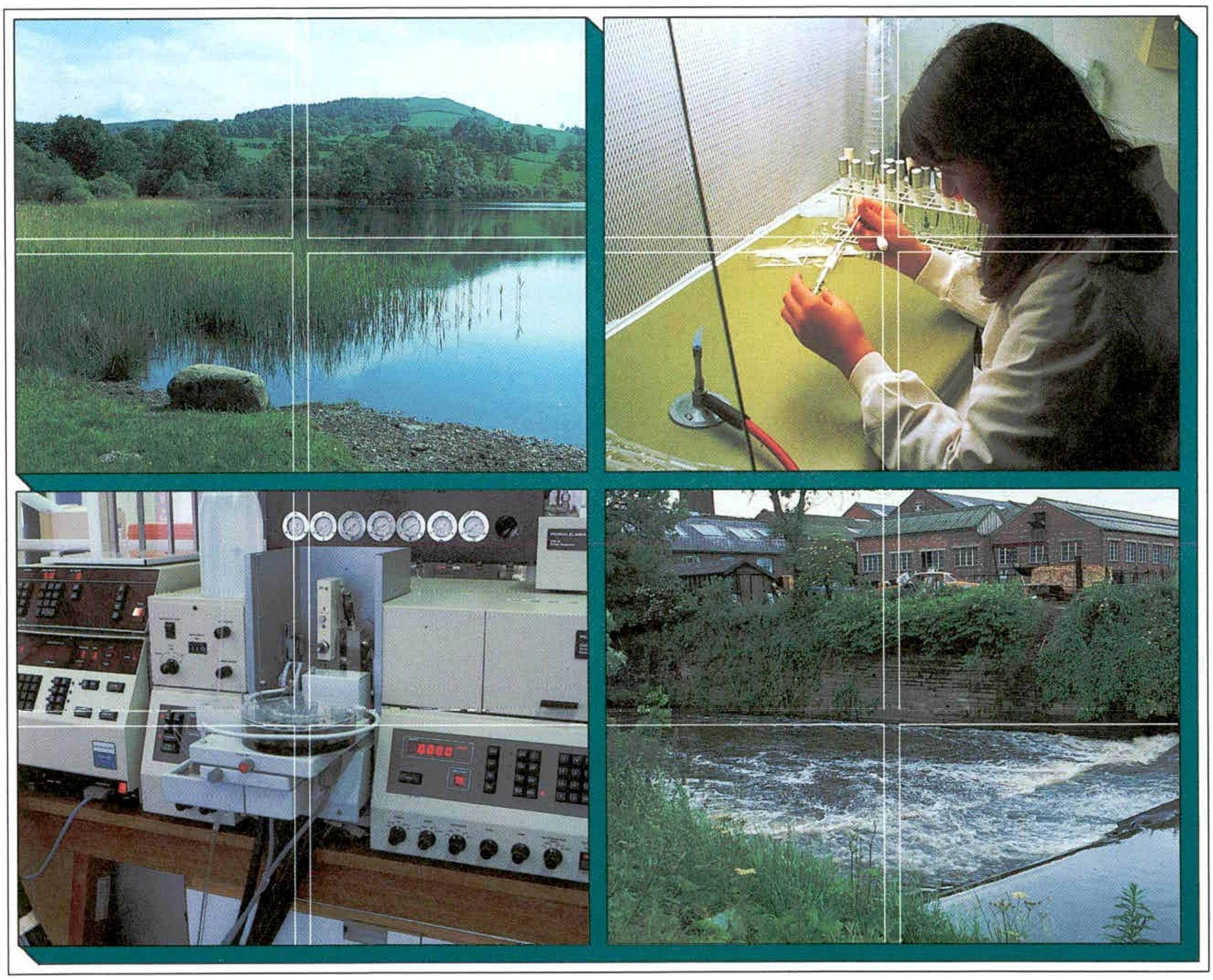
Institute of Freshwater Ecology

# Proposed upgrading of sewage treatment works in Wales: assessment of the likely effects on the quality of stream waters receiving the effluents.

## Phase II: assessment of the zone of effect of the outfalls.

Project Manager: A E Bailey-Watts

Report to the Welsh Water PLC



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**PROPOSED UPGRADING OF SEWAGE TREATMENT WORKS IN WALES: ASSESSMENT OF THE LIKELY EFFECTS ON THE QUALITY OF STREAM WATERS RECEIVING THE EFFLUENTS. Phase II: Assessment of the zone of effect of the outfalls**

Project Manager: A E Bailey-Watts

Report to the Welsh Water plc
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## Abstract

The dispersion of soluble reactive phosphorus (SRP) in 46 Welsh streams receiving sewage treatment works (STWs) effluent is used to assess the zone of effect of the discharges. Fifteen of the sites are situated in the South-East region of the Welsh Water plc area, 10 in the South-West and 21 in the North.

Crude estimates of the dilution of effluent were obtained from the SRP concentrations recorded and from measurements (with a miniature pulse meter) of the discharge of the effluent, and the flow of the streams at points a few metres upstream of the outfall, and at 1 m, 10 m, 20 m and 50 m downstream of the pipe. Occasional samples for SRP were paired with collections for BOD determinations.

The patterns of SRP spread vary considerably between the sites, but the usual hot spots are found at only one or two points, or there is evidence of the waste water keeping to one stream bank, for example. In comparing the conditions found at the different sites, it was useful to consider 4 main types of situation. In one, the effluent elevates the stream levels of SRP by only a few-fold at most, over the background values (and usually only at localised points) primarily because the effluent SRP is relatively dilute e.g. 500 $\mu g\ l^{-1}$. In another situation, effluents with a high SRP content are involved e.g. > 10 mg $l^{-1}$, but due to dilution by the receiving stream, the effects are also minor. A third situation sees order-of-magnitude increases in stream SRP as a result of the discharges, but these still represent 30- to 40-fold dilution of the effluent. The final situation is exemplified by sites where extremely rich effluents of > 10 mg SRP $l^{-1}$ enter relatively small, 'pristine' waters, such that the in-stream concentrations are raised by more than 100-fold. These assessments are based on a comparison of background levels with the maximum concentrations detected downstream of the discharges. In all but a very few 'major effect-concentrated effluent' sites the effects are extremely localised. Indeed, the maximum SRP concentration at 1 m below the outfall is generally less than 5 times that measured upstream of the pipe.

The relationship between SRP and BOD has been explored. While for one site (i.e. one STW-receiving stream combination) some 90% of the variation in BOD can be associated with the variation in SRP, this has been found not to be the case where measurements from different sites are combined.

On the basis of the SRP dispersion data, but also taking account of e.g. accessibility of the site, and the presence of road works that might affect the streams, 30 sites are selected for the invertebrate work, and these are listed in an Appendix.

# 1. INTRODUCTION

## 1.1 Background to Phase II of the study and aims of the work

This document investigates the dispersion ('zone of effect' - ZoE) of effluent discharging from 46 sewage treatment works (STWs), to assess the most suitable site and locations for sampling the invertebrate assemblages, in order to gauge water quality in Welsh streams receiving treated sewage effluent,. The work comprises the second part of a report aimed at assessing the affects of discharges of sewage on stream water quality in Wales, following the publication of the Kinnersley Report which proposes that BOD consents on all such discharges should not exceed 50 mg $l^{-1}$. This is in the light of many of the present works in Wales operating according to consents of > 50 mg $l^{-1}$ and in some cases > 300 mg $l^{-1}$. To upgrade these works, an expenditure of *ca* £12 M has been estimated. The present study would enable Welsh Water plc to adjudge the necessity for upgrading, regardless of the high consents. In general, it is felt that the current operating standards are acceptable, because the majority of works discharge into fast-flowing streams - bringing about rapid and marked dilution; moreover, they quickly reach the sea. Indeed, the report on Phase I of the study which decided which sites should be visited for the ZoE work, supports this view; much of the recorded range of BOD levels adjusted for dilution by stream water, and relating to effluents from works meeting consents of between 100 and 300 mg BOD $l^{-1}$ (ie 0.001 to 80 mg $l^{-1}$) - overlaps with that for situations where consents as low as 50 mg $l^{-1}$ are met (ie 0.1 to 25 mg $l^{-1}$).

## 1.2 Approaches adopted

The ZoE work uses the soluble reactive phosphorus (SRP) constituent of the works effluents, as the main 'tracer' at each site. However, a number of the SRP samples are paired with collections of water for the more complex analysis of BOD, in order to explore the possibility of predicting BOD from SRP. This is because effluent quality and STW consents (as discussed in the report on Phase I of this work - Bailey-Watts *et al*, 1991) are determined as BOD, not SRP.

