Marine Water Quality in Okat, Kosrae for Airport and Dock Facility Construction Project Part B Construction

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APPENDIX B

Table B1. Trust Territory of the Pacific Islands (TTPI) Marine Water Quality Standards.

PARAMETER	UNITS	CLASS AA	CLASS A	CLASS B
Total Coliform	#/100ml	<230		
Fecal Coliform	#/100ml		<400	<400
pH		Normal ±0.2	Normal ±0.2	Normal ±0.5
		----------[6.5<pH<8.5]----------		
Total Nitrogen TN	mg/l	≤0.40	≤0.75	≤1.50
		----------[Normal ± 10%]----------		
Total Phosphorus (TP)	mg/l	≤0.025	≤0.050	≤0.100
		----------[Normal ± 10%]----------		
TN/TP (ratio)	--	----------[Normal ± 10%]----------		
Dissolved Oxygen (D.O.)	mg/l	≥6.0 or 75% of saturation whichever is greater	≥5.0	≥4.5
Total Dissolved Solids (TDS)	mg/l	----------[Normal ± 10%]----------		
Salinity	o/oo	----------[Normal ± 10%]----------		
Temperature	°C	----------[Normal ± 0.9]----------		
Turbidity	NTU, JTU, TU	Normal ±5%	Normal ±10%	Normal ±20%
Heavy Metals:				
Arsenic	µg/l	10.0	All marine water classess have the same standards	
Copper		10.0		
Lead		10.0		
Mercury		0.10		
Zinc		20.0		
Nickel		2.0		
Chromium		50.0		
Cadmium		5.0		

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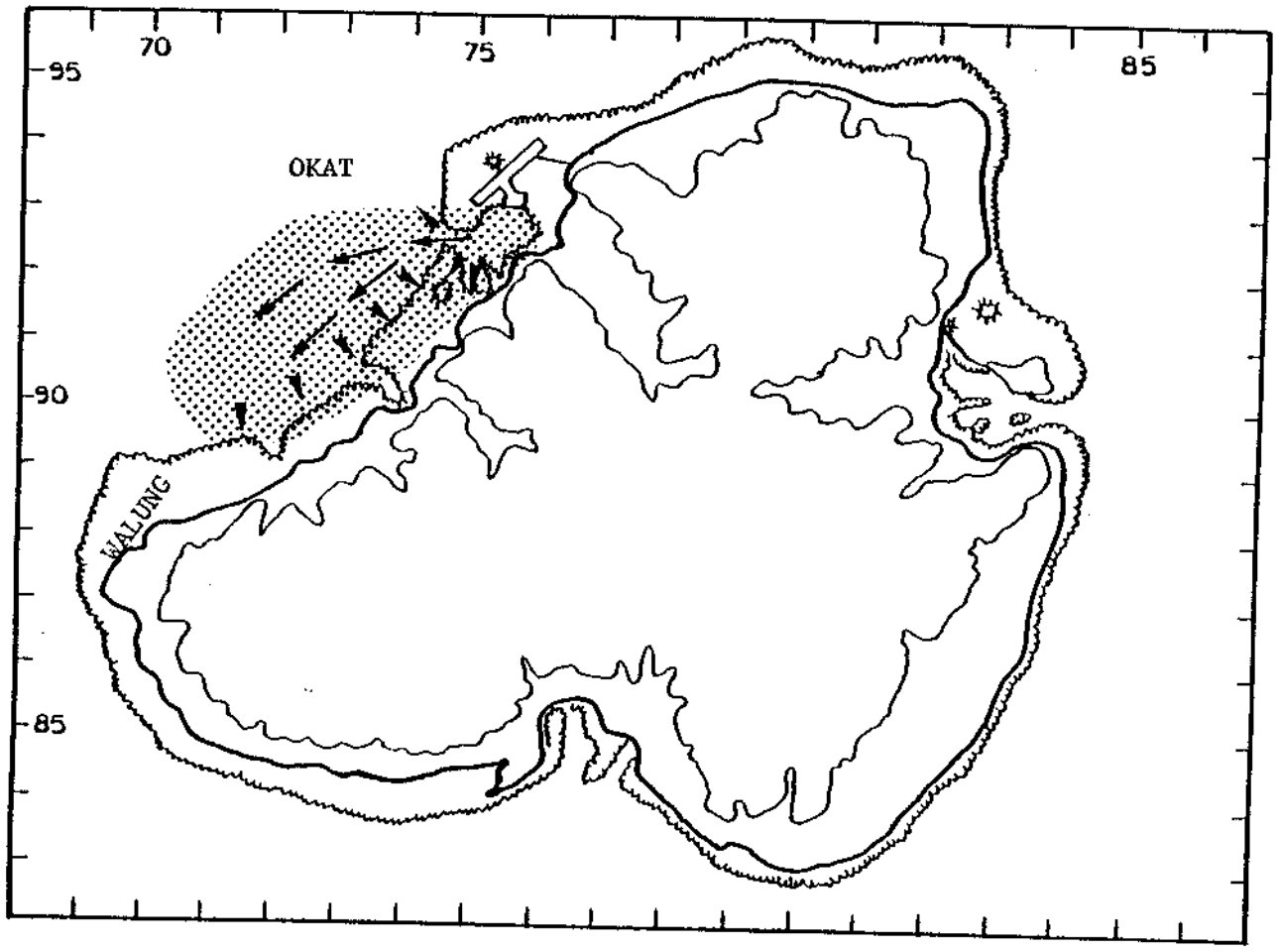

Figure 9. Extent of turbidity plume made by dredge spoil clean-up operation, April 1984.

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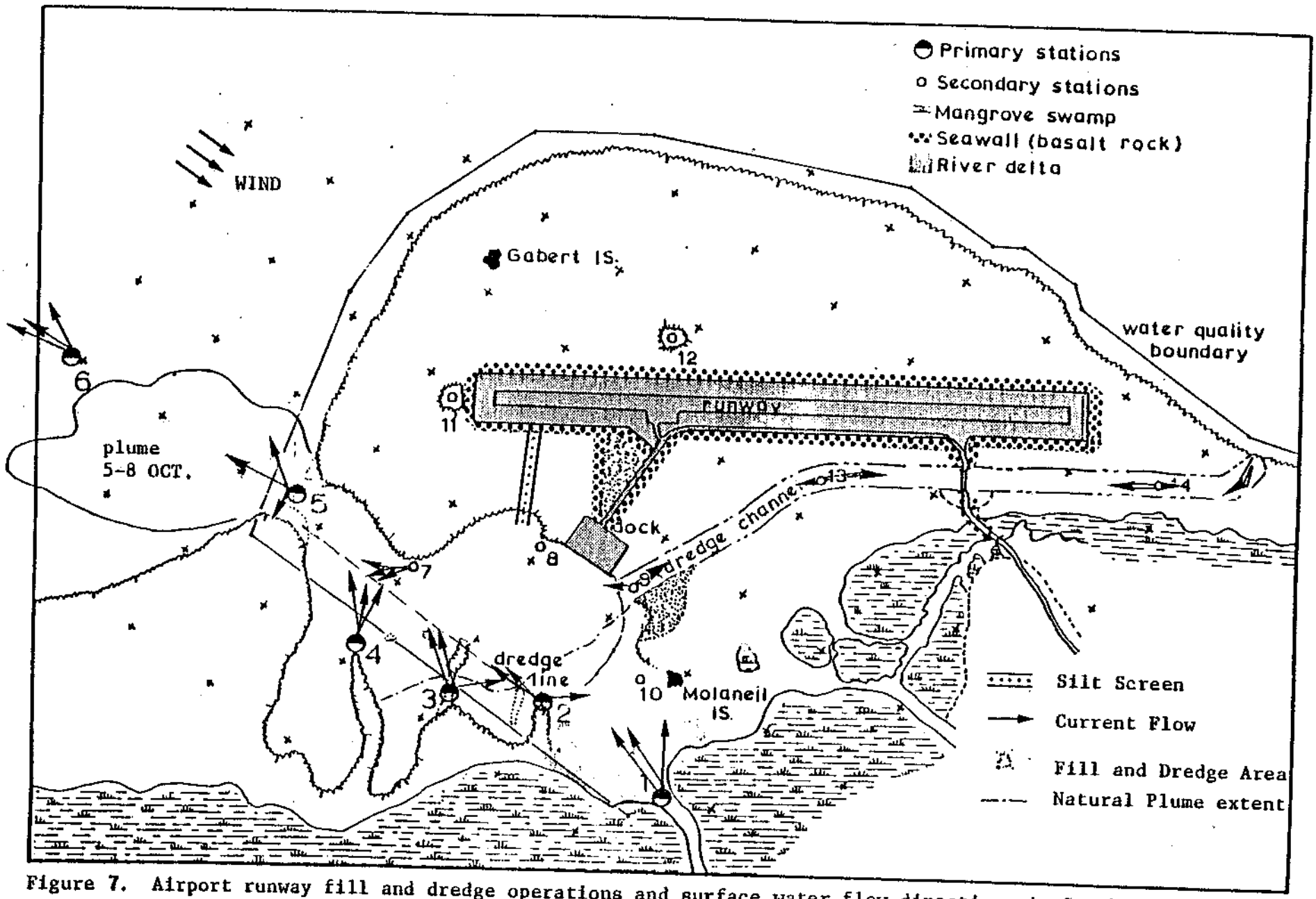

Figure 7. Airport runway fill and dredge operations and surface water flow directions in October, 1983. The runway fill area has been completed.

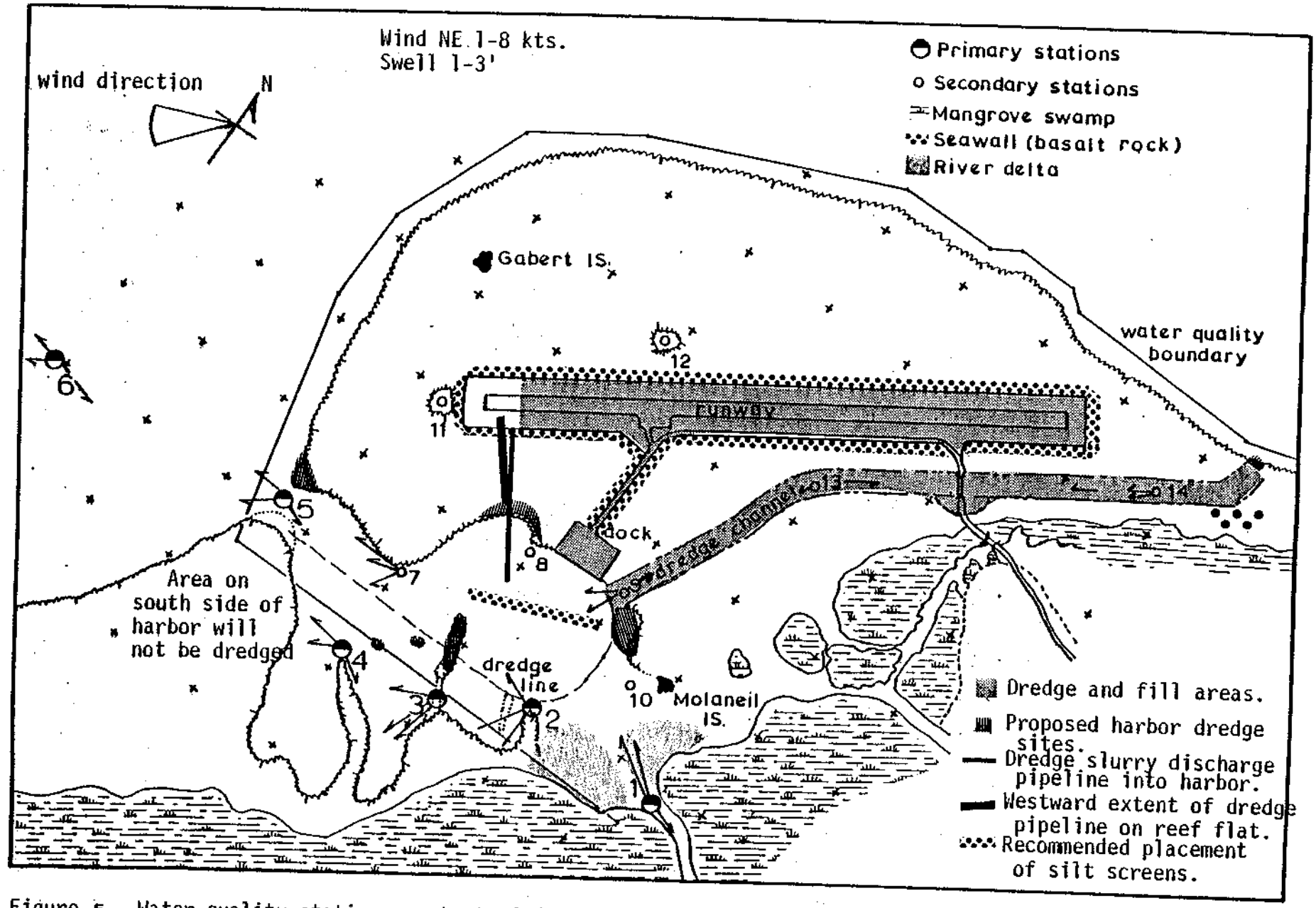

Figure 5. Water quality stations, extent of dredge and fill operations, surface water flow patterns, and recommended placement of silt screens for dock area construction project, April 1983. The symbol •,•,• represents a recommended area for placement of a small boulder pile which would reduce the wave action in the adjacent mangrove area.

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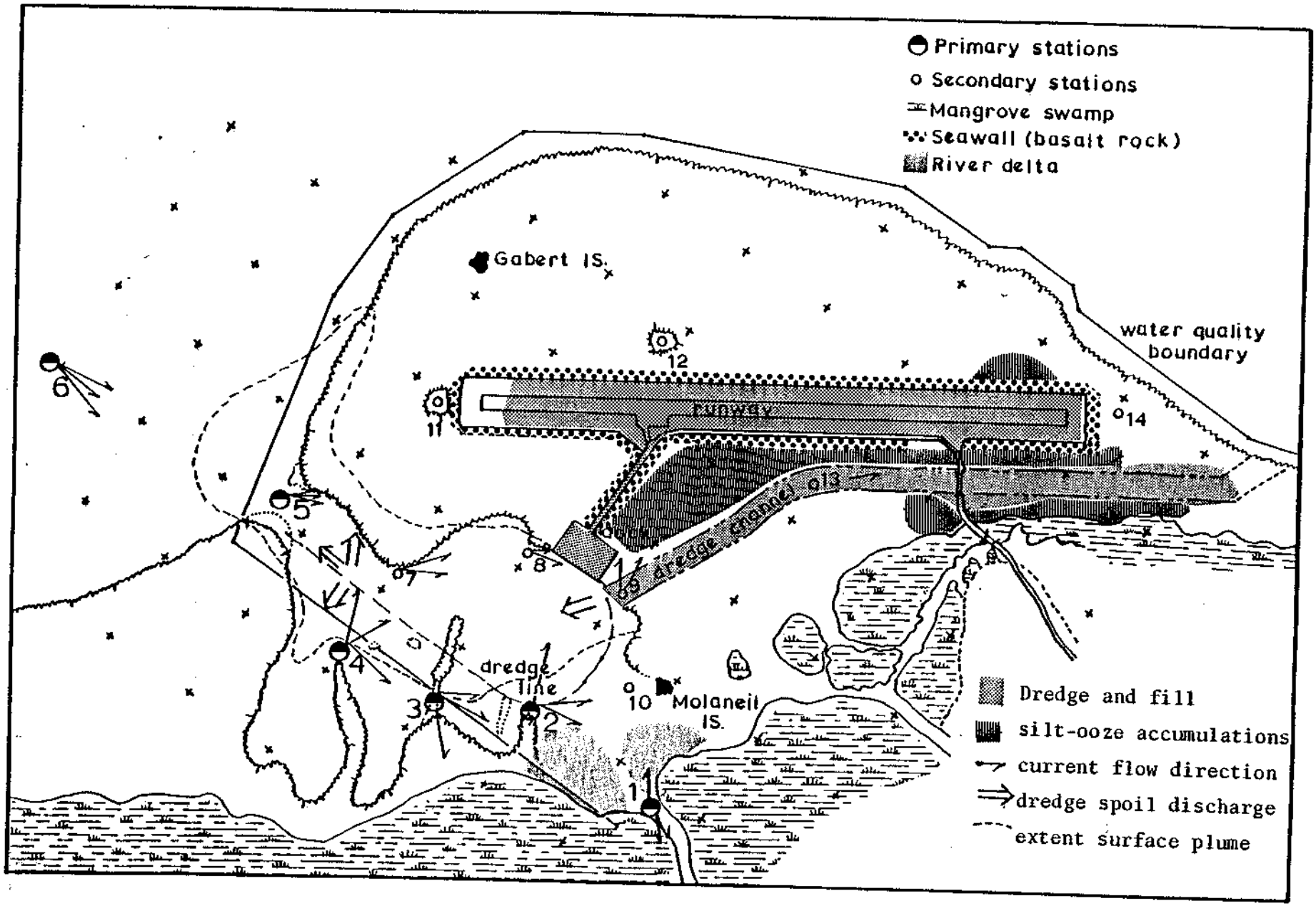

Figure 3. Water quality stations, extent of dredge and fill operations and surface water flow patterns, November 1982.

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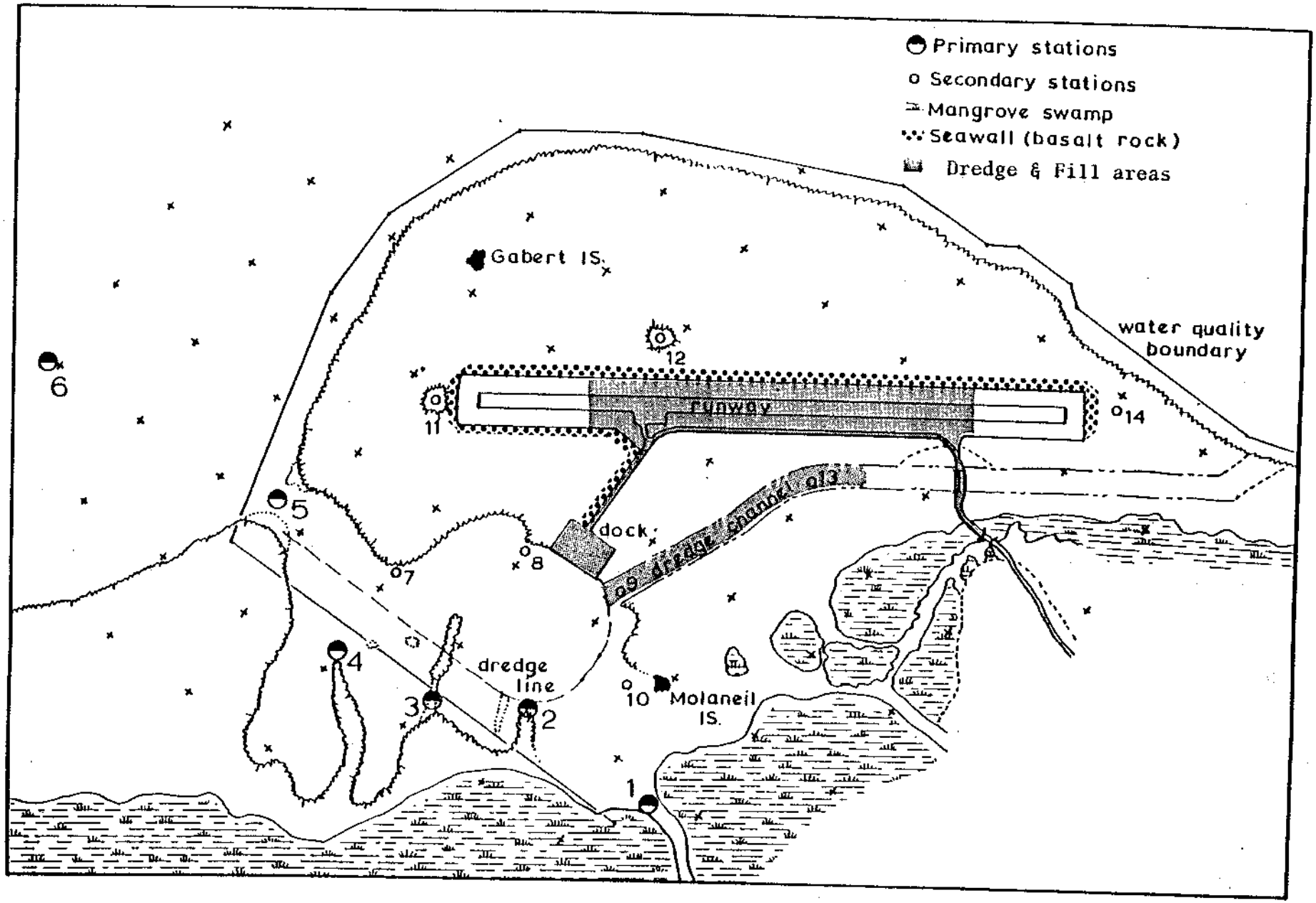

Figure 1. Water quality stations and extent of dredge and fill operations, July 1982.

INTRODUCTION

Construction of an airport runway and docking facility was begun in early 1981 for Kosrae State (FSM). The construction project was located in a previously pristine marine environment near the natural deep-water harbor at Okat on the northeast end of Kosrae Island (Figure 1). The runway and docking facility were constructed entirely on the wide fringing reef-flat complex north of Okat harbor (Figure 2). The Kosrae airport and docking facility Part B Construction marine water quality monitoring program was initiated in May 1982 and continued through July 1984. Marine water in the vicinity of the construction project, primarily within Okat harbor, was monitored on a quarterly basis. Results of water quality analyses were used to assess compliance with the Trust Territory of the Pacific Islands (TTPI) marine water quality standards and the Part A Pre-construction (base-line environmental impact statement) recommended turbidity standard as established by Chun et al. (1979), and the TTEPB earth moving permit for the project.

Project plans called for the construction of a 1940 m long by 52 m wide (6400 ft by 500 ft) runway and a rectangular docking area measuring 168 m by 104 m (550 ft by 340 ft). Fill material for these structures would be obtained by dredging a section of reef-flat complex and environmental features (ie., patch reef, river delta) within Okat harbor. Fill material would be composed of recent carbonate reef deposits (ie., coral, calcareous algae, shell debris, sediments). Runway and docking areas would be bounded by a peripheral seawall composed of quarried basalt rock (armor stone). Since dredged material would be deposited as a slurry, the seawall was also designed to act as a retaining wall for dredge slurry discharges. Dredging operations on the reef-flat would produce a small boat channel, which would run parallel to the runway. The dredge channel would be cut to a maximum depth of 8 m (25 ft) and up to 75 m wide (250 ft). An access road would be built between the runway and the island of Kosrae, which would cut through the coastal mangrove fringe. Two bridges would be required along this access road: one to span the existing traditional canoe channel that meanders through the coastal mangroves; and a second bridge across the dredged small boat channel. Runway and dock site construction projects were well underway at the onset of Part B monitoring program which had an unavoidable delay in its initiation. The Pacific Division Naval Facilities Engineering Command (PACNAVFACENGCOM) attempted to delete both the water quality and biological portions of an environmental monitoring program for the Kosrae airport and runway construction project. Objections were made by Guam and Trust Territory agencies to the removal of environmental monitoring programs. The Trust Territory Environmental Protection Board (TTEPB) objected to deletion of a water quality WQ monitoring program and requested that PACNAVFACENGCOM include a monitoring program for the Part B Construction phase and a Part C Post-Construction monitoring trip. The Water and Energy Research Institute (WERI) proposed a modified water quality program which was acceptable to both PACNAVFACENGCOM and the TTEPB. Biological monitoring programs were deleted for the Part B Construction and Part C Post-construction phases. The time required to settle this

Trust Territory of the Pacific Islands. 1978. Marine and fresh water quality standard regulations. Public Law 4C-78. Territorial Register, TTPI.

United States Environmental Protection Agency (USEPA). 1979. US EPA methods for chemical analysis of water and wastes. US EPA, 600/4-79-020.

Zolan, W.J. 1983. Water quality monitoring program Palau Airport project, Ngurusar Bay - Toagel Mid Channel, Babelthaup and Koror Islands, Palau District, Trust Territory of the Pacific Islands. Part B, Construction. Univ. Guam, WERI, Tech. Rept. 46:36 p.

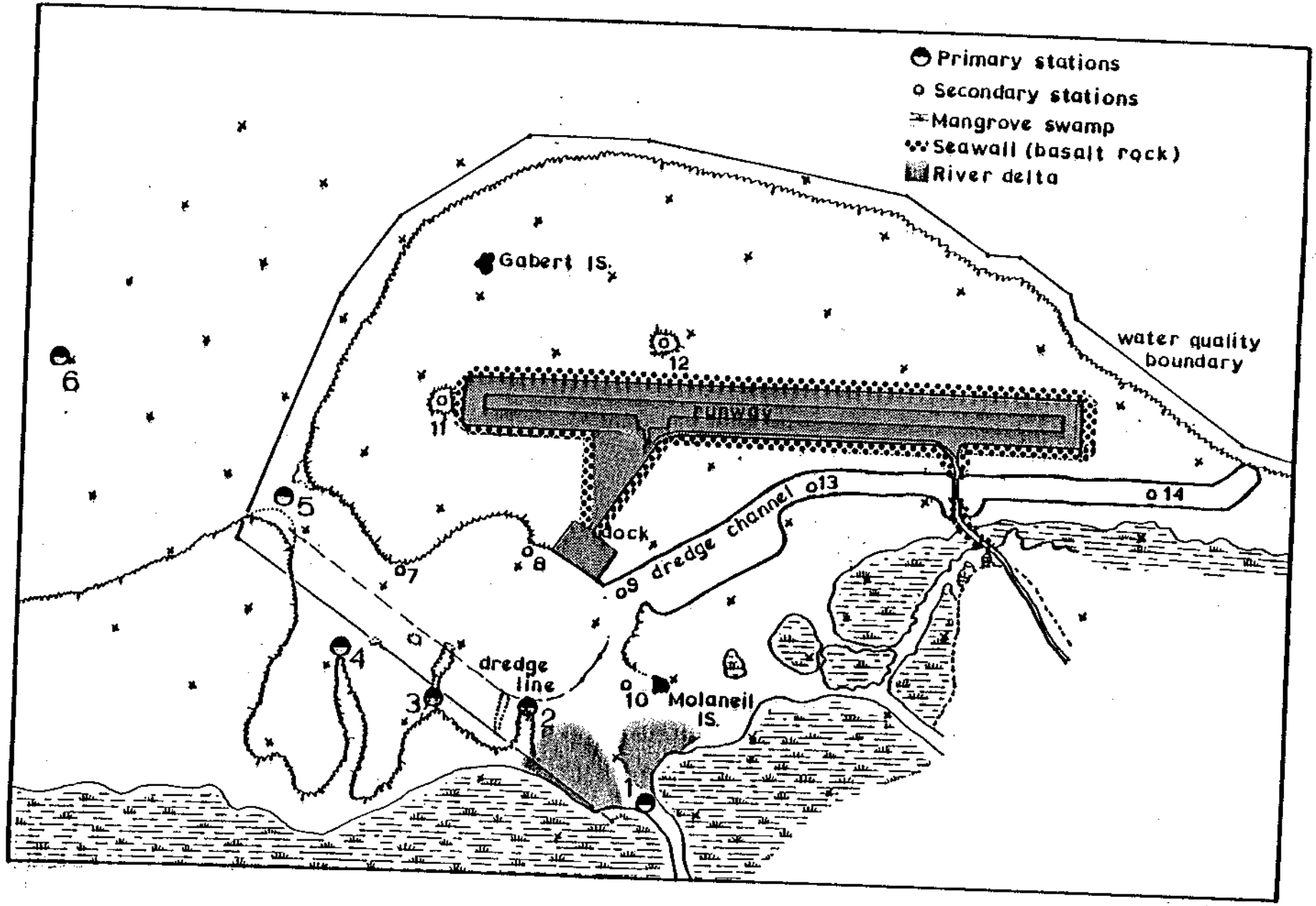

Figure 2. Airport construction at completion of project with locations of primary and secondary water quality stations.

sediment outwash. There was a distinct stratification of the water column within the channel. The stronger surface currents tended to trap the suspended load within the lower channel waters, causing restricted removal toward the harbor end.

Although other chemical and physical WQ parameters (ie., temperature, salinity, pH, DO, phosphorus and nitrogen) show statistically significant differences between stations and sampling quarters throughout the Part B monitoring program, these fluctuations cannot be wholly attributed to construction operations. Many of these fluctuations were temporal changes caused by meteorological and hydrographic influences which overshadowed man-induced perturbations.

Heavy metal analyses showed that the Okat area had total mercury concentrations in excess of the TTPI marine water quality standard throughout the construction project. Mercury, in part, entered the harbor water mass from the construction area. There was no obvious low level chronic mercury source located at the construction site. Elevated mercury concentration in Okat waters resulted in food fish, those caught from this area, in having significantly higher mean mercury concentrations in their tissues than normally found in coastal fish. It is anticipated that most excess mercury in Okat marine waters will become bound within marine sediments.

METHODS

In order to evaluate the environmental impact during the construction period, water quality sampling stations were established and monitored over an 11 day period, summer 1979, as a portion of the Part A Pre-construction Baseline Monitoring Program (Chun et al., 1979). The sampling frequency, chemical and physical water quality parameters, and analytical techniques were designated by the contracting agency (PACNAVFACENGCOM). Water quality parameters analyzed in the Part A Pre-construction monitoring program by Chun et al. (1979) included turbidity, dissolved oxygen, temperature, salinity, pH, total nitrogen, total phosphorus, lead, mercury, zinc, copper, arsenic, nickel, cadmium and chromium. Chun et al. (1979) established 8 water quality sampling stations in the vicinity of Okat harbor (Figure 2). These stations were initially selected to be used in the Part B Construction and Part C Post-construction monitoring programs. However, 4 of these stations were located within the designated water quality boundary (Figure 2). According to PACNAVFACENGCOM, water quality stations had to be placed beyond this water quality (WQ) boundary for purposes of compliance monitoring. Therefore, those stations originally located within the WQ boundary could not be used as primary stations. The remaining 4 stations located in the Part A baseline study were adopted for the Part B Construction monitoring program.

Six primary water quality stations were established in the vicinity of the WQ boundary in Okat harbor (Figure 2). All of the primary WQ stations could not be located outside the WQ boundary (1, 2 and 5) and still provide both expedient and significant environmental monitoring. The major difficulties with having all the monitoring stations outside the WQ boundary included: 1) the expanse of the boundary in relation to the construction limits; 2) the location of the boundary in relations to existing reef features; 3) the frequent exposure of the reef flat in low tide periods; and 4) the greatly restricted sampling period due to the low tide reef exposure problem. In an attempt to further delineate turbidity water quality, secondary turbidity stations were established within the WQ boundary (Figure 2). The latter stations were selected in order to better assess the movement of turbid water (natural and man-made) and sources of higher turbidity. The most frequently sampled secondary stations were 7, 9, 13 and 14. Monitoring of stations 9, 13 and 14 provided an assessment of water quality in the dredged channel. Station 7 was located in a surface outflow current, which also flowed past the dock site (Figure 3).

