National Rivers Authority

Welsh Region

South West Division

A Status Report on the Direct Oxygenation of the Tywi Estuary - October 1989

EAW/90/3

Environmental Appraisal Unit (SW)
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CIRCULATION LIST

SUMMARY	FULL REPORT
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Regional Environmental Appraisal Scientist.	

SUMMARY

1. Investigations into the well documented oxygen depletion problem in the Tywi estuary have continued during 1989. Continuous monitoring at four sites supported by boat surveys, has shown dissolved oxygen sags similar to those observed in previous years. Dissolved oxygen minima approached 1 mgl^{-1} for short periods.

2. As has been observed in previous years, marine and estuarine algal blooms had a significant influence on estuarine water quality.

3. Localised dissolved oxygen depletion occurs in the vicinity of Parc-y-Splotts STW, under freshwater flows, but only during neap tides.

4. Even in the adverse conditions of the summer of 1989, when flows were low for a prolonged period and water temperatures were high, there was no evidence of fish mortalities in the estuary in spite of intensive fieldwork being undertaken by NRA personnel.

5. The 2 tonne per day oxygenation plant has been poorly maintained and evaluation of the technique of direct oxygenation has been impossible this year. A 12 tonne per day unit is due to be installed on the estuary as a result of an agreement between the NRA and Welsh Water plc. Calculations suggest that the 12 tonne per day plant may be of inadequate capacity due to the magnitude of the tidal flow in this estuary.

Keywords:

Oxygenation, Water Quality, Dissolved Oxygen depletion, Tywi estuary, Vitox.

INTRODUCTION

There is a well documented oxygen depletion problem in the Tywi estuary which occurs under a combination of spring tides, low river flows and high water temperatures (Owen 1988a). There are numerous other factors which may influence dissolved oxygen concentrations and these must be taken into consideration when interpreting data from the estuary. In particular, the density and distribution of certain algal species are implicated (Jones and Boarer 1986).

In 1986 a British Oxygen Company (BOC) 'Vitox' direct oxygen injection system was installed on the Tywi estuary, near the Parc-y-Splotts sewage treatment works (STW), so that it could be assessed as a means of alleviating the dissolved oxygen problem.

In 1987, data obtained suggested that this plant, nominally a 2 tonne per day unit, was of inadequate capacity (Owen 1988b). Subsequently a second-hand, 12 tonne per day 'Vitox' unit became available from Northumbrian Water, and was purchased. The larger plant has not yet been commissioned and the 2 tonne per day plant was the only means of direct oxygenation of the Tywi estuary during 1989.

The summer of 1989 was particularly hot and dry with prolonged low river flows representing conditions which might have been expected to cause severe dissolved oxygen sags. Continuous monitoring equipment was used to assess the water quality of the estuary during this period. An assessment of the 2 tonne per day 'Vitox' unit, which was operated on a number of occasions was carried out in conjunction with boat surveys of the estuary. Telemetry equipment was also employed in order to provide 'real-time' data on which to base decisions regarding oxygenation or additional survey work.

The current situation regarding the 12 tonne per day plant is that an operating agreement (Appendix 1) between the National Rivers Authority (NRA) and Welsh Water plc (PLC) has been signed by both parties. This agreement requires the PLC to operate the oxygenation plant when requested to by the NRA. It also requires the NRA to evaluate the system during the next five years if weather conditions are suitable.

The purpose of this report is to document the work carried out in 1989, highlighting that water quality data which is of particular interest. The report also outlines the status of the Tywi Oxygenation Project and puts forward suggestions for the evaluation of the 12 tonne per day plant when it is commissioned. Some suggestions are also made as to the most significant factors in the causation of the DO sag although detailed investigation of this subject is outside the objectives of this project.

