



NRL/MR/6110--05-8854

# Ambient PAH and Metal Concentration in Intertidal Sediments of Coaster's Harbor and Narragansett Bay

MICHAEL T. MONTGOMERY

THOMAS J. BOYD

CHRISTOPHER L. OSBURN

*Chemical Dynamics and Diagnostics Branch  
Chemistry Division*

DAVID C. SMITH

*University of Rhode Island  
Narragansett, RI*

January 12, 2005

# REPORT DOCUMENTATION PAGE

*Form Approved*  
**OMB No. 0704-0188**

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing this collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden to Department of Defense, Washington Headquarters Services, Directorate for Information Operations and Reports (0704-0188), 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to any penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number. **PLEASE DO NOT RETURN YOUR FORM TO THE ABOVE ADDRESS.**

<b>1. REPORT DATE (DD-MM-YYYY)</b> 12-01-2005			<b>2. REPORT TYPE</b> Memorandum			<b>3. DATES COVERED (From - To)</b> 1 January 2004-10 November 2004			
<b>4. TITLE AND SUBTITLE</b>  Ambient PAH and Metal Concentration in Intertidal Sediments of Coaster's Harbor and Narragansett Bay						<b>5a. CONTRACT NUMBER</b> 61-5557-K4			
						<b>5b. GRANT NUMBER</b>			
						<b>5c. PROGRAM ELEMENT NUMBER</b>			
<b>6. AUTHOR(S)</b>  Michael T. Montgomery, Thomas J. Boyd, Christopher L. Osburn, and David C. Smith*						<b>5d. PROJECT NUMBER</b>			
						<b>5e. TASK NUMBER</b>			
						<b>5f. WORK UNIT NUMBER</b>			
<b>7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)</b>  Naval Research Laboratory, Code 6110 4555 Overlook Avenue, SW Washington, DC 20375-5320						<b>8. PERFORMING ORGANIZATION REPORT NUMBER</b>  NRL/MR/6110--05-8854			
<b>9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)</b>  Engineering Field Activity Northeast NAVFACENGCOM 10 Industrial Highway, MSC82 Lester, PA 19113-2090						<b>10. SPONSOR / MONITOR'S ACRONYM(S)</b>  NAVFAC			
						<b>11. SPONSOR / MONITOR'S REPORT NUMBER(S)</b>			
<b>12. DISTRIBUTION / AVAILABILITY STATEMENT</b>  Approved for public release; distribution is unlimited.									
<b>13. SUPPLEMENTARY NOTES</b>  *University of Rhode Island, Narragansett, RI									
<b>14. ABSTRACT</b>  Previous studies of sediment adjacent to the Old Fire Fighting Training Area (OFFTA) in Coaster's Harbor, Rhode Island, compared values for polynuclear aromatic hydrocarbon (PAH) concentrations for intertidal stations with fully submerged reference stations. NRL and URI have previously reported that the ambient sediment PAH concentrations at that site are low and typical of urbanized estuarine sediments. Bacterial PAH degradation in these sediments results in pool turnover times that suggest the PAH concentrations result from current sources. A Navy fingerprinting study also indicated that the likely source of PAH to Coaster's Harbor sediment is urban runoff. If intertidal and submerged sediments are being impacted by current non-point inputs to surface water, then PAH concentrations may be higher in intertidal sediments. PAHs are relatively hydrophobic and tend to collect at marine interfaces, including the air-sea interface. Wave action in the intertidal zone could deposit hydrophobic contaminants on the surface sediment. An intertidal sediment sampling event was performed in the area adjacent to the OFFTA to evaluate PAH concentrations. In addition, metals analysis was also conducted.									
<b>15. SUBJECT TERMS</b>  PAH; Newport; Narragansett Bay; Contaminated sediment; Intertidal; Metals; OFFTA									
<b>16. SECURITY CLASSIFICATION OF:</b>				<b>17. LIMITATION OF ABSTRACT</b>		<b>18. NUMBER OF PAGES</b>		<b>19a. NAME OF RESPONSIBLE PERSON</b>	
<b>a. REPORT</b>		<b>b. ABSTRACT</b>		<b>c. THIS PAGE</b>		UL		Michael T. Montgomery	
Unclassified		Unclassified		Unclassified		24		<b>19b. TELEPHONE NUMBER (include area code)</b> (202) 404-6419	

## CONTENTS

EXECUTIVE SUMMARY .....	1
PAH CONCENTRATION .....	1
METAL CONCENTRATION .....	2
CONCLUSIONS .....	2
SUPPORTING REFERENCES .....	10
APPENDIX I – Data from the Second NRL Sampling (October 2002) of OFFTA in Coaster’s Harbor and Reference Stations in Narragansett Bay .....	11
APPENDIX II – Pictures of Intertidal Locations from May 2004 Sampling Event .....	18

# AMBIENT PAH AND METAL CONCENTRATION IN INTERTIDAL SEDIMENTS OF COASTER'S HARBOR AND NARRAGANSETT BAY

## EXECUTIVE SUMMARY

Previous studies of sediment adjacent to the Old Fire Fighting Training Area in Coaster's Harbor, Rhode Island compared values for PAH concentration for intertidal stations with fully submerged reference stations (Battelle Ocean Sciences 1994, Brown and Root 1997, Montgomery et al. 2003). The Naval Research Laboratory and University of Rhode Island (Montgomery et al. 2003) have previously reported that the ambient sediment PAH concentrations at this site are low and typical of urbanized estuarine sediments. In addition, bacterial PAH degradation in these sediments results in contaminant pool turnover times rapid enough to suggest PAH concentrations result from current non-point sources and not historical input (Montgomery et al. 2003). A recent fingerprinting study conducted by the Navy (Emsbo-Mattingly 2002) also indicated that the likely source of PAH to Coaster's Harbor sediment is surface runoff typical of urbanized areas. If intertidal and submerged sediments are being impacted by current non-point inputs to surface water (e.g. street runoff, ship traffic), then PAH concentrations may be higher in intertidal sediments. PAHs are relatively hydrophobic and tend to collect at marine interfaces including the air-sea interface. Wave action in the intertidal zone could deposit hydrophobic contaminants on the surface sediment. An intertidal sediment sampling event was performed from shore by the Naval Research Laboratory and University of Rhode Island on 12 May 2004 in the area adjacent to the Old Fire Fighting Training Area (OFFTA) and various reference areas to evaluate PAH concentrations and spatial distribution within intertidal sediments. In addition, metals analysis was also conducted to assess concentrations and spatial distribution within the same areas.

