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South West Region

ENVIRONMENTAL PROTECTION

AN INVESTIGATION OF THE MADFORD RIVER POLLUTION INCIDENT OF 29 JULY 1989

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AN INVESTIGATION OF THE MADFORD RIVER

POLLUTION INCIDENT OF 29 JULY 1989

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C O N F I D E N T I A L

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AN INVESTIGATION OF THE MADFORD RIVER POLLUTION INCIDENT OF 29 JULY 1989

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Fig. 1 Location of the Madford River Catchment.


River Exe
River Culm
Bolham River
Madford River
Exeter

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EXECUTIVE SUMMARY

On 29 July 1989 approximately 100,000 gallons of pig slurry were discharged from Westerhope Farm into the headwaters of the Madford River in East Devon (Figure 1). This had a significant impact on the river and in view of this and the history of pollution problems in the catchment, an environmental investigation of the Madford River sub-catchment has been undertaken.

The purpose of this report is to describe the pollution event in terms of its effect on water quality, aquatic invertebrates and fish stocks and to monitor the recovery of the river.

The pollution incident severely affected chemical water quality throughout much of the Madford River and to a lesser extent, the River Culm of which it is a tributary. The impact on the River Culm was minimised by temporarily damming the Madford River near its confluence with the Bolham River and irrigating the polluted water onto nearby fields. A fish rescue was carried out upstream of the dam and oxygen injection equipment was used in an attempt to alleviate the problem of low dissolved oxygen.

No fish mortality was detected downstream of the dam although an estimated 1500 fish were killed upstream. The effects on the aquatic invertebrate community were most significant upstream of the dam, particularly in the upper reaches.

Water quality improved quickly after the pollution event. River sediments were contaminated with copper and zinc although the levels found are not considered to pose a risk to biota. Three months after the pollution event metal levels in sediments were considerably lower.

Aquatic invertebrates in the lower reaches of the Madford River had recovered within three months of the incident but only a partial recovery was detectable in the headwaters.

Remedial measures required at Westerhope Farm to minimise the risk of further pollution have been identified.

It is recommended that :

1. The remedial measures required at Westerhope Farm are progressed as soon as practicable.

2. Further surveys are required to monitor the recovery of the Madford River.

3. Rehabilitation of salmonid habitat is required to maximise recovery by natural fish stocks.

The investigation has identified other water quality problems in the sub-catchment. These are being studied further and the findings will be the subject of a second report.

1. INTRODUCTION

The Madford River is a small tributary of the River Culm in East Devon. Its location is indicated on the map in Figure 1.

On 29 July 1989 a major pollution incident occurred in the Madford River involving the discharge of approximately 100,000 gallons of pig slurry to a headwaters tributary near Dunkeswell. Due to the major impact of the pollution incident and the history of pollution incidents in the catchment a comprehensive environmental investigation has been carried out. This report describes the incident and its effect on water quality and biota together with an assessment of recovery after three months.

The Madford River drains an area of the Blackdown Hills between Dunkeswell and Hemyock. The geology is greensand overlying Keuper Marls and land use is predominantly dairy farming on grassland. There is an industrial estate and housing development at Dunkeswell in the upper reaches of the catchment. The river is small, being about 2 metres wide at Dunkeswell and about 5 metres wide in the lower reaches. During summer 1989 drought conditions resulted in low flows. Spot gaugings were done on 2 August during a period of stable flow. At Dunkeswell Bridge the flow was 29.3 l/sec, at Madford Bridge it was 143 l/sec and at Culm Bridge it was 212 l/sec.

The Madford River has a history of pollution events, summarised in Table 1. The most serious incidents have been caused by the discharge of pig slurry from Westerhope Farm and have led to extensive fish mortalities.

2. THE POLLUTION EVENT

Early in the morning of 29 July 1989 approximately 100,000 gallons of pig slurry were discharged from the slurry store at Westerhope Pig Farm, Dunkeswell. The slurry overflowed a catch-pit into an area designed to hold such a spillage. However, a pipe within the earth bund, installed to drain rain-water from the containment area, allowed the slurry to discharge into a ditch which ultimately flows into the drainage network of Dunkeswell Aerodrome and thence to the headwaters of the Dunkeswell Stream (Figure 2, photographs 1 and 2).

As soon as the pollution was discovered, staff at Westerhope Farm closed the sluice gate on the slurry store, blocked the drain through the bund and reported the incident.

A temporary dam was constructed across the Madford River about 50 metres upstream of the Bolham River confluence so that polluted water could be contained and pumped onto adjacent fields.

A fish rescue was undertaken upstream of the dam before the polluted water arrived. These rescued fish were transferred to the River Culm at Flashford Bridge (ST 146 139). However, it was estimated that about 1500 trout, bullheads, stone loach and eels were killed during the incident. This is likely to be an under-estimate due to the inaccessibility of some reaches.

Downstream riparian users were informed of the incident and advised to make alternative arrangements for livestock watering and industrial abstraction.

At Madford Trout Farm oxygen diffusers were installed and the intake closed before the arrival of polluted water to protect fish stocks.

A tripartite formal sample was taken of the discharge at 0945 hours and one portion was served on a representative of the company concerned. River water samples were taken from a number of sites in the Rivers Madford and Culm over a period of 13 days. The locations of these sites are shown in Figures 2 (Madford) and 3 (Culm).

Oxygen injection equipment was installed at Hemyock on the River Culm on 30 July and operated for about 8 hours.

When it was clear that water quality in the Madford River had returned to an acceptable condition the pumps were removed and the dam was demolished.

3. EFFECT ON ENVIRONMENTAL QUALITY

(a) Chemistry

(i) Water

Water quality data are given in Table 2. Settled pig slurry is known to be a strong water pollutant with Biochemical Oxygen Demand (BOD) concentrations typically 5,000 mg/l and with high concentrations of ammonia, suspended solids and the metals, copper and zinc which are used as additives in pig feed. A sample of the effluent taken at 0945 hours on 29 July had a BOD of 4250 mg/l, ammonia was 2510 mg/l N, suspended solids 105oc was 1525 mg/l, total copper 5.8 mg/l and total zinc 8.6 mg/l. Samples from the drainage ditch some 400m downstream of the discharge and from the outfall from the aerodrome to the Dunkeswell Steam had a similar quality.

At Dunkeswell Bridge at 1020 hours on 29 July water quality was bad, with BOD at 1650 mg/l, ammonia at 1088 mg/l, suspended solids at 1450 mg/l and dissolved oxygen less than 1% saturation.

