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South West Region

ENVIRONMENTAL PROTECTION

ASSESSMENT OF THE IMPACT OF DISCHARGES FROM MELDON QUARRY ON THE WATER QUALITY OF THE WEST OKEMENT RIVER

JANUARY 1990
FWI/90/001

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FRESHWATER INVESTIGATION UNIT
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MANLEY HOUSE
EXETER

ASSESSMENT OF THE IMPACT OF DISCHARGES FROM MELDON QUARRY ON THE WATER QUALITY OF THE WEST OKEMENT RIVER

1. Introduction

On 16 September 1989 a fish mortality occurred in the West Okement River downstream of the main discharge points from the Meldon Quarry complex. The West Okement River had been experiencing extreme drought conditions during the summer of 1989 and the fish mortality coincided with the first significant rainfall at the end of the drought period.

Following the mortality an investigation was undertaken between 20 and 23 October 1989 to assess the effect of the major discharges from the quarry complex on water quality in the West Okement. The survey was carried out during the next period of significant rainfall following the fish mortality (see Fig. 2). Water quality has been examined in terms of compliance with applicable environmental quality standards (EQS) and general changes in quality.

The hardness of water is particularly important in determining EQS's for metals in List II of the Dangerous Substances Directive. In the West Okement River water hardness is very low (less the 50 mg/l ($CaCO_3$)). This makes the EQS's for lead, zinc and copper exceptionally low. (See Appendix 1).

A biological survey of the effect of discharges from the quarry complex was also undertaken. Samples of aquatic macro-invertebrates were obtained by standard methods to assess the effects of the major discharges from the quarry complex during the drought period and following the initial significant rains when the fish mortality occurred in September.

The West Okement River has a River Quality Objective of National Water Council (NWC) Class 1A from its source to its confluence with the East Okement River.

The West Okement River has been designated under the EC Freshwater Fish Directive for the protection of salmonid fish from Meldon Reservoir to its confluence with the East Okement River.

The following use related objectives have been adopted for the West Okement River:

Protection of:

Aesthetic Quality
Suitability for abstraction for potable supply
Salmonid fish
Other aquatic life/dependent organisms
Livestock watering
Crop irrigation

2. Method

2.1 Water Quality Survey

Samples were obtained from the sites shown in Figure 1 in accordance with a programme defined by the East area Pollution Inspectorate. Specific site details are given in Table 1. Most samples were obtained manually, however some samples from sites 3,5 and 6 were obtained using automatic sampling equipment (samples obtained by this means are identified in Table 2).

2.2 Biological Survey

Samples of aquatic macro-invertebrates were obtained from 4 sites shown in Figure 1. Samples were obtained by standard kick sampling methods, the animals were identified to species level and estimations of abundance of each species was made.

3. Results

3.1 Flow Data

Relevant flow data is unavailable as the only flow gauging stations in the West Okement are upstream of Meldon Reservoir and immediately downstream of the reservoir. As the reservoir was not overspilling during the survey period, this gauging station merely measured the compensation release from the reservoir. However, visual observation of flows in the Red-a-ven Brook and West Okement below the Red-a-ven confluence indicated flows considerably increased during the survey period.

3.2 Rainfall Data

Rainfall data for the relevant period is shown in Fig. 2 for stations at N. Wyke NGR SX 661983 and Higher Brockscombe NGR SX 462950. Normally the site at Okehampton Pleasure Gardens would be used for rainfall information. However, the gauge developed a fault during the survey period. Higher Brockscombe is in the R. Wolf catchment 10 km to the North West of Meldon Quarry and North Wyke is 10.5 km East North East of Meldon Quarry in the Taw catchment. These two sites are the nearest to Meldon Quarry with a constant readout of rainfall. However, these sites do give some indication of the rainfall occurring in the area at the time.

3.3 The results of chemical analyses of relevant parameters at the sites examined are shown in Table 2.

Changes in quality of pH, aluminium, zinc, nickel, copper and cadmium are shown graphically for sites 3,5 and 6 in figures 3-8 respectively.

3.4 The species composition of samples obtained during the biological surveys are shown in Table 3.

4. Discussion

West Okement River below Meldon Dam

4.1 Water Quality was found to be good in the West Okement downstream of Meldon Dam. The West Okement immediately below Meldon dam complied with the Environmental Quality Standards for pH, copper, nickel, zinc, lead, cadmium and aluminium and water quality was Class 1A.

Red-a-ven Brook

4.2 Three samples were taken from the Red-a-ven Brook, a tributary of the West Okement River. Quality was originally good when sampled on 18 and 20 October, but suffered from a depression in pH on 22 October which caused the EQS for pH and the tentative EQS for aluminium to be exceeded. The cause of this change is not known positively but it is likely to be due to natural moorland run-off following rainfall after a long dry period. However, as there are both disused mine workings and part of the Meldon Quarry complex is in the catchment of this brook, it is possible that these factors influenced water quality changes.

West Okement at Meldon Viaduct

4.3 Water quality in the West Okement at Meldon Viaduct showed exceedance of the EQS's for pH, Zinc and Aluminium. The EQS for zinc was exceeded by only a small margin.

The reason these EQS's were exceeded is not known and it is impossible to determine if the Red-a-ven Brook was a major contributor due to inadequate data. Previous surveys have identified the presence of an input of zinc and copper and nickel to the West Okement River between the Red-a-ven confluence and the Meldon Viaduct. However, before the small inputs could be investigated many had dried up under receding flows. It is likely that the EQS for copper was also exceeded at this site as total values exceeded the EQS by small amounts. Although analysis was not undertaken for dissolved copper on the majority of samples it is likely that most of the total copper was in dissolved form based on evidence from other sites.

Youlditch Stream

4.4 One sample was obtained from the Youlditch Tributary on 29 October, this tributary enters the West Okement immediately upstream of Meldon Quarry drainage tunnel. This sample was taken after the main survey period. Quality was good except for the concentration of zinc which exceeded the EQS.

West Okement 50m downstream of Meldon Quarry drainage tunnel

4.5 Samples from the site 50m below Meldon Quarry drainage tunnel exceeded the EQS for pH, zinc and cadmium. Due to the limited data on dissolved metals it is impossible to determine whether the EQS's for copper, nickel and aluminium were exceeded. However, in the two samples where dissolved metals were analysed, the majority of these metals were found to be in the dissolved form and as such the EQS's for these metals are likely to have been exceeded.

Cadmium showed a significant increase in concentration at this site with values almost an order of magnitude above the EQS despite the fact that concentrations were below the limit of detection at the upstream site. The source of the metals seems likely to be the drainage tunnel from Meldon Quarry although there are no data available on the quality of water leaving the tunnel to assess this.

Meldon Quarry Stream

4.6 The Meldon Quarry Stream was found to be very poor quality with a low pH and high metal levels, particularly copper, nickel, zinc, cadmium and aluminium. Hardness and conductivity were also very high. The Meldon Quarry Stream is essentially derived from ground and surface water drainage from part of the Meldon Quarry site. The activities of quarrying are exposing pyritic shales which are oxidising to produce acid. The low pH of the water is assisting in leaching metals from the strata of the quarry complex. Consequently the water draining the quarry area is rich in the metals present in the geology of the site. The Meldon Quarry Stream has no designated use and therefore EQS's are not applicable.

West Okement River below Meldon Quarry

4.7 The West Okement River 200m downstream of Meldon Quarry Bridge is downstream of the discharge point of a road drain which receives the Meldon Quarry Stream. Three samples were taken at this site during the survey period. The EQS's were exceeded for pH, copper, zinc, nickel and aluminium. In the two samples that were comparable with samples taken upstream at the same date and time, it would appear that cadmium concentration had decreased at this site whilst copper, zinc, aluminium and nickel concentrations had been further increased, probably as a result of the discharge of the Meldon Quarry Stream. However, the contributions of general road drainage and the land drains which discharge into this drainage system were not recorded.

Biological Survey

4.8 Biological samples taken from the West Okement during the drought period upstream of the main quarry discharges showed a typical moorland aquatic invertebrate community to be present, and little change was detected in this community after the first rains in September when the fish mortality occurred.

Downstream of Meldon Quarry drainage tunnel little effect was detected on the invertebrate community, either before or after the initial rains at the end of the drought although significant iron deposition had occurred in the river downstream of the drainage tunnel discharge.

Downstream of the Meldon Quarry Stream discharge point a severely restricted invertebrate fauna was present both before and after the initial rains which coincided with the fish mortality in September. The fauna at this site was consistent with a community resulting from the influence of significant toxic pollution.

5. Conclusions

5.1 Upstream of the main discharges from Meldon Quarry complex the EQS's for pH and zinc were definitely exceeded although zinc only exceeded the EQS by small quantities. It is likely that copper also exceeded the EQS above the main quarry discharges by small quantities but the data are insufficient to determine this. Aluminium is also likely to have exceeded the EQS value which has tentatively been suggested for this metal but again the data are insufficient for confirmation.

5.2 In the West Okement River downstream of the main discharge from Meldon Quarry, those parameters found to exceed their EQS's at the upstream site continued to exceed their EQS's but by greater margins. Concentrations of nickel were also found to exceed the EQS downstream of the quarry complex.

5.3 Downstream of Meldon Quarry drainage tunnel the EQS for cadmium was exceeded in the West Okement River but concentrations had apparently reduced below the EQS in the West Okement River 200m downstream of Meldon Quarry Bridge.

5.4 Concentrations of zinc, copper, nickel, aluminium, conductivity and hardness significantly increased in the West Okement River downstream of the main quarry discharges.

5.5 Biological monitoring of the West Okement River showed a significant effect on the aquatic invertebrate fauna downstream of the main discharges from Meldon Quarry. The fauna present downstream was typical of a community experiencing severe toxic pollution.