### PAH Concentration

Total PAH concentrations in nine intertidal sediment samples from Coaster's Harbor and six samples from Narragansett Bay (Figures 1, 2, Table 3) ranged from 0.8 to 24.1 ppm (Table 1). Two of the three highest PAH concentrations (24.1 and 13.5 ppm) were found in the intertidal sediment adjacent to the Middletown boat launch (Latitude: 41°N 34.47000; Longitude: 71°W 17.31040). We previously reported that submerged sediment PAH concentrations near this boat launch reference site were 1.1 ppm (Montgomery et al. 2003). PAH concentrations in the intertidal areas of OFFTA ranged from 1.5 to 21.5 ppm and averaged 7.7 ppm for nine samples whereas the adjacent submerged sediment ranged from 0.11 to 1.3 ppm (Appendix I). PAH concentrations in the six samples from the boat launch and a Tetratex reference area (west side of Narragansett Bay) ranged from 0.8 to 24.1 ppm and averaged 7.1 ppm but the adjacent submerged sediments ranged from 0.03 to 0.22 ppm (Appendix I). For each of these three intertidal sites, the average PAH concentrations from the intertidal sediments are higher than those for the nearby submerged sediment (Montgomery et al. 2003, Appendix I). In addition, the individual PAH compounds that have the highest concentration in the intertidal boat launch sediments (phenanthrene, fluoranthene, and pyrene) are the same compounds that are highest in the most impacted samples from the Coaster's Harbor survey site (Stations 2, 7, 9). These findings support the hypothesis that current surface water inputs are impacting the ambient PAH concentrations in the sediment. Though a major PAH transport study was not performed during the course of this site investigation, the elevated PAH concentrations at the boat launch suggest that local ship traffic may be a significant non-point source. These findings also indicate that submerged reference stations should not be used as reference sites for intertidal sediments because of their differential susceptibility to current day inputs of hydrophobic contaminants to surface waters.

## **Metal Concentration**

Metal concentrations (measured by Battelle Marine Sciences Laboratories, Table 2) in Coaster's Harbor sediment were generally unremarkable relative to that reported for natural soil ([http://pubs.usgs.gov/prof/p1634j/html/fm\\_range.htm](http://pubs.usgs.gov/prof/p1634j/html/fm_range.htm)) and compared with the reference sites.

## **Conclusions**

This sampling compared intertidal sediment reference sites in Narragansett Bay with intertidal sediments from Coaster's Harbor. Previous samplings of intertidal sediment at Coaster's Harbor were compared with submerged sediment at reference sites. Analyses of data collected in previous samplings of the Coaster's Harbor site by Tetrattech (Emsbo-Mattingly 2002), University of Rhode Island (Quinn et al. 1998), Brown and Root Environmental (1997), Battelle Ocean Sciences (1994) and the Naval Research Laboratory (Montgomery et al. 2003) have provided evidence that ambient PAH concentrations are the net result of current day inputs and biodegradation and not the result of historical input. In this study, we found elevated PAH concentrations in the intertidal sediments at both Coaster's Harbor and the boat launch relative to the submerged sediment concentration at both sites. These data support the site conceptual model that non-point source petroleum inputs (e.g. surface runoff, ship traffic) to surface water are the primary influence on ambient PAH concentrations in Coaster's Harbor sediments. Petroleum input via this pathway to these intertidal sediments would be exposed to rapid photodegradation, volatilization, and biodegradation in this relatively high energy environment. The alternate site conceptual model that the PAH concentrations in the submerged and intertidal sediments are the result of historical input is not supported by the data. In the absence of substantial, conflicting information on PAH flux and transport in Coaster's Harbor, it is not scientifically defensible to expect that removal or manipulation of either the submerged or intertidal sediments will result in a net long term reduction in ambient PAH concentrations. In addition, it is recommended that in the future any intertidal sediment samples collected in Coaster's Harbor, adjacent to the OFFTA site, be compared to reference samples that are also collected from intertidal areas with similar environmental influences.

Figure 1. Sample locations for stations 1-9 at OFFTA in Coaster's Harbor for May 2004.