The water quality parameters and analytical techniques used in the Part B monitoring were similar to those used in the Part A monitoring program. The water quality parameters routinely measured were pH, temperature, salinity, turbidity, total non-filtrable residue (TNFR), dissolved oxygen (DO), total phosphorus (TP), ortho-phosphate (OP), total Kjeldahl nitrogen (TKN), total nitrogen (TN), nitrite + nitrate-nitrogen (NO) and ammonia nitrogen (NH). Water quality parameters were analyzed in accordance to Standard Methods (APHA, 1980).

activities. DO showed decreases at all the stations for the Part B monitoring period. However, these decreases were not significant. There were no changes in surface temperatures or pH measurements between monitoring periods. The nutrients were more variable with generally similar TKN concentrations and higher TP concentrations. These changes in nutrient levels were a result of both man-induced and natural perturbations.

SUMMARY

The Part B Construction monitoring program at Okat harbor showed a degradation of marine water quality (WQ) around the airport runway, docking facility, harbor system and surrounding reef-flat complex. The major impact was caused by increased turbidity levels attributed to construction operations.

The mean turbidities at primary WQ stations 1, 2 and 3, as well as secondary WQ stations 7, 9 and 13, exceeded the turbidity standard. This indicates that these stations were subjected to excessive turbidities which could cause environmental degradations. The high mean turbidity at station 3 indicates that turbidity levels in excess of the standard occurred beyond the WQ boundary. The high mean turbidities at stations 1 and 2 were caused, for the most part, by the natural river discharge and tidal flushing from the adjacent mangrove fringe.

The increased turbidity levels and associated turbidity plumes that were caused by dredge and fill operations had the potential to stress the marine biota throughout the Okat coastal zone. The harbor area received the principle environmental degradation, but the adjacent fringing mangrove system and the reef flat west of the harbor also received periodic heavy stress from excessive turbidity plumes. Oil and grease surface films were frequently associated with these large turbidity plumes.

Accumulations of lime-muds deposited in the shallow waters adjacent to the runway and docking facility and in the dredge channel were easily resuspended into the water column by normal tidal changes and hydrographic conditions. These resuspended turbidity plumes impacted large areas of the harbor complex and mangrove system, including periodic influence on the off-shore control site. It is anticipated that these lime-mud deposits will eventually become stabilized, which will minimize resuspension. However, there may be a long-term period required for stabilization. Therefore, the marine ecosystem in Okat harbor may become modified as a result of this long-term stress. The restricted water circulation within Okat harbor has hindered the removal of the silty-ooze and lime-mud deposits to deeper off-shore waters. This problem was caused in part by having the dredge channel left closed at the seaward end. Although there were strong currents within the dredge channel during strong tidal change and heavy surf periods, these currents were insufficient to cause extensive

The water column at each station was sampled near the surface at a depth of -1 m. Samples were mostly taken between 0700 and 1600 hours with a PVC Van Dorn sampler. Temperature and salinity were measured in the field. Turbidity, pH, TNFR, and DO were analyzed at the Kosrae Environmental Health Laboratory. The nutrient samples were frozen, transported in ice and analyzed at the WERI Laboratory in Guam. Field salinity measurements were taken with a hand-held refractometer. Salinity was measured in near surface and -1 m water samples. Temperatures were taken with hand-held mercury thermometers for surface and -1 m water samples. Turbidity was nephelometrically measured with a model 2100A Hach Turbidimeter. TNFR was measured by filtering a 1 liter (1) water sample through a glass fiber filter and drying a 105 degrees C for 24 hours. Table 1 presents the water quality parameters with methods and type of analysis. Abbreviations of water quality parameters found in the text and tables are shown in Table 1.

Heavy metal samples were collected from near surface (-1m) waters at primary and secondary water quality stations in November 1982, July 1983, and July 1984. The samples were preserved with nitric acid and transported to the WERI Laboratory in Guam for analyses. The water sample for each station was analyzed for zinc (Zn), copper (Cu), lead (Pb), mercury (Hg), arsenic (As), Cadmium (Cd), Chromium (Cr) and Nickel (Ni). Total heavy metal concentrations were determined by atomic absorption with a Perkin Elmer 560 Atomic Absorption Spectrophotometer. Arsenic and Selenium were determined by Hydride generation. Mercury was determined by cold vapor. All other metals were determined by electrothermal graphite furnace. Metals were analyzed according to United States Environmental Protection Agency (USEPA) methods of analyses (USEPA, 1979) and Standard Methods (APHA, 1980).

Wind direction and relative speed were measured at the beginning of each sampling set for all stations. Surface water current flow directions and estimated speeds were obtained at each sampling station by measuring the movement of fluorescein dye tracks. Flow speeds were classified as slow, intermediate and fast. Flow speed were classified as slow when flow movement was less than 5 m/minute, while fast flow movements exceeded 10 m/minute. Three types of rainfall occurrence events were recorded for each sampling day: no rainfall in last 12 hours; rainfall in mountains which could produce runoff into Okat harbor; rainfall at Okat harbor within previous 12 hours. Tidal cycle changes were noted with sampling sets taken from rising, falling neap tides.

The water quality data were analyzed with a Statistical Analysis System (SAS) software program on an IBM 4332 computer. Input also included meteorological and hydrographic data collected for each sampling set by station. Two primary statistical programs were used to analyze data; Univariate and analysis-of-variance (ANOVA) (SAS, 1982). The ANOVA statistical analyses were run with a 5 percent level of significance (P 0.05).

Table 48. continued.

Station	Parameter	WIND DIRECTION F-Value	WIND DIRECTION Significance	RAINFALL F-Value	RAINFALL Significance	TIDAL CYCLE F-Value	TIDAL CYCLE Significance	3-way ANOVA
14	Turbidity	1.22	NS	3.49	NS	4.51	.044	*
	TNFR	1.05	NS	6.96	.013	1.26	NS	*
	Sur. Temp	0.32	NS	0.05	NS	1.48	NS	
	-1m Temp	1.53	NS	1.13	NS	1.23	NS	
	Sur. Salinity	0.09	NS	1.02	NS	0.36	NS	
	-1m Salinity	2.45	NS	2.50	NS	0.28	NS	*
	pH	0.72	NS	0.05	NS	0.22	NS	
	Dis. Oxygen	0.08	NS	3.65	NS	0.13	NS	
	Total Nitrogen	4.74	NS	0.58	NS	5.59	.050	
	TKN	4.23	N3	0.44	NS	4.71	NS	
	Nitrate	2.06	NS	2.75	NS	2.51	NS	
	Ammonia	2.27	NS	1.91	NS	1.91	NS	
	Ortho Phos	4.08	.039	9.66	.005	1.39	NS	*
	Total Phos	2.72	NS	6.63	.015	2.48	NS	

RESULTS AND DISCUSSION

Water Quality Standards

Physical and chemical water quality (WQ) parameters at the monitoring stations were evaluated and regulated by the Part A Pre-construction turbidity standard (1.5 NTU) and the TTPI Marine Water Quality Standards (TTPI, 1978). See Appendix B for the TTPI marine water quality standards for different classes of marine water. The construction site is classed B water. The TTPI standards provide numerical limits for total phosphorus (TP), total nitrogen (TN), pH and dissolved oxygen (DO) and heavy metals. The limits for temperature and salinity are "natural conditions" +10 percent.

The turbidity standard was established by Chun et al. (1979) as part of the Part A Pre-construction base-line environmental impact statement. The justification used by Chun et al. (1979) for establishing a 1.5 NTU [TU=NTU] turbidity standard was as follows:

> "In establishing the turbidity standard for the proposed airport/harbor project at Okat, Kosrae, consideration was given to 1) the short duration of the sampling program, which provided data limited to a time span of only 11 days, 2) the Trust Territory of the Pacific Islands (TTPI) Water Quality Standards, and 3) the fact that the harbor and reef waters would be most affected by construction activities.
>
> It was felt that a fair compromise to establishing a standard based on an arithmetic or geometric mean computed from limited data would be a standard based on a T_{90} value. For the harbor waters this was 0.87 TU and for the reef waters 0.65 TU. This is not to say that the geometric or arithmetic means are statistically inadequate, rather the T_{90} values allow for natural fluctuations and do not penalize the construction activities for these fluctuations.
>
> The turbidity standard for TTPI requires that natural turbidities not be affected by more than 10% in Class A waters (recreational, aesthetic enjoyment, support and propagation of aquatic life) and no more than 20% in Class B waters (areas immediately adjacent to boat docking facilities). Classification of the harbor waters after project completion would probably be Class B, however during construction a higher deviation from natural levels (greater than 20 percent) should be acceptable, considering the temporary nature of this activity.
>
> On the basis of the preceding, it is recommended that a turbidity standard of 1.5 TU be established for the harbor waters (as represented by Stations 1, 2, 5 and 6) and reef waters (as

Table 48. continued.

Station	Parameter	WIND DIRECTION F-Value	WIND DIRECTION Significance	RAINFALL F-Value	RAINFALL Significance	TIDAL CYCLE F-Value	TIDAL CYCLE Significance	3-way ANOVA
4	Turbidity	0.38	NS	9.62	.001	1.04	NS	*
	TNFR	0.56	NS	1.19	NS	0.23	NS	
	Sur. Temp	1.65	NS	19.82	.001	0.02	NS	*
	-1m Temp	2.85	NS	18.66	.001	0.32	NS	*
	Sur. Salinity	0.38	NS	7.03	.004	1.37	NS	*
	-1m Salinity	0.98	NS	13.62	.001	2.76	NS	*
	pH	1.32	NS	0.64	NS	0.16	NS	*
	Dis. Oxygen	5.03	.010	1.62	NS	0.24	NS	*
	Total Nitrogen	1.26	NS	0.65	Ns	7.42	.004	*
	TKN	1.53	NS	0.57	NS	8.32	.002	*
	Nitrate	0.61	NS	2.66	NS	0.09	NS	
	Ammonia	0.71	NS	1.50	NS	1.26	NS	
	Ortho Phos	2.03	NS	2.53	NS	0.32	NS	
	Total Phos	2.07	NS	4.47	.025	0.18	NS	
5	Turbidity	0.22	NS	2.84	NS	2.07	NS	
	TNFR	0.09	NS	0.25	NS	0.71	NS	
	Sur. Temp	0.23	NS	9.50	.001	0.32	NS	*
	-1m Temp	0.20	NS	6.47	.005	1.02	NS	*
	Sur. Salinity	0.50	NS	6.36	.006	0.83	NS	*
	-1m Salinity	1.13	NS	5.99	.007	0.71	NS	*
	pH	1.72	NS	0.45	NS	0.16	NS	
	Dis. Oxygen	0.42	NS	1.15	NS	0.49	NS	
	Total Nitrogen	1.09	NS	2.85	NS	3.96	.034	*
	TKN	1.13	NS	2.78	NS	4.03	.032	*
	Nitrate	1.73	NS	2.99	NS	0.13	NS	
	Ammonia	2.58	NS	0.42	NS	2.83	NS	
	Ortho Phos	2.72	NS	1.56	NS	0.80	NS	
	Total Phos	4.11	.018	3.96	.034	0.15	NS	*
6	Turbidity	3.35	.034	9.80	.001	3.76	.036	*
	TNFR	0.49	NS	1.87	NS	0.34	NS	
	Sur. Temp	0.04	NS	10.16	.001	0.82	NS	*
	-1m Temp	0.13	NS	10.24	.001	0.05	NS	*
	Sur. Salinity	3.16	.041	7.47	.003	3.21	NS	*
	-1m Salinity	6.61	.001	16.18	.001	1.45	NS	*
	pH	0.12	NS	2.75	NS	0.42	NS	
	Dis. Oxygen	0.37	NS	1.29	NS	1.57	NS	
	Total Nitrogen	0.63	NS	6.75	.005	2.76	NS	*
	TKN	0.70	NS	6.95	.005	2.70	NS	*
	Nitrate	0.13	NS	0.24	NS	0.37	NS	
	Ammonia	1.13	NS	7.81	.003	3.03	NS	*
	Ortho Phos	2.13	NS	0.87	NS	0.51	NS	
	Total Phos	2.84	N	3.78	.039	0.19	NS	

anticipated that a quarterly monitoring program would be the longest monitoring interval which would still provide sufficient WQ data to assess environmental change. Although, a comprehensive monthly WQ monitoring program would still be the best to quantify impacts from construction activities, seasonal fluctuations and natural environmental changes. A quarterly sampling program makes it difficult to determine seasonal WQ fluctuations. A quarterly sampling period was used for the Kosrae project because of the logistic problems of traveling to Kosrae and returning samples to WERI for analyses. This sampling period provided an adequate data base to assess marine WQ changes in Okat harbor and surrounding reefs as a result of construction activities and some environmental factors. These environmental factors included wind direction and speed, tidal cycle, rainfall occurrence and current flow direction.

Runway construction was well underway at the onset of Part B monitoring (Appendix A, Figure 1). The access roads were completed. Basalt seawalls surrounding the runway were in place. The central portion of the runway was infilled with dredged coral fill. Dredge filling at the dock site was completed in May 1982. Dredging in the small boat channel was 40% completed.

The construction project at the onset of Part B construction monitoring appeared to be progressing with, generally, minimum WQ degradation. However, within the confines of the WQ boundary, there were locations with substantial accumulations of silty ooze which influenced WQ within the harbor area. Turbidity plumes originating from the dredge channel and dock area produced turbidity levels in excess of the 1.5 NTU standard at stations 3 (June 2; 1.7 NTU) and 5 (June 1; 2.2 NTU). Turbidity plumes were observed to move southward across Okat harbor when the wind came from the N to NE. Turbidity levels in excess of the standard were also observed at stations 1 and 2. However, these higher turbidities were due to natural conditions. The other WQ parameters analyzed (temperature, salinity, pH, dissolved oxygen, total non-filtrable residue, nitrogen and phosphorus) were not abnormal for mangrove influenced marine waters. However, nutrient levels (ammonia-nitrogen and ortho-phosphorus) were higher than anticipated.

WQ data was tabulated and analyzed by both quarterly sampling sets and by station. Tables 2 to 7 show WQ analyses results by date for the 6 primary WQ stations, respectively, and Tables 8 to 11 show results for secondary WQ stations 7, 9, 13 and 14, respectively. Tables 2 to 11 are a compilation of all WQ data as presented to the TTEPB in quarterly letter reports. Mean values of WQ parameters were calculated by quarterly sampling periods (Table 12). These mean values were used to evaluate the station WQ for compliance monitoring after each sampling set. Table 12 shows the general trend in WQ by parameter for the entire monitoring program.

Station 1 was located in the marine delta flood-plain of a major river discharge on the seaward edge of the mangrove fringe (Figure 2). Dependent on rainfall conditions, river discharges could potentially

Table 47. continued.

Station	Parameter	N	Mean	Root MSE	F-Value	Significance	Station Source
10	Turbidity	29	2.4	0.9	4.96	.002	6 lower
	TNFR	30	37	21	2.23	NS	
	Sur. Temp	30	28.6	0.5	1.02	NS	
	-1m Temp	30	28.7	0.4	0.48	NS	
	Sur. Salinity	30	34.3	1.9	1.20	NS	
	-1m Salinity	30	34.6	0.4	2.07	NS	
	pH	30	7.82	1.47	1.06	NS	
	Dis. Oxygen	30	5.5	0.7	4.12	.004	9 higher; 1 lower
	Total Nitrogen	27	0.084	0.079	0.60	NS	
	TKN	27	0.076	0.079	0.56	NS	
	Nitrate	30	0.006	0.002	3.92	.005	6 lower
	Ammonia	30	0.015	0.007	0.94	NS	
	Ortho Phos	30	0.009	0.002	6.48	.001	6 lower
	Total Phos	30	0.019	0.025	1.21	NS	
11	Turbidity	30	2.4	0.9	10.19	.001	6, 14 lower
	TNFR	30	52	54	0.85	NS	
	Sur. Temp	30	29.1	0.6	0.92	NS	
	-1m Temp	30	29.1	0.6	0.96	NS	
	Sur. Salinity	30	34.7	3.2	1.60	NS	
	-1m Salinity	30	35.3	0.5	2.05	NS	
	pH	30	8.19	0.06	5.27	.001	14 higher
	Dis. Oxygen	30	5.7	1.0	0.64	NS	
	Total Nitrogen	27	0.110	0.054	0.27	NS	
	TKN	27	0.100	0.053	0.30	NS	
	Nitrate	30	0.015	0.022	0.68	NS	
	Ammonia	30	0.057	0.023	4.54	.002	6 lower
	Ortho Phos	30	0.008	0.002	7.31	.001	1 higher
	Total Phos	30	0.016	0.006	10.58	.001	1 higher

Table 3. Water quality at station 2 in Okat harbor. A period represents a "no sample taken" for sample period.

Date	Time	Turb	TNFR	Surface Temp	-1m Temp.	Surface Salinity	-1m Salinity	pH	DO	TN	TKN	NO	NH	TP	OP
05-19-82	0925	0.9	49	29.0	29.0	33.3	34.4	8.05	.	0.45	0.44	0.009	0.023	0.016	0.010
05-20-82	0945	1.2	227	30.0	30.0	33.3	35.5	8.00	.	0.26	0.26	0.005	0.043	0.160	0.100
05-21-82	1300	0.54	18	30.0	30.0	33.3	33.3	8.03	.	.	.	.	.	.	.
05-28-82	0930	1.2	22	31.0	31.0	33.9	35.5	8.10	4.9	.	.	.	.	.	.
06-01-82	1000	1.1	18	30.0	30.0	35.5	36.6	8.20	.	.	.	.	.	.	.
06-02-82	0950	3.4	33	30.0	30.0	34.4	34.4	8.30	.	.	.	.	.	.	.
06-03-82	0745	1.8	22	30.0	30.0	32.2	34.4	8.30	.	.	.	.	.	.	.
08-05-82	1015	3.0	51	28.0	28.0	31.1	31.1	7.90	4.0	0.16	0.15	0.006	0.028	0.027	0.013
08-07-82	0735	2.0	43	28.5	28.0	30.0	32.8	8.08	4.6	0.24	0.23	0.006	0.048	0.028	0.020
08-08-82	0810	3.5	54	29.0	29.0	30.5	33.3	8.00	4.6	0.14	0.13	0.006	0.040	0.035	0.013
11-10-82	1455	3.7	51	28.7	28.7	33.3	32.2	7.91	5.1	0.19	0.18	0.024	0.005	0.021	0.009
11-11-82	1050	3.7	36	27.8	27.9	32.2	33.3	7.65	4.6	0.43	0.41	0.024	0.013	0.071	0.071
11-12-82	1105	2.4	27	28.5	28.8	33.3	33.9	8.15	5.2	0.46	0.44	0.024	0.008	0.023	0.008
01-11-83	0918	2.5	58	28.1	27.8	35.5	35.5	8.28	6.0	0.65	0.64	0.006	0.007	0.122	0.122
01-12-83	0905	4.0	38	27.4	27.8	34.4	35.5	8.22	5.1	0.24	0.23	0.007	0.009	0.057	0.057
01-13-83	0840	2.3	34	27.2	27.5	35.0	35.5	8.00	5.6	0.10	0.09	0.006	0.016	0.145	0.145
01-14-83	0810	1.2	40	27.8	27.3	35.0	35.0	8.10	5.4	0.22	0.17	0.051	0.032	0.131	0.131
04-07-83	0845	1.1	12	28.4	28.0	35.5	35.5	7.95	5.8	0.08	0.08	.	0.027	0.028	0.007
04-08-83	0915	1.7	80	27.7	28.7	35.5	35.0	8.10	5.8	0.06	0.05	0.005	0.012	0.010	0.006
04-11-83	0910	2.3	33	28.4	28.6	35.0	35.0	8.00	5.4	0.17	0.13	0.044	0.018	0.010	0.009
07-07-83	1125	4.3	71	29.1	29.1	33.3	33.3	7.95	4.8	0.36	0.35	0.009	0.067	0.640	0.145
07-08-83	0930	4.7	27	28.9	28.8	32.2	32.2	7.95	4.6	0.34	0.33	0.011	0.067	0.726	0.242
07-11-83	0905	1.5	118	28.8	28.6	33.3	33.9	8.20	5.1	0.29	0.29	0.006	0.043	0.576	0.063
10-07-83	0945	2.1	56	29.5	29.0	25.5	32.2	8.00	3.9	0.81	0.77	0.035	0.012	0.020	0.005
10-11-83	0900	1.7	23	29.0	29.5	27.8	34.4	8.18	4.9	0.87	0.85	0.018	0.011	0.013	0.004
10-10-83	0900	3.4	25	29.0	30.1	32.2	34.4	8.00	5.1	0.87	0.85	0.016	0.012	0.020	0.005
01-18-84	1020	2.2	20	29.4	29.6	33.3	33.3	8.12	5.4	0.59	0.58	0.011	0.026	0.202	0.124
01-19-84	1000	1.9	35	29.0	28.9	33.3	33.3	8.18	4.8	0.58	0.56	0.017	0.024	0.192	0.105
01-20-84	0938	2.4	41	29.2	29.4	33.3	33.9	8.12	6.0	0.16	0.15	0.012	0.023	0.245	0.118
04-03-84	1140	3.9	55	29.1	29.1	34.4	34.4	8.22	5.3	0.13	0.12	0.006	0.023	0.017	0.009
04-04-84	0940	3.6	44	28.3	28.7	33.9	34.4	8.00	4.8	0.03	0.03	0.012	0.014	0.021	0.013
04-06-84	0930	2.5	32	28.2	28.3	34.4	34.4	8.00	5.1	0.05	0.03	0.013	0.015	0.022	0.015
07-12-84	1435	2.1	11	28.9	28.9	35.5	35.5	8.10	5.6	0.09	0.09	0.004	0.060	0.012	0.006
07-16-84	0830	2.8	44	28.5	28.9	34.4	35.5	8.10	5.4	0.08	0.06	0.074	0.061	0.025	0.018
07-17-84	0715	2.5	15	28.9	28.6	35.5	35.5	8.22	6.6	0.13	0.12	0.010	0.061	0.014	0.008

Table 47. continued.

Station	Parameter	N	Mean	Root MSE	F-Value	Significance	Station Source
4	Turbidity	26	3.4	2.9	8.60	.001	1 higher; 6 lower
	TNFR	18	113	125	8.24	.001	1 higher
	Sur. Temp	26	28.3	0.6	1.62	NS	
	-1m Temp	26	28.6	0.5	0.42	NS	
	Sur. Salinity	26	32.1	3.4	4.51	.004	1 lower
	-1m Salinity	26	33.4	0.7	4.76	.003	1 lower
	pH	26	8.10	0.17	7.26	.003	1 lower; 6 higher
	Dis. Oxygen	19	4.9	0.5	3.87	.022	1 lower; 6 higher
	Total Nitrogen	18	0.384	0.168	4.79	.012	1 higher
	TKN	18	0.350	0.159	5.03	0.010	1 higher
	Nitrate	26	0.022	0.006	10.48	.001	1 higher
	Ammonia	26	0.026	0.022	0.68	NS	
	Ortho Phos	26	0.015	0.013	3.31	0.018	1, 2 higher; 6 lower
	Total Phos	26	0.020	0.013	7.72	.001	1, 2 higher; 6 lower
5	Turbidity	30	2.5	1.8	3.67	.008	1, 13 higher; 6 lower
	TNFR	21	35	11	15.77	.001	1 higher
	Sur. Temp	30	27.8	0.4	4.53	.003	1 lower; 6 higher
	-1m Temp	30	27.8	0.4	3.97	.005	1 lower; 6 higher
	Sur. Salinity	30	35.1	0.6	3.48	.010	1 lower
	-1m Salinity	30	35.1	0.5	1.26	NS	
	pH	30	8.09	0.15	3.10	.018	1 lower
	Dis. Oxygen	28	5.5	0.4	2.19	NS	
	Total Nitrogen	23	0.480	0.309	1.53	NS	
	TKN	23	0.469	0.312	1.50	NS	
	Nitrate	28	0.011	0.009	0.92	NS	
	Ammonia	28	0.023	0.032	1.62	NS	
	Ortho Phos	29	0.048	0.052	1.81	NS	
	Total Phos	29	0.050	0.051	1.83	NS	
6	Turbidity	30	1.0	0.4	6.91	.001	1, 2 higher; 6 lower
	TNFR	30	46	34	0.28	NS	
	Sur. Temp	30	28.5	0.6	1.99	NS	
	-1m Temp	30	28.5	0.4	2.40	.050	1 lower; 14 higher
	Sur. Salinity	30	35.3	0.2	7.20	.001	1 lower
	-1m Salinity	30	35.2	0.3	3.89	.006	1 lower
	pH	30	8.08	0.16	2.58	.037	1 lower
	Dis. Oxygen	29	5.5	0.5	5.45	.001	1 lower
	Total Nitrogen	22	0.136	0.079	0.71	NS	
	TKN	22	0.117	0.079	0.60	NS	
	Nitrate	29	0.018	0.016	3.29	0.014	1 higher
	Ammonia	30	0.023	0.008	0.99	NS	
	Ortho Phos	30	0.008	0.003	4.77	.002	1 higher
	Total Phos	30	0.018	0.031	0.87	NS	

Table 5. Water quality at station 4 in Okat harbor. A period represents a "no sample taken" for sample period.

Date	Time	Turb	TNFR	Surface Temp	-1m Temp.	Surface Salinity	-1m Salinity	pH	DO	TN	TKN	NO	NH	TP	OP
05-17-82	1025	0.25	12	30.0	30.0	35.5	34.4	8.15	.	0.23	0.23	0.002	0.024	0.009	0.004
05-19-82	0940	0.66	25	29.0	29.0	34.4	34.4	8.01	.	0.43	0.38	0.050	0.044	0.011	0.006
05-20-82	1005	0.34	24	29.5	29.5	33.9	35.5	8.00	.	0.14	0.13	0.006	0.056	0.010	0.007
05-21-82	1310	0.62	30	31.0	31.0	33.3	34.4	8.04	.	.	.	.	.	.	.
05-28-82	0950	0.42	18	31.0	31.0	35.5	35.5	8.20	5.5	.	.	.	.	.	.
06-01-82	1120	0.47	100	30.0	30.0	36.6	35.5	8.30	.	.	.	.	.	.	.
06-02-82	1005	0.65	15	30.0	30.0	34.4	34.4	8.25	.	.	.	.	.	.	.
06-03-82	800	1.3	31	30.0	30.0	32.2	32.2	8.30	.	.	.	.	.	.	.
08-05-82	1040	0.88	48	28.0	28.0	34.4	34.4	8.31	4.3	0.24	0.23	0.006	0.036	0.012	0.012
08-07-82	0750	0.98	36	28.5	28.5	33.9	33.9	8.22	4.9	0.20	0.23	0.005	0.040	0.010	0.000
08-08-82	0825	0.76	32	29.0	29.5	34.4	34.4	7.95	5.6	0.11	0.10	0.006	0.044	0.018	0.011
11-10-82	1510	1.8	35	28.9	28.6	33.9	33.3	8.20	4.0	0.27	0.25	0.019	0.010	0.005	0.005
11-11-82	1105	1.6	29	28.3	28.2	33.9	34.4	8.23	4.5	0.08	0.06	0.023	0.072	0.014	0.007
11-12-82	1055	1.4	13	28.4	28.7	34.4	33.3	8.20	4.8	0.36	0.15	0.024	0.013	0.017	0.009
01-12-82	0925	1.1	10	28.0	28.0	35.0	35.5	8.29	5.5	0.33	0.32	0.006	0.002	0.091	0.091
01-13-83	0905	0.90	17	28.3	28.0	35.5	35.0	8.20	5.6	1.5	41.44	0.005	0.07	0.008	0.008
01-14-83	0830	0.70	16	28.3	28.1	35.5	35.0	8.05	5.6	0.90	0.89	0.006	0.013	0.003	0.002
04-07-83	0905	0.85	38	28.4	28.2	35.5	35.5	8.00	5.4	0.07	0.06	0.011	0.025	0.008	0.006
04-08-83	0925	0.43	126	28.5	28.8	35.5	35.5	8.20	5.6	0.09	0.09	0.002	0.011	0.010	0.005
04-11-83	0930	0.80	21	28.5	28.6	35.5	35.5	8.02	5.8	0.16	0.15	0.011	0.025	0.009	0.006
07-07-83	1145	1.3	13	28.8	28.8	33.3	33.9	7.95	5.1	0.30	0.29	0.007	0.019	0.093	0.091
07-08-83	0945	1.8	20	28.6	28.9	31.1	32.7	8.05	5.2	0.29	0.29	0.005	0.068	0.680	0.351
07-11-83	0920	1.5	37	28.5	28.5	33.3	33.3	8.08	4.6	0.36	0.35	0.006	0.039	0.439	0.038
10-07-83	1005	1.3	28	29.6	29.0	28.9	33.3	8.10	4.8	1.50	1.48	0.026	0.016	0.017	0.006
10-11-83	0920	1.2	20	29.4	30.1	33.4	34.4	8.02	5.2	0.64	0.63	0.014	0.005	0.011	0.003
10-10-83	0920	1.6	10	29.4	29.4	34.4	33.3	8.18	4.9	0.93	0.91	0.019	0.018	0.012	0.004
01-18-84	1032	1.4	6	29.3	29.5	32.2	33.3	8.15	5.6	0.46	0.45	0.011	0.022	0.154	0.080
01-19-84	1012	1.2	25	28.9	29.0	32.2	32.2	8.20	5.3	0.71	0.69	0.015	0.022	0.198	0.100
01-20-84	0950	1.6	23	28.8	28.8	32.2	32.2	8.18	5.1	0.42	0.41	0.013	0.022	0.172	0.073
04-03-84	1153	2.3	117	28.9	29.1	34.4	34.4	8.18	4.7	0.33	0.32	0.006	0.025	0.012	0.008
04-04-84	0952	1.8	27	28.7	28.8	34.4	34.4	8.20	6.0	0.03	0.02	0.006	0.008	0.011	0.006
04-06-84	0943	1.2	18	28.4	28.4	34.4	34.4	8.08	5.3	0.03	0.02	0.008	0.018	0.012	0.008
07-12-84	1447	1.5	14	29.1	19.3	35.5	35.5	8.09	5.4	0.08	0.07	0.006	0.105	0.014	0.008
07-16-84	0850	1.3	94	28.9	29.1	35.5	35.5	8.13	5.1	0.12	0.10	0.016	0.084	0.009	0.007
07-17-84	0735	1.2	18	28.9	28.6	35.3	35.5	8.20	5.4	0.14	0.13	0.009	0.070	0.011	0.007

Table 46. continued.

Station	Parameter	N	Mean	Root MSE*	F-Value	Significance
14	Turbidity	17	1.1	0.3	4.74	.015
	TNFR	18	29	22	1.30	NS
	Sur. Temp	18	29.5	0.9	0.15	NS
	-1m Temp	18	29.3	0.5	1.80	NS
	Sur. Salinity	18	34.9	0.4	5.08	.010
	-1m Salinity	18	34.7	0.4	10.47	.001
	pH	18	8.23	0.11	0.67	NS
	Dis. Oxygen	17	6.3	0.9	0.50	NS
	Total Nitrogen	13	0.147	0.060	9.88	.003
	TKN	13	0.143	0.065	7.13	.009
	Nitrate	18	0.011	0.004	8.51	.001
	Ammonia	18	0.029	0.016	3.04	NS
	Ortho Phos	18	0.050	0.005	709.40	.001
	Total Phos	18	0.196	0.058	122.19	.001

* Root MSE - Root Mean Square Error.
** NS - Not significant at $P \geq 0.05$.

