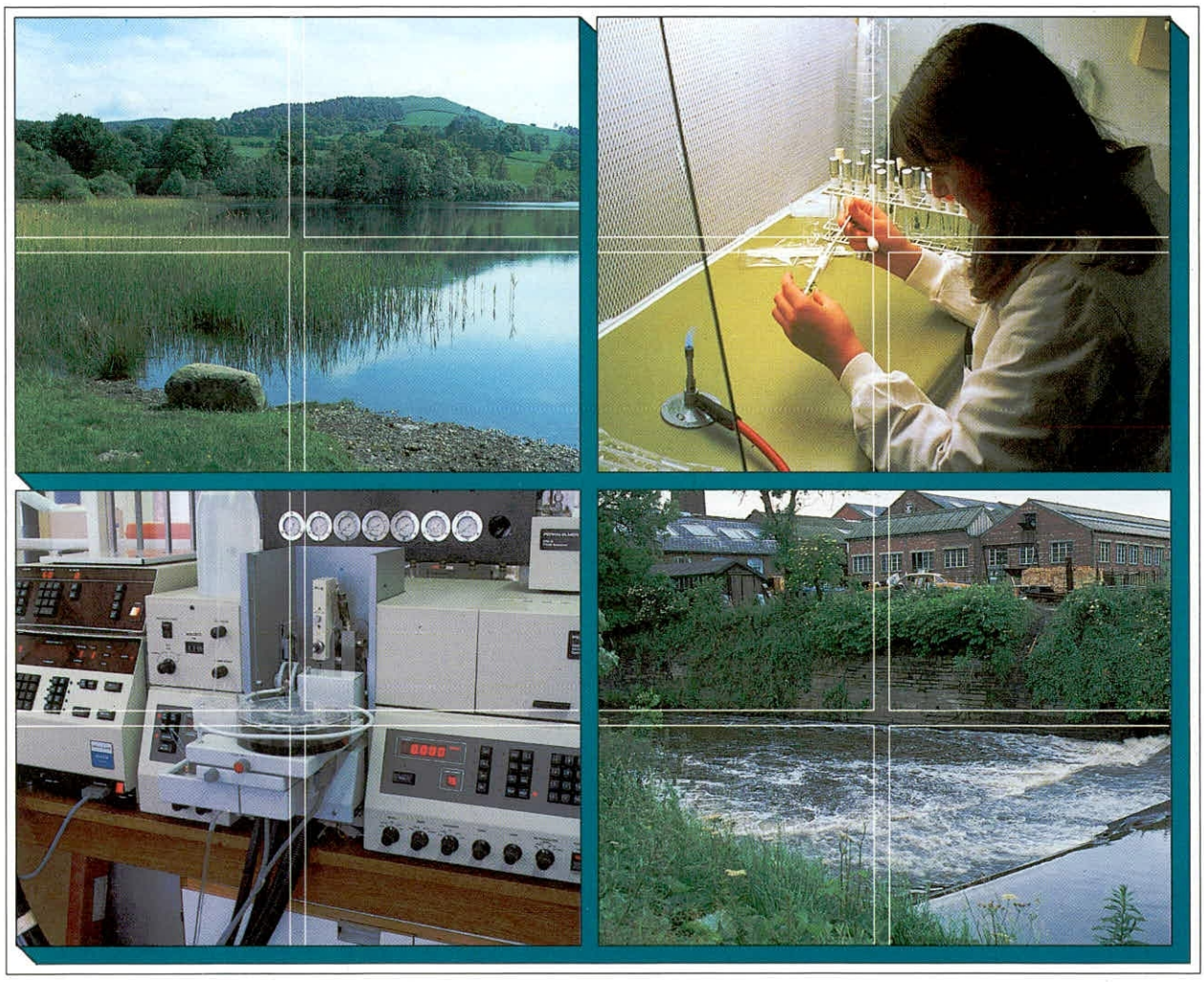
Institute of Freshwater Ecology

Purbeck-Southampton Pipeline: Final Report of Botanical, Morphological and Reinstatement Post-Construction Surveys

R.M.K. Saunders PhD FLS
F.H. Dawson PhD MIWEM CBiol FIBiol
S.M. Smith



Natural Environment Research Council

INSTITUTE OF FRESHWATER ECOLOGY
River Laboratory, East Stoke, Wareham, Dorset BH20 6BB

Tel.: 0929 462314
Fax: 0929 462180

Purbeck-Southampton Pipeline: Final Report of Botanical, Morphological and Reinstatement Post-Construction Surveys

R.M.K. Saunders PhD FLS
F.H. Dawson PhD MIWEM CBiol FIBiol
S.M. Smith

Project leader:	F.H. Dawson
Report date:	July 1992
Report to:	BP Petroleum Development Ltd
Contract no.:	CC/WYT 0015 2.8.91
IFE report ref.:	RL/T04053d1/5
TFS project no.:	T04053d1

The Institute of Freshwater Ecology is part of the Terrestrial and Freshwater Sciences Directorate of the Natural Environment Research Council.

CONTENTS

EXECUTIVE SUMMARY

This report forms a continuation of a study by the Institute of Freshwater Ecology (IFE) on the environmental impact of the construction of the Purbeck-Southampton pipeline. Pre-construction environmental surveys were conducted in 1987, and post-construction surveys in 1989. Extensive follow-up surveys of nine sites were conducted in 1990 to assess whether the artificial banks were resisting erosion, and to assess the degree of re-vegetation occurring. This report forms a continuation of these surveys, with environmental assessments of the remaining 16 stream and river crossing points.

Preliminary analysis of data indicates that the majority of the riparian zones, together with stream beds and banks, are stable and of above average standard; the stability of the banks is, however, mostly due to the use of concrete-filled bags. The combination of such bags with the near vertical slopes has resulted in poor quality re-vegetation of the bank sides and tops, where top soil has not already been lost; in addition, the steep almost vertical stream banks, which is not natural for most of these streams, further discourages re-vegetation. Further reinstatement work is suggested for the Ripley Brook, Danes Stream and Avon Water Tributary sites, either to re-stabilise the bases of most of the concrete bag walls or to replace them altogether with earth filled hessian bags now that the back-filled working trench has consolidated. Some degradation has occurred as a result of agricultural activity, especially poaching of the banks by cattle.

A visual re-assessment of five sites previously surveyed in 1990 showed acceptable levels of re-vegetation and little apparent erosion. No reinstatement work is therefore considered necessary for these sites.

Alternative bank reinstatement techniques are described for possible use in future construction work. It is recommended that these techniques be critically evaluated.

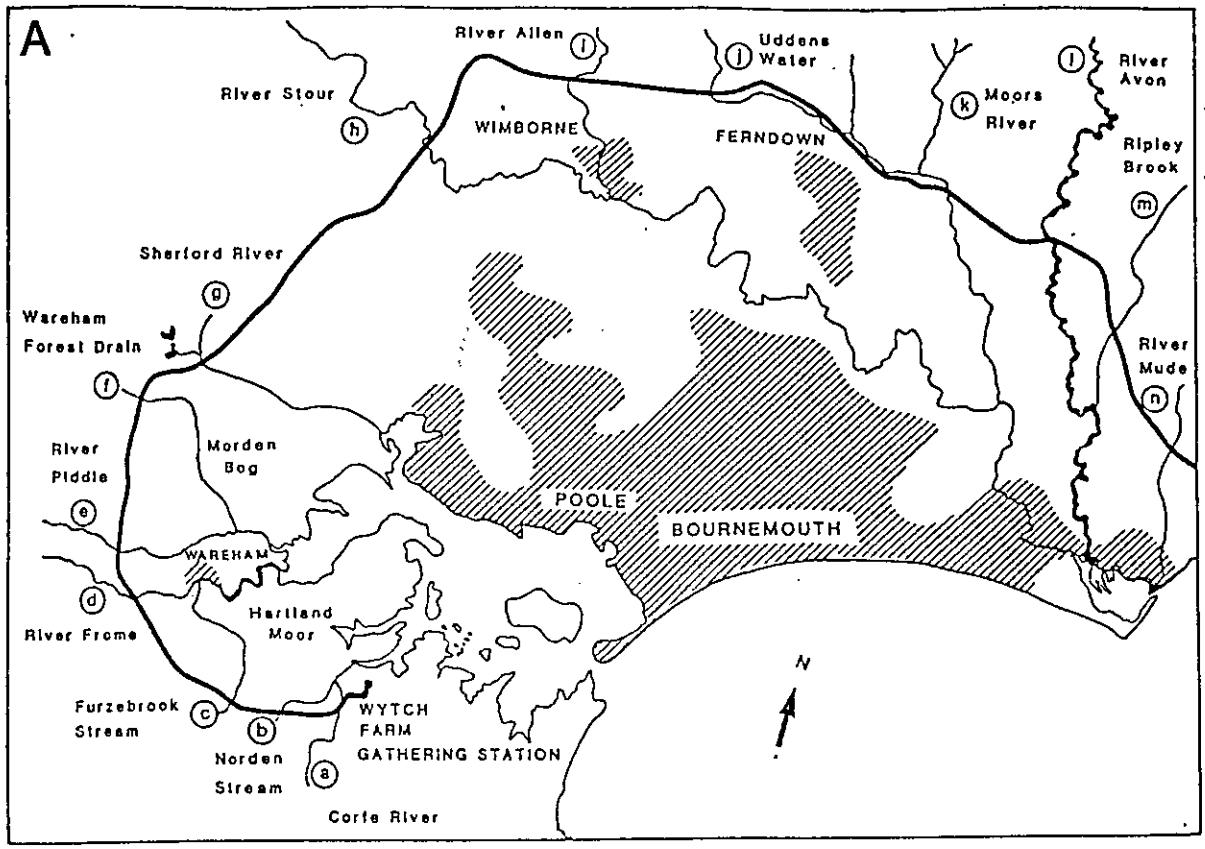
1. INTRODUCTION

The 90 km pipeline route links the Wytch Farm Gathering Station to the oil terminal at Hamble, across the Southampton Water (Figure 1). Although the route avoids the main centres of population (*e.g.* Bournemouth, Christchurch and Lymington) it does pass through, or close to, several National Nature Reserves, Sites of Special Scientific Interest (SSSI) and part of the New Forest 'perambulation'; several of the rivers and streams crossed along the route also flow into such reserves. The pipeline itself consists of six pipes running from the Wytch Farm Gathering Station to the Wareham Oilfield Development, and then four in-field flowlines to connect the well sites at Worgret, near Wareham. The main part of the export pipeline system subsequently consists of two pipes, one 16" oil pipe and one 8" gas pipe, with the latter terminating at Sopley after crossing the River Avon.

The Institute of Freshwater Ecology (IFE) has been contracted to provide guidelines for maintaining the ecological and taxonomic diversity of the sites during and after construction, and to ensure that subsequent erosion and environmental damage does not occur. This work has already resulted in the production of several unpublished reports (Dawson *et al.*, 1986a, 1986b, 1987, 1989a, 1989b; Dawson & Westlake, 1991).

A baseline survey of the sites was carried out in 1987 to assess the potential impact of construction of the buried pipelines on rivers and streams, resulting from the excavation and reinstatement of the banks and bed (Dawson *et al.*, 1987). The report concluded that few botanical problems would be expected if minor diversions of the pipeline were undertaken to avoid worthwhile bankside trees and wetland areas. Following construction of the pipeline in 1988, preliminary post-construction botanical surveys were also conducted at a selection of nine rivers and three ditch systems (Table 1; Dawson *et al.*, 1989a, 1989b). Although this work suggested that the bank and channel vegetation was recovering well, it was recommended that further survey work should be undertaken to monitor plant reinstatement and erosion. Nine sites were consequently studied in 1990 (Dawson & Westlake, 1991). The remaining 16 sites have been surveyed as part of the present report. It is hoped that this work will enable the development of guidelines for future pipeline construction work, and will suggest ways in which existing sites can be improved if necessary.

FIGURE 1. The position of selected sites on (a) the western, and (b) the eastern sections of the Purbeck-Southampton pipeline route.



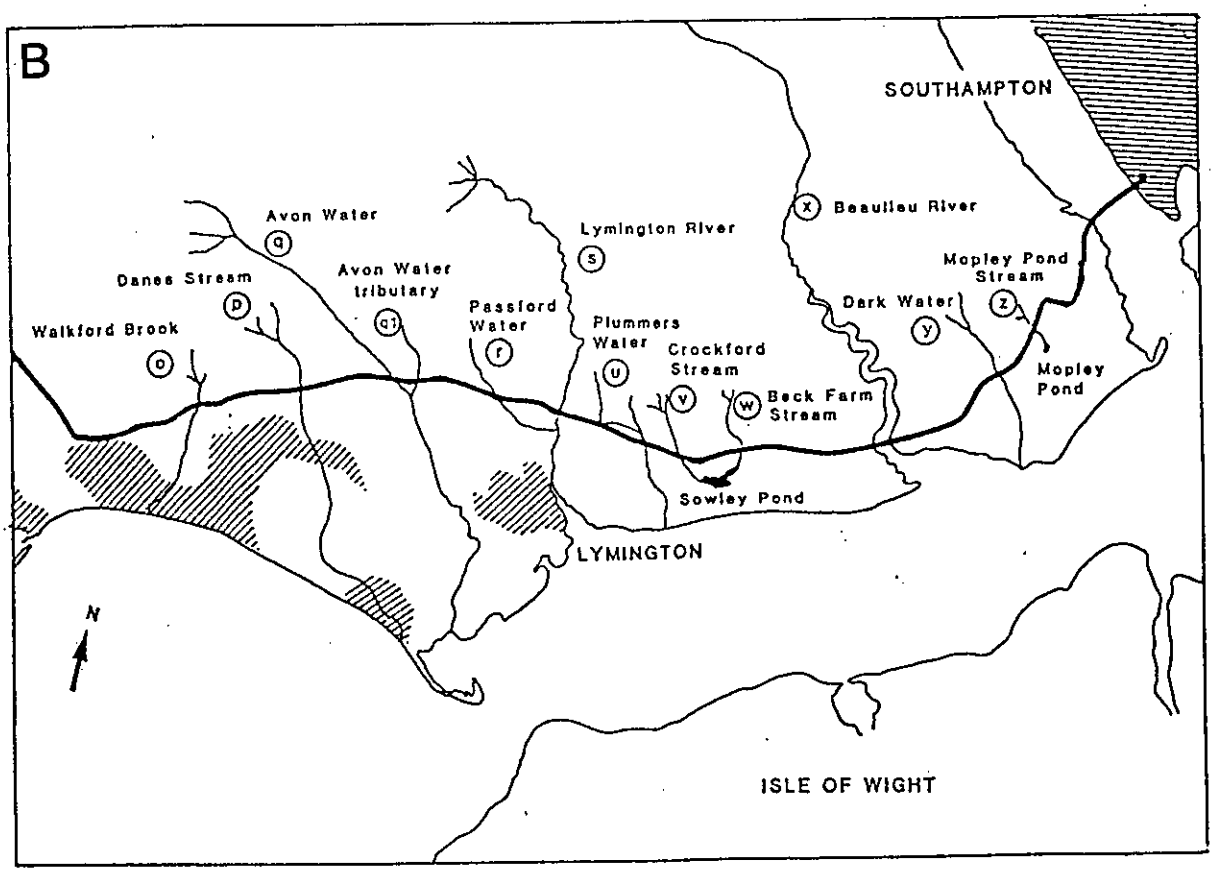


TABLE 1. List of river sites crossed by Purbeck to Southampton pipeline.

	Pre-construction survey	Post-construction survey	Current survey
A Corfe River	*	*	
B Norden Stream			*
C Furzebrook Stream			*
D River Frome	*	*	
E River Piddle			*
F Wareham Forest Drain			*
G Sherford River		*	
H River Stour	*	*	
I River Allen	*	*	
J Uddens Water			*
K Moors River	*	*	
L River Avon	*	*	
M Ripley Brook			*
N River Mude			*
O Walkford Brook			*
P Danes Stream			*
Q Avon Water	*	*	
Avon Water Tributary			*
R Passford Water			*
S Lymington River	*	*	
U Plummers Water			*
V Crockford Stream			*
W Beck Farm Stream			*
X Beaulieu River			
Y Dark Water			*
Z Mopley Pond Stream			*

2. METHODS

The following sixteen different river and stream sites were chosen for botanical and morphological analysis: Norden Stream, Furzebrook Stream, River Piddle, Wareham Forest Drain, Uddens Water, Ripley Brook, River Mude, Walkford Brook, Danes Stream, Avon Water Tributary, Passford Water, Plummers Water, Crockford Stream, Beck Farm Stream, Dark Water and Mopley Pond Stream. All these sites were initially used for reconnaissance surveys; eight of these sites were then selected as being representative of poorly re-vegetated or badly eroded sites, and were analysed in greater detail. Access to the sites was arranged by BP, who also supplied detailed site maps (scale of 1:10,000).

2.1 Reconnaissance surveys

The reconnaissance surveys included:

(i) An estimation of the physical characteristics, including: channel width and average depth at the pipeline crossing point; and water velocity (m s^{-1}), measured using a Sensa-RC2 water velocity meter (Aqua Data Services Ltd., Chippenham). This data was then used to calculate the estimated discharge of the river (Q), measured in m^3 s^{-1}, which is the product of the water velocity (V) and the cross-sectional area (A) of the river (*i.e.* Q = VA).

(ii) A classification of the substrate types of the bed, banks and adjacent land as either: bed rock, boulder, cobble, pebbles, gravel, sand, silt, clay or peat.

(iii) A water sample was also collected for subsequent laboratory analysis of the water chemistry. The characteristics investigated included: pH, conductivity (μs cm^{-1}), calcium carbonate levels (mg l^{-1}), the presence of anions and cations (mg l^{-1}), and the consequent ion balance.

(iv) A study of the adjacent features, including: land use either side of the river; land use upstream and downstream of the crossing point; the degree of maintenance of the river; and the importance of the river for fishing. The presence of features such as pipes, drains, bridges, culverts, etc. were also noted.

(v) A study of any erosion occurring, especially with respect to the artificially constructed channel banks and the effect these have on the natural banks downstream.

(vi) A list of all plant genera (and the number of species in each genus) growing in the

channel and the adjacent land area that is affected by the pipeline construction. Plant identifications were corroborated where necessary by taking specimens back to the laboratory and using standard taxonomic reference texts (*e.g.* Haslam *et al.*, 1975 and Clapham *et al.*, 1987).

(vii) Photographs were also taken across the river at the crossing point, and upstream and downstream, to show the vegetation cover.

2.2 Detailed surveys

The detailed surveys included all the above, together with the following:

(i) List of all plant species rather than genera growing at the site. Plant identifications were again corroborated by reference to Haslam *et al.* (1975) and Clapham *et al.* (1987).

(ii) A detailed map illustrating the position and degree of cover of the various plant stands. The accuracy of the maps was achieved by stretching a tape measure along the river banks. It was not necessary to map 100 m stretches at many of the sites because of their narrow width.

3. RESULTS

The occurrence of the various plant genera at each site is given in Table 2, with the number of species in each genus. A total of 96 different genera and 110 different species were identified for the sites.