Further downstream at Madford Bridge water quality was good at 1035 and remained so until 1545 hours after which it deteriorated rapidly. This is shown in Figure 4. The peak of the pollution at this point occurred at approximately 1900 hours. At 2220 hours water quality was still bad although some recovery was apparent.

Immediately downstream of the dam, flow was significantly reduced by the effect of the pumps although some polluted water by-passed the dam. Over the period 2045 hours to 2145 hours water quality downstream of the dam was bad.

On the Madford River 50 metres downstream of the confluence with the Bolham River quality was poor at 2205 hours although it was better than at the dam site. Clearly the Bolham River was diluting the contaminated water.

By 30 July the polluted water which by-passed the dam had moved downstream into the River Culm. There was evidence of poor quality at Hemyock and Whitehall by 0955 hours and 0940 hours respectively but not at Culmstock or Uffculme (see Figure 3) even at 1145 hours. The leading edge of the attenuated section of polluted water must have been between Whitehall and Culmstock at 1145 hours. The worst conditions observed were 23 mg/l BOD, 19 mg/l ammonia, 36 mg/l suspended solids and 57% dissolved oxygen, considerably better than on the previous day.

By 31 July the quality of the stretch of polluted water was very much improved. Maximum observed BOD was 7.5 mg/l and for ammonia it was 6.4 mg/l. Attenuation was pronounced and the leading edge arrived at Willand between 1215 hours and 1600 hours.

On 1 August only the ammonia values at Uffculme and Higher Upton were greater than normal. There was no evidence of polluted water elsewhere.

(ii) Sediments

Samples of organic sediments were obtained at Dunkeswell, Madford and Culm Bridges on 31 July and analysed for heavy metals. Results are shown in Table 3.

Only copper and zinc levels at Dunkeswell Bridge were greater than expected.

(b) Invertebrates

Samples of aquatic macroinvertebrates were obtained from sites 1, 3, 5, 6, 7 and 8 (Figure 2) on the Madford and Bolham Rivers on 3 and 4 August. The standard 2-minute kick technique was used and samples were analysed on-site to determine the diversity and abundance of the invertebrate fauna. Biological Monitoring Working Party (BMWP) scores were calculated and are shown in Table 4 and Figure 5. Low scores are generally indicative of pollution tolerant communities and high scores indicate pollution sensitive communities living in clean water. Abundance was low throughout

the system. The most significantly affected site was at Dunkeswell Bridge which had low numbers of pollution tolerant taxa. Further downstream there was a greater proportion of pollution sensitive taxa.

(c) Fish

Fish population densities were assessed at three affected and two control sites on the Rivers Madford, Bolham and Culm between 2 and 8 August 1989.

Results are shown in Table 5.

No live fish were found at Madford Bridge, upstream of the temporary dam. At the other affected sites, five species were present at densities similar to those obtained at the two control sites. There was no detectable effect of the pollution on fish stocks downstream of the dam.

Trout fry were absent, or present in very low densities, at all these sites, which suggests that recruitment of this species is limited in this part of the river system.

4. RECOVERY OF ENVIRONMENTAL QUALITY

(a) Chemistry

(i) Water

Chemical water quality recovered rapidly once the body of polluted water had passed. Sites on the Madford River had returned to normal by 31 July, except for ammonia levels which were still slightly elevated. On 1 August, three days after the event, this situation had improved and continued to do so until significant rainfall on 9 August resulted in elevated BOD levels on the following day. In the River Culm, as the polluted water moved downstream, reduced quality was followed by total recovery within 24 hours.

(ii) Sediments

Samples were taken at sites 1, 2, 3, 5 and 6 (Figure 2) and also at an off stream pond between Dunkeswell (Site 1) and Riverside Cottage (Site 3) on 18 September 1989. Results for heavy metals are shown in Table 3.

At Dunkeswell Bridge there had been a marked reduction in copper and zinc levels although the lead concentration was higher than earlier. When compared with results from the control site levels of copper and zinc at affected sites are generally greater but the significance of these differences is unknown. The observed levels of lead are unlikely to be connected with the pollution by pig slurry and may need further investigation.

(b) Invertebrates

On 23 October 1989, approximately three months after the incident, a survey was carried out to assess the recovery of aquatic invertebrates. Samples were taken at three affected sites (1, 3 and 5, Figure 2) and two control sites (2 and 4). The taxa found are shown in Table 6. BMWP scores were calculated and are shown in Figure 5.

There had been a considerable recovery at Dunkeswell Bridge but at Riverside Cottage (site 3) a further deterioration was apparent. The control site at Rough Grey Bottom (Site 2) had an impoverished fauna restricted to pollution tolerant taxa. This implies that the cause of the reduced score at Riverside Cottage was probably due to a water quality problem in the upper reaches of the Madford River and was unlikely to be connected with the pollution incident from Westerhope Farm.

The fauna at Madford Bridge was fully recovered and had a similar composition and diversity to that of the second control site on the Abbey Stream (Site 4).

(c) Fish

There has been no assessment of the recovery of fish stocks. This would be inappropriate so soon after the pollution event. Fish stocks normally require three years or more to fully recover from an incident of this nature.

5. REMEDIAL MEASURES

Following the spillage of slurry from Westerhope Farm a joint site meeting was held between staff from Lloyd Maunder Ltd. (owners of Westerhope Farm), the Agricultural Development and Advisory Service (A.D.A.S.) and the NRA SW Region to draw up an action plan to minimise the risk of further pollution incidents from this farm.

The following improvements have been agreed (see Fig. 6):

(i) High level alarm (audio and visual) to be fitted to the slurry store catch-pit.

(ii) Outlet sluices on the above ground store to be modified so that the maximum outflow is within the capacity of the transfer pump to return it to the store.

(iii) An earth bank to be constructed around the store of suitable capacity and strength to contain the total contents of the store.

(iv). Rainwater falling within the bund to be directed to a pump sump and from there irrigated over grassland. The pump is to be manually operated with a low level automatic cut-out to switch the pump off.

(v) Clean roof and yard water to be directed to a bunded lagoon fitted with a valve to allow manual release of water if unpolluted.

(vi) The ditch running alongside the slurry store to be culverted. Should a future loss of slurry occur access to the ditch will be prevented.

(vii) The above proposals should ensure that no further slurry discharges occur. A letter has been forwarded to Lloyd Maunder Ltd., in order that a grant can be obtained from the Ministry of Agriculture Fisheries and Food for the pollution control measures being undertaken.

6. OTHER WATER QUALITY PROBLEMS IN THE CATCHMENT

There are two routine chemical monitoring points in the Madford and Bolham catchments. Both fail to comply with their River Quality Objectives. The causes of this non-compliance need to be investigated.

