ENVIRONMENT AGENCY

SOUTH WEST
REGION

FAL ESTUARY
TBT MONITORING PROGRAMME

1997 BASELINE SURVEY

Tidal Water Quality

Report No. TWQ/98/02

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1. INTRODUCTION

Historically, samples of water and sediments taken in the Fal Estuary have shown very high levels of Tributyltin (TBT), with levels in sediments being among the highest found in the UK[1]. TBT is a prescribed substance for release to water and is also a List II substance with an Environmental Quality Standard (EQS) of 2 ng TBT^{+}/l. TBT is known to be toxic to aquatic organisms by affecting a wide range of fundamental biological processes at very low concentrations[2], and since 1987 its use for antifouling boats of under 25m has been banned[1]. However, discharges to the marine environment in the Falmouth area continue from dockyard activities, leaching from historically contaminated sediments and other diffuse sources. TBT has a variable half life depending on where it is found, e.g. 9-19 months in aerobic sediments, at least 21 months in anaerobic sediments, and in the order of 20 years for very highly contaminated sediments[1]. Although this study focuses on levels of TBT and Dibutyltin (DBT), studies conducted by MAFF between 1986 and 1993 also identified the presence of Triphenyltin (TPT), albeit in much lower concentrations than TBT. TPT ceased to be used in antifoulants in 1995 as a result of the Pesticides Advisory Committee review on the use of triorganotins (HSE pers comm).

The most significant source of TBT input to the Fal area is Falmouth Dockyard. Effluent from dockyard operations has contributed very significant loads of both TBT and TPT to the marine environment: firstly from the discharge of contaminated waste from stripping and painting of ships; and secondly from historically contaminated sediments. When ships enter the dry dock these sediments are disturbed and resuspend TBT/TPT in the water column. There are also several additional sources of contamination of waters outside Falmouth Dockyards comprising sewage outfalls, vessel traffic, vessel mooring, and contaminated sediments. Sources of TBT entering the sewage outfalls are being investigated; it is possible that air-borne TBT from the dockyard is being washed into the sewerage system (Environment Agency Integrated Pollution Control (IPC) pers comm).

In November 1996 Falmouth Dockyard Engineering Co (FDEC) was granted IPC Authorisation for the application and removal of organotin antifoulants. The Authorisation requires FDEC to undertake an improvement programme to a specified timetable starting in September 1998, resulting in a reduction in the introduction of TBT to the receiving environment. During the period leading up to the Authorisation the Agency conducted an environmental impact study to assess the inputs of TBT to the estuary from Falmouth Dockyard operations[3]. The studies showed that the presence of newly painted ships in the dockyard might be contributing much more TBT to the general environment than the monitored discharge. As a result, the initiation of a long-term programme to monitor levels of TBT in the receiving environment in the vicinity of Falmouth Dockyard and the Fal Estuary was proposed. DBT was also included to indicate the extent of TBT degradation, i.e. whether the TBT originated from a fresh source or from historical contamination.

The programme has been drawn up from the following information:

i. Fal Estuary TBT Monitoring Programme, contract report by MAFF, 28 June 1996. This is a collation of data on TBT levels in water, sediment and shellfish in the Fal Estuary, followed by recommendations for a five year monitoring programme.

ii. Site visits conducted by the Agency in February 1997 to identify possible TBT sources and sinks in the Fal Estuary[4].

iii. Existing and historical data from Agency monitoring programmes.

This report describes the results of surveys undertaken during 1997 and provides recommendations for future monitoring during 1998.

1.1 Study Area and Survey Objectives

The monitoring programme has been designed to target sources and sinks of TBT within the Fal Estuary, and includes known areas where the EQS for TBT (2 ng TBT^{+}/l) is currently routinely exceeded. The study area (Figure 1) extends from Pennance Point to offshore of Zone Point in the south, Falmouth Docks, Carrick Roads, and the rivers and tributaries into the Fal Estuary to the north at Malpas.

The main 'controllable' inputs are Falmouth Dockyard, and the South West Water sewage discharges at Pennance Point and Middle Point. These sewage discharges ceased at the end of April 1998 when they were transferred to a new outfall 600m off Middle Point to the NNW of Black Rock. Sampling points located throughout the Fal estuary system have been chosen to relate to locations where there is known or suspected TBT inputs and accumulation, as well as distant localities for the assessment of background levels.

The overall aim of the sampling programme is to monitor the Fal Estuary with respect to TBT for the long-term achievement of Environmental Quality Standards. Objectives for the programme are as follows:

1. Spatial Intensive (Baseline) Survey: To enable the Agency to extend existing information regarding the distribution and quantity of TBT present in sediments, shellfish tissue, and the water column. This will provide a baseline for the measurement of future improvements. A survey of dogwhelk populations will also be used as a base for long-term indications.

2. Trend Monitoring Surveys: To monitor spatial and temporal changes in the quality of water, sediment, and shellfish tissue. These long-term surveys will aim to demonstrate any significant trends.

3. Compliance Audit: The results from 1 and 2 will allow the Agency to assess the possibility of setting targets with respect to expected reduction levels and time scales both in the 'near field' close to the dockyard and sewage outfalls, and the 'far field', the Fal Estuary;

2. SAMPLING PROGRAMME

2.1 Programme of Work

The survey programme completed during 1997 is summarised below. Survey locations are presented in Figures 1, 2, 3 and 4.

Date	Survey Description	Survey	Determinands	No. of Samples
5/7 Feb	Site reconnaissance visits			
12/13 May 4 Aug	Falmouth Dockyard sediment collection by Posford Duvivier	Baseline	TBT+	13
13 May	Sediment sampling trials			
12 Jun	Offshore sediment sampling Fal Estuary water sampling (HW)	Baseline	TBT+ TBT+, salinity, SS (105°)	15 of 29 planned 65
12/24 Jun, 3 Jul	Inshore sediment sampling	Baseline	TBT+	36 of 38 planned
4 Jul	Dogwhelk survey	Baseline		
15 Jul	Mussel collection at Whitsand Bay	Trend	TBT+, Length, Weight	1 background
16 Jul	Deployment of mussel cages/bags	Trend		16 cages of 100
6 Aug	Water sampling over HW	Trend	TBT+, salinity, SS (105°)	5
13 Aug	Mussel sampling	Trend	TBT+, DBT+, Length, Shell and Tissue Weight	15 cages of 30
15 Sep	Mussel sampling	Trend	TBT+, DBT+, Length, Shell and Tissue Weight	13 cages of 30
7 Oct	Water sampling	Trend	TBT+, salinity, SS (105°)	7
28 Oct	Mussel sampling	Trend	TBT+, DBT+, Length, Shell and Tissue Weight	9 cages of 30
12 Nov	Water sampling (HW)	Trend	TBT+, salinity, SS (105°)	8
3 Dec	Water sampling (HW+3)	Trend	TBT+, salinity, SS (105°)	9

2.2 Sampling Methods and Equipment

Baseline Survey Sediments

Surface sediment samples were collected in accordance with standard Agency procedures[5]. The survey locations are presented in Figure 1. Offshore samples were obtained using hand operated weighted Van Veen grabs, with sub-samples typically scooped from the top 10cm of the grabbed sample. Some difficulty was experienced in the areas around Black Rock and Middle Point due to the rock and kelp substrate. As a result, the number of offshore samples collected was reduced from 29 to 15. A total of 36 of the proposed 38 inshore sediment samples were collected on 12th and 24th June and 3rd July 1997. All samples were transferred to 250ml glass jars using teflon scoops, and a log was completed with time, location and sample composition. During transit to the Agency laboratories in Exeter and prior to the analysis the samples were kept cold in the dark.

In addition to the estuary sediment samples, a total of 13 samples were collected from Falmouth Dockyard by Posford Duvivier on 12th and 13th May and 4th August 1997. These samples were retrieved from surface sediments using a teflon scoop by a SCUBA diver undertaking a separate core sampling programme commissioned by FDEC.

Baseline Survey Water Samples

Water samples were collected in accordance with standard Agency procedures[5]. The locations are presented in Figure 2. A total of 65 samples were collected on 12th June 1997 over a period of 3 hours (1.5 hours either side of High Water). Samples were taken in duplicate from subsurface waters for high level (>7500 ng TBT+/l) or low level analysis. Duplicate sampling was necessary because a slightly different non-repeatable analytical technique is used depending on the expected level of TBT in the sample. Two ad hoc samples were also obtained close to large vessels moored alongside in Falmouth Dockyard and at King Harry Ferry.

Baseline Survey of Dogwhelks

The toxicity of TBT to shellfish is well known; causing imposex in the dog whelk *Nucella lapillus*.

On 4th July 1997, various locations within the study area were surveyed for presence/absence of dogwhelks over the low water period (Figure 3). The locations were selected from the shore sediment sites and from past dogwhelk surveys conducted by Plymouth Marine Laboratories (PML)[6]. Peter Gibbs at PML recommended the survey methods used:

1. At each site there was a search and count for ten minutes by each of two scientists amongst rocks and crevices between the mid-tide and low water areas.

2. Measurements of shell height and thickness were made, and the presence/absence of teeth on the shell was noted. This information was used to assess the population structure and give a ratio of adults to juveniles; in general, for animals up to 3 years old the shell margin is sharp, but after this time the margin often thickens and produces teeth.

3. There was a search for eggs and a record of presence/absence was made.

4. Photographs of each site were taken for survey repeatability.

Trend Monitoring of Mussels

Mussels are good accumulators of TBT[1], therefore, *Mytilus edulis* has been used as the bioindicator of TBT contamination for this study.

On 16th July 1997, 16 cages of 'TBT free' mussels originating from Whitsand Bay were deployed throughout the study area (Figures 4 and 5) by the Agency and Dr Mike

Waldock of CEFAS. Methods of deployment were in accordance with MAFF procedures developed over a number of years.

Ten of the twelve inshore cages were attached to breeze-blocks and placed at the low water mark. Two further cages were suspended from a ladder at Islington Quay (Penryn), and from a pontoon at Mylor Yacht Harbour. The three offshore bags were suspended at 2m below the water surface on moorings prepared by Falmouth Harbour Authority (sites 6 and 16), and Agency staff (site 13). Approximately 100 mussels of approximately 2cm length were placed in each cage/bag. Samples of 30 individuals from each cage/bag were collected on 13th August, 15th September, and 28th October, and sent to the CEFAS laboratories at Burnham-on-Crouch for determination of TBT and DBT in mussel tissue, and for measurement of shell length, tissue weight and shell weight.

Trend Monitoring Monthly Water Sampling

From the preliminary results of water, sediment, and mussel tissue samples, TBT 'hot spots' and background sites were identified for monthly water sampling surveys. The locations are presented in Figure 4. During December 1997, the nine sampling locations became part of the Agency Dangerous Substances Monitoring Programme, which continues throughout the year.

2.3 Laboratory Analysis

All sediment and water samples were analysed by the Agency laboratories in Exeter for the following determinands:

Water Samples	Saline TBT+ (ng/l) Salinity (PSU) Suspended Solids (105°C) (mg/l)
Sediment Samples	TBT+ (µg/kg) - Samples sieved to <63 microns where possible

3. RESULTS

The results are split into two sections: Baseline Surveys comprising sediment, water and dogwhelk surveys; and Trend Monitoring Surveys comprising mussel and monthly water sampling surveys.

3.1 Baseline Surveys

Sediment Samples

Sediment sampling locations and results are presented in Figures 6 and Table 1, and summarised in Figure 8. The results are summarised as follows:

*Mean Result less than laboratory limit of detection (66 µg TBT^+/kg)	7.8%
*Mean Result less than limit of detection (66 to 603 µg TBT^+/kg)	37.5%
Mean Result between LOD and 499 µg TBT^+/kg	10.9%
Mean Result between 500 and 999 µg TBT^+/kg	9.4%
Mean Result between 1000 and 4999 µg TBT^+/kg	18.8%
Mean Result between 5000 and 9999 µg TBT^+/kg	6.3%
Mean Result equal or greater than 10000 µg TBT^+/kg	9.4%

* At present the Agency's lowest detection limit is 66 µg TBT^+/kg dry weight, however, many of the results had a higher detection limit (up to 603 µg TBT^+/kg). This was due to the amount of water contained in the sample, which when sieved and dried, reduced the amount of sample available for analysis, thus raising the detection limit.

The highest levels of TBT in the sediment samples were found at Falmouth Dockyard, Penryn River, Mylor Yacht Club, and St. Mawes Harbour.

Water Samples

Water sampling locations and results are presented in Figures 7 and Table 2, and summarised in Figure 8. The results are summarised as follows:

Result less than laboratory limit of detection (2 ng TBT^+/l)	4.6%
Result between 2 and 9 ng TBT^+/l	67.7%
Result between 10 and 19 ng TBT^+/l	13.8%
Result equal or greater than 20 ng TBT^+/l	13.8%

The highest levels of TBT in the water samples were found at Falmouth Dockyard and Penryn River.

Dogwhelk Survey

Of the 21 sites visited below (the 'bold' locations indicate sites at which animals were known to exist[7]), populations were found at only three locations - Towan Beach outside the estuary to the east, St Mawes Castle, and the eastern end of Gyllingvase Beach – Castle Drive (Site A). These sites appear to constitute the last remaining dogwhelk populations in the area and will be used as long-term monitors.

No.	Location	East	North
A	**Gyllingvase - Castle Drive**	**182150**	**31750**
B	**Gyllingvase in front of Falmouth Hotel**	**181700**	**31950**
10	**Prince of Wales Pier**	**181318**	**32482**
9	Royal Cornwall Yacht Club	180600	33500
1	Islington Quay - Penryn	178700	34500
8	Penryn River near Flushing	180430	34020
14	**Hammerhead Wharf at Mylor Yacht Club**	**181890**	**35370**
15	Mill Quay slipway - Mylor Creek	180560	35930
16	**Carrick between Mylor and Restronguet**	**182150**	**36130**
17	**Restronguet Point**	**181660**	**37100**
20	Loe Beach	182500	38050
21	**King Harry Ferry**	**184070**	**39500**
22	Coombe Creek	184035	40281
23	Malpas	184423	42723
26	Turnaware Point	183500	38300
28	Messack Point	184108	35740
29	Just Creek - St Just in Roseland	184800	35800
31	St Mawes Castle	184151	32611
35	Pelyn Creek - Percuil	186200	33900
C	**Between Carricknath Pt & Amsterdam Pt.**	**184900**	**23950**
	Towan Beach	187000	32800

Samples of each of the three populations were taken for the assessment of imposex using the Relative Penis Size index (RPS), which is the ratio of the size of the female penis to that of the male[6]. Full details of this assessment are presented and discussed in a report by Emma Davies of the University of Plymouth[8]. The results are summarised in the table below:

Location	Population Size	RPS (%)	Jeuveniles
Gyllingvase - Castle Drive	Abundant	34.9	5%
St Mawes Castle	Low	45.5	21%
Towan Beach	Abundant	29.8	39%

It is concluded that at all three sites the populations are in a poor state of health since the RPS values and the ratio of adults to juveniles are both high, and no egg capsules were found. An RPS of 5% is considered to be consistent with areas away from boating activity[8]. Although the RPS values are high, a comparison with previous data collected from the three locations by Bryan in 1985[7] shows a decrease in the RPS which may suggest a slight recovery of these populations. This is discussed in more detail in the report mentioned above[8].