## 1.3 Scope and structure of the report

The geographical distribution of the works visited, field measurements, and the dispersion of the sites sampled on the streams receiving the discharges, are outlined in Section 2, along with a description of the methods used for analysing SRP and BOD. The results - in Section 3 - are described with reference mainly to the findings from the SRP dispersion work. The selection of the 30 sites for invertebrate analysis is described in Section 4, while the main elements of this biological work (which comprises Phase III of the study) are enumerated in Section 5.

## 2. FIELD AND LABORATORY METHODS

### 2.1 General considerations

With the view to exploring the dispersion of effluent at *ca* 60 sites, the 78 sites listed in Appendix I were selected, as described in the report on the the first part of this study. This number was reduced to 61 in consultation with Welsh Water staff, who identified as unsuitable for the investigation, tidal sites and sites where soakaways rather than piped systems existed. In the event, although all 61 sites were visited, only 46 were sampled - as indicated in Appendix I; the shortfall of 15 corresponds to works found to be closed or inaccessible, for example. Of the 46, 15 are located in the South-East region of the Welsh Water area, 10 in the South-West region and 21 in the North.

### 2.2 Field measurements and dispersion of sampling points

Water for chemical analysis was taken at all sites - from (i) the effluent itself, and (ii) the stream at each of 3 points (mid-way and at points half-way between this and each bank) at up to 5 m above the point of discharge, and at 1 m, 10 m, 20 m and usually 50 m, below this point. At a few sites, the receiving stream joined another course within 50 m of the entry of the effluent; Llanwrthwl on a tributary of the Wye is an example. Where the receiving stream channel was less than 1 m wide, a single sample per 'transect' was taken.

At each sampling point, a sub-surface dip was taken with a 0.5-litre, wide-mouth jar and a 150-ml subsample was transferred to a polyethylene bottle for SRP analysis. This sample was shaken, and a proportion was filtered with a plastic syringe connected to Nuclepore filter-holder with a 2.5-cm diameter GF/C grade Whatman filter disc. The filtrate was transferred to a 15-ml polypropylene centrifuge tube, which had been filled with distilled water until use. Water was collected for BOD analysis at each point sampled for SRP at 2 locations - Saighton and Dobshill - and at a single point upstream of the STW discharge point, and from the effluent itself, at each of another 25 sites. For this, 1-litre polyethylene bottles were used. The Saighton and Dobshill samples were transported to the Windermere Laboratory of IFE where the analyses were done the day after sampling. The BOD samples collected from the other sites, were stored in the dark and kept as cool as possible, until the end of the trip, when they were also taken to the Windermere Laboratory.

A photograph was taken and a sketch made of each stream system, in order that major alterations to the site between this and subsequent visits could be recorded. An estimate of effluent discharge rate was also obtained, except at the few sites where there was virtually no flow, or where the opening of the effluent pipe was under water. The time taken to fill a 1-litre jug, or 5-litre bucket was recorded for small pipes. In the case of larger conduits, a 'Braystoke' miniature flow (pulse) meter was used, and the dimensions and fullness of the pipe noted. Stream flow was estimated with the same current meter. The total width and depth of these water courses at the banks, and at one quarter, one half and three quarters width at each transect, were recorded. Current velocities were measured at a 'suitable' site, at half-depth at the quarter, half and three-quarter points. Flows were than calculated using the velocity-area method as described by the British Standards Institution(1964).

Temperature, conductivity and pH were measured at each site with a Corning 'Check Mate' probe system.

### 2.3 Laboratory analyses

Soluble reactive P was determined by absorption spectroscopy, using the method of Mullin and Riley (1964) involving the formation of a phospho-molybdate complex. BOD analyses followed the procedures recommended by HMSO (1981).

## 3. RESULTS

### 3.1 Zones of influence of STW discharges as indicated by the distribution of phosphate

The pattern of distribution of SRP varied considerably between the sites. **Figure 1** illustrates this with examples of 4 types of situation as regards (i) the effect of the effluent on the stream concentrations, and (ii) these concentrations expressed as a percentage of the effluent values.

**Figure 1a** displays data from Rhyd Uchaf where the effluent elevates the stream SRP levels by only 2-fold - and even then only locally near the outfall; in this case the maximum concentration is equivalent to only 8% of the effluent value of 600 $\mu g\ l^{-1}$. Other sites like this include (i) Glewstone where stream SRP levels are equivalent to *ca* 30% of the effluent concentration (550 $\mu g\ l^{-1}$) both upstream and downstream of the outfall, and (ii) Llanwrthwl, with 640 $\mu g$ SRP $l^{-1}$ of effluent which effects a localised trebling of the background stream levels, but to values equivalent to < 2% of that in the outfall. An albeit extreme example of the 'minor effect-dilute effluent' situation is Bronaber with an effluent SRP of < 50 $\mu g\ l^{-1}$ raising the background levels in the receiving stream (*ca* 13 $\mu g\ l^{-1}$) to only 16 $\mu g\ l^{-1}$.

Sites at Much Dewchurch, Llanwnan Lower and Capel Bangor (the latter being referred to in **Figure 1b**) provide examples of a situation where the effluent SRP levels are among the highest recorded (13-19 **mg** $l^{-1}$), but the effect on the receiving stream is not major, because of high dilution; thus, while the rich outfall at Capel Bangor effects localised increases - to values equivalent to *ca* 6% of the effluent concentration, and 20 to 30 times greater than the natural stream values - the levels at 50 m downstream suggest a 70-fold dilution, and the values are only 4 or 5 times those measured above the outfall.

The third situation identified relates to major effects of quite weak effluents, in that maximum SRP concentrations measured below the outfalls - however localised these 'hot spots' are - still represent order-of-magnitude increases over the natural stream levels. **Figure 1c** uses data from Bethesda (where the receiving water course joined another system within 20 m of the STW outfall) to illustrate an example where the effluent values are *ca* $10^3$ SRP $l^{-1}$. Note that in this case the elevated phosphate concentrations are equivalent to a minor percentage of the effluent content; in the extreme case of the 'major effect-dilute effluent' situation, ie at Dolwyddelan, the effluent (of only 170 $\mu g$ SRP $l^{-1}$) appears to keep to one bank and raises the stream concentrations to 8% of this effluent value at least as far as 50 m downstream of the outfall.

The extreme case within the fourth situation category - 'major effect-concentrated effluent' - is that of Ruardean Woodside (**Figure 1(d)**). The effluent from this works is extremely rich (*ca* 16 mg SRP $l^{-1}$), while the SRP in the receiving stream - which is very small -above the outfall is very dilute, ie 4.3 $\mu g\ l^{-1}$ in this case. As a result, at the point *ca* 1 m below the pipe, and near the bank where that pipe is situated, the SRP levels were raised some 800-fold. A similar situation prevails at Friog where although by comparison with Ruardean Woodside, the effluent SRP is low - *ca* 7 mg $l^{-1}$ - the receiving stream concentrations are raised (from a background level of *ca* 7 $\mu g\ l^{-1}$) 170-fold just below the outfall, 30-fold by 10 m downstream, and still 20-fold at 20 m, although 7-fold by 50 m.

In concluding this section, it is emphasised that in the large majority of cases, the effect of the STWs discharges on the receiving waters has been deliberately over-stated. This is because the changes in stream/river SRP concentrations have been assessed on the basis of how the background levels, (ie those measured at points upstream of the outfalls) compare with the maximum concentrations found over the grid of up to 12 sampling points below the works. In all but a few of the extreme 'major effect-concentrated effluent' sites, the effect is very localised. Even though the initial selection of these sites biased towards 'minimum dilution' situations, the sample as a whole is still dominated by fairly 'benign' works. **Figure 2** shows that at the majority of sites, the maximum ratio of the phosphate concentration measured at 1 m below the outfall to those found upstream of the pipe, is < 5:1; only 5 sites produced ratios of > 50:1 at 1 m, and by 10 m only 2 sites exceeded this ratio (Ruardean Woodside and Dobshill). Interestingly, Dobshill exhibited an increase in SRP levels passing from 1 m below the discharge to 10 m (**Figure 3**).

### 3.2 The relationship between BOD and phosphate

The relationships found between these two indices of the treated sewage content of the waters, varied between the different sample sets. The data for Dobshill exhibited a strong relationship, with some 90% of the variation in (log) BOD values being associated with the variation in (log) SRP concentrations (**Figure 4**) - and that association includes the datum corresponding to the effluent itself (3710 $\mu g$ SRP $l^{-1}$), which had a large residual. By contrast, the equivalent data set for Saighton (with an effluent SRP concentration of 2344 $\mu g\ l^{-1}$) showed no clear relationship. There was a reasonably clear association between log-transformed values of SRP and BOD in the effluents of 12 sites sampled on the second 'zone of effect' field trip, but no relationship between these determinands in the comparatively dilute samples taken above the outfalls (**Figure 5**).