A number of factors have been identified as potential risks to water quality in the Madford sub-catchment. These include slurry and chemical storage, farm drainage systems, discharges from the industrial estate, sewage treatment works, housing development and the aerodrome at Dunkeswell, waste disposal systems for slurry onto land, a recent pollution in the upper reaches of the Madford River, effluent from a fish farm and the storage of domestic and industrial fuel. Some of these have been investigated; others remain to be done. The results of these investigations will be reported separately.

7. DISCUSSION

It is clear that the major impact of the pollution was in the upper reaches of the Dunkeswell Stream and the Madford River. As the effluent moved downstream it became attenuated and diluted. In the upper reaches the leading edge was travelling at about 0.5 km/hr whereas the peak concentration was slightly slower at about 0.4 km/hr. Downstream of the temporary dam the leading edge travelled more slowly, at about 0.3 km/hr. This increased to about 0.35 km/hr in the River Culm.

Whilst the rate of flow would increase with higher flows further downstream in the River Culm it is calculated that the leading edge would have taken at least sixty hours to reach the junction with the River Exe. The peak concentration and the trailing edge would have taken correspondingly longer. However, natural processes acted to reduce the impact on water quality and as a consequence there was no detectable effect on water chemistry beyond the middle reaches of the River Culm.

It is apparent that concentrations of copper and zinc in the organic sediment were higher than expected in the reaches worst affected by the pollution. Sediment of this nature may have a number of effects including the exertion of a high BOD to the detriment of invertebrates, consolidation of gravels to the detriment of spawning salmonids, and a direct toxic action by the metals. The first two effects are well understood but the latter is less well so. In other parts of the South

West river sediments contain considerably more copper and zinc and these rivers continue to maintain populations of trout. It is unlikely that the concentrations found in the Madford River have any significance for future stocks of fish.

The action of damming the river and pumping the polluted water to land had a beneficial effect downstream. Although it is clear that chemical quality was reduced downstream there were no fish mortalities reported and the densities of live fish were comparable to those in control reaches. These affected sites were also downstream of tributaries which must have diluted the effluent and minimised the effect on biota.

The use of oxygen injection equipment at Hemyock on the River Culm had no beneficial effect on water quality. Oxygen saturation was the same before and after injection. Only about 2% of the flow was extracted for oxygen addition and this was insufficient to make any impact on the whole flow.

It is quite normal for water chemistry to recover rapidly whereas invertebrates take somewhat longer, fish taking longer still. Denuded areas are recolonised by invertebrates by the processes of downstream drift, positive upstream migration and aerial immigration by reproductively active adults. Since the pollution occurred in the absolute headwaters of the Dunkeswell Stream, downstream drift, the most important factor in recolonisation, is impossible and total recovery will take longer here. Further downstream, drift will have taken place from unaffected tributaries and, as a consequence, recovery has been more rapid.

Although fish stocks will take longer to recover, the natural process is preferable to restocking. In terms of the stocks in the upper reaches of the River Culm and its tributaries, only a tiny proportion has been lost. There are many arguments against restocking with fish of non-indigenous genotype. Generally the approach of ensuring a satisfactory environment for natural restocking is the favoured option. After a pollution incident of this nature it may be necessary to take positive action to improve the quality of the habitat by actions such as trash dam clearance, gravel regrading and fish pass improvements. These are likely to be expensive and it would be sensible to recover the costs from the polluter.

8. CONCLUSIONS

(a) The pollution incident which occurred on 29 July 1989 as the result of the release of approximately 100,000 gallons of pig slurry from Westerhope Farm caused a serious deterioration in water quality in the Dunkeswell Stream and Madford River. It also caused a significant impact on the aquatic invertebrate fauna and brought about a total fish kill in about 4km of stream.

(b) The pollution control measures undertaken by NRA SW to minimise the extent of the impact of the pollution incident worked well. The effect on water quality was ameliorated to the extent that both fish stocks and aquatic invertebrate communities were not significantly affected in the lower reaches of the Madford River or the River Culm. The use of oxygen injection equipment on the River Culm was ineffective.

(c) Water quality rapidly improved after the incident and no effect was detectable on water quality ten days after the event.

(d) After the pollution event, analysis of sediments from the Madford River showed elevated levels of copper and zinc. Seven weeks after the event these values had considerably decreased indicating that these metals were being flushed out of the river system. Metal levels recorded in the sediment were not considered to be high enough to affect fish populations.

(e) Follow up surveys showed the aquatic invertebrate fauna of the lower reaches of the Madford River had recovered three months after the event. However, an effect was still detectable in the invertebrate community of the upper reaches of the Dunkeswell Stream although a partial recovery had occurred.

(f) During the investigation water quality problems were identified in the upper reaches of the Madford River which were not associated with the Westerhope Farm incident. The causes of these problems are the subject of separate investigations.

9. RECOMMENDATIONS

		Action
(a)	Recovery of sediment quality and invertebrate communities be assessed by further monitoring during 1990.	WQP
(b)	Recovery of fish stocks should be assessed during 1990.	F
(c)	Criteria for the use of oxygen injection equipment should be developed.	PI
(d)	In the upper reaches of the Madford River trash dams should be removed and gravels regraded to rehabilitate spawning habitat for salmonids.	F
(e)	Costs should be recovered from the polluter.	L
(f)	Account should be taken of information obtained in this investigation during the assessment of pollution risks for the whole sub-catchment.	WQP

WQP = Water Quality Planning F = Fisheries PI = Pollution Inspectorate
L = Legal

PHOTOGRAPH 1. Slurry Storage Tank at Westerhope Farm Showing the Fall in Level Associated with the Discharge.

PHOTOGRAPH 2. Dunkeswell Stream at Dunkeswell Bridge During the Pollution Event.

Fig. 2 Location of Sampling Sites in the Madford River Catchment.

Key to Madford River Sampling Sites.