6. Recommendations

6.1 The discharges from Meldon Quarry should be consented so that quality controls can be imposed and limits applied to protect designated uses in the West Okement River.

6.2 The problem of EQS exceedance which is occurring upstream of the main discharge points of the Meldon Quarry complex should be taken into account when producing the Water Quality Management Plan for the River Torridge catchment.

FIGURE 1

MONITORING SITES FOR THE ASSESSMENT OF THE EFFECTS OF MELDON QUARRY ON THE WATER QUALITY OF THE WEST OKEMENT

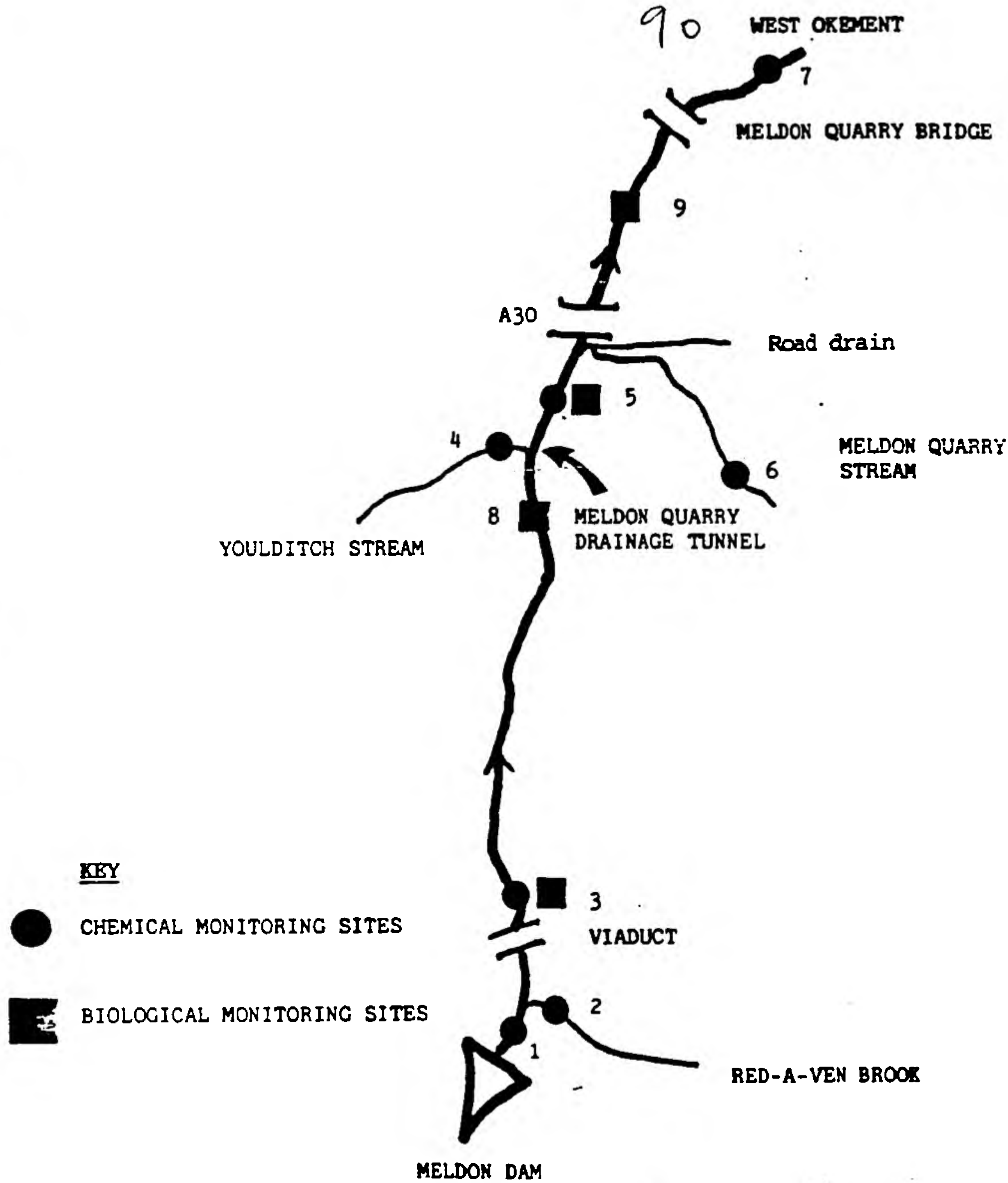
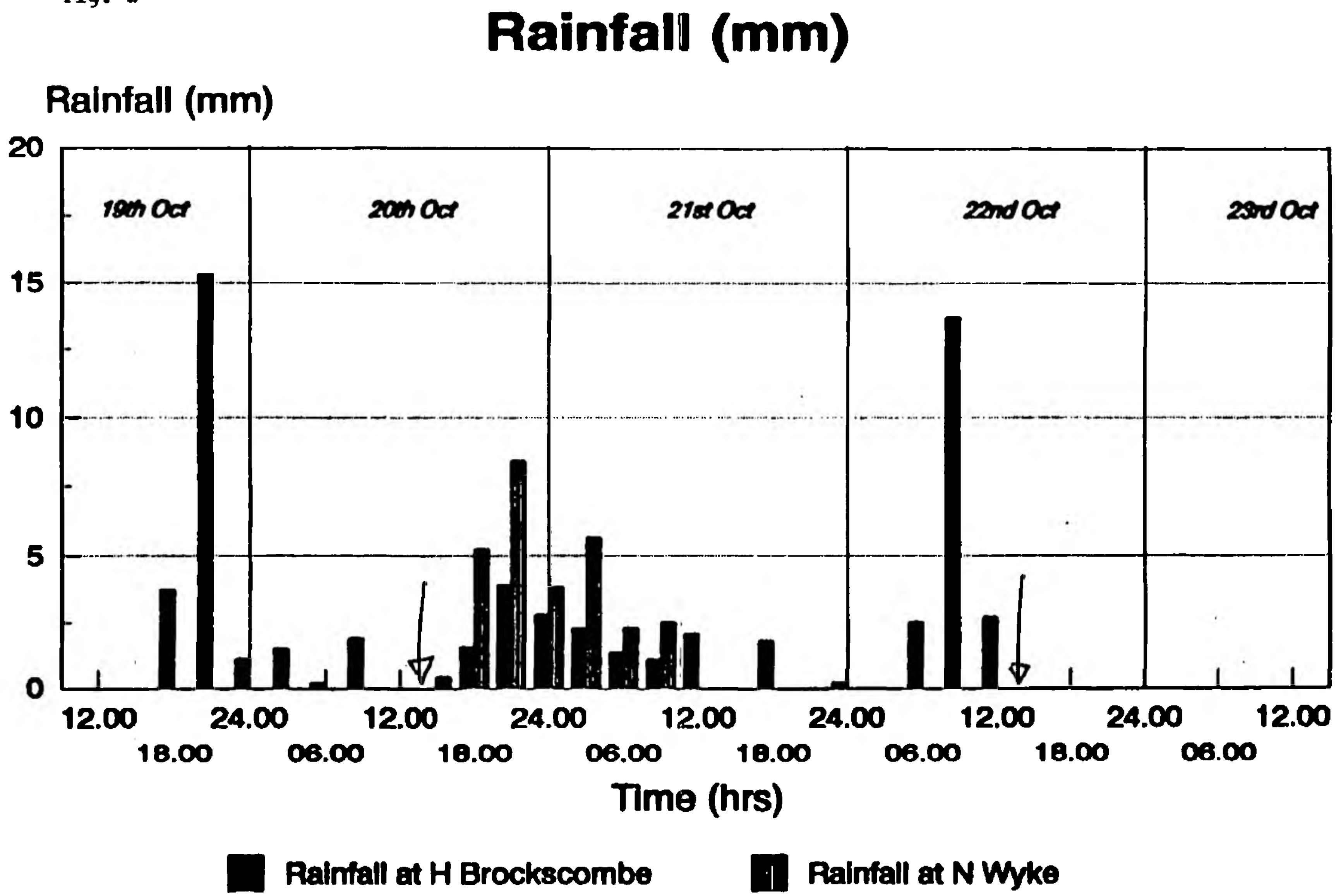