The details of topography, water chemistry, and adjacent features are given separately for each site in sections 3.1 to 3.16, together with a discussion of the botanical and morphological quality of the sites. The maps given in each section are based on the 1:10,000 site maps provided by BP, and illustrate the precise positions of the pipeline crossing points.

TABLE 2. Occurrence of plant genera at the sites. Site codes refer to Table 1. Numbers indicate number of species of each genus present at site. (Continued overleaf).

Site code:	B	C	E	F	J	M	N	O	P	Q	R	U	V	W	Y	Z
Achillea		1					2						1	1		1
Agrostis	1						1		1	1	1		1	1	1	
Alisma					1		1				1			1	1	1
Alnus							1			1						
Alopecurus																1
Anagallis	1	1				1					1					
Anthriscus									1							
Apium	1	1	1			1	1		1		1	1	1	1		
Artemisia							1									
Bellis	1												1			
Betula										1						
Blechnum										1						
Callitriche	1	1	1		1		1	1			1		2	1	2	1
Calystegia															1	
Centaurium											1		1			
Circaea								1					1			
Cirsium	1	1	1		1		1	1		1		1		1	1	1
Cladophora							1					1				
Convolvulus											1	1				
Corylus	1										1			1		
Crataegus	1								1	1		1	1	1		
Cuscuta																1
Dactylis														1		
Digitalis								1			1				1	
Dipsacus														1		1
Dryopteris										1						
Elodea							1									
Epilobium	1	1	1		1	1	2		2	2	2		1	1		1
Equisetum												1				
Eupatorium														1		
Fagus										1						

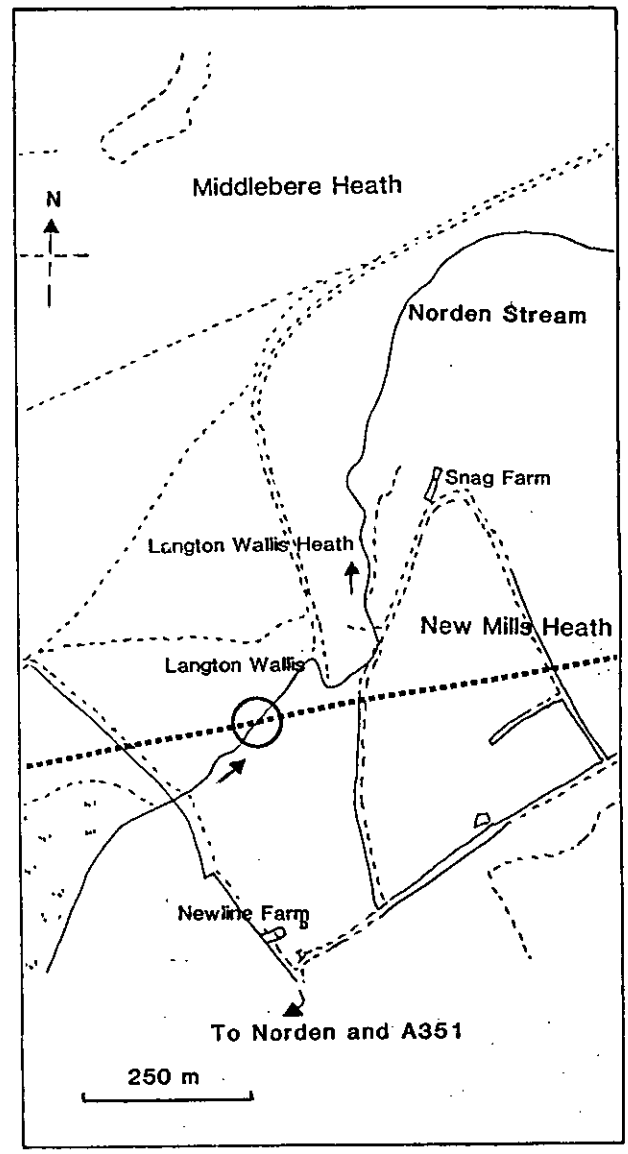
Table 2. (Continued)

Site code:	B	C	E	F	J	M	N	O	P	Q	R	U	V	W	Y	Z
Fraxinus									1	1						
Galium	1				1	1		1	1		1		1	1	2	
Geranium		1					2	1	1		1		1			
Glyceria			1					1		1						
Hedera								1	1	1			1			
Hieracium	1	1				1	1				1			1		
Hypericum	1		1					1								
Ilex	1							1		1			1			
Impatiens															1	
Iris			1												1	
Juncus	1	1	1	1	1	1	1	1		1	1				1	1
Lamium						1	1									
Lapsana								1								
Lemna			1				1									
Ligustrum										1					1	
Lotus	1					1	1				1				1	1
Lythrum															1	
Lysimachia															1	
Malva							1									
Mentha														1	1	1
Molinia										1						1
Myosotis	1		1									1	1			
Myrica																1
Nasturtium					1							1	1	1		
Nuphar			1													
Oenanthe		1	1		1	1	1	1				1	1	1	2	1
Petasites															1	1
Phalaris							1								1	
Phragmites																1
Plantago	1	1	1				1					1	1	1		1
Polygonum	1	1	1				2									
Polypodium													1			
Potamogeton											1					

Table 2. (Continued)

Site code:	B	C	E	F	J	M	N	O	P	Q	R	U	V	W	Y	Z
Potentilla		1														1
Prunella		1						1					1			
Prunus																1
Pteridium	1	1								1	1			1		
Pulicaria															1	
Quercus										1	1		1	1	1	1
Ranunculus		1	2		1	1		1	1		2	1	1		2	1
Rhododendron										1						
Rosa									1						1	
Rubus	1					1			1	1	1	1	1	1	1	1
Rumex	1				1	1	1	1	1	1	1	1	1	1	1	1
Salix	1									1	1			1	1	1
Sambucus															1	
Scrophularia		1	1			1		1					1		1	1
Scutellaria						1										
Senecio		1	1			1	1				1	1	1	1		1
Solanum							1				1			1		
Solidago																1
Sparganium			1											1		
Sphagnum																1
Stachys							1	1							1	1
Stellaria	1			1			1					1				
Symphytum			1				1									
Taraxacum	1						1									
Taxus										1						
Teucrium													1			
Trifolium	1	1	1		1	1					2	1	2			
Typha																1
Ulex	1			1						1	1			1		1
Urtica	1				1	1		1	1	1	1	1	1	1	1	1
Veronica			1				1					2			2	
Vicia								1								

3.1 NORDEN STREAM
(Nat. grid ref.: SY 952841)



Topography:
Width: 1.0 m Depth: 1.53 m
Velocity: negligible
Discharge: not applicable
Substrate: bed - pebbles, gravel, sand; banks - concrete bags (right bank with turfs); adjacent land - soil

Water Chemistry:
pH: 7.10 Conductivity: 278.0 μs cm^{-1}
Calcium carbonate: 43.0 mg l^{-1}

Anions, mg l^{-1}:	Cations, mg l^{-1}:
Alkalinity 0.9	Calcium 27.0
Chloride 40.1	Magnesium 3.6
Sulphate 27.9	Sodium 14.9
Nitrate N 0.4	Potassium 0.4

Phosphate P 0.02
Silicate Si 2.8
Ion balance: 2.57 : 2.30 m.e.l.

Adjacent features:
Land use: pasture
Upstream: pasture and copse
Downstream: pasture and copse
Fishery interest: none
Maintenance: none

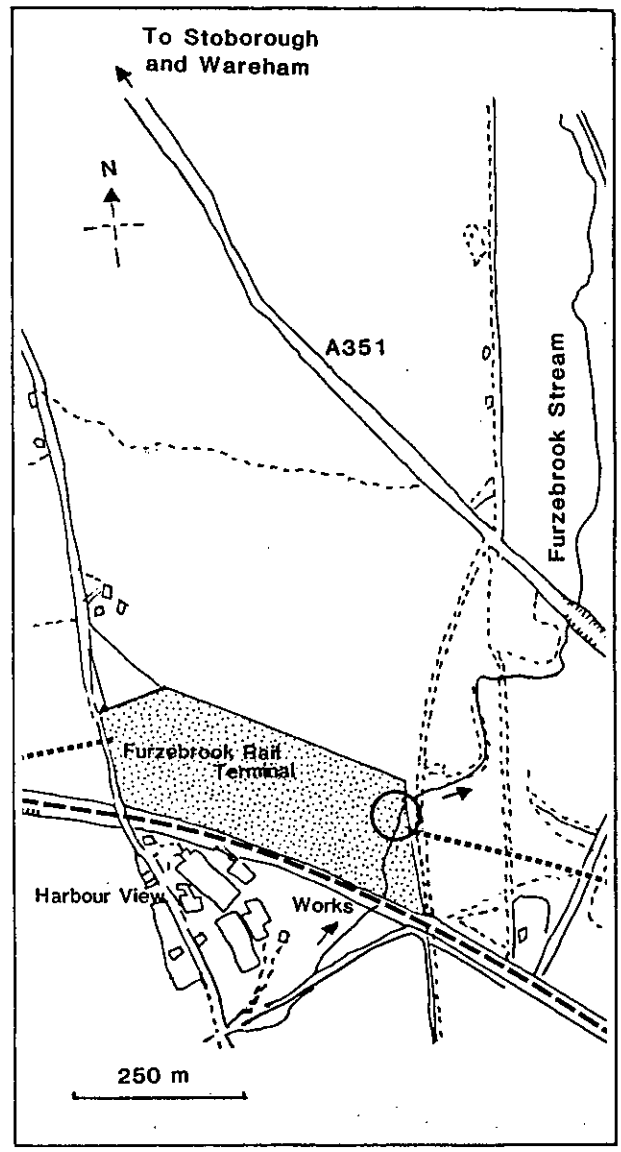
Discussion:
The Norden Stream lies in the ecologically important Middlebere Heath. Both artificial banks have been constructed from concrete bags, and have become well vegetated. The immediate bank flora consists of many ephemeral weedy plants including *Anagallis arvensis* L., *Galium palustre* L., *Hieracium* L. sp., *Lotus corniculatus* L., *Plantago major* L., *Polygonum* L. sp., *Rumex* L. sp., *Stellaria* L. sp., *Taraxacum* Weber sp., *Trifolium* L. sp., *Urtica dioica* L. and several terrestrial grasses. There are also hazel saplings (*Corylus avellana* L.), and the hawthorn (*Crataegus monogyna* Jacq.) hedgerow has been replanted above the left bank; these shrubs will be beneficial in helping to bind the soil and prevent erosion. There does not appear to be any erosion resulting from the artificial banks at this site.

The Norden Stream is shaded by alders (*Alnus glutinosa* (L.) Gaertner) and oaks (*Quercus robur* L.) both upstream and downstream of the pipeline crossing site. This heavy shading was recorded for the crossing point in a previous report (Dawson *et al.*, 1986b). Despite the

removal of the trees during construction work, the aquatic vegetation is sparse, with only small populations of *Apium nodiflorum* (L.) Lag., *Callitriche* L. sp., and *Myosotis scorpioides* L.

The construction of the pipeline does not appear to have resulted in any deleterious effects downstream such as erosion problems, sedimentation or alteration in water flow rate.

3.2 FURZEBROOK STREAM
(Nat. grid ref.: SY 934842)



Topography:
Width: 0.6 m Depth: 0.26 m
Velocity: 0.002 ms^{-1}
Discharge: 0.0003 $m^3 s^{-1}$
Substrate: bed - pebbles, gravel; banks - boulder, cobble, pebble, gravel, sand; adjacent land - not applicable

Water Chemistry:
pH: 6.87 Conductivity: 337 $\mu s\ cm^{-1}$
Calcium carbonate: 75.7 mg l^{-1}

Anions, mg l^{-1}:	Cations, mg l^{-1}:
Alkalinity 1.5	Calcium 36.4
Chloride 40.1	Magnesium 4.1
Sulphate 28.3	Sodium 22.9
Nitrate N 0.7	Potassium 1.2
Phosphate P 0.05	
Silicate Si 2.0	

Ion balance: 3.23 : 3.19 m.e.l.

Adjacent features:
Land use: LPG rail terminal
Upstream: clay works
Downstream: nature reserve, Stoborough SSSI
Fishery interest: none
Maintenance: none

Discussion:
The artificial banks have been constructed using boulders overlaid with two-inch wire mesh and top-soil; this soil layer has largely eroded, and numerous gaps are consequently developing between the boulders. The vegetation which is able to grow over these artificial banks is ephemeral, with weedy species including: *Achillea millefolium* L., *Anagallis arvensis* L., *Cirsium* L. sp., *Epilobium* L. sp., *Geranium robertianum* L., *Hieracium* L. sp., *Plantago major* L., *Polygonum* L. sp., *Potentilla* L. sp., *Prunella vulgaris* L., *Pteridium aquilinum* (L.) Kuhn, *Ranunculus acris* L., *Senecio jacobaea* L., *Trifolium repens* L. and several terrestrial grasses.

Removal of shrubs *etc.* during the pipeline construction work enabled the development of a dense riparian flora, consisting of both the ephemeral terrestrial plants listed above, and *Oenanthe* L. The aquatic vegetation is dominated by *Callitriche* L., which will alter the flow rate immediately downstream.

The pipeline crossing site on the Furzebrook Stream is located within the BP LPG terminal. Although the necessity for maintaining this site to a high 'aesthetic' standard is therefore not as important, the stream flows into a National Nature Reserve and consequently the prevention of water pollution is of paramount importance. It is therefore significant that analysis of the water chemistry does not show any pollution. BP have provided a permanent sluice gate at the site, so that any accidental spillage of oil can be held within the terminal and will not flow into the adjacent nature reserve.

3.3 RIVER PIDDLE
(Nat. grid ref.: SY 898881)

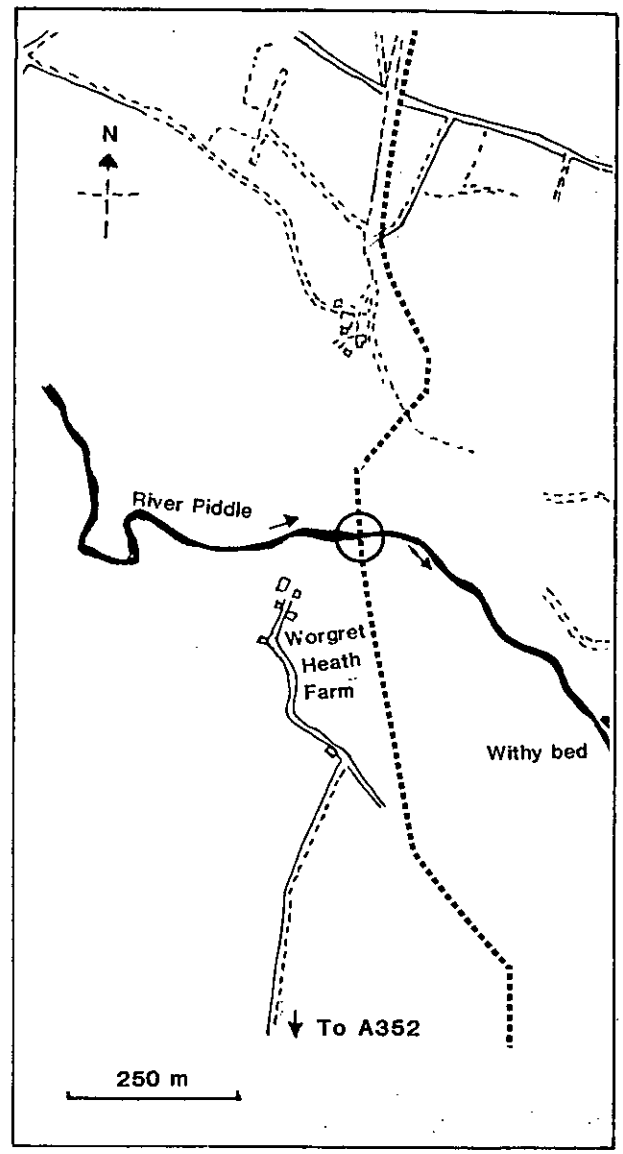
Topography:
Width: c. 7 m Depth: 0.85 m
Velocity: c 2.92 ms^{-1}
Discharge: c. 0.49 $m^3 s^{-1}$
Substrate: bed - boulder, cobble;
banks - concrete bags with clay and silt; adjacent land - soil

Water Chemistry:
pH: 7.64 Conductivity: 503 $\mu s\ cm^{-1}$
Calcium carbonate: 200.5 mg l^{-1}

Anions, mg l^{-1}:	Cations, mg l^{-1}:
Alkalinity 4.0	Calcium 91.8
Chloride 20.6	Magnesium 2.5
Sulphate 38.4	Sodium 9.5
Nitrate N 4.7	Potassium 0.7
Phosphate P 0.06	
Silicate Si 3.0	

Ion balance: 5.39 : 5.21 m.e.l.

Adjacent features:
Land use: pasture
Upstream: pasture
Downstream: pasture
Fishery interest: salmon/trout fishery
Maintenance: none



Discussion:
The River Piddle is a typical chalk stream; this is indicated by the relatively high calcium carbonate ($CaCO_3$) value of 200.5 mg l^{-1}.

Both artificial banks of the river at the pipeline crossing point are almost vertical, and have been constructed using concrete bags. Although these banks were therefore incapable of sustaining vegetation, the concrete bags are largely obscured from view by overhanging bank vegetation (predominantly grasses). There does not appear to be any erosion resulting from the artificial banks.

The flora immediately behind the artificial banks has become well vegetated, with *Cirsium* L. sp., *Epilobium* L. sp., *Hypericum* L. sp., *Matricaria* L. sp., *Plantago major* L., *Polygonum* L. sp., *Ranunculus acris* L., *Senecio jacobaea L.*, *Symphytum officinale* L., *Trifolium* L. sp. and numerous terrestrial grass species.

The aquatic flora is dominated by *Ranunculus penicillatus* (Dumort.) Bab. var. *calcareus* (R.W. Butcher) C.D.K. Cook, *Oenanthe crocata* L., *Juncus* L. sp., and *Callitriche* L. sp. The flora is very diverse, however, and also includes: *Glyceria maxima* (Hartm.) Holmberg, *Iris pseudacorus* L., *Lemna trisulca* L., *Myosotis scorpioides* L., *Nuphar lutea* (L.) Sm., *Scrophularia auriculata* L., *Sparganium erectum* L., and *Veronica anagallis-aquatica* L.