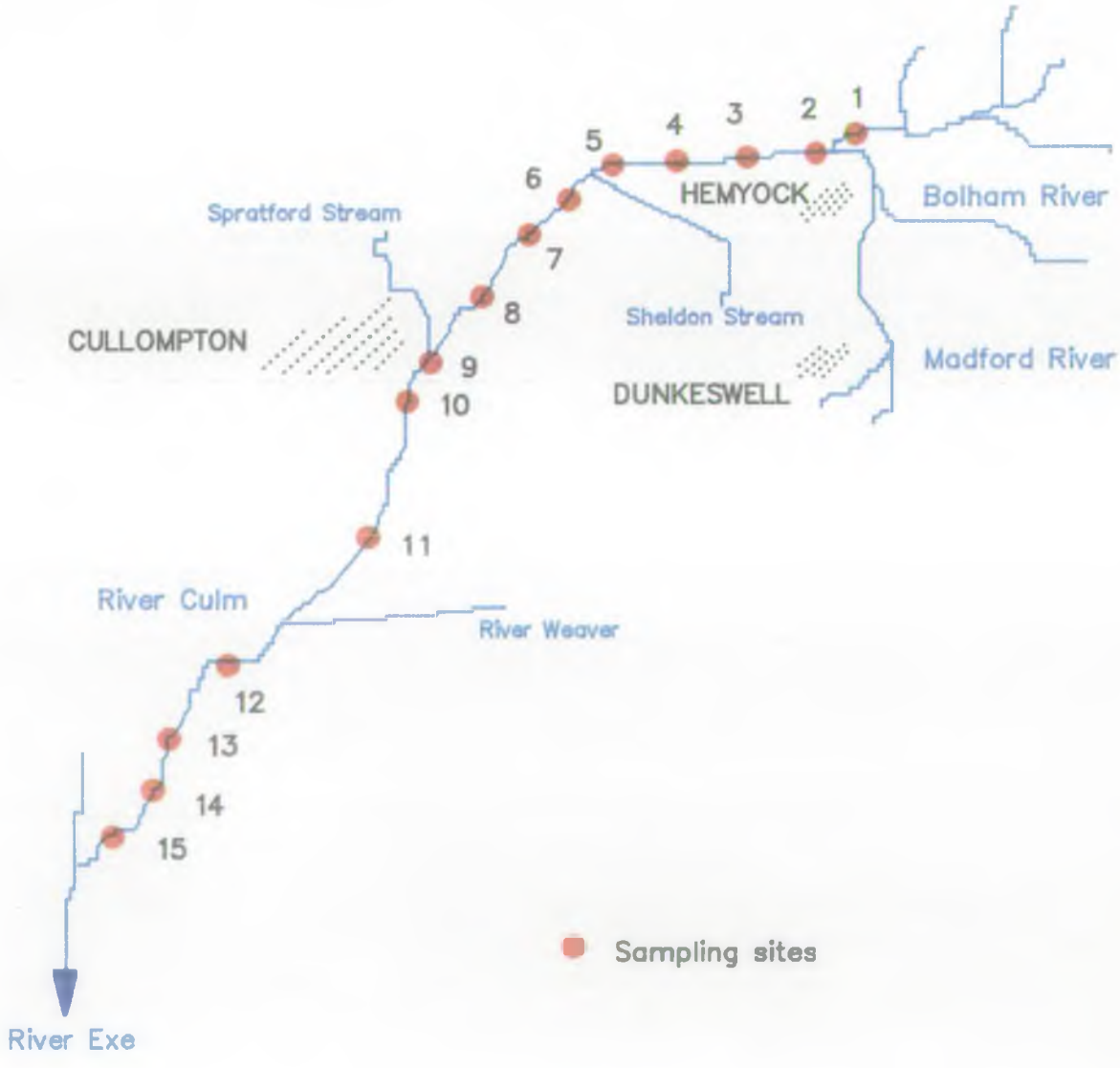
1. Dunkeswell Bridge ST 140075
2. Rough Grey Bottom ST 152073
3. Riverside Cottage ST 153087
4. Abbey Bridge ST 141106
5. Madford Bridge ST 144112
6. Upstream of temporary dam ST 149124
7. Bolham River ST 1501276
8. Downstream of confluence with Bolham River ST 149126

Routine River Quality Monitoring Points

A. Culm Bridge, Hemyock ST 144 135

B. Five Bridges ST 150 125

Fig. 3 Location of Sampling Sites in the River Culm.



Key to River Culm Sampling Sites.

1. Flashford Bridge ST 139147.
2. Hemyock ST 138139.
3. Whitehall ST 125138.
4. Culmstock ST 102137.
5. Five Fords ST 078133.
6. Uffculme ST 070126.
7. Smithincott ST 063119.
8. Willand ST 043102.
9. Cullompton ST 026077.
10. Higher Upton ST 027065.
11. Westcott ST 014043.
12. Hele SS 995024.
13. Silverton Paper Mill SS 977011.
14. Columbjohn SX 958998.
15. Stoke Canon SX 939976.

Fig. 4. Variation in ammonia, dissolved oxygen, BOD and suspended solids concentration at Madford Bridge during the pollution event on 29 July 1989.