Fig. 2



Rainfall 3 hourly intervals

FIG. 3

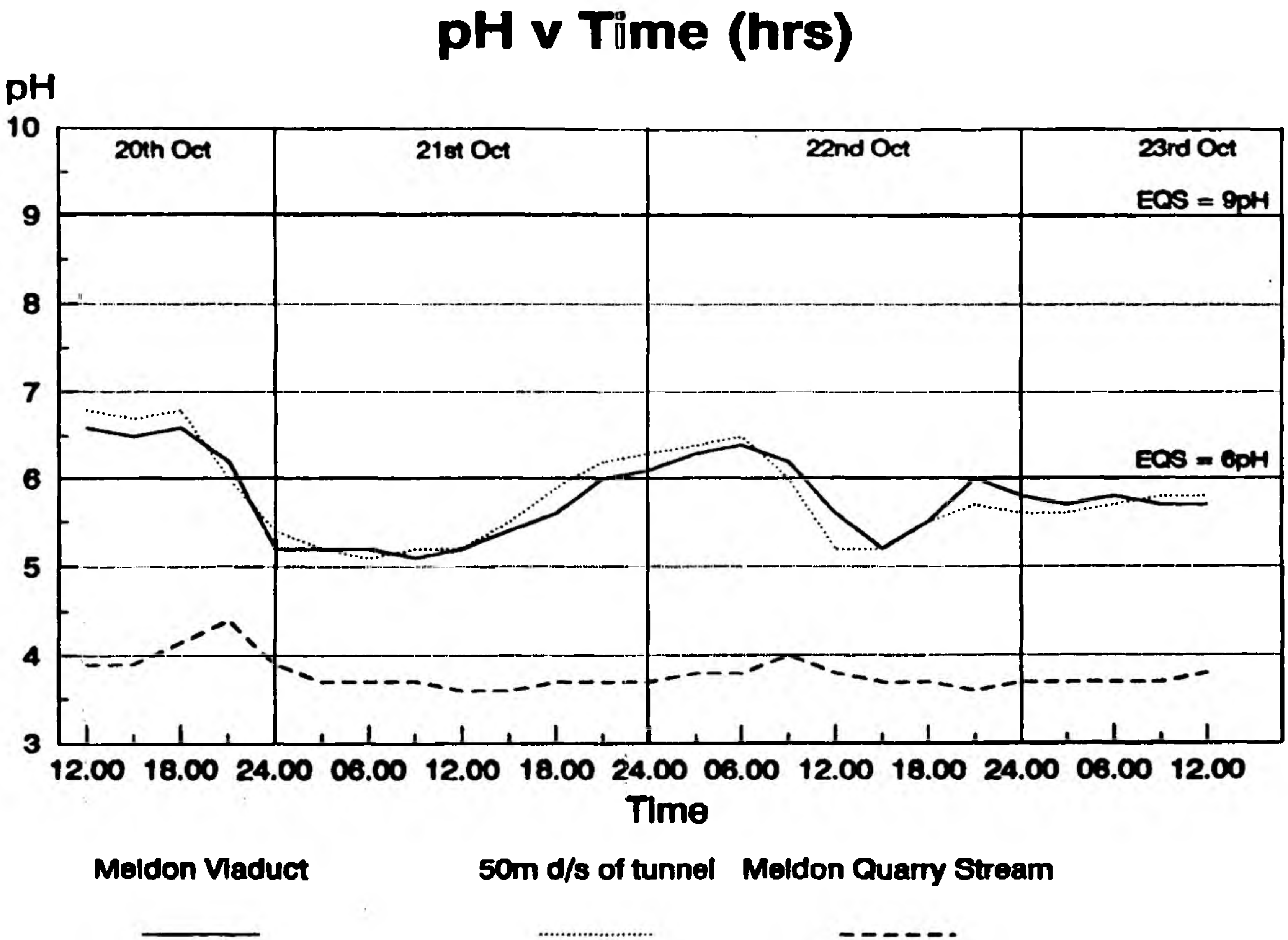
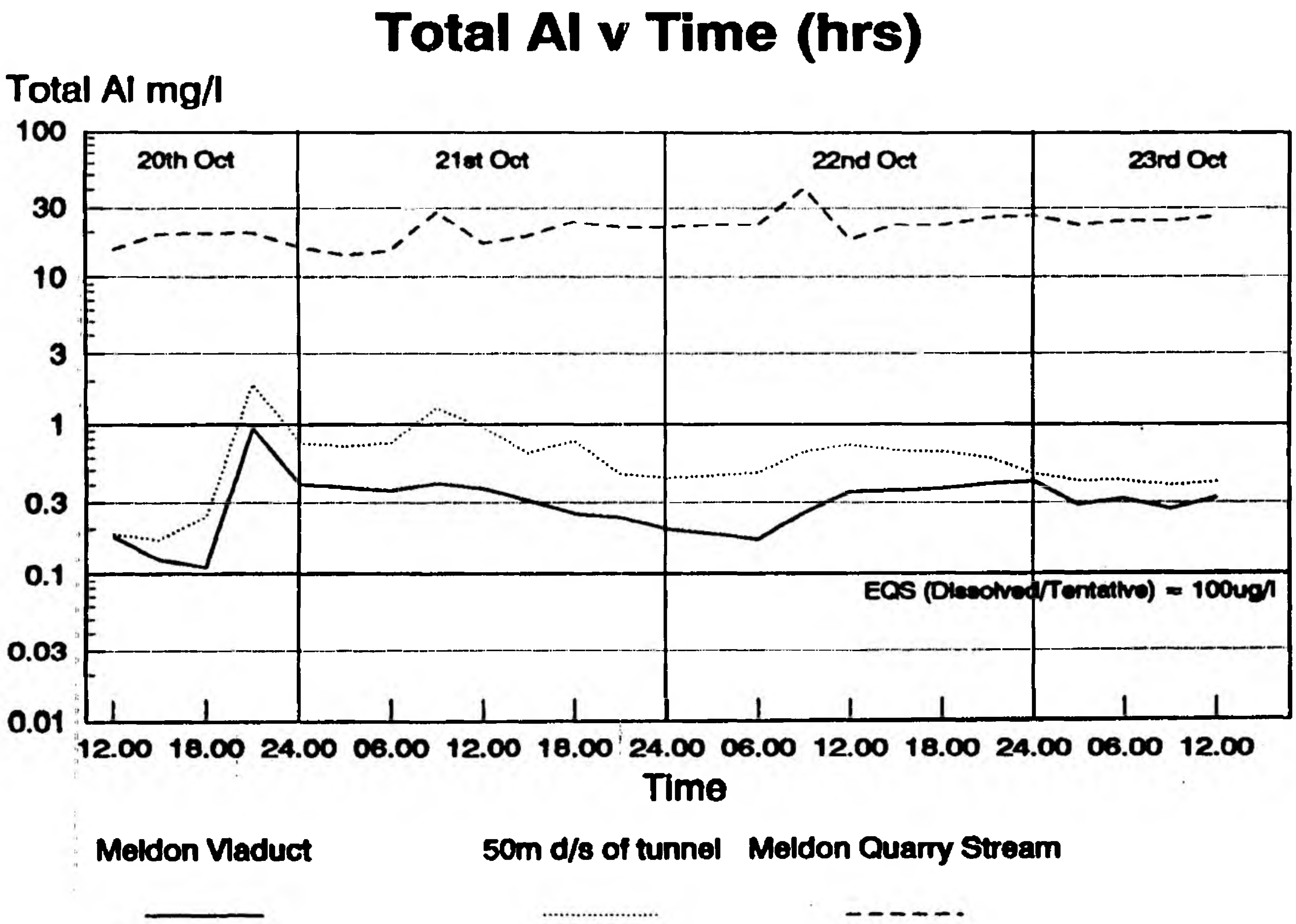
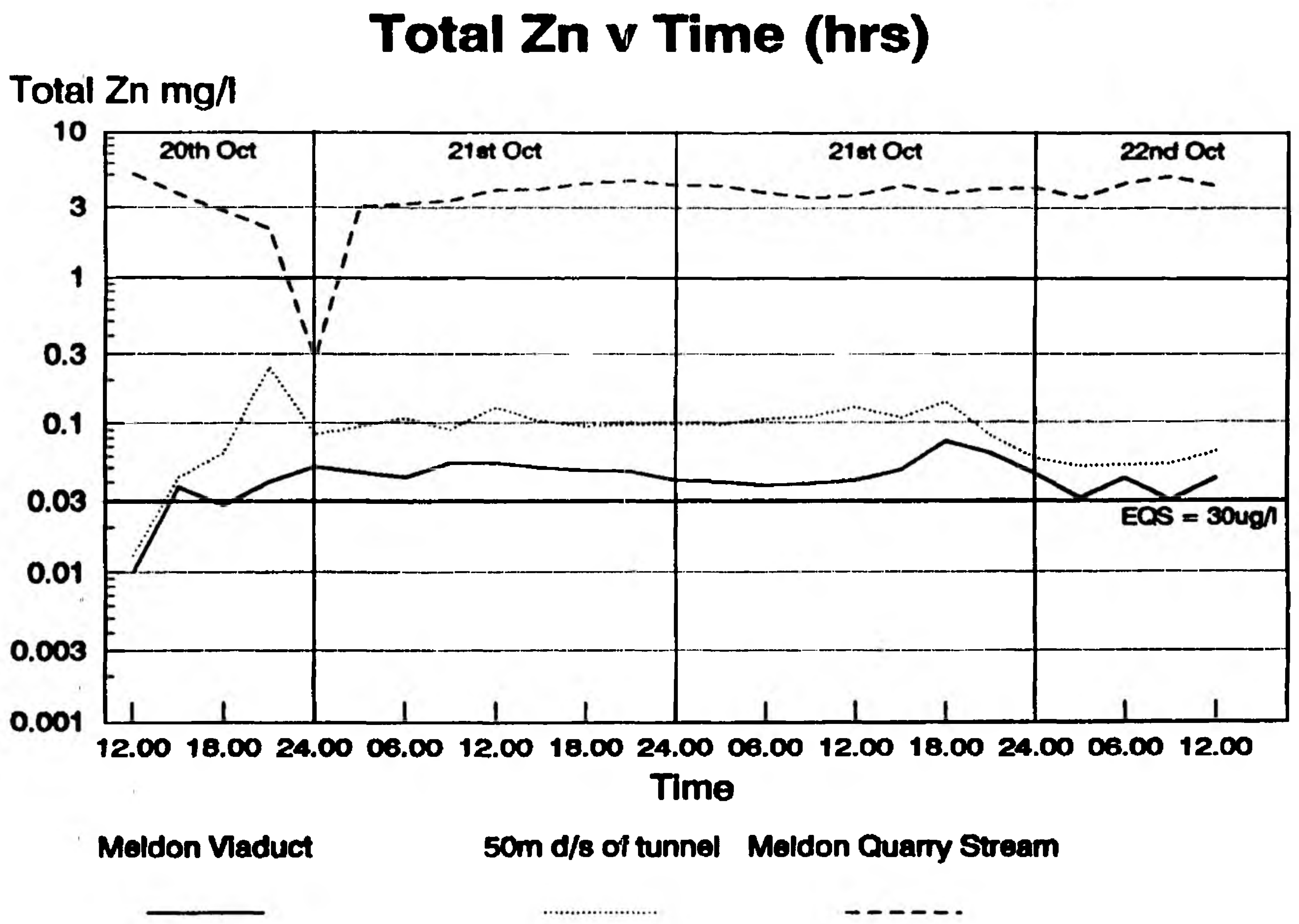

pH v Time (hrs)
pH
10
9
8
7
6
5
4
3
20th Oct
21st Oct
22nd Oct
23rd Oct
EQS = 9pH
EQS = 6pH
12.00 18.00 24.00 06.00 12.00 18.00 24.00 06.00 12.00 18.00 24.00 06.00 12.00
Time
Meldon Viaduct
50m d/s of tunnel
Meldon Quarry Stream