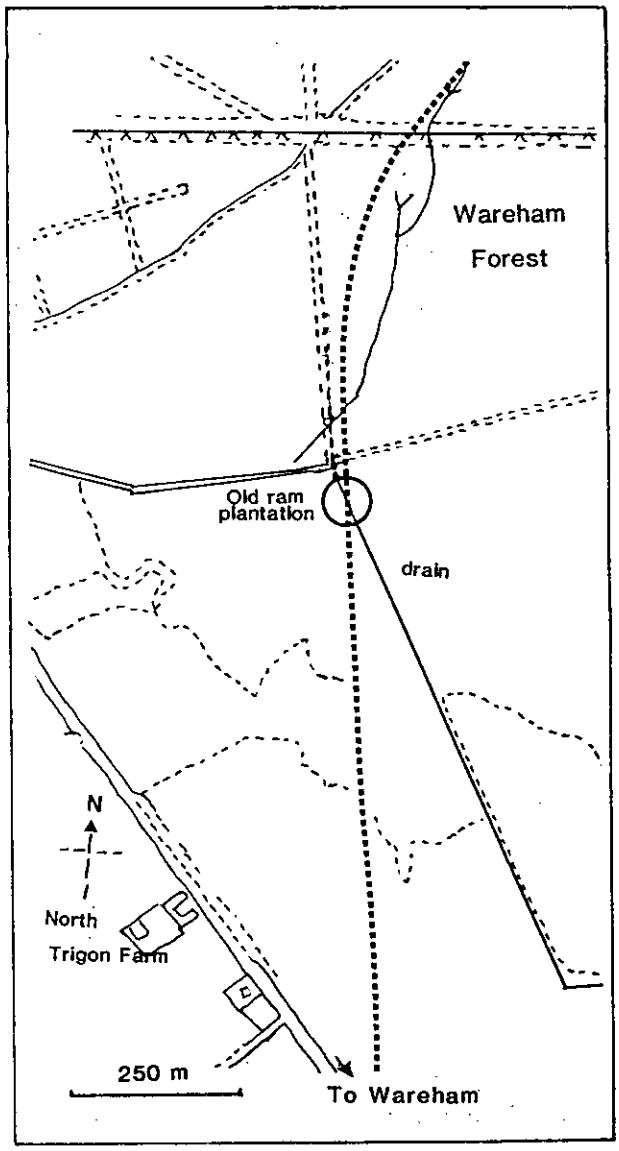
The construction of the pipeline does not appear to have resulted in many deleterious effects downstream, although the dense aquatic vegetation is presumably the result of the removal of shading by trees; this will inevitably have affected the flow rate downstream.

3.4 WAREHAM FOREST DRAIN
(Nat. grid ref.: SY 895915)

Topography:
Width: 1.0 m Depth: 0 m (dry)
Velocity: not applicable
Discharge: not applicable
Substrate: bed - pebbles, gravel, silt, clay; banks - concrete bags; adjacent land - sand, silt, clay

Water Chemistry:
not applicable

Adjacent features:
Land use: heathland
Upstream: heathland
Downstream: heathland, national nature reserve & SSSI
Fishery interest: none
Maintenance: none



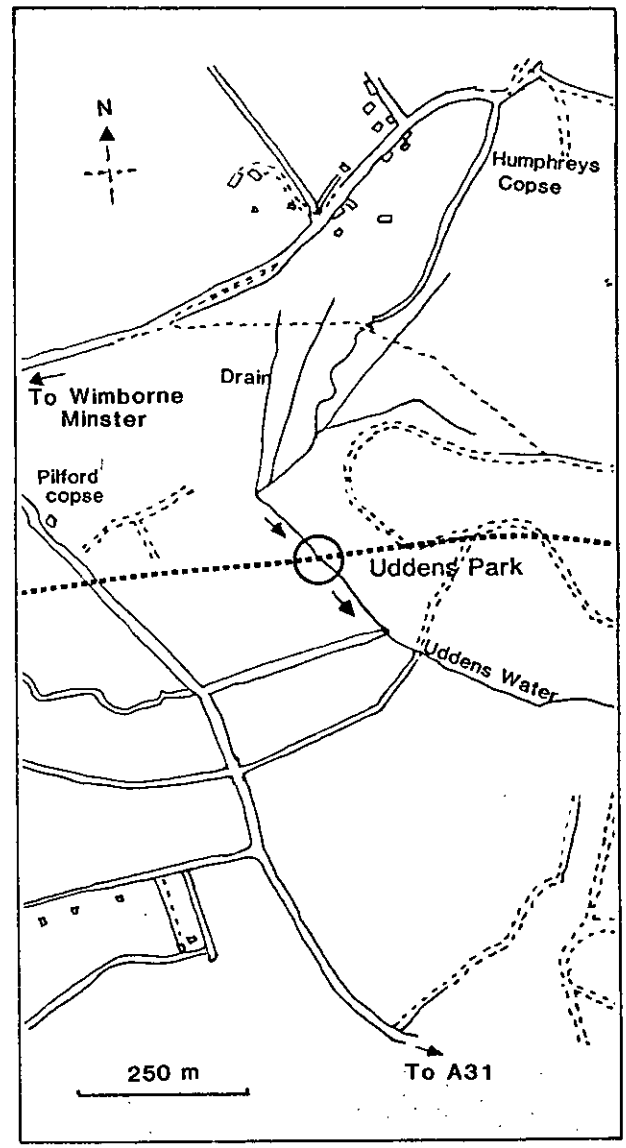
Discussion:
The Wareham Forest Drain is an entirely artificial channel; it is ecologically important, however, since it drains towards Morden Bog, which is a National Nature Reserve and a Site of Special Scientific Interest (SSSI)

The artificial banks are constructed from concrete filled bags, overlaid with a rope mesh. The vertical faces of the banks are unvegetated, although the top of the banks are covered with terrestrial grasses, and several gorse bushes (*Ulex europaeus* L.).

The aquatic vegetation is limited by periodic drying (as when the survey was conducted). Most of the plants in the channel are therefore either terrestrial (mainly grasses, with *Stellaria* L. sp.), or are semi-aquatic plants that can survive periods with lack of surface water (including *Juncus* L. sp.). There does not appear to be any erosion resulting from the artificial banks at this site.

3.5 UDDENS WATER

(Nat. grid ref.: SU 041026)



Topography:
Width: 1.82 m Depth: 0.21 m
Velocity: 0.215 ms^{-1}
Discharge: 0.082 $m^3 s^{-1}$
Substrate: bed - boulder, cobble, silt; banks - concrete bags; adjacent land - soil

Water Chemistry:
pH: 7.25 Conductivity: 416 $\mu s\ cm^{-1}$
Calcium carbonate: 96.5 mg l^{-1}

Anions, mg l^{-1}:	Cations, mg l^{-1}:
Alkalinity 1.9	Calcium 50.0
Chloride 31.6	Magnesium 8.6
Sulphate 60.0	Sodium 17.0
Nitrate N 2.8	Potassium 4.1
Phosphate P 0.07	
Silicate Si 4.6	

Ion balance: 4.07 : 4.05 m.e.l.

Adjacent features:
Land use: pasture
Upstream: pasture
Downstream: pasture
Fishery interest: none
Maintenance: none

Discussion:
The artificial banks are constructed using concrete filled bags, and consequently there is no vegetation on the right bank which is nearly vertical; the left bank has been built at a markedly more shallow gradient. The vegetation on the bank behind the concrete bags is dense, although not very diverse, consisting of *Cirsium* Miller sp., *Epilobium* L. sp., *Galium* L. sp., *Ranunculus acris* L., *Rumex* L. sp., *Trifolium* L. sp., *Urtica dioica* L. and several terrestrial grass species. No orchids were discovered in the adjacent field, as reported by Dawson *et al.* (1986b).

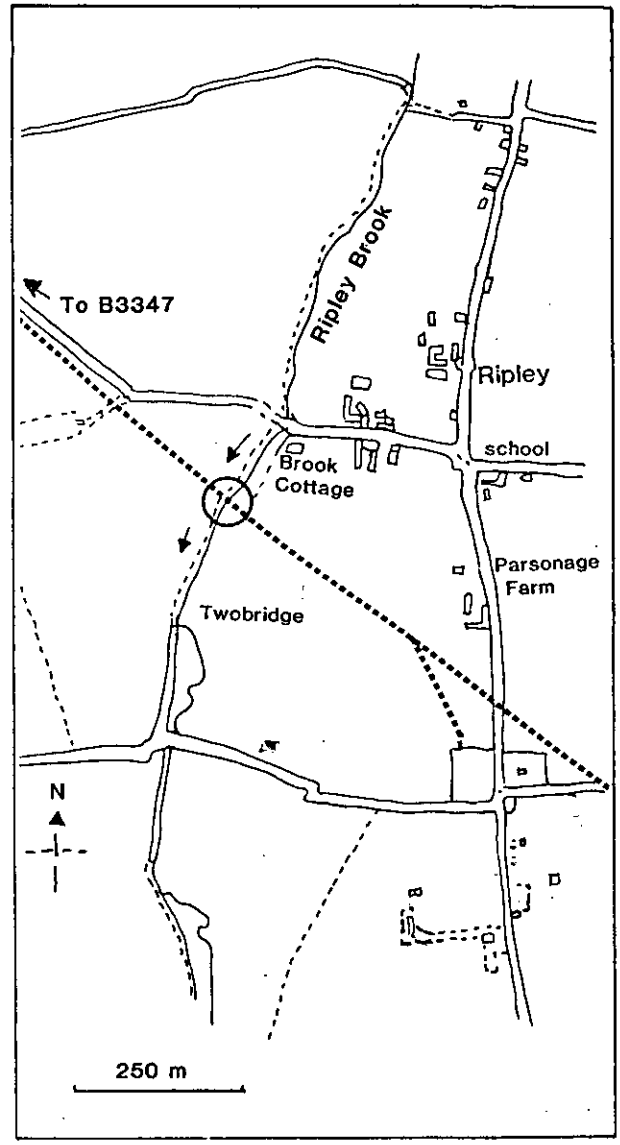
The aquatic flora is dominated by *Callitriche* L. sp. due to the lack of shading, although *Alisma plantago-aquatica* L., *Nasturtium officinale* R. Br. and *Oenanthe crocata* L. also occur; this will alter the flow rate immediately downstream.

There does not appear to be an erosion problem, although cattle use the left bank as a watering point and consequently cause some soil poaching. Slight erosion is also occurring downstream of the concrete bags forming the right bank, although this seems to be due to

water drainage from the adjacent field feeding into the Uddens Water; further erosion will be largely prevented by a concrete block which is situated immediately downstream on the right hand bank.

3.6 RIPLEY BROOK

(Nat. grid ref.: SZ 158985)



Topography:
Width: 3.2 m Depth: 0.125 m
Velocity: 0.12 m s^{-1}
Discharge: 0.048 m^3 s^{-1}
Substrate: bed - boulder, cobble, pebble, gravel; banks - concrete bags; adjacent land - pebble, gravel, sand

Water Chemistry:
pH: 6.37 Conductivity: 151 μs cm^{-1}
Calcium carbonate: 19.5 mg l^{-1}

Anions, mg l^{-1}:	Cations, mg l^{-1}:
Alkalinity 0.4	Calcium 10.4
Chloride 21.3	Magnesium 3.1
Sulphate 19.2	Sodium 10.9
Nitrate N 1.2	Potassium 0.3
Phosphate P 0.02	
Silicate Si 3.2	

Ion balance: 1.39 : 1.25 m.e.l.

Adjacent features:
Land use: arable
Upstream: through pasture
Downstream: through pasture
Fishery interest: not known
Maintenance: none

Discussion:
Both banks have been constructed from artificial concrete bags, with negligible re-vegetation occurring due to lack of top-soil; much of the left bank is obscured by overhanging terrestrial vegetation, however. Erosion is occurring along most of the right bank beneath the lowermost concrete bags; this has resulted in the loosening of the lower bags, and might ultimately result in the collapse of the bank.

There has been a marked accumulation of silt at the pipeline crossing point and immediately downstream. This alteration of the habitat will possibly have affected the aquatic flora and fauna.

Although there is no aquatic vegetation, there is a considerable amount of vegetation growing in the margins of the channel on the accumulated silt (Table 3). This vegetation is dominated by *Urtica dioica* L., *Rumex hydrolapathum* Hudson and various terrestrial grasses.

FIGURE 2. Map of Ripley Brook at the site of the oil pipeline crossing, showing location of major plant populations etc. BP = position of BP pipeline marker post; CB = artificial bank constructed using concrete bags; Oen = *Oenanthe crocata* L.; Sen = *Senecio jacobaea* L.; TG = terrestrial grasses. Dashed lines indicate position of artificial banks.

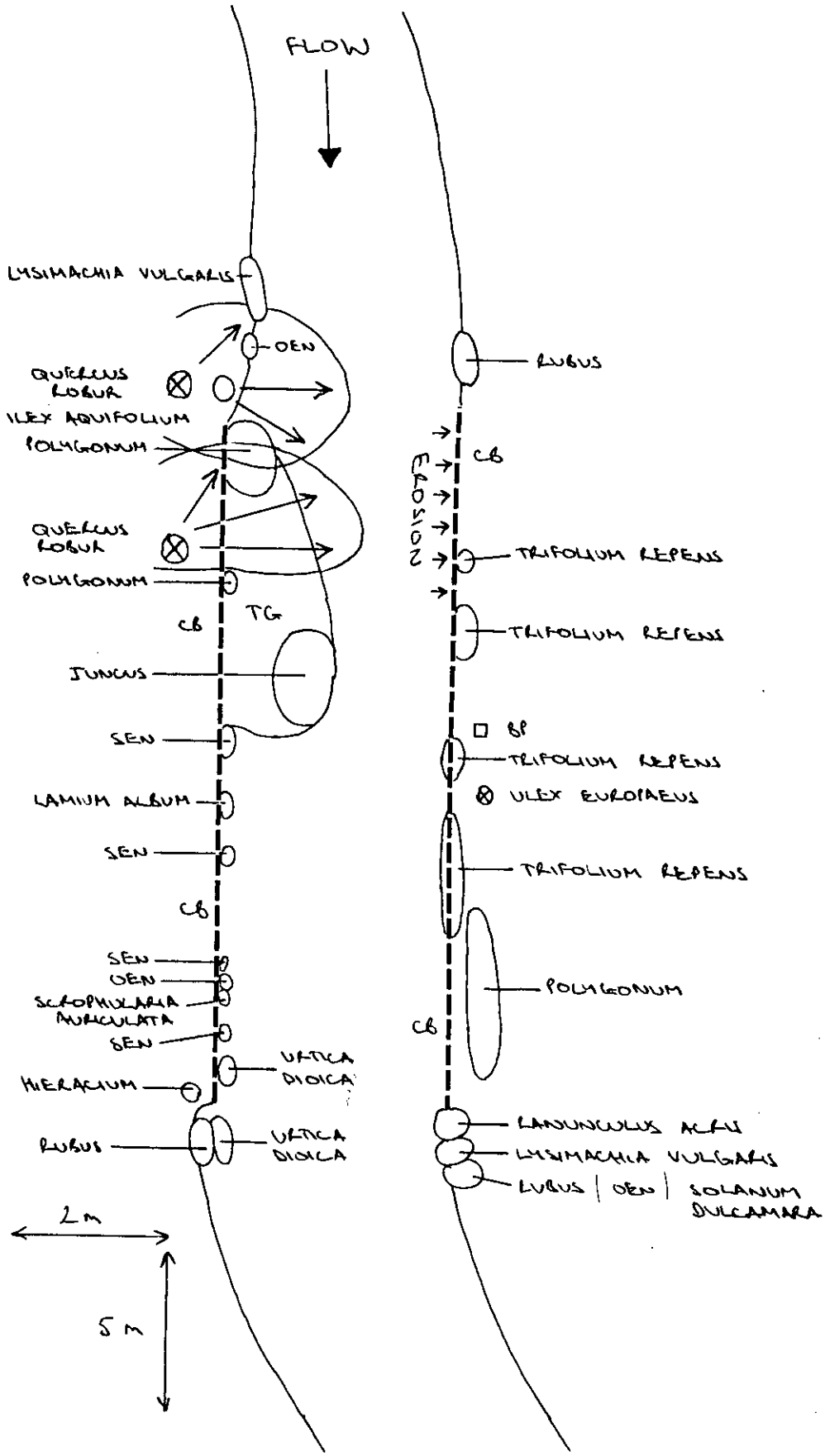
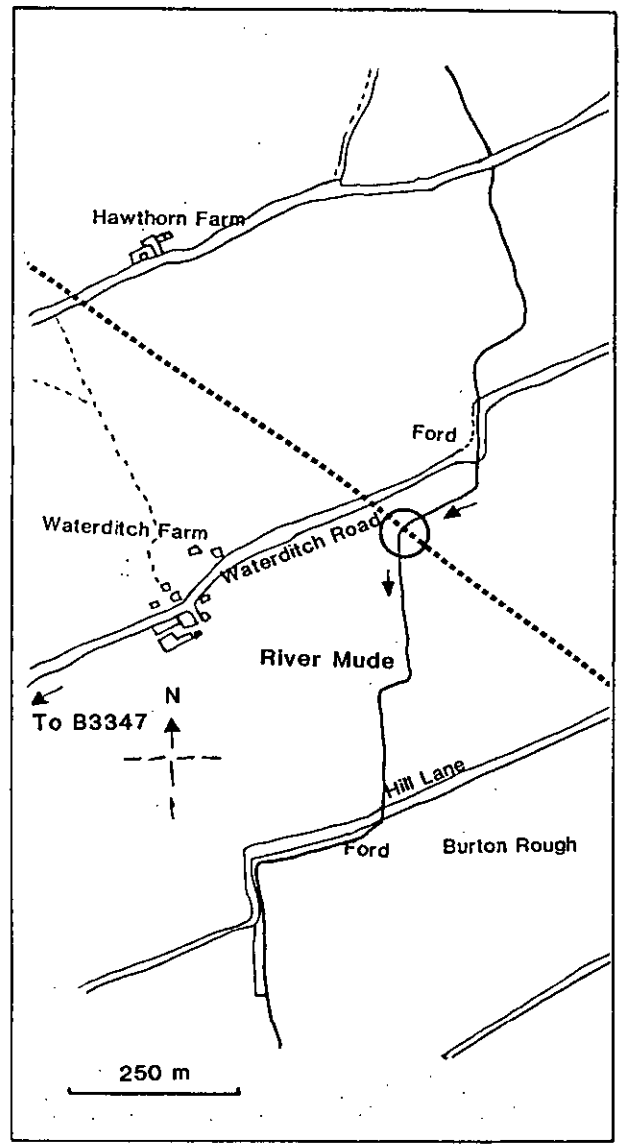


TABLE 3. List of species occurring at the Ripley Brook site in August 1991. Taxa listed alphabetically to species level where possible, with appropriate family and common names.

Anagallis arvensis L. (Primulaceae)	Scarlet pimpernel
Apium nodiflorum (L.) Lag. (Umbelliferae)	Fool's watercress
Epilobium palustre L. (Onagraceae)	Marsh willow-herb
Galium palustre L. (Rubiaceae)	Lesser marsh bedstraw
Hieracium L. sp. (Compositae)	Hawkweed
Juncus L. sp. (Juncaceae)	Rush
Lamium album L. (Labiatae)	White dead-nettle
Lotus corniculatus L. (Leguminosae)	Common birdsfoot-trefoil
Matricaria recutita L. (Compositae)	Wild chamomile
Oenanthe crocata L. (Umbelliferae)	Hemlock water-dropwort
Ranunculus acris L. (Ranunculaceae)	Meadow buttercup
Rubus L. sp. (Rosaceae)	Bramble
Rumex hydrolapathum Hudson (Polygonaceae)	Water dock
Scrophularia auriculata L. (Scrophulariaceae)	Water figwort
Scutellaria galericulata L. (Labiatae)	Skullcap
Senecio jacobaea L. (Compositae)	Ragwort
Trifolium repens L. (Leguminosae)	White clover, Dutch clover
Urtica dioica L. (Urticaceae)	Stinging nettle

3.7 RIVER MUDE

(Nat. grid ref.: SZ 184957)



Topography:

Width: 2.5 m Depth: 0.198 m
Velocity: 0.60 m s^{-1}
Discharge: 0.297 m^3 s^{-1}
Substrate: bed - pebbles, gravel, silt; banks - clay over concrete bags; adjacent land - soil

Water Chemistry:

pH: 7.10 Conductivity: 346 μs cm^{-1}
Calcium carbonate: 42.5 mg l^{-1}

Anions, mg l^{-1}:	Cations, mg l^{-1}:
Alkalinity 0.9	Calcium 34.4
Chloride 44.7	Magnesium 5.8
Sulphate 53.3	Sodium 20.5
Nitrate N 5.4	Potassium 1.6
Phosphate P 0.03	
Silicate Si 3.6	

Ion balance: 3.22 : 3.12 m.e.l.