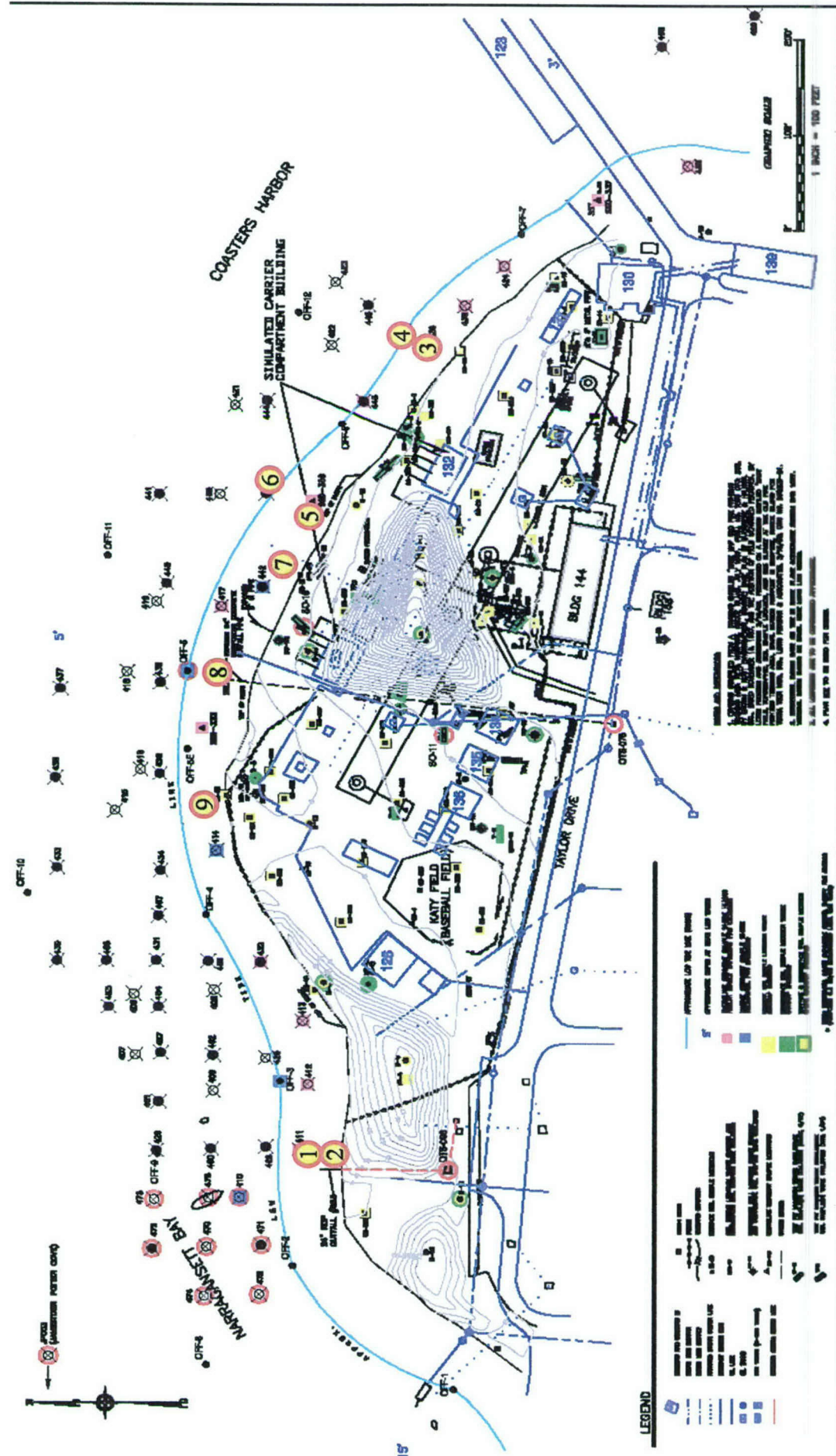


Figure 2. May 2004 sampling stations for Middleton boat launch (Stations 10M (high), 11M (mid), 12M (low water line)) and for the Tetrtech background site on the west side of Narragansett Bay (Stations 13B (high), 14B (mid), 15B (low water line)).

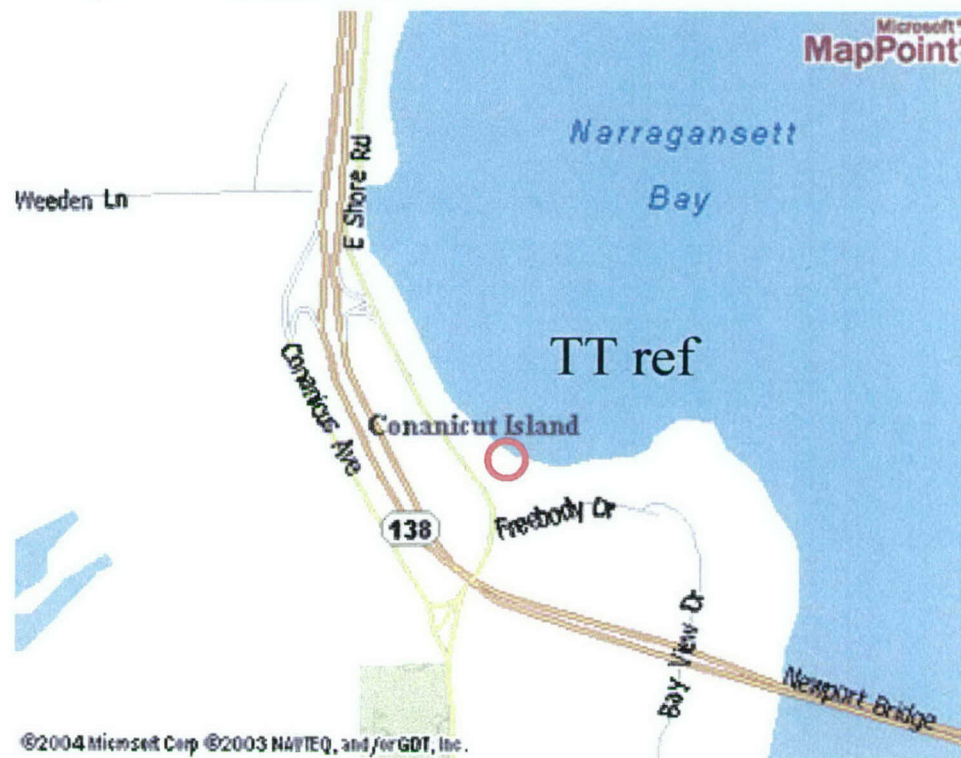


Table 1. Individual and total PAH concentrations (ppm) for intertidal sediment in Coaster's Harbor (Stations 1-9), the Middleton boat launch (Stations 10M-12M), and the west Bay reference site (Stations 13V-15B) for May 2004.