3.2 Trend Monitoring Surveys

Mussel Samples

The results of the mussel bioaccumulation survey are presented in Table 3, and summarised in Figure 8. Details of mussel tissue and shell weights and lengths are contained in Appendix 2. Unfortunately only nine of the sixteen cages survived until October. However, there is at least one month of data for all sites, apart from Pennance Point where the cage was lost shortly after deployment due to its exposed location. During the first month of deployment from 16th July 1997 to 13th August 1997, levels of TBT bioaccumulated by the mussels are summarised as follows:

<0.1 mg TBT+/kg:	Vilt Buoy
0.1 to 0.19 mg TBT+/kg:	Middle Point, Restronguet Point, King Harry Ferry, Malpas, Deer Park, Turnaware Point, Carrick Roads, Messack Point, St Mawes Harbour, Black Rock Buoy
0.2 to 0.49 mg TBT+/kg:	Mylor Yacht Club
>0.5 mg TBT+/kg:	Falmouth Dockyard, Islington Quay, Flushing

For the period from 16th July 1997 to 15th September 1997, cages were lost at Middle Point and Vilt Buoy, and notable increases in bioaccumulation of TBT were recorded at King Harry Ferry and Messack Point. The results of the bioaccumulation of TBT are as follows:

<0.1 mg TBT+/kg:	No sites
0.1 to 0.19 mg TBT+/kg:	Restronguet Point, Malpas, Deer Park, Turnaware Point, Carrick Roads, St Mawes Harbour, Black Rock Buoy
0.2 to 0.49 mg TBT+/kg:	King Harry Ferry, Mylor Yacht Club, Messack Point
>0.5 mg TBT+/kg:	Falmouth Dockyard, Islington Quay, Flushing

For the period from 15th September 1997 to 28th October 1997, further cages were lost at Falmouth Dockyard, Malpas, Carrick Roads, and Black Rock Buoy. Notable increases in bioaccumulation of TBT were recorded at Mylor Yacht Club, Deer Park, and Turnaware Point. At St Mawes Harbour and Messack Point levels of TBT in the mussels decreased i.e. TBT was being depurated. The results of the bioaccumulation of TBT are as follows:

<0.1 mg TBT+/kg:	St Mawes Harbour
0.1 to 0.19 mg TBT+/kg:	Restronguet Point, Messack Point
0.2 to 0.49 mg TBT+/kg:	King Harry Ferry, Deer Park, Turnaware Point
>0.5 mg TBT+/kg:	Islington Quay, Flushing, Mylor Yacht Club,

The maximum levels over the entire deployment period are presented in Figure 8 which shows the highest concentrations were recorded at Falmouth Dockyard, Islington Quay, Flushing, and Mylor Yacht Club.

Monthly Water Samples

The results from monthly water sampling surveys are presented in Table 4 and Figures 9 and 10. As well as the data collected in August, October and November 1997, results were available up to the 17th April 1998 and have been included in this report. In addition to the nine sites specified for monthly water sampling, samples were also collected from Falmouth Dockyard outfall final effluent and surface boil, and Middle Point outfall surface boil (up until commissioning of the new Black Rock outfall in April 1998).

Figure 9 gives a spatial presentation of the mean results for the duplicate samples and Figure 10 presents the data over time at each site. Mean results for each site for the period 7th August 1997 to 17th April 1998 are presented below together with the result from the baseline water survey on 12th June 1997 for comparison.

Site Code	Site No.	Site Name	East	North	Baseline TBT Results 12/6/97 (ng TBT+/l)	Mean Monthly TBT (ng TBT+/l)
81914855	1	Middle Pt. Boil	182700	32000	16 (site 21)	19
81910121	2	Middle Pt. 500m N	182635	32500	26 (site 24)	10
81910616	3	Fal Docks Eff.	181800	32500	no sample	8713
81910620	4	Fal Docks Boil	181900	32650	no sample	2189
81910622	5	Fal Docks Penryn	181758	33195	15 (site 35)	17
81910649	6	Islington Quay	178700	34500	no sample	34
81910635	7	Falmouth Marina	180137	33983	49 (site 38)	50
81910170	8	Carrick Roads	183000	36330	3 (site 40)	5
81910157	9	Mylor	182176	35436	8 (site 42)	6
81920220	10	Deer Park	185006	41027	5 (site 61)	11
81910139	11	Vilt Buoy	183135	34023	3 (site 47)	4
81910116	12	Black Rock	182635	31568	3 (site 19)	5

NB Results of less than the limit of detection have been set at the detection limit for the purposes of the calculations above.

4. DISCUSSION

From the data described above and summarised in Figure 8, there are TBT 'hotspots' evident in sediment, water and mussel tissue at locations in the Penryn River, Falmouth Dockyard, and Mylor Yacht Club.

The 1997 results were submitted to WRc for analysis under the terms of the Environmental Quality Sampling and Statistics Technical Service. A report of the analysis from WRc is included in Appendix 1. Specific questions were raised by the Agency and salient points from the analysis are summarised as follows:

4.1 Spatial Distribution of TBT

Q1. Is it possible to carry out any statistical analysis on spatial differences in TBT between sites ?

Yes, the analysis is possible and has been undertaken by WRc in the form of grouping sites and performing t-tests to compare variability within and between groups. The analysis showed no relationship between water and sediment levels for the 21 jointly sampled sites, and suggested that if the 'hotspot' mechanisms were similar it would be desirable for a greater proportion of joint water and sediment sites to be sampled in the future.

Q2. Will it be possible to look for any differences in TBT between two spatial surveys in the future ?

Yes, this is possible provided that the site locations remain comparable. 'The great advantage of using only site-paired data (in the analysis) is that we can calculate paired differences. This removes all of the 'nuisance' site-to-site spatial variation, and so greatly improves the statistical precision of the temporal comparison. *This is important because the temporal differences may be relatively small in comparison with spatial variations through the estuary.*'

4.2 Monthly Monitoring of TBT Water Quality

Q3. What is an appropriate statistical method for looking at time trends in TBT water quality ?

Cusum analysis using either WRc's statistics package – AARVARK, or the Agency's statistics package - LAPWING

What is an appropriate statistical method for looking at differences in TBT water quality between sites ?

LAPWING. 'In the present case, the spatial pattern is too complex for all nine sites to be sensibly viewed as a one-dimensional sequence. *However, it might be reasonable to do one LAPWING run on sites 11, 13, 7, 6, 2, and 16 (to characterise the spatial trend down Carrick Roads), and another run on sites 5, 3, 2, and 16 (for the Penryn arm of the spatial trend).*'

4.3 Mussel Tissue TBT Concentrations

Q5. What is an appropriate statistical method for looking at time trends in mussel tissue TBT concentration ?

Friedman's two-way analysis of variance test (ANoVA). The use of Friedman's test statistic X^2 on the nine sites that had TBT bioaccumulation results for all three months showed no common seasonal pattern. *'However, on repeating the test omitting Islington Quay and Flushing, a clear seasonal pattern was shown by the remaining sites'.*

This result raised questions to be considered following the results of the 1998 surveys (see page 11 of Appendix 1). It was also noted that at five of the nine sites, concentrations were highest in October, which apparently conflicts with the view that 'in autumn, levels of TBT will be decreasing as the mussels depurate' (CEFAS pers comm). Investigating this further involved comparison of the October mussel tissue data (Table 3) with the October water quality data (Figures 9 and 10). Unfortunately there is insufficient paired data to comment, however, the only paired result available at Deer Park does show a maximum water TBT concentration in October. Elevated levels of TBT in the water are to be expected in the Autumn months as a result of boats being winterised. This question may be investigated further following the 1998 surveys.

Q6. What is an appropriate statistical method for looking at differences in mussel tissue TBT concentration between sites ?

ANoVA

Q7. Is there much gained by having duplicate monthly water samples ?

The analysis confirms that the agreement between duplicate samples is very good, therefore there is little benefit to collecting extra data in the future.

5. RECOMMENDATIONS

From the results of the 1997 monitoring programme and statistical analysis discussed above, a programme of water sampling and mussel deployments was recommended and undertaken in 1998 as follows:

5.1 1998 Mussel Deployments

Four cages of mussels were deployed on 26/2/98 at Pennance Point, Middle Point, Falmouth Dockyard, and Black Rock Buoy. There were sufficient mussels deployed to facilitate sampling in April, May, June, July, and August.

The main survey period is from mid-May to mid-September with mussels deployed at the seventeen locations listed below. The overlap of sampling at the four March locations during June, July, and August is designed to serve two objectives. Firstly, to observe any changes at the old Middle Point outfall due to the Falmouth Sewage Scheme commissioned in April 1998, and secondly, to test mussels exposed to 1 month's bioaccumulation of TBT against mussels which have been bioaccumulating since March.

1998 Mussel Deployment Locations

No.	Location	Easting	Northing
1	Pennance Point	180330	30800
2	Middle Point	182700	31850
3	Falmouth Docks - Northern Wharf	182000	32980
4	Islington Quay - Penryn	178900	34320
5	Penryn River near Flushing	180600	33950
6	Vilt Buoy	183135	34023
7	Pontoon at Mylor Yacht Club	182000	35400
8	Restronguet Point	181570	37150
9	King Harry Ferry	184000	39550
10	Malpas	184500	42770
11	Deer Park	185000	40930
12	Turnaware Point	183500	38200
13	Carrick Roads mid channel	182800	36600
14	Messack Point	184000	35800
15	St Mawes Harbour	184950	32500
16	Black Rock Buoy	183675	31568
17	Percuil River - Mid Estuary	185650	34050

These locations are consistent with the 1997 surveys (although only nine of the sixteen 1997 sites had data for all three months) so that between site and between year comparisons may be made. One additional site has been chosen in the Percuil River.

5.2 1998 Monthly Water Sampling

Some of the 1997 monthly water sampling locations have been amended so that they are taken at the same location as the mussels. In addition, there are four new water sampling sites at the mussel cages at Falmouth Dockyard Northern Wharf, Middle Point, St Mawes, and Messack Point. The locations are listed below. This gives a total of 13 monthly water samples; 11 coincide with mussels and 2 are outside Falmouth Dockyard.

Location	Easting	Northing
Falmouth Dockyard Final Effluent	181800	32500
Falmouth Dockyard Surface Boil	181900	32650
Old Middle Point Outfall - 500m North	182635	32500
Penryn River off Falmouth Dockyard	181758	33195
Middle Point	182700	31850
Falmouth Docks - Northern Wharf	182000	32980
Islington Quay - Penryn	178900	34320
Penryn River near Flushing	180600	33950
Vilt Buoy	183135	34023
Pontoon at Mylor Yacht Club	182000	35400
Deer Park	185000	40930
Carrick Roads mid channel	182800	36600
Messack Point	184000	35800
St Mawes Harbour	184950	32500
Black Rock Buoy	183675	31568

A further recommendation has been made to take water samples at all 17 mussel locations plus the two locations outside Falmouth Dockyard at High Water and at Low

Water in June and September and continue at 2 monthly intervals throughout the year if feasible (see Figure 11). The results from the 1998 surveys will be reported in January 1999.

6. REFERENCES

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8. The current status of Dogwhelk, *Nucella lapillas* (L.) populations on SW shores in relation to the impact of TBT pollution, Emma Davies, University of Plymouth, 1998

TABLES

TABLE 1 Fal Estuary TBT Monitoring - Sediment Sampling

No.	Location	Easting	Northing	Time (GMT)	TBT+ (ug/kg)	TBT+ (ug/kg)	Mean TBT+ (ug/kg)	Notes
	Inshore Sediment Samples (24/6/97)							
1	Islington Quay - Penryn	178700	34500	12:34	1626*	1945*	1786	Mud
2	Town Quay coal stores - Penryn	178870	34350	12:54	1549	1358	1454	Mud
3	Penryn Marina	179000	34210	13:14	988	1185	1087	Mud
4	Between Penryn Marina and Ponsharden	179370	34370	15:24	1144	341	743	Mud
5	Ponsharden Boatyard - Penryn	179500	34000	13:24	998	677	838	Mud
6	Falmouth Boatyard	179700	33800	14:04	5417	5261	5339	Mud
7	Falmouth Marina	179760	34000	13:55	3206	2938	3072	Mud
8	Penryn River near Flushing	180430	34020	15:44	336	328	332	Coarse sand, some mud
9	Royal Cornwall Yacht Club	180600	33500	14:24	1028*	854*	941	Mud
10	Port Pendennis	181318	32482	14:45	24623*	16687*	20655	Coarse sand, some mud
11	Carrick Roads western shore	182556	34196	13:33	<91		<91	12/06/97
12	Pontoons at Mylor Yacht Club	182150	35330	12:32	2470	2280	2375	Mud
13	Boat grids at Mylor Yacht Club	182020	35350	12:42	2990*	1810*	2400	Mud
14	Hammerhead Wharf at Mylor Yacht Club	181890	35370	12:52	24205*	7010	15608	Mud
15	Mill Quay slipway - Mylor Creek	180560	35930	13:12	402*	536*	469	Mud
16	Carrick Roads between Mylor and Restronguet	182150	36130	13:05	<139		<139	12/06/97
17	Restronguet Point	181660	37100	14:12	<66*	<66	<66	Mud
18	Restronguet Quay	181440	37460	13:32	781*	<66	781	Mud
19	EA Routine Site at Restronguet Creek - Devoran	179560	38850	13:42	<66*	<66	<66	Mud
20	Loe Beach	182500	38050	14:32	<72*	<66*	<72	Fine sand
21	King Harry Ferry	184070	39500	14:42	659	521	590	Mud
22	Coombe Creek	184035	40281	15:22	<66	<66	<66	Mud
23	Malpas	184423	42723	15:53	<66		<66	Mud
24	Deer Park	185006	41027	08:20	271		271	03/07/97
25	EA Routine Site at Penperth	184207	38981	08:15	220	734	477	03/07/97
26	Turnaware Point	183500	38300	15:10	<521	<603	<603	Mud
27	Carrick Road between Turnaware and Messack	183810	36920	13:17	<98		<98	12/06/97
28	Messack Point	184108	35740	11:57	<104		<104	12/06/97
29	Just Creek - St Just in Roseland	184800	35800	14:40	<128*	<274	<274	Mud
30	St Mawes Bank Northernmost Buoy	183815	34095	11:31	<103		<103	12/06/97 - 1 sample only
31	St Mawes Castle	184151	32611					No sample
32	St Mawes Harbour	184880	32988	14:00	723*	2276*	1500	Mud
33	Percuil River - upper estuary	186220	34680	13:30	<325	<383	<383	Mud
34	Percuil River - mid estuary	185780	34030	13:10	3340	3329	3335	Mud
35	Pelyn Creek - Percuil	186200	33900	13:00	237	<66	237	Mud
36	Cellars Beach -Percuil	185500	32300	12:40	<66	972	972	Mud
37	Carricknath Point	184546	32097	12:20	<66*	<66*	<66	Fine sand
38	Pendennis Point	182708	31469					No sample
	Dockyard Sediment Samples (12-13/5/97, and)							
1	Channel Centre	182463	33006	11:55	339		339	13/05/97
2	Channel Edge	182413	32952	10:50	< 83		< 83	13/05/97
3	Docks Basin	181942	32804	12:00	22300		22300	04/08/97
4	Docks Basin	182028	32856	15:45	12430		12430	12/05/97
5	Docks Basin	182080	32965	17:20	2120		2120	12/05/97
6	Docks Basin	181961	32989	18:00	10800		10800	12/05/97
7	Docks Basin	181865	32956	19:00	9470		9470	12/05/97
8	Northern Wharf East	181871	33104	13:15	4300		4300	13/05/97
9	Northern Wharf West	181787	33089	14:00	5360		5360	13/05/97
10	Duchy Wharf East	181462	32731	15:10	9360		9360	13/05/97
11	Duchy Wharf West	181618	32743	15:45	10200		10200	13/05/97
12	County Wharf East	181423	32640	17:10	1520		1520	13/05/97
13	County Wharf West	181466	32546	17:40	1180		1180	13/05/97
	Offshore Sediment Samples (12/6/97)							
51	Old Middle Point Outfall - 1000m SE of discharge	183160	31240					No sample
52	Old Middle Point Outfall - 500m SE of discharge	182890	31595	14:00	<69		<69	(182630,318311)
53	Old Middle Point Outfall - 250m SE of discharge	182760	31805					No sample
54	Old Middle Point Outfall	182700	32000					No sample
55	Old Middle Point Outfall - 250m North of discharge	182655	32245					No sample
56	Old Middle Point Outfall - 500m North of discharge	182635	32500					No sample
57	300m East of Eastern Breakwater	182610	32827	11:14	<88		<88	1 sample only
58	Southern Carrick Roads - mid channel	182978	33283					No sample
59	New Middle Point Outfall - 250m North	183160	32490					No sample
60	New Middle Point Outfall	183160	32240	10:52	<97		<97	
61	New Middle Point Outfall - 250m South	183160	31990	11:40	<85		<85	
62	New Middle Point Outfall - 250m East	183410	32240					No sample
63	St Mawes Buoy	184106	32328					No sample
64	Pennance Point Outfall - 500m NE of discharge	180780	30825					No sample
65	Pennance Point Outfall - 250m NE of discharge	180615	30625					No sample
66	Pennance Point Outfall	180500	30450	12:40	<89		<89	
67	Pennance Point Outfall - 250m SW of discharge	180130	30315	12:35	<87		<87	
68	Pennance Point Outfall - 500m SW of discharge	180060	30135	12:27	<86		<86	(180004, 30131)
69	Pennance Point Outfall - 250m SE of discharge	180540	30295	12:52	<78		<78	(180739, 30522)
70	Pennance Point Outfall - 500m SE of discharge	182143	30085	13:05	<81		<81	(181020, 30211)
71	Mid Channel off Restroguet Point	183000	37250	13:22	373		373	
72	EA Routine Site at Carrick Roads - Mid Channel	183000	36330	13:12	<133		<133	
73	Mid Channel between Messack Pt and Mylor	183078	35576	12:06	<103		<103	
74	North Bank Buoy	183348	34653	11:42	<111		<111	
75	EA Routine Site at Vilt Buoy	183135	34023					No sample
76	Black Rock Buoy	183675	31568					No sample
77	EA Routine Site at Middle Point Network Site	183500	31000					No sample
78	Falmouth Bay	181500	30500	12:15	<88	<72	<88	
79	500m South of Zone Point	185000	30500	13:25	<88		<88	Mud (184769,30983)