Adjacent features:

Land use: pasture
Upstream: pasture
Downstream: arable
Fishery interest: not known
Maintenance: none

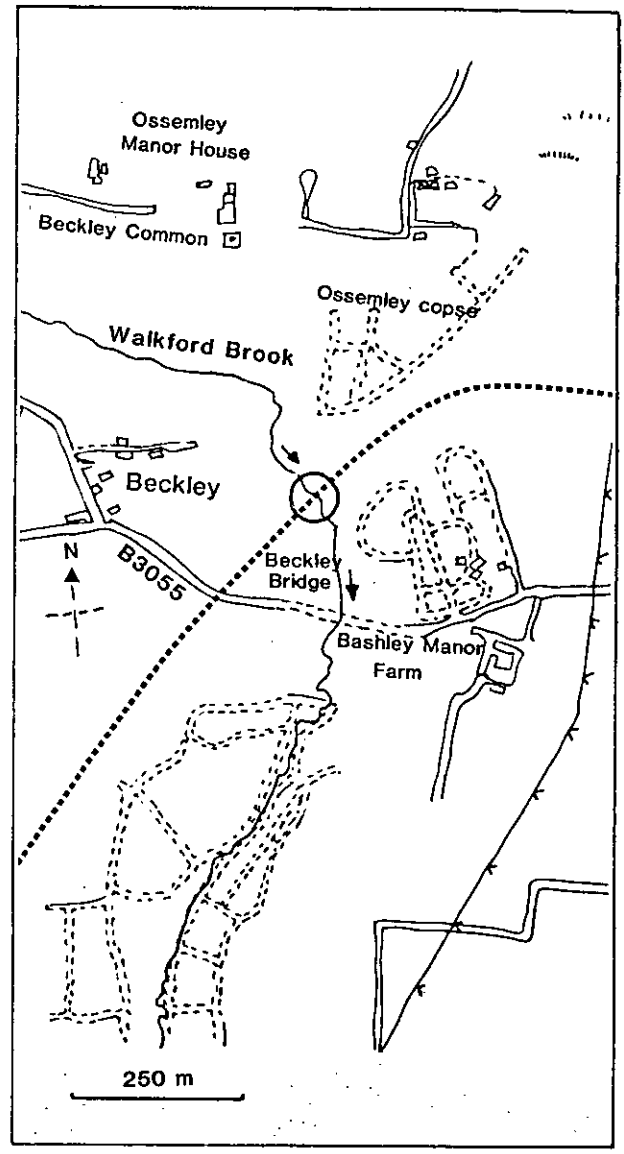
Discussion:

Both artificial banks are apparently constructed from concrete filled bags, although the bags are almost completely obscured from view by a layer of topsoil (mainly clay); this topsoil was probably laid during construction work to aid re-vegetation. The flora of this topsoil is dense, although it is predominantly grasses, which were probably planted (either as seeds or turves) during the construction work. There are, however, large areas of *Epilobium hirsutum* L.

The aquatic and riparian flora is both rich and diverse, with large stands of *Veronica beccabunga* L., *Apium nodiflorum* (L.) Lag., *Sparganium erectum* L. and *Phalaris arundinacea* L. The water also contains considerable quantities of the filamentous green alga *Cladophora* Kütz. sp., which is typically indicative of highly eutrophic (organically rich) water. The analysis of the water chemistry indicates relatively high nitrate and phosphate values of 5.41 mg l^{-1} and 30.5 μg l^{-1} respectively.

The construction of the pipeline does not appear to have resulted in any deleterious effects downstream such as erosion problems, sedimentation or alteration in water flow rate.

3.8 WALKFORD BROOK
(Nat. grid ref.: SZ 240966)



Topography:
Width: 1.3 m Depth: 0.155 m
Velocity: 0.07 m s^{-1}
Discharge: 0.014 m^3 s^{-1}
Substrate: bed - silt, clay;
banks - concrete bags;
adjacent land - soil

Water Chemistry:
pH: 7.08 Conductivity: 398 μs cm^{-1}
Calcium carbonate: 89.5 mg l^{-1}

Anions, mg l^{-1}:	Cations, mg l^{-1}:
Alkalinity 1.8	Calcium 44.8
Chloride 38.3	Magnesium 6.2
Sulphate 45.6	Sodium 20.3
Nitrate N 2.8	Potassium 1.6
Phosphate P 0.12	
Silicate Si 4.2	

Ion balance: 3.82 : 3.67 m.e.l.

Adjacent features:
Land use: rough grassland
Upstream: woodland
Downstream: woodland, sewage outlet
Fishery interest: none
Maintenance: none

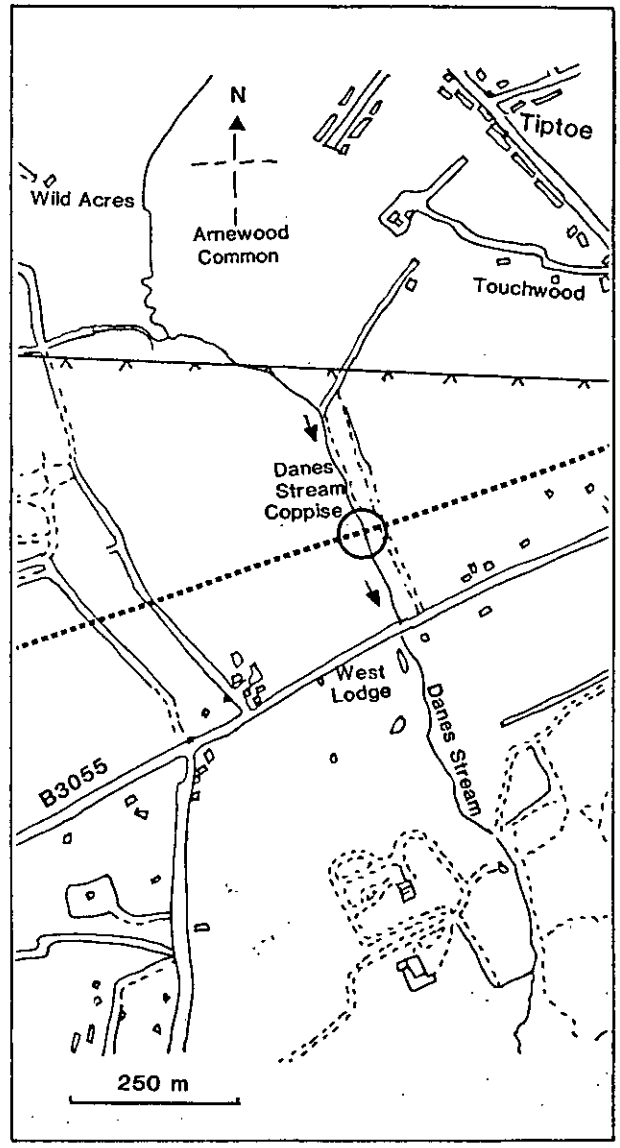
Discussion:
Both artificial banks have been constructed from concrete filled bags. The margins are very steep, and consequently there is no vegetation, although both margins are partially obscured by overhanging terrestrial plants. The terrestrial vegetation is dominated by grasses, although the site is very species rich (Table 4).

The aquatic flora is sparse, although with small populations of *Callitriche* L. sp. which are able to grow in the increased light levels that resulted from the removal of trees during construction of the pipeline.

The construction of the pipeline does not appear to have resulted in any deleterious effects downstream such as erosion problems, sedimentation or alteration in water flow rate.

3.9 DANES STREAM

(Nat. grid ref.: SZ 253972)



Topography:
Width: 0.55 m Depth: 0.05 m
Velocity: moderately fast (not measured)
Discharge: not applicable
Substrate: bed - pebble, gravel, sand; banks - concrete bags; adjacent land - soil

Water Chemistry:
pH: 6.81 Conductivity: 425 $\mu s\ cm^{-1}$
Calcium carbonate: 64.5 mg l^{-1}

Anions, mg l^{-1}:	Cations, mg l^{-1}:
Alkalinity 1.3	Calcium 49.6
Chloride 50.7	Magnesium 6.2
Sulphate 66.8	Sodium 20.6
Nitrate N 4.7	Potassium 3.6
Phosphate P 147	
Silicate Si 3.7	

Ion balance: 4.11 : 3.98 m.e.l.

Adjacent features:
Land use: wasteland
Upstream: wasteland
Downstream: wasteland
Fishery interest: none
Maintenance: none

Discussion:
Both artificial banks are very steep, and have been constructed from concrete filled bags without any topsoil. As a consequence of this, there is no vegetation, although both banks are obscured by overhanging terrestrial grasses. The central area of the left bank is showing erosion beneath the lowermost of concrete bags; this is resulting in subsidence, which may possibly cause collapse of the bank.

The terrestrial vegetation adjacent to the artificial banks is predominantly grass, although several other species also occur (Table 4). A hawthorn hedgerow (*Crataegus monogyna* Jacq.) has been planted above the right bank. The aquatic flora is similarly species poor, being dominated by *Apium nodiflorum* L. There is, however, a large silted area within the channel, which has become colonised by terrestrial plants including *Galium aparine* L. This accumulation of silt will possibly result in deleterious effects on the downstream flora and fauna.

FIGURE 3. Map of Danes Stream at the site of the oil pipeline crossing, showing location of major plant populations etc. CB = artificial bank constructed using concrete bags; TG = terrestrial grasses. Dashed lines indicate position of artificial banks.

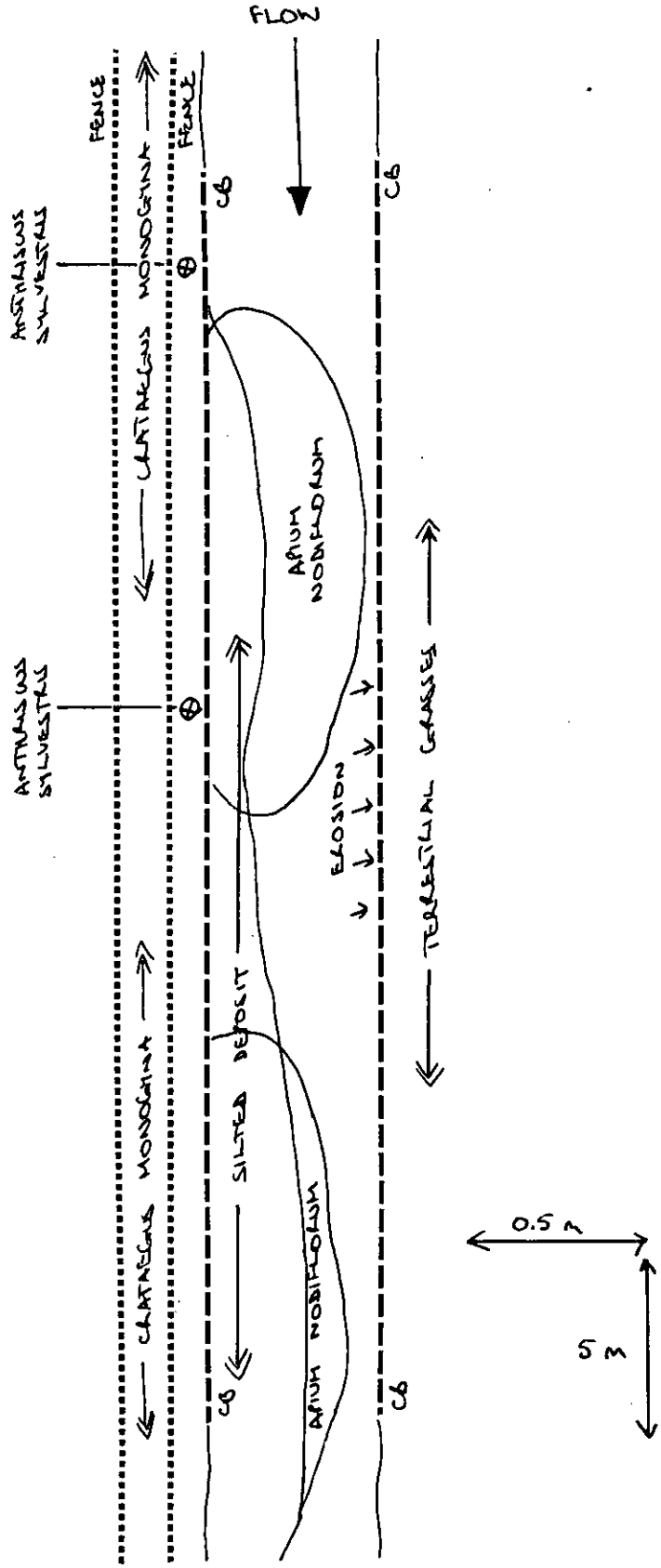
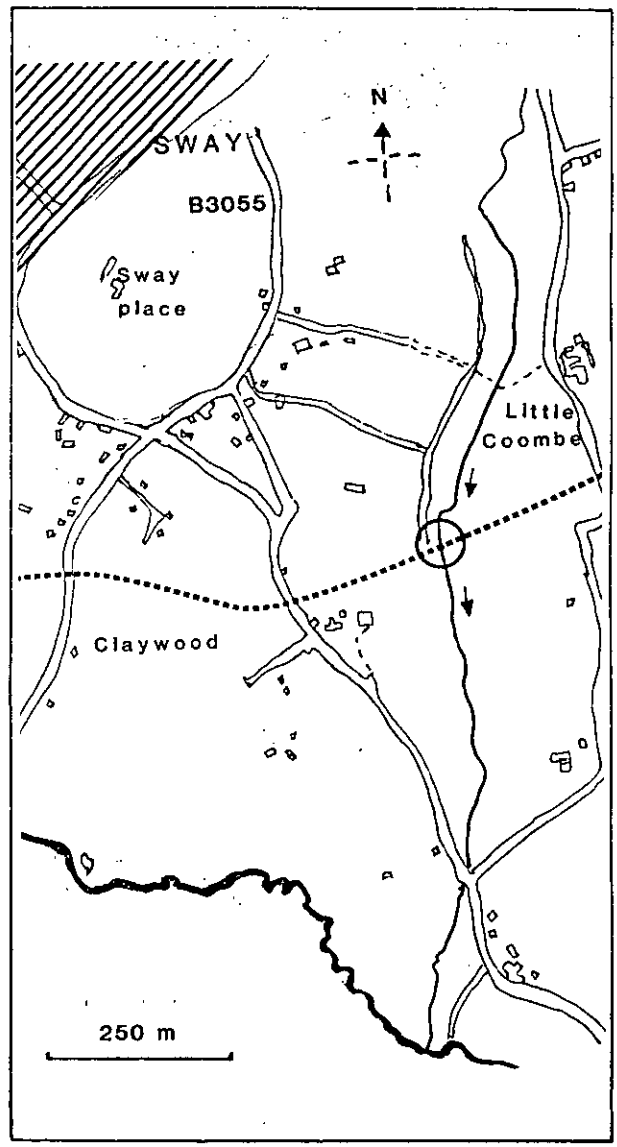


TABLE 4. List of species occurring at the Danes Stream site in August 1991. Taxa listed alphabetically to species level where possible, with appropriate family and common names.

Agrostis capillaris L. [synonym: *A. tenuis* Sibth.] (Gramineae)	Common bent-grass
Anthriscus sylvestris (L.) Hoffm. (Umbelliferae)	Cow parsley
Apium nodiflorum (L.) Lag. (Umbelliferae)	Fool's watercress
Crataegus monogyna Jacq. (Rosaceae)	Hawthorn
Epilobium hirsutum L. (Onagraceae)	Great hairy willow-herb
Epilobium palustre L. (Onagraceae)	Marsh willow-herb
Fraxinus excelsior L. (Oleaceae)	Ash
Galium aparine L. (Rubiaceae)	Goosegrass, Cleavers
Geranium robertianum L. (Geraniaceae)	Herb-Robert
Hedera helix L. (Araliaceae)	Ivy
Ranunculus acris L. (Ranunculaceae)	Meadow buttercup
Rosa L. sp. (Rosaceae)	Wild rose
Rubus L. sp. (Rosaceae)	Bramble
Rumex L. sp. (Polygonaceae)	Sorrel, Dock
Urtica dioica L. (Urticaceae)	Stinging nettle

3.10 AVON WATER TRIBUTARY
(Nat. grid ref.: SZ 284978)



Topography:
Width: 0.75 m Depth: 0.12 m
Velocity: 0.059 m s^{-1}
Discharge: 0.005 m^3 s^{-1}
Substrate: bed - stones, with silt at sides; banks - concrete bags, and stones with cement; adjacent land - soil.

Water Chemistry:
pH: 6.68 Conductivity: 323 μs cm^{-1}
Calcium carbonate: 44.5 mg l^{-1}

Anions, mg l^{-1}:	Cations, mg l^{-1}:
Alkalinity 0.9	Calcium 32.8
Chloride 34.4	Magnesium 4.2
Sulphate 50.9	Sodium 28.1
Nitrate N 3.4	Potassium 3.4
Phosphate P 20.7	
Silicate Si 4.7	

Ion balance: 2.92 : 3.30 m.e.l.

Adjacent features:
Land use: pasture
Upstream: copse
Downstream: copse
Fishery interest: none
Maintenance: negligible

Discussion:
The artificial banks have been constructed using two different methods, *viz.*: concrete filled bags, and stones cemented together. Both types of banks have been constructed at a very steep angle, which has prevented re-vegetation. Large sections of both banks (but particularly the right bank) have collapsed due to the undermining of the lowermost layer of stones; this was especially noticeable in the stone/cement banks.

The hawthorn (*Crataegus monogyna* Jacq.) hedgerow planted above the right bank has not grown well, and should possibly be re-planted.

The aquatic vegetation is negligible, except for several stands of *Glyceria fluitans* (L.) R. Br. Towards the artificial banks, however, there are comparatively large areas of silt, which now support a limited weedy vegetation. This accumulation of silt will possibly result in deleterious effects on the downstream flora and fauna.

FIGURE 4. Map of Avon Water Tributary at site of oil pipeline crossing, showing location of major plant populations etc. BP = position of BP pipeline marker post; CB = artificial bank constructed using concrete bags; B/W = barbed wire fence.