Station	Naphthalene	Acenaphthylene	Biphenyl	Fluorene	Phenanthrene	Anthracene	Fluoranthene	Pyrene	Benzo[a]anthracene	Chrysene	Benzo[b]fluoranthene	Benzo[k]fluoranthene	Benzo[a]pyrene	Indeno[1,2,3-cd]pyrene	Dibenz[a,h]anthracene	Benzo[g,h,i]perylene	Total
1	0.01	0.03	0.00	0.01	0.17	0.04	0.33	0.27	0.12	0.12	0.08	0.09	0.09	0.00	0.06	0.06	1.5
2	0.17	0.95	0.08	0.30	4.61	0.77	5.52	4.51	0.45	0.78	0.72	0.80	0.89	0.11	0.42	0.39	21.5
3	0.02	0.09	0.01	0.04	0.56	0.12	0.75	0.64	0.22	0.19	0.10	0.12	0.12	0.02	0.07	0.07	3.1
4	0.04	0.08	0.01	0.02	0.42	0.10	0.57	0.49	0.13	0.13	0.06	0.07	0.07	0.01	0.04	0.05	2.3
5	0.04	0.23	0.01	0.06	0.98	0.23	1.38	1.05	0.33	0.27	0.13	0.16	0.17	0.01	0.10	0.09	5.2
6	0.12	0.37	0.03	0.11	1.76	0.20	2.43	2.13	0.61	0.48	0.33	0.39	0.43	0.06	0.25	0.25	9.9
7	0.09	0.42	0.02	0.10	2.14	0.44	2.64	1.97	0.59	0.47	0.22	0.26	0.29	0.04	0.16	0.14	10.0
8	0.07	0.30	0.03	0.14	2.84	0.62	2.46	1.91	0.61	0.49	0.24	0.29	0.30	0.04	0.16	0.14	10.6
9	0.06	0.26	0.02	0.14	2.08	0.36	0.12	1.01	0.28	0.23	0.11	0.13	0.14	0.02	0.08	0.06	5.1
10M	0.08	0.00	0.34	0.27	2.64	0.56	2.42	2.39	0.99	0.97	0.56	0.56	0.81	0.11	0.35	0.42	13.5
11M	0.11	0.00	0.71	0.62	5.49	1.20	5.22	4.24	0.47	1.22	1.09	1.18	1.42	0.15	0.27	0.74	24.1
12M	0.01	0.00	0.03	0.03	0.30	0.05	0.34	0.37	0.18	0.21	0.10	0.10	0.16	0.02	0.08	0.09	2.1
13B	0.00	0.07	0.00	0.00	0.07	0.03	0.20	0.20	0.08	0.09	0.05	0.05	0.06	0.01	0.03	0.03	1.0
14B	0.00	0.05	0.01	0.00	0.05	0.03	0.18	0.18	0.07	0.07	0.04	0.04	0.05	0.00	0.03	0.03	0.8
15B	0.00	0.09	0.02	0.01	0.06	0.00	0.17	0.19	0.07	0.07	0.04	0.04	0.05	0.01	0.03	0.03	0.9

Table 2. Metals concentrations (ppm) for intertidal sediment in Coaster's Harbor (Stations 1-9), the Middleton boat launch (Stations 10M-12M), and the west Bay reference site (Stations 13V-15B) for May 2004.

<b>BATTELLE MARINE SCIENCES LABORATORIES</b>														
Jill Brandenberger, Project Manager														
1529 West Sequim Bay Road														
Sequim, Washington 98382														
(360) 681-4564														
<b>SPONSOR CODE</b>	<b>Percent Moisture</b>	<b>Ag</b>		<b>Al</b>		<b>As</b>		<b>Ba</b>		<b>Be</b>		<b>Ca</b>		<b>Cd</b>
	Method:	GFAA		ICP-OES		ICP-MS		ICP-OES		ICP-OES		ICP-OES		ICP-MS
	Digestion:	BA		BA		SE		BA		BA		BA		SE
<b>Achieved MDLs<sup>1</sup></b>		<b>0.0280</b>		<b>7.17</b>		<b>0.0277</b>		<b>0.104</b>		<b>0.0262</b>		<b>1.24</b>		<b>0.0105</b>
<b>Achieved RLs<sup>2</sup></b>		<b>0.0890</b>		<b>22.8</b>		<b>0.088</b>		<b>0.331</b>		<b>0.0833</b>		<b>3.94</b>		<b>0.0334</b>
NRL-1	10.2	0.0334	J	40030		5.01		278		1.35		29655		0.203
NRL-2	6.01	0.0327	J	50467		5.21		488		1.99		6872		0.331
NRL-3	7.39	0.0280	U	44128		5.87		325		1.54		57156		0.196
NRL-4	26.2	0.140		41634		4.24		399		1.44		11124		0.283
NRL-5	17.7	0.0404	J	41262		6.60		344		1.29		22158		0.296
NRL-6	25.3	0.0531	J	36540		5.93		335		1.17		26051		0.314
NRL-6	25.3	0.0524	J	40242		4.15		675		1.28		18775		0.285
NRL-7	8.03	0.0677	J	45834		7.91		386		1.51		31217		0.265
NRL-8	10.7	0.0488	J	42254		6.06		337		1.49		24187		0.214
NRL-9	4.18	0.0280	U	46505		15.0		295		1.67		20207		0.204
NRL-10M	3.26	0.0280	U	32911		5.75		275		1.06		5492		0.174
NRL-11M	11.3	0.0280	U	33440		2.84		306		1.05		4997		0.115
NRL-12M	3.55	0.0280	U	33611		4.49		270		1.12		13401		0.131
NRL-13B	18.4	0.0280	U	38723		1.44		335		1.33		4722		0.174
NRL-14B	16.0	0.0280	U	42271		1.63		330		1.53		5765		0.189
NRL-15B	16.9	0.0280	U	36212		1.68		312		1.34		5112		0.242

Table 2. Metals concentrations (ppm; continued).

<b>BATTELLE MARINE SCIENCES LABORATORIES</b>												
Jill Brandenberger, Project Manager												
1529 West Sequim Bay Road												
Sequim, Washington 98382												
(360) 681-4564												
<b>SPONSOR CODE</b>	<b>Percent Moisture</b>	<b>Co</b>	<b>Cr</b>	<b>Cu</b>	<b>Fe</b>	<b>Hg</b>	<b>K</b>	<b>Mg</b>				
	Method:	ICP-MS	ICP-MS	ICP-MS	ICP-OES	CVAA	ICP-OES	ICP-OES				
	Digestion:	SE	SE	SE	BA	SE	BA	BA				
<b>Achieved MDLs<sup>1</sup></b>		<b>0.0103</b>	<b>0.0631</b>	<b>0.153</b>	<b>1.0</b>	<b>0.0043</b>	<b>1.05</b>	<b>1.29</b>				
<b>Achieved RLs<sup>2</sup></b>		<b>0.0328</b>	<b>0.201</b>	<b>0.487</b>	<b>3.2</b>	<b>0.014</b>	<b>3.34</b>	<b>4.10</b>				
NRL-1	10.2	7.47	29.1	16.8	20129	0.0315	12643	17189				
NRL-2	6.01	7.28	25.7	19.1	29820	0.0377	18035	7242				
NRL-3	7.39	7.85	22.8	12.5	23434	0.0145	14698	12781				
NRL-4	26.2	6.12	23.5	20.1	21520	0.0190	16820	6150				
NRL-5	17.7	8.11	35.5	19.3	26629	0.0223	15044	5200				
NRL-6	25.3	7.18	31.1	28.9	25071	0.0362	14764	5921				
NRL-6	25.3	5.42	27.6	20.6	51364	0.0327	14289	6029				
NRL-7	8.03	10.2	36.5	22.0	28664	0.0178	17895	9353				
NRL-8	10.7	7.03	34.6	18.4	31443	0.0138	J 16100	6354				
NRL-9	4.18	14.3	33.7	31.9	27233	0.0088	J 16466	11811				
NRL-10M	3.26	8.00	19.1	13.2	25203	0.0118	J 10156	2322				
NRL-11M	11.3	3.65	19.2	8.60	13050	0.0222	12773	2210				
NRL-12M	3.55	4.60	21.2	13.9	15238	0.0107	J 11447	2195				
NRL-13B	18.4	4.88	24.8	10.8	15362	0.0133	J 15055	4174				
NRL-14B	16.0	6.57	24.2	9.90	22802	0.0128	J 16259	4133				
NRL-15B	16.9	5.22	23.1	10.7	17618	0.0127	J 13926	3174				

