation measures described in the “Practice Note for Professional Persons on Construction Site Drainage”, Professional Persons Environmental Consultative Committee, 1994 (ProPECC PN 1/94) should be followed as far as practicable. These practices include the following:

- sediment tanks of sufficient capacity are recommended as a general mitigation measure which can be used for settling wastewaters prior to disposal. The system capacity should be flexible and able to handle multiple inputs from a variety of sources and particularly suited to applications where the influent is pumped. Various physical and chemical filters can be added should refinement of the sedimentation process be required;

- ideally, the detailed design should be formulated such that construction works are programmed to minimise surface excavations during the rainy season (April to September). If excavation of soil cannot be avoided during the rainy season, or at any time of year when rainstorms are likely, exposed slope surfaces should be covered by a tarpaulin or other means. Other measures that need to be implemented before, during and after rainstorms are summarised in ProPECC PN 1/94;

- earthworks final surfaces should be well compacted and subsequent permanent work or surface protection works should be carried out immediately after final surfaces have been formed in order to prevent rainstorm erosion;

- all drainage facilities and erosion and sediment control structures should be regularly inspected and maintained to ensure proper and efficient operation at all times and particularly following rainstorms. Deposited silt and grit should be removed regularly and disposed of to the salt pan area during periods of low-tide;

- measures should be taken to minimise the ingress of site drainage into excavations. If the excavation of trenches in wet periods is necessary, they should be dug and backfilled in short sections wherever practicable. Water pumped out from trenches or foundation excavations should be discharged via the silt removal facilities;

- both during and following construction of the reclamation areas, open stockpiles of inert construction materials (e.g. aggregates, sand and fill material) of more than $50m^3$ should be covered with a tarpaulin or similar fabric during rainstorms. Measures should be taken to prevent the washing away of construction materials, soil, silt or debris into any drainage system;

- stockpiles of cement and other construction material should be kept covered when not being used;

- manholes (including newly constructed ones) should always be adequately covered and temporarily sealed so as to prevent silt, construction materials or debris being washed into the drainage system and storm run-off being directed into foul sewers. Discharge of surface run-off into foul sewers must always be prevented to avoid overloading the foul sewerage system;

- all vehicles and plant should be cleaned before leaving the construction site to ensure no earth, mud and debris is deposited on roads. An adequately designed and sited wheel washing bay should be provided at every site exit (if any) and wash-water should have sand and silt settled out and removed at least on a weekly basis to ensure the continued efficiency of the process. The section of access road leading to and exiting from the wheel-wash bay to the public road should be paved with sufficient backfill toward the wheel-wash bay to prevent vehicle tracking of soil and silty water to public roads and drains;

- water used for construction purposes on site should, as far as practical, be recycled for use;

- information detailing storm run-off and wastewater discharge points and the corresponding maximum (or range of) volumes of discharges expected from the construction sites on a dry day should be provided in the WPCO licence application. In general, assuming adequate information has been provided together with the licence application, EPD would need at least 20 days for the processing of a licence for a discharge. It is, therefore, recommended that the Contractor submit the licence application to EPD as early as possible before the commencement of any discharge;

- entry points into the surface drainage system should be fitted with oil interceptors;

- waste oils and other chemical waste as defined in the Waste Disposal (Chemical Waste) (General) Regulation will require disposal by an appropriate means and could require pre-notification to EPD prior to disposal. An appropriate disposal facility could be the Chemical Waste Treatment Centre (CWTC) at Tsing Yi. If chemical wastes are to be generated, the Contractor will need to register with EPD as a chemical waste producer and observe the requirements for chemical waste storage, labelling, transportation and disposal.

If the best management practices as defined above are implemented, adverse impacts on Tai O Bay, the existing drainage system and sewerage system should be avoided from general construction site activities required for reclamation formation.