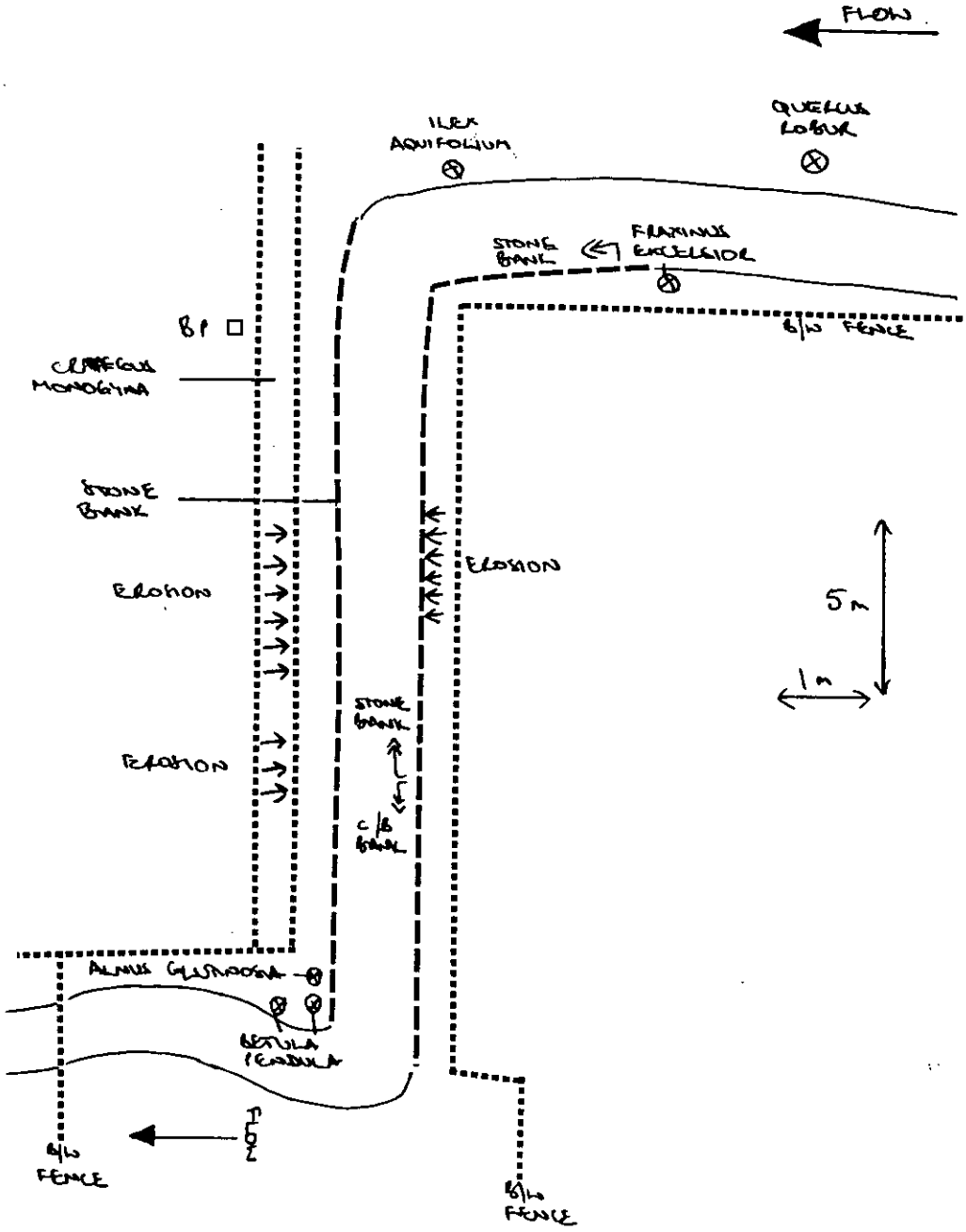


TABLE 5. List of species occurring at the Avon Water Tributary site in November 1991. Taxa listed alphabetically to species level where possible, with appropriate family and common names.

Agrostis stolonifera L. (Gramineae)	Fiorin
Alnus glutinosa (L.) Gaertner (Betulaceae)	Alder
Betula pendula Roth (Betulaceae)	Silver Birch
Blechnum spicant (L.) Roth (Blechnaceae)	Hard fern
Cirsium Miller sp. (Compositae)	Thistle
Crataegus monogyna Jacq. (Rosaceae)	Hawthorn
Dryopteris dilatata (Hoffmann) A. Gray (Aspidiaceae)	Broad buckler-fern
Epilobium hirsutum L. (Onagraceae)	Great hairy willow-herb
Epilobium tetragonum L. (Onagraceae)	Square-stemmed willow-herb
Fagus sylvatica L. (Fagaceae)	Beech
Fraxinus excelsior L. (Oleaceae)	Ash
Glyceria fluitans (L.) R. Br. (Gramineae)	Floating sweet-grass, Flote-grass
Hedera helix L. (Araliaceae)	Ivy
Ilex aquifolium L. (Aquifoliaceae)	Holly
Juncus L. sp. (Juncaceae)	Rush
Ligustrum vulgare L. (Oleaceae)	Common privet
Molinia caerulea (L.) Moench (Gramineae)	Purple moor-grass
Pteridium aquilinum (L.) Kuhn (Hypolepidaceae)	Bracken
Quercus robur L. (Fagaceae)	Common oak, Pedunculate oak
Rhododendron ponticum L. (Ericaceae)	Rhododendron
Rubus fruticosus sensu lato (Rosaceae)	Blackberry, Bramble
Rumex L. sp. (Polygonaceae)	Sorrel, Dock
Salix L. sp. (Salicaceae)	Willow
Taxus baccata L. (Taxaceae)	Yew
Ulex europaeus L. (Leguminosae)	Furze, Gorse
Urtica dioica L. (Urticaceae)	Stinging nettle

3.11 PASSFORD WATER
(Nat. grid ref.: SZ 305978)

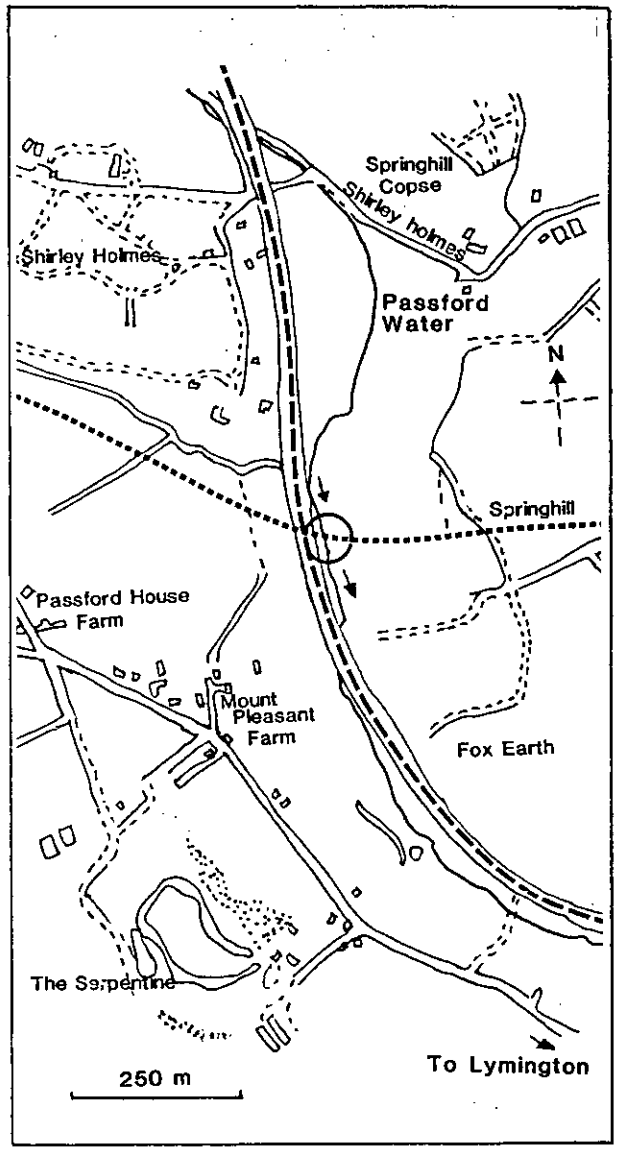
Topography:
Width: 1.2 m Depth: 0.03 m
Velocity: negligible
Discharge: not applicable
Substrate: bed - pebbles, gravel; banks - concrete bags, stone cladding; adjacent land - pebbles, gravel

Water Chemistry:
pH: 5.94 Conductivity: 231 $\mu s\ cm^{-1}$
Calcium carbonate: 28.0 mg l^{-1}

Anions, mg l^{-1}:	Cations, mg l^{-1}:
Alkalinity 0.6	Calcium 18.2
Chloride 28.0	Magnesium 21.5
Sulphate 33.6	Sodium 20.8
Nitrate N 0.3	Potassium 2.5
Phosphate P 0.02	
Silicate Si 4.4	

Ion balance: 2.05 : 2.05 m.e.l.

Adjacent features:
Land use: wasteland
Upstream: copse
Downstream: copse
Fishery interest: none, but with adjacent fishing lake
Maintenance: none



Discussion:
The left artificial bank is constructed from concrete filled bags; the downstream half of this bank is covered with rope mesh, and there is an outflow pipe from the adjacent fishing lake entering through upstream half. The right artificial bank is primarily constructed out of steep stone cladding, but with concrete filled bags on the upstream quarter. Both banks have been constructed to a far greater height than was observed at any of the other pipeline crossing sites; this is apparently so that periodic high flood levels can be accommodated without breaching the banks.

Neither artificial bank shows any vegetation, with the exception of a small *Corylus avellana* L. sapling growing from the right bank. The flora of the adjacent land is detailed in Table 6. There is little aquatic vegetation, although the filamentous green alga *Cladophora* Kütz. sp. was widespread; this is indicative of highly eutrophic (organically rich) water. Analysis of the water chemistry indicates a markedly high magnesium value of 21.5 mg l^{-1}.

The channel is heavily silted, with large areas of terrestrial grasses etc. growing within the main channel. This accumulation of silt will possibly result in deleterious effects on the downstream flora and fauna.

FIGURE 5. Map of Passford Water at the site of the oil pipeline crossing, showing location of major plant populations etc. BP = position of BP pipeline marker post; CB = artificial bank constructed using concrete bags; Pot = *Potamogeton polygonifolius* Pourret; St = stones; TG = terrestrial grasses. Dashed lines indicate position of artificial banks.

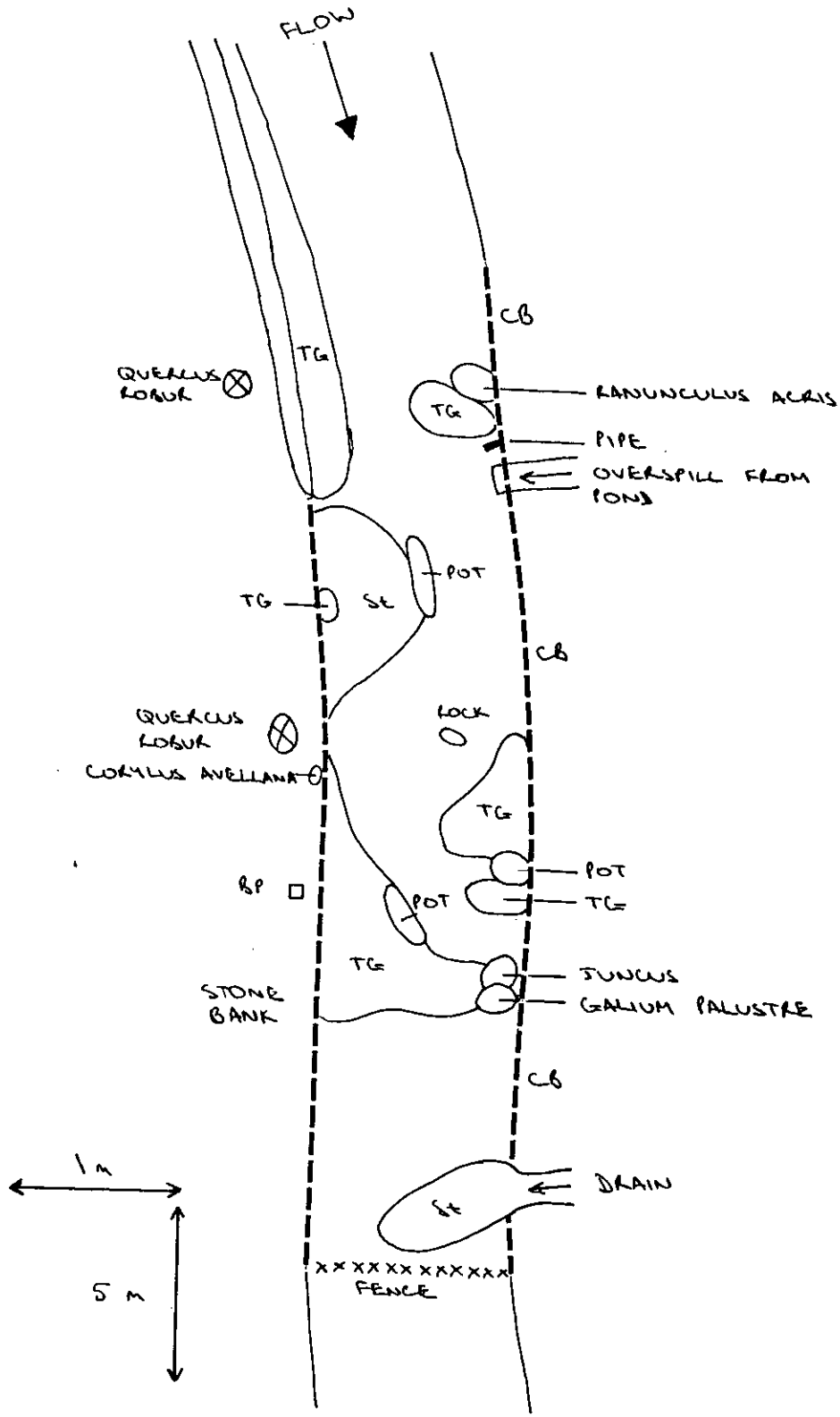


TABLE 6. List of species occurring at the Passford Water site in August 1991. Taxa listed alphabetically to species level where possible, with appropriate family and common names.

Agrostis capillaris L. [synonym: *A. tenuis* Sibth.] (Gramineae)	Common bent-grass
Alisma plantago-aquatica L. (Alismataceae)	Water-plantain
Anagallis arvensis L. (Primulaceae)	Scarlet pimpernel
Apium nodiflorum (L.) Lag. (Umbelliferae)	Fool's watercress
Callitriche stagnalis Scop./*C. platycarpa* Kütz. (Callitrichaceae)	Water starwort
Centaurium erythraea Rafn. (Gentianaceae)	Common Centaury
Convolvulus arvensis L. (Convolvulaceae)	Field bindweed
Corylus avellana L. (Corylaceae)	Hazel
Digitalis purpurea L. (Scrophulariaceae)	Foxglove
Epilobium hirsutum L. (Onagraceae)	Great hairy willow-herb
Epilobium palustre L. (Onagraceae)	Marsh willow-herb
Galium palustre L. (Rubiaceae)	Lesser marsh bedstraw
Geranium robertianum L. (Geraniaceae)	Herb-Robert
Hieracium L. sp. (Compositae)	Hawkweed
Juncus L. sp. (Juncaceae)	Rush
Lotus corniculatus L. (Leguminosae)	Common birdsfoot-trefoil
Matricaria recutita L. (Compositae)	Wild chamomile
Potamogeton polygonifolius Pourret (Potamogetonaceae)	Bog Pondweed
Pteridium aquilinum (L.) Kuhn (Hypolepidaceae)	Bracken
Quercus robur L. (Fagaceae)	Common oak, Pedunculate oak
Ranunculus acris L. (Ranunculaceae)	Meadow buttercup
Ranunculus flammula L. (Ranunculaceae)	Lesser spearwort
Rubus L. sp. (Rosaceae)	Bramble
Rumex L. sp. (Polygonaceae)	Sorrel, Dock
Salix L. sp. (Salicaceae)	Willow
Senecio jacobaea L. (Compositae)	Ragwort
Solanum dulcamara L. (Solanaceae)	Woody nightshade
Trifolium dubium Sibth. (Leguminosae)	Suckling clover, Lesser trefoil
Trifolium repens L. (Leguminosae)	White clover, Dutch clover
Ulex europaeus L. (Leguminosae)	Furze, Gorse
Urtica dioica L. (Urticaceae)	Stinging nettle

3.12 PLUMMERS WATER
(Nat. grid ref.: SZ 356973)

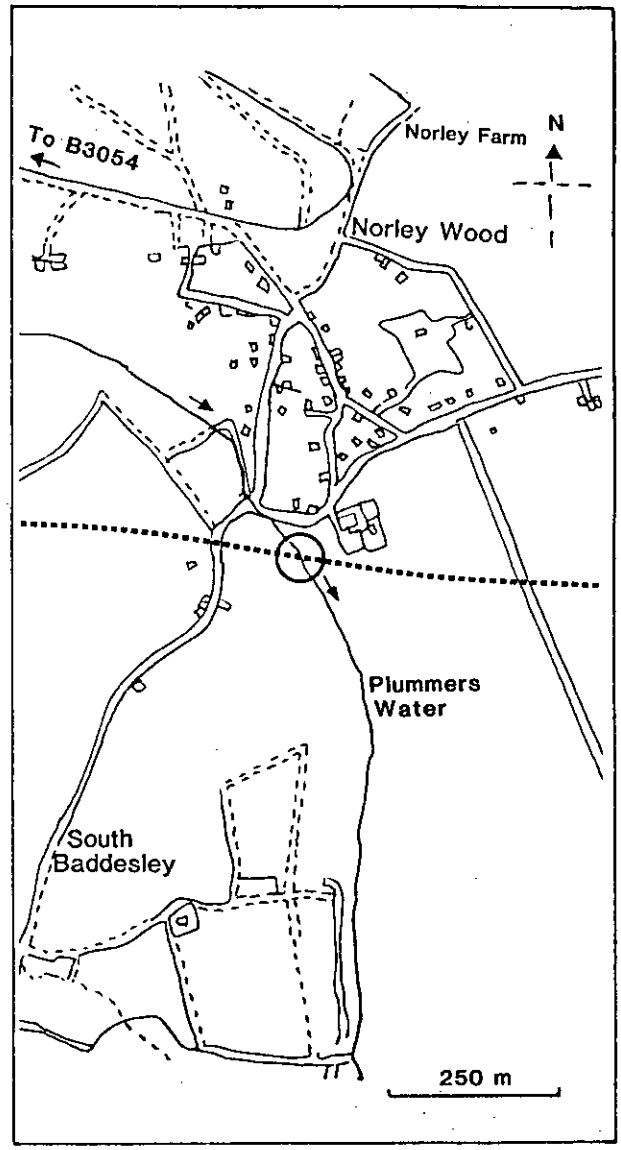
Topography:
Width: 0.82 m Depth: 0.053 m
Velocity: 0.39 m s^{-1}
Discharge: 0.0168 m^3 s^{-1}
Substrate: bed - pebbles, gravel, silt; banks - pebbles, gravel, silt; adjacent land - soil

Water Chemistry:
pH: 7.04 Conductivity: 416 μs cm $^{-1}$
Calcium carbonate: 55.5 mg l^{-1}

Anions, mg l^{-1}:	Cations, mg l^{-1}:
Alkalinity 1.1	Calcium 42.4
Chloride 51.8	Magnesium 6.1
Sulphate 61.0	Sodium 20.8
Nitrate N 7.3	Potassium 4.1
Phosphate P 0.66	
Silicate Si 3.7	

Ion balance: 3.84 : 3.63 m.e.l.