* Samples analysed as 'whole sample' rather than sieved to <63 microns

TABLE 2 Fal Estuary TBT Monitoring 1997 - Baseline Water Sampling (12/6/97)

No.	Location	East	North	Time (GMT)	HW Rel	TBT+ (ng/l)	SS 105 (mg/l)	Salinity (PSU)	Notes
AH1	Falmouth Docks 'Salgir'	181707	33062	08:29	- 00:56	440			No prop. - ship probably been along side for some time
AH2	Ships near King Harry Ferry	184070	39600	09:15	- 00:10	9			Sample taken within 5m from a group of 5 ships 100m north of King Harry Ferry
1	Mean Porth Bathing Water	179000	29600	10:28	+ 01:03	3	<3.0	35.1	
2	Pennance Point Outfall - 500m SW of discharge	180060	30135	10:30	+ 01:05	4	<3.0	35.1	
3	Pennance Point Outfall - 500m SE of discharge	180682	30085	10:24	+ 00:59	2	37	35.1	
4	Pennance Point Outfall	180500	30450	10:34	+ 01:09	18	<3.0	31.7	Tide flooding in Bay
5	Pennance Point Outfall - 500m NE of discharge	180780	30825	10:36	+ 01:11	3	<3.0	35.1	Tide flooding in Bay
6	Swanpool Baech Bathing Water	180300	31300	10:40	+ 01:15	<2	<3.0	35	Tide flooding in Bay
7	Gyllyngvase Beach Bathing Water	180900	31600	10:47	+ 01:22	2	<3.0	35.1	Tide flooding in Bay
8	Falmouth Bay	181350	31120	10:45	+ 01:20	2	<3.0	35.2	Tide flooding in Bay
9	Falmouth Bay	181920	31400	10:51	+ 01:26	2	<3.0	35.1	Tide flooding in Bay
10	Falmouth Bay	181500	30500	10:21	+ 00:56	2	<3.0	35.1	Tide flooding in Bay, Wind 4m/s SW
11	EA Routine Site at Middle Point Network Site	183500	31000	10:14	+ 00:49	6	<3.0	35.1	Wind over tide
12	500m South of Zone Point	185000	30500	10:07	+ 00:42	<2	<3.0	35.2	Flood
13	Percuil River - upper estuary	186220	34680	09:11	- 00:14	3	<3.0	34.3	Flood
14	Percuil River - mid estuary	185780	34030	09:00	- 00:25	5	<3.0	34.7	
15	EA Routine Monitoring - Percuil River	185700	33500	08:57	- 00:28	3	<3.0	34.9	
16	EA Routine Monitoring - Percuil River, Lower Estuary	185650	33000	08:54	- 00:31	7	<3.0	34.9	Flood
17	Percuil River off St Mawes Harbour	184766	32635	08:49	- 00:36	2	<3.0	35	
18	St Mawes Buoy	184106	32328	08:45	- 00:40	<2	<3.0	35.2	Wind 3 m/s SW
19	Black Rock Buoy	183675	31568	10:00	+ 00:35	3	<3.0	34.8	
20	Off Pendennis Point	183145	31637	10:55	+ 01:30	13	<3.0	34.6	Ebbing
21	Middle Point Existing Outfall	182700	32000	11:03	+ 01:38	16	10	33.1	Ebbing
22	Middle Point New Outfall	183160	32240	08:42	- 00:43	4	<3.0	34.6	
23	Governor Buoy	182959	32475	08:40	- 00:45	5	<3.0	34.3	
24	Old Middle Point Outfall - 500m North of discharge	182635	32500	08:39	- 00:46	26	<3.0	34.4	Flood
25	West Narrows Buoy	183353	32898	10:10	+ 00:45	2	<3.0	34.5	
26	Mid channel between Falmouth Docks and St Mawes	182961	32880	10:12	+ 00:47	3	<3.0	34.5	
27	Falmouth Docks east of Eastern Breakwater	182610	32827	10:14	+ 00:49	9	<3.0	34.4	
28	Southern Carrick Roads - mid channel	182978	33283	10:17	+ 00:52	2	<3.0	34.6	
29	Old EA Monitoring Site - Carrick Roads	182550	33200	10:18	+ 00:53	13	<3.0	34.4	
30	Falmouth Docks north of Eastern Breakwater	182276	33108	10:20	+ 00:55	16	<3.0	34.3	
31	Falmouth Docks Basin	182007	32728	08:36	- 00:49	37	<3.0	34.6	Sample taken approx. 20 m from 100m vessel 'Star Bergen'
32	Falmouth Docks Basin	182125	32882	08:34	- 00:51	6	<3.0	34.2	
33	Falmouth Docks Basin	181930	32895	08:32	- 00:53	15	<3.0	34.5	Three vessels in dry dock
34	Falmouth Quays	181370	32780	08:19	- 01:06	54	<3.0	34.1	
35	Penryn River off Falmouth Docks	181758	33195	08:22	- 01:03	15	<3.0	34.3	Off 'Salgir'
36	EA Routine Monitoring - Penryn River, Falmouth Road	181100	33200	08:21	- 01:04	27	<3.0	34.3	Flood
37	Penryn River off Royal Cornwall Yacht Club	180622	33650	08:17	- 01:08	40	<3.0	33.5	Flood
38	Penryn River off Falmouth Marina	180137	33983	08:15	- 01:10	49	<3.0	33.7	Flood
39	EA Routine Monitoring - Penryn River, Trevissome	179500	34120	08:10	- 01:15	38	<3.0	33.6	Flood
40	EA Routine Monitoring - Carrick Roads mid channel	183000	36330	09:43	+ 00:18	3	<3.0	34.6	
41	Off Messack Point	183813	35856	09:46	+ 00:21	3	<3.0	34.1	

TABLE 2 Fal Estuary TBT Monitoring 1997 - Baseline Water Sampling (12/6/97)

No.	Location	East	North	Time (GMT)	HW Rel	TBT+ (ng/l)	SS 105 (mg/l)	Salinity (PSU)	Notes
42	Off Mylor Yacht Club	182176	35436	08:14	- 01:11	8	<3.0	33.9	Tide appears slack
43	Mylor Creek	181100	35520	08:21	- 01:04	10	<3.0	34	Tide appears slack
44	Mid channel between Messack Point and Mylor	183078	35576	09:48	+ 00:23	8	<3.0	34.5	
45	St Just Pool	184000	38000	09:49	+ 00:24	4	<3.0	34.1	Sampling location positioned by eye
46	North Bank Buoy	183348	34653	09:54	+ 00:29	23	<3.0	34.5	
47	EA Routine Monitoring - Vilt Buoy	183135	34023	10:00	+ 00:35	3	<3.0	34.6	
48	St Mawes Bank Northernmost Buoy	183815	34095	09:57	+ 00:32	5	<3.0	34.4	
49	St Mawes Bank Southernmost Buoy	183670	33599	10:08	+ 00:43	7	<3.0	34.3	
50	Carrick Roads off St Mawes Bank	183000	33630	10:07	+ 00:42	5	<3.0	34.6	
51	Carrick Roads - Falmouth Bank	182527	33685	08:05	- 01:20	8	<6.0	34.4	Weather overcast and dry
52	Carrick Roads off Trefusis Point	182193	33440	08:02	- 01:23	11	<3.0	34.4	Wind F3 SW
53	Restronguet Creek	181150	57990	08:44	- 00:41	3	<3.0	33.7	No GPS, sample taken mid channel opposite short sandy cliff on NE shore
54	Restronguet Point	181660	37100	08:38	- 00:47	5	<3.0	3.6	Tide slack
55	Mid Channel off Restroguet Point	183000	37250	09:38	+ 00:13	4	<3.0	33.4	
56	Turnaware Point	183570	37780	09:00	- 00:25	5	<3.0	33.2	
57	Loe Beach	182500	38050	08:55	- 00:30	3	<3.0	33.8	Tide slack
58	King Harry Ferry	184070	39500	09:10	- 00:15	6	3.5	30.8	Sample taken by slip
59	Coombe Creek	184035	40281	09:19	- 00:06	4	3.5	31.1	
60	Malpas	184423	42723	09:28	+ 00:03	5	4.1	30.6	Sample taken by slip
61	Deer Park	185006	41027	09:23	- 00:02	5	4.8	31.3	Wind dropped
62	EA Routine Site at Penperth	184207	38981	09:07	- 00:18	4	3	31.8	
63	Carrick Road between Turnaware and Messack	183810	36920	09:41	+ 00:16	5	<3.0	33.9	

TABLE 3 . Fal Estuary TBT Monitoring - Mussel Tissue

No.	Location	Easting	Northing	13th August 1997		15th September 1997		28th October 1997	
				DBT (mg/kg)	TBT (mg/kg)	DBT (mg/kg)	TBT (mg/kg)	DBT (mg/kg)	TBT (mg/kg)
0	Background levels at Whitsand Bay (15/07/97)			0.009	0.016				
1	Pennance Point	180430	30770	No sample		No sample		No sample	
2	Middle Point	182735	31800	0.061	0.183	No sample		No sample	
3	Falmouth Docks - Northern Wharf	181860	33000	0.163	0.503	0.136	0.531	No sample	
4	Islington Quay - Penryn	178700	34500	0.238	0.971	0.266	0.747	0.320	0.716
5	Penryn River near Flushing	180650	33890	0.151	0.603	0.215	0.596	0.298	0.516
6	Vilt Buoy	183135	34023	0.031	0.066	No sample		No sample	
7	Pontoon at Mylor Yacht Club	181890	35370	0.087	0.287	0.157	0.350	0.153	0.505
8	Restronguet Point	181660	37100	0.042	0.123	0.034	0.122	0.064	0.166
9	King Harry Ferry	184070	39500	0.039	0.136	0.053	0.212	0.101	0.257
10	Malpas	184423	42723	0.040	0.140	0.052	0.185	No sample	
11	Deer Park	185006	41027	0.043	0.122	0.062	0.168	0.122	0.212
12	Turnaware Point	183500	38300	0.044	0.117	0.051	0.143	0.090	0.329
13	EA Routine Site - Carrick Roads mid channel	183000	36330	0.053	0.110	0.044	0.150	No sample	
14	Messack Point	184108	35740	0.035	0.122	0.049	0.277	0.053	0.162
15	St Mawes Harbour	185045	32585	0.055	0.118	0.035	0.127	0.031	0.068
16	Black Rock Buoy	183675	31568	0.048	0.173	0.033	0.117	No sample	