Table 7. Water quality at station 6 in Okat harbor. A period represents a "no sample taken" for sample period.

Date	Time	Turb	TNFR	Surface Temp	-1m Temp.	Surface Salinity	-1m Salinity	pH	DO	TN	TKN	NO	NH	TP	OP
05-17-82	1100	0.14	3	30.0	30.0	35.5	35.5	8.25	.	0.10	0.10	0.002	0.045	0.007	0.003
05-19-82	1005	0.27	16	29.5	29.5	34.4	34.4	8.15	.	0.15	0.15	0.001	0.031	0.012	0.004
05-20-82	1025	0.33	60	29.0	29.0	35.5	35.5	8.18	.	0.01	0.01	0.001	0.092	0.007	0.004
05-21-82	1340	0.44	4	30.0	30.0	35.5	35.5	8.13	.	.	.	.	.	.	.
05-28-82	1005	0.42	16	30.0	30.0	34.4	35.5	8.25	6.0	.	.	.	.	.	.
06-01-82	1135	0.28	7	30.0	30.0	35.5	35.5	8.35	.	.	.	.	.	.	.
06-02-82	1030	0.24	4	30.0	30.0	35.5	35.5	8.25	.	.	.	.	.	.	.
06-03-82	0820	0.45	18	30.0	30.0	34.4	34.4	8.05	.	.	.	.	.	.	.
08-05-82	1100	0.55	33	28.0	28.0	34.4	35.0	8.12	6.1	0.14	0.10	0.002	0.040	0.016	0.005
08-07-82	0810	0.26	17	28.0	28.0	34.4	34.4	8.32	5.6	0.25	0.25	0.002	0.048	0.016	0.005
08-08-82	0845	0.27	30	28.5	28.0	34.4	35.0	8.12	5.8	0.19	0.19	0.001	0.040	0.010	0.003
11-10-82	1530	0.65	16	28.8	28.8	34.4	34.4	8.30	5.9	0.29	0.28	0.007	0.033	0.008	0.000
11-11-82	1120	0.52	20	28.8	28.7	34.4	34.4	8.35	4.6	0.36	0.35	0.007	0.045	0.005	0.001
11-12-82	1040	0.58	6	28.9	29.2	34.4	34.4	8.35	5.4	0.39	0.38	0.007	0.028	0.005	0.000
01-12-83	0945	0.47	13	28.1	28.2	35.5	35.5	8.09	5.8	0.32	0.32	0.001	0.016	0.070	0.070
01-13-83	0925	0.45	10	28.3	28.3	35.0	35.0	8.18	5.6	0.55	0.55	0.002	0.011	0.102	0.102
01-14-83	0900	0.66	38	28.2	28.2	35.5	35.5	8.10	5.8	0.49	0.48	0.008	0.005	0.003	0.003
04-07-83	0925	0.67	30	28.4	28.4	35.5	35.5	8.12	6.7	0.07	0.05	0.018	0.014	0.007	0.007
04-08-83	0940	0.41	79	28.5	28.7	35.5	35.0	8.25	5.1	0.09	0.09	0.000	0.028	0.010	0.006
04-11-83	0950	0.42	29	28.5	28.6	35.5	35.5	8.08	5.8	0.21	0.21	0.000	0.010	0.010	0.006
07-07-83	1155	0.92	26	29.2	29.2	34.4	35.0	8.00	5.8	0.25	0.25	0.003	0.034	0.772	0.050
07-08-83	1000	0.75	11	29.1	29.1	34.4	35.0	8.18	6.0	0.24	0.24	0.002	0.039	0.863	0.210
07-11-83	0935	0.85	13	28.8	28.8	33.4	34.4	8.22	5.5	0.85	0.85	0.002	0.019	0.713	0.038
10-07-83	1015	0.60	23	29.2	29.7	33.3	34.4	8.20	4.8	0.27	0.27	0.001	0.007	0.009	0.002
10-11-83	0940	0.62	13	29.8	30.1	35.0	34.4	8.18	5.6	0.70	0.70	0.001	0.007	0.008	0.001
10-10-83	0940	0.85	21	29.8	29.5	34.4	34.4	8.22	5.5	0.48	0.48	0.001	0.007	0.009	0.002
01-18-84	1050	0.68	14	29.5	29.5	35.5	35.5	8.28	6.0	0.49	0.49	0.004	0.014	0.151	0.049
01-19-84	1030	0.64	13	29.4	29.8	35.0	35.0	8.32	5.7	0.54	0.53	0.003	0.014	0.124	0.045
01-20-84	1005	0.43	7	28.8	29.7	35.0	35.0	8.32	6.0	0.48	0.48	0.001	0.016	0.147	0.047
04-03-84	1205	0.55	16	28.9	29.0	35.5	35.5	8.25	6.0	0.07	0.07	0.001	0.012	0.009	0.004
04-04-84	1005	0.68	21	28.8	28.9	35.0	35.0	8.25	6.2	0.13	0.13	0.001	0.014	0.008	0.004
04-06-84	0956	0.75	7	28.4	28.4	35.5	35.5	8.22	5.4	0.01	0.01	0.003	0.010	0.010	0.006
07-12-84	1505	0.68	21	28.8	28.8	35.0	35.0	8.15	5.1	0.09	0.09	0.002	0.025	0.011	0.005
07-16-84	0910	0.85	36	28.8	28.8	35.5	35.5	8.28	4.8	0.08	0.08	0.002	0.020	0.10	0.005
07-17-84	0800	0.72	10	28.8	28.8	35.5	35.5	8.20	6.8	0.13	0.13	0.004	0.019	0.009	0.005

Table 46. continued.

Station	Parameter	N	Mean	Root MSE*	F-Value	Significance
4	Turbidity	34	1.1	0.3	7.84	.001
	TNFR	34	33	31	0.77	NS
	Sur. Temp	34	29.0	0.4	8.23	.001
	-1m Temp	34	29.0	0.5	5.67	.001
	Sur. Salinity	34	34.1	1.2	3.12	.011
	-1m Salinity	34	34.3	0.7	5.20	.001
	pH	34	8.14	0.87	2.24	NS
	Dis. Oxygen	27	5.2	0.4	2.42	NS
	Total Nitrogen	29	0.386	0.253	5.04	.001
	TKN	29	0.367	0.249	5.35	.001
	Nitrate	29	0.012	0.009	1.41	NS
	Ammonia	29	0.032	0.017	5.54	.001
	Ortho Phos	29	0.033	0.057	2.41	NS
	Total Phos	29	0.071	0.097	5.15	.001
5	Turbidity	35	1.1	0.5	5.12	.001
	TNFR	35	29	18	0.85	NS
	Sur. Temp	35	29.0	0.4	8.60	.001
	-1m Temp	35	29.0	0.4	7.22	.001
	Sur. Salinity	35	34.0	1.0	4.79	.001
	-1m Salinity	35	34.5	0.6	4.18	.002
	pH	35	8.15	0.10	1.31	NS
	Dis. Oxygen	28	5.6	0.5	0.55	NS
	Total Nitrogen	30	0.298	0.150	7.19	.001
	TKN	30	0.289	0.150	7.26	.001
	Nitrate	30	0.007	0.003	5.43	.001
	Ammonia	30	0.029	0.015	2.19	NS
	Ortho Phos	30	0.033	0.053	2.56	.038
	Total Phos	30	0.086	0.066	20.40	.001
6	Turbidity	35	0.54	0.12	7.22	.001
	TNFR	35	20	15	1.33	NS
	Sur. Temp	35	29.0	0.3	17.74	.001
	-1m Temp	35	29.1	0.3	19.96	.001
	Sur. Salinity	35	34.9	0.5	4.05	.002
	-1m Salinity	35	35.0	0.04	3.19	.009
	pH	35	8.21	0.08	2.25	NS
	Dis. Oxygen	28	5.7	0.5	0.37	NS
	Total Nitrogen	30	0.281	0.143	4.89	.001
	TKN	30	0.277	0.144	4.82	.002
	Nitrate	30	0.003	0.003	0.95	NS
	Ammonia	30	0.025	0.012	5.60	.001
	Ortho Phos	30	0.023	0.034	2.91	.022
	Total Phos	30	0.104	0.029	206.60	.001

* Root MSE - Root Mean Square Error.
** NS - Not significant at $P \geq 0.05$.

Table 9. Water quality at station 9 in Okat harbor. A period represents a "no sample taken" for sample period.

Date	Time	Turb	TNFR	Surface Temp	-1m Temp.	Surface Salinity	-1m Salinity	pH	DO	TN	TKN	NO	NH	TP	OP
05-19-82	1025	0.55	37	30.0	30.0	34.4	35.0	8.15	.	.	.	.	.	.	.
05-19-82	1040	0.78	27	30.0	30.0	34.4	34.4	8.13	.	.	.	.	.	.	.
05-20-82	1040	1.2	153	29.0	29.0	34.4	34.4	7.98	.	.	.	.	.	.	.
05-20-82	1050	0.65	106	29.0	29.0	35.5	36.1	8.05	.	.	.	.	.	.	.
08-07-82	0830	2.4	.	28.5	28.0	28.9	32.2	8.08	.	.	.	.	.	.	.
08-08-82	0900	7.4	.	29.5	29.0	32.2	33.3	7.80	.	0.25	0.25	0.004	0.040	.	.
11-11-82	1145	1.7	.	28.2	28.5	33.3	33.3	8.27	.	.	.	0.013	0.023	0.012	0.005
11-11-82	1150	1.0	.	28.3	28.5	33.3	33.3	8.25	.	.	.	0.018	0.020	0.008	0.005
11-12-82	1130	1.5	.	28.4	28.9	33.9	33.3	7.70	.	.	.	0.021	0.020	0.015	0.012
01-12-83	1000	2.8	.	27.5	27.8	35.0	35.5	8.05	.	.	.	0.004	0.077	0.005	0.003
01-13-83	0940	2.2	.	27.9	28.2	35.0	35.0	8.00	5.8	0.35	0.34	0.006	0.008	0.005	0.001
01-14-83	0925	2.1	.	27.8	27.9	35.0	35.0	8.05	5.4	.	.	0.007	0.110	0.007	0.001
04-07-83	0945	1.3	12	28.5	28.2	35.5	35.5	8.18	5.8	0.16	0.15	0.011	0.027	0.014	0.006
04-08-83	1005	1.5	97	28.6	29.1	35.5	35.5	8.40	5.8	.	.	0.005	0.034	0.008	0.005
04-11-83	1020	0.21	49	28.8	28.7	35.5	35.5	8.10	5.5	.	.	0.019	0.022	0.013	0.006
07-07-83	1215	2.7	39	29.5	29.3	33.9	33.3	8.00	5.1	.	.	0.003	0.063	0.603	0.259
07-08-83	1020	3.8	48	28.8	29.2	32.2	33.9	8.10	4.8	.	.	0.004	0.092	0.873	0.338
07-11-83	0955	3.8	65	28.8	28.8	31.1	31.1	8.10	4.8	.	.	0.007	0.070	1.179	0.451
10-07-83	1040	3.4	28	29.4	29.6	31.1	32.2	8.10	4.9	1.44	1.41	0.018	0.027	0.013	0.005
10-11-83	1005	3.7	27	28.9	29.6	17.8	34.4	8.08	5.1	0.56	0.55	0.018	0.008	0.012	0.005
10-10-83	1005	3.3	40	28.9	29.4	26.6	33.3	8.08	4.3	0.69	0.67	0.015	0.018	0.012	0.005
01-18-84	1110	1.4	19	29.6	29.7	30.0	33.3	8.08	6.0	0.23	0.22	0.006	0.022	0.151	0.069
01-09-84	1050	2.8	15	29.3	29.3	34.4	34.4	8.00	6.0	0.22	0.21	0.008	0.024	0.125	0.068
01-20-84	1025	1.8	36	29.4	29.7	33.9	33.9	8.12	6.1	0.26	0.25	0.006	0.023	0.192	0.008
04-03-84	1225	3.6	31	28.8	28.7	34.4	34.4	8.05	6.8	0.07	0.06	0.005	0.008	0.012	0.008
04-04-84	1024	2.2	25	28.7	28.8	34.4	34.4	8.15	5.6	0.06	0.06	0.004	0.007	0.011	0.006
04-06-84	1014	1.5	14	28.1	28.1	34.4	35.0	8.05	6.0	0.02	0.01	0.006	0.001	0.015	0.007
07-12-84	1523	3.0	34	28.8	28.8	35.5	34.4	8.12	5.4	0.05	0.04	0.013	0.022	0.011	0.005
07-16-84	0930	2.5	158	29.2	29.2	35.5	35.5	8.25	5.0	0.28	0.27	0.005	0.059	0.013	0.007
07-17-84	0840	3.1	50	28.8	29.0	35.5	35.5	8.22	6.4	0.08	0.07	0.007	0.024	0.014	0.007

Table 44. Concentration of heavy metals in marine waters at Okat Harbor, July 1984. See Table 42 for TTPI marine water supply quality standards for heavy metals.

Water Quality Stations	Heavy Metal (µg/ℓ) As	Cd	Cr	Cu	Hg	Ni	Pb	Zn
1	1.2	0.2	1.8	1.5	1.9*	< 1.0	< 1.0	1.6
2	2.3	0.2	1.7	2.1	0.8*	< 1.0	< 1.0	2.1
3	1.9	0.4	1.5	0.6	1.5*	< 1.0	< 1.0	1.1
4	2.1	0.2	1.3	2.4	0.9*	1.0	12*	5.3
5	1.0	0.6	1.7	3.1	0.9*	3.5*	< 1.0	0.8
6	1.9	0.3	1.4	0.8	1.4*	4.2*	< 1.0	5.6
7	1.9	0.2	1.7	0.6	2.1*	< 1.0	3.1	6.9
9	2.0	0.4	1.4	1.1	1.4*	< 1.0	2.8	13.0
13	2.2	0.2	1.4	2.0	1.1*	< 1.0	1.3	1.7
14	2.1	0.4	1.5	0.4	0.5*	< 1.0	< 1.0	0.3

* exceeds TTPI standard.

Table 45. Summary of mercury concentrations in near-surface marine water at Okat Harbor water quality monitoring stations. The TTPI marine water quality standard for mercury is 0.10 µg/ℓ. Figure 2 for locations of water quality stations. The August 1979 sampling was done by Chun et al., (1979).

Water Quality Station	Heavy Metal Mercury (µg/ℓ) Aug. 1979	Nov. 1982	July 1983	July 1984
1	< 0.1	6.6	0.4	1.9
2	-	7.1	1.0	0.8
3	< 0.1	4.7	1.0	1.5
4	< 0.1	4.6	2.0	0.9
5	< 0.1	2.3	2.6	0.9
6	-	2.8	2.6	1.4
7	< 0.1	3.0	1.6	2.1
8	-	3.1	0.4	-
9	-	2.6	1.4	1.4
10	< 0.1	2.2	-	-
13	-	-	1.2	1.1
14	-	-	< 0.1	0.5
Mean (µg/ℓ)	< 0.1	3.9	1.3	1.3
± S.D.	-	1.8	0.8	0.5
Number of stations	10	10	11	10

Table 11. Water quality at station 14 in Okat harbor. A period represents a "no sample taken" for sample period.

Date	Time	Turb	TNFR	Surface Temp	-1m Temp.	Surface Salinity	-1m Salinity	pH	DO	TN	TKN	NO	NH	TP	OP
04-07-82	1000	0.56	16	28.5	28.5	35.0	35.5	8.15	.	0.27	0.25	0.015	0.016	0.010	0.006
04-08-82	1020	0.74	80	28.8	29.0	35.0	35.5	8.38	6.6	.	.	0.028	0.025	0.006	0.006
04-11-82	1045	0.78	50	31.5	29.2	35.5	35.0	8.10	6.2	.	.	0.029	0.034	0.173	0.007
07-07-83	1230	1.2	20	30.7	30.5	34.4	33.9	8.08	6.2	.	.	0.003	0.082	0.882	0.202
07-08-83	1035	1.6	22	29.8	29.3	33.9	34.4	8.42	5.5	.	.	0.008	0.082	0.886	0.206
07-11-83	1015	1.8	20	28.7	28.6	34.4	34.4	8.18	5.6	.	.	0.003	0.024	1.064	0.200
10-07-83	1100	1.2	11	29.7	30.2	34.4	34.4	8.20	6.4	0.02	0.01	0.010	0.027	0.010	0.003
10-11-83	1030	1.8	27	29.6	29.8	35.0	33.3	8.10	6.0	0.02	0.01	0.012	0.012	0.013	0.004
10-10-83	1030	2.4	18	29.6	29.8	34.4	33.3	8.20	6.0	0.03	0.10	0.019	0.034	0.012	0.004
01-18-84	1130	0.70	13	29.6	29.8	35.2	34.4	8.22	6.0	0.26	0.25	0.007	0.018	0.124	0.070
01-19-84	1110	0.75	31	29.4	29.1	34.4	34.4	8.25	6.3	0.40	0.39	0.007	0.018	0.153	0.068
01-20-84	1044	0.88	11	29.4	29.7	34.4	34.4	8.32	6.5	0.25	0.24	0.007	0.018	0.129	0.090
04-03-84	1240	0.70	25	30.3	29.5	34.4	34.4	8.25	7.9	0.21	0.20	0.006	0.009	0.009	0.006
04-04-84	1042	1.3	21	28.7	28.9	35.0	35.0	8.18	5.7	0.07	0.06	0.009	0.040	0.013	0.009
04-06-84	1030	.	13	28.7	28.7	35.5	35.5	8.05	6.9	0.08	0.07	0.006	0.008	0.009	0.006
07-12-84	1539	0.92	28	29.2	29.2	35.5	35.5	8.32	6.8	0.07	0.06	0.013	0.023	0.013	0.007
07-16-84	0945	1.4	92	29.3	29.3	35.5	35.5	8.23	4.8	0.14	0.13	0.007	0.024	0.011	0.006
07-17-84	0900	0.85	17	29.4	29.0	36.0	36.0	8.32	8.5	0.10	0.09	0.007	0.028	0.011	0.006

Table 42. Concentration of heavy metals in marine waters at Okat Harbor, November 1982.

Water Quality Stations	Heavy Metal (µg/ℓ) As	Cd	Cr	Cu	Hg	Ni	Pb	Zn
1	1.8	0.9	1.8	3.0	6.6*	8.3*	2.1	12.4
2	1.2	0.1	1.3	0.8	7.1*	1.7	1.9	16.7
3	1.2	0.1	2.4	0.6	4.7*	0.7	1.4	8.2
4	0.9	0.1	2.8	0.6	4.6*	1.3	1.9	5.9
5	1.0	0.2	1.5	0.6	2.3*	1.0	1.5	18.8
6	1.0	0.2	1.1	0.5	2.8*	0.6	1.6	10.0
7	0.9	0.1	6.3	0.5	3.0*	0.8	1.4	7.5
8	0.9	0.1	7.8	0.5	3.1*	0.8	1.0	3.2
9t	0.9	0.1	4.3	0.6	2.6*	0.8	1.5	4.4
10t	0.9	0.7	7.2	0.8	2.2*	0.9	2.1	5.4
TTPI Marine WQ Standards (µg/ℓ)	10.0	5.0	50.0	10.0	0.10	2.0	10.0	20.0

*exceeds TTPI standard

Table 43. Concentration of heavy metals in marine waters at Okat Harbor, July 1983. See Table 42 for TTPI marine water quality standards for heavy metals.

Water Quality Stations	Heavy Metal (µg/ℓ) As	Cd	Cr	Cu	Hg	Ni	Pb	Zn
1	3.1	1.0	0.6	20*	0.4*	26*	2.8	25*
2	0.9	0.8	0.2	0.5	1.0*	0.8	2.3	<1
3	1.4	1.0	0.1	2.3	1.0*	1.6	1.9	2
4	1.2	0.8	<0.1	0.3	2.0*	0.4	1.8	9
5	1.2	0.8	0.2	2.1	2.6*	0.7	2.8	16
6	0.6	1.0	0.2	2.8	2.6*	0.5	2.1	2
7	0.8	0.7	0.2	0.5	1.6*	1.1	6.3	16
8	1.4	0.9	0.2	1.6	0.4*	1.3	1.8	6
9	1.3	0.7	0.2	0.3	1.4*	0.5	2.0	1
13	1.8	0.8	0.2	3.4	1.2*	0.4	1.9	3
14	1.7	0.8	<0.1	0.4	<0.1	0.3	2.8	1

*exceeds TTPI standard

Table 12. Mean water quality at stations for quarterly sampling periods. See Table 1 for definitions of abbreviated water quality parameters.

Station	Quarter	TURB	TNFR	SUR TEMP	-1m TEMP	SUR SAL	-1m SAL	DO	PH	TKN	TN	NO_3	NH_3	OP	TP
1	1	2.7	110	30.5	30.5	19.7	33.7	-	7.83	.167	.175	.009	.056	.020	.029
	2	15.6	270	29.7	29.7	12.0	25.8	4.0	7.76	.	.	.	.	.	.
	3	13.3	459	28.3	28.2	22.8	25.3	3.0	7.30	.250	.260	.007	.039	.029	.134
	4	16.0	536	27.4	28.3	21.1	31.3	4.0	7.53	.747	.807	.048	.026	.047	.068
	5	5.7	78	26.8	27.1	33.7	34.9	4.7	7.77	.207	.217	.010	.014	.050	.057
	6	2.3	54	27.6	27.6	34.6	34.4	3.8	7.71	.110	.173	.062	.019	.018	.020
	7	19.0	433	27.4	28.6	12.9	26.3	3.4	7.74	.330	.407	.019	.050	.323	.872
	8	6.0	81	27.3	28.7	15.7	26.3	3.7	7.78	.683	.720	.037	.021	.003	.036
	9	3.0	52	28.5	29.1	23.9	31.8	4.3	7.98	.353	.363	.010	.026	.157	.266
	10	5.0	75	28.1	28.5	31.1	34.0	3.8	7.83	.050	.057	.006	.020	.017	.027
	11	6.3	81	28.8	29.0	28.1	34.6	5.0	8.03	.097	.113	.031	.076	.018	.049
2	1	0.88	98	29.7	29.7	33.3	34.4	.	8.03	.350	.355	.007	.033	.055	.088
	2	1.9	24	30.2	30.2	34.0	35.2	4.9	8.22	.	.	.	.	.	.
	3	2.8	49	28.5	28.3	30.5	32.4	4.4	7.99	.170	.180	.006	.039	.015	.030
	4	3.3	38	28.3	28.5	32.9	33.1	5.0	7.90	.343	.360	.024	.009	.029	.038
	5	2.5	42	27.6	27.6	35.0	35.3	5.5	8.15	.282	.302	.017	.016	.114	.114
	6	1.7	42	28.2	28.4	35.3	35.2	5.7	8.02	.087	.103	.024	.019	.007	.016
	7	3.5	72	28.9	28.8	32.9	33.1	4.8	8.03	.323	.330	.009	.059	.150	.647
	8	2.4	35	29.2	29.5	28.5	33.7	4.6	8.06	.823	.850	.023	.014	.005	.016
	9	2.2	32	29.2	29.3	33.3	33.5	5.4	8.14	.430	.443	.013	.024	.116	.213
	10	3.3	44	28.5	28.7	34.2	34.4	5.1	8.07	.060	.070	.010	.017	.012	.020
	11	2.5	23	28.8	28.8	35.1	35.5	5.9	8.14	.090	.100	.029	.061	.011	.017
3	1	0.64	37	29.7	29.6	34.1	35.0	.	8.09	.297	.300	.004	.017	.006	.010
	2	1.1	21	30.0	30.0	34.1	34.9	5.2	8.26	.	.	.	.	.	.
	3	1.2	31	28.3	28.2	33.3	33.4	5.0	8.08	.287	.297	.006	.039	.011	.016
	4	1.7	34	28.3	28.5	33.3	33.9	5.0	8.14	.247	.263	.024	.012	.006	.008

Sedimentation experiments were conducted at the bridge site from 11 October 1983 to 19 January 1984 to assess sediment "rain" changes within the channel environment, along the reef-flat plate and within the mangrove fringe. These sedimentation tests were designed to determine both the composition of the suspended load and amount of resuspension of lime-mud occurring within the area. There was a substantial increase in sediment "rain" occurring in the channel environment and extending in the mangrove fringe. The suspended load was composed of white clay/silt sized particles (lime-mud) in the channel and reef-flat environments with 20 to 30% fine sand. The results of this study are as follows:

SITE	SEDIMENT "RAIN"	
	$ml/m^2/day$	$g/day/m^2$
BRIDGE CHANNEL, 3m Depth	1750	586
	1935	611
	2120	739
	2025	695
	mean=1957	mean=658
EDGE REEF FLAT, Channelcut	1250	304
REEFFLAT, Edge Mangroves	1160	480
MANGROVE FRINGE	3230	315

These high sediment "rain" rates indicate that the channel environment was not becoming stabilized in relation to sediment deposits. These fine textured (clay/silt) sediments in the channel floor were subject to easy resuspension by water currents. These sediments pose a potential long-term WQ problem.

A large quantity of silty-ooze was deposited along the runway and adjacent to the docking area. The Hawaii Corp of Engineers recommended in the summer of 1984 that the silty mud and rubble accumulated along the runway and dock area be piled along the edge of the reef plate and dumped (by both suction dredge and bulldozer) into deeper harbor waters. Sediments along the dredge channel were scraped into the channel at low tides. Both of these clean-up operations caused extensive degradation of the marine water quality. A highly turbid plume was produced by the suction dredge operation in the harbor. This plume was observed to extend into the mangrove area south of the harbor, onto the western fringing reef and extended out the harbor toward Walung (Appendix A, Figure 9). The channel floor already had a silt load that was not being removed by currents. The additional material introduced into the channel and onto the upper slopes of the harbor reef complex became a potentially long-term source of fine material. These sediments could be periodically resuspended into the harbor water mass. Since the dredge channel was not opened at the seaward end, the silt load in the channel environment will remain for a long time period with only minor stabilization. Sedimentation studies made in the channel near the bridge showed silty-sand "rain" (resuspended outfall) at a rate of 1 cm/square meter/day. This rate will greatly reduce reestablishment of marine biota.

Table 12. continued.

Station	Quarter	TURB	TNFR	SUR TEMP	-1m TEMP	SUR SAL	-1m SAL	DO	PH	TKN	TN	NO_3	NH_3	OP	TP
6	1	0.30	21	29.6	29.6	35.2	35.2	.	8.18	.087	.087	.001	.056	.004	.009
	2	0.36	11	30.0	30.0	34.9	35.2	6.0	8.22	.	.	.	.	.	.
	3	0.36	27	28.2	28.2	34.4	34.8	5.8	8.10	.180	.193	.002	.043	.004	.012
	4	0.58	14	28.8	28.9	34.4	34.4	5.3	8.33	.337	.347	.007	.035	.	.006
	5	0.53	20	28.2	28.2	35.3	35.3	5.7	8.12	.450	.453	.004	.011	.058	.058
	6	0.50	46	28.5	28.6	35.5	35.3	5.9	8.15	.117	.123	.006	.017	.006	.009
	7	0.84	17	29.0	29.0	34.1	34.8	5.8	8.13	.447	.447	.002	.031	.099	.783
	8	0.69	19	29.6	29.8	34.2	34.4	5.6	8.20	.483	.483	.001	.007	.002	.009
	9	0.58	11	29.2	29.7	35.2	35.2	5.9	8.31	.500	.503	.003	.015	.042	.141
	10	0.66	15	28.7	28.8	35.3	35.3	5.9	8.24	.070	.070	.002	.012	.005	.009
	11	0.75	22	28.8	28.8	35.3	35.2	5.6	8.21	.100	.100	.003	.021	.005	.010
7	1	0.65	134	30.0	39.9	33.4	34.2	.	8.03	.	.	.	.	.	.
	3	2.1	.	28.2	28.0	31.1	32.7	.	7.91	.010	.020	.006	.040	.	.
	4	1.5	.	28.5	28.7	33.3	33.6	5.8	8.31	.	.	.018	.037	.006	.010
	5	2.4	.	28.1	28.2	35.2	35.5	5.5	8.08	.420	.420	.005	.004	.102	.102
	6	0.88	45	28.6	28.8	35.3	35.1	5.3	8.11	.180	.200	.009	.019	.005	.014
	7	1.8	27	28.9	28.8	33.3	32.9	5.6	8.09	.	.	.011	.063	.311	.705
	8	1.8	28	29.1	29.6	31.6	32.2	4.9	8.12	.953	.970	.020	.025	.006	.014
	9	1.8	.	28.9	29.2	30.0	32.9	5.2	8.21	.660	.673	.014	.023	.071	.160
	10	2.3	33	28.6	28.7	34.8	34.6	5.4	8.09	.060	.070	.005	.014	.010	.014
	11	1.8	108	29.1	29.0	35.5	34.8	5.8	8.20	.073	.087	.011	.082	.006	.011
9	1	0.80	81	29.5	29.5	34.7	35.0	.	8.08	.	.	.	.	.	.
	3	4.9	.	29.0	28.5	30.5	32.7	.	7.94	.250	.250	.004	.040	.	.
	4	1.4	.	28.3	28.6	33.5	33.3	.	8.07	.	.	.017	.021	.007	.012
	5	2.4	.	27.7	28.0	35.0	35.2	5.6	8.03	.340	.350	.006	.065	.002	.006
	6	1.0	53	28.6	28.7	35.5	35.3	5.7	8.23	.150	.160	.012	.028	.006	.012
	7	3.4	51	29.0	29.1	32.4	32.8	4.9	8.07	.	.	.005	.075	.349	.855
	8	3.5	32	29.1	29.5	25.2	33.3	4.8	8.09	.877	.897	.017	.018	.005	.013
	9	2.0	23	29.4	29.6	32.8	33.9	6.0	8.07	.227	.237	.007	.023	.077	.156
	10	2.4	23	28.5	28.5	34.4	34.6	6.1	8.08	.043	.050	.005	.005	.007	.013
	11	2.9	81	29.0	29.0	35.5	35.1	5.6	8.20	.127	.137	.008	.035	.006	.013

Table 41. Volatile non-filtrable residue (VNFR) and percent organic matter in total residue (TNFR) at water quality stations. The units for VNFR are mg/ℓ.

Water Quality Station	7 July 83		8 July 83		11 July 83	
	VNFR	% Organic	VNFR	% Organic	VNFR	% Organic
1	130	50	272	29	40	47
2	19	70	32	45	103	13
3	10	50	26	52	20	50
4	18	90	11	85	20	46
5	13	93	20	69	18	40
6	8	73	4	15	4	69
7	8	76	4	11	2	91
9	17	40	7	18	28	57
13	24	55	23	59	31	38
14	14	64	6	30	5	75

Water Quality Station	7 October 83		10 October 83		11 October 83	
	VNFR	% Organic	VNFR	% Organic	VNFR	% Organic
1	57	43	30	53	14	26
2	17	30	21	84	0	0
3	11	24	4	29	22	73
4	2	7	0	0	16	80
5	15	39	13	48	18	95
6	12	52	9	43	13	100
7	7	25	13	41	19	76
9	24	86	11	28	21	78
14	11	0	0	0	17	63

any turbidity plumes coming from the Okat area. The station was used to sample the marine water which was not influenced by construction activities. WQ data from this station provided a background marine WQ which could be used to evaluate changes in WQ within the Okat harbor marine system. Turbidities were generally very low with a range of 0.14 to 0.92 NTU and a mean of 0.54 NTU. The higher turbidities were associated with higher surf periods and heavy rainfalls.