Adjacent features:
Land use: pasture
Upstream: copse, with ford across road
Downstream: arable
Fishery interest: none
Maintenance: negligible



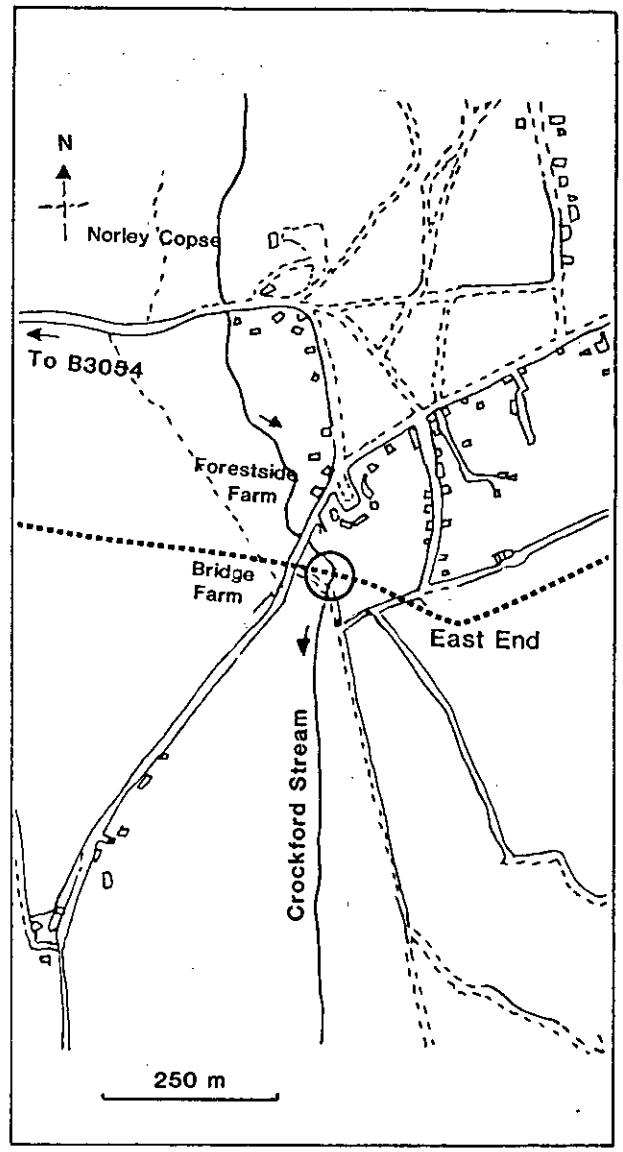
Discussion:
Both artificial banks have been constructed out of shallow topsoil, and are well vegetated with *Cirsium* Miller sp., *Equisetum* L. sp., *Ranunculus acris* L., *Rumex* L. sp., *Trifolium repens* L. and various terrestrial grasses. Other less abundant plants growing along the banks and immediately adjacent land include: *Apium nodiflorum* L., *Convolvulus arvensis* L., *Matricaria* L. sp., *Myosotis scorpioides* L., *Nasturtium officinale* R. Br., *Oenanthe crocata* L., *Plantago major* L., *Senecio jacobaea* L., *Stellaria* L. sp., *Urtica dioica* L. and *Veronica beccabunga* L.

The aquatic flora is very species poor, with only the filamentous green alga *Cladophora* Kütz. sp.; this is indicative of highly eutrophic (organically rich) water. This is confirmed by the analysis of the water chemistry shows high nitrate and phosphate values of 7.27 mg l^{-1} and 656.0 μg l^{-1} respectively.

The left bank is showing a limited degree of poaching due to cattle drinking from the stream. The right bank has been re-planted with a hawthorn hedgerow (*Crataegus monogyna* Jacq.).

The construction of the pipeline does not appear to have resulted in any deleterious effects downstream such as erosion problems, sedimentation or alteration in water flow rate.

3.13 CROCKFORD STREAM
(Nat. grid ref.: SZ 365973)



Topography:
Width: 1.9 m Depth: 0.06 m
Velocity: 0.24 m s^{-1}
Discharge: 0.027 m^3 s^{-1}
Substrate: bed - pebbles, gravel, silt; banks - pebbles, gravel, sand, silt; adjacent land - silt, clay

Water Chemistry:
pH: 7.24 Conductivity: 208 μs cm^{-1}
Calcium carbonate: 38.5 mg l^{-1}

Anions, mg l^{-1}:	Cations, mg l^{-1}:
Alkalinity 0.8	Calcium 18.8
Chloride 25.1	Magnesium 3.7
Sulphate 22.1	Sodium 12.8
Nitrate N 0.6	Potassium 0.5
Phosphate P 0.10	
Silicate Si 1.4	

Ion balance: 1.94 : 1.82 m.e.l.

Adjacent features:
Land use: arable
Upstream: arable
Downstream: pasture
Fishery interest: not known
Maintenance: none

Discussion:
The artificial left bank is shallow, and has been constructed using an earth/gravel mixture; slight erosion has occurred, resulting in a soil area within the channel which has become vegetated with both semi-aquatic and terrestrial plants. The right bank forms a large levee protecting the adjacent field; it is similar to the left bank, although it is steeper and shows a greater degree of erosion. Most of the erosion appears to be occurring on the existing levee, however, whereas the newly constructed levee resulting from the BP pipeline is quite well vegetated and is resisting erosion.

The terrestrial vegetation is moderately diverse (see Table 7), although many of these plants are ephemeral weeds. The aquatic vegetation is negligible, except for stands of *Callitriche* L. sp.

The construction of the pipeline does not appear to have resulted in any deleterious effects downstream such as erosion problems, sedimentation or alteration in water flow rate.

FIGURE 6. Map of Crockford Stream at the site of the oil pipeline crossing, showing location of major plant populations etc. BP = position of BP pipeline marker post; TG = terrestrial grasses. Dashed lines indicate position of artificial banks.

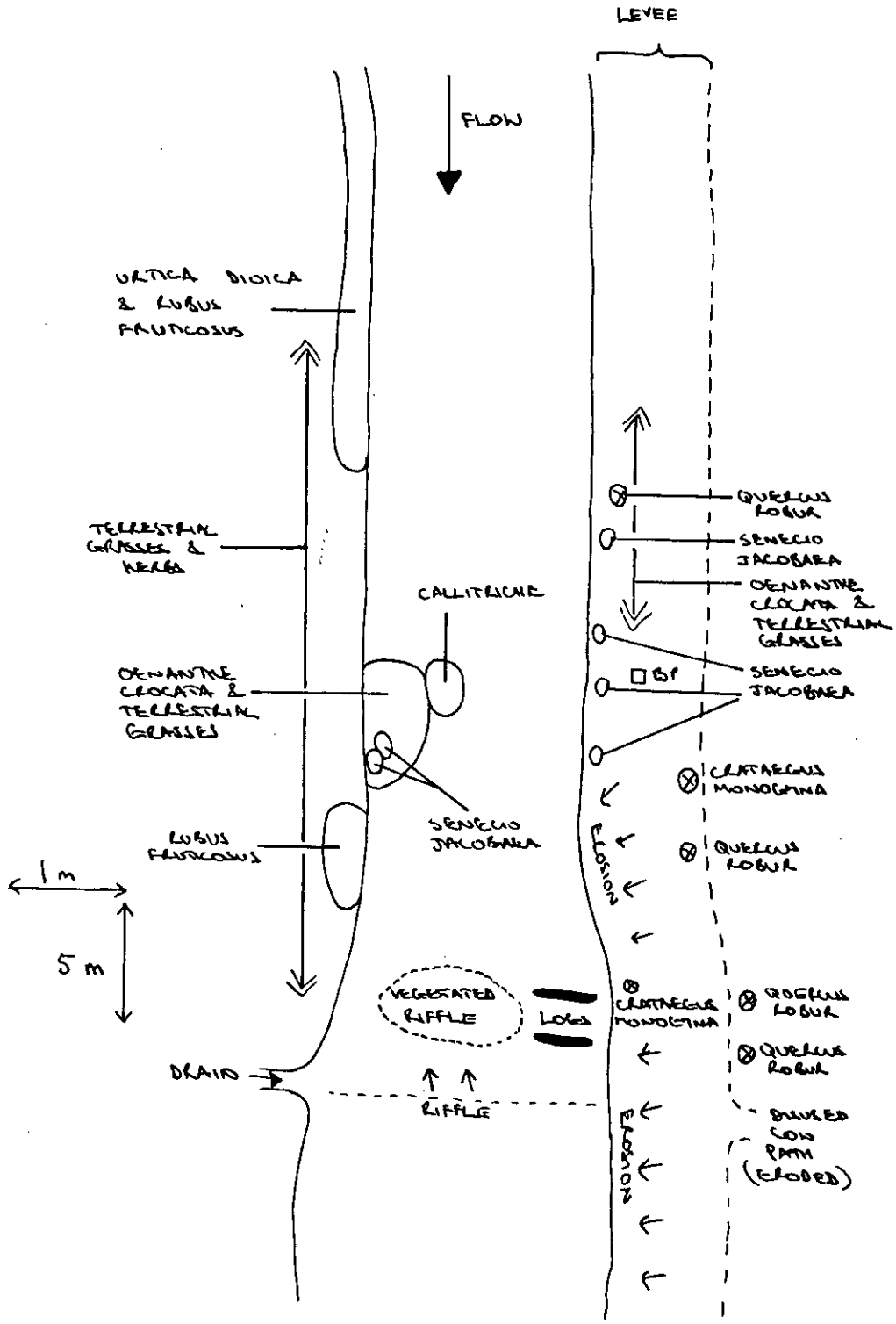
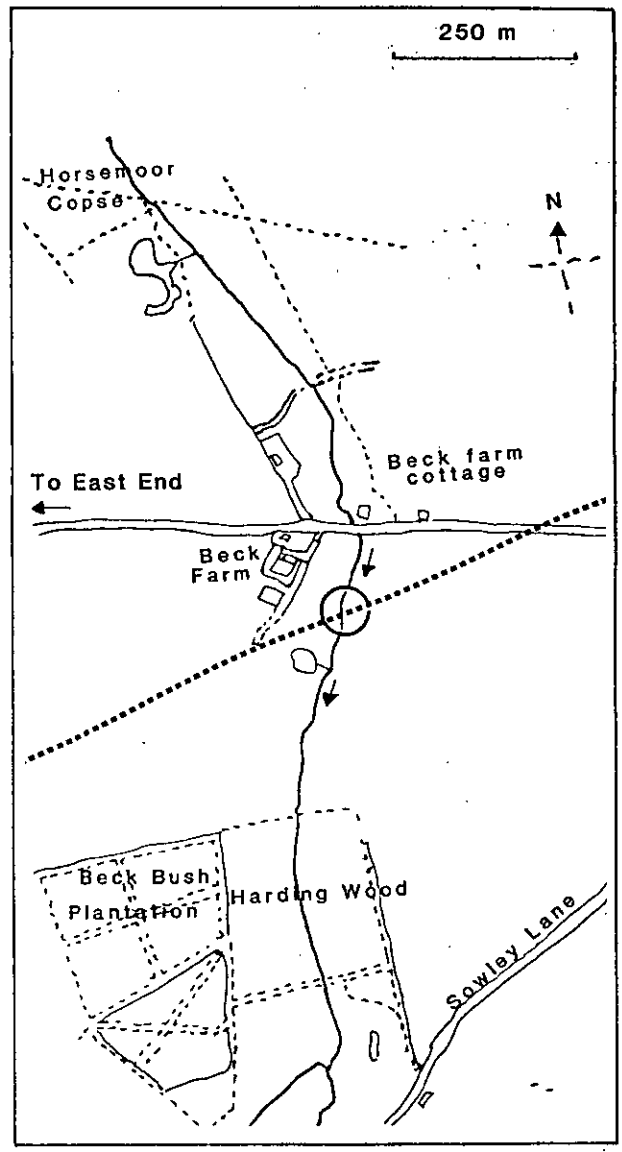


TABLE 7. List of species occurring at the Crockford Stream site in August 1991. Taxa listed alphabetically to species level where possible, with appropriate family and common names.

Achillea millefolium L. (Compositae)	Yarrow, Milfoil
Agrostis capillaris L. [synonym: *A. tenuis* Sibth.] (Gramineae)	Common bent-grass
Apium nodiflorum (L.) Lag. (Umbelliferae)	Fool's watercress
Bellis perennis L. (Compositae)	Daisy
Callitriche stagnalis Scop./*C. platycarpa* Kütz. (Callitrichaceae)	Water starwort
Callitriche c.f. *brutia* Petagna (Callitrichaceae)	Water starwort
Centaurium erythraea Rafn. (Gentianaceae)	Common Centaury
Circaea lutetiana L. (Onagraceae)	Common enchanter's nightshade
Crataegus monogyna Jacq. (Rosaceae)	Hawthorn
Epilobium palustre L. (Onagraceae)	Marsh willow-herb
Galium palustre L. (Rubiaceae)	Lesser marsh bedstraw
Geranium robertianum L. (Geraniaceae)	Herb-Robert
Hedera helix L. (Araliaceae)	Ivy
Ilex aquifolium L. (Aquifoliaceae)	Holly
Myosotis scorpioides L. (Boraginaceae)	Water forget-me-not
Nasturtium officinale R. Br. [synonym: *Rorippa nasturtium-aquaticum* (L.) Hayek] (Cruciferae)	Watercress
Oenanthe crocata L. (Umbelliferae)	Hemlock water-dropwort
Plantago major L. (Plantaginaceae)	Plantain
Polypodium vulgare L. (Polypodiaceae)	Polypody
Prunella vulgaris L. (Labiatae)	Selfheal
Quercus robur L. (Fagaceae)	Common oak, Pedunculate oak
Ranunculus acris L. (Ranunculaceae)	Meadow buttercup
Rubus L. sp. (Rosaceae)	Bramble
Rumex L. sp. (Polygonaceae)	Sorrel, Dock
Scrophularia auriculata L. (Scrophulariaceae)	Water figwort
Senecio jacobaea L. (Compositae)	Ragwort
Teucrium scorodonia L. (Labiatae)	Wood sage
Trifolium dubium Sibth. (Leguminosae)	Suckling clover, Lesser trefoil
Trifolium repens L. (Leguminosae)	White clover, Dutch clover
Urtica dioica L. (Urticaceae)	Stinging nettle

3.14 BECK FARM STREAM

(Nat. grid ref.: SZ 381977)



Topography:
Width: 1.3 m Depth: 0.28 m
Velocity: 0.05 m s^{-1}
Discharge: 0.018 m^3 s^{-1}
Substrate: bed - silt, pebbles & gravel; banks - soil; adjacent land - soil.

Water Chemistry:
pH: 6.82 Conductivity: 425 μs cm^{-1}
Calcium carbonate: 81.5 mg l^{-1}

Anions, mg l^{-1}:	Cations, mg l^{-1}:
Alkalinity 1.6	Calcium 53.6
Chloride 44.8	Magnesium 5.9
Sulphate 63.4	Sodium 15.8
Nitrate N 6.6	Potassium 8.7
Phosphate P 313	
Silicate Si 3.1	

Ion balance: 4.18 : 4.06 m.e.l.

Adjacent features:
Land use: pasture
Upstream: pasture
Downstream: pasture
Fishery interest: none
Maintenance: none, considerable previous maintenance

Discussion:
The entire stretch of the stream running alongside Beck Farm has previously been straightened and realigned. The artificial banks at the pipeline construction point appear to be constructed from soil, and not concrete bags; the angle of the right bank is markedly shallower than the left. There is erosion of the soil banks at several positions along the river, although this does not appear to be restricted to the pipeline construction zone.

The aquatic vegetation is dominated by *Nasturtium officinale* R. Br., which considerably reduces the water velocity and flow downstream. The riparian flora primarily consists of *N. officinale* and *Oenanthe crocata* L., with other large stands of *Urtica dioica* L., *etc.* Several small shrubs (including *Salix* L. sp. and *Ulex europaeus* L.) were found growing on the banks of the channel, suggesting that reasonable re-vegetation is occurring.

FIGURE 7. Map of Beck Farm Stream at the site of the oil pipeline crossing, showing location of major plant populations etc. BP = position of BP pipeline marker post; B/W = barbed wire fence. Dashed lines indicate position of artificial banks.