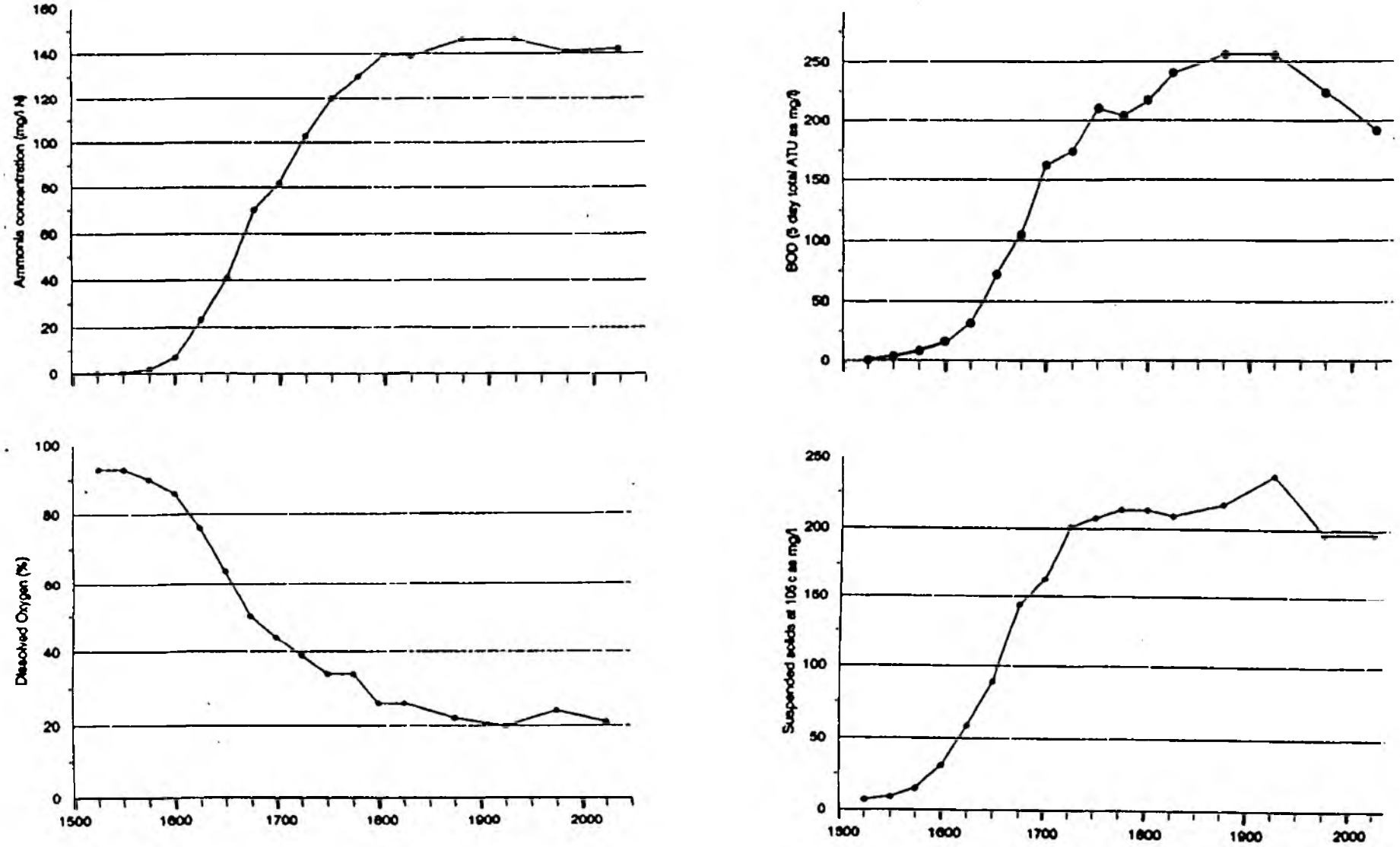


Fig. 5. Variation of BMWP Sores at 8 sites in the Madford Catchment 4 August 1989 and 23 October 1989.