5.10.3 Salt Pan Infilling/Reworking

Many of the general construction site mitigation activities as detailed above are also applicable to activities occurring within the salt pan area. In order to further minimise the potential for the loss of material from the salt pans (refer to Section 5.8.4), the following mitigation measures should also be employed:

- material placement and reworking should only occur during low tidal conditions;

- dredged material to be placed in the salt pans should be dredged using grab dredgers in order to minimise the sediment moisture content and facilitate rapid material consolidation;

- a low rate of sediment reworking should be practised in order to minimise sediment disturbance (e.g. placement of approximately $100m^3$ of dredged material in the salt pans per day and reworking of approximately $230m^3$ of material a day);

- placed mud should be mixed with the relatively coarser salt pan bed material to reduce erosion potential and enhance consolidation;

- all material placed in the salt pans should be spread and mixed with existing bed material before completion of the day's work such that there is no material stockpiling;

- the outer seawall should be breached in order to reduce the velocity of water entering and leaving the salt pans and thus reduce the risk of erosion of newly placed or moved materials. Material from around the breached areas should be removed prior to reworking.

If such practices are adopted, significant sediment loss during salt pan reworking should be avoided.

5.10.4 Worker Generated Waste

The construction work force should use the existing toilet facilities next to the bus depot. Alternatively, portable toilets could be used. Overall it is considered that no water quality impacts are expected to arise from on-site generated sewage if such sewage arrangements are provided.

5.11 Mitigation Requirements - Operational Phase

Section 5.9 indicated that there may be water quality impacts associated with the accumulation of pollutants such as faecal coliforms within the sheltered boat anchorage. The water quality modelling exercise undertaken illustrates that the major source of pollutants to Tai O Bay are the unsewered village areas as well as contributions from vessels moored in the anchorage.

Whilst it is not considered necessary or feasible to restrict boat use of the sheltered anchorage, it is recommended that measures are taken to limit pollutant discharges into the anchorage, and especially the discharge of bilge water and oil residues from vessels. The only methods of mitigation available relate to the control of the behaviour of anchorage users through education. It is also noted that whilst the created mangrove habitat area is defined as a water sensitive receiver, as illustrated in Chapter 6, such ecosystems have the natural capacity to store and process nutrients and metals and thus act to mitigate impacts associated with sewage/boat discharges. Nevertheless, the ability of mangrove to treat effluents should not be overstated and the mangrove habitat should be protected from pollution sources as much as feasible.

5.11.1 Boat Effluents

Pollutant assimilation can be limited by restricting the number of effluent discharges made into the sheltered boat anchorage area. Whilst it is difficult to control the behaviour of vessels using the anchorage, it is considered that specific guidance and advice should be provided to anchorage users that aim to minimise pollution discharge - the following sections consider means of controlling the discharge of sewage effluents and bilge.

Sewage Discharges

Whilst it is very difficult to control sewage discharges from boats, it is recommended that notices be placed at strategic locations within the anchorage stating that toilet facilities should not be used within the anchorage unless the vessel has a sewage holding tank.

It is not considered appropriate to provide a marine sanitation pump-out system at the sheltered boat anchorage given that the vast majority of the fishing vessels using the anchorage will not have sewage holding tanks. However, the types of vessels using the anchorage may change with time, and as such the requirement for such a marine sanitation pump-out system should be periodically reviewed. If such systems are found to be viable, the guidance provided in the Permanent International Association of Navigation Congresses (PIANC) Guidance on Marine Sanitation Pumpouts SPN Report of Working Group 7 Supplement to Bulletin No 93 (1997) should be followed.