## 4. SELECTION OF SITES FOR BIOLOGICAL ANALYSIS

The major criteria used in selecting a site for invertebrate work relate to the issues discussed in Section 3.1, ie the actual SRP content of the effluent, the concentrations it effects at various points along the receiving water course, and how these concentrations compare with the background levels in the streams. Indeed, of the 12 sites highlighted for one reason or another in the discussions on phosphate, 9 are included in the list of 30 sites to be visited for the zoobenthos assessments (Appendix 2). The 3 sites not selected from the 12 already referred to, are (i) Rhyd Uchaf which was geographically remote and a 'dilute' site like many others that were included, (ii) Bronaber, another dilute site but in this instance affected by major reconstruction work, and (iii) Dobshill which, although a rich site, was one likely to be affected considerably by a recently-constructed dual carriageway nearby. The other major factor that determined whether a site was selected for the biological work, related to the availability of substrates suitable for invertebrate sampling.

Even having taken all of these types of factors into account, the final sample of 30 sites covers the broad spectrum of conditions indicated by the initial examination of the whole 'population' of *ca* 200 STWs with BOD consents of $\geq 100$ mg $l^{-1}$, described in the report on Phase I of this study (Bailey-Watts *et al* 1991). So, it includes situations where the effluent SRP concentrations have exceeded 10 mg $l^{-1}$ and discharge into watercourse varying considerably in flow, and sites where more moderate SRP levels in the effluents prevail, but where these may also discharge into a relatively small stream ('low dilution') or large river ('high dilution').

## 5. THE MAIN ELEMENTS OF THE INVERTEBRATE STUDIES (Phase III)

Naturally, the macro-invertebrate benthos is the main focus of this phase of the work. Samples are to be taken at 3 points across the streams receiving the STWs effluents, at each of the following places:

- a few metres upstream of the outfall
- well within the zone of effect of the discharge, as defined by the SRP dispersion patterns discussed in Section 3.1
- at a point beyond this zone.

It is likely that the zone of effect will vary with changing conditions of stream flow and the phosphate and/or BOD concentrations of the effluents as well as the streams themselves. For this reason, water for SRP analysis will also be taken at the invertebrate sampling points, and from the effluents.

## 6. REFERENCES

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## 7. ACKNOWLEDGEMENTS

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Appendix 1. The 78 sites originally considered for the zone of effect studies, including the 46 actually sampled (s) and another 15 visited (v).

| WWA no. | region | STW name | receiving water |
|---|---|---|---|
| 230 v | SE | ABBEYDORE | DORE RIVER TRIB. |
| 234 | SE | ORCOP-COPWELL EST | GARREN BROOK TRIB. |
| 235 v | N | BARTON-CODDINGTON LANE | PLOWLEY BROOK TRIB. |
| 239 s | SE | GLEWSTONE-WILSON BROOK | LUKE BROOK |
| 240 s | SW | LLANWNEN LOWER | GRANNELL AFON |
| 242 s | N | FRIOG | MAWDDACH RIVER TRIB. |
| 246 v | N | PENRHOS SMALL | PENRHOS AFON TRIB. |
| 247 v | SE | LLANGYBI | USK RIVER |
| 248 s | N | SAIGHTON | POWSEY BROOK TRIB. |
| 250 s | SE | RUARDEAN-WOODSIDE | GREATHOUGH BROOK |
| 251 | SE | ST OWENS CROSS | GARREN BROOK TRIB. |
| 252 | SE | WESTON-U-PENYARD DAIRY COTTAGES | RUDHALL BROOK TRIB. |
| 255 | N | CAPEL GARMON | EYARTH AFON TRIB. |
| 260 v | SE | NEWLAND | VALLEY BROOK |
| 262 s | N | PISTYLL | PENISAR LON |
| 264 s | SW | CAPEL BANGOR | MELINDWR AFON TRIB. DITCH |
| 267 s | SW | CASTLEMORRIS | WESTERN CLEDDAU TRIB. |
| 268 s | N | TYDDYN HYWEL | UNNAMED STREAM |
| 269 | SE | ACTON BEAUCHAMP [GREEN] | FROME RIVER TRIB. |
| 275 s | N | HUGMORE LANE | DEVON BROOK |
| 276 s | SE | BUILTH ROAD | DULAS BROOK |
| 280 | N | CORNIST HALL | NANT-Y-FFLINT TRIB. |
| 289 | N | EYTON | DEE RIVER TRIB. |
| 297 s | SE | LLANWRTHWL | WYE RIVER TRIB. |
| 302 s | N | CLOCAENOG | CLWYD RIVER TRIB. |
| 303 s | N | CLUTTON-TATTENHALL | CARDEN BROOK |
| 304 | N | CLYNNOG FAWR | UNNAMED STREAM |
| 305 s | N | CROESOR 3 | CROESOR |
| 310 v | N | GAERWEN | CEFNI RIVER |
| 312 s | N | GRAIANRHYD | TERRIG RIVER TRIB. |
| 317 v | N | KINNERTON LOWER | PULFORD BROOK TRIB. |
| 319 s | N | LLANBRYNMAIR | LAEN |
| 327 s | N | PENTREFELIN (GLAN CONWY) | NANT Y GARREG DDU |
| 329 s | N | RHYDUCHAF | ABERDULDOG NANT |
| 330 v | N | SEION 1 NEW | NANT Y GARTH TRIB. |
| 331 s | N | TRAWSFYNYDD | PRYSOR AFON |
| 333 s | SE | ABERBAIDEN | USK RIVER |
| 336 | SE | BWLCH [NORTH] | LLYNFI RIVER |
| 342 s | SE | DEVAUDEN | PILL BROOK TRIB. |
| 348 s | SE | LLANDEGLEY | MITHIL BROOK |
| 353 s | SE | LLANSOY | PILL BROOK |
| 363 | SE | PONTSTICILL [VILLAGE] | TAFF FECHAN |
| 366 s | SE | ST FAGANS | ELY RIVER |
| 380 s | SW | GLOGUE | TAF AFON |
| 381 | SW | HUNDLETON | PEMBROKE RIVER |
| 386 | SW | UZMASTON | WESTERN CLEDDAU TRIB. |
| 388 s | N | GWYDDELWERN | CAMDDWR |
| 390 v | N | LLANGEFNI | CEFNI |
| 392 s | SE | FELINDRE | FELINDRE BROOK |
| 393 s | SE | LLANGARRON (HERBERTS HILL) | LLANERCH BROOK TRIB. |
| 398 s | SW | CARWAY | GWENDRAETH FAWR TRIB. |
| 399 s | N | BRONABER | EDEN RIVER |
| 403 v | N | LLANFOR | DEE RIVER |
| 404 s | N | MELIN-Y-COED | NANT Y GORON |
| 405 s | SE | RUARDEAN | LODGEGROVE BROOK TRIB. |
| 410 | N | CAER ESTYN | PULFORD BROOK TRIB. |
| 411 s | N | DOBSHILL | BROUGHTON BROOK TRIB. |
| 412 s | N | DOLWYDDELAN | LLEDR AFON |

| | | | | |
|---|---|---|---|---|
| 413 | s | N | LLANEFYDD | FFYNNON NEFYDD |
| 414 | s | SE | MUCH DEWCHURCH | WORM BROOK |
| 415 | s | SE | OLD DROPE | NANT Y DROPE |
| 418 | s | N | BETHESDA | OGWEN RIVER |
| 421 | | N | CEFN MAWR | DEE RIVER |
| 425 | s | N | TILSTON | CARDEN BROOK TRIB. |
| 426 | v | N | TREGARTH | OGWEN |
| 428 | | SE | CEFN COED | TAFF FAWR |
| 429 | s | SE | LIBANUS | TARELL |
| 430 | v | SE | LITTLE DEWCHURCH | WRIGGLE BROOK TRIB. |
| 433 | s | SE | PIPE & LYDE | LUGG RIVER TRIB. |
| 435 | s | SE | WALFORD (COUGHTON PLACE) | WALFORD BROOK |
| 438 | s | SW | CILYCWM | GWENLAS AFON |
| 439 | | SW | FFAIRFACH | TYWI AFON |
| 441 | s | SW | LLANFARIAN | YSTWYTH AFON |
| 442 | v | SW | LLANYBYTHER | TEIFI AFON |
| 443 | s | SW | PENPARC | RHYD Y FUWCH NANT |
| 444 | s | SW | PONTRHYDYCEIRT | MORGENAU AFON |
| 445 | | SW | RHOSCROWTHER | ANGLE BAY-TRIB. |
| 447 | v | SW | TREGARON | TEIFI AFON |

Appendix 2. The 30 sites selected for water quality evaluation by invertebrate analysis.