FIG. 4



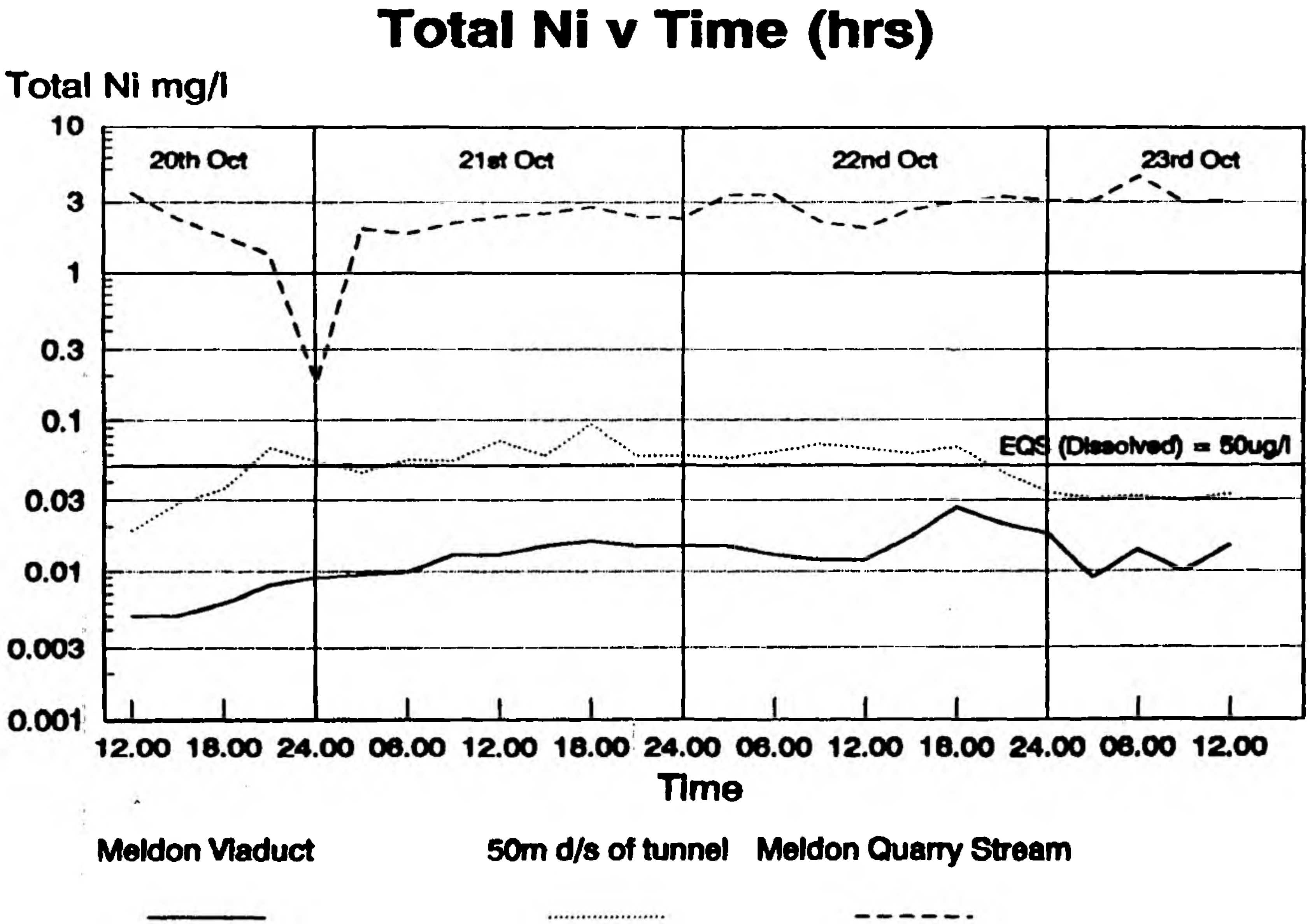
Total Al v Time (hrs)
Total Al mg/l
100
30
10
3
1
0.3
0.1
0.03
0.01
20th Oct
21st Oct
22nd Oct
23rd Oct
EQS (Dissolved/Tentative) = 100ug/l
12.00 18.00 24.00 06.00 12.00 18.00 24.00 06.00 12.00 18.00 24.00 06.00 12.00
Time
Meldon Viaduct
50m d/s of tunnel
Meldon Quarry Stream

FIG. 5



Total Zn v Time (hrs)
Total Zn mg/l
10
3
1
0.3
0.1
0.03
0.01
0.003
0.001
20th Oct
21st Oct
21st Oct
22nd Oct
EQS = 30ug/l
12.00 18.00 24.00 06.00 12.00 18.00 24.00 06.00 12.00 18.00 24.00 06.00 12.00
Time
Meldon Viaduct
50m d/s of tunnel
Meldon Quarry Stream

FIG. 6



Total Ni v Time (hrs)
Total Ni mg/l
10
3
1
0.3
0.1
0.03
0.01
0.003
0.001
20th Oct
21st Oct
22nd Oct
23rd Oct
EQS (Dissolved) = 50ug/l
12.00 18.00 24.00 06.00 12.00 18.00 24.00 06.00 12.00 18.00 24.00 06.00 12.00
Time
Meldon Viaduct
50m d/s of tunnel
Meldon Quarry Stream

FIG. 7

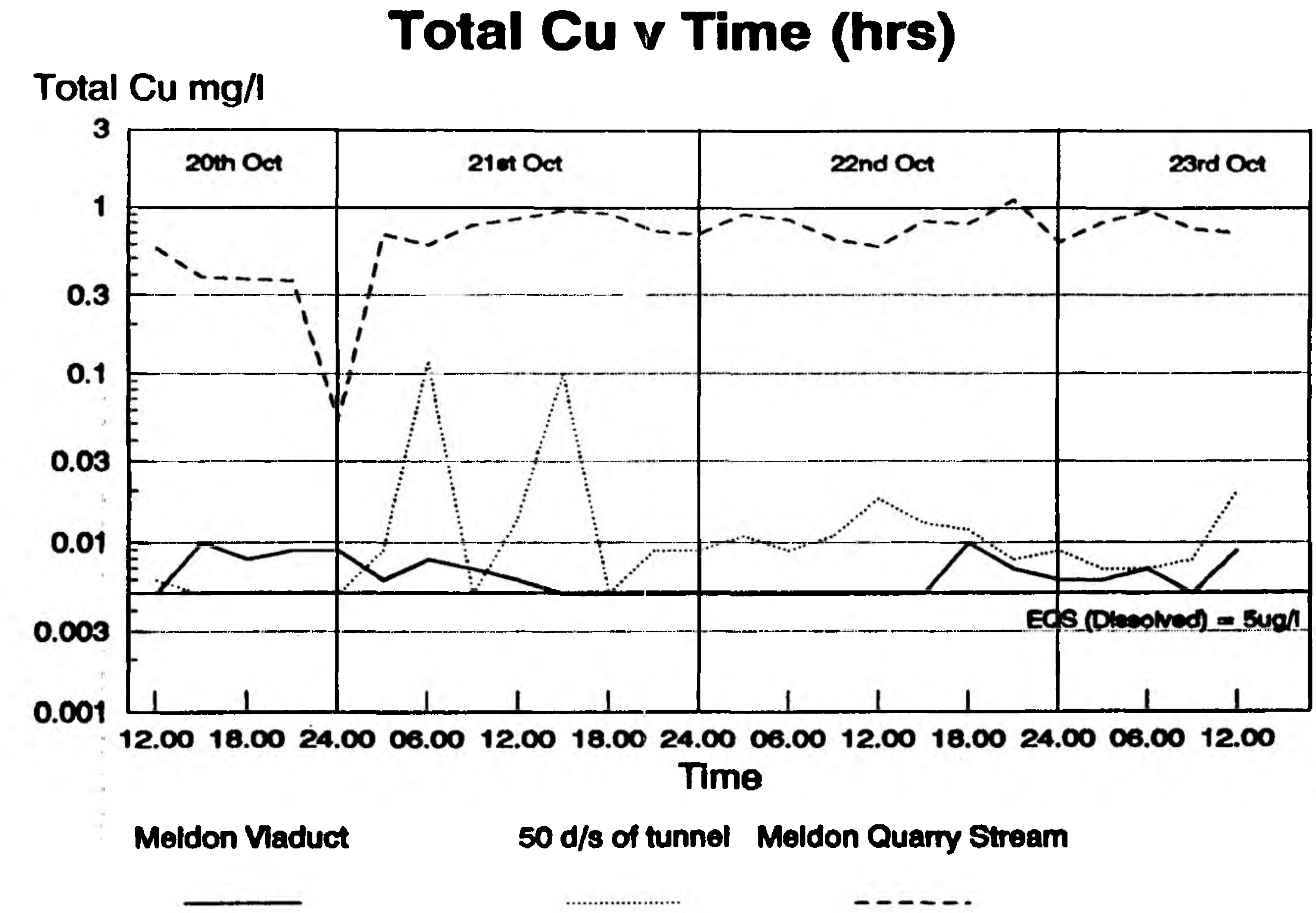

Total Cu v Time (hrs)
Total Cu mg/l
3
1
0.3
0.1
0.03
0.01
0.003
0.001
20th Oct
21st Oct
22nd Oct
23rd Oct
EQS (Dissolved) = 5ug/l
12.00 18.00 24.00 06.00 12.00 18.00 24.00 06.00 12.00 18.00 24.00 06.00 12.00
Time
Meldon Viaduct
50 d/s of tunnel
Meldon Quarry Stream