Bilge Discharges

Whilst it is an offence to discharge bilge water contaminated with oils, it is considered that additional measures need to be specified in order to afford greater protection of water quality in Tai O Bay and the mangrove habitat. In order to minimise bilge pollution impacts within the anchorage, the following mitigation measures are recommended for implementation:

- boat owners should maintain vessels in a good condition and make sure that the engine(s) are in working order with no leaking seals, gaskets or hoses;

- portable fuel tanks and spare fuel containers should be filled away from the waters edge. To avoid spillage and bilge contamination any containers should not be overfilled. Fuel tanks should be sited and secured safely on the vessel to minimise the risk of collision damage, accidental spillage overboard or unauthorised interference;

- inboard engines should have a drip tray under the engine and gearbox to prevent oil contamination of the bilge. The drip tray should be maintained in a clean and dry condition, and drain into a holding tank or drum for subsequent on-shore disposal;

- use of high efficiency by-pass oil filters should be encouraged as these can extend the life of the engine oil and decrease the frequency of oil changes;

- automatic bilge pumps should only be used in the anchorage when required and when the bilge contains only water;

- if fuel or lubricant is found in the bilge, the bilge pump should be turned off immediately, thereafter, oil should be soaked up with absorbent “bilge pillows” which are designed to absorb petroleum products and repel water. To reuse such cloths, they can be wrung out with the oil being collected for subsequent disposal. When the cloth can be no longer used, it should be disposed of in approved garbage containers;

- an oil-absorbent filter should be fitted to the bilge pump overhead discharge hose;

- if any vessel develops a problem involving loss of oil/fuel, normal activities should be stopped until the problem is resolved.

Bilge cleaners, even ones that are reported to be biodegradable, should not be used as these merely emulsify or break down the oil into tiny, less visible droplets. As detailed above, if bilge is found to be contaminated with oil, the most effective method for preventing oil discharge is through the use of absorbent fabric.

It is noted that many of measures highlighted above rely upon educating boat users in the environmentally acceptable operation of their vessels. Therefore, boat owners/operators using the Tai O sheltered boat anchorage should be made aware that the measures defined above are available for use. This could be undertaken through the production of educational leaflets which could be distributed to fishermen through the Tai O fisherman's association. Leaflets should emphasise that the actions defined in the guidance note aim to protect the area's fishery resources which has a direct impact upon the fishermen's livelihood. Such anchorage good practices are specified in numerous countries world-wide.

5.11.2 Litter

A litter control programme will be required during sheltered boat anchorage operation. Litter control is required to prevent problems of floating debris in the anchorage itself, as well as litter entrainment in the mangrove habitat. This issue is discussed in detail in Chapter 9.

5.11.3 Urban Runoff

The detailed design should ensure that surface waters from the eastern reclamation should be directed towards the salt pans (if used for a non-polluting activity) - this will allow the mangrove area to receive freshwater, whilst also assisting in the degradation of surface runoff pollutants.

The detailed design should ensure that surface runoff from the western reclamation should be directed to Tai O Bay - however, prior to discharge dry weather interceptors should be installed in order to control the discharge of suspended solids.

5.11.4 Sewage Effluents

The detailed design should ensure that any sewage discharges from either of the new reclamation areas is connected to the existing trunk sewerage system and delivered to the Kau San Tei STW for treatment (refer to Section 5.13.1).

5.11.5 Process Wastes

Wastewaters generated by the proposed boat maintenance facilities on the western reclamation area must not be permitted to enter the marine environment without treatment. It is initially considered that if boat paint stripping, painting etc. are to be carried out, then a centralised wastewater collection and treatment facility should be included in the design. The most appropriate method of treatment would appear to be an underground sand filtration system. This would remove the suspended solids load, including any paint particulates from the collected wastewater, with the filtrate being discharged if it is compliant with the terms given in the TMES.

Whilst the routine operation of boat maintenance facilities is not anticipated to impact upon the wider environment if the mitigation measures defined above are implemented, given that the elevation of the western reclamation area is below the 1 in 10 year return period flood protection level either the reclamation elevation should be raised, or the land use be changed to one that does not present an environmental risk during flooding.

5.12 Environmental Monitoring Requirements

A programme of water quality monitoring will be required during the sheltered boat anchorage construction and operational phases. Details of the programme are provided in the EM&A Manual, although the sections below provide an overview of the recommended monitoring requirements.