Tidal changes can affect monitoring station turbidities and other WQ parameters. In falling tide periods, surface water flow (to -1m) from the river influences stations 1 to 4, while station 5 receives mixed waters from the dredges channel, adjacent reef-flats and river. In periods of rising and neap tides, turbidity plumes originating from the dredge channel moved southwest across Okat harbor toward the adjoining reef-flat. The primary surface flows were observed to move between stations 2 and 4. General water flow patterns during sampling periods are shown in Appendix A, Figures 1 to 10.

Parameter Water Quality

WQ data was analyzed by station and sampling quarter using a univariate statistics program. Univariate statistics characterize the WQ data for basic statistical trends. Tables 13 to 26 present the univariate statistics by station and sampling quarter for the WQ parameters: turbidity, TNFR, surface temperature, sub-surface (-1m) temperature, surface salinity, sub-surface (-1m) salinity, pH, dissolved oxygen, total nitrogen, TKN, nitrate plus nitrite-nitrogen, ammonia-nitrogen, total phosphorus, and ortho-phosphate.

In order to use tables 13 to 26, it is necessary to understand the output results of various test types. The number of samples is the total data set taken for each parameter by either WQ station or sampling quarter. The mean or arithmetic mean, commonly called the average, is calculated by summing all observations and dividing this sum by the total number of observations. The mean is a statistic of location measurement and describes and central tendency of data. However, it does not describe the shape of data or frequency distribution. The mode refers to the most frequently encountered set of data values. It is a measure of where the frequency distribution data curve peaks. Statistics of dispersion are a measure of data scatter in a frequency distribution from a set of data. These dispersion statistics include range and standard deviation. The range is the total spread of data points from a minimum to a maximum value and is a measure of the total variation in a data set. The standard deviation is an arithmetic measure of data variance from a mean value.

The normal distribution in statistics can be defined in terms of moments. These moments are computed by a frequency function and determine distance away from an arbitrary point, usually the mean, in the normal

Table 40. Univariate statistics of ortho-phosphorus analyzed by wind direction and speed, tidal cycle and rainfall occurrence.

Parameter: Ortho-phosphorus (mg/ℓ)

Wind Direction	Number Samples	Mean	Standard Deviation	Mode	Minimum	Range Median	Maximum	Skewness	Kurtosis
NE to SE	121	0.045	0.072	0.006	0.001	0.009	0.451	2.9	11.1
SE to SW	29	0.006	0.006	0.005	0.000	0.005	0.033	2.9	9.9
SW to NW	44	0.010	0.012	0.005	0.000	0.005	0.071	3.3	13.4
NW to NE	69	0.085	0.116	0.006	0.004	0.009	0.472	1.4	1.1
None	8	0.035	0.034	0.005	0.005	0.022	0.100	1.4	0.9
WIND SPEED									
0-5 kts	182	0.044	0.081	0.005	0.000	0.007	.472	3.0	10.0
5-10 kts	80	0.045	0.082	0.006	0.000	0.008	.351	2.3	4.7
> 10 kts	9	0.065	0.069	0.001	0.001	0.07	.199	.8	.1
TIDE									
Rising	127	0.054	0.093	0.006	0.000	0.007	.472	2.3	4.7
Falling	82	0.029	0.075	0.006	0.001	0.007	.451	4.1	17.6
Neap	62	0.047	0.051	0.005	0.000	0.019	.199	.9	0.0
RAINFALL									
At Okat	132	0.073	0.104	0.005	0.000	0.016	.472	1.8	2.9
Runoff	111	0.019	0.034	0.006	0.001	0.007	.199	3.1	9.9
None	28	0.013	0.018	0.005	0.003	0.007	.100	4.2	19.4

Table 14. Univariate statistics for TNFR by station and sampling quarter,

Parameter: Total non-filtrable residue (mg/ℓ)

WQ Station	Number Samples	Mean	Standard Deviation	Mode	Minimum	Range Median	Maximum	Skewness	Kurtosis
1	37	179	251	42	12	79	988	2.4	5.2
2	35	45	38	18	11	36	227	3.5	15.6
3	35	32	14	30	13	30	72	0.9	0.8
4	35	33	30	18	6	24	126	2.2	4.0
5	35	29	18	13	6	26	94	1.7	4.4
6	35	20	15	13	3	16	79	2.1	5.8
7	20	70	106	22	18	33	485	3.5	13.3
9	22	50	41	27	12	36	158	1.7	2.2
13	18	68	51	8	8	52	183	0.9	-0.1
14	18	29	23	11	11	20	92	2.1	3.6
Quarter									
1	38	80	102	18	3	39	485	2.6	7.8
2	24	65	147	18	4	22	730	4.3	20.0
3	18	105	227	30	13	35	988	3.9	15.7
4	18	113	221	36	6	35	844	2.8	7.4
5	21	34	26	17	6	34	90	0.8	-0.4
6	30	46	29	80	8	37	126	0.8	0.2
7	30	75	174	20	11	33	964	4.9	25.4
8	27	32	24	27	10	27	132	3.0	11.9
9	24	25	14	13	6	21	58	0.8	-0.1
10	30	37	25	21	7	30	117	1.7	3.5
11	30	52	52	17	10	32	206	1.9	2.9

Table 38. Univariate statistics of Amonia-Nitrogen analyzed by wind direction and speed, tidal cycle and rainfall occurrence.

Parameter: Ammonia-Nitrogen (mg/ℓ)

Wind Direction	Number Samples	Mean	Standard Deviation	Mode	Minimum	Range Median	Maximum	Skewness	Kurtosis
NE to SE	120	0.026	0.026	0.016	0.001	0.018	0.16	2.6	7.9
SE to SW	32	0.039	0.067	0.040	0.005	0.029	0.40	5.3	29.0
SW to NW	44	0.032	0.047	0.024	0.003	0.024	0.32	5.4	33.1
NW to NE	69	0.043	0.027	0.018	0.011	0.034	0.117	0.9	-0.3
None	8	0.045	0.025	0.017	0.017	0.041	0.10	1.7	4.0
WIND SPEED									
0-5 kts	185	0.034	0.024	0.018	0.003	0.026	0.117	1.5	1.7
5-10 kts	79	0.026	0.027	0.012	0.001	0.016	0.160	2.6	8.5
J 10 kts	9	0.012	0.005	0.011	0.005	0.011	0.022	.6	0.0
TIDE									
Rising	126	0.035	0.028	0.025	0.002	0.025	0.16	1.7	3.1
Falling	85	0.037	0.047	0.040	0.001	0.024	0.40	5.8	43.8
Neap	62	0.026	0.041	0.022	0.003	0.019	0.32	6.4	45.5
RAINFALL									
At Okat	132	0.032	0.024	0.022	0.003	0.024	0.107	1.5	1.3
Runoff	113	0.028	0.036	0.012	0.001	0.018	0.32	5.4	38.0
None	28	0.061	0.071	0.048	0.007	0.046	0.40	4.2	20.2

Table 16. Univariate statistics for -1m temperature by station and sampling quarter.

Parameter: Temperature, -1m (°C)

WQ Station	Number Samples	Mean	Standard Deviation	Mode	Minimum	Range Median	Maximum	Skewness	Kurtosis
1	37	28.8	1.2	28.5	26.3	28.6	31.0	0.1	-0.5
2	35	28.9	0.8	30.0	27.3	28.9	31.0	0.3	-0.1
3	35	28.9	0.7	30.0	27.8	28.8	30.1	0.3	-1.1
4	35	29.0	0.8	28.8	28.0	28.9	31.0	0.8	0.4
5	35	29.0	0.7	30.0	28.0	29.0	31.0	0.6	0.002
6	35	29.1	0.6	30.0	28.0	29.0	30.1	0.1	-1.2
7	32	29.0	0.7	29.1	28.0	29.0	31.0	0.7	0.9
9	30	28.9	0.6	29.0	27.8	29.0	30.0	-0.1	-0.6
13	30	29.0	1.0	29.0	27.2	29.0	31.8	0.5	1.4
14	18	29.3	0.5	29.8	28.5	29.3	30.5	0.4	-0.2
Quarter									
1	38	29.8	0.6	30.0	29.0	30.0	31.0	0.4	-0.6
2	24	30.1	0.6	30.0	28.0	30.0	31.0	-1.4	7.1
3	24	28.3	0.6	28.0	27.0	28.0	30.0	0.9	1.5
4	26	28.6	0.5	28.7	27.3	28.7	29.6	-0.5	1.4
5	30	27.8	0.5	27.8	26.3	28.0	28.3	-1.7	3.0
6	30	28.5	0.5	28.6	27.3	28.6	29.3	-0.8	1.3
7	30	28.9	0.4	28.8	28.0	28.8	30.5	1.3	4.9
8	30	29.5	0.5	30.1	28.5	29.6	30.2	-0.6	-0.5
9	30	29.3	0.4	29.5	28.6	29.4	30.1	-0.2	-0.6
10	30	26.7	0.3	28.9	28.1	28.8	29.5	0.1	-0.6
11	30	29.0	0.6	28.8	28.5	29.0	31.8	3.9	18.5

Table 36. Univariate statistics of TKN analyzed by wind direction and speed, tidal cycle and rainfall occurrence.

Parameter: Total Kjeldhal Nitrogen (mg/ℓ)

Wind Direction	Number Samples	Mean	Standard Deviation	Mode	Minimum	Range Median	Maximum	Skewness	Kurtosis
NE to SE	103	0.267	0.256	0.06	0.01	0.21	1.44	1.7	3.9
SE to SW	32	0.383	0.309	0.01	0.01	0.25	1.01	0.5	-1.1
SW to NW	36	0.449	0.389	0.15	0.01	0.28	1.48	1.2	0.7
NW to NE	55	0.230	0.198	0.09	0.01	0.15	0.87	1.4	1.4
None	8	0.245	0.119	0.23	0.12	0.23	0.5	1.5	2.9
WIND SPEED									
0-5 kts	165	0.322	0.285	0.15	0.01	0.23	1.48	1.5	2.3
5-10 kts	61	0.223	0.268	0.06	0.01	0.13	1.44	2.4	7.1
> 10 kts	8	0.464	0.217	0.13	0.13	0.44	0.84	0.3	0.4
TIDE									
Rising	98	0.241	0.194	0.06	0.01	0.20	0.95	1.3	1.8
Falling	77	0.252	0.271	0.01	0.01	0.13	1.01	1.3	0.5
Neap	59	0.464	0.354	0.15	0.01	0.35	1.48	1.2	1.1
RAINFALL									
At Okat	111	0.420	0.303	0.35	0.01	0.35	1.48	1.0	1.1
Runoff	96	0.196	0.233	0.06	0.01	0.13	1.44	2.8	9.6
None	27	0.188	0.120	0.13	0.01	0.17	0.56	1.3	2.5

Table 18. Univariate statistics for -1m salinity by station and sampling quarter.

Parameter; Salinity, -1m (ppt)

WQ Station	Number Samples	Mean	Standard Deviation	Mode	Minimum	Range Median	Maximum	Skewness	Kurtosis
1	37	30.9	6.2	34.4	2.2	33.3	36.6	-3.0	12.3
2	35	34.2	1.2	35.5	31.1	34.4	36.6	-0.5	-0.1
3	35	34.4	1.0	35.5	32.2	34.4	35.5	-0.2	-1.2
4	35	34.3	1.0	34.4	32.2	34.4	35.5	-0.5	-0.6
5	35	34.5	0.8	34.4	33.3	34.4	36.1	0.04	-0.9
6	35	35.0	0.5	35.5	34.4	35.0	35.5	-0.4	-1.5
7	32	33.9	1.3	34.4	30.0	34.4	36.6	-0.8	1.2
9	30	34.2	1.1	33.3	31.1	34.4	36.1	-0.7	0.3
13	30	34.5	1.0	34.4	32.2	34.4	36.6	-0.7	0.9
14	18	34.7	0.8	34.4	33.3	34.4	36.0	-0.2	-0.6
Quarter									
1	38	34.6	0.9	34.4	32.2	34.4	36.6	-0.7	1.1
2	24	33.4	6.7	35.5	2.2	34.4	36.6	-4.7	22.8
3	24	32.4	2.9	33.4	24.4	33.3	35.0	-1.9	3.0
4	26	33.4	1.0	33.	30.5	33.3	34.4	-1.2	1.4
5	30	35.1	0.5	35.5	34.4	35.0	36.5	0.4	1.2
6	30	35.2	0.4	35.5	34.4	35.5	35.5	-1.2	0.3
7	30	32.8	2.7	34.4	21.1	33.35	35.0	-3.2	12.1
8	30	32.8	2.6	32.3	22.2	33.3	34.4	-2.9	9.8
9	30	33.5	1.1	33.3	30.0	33.6	35.5	-1.1	2.7
10	30	34.6	0.5	34.4	33.3	34.4	35.5	-0.5	1.3
11	30	35.3	0.5	35.5	33.9	35.5.	36.6	-0.7	1.8

Table 34. Univariate statistics of dissolved oxygen analyzed by wind direction and speed, tidal cycle and rainfall occurrence.

Parameter: Dissolved Oxygen (mg/ℓ)

Wind Direction	Number Samples	Mean	Standard Deviation	Mode	Minimum	Range	Maximum	Skewness	Kurtosis
						Median			
NE to SE	113	5.5	0.7	5.6	3.1	5.6	7.9	-0.8	3.4
SE to SW	29	5.1	0.7	4.9	2.8	5.1	6.0	-1.3	2.8
SW to NW	37	4.8	0.7	4.6	3.4	4.8	6.5	0.2	-0.3
NW to NE	69	5.4	0.8	4.8	3.1	5.4	8.5	0.1	2.8
None	2	3.1	1.0	2.4	2.4	3.1	3.8		
WIND SPEED									
0-5 kts	163	5.1	.8	5.1	2.4	5.2	8.5	-0.3	1.6
5-10 kts	77	5.6	.6	5.6	3.2	5.6	7.6	-0.3	4.0
> 10 kts	10	5.7	.2	5.6	5.5	5.6	6.0	0.7	-0.9
TIDE									
Rising	103	5.4	.7	5.8	3.1	5.5	7.9	-0.4	2.3
Falling	88	5.2	.9	5.1	2.4	5.2	8.5	-0.2	2.3
Neap	59	5.3	.8	5.6	3.7	5.5	6.5	-0.7	-0.5
RAINFALL									
At Okat	119	5.2	.7	5.1	3.1	5.2	6.8	-0.6	0.1
Runoff	109	5.5	.9	5.6	2.4	5.6	8.5	-0.5	3.2
None	22	4.8	.7	4.8	2.8	4.9	6.0	-1.4	3.1

Table 20. Univariate statistics for dissolved oxygen by station and sampling quarter.

Parameter: Dissolved oxygen (mg/ℓ)

WQ Station	Number Samples	Mean	Standard Deviation	Mode	Minimum	Range Median	Maximum	Skewness	Kurtosis
1	29	4.0	0.9	2.8	2.4	3.8	6.2	0.7	0.3
2	29	5.1	0.6	5.1	3.9	5.1	6.6	0.1	0.5
3	28	5.3	0.4	5.2	4.6	5.2	6.4	0.3	-0.1
4	28	5.2	0.5	5.6	4	5.2	6.0	-0.6	0.1
5	28	5.6	0.5	5.7	4.8	5.6	6.5	0.1	-0.6
6	28	5.7	0.5	5.8	4.6	5.8	6.8	-0.1	1.1
7	22	5.4	0.5	5.5	4.3	5.5	6.6	-0.01	0.7
9	20	5.5	0.6	5.8	4.3	5.5	6.8	0.01	-0.2
13	21	5.5	0.5	4.8	4.8	5.5	6.3	-0.1	0.0
14	17	5.3	0.9	6	4.8	6.2	8.5	0.9	1.7
Quarter									
1	0								
2	6	5.1	0.7	4.0	4.0	5.2	6.0	-0.7	1.4
3	18	4.8	1.0	4.6	2.4	5.0	6.1	-1.0	0.5
4	19	4.9	0.7	4	3.8	4.9	6.5	0.3	0.1
5	28	5.5	0.5	5.6	3.8	5.6	6.0	-2.5	7.1
6	29	5.4	0.7	5.8	3.1	5.6	6.7	-1.4	3.2
7	30	5.1	0.7	5.1	3.1	5.2	6.2	-1.1	1.4
8	30	5.0	0.7	4.9	3.4	4.9	6.4	-0.2	-0.0
9	30	5.6	0.6	6.0	3.9	5.7	6.5	-1.2	1.6
10	30	5.5	0.9	5.3	3.1	5.5	7.9	-0.4	2.3
11	30	5.6	0.9	5.4	3.5	5.4	8.5	0.7	2.4

Table 32. Univariate statistics of -1m salinity analyzed by wind direction and speed, tidal cycle and rainfall occurrence.

Parameter: Salinity, -1m (ppt)

Wind Direction	Number Samples	Mean	Standard Deviation	Mode	Minimum	Range Median	Maximum	Skewness	Kurtosis
NE to SE	151	34.6	1.4	34.4	21.1	34.4	36.6	-5.7	49.4
SE to SW	40	33.3	1.9	34.4	24.4	33.3	35.5	-3.0	11.9
SW to NW	46	33.0	2.4	33.3	22.2	33.3	35	-3.1	11.1
NW to NE	75	34.4	1.4	35.5	26.6	35.0	36.6	-2.5	10.5
None	10	30.0	10.2	32.2	2.2	33.3	36.6	-2.7	7.8
WIND SPEED									
0-5 kts	232	33.7	2.9	34.4	2.2	34.4	36.6	-6.5	60.6
5-10 kts	80	34.8	.7	34.4	32.2	35.0	35.5	-1.2	2.4
> 10 kts	10	35.1	.6	35	34.4	35.0	36.6	1.3	2.8
TIDE									
Rising	157	34.2	2.8	34.4	2.2	34.4	36.6	-9.4	104.4
Falling	103	34.0	2.2	34.4	21.1	34.4	36.6	-3.2	13.5
Neap	62	33.6	2.2	35	22.2	34.4	35.5	-3.3	13.6
RAINFALL									
At Okat	143	33.2	1.7	34.4	2.2	33.9	36.1	-6.8	59.2
Runoff	115	34.7	1.4	35.5	25.0	35.0	36.6	-4.6	27.1
None	64	34.6	1.7	35.5	24.4	35.45	36.6	-3.8	21.2

Table 22. Univariate statistics for TKN by station and sampling quarter.

Parameter: Total Kjeldhal Nitrogen (mg/ℓ)

WQ Station	Number Samples	Mean	Standard Deviation	Mode	Minimum	Range Median	Maximum	Skewness	Kurtosis
1	32	0.292	0.272	0.15	0.01	0.20	1.13	1.5	2.0
2	30	0.293	0.246	0.03	0.03	0.205	0.85	1.0	0.1
3	30	0.304	0.233	0.30	0.03	0.255	0.95	1.3	1.4
4	30	0.362	0.379	0.23	0.02	0.24	1.48	1.8	3.2
5	30	0.289	0.256	0.06	0.01	0.24	1.01	1.2	1.2
6	30	0.277	0.213	0.48	0.01	0.245	0.85	0.9	0.3
7	15	0.390	0.393	0.06	0.01	0.18	1.01	0.6	-1.5
9	15	0.304	0.358	0.06	0.01	0.22	1.41	2.4	6.5
13	9	0.339	0.332	0.01	0.01	0.18	0.82	0.4	-1.9
14	13	0.143	0.114	0.01	0.01	0.1	0.39	0.8	0.02
Quarter									
1	18	0.228	0.117	0.23	0.01	0.23	0.44	0.3	-0.2
2	0	0							
3	21	0.188	0.110	0.23	0.01	0.16	0.56	1.8	5.9
4	18	0.350	0.235	0.25	0.06	0.285	1.13	2.3	6.9
5	23	0.469	0.339	0.32	0.04	0.42	1.44	1.1	1.6
6	22	0.117	0.071	0.05	0.03	0.11	0.25	0.4	-1.0
7	18	0.345	0.173	0.29	0.01	0.32	0.85	1.4	4.3
8	30	0.624	0.401	0.01	0.01	0.65	1.48	-.0	-0.3
9	30	0.434	0.208	0.35	0.14	0.41	0.87	0.4	-0.7
10	27	0.076	0.073	0.06	0.01	0.06	0.32	2.0	4.3
11	27	0.100	0.047	0.09	0.04	0.09	0.27	1.8	5.3

Table 30. Univariate statistics of -1m temperature analyzed by wind direction and speed, tidal cycle and rainfall occurrence.

Parameter: Temperature, -1m (°C)

Wind Direction	Number Samples	Mean	Standard Deviation	Mode	Minimum	Range Median	Maximum	Skewness	Kurtosis
NE to SE	151	28.9	0.9	30.0	26.3	28.9	31.0	-0.0	0.3
SE to SW	40	29.2	0.8	28.0	27.0	29.5	30.1	-0.6	-0.6
SW to NW	46	28.8	0.7	28.0	27.3	28.7	30.2	0.4	-0.3
NW to NE	75	29.0	0.6	28.8	27.3	28.9	31.8	1.5	4.7
None	10	29.3	1.3	30.0	27.3	29.75	31.0	-0.4	-1.2
WIND SPEED									
0-5 kts	232	29.2	0.8	30.0	27.0	29.0	31.8	0.2	0.3
5-10 kts	80	28.6	0.7	29.1	26.3	28.6	30.5	-0.4	1.3
> 10 kts	10	28.0	0.3	28.2	27.4	28.2	28.3	-1.3	1.3
TIDE									
Rising	157	29.0	0.8	30	27.2	29	31.	.1	.1
Falling	103	29.1	0.8	28.5	27	28.8	31.8	.6	.5
Neap	62	28.7	0.0	28	9	28.75	30.2	-6.7	50.0
RAINFALL									
At Okat	143	29.1	0.6	28.8	27.3	29.1	30.5	-0.1	-0.2
Runoff	115	28.4	0.6	28.0	26.3	28.5	30.0	-0.6	1.5
None	64	29.6	1.0	30.0	27	30.0	31.8	-0.3	-0.1

Table 24. Univariate statistics for ammonia-nitrogen by station and sampling quarter.

Parameter: Ammonia-Nitrogen (mg/ℓ)

WQ Station	Number Samples	Mean	Standard Deviation	Mode	Minimum	Range Median	Maximum	Skewness	Kurtosis
1	32	0.035	0.024	0.024	0.010	0.026	0.100	1.6	1.8
2	30	0.028	0.019	0.023	0.005	0.023	0.067	0.8	-0.5
3	30	0.025	0.017	0.022	0.006	0.022	0.08	1.3	1.9
4	30	0.032	0.026	0.022	0.002	0.023	0.105	1.3	1.0
5	30	0.029	0.017	0.014	0.003	0.024	0.72	1.0	0.7
6	30	0.025	0.018	0.014	0.005	0.019	0.092	1.8	5.1
7	25	0.035	0.031	0.027	0.004	0.024	0.117	1.6	1.7
9	25	0.034	0.028	0.008	0.001	0.023	0.11	1.3	1.1
13	23	0.044	0.040	0.016	0.011	0.024	0.16	1.6	1.8
14	18	0.029	0.021	0.018	0.008	0.024	0.082	1.9	3.3
Quarter									
1	18	0.040	.024	0.043	0.007	0.0385	0.1	1.3	1.9
2	0								
3	21	0.40	0.005	0.04	0.028	0.04	0.048	-0.3	-0.2
4	26	0.026	0.020	0.013	0.003	0.02	0.078	1.5	1.6
5	28	0.023	0.035	0.016	0.002	0.012	0.16	3.0	9.3
6	30	0.023	0.008	0.025	0.01	0.024	0.041	0.3	-0.0
7	30	0.055	0.022	0.039	0.019	0.056	0.096	0.0	-1.0
8	30	0.018	0.008	0.007	0.005	0.018	0.034	0.2	-0.6
9	30	0.021	0.003	0.022	0.014	0.022	0.027	-0.3	-0.6
10	30	0.014	0.008	0.008	0.001	0.014	0.04	1.5	3.2
11	30	0.057	0.033	0.021	0.019	0.055	0.117	0.4	-1.4

Table 28. Univariate statistics of TNFR analyzed by wind direction and speed, tidal cycle and rainfall occurrence.

Parameter: Total Non-filtrable Residue (mg/ℓ)

Wind Direction	Number Samples	Mean	Standard Deviation	Mode	Minimum	Range Median	Maximum	Skewness	Kurtosis
NE to SE	138	44	52	13	3	29	485	5.1	38.1
SE to SW	32	32	37	27	4	27	225	4.8	25.5
SW to NW	37	88	205	28	6	35	988	3.9	15.0
NW to NE	73	61	117	20	4	34	964	6.7	50.7
None	10	164	173	12	12	88	532	1.4	1.0
WIND SPEED									
0-5 kts	210	68	133	13	3	32	988	5.0	28.2
5-10 kts	74	32	22	16	6	27	117	1.7	3.4
> 10 kts	6	38	33	9	9	29	90	.8	-.7
TIDE									
Rising	143	61	121	20	3	30	964	5.6	35.5
Falling	95	44	45	13	7	27	225	2.4	5.5
Neap	52	67	146	28	6	34	988	5.4	32.6
RAINFALL									
At Okat	126	54	122	20	6	27.5	964	6.0	39.0
Runoff	103	49	98	17	6	33	988	8.9	85.5
None	61	74	92	18	3	36	485	2.5	7.7

Table 26. Univariate statistics for ortho-phosphorus by station and sampling quarter.

Parameter: Ortho-Phosphorus (mg/ℓ)

WQ Station	Number Samples	Mean	Standard Deviation	Mode	Minimum	Range Median	Maximum	Skewness	Kurtosis
1	32	0.066	0.101	0.003	0.002	0.023	0.472	2.7	8.1
2	30	0.053	0.062	0.009	0.004	0.014	0.242	1.3	1.2
3	30	0.030	0.059	0.005	0.004	0.007	0.30	3.6	14.9
4	30	0.033	0.067	0.005	0.002	0.007	0.351	3.9	17.8
5	30	0.033	0.065	0.006	0.001	0.006	0.329	3.6	15.5
6	30	0.023	0.043	0.005	0	0.005	0.21	3.2	12.0
7	24	0.060	0.107	0.005	0.004	0.007	0.355	2.0	2.6
9	24	0.057	0.119	0.005	0.001	0.006	0.451	2.5	5.6
13	23	0.052	0.089	0.007	0.003	0.007	0.291	2.0	3.0
14	18	0.050	0.075	0.006	0.003	0.006	0.206	1.5	0.8
Quarter									
1	18	0.014	0.022	0.004	0.003	0.007	0.1	3.6	13.9
2	0	0	0	0	0	0	0	0	0
3	18	0.012	0.009	0.005	0	0.010	0.033	1.3	1.3
4	26	0.013	0.019	0.005	0	0.005	0.073	2.5	5.6
5	29	0.048	0.058	0.003	0.001	0.008	0.199	0.9	-0.1
6	30	0.008	0.004	0.006	0.004	0.006	0.023	0.2	7.7
7	30	0.216	0.124	0.038	0.038	0.234	0.472	0.1	-0.8
8	30	0.004	0.001	0.005	0.001	0.004	0.008	0.02	0.9
9	30	0.087	0.031	0.068	0.045	0.08	0.163	1.0	0.8
10	30	0.009	0.004	0.006	0.004	0.008	0.023	1.8	4.3
11	30	0.008	0.004	0.007	0.005	0.007	0.022	2.2	4.2

The maximum TSIN/ORTHO-PO mass ratio where nitrogen is still the limiting nutrient is 15/1 (Specht, 1975). The TSIN/ORTHO-PO mass ratios were calculated for each WQ station by sampling quarter. Previous studies (eg. Cowan and Clayshulte, 1980) showed nitrogen to be the limiting nutrient in all marine waters of Kosrae. Nitrogen was the limiting nutrient throughout the Part B monitoring for primary stations 2, 3, 4 and secondary station 14. The remaining stations had both single occurrences and longer periods when phosphorus was the limiting nutrient: station 1 in 10-83 at 19/1; station 5 in 10-83 at 16/1; station 6 in 05-82 and 11-82 at 16/1 and 67/1, respectively; station 7 in 07-84 at 16/1; station 9 in 01-83 at 53/1; and station 13 in 01-83 and 07-84 at 19/1 and 15/1, respectively. These changes in TSIN/ORTHO-PO mass ratios indicated that the marine ecosystem was being stressed by either natural or man-induced perturbations.

Tidal and Weather Affects

WQ quality parameters were analyzed in relation to weather and tidal changes to assess the influence of natural factors on water quality. WQ parameters were assessed by wind direction and speed, tidal cycle and rainfall occurrence. Univariate statistics were generated for each WQ parameter (Tables 27 to 40). Wind direction and speed were recorded for each WQ station at the time of sampling. Wind directions were divided into 5 categories: NE to SE, SE to SW, SW to NW, NW to NE, and none. Wind speed was divided into 3 categories: 0-5 kts, 5-10 kts and greater than 10 kts. Tidal change was recorded as rising, falling or neap. Rainfall occurrence was recorded as: recent rain at Okat; rain within 24 hours in mountains which produced runoff; and no rain within 24 hours.

Turbidity and TNFR (Tables 27 and 28) did not show significant trends when assessed by weather or tidal patterns. Mean turbidity levels were higher during rainfall periods and in high wind periods. Temperature (Tables 29 and 30) and pH (table 33) generally did not correlate with weather or tidal patterns. Mean salinities were reduced during rainfall periods and under low wind speed conditions. Higher wind speeds, particularly when the wind was from the NE to SE, caused increased dissolved oxygen concentrations (Table 34). Nitrogen and phosphorus concentrations showed significant correlations with both weather conditions and tidal changes (Tables 35 to 40).