FIG. 8

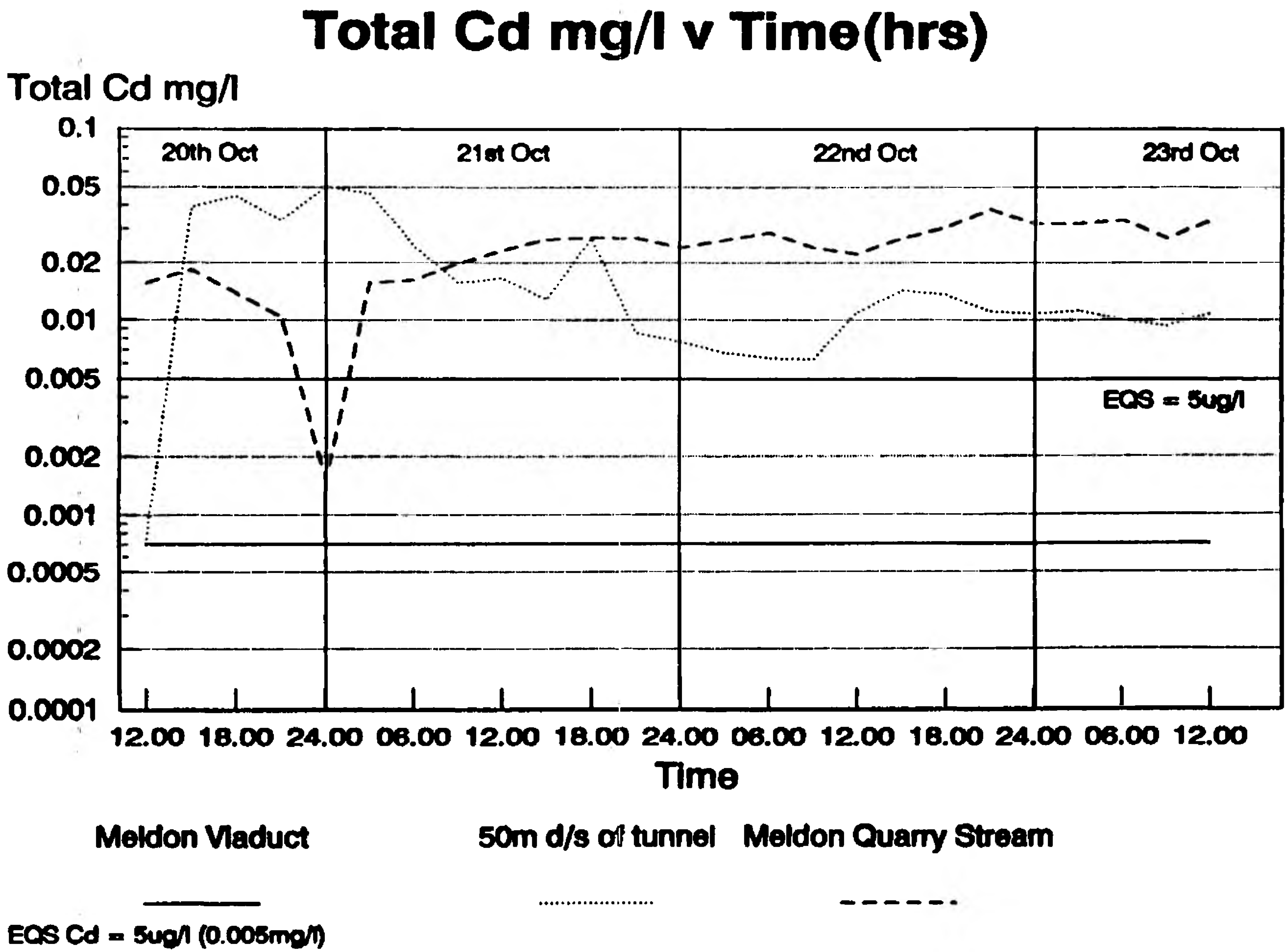

Total Cd mg/l v Time(hrs)
Total Cd mg/l
0.1
0.05
0.02
0.01
0.005
0.002
0.001
0.0005
0.0002
0.0001
20th Oct
21st Oct
22nd Oct
23rd Oct
EQS = 5ug/l
12.00 18.00 24.00 06.00 12.00 18.00 24.00 06.00 12.00 18.00 24.00 06.00 12.00
Time
Meldon Viaduct
50m d/s of tunnel
Meldon Quarry Stream
EQS Cd = 5ug/l (0.005mg/l)

TABLE 1

CHEMICAL SAMPLING POINTS

Site No.	Description	NGR
1.	W. Okement below Meldon Dam	SX 563917
2.	Red-A-Ven Brook prior to confluence with W. Okement	SX 566920
3.	W. Okement at Meldon Viaduct	SX 565924
4.	Youlditch Stream prior to confluence with W. Okement	SX 564928
5.	W. Okement 50m d/s quarry drainage tunnel	SX 565932
6.	Meldon Quarry Stream prior to road drain	SX 568928
7.	W. Okement 200m d/s Meldon Bridge	SX 566934

BIOLOGICAL SAMPLING POINTS

Site No.	Description	NGR
3.	W. Okement at Meldon Viaduct (as Chem. site 3)	SX 565924
8.	W. Okement 100m u/s Meldon Quarry drainage tunnel	SX 565928
5.	W. Okement 50m d/s quarry tunnel (as Chem. site 5)	SX 565932
9.	W. Okement 150m d/s A30 roadbridge	SX 566931

TABLE 2 Results of selected Water Quality determinands West Okement River 18 September 1989 - 29 October 1989

Site | 1 BELOW MELDON DAM WEST OKEMENT

Date/ Time	pH	Cond	105°C SS	Diss Cu mg/ℓ	Total Cu mg/l	Diss Pb mg/ℓ	Total Pb mg/ℓ	Diss Ni mg/ℓ	Total Ni mg/ℓ	Diss As mg/ℓ	Total As mg/ℓ	Total Zn mg/ℓ	Total Cd mg/ℓ	Diss Al mg/ℓ	Total Al mg/ℓ
18.09 1050	6.8	-	-	<.005	<.005	<.008	<.008	<.005	<.005	-	-	.009	<0.0007	.027	.127
20.10 1400	6.5	50	3	<.005	<.005	<.008	<.008	<.005	<.005	-	<.01	<.005	<0.0007	. 62	.191
22.10 1345	6.6	17	4	<.005	.008	<.008	<.008	<.005	<.005	-	<.01	0. 16	<0.0007	.133	.190

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Site 2 RED-A-VENN STREAM

Date/ Time	pH	Cond	105°C SS	Diss Cu mg/ℓ	Total Cu mg/l	Diss Pb mg/ℓ	Total Pb mg/ℓ	Diss Ni mg/ℓ	Total Ni mg/ℓ	Diss As mg/ℓ	Total As mg/ℓ	Total Zn mg/ℓ	Total Cd mg/ℓ	Diss Al mg/ℓ	Total Al mg/ℓ	
18.09 1100	5.8	-	-	<.005	<.005	<.008	<.008	<.005	<.005	-	-	0.12	0.0012	.161	.178	
20.10 1400	6.0	55	2	<.005	<.005	<.008	<.008	<.005	<.005	-	<.01	0.14	<0.0007	.172	.235	
22.10 1330	4.9	52	6	<.005	<.005	<.008	<.008	<.005	<.005	-	<.01	0.18	<0.0007	.313	.384	

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Site	3 MELDON VIADUCT WEST OKEMENT															
Date/ Time	pH	Cond	105°C SS	Diss Cu mg/ℓ	Total Cu mg/l	Diss Pb mg/ℓ	Total Pb mg/ℓ	Diss Ni mg/ℓ	Total Ni mg/ℓ	Diss As mg/ℓ	Total As mg/ℓ	Total Zn mg/ℓ	Total Cd mg/ℓ	Diss Al mg/ℓ	Total Al mg/ℓ	
20.10 1415	6.6	71	<5	<.005	<.005	<.008	<.008	<.005	<.005	-	<.01	.010	0.0007 0.0007	.103	.179	Sampled by PI
20.10 1500	6.5	-	-	-	.010	-	<.008	-	<.005	-	-	.037	<0.0007	-	.127	Auto Sampler
" 1800	6.6	-	-	-	.008	-	<.008	-	.006	-	-	.028	<0.0007	-	.113	"
" 2100	6.2	-	-	-	.009	-	.013	-	.008	-	-	.040	0.0007	-	.945	"
" 2359	5.2	-	-	-	.009	-	<.008	-	.009	-	-	.051	<0.0007	-	.404	"
21.10 0600	5.2	-	-	-	.006	-	<.008	-	.010	-	-	.043	<0.0007	-	.368	"
" 0900	5.1	-	-	-	.008	-	<.008	-	.013	-	-	.054	<0.0007	-	.410	"
" 1200	5.2	-	-	-	.007	-	<.008	-	.013	-	-	.054	<0.0007	-	.378	"
" 1500	5.4	-	-	-	.006	-	<.008	-	.015	-	-	.050	<0.0007	-	.314	"
" 1800	5.6	-	-	-	<.005	-	<.008	-	.016	-	-	.048	<0.0007	-	.255	"
" 2100	6.0	-	-	-	<.005	-	<.008	-	.015	-	-	.047	<0.0007	-	.239	"
" 2359	6.1	-	-	-	<.005	-	<.008	-	.015	-	-	.041	<0.0007	-	.199	"
22.10 0300	6.3	-	-	-	<.005	-	<.008	-	.015	-	-	.040	<0.0007	-	.186	"
" 0600	6.4	-	-	-	<.005	-	<.008	-	.013	-	-	.038	<0.0007	-	.171	"
" 0900	6.2	-	-	-	<.005	-	<.008	-	.012	-	-	.039	<0.0007	-	.256	"
" 1200	5.6	-	-	-	<.005	-	<.008	-	.012	-	-	.041	<0.0007	-	.359	"