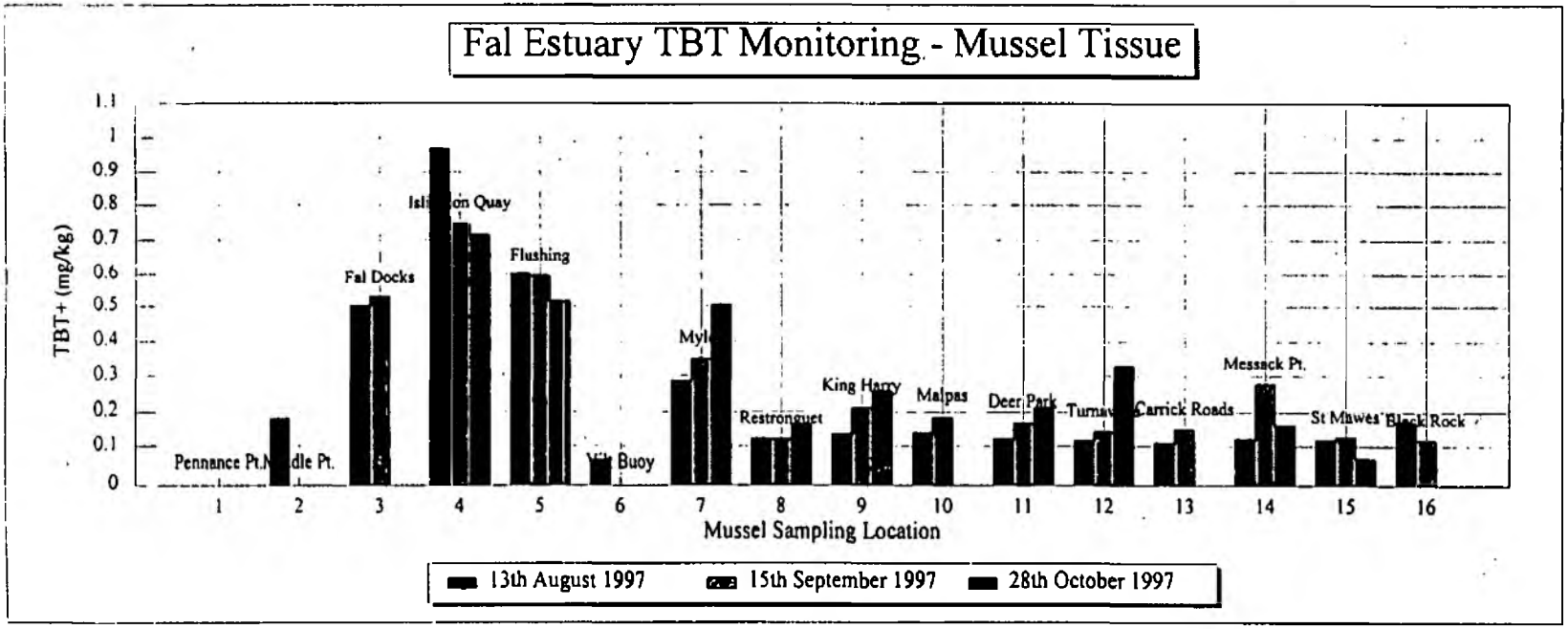

TABLE 4 Fal Estuary TBT Monitoring - Monthly Water Sampling Results

Location	No.	Site Code	Date	Time	Salinity 3028	TBT+ 3831	TBT+ 3831	Mean TBT+
Old Middle Point Outfall Surface Boil	1	81914855	07-Aug-97	1110	26.9	< 18		18
Falmouth Dockyard Combined Outfall - Final Effluent	3	81910616	07-Aug-97	1035		570		570
Falmouth Dockyard Combined Outfall - Surface Boil	4	81910620	07-Aug-97	1040	34	1045		1045
Penryn River off Falmouth Docks	5	81910622	07-Aug-97	07:21	32.4	45	25	35
Penryn River off Falmouth Marina	7	81910635	07-Aug-97	07:05	29.7	89	101	95
EA Routine Monitoring - Carrick Roads mid channel	8	81910170	07-Aug-97	06:02	33.3	< 5	< 5	5
EA Routine Monitoring - Vilt Buoy	11	81910139	07-Aug-97	06:09	31.4	< 5	< 3	4
Black Rock Buoy	12	81910116	07-Aug-97	06:51	33.8	< 2	< 2	2
Old Middle Point Outfall Surface Boil	1	81914855	07-Oct-97	1110	30.2	< 30		15
Old Middle Point Outfall - 500m North of discharge	2	81910121	07-Oct-97	09:15	34.9	19	20	19.5
Falmouth Dockyard Combined Outfall - Final Effluent	3	81910616	07-Oct-97	1050		10800		10800
Falmouth Dockyard Combined Outfall - Surface Boil	4	81910620	07-Oct-97	1040	34.5	> 7500		7500
Penryn River off Falmouth Docks	5	81910622	07-Oct-97	08:20	34.8	16	11	13.5
Penryn River off Falmouth Marina	7	81910635	07-Oct-97	08:05	33.2	48	37	42.5
EA Routine Monitoring - Carrick Roads mid channel	8	81910170	07-Oct-97	08:15	34.8	6	9	7.5
Deer Park	10	81920220	07-Oct-97	08:40	32.7	26	29	27.5
EA Routine Monitoring - Vilt Buoy	11	81910139	07-Oct-97	09:00	35.1	5	5	5
Black Rock Buoy	12	81910116	07-Oct-97	09:50	35.2	8	8	8
Old Middle Point Outfall Surface Boil	1	81914855	12-Nov-97	1725	33.8	22.6		22.6
Old Middle Point Outfall - 500m North of discharge	2	81910121	12-Nov-97	1655	34.3	11	< 2	6.5
Falmouth Dockyard Combined Outfall - Final Effluent	3	81910616	12-Nov-97	1230		12000		12000
Falmouth Dockyard Combined Outfall - Surface Boil	4	81910620	12-Nov-97	1235	33.8	2000		2000
Off Mylor Yacht Club	9	81910157	12-Nov-97	1510	33.6	8	9	8.5
Deer Park	10	81920220	12-Nov-97	1500	31.7	10		10
EA Routine Monitoring - Vilt Buoy	11	81910139	12-Nov-97	1515	34.6	6	4	5
Black Rock Buoy	12	81910116	12-Nov-97	1520	34.7	19.8	< 2	10.9
Falmouth Dockyard Combined Outfall - Final Effluent	3	81910616	03-Dec-97	1125		16532		16532
Old Middle Point Outfall Surface Boil	1	81914855	03-Feb-98	1210	32	22		22
Old Middle Point Outfall - 500m North of discharge	2	81910121	03-Feb-98	1200	33.9	13	13	13
Falmouth Dockyard Combined Outfall - Final Effluent	3	81910616	03-Feb-98	1145		9680		9680
Falmouth Dockyard Combined Outfall - Surface Boil	4	81910620	03-Feb-98	1150	34	2200		2200
Penryn River off Falmouth Docks	5	81910622	03-Feb-98	1035	33.4	14	18	16
Islington Quay - Penryn	6	81910649	03-Feb-98	1015	23.9	24	31	27.5
Penryn River off Falmouth Marina	7	81910635	03-Feb-98	1025	31.3	20	23	21.5
EA Routine Monitoring - Carrick Roads mid channel	8	81910170	03-Feb-98	1050	32.7	6	4	5
Off Mylor Yacht Club	9	81910157	03-Feb-98	1045	32.6	7	8	7.5
Deer Park	10	81920220	03-Feb-98	1055	30	6	6	6
EA Routine Monitoring - Vilt Buoy	11	81910139	03-Feb-98	1040	33.6	5	7	6
Black Rock Buoy	12	81910116	03-Feb-98	1230	34.2	4	4	4
Old Middle Point Outfall Surface Boil	1	81914855	18-Feb-98	1130	29.6	19		19
Falmouth Dockyard Combined Outfall - Final Effluent	3	81910616	18-Feb-98	1115		> 15000		15000
Falmouth Dockyard Combined Outfall - Surface Boil	4	81910620	18-Feb-98	1110	34.1	762	13	387.5
Old Middle Point Outfall - 500m North of discharge	2	81910121	27-Mar-98	1713	34.9	< 2	< 2	2
Penryn River off Falmouth Docks	5	81910622	27-Mar-98	1645	34.5	< 2	< 8	5
Islington Quay - Penryn	6	81910649	27-Mar-98	1705	10	41	40	40.5
Penryn River off Falmouth Marina	7	81910635	27-Mar-98	1655	34.2	39	39	39
EA Routine Monitoring - Carrick Roads mid channel	8	81910170	27-Mar-98	1726	34.4	< 4	< 3	3.5
Off Mylor Yacht Club	9	81910157	27-Mar-98	1734	34.2	< 2	< 2	2
Deer Park	10	81920220	27-Mar-98	1515	30.6	< 2	< 2	2
EA Routine Monitoring - Vilt Buoy	11	81910139	27-Mar-98	1746	34.8	< 2	< 2	2
Black Rock Buoy	12	81910116	27-Mar-98	1657	35	< 2		2
Falmouth Dockyard Combined Outfall - Final Effluent	3	81910616	17-Apr-98	1050		5120		5120

FIGURES

FIGURE 1 SEDIMENT SAMPLING LOCATIONS


FIGURE 2 FAL ESTUARY WATER SAMPLING SITES
FALMOUTH
Falmouth Bay
Main Perth Beach
ISW 798 290
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FIGURE 3 DOGWHELK SURVEY LOCATIONS


FIGURE 4 MUSSEL DEPLOYMENT LOCATIONS AND MONTHLY WATER SAMPLING
Mussel Cage Deployment Location
Mussel Cage Deployment Location and Monthly Water Sampling
Monthly Water Sampling Locations
Outfalls Monitored in 1997 for Dangerous Substances Programme
183240E, 43200N
Newton STW
10
11
Oar Park
9
12
13
14
8
7
6
5
4
3
2
1
15
16
FALMOUTH
Falmouth Bay

Figure 5 Whitsand Bay
Source of 'TBT Free' Mussels

FIGURE 6 SEDIMENT TBT RESULTS (ug TBT+/kg)


FIGURE 7 WATER TBT RESULTS (ng TBT+/l)
FALMOUTH
Falmouth Bay
Swanpool Beach
Gyllyngvase Beach
Pendennis Point
Mawnan Porth Beach
ISW 798 266

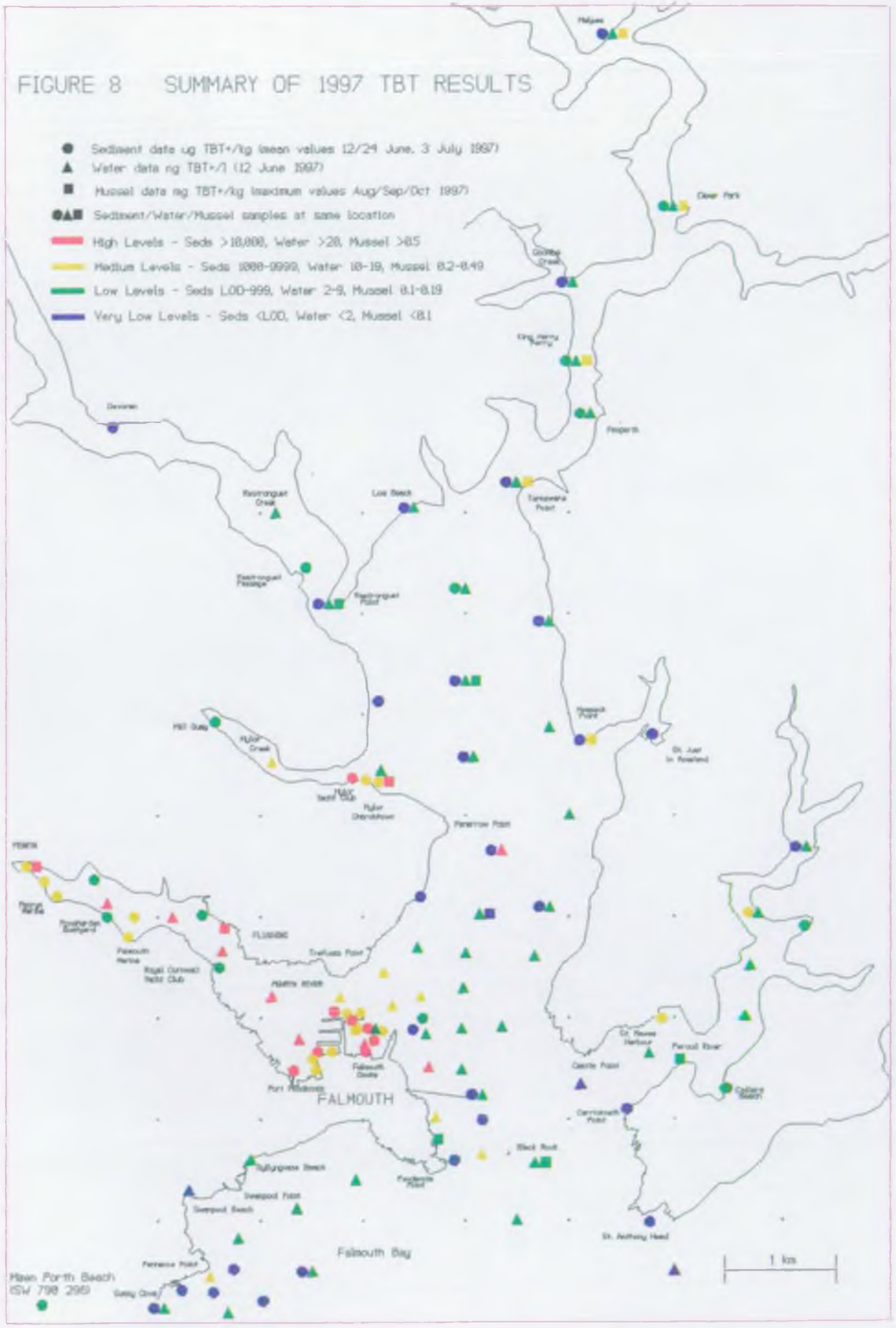


FIGURE 8 SUMMARY OF 1997 TBT RESULTS
Sediment data ug TBT+/kg (mean values 12/24 June, 3 July 1997)
Water data ng TBT+/l (12 June 1997)
Mussel data ng TBT+/kg (maximum values Aug/Sep/Oct 1997)
Sediment/Water/Mussel samples at same location
High Levels - Seds >18,000, Water >28, Mussel >8.5
Medium Levels - Seds 1000-9999, Water 18-19, Mussel 8.2-8.49
Low Levels - Seds LOD-999, Water 2-9, Mussel 8.1-8.19
Very Low Levels - Seds <LOD, Water <2, Mussel <8.1
Clear Park
Devoran
Low Beach
Restronguet Point
Penarrow Point
FALMOUTH
Falmouth Docks
Port Pendennis
Trefusis Point
Castle Point
Pendennis Point
Black Rock
Swanpool Point
Swanpool Beach
Falmouth Bay
Maen Porth Beach
(SW 798 295)
1 km

Figure 9 Fal Estuary TBT Monitoring - Monthly Water Sampling•Spatial Presentation

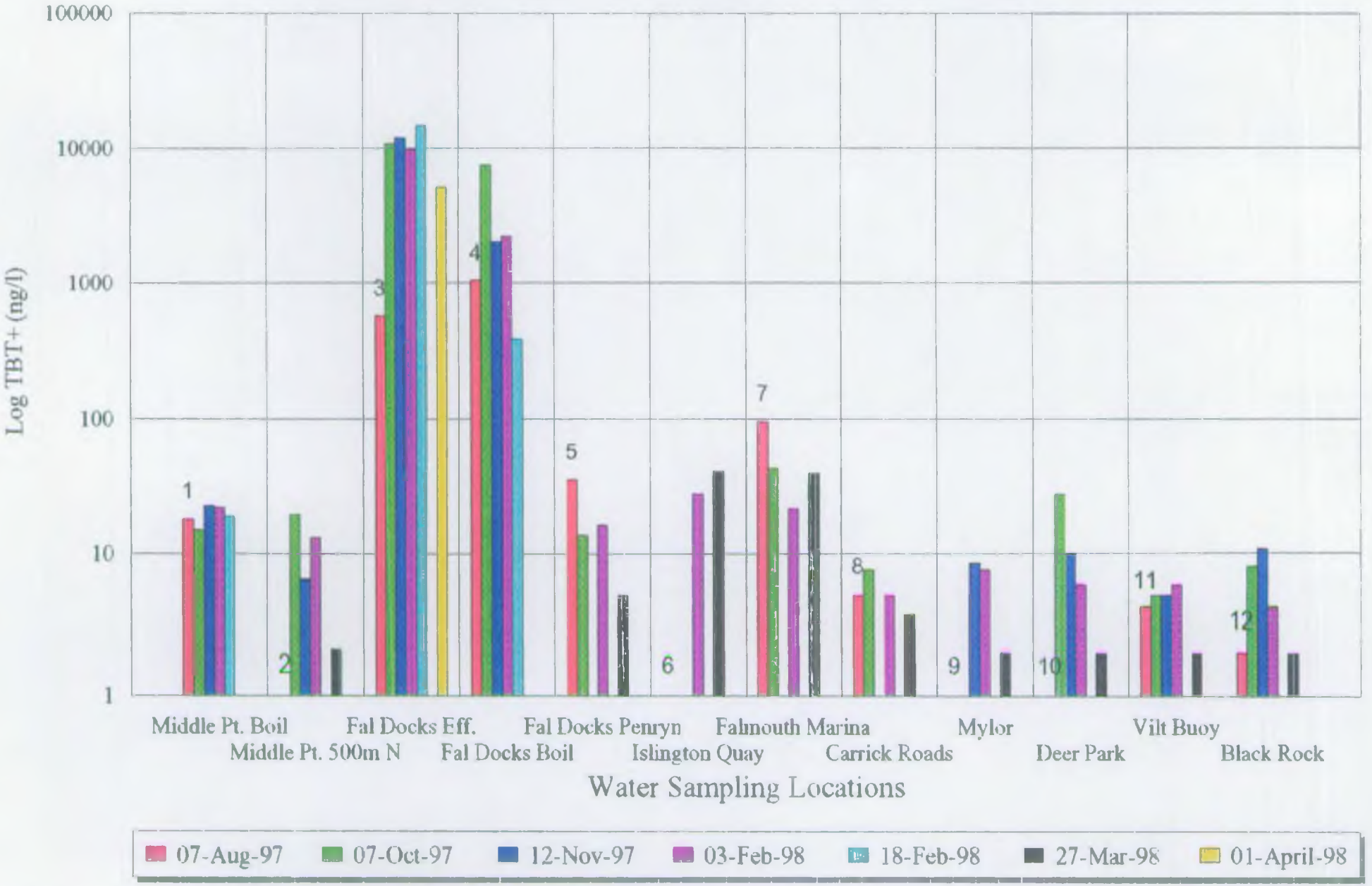
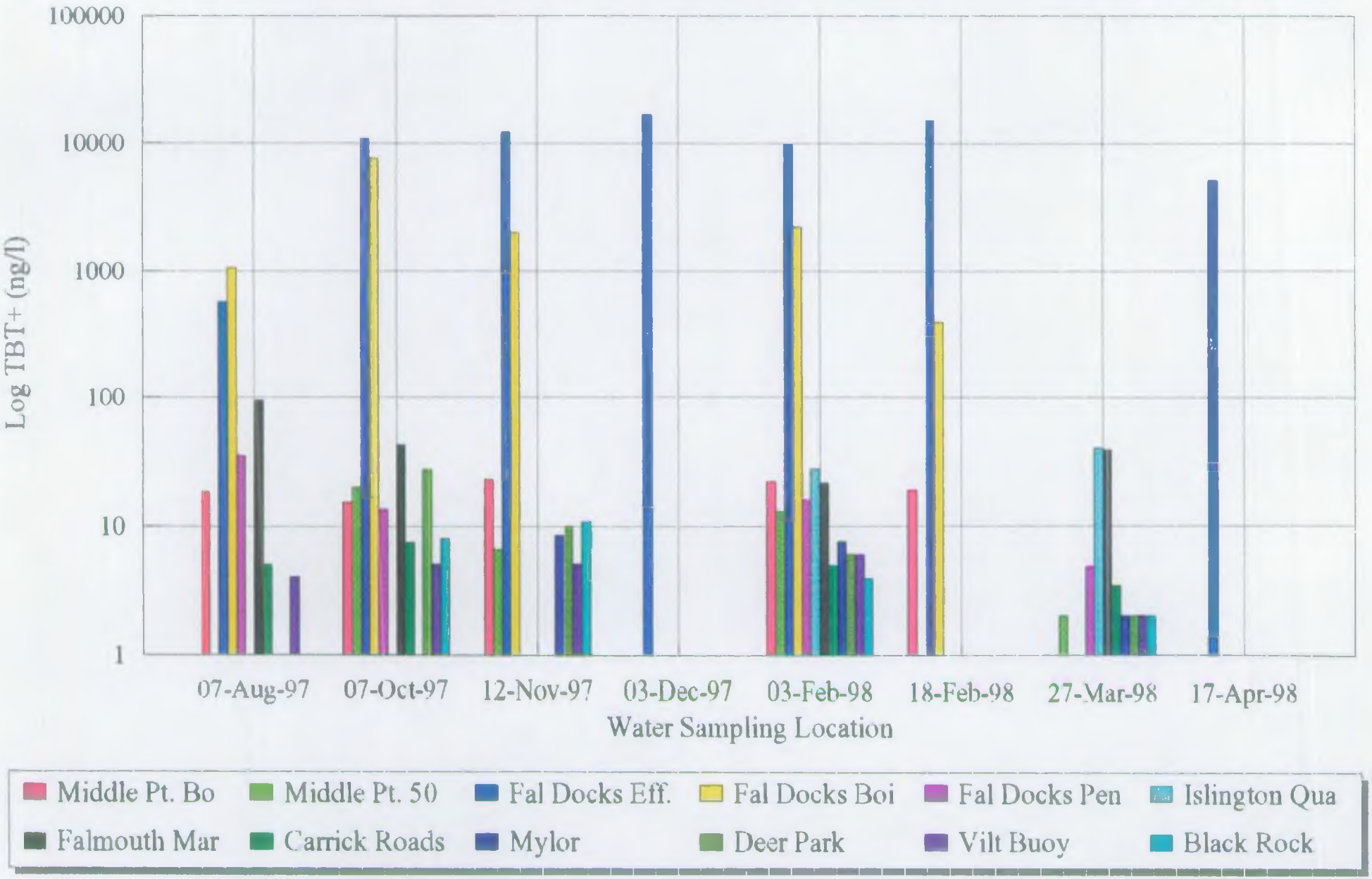