Table 2. Metals concentrations (ppm; continued).

<b>BATTELLE MARINE SCIENCES LABORATORIES</b>													
Jill Brandenberger, Project Manager													
1529 West Sequim Bay Road													
Sequim, Washington 98382													
(360) 681-4564													
<b>SPONSOR</b>	<b>Percent</b>												
<b>CODE</b>	<b>Moisture</b>	<b>Ni</b>	<b>Pb</b>	<b>Sb</b>	<b>Se</b>	<b>Tl</b>	<b>V</b>	<b>Zn</b>					
	Method:	ICP-MS	ICP-MS	ICP-MS	ICP-MS	ICP-MS	ICP-MS	ICP-MS					
	Digestion:	SE	SE	SE	SE	SE	SE	SE					
<b>Achieved MDLs<sup>1</sup></b>		<b>0.0538</b>	<b>0.0429</b>	<b>0.00330</b>	<b>0.181</b>	<b>0.0115</b>	<b>0.111</b>	<b>0.459</b>					
<b>Achieved RLs<sup>2</sup></b>		<b>0.171</b>	<b>0.136</b>	<b>0.0105</b>	<b>0.576</b>	<b>0.0366</b>	<b>0.353</b>	<b>1.46</b>					
NRL-1	10.2	14.9	52.8	0.697	0.181	U	0.358	46.2	67.0				
NRL-2	6.01	17.0	52.5	0.738	0.181	U	0.396	46.4	75.1				
NRL-3	7.39	18.8	26.3	0.359	0.181	U	0.183	45.5	94.6				
NRL-4	26.2	12.2	46.8	0.698	0.181	U	0.358	48.5	107				
NRL-5	17.7	17.7	43.3	0.709	0.181	U	0.455	66.5	128				
NRL-6	25.3	17.4	53.1	0.765	0.181	U	0.349	53.7	138				
NRL-6	25.3	13.0	65.3	0.912	0.181	U	0.357	45.6	102				
NRL-7	8.03	21.2	54.2	0.705	0.181	U	0.435	70.2	128				
NRL-8	10.7	16.6	70.2	0.952	0.181	U	0.354	61.3	112				
NRL-9	4.18	22.9	50.9	0.991	0.181	U	0.291	66.3	129				
NRL-10M	3.26	20.6	12.0	0.307	0.181	U	0.286	32.1	95.4				
NRL-11M	11.3	8.36	13.1	0.243	0.181	U	0.289	30.9	54.2				
NRL-12M	3.55	11.4	12.5	0.335	0.181	U	0.331	36.0	78.0				
NRL-13B	18.4	11.2	13.3	0.189	0.181	U	0.366	36.7	59.7				
NRL-14B	16.0	11.2	12.7	0.131	0.181	U	0.372	41.7	61.0				
NRL-15B	16.9	9.61	14.1	0.178	0.181	U	0.345	35.5	63.2				

Table 3. Sample locations for OFFTA stations in Northings and Eastings, or latitude and longitude for reference stations for May 2004.

<b>Station</b>		<b>Coordinates</b>	
<b>NRL</b>	<b>Site</b>	<b>Northing</b>	<b>Easting</b>
1	OFFTA	157003	546800
2		156988	546803
3		156875	547695
4		156890	547706
5		157035	547465
6		157072	547480
7		157098	547395
8		157098	547280
9		157115	547200
		<b>Latitude (41°N)</b>	<b>Longitude (71°W)</b>
10M	Boat Launch	34.4700	17.31040
11M		34.4700	17.31040
12M		34.4700	17.31040
13B	TetraTech	30.6470	21.7300
14B	Bay	30.6470	21.7300
15B	Reference	30.6470	21.7300

## Supporting References

Battelle Ocean Sciences. 1994. Off-shore investigation of the Site 01 – McAllister Point Landfill, Site 02 – Melville North Landfill, and Site 09 – Old Fire Fighting Training Area at the Naval Education and Training Center (NETC), Newport, Rhode Island: Assessment of Chemical Contamination, Final Report submitted to the US Navy, July 21, 139 pp.

Brown and Root Environmental. 1997. Source removal evaluation report for the Old Fire Fighting Training Area, Naval Education and Training Center, Newport, Rhode Island, Comprehensive Long-term Environmental Action Navy (Clean) Contract, submitted to the Northern Division, Environmental Branch, Code 1823/JS, Naval Facilities Engineering Command, Contract Number N62472-90-D-1298, "Clean" Contract Task Order No. 0288, December.

Emsbo-Mattingly, S. 2002. Environmental forensic investigation of hydrocarbon sources at the Old Fire Fighting Training Area: Naval Station Newport, Rhode Island. Final Report. Battelle Memorial Institute, Duxbury MA. September 18, provided as Appendix A to the: "Phase II Pre-design Investigation for the Old Firefighting Training Area", Naval Station Newport, Newport Rhode Island, Tetra Tech NUS, Inc. September 2002.