5.12.1 Construction Phase

During the construction phase, a water quality EM&A programme is required to verify whether impact predictions made herein are representative and ensure that dredging and associated activities do not result in unacceptable impacts. Where the monitoring programme indicates that dredging operations are having a deleterious impact upon water quality to an unacceptable level, appropriate action plans such as changes to operations will need to be introduced (such as the use of silt curtains).

The EM&A programme will involve baseline and impact water quality monitoring as follows:

Baseline Monitoring

Baseline water quality conditions need to be established and agreed with EPD prior to the commencement of the works. The purpose of the baseline monitoring is to establish ambient conditions prior to commencement of the works and to demonstrate the suitability of the proposed impact, control and reference stations. Baseline monitoring should include monitoring for the following parameters:

- temperature;
- pH (pH units);
- turbidity (NTU);
- water depth (m);
- salinity (mg/L);
- dissolved oxygen (mg/L and % saturation); and
- suspended solids (mg/L).

The measurements should be undertaken at all designated stations including control stations, 3 days per week, at mid-flood and mid-ebb tides, for four weeks prior to the initiation of marine works. There shall not be any marine activities in the vicinity of the stations during the baseline monitoring.

Impact Monitoring

During the course of the works, monitoring shall be undertaken 3 days per week, at mid-flood and mid-ebb tides, with sampling/measurements at designated monitoring stations. The interval between two sets of monitoring shall not be less than 36 hours except where there are exceedances of Action and/or Limit levels (as specified in the EM&A Manual) in which case the frequency shall be increased.

Upon completion of all work activities, a post-construction water quality monitoring exercise shall be carried out for 4 weeks in the same manner as the impact monitoring.

5.12.2 Operational Phase

During the operational phase a water quality monitoring programme is recommended to ensure that problems of pollutant assimilation within the sheltered boat anchorage do not occur and that the EIA predictions are accurate. Key water quality monitoring parameters will include the parameters detailed in **Table 5.20**.

Table 5.20 Proposed Parameters for Tai O Sheltered Boat Anchorage Operational Phase Water Quality Monitoring.

Parameter	**Unit**
Dissolved oxygen (DO)	mg/L and % saturation
pH	pH units
Suspended solids	mg/L
BOD_5	mg/L
Ammoniacal nitrogen	mg/L
Total inorganic nitrogen	mg/L
Oil and grease	mg/L
E.coli	cfu/100mL
Faecal coliform	cfu/100mL

These parameters are routinely monitored by EPD in Hong Kong typhoon shelters. Further details regarding the requirements for the sheltered boat anchorage operational phase water quality monitoring are presented in the EM&A Manual.

5.13 Adequacy of Sewerage System to Accept Wastes and Requirement for a Public Toilet

In accordance with the Study Brief, this section examines the adequacy for the sewerage system to accept wastewaters and the requirement for a public toilet.

5.13.1 Adequacy of Sewage System to Accept Wastes

The only wastes that are likely to require discharge to the sewage system during anchorage operation are sewage effluents. Given that the land uses on these reclamation areas will not be defined until the detailed design stage, it is not possible to accurately estimate the total volume of sewage effluents that are likely to be generated. At this stage it is estimated that if the eastern reclamation is to be used as a visitor centre and that the western reclamation used for boat maintenance facilities, the total number of workers is not anticipated to be in excess of 20. The total volume of sewage expected to be generated by 20 workers is equal to approximately $1.2m^3$ (0.04 litres per second - assumes workers on site for 8 hours a day).