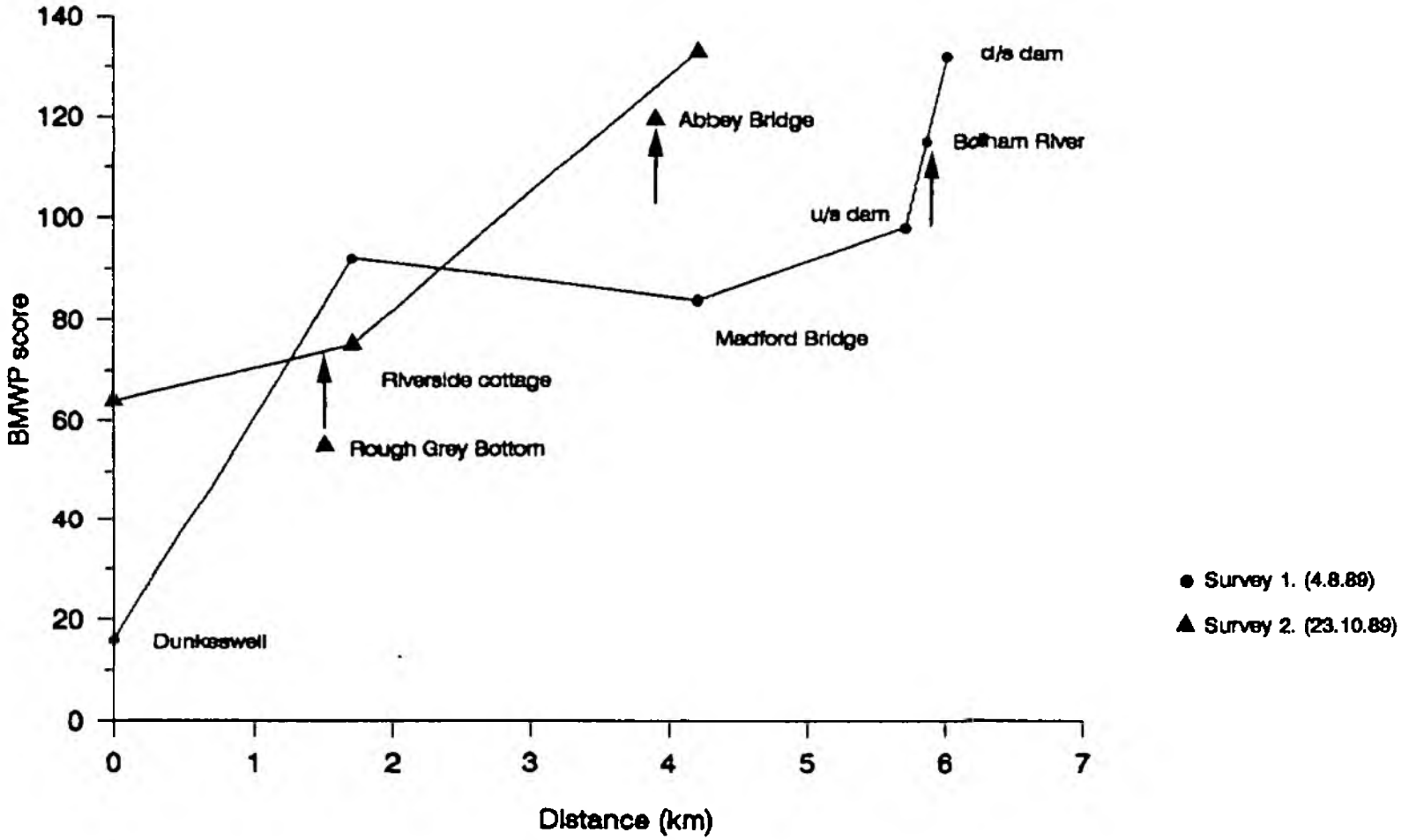


Fig. 6. Schematic diagram showing proposed modifications to Westerhope Farm

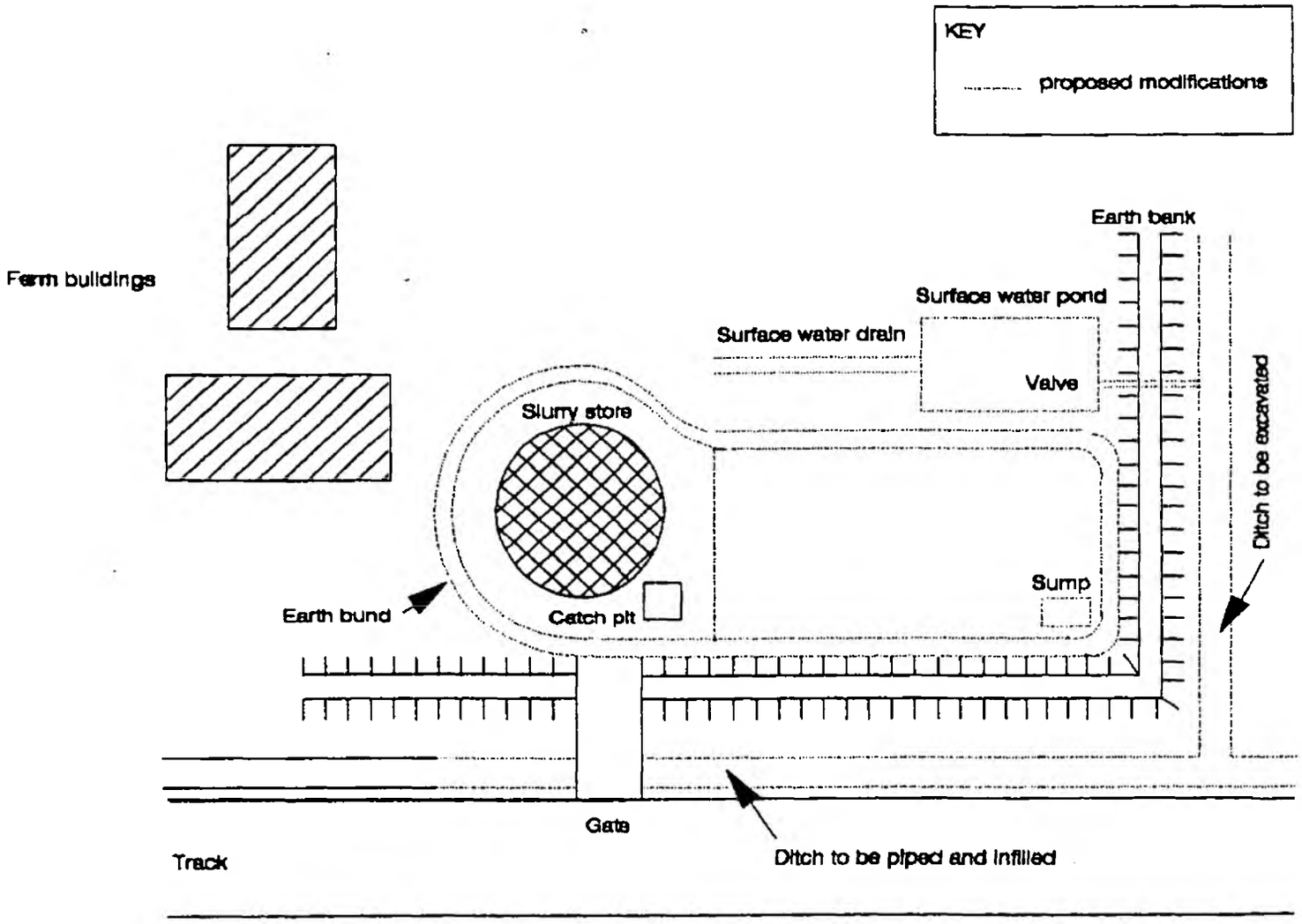


Table 1. List of Pollution Events Occurring in the Madford Catchment.

Date	Pollution Event	Origin	Action taken
29.7.89	Major discharge of pig slurry.	Westerhope Farm, Dunkeswell.	Formal samples taken, remedial actions agreed.
5.7.89	High suspended solids.	Highwood housing development.	Site visited, no environmental effect.
30.6.89	Unknown quantity of heating oil.	The Royal Oak Inn, Dunkeswell.	Tank replaced and bunded.
12.4.89	Slight field run-off of whey.	Dunkeswell Aerodrome.	Site visited, no environmental effect.
22.3.89	High suspended solids.	Highwood housing development.	Site visited, remedial actions to be arranged.
25.1.89	Run-off from slurry store.	Highwood Farm, Dunkeswell.	Temporary remedial actions permenant action to follow
23.7.87	Septic tank discharge.	Knap Cottage, Dunkeswell.	Remedial actions agreed.
1987	Field run-off of whey.	Dunkeswell Aerodrome.	Whey spreading ceased in agreed areas.
14.10.86	Yard run-off.	Connetts Farm.	Prosecuted, remedial actions agreed.
21.8.86	Discolouration of river.	Drainage works.	Site visited, no environmental effect.
3.5.83	Major discharge of slurry.	Holmwood Farm.	Prosecuted, remedial actions agreed.
9.1.83	Field run-off of pig slurry.	Westerhope Farm, Dunkeswell.	Contractors prosecuted, remedial actions agreed.
10.4.81	Major discharge of pig slurry.	Westerhope Farm, Dunkeswell.	Warning letter, remedial actions agreed.
2.4.81	Discharge of red-coloured matter.	Drum washing company.	Remedial actions agreed.

ABLE 2 RESULTS OF CHEMICAL SAMPLES TAKEN DURING THE MADFORD RIVER POLLUTION INCIDENT OF 29 JULY 1989

adford River at Dunkeswell Bridge

		pH	Biochemical Oxygen Demand (5 day) mg/l 0	Suspended Solids mg/l (105°C)	Ammonia mg/l N	Dissolved Oxygen % Saturation	Copper mg/l	Zinc mg/l
9/7/89	10.20	8.1	1650	1450	1088	<1	1.2	-
1/7/89	13.25	7.2	3.3	4	2.8	82	<0.005	0.01
/8/89	11.45	6.9	1.4	1	0.93	85	<0.005	0.009
/8/89	12.30	6.7	0.9	3	0.44	84	<0.005	0.008
0/8/89	10.00	6.8	1.8	2	0.7	80	<0.005	0.021

adford River at Madford Bridge

9/7/89	10.35	7.6	1.3	7	0.2	98	-	-
	15.15							
			SEE GRAPHS IN FIGURE 4					
	20.15							
	22.20	8.1	138	153	100	32	-	-
1/7/89	14.00	7.7	2.4	2	1.7	88	-	-
/8/89	10.45	7.6	2.5	5	0.76	50	<0.005	<0.005
0/8/89	10.20	7.3	>23	9	0.18	85		

adford River Upstream Dam

0/8/89	09.30	7.7	14	28	19.4	-	-	-

adford River Downstream Dam

9/7/89	20.45	7.8	33	61	16.0	-	-	-
	21.00	7.9	66	75	29.1	-	-	-
	21.15	7.9	84	79	43.4	-	-	-
	21.30	7.9	100	133	60.0	46	-	-
	21.45	7.9	116	115	79.1	38	-	-

Madford River 50m d/s Bolham Confluence

		pH	Biochemical Oxygen Demand (5 day) mg/l 0
29/7/89	22.05	7.8	23

Bolham River Prior to Confluence with Madford River

10/8/89	10.35	7.4	5.1

Madford River Prior to Confluence with River Culm

30/7/89	10.30	7.7	12
31/7/89	14.20	7.9	2.8
1/8/89	11.20	7.8	2.1

River Culm at Flashford Bridge (u/s Madford Confluence)