Figure 10 Fal Estuary TBT Monitoring - Monthly Water Sampling•Temporal Present




183240E, 43200N
Newham STW
FIGURE 11 1998 MUSSEL DEPLOYMENT LOCATIONS
AND WATER SAMPLING LOCATIONS (JUNE 1998)
Mussel Cage Deployment Location and Monthly Water Sampling
Monthly Water Sampling Locations
Outfalls Monitored for Dangerous Substances Programme
10
11
Deer Park
9
12
Tolverne Point
Restronguet Point
8
13
14
Penarrow Point
6
17
5
FLUSHES
Trefusis Point
3
Falmouth Docks
FALMOUTH
2
15
Carricknath Point
16
Black Rock
1
Pendennis Point
Falmouth Bay

APPENDIX 1

TBT monitoring of the Fal Estuary: Advice on aspects of monitoring programme design

1. Introduction

1.1 Background

South Western Region of the Environment Agency is undertaking an extensive monitoring programme to look at TBT contamination of the Fal Estuary. This has a number of different elements:

- In June 1997 a *spatial* survey was carried out of water and sediment TBT quality at 64 sites in the estuary; the survey is to be repeated at intervals yet to be determined (2 - 5 years).
- Monthly water quality samples are being taken at nine key sites for the purpose of *trend monitoring*.
- Mussels are being deployed at 16 sites as *bio-indicators* of TBT contamination. The first year's monitoring took place in Aug-Oct 1997; and mussels will similarly be sampled over three consecutive months in subsequent summers.

Under the terms of the Environmental Quality Sampling and Statistics Technical Service, WRc was recently invited to advise on a number of issues relating to the interpretation of the data already to hand, and the planning of the future monitoring programme. To assist in this, data from the 1997 programme was made available, both as hard copy and as Lotus WK4 files on diskette.

1.2 Questions asked

Six specific questions were posed in the initial fax (dated 3 March) received from Dr Margaret Waite; a seventh question was raised in the subsequent letter accompanying the data diskette. The questions were as follows:

Present spatial survey

Q1: Is it possible to carry out any statistical analysis on spatial differences in TBT between sites? Yes, groups 0, 1, 2, 3, 4, water and sediment
No relationship between water and sediment (2 months)
If 'hot-spot' mechanism similar then sample more sites
closer together

Proposed future spatial survey

Q2: Will it be possible to look for any differences in TBT between the two spatial surveys? Yes but keep data locations comparable between
1st and the next.

Monthly water quality programme at nine sites

Q3: What is an appropriate statistical method for looking at time trends in TBT water quality? [illegible] 3 AARDVARK, LAPWING

Q4: What is an appropriate statistical method for looking at differences in TBT water quality between sites? LAPWING

Mussel deployment at 16 sites

Q5: What is an appropriate statistical method for looking at time trends in mussel tissue TBT concentration? ANOVA

Q6: What is an appropriate statistical method for looking at differences in mussel tissue TBT concentration between sites? ANOVA

Present duplication of water quality sampling

Q7: Is there much gained by having duplicate monthly water samples? No

In addressing these questions in Sections 2, 3 and 4 following, we have illustrated our answers wherever possible using relevant data from the 1997 monitoring programme.

2. Spatial distribution of TBT

Q1: Is it possible to carry out any statistical analysis on spatial differences in TBT between sites?

An extensive spatial sampling programme was carried out by the Agency during 12/13 June 1997. Water spot samples were taken at 65 locations, and sediment spot samples at 64 locations. Figure 1 shows the locations of the water and sediment sampling points - from which can be seen the 21 locations that were common to both data sets.

2.1 Water quality

Figure 2(a) shows a histogram of the water concentrations. There is one very high hot-spot value - 440 ng/l for the Falmouth Docks 'Salgit' sample. A further 16 values are greater than 10 ng/l. There are only three less-than values in the data set; we have set these at the limit value of 2 ng/l.

A good way to begin investigating the spatial distribution of quality over the estuary is to use *prior knowledge* of the locations at which concentrations are expected to be at background and at elevated levels respectively. To illustrate the approach, we have devised a rough grouping of the 65 locations as detailed in Table 1. A plot of water concentrations against Site Group, as shown in Figure 2(b), then gives a clear indication of the differences in mean quality *between* Groups in relation to *within*-Group variability. In this illustration, Groups 1, 3 and 4 are all noticeably higher than Group 0, and have broadly similar median TBT levels, whereas concentrations at Group 2 sites are no different from those in Group 0 except for an isolated sample.

Summary statistics for the five groups are as follows:

Group	N	Mean	St.dev.
0	47	5.2	3.9
1	7	82.4	159.0
2	4	6.8	7.5
3	2	21.0	7.1
4	5	33.8	13.1

Figure 1 - Water and sediment sampling locations

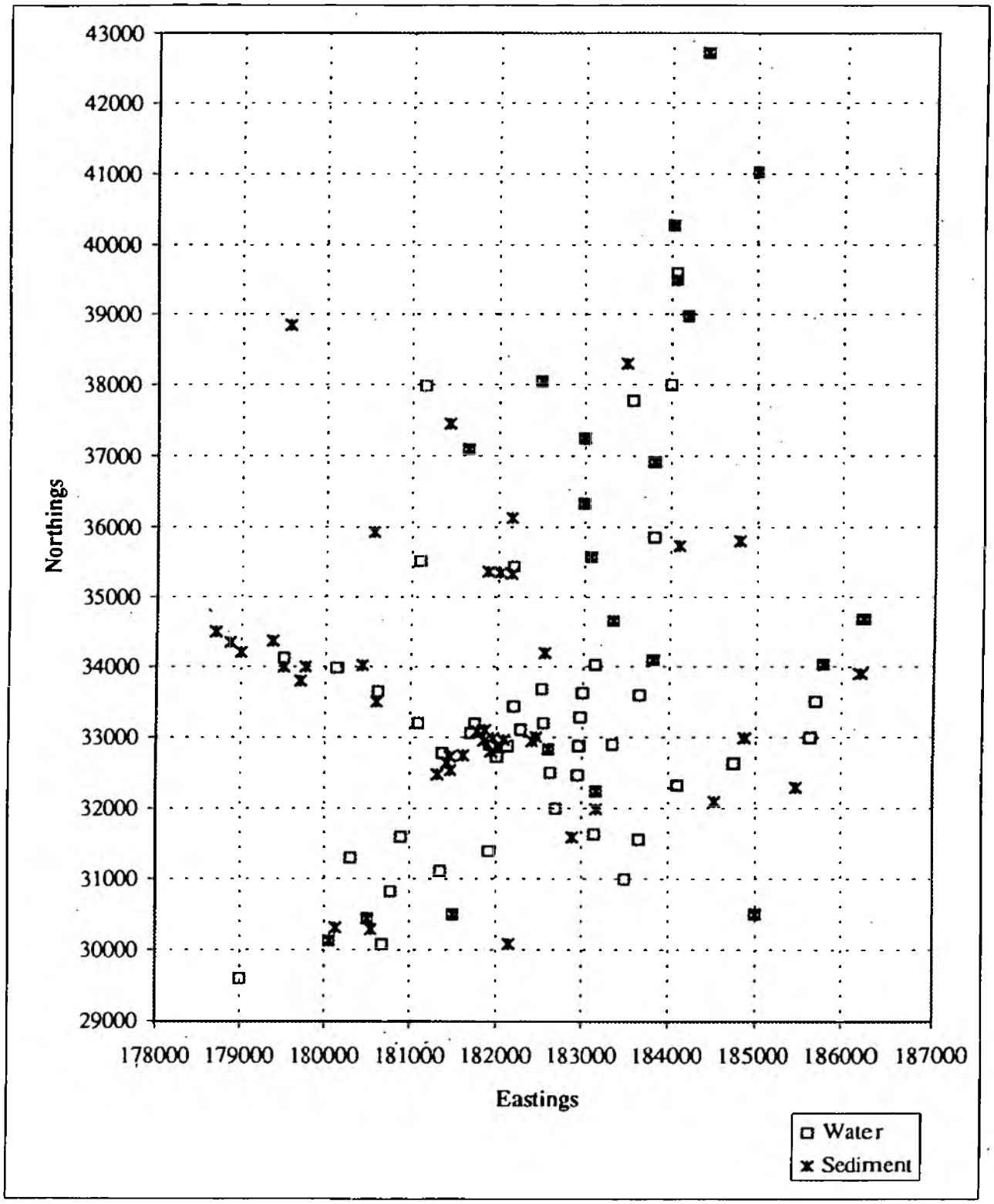
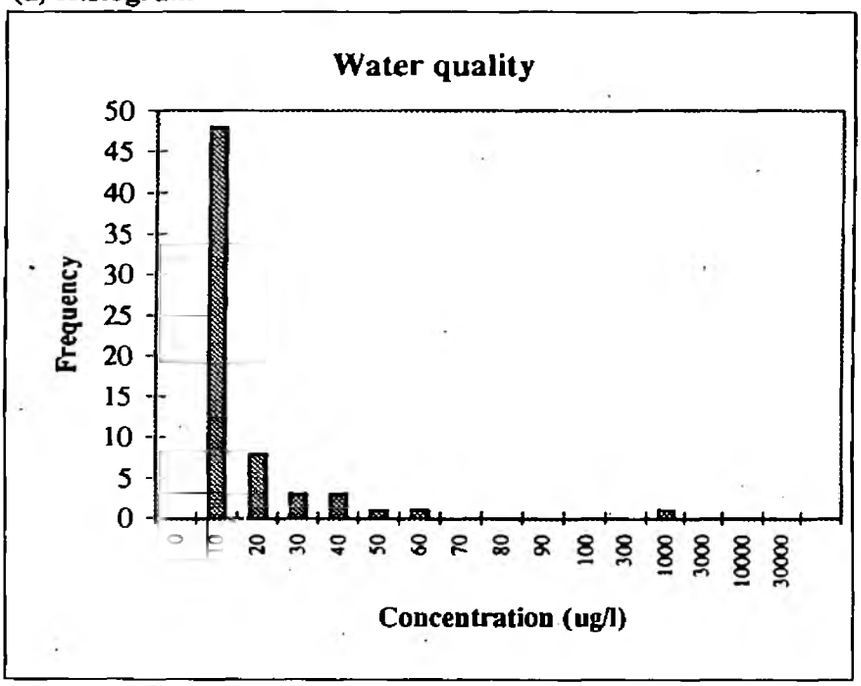
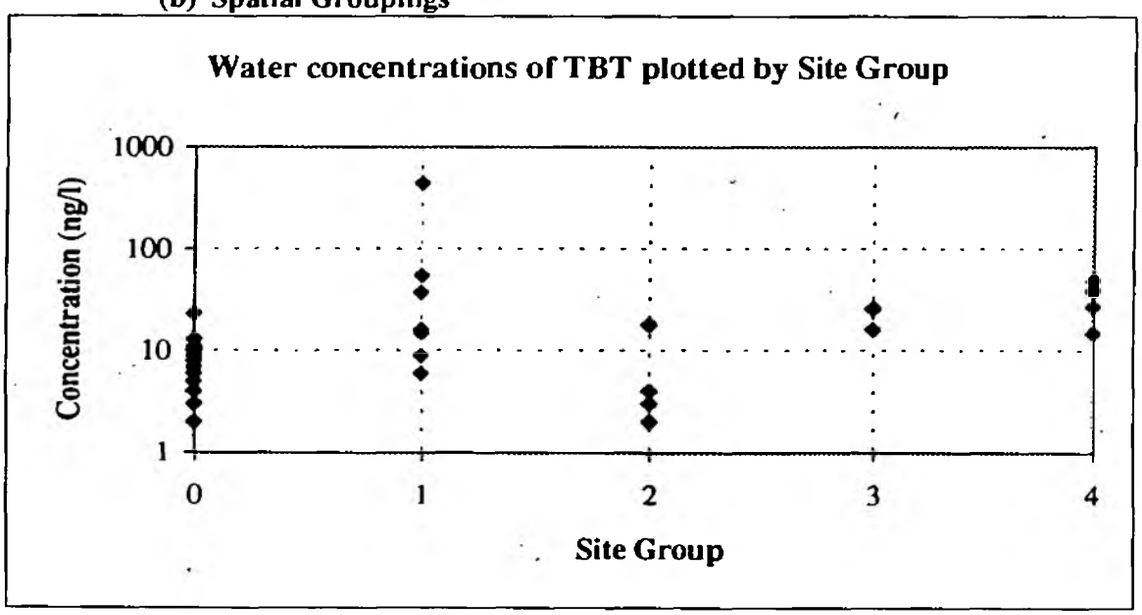


Figure 2 - Distribution of TBT in water

(a) Histogram



(b) Spatial Groupings



Key

Group	Location key-word
1	Falmouth docks
2	Pennance Point Outfall
3	Middle Point Outfall (Old & Existing)
4	Penryn River
0	All other sites

Table 1 - Illustrative grouping of sites

Group 0 - 'Other'	
Ships near King Harry Ferry	Turnaware Point
Mean Porth Bathing Water	Loe Beach
Swanpool Beach Bathing Water	King Harry Ferry
Gyllyngvase Beach Bathing Water	Coombe Creek
Falmouth Bay	Malpas
Falmouth Bay	Deer Park
Falmouth Bay	EA Routine Site at Penperth
EA Routine Site at Middle Point Network Site	Carrick Road between Turnaware and Messack
500m South of Zone Point	
Percuil River - upper estuary	
Percuil River - mid estuary	
EA Routine Monitoring - Percuil River	**Group 1**
EA Routine Monitoring - Percuil River, Lower Est.	Falmouth Docks 'Salgir'
Percuil River off St Mawes Harbour	Falmouth Docks east of Eastern Breakwater
St Mawes Buoy	Falmouth Docks north of Eastern Breakwater
Black Rock Buoy	Falmouth Docks Basin
Off Pendennis Point	Falmouth Docks Basin
Middle Point New Outfall	Falmouth Docks Basin
Governor Buoy	Falmouth Quays
West Narrows Buoy	
Mid channel between Falmouth Docks and St Mawes	
Southern Carrick Roads - mid channel	**Group 2**
Old EA Monitoring Site - Carrick Roads	Pennance Point Outfall - 500m SW of discharge
EA Routine Monitoring - Carrick Roads mid channel	Pennance Point Outfall - 500m SE of discharge
Off Messack Point	Pennance Point Outfall
Off Mylor Yacht Club	Pennance Point Outfall - 500m NE of discharge
Mylor Creek	
Mid channel between Messack Point and Mylor	
St Just Pool	**Group 3**
North Bank Buoy	Middle Point Existing Outfall
EA Routine Monitoring - Vilt Buoy	Old Middle Point Outfall - 500m N of discharge
St Mawes Bank Northernmost Buoy	
St Mawes Bank Southernmost Buoy	
Carrick Roads off St Mawes Bank	**Group 4**
Carrick Roads - Falmouth Bank	Penryn River off Falmouth Docks
Carrick Roads off Trefusis Point	EA Routine Monit'g - Penryn River, Falmouth Rd
Restronguet Creek	Penryn River off Royal Cornwall Yacht Club
Restronguet Point	Penryn River off Falmouth Marina
Mid Channel off Restronguet Point	EA Routine Monit'g - Penryn River, Trevissome

Even with this imperfect spatial grouping, t-tests confirm that there are highly significant differences between the Group 0 mean and the means in Group 3 ($t = 3.1$) and Group 4 ($t = 4.8$). Clearly, therefore, there is ample scope for the approach to be refined with a more considered definition of Groups.