Montgomery, M. T., Boyd, T. J., Osburn, C. L., and D. C. Smith. 2003. PAH biodegradation, turnover, and ambient concentrations in surface sediments of Coaster's Harbor and Narragansett Bay. NRL Technical Memorandum NRL/MR/6110--03-8657.

Nixon, S. W., Hunt, C. D., and B. L. Nowicki. 1986. The retention of nutrients (C, N, P), heavy metals (Mn, Cd, Pb, Cu), and petroleum hydrocarbons in Narragansett Bay. pp. 99-122 in: and J. M. Martin and P. Lasserre, (eds.) Biogeochemical Processes at the Land-Sea Boundary. Elsevier Press, Amsterdam.

Quinn, J. G., Cairns, R. W., Hartmann, P. C., Kittredge, M. W., and A. R. Aukerman. 1998. Nature and extent of organic contaminants in sediments and elutriate samples from the Old Fire Fighting Training Area, Naval Education and Training Center, Newport, Rhode Island. Graduate School of Oceanography, University of Rhode Island, Narragansett, RI.

## Appendix I

### **Data from the second NRL sampling (October 2002) of OFFTA in Coaster's Harbor and reference stations in Narragansett Bay.**

Figure A1. Sample locations for stations 1-8 at Coaster's Harbor for October 2002.

Figure A2. Sampling stations for submerged sediment from the Tetrattech background site on the west side of Narragansett Bay (Stations 9), off the McAllister Point landfill (Station 10) and off the Middleton boat launch (Station 11) for October 2002.

Table A1. PAH concentrations in Coaster's Harbor and Narragansett Bay sediment ranged from 0.08 to 1.33 ppm during October 2002 sampling. Ambient PAH concentration was low (< 12 ppm) for three samplings in '02 compared to 6-132 ppm in (Battelle Ocean Sciences 1994), 47 ppm in '97 (Brown and Root Environmental 1997), and to >4 ppm (7 stations), >44 ppm (4 stations) and >132 ppm (1 station) in '98 (Quinn et al. 1998).

Table A2. Mineralization rates for naphthalene, phenanthrene and fluoranthene in Coaster's Harbor and Narragansett Bay sediment for October 2002 sampling. PAH mineralization rates were consistent with those found in other estuarine sediment sites with low PAH concentration and flux.

Table A3. Turnover times for PAHs in Coaster's Harbor and Narragansett Bay sediment for October 2002 sampling. PAH turnover was rapid enough to metabolize current PAH flux through sediment in days to months to two years. This is consistent with the attenuation of ambient PAH concentration at the site since 1994.

Table A4. Bacterial production in sediments of Coaster's Harbor and Narragansett Bay sediment for October 2002 sampling was within the range typically found for sediments in urbanized estuaries.

Figure A1. Sample locations for stations 1-8 at Coaster's Harbor for October 2002.

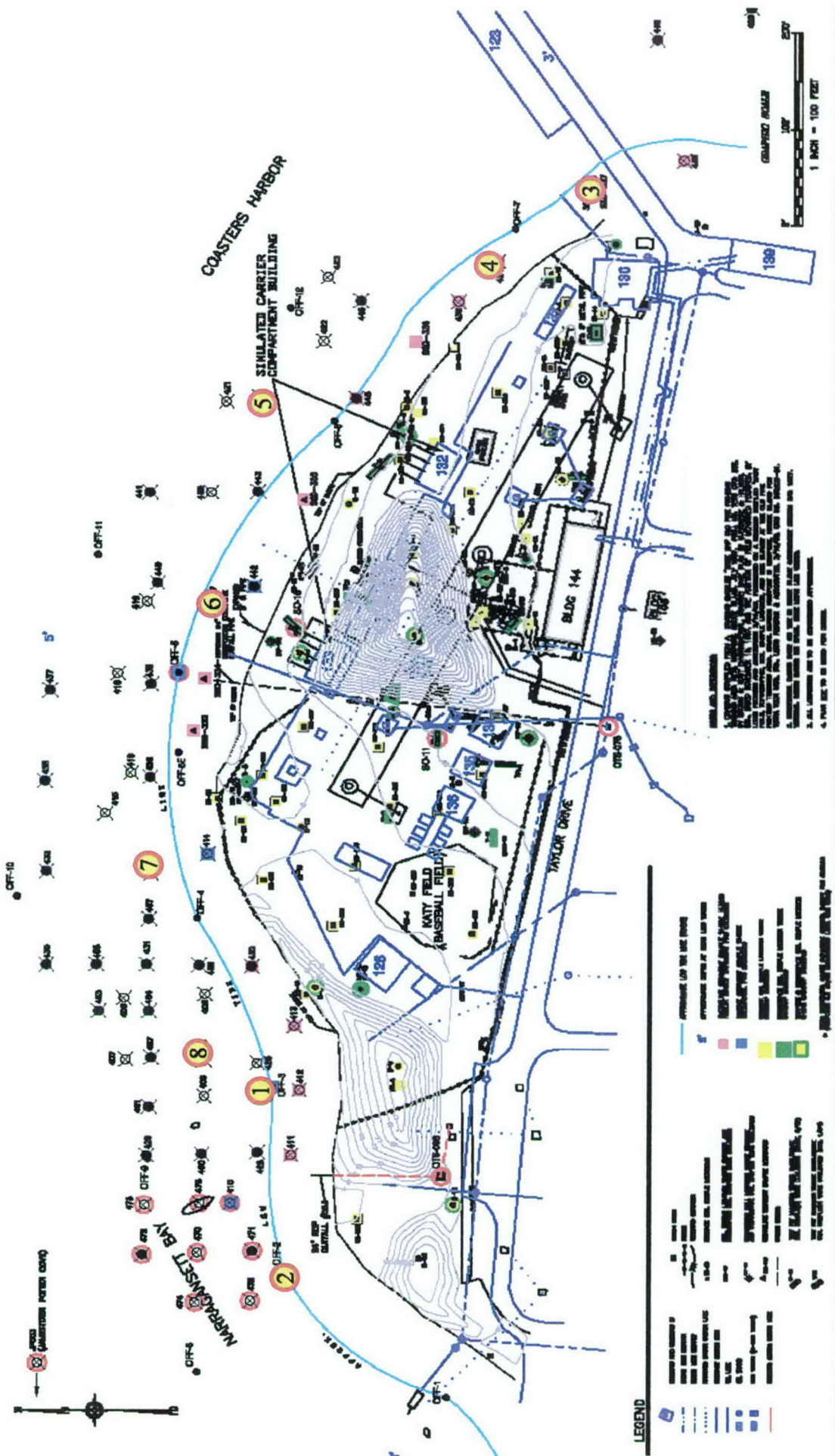


Figure A2. Sampling stations for submerged sediment from the Tetrtech background site on the west side of Narragansett Bay (Stations 9), off the McAllister Point landfill (Station 10) and off the Middleton boat launch (Station 11) for October 2002.