30/7/89	10.15	7.8	0.9

River Culm at Hemyock

30/7/89	9.55	7.4	17.0
	10.20	7.5	19.0
31/7/89	10.40	7.8	2.4

River Culm Upstream Vitox discharge

30/7/89	12.10	7.7	8.1

River Culm downstream Vitox discharge

30/7/89	12.00	7.7	15.0

Vitox discharge

30/7/89	11.05	-	-

Suspended Solids mg/l (105°C)	Ammonia mg/l N	Dissolved Oxygen % Saturation	Copper mg/l	Zinc mg/l
15	13.5	-	-	-
27	0.08	77	-	-
28	18.6	65	-	-
3	2.1	99	-	-
3	0.64	94	-	-
5	0.01	90	<0.005	<0.005
33	19.0	71	-	-
31	17.9	57	0.048	0.048
8	1.7	84	0.008	0.017
22	8.6	85	-	-
28	13.4	85	-	-
-	-	95	-	-

River Culm at Whitehall

		pH	Biochemical Oxygen Demand (5 day) mg/l 0
30/7/89	9.40	7.5	10.0
	11.35	7.5	23.0
31/7/89	10.55	7.9	2.1

River Culm at Culmstock

30/7/89	9.20	7.7	1.1
	11.45	8.0	1.0
31/7/89	11.03	8.0	3.2

River Culm at Five Fords

31/7/89	11.30	8.0	4.4

River Culm at Uffculme

30/7/89	09.00	7.8	1.1
31/7/89	14.00	7.9	6.3
1/8/89	11.55	7.9	2.2

River Culm at Smithincott

31/7/89	11.55	8.0	7.5
	15.45	8.0	4.8

River Culm at Willand

31/7/89	12.15	8.1	1.9
	16.00	8.1	4.9

River Culm at Cullompton

31/7/89	12.45	8.2	1.8
	16.40	8.3	2.2

Suspended Solids mg/l (105°C)	Ammonia mg/l N	Dissolved Oxygen % Saturation	Copper mg/l	Zinc mg/l
26	8.7	73	-	-
36	18.3	-	0.05	0.052
4	1.6	93	0.006	0.008
5	0.01	80	-	-
6	0.01	-	0.046	0.048
7	3.5	97	0.006	0.008
7	5.2	92	0.009	0.007
5	0.02	81	-	-
9	6.4	91	0.011	0.009
1	0.72	98	<0.005	<0.005
13	6.2	90	0.01	0.01
6	52.0	93	0.008	0.006
5	0.03	98	<0.005	0.008
26	1.00	93	0.008	0.021
3.0	0.03	110	<0.005	<0.005
1.0	0.03	107	<0.005	<0.005

River Culm at Higher Upton

		pH	Biochemical Oxygen Demand (5 day) mg/l 0
1/8/89	12.25	7.9	3.0

River Culm at Westcott

31/7/89	13.05	8.1	2.1
	16.55	8.2	2.4
1/8/89	10.05	7.8	2.8

River Culm at Hele

1/8	10.20	7.9	2.5

River Culm at Silverton Paper Mills

31/7/89	17.35	8.0	3.5
1/8/89	10.45	7.9	3.2

River Culm at Culmjohn

1/8/89	11.10	7.9	2.9

River Culm at Stoke Canon

1/8/89	11.30	8.0	2.8

\HSH\REPS\MRNN1-12

Suspended Solids mg/l (105°C)	Ammonia mg/l N	Dissolved Oxygen % Saturation	Copper mg/l	Zinc mg/l
4.0	1.86	79	<0.005	0.006
2.0	0.02	95	<0.005	<0.005
3.0	0.01	104	<0.005	<0.005
4.0	0.46	75	<0.005	0.006
5.0	0.03	84	<0.005	0.05
9.0	0.04	93	<0.005	<0.01
4.0	0.24	76	<0.005	0.006
2.0	0.05	84	<0.005	0.006
3.0	0.01	97	<0.005	<0.005

Table 3
Total Metals in Sediments, mg/kg dry weight, 31 July and 18 September

Total Metals in Sediments, mg/kg dry weight, 31 July

	Cu	Zn	Cd	Pb	Ni
Dunkeswell Br	253.0	402	1.1	50.5	31.5
Madford Br	42.2	125	0.8	16.6	22.5
Culm Br	26.5	139	-	18.0	22.9

Total Metals in Sediments, mg/kg dry weight, 18 September

Affected Sites	Cu	Zn	Cd	Pb	Cr	Ni
Dunkeswell Bridge	50.8	248	2.1	114	35.9	64.4
Off Stream Pond	53.2	290	2.1	115	29.7	50.3
Riverside Cottage	78.5	262	3.1	34.6	34.0	78.9
Madford Bridge	57.3	194	1.5	29.1	24.1	48.1
u/s Dam Site	29.7	139	1.2	28.1	24.5	39.1
Control Site						
Rough Grey Bottom	20.6	148	1.4	24.6	35.0	57.8

Table 4 Aquatic Invertebrate Taxa obtained from a survey of the Madford River on 4 August 1989 following the pollution incident

TAXA	LINKESWELL BRIDGE (SITE 1)	RIVERSIDE COTTAGE (SITE 3)	MADFORD ROAD BRIDGE (SITE 5)	MADFORD UPSTREAM OF TEMPORARY DAM (SITE 6)	BOLHAM RIVER (SITE 7)	DOWNSTREAM OF CONFLUENCE WITH BOLHAM RIVER (SITE 8)
HEXAPODA (INSECTA)						
EPHEMEROPTERA						
HEPTAGENIDAE		R	R	R	O/C	C
EPHEMERIDAE			O	R		
EPHEMERELLIDAE		O	O/C	C	C	O/C
CAENIDAE						
BAETIDAE		R	O	O	C	C
LEPTOPHLEBIIDAE						
PLECOPTERA						
LEUCTRIDAE		R	O		O/C	C
PERLODIDAE					R	
NEMOURIDAE						
TRICHOPTERA						
RHYACOPHILIDAE		O	O	O	O/C	O
LIMNEPHILIDAE		O				
HYDROPSYCHIDAE						
POLYCENTROPIDAE					R	
ODONTOCERIDAE			O	R		
SERICOSTOMATIDAE		R		R	R	R
GOERIDAE					R	O
DIPTERA						
TIPULIDAE		R		R	O	
SIMULIIDAE		O	O	O/A	C	C
CHIRONOMIDAE	R	O	O	C	O	C
MUSCIDAE						
COLEOPTERA						
DYTISCIDAE	R	R		R		R
HYDROPHILIDAE		R	R	O	O	R
ELMIDAE	O	O/C	C	C	C	C
GYRINIDAE						
CRUSTACEA						
AMPHIPODA						
GAMMARIDAE				R	C	C
ISOPODA						
ASELLIDAE						
CLADOCERA						
CHELICERATA						
HYDRACARINA						
MOLLUSCA						
GASTROPODA						
ANCYLIDAE					O	O
LYMNAEIDAE						O
HYDROBIIDAE	O				R	O
SPHAERIIDAE		R				