Site 3 MELDON VIADUCT WEST OKEMENT (Continued)

Date/ Time	pH	Cond	105°C SS	Diss Cu mg/l	Total Cu mg/l	Diss Pb mg/l	Total Pb mg/l	Diss Ni mg/l	Total Ni mg/l	Diss As mg/l	Total As mg/l	Total Zn mg/l	Total Cd mg/l	Diss Al mg/l	Total Al mg/l	
" 1300	5.3	6+	6	<.005	<.005	<.008	<.008	.011	.011	-	<.01	.038	<0.0007	.327	.399	Sampled by PI
" 1500	5.2	-	-	-	<.005	-	<.008	-	.017	-	-	.048	<0.0007	-	.366	Auto Sampler
" 1800	5.5	-	-	-	.010	-	<.008	-	.027	-	-	.076	<0.0007	-	.379	"
" 2100	6.0	-	-	-	.007	-	<.008	-	.021	-	-	.063	<0.0007	-	.404	"
" 2359	5.8	-	-	-	.006	-	<.008	-	.018	-	-	.045	<0.0007	-	.423	"
23.10 0300	5.7	-	-	-	.006	-	<.008	-	.009	-	-	.031	<0.0007	-	.292	"
" 0600	5.8	-	-	-	.007	-	<.008	-	.014	-	-	.042	<0.0007	-	.324	"
0900	5.7	-	-	-	<.005	-	<.008	-	.010	-	-	.030	<0.0007	-	.273	"
23.10 1200	5.7	-	-	-	.009	-	<.008	-	.015	-	-	.042	<0.0007	-	.325	Auto Sampler

\LH\TABLES\MN15-1

Site | 4 YOULDITCH TRIB PRIOR TO CONLFLUENCE WITH WEST OKEMENT

Date/ Time	pH	Cond	105°C SS	Diss Cu mg/ℓ	Total Cu mg/l	Diss Pb mg/ℓ	Total Pb mg/ℓ	Diss Ni mg/ℓ	Total Ni mg/ℓ	Diss As mg/ℓ	Total As mg/ℓ	Total Zn mg/ℓ	Total Cd mg/ℓ	Diss Al mg/ℓ	Total Al mg/ℓ	
29.10 1435	6.8	159	24	<.005	.010	<.008	<.008	0.011	0.016	-	-	.131	0.0011	.060	.600	

\LH\TABLES\WW15-1

Site | 5 WEST OKEMENT 50M D/S OF MELDON QUARRY DRAINAGE TUNNEL   R29D033

Date/ Time	pH	Cond	105°C SS	Diss Cu mg/l	Total Cu mg/1	Diss Pb mg/l	Total Pb mg/l	Diss Ni mg/l	Total Ni mg/l	Diss As mg/l	Total As mg/l	Total Zn mg/l	Total Cd mg/l	Diss Al mg/l	Total Al mg/l	
20/10 1438	6.8	76	2	0.006	0.006	<.008	<0.008	0.011	0.019	-	<0.01	0.013	<0.0007	0.185	0.187	Manual Sample
20/10 1500	6.7	-	-	-	<0.005	-	<0.008	-	0.029	-	-	0.043	0.0394	-	0.172	Auto Sample
1800	6.8	-	-	-	<0.005	-	<0.008	-	0.036	-	-	0.064	0.0453	-	0.244	
2100	6.0	-	-	-	<0.05	-	<0.08	-	0.067	-	-	0.248	0.0336	-	1.91	
2359	5.4	-	-	-	<0.05	-	<0.08	-	0.054	-	-	0.085	0.0504	-	0.759	
21/10 0300	5.2	-	-	-	0.009	-	<0.008	-	0.046	-	-	0.095	0.0460	-	0.713	
0600	5.1	-	-	-	0.120	-	<0.008	-	0.056	-	-	0.109	0.0247	-	0.760	
0900	5.2	-	-	-	<0.05	-	<0.08	-	0.055	-	-	0.091	0.0158	-	1.30	
1200	5.2	-	-	-	0.014	-	<0.008	-	0.074	-	-	0.128	0.0166	-	0.955	
1500	5.5	-	-	-	0.10	-	<0.008	-	0.059	-	-	0.103	0.0129	-	0.647	
1800	5.9	-	-	-	<0.05	-	<0.08	-	0.096	-	-	0.096	0.0270	-	0.786	
2100	6.2	-	-	-	0.009	-	<0.08	-	0.059	-	-	0.098	0.0087	-	0.474	
2359	6.3	-	-	-	0.009	-	<0.08	-	0.059	-	-	0.098	0.0077	-	0.449	
22/10 0300	6.4	-	-	-	0.011	-	<0.08	-	0.057	-	-	0.098	0.0068	-	0.461	
0600	6.5	-	-	-	0.009	-	<0.08	-	0.063	-	-	0.106	0.0064	-	0.485	
0900	6.0	-	-	-	0.011	-	<0.008	-	0.071	-	-	0.111	0.0063	-	0.663	

Site 5 WEST OKEMENT 50M D/S OF MELDON QUARRY DRAINAGE TUNNEL R29D033 (Continued)

Date/ Time	pH	Cond	105°C SS	Diss Cu mg/ℓ	Total Cu mg/l	Diss Pb mg/ℓ	Total Pb mg/ℓ	Diss Ni mg/ℓ	Total Ni mg/ℓ	Diss As mg/ℓ	Total As mg/ℓ	Total Zn mg/ℓ	Total Cd mg/ℓ	Diss Al mg/ℓ	Total Al mg/ℓ	
1200	5.2	-	-	-	0.016	-	<0.008	-	0.067	-	-	0.128	0.0110	-	0.738	
1245	5.0	98	8	0.014	0.014	<0.008	<0.008	0.095	0.194	-	<0.01	0.253	<0.007	0.777	1.23	Manual Sample
1500	5.3	-	-	-	0.013	-	<0.008	-	0.061	-	-	0.108	0.0143	-	0.672	
1800	5.5	-	-	-	0.012	-	<0.008	-	0.068	-	-	0.140	0.0136	-	0.661	
2100	5.7	-	-	-	0.008	-	<0.008	-	0.046	-	-	0.082	0.0112	-	0.606	
2359	5.6	-	-	-	0.009	-	<0.008	-	0.034	-	-	0.058	0.0109	-	0.476	
23/10 0300	5.6	-	-	-	0.007	-	<0.008	-	0.031	-	-	0.051	0.0113	-	0.424	
23.10 06.00	5.7	-	-	-	0.007	-	<0.008	-	0.032	-	-	0.052	0.0101	-	0.432	
09.00	5.8	-	-	-	0.008	-	<0.08	-	0.030	-	-	0.053	0.0094	-	0.396	
12.00	5.8	-	-	-	0.020	-	<0.08	-	0.033	-	-	0.065	0.0109	-	0.417	

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Site: 6 MELDON QUARRY STREAM PRIOR TO CONFLUENCE WITH WEST OKEMENT

Date/ Time	pH	Cond	105°C SS	Diss Cu mg/l	Total Cu mg/l	Diss Pb mg/l	Total Pb mg/l	Diss Ni mg/l	Total Ni mg/l	Diss As mg/l	Total As mg/l	Total Zn mg/l	Total Cd mg/l	Diss Al mg/l	Total Al mg/l	
20.10 1444	3.9	1157	19	.372	.573	.033	.051	3.40	3.48	-	<.01	5.10	0.0157	14.2	15.3	Sampled by PI
20.10 1500	3.9	-	-	-	.388	-	<.08	-	2.29	-	-	3.72	0.0184	-	19.6	Auto Sampler
20.10 2100	4.4	-	-	-	.270	-	<.08	-	1.32	-	-	2.14	0.0104	-	20.0	"
20.10 2359	3.9	-	-	-	.052	-	<.008	-	.178	-	-	.282	0.0015	-	16.0	"
21.10 0300	3.7	-	-	-	.690	-	<.08	-	1.97	-	-	3.04	0.0158	-	14.0	"
" 0600	3.7	-	-	-	.598	-	<.08	-	1.82	-	-	3.19	0.0162	-	15.0	"
" 0900	3.7	-	-	-	.781	-	<.08	-	2.15	-	-	3.35	0.0198	-	28.0	"
" 1200	3.6	-	-	-	.852	-	<.08	-	2.40	-	-	3.97	0.0232	-	17.0	"
" 1500	3.6	-	-	-	.952	-	<.08	-	2.52	-	-	4.02	0.0265	-	19.0	"
" 1800	3.7	-	-	-	.921	-	<.08	-	2.77	-	-	4.42	0.0271	-	24.0	"
" 2100	3.7	-	-	-	.724	-	<.08	-	2.39	-	-	4.62	0.0270	-	22.0	"
" 2359	3.7	-	-	-	.659	-	<.08	-	2.32	-	-	4.33	0.0241	-	22.0	"
22.10 0300	3.8	-	-	-	.913	-	.017	-	3.40	-	-	4.33	0.0263	-	23.0	"
" 0600	3.8	-	-	-	.847	-	.030	-	3.40	-	-	3.81	0.0289	-	23.0	"
" 0900	4.0	-	-	-	.852	-	.096	-	2.19	-	-	3.55	0.0242	-	41.0	"
" 1200	3.8	-	-	-	.589	-	<.08	-	1.99	-	-	3.68	0.0223	-	18.0	"