| WWA no. | region | STW name | receiving water |
|---|---|---|---|
| 239 | SE | GLEWSTONE-WILSON BROOK | LUKE BROOK |
| 240 | SW | LLANWNAN LOWER | GRANNELL AFON |
| 242 | N | FRIOG | MAWDDACH RIVER TRIB. |
| 248 | N | SAIGHTON | POWSEY BROOK TRIB. |
| 250 | SE | RUARDEAN-WOODSIDE | GREATHOUGH BROOK |
| 262 | N | PISTYLL | PENISAR LON |
| 264 | SW | CAPEL BANGOR | MELINDWR AFON TRIB. DITCH |
| 268 | N | TYDDYN HYWEL | UNNAMED STREAM |
| 275 | N | HUGMORE LANE | DEVON BROOK |
| 276 | SE | BUILTH ROAD | DULAS BROOK |
| 297 | SE | LLANWRTHWL | WYE RIVER TRIB. |
| 302 | N | CLOCAENOG | CLWYD RIVER TRIB. |
| 305 | N | CROESOR 3 | CROESOR |
| 312 | N | GRAIANRHYD | TERRIG RIVER TRIB. |
| 331 | N | TRAWSFYNYDD | PRYSOR AFON |
| 342 | SE | DEVAUDEN | PILL BROOK TRIB. |
| 348 | SE | LLANDEGLEY | MITHIL BROOK |
| 380 | SW | GLOGUE | TAF AFON |
| 392 | SE | FELINDRE | FELINDRE BROOK |
| 398 | SW | CARWAY | GWENDRAETH FAWR TRIB. |
| 404 | N | MELIN-Y-COED | NANT Y GORON |
| 405 | SE | RUARDEAN | LODGEGROVE BROOK TRIB. |
| 412 | N | DOLWYDDELAN | LLEDR AFON |
| 413 | N | LLANEFYDD | FFYNNON NEFYDD |
| 414 | SE | MUCH DEWCHURCH | WORM BROOK |
| 425 | N | TILSTON | CARDEN BROOK TRIB. |
| 438 | SW | CILYCWM | GWENLAS AFON |
| 441 | SW | LLANFARIAN | YSTWYTH AFON |
| 443 | SW | PENPARC | RHYD Y FUWCH NANT |
| 444 | SW | PONTRHYDYCEIRT | MORGENAU AFON |

**FIGURES**

**Figure 1(a)** The dispersion of SRP at Rhyd Uchaf, to illustrate a situation where the discharge of dilute effluent results in only minor, and localised elevations of the levels in the receiving watercourse

effluent dispersion: SRP as % of effluent conc.(*)
above, and upto 50m below outfall
SITE=Rhyd Uchaf (*600μg/1)

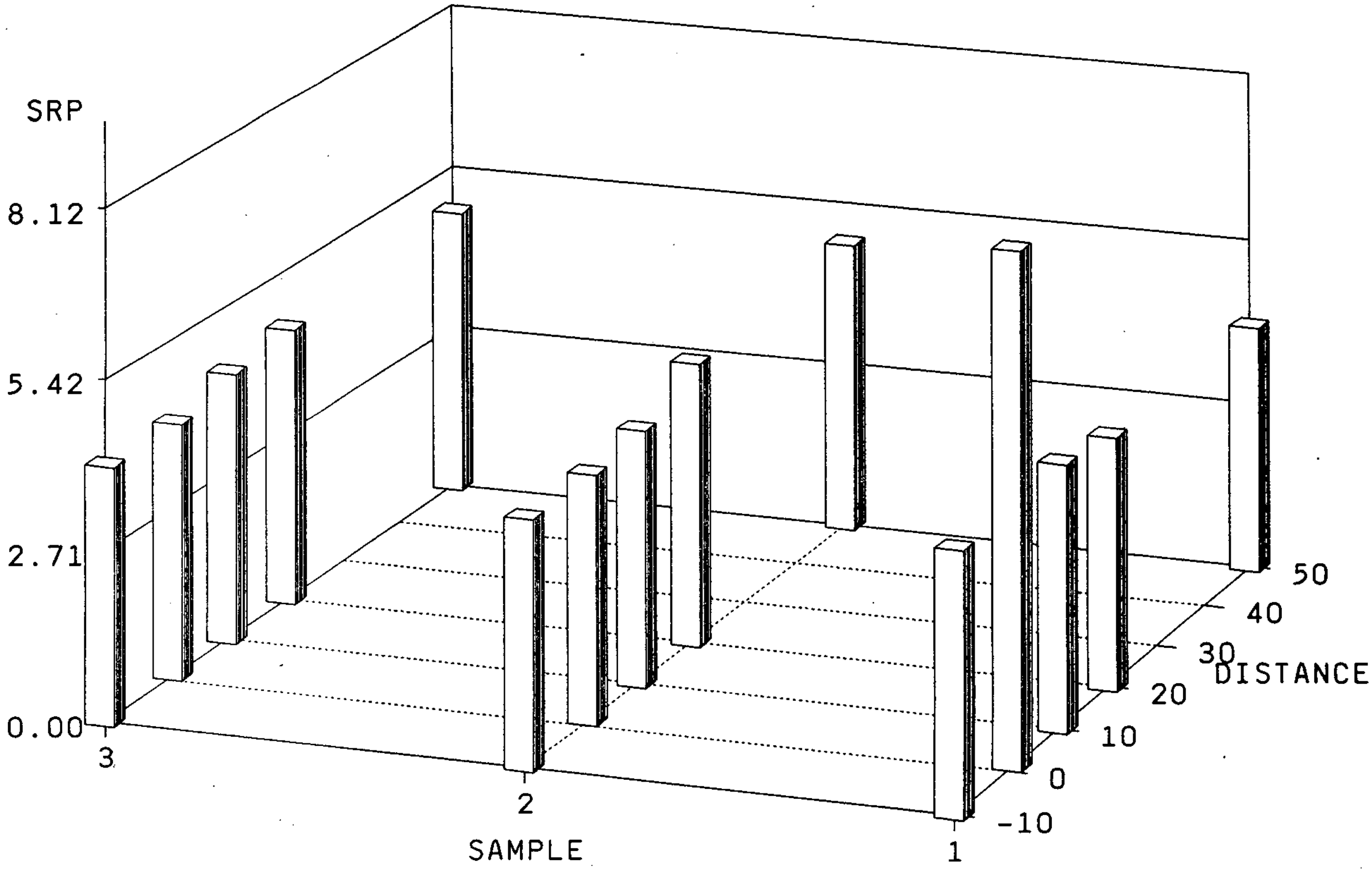


**Figure 1(b)** As Figure 1(a) for a site where the effluent is very rich in SRP

Effluent dispersion: SRP as % of effluent conc.(*)
above, and upto 50m below outfall
SITE=Capel Bangor (*13080 µg/1)