Sediments

To maintain fine sand in the suspended sediment load of a turbidity plume, the average water current must be above 50 cm/sec. Water velocities in Okat harbor were measured with drift drogues in a pre-construction marine environmental survey (Eldredge et al., 1979). Water velocities ranged from less than 1 to 17 cm/sec, dependent on tidal change. Subsequent velocities measured with dye tracks in the Part B

Turbidity and TNFR data were tabulated by station and sampling period (Tables 13 and 14). The mean station turbidities at WQ stations 1, 2, 3, 7, 9, and 13 exceeded the turbidity standard. This indicates that these stations were subjected to turbidity levels throughout the Part B monitoring period which could cause environmental degradation of surrounding marine biota. The high mean turbidity levels at stations 1 and 2 were caused for the most part, by the natural discharge of river water and tidal flushing from the adjacent mangrove fringe. Station 3 was subjected to higher turbidity waters which were traceable to both the river/mangrove discharge water complex and construction related turbidity plumes. Stations 7, 9 and 13 were secondary stations within the WQ boundary. As a result, higher mean turbidities were anticipated at these stations. Stations 7 and 9 were source areas for the origination of sedimentation plumes resulting from construction activities. The dredge channel (stations 9 and 13) was a major source area for fine grained lime-muds which were continually resuspended into the water column and dispersed throughout the Okat harbor area. These lime-mud deposits were generated as a result of dredging and slurry discharge activities. The suction dredge used to obtain coral-fill had an effective recovery system and did not generate extensive sediment plumes. However, the dredge discharge operations and a leaky slurry pipeline did produce chronic sediment plumes. These turbidity plumes were dispersed by existing meteorological and hydrographic conditions throughout the Okat area, after beyond the WQ boundary. Frequently these plumes contained observable amounts of oil and grease. Sedimentation tubes recovered at WQ stations 1, 2 and 13 had measurable quantities of oil and grease trapped in the sediments and sedimentation tubes. These oil and grease spills were usually attributable to the suction dredge operation. On sampling trips in 1982 and 1983, extensive oil and grease films in plumes were observed to extend beyond the WQ boundary. These plumes were flushed into the mangrove fringe and out the harbor mouth.

The univariate statistics for temperature (Tables 15 and 16), salinity (Tables 17 and 18), pH (Table 19) and dissolved oxygen (Table 20) showed no abnormal trends. Mean near-surface temperatures were between 28 and 30 degrees C for WQ stations and showed no quarterly pattern. Mean near-surface salinities were more variable, but were still in a normal range for a coastal marine system. Higher mean salinities were correlated with lower rainfall periods. The highest mean salinities occurred in quarters 5 and 6 which were during a major drought. Although pH measurements were slightly low, they were still typical of coastal marine waters. Dissolved oxygen levels at station 1 were periodically low as a result of rive discharges.

Total nitrogen (Table 21) is composed of several nitrogen species which include organic- and ammonia-nitrogen (= total Kjeldahl nitrogen) and nitrite-nitrate nitrogen. Nitrite-nitrogen is a readily convertible nitrogen species (to nitrate-nitrogen and is generally measured at low levels in marine waters. Cown and Clayshulte (1979) in a baseline study of

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Tidal and Weather Affects

WQ quality parameters were analyzed in relation to weather and tidal changes to assess the influence of natural factors on water quality. WQ parameters were assessed by wind direction and speed, tidal cycle and rainfall occurrence. Univariate statistics were generated for each WQ parameter (Tables 27 to 40). Wind direction and speed were recorded for each WQ station at the time of sampling. Wind directions were divided into 5 categories: NE to SE, SE to SW, SW to NW, NW to NE, and none. Wind speed was divided into 3 categories: 0-5 kts, 5-10 kts and greater than 10 kts. Tidal change was recorded as rising, falling or neap. Rainfall occurrence was recorded as: recent rain at Okat; rain within 24 hours in mountains which produced runoff; and no rain within 24 hours.

Turbidity and TNFR (Tables 27 and 28) did not show significant trends when assessed by weather or tidal patterns. Mean turbidity levels were higher during rainfall periods and in high wind periods. Temperature (Tables 29 and 30) and pH (table 33) generally did not correlate with weather or tidal patterns. Mean salinities were reduced during rainfall periods and under low wind speed conditions. Higher wind speeds, particularly when the wind was from the NE to SE, caused increased dissolved oxygen concentrations (Table 34). Nitrogen and phosphorus concentrations showed significant correlations with both weather conditions and tidal changes (Tables 35 to 40).

Sediments

To maintain fine sand in the suspended sediment load of a turbidity plume, the average water current must be above 50 cm/sec. Water velocities in Okat harbor were measured with drift drogues in a pre-construction marine environmental survey (Eldredge et al., 1979). Water velocities ranged from less than 1 to 17 cm/sec, dependent on tidal change. Subsequent velocities measured with dye tracks in the Part B

Table 28. Univariate statistics of TNFR analyzed by wind direction and speed, tidal cycle and rainfall occurrence.

Parameter: Total Non-filtrable Residue (mg/ℓ)

Wind Direction	Number Samples	Mean	Standard Deviation	Mode	Minimum	Range Median	Maximum	Skewness	Kurtosis
NE to SE	138	44	52	13	3	29	485	5.1	38.1
SE to SW	32	32	37	27	4	27	225	4.8	25.5
SW to NW	37	88	205	28	6	35	988	3.9	15.0
NW to NE	73	61	117	20	4	34	964	6.7	50.7
None	10	164	173	12	12	88	532	1.4	1.0
WIND SPEED									
0-5 kts	210	68	133	13	3	32	988	5.0	28.2
5-10 kts	74	32	22	16	6	27	117	1.7	3.4
> 10 kts	6	38	33	9	9	29	90	.8	-.7
TIDE									
Rising	143	61	121	20	3	30	964	5.6	35.5
Falling	95	44	45	13	7	27	225	2.4	5.5
Neap	52	67	146	28	6	34	988	5.4	32.6
RAINFALL									
At Okat	126	54	122	20	6	27.5	964	6.0	39.0
Runoff	103	49	98	17	6	33	988	8.9	85.5
None	61	74	92	18	3	36	485	2.5	7.7

Table 30. Univariate statistics of -1m temperature analyzed by wind direction and speed, tidal cycle and rainfall occurrence.

Parameter: Temperature, -1m (°C)

Wind Direction	Number Samples	Mean	Standard Deviation	Mode	Minimum	Range Median	Maximum	Skewness	Kurtosis
NE to SE	151	28.9	0.9	30.0	26.3	28.9	31.0	-0.0	0.3
SE to SW	40	29.2	0.8	28.0	27.0	29.5	30.1	-0.6	-0.6
SW to NW	46	28.8	0.7	28.0	27.3	28.7	30.2	0.4	-0.3
NW to NE	75	29.0	0.6	28.8	27.3	28.9	31.8	1.5	4.7
None	10	29.3	1.3	30.0	27.3	29.75	31.0	-0.4	-1.2
WIND SPEED									
0-5 kts	232	29.2	0.8	30.0	27.0	29.0	31.8	0.2	0.3
5-10 kts	80	28.6	0.7	29.1	26.3	28.6	30.5	-0.4	1.3
> 10 kts	10	28.0	0.3	28.2	27.4	28.2	28.3	-1.3	1.3
TIDE									
Rising	157	29.0	0.8	30	27.2	29	31.	.1	.1
Falling	103	29.1	0.8	28.5	27	28.8	31.8	.6	.5
Neap	62	28.7	0.0	28	9	28.75	30.2	-6.7	50.0
RAINFALL									
At Okat	143	29.1	0.6	28.8	27.3	29.1	30.5	-0.1	-0.2
Runoff	115	28.4	0.6	28.0	26.3	28.5	30.0	-0.6	1.5
None	64	29.6	1.0	30.0	27	30.0	31.8	-0.3	-0.1

Table 32. Univariate statistics of -1m salinity analyzed by wind direction and speed, tidal cycle and rainfall occurrence.

Parameter: Salinity, -1m (ppt)

Wind Direction	Number Samples	Mean	Standard Deviation	Mode	Minimum	Range Median	Maximum	Skewness	Kurtosis
NE to SE	151	34.6	1.4	34.4	21.1	34.4	36.6	-5.7	49.4
SE to SW	40	33.3	1.9	34.4	24.4	33.3	35.5	-3.0	11.9
SW to NW	46	33.0	2.4	33.3	22.2	33.3	35	-3.1	11.1
NW to NE	75	34.4	1.4	35.5	26.6	35.0	36.6	-2.5	10.5
None	10	30.0	10.2	32.2	2.2	33.3	36.6	-2.7	7.8
WIND SPEED									
0-5 kts	232	33.7	2.9	34.4	2.2	34.4	36.6	-6.5	60.6
5-10 kts	80	34.8	.7	34.4	32.2	35.0	35.5	-1.2	2.4
> 10 kts	10	35.1	.6	35	34.4	35.0	36.6	1.3	2.8
TIDE									
Rising	157	34.2	2.8	34.4	2.2	34.4	36.6	-9.4	104.4
Falling	103	34.0	2.2	34.4	21.1	34.4	36.6	-3.2	13.5
Neap	62	33.6	2.2	35	22.2	34.4	35.5	-3.3	13.6
RAINFALL									
At Okat	143	33.2	1.7	34.4	2.2	33.9	36.1	-6.8	59.2
Runoff	115	34.7	1.4	35.5	25.0	35.0	36.6	-4.6	27.1
None	64	34.6	1.7	35.5	24.4	35.45	36.6	-3.8	21.2

Table 34. Univariate statistics of dissolved oxygen analyzed by wind direction and speed, tidal cycle and rainfall occurrence.

Parameter: Dissolved Oxygen (mg/ℓ)

Wind Direction	Number Samples	Mean	Standard Deviation	Mode	Minimum	Range	Maximum	Skewness	Kurtosis
						Median			
NE to SE	113	5.5	0.7	5.6	3.1	5.6	7.9	-0.8	3.4
SE to SW	29	5.1	0.7	4.9	2.8	5.1	6.0	-1.3	2.8
SW to NW	37	4.8	0.7	4.6	3.4	4.8	6.5	0.2	-0.3
NW to NE	69	5.4	0.8	4.8	3.1	5.4	8.5	0.1	2.8
None	2	3.1	1.0	2.4	2.4	3.1	3.8		
WIND SPEED									
0-5 kts	163	5.1	.8	5.1	2.4	5.2	8.5	-0.3	1.6
5-10 kts	77	5.6	.6	5.6	3.2	5.6	7.6	-0.3	4.0
> 10 kts	10	5.7	.2	5.6	5.5	5.6	6.0	0.7	-0.9
TIDE									
Rising	103	5.4	.7	5.8	3.1	5.5	7.9	-0.4	2.3
Falling	88	5.2	.9	5.1	2.4	5.2	8.5	-0.2	2.3
Neap	59	5.3	.8	5.6	3.7	5.5	6.5	-0.7	-0.5
RAINFALL									
At Okat	119	5.2	.7	5.1	3.1	5.2	6.8	-0.6	0.1
Runoff	109	5.5	.9	5.6	2.4	5.6	8.5	-0.5	3.2
None	22	4.8	.7	4.8	2.8	4.9	6.0	-1.4	3.1

Table 36. Univariate statistics of TKN analyzed by wind direction and speed, tidal cycle and rainfall occurrence.

Parameter: Total Kjeldhal Nitrogen (mg/ℓ)

Wind Direction	Number Samples	Mean	Standard Deviation	Mode	Minimum	Range	Median	Maximum	Skewness	Kurtosis
NE to SE	103	0.267	0.256	0.06	0.01	0.21		1.44	1.7	3.9
SE to SW	32	0.383	0.309	0.01	0.01	0.25		1.01	0.5	-1.1
SW to NW	36	0.449	0.389	0.15	0.01	0.28		1.48	1.2	0.7
NW to NE	55	0.230	0.198	0.09	0.01	0.15		0.87	1.4	1.4
None	8	0.245	0.119	0.23	0.12	0.23		0.5	1.5	2.9
WIND SPEED										
0-5 kts	165	0.322	0.285	0.15	0.01	0.23		1.48	1.5	2.3
5-10 kts	61	0.223	0.268	0.06	0.01	0.13		1.44	2.4	7.1
> 10 kts	8	0.464	0.217	0.13	0.13	0.44		0.84	0.3	0.4
TIDE										
Rising	98	0.241	0.194	0.06	0.01	0.20		0.95	1.3	1.8
Falling	77	0.252	0.271	0.01	0.01	0.13		1.01	1.3	0.5
Neap	59	0.464	0.354	0.15	0.01	0.35		1.48	1.2	1.1
RAINFALL										
At Okat	111	0.420	0.303	0.35	0.01	0.35		1.48	1.0	1.1
Runoff	96	0.196	0.233	0.06	0.01	0.13		1.44	2.8	9.6
None	27	0.188	0.120	0.13	0.01	0.17		0.56	1.3	2.5

Table 38. Univariate statistics of Amonia-Nitrogen analyzed by wind direction and speed, tidal cycle and rainfall occurrence.

Parameter: Ammonia-Nitrogen (mg/ℓ)

Wind Direction	Number Samples	Mean	Standard Deviation	Mode	Minimum	Range Median	Maximum	Skewness	Kurtosis
NE to SE	120	0.026	0.026	0.016	0.001	0.018	0.16	2.6	7.9
SE to SW	32	0.039	0.067	0.040	0.005	0.029	0.40	5.3	29.0
SW to NW	44	0.032	0.047	0.024	0.003	0.024	0.32	5.4	33.1
NW to NE	69	0.043	0.027	0.018	0.011	0.034	0.117	0.9	-0.3
None	8	0.045	0.025	0.017	0.017	0.041	0.10	1.7	4.0
WIND SPEED									
0-5 kts	185	0.034	0.024	0.018	0.003	0.026	0.117	1.5	1.7
5-10 kts	79	0.026	0.027	0.012	0.001	0.016	0.160	2.6	8.5
J 10 kts	9	0.012	0.005	0.011	0.005	0.011	0.022	.6	0.0
TIDE									
Rising	126	0.035	0.028	0.025	0.002	0.025	0.16	1.7	3.1
Falling	85	0.037	0.047	0.040	0.001	0.024	0.40	5.8	43.8
Neap	62	0.026	0.041	0.022	0.003	0.019	0.32	6.4	45.5
RAINFALL									
At Okat	132	0.032	0.024	0.022	0.003	0.024	0.107	1.5	1.3
Runoff	113	0.028	0.036	0.012	0.001	0.018	0.32	5.4	38.0
None	28	0.061	0.071	0.048	0.007	0.046	0.40	4.2	20.2

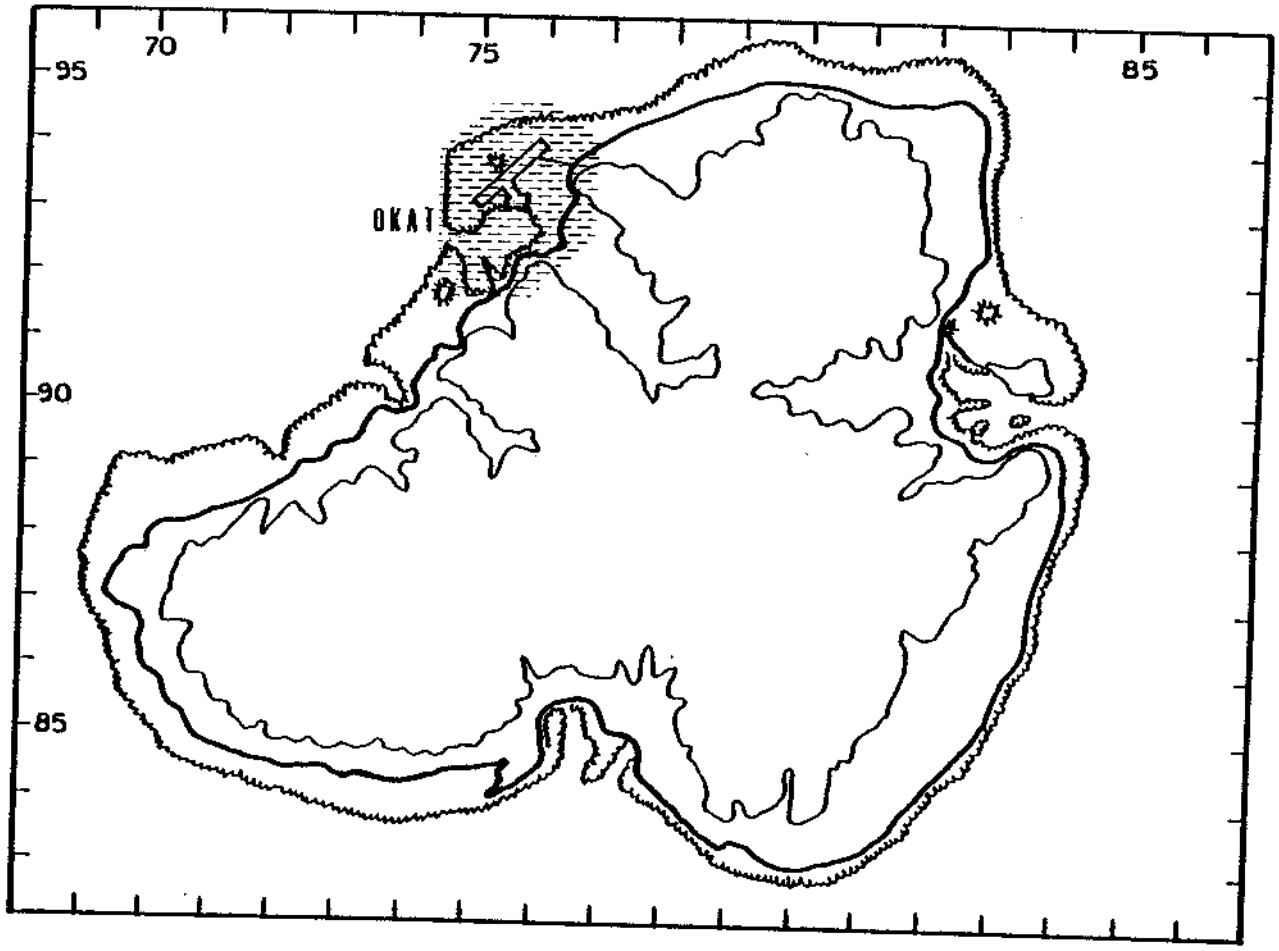

Figure 1. Kosrae State with location of Okat harbor.

Table 40. Univariate statistics of ortho-phosphorus analyzed by wind direction and speed, tidal cycle and rainfall occurrence.

Parameter: Ortho-phosphorus (mg/ℓ)

Wind Direction	Number Samples	Mean	Standard Deviation	Mode	Minimum	Range Median	Maximum	Skewness	Kurtosis
NE to SE	121	0.045	0.072	0.006	0.001	0.009	0.451	2.9	11.1
SE to SW	29	0.006	0.006	0.005	0.000	0.005	0.033	2.9	9.9
SW to NW	44	0.010	0.012	0.005	0.000	0.005	0.071	3.3	13.4
NW to NE	69	0.085	0.116	0.006	0.004	0.009	0.472	1.4	1.1
None	8	0.035	0.034	0.005	0.005	0.022	0.100	1.4	0.9
WIND SPEED									
0-5 kts	182	0.044	0.081	0.005	0.000	0.007	.472	3.0	10.0
5-10 kts	80	0.045	0.082	0.006	0.000	0.008	.351	2.3	4.7
> 10 kts	9	0.065	0.069	0.001	0.001	0.07	.199	.8	.1
TIDE									
Rising	127	0.054	0.093	0.006	0.000	0.007	.472	2.3	4.7
Falling	82	0.029	0.075	0.006	0.001	0.007	.451	4.1	17.6
Neap	62	0.047	0.051	0.005	0.000	0.019	.199	.9	0.0
RAINFALL									
At Okat	132	0.073	0.104	0.005	0.000	0.016	.472	1.8	2.9
Runoff	111	0.019	0.034	0.006	0.001	0.007	.199	3.1	9.9
None	28	0.013	0.018	0.005	0.003	0.007	.100	4.2	19.4

controversy about the need for environmental monitoring caused a delay in the initiation of water quality monitoring. WERI was contracted by the TTEPB (TTPI contract number CT210014) to monitor marine water in the vicinity of Okat harbor, Kosrae. Monitoring was to be conducted for 3 days on a quarterly basis over a 30-month period.

There was a considerable amount of construction activity completed and in progress by the first monitoring trip in May 1982. An access road was built through the extensive coastal mangrove swamp (Figure 2). A bridge was built over the traditional canoe which runs through the mangrove swamp. Basalt rock seawalls made of large (greater than 1m in diameter) basalt armor stone were in place around the periphery of the runway and dock area. A central portion of the runway was already being infilled with dredged coral fill material derived from the adjacent reef-flat. Dredge filling was almost completed at the dock site. The small boat channel was about 40% completed. A bridge was under construction which would span the small boat channel. As a result of these construction activities, there were locations adjacent to the construction project which already had substantial accumulations of silty ooze originating from dredge and filling operations. Therefore, the initial monitoring trip assessed a marine environment at Okat which had been and was undergoing some degree of degradation due to construction activities (Figure 1, Appendix A).

A figure was drawn for each monitoring period which included WQ stations, extent of dredge and fill operations, surface flow patterns, location of turbidity plumes and other pertinent construction related activities or perturbations. These figures are presented in Appendix A in chronological order from July 1982 to July 1984.

OBJECTIVES

The primary objective of this study was to conduct monitoring of selected water quality parameters in marine waters outside the water quality project boundary adjacent to Okat harbor. A further objective was to provide for comprehensive and timely reporting of quarterly results to the TTEPB. A final objective was to provide a training program for Kosrae Environmental Health Department technicians in relation to the Okat monitoring program and also to help them perform more comprehensive laboratory and field service in support of other non-related projects.

Table 41. Volatile non-filtrable residue (VNFR) and percent organic matter in total residue (TNFR) at water quality stations. The units for VNFR are mg/ℓ.

Water Quality Station	7 July 83		8 July 83		11 July 83	
	VNFR	% Organic	VNFR	% Organic	VNFR	% Organic
1	130	50	272	29	40	47
2	19	70	32	45	103	13
3	10	50	26	52	20	50
4	18	90	11	85	20	46
5	13	93	20	69	18	40
6	8	73	4	15	4	69
7	8	76	4	11	2	91
9	17	40	7	18	28	57
13	24	55	23	59	31	38
14	14	64	6	30	5	75

Water Quality Station	7 October 83		10 October 83		11 October 83	
	VNFR	% Organic	VNFR	% Organic	VNFR	% Organic
1	57	43	30	53	14	26
2	17	30	21	84	0	0
3	11	24	4	29	22	73
4	2	7	0	0	16	80
5	15	39	13	48	18	95
6	12	52	9	43	13	100
7	7	25	13	41	19	76
9	24	86	11	28	21	78
14	11	0	0	0	17	63

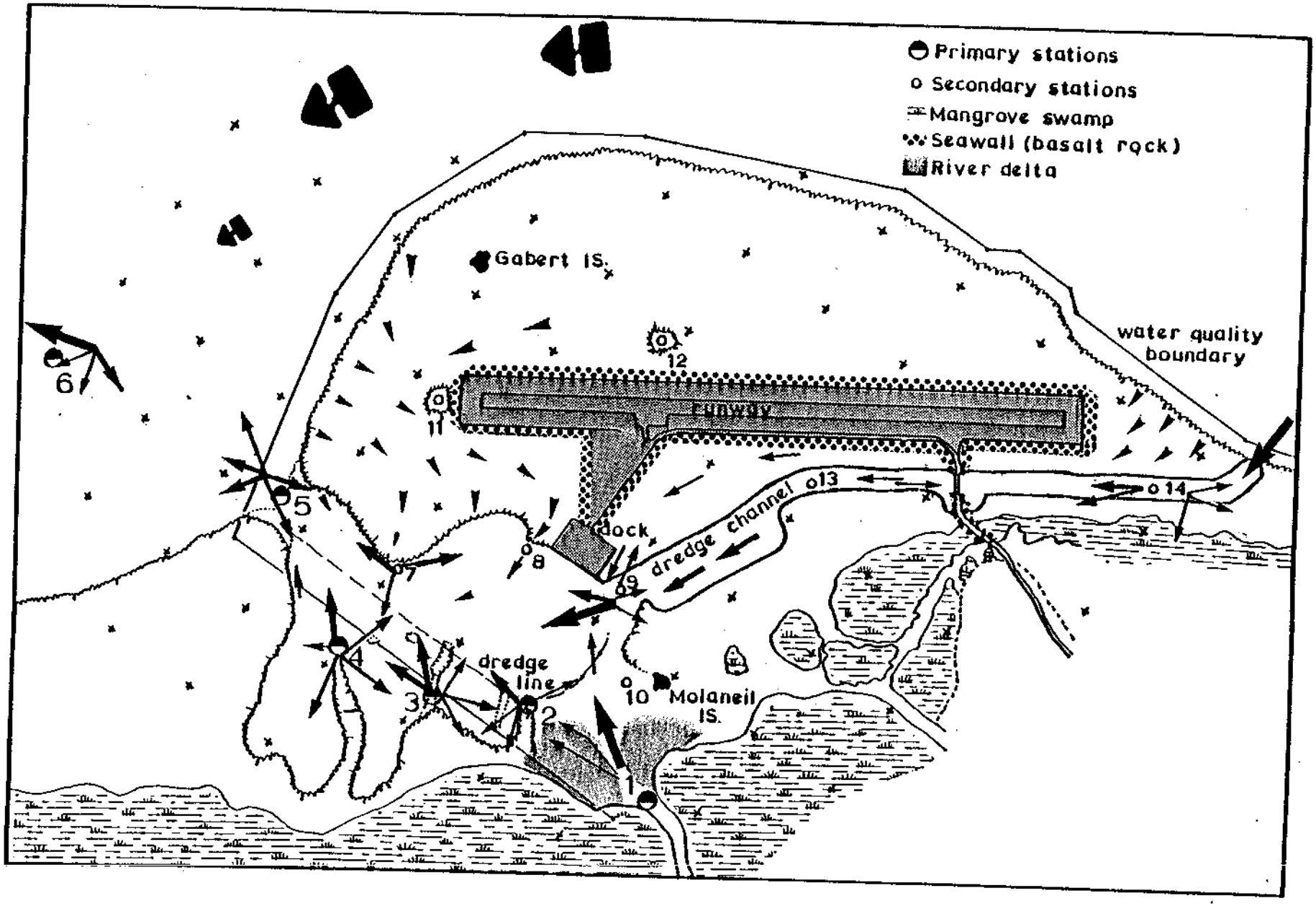

Figure 3. General water current trends in Okat harbor.

Sedimentation experiments were conducted at the bridge site from 11 October 1983 to 19 January 1984 to assess sediment "rain" changes within the channel environment, along the reef-flat plate and within the mangrove fringe. These sedimentation tests were designed to determine both the composition of the suspended load and amount of resuspension of lime-mud occurring within the area. There was a substantial increase in sediment "rain" occurring in the channel environment and extending in the mangrove fringe. The suspended load was composed of white clay/silt sized particles (lime-mud) in the channel and reef-flat environments with 20 to 30% fine sand. The results of this study are as follows:

SITE	SEDIMENT "RAIN"	
	$ml/m^2/day$	$g/day/m^2$
BRIDGE CHANNEL, 3m Depth	1750	586
	1935	611
	2120	739
	2025	695
	mean=1957	mean=658
EDGE REEF FLAT, Channelcut	1250	304
REEFFLAT, Edge Mangroves	1160	480
MANGROVE FRINGE	3230	315

These high sediment "rain" rates indicate that the channel environment was not becoming stabilized in relation to sediment deposits. These fine textured (clay/silt) sediments in the channel floor were subject to easy resuspension by water currents. These sediments pose a potential long-term WQ problem.

A large quantity of silty-ooze was deposited along the runway and adjacent to the docking area. The Hawaii Corp of Engineers recommended in the summer of 1984 that the silty mud and rubble accumulated along the runway and dock area be piled along the edge of the reef plate and dumped (by both suction dredge and bulldozer) into deeper harbor waters. Sediments along the dredge channel were scraped into the channel at low tides. Both of these clean-up operations caused extensive degradation of the marine water quality. A highly turbid plume was produced by the suction dredge operation in the harbor. This plume was observed to extend into the mangrove area south of the harbor, onto the western fringing reef and extended out the harbor toward Walung (Appendix A, Figure 9). The channel floor already had a silt load that was not being removed by currents. The additional material introduced into the channel and onto the upper slopes of the harbor reef complex became a potentially long-term source of fine material. These sediments could be periodically resuspended into the harbor water mass. Since the dredge channel was not opened at the seaward end, the silt load in the channel environment will remain for a long time period with only minor stabilization. Sedimentation studies made in the channel near the bridge showed silty-sand "rain" (resuspended outfall) at a rate of 1 cm/square meter/day. This rate will greatly reduce reestablishment of marine biota.

Table 1. Water quality parameters and methods of analyses. Abbreviations of parameters used in the text and tables are shown for each parameter.

Water Quality Parameter	Units	Parameter Abbreviation	Method	Type of Analysis
Turbidity	NTU	Turb	Turbidimeter	direct measurement with nephlometer
Total Non-filtrable Residue	mg/ℓ	TNFR	Standard Methods*	membrane dried at 105°C for 24 hr.
Temperature (surface) (at depth)	°C	Sur. Temp -1m Temp	Thermometer	mercury thermometer, 20-50°C
Salinity (surface) (at depth)	ppt	Sur. Sal -1m Sal	Refractive Index	hand-held refractometer, refractive index conversion to salinity (graphic)
pH	pH	pH	pH probe	Specific ion meter and combination probe
Dissolved Oxygen	mg/ℓ	DO/Dis. Oxygen	Standard Methods	Winkler titration
Total Nitrogen	mg/ℓ	TN	Standard Methods	calculation from other nitrogen data
Total Kjeldahl Nitrogen	mg/ℓ	TKN	Standard Methods	macro-Kjeldahl, digestion and distillation
Nitrate + Nitrite-Nitrogen	mg/ℓ	Nitrate/NO	Standard Methods	cadmium-reduction, nitrite determination
Ammonia-Nitrogen	mg/ℓ	Ammonia/NH	Solorzano, 1969	Indophenol technique
Ortho-Phosphorus	mg/ℓ	Ortho Phos/OP	Standard Methods	Ascorbic acid technique
Total Phosphorus	mg/ℓ	Total Phos/TP	Standard Methods	Ammonium persulfate and acid digestion, ascorbic acid

* Standard Methods - Standard methods for the examination of water and wastewater, 15th edition, 1980.

Table 42. Concentration of heavy metals in marine waters at Okat Harbor, November 1982.

Water Quality Stations	Heavy Metal (µg/ℓ) As	Cd	Cr	Cu	Hg	Ni	Pb	Zn
1	1.8	0.9	1.8	3.0	6.6*	8.3*	2.1	12.4
2	1.2	0.1	1.3	0.8	7.1*	1.7	1.9	16.7
3	1.2	0.1	2.4	0.6	4.7*	0.7	1.4	8.2
4	0.9	0.1	2.8	0.6	4.6*	1.3	1.9	5.9
5	1.0	0.2	1.5	0.6	2.3*	1.0	1.5	18.8
6	1.0	0.2	1.1	0.5	2.8*	0.6	1.6	10.0
7	0.9	0.1	6.3	0.5	3.0*	0.8	1.4	7.5
8	0.9	0.1	7.8	0.5	3.1*	0.8	1.0	3.2
9t	0.9	0.1	4.3	0.6	2.6*	0.8	1.5	4.4
10t	0.9	0.7	7.2	0.8	2.2*	0.9	2.1	5.4
TTPI Marine WQ Standards (µg/ℓ)	10.0	5.0	50.0	10.0	0.10	2.0	10.0	20.0

*exceeds TTPI standard

Table 43. Concentration of heavy metals in marine waters at Okat Harbor, July 1983. See Table 42 for TTPI marine water quality standards for heavy metals.