Under Contract No IS 9/97, the Tai O sewerage system is being upgraded and involves the construction of a 300mm diameter trunk sewer with a full flow design capacity of 70 litres per second. As reported in ERM (1999), the sewerage system being implemented has a spare capacity. As discussed in the sections above, during anchorage operation the dry weather sewage flow delivered to the trunk sewer and the sewage treatment works would be in the order $550m^3$ per day. Given the provision of a trunk sewer with a full flow design capacity of 70 litres per second illustrates that the minimal volume of sewage effluent anticipated to be generated from the reclamation areas will not in any way adversely affect the performance of the proposed sewerage system. It is noted that due to the uncertainties over the use of the reclamation areas, it is not possible to definitively assess the impacts to the Tai O sewerage system. The whole of the Tai O sewerage system will be reviewed under the Outlying Island Sewage Masterplan (SMP) Stage Review study which will need to take into consideration sewage effluents generated at the reclamation sites.

5.13.2 Requirement for a Public Toilet

It is currently uncertain as to the effect of the sheltered boat anchorage and mangrove habitat creation on Tai O visitor numbers. As detailed in the Study on the Revitalisation of Tai O, approximately 0.3 million people currently visit Tai O annually (ERM 1999). Visitors to Tai O and the surrounding areas can currently make use of several Regional Services Department toilet facilities, including those at Nam Chung Tsuen, Leung Uk Tsuen as well as public toilets within Tai O near the ferry pier, on Shek Tsai Po Street near the market as well as the public toilet operated by private contractors near the bus depot. As such, visitors to the sheltered boat anchorage and mangrove habitat will be in easy reach of several toilet facilities, but are most likely to use the most convenient toilet situated near the bus depot. Given the availability of such facilities, the development of the sheltered boat anchorage and mangrove does not seem to warrant to development of a new toilet, however, if Tai O is to be strategically revitalised with an anticipated significant growth in the number of visitors, additional toilet facilities may be required in the future, although this is beyond the scope of the present Assignment.

5.14 Conclusions

5.14.1 Construction Phase

During anchorage construction the greatest potential water quality impacts are likely to arise during dredging activities. The water quality modelling exercise undertaken illustrates that dredging will locally increase water suspended solids levels, especially in the inner parts of Tai O Bay. However, the observed suspended solids elevations are not predicted to significantly impact upon sensitive receivers within the bay or in the upper reaches of Tai O Creek. Whilst dredging has the ability to generate sediment plumes, the modelling results indicate that mean suspended solids concentrations outside the bay are below the WQO suspended solids criteria of 4.6mg/L.

Whilst the dredging activities are not anticipated to significantly impact upon any identified sensitive receivers, appropriate dredging techniques have been specified together with applicable mitigation and working methods. Other water quality impacts resulting from reclamation and salt pan reworking, while of concern, can be controlled through the adoption of appropriate working methods and construction programming.

5.14.2 Operational Phase

During boat anchorage operation, the main water quality concern relates to the accumulation of pollutants within the anchorage area - especially sewage effluents released from vessels. The water quality modelling exercise undertaken illustrates that during anchorage operation the main pollution sources are Tai O village and Nam Chung Tsuen, although vessel discharges make contributions with respect to anchorage BOD, ammonia and faecal coliform levels. Although there may be local elevations of *E.coli* in the northern and southern parts of the anchorage during low and ebb tidal conditions, such *E.coli* elevations are currently known to occur at elevations greater than anticipated as a result of the anchorage. Notwithstanding the inputs from the identified sources, impacts upon water quality within the anchorage are not anticipated to be significant and water quality is predicted to comply with the defined WQOs for all parameters.

Water quality impacts during anchorage operation are not anticipated to significantly impact upon any identified sensitive receivers outside Tai O Bay (such as the secondary contact recreation subzones along both sides of outer Tai O Bay) or within Tai O Bay/Tai O Creek (including the mangrove habitat created in the salt pan). The mangrove stands in the upper parts of Tai O Creek are routinely exposed to higher pollutant loads than are predicted to occur within the salt pan area. Nevertheless, methods to control the discharge of sewage effluents, boat bilge and litter into the anchorage have been proposed. Many of the mitigation measures proposed rely on the education and co-operation of anchorage users, as well as the strict enforcement of relevant water pollution control legislation.