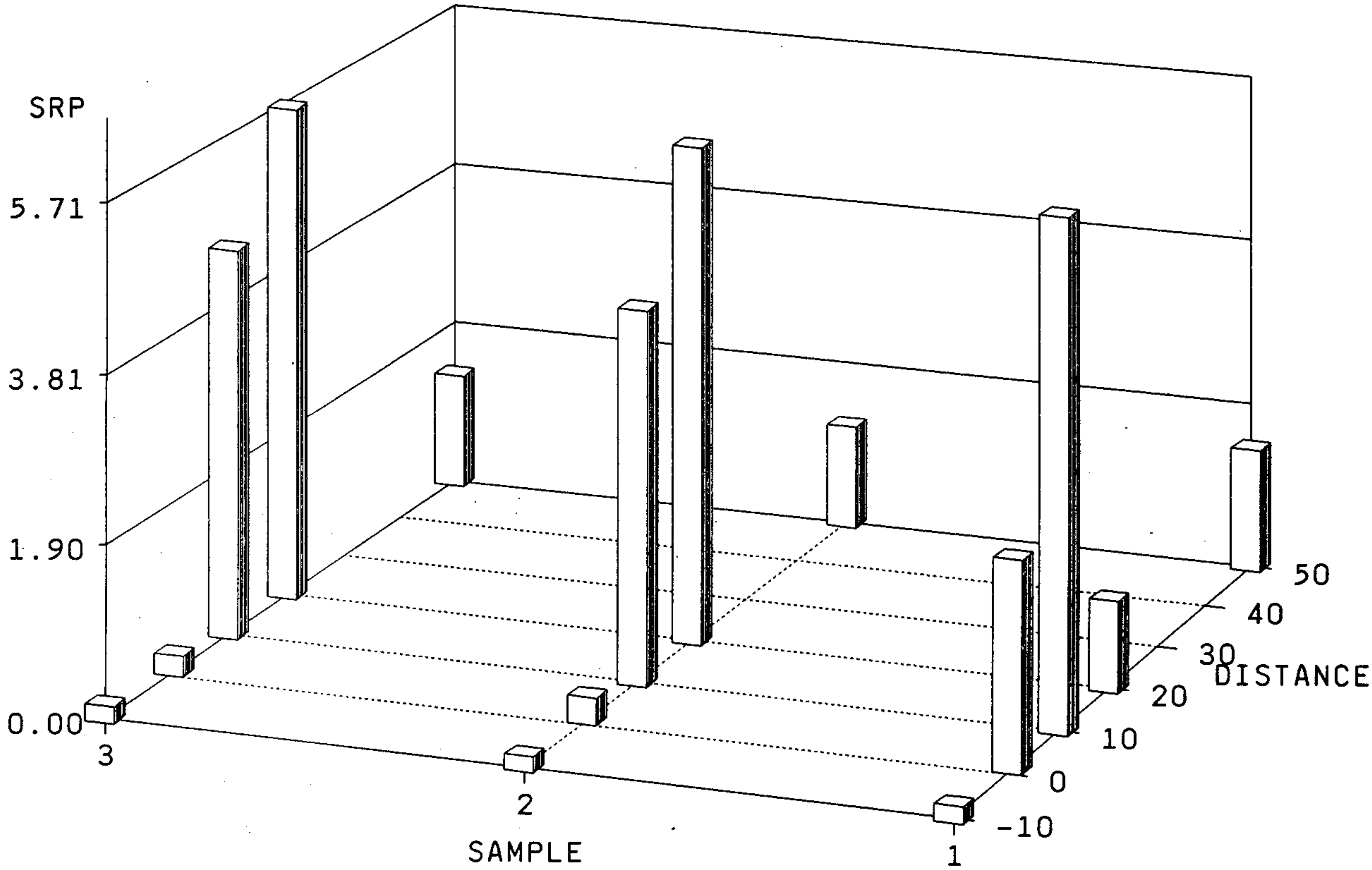


**Figure 1(c)** As Figure 1(a), for a site where a relatively weak effluent still effects order-of-magnitude increases in SRP in the receiving water. NB: the water course receiving Bethesda STW effluent meets another stream within 25 m of the outfall.

effluent dispersion: SRP as % of effluent conc.(*)
above, and upto 50m below outfall
SITE=Bethesda (*1400 µg/l)

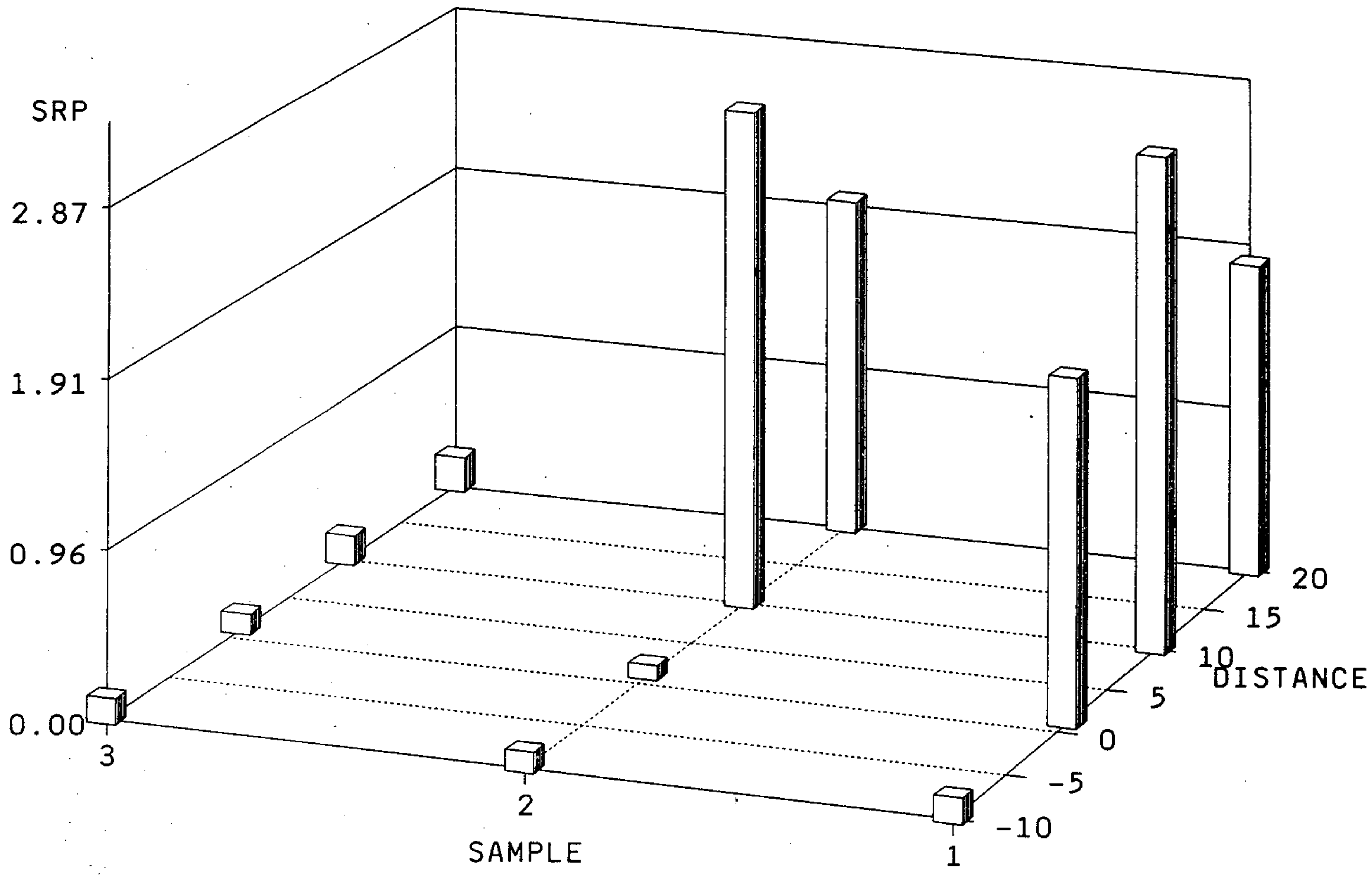


**Figure 1(d).** As Figure 1(a), for a small, pristine stream receiving an extremely concentrated effluent.
NB: at each of the points 10 m and farther below the discharge to this narrow stream, only 1 sample for SRP was collected.

effluent dispersion: SRP as % of effluent conc.(*)
above, and upto 50m below outfall
SITE=Ruardean Woodside (*15580 µg/1)