Water Quality Stations	Heavy Metal (µg/ℓ) As	Cd	Cr	Cu	Hg	Ni	Pb	Zn
1	3.1	1.0	0.6	20*	0.4*	26*	2.8	25*
2	0.9	0.8	0.2	0.5	1.0*	0.8	2.3	<1
3	1.4	1.0	0.1	2.3	1.0*	1.6	1.9	2
4	1.2	0.8	<0.1	0.3	2.0*	0.4	1.8	9
5	1.2	0.8	0.2	2.1	2.6*	0.7	2.8	16
6	0.6	1.0	0.2	2.8	2.6*	0.5	2.1	2
7	0.8	0.7	0.2	0.5	1.6*	1.1	6.3	16
8	1.4	0.9	0.2	1.6	0.4*	1.3	1.8	6
9	1.3	0.7	0.2	0.3	1.4*	0.5	2.0	1
13	1.8	0.8	0.2	3.4	1.2*	0.4	1.9	3
14	1.7	0.8	<0.1	0.4	<0.1	0.3	2.8	1

*exceeds TTPI standard

represented by Stations 7 and 8). This standard would allow for a change in background turbidities of up to 70% and 130% over the T_{90} values observed in this study, for the harbor and reef waters, respectively.

The turbidity standard that was established by WERI for the Truk Airport expansion monitoring program was 2.0 NTU (Clayshulte et al., 1979) and for the Belau monitoring program the turbidity standard was 5.0 NTU (Zolan, 1983). These standards were based on Part A Pre-construction monitoring studies and on a TPPI baseline water quality survey of different marine water classes (Cowan and Clayshulte, 1980). These turbidity standards for Kosrae, Truk and Belau were all established at levels above ambient or natural turbidities. Turbidity was identified in the Part A Pre-construction studies for Truk and Belau as the water quality parameter which would be most effected by construction related operations. Periodic exceedences of these turbidity standards were expected to occur at the construction water quality boundaries. However, it was anticipated that if the marine water turbidity levels were kept, for the most part, below these standards, then long-term environmental degradation would be minimized.

There were other water quality parameters analyzed which were not included in the TTPI water quality standards. These parameters were total Kjeldahl nitrogen, nitrate+nitrite-nitrogen, ammonia-nitrogen, ortho-phosphate and total non-filtrable residue. Analyses of these parameters were made in order to provide a more comprehensive evaluation of nutrient and residue cycles in Okat harbor as affected by construction activities and natural processes. Marine water quality in the vicinity of Okat harbor was modified by river discharges and tidal flush from the coastal mangrove complex adjacent to the construction area. Therefore, it was deemed necessary to conduct these additional water quality analyses in order to distinguish changes in water quality between construction activities and natural processes.

Station Water Quality

Marine water quality (WQ) was monitored at 6 primary and up to 6 secondary WQ stations on a quarterly basis from 05-17-82 to 07-17-84. Primary and secondary WQ station locations are shown in Figure 2. WQ stations were monitored a minimum of 3 days for each quarterly sampling set. There were 11 quarterly sampling sets. A quarterly sampling set with a 3-day monitoring period was established based on results from previous large scale marine monitoring programs in construction phases (Clayshulte, 1983; Clayshulte and Zolan 1982; Zolan 1983). These studies showed that WQ could vary considerably within short-time periods. These variations were not only on construction activities but also on temporal environmental factors (ie., tidal surf and weather conditions) and seasonal hydrographic and meteorological fluctuations. It was determined that a 3-day to 5-day average of WQ data would provide a more realistic assessment of general WQ at a specific WQ station for WQ compliance purposes. It was

Table 44. Concentration of heavy metals in marine waters at Okat Harbor, July 1984. See Table 42 for TTPI marine water supply quality standards for heavy metals.

Water Quality Stations	Heavy Metal (µg/ℓ) As	Cd	Cr	Cu	Hg	Ni	Pb	Zn
1	1.2	0.2	1.8	1.5	1.9*	< 1.0	< 1.0	1.6
2	2.3	0.2	1.7	2.1	0.8*	< 1.0	< 1.0	2.1
3	1.9	0.4	1.5	0.6	1.5*	< 1.0	< 1.0	1.1
4	2.1	0.2	1.3	2.4	0.9*	1.0	12*	5.3
5	1.0	0.6	1.7	3.1	0.9*	3.5*	< 1.0	0.8
6	1.9	0.3	1.4	0.8	1.4*	4.2*	< 1.0	5.6
7	1.9	0.2	1.7	0.6	2.1*	< 1.0	3.1	6.9
9	2.0	0.4	1.4	1.1	1.4*	< 1.0	2.8	13.0
13	2.2	0.2	1.4	2.0	1.1*	< 1.0	1.3	1.7
14	2.1	0.4	1.5	0.4	0.5*	< 1.0	< 1.0	0.3

* exceeds TTPI standard.

Table 45. Summary of mercury concentrations in near-surface marine water at Okat Harbor water quality monitoring stations. The TTPI marine water quality standard for mercury is 0.10 µg/ℓ. Figure 2 for locations of water quality stations. The August 1979 sampling was done by Chun et al., (1979).

Water Quality Station	Heavy Metal Mercury (µg/ℓ) Aug. 1979	Nov. 1982	July 1983	July 1984
1	< 0.1	6.6	0.4	1.9
2	-	7.1	1.0	0.8
3	< 0.1	4.7	1.0	1.5
4	< 0.1	4.6	2.0	0.9
5	< 0.1	2.3	2.6	0.9
6	-	2.8	2.6	1.4
7	< 0.1	3.0	1.6	2.1
8	-	3.1	0.4	-
9	-	2.6	1.4	1.4
10	< 0.1	2.2	-	-
13	-	-	1.2	1.1
14	-	-	< 0.1	0.5
Mean (µg/ℓ)	< 0.1	3.9	1.3	1.3
± S.D.	-	1.8	0.8	0.5
Number of stations	10	10	11	10

Table 2. Water quality at station 1 in Okat harbor. A period represents a "no sample taken" for sample period.

Date	Time	Turb	TNFR	Surface Temp	-1m Temp.	Surface Salinity	-1m Salinity	pH	DO	TN	TKN	NO	NH	TP	OP
05-17-82	0955	4.5	51	31.0	31.0	11.1	34.4	8.05	.	0.14	0.14	0.002	0.100	0.021	0.018
05-19-82	0905	3.4	63	30.0	30.0	8.9	32.2	7.65	.	0.23	0.23	0.004	0.040	0.040	0.028
05-20-82	0930	2.5	394	29.5	29.5	10.0	32.2	7.40	.	0.15	0.12	0.028	0.054	0.041	0.025
05-21-82	1255	2.4	28	31.0	31.0	33.3	33.3	7.83	.	.	.	.	.	.	.
05-28-82	0915	2.4	63	31.0	31.0	20.0	33.3	7.70	4.0	.	.	.	.	.	.
06-01-82	0930	1.4	94	30.0	30.0	11.1	34.4	7.90	.	.	.	.	.	.	.
06-02-82	0940	15.5	191	30.0	30.0	16.7	33.3	7.80	.	.	.	.	.	.	.
06-03-82	0730	43.	730	28.0	28.0	0.1	2.2	7.65	.	.	.	.	.	.	.
08-05-82	1000	24.	988	30.0	30.0	25.0	25.0	7.55	3.7	0.29	0.28	0.006	0.032	0.083	0.033
08-07-82	0725	6.7	225	27.5	27.0	20.0	24.4	7.25	2.8	0.25	0.24	0.007	0.040	0.226	0.033
08-08-82	0755	9.2	164	27.5	27.5	23.3	26.6	7.10	2.4	0.24	0.23	0.009	0.044	0.092	0.020
11-10-82	1420	14.	233	26.7	28.6	14.4	31.1	7.45	4.0	1.20	1.13	0.033	0.030	0.067	0.034
11-11-82	1035	25.	532	26.5	27.3	16.7	30.5	7.35	3.8	0.56	0.50	0.064	0.033	0.091	0.073
11-12-82	1110	8.9	844	28.9	29.0	32.2	32.2	7.80	4.3	0.66	0.61	0.046	0.016	0.046	0.035
01-11-83	0900	9.8	90	27.8	28.1	32.2	34.4	7.92	5.6	0.14	0.13	0.008	0.013	0.029	0.002
01-12-83	0955	7.7	84	27.5	27.5	35.5	35.5	7.92	5.4	0.05	0.04	0.010	0.013	0.106	0.106
01-13-83	0830	4.0	61	25.8	26.4	33.9	34.4	7.65	3.8	0.23	0.22	0.012	0.012	0.083	0.083
01-14-83	0800	1.5	79	26.3	26.3	33.3	35.5	7.58	4.2	0.45	0.44	0.011	0.017	0.009	0.009
04-07-83	0835	2.7	42	27.5	27.3	34.4	34.4	7.30	3.8	0.22	0.15	0.072	0.024	0.026	0.023
04-08-83	0855	2.6	85	26.9	27.3	35.0	34.4	7.82	3.1	0.15	0.05	0.095	0.014	0.025	0.023
04-11-83	0855	1.6	35	28.4	28.2	34.4	34.4	8.00	4.5	0.15	0.13	0.019	0.018	0.010	0.009
07-07-83	1115	38.	964	29.3	29.3	23.3	31.1	7.80	3.6	0.65	0.63	0.029	0.053	0.852	0.226
07-08-83	0915	15.	260	25.8	28.5	2.2	26.6	7.70	3.6	0.21	0.01	0.020	0.072	0.937	0.472
07-11-83	0855	4.1	76	27.2	28.0	13.3	21.1	7.72	3.1	0.36	0.35	0.009	0.024	0.827	0.271
10-07-83	0935	8.3	132	29.0	29.1	18.3	22.2	7.55	3.8	1.00	0.95	0.046	0.024	0.041	0.003
10-11-83	0830	5.0	54	26.4	28.5	18.7	28.9	7.98	3.9	0.58	0.55	0.033	0.016	0.034	0.003
10-10-83	0830	4.6	57	26.4	28.5	10.0	27.8	7.80	3.4	0.58	0.55	0.033	0.024	0.033	0.003
01-18-84	0955	2.4	42	29.2	30.1	21.1	33.3	8.05	5.0	0.36	0.35	0.10	0.026	0.236	0.149
01-19-84	0950	3.5	58	28.6	28.7	30.5	32.2	8.00	4.1	0.57	0.56	0.010	0.026	0.273	0.158
01-20-84	0930	3.0	55	27.8	28.6	20.0	30.0	7.88	3.9	0.16	0.15	0.011	0.027	0.290	0.163
04-03-84	1130	4.9	65	28.9	29.1	34.4	34.4	8.10	5.1	0.08	0.08	0.004	0.015	0.021	0.011
04-04-84	0930	7.0	101	28.0	28.3	34.4	34.4	7.88	3.2	0.03	0.02	0.007	0.014	0.029	0.018
04-06-84	0920	3.0	59	27.5	28.2	24.4	33.3	7.50	3.1	0.06	0.05	0.008	0.031	0.032	0.023
07-12-84	1420	4.7	21	29.7	29.7	16.7	33.9	8.00	6.2	0.09	0.08	0.006	0.094	0.030	0.015
07-16-84	0815	5.6	206	27.9	28.9	32.2	35.5	8.00	3.5	0.08	0.06	0.075	0.092	0.053	0.017
07-17-84	0650	8.7	17	28.8	28.5	35.5	34.4	8.08	5.2	0.17	0.15	0.011	0.043	0.063	0.022

Table 46. continued.

Station	Parameter	N	Mean	Root MSE*	F-Value	Significance
4	Turbidity	34	1.1	0.3	7.84	.001
	TNFR	34	33	31	0.77	NS
	Sur. Temp	34	29.0	0.4	8.23	.001
	-1m Temp	34	29.0	0.5	5.67	.001
	Sur. Salinity	34	34.1	1.2	3.12	.011
	-1m Salinity	34	34.3	0.7	5.20	.001
	pH	34	8.14	0.87	2.24	NS
	Dis. Oxygen	27	5.2	0.4	2.42	NS
	Total Nitrogen	29	0.386	0.253	5.04	.001
	TKN	29	0.367	0.249	5.35	.001
	Nitrate	29	0.012	0.009	1.41	NS
	Ammonia	29	0.032	0.017	5.54	.001
	Ortho Phos	29	0.033	0.057	2.41	NS
	Total Phos	29	0.071	0.097	5.15	.001
5	Turbidity	35	1.1	0.5	5.12	.001
	TNFR	35	29	18	0.85	NS
	Sur. Temp	35	29.0	0.4	8.60	.001
	-1m Temp	35	29.0	0.4	7.22	.001
	Sur. Salinity	35	34.0	1.0	4.79	.001
	-1m Salinity	35	34.5	0.6	4.18	.002
	pH	35	8.15	0.10	1.31	NS
	Dis. Oxygen	28	5.6	0.5	0.55	NS
	Total Nitrogen	30	0.298	0.150	7.19	.001
	TKN	30	0.289	0.150	7.26	.001
	Nitrate	30	0.007	0.003	5.43	.001
	Ammonia	30	0.029	0.015	2.19	NS
	Ortho Phos	30	0.033	0.053	2.56	.038
	Total Phos	30	0.086	0.066	20.40	.001
6	Turbidity	35	0.54	0.12	7.22	.001
	TNFR	35	20	15	1.33	NS
	Sur. Temp	35	29.0	0.3	17.74	.001
	-1m Temp	35	29.1	0.3	19.96	.001
	Sur. Salinity	35	34.9	0.5	4.05	.002
	-1m Salinity	35	35.0	0.04	3.19	.009
	pH	35	8.21	0.08	2.25	NS
	Dis. Oxygen	28	5.7	0.5	0.37	NS
	Total Nitrogen	30	0.281	0.143	4.89	.001
	TKN	30	0.277	0.144	4.82	.002
	Nitrate	30	0.003	0.003	0.95	NS
	Ammonia	30	0.025	0.012	5.60	.001
	Ortho Phos	30	0.023	0.034	2.91	.022
	Total Phos	30	0.104	0.029	206.60	.001

* Root MSE - Root Mean Square Error.
** NS - Not significant at $P \geq 0.05$.

Table 4. Water quality at station 3 in Okat harbor. A period represents a "no sample taken" for sample period.

Date	Time	Turb	TNFR	Surface Temp	-1m Temp.	Surface Salinity	-1m Salinity	pH	DO	TN	TKN	NO	NH	TP	OP
05-17-82	1010	0.21	38	30.5	30.0	35.5	35.5	8.22	.	0.29	0.29	0.003	0.007	0.008	0.005
05-19-82	0930	1.2	21	29.5	29.5	34.4	34.4	8.10	.	0.31	0.30	0.008	0.026	0.014	0.007
05-20-82	1000	0.29	65	29.0	29.0	33.3	35.5	8.05	.	0.30	0.30	0.002	0.017	0.008	0.005
05-21-82	1305	0.85	24	30.0	30.0	33.	34.4	8.00	.	.	.	.	.	.	.
05-28-82	0940	0.73	30	30.0	30.0	34.4	35.5	8.15	5.2	.	.	.	.	.	.
06-01-82	1025	0.67	14	30.0	30.0	35.5	35.5	8.30	.	.	.	.	.	.	.
06-02-82	0955	1.7	13	30.0	30.0	34.4	34.4	8.30	.	.	.	.	.	.	.
06-03-82	0755	1.4	27	30.0	30.0	32.2	34.4	8.30	.	.	.	.	.	.	.
08-05-82	1030	1.3	29	28.0	28.0	33.3	33.3	8.22	5.2	0.16	0.15	0.007	0.032	0.018	0.010
08-07-82	0745	0.98	30	28.0	28.0	32.8	33.3	8.18	4.6	0.57	0.56	0.005	0.040	0.015	0.012
08-08-82	0815	1.3	35	29.0	28.5	33.9	33.3	7.85	5.1	0.16	0.15	0.007	0.044	0.014	0.010
11-10-82	1500	1.8	40	28.7	28.7	33.3	33.3	8.05	5.2	0.30	0.29	0.024	0.012	0.007	0.005
11-11-82	1056	1.8	38	27.9	28.2	32.2	33.9	8.18	4.8	0.28	0.26	0.025	0.006	0.007	0.005
11-12-82	1100	1.5	23	28.4	28.7	34.4	34.4	8.20	5.1	0.21	0.19	0.024	0.018	0.009	0.007
01-12-83	0915	1.5	17	28.0	27.9	35.5	35.5	8.25	5.8	0.96	0.95	0.006	0.006	0.005	0.004
01-13-83	0855	1.3	46	28.3	28.0	35.5	35.0	8.05	6.0	0.85	0.84	0.010	0.016	0.005	0.005
01-14-83	0820	1.1	36	28.0	27.8	35.5	35.5	8.15	5.8	0.46	0.42	0.040	0.016	0.005	0.004
04-07-83	0900	0.78	47	28.4	28.0	35.5	35.5	8.05	5.6	0.05	0.03	-0.017	0.018	0.006	0.006
04-08-83	0920	0.94	72	28.5	28.7	35.5	35.5	8.15	5.5	0.06	0.05	0.007	0.027	0.009	0.006
04-11-83	0920	0.53	37	28.5	28.6	35.5	35.5	8.10	5.6	0.20	0.19	0.007	0.041	0.008	0.007
07-07-83	1135	2.6	50	28.8	28.8	33.9	34.4	8.02	5.1	0.40	0.39	0.008	0.058	0.094	0.087
07-08-83	0935	3.1	20	28.6	28.8	30.0	32.2	8.02	5.5	0.46	0.45	0.008	0.034	0.443	0.300
07-11-83	0915	1.2	40	28.9	28.5	33.3	33.3	8.25	5.2	0.31	0.25	0.064	0.043	0.530	0.054
10-07-83	0955	5.9	48	29.0	28.5	30.5	33.3	8.00	4.9	0.65	0.63	0.025	0.012	0.120	0.004
10-11-83	0910	2.5	30	29.7	30.1	34.4	34.4	7.78	4.6	0.76	0.74	0.023	0.006	0.012	0.004
10-10-83	0910	2.8	14	29.7	30.1	34.4	33.3	8.12	5.2	0.29	0.27	0.023	0.022	0.012	0.005
01-18-84	1025	1.7	20	29.1	29.5	31.1	33.3	8.10	5.9	0.24	0.21	0.029	0.022	0.180	0.108
01-19-84	1005	1.7	20	29.0	28.8	33.3	33.3	8.20	5.3	0.31	0.30	0.011	0.022	0.178	0.078
01-20-84	0943	1.9	24	29.0	29.3	33.3	33.3	8.20	5.8	0.15	0.14	0.009	0.022	0.200	0.099
04-03-84	1145	2.7	49	28.9	28.9	33.3	33.3	8.35	5.6	0.25	0.24	0.006	0.011	0.013	0.009
04-04-84	0947	3.8	30	28.5	28.6	34.4	34.4	8.08	5.1	0.04	0.03	0.007	0.012	0.019	0.012
04-06-84	0936	1.8	21	28.4	28.4	35.0	35.0	8.00	5.3	0.13	0.12	0.009	0.008	0.150	0.010
07-12-84	1440	1.8	30	29.0	29.3	34.4	35.5	8.22	5.7	0.09	0.09	0.004	0.030	0.013	0.007
07-16-84	0840	2.4	40	29.1	28.8	35.5	35.5	8.22	4.8	0.18	0.17	0.072	0.052	0.012	0.009
07-17-84	0725	2.3	18	28.9	28.6	35.5	35.5	8.30	6.4	0.13	0.12	0.007	0.080	0.021	0.007

Table 46. continued.

Station	Parameter	N	Mean	Root MSE*	F-Value	Significance
14	Turbidity	17	1.1	0.3	4.74	.015
	TNFR	18	29	22	1.30	NS
	Sur. Temp	18	29.5	0.9	0.15	NS
	-1m Temp	18	29.3	0.5	1.80	NS
	Sur. Salinity	18	34.9	0.4	5.08	.010
	-1m Salinity	18	34.7	0.4	10.47	.001
	pH	18	8.23	0.11	0.67	NS
	Dis. Oxygen	17	6.3	0.9	0.50	NS
	Total Nitrogen	13	0.147	0.060	9.88	.003
	TKN	13	0.143	0.065	7.13	.009
	Nitrate	18	0.011	0.004	8.51	.001
	Ammonia	18	0.029	0.016	3.04	NS
	Ortho Phos	18	0.050	0.005	709.40	.001
	Total Phos	18	0.196	0.058	122.19	.001

* Root MSE - Root Mean Square Error.
** NS - Not significant at $P \geq 0.05$.

Table 6. Water quality at station 5 in Okat harbor. A period represents a "no sample taken" for sample period.

Date	Time	Turb	TNFR	Surface	-1m Temp	Surface Temp.	-1m Salinity	pH Salinity	DO	TN	TKN	NO	NH	TP	OP
05-17-82	1045	0.12	18	30.0	30.0	35.5	34.4	8.20	.	0.44	0.44	0.002	0.037	0.010	0.009
05-19-82	0950	0.55	59	29.0	29.0	33.3	34.4	8.10	.	0.23	0.23	0.001	0.025	0.016	0.006
05-20-82	1015	0.40	94	29.0	29.0	33.3	35.5	8.05	.	0.18	0.18	0.001	0.043	0.010	0.008
05-21-82	1320	0.24	15	30.0	30.0	33.3	34.4	8.13	.	.	.	.	.	.	.
05-28-82	1000	0.62	26	30.0	30.0	34.4	35.5	8.12	5.1	.	.	.	.	.	.
06-01-82	1130	2.2	13	31.0	31.0	35.5	35.5	7.80	.	.	.	.	.	.	.
06-02-82	1015	0.90	30	30.0	30.0	34.4	34.4	8.25	.	.	.	.	.	.	.
06-03-82	0810	0.69	21	30.0	30.0	31.1	33.3	8.30	.	.	.	.	.	.	.
08-05-82	1050	0.62	37	28.0	28.0	34.4	35.0	8.05	5.8	0.06	0.06	0.004	0.036	0.012	0.005
08-07-82	0800	0.47	13	28.5	28.0	33.3	33.9	8.28	5.4	0.13	0.13	0.002	0.048	0.008	0.005
08-08-82	0835	0.75	26	29.0	28.5	33.3	34.4	8.05	5.5	0.14	0.13	0.005	0.032	0.019	0.007
11-10-82	1520	1.7	36	28.8	28.6	33.3	33.3	8.23	6.5	0.27	0.25	0.016	0.003	0.009	0.003
11-11-82	1112	1.6	46	28.2	28.4	33.3	34.4	8.35	4.9	0.25	0.23	0.020	0.071	0.007	0.004
11-12-82	1050	0.55	15	28.9	29.0	34.3	34.4	8.30	5.4	0.36	0.35	0.010	0.013	0.013	0.004
01-12-83	0935	0.68	7	28.2	28.2	35.0	34.4	8.00	5.2	0.06	0.06	0.001	0.007	0.036	0.036
01-13-83	0915	0.55	6	28.3	28.0	35.5	34.4	8.20	5.6	0.80	0.80	0.007	0.016	0.124	0.124
01-14-83	0840	0.57	17	28.2	28.1	35.5	35.0	8.15	5.8	0.54	0.53	0.004	0.012	0.004	0.001
04-07-83	0915	0.52	10	28.4	28.1	35.5	35.5	8.08	6.0	0.04	0.03	0.009	0.025	0.023	0.015
04-08-83	0935	0.58	59	28.5	28.6	35.5	35.5	8.18	4.9	0.04	0.003	0.005	0.039	0.008	0.006
04-11-83	0945	0.47	20	28.5	29.3	35.5	35.5	8.02	5.8	0.27	0.25	0.018	0.023	0.011	0.007
07-07-83	1150	1.1	29	29.1	29.1	34.4	34.4	8.00	5.7	0.34	0.33	0.007	0.055	0.594	0.060
07-08-83	0950	2.2	14	28.8	29.2	32.2	33.3	8.15	5.7	0.32	0.31	0.004	0.072	0.737	0.329
07-11-83	0925	1.4	30	28.6	28.5	33.9	33.4	8.10	5.2	0.27	0.26	0.007	0.039	0.343	0.060
10-07-83	1010	2.0	38	28.8	28.8	32.2	33.3	8.20	4.8	1.02	1.01	0.014	0.014	0.011	0.004
10-11-83	0930	1.1	19	29.5	29.9	34.4	34.4	8.15	5.1	0.82	0.81	0.010	0.026	0.009	0.002
10-10-83	0930	2.2	27	29.5	30.0	33.3	33.3	8.15	5.6	0.64	0.63	0.011	0.034	0.010	0.002
01-18-84	1040	1.4	43	29.2	29.5	31.1	33.3	8.20	6.2	0.46	0.45	0.008	0.016	0.150	0.080
01-19-84	1020	1.2	30	29.0	29.0	31.1	33.9	8.20	5.6	0.42	0.41	0.008	0.019	0.180	0.088
01-20-84	0958	1.3	13	28.4	29.2	32.2	33.9	8.22	6.1	0.36	0.35	0.011	0.019	0.175	0.081
04-03-84	1200	3.1	36	28.9	29.2	34.4	34.4	8.10	5.7	0.07	0.06	0.005	0.024	0.013	0.008
04-04-84	1000	1.8	25	28.8	28.9	35.0	34.4	8.10	6.2	0.02	0.01	0.005	0.014	0.010	0.006
04-06-84	0950	1.8	22	28.4	28.4	35.0	35.0	8.10	5.3	0.07	0.06	0.008	0.008	0.010	0.008
07-12-84	1455	1.4	50	29.1	29.1	36.1	36.1	8.20	5.7	0.07	0.06	0.009	0.021	0.011	0.005
07-16-84	0900	1.1	24	28.8	28.8	35.5	35.5	8.22	4.8	0.10	0.09	0.005	0.023	0.013	0.006
07-17-84	0745	1.4	34	28.9	28.8	35.5	35.5	8.32	6.4	0.15	0.14	0.007	0.044	0.012	0.006

Table 47. continued.

Station	Parameter	N	Mean	Root MSE	F-Value	Significance	Station Source
4	Turbidity	26	3.4	2.9	8.60	.001	1 higher; 6 lower
	TNFR	18	113	125	8.24	.001	1 higher
	Sur. Temp	26	28.3	0.6	1.62	NS	
	-1m Temp	26	28.6	0.5	0.42	NS	
	Sur. Salinity	26	32.1	3.4	4.51	.004	1 lower
	-1m Salinity	26	33.4	0.7	4.76	.003	1 lower
	pH	26	8.10	0.17	7.26	.003	1 lower; 6 higher
	Dis. Oxygen	19	4.9	0.5	3.87	.022	1 lower; 6 higher
	Total Nitrogen	18	0.384	0.168	4.79	.012	1 higher
	TKN	18	0.350	0.159	5.03	0.010	1 higher
	Nitrate	26	0.022	0.006	10.48	.001	1 higher
	Ammonia	26	0.026	0.022	0.68	NS	
	Ortho Phos	26	0.015	0.013	3.31	0.018	1, 2 higher; 6 lower
	Total Phos	26	0.020	0.013	7.72	.001	1, 2 higher; 6 lower
5	Turbidity	30	2.5	1.8	3.67	.008	1, 13 higher; 6 lower
	TNFR	21	35	11	15.77	.001	1 higher
	Sur. Temp	30	27.8	0.4	4.53	.003	1 lower; 6 higher
	-1m Temp	30	27.8	0.4	3.97	.005	1 lower; 6 higher
	Sur. Salinity	30	35.1	0.6	3.48	.010	1 lower
	-1m Salinity	30	35.1	0.5	1.26	NS	
	pH	30	8.09	0.15	3.10	.018	1 lower
	Dis. Oxygen	28	5.5	0.4	2.19	NS	
	Total Nitrogen	23	0.480	0.309	1.53	NS	
	TKN	23	0.469	0.312	1.50	NS	
	Nitrate	28	0.011	0.009	0.92	NS	
	Ammonia	28	0.023	0.032	1.62	NS	
	Ortho Phos	29	0.048	0.052	1.81	NS	
	Total Phos	29	0.050	0.051	1.83	NS	
6	Turbidity	30	1.0	0.4	6.91	.001	1, 2 higher; 6 lower
	TNFR	30	46	34	0.28	NS	
	Sur. Temp	30	28.5	0.6	1.99	NS	
	-1m Temp	30	28.5	0.4	2.40	.050	1 lower; 14 higher
	Sur. Salinity	30	35.3	0.2	7.20	.001	1 lower
	-1m Salinity	30	35.2	0.3	3.89	.006	1 lower
	pH	30	8.08	0.16	2.58	.037	1 lower
	Dis. Oxygen	29	5.5	0.5	5.45	.001	1 lower
	Total Nitrogen	22	0.136	0.079	0.71	NS	
	TKN	22	0.117	0.079	0.60	NS	
	Nitrate	29	0.018	0.016	3.29	0.014	1 higher
	Ammonia	30	0.023	0.008	0.99	NS	
	Ortho Phos	30	0.008	0.003	4.77	.002	1 higher
	Total Phos	30	0.018	0.031	0.87	NS	

Table 8. Water quality at station 7 in Okat harbor. A period represents a "no sample taken" for sample period.

Date	Time	Turb	TNFR	Surface Temp	-1m Temp.	Surface Salinity	-1m Salinity	pH	DO	TN	TKN	NO	NH	TP	OP
05-17-82	1115	0.50	18	31.5	31.0	34.4	34.4	8.20	.	.	.	.	.	.	.
05-19-82	1015	0.73	92	29.0	29.0	32.7	34.4	8.00	.	.	.	.	.	.	.
05-19-82	1020	0.61	41	30.0	30.0	34.4	34.4	8.12	.	.	.	.	.	.	.
05-20-82	1030	0.90	36	29.5	29.5	32.2	33.3	7.98	.	.	.	.	.	.	.
05-20-82	1035	0.52	485	30.0	30.0	33.2	33.3	7.98	.	.	.	.	.	.	.
08-07-82	0825	2.0	.	28.0	28.0	32.2	34.4	7.85	.	.	.	.	.	.	.
08-08-82	0855	2.2	.	28.5	28.0	30.0	33.3	7.65	.	0.02	0.01	0.006	0.040	.	.
11-11-82	1135	1.6	.	28.2	28.1	32.2	33.3	8.28	.	.	.	0.018	0.024	0.013	0.006
11-11-82	1140	2.3	.	27.9	28.1	32.2	32.2	8.23	.	.	.	0.019	0.078	0.009	0.007
11-12-82	1120	1.1	.	28.9	29.2	34.4	34.4	8.32	5.8	.	.	0.015	0.018	0.006	0.005
11-12-82	1125	1.1	.	29.0	29.2	34.4	34.4	8.42	.	.	.	0.020	0.022	0.014	0.005
01-12-83	0955	5.3	.	28.0	28.3	35.0	36.6	8.00	5.6	.	.	.	.	.	.
01-13-83	0935	1.0	.	28.2	28.2	35.5	35.0	8.13	5.5	0.42	0.42	0.002	0.005	0.199	0.199
01-14-83	0915	0.88	.	28.2	28.0	35.0	35.0	8.10	5.5	.	.	0.008	0.004	0.005	0.005
04-07-83	0935	0.88	27	28.4	28.5	35.5	35.5	8.10	5.4	0.20	0.18	0.021	0.027	0.015	0.006
04-08-83	0955	0.85	80	28.6	29.2	35.5	34.4	8.18	4.9	.	.	0.000	0.019	0.016	0.004
04-11-83	1005	0.93	28	28.7	28.7	35.0	35.5	8.05	5.6	.	.	0.005	0.011	0.012	0.006
07-07-83	1210	1.2	32	29.1	29.1	34.4	34.4	8.08	5.8	.	.	0.007	0.039	0.937	0.261
07-08-83	1010	2.8	21	28.9	28.7	33.33	32.2	8.10	4.9	.	.	0.007	0.087	0.822	0.317
07-11-83	0845	1.4	22	28.7	28.7	32.2	32.2	8.10	6.2	.	.	0.018	0.063	0.355	0.355
10-07-83	0945	1.4	22	28.9	29.1	33.3	33.3	8.08	4.6	1.03	1.01	0.024	0.031	0.012	0.005
10-11-83	0955	1.5	25	29.2	30.1	31.1	33.3	8.21	5.7	1.02	1.01	0.015	0.018	0.014	0.005
10-10-83	0955	2.0	32	29.2	29.5	30.5	30.0	8.08	4.3	0.86	0.84	0.022	0.027	0.017	0.008
01-18-84	1105	2.0	.	29.1	29.2	28.9	32.2	8.25	5.1	0.77	0.76	0.013	0.024	0.176	0.088
01-19-84	1045	1.6	.	28.8	29.1	31.1	32.7	8.08	5.1	0.88	0.87	0.009	0.022	0.147	0.047
01-20-84	1018	1.8	.	28.8	29.2	30.0	33.9	8.30	5.5	0.37	0.35	0.020	0.022	0.158	0.078
04-03-84	1215	2.9	47	28.9	29.1	34.4	34.4	8.05	5.3	0.07	0.06	0.004	0.015	0.012	0.010
04-04-84	1015	2.2	34	28.6	28.8	35.0	35.0	0.02	5.6	0.07	0.06	0.004	0.012	0.016	0.008
04-04-84	1005	1.7	19	28.4	28.3	35.0	34.4	8.00	5.4	0.07	0.06	0.008	0.015	0.015	0.011
07-12-84	1515	2.0	22	29.0	29.0	35.5	34.4	8.18	5.9	0.05	0.04	0.006	0.107	0.009	0.005
07-16-84	0920	1.8	193	29.0	29.0	35.5	35.0	8.20	5.0	0.10	0.09	0.012	0.021	0.011	0.006
07-17-84	0820	1.7	108	29.2	29.1	35.5	35.0	8.22	6.6	0.11	0.09	0.016	0.117	0.012	0.007

Table 47. continued.