Site	6 WELDON QUARRY STREAM PRIOR TO CONFLUENCE WITH WEST OKEMENT (Continued)															
Date/ Time	pH	Cond	105°C SS	Diss Cu mg/ℓ	Total Cu mg/l	Diss Pb mg/ℓ	Total Pb mg/ℓ	Diss Ni mg/ℓ	Total Ni mg/ℓ	Diss As mg/ℓ	Total As mg/ℓ	Total Zn mg/ℓ	Total Cd mg/ℓ	Diss Al mg/ℓ	Total Al mg/ℓ	
" 1233	3.8	979	47.0	.568	.615	.011	.015	2.01	2.66	-	6.01	4.07	0.0185	14.2	17.5	Sampled by PI
" 1500	3.7	-	-	-	.831	-	<.08	-	2.66	-	-	4.30	0.0269	-	23.0	
" 1800	3.7	-	-	-	.798	-	.022	-	2.98	-	-	3.81	0.0306	-	23.0	
" 2100	3.6	-	-	-	1.118	-	.015	-	3.30	-	-	4.09	0.0382	-	26.0	
" 2359	3.7	-	-	-	.625	-	.031	-	3.11	-	-	4.15	0.0321	-	27.0	
23.10 0300	3.7	-	-	-	.815	-	.077	-	3.07	-	-	3.53	0.0319	-	23.0	
" 0600	3.7	-	-	-	.959	-	.018	-	4.50	-	-	4.49	0.0335	-	24.6	
" 0900	3.7	-	-	-	.747	-	<.08	-	2.97	-	-	4.96	0.0272	-	24.7	
" 1200	3.8	-	-	-	.710	-	<.008	-	3.14	-	-	4.29	0.0329	-	26.5	

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Site	7 WEST OKEMENT 200M DOWNSTREAM OF MELDON QUARRY STREAM R29D030														
Date/ Time	pH	Cond	105°C SS	Diss Cu mg/l	Total Cu mg/l	Diss Pb mg/l	Total Pb mg/l	Diss Ni mg/l	Total Ni mg/l	Diss As mg/l	Total As mg/l	Total Zn mg/l	Total Cd mg/l	Diss Al mg/l	Total Al mg/l
18.09 1115	5.0	-	-	.045	.045	<.008	<.008	.161	.199	-	-	.310	0.0016	.972	2.58
20.10 1500	6.4	162	6	.017	.018	<.008	<.008	.194	.211	-	<.01	.170	<0.0007	.016	.899
22.10 1222	5.2	118	26	.018	.026	<.008	<.008	.090	.092	-	<.01	.177	0.0013	.455	1.05

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Table 3. Results of Surveys of invertebrates on the West Okement River 9 September and 20 September 1989.

	Abundance Rating							
Site	3		8		5		9	
Taxa / **Sample***	a	b	a	b	a	b	a	b
CLITELLATA								
Tubificidae								
Lumbriculidae	2	1	3		2	2	2	1
Sparganophilus ?	1		2	1				1
ACARI								
Limnoacaridae		1						
EPHEMEROPTERA								
Ephemerella ignita			1					
Baetis rhodani	2	2	3	2	3	2		
Ecdyonurus spp	2	2	3	2	1			
PLECOPTERA								
Leuctra fusca		2	3	2	3	2		1
Perlodes microcephala	2	2	2	2	2			
Dinocras cephalotes	2		1	2				
TRICHOPTERA								
Rhyacophila dorsalis	3	2	2	2	2			
Hydropsyche siltalai			2	1				
Polycentropus flavomaculatus	1	1	2	2	2	2		
Plectrocnemia geniculata		1						
COLEOPTERA								
Orectochilus villosus			1		2	1		

Abundance Rating

Taxa	Site Sample*	3 a	3 b	8 a	8 b	5 a	5 b	9 a	9 b
DIPTERA									
Dicranota sp							2		
Simuliidae				3	2				
Chironomidae		2	2	2		2			
Atherix sp (larvae)			1	2					
TOTAL NUMBER OF TAXA		9	11	15	10	9	6	1	3

* a = 8.9.1989 b = 20.9.1989

Abundance Categories

1 = 1 individuals
2 = 2-10 "
3 = 11-100 "
4 = 101-1000 "

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Table A- Water quality standards for List I substances. (See explanatory notes)

Parameter	Unit	Water quality standard						Standstill provision[a]
		Inland		Estuary		Marine		
Mercury	μg Hg/l	1	TAA	0.5	DAA	0.3	DAA	yes[b]
Cadmium	μg Cd/l	5	TAA	5	DAA	2.5	DAA	yes
Hexachlorocyclohexane	μg HCH/l	0.1	TAA	0.02	TAA	0.02	TAA	yes
Carbon tetrachloride	μg CCl_4/l	12	TAA	12	TAA	12	TAA	no
Dichlorodiphenyltrichloroethane								
(all 4 isomers, total DDT)	μg DDT/l	0.025	TAA	0.025	TAA	0.025	TAA	yes
(para, para-DDT)	μg ppDDT/l	0.01	TAA	0.01	TAA	0.01	TAA	yes
Pentachlorophenol	μg PCP/l	2	TAA	2	TAA	2	TAA	yes
Total 'drins'	μg/l	0.03	TAA	0.03	TAA	0.03	TAA	yes
Aldrin[d]	μg/l	0.01	TAA	0.01	TAA	0.01	TAA	yes
Dieldrin[d]	μg/l	0.01	TAA	0.01	TAA	0.01	TAA	yes
Endrin	μg/l	0.005	TAA	0.005	TAA	0.005	TAA	yes
Isodrin[d]	μg/l	0.005	TAA	0.005	TAA	0.005	TAA	yes
Hexachlorobenzene[e]	μg HCB/l	0.03	TAA	0.03	TAA	0.03	TAA	yes
Hexachlorobutadiene[e]	μg HCBD/l	0.1	TAA	0.1	TAA	0.1	TAA	yes
Chloroform[e]	μg $CHCl_3$/l	12	TAA	12	TAA	12	TAA	no

Explanatory notes to Table A

Substances are listed in the order of publication of directives.

Standards for the following further List I substances have been proposed but not yet agreed (see Table 15): 1,2-dichloroethane (ethylene dichloride, EDC); tetrachloroethylene (perchloroethylene, PER); trichlorobenzene (all isomers, TCB); and trichloroethylene (TRI).

Key to Symbols

D - dissolved concentration, ie usually involving filtration through a 0.45-μm membrane filter before analysis
T - total concentration (ie without filtration)
AA - standard defined as annual average

Footnotes

a Most directives include, in addition to the standards for inland, estuary and marine waters, a provision that the total concentration of the substance in question in sediments and/or shellfish and/or fish must not increase significantly with time (the "standstill" provision). For precise details of the wording see the individual directives and Appendix 1 of Reference 2.
b In addition to a standstill provision applying to sediments or shellfish there is a further environmental quality standard of 0.3 mg Hg/kg wet flesh "in a representative sample of fish flesh chosen as an indicator".
c All isomers, including lindane
d The standard relating to the concentration of this substance comes into effect on 1 January 1994.
e The provisions of the directive on this substance come into force on 1 January 1990.

Table B- Quality standards for fresh water required to support fish. (See explanatory notes)

Parameter	Unit	Waters designated under the freshwater fisheries directive[5]				Protection of freshwater life	
		Protection of salmonid fish		Protection of cyprinid fish		Protection of sensitive aquatic organisms (eg salmonid fish)[a]	Protection of other aquatic organisms (eg cyprinid fish)[a]
		G	I	G	I		
A GENERAL PHYSICO-CHEMICAL PARAMETERS							
Ammonia, total	mg N/l	0.031 T95	0.78 T95[b]	0.155 T95	0.78 T95[b]		
Ammonia, unionized	mg N/l	0.004 T95[c]	0.021 T95[c]	0.004 T95[c]	0.021 T95[c]	(d)	(d)
BOD[e]	mg O_2/l	3 T95		6 T95			
Dissolved oxygen	mg O_2/l	$\geq$9 TAA[f]	$\geq$9 TAA[g]	$\geq$8 TAA[h]	$\geq$7 TAA[i]		
pH	pH unit		6 - 9 T95[j,k]		6 - 9 T95[j,k]	6 - 9 T95	6 - 9 T95
Residual chlorine	mg Cl_2/l		0.0068 T95[l]		0.0068 T95[l]		
Suspended solids	mg/l	25 TAA[j]		25 TAA[j]			
Temperature			(m)		(n)		
B INORGANIC ANIONS							
Arsenic	mg As/l					0.05 DAA	0.05 DAA
Boron	mg B/l					2 TAA[o]	2 TAA[o]
Nitrite	mg N/l	0.003 T95		0.009 T95			
Phosphorus	mg P/l	0.065 TAA[p]		0.13 TAA[p]			
Sulphide	mg S/l					(q)	(q)

C METALS

See Table C

Table B- continued

Parameter	Unit	Waters designated under the freshwater fisheries directive[5]				Protection of freshwater life	
		Protection of salmonid fish		Protection of cyprinid fish		Protection of sensitive aquatic organisms (eg salmonid fish)	Protection of other aquatic organisms (eg cyprinid fish)
		G	I	G	I	I	I
D ORGANIC SUBSTANCES							
Hydrocarbons			(r)		(r)		
Mothproofing agents							
Cyfluthrin	μg/l					0.001 T95*	0.001 T95*
Flucofuron	μg/l					1 T95*	1 T95*
PCSDs and PADs	μg/l					0.05 T95*	0.05 T95*
Permethrin	μg/l					0.01 T95*	0.01 T95*
Sulcofuron	μg/l					25 T95*	25 T95*
Organotin compounds							
Tributyltin	μg/l					0.02 TMA°	0.02 TMA°
Triphenyltin	μg/l					0.02 TMA°	0.02 TMA°
Phenols						(t)	(t)
E LIST I SUBSTANCES							
The EQS values listed in Table 4 for inland water apply							

Explanatory notes to Table B

Most of the water quality standards in this table are defined by the European directive on the quality of fresh waters needing protection or improvement in order to support fish life[5]. These apply only to waters designated under the directive. Derogation is allowed when designated waters undergo natural enrichment, as defined in Article 11 of the directive. Additional derogations may also be allowed as indicated in the table. Other standards, shown in the last two columns, have been set in the UK for List II substances. These apply to all fresh waters supporting aquatic life. Standards for un-ionised

Explanatory notes to Table B - continued

ammonia and sulphide have been suggested in WRc Technical Reports (References 31 and 28, respectively) but have not yet been adopted in the UK and are therefore very tentative. Standards for most metals depend on the hardness of the water and these are therefore shown separately in Table 8.