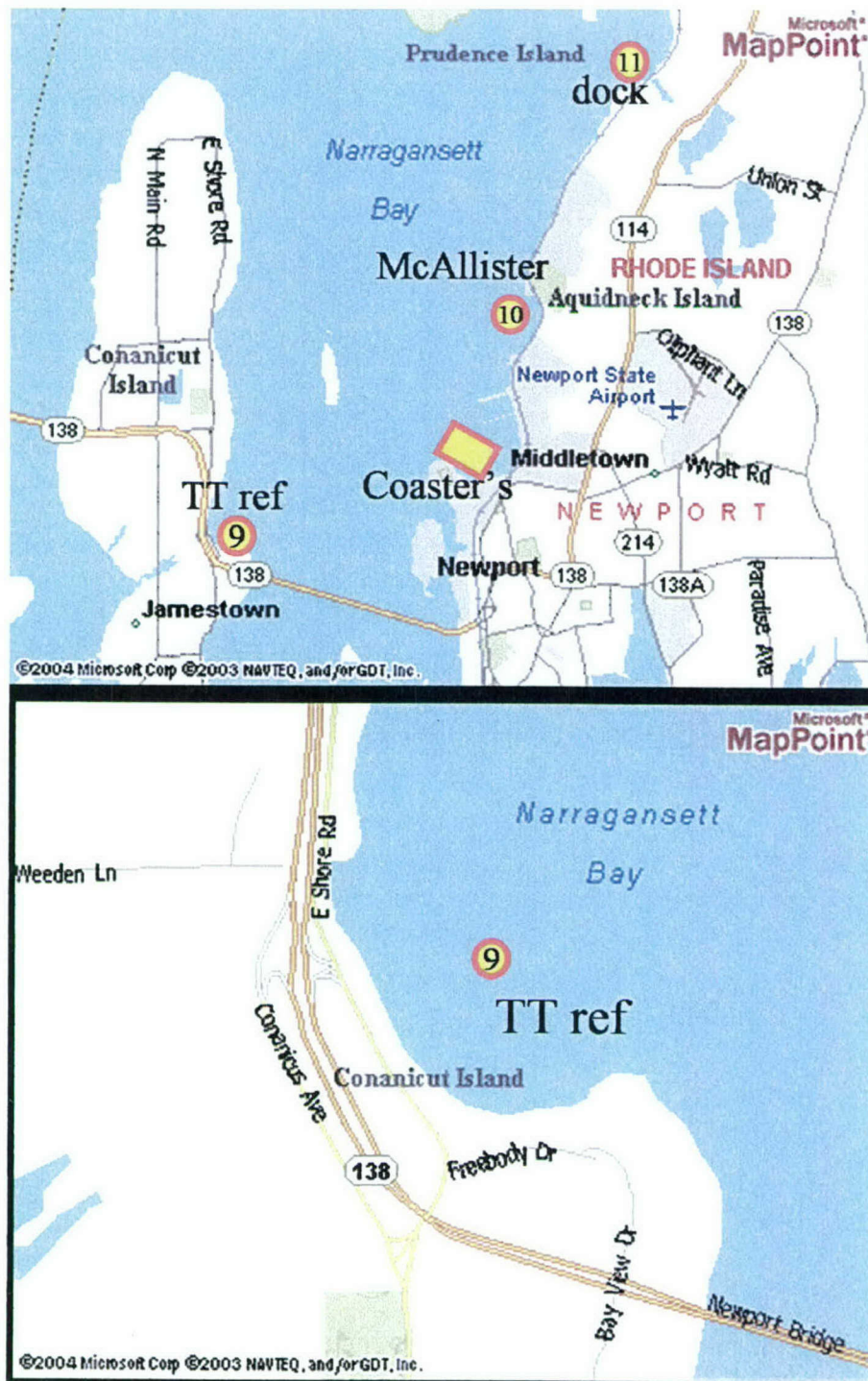


Table A1. PAH concentrations in Coaster's Harbor and Narragansett Bay sediment ranged from 0.08 to 1.33 ppm during October 2002 sampling. Ambient PAH concentration was low (< 12 ppm) for three samplings in '02 compared to 6-132 ppm in (Battelle Ocean Sciences 1994), 47 ppm in '97 (Brown and Root Environmental 1997), and to >4 ppm (7 stations), >44 ppm (4 stations) and >132 ppm (1 station) in '98 (Quinn et al. 1998).

Tetrtech	NRL	Total PAH (ppm)
OFF-3	1	0.96
OFF-2	2	0.24
SSD-337	3	0.98
424	4	1.33
444	5	0.41
417	6	0.15
434	7	0.08
462	8	0.11
Reference	9	0.03
MacAllister	10	0.08
dock	11	0.22

Table A2. Mineralization rates for naphthalene, phenanthrene and fluoranthene in Coaster's Harbor and Narragansett Bay sediment for October 2002 sampling. PAH mineralization rates were consistent with those found in other estuarine sediment sites with low PAH concentration and flux.