Station	Parameter	N	Mean	Root MSE	F-Value	Significance	Station Source
10	Turbidity	29	2.4	0.9	4.96	.002	6 lower
	TNFR	30	37	21	2.23	NS	
	Sur. Temp	30	28.6	0.5	1.02	NS	
	-1m Temp	30	28.7	0.4	0.48	NS	
	Sur. Salinity	30	34.3	1.9	1.20	NS	
	-1m Salinity	30	34.6	0.4	2.07	NS	
	pH	30	7.82	1.47	1.06	NS	
	Dis. Oxygen	30	5.5	0.7	4.12	.004	9 higher; 1 lower
	Total Nitrogen	27	0.084	0.079	0.60	NS	
	TKN	27	0.076	0.079	0.56	NS	
	Nitrate	30	0.006	0.002	3.92	.005	6 lower
	Ammonia	30	0.015	0.007	0.94	NS	
	Ortho Phos	30	0.009	0.002	6.48	.001	6 lower
	Total Phos	30	0.019	0.025	1.21	NS	
11	Turbidity	30	2.4	0.9	10.19	.001	6, 14 lower
	TNFR	30	52	54	0.85	NS	
	Sur. Temp	30	29.1	0.6	0.92	NS	
	-1m Temp	30	29.1	0.6	0.96	NS	
	Sur. Salinity	30	34.7	3.2	1.60	NS	
	-1m Salinity	30	35.3	0.5	2.05	NS	
	pH	30	8.19	0.06	5.27	.001	14 higher
	Dis. Oxygen	30	5.7	1.0	0.64	NS	
	Total Nitrogen	27	0.110	0.054	0.27	NS	
	TKN	27	0.100	0.053	0.30	NS	
	Nitrate	30	0.015	0.022	0.68	NS	
	Ammonia	30	0.057	0.023	4.54	.002	6 lower
	Ortho Phos	30	0.008	0.002	7.31	.001	1 higher
	Total Phos	30	0.016	0.006	10.58	.001	1 higher

Table 10. Water quality at station 13 in Okat harbor. A period represents a "no sample taken" for sample period.

Date	Time	Turb	TNFR	Surface Temp	-1m Temp.	Surface Salinity	-1m Salinity	pH	DO	TN	TKN	NO	NH	TP	OP
05-19-82	1050	4.4	149	30.0	30.0	35.0	35.0	8.15	.	.	.	.	.	.	.
05-20-82	1042	7.7	133	29.0	29.0	34.4	34.4	7.80	.	.	.	.	.	.	.
05-20-82	1043	4.6	183	29.0	29.0	34.4	35.4	7.80	.	.	.	.	.	.	.
05-20-82	1044	5.8	118	30.0	30.0	34.4	35.5	8.00	.	.	.	.	.	.	.
05-20-82	1045	6.5	122	30.5	30.5	34.4	35.5	8.04	.	.	.	.	.	.	.
08-07-82	0832	6.1	.	28.0	28.0	32.2	32.2	8.02	.	.	.	.	.	.	.
08-08-82	0905	5.6	.	29.0	29.0	32.2	32.2	7.75	.	0.16	0.16	0.004	0.040	.	.
11-12-82	1135	5.9	.	27.8	28.2	33.3	33.3	7.80	.	.	.	0.022	0.037	0.018	0.018
01-12-83	1005	6.3	.	27.3	27.3	35.5	35.5	8.63	.	.	.	.	.	0.007	0.003
01-12-83	1008	6.0	.	27.3	27.2	35.5	34.4	8.10	5.6	.	.	0.005	0.160	0.007	0.003
01-13-83	0945	4.9	9	27.5	27.4	35.5	35.0	8.08	5.6	0.48	0.47	0.006	0.011	0.079	0.079
01-14-83	0930	2.0	.	27.8	27.8	35.5	34.4	8.05	5.5	.	.	0.005	0.022	0.005	0.003
04-07-83	0950	0.88	28	28.3	28.3	35.0	35.0	8.12	6.0	0.19	0.18	0.013	0.026	0.011	0.007
04-08-83	1015	1.1	55	28.3	28.8	35.0	35.0	8.28	5.5	.	.	0.022	0.025	0.007	0.007
04-11-83	1030	1.4	8	28.8	28.4	35.0	35.5	7.95	4.8	.	.	0.027	0.023	0.012	0.006
07-07-83	1220	3.7	39	29.6	29.5	34.4	33.9	8.00	5.4	.	.	0.003	0.096	0.831	0.291
07-08-83	1025	3.8	44	28.8	28.8	33.3	33.3	8.08	6.1	.	.	0.004	0.034	0.957	0.262
07-11-83	1000	3.4	50	28.8	28.8	34.4	34.4	8.15	4.9	.	.	0.003	0.072	0.717	0.252
10-07-83	1045	2.8	.	29.8	29.5	32.2	34.4	8.12	5.5	0.03	0.01	0.020	0.024	0.013	0.005
10-11-83	1020	4.2	.	29.8	29.8	34.4	34.4	8.10	4.8	0.03	0.01	0.023	0.020	0.023	0.005
10-10-83	1020	2.8	.	29.8	29.5	30.5	33.3	8.02	4.9	0.03	0.01	0.015	0.016	0.012	0.004
01-18-84	1120	1.8	.	29.2	29.5	33.3	33.9	8.18	5.7	0.71	0.70	0.007	0.018	0.151	0.073
01-19-84	1100	1.5	.	29.3	29.3	34.4	34.4	8.10	5.9	0.70	0.69	0.008	0.020	0.158	0.068
01-20-84	1033	1.2	.	29.8	29.7	34.4	34.4	8.18	5.7	0.83	0.82	0.007	0.018	0.132	0.065
04-03-84	1232	2.0	47	28.8	28.9	34.4	34.4	8.02	6.3	.	.	0.005	0.017	0.010	0.007
04-04-84	1031	1.8	60	28.4	28.5	35.0	35.0	8.10	6.2	.	.	0.005	0.016	0.011	0.006
04-06-84	1022	2.0	33	28.4	28.5	34.4	35.0	8.02	4.8	.	.	0.006	0.012	0.016	0.009
07-12-84	1530	3.9	56	28.9	29.0	35.5	35.0	8.22	5.9	.	.	0.012	0.100	0.017	0.007
07-16-84	0940	6.3	80	31.8	31.8	35.5	35.5	8.12	5.1	.	.	0.007	0.108	0.014	0.009
07-17-84	0850	2.5	20	29.0	29.0	36.6	36.6	8.18	5.4	.	.	0.024	0.089	0.013	0.008

Table 48. continued.

Station	Parameter	WIND DIRECTION F-Value	WIND DIRECTION Significance	RAINFALL F-Value	RAINFALL Significance	TIDAL CYCLE F-Value	TIDAL CYCLE Significance	3-way ANOVA
4	Turbidity	0.38	NS	9.62	.001	1.04	NS	*
	TNFR	0.56	NS	1.19	NS	0.23	NS	
	Sur. Temp	1.65	NS	19.82	.001	0.02	NS	*
	-1m Temp	2.85	NS	18.66	.001	0.32	NS	*
	Sur. Salinity	0.38	NS	7.03	.004	1.37	NS	*
	-1m Salinity	0.98	NS	13.62	.001	2.76	NS	*
	pH	1.32	NS	0.64	NS	0.16	NS	*
	Dis. Oxygen	5.03	.010	1.62	NS	0.24	NS	*
	Total Nitrogen	1.26	NS	0.65	Ns	7.42	.004	*
	TKN	1.53	NS	0.57	NS	8.32	.002	*
	Nitrate	0.61	NS	2.66	NS	0.09	NS	
	Ammonia	0.71	NS	1.50	NS	1.26	NS	
	Ortho Phos	2.03	NS	2.53	NS	0.32	NS	
	Total Phos	2.07	NS	4.47	.025	0.18	NS	
5	Turbidity	0.22	NS	2.84	NS	2.07	NS	
	TNFR	0.09	NS	0.25	NS	0.71	NS	
	Sur. Temp	0.23	NS	9.50	.001	0.32	NS	*
	-1m Temp	0.20	NS	6.47	.005	1.02	NS	*
	Sur. Salinity	0.50	NS	6.36	.006	0.83	NS	*
	-1m Salinity	1.13	NS	5.99	.007	0.71	NS	*
	pH	1.72	NS	0.45	NS	0.16	NS	
	Dis. Oxygen	0.42	NS	1.15	NS	0.49	NS	
	Total Nitrogen	1.09	NS	2.85	NS	3.96	.034	*
	TKN	1.13	NS	2.78	NS	4.03	.032	*
	Nitrate	1.73	NS	2.99	NS	0.13	NS	
	Ammonia	2.58	NS	0.42	NS	2.83	NS	
	Ortho Phos	2.72	NS	1.56	NS	0.80	NS	
	Total Phos	4.11	.018	3.96	.034	0.15	NS	*
6	Turbidity	3.35	.034	9.80	.001	3.76	.036	*
	TNFR	0.49	NS	1.87	NS	0.34	NS	
	Sur. Temp	0.04	NS	10.16	.001	0.82	NS	*
	-1m Temp	0.13	NS	10.24	.001	0.05	NS	*
	Sur. Salinity	3.16	.041	7.47	.003	3.21	NS	*
	-1m Salinity	6.61	.001	16.18	.001	1.45	NS	*
	pH	0.12	NS	2.75	NS	0.42	NS	
	Dis. Oxygen	0.37	NS	1.29	NS	1.57	NS	
	Total Nitrogen	0.63	NS	6.75	.005	2.76	NS	*
	TKN	0.70	NS	6.95	.005	2.70	NS	*
	Nitrate	0.13	NS	0.24	NS	0.37	NS	
	Ammonia	1.13	NS	7.81	.003	3.03	NS	*
	Ortho Phos	2.13	NS	0.87	NS	0.51	NS	
	Total Phos	2.84	N	3.78	.039	0.19	NS	

contribute considerable quantities of suspended sediments, particulate matter and nutrients to the marine system within Okat harbor and the surrounding reef complex. Therefore, it was essential to establish a WQ station which monitored this river discharge. WQ data from this station made it possible to distinguish changes in marine WQ between man-made and natural processes. Although station 1 is a primary WQ station located near the WQ boundary, fluctuations in WQ reflected natural changes and were not attributable to construction related perturbations. Mean turbidity levels at station 1 always exceeded the turbidity standard with the lowest turbidity occurring in quarter 6 (2.3 NTU) and the highest in quarter 7 (43 NTU). Sampling in quarter 6 was conducted during a major drought when river discharges were minimized, while quarter 7 represents the first time period after the drought in a heavy rainfall period.

Station 2 was located along the edge of a fringing reef adjacent to the marine delta flood-plain. This station received periodic impacts from river discharges, particularly in periods of heavy runoff. Turbidity plumes originating from the construction site, primarily the dredge channel and docking area, were observed to commonly inundate this station. Turbidity ranged from 0.54 to 4.7 NTU with a mean of 2.4 NTU.

Station 3 was located along the southeast edge of a patch reef. This patch reef had luxuriant coral growth. The upper surface of this patch reef exposed at low tide. The northern edge was subsequently dredged during the construction phase. Turbidity ranged from 0.21 to 5.9 NTU with a mean of 1.7 NTU. A substantial amount of sedimentation occurred at this station as a result of the adjacent dredge operations.

Station 4 was located on the northwestern tip of an extended portion of the SE fringing reef of Okat harbor. The coral growth was similar to that found at station 3. This station was frequently inundated by construction related sedimentation plumes. Turbidity ranged from 0.25 to 2.3 NTU with a mean of 1.1 NTU. Strong tidal currents in this area kept this station mostly swept clean of fine sediments.

Station 5 was located in the central portion of the harbor mouth. Since the boat could not be anchored in this location due to water depth, strong currents and wave action, samples were collected as the boat drifted. The water mass sampled at this station was either an incoming or outgoing flow, dependent on tidal conditions. For the most part, this station was sampled on an outflowing tide. Additionally, surface outflows occurred within the harbor mouth during rising tide periods as a result of flow across the reef flat and wind conditions. Major inflow into the harbor generally occurred at deeper depths. Turbidity ranged from 0.12 to 3.1 NTU with a mean of 1.1 NTU. There were large turbidity plumes at this station during outflowing tides. Generally, these plumes contained extensive quantities of organic matter.

Station 6 was a control station established away from the harbor. There was no fixed location for this station. The boat was run seaward until it either was beyond the outer extend of the fringing reef or beyond

Table 48. continued.

Station	Parameter	WIND DIRECTION F-Value	WIND DIRECTION Significance	RAINFALL F-Value	RAINFALL Significance	TIDAL CYCLE F-Value	TIDAL CYCLE Significance	3-way ANOVA
14	Turbidity	1.22	NS	3.49	NS	4.51	.044	*
	TNFR	1.05	NS	6.96	.013	1.26	NS	*
	Sur. Temp	0.32	NS	0.05	NS	1.48	NS	
	-1m Temp	1.53	NS	1.13	NS	1.23	NS	
	Sur. Salinity	0.09	NS	1.02	NS	0.36	NS	
	-1m Salinity	2.45	NS	2.50	NS	0.28	NS	*
	pH	0.72	NS	0.05	NS	0.22	NS	
	Dis. Oxygen	0.08	NS	3.65	NS	0.13	NS	
	Total Nitrogen	4.74	NS	0.58	NS	5.59	.050	
	TKN	4.23	N3	0.44	NS	4.71	NS	
	Nitrate	2.06	NS	2.75	NS	2.51	NS	
	Ammonia	2.27	NS	1.91	NS	1.91	NS	
	Ortho Phos	4.08	.039	9.66	.005	1.39	NS	*
	Total Phos	2.72	NS	6.63	.015	2.48	NS	

Table 12. continued.

Station	Quarter	TURB	TNFR	SUR TEMP	-1m TEMP	SUR SAL	-1m SAL	DO	PH	TKN	TN	NO_3	NH_3	OP	TP
3	5	1.3	33	28.1	27.9	35.5	35.3	5.9	8.15	.737	.757	.019	.013	.004	.005
	6	0.75	52	28.5	28.4	35.5	35.5	5.6	8.10	.090	.103	.010	.029	.006	.008
	7	2.3	37	28.8	28.7	32.4	33.3	5.3	8.10	.363	.390	.027	.045	.147	.356
	8	3.7	31	29.5	29.6	33.1	33.7	4.9	7.97	.547	.567	.024	.013	.004	.048
	9	1.8	21	29.0	29.2	32.6	33.3	5.7	8.17	.217	.233	.016	.022	.095	.186
	10	2.8	33	28.6	28.6	34.2	34.2	5.3	8.14	.130	.140	.007	.010	.010	.061
	11	2.2	29	29.0	28.9	35.1	35.5	5.6	8.25	.127	.133	.028	.054	.008	.015
4	1	0.47	23	29.9	29.9	34.3	34.7	.	8.05	.247	.0267	.019	.041	.006	.010
	2	0.71	41	30.2	30.2	34.7	34.4	5.5	8.26	.	.	.	.	.	.
	3	0.87	39	28.7	28.7	34.2	34.2	4.9	8.16	.187	.197	.006	.040	.011	.016
	4	1.6	27	28.5	28.5	34.1	33.2	4.4	8.21	.153	.237	.022	.032	.007	.012
	5	0.90	14	28.2	28.0	35.3	35.2	5.6	8.18	.883	.893	.006	.007	.034	.034
	6	0.70	62	28.5	28.5	35.5	35.5	5.6	8.07	.100	.107	.008	.020	.006	.009
	7	1.5	23	28.6	28.7	32.6	33.3	5.0	8.03	.310	.310	.006	.042	.160	.404
	8	1.4	19	29.5	29.5	32.2	33.7	5.0	8.10	1.007	1.023	.020	.013	.004	.013
	9	1.4	18	29.0	29.1	32.2	32.6	5.3	8.18	.517	.530	.013	.022	.084	.175
	10	1.8	54	28.7	28.8	34.4	34.4	5.3	8.15	.120	.130	.007	.017	.007	.012
	11	1.3	42	29.0	29.0	35.4	35.5	5.3	8.14	.100	.113	.010	.086	.007	.011
5	1	0.33	46	29.5	29.5	33.8	34.7	.	8.12	.283	.283	.001	.035	.008	.012
	2	1.1	22	30.2	30.2	33.8	34.7	5.1	8.12	.	.	.	.	.	.
	3	0.61	25	28.5	28.2	33.7	34.4	5.6	8.13	.107	.110	.004	.039	.006	.013
	4	1.3	32	28.6	28.7	33.6	34.0	5.6	8.29	.277	.293	.015	.029	.004	.009
	5	0.60	10	28.2	28.1	35.3	34.6	5.5	8.12	.463	.467	.004	.012	.054	.055
	6	0.52	30	28.5	28.7	35.5	35.5	5.6	8.09	.103	.117	.011	.029	.009	.014
	7	1.6	24	28.8	28.9	33.5	33.7	5.5	8.08	.300	.310	.006	.055	.150	.558
	8	1.8	28	29.3	29.6	33.3	33.7	5.2	8.17	.817	.827	.012	.025	.003	.010
	9	1.3	29	29.2	29.2	31.5	33.7	6.0	8.21	.403	.413	.009	.018	.083	.168
	10	2.2	28	28.2	28.8	34.8	34.6	5.7	8.10	.043	.053	.006	.015	.007	.011
	11	1.3	36	28.9	28.9	35.7	35.7	5.6	8.25	.097	.107	.007	.029	.006	.012

activities. DO showed decreases at all the stations for the Part B monitoring period. However, these decreases were not significant. There were no changes in surface temperatures or pH measurements between monitoring periods. The nutrients were more variable with generally similar TKN concentrations and higher TP concentrations. These changes in nutrient levels were a result of both man-induced and natural perturbations.

SUMMARY

The Part B Construction monitoring program at Okat harbor showed a degradation of marine water quality (WQ) around the airport runway, docking facility, harbor system and surrounding reef-flat complex. The major impact was caused by increased turbidity levels attributed to construction operations.

The mean turbidities at primary WQ stations 1, 2 and 3, as well as secondary WQ stations 7, 9 and 13, exceeded the turbidity standard. This indicates that these stations were subjected to excessive turbidities which could cause environmental degradations. The high mean turbidity at station 3 indicates that turbidity levels in excess of the standard occurred beyond the WQ boundary. The high mean turbidities at stations 1 and 2 were caused, for the most part, by the natural river discharge and tidal flushing from the adjacent mangrove fringe.

The increased turbidity levels and associated turbidity plumes that were caused by dredge and fill operations had the potential to stress the marine biota throughout the Okat coastal zone. The harbor area received the principle environmental degradation, but the adjacent fringing mangrove system and the reef flat west of the harbor also received periodic heavy stress from excessive turbidity plumes. Oil and grease surface films were frequently associated with these large turbidity plumes.

Accumulations of lime-muds deposited in the shallow waters adjacent to the runway and docking facility and in the dredge channel were easily resuspended into the water column by normal tidal changes and hydrographic conditions. These resuspended turbidity plumes impacted large areas of the harbor complex and mangrove system, including periodic influence on the off-shore control site. It is anticipated that these lime-mud deposits will eventually become stabilized, which will minimize resuspension. However, there may be a long-term period required for stabilization. Therefore, the marine ecosystem in Okat harbor may become modified as a result of this long-term stress. The restricted water circulation within Okat harbor has hindered the removal of the silty-ooze and lime-mud deposits to deeper off-shore waters. This problem was caused in part by having the dredge channel left closed at the seaward end. Although there were strong currents within the dredge channel during strong tidal change and heavy surf periods, these currents were insufficient to cause extensive

Table 12. continued.

Station	Quarter	TURB	TNFR	SUR TEMP	-1m TEMP	SUR SAL	-1m SAL	DO	PH	TKN	TN	NO_3	NH_3	OP	TP
13	1	5.8	141	29.7	29.7	34.5	35.2	.	7.97	.	.	.	.	.	.
	3	5.8	.	29.5	28.5	32.2	32.2	.	7.88	.160	.160	.004	.040	.	.
	4	5.9	.	27.8	28.2	33.3	33.3	.	7.80	.	.	.022	.037	.018	.018
	5	4.8	9	27.5	27.4	35.5	34.8	5.6	8.21	.470	.480	.005	.064	.022	.024
	6	1.1	30	28.5	28.5	35.0	35.2	5.4	8.12	.180	.190	.021	.025	.007	.010
	7	3.6	44	29.1	29.0	34.0	33.9	5.5	8.08	.	.	.003	.067	.268	.835
	8	3.3	.	29.8	29.6	32.4	34.0	5.1	8.08	.010	.030	.019	.020	.005	.016
	9	1.5	.	29.4	29.5	34.0	34.2	5.8	8.15	.737	.747	.007	.019	.069	.147
	10	1.9	47	28.5	28.6	34.6	34.8	5.8	8.05	.	.	.005	.015	.007	.012
	11	4.2	52	29.9	29.9	35.9	35.7	5.5	8.17	.	.	.014	.099	.008	.015
14	6	0.7	49	29.6	28.9	35.2	35.3	6.4	8.21	.250	.270	.024	.250	.006	.063
	7	1.5	21	29.7	29.5	34.2	34.2	5.8	8.23	.	.	.005	.063	.203	.944
	8	1.8	19	29.6	29.9	34.6	33.7	6.1	8.17	.040	.023	.014	.024	.004	.012
	9	0.8	18	29.5	29.5	34.7	34.4	6.3	8.26	.293	.303	.007	.018	.076	.135
	10	1.0	20	29.2	29.0	35.0	35.0	6.8	8.16	.110	.120	.007	.019	.007	.010
	11	1.0	46	29.3	29.2	35.7	35.7	6.7	8.29	.093	.103	.009	.025	.006	.012

sediment outwash. There was a distinct stratification of the water column within the channel. The stronger surface currents tended to trap the suspended load within the lower channel waters, causing restricted removal toward the harbor end.

Although other chemical and physical WQ parameters (ie., temperature, salinity, pH, DO, phosphorus and nitrogen) show statistically significant differences between stations and sampling quarters throughout the Part B monitoring program, these fluctuations cannot be wholly attributed to construction operations. Many of these fluctuations were temporal changes caused by meteorological and hydrographic influences which overshadowed man-induced perturbations.

Heavy metal analyses showed that the Okat area had total mercury concentrations in excess of the TTPI marine water quality standard throughout the construction project. Mercury, in part, entered the harbor water mass from the construction area. There was no obvious low level chronic mercury source located at the construction site. Elevated mercury concentration in Okat waters resulted in food fish, those caught from this area, in having significantly higher mean mercury concentrations in their tissues than normally found in coastal fish. It is anticipated that most excess mercury in Okat marine waters will become bound within marine sediments.

Table 13. Univariate statistics for turbidity by station and sampling quarter.

Parameter: Turbidity (NTU)

WQ Station	Number Samples	Mean	Standard Deviation	Mode	Range Minimum	Median	Maximum	Skewness	Kurtosis
1	37	8.4	9.6	2.4	0.90	4.7	43	2.4	5.6
2	35	2.4	1.1	1.2	0.54	2.3	4.7	0.3	-0.7
3	35	1.7	1.1	1.8	0.21	1.5	5.9	1.8	5.4
4	35	1.1	0.5	1.2	0.25	1.2	2.3	0.1	-0.4
5	35	1.1	0.7	1.4	0.12	1.1	3.1	0.8	0.4
6	35	0.54	0.20	0.68	0.14	0.55	0.92	-0.1	-0.7
7	32	1.6	0.9	2.0	0.5	1.6	5.3	2.1	7.1
9	30	2.3	1.4	1.5	0.21	2.2	7.4	4.4	-1.2
13	30	3.8	2.0	2.0	0.88	3.75	7.7	0.2	-1.2
14	17	1.1	0.5	0.7	0.56	0.92	2.4	1.0	0.6
Quarter									
1	38	1.5	1.9	0.9	0.12	0.65	7.7	1.8	2.5
2	24	3.4	8.9	0.42	0.25	1.0	43	4.2	18.2
3	24	3.5	5.0	0.98	0.26	1.65	24	3.2	12.1
4	26	3.4	5.3	1.6	0.52	1.65	25	3.3	11.5
5	30	2.5	2.4	1.1	0.45	1.5	9.8	1.5	1.8
6	30	1.0	0.6	0.78	0.21	0.85	2.7	1.4	1.5
7	30	3.9	6.9	1.2	0.75	2.0	38	4.5	21.6
8	30	2.6	1.7	2.8	0.60	2.15	8.3	1.6	3.2
9	30	1.6	0.7	1.2	0.43	1.6	3.5	0.6	0.5
10	29	2.4	1.4	1.8	0.55	2.0	7	1.4	3.2
11	30	2.4	1.8	1.4	0.68	1.9	8.7	1.9	4.2

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Table 15. Univariate statistics for surface temperature by station and sampling quarter.

Parameter: Temperature, surface (°C)

WQ Station	Number Samples	Mean	Standard Deviation	Mode	Minimum	Range Median	Maximum	Skewness	Kurtosis
1	37	28.4	1.5	27.5	25.8	28.0	31.0	0.2	-0.9
2	35	28.8	0.8	29.0	27.2	28.9	31.0	0.3	0.2
3	35	28.9	0.7	29.0	27.9	28.9	30.5	0.4	-0.6
4	35	29.0	0.7	28.9	28.0	28.9	31.0	1.1	1.0
5	35	29.0	0.7	28.8	28.0	28.9	31.0	1.0	1.0
6	35	29.0	0.6	28.8	28.0	28.8	30.0	0.1	-1.0
7	32	28.9	0.7	28.9	27.9	28.9	31.5	1.8	5.6
9	30	28.8	0.6	28.8	27.5	28.8	30.0	-0.1	-0.1
13	30	29.0	1.0	28.8	27.3	28.9	31.8	0.5	0.9
14	18	29.5	0.7	28.7	28.5	29.4	31.5	1.1	1.7
Quarter									
1	38	29.8	0.7	30	29.0	20.0	31.5	0.5	-0.3
2	24	30.1	0.6	30	28.0	30.0	31.0	-1.4	7.1
3	24	28.4	0.6	28	27.5	28.5	30.0	0.7	0.4
4	26	28.3	0.6	28.9	26.5	28.4	29.0	-1.6	2.8
5	30	27.8	0.6	28.2	25.8	28.0	28.3	-1.9	4.3
6	30	28.5	0.7	28.5	26.9	28.5	31.5	2.5	13.1
7	30	28.8	0.8	28.8	25.8	28.8	30.7	-1.8	7.9
8	30	29.2	0.8	29.8	26.4	29.4	29.8	-2.7	7.8
9	30	29.1	0.4	29.4	27.8	29.2	29.8	-1.4	4.3
10	30	28.6	0.5	28.4	27.5	28.7	30.3	1.1	5.7
11	30	29.0	0.6	28.9	27.9	28.9	31.8	3.3	16.1

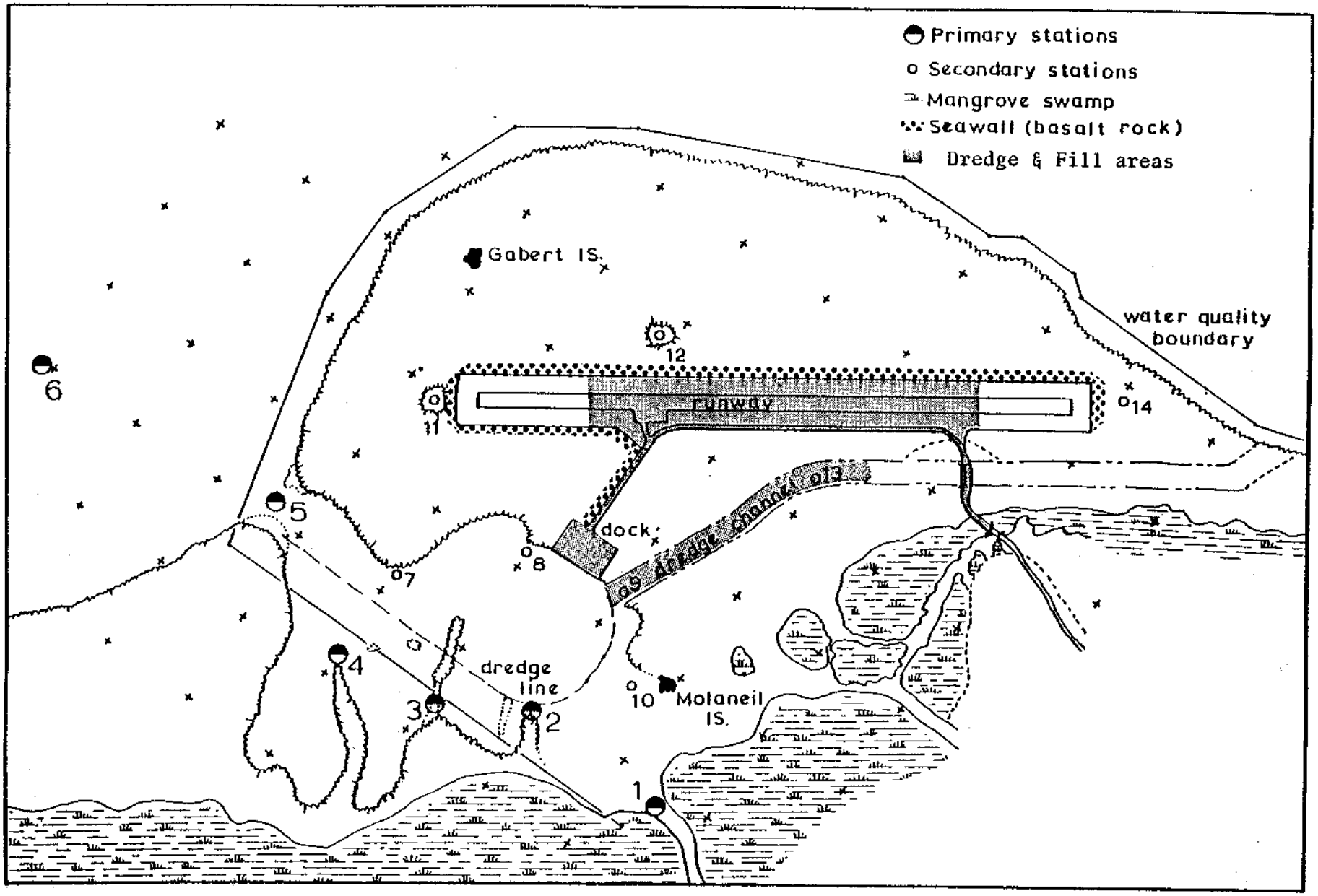

Figure 1. Water quality stations and extent of dredge and fill operations, July 1982.