Key to Symbols

G - guide value
I - imperative (mandatory) value
T - total concentration (ie without filtration)
D - dissolved concentration ie usually involving filtration through a 0.45-μm membrane filter before analysis
AA - standard defined as annual average
95 - standard defined as 95-percentile
MA - maximum allowable concentration

Footnotes

a In certain circumstances more stringent values may be appropriate locally to protect especially sensitive flora or fauna (see relevant WRc Reports, References 18 to 32).
b In particular geographic or climatic conditions, and particularly in cases of low water temperature and of reduced nitrification, or where the competent authority can prove that there are no harmful consequences for the balanced development of the fish population, a standard higher than 0.78 mg N/l may be permitted.
c This value may be exceeded for short periods during daylight hours.
d A value of 0.015 TAA has been proposed (Reference 31) but not yet agreed, and is therefore very tentative.
e Without inhibition of nitrification.
f Minimum guide value 7 mg O_2/l.
g When the concentration of dissolved oxygen falls below 6 mg O_2/l the cause is to be investigated and appropriate measures are to be taken (see Article 7(3) of Ref 5, which states that in the event of failure to comply with either a G or I value, the competent authority should establish whether this is the result of chance, a natural phenomenon or pollution, and adopt appropriate measures). The competent authority must also prove that the situation will have no harmful consequences for the balanced development of the fish population.
h Minimum guide value 5 mg O_2/l.
i When the concentration of dissolved oxygen falls below 4 mg O_2/l the cause is to be investigated and appropriate measures taken, as in Footnote g, above.
j Derogation is allowed in the event of exceptional meteorological or geographical conditions.
k An additional footnote to Annex 1 of Ref 5 states that artificial pH variations with respect to the unaffected values shall not exceed ±0.5 of a pH unit within the limits falling between 6.0 and 9.0 provided that these variations do not increase the harmfulness of other substances present in the water.

Explanatory notes to Table B - continued

l This value applies at pH 6. Higher concentrations of residual chlorine can be tolerated if the pH is higher.
m Thermal discharges must not cause a rise in temperature of more than 1.5 °C (although limited derogations may be allowed) and (except under very unusual meteorological or geographical conditions) should not raise the temperature of the water above 21.5 °C or 10 °C during the breeding periods of species which need cold water for reproduction. These standards are expressed as 98-percentiles.
n Thermal discharges must not cause a rise in temperature of more than 3 °C (although limited derogations may be allowed) and (except under very unusual meteorological or geographical conditions) should not raise the temperature of the water above 28 °C or 10 °C during the breeding periods of species which need cold water for reproduction. These standards are expressed as 98-percentiles.
o This standard comes into effect in 1990 (see Reference 2).
p Indicative value (given in the 'Observations" column of Annex 1, Ref 5). A formula giving the suggested maximum load of phosphate to a lake of average depth 18 m to 300 m is also included, viz:

$$L \leq 10 \frac{Z}{T} (1 + \sqrt{T})$$

where L is the load of phosphorus to the lake expressed as mg P per square metre of lake surface per year, Z is the mean depth of the lake in metres and T is the theoretical renewal time of the water of the lake in years.
q The following standards have been proposed for undissociated hydrogen sulphide (Reference 28) but not yet agreed, and are therefore very tentative. At water temperatures below 15 °C, 0.0005 mg S/l if the concentration of dissolved oxygen is below 5 mg O_2/l and 0.001 mg S/l at higher concentrations of dissolved oxygen. At water temperatures above 15 °C, 0.00025 mg S/l if the concentration of dissolved oxygen is below 5 mg O_2/l and 0.0005 mg S/l at higher concentrations of dissolved oxygen. These standards are for the protection of salmonid and cyprinid fish. For the protection of other forms of aquatic life, in particular freshwater crustaceans, on which the values are based, a standard of 0.002 mg S/l could be appropriate at temperatures below 15 °C, and 0.001 mg S/l above 15 °C. All of the above standards are expressed relative to the annual average of results. During any period of 24 hours the average concentration of sulphide should not exceed 10 times the annual average.
r Petroleum products must not be present in such concentrations that they form a visible film on the surface of the water, impart a detectable taste to fish flesh or produce harmful effects in fish.
s This standard comes into effect in 1992 (see Reference 2).
t Phenolic compounds must not be present in such concentrations that they adversely affect the flavour of fish

Table 0- Quality standards for metals in fresh waters required to support fish. (See explanatory notes)

Element	Unit	Protection of sensitive aquatic life eg salmonid fish Total hardness (as mg $CaCO_3$/l)						Protection of other aquatic life eg cyprinid fish Total hardness (as mg $CaCO_3$/l)					
		0 to 50	50 to 100	100 to 150	150 to 200	200 to 250	Above 250	0 to 50	50 to 100	100 to 150	150 to 200	200 to 250	Above 250
Chromium	µgCr/l	5 DAA	10 DAA	20 DAA	20 DAA	50 DAA	50 DAA	150 DAA	175 DAA	200 DAA	200 DAA	250 DAA	250 DAA
Copper[a] (DF)	µgCu/l	5 D95[b]	22 D95	40 D95	40 D95	40 D95	112 D95[c]	5 D95[b]	22 D95	40 D95	40 D95	40 D95	112 D95[c]
Copper[d] (AF)	µgCu/l	1 DAA	6 DAA	10 DAA	10 DAA	10 DAA	28 DAA	1 DAA	6 DAA	10 DAA	10 DAA	10 DAA	28 DAA
Iron[e,f]	µgFe/l	1000 DAA	1000 DAA	1000 DAA	1000 DAA	1000 DAA	1000 DAA	1000 DAA	1000 DAA	1000 DAA	1000 DAA	1000 DAA	1000 DA
Lead[j]	µgPb/l	4 DAA[h]	10 DAA[h]	10 DAA[h]	20 DAA[h]	20 DAA[h]	20 DAA[h]	50 DAA	125 DAA	125 DAA	250 DAA	250 DAA	250 DAA
Nickel	µgNi/l	50 DAA	100 DAA	150 DAA	150 DAA	200 DAA	200 DAA	50 DAA	100 DAA	150 DAA	150 DAA	200 DAA	200 DAA
Vanadium[e]	µgV/l	20 TAA	20 TAA	20 TAA	20 TAA	60 TAA	60 TAA	20 TAA	20 TAA	20 TAA	20 TAA	60 TRAA	60 TAA
Zinc[i] (DF)	µgZn/l	30 T95	200 T95	300 T95	300 T95	300 T95	300 T95[j]	300 T95	700 T95	1000 T95	1000 T95	1000 T95	1000 T95[k]
Zinc (AF)	µgZn/l	8 TAA	50 TAA	75 TAA	75 TAA	75 TAA	125 TAA	75 TAA	175 TAA	250 TAA	250 TAA	250 TAA	500 TAA

Explanatory notes to Table 8

Most of the water quality standards in this table are UK standards (Doe Circular[2]). Only for copper and zinc are standards defined in the European Freshwater Fisheries Directive[5], which however, apply only to waters designated under the directive. But it should be noted that the directive and UK standards are almost equivalent, assuming that the statistical distribution of the results is such that the 95-percentile is approximately four times the arithmetic mean. In certain circumstances more stringent values than those for the protection of salmonid fish may be appropriate locally to protect especially sensitive flora or fauna (see relevant WRc report, References 18 to 22, 24 and 29).

Water quality standards have also been proposed for inorganic tin[25] but these have not yet been adopted in the UK and are therefore very tentative. The standard proposed is 25 µgSn/l for the protection of both sensitive aquatic life (eg salmonid fish) and of other aquatic life (eg cyprinid fish) and is independent of water hardness.

Key to Symbols

T - total concentration (ie without filtration)
D - dissolved concentration ie usually involving filtration of the sample through a 0.45-µm membrane filter before analysis
AA - standard defined as annual average
95 - standard defined as 95-percentile
DF - designated fisheries: waters designated under the Freshwater Fish Directive[5]
AF - all waters required to support fish and/or other aquatic life

Footnotes

a Guide value. Derogation is allowed in the event of natural enrichment (ie the process whereby, without human intervention, a given body of water receives from the soil certain substances contained therein), see Article 11 of Reference 5.
b The presence of fish in waters containing higher concentrations of copper may indicate a predominance of dissolved organo-cupric complexes.

Explanatory notes to Table C- continued

c Between water hardnesses of 250 and 300 mgCaCO$_3$/l the water quality standard is 40 μgCu/l.
d Higher concentration of copper may be acceptable where the presence of organic matter could lead to complexation.
e These standards come into effect in 1990 (See Reference 2).
f The toxicity of iron increases as the pH decreases, and more stringent standards may be necessary below pH 6.5.
g These standards are based on the toxic effects of inorganic lead; if a significant proportion of organolead complexes is present, more stringent standards may be necessary.
h Where breeding populations of rainbow trout are present the standard given should be halved.
i Imperative value. Derogation allowed in the event of natural enrichment (as defined in Footnote a).
j Above a water hardness of 500 mgCaCO$_3$/l the water quality standard is 500 μgZn/l.
k Above a water hardness of 500 mgCaCO$_3$/l the water quality standard is 2000 μgZn/l.