Station	Mineralization Rate ( $\mu\text{g g}^{-1} \text{d}^{-1}$ )					
	Naphthalene		Phenanthrene		Fluoranthene	
	AVG	SD	AVG	SD	AVG	SD
1	1.09E-05	7.76E-05			2.11E-04	7.26E-04
2			3.50E-03	7.98E-03	1.94E-05	3.36E-05
3	4.67E-04	2.41E-04	2.91E-03	3.24E-03		
4	1.79E-05	6.11E-05				
6	9.67E-04	2.35E-04	3.98E-03	2.55E-03	1.89E-03	2.13E-03
7			5.09E-04	1.11E-02		
8	8.52E-05	1.29E-04				
9	1.38E-04	4.36E-05				
10	3.26E-04	2.20E-04	3.75E-03	1.02E-03		

Table A3. Turnover times for PAHs in Coaster's Harbor and Narragansett Bay sediment for October 2002 sampling. PAH turnover was rapid enough to metabolize current PAH flux through sediment in days to months to two years. This is consistent with the attenuation of ambient PAH concentration at the site since 1994.

Station	PAH Turnover Time (days)	
	Phenanthrene	Fluoranthene
1		939
2	11	3257
3	62	
4		
6	9	18
7	18	
8		
9		
10	4	

Table A4. Bacterial production in sediments of Coaster's Harbor and Narragansett Bay sediment for October 2002 sampling was within the range typically found for sediments in urbanized estuaries.

Station	Sample Type	Bacterial Production ( $\mu\text{g C kg}^{-1} \text{d}^{-1}$ )	
		AVG	SD
1	sediment	7.9	2.3
2	sediment	6.7	1.0
3	sediment	20.3	7.5
4	sediment	10.0	3.9
5	sediment	8.7	1.3
6	sediment	11.8	0.9
7	sediment	5.8	1.7
8	sediment	9.7	5.4
9	sediment	9.9	1.5
10	sediment	4.5	0.0
11	sediment	12.4	1.9

## Appendix II

### **Pictures of intertidal locations from May 2004 sampling event.**

Figure B1. May 2004 sampling locations at OFFTA for NRL-1, NRL-5, and NRL-8.

Figure B2. May 2004 sampling locations at the Middleton Marina for NRL-10M and NRL-11M.

Figure B3. May 2004 sampling locations near the TetraTech west Narragansett Bay reference site for NRL-14B and NRL-15 M.

Figure B1. May 2004 sampling locations at OFFTA for NRL-1, NRL-5, and NRL-8.



Figure B2. May 2004 sampling locations at the Middleton Marina for NRL-10M and NRL-11M.

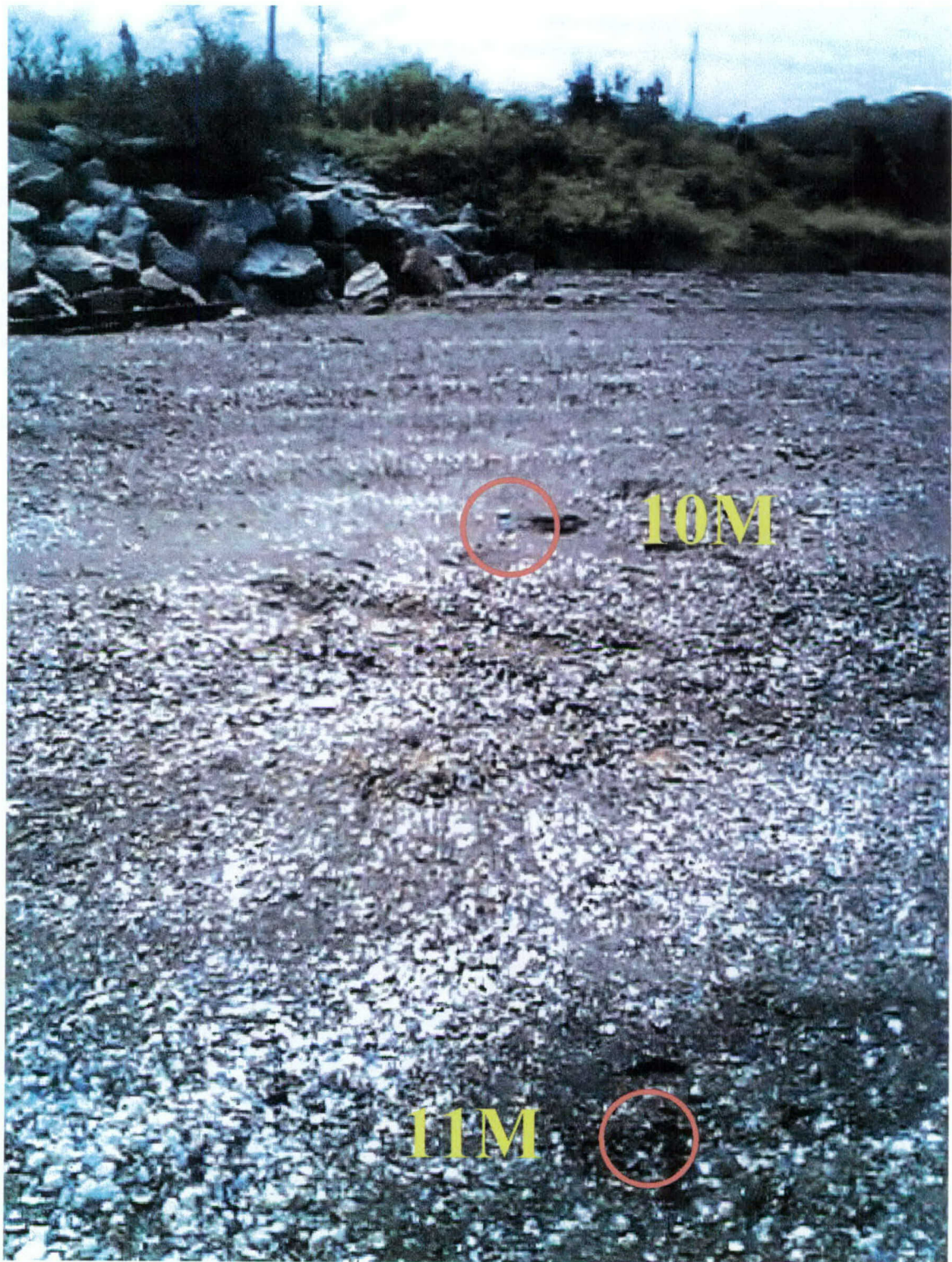


Figure B3. May 2004 sampling locations near the TetraTech west Narragansett Bay reference site for NRL-14B and NRL-15M.