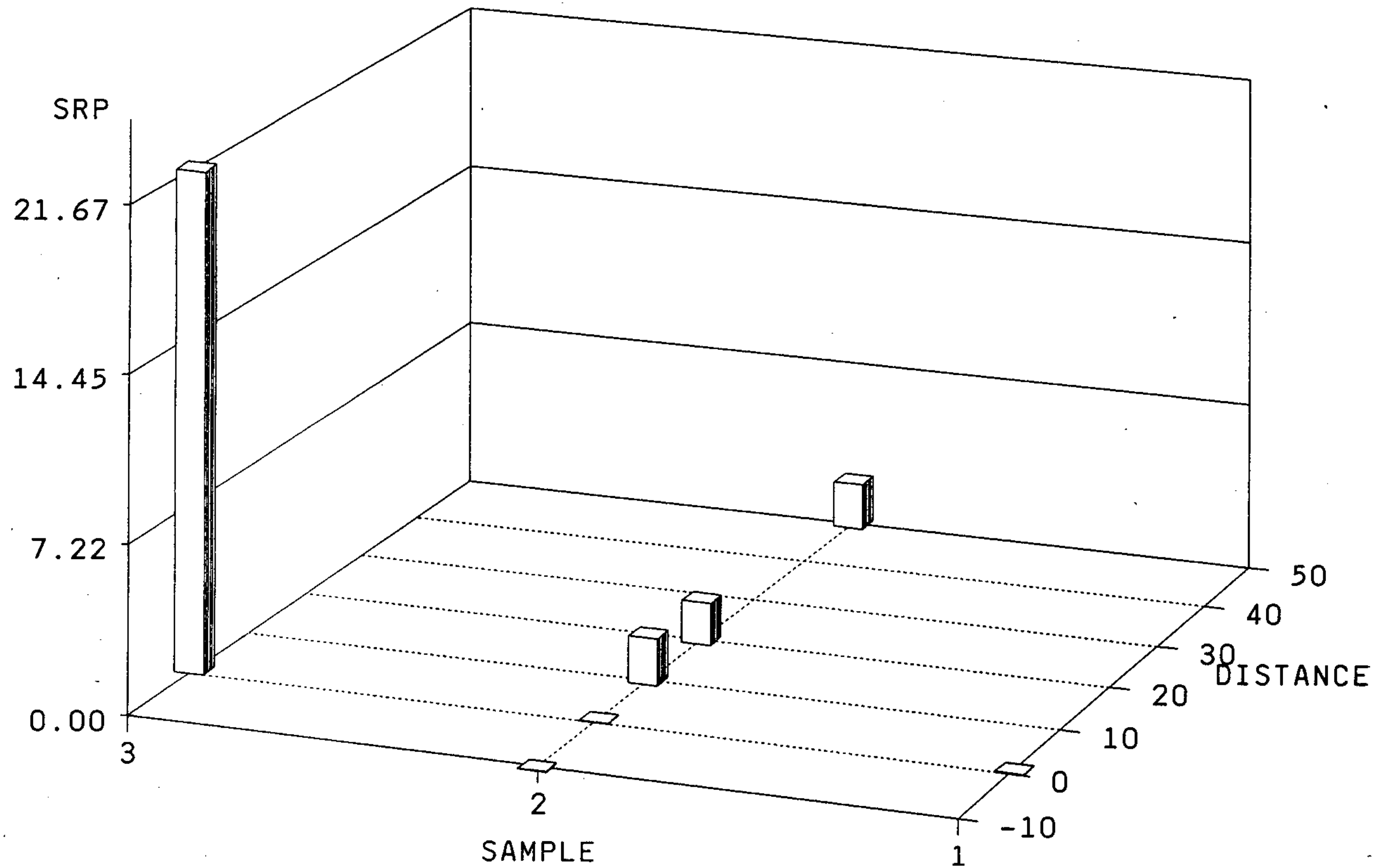
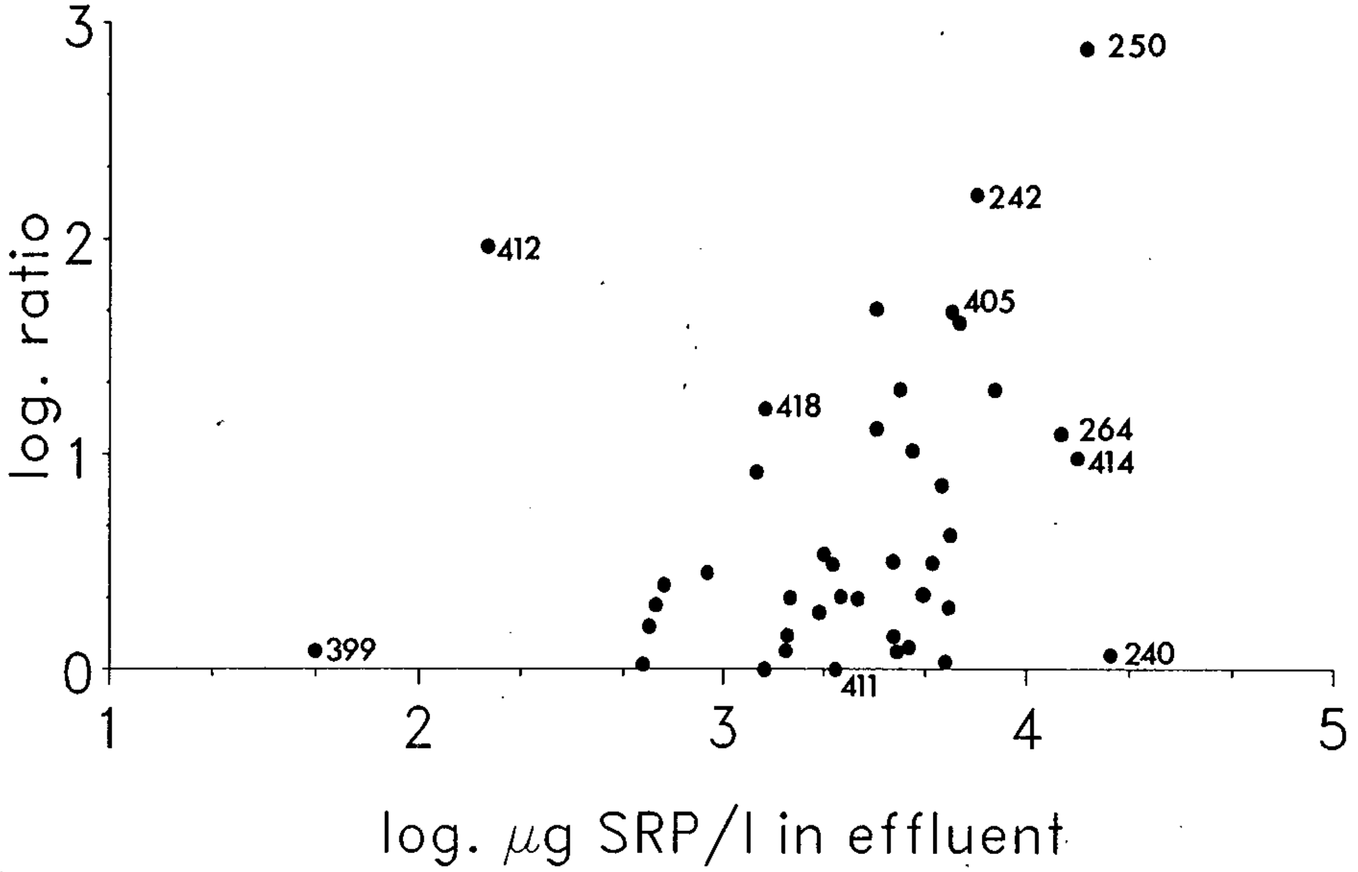


**Figure 2 (upper panel).** The ratio of the SRP concentration in a receiving stream 1 m below the STW outfall to that measured above the outfall, related to the effluent SRP concentration. Numbers correspond to the sites listed in Appendix I.

**(lower panel).** As above but for the ratio of the SRP concentrations at a point 10 m below the outfall, to that found above the outfall.

max. SRP ratio – 1m below pipe : 5m above, related to the effluent concentration




max. SRP ratio – 10m below pipe : 5m above, related to the effluent concentration