Table 17. Univariate statistics for surface salinity by station and sampling quarter.

Parameter: Salinity, surface (ppt)

WQ Station	Number Samples	Mean	Standard Deviation	Mode	Minimum	Range Median	Maximum	Skewness	Kurtosis
1	37	23.0	10.4	34.4	0.1	23.3	35.5	-0.4	-0.9
2	35	33.3	2.2	33.3	25.5	33.3	35.5	-1.8	4.1
3	35	33.9	1.5	35.5	30	34.4	35.5	-1.0	0.7
4	35	34.1	1.5	34.4	28.9	34.4	36.6	-1.3	2.7
5	35	34.0	1.4	35.5	31.1	34.4	36.1	-0.6	-0.4
6	35	34.9	0.6	35.5	33.3	35	35.5	-0.8	0.1
7	32	33.4	1.9	34.4	28.9	34.4	35.5	-0.7	-0.5
9	30	33.1	3.6	34.4	17.8	34.4	35.5	-3.0	10.9
13	30	34.3	1.3	34.4	30.5	34.4	36.6	-1.2	1.8
14	18	34.9	0.6	34.4	33.9	35	36.0	0.2	-0.9
Quarter									
1	38	32.3	6.7	34.4	8.9	34.4	35.5	-3.1	8.7
2	24	30.6	9.2	34.4	0.1	34.4	36.6	-2.3	5.1
3	24	31.4	3.9	34.4	20.0	32.5	34.4	-1.8	3.1
4	26	32.1	4.9	33.3	14.4	33.3	34.4	-3.2	9.7
5	30	35.1	0.7	35.5	32.2	35.5	35.5	-2.6	7.4
6	30	35.3	0.3	35.5	34.4	35.5	35.5	-1.5	1.6
7	30	31.2	6.9	34.4	2.2	33.3	34.4	-3.4	12.1
8	30	30.1	6.2	34.4	10.0	32.2	35.0	-1.9	3.1
9	30	32.0	3.6	33.3	20.0	33.3	35.5	-2.3	6.0
10	30	34.3	1.9	34.4	24.4	34.4	35.5	-4.9	26.1
11	30	34.7	3.5	35.5	16.7	35.5	36.6	-5.1	27.2

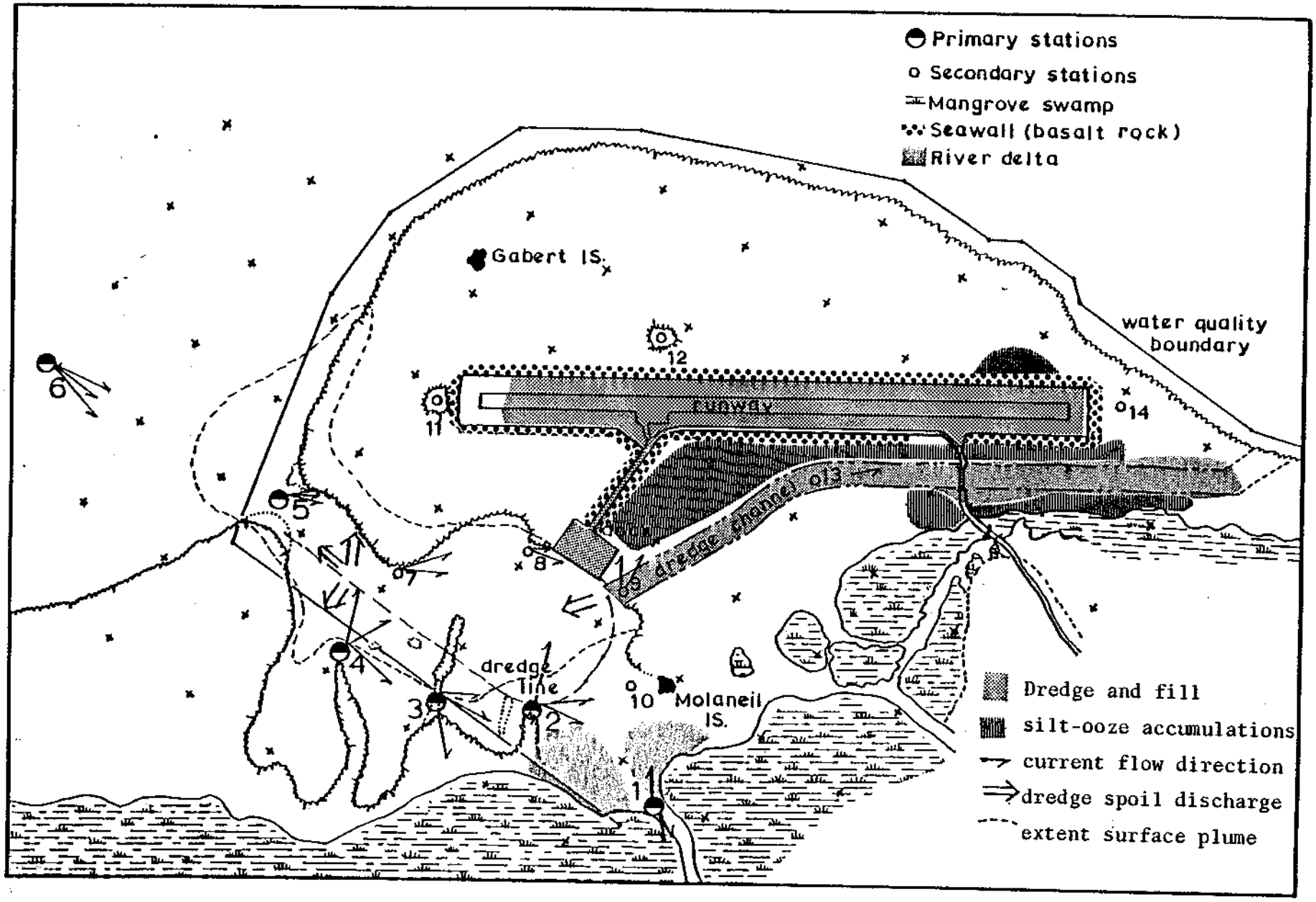

Figure 3. Water quality stations, extent of dredge and fill operations and surface water flow patterns, November 1982.

Table 19. Univariate statistics for pH by station and sampling quarter.

Parameter: pH

WQ Station	Number Samples	Mean	Standard Deviation	Mode	Minimum	Range Median	Maximum	Skewness	Kurtosis
1	37	7.75	0.26	7.80	7.10	7.80	8.20	-0.6	-0.2
2	35	8.08	0.13	8.00	7.65	8.10	8.30	-0.7	1.6
3	35	8.13	0.13	8.05	8.78	8.15	8.35	-0.7	0.7
4	35	8.14	0.10	8.20	7.95	8.18	8.31	-0.2	-0.9
5	35	8.15	0.11	8.20	7.8	8.15	8.35	-0.7	1.8
6	35	8.21	0.09	8.25	8.00	8.22	8.35	-0.2	-0.6
7	32	8.12	0.14	8.08	7.65	8.10	8.42	-0.9	2.7
9	30	8.09	0.13	8.05	7.7	8.09	8.40	-0.6	2.8
13	30	8.07	0.16	8.02	7.75	8.09	8.63	0.8	4.0
14	18	8.22	0.10	8.32	8.05	8.21	8.42	0.2	-0.6
Quarter									
1	38	8.03	0.16	8.00	7.40	8.05	8.25	-1.9	5.1
2	24	8.14	0.21	8.30	7.65	8.25	8.35	-1.3	0.3
3	24	7.96	0.31	8.05	7.10	8.05	8.32	-1.4	1.7
4	26	8.10	0.29	8.20	7.35	8.215	8.42	-1.3	0.7
5	30	8.08	0.18	8.05	7.58	8.095	8.63	-0.2	3.6
6	30	8.08	0.19	8.10	7.30	8.10	8.40	-2.2	9.3
7	30	8.06	0.15	8.10	7.70	8.08	8.42	-0.4	1.5
8	30	8.07	0.15	8.08	7.55	8.10	8.22	-2.0	4.9
9	30	8.16	0.10	8.20	7.88	8.18	8.32	-0.9	0.7
10	30	8.09	0.15	8.10	7.50	8.09	8.35	-1.9	7.2
11	30	8.19	0.08	8.22	8.00	8.20	8.32	-0.4	-0.0

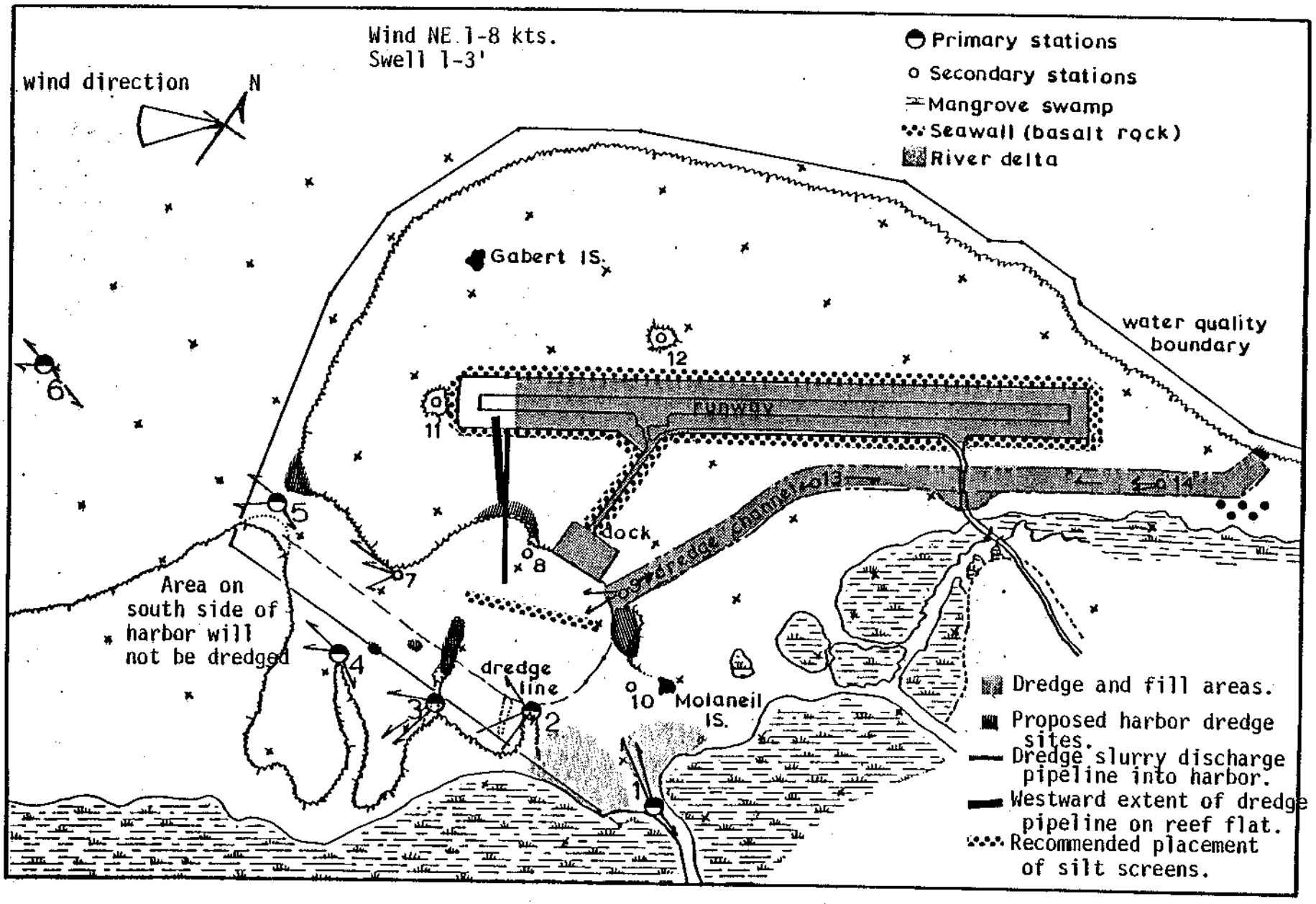

Figure 5. Water quality stations, extent of dredge and fill operations, surface water flow patterns, and recommended placement of silt screens for dock area construction project, April 1983. The symbol •,•,• represents a recommended area for placement of a small boulder pile which would reduce the wave action in the adjacent mangrove area.

Table 21. Univariate statistics for total-nitrogen by station and sampling quarter,

Parameter: Total-Nitrogen (mg/ℓ)

WQ Station	Number Samples	Mean	Standard Deviation	Mode	Minimum	Range Median	Maximum	Skewness	Kurtosis
1	32	0.32	0.28	0.15	0.03	0.22	1.20	1.6	2.5
2	30	0.31	0.25	0.08	0.03	0.23	0.87	1.1	0.1
3	30	0.39	0.23	0.31	0.04	0.28	0.96	1.3	1.3
4	30	0.38	0.38	0.03	0.03	0.28	1.5	1.8	3.1
5	30	0.30	0.26	0.07	0.02	0.26	1.02	1.2	1.2
6	30	0.28	0.21	0.01	0.01	0.24	0.85	0.9	0.3
7	15	0.40	0.39	0.07	0.02	0.20	1.03	0.6	-1.4
9	15	0.31	0.36	0.02	0.02	0.23	1.44	2.4	6.6
13	9	0.35	0.33	0.03	0.03	0.19	0.83	0.4	-1.9
14	13	0.15	0.12	0.02	0.02	0.10	0.40	0.8	-0.3
Quarter									
1	18	0.23	0.12	0.23	0.01	0.23	0.45	0.4	-0.2
2	0								
3	21	0.19	0.11	0.16	0.02	0.16	0.57	1.9	6.5
4	18	0.38	0.24	0.36	0.08	0.33	1.20	2.4	7.2
5	23	0.48	0.34	0.05	0.05	0.45	1.45	1.1	1.7
6	22	0.14	0.07	0.04	0.04	0.15	0.27	0.3	-1.1
7	18	0.35	0.15	0.36	0.21	0.33	0.85	2.2	5.3
8	30	0.64	0.41	0.03	0.02	0.67	1.50	-0.0	-0.4
9	30	0.44	0.21	0.16	0.15	0.42	0.88	0.4	-0.7
10	27	0.08	0.07	0.07	0.01	0.07	0.33	2.0	4.4
11	27	0.11	0.05	0.08	0.05	0.10	0.28	1.8	5.2

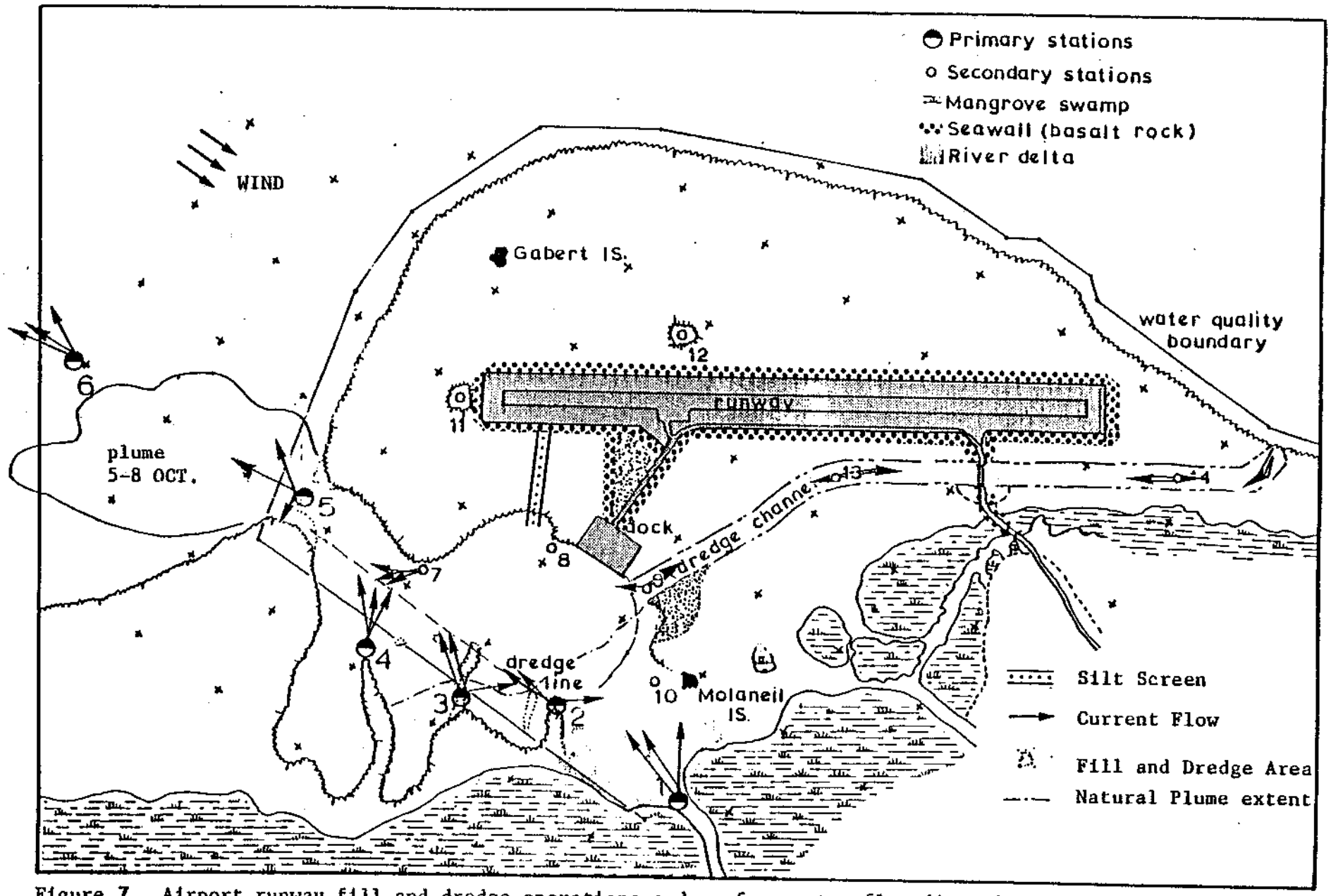

Figure 7. Airport runway fill and dredge operations and surface water flow directions in October, 1983. The runway fill area has been completed.

Table 23. Univariate statistics for nitrate plus nitrite-nitrogen by station and sampling quarter.

Parameter: Nitrate + Nitrite-Nitrogen (mg/ℓ)

WQ Station	Number Samples	Mean	Standard Deviation	Mode	Minimum	Range Median	Maximum	Skewness	Kurtosis
1	32	0.023	0.024	0.010	0.002	0.011	0.095	1.6	1.8
2	29	0.016	0.016	0.006	0.004	0.011	0.074	2.2	5.2
3	30	0.016	0.017	0.007	0.002	0.008	0.072	2.1	4.6
4	30	0.012	0.010	0.006	0.002	0.007	0.05	2.4	7.4
5	30	0.007	0.005	0.005	0.001	0.007	0.02	0.9	0.7
6	30	0.003	0.003	0.001	0	0.002	0.018	2.9	10.6
7	25	0.012	0.007	0.004	0	0.012	0.024	0.1	-1.3
9	25	0.009	0.006	0.004	0.003	0.007	0.021	0.8	-0.8
13	23	0.011	0.008	0.005	0.003	0.007	0.027	0.8	-0.9
14	18	0.011	0.007	0.007	0.003	0.007	0.029	1.5	1.7
Quarter									
1	18	0.007	0.012	0.002	0.001	0.002	0.05	3.0	8.0
2	0								
3	21	0.005	0.002	0.006	0.001	0.006	0.009	-0.4	-0.1
4	26	0.022	0.012	0.024	0.007	0.0205	0.064	2.0	6.0
5	28	0.009	0.011	0.006	0.001	0.006	0.051	3.2	10.6
6	29	0.018	0.021	0.005	0	0.013	0.095	2.4	6.7
7	30	0.009	0.012	0.003	0.002	0.007	0.064	3.8	16.3
8	30	0.019	0.010	0.001	0.001	0.018	0.046	0.5	1.0
9	30	0.010	0.005	0.007	0.001	0.009	0.029	1.7	4.9
10	30	0.006	0.003	0.006	0.001	0.006	0.013	0.5	1.3
11	30	0.015	0.020	0.007	0.002	0.007	0.075	2.5	5.4

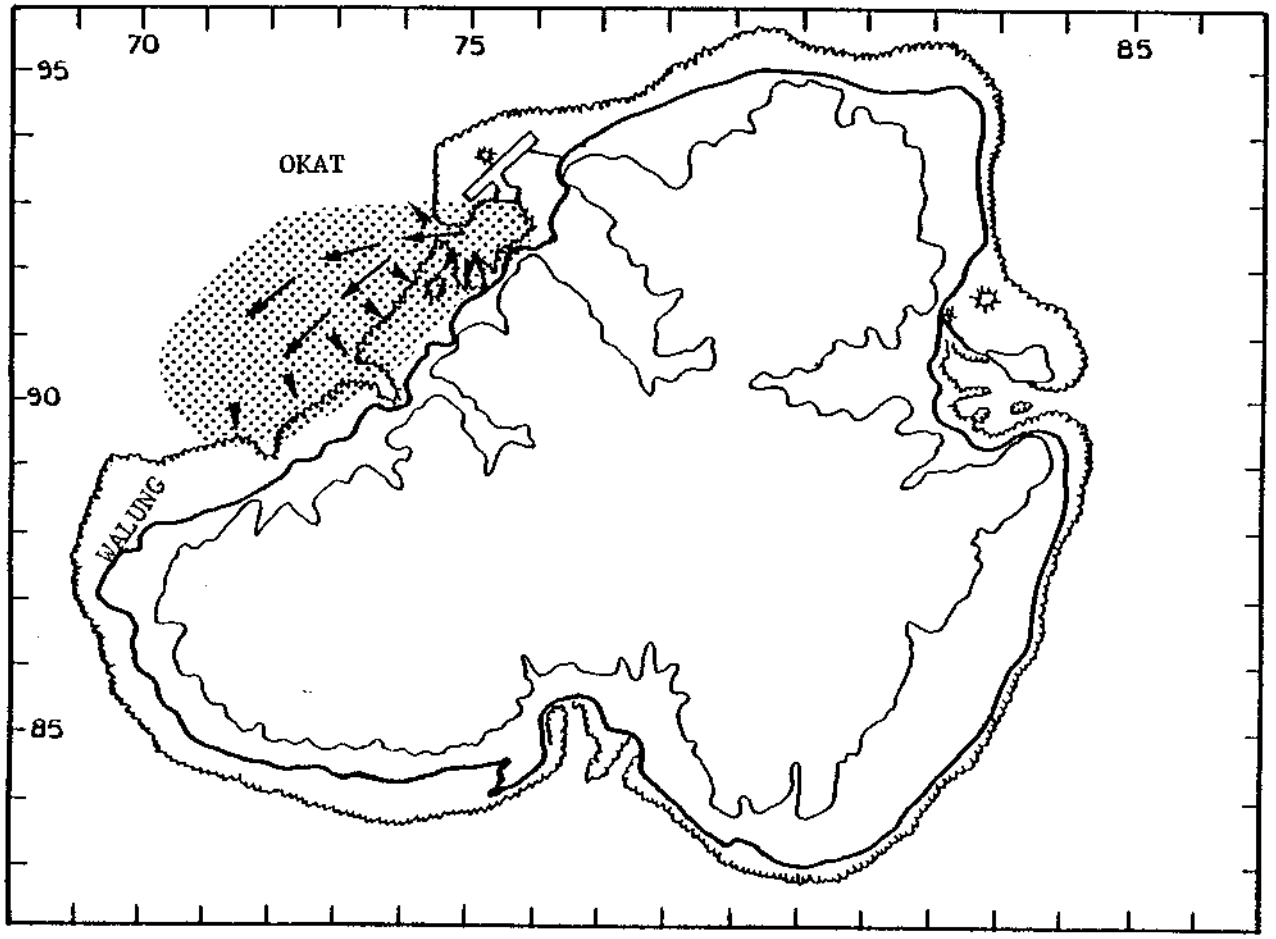

Figure 9. Extent of turbidity plume made by dredge spoil clean-up operation, April 1984.

Table 25. Univariate statistics for total-phosphorus by station and sampling quarter.

Parameter: Total-Phosphorus (mg/ℓ)

WQ Station	Number Samples	Mean	Standard Deviation	Mode	Minimum	Range Median	Maximum	Skewness	Kurtosis
1	32	0.149	0.248	0.21	0.009	0.043	0.937	2.5	5.4
2	30	0.121	0.191	0.01	0.01	0.027	0.726	2.3	4.6
3	30	0.071	0.128	0.005	0.005	0.013	0.53	2.6	6.7
4	30	0.069	0.146	0.011	0.003	0.012	0.68	3.2	11.2
5	30	0.086	0.176	0.01	0.004	0.011	0.737	2.8	7.8
6	30	0.104	0.234	0.009	0.003	0.01	0.863	2.7	6.0
7	24	0.125	0.249	0.012	0.005	0.014	0.937	2.6	6.5
9	24	0.138	0.304	0.013	0.005	0.013	1.179	2.7	6.5
13	23	0.140	0.281	0.007	0.005	0.014	0.957	2.3	4.0
14	18	0.196	0.351	0.013	0.006	0.013	1.064	1.9	2.1
Quarter									
1	18	0.023	0.036	0.01	0.007	0.011	0.16	3.7	14.7
2	0								
3	18	0.036	0.053	0.01	0.008	0.017	0.226	3.1	10.3
4	26	0.020	0.023	0.005	0.005	0.011	0.091	2.2	3.9
5	29	0.050	0.056	0.005	0.003	0.009	0.199	1.0	-0.0
6	30	0.017	0.030	0.01	0.006	0.01	0.173	5.1	27.5
7	30	0.699	0.26	0.937	0.093	0.731	1.179	-0.7	0.4
8	30	0.019	0.021	0.012	0.008	0.12	0.12	4.4	21.2
9	30	0.175	0.042	0.151	0.124	0.165	0.29	1.2	1.3
10	30	0.019	0.025	0.01	0.008	0.012	0.15	5.0	26.6
11	30	0.016	0.012	0.011	0.009	0.012	0.063	3.0	9.0

APPENDIX B

Table B1. Trust Territory of the Pacific Islands (TTPI) Marine Water Quality Standards.

PARAMETER	UNITS	CLASS AA	CLASS A	CLASS B
Total Coliform	#/100ml	<230		
Fecal Coliform	#/100ml		<400	<400
pH		Normal ±0.2	Normal ±0.2	Normal ±0.5
		[6.5<pH<8.5]		
Total Nitrogen TN	mg/l	≤0.40	≤0.75	≤1.50
		[Normal ± 10%]		
Total Phosphorus (TP)	mg/l	≤0.025	≤0.050	≤0.100
		[Normal ± 10%]		
TN/TP (ratio)	--	[Normal ± 10%]		
Dissolved Oxygen (D.O.)	mg/l	≥6.0 or 75% of saturation whichever is greater	≥5.0	≥4.5
Total Dissolved Solids (TDS)	mg/l	[Normal ± 10%]		
Salinity	o/oo	[Normal ± 10%]		
Temperature	°C	[Normal ± 0.9]		
Turbidity	NTU, JTU, TU	Normal ±5%	Normal ±10%	Normal ±20%
Heavy Metals:				
Arsenic	µg/l	10.0	All marine water classess have the same standards	
Copper		10.0		
Lead		10.0		
Mercury		0.10		
Zinc		20.0		
Nickel		2.0		
Chromium		50.0		
Cadmium		5.0		

distribution curve. Therefore, moments describe characteristics of the normal distribution in mathematical terms. The mean of the curve is the first moment and it is convenient to use it to calculate the higher moments. The second moment is a measure of the dispersion of data around the mean and is called standard deviation. The third moment is a measure of the deviation from symmetry of the curve about the mean and is termed skewness. Skewness is a measure of deviation of data from a normal distribution. A positive skewness value indicates an excess of distribution of data points to the right of the mean and negative skewness is an excess of data to the left of the mean. The value for skewness is a normal distribution is zero. The fourth moment is a measure of the peakedness, or kurtosis of the distribution curve. This kurtosis moment provides a measure of the grouping of data points in relation to normal distribution. If there are an excess of points around the mean, the distribution curve will have a sharp central peak. This type of curve is called leptokurtic. A flatter curve with a wider distribution of data away from the mean is called platykurtic. A bimodial curve (two peaks) is an extreme platykurtic distribution curve. A normal distribution curve is called mesokurtic. A frequency distribution is generally considered normal if its skewness is 0 and its kurtosis is 3.

There are numerical limits that can be set for skewness and kurtosis:

SKEWNESS VALUE	VERBAL TERM
-4.0 to -0.1	negative skewed
-0.1 to +0.1	almost symmetrical
+0.1 to +4.0	positive skewed
+4.0	very positive skewed

KURTOSIS VALUE	VERBAL TERM
0.9	platykurtic
0.9 to 1.1	mesokurtic
1.1 to 3.0	leptokurtic
3.0	extremely leptokurtic

Based on other marine monitoring programs in Truk and Belau (Clayshulte, 1983; and Zolan, 1983), turbidity was identified as the water quality parameter which would probably be most affected by construction related operations. Turbidity is a measure of the clarity of a water sample. The amount of suspended matter (clay, silt, very fine organic and inorganic matter, soluble colored organic compounds, microscopic plants and animals) affects turbidity levels. Turbidity is measured by the amount of light scattered and absorbed when a light source is shone through the water sample. The more scatter or absorption of light, the higher the turbidity. Correlation of turbidity with weight concentrations of suspended matter is difficult. As a result, it was not possible to get a good correlation between turbidity measurements and TNFR amounts at the WQ stations.