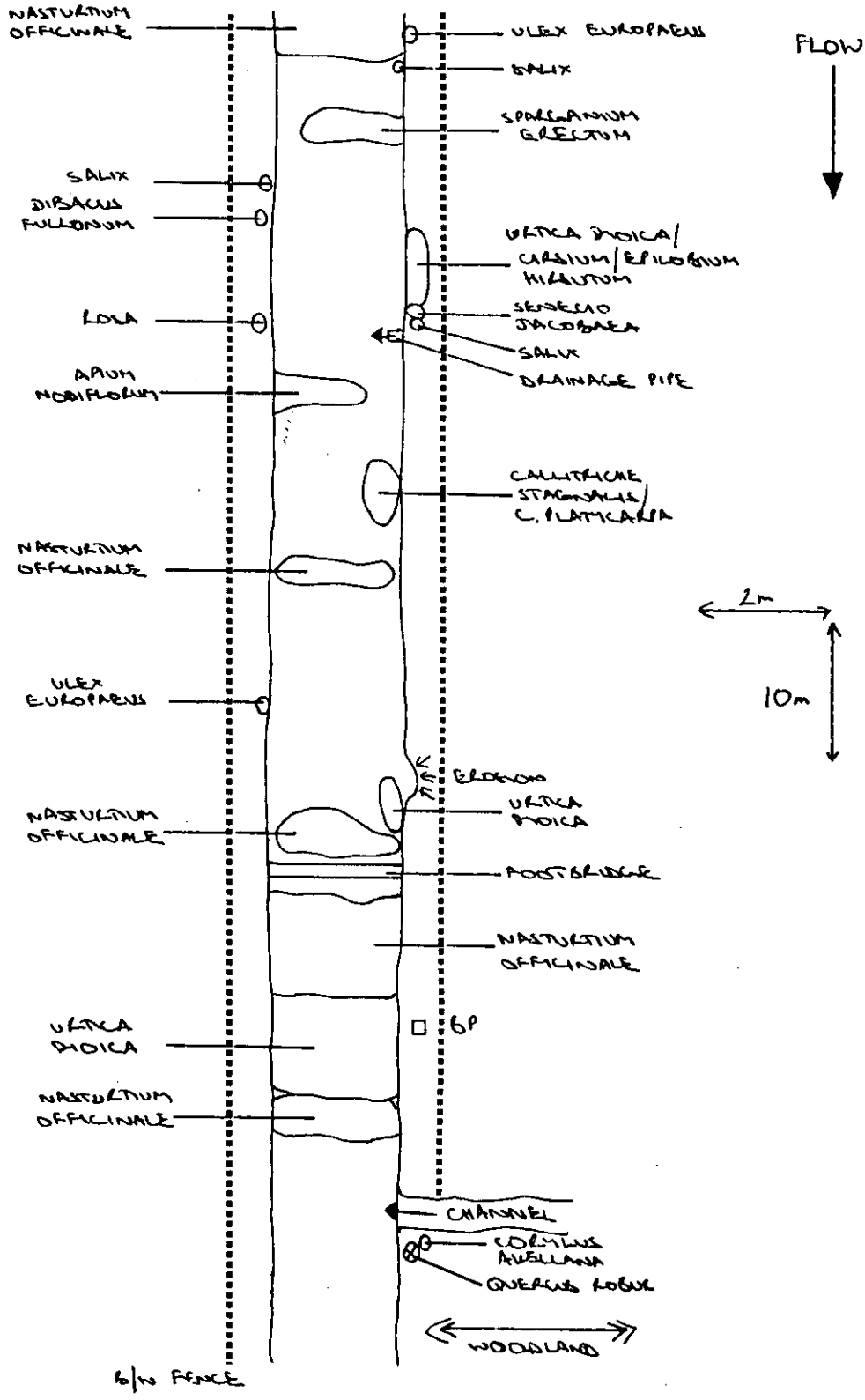
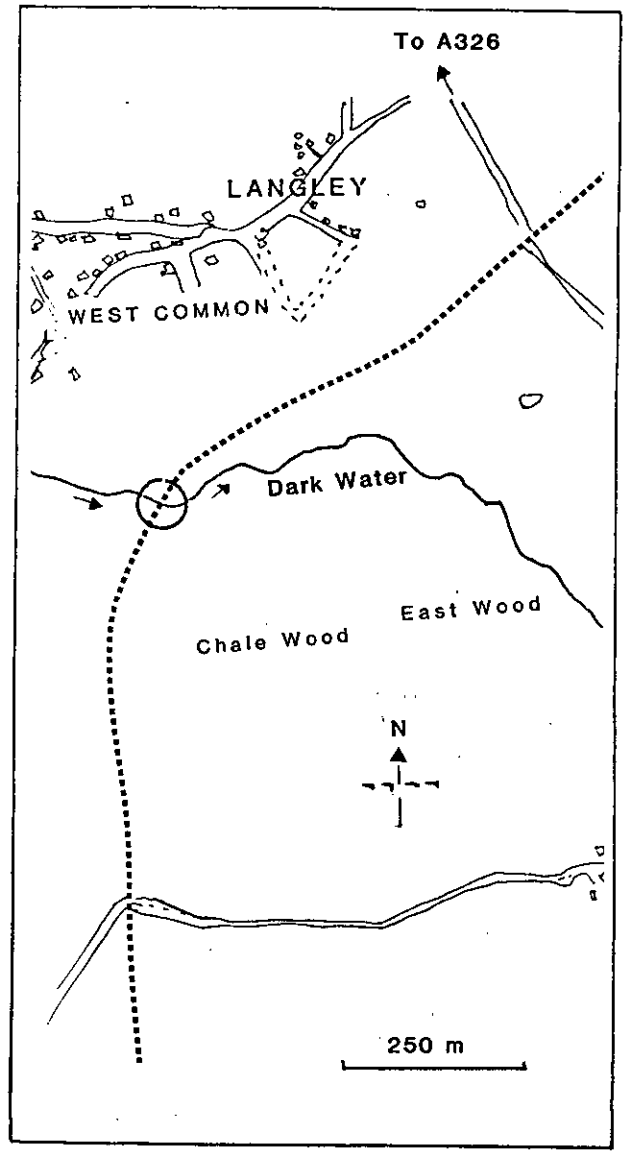


TABLE 8. List of species occurring at the Beck Farm Stream site in November 1991. Taxa listed alphabetically to species level where possible, with appropriate family and common names.

Achillea millefolium L. (Compositae)	Yarrow, Milfoil
Agrostis L. sp. (Gramineae)	Bent-grass
Alisma plantago-aquatica L. (Alismataceae)	Water-plantain
Apium nodiflorum (L.) Lag. (Umbelliferae)	Fool's watercress
Callitriche stagnalis Scop./*C. platycarpa* Kutz. (Callitrichaceae)	Water starwort
Cirsium Miller sp. (Compositae)	Thistle
Corylus avellana L. (Corylaceae)	Hazel
Crataegus monogyna Jacq. (Rosaceae)	Hawthorn
Dactylis glomerata L. (Gramineae)	Cock's-foot
Dipsacus fullonum L. (Dipsacaceae)	Wild teasel
Epilobium hirsutum L. (Onagraceae)	Great hairy willow-herb
Eupatorium cannabinum L. (Compositae)	Hemp-agrimony
Galium aparine L. (Rubiaceae)	Goosegrass, Cleavers
Hieracium L. sp. (Compositae)	Hawkweed
Ligustrum vulgare L. (Oleaceae)	Common privet
Mentha aquatica L. (Labiatae)	Water mint
Nasturtium officinale R. Br. [synonym: *Rorippa nasturtium-aquaticum* (L.) Hayek] (Cruciferae)	Watercress
Oenanthe crocata L. (Umbelliferae)	Hemlock water-dropwort
Plantago major L. (Plantaginaceae)	Plantain
Pteridium aquilinum (L.) Kuhn (Hypolepidaceae)	Bracken
Quercus robur L. (Fagaceae)	Common oak, Pedunculate oak
Rosa L. sp. (Rosaceae)	Wild rose
Rubus fruticosus sensu lato (Rosaceae)	Blackberry, Bramble
Rumex L. sp. (Polygonaceae)	Sorrel, Dock
Salix L. sp. (Salicaceae)	Willow
Solanum dulcamara L. (Solanaceae)	Woody nightshade
Sparganium erectum L. (Sparganiaceae)	Branched bur-reed
Ulex europaeus L. (Leguminosae)	Furze, Gorse
Urtica dioica L. (Urticaceae)	Stinging nettle

3.15 DARK WATER

(Nat. grid ref.: SU 440006)



Topography:
Width: 1.95 m Depth: 0.197 m
Velocity: 0.179 m s^{-1}
Discharge: 0.069 m^3 s^{-1}
Substrate: bed - silt; banks - soil; adjacent land - soil

Water Chemistry:
pH: 7.07 Conductivity: 346 μs cm^{-1}
Calcium carbonate: 55.0 mg l^{-1}

Anions, mg l^{-1}:	Cations, mg l^{-1}:
Alkalinity 1.1	Calcium 32.4
Chloride 25.9	Magnesium 4.9
Sulphate 45.1	Sodium 20.5
Nitrate N 2.0	Potassium 1.3
Phosphate P 0.05	
Silicate Si 3.8	

Ion balance: 2.77 : 2.94

Adjacent features:
Land use: pasture (left bank) and wasteland (right bank)
Upstream: copse
Downstream: copse
Fishery interest: none
Maintenance: none

Discussion:
The artificial banks have been constructed from soil (possibly laid over concrete bags, although these are not visible). The banks are highly vegetated with ephemeral weedy species, and mainly *Impatiens glandulifera* Royle and *Rumex* L. sp. The top of the left bank has been replanted with a hawthorn hedgerow (*Crataegus nonogyna* Jacq.), although the area is largely dominated by *Impatiens glandulifera.*

The aquatic vegetation is almost totally dominated by large stands of *Callitriche* L. sp., which is able to grow because of the lack of shading; this will inevitably have affected the flow rate dowmstream.

FIGURE 8. Map of Dark Water at the site of the oil pipeline crossing, showing location of major plant populations etc. BP = position of BP pipeline marker post; TG = terrestrial grasses. Dashed lines indicate position of artificial banks.

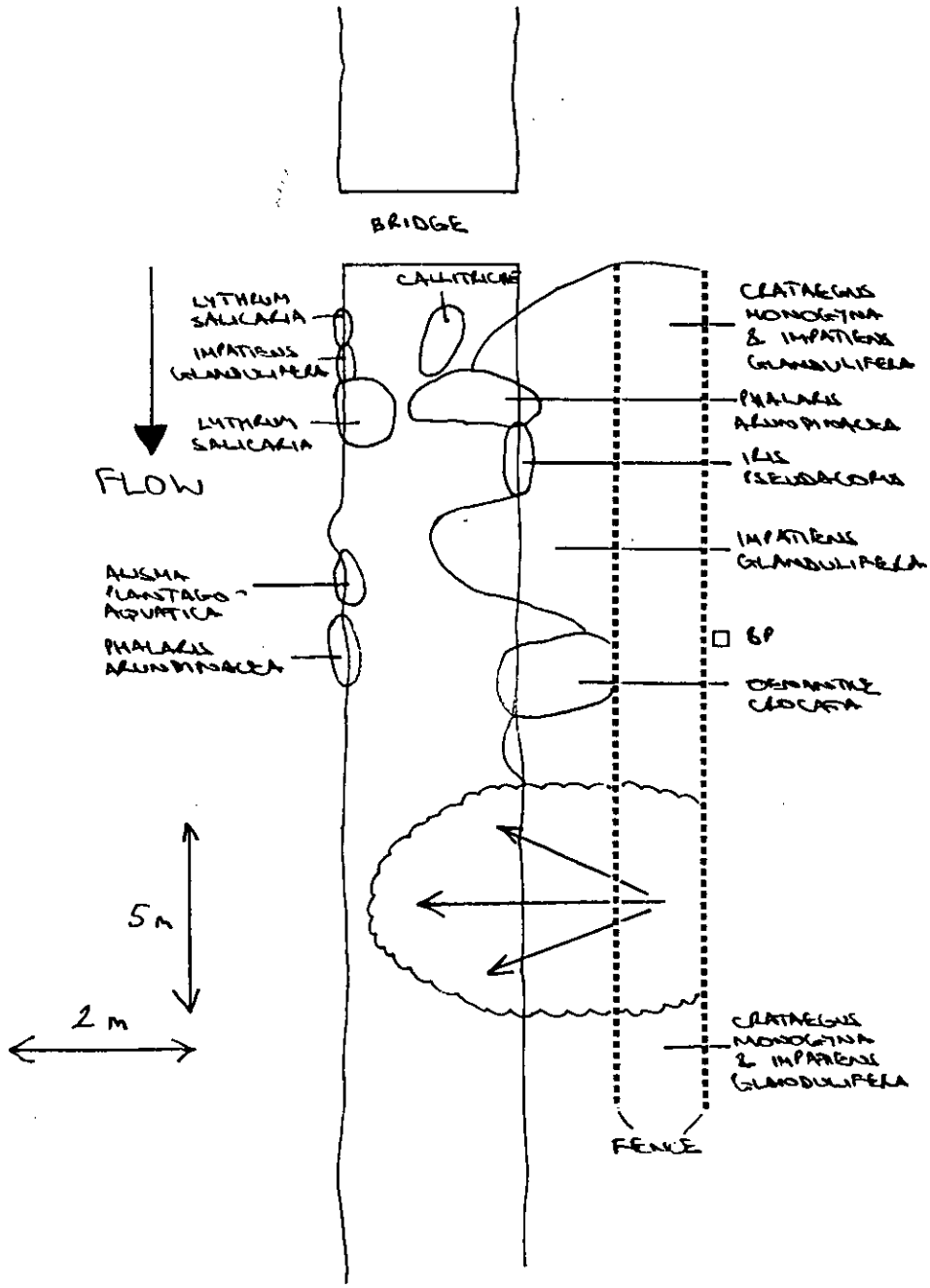
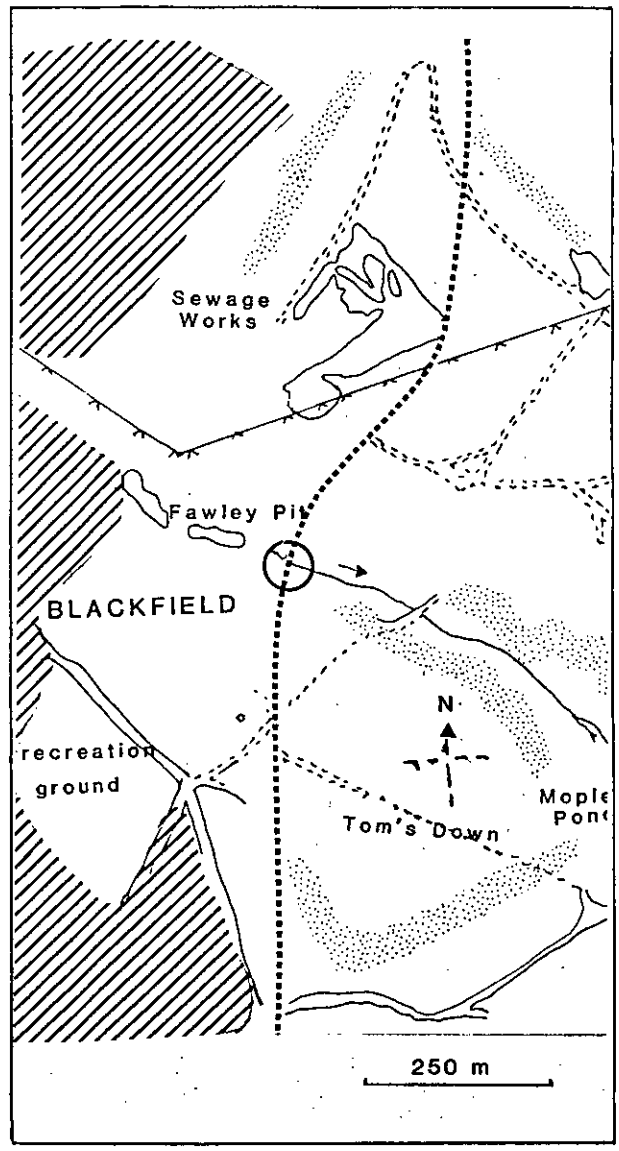


TABLE 9. List of species occurring at the Dark Water site in August 1991. Taxa listed alphabetically to species level where possible, with appropriate family and common names.

Agrostis capillaris L. [synonym: *A. tenuis* Sibth.] (Gramineae)	Common bent-grass
Alisma plantago-aquatica L. (Alismataceae)	Water-plantain
Callitriche c.f. *brutia* Petagna (Callitrichaceae)	Water starwort
Callitriche stagnalis Scop./*C. platycarpa* Kütz. (Callitrichaceae)	Water starwort
Calystegia sepium (L.) R. Br. (Convolvulaceae)	Belbine, Hedge bindweed
Cirsium Miller sp. (Compositae)	Thistle
Digitalis purpurea L. (Scrophulariaceae)	Foxglove
Galium aparine L. (Rubiaceae)	Goosegrass, Cleavers
Galium palustre L. (Rubiaceae)	Marsh bedstraw
Impatiens glandulifera Royle (Balsaminaceae)	Indian balsam
Iris pseudacorus L. (Iridaceae)	Yellow iris, Yellow flag
Juncus L. sp. (Juncaceae)	Rush
Lotus corniculatus L. (Leguminosae)	Common birdsfoot-trefoil
Lysimachia vulgaris L. (Primulaceae)	Yellow loosestrife
Lythrum salicaria L. (Lythraceae)	Purple loosestrife
Mentha aquatica L. (Labiatae)	Water mint
Oenanthe crocata L. (Umbelliferae)	Hemlock water-dropwort
Oenanthe fluviatilis (Bab.) Coleman (Umbelliferae)	River water-dropwort
Petasites fragrans (Vill.) C. Presl (Compositae)	Winter heliotrope
Phalaris arundinacea L. (Gramineae)	Reed-grass
Pulicaria dysenterica (L.) Bernh. (Compositae)	Fleabane
Quercus robur L. (Fagaceae)	Common oak, Pedunculate oak
Ranunculus acris L. (Ranunculaceae)	Meadow buttercup
Ranunculus flammula L. (Ranunculaceae)	Lesser spearwort
Rubus L. sp. (Rosaceae)	Bramble
Rumex L. sp. (Polygonaceae)	Dock, Sorrel
Salix L. sp. (Salicaceae)	Willow
Sambucus nigra L. (Caprifoliaceae)	Elder
Scrophularia auriculata L. (Scrophulariaceae)	Water figwort
Stachys palustris L. (Labiatae)	Marsh woundwort
Urtica dioica L. (Urticaceae)	Stinging nettle
Veronica anagallis-aquatica L. (Scrophulariaceae)	Blue water-speedwell
Veronica beccabunga L. (Scrophulariaceae)	Brooklime

3.16 MOPLEY POND STREAM
(Nat. grid ref.: SZ 450021)



Topography:
Width: 0.5 m Depth: 0.1 m
Velocity: negligible
Discharge: negligible
Substrate: bed - boulders and solid bedrock; banks - soil; adjacent land - soil

Water Chemistry:
pH: 8.89 Conductivity: 785 $\mu s\ cm^{-1}$
Calcium carbonate: 108.5 mg l^{-1}

Anions, mg l^{-1}:	Cations, mg l^{-1}:
Alkalinity 2.2	Calcium 69.6
Chloride 141.5	Magnesium 5.7
Sulphate 50.0	Sodium 80.6
Nitrate N 0.1	Potassium 4.4
Phosphate P 12.9	
Silicate Si 4.5	

Ion balance: 7.20 : 7.56 m.e.l.

Adjacent features:
Land use: quarry & conifer plantation
Upstream: quarry
Downstream: pond
Fishery interest: none
Maintenance: negligible

Discussion:
The Mopley Pond Stream is very small, and flows over large boulders and solid bedrock into a large and stagnant pond. Both the stream and the pond are polluted with a surface layer of oil (or possibly bacteria), which has probably originated from the quarry immediately upstream. There is very little aquatic vegetation in the stream due to the nature of the substratum. The artificial banks of the stream at the crossing point are very tall but are earthen and are therefore able to sustain a considerable degree of re-vegetation. The flora of the right bank is largely restricted to weedy species, although a blackthorn (*Prunus spinosa* L.) hedgerow has been planted. The left bank has numerous gorse shrubs (*Ulex europaeus* L.), which are also possibly planted. Some of the stinging nettles (*Urtica dioica* L.) were observed to have the parasitic dodder *Cuscuta europaea* L. growing on them; this is a rare plant which is believed to be decreasing in Britain (Clapham *et al.*, 1987: 365-366).

The pond immediately downstream of the crossing point is also very species poor, although a small number of *Callitriche* L. plants were observed. The marginal vegetation was dominated by bulrushes (*Typha latifolia* L.).

The construction of the pipeline does not appear to have resulted in any deleterious effects downstream such as erosion problems, sedimentation or alteration in water flow rate.

FIGURE 9. Map of Mopley Pond Stream at the site of the oil pipeline crossing, showing location of major plant populations etc. BP = position of BP pipeline marker post; B/W = barbed wire fence.