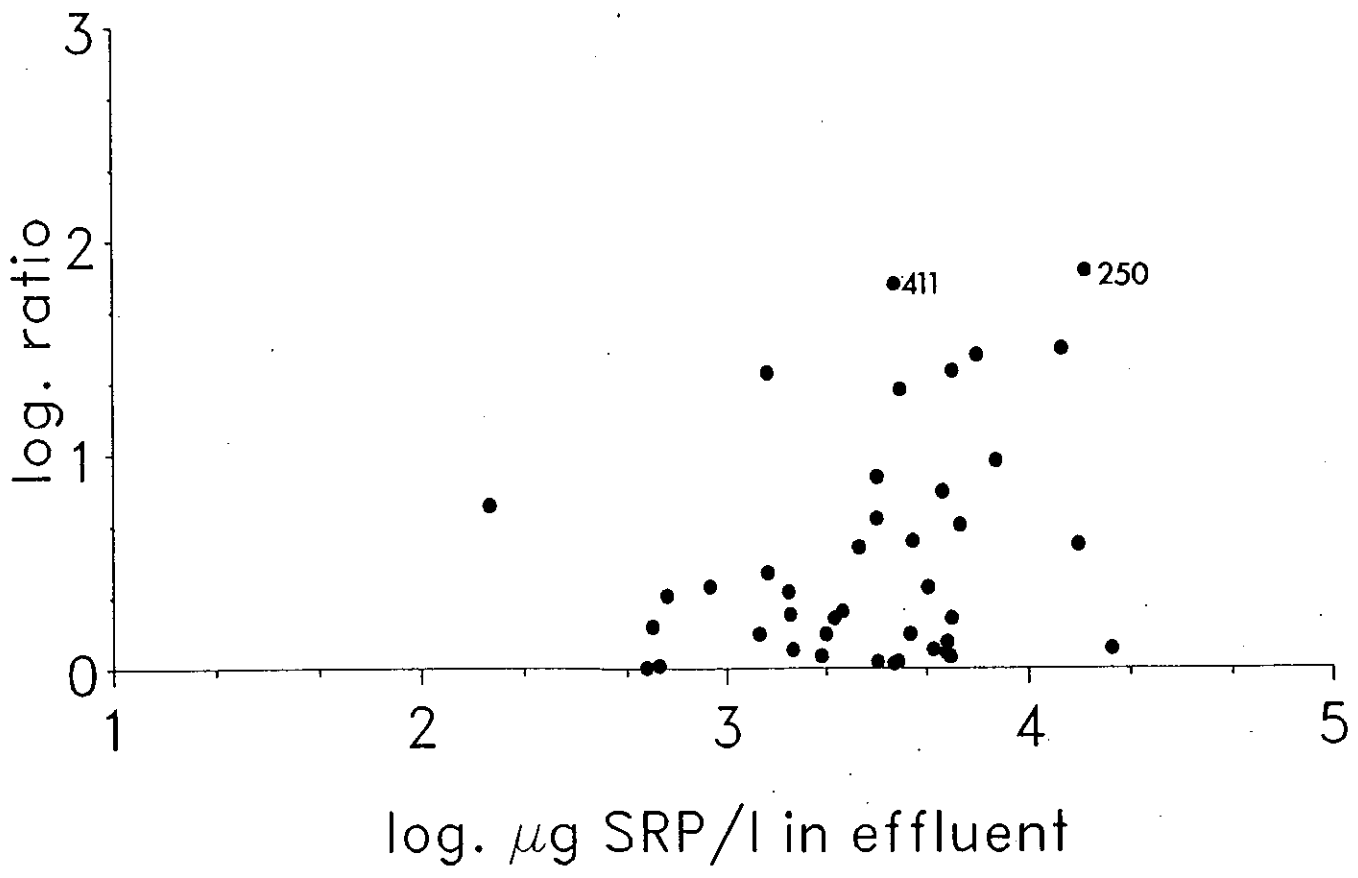


**Figure 3.** As Figure 1 for a site where the maximum SRP concentration was recorded some 10 m below the STW outfall rather than at 1 m

effluent dispersion: SRP as % of effluent conc.(*)
above, and upto 50m below outfall
SITE=Dobshill (*3710 µg/l)

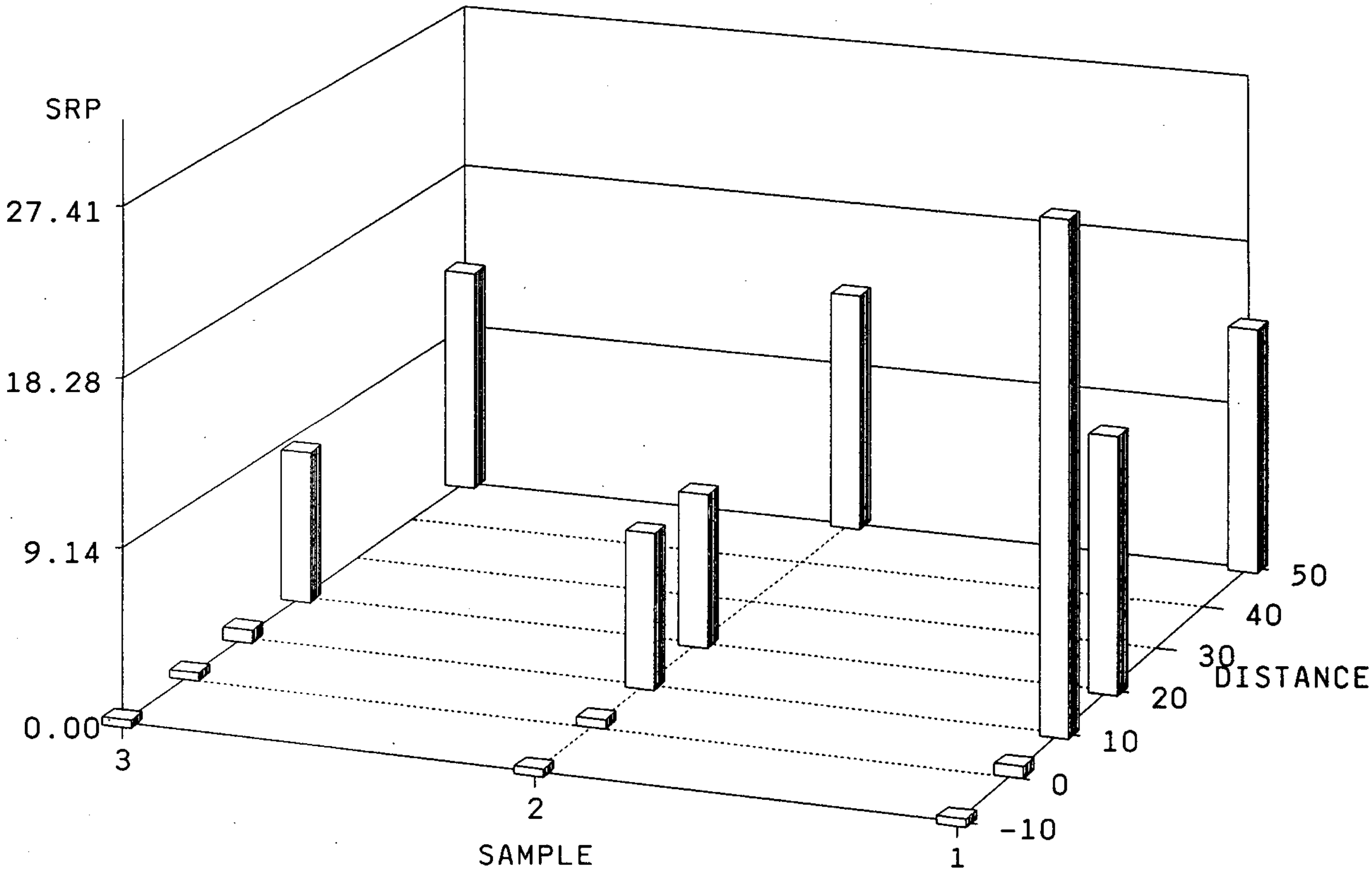


**Figure 4.** The relationship between the BOD and SRP concentrations measured at Dobshill

Dobshill STW: BOD related to SRP in the effluent
(●) and the receiving stream (o) – March 1991