TAXA	DUNKESWELL BRIDGE (SITE 1)	RIVERSIDE COTTAGE (SITE 3)	MADFORD ROAD BRIDGE (SITE 5)	MADFORD UPSTREAM OF TEMPORARY DAM (SITE 6)	BOLHAM RIVER (SITE 7)	DOWNSTREAM OF CONFLUENCE WITH BOLHAM RIVER (SITE 8)
ANNELIDA						
OLIGOCHAETA	R	R	R	R	O	R
HIRUDINEA						
ERPOBDELLIDAE				R	R	R
PISCICOLIDAE						R
GLOSSIPHONIIDAE		R			R/O	R
NEMATOMORPHA						
NEMATODA						
PLATYHELMINTHES						
TURBELLARIA						
PLANARIIDAE					R	
NUMBER OF TAXA	5	16	13	16	22	21
BMWP SCORE	16	92	84	98	132	117
AVERAGE SCORE PER TAXON	3.2	5.75	6.5	6.1	6	6
SUBSTRATE (%):						
BOULDERS (>256 mm)	50	45	30	20	35	50
COBBLES (64-256 mm)						
PEBBLES/GRAVEL (2-64 mm)	40	50	65	75	60	45
SAND		5	5	5	5	5
SILT	10					
CLAY						
WIDTH (m)	1.75	2.3	2.2	3	5.5	1.5
DEPTH (m):						
1/4 WIDTH	8	20	18	15	15	14
1/2 WIDTH	8	20	18	15	15	14
3/4 WIDTH	8	20	18	15	15	14
FLOW (m/s)	30	71	83	63	100	105
TURBIDITY						
COLOUR						
MACROPHYTE COVER (%)						

Table 5 Fish Densities, Numbers/100m2

	TO+	T⩾1+	L	B	M	E
Affected Sites						
1. R Madford, Madford Br	0	0	0	0	0	0
2. R Madford, Culm Br	0	⩾5.7	⩾0.3	31.2	⩾3.9	⩾1.8
3. R Culm, Hemyock	0	6.1	6.6	78.3	9.5	2.6
Control Sites						
4. R Bolham, Hartsmoor	0	⩾15.2	0	37.7	0	⩾0.7
5. R Culm, Palmers Farm	⩾0.6	9.0	11.2	43.7	⩾5.3	⩾2.8

TO+ = Trout less than one year old
T⩾1+ = Trout greater than one year old
L = Stone loach
B = Bullhead
M = Minnow
E = Eel

Table 6. Family List of Aquatic Invertebrate Survey of the Madford River and Tributaries 23 October 1989.

R = Rare, O = Occasional, C = Common, A = Abundant, VA = Very Abundant.

TAXA	DUNKESWELL BRIDGE (SITE 1)	RIVERSIDE COTTAGE (SITE 3)	MADFORD BRIDGE (SITE 5)	ROUGH GREY BOTTOM (SITE 2)	ABBEY BRIDGE (SITE 4)
HEXAPODA(INSECTA)					
EPHEMEROPTERA					
HEPTAGENIDAE			C		VA
EPHEMERIDAE			R		R
EPHEMERELLIDAE			R		
CAENIDAE			R		
BAETIDAE	VA	C	VA		C
LEPTOPHLEBIIDAE		O			O
PLECOPTERA					
LEUCTRIDAE		C	O	R	R
PERLODIDAE		R	R		R
NEMOURIDAE	R	R	R		R
TRICHOPTERA					
RHYACOPHILIDAE	C		O		O
LIMNEPHILIDAE	R	R	R	O	R
HYDROPSYCHIDAE			C	O	
POLYCENTROPIDAE	R				
DIPTERA					
TIPULIDAE	R	A	A		O
SIMULIIDAE	C	C	C	O	C
CHIRONOMIDAE	VA	C	R	C	C
MUSCIDAE	R				
COLEOPTERA					
DYTISCIDAE			C	R	O
HYDROPHILIDAE			R		
ELMIDAE	O	O	A		C
GYRINIDAE					R
CRUSTACEA					
AMPHIPODA					
GAMMARIDAE	O	C	O	C	C
ISOPODA					
ASELLIDAE			O		
CLADOCERA		R			
CHELIICERATA					
HYDRACARINA		C			
MOLLUSCA					
GASTROPODA					
ANCYLIDAE			R	O	R
LYMNAEIDAE			R		
HYDROBIIDAE	O				R
ANNELIDA					
OLIGOCHEATA	C	C	A	C	O

TAXA	DUNKESWELL BRIDGE (SITE 1)	RIVERSIDE COTTAGE (SITE 3)	MADFORD BRIDGE (SITE 5)	ROUGH GREY BOTTOM (SITE 2)	ABBEY BRIDGE (SITE 4)
HIRUDINEA					
ERPOBDELLIDAE		R		R	
PISICOLIDAE				R	
PLATYHELMINTHES					
TURBELLARIA					
PLANARIIDAE	R				R
NUMBER OF BMWP SCORING TAXA	13	13	22	11	20
BMWP SCORE	64	75	133	54	123
AVERAGE SCORE PER TAXON	4.92	5.77	6.04	4.91	6.15
SUBSTRATE (%):					
BOULDERS (>256 mm)					
COBBLES (64-256 mm)	50	30	50	50	50
PEBBLES/GRAVEL (2-64 mm)	50	70	50	50	50
SAND					
SILT					
CLAY					
WIDTH (m)	1	4	3	1.2	1.3
DEPTH (m):					
1/4 WIDTH	0.1	0.1	0.32	0.11	0.1
1/2 WIDTH	0.12	0.15	0.35	0.12	0.12
3/4 WIDTH	0.12	0.1	0.32	0.15	0.07
FLOW (m/s)	0.75	0.75	>1.0	0.75	0.75
TURBIDITY	ZERO	LOW	SLIGHT	LOW	ZERO
COLOUR	CLEAR	CLEAR	BROWN	BROWN	CLEAR
MACROPHYTE COVER (%)	0	0	5	0	0