2.2 Sediment quality

Figure 3(a) similarly shows a histogram of the sediment TBT concentration data. In comparison with the water data, there are many more less-thans here, amounting to nearly half of the 64 values. Although such a high proportion of less-thans can pose potential difficulties for data analysis, there is not a problem in this particular example, as those concentrations that do actually get reported are often several orders of magnitude greater than the limit of detection. As before, therefore, we have used a simple substitution approach and replaced less-thans by the corresponding limit values (hence the tower in the "<100" bin of the histogram). In a more comprehensive study, however, the issue of less-thans would need more careful thought.

The spatial pattern in sediment TBT concentrations is plotted in Figure 3(b) using as before the illustrative Site Groups listed in Table 1. There are several marked differences from the pattern of Figure 2(b): now Group 1 (Falmouth Docks) is by far the dominant hot-spot, whilst concentrations in Groups 2 and 3 are actually lower than for the majority of samples in Group 0.

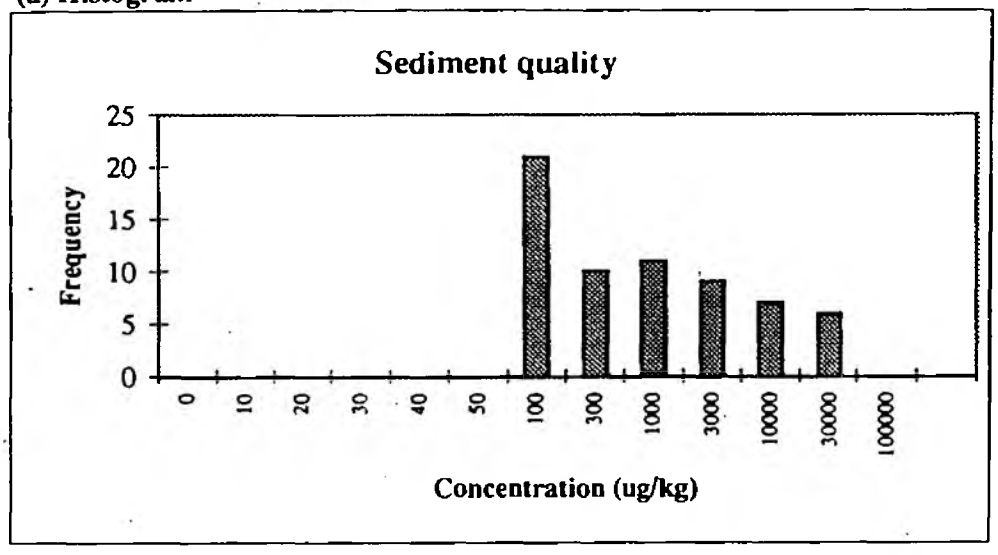
Summary statistics for the five groups are as follows:

Group	N	Mean	St.dev.
0	36	1780	5620
1	15	6540	6000
2	5	84	5
3	1	69	0
4	7	1096	430

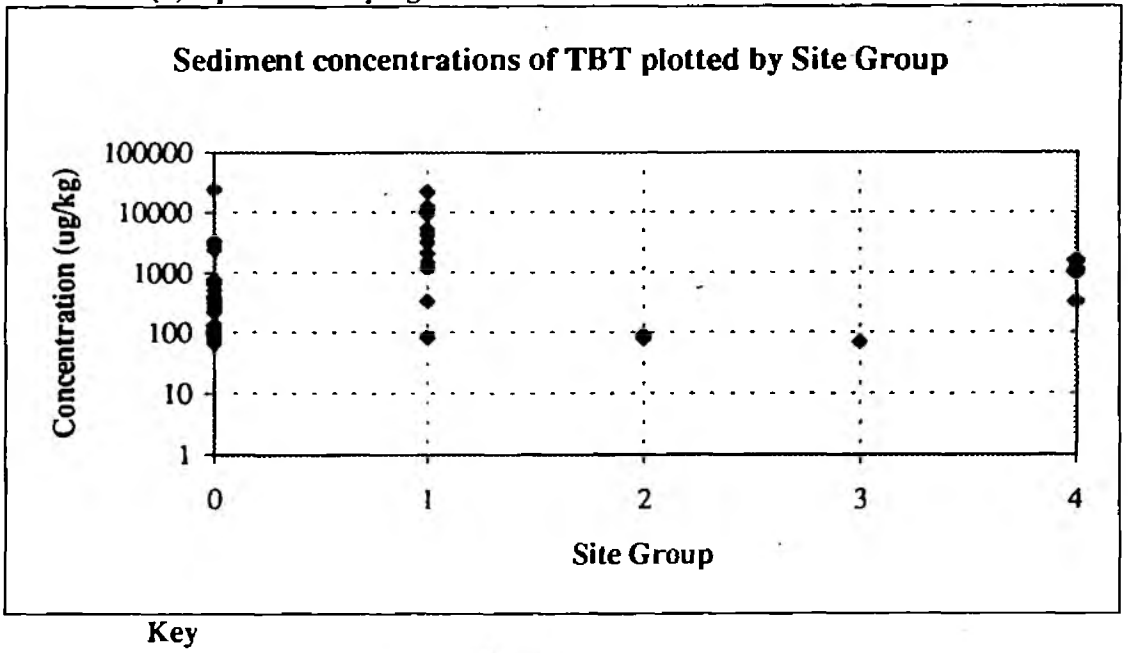
The high standard deviation for Group 0 is a clear pointer to a lack of homogeneity - that is, Group 0 contains hot-spots that we might hope would themselves constitute further Groups in a more refined version of Table 1. In spite of this, a t-test between Groups 0 and 1 is highly significant ($t = 2.7$), again showing the potential of the general approach.

Figure 3 - Distribution of TBT in sediment

(a) Histogram



(b) Spatial Groupings



Key

Group	Location key-word
1	Falmouth docks
2	Pennance Point Outfall
3	Middle Point Outfall (Old & Existing)
4	Penryn River
0	All other sites

2.3 Association between water and sediment TBT concentrations

As noted earlier, there were 21 locations common to the water and sediment data sets. We can use the paired data from these sites to look for an association between water and sediment concentrations. From the resulting scatter plot, shown in Figure 4, it is clear that there is no hint of a relationship. Several questions arise from this:

- Is a complete lack of correlation to be expected? Or is it just bad luck, compounded by the small number of samples available?
- Would water hot spots and sediment hot spots be expected to occur in (a) *different* locations, or (b) *similar* locations?
- If hot-spot mechanisms are *different*, how does this impinge on the future selection of both types of sampling location?...
- ... Whereas if they are *similar*, it would be desirable for there to be a greater proportion of jointly-sampled locations than the 30% seen in the June '97 survey. Is this practicable?

2.4 Comparisons between spatial surveys

Q2: Will it be possible to look for any differences in TBT between the two spatial surveys?

In planning the second spatial survey (whether water or sediment), it is crucial to ensure that the site locations remain comparable. Of course, that does not prevent some of the existing 65 sites from being discarded if analysis of the 1997 data indicates that they are unnecessary. The important point is that no new sites are added, unless there are good reasons for doing so. (And even then, they should be omitted from any comparison of the two spatial surveys.)

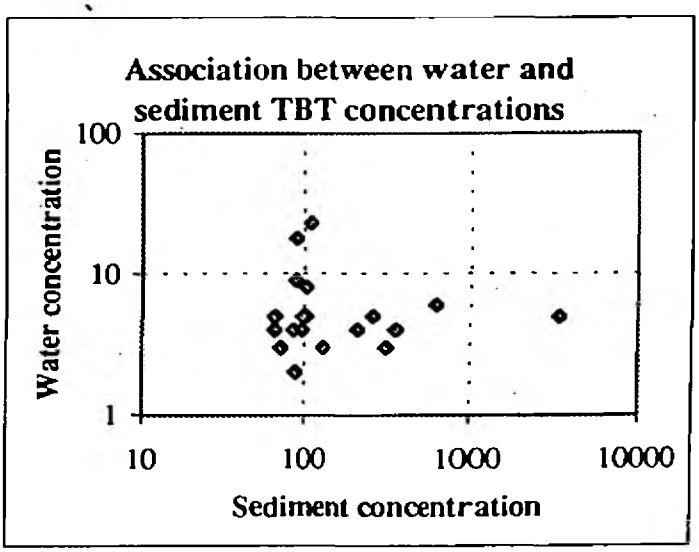
The great advantage of using only site-paired data is that the we can calculate paired differences. This removes all of the 'nuisance' site-to-site spatial variation, and so greatly improves the statistical precision of the temporal comparison. This is important because the temporal differences may be relatively small in comparison with spatial variations through the estuary.

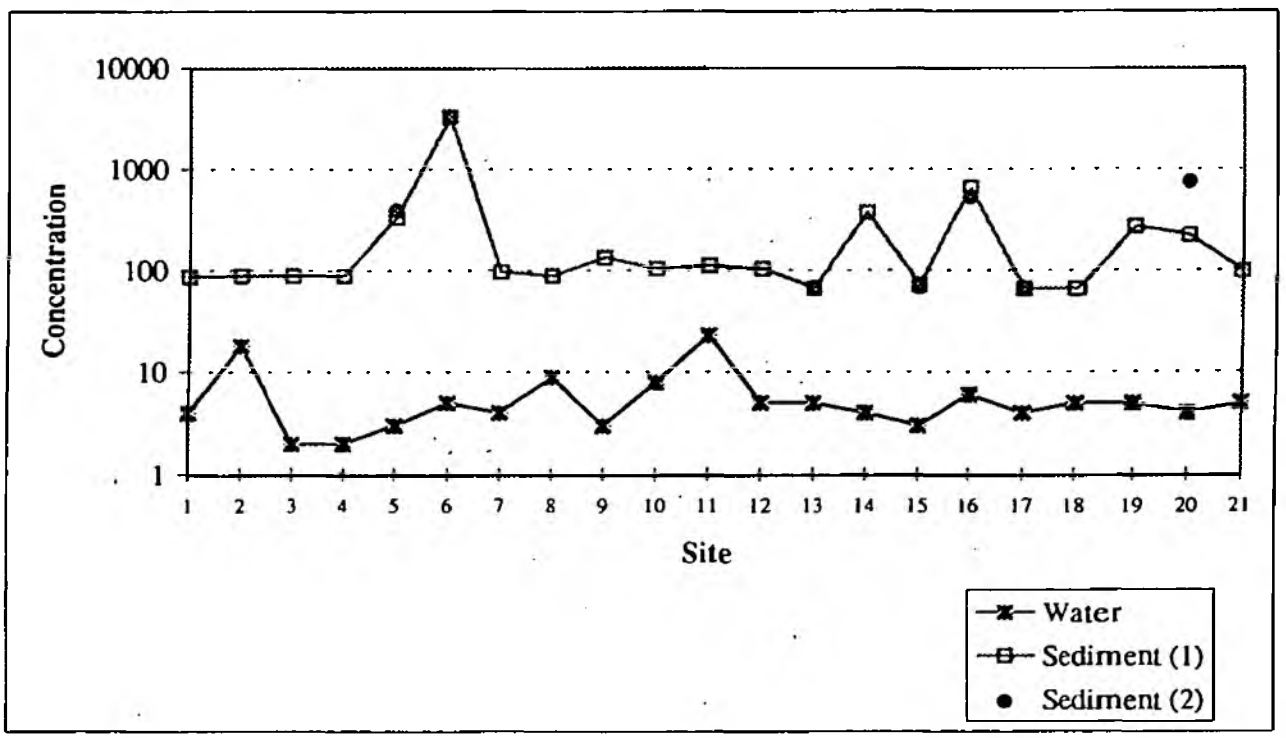
The statistical benefit brought by same-site sampling does rely on the assumption that, over the period between one survey and the next, there has not been a substantial shift in the true spatial distribution of TBT concentrations. However, even if this turns out to be incorrect, nothing will have been lost by keeping to the same locations. Furthermore, the knowledge that the spatial distribution was not broadly stable through time would be useful information in itself - and something that could not easily have been ascertained *without* same-site sampling.

Figure 4 - Association between water and sediment TBT concentrations

Site Name

1 Pennance Point Outfall - 500m SW of discharge
2 Pennance Point Outfall
3 Falmouth Bay
4 500m South of Zone Point
5 Percuil River - upper estuary
6 Percuil River - mid estuary
7 Middle Point New Outfall
8 Falmouth Docks east of Eastern Breakwater
9 EA Routine Site - Carrick Roads mid channel
10 Mid channel between Messack Pt and Mylor
11 North Bank Buoy
12 St Mawes Bank Northernmost Buoy
13 Restronguet Point
14 Mid Channel off Restronguet Point
15 Loe Beach
16 King Harry Ferry
17 Coombe Creek
18 Malpas
19 Deer Park
20 EA Routine Site at Penperth
21 Carrick Road between Tumaware and Messack





3. Monthly monitoring of TBT water quality

3.1 Time trends

Q3: What is an appropriate statistical method for looking at time trends in TBT water quality?

A technique that we have found extremely useful and robust when looking for time trends in routine quality data is *cusum analysis*. Cusums are particularly suitable when data frequencies are fairly low (e.g. monthly), and so we would recommend this approach here.

It can also be important to de-seasonalise the data - though we are unsure as to the extent to which that is an issue here. Presumably it will be important to allow for tidal factors - whether by sampling at a fixed point in the cycle (e.g. ±1 hour from high tide) or by some form of data correction.

All statistics packages (e.g. Minitab; GENSTAT; SPSS) are able to offer a variety of time series analysis methods. However, cusum significance testing is less readily available, and so for this we suggest using WRc's statistics package AARDVARK (many copies of which can be found in the Agency's South Western region). AARDVARK provides cusum analysis as one of its main trend analysis techniques. It also offers options for testing for seasonality, and using the resulting seasonal model (where necessary) to deseasonalise the data.

It may be that the temporal trend applies similarly across all sites. If this is believed to be the case, a more reliable estimate of the trend can be obtained by *jointly* analysing the data for all nine sites. This is something that is done automatically by the LAPWING package, as outlined in the next section.

3.2 Differences between sites

Q4: What is an appropriate statistical method for looking at differences in TBT water quality between sites?

In using routine water quality data to evaluate spatial differences between *river* sites, the most appropriate data analysis tool is the Agency's LAPWING package (developed in the early 1990s by WRc). LAPWING can be used equally successfully for comparing *marine* sites provided they can be placed in a logical spatial order (e.g. by reference to 'distance along a transect'). In the present case, the spatial pattern is too complex for all nine sites to be sensibly viewed as a one-dimensional sequence. However, it might be reasonable to do one LAPWING run on sites 11, 13, 7, 6, 2 and 16 (to characterise the spatial trend down Carrick Roads) and another run on sites 5, 3, 2 and 16 (for the Penryn arm of the spatial trend).

Even if LAPWING's one-dimensional spatial-pattern algorithm were felt to be inappropriate, LAPWING would still provide a good starting point for a spatial analysis. Its prelimary analysis of the data involves fitting a three-way factorial ANoVA with factors *season*, *year* and *site*, and from this - as in the example described later in Section 4.2 - we would be able to determine which sites were statistically significantly different from which others.