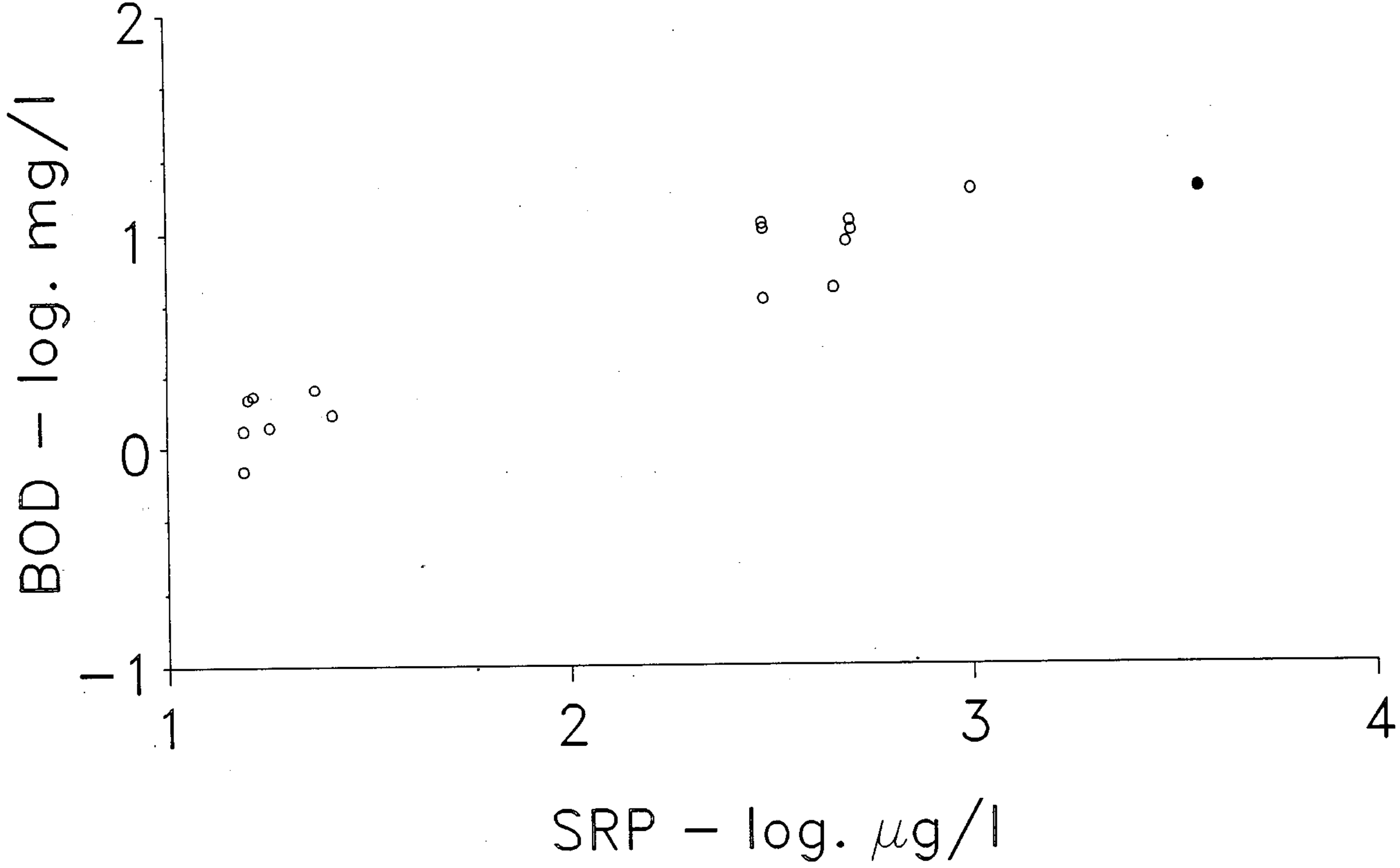
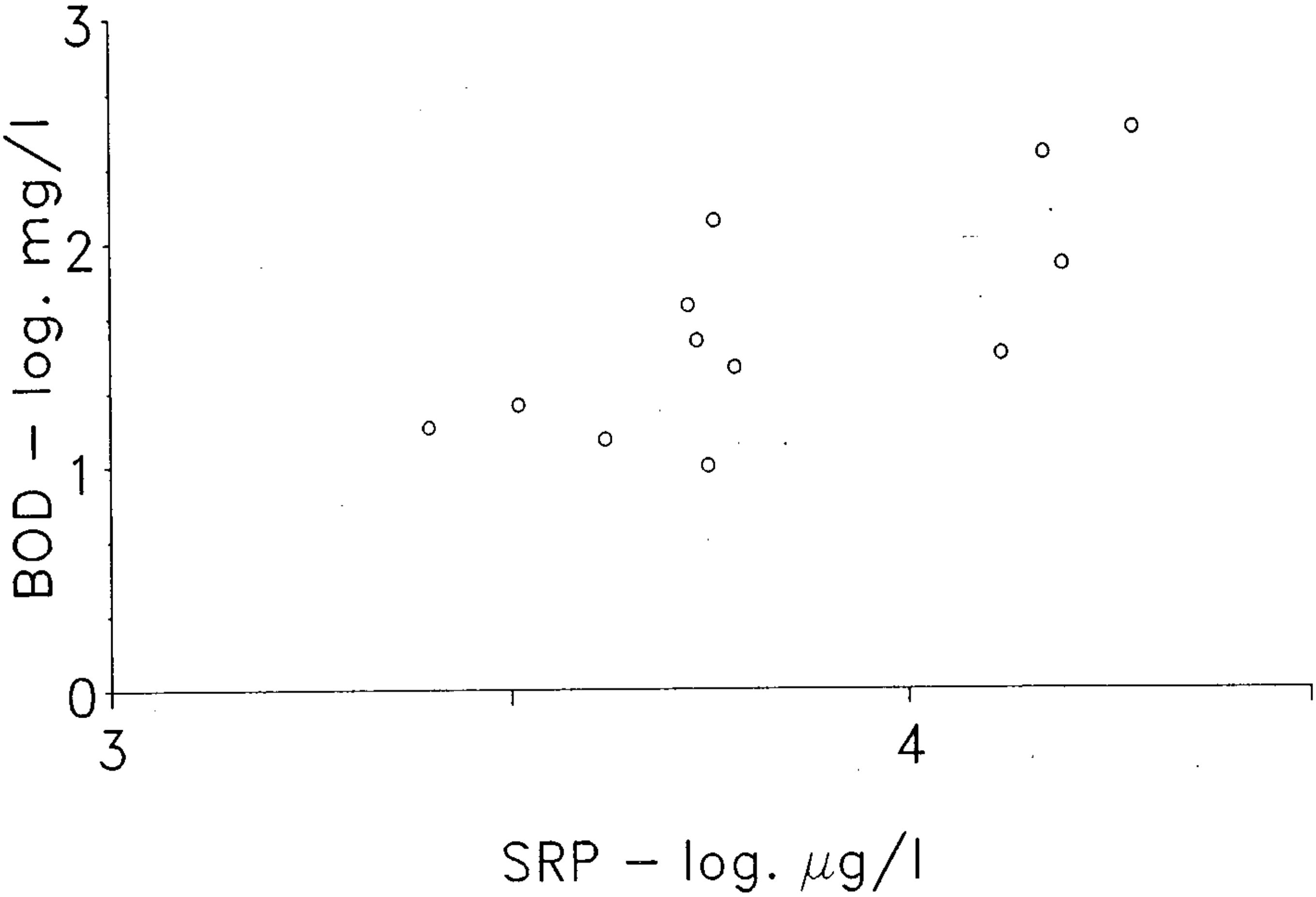
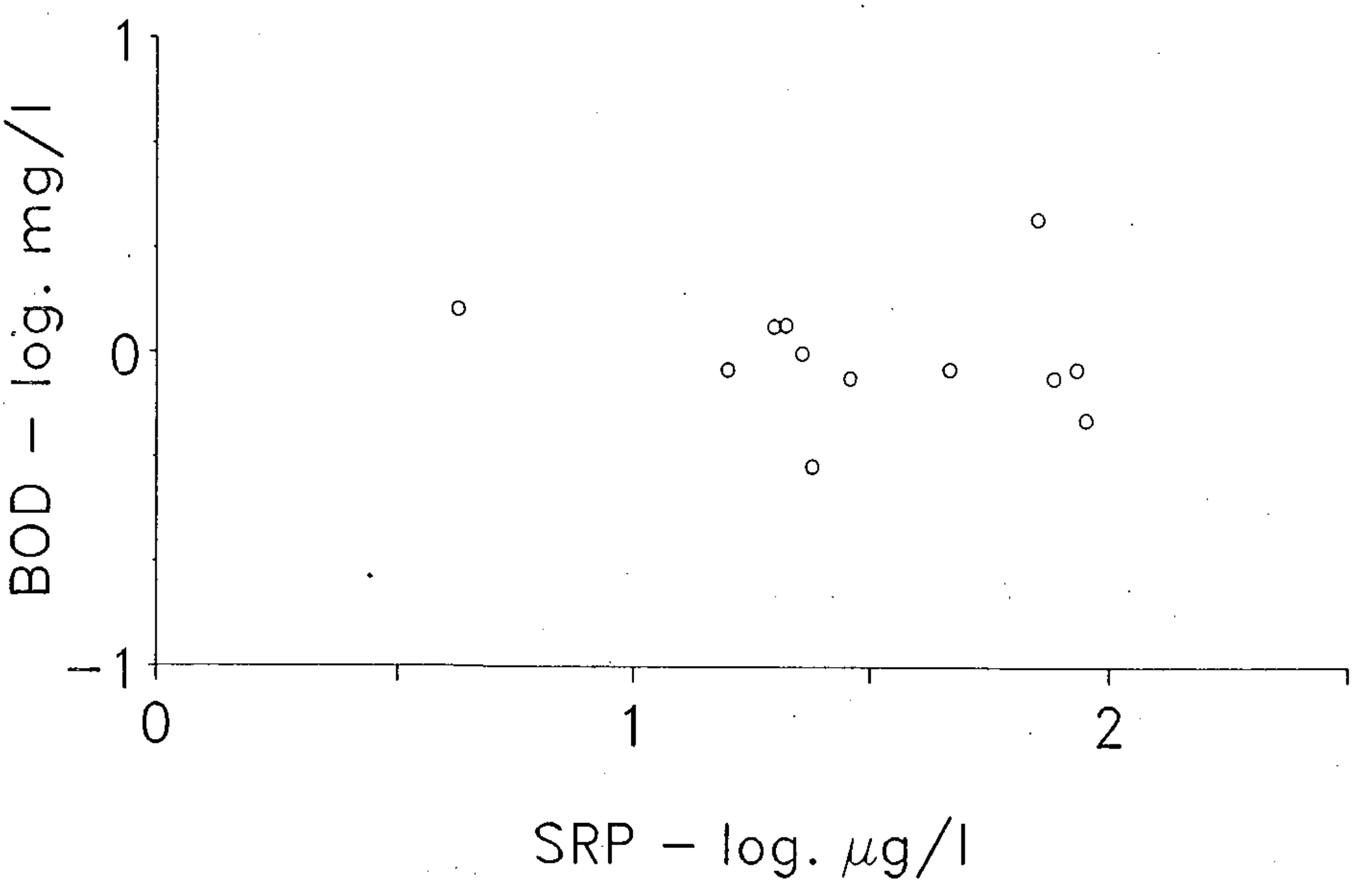


**Figure 5.** As Figure 4 for samples of the effluents (upper panel) and of the upstream stretches (lower panel) of 12 STWs.

Welsh STWs: BOD related to SRP in the effluent




Welsh STWs: BOD related to SRP in the receiving stream above the works



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