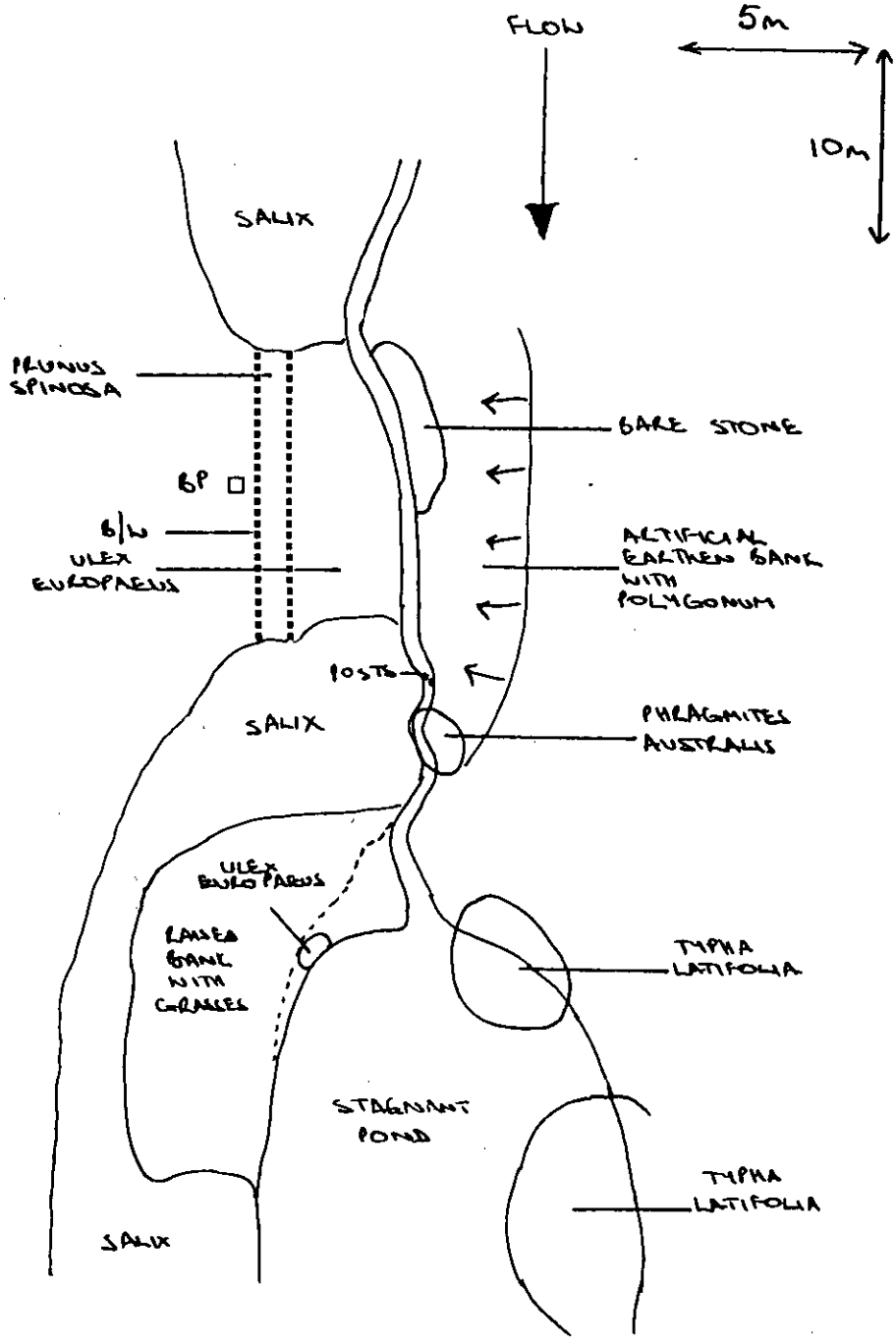


TABLE 10. List of species occurring at the Mopley Pond Stream site in November 1991. Taxa listed alphabetically to species level where possible, with appropriate family and common names.

Achillea millefolium L. (Compositae)	Yarrow, Milfoil
Alisma plantago-aquatica L. (Alismataceae)	Water-plantain
Alopecurus geniculatus L./*A. pratensis* L. (Gramineae)	Marsh Foxtail/Meadow Foxtail
Callitriche platycarpa Kütz. (Callitrichaceae)	Water starwort
Cirsium Miller sp. (Compositae)	Thistle
Cuscuta europaea L. (Convolvulaceae)	Greater dodder
Dipsacus fullonum L. (Dipsacaceae)	Wild teasel
Epilobium hirsutum L. (Onagraceae)	Great hairy willow-herb
Juncus c.f. *compressus* Jacq. (Juncaceae)	Round-fruited rush
Lotus corniculatus L. (Leguminosae)	Common birdsfoot-trefoil
Mentha aquatica L. (Labiatae)	Water mint
Molinia caerulea (L.) Moench. (Gramineae)	Purple moor-grass
Myrica gale L. (Myricaceae)	Bog myrtle, Sweet gale
Oenanthe crocata L. (Umbelliferae)	Hemlock water-dropwort
Petasites fragrans (Vill.) C. Presl (Compositae)	Winter Heliotrope
Phragmites australis (Cav.) Trin. ex Steudel [synonym: *P. communis* Trin.] (Gramineae)	Common reed
Plantago lanceolata L. (Plantaginaceae)	Ribwort plantain
Potentilla anserina L. (Rosaceae)	Silverweed
Prunus spinosa L. (Rosaceae)	Blackthorn, Sloe
Quercus robur L. (Fagaceae)	Common oak, Pedunculate oak
Ranunculus c.f. *acris* L. (Ranunculaceae)	Meadow buttercup
Rubus fruticosus sensu lato (Rosaceae)	Bramble
Rumex L. sp. (Polygonaceae)	Sorrel, Dock
Salix L. sp. (Salicaceae)	Willow
Scrophularia auriculata L. (Scrophulariaceae)	Water figwort
Senecio jacobaea L. (Compositae)	Ragwort
Solidago virgaurea L. (Composiate)	Golden-rod
Sphagnum L. (Sphagnaceae)	Sphagnum
Stachys palustris L. (Labiatae)	Marsh woundwort
Typha latifolia L. (Typhaceae)	Bulrush, Cat's-tail
Ulex europaeus L. (Leguminosae)	Furze, Gorse
Urtica dioica L. (Urticaceae)	Stinging nettle

4. DISCUSSION

4.1 Erosion at crossing points

The artificial channels at the pipeline crossing points have been constructed so that bends in the river have been avoided. This largely prevents problems of bank erosion that result from the altering of the water flows. One example of this type of erosion in the sites examined, however, is Uddens Water, which appears to have slight erosion occurring immediately downstream of the artificial bank; this is possibly due to drainage from the adjacent field, however, and further erosion will be prevented by a large concrete block which has been laid into the margin.

Most of the sites examined have artificial banks that are apparently constructed using concrete filled bags. The Ripley Brook and Danes Stream sites are showing erosion of the river bed substrate immediately beneath the lowermost concrete bags; this is loosening the bags, and will ultimately result in collapse of the entire bank. It is possible that all other sites constructed using concrete filled bags will become subject to this form of erosion. A similar pattern of erosion was observed at the Avon Water Tributary site, where erosion is occurring beneath the artificial banks constructed from stone.

The pipeline crossing at Furzebrook Stream has been constructed using boulders overlaid with a two-inch wire mesh and topsoil. The soil layer has largely eroded, however, and numerous gaps are consequently developing between the boulders. The potential collapse of the bank is prevented by the wire mesh and by the relatively shallow gradient at which it has been constructed; the erosion is preventing revegetation by any plants other than weedy ephemeral species.

The only other form of erosion commonly encountered during the site visits was due to farming activity. This was largely due to cattle drinking from the rivers at the crossing points and causing soil poaching; this occurs where the obstructing vegetation has been removed during construction, and was observed at Uddens Water, Plummers Water and Crockford Stream. Crockford Stream also shows erosion of the artificial levee along the right bank; this was only observed upstream and downstream of the crossing point, however,

and the levee that was built during the pipeline construction appears to be resisting erosion.

4.2 Reinstatement of vegetation at crossing points

Most of the pipeline crossing sites have artificial banks that have been constructed using concrete filled bags, forming an almost vertical face. This means that the bank cannot sustain a layer of topsoil, and as a consequence revegetation is virtually impossible. This is found at the following sites: River Piddle, Wareham Forest Drain, Uddens Water, Ripley Brook, Walkford Brook, Danes Stream, Avon Water Tributary and Passford Water. Although some sites, such as the River Piddle crossing, are aesthetically improved by terrestrial plants that are overhanging and obscuring the concrete bags, this is not generally the case.

The limited re-vegetation that was found in the terrestrial and riparian environments was generally restricted to ephemeral weeds, including species of: *Achillea*, *Agrostis*, *Anagallis*, *Anthriscus*, *Centaurium*, *Cirsium*, *Convolvulus*, *Epilobium*, *Equisetum*, *Galium*, *Hieracium*, *Hypericum*, *Impatiens*, *Lamium*, *Lapsana*, *Lotus*, *Polygonum*, *Polypodium*, *Potentilla*, *Prunella*, *Pteridium*, *Pulicaria*, *Ranunculus*, *Rumex*, *Scrophularia*, *Scutellaria*, *Senecio*, *Solanum*, *Stachys*, *Stellaria*, *Symphytum*, *Taraxacum*, *Teucrium*, *Trifolium*, *Urtica*, and *Veronica*.

4.3 Downstream consequences

The environmental changes resulting from pipeline crossings of fluvial systems not only affect the immediate vicinity of the construction spread, but also have serious repercussions downstream (Brookes, 1988). Many of these effects, including the risk of flooding, are not a serious consideration for the small river and stream sites studied in the present report. Other effects such as the impact on geomorphology and biology are important, however.

The potential morphological impacts include scour at the tail-end of the concrete banks. This creates problems of sediment deposition, which was especially marked at the Ripley Brook, Walkford Brook, Danes Stream, Avon Water Tributary, Passford Water and Dark Water sites. The effects of sedimentation are very significant, and include:

(1) a direct effect on fish and other aquatic fauna (references in Brookes, 1988);

(2) the smothering of plants, reducing photosynthetic rates;
(3) the creation of anaerobic conditions around roots;
(4) the alteration of the nutrient status of the water; and
(5) the morphological simplification of the substrate.

The construction work will also alter riffle-pool sequences downstream of the crossing point, affecting the environmental habitats available for the aquatic flora and fauna. Removal of trees and shrubs and the consequent reduction in shading encourages the growth of aquatic weeds such as *Callitriche* L., which will alter water flows and again affect the aquatic habitat.

The consequences of this will be an alteration of the ecological balance of the sites, and a reduction in the taxonomic diversity of both plants and animals.

4.4 Re-examination of selected sites originally surveyed in 1990

Of the sites surveyed by Dawson & Westlake (1991), the following five reportedly showed the poorest degree of re-vegetation and morphological bank reinstatement: Corfe River, River Stour, River Allen, Moors River and Lymington River. These sites were re-examined during July 1992 as part of the present study. A visual assessment of the degree of erosion and re-vegetation was achieved by walking both banks and taking notes and photographs of the crossing point and the adjacent land. Comparisons between this information and the results obtained by Dawson & Westlake (1991) enabled an assessment of the current condition of the site and recommendations for potential bank reinstatement. The following results were obtained:

Corfe River: No noticeable bank erosion; this is partly due to the use of a raised stone substrate along the river margins, reducing water depth and flow (and hence stream power). Banks well re-vegetated, with many *Scrophularia nodosa* L. (Common Figwort) plants.

River Stour: No significant bank erosion apparent, although some poaching of soil by cattle. Banks well re-vegetated, with large stands of *Phragmites australis* (Cav.) Trin. ex

Steudel (Common Reed) and *Phalaris arundinacea* L. (Reed-grass) on both banks. Rich aquatic vegetation at pipeline crossing point, dominated by *Potamogeton* L. sp. (Pondweed), *Sparganium emersum* Rehmann (Unbranched Bur-reed) and *Nuphar lutea* (L.) Sm. (Yellow Water-lily).

River Allen: No significant bank erosion apparent. Concrete bags visible along most of both artificial banks, preventing re-vegetation; upper length of artificial right bank is well re-vegetated, however. Not well re-vegetated behind artificial banks.

Moors River: Left bank well re-vegetated, although with slight slumping of soil. Right bank heavily poached by cattle; this has disturbed the rocks used for bank stabilisation, and has prevented good re-vegetation.

Lymington River: No erosion evident. Both banks well re-vegetated with *Alisma plantago-aquatica* L. (Water-plantain), *Epilobium* L. sp. (Willow-herb), *Myosotis scorpioides* L. (Water Forget-me-not) and *Phalaris arundinacea* L. (Reed-grass), although considerable numbers of the weed *Senecio jacobaea* L. (Ragwort) also present. There is a large riffle at the crossing point, with deeper and faster flowing water along the right bank.

Although the River Allen site shows poor re-vegetation, the remaining sites are all acceptable. None of the sites require bank reinstatement.

5. RECOMMENDATIONS

The use of concrete filled bags for the construction of artificial river banks is widespread. Its use often causes erosion of the substratum, however, beneath the lowermost layer of bags. Several of the sites studied have been highlighted as exhibiting unacceptable levels of this pattern of erosion, *viz.* Ripley Brook, Danes Stream and the Avon Water Tributary; it is recommended that these sites be further reinstated.

The concrete bags used are generally constructed so that the angle of the artificial bank is similar or steeper than that of the natural bank upstream and downstream of the pipeline crossing point. The consequence of this is that topsoil cannot be maintained over the artificial bank surface, and this severely restricts the degree of re-vegetation that is possible. Although reducing the angle of the artificial bank would be beneficial is this respect, it would possibly create an unnatural appearance following re-vegetation.

There are several alternative procedures that could be adopted to avoid the problem of erosion and to encourage more rapid re-vegetation. One option would be the use of a wall of earth-filled hessian bags along the outermost face of the bank, strengthened by a layer of concrete-filled bags a pre-determined distance behind. This would enable a limited degree of lateral movement in the river. The soil used to fill the bags could be obtained *on-site* from the appropriate level; this would enable the re-vegetation to include many of the natural plants present in the dormant 'seed bank' of the soil. As the hessian bags degrade, the soil layer will become consolidated by the roots of this natural vegetation. The use of a mixture that would provide greater strength than pure soil would be a further means of ensuring bank stability; this might be an important consideration for use in critical stretches of the river where erosion is predicted.

An alternative option would be the use of an artificial matting to maintain a layer of soil over the bank face; these geotextiles are made from biodegradable plant materials laid over a photodegradable polymer mesh which would provide the necessary protection from erosion until the establishment of plants. The geotextiles can be manufactured with seeds incorporated in them to promote the rapid establishment of plants (*e.g.* 'Greenfix'). The

seeds that can be incorporated in the matting can be chosen to complement the particular environment being created. It is suggested that seeds of the following plants could be used: *Carex* L. species (sedges) including *C. riparia* Curtis and *C. acutiformis* Ehrh.; *Juncus* L. species (rushes); *Glyceria maxima* (Hartm.) Holmb. (reed sweet-grass); and *Phalaris arundinacea* L. (reed-grass). These species produce close growth which would help consolidate the banks, and are also natural vegetation plants which are typical of the pipeline crossing sites. In addition, the shorter grasses *Agrostis stolonifera* L. var. *palustris* (Huds.) Farw. (marsh bent) and *Poa trivialis* L. (rough meadow grass) grow in wet habitats and are stoloniferous and would therefore also help bind the soil of the river bank (Hubbard, 1984). Other grasses which could possibly be included in the matting are *Alopecurus geniculatus* L. (marsh fox-tail) and *Deschampsia cespitosa* (L.) Beauv. (tufted hair-grass).

Although many of the sites on the Purbeck-Southampton pipeline route lack significant bank vegetation as a result of the use of concrete bags, bank reinstatement to alleviate this problem alone is not regarded as necessary. The problem of erosion of the artificial banks is more critical, however: as noted above, the Ripley Brook, Danes Stream and Avon Water Tributary sites are recommended for further bank reinstatement.

In future bank reinstatement work, consideration should be given to the use of alternative techniques, such as those outlined above. It is important that these techniques are critically evaluated using rivers of different sizes, cross-sectional profiles, substrate types, *etc.* Full evaluation would enable the most appropriate reinstatement technique to be employed for specific environments; this would not only enhance the environmental quality of the site, but would also reduce the expenditure currently required in the maintenance and reinstatement of sites that are deteriorating.

ACKNOWLEDGEMENTS

We are grateful to Paul Henville, Cheryl Case and Peter Sage for assistance with the field work, and for drawing the site location maps.

REFERENCES

BROOKES, A. 1988. *Channelized Rivers: Perspectives for Environmental Management.* John Wiley, Chichester, 326 pp.

CLAPHAM, A.R., TUTIN, T.G. & MOORE, D.M. 1987. *Flora of the British Isles.* 3rd ed. Cambridge Univ. Press, Cambridge, 688 pp.

DAWSON, F.H., BASS, J.A.B., HENVILLE, P., LADLE, M. & WESTLAKE, D.F. 1987. *Purbeck-Southampton Pipeline. The Assessment of the Effects of Pipeline Construction on the Biology and Related Physical Parameters Around the Crossing Points of Selected Rivers, Streams and Ditches with Advice on Reinstatement. Interim Report.* Unpublished report to BP Petroleum Development Ltd., 42 pp.

DAWSON, F.H., MANN, R.H.K. & WESTLAKE, D.F. 1986b. *The Rivers along the Purbeck-Southampton Pipeline Route. On-site Assessment of the Possible Environmental Effects of Construction on Fish and Flora at the Probable Crossing Points of the Rivers.* Unpublished report to BP Petroleum Development Ltd., 23 pp.

DAWSON, F.H., WELTON, J.S., HENVILLE, P., LADLE, M. & WESTLAKE, D.F. 1989a. *Purbeck-Southampton Pipeline - Report of On-Site Monitoring During Construction and Post-Construction Surveys. Volume 1.* Unpublished report to BP Petroleum Development Ltd., 35 pp.

DAWSON, F.H., WELTON, J.S., HENVILLE, P., LADLE, M. & WESTLAKE, D.F. 1989b. *Purbeck-Southampton Pipeline - Report of On-Site Monitoring During Construction and Post-Construction Surveys. Volume 2 - Appendices 1-3.* Unpublished report to BP Petroleum Development Ltd., 137 pp.

DAWSON, F.H. & WESTLAKE, D.F. 1991. *Purbeck-Southampton Pipeline - Report of Botanical, Morphological and Reinstatement Post-Construction Surveys.* Unpublished report to BP Petroleum Development Ltd., 81 pp.

DAWSON, F.H., WRIGHT, J.F. & MANN, R.H.K. 1986a. *The Rivers along the Purbeck-Southampton Pipeline Route. A Compilation of Available Environmental Information Relating to the Probable Crossing Points of the Rivers.* Unpublished report to BP Petroleum Development Ltd., 35 pp.

HASLAM, S.M., SINKER, C.A. & WOLSELEY, P.A. 1975. British water plants. *Field Stud.* 4: 243-351.

HUBBARD, C.E. 1984. *Grasses. A Guide to their Structure, Identification, Uses and Distribution in the British Isles.* 3rd ed. Penguin Books, Harmondsworth, 476 pp.


Natural
Environment
Research
Council