4. Mussel tissue TBT concentrations

4.1 Seasonal pattern

The 1997 TBT data consists of (up to) three monthly concentrations (for Aug, Sep and Oct) for each of 16 sites. Nine of the sites had concentrations for all three months. In the graphical summary provided by the Agency it was particularly noticeable that the seasonal pattern for the first two sites - Islington Quay and Flushing - ran counter to the typical pattern for the other sites, and so we have briefly investigated this using Friedman's two-way Analysis of Variance (ANoVA) test.

The ranked seasonal patterns for the nine sites are as shown below. Friedman's test statistic X^2 turned out to be 1.6 - way below the critical χ^2 value of 5.99 needed for P=0.05. This showed that (as we suspected) there was no statistically significant *common* seasonal pattern. However, on repeating the test omitting the first two contrary sites, we found that X^2 increased to 6.0 - this time confirming the clear seasonal pattern shown by the remaining sites.

	Isl. Quay	Flush.	Mylor	Rcstr.	King H.	Deer P.	Turnaw.	Mess.P.	St Mawes
Aug	1	1	3	2	3	3	3	3	2
Sep	2	2	2	3	2	2	2	1	1
Oct	3	3	1	1	1	1	1	2	3

This raises several questions which would be worth considering in the context of the mussel programme for future years.

- Is there a ready explanation for this apparent difference in seasonal pattern between sites?
- Might a similar effect arise in Jun, Jul and Aug - the months to be targetted in future sampling?
- If so, is it possible that the timing of the worst-case scenario might vary according to location?
- At five of the nine sites, concentrations were highest in Oct. How does this tie in with the view that "in the autumn, levels of TBT will be decreasing as the mussels depurate"?

4.2 Temporal and spatial trends

Q5: What is an appropriate statistical method for looking at time trends in mussel tissue TBT concentration?

Q6: What is an appropriate statistical method for looking at differences in mussel tissue TBT concentration between sites?

Although we used a non-parametric test in the previous section to look briefly at the seasonal pattern in tissue concentrations, conventional parametric ANoVA would be the appropriate method for assessing *between-site* differences. This approach would also readily extend to evaluating *between-year* differences (when another year's survey data has been generated).

To illustrate the testing of differences between sites, we have carried out a two-way ANoVA on the TBT concentration data for the same nine sites as discussed above. Relevant parts of the results are shown in Table 2.

From the residual variance we can calculate the minimum significant difference for site mean comparisons as:

MinSigDiff = $t^*0.00731\sqrt{(1/3 + 1/3)}$ = **0.15** (for two-sided 95% confidence).

This gives us an objective yardstick for determining which sites are genuinely different from which others. For example, the means for King Harry Ferry and St Mawes (0.20 and 0.10 ng/l) differ by less than 0.15, and so we cannot claim that they are significantly different. For King Harry Ferry and Mylor, however, the means differ by 0.18, and so these sites *are* .

Table 2 - Results from a two-way ANoVA of the mussel tissue data

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Rows	0.006	2	0.00308	0.42172	0.663	3.634
Columns	1.371	8	0.17139	23.4571	<0.001	2.591
Error	0.117	16	**0.00731**			
Total	1.494	26				

Site	**Mean**
Isl.Quay	0.81
Flush.	0.57
Mylor	0.38
Restr.	0.14
King H.	0.20
Deer P.	0.17
Turnaw.	0.20
Mess.P.	0.19
St Mawes	0.10

significantly different. (The MinSigDiff criterion also confirms the statistical significance of the huge mean differences between Islington Quay, Flushing and Mylor and the remaining sites - although these are so obvious that formal testing is unnecessary.)

To keep the above illustration brief we have cut a few corners. Issues that would need careful consideration in a proper assessment would include:

- Testing of the Normality assumption
- Data transformation (e.g. logging)?
- Dealing with missing monthly values.

5. Duplicate sampling

Q7: Is there much gained by having duplicate monthly water samples?

From the duplicate monthly water samples we can calculate paired differences, and hence estimate the standard deviation associated with sampling and analytical error. Table 3 presents the details. The analysis confirms that the agreement between duplicate samples is very good - sampling and analytical error accounting for only 5% of total variability. Another way of looking at this is to note that the standard deviation of paired mean concentrations is scarcely any less than the average standard deviation of either the TBT1 data or the TBT2 data on its own (28.2 versus 28.6).

This supports the Agency's view that little is gained by the extra data.

Table 3 - Analysis of the paired water sample data
(Note: pairs of less-thans are ignored)

	TBT1	TBT2	Diff.	Mean
	45	25	20	35
	89	101	-12	95
	19	20	-1	19.5
	16	11	5	13.5
	48	37	11	42.5
	6	9	-3	7.5
	26	29	-3	27.5
	5	5	0	5
	8	8	0	8
Mean	29.11	27.22	1.89	28.17
St.dev	27.48	29.70	9.20	28.24

Also, pooled estimate of overall st.dev. = **28.6**
And st.dev. of replicate means = **28.2** (only a very small reduction)

From difference data, estimated st.dev. of replication error is 9.20/root2 = **6.51**

As a proportion of total variance, therefore, environmental and analytical error accounts for only $(6.51/28.6)^2$ = **5.2%**

APPENDIX 2

TABLE 5a Fal Estuary TBT Monitoring - Mussel Shell Weight and Length 13/08/97

No.	Location	LSN	Length (cm)	Weight (g)	Shell Weight (g)
2	Middle Point	97/5292	2.53	3.2	2.4
		5293	2.75	3.1	2.1
		5294	2.96	2.7	2.0
		5295	2.84	2.4	1.7
		5296	2.77	3.7	2.9
		5297	2.92	2.7	1.9
		5298	3.01	3.0	2.1
		5299	2.91	3.0	2.2
		5300	3.25	3.8	2.8
		5301	3.42	3.6	2.7
3	Falmouth Docks - Northern Wharf	97/5303	2.78	1.9	1.2
		5304	2.49	1.8	1.6
		5305	2.80	2.7	2.0
		5306	2.81	2.6	1.9
		5307	2.89	3.3	2.5
		5308	2.81	2.7	2.0
		5309	2.92	2.6	1.9
		5310	3.14	3.1	2.4
		5311	3.19	3.6	2.4
		5312	2.85	3.3	2.5
4	Islington Quay - Penryn	97/5314	2.84	3.3	2.3
		5315	3.40	4.0	2.9
		5316	3.01	5.3	4.4
		5317	3.23	4.5	3.3
		5318	3.35	5.2	3.8
		5319	3.22	4.8	3.7
		5320	3.31	3.9	2.8
		5321	3.45	4.4	2.9
		5322	3.43	5.0	3.9
		5323	3.83	4.9	3.4
5	Penryn River near Flushing	97/5325	2.88	2.7	1.7
		5326	2.69	3.0	2.4
		5327	2.89	3.1	2.2
		5328	2.62	3.0	2.2
		5329	2.94	3.8	2.1
		5330	3.01	3.4	2.6
		5331	3.06	4.1	2.1
		5332	2.89	3.4	2.2
		5333	3.36	3.5	2.7
		5334	2.96	3.8	2.6
6	Vilt Buoy	97/5336	3.89	5.5	3.5
		5337	3.86	6.5	5.0
		5338	4.08	7.2	5.2
		5339	3.89	6.1	4.7
		5340	4.21	5.5	4.0
		5341	3.92	5.9	4.2
		5342	4.25	6.6	5.0
		5343	4.04	6.1	4.8
		5344	4.36	7.2	5.8
		5345	4.74	8.6	6.0

No.	Location	LSN	Length (cm)	Weight (g)	Shell Weight (g)
7	Hammerhead Wharf at Mylor Yacht Club	97/5347	3.27	3.0	1.8
		5348	3.12	3.4	1.9
		5349	3.07	3.0	1.9
		5350	3.10	4.5	3.4
		5351	3.07	4.0	2.8
		5352	3.33	3.4	2.1
		5353	3.63	5.9	4.3
		5354	3.10	4.9	3.6
		5355	3.26	4.7	3.4
		5356	3.34	5.7	4.3
8	Restronguet Point	97/5358	3.23	3.5	2.4
		5359	2.86	3.1	2.2
		5360	3.39	4.7	3.3
		5361	3.34	4.6	3.4
		5362	3.18	4.5	3.4
		5363	3.22	4.2	3.0
		5364	3.48	4.2	2.8
		5365	3.58	5.2	3.5
		5366	3.29	5.7	4.5
		5367	3.47	6.8	4.9
9	King Harry Ferry	97/5369	3.64	5.8	3.6
		5370	3.82	6.6	4.4
		5371	3.96	6.5	3.8
		5372	4.13	6.7	4.2
		5373	4.10	7.7	4.8
		5374	4.14	6.6	4.3
		5375	4.22	8.3	5.2
		5376	4.22	5.8	3.6
		5377	4.29	8.2	4.6
		5378	4.41	7.4	4.2
10	Malpas	97/5380	3.13	3.9	2.2
		5381	3.29	4.6	3.0
		5382	3.26	4.5	2.6
		5383	3.15	4.8	2.7
		5384	3.52	4.8	2.8
		5385	3.47	5.0	2.7
		5386	3.45	7.7	5.1
		5387	3.75	4.5	2.5
		5388	3.53	4.9	3.3
		5389	3.52	4.6	2.3
11	Deer Park	97/5391	2.93	2.9	2.0
		5392	3.09	3.3	2.2
		5393	3.04	3.6	2.3
		5394	3.37	4.7	3.0
		5395	2.97	3.5	2.2
		5396	3.12	3.6	2.3
		5397	3.16	3.7	2.4
		5398	3.33	4.6	3.0
		5399	3.43	5.0	3.0
		5400	3.43	5.0	3.0

No.	Location	LSN	Length (cm)	Weight (g)	Shell Weight (g)
12	Turnaware Point	97/5402	2.79	3.4	2.2
		5403	2.83	3.6	2.5
		5404	3.12	4.0	3.2
		5405	2.91	4.7	3.6
		5406	3.42	4.3	3.1
		5407	3.31	4.6	3.3
		5408	3.39	4.0	2.9
		5409	3.31	5.3	4.2
		5410	3.51	5.3	3.8
		5411	3.49	5.1	3.5
13	EA Routine Site - Carrick Roads mid channel	97/5413	2.79	3.1	1.6
		5414	2.71	2.6	1.5
		5415	3.01	2.8	1.6
		5416	2.76	2.2	1.2
		5417	2.88	2.5	1.5
		5418	2.89	3.4	1.6
		5419	3.02	4.1	2.1
		5420	2.98	3.3	2.0
		5421	3.19	3.4	2.3
		5422	3.15	3.2	1.9
14	Messack Point	97/5424	2.74	3.1	2.1
		5425	2.76	2.7	1.9
		5426	2.93	3.0	2.2
		5427	2.90	3.1	2.2
		5428	3.19	3.9	2.8
		5429	3.02	4.3	3.2
		5430	3.33	4.4	3.4
		5431	3.22	3.8	2.8
		5432	3.34	5.5	4.1
		5433	3.29	3.9	2.6
15	St Mawes Harbour	97/5435	2.93	2.8	1.9
		5436	2.92	3.0	2.2
		5437	2.99	2.9	1.8
		5438	2.97	2.4	1.5
		5439	2.98	3.2	2.5
		5440	3.24	3.3	2.5
		5441	3.06	3.6	2.5
		5442	3.05	3.9	2.8
		5443	3.16	3.0	2.0
		5444	3.55	4.3	2.9
16	Black Rock Buoy	97/5446	3.47	4.1	2.7
		5447	3.63	5.3	3.4
		5448	3.59	5.7	4.1
		5449	3.81	5.7	3.6
		5450	3.88	6.6	5.0
		5451	4.00	6.3	4.3
		5452	4.30	6.8	5.0
		5453	4.29	6.7	4.7
		5454	4.40	7.4	5.0
		5455	4.38	6.9	4.8

TABLE 5b Fal Estuary TBT Monitoring - Mean Mussel Shell Weight and Length 13/08/97

No.	Location	Dist from Docks (m)	Length (cm)	Weight (g)	Shell Weight (g)
2	Middle Point	1.7	2.94	3.1	2.3
3	Falmouth Docks - Northern Wharf	0.4	2.87	2.8	2.0
4	Islington Quay - Penryn	4.0	3.31	4.5	3.3
5	Penryn River near Flushing	2.1	2.93	3.4	2.3
6	Vilt Buoy	1.7	4.12	6.5	4.8
7	Hammerhead Wharf at Mylor Yacht Club	3.6	3.23	4.3	3.0
8	Restronguet Point	5.0	3.30	4.7	3.3
9	King Harry Ferry	7.4	4.09	7.0	4.3
10	Malpas	11.4	3.41	4.9	2.9
11	Deer Park	9.4	3.19	4.0	2.5
12	Turnaware Point	5.9	3.21	4.4	3.2
13	EA Routine Site - Carrick Roads mid channel	3.9	2.94	3.1	1.7
14	Messack Point	3.7	3.07	3.8	2.7
15	St Mawes Harbour	3.2	3.09	3.2	2.3
16	Black Rock Buoy	2.3	3.98	6.2	4.3