METHODS

1) Continuous Monitoring

All continuous monitoring was undertaken using a combination of pHOX 100 DPM multiparameter water quality monitors in conjunction with Technolog Tinylog data recorders. Data was processed on a Data General minicomputer using the 'Logsys' suite of programs. The parameters monitored were dissolved oxygen, temperature and conductivity. Regular servicing of monitors was carried out on a weekly basis. The sites monitored and the period of deployment were as follows:-

i) Greencastle

Monitoring was undertaken at this site (SN 399 164 fig.1) between 12th April and 30th November.

ii) Submersible

Monitoring was undertaken using an experimental submersible unit at a point approximately 50 metres downstream of the Parc-y-Splotts outfall (SN 403 174) between the 31st May and the 9th June.

iii) Parc-y-Splotts

A continuous monitor was deployed approximately 250 metres downstream of the Parc-y-Splotts outfall (SN 399 179) between 19th July and 14th August.

iv) Carmarthen Railway Bridge

Monitoring was undertaken at this site (SN 406 193) between 14th July and 3rd September.

2) Boat Surveys

In order to obtain longitudinal profiles of estuarine water quality and verify continuous monitoring data five boat surveys were undertaken, on early morning spring tides, when water quality conditions were expected to be at their worst. The boat was launched at Ferryside, approximately 1 hour before high water, and measurements of dissolved oxygen saturation, salinity and temperature were made at the sampling locations used in previous years (fig.1). Sampling commenced at M3, just upstream of Ferryside and continued inland until the lowest oxygen levels had been passed and at least three consecutive samples had increasing dissolved oxygen concentrations.

3) Oxygenator Assessment

The oxygenation system was assessed on two occasions when boat surveys were being undertaken. The assessment involved in situ measurements of oxygen saturation at locations selected to form a grid extending from approximately 100 metres upstream to 100 metres downstream of the oxygenator and from the bankside near the installation to the middle of the river. In practice all of the grid points were not used (see results). Visual observation also provided information on the effectiveness of the sparge bars in mixing and distributing the oxygenated water.

4) Telemetry

During the period between August 23rd and October 3rd a 'Meteorburst' telemetry system was deployed at the Greencastle site in order to provide 'real-time' data on estuarine water quality. The rapid provision of data allowed decisions on operation of the oxygenator to be made on the basis of real water quality measurements rather than supposition.

RESULTS

1) Continuous Monitors

i) Greencastle

Over the period monitored the results were generally similar to previous years at this location with a close relationship between spring tides (fig.2a), river flows (fig.2b) and low dissolved oxygen events (fig. 2c). The minimum dissolve oxygen concentration measured was 1.3 mgl^{-1} on 30th May (fig.3a). At this time

temperature showed a diurnal variation between a minimum of 15°C and a maximum of 18°C (fig.3b). The conductivity at high water was approximately 15,000* Siemens cm^{-1} indicating a return to higher tides following a period of neaps (fig.3c).

ii) Submersible

Data from this monitor showed a similar relationship between high tides and low dissolved oxygen events as demonstrated at Greencastle during spring tide periods. However, during neap tide periods, dissolved oxygen sags occurred under freshwater flows and not at high water (fig.4). The minimum dissolved oxygen concentration, during the period monitored, on a spring tide was 6.5 mgl^{-1} on the 1st of June and the minimum on a neap tide was 6.8 mgl^{-1} on the 8th June.

The oxygenator was operated on the 5th July for approximately 4 hours and on the basis of its timing and the lack of corresponding DO peaks on other tides apparently led to an increase in the dissolved oxygen concentration of approximately 1 mgl^{-1} at this location which was very close to the point of oxygen injection (fig.4).

iii) Parc-y-Splotts

The Parc-y-Splotts monitor showed similar results to the submersible unit with minima during spring tide periods at high water and minima during neap tide periods at low water (fig.5a). The lowest oxygen concentration measured was 3.9 mgl^{-1} on the 30th August. Conductivity measurements indicate that this occurred at low water (fig.5b).

iv) Carmarthen Railway Bridge

The railway bridge monitor, which was the furthest upstream, showed interesting differences compared to the Greencastle data. Between July 14th and July 19th as tides increased after neaps, the dissolved oxygen sags increased on the early morning tides each day but afternoon tides showed a dissolved oxygen peak corresponding to high water (fig.6).

2) Boat Surveys

The data obtained on boat surveys showed a decrease in salinity from about 32 ppt in the outer estuary (figs.7-11). Dissolved oxygen