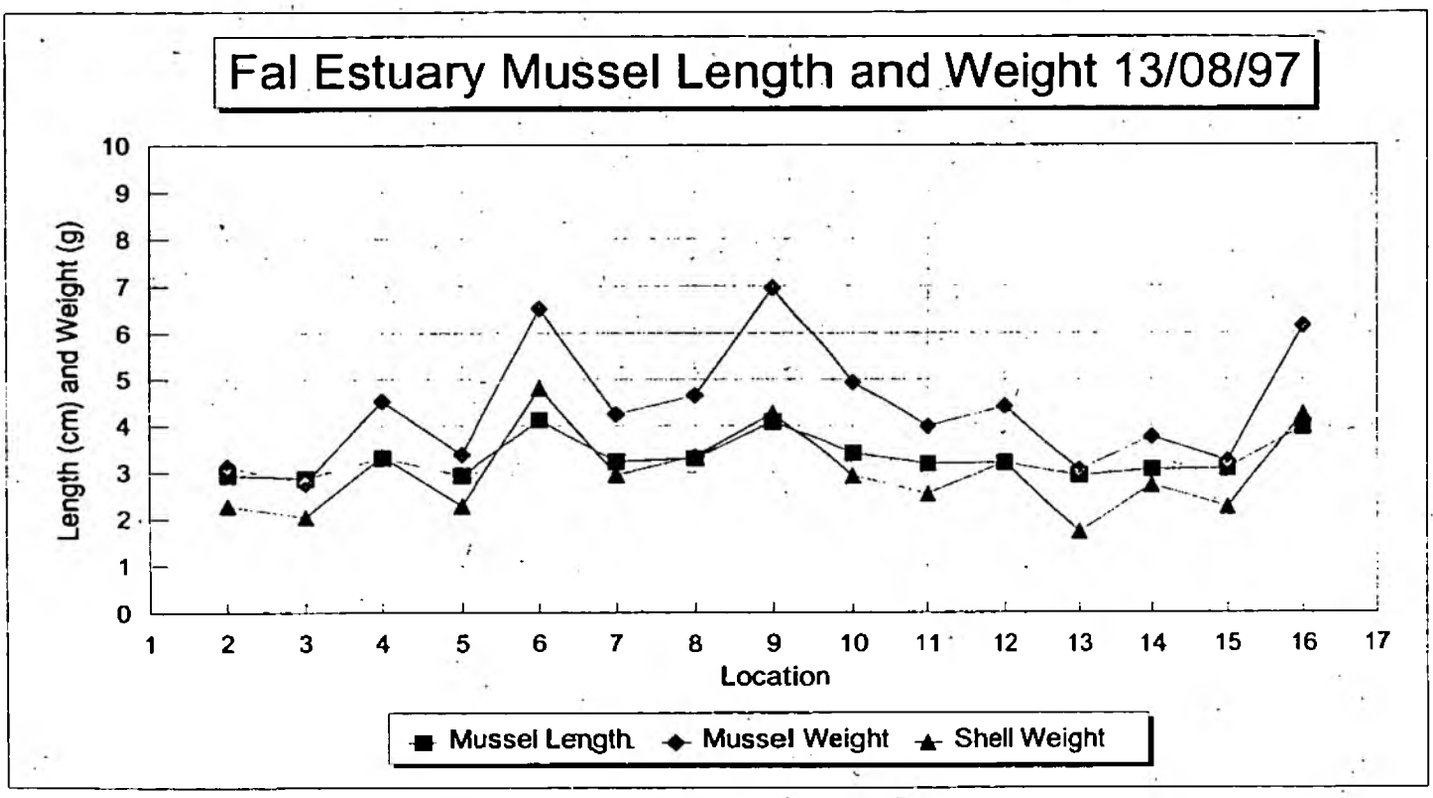


TABLE 5c Fal Estuary TBT Monitoring - Mussel Shell Weight and Length 15/09/97

No.	Location	LSN	Length (cm)	Weight (g)	Shell Weight (g)
3	Falmouth Docks - Northern Wharf	97/5901	2.46	1.8	1.2
		5902	2.54	3.0	2.1
		5903	2.66	2.9	1.9
		5904	2.85	3.5	2.3
		5905	2.80	3.4	1.9
		5906	2.87	4.2	2.5
		5907	2.96	4.5	2.9
		5908	3.38	4.5	2.8
		5909	3.06	3.7	2.2
		5910	3.10	4.2	2.7
4	Islington Quay - Penryn	97/5912	3.03	4.2	2.3
		5913	3.16	4.5	2.9
		5914	3.24	5.5	3.8
		5915	3.21	5.5	3.3
		5916	3.40	5.7	3.8
		5917	3.40	4.9	3.0
		5918	3.46	4.4	2.7
		5919	3.68	5.3	3.0
		5920	3.58	7.7	4.3
		5921	3.84	7.8	4.2
5	Penryn River near Flushing	97/5923	3.03	3.4	1.9
		5924	3.05	3.6	2.1
		5925	3.10	4.4	2.9
		5926	3.34	3.9	2.3
		5927	3.34	3.7	2.2
		5928	3.36	4.3	2.6
		5929	3.41	5.0	2.9
		5930	3.50	6.1	4.1
		5931	3.56	5.5	3.7
		5932	3.68	5.5	3.4
7	Hammerhead Wharf at Mylor Yacht Club	97/5934	2.56	3.4	2.2
		5935	2.78	2.6	1.3
		5936	2.58	3.7	2.6
		5937	2.94	3.0	1.6
		5938	3.23	2.8	1.5
		5939	3.57	4.1	2.5
		5940	3.24	3.9	1.9
		5941	3.55	4.3	2.3
		5942	3.51	4.2	2.3
		5943	3.46	5.2	2.9
8	Restronguet Point	97/5945	3.31	3.3	2.0
		5946	3.34	3.8	2.4
		5947	3.22	4.2	2.8
		5948	3.73	5.0	3.0
		5949	3.53	8.3	5.7
		5950	3.89	5.5	3.5
		5951	3.85	6.3	4.2
		5952	3.98	5.9	3.8
		5953	3.97	6.0	3.7
		5954	4.17	7.0	4.3

No.	Location	LSN	Length (cm)	Weight (g)	Shell Weight (g)
9	King Harry Ferry	97/5956	3.84	6.5	3.9
		5957	4.00	6.6	4.0
		5958	4.22	9.9	6.1
		5959	4.22	9.8	5.9
		5960	4.21	9.7	5.6
		5961	4.31	8.0	4.9
		5962	4.22	7.7	4.5
		5963	4.52	10.4	6.6
		5964	4.53	9.2	4.9
		5965	4.85	12.0	7.9
10	Malpas	97/5967	3.73	5.1	2.9
		5968	3.79	6.4	3.1
		5969	3.82	5.8	2.9
		5970	3.92	6.9	3.6
		5971	3.23	5.4	2.9
		5972	3.81	5.7	3.1
		5973	3.86	6.8	2.9
		5974	4.15	6.9	3.4
		5975	4.12	7.3	3.2
		5976	4.11	6.9	3.8
11	Deer Park	97/5978	2.76	3.5	2.0
		5979	3.11	3.3	1.8
		5980	3.22	4.5	2.4
		5981	3.40	3.8	2.0
		5982	3.47	4.9	3.0
		5983	3.28	4.2	2.7
		5984	3.41	5.9	3.4
		5985	3.41	5.3	3.0
		5986	3.55	4.7	3.7
		5987	3.58	4.5	2.7
12	Turnaware Point	97/5989	3.37	3.7	2.2
		5990	3.16	3.7	2.6
		5991	3.08	4.4	2.8
		5992	3.24	3.8	2.5
		5993	3.53	4.7	2.8
		5994	3.52	3.8	2.3
		5995	3.54	5.3	3.4
		5996	3.54	4.7	2.9
		5997	3.82	5.3	3.2
		5998	3.81	5.1	3.2
13	EA Routine Site - Carrick Roads mid channel	97/6000	3.28	4.3	2.5
		6001	3.27	3.9	2.1
		6002	3.39	4.9	2.6
		6003	3.39	4.5	2.6
		6004	3.30	4.5	2.3
		6005	3.31	3.8	2.0
		6006	3.61	5.0	2.5
		6007	3.74	5.2	2.6
		6008	3.45	5.1	2.9
		6009	3.78	5.0	2.8

No.	Location	LSN	Length (cm)	Weight (g)	Shell Weight (g)
14	Messack Point	97/6011	2.96	2.6	1.8
		6012	2.86	2.9	1.7
		6013	3.06	3.1	1.9
		6014	2.95	3.3	2.4
		6015	2.82	3.7	2.6
		6016	3.21	3.7	2.2
		6017	3.11	3.5	2.3
		6018	3.07	3.1	1.9
		6019	3.38	3.4	2.2
		6020	3.41	5.2	3.4
15	St Mawes Harbour	97/6022	2.91	2.6	1.5
		6023	3.03	3.0	2.0
		6024	2.93	3.6	2.2
		6025	2.98	3.2	2.2
		6026	3.22	3.5	2.4
		6027	3.24	3.8	2.6
		6028	3.37	3.8	2.3
		6029	3.51	3.7	2.1
		6030	3.48	4.9	3.3
		6031	3.57	4.2	2.6
16	Black Rock Buoy	97/6033	4.35	7.4	4.2
		6034	4.27	7.0	4.1
		6035	4.10	6.5	4.4
		6036	4.35	6.9	4.2
		6037	4.11	7.3	3.6
		6038	4.15	5.8	4.6
		6039	4.35	9.3	5.3
		6040	4.34	10.3	5.8
		6041	4.58	10.3	6.8
		6042	4.79	12.1	6.9

TABLE 5d Fal Estuary TBT Monitoring - Mean Mussel Shell Weight and Length 15/09/97

No.	Location	Dist from Docks (m)	Length (cm)	Weight (g)	Shell Weight (g)
3	Falmouth Docks - Northern Wharf	0.4	2.87	3.6	2.3
4	Islington Quay - Penryn	4.0	3.40	5.6	3.3
5	Penryn River near Flushing	2.1	3.34	4.5	2.8
7	Hammerhead Wharf at Mylor Yacht Club	3.6	3.14	3.7	2.1
8	Restronguet Point	5.0	3.70	5.5	3.5
9	King Harry Ferry	7.4	4.29	9.0	5.4
10	Malpas	11.4	3.85	6.3	3.2
11	Deer Park	9.4	3.32	4.5	2.7
12	Turnaware Point	5.9	3.46	4.5	2.8
13	EA Routine Site - Carrick Roads mid channel	3.9	3.45	4.6	2.5
14	Messack Point	3.7	3.08	3.5	2.2
15	St Mawes Harbour	3.2	3.22	3.6	2.3
16	Black Rock Buoy	2.3	4.34	8.3	5.0

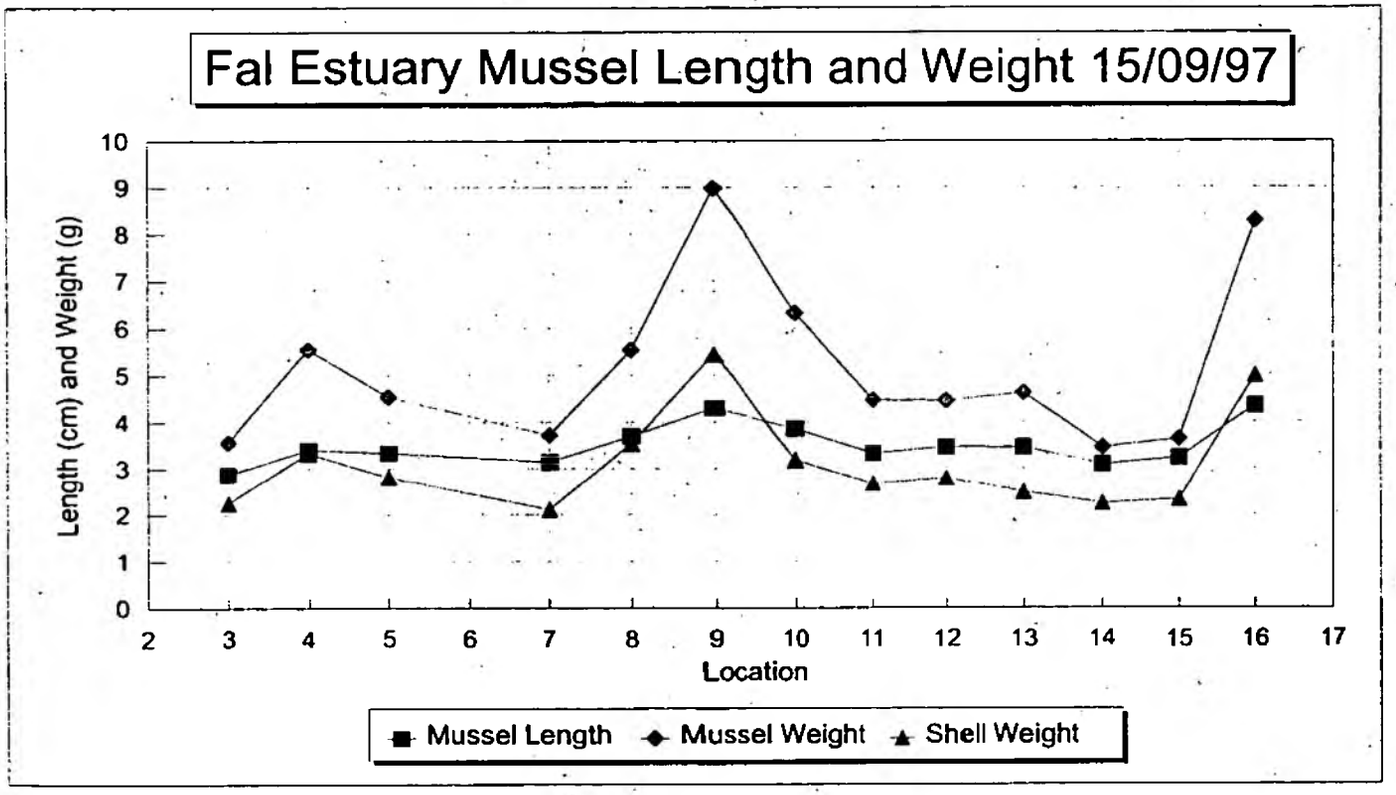


TABLE 5e Fal Estuary TBT Monitoring - Mussel Shell Weight and Length 28/10/97

No.	Location	LSN	Length (cm)	Weight (g)	Shell Weight (g)
0	Background levels at Whitsand Bay (15/07/97)	6581	3.22	2.1	3.1
		6583	3.16	2.7	3.6
		6584	3.18	2.5	3.4
		6585	3.35	2.6	3.7
		6586	3.53	2.7	3.9
		6587	3.23	2.0	3.1
		6588	3.27	2.1	3.1
		6589	3.41	2.9	4.2
		6590	3.60	3.6	4.9
		6591	3.62	3.6	4.9
4	Islington Quay - Penryn	6482	3.80	4.7	7.2
		6483	3.69	4.3	6.9
		6484	3.50	3.7	6.1
		6485	3.81	3.6	5.9
		6486	3.64	4.2	6.4
		6487	3.48	3.8	6.1
		6488	3.56	3.4	5.4
		6489	3.56	2.7	5.1
		6490	3.43	3.3	5.2
		6491	3.33	2.7	4.9
5	Penryn River near Flushing	6493	3.73	3.5	6.3
		6494	3.50	3.7	5.5
		6495	3.56	3.3	5.8
		6496	3.60	2.1	4.4
		6497	3.41	2.9	4.9
		6498	3.44	2.3	3.9
		6499	3.40	3.1	5.1
		6500	3.32	2.2	4.1
		6501	3.08	3.0	4.6
		6502	3.15	2.3	3.9
7	Hammerhead Wharf at Mylor Yacht Club	6504	4.71	5.0	8.3
		6505	4.43	3.3	6.8
		6506	4.11	3.2	5.5
		6507	3.73	3.1	6.5
		6508	3.71	3.5	5.1
		6509	3.60	3.4	4.8
		6510	3.76	2.9	4.7
		6511	3.50	3.6	5.4
		6512	3.72	2.3	4.4
		6513	3.48	2.3	4.1
8	Restronguet Point	6515	3.74	2.9	5.1
		6516	3.82	3.8	6.6
		6517	3.44	3.7	6.1
		6518	3.85	4.0	6.2
		6519	3.68	4.8	7.6
		6520	3.77	4.4	7.6
		6521	4.04	4.2	7.5
		6522	4.03	4.1	6.9
		6523	4.23	4.1	7.9
		6524	4.59	5.5	9.5

No.	Location	LSN	Length (cm)	Weight (g)	Shell Weight (g)
9	King Harry Ferry	6526	5.08	7.3	11.4
		6527	4.84	4.8	8.0
		6528	4.78	7.3	11.0
		6529	4.71	6.1	9.3
		6530	4.48	4.5	8.4
		6531	4.37	4.5	8.0
		6532	4.17	5.0	8.1
		6533	4.16	5.0	7.9
		6534	4.24	3.9	7.5
		6535	3.90	3.7	6.6
11	Deer Park	6537	3.60	3.2	5.4
		6538	3.68	3.5	5.6
		6539	4.26	3.7	7.1
		6540	4.17	3.5	6.9
		6541	3.83	4.1	7.0
		6542	4.18	4.8	8.6
		6543	3.84	3.8	7.2
		6544	3.84	3.7	6.2
		6545	4.00	3.0	5.5
		6546	3.90	3.6	6.4
12	Turnaware Point	6548	3.80	2.8	5.4
		6549	4.01	3.1	5.2
		6550	4.07	3.0	5.0
		6551	3.63	4.3	7.1
		6552	3.95	4.1	7.8
		6553	4.11	3.8	7.4
		6554	4.33	4.0	6.5
		6555	3.93	3.8	7.2
		6556	4.47	4.9	7.9
		6557	4.47	4.7	7.7
14	Messack Point	6559	3.58	2.7	4.8
		6560	3.13	3.4	5.1
		6561	3.49	3.0	4.8
		6562	3.47	4.1	6.1
		6563	3.57	2.9	5.1
		6564	3.57	3.4	6.0
		6565	3.42	2.5	4.6
		6566	3.99	3.7	5.7
		6567	3.75	3.5	5.6
		6568	3.69	3.3	5.1
15	St Mawes Harbour	6570	3.07	2.1	3.7
		6571	3.00	1.6	3.1
		6572	3.36	2.9	4.7
		6573	3.32	2.8	4.7
		6574	3.44	2.8	4.3
		6575	3.55	2.5	4.2
		6576	3.42	2.8	4.7
		6577	3.63	3.3	5.7
		6578	3.60	2.6	4.5
		6579	3.70	3.3	5.3

TABLE 5f Fal Estuary TBT Monitoring - Mean Mussel Shell Weight and Length 28/10/97

No.	Location	Dist fro Docks (m	Length (cm)	Weight (g)	Shell Weight (g)
4	Islington Quay - Penryn	4.0	3.58	3.6	5.9
5	Penryn River near Flushing	2.1	3.42	2.8	4.8
7	Hammerhead Wharf at Mylor Yacht Club	3.6	3.88	3.3	5.6
8	Restronguet Point	5.0	3.92	4.2	7.1
9	King Harry Ferry	7.4	4.47	5.2	8.6
11	Deer Park	9.4	3.93	3.7	6.6
12	Turnaware Point	5.9	4.08	3.9	6.7
14	Messack Point	3.7	3.57	3.3	5.3
15	St Mawes Harbour	3.2	3.41	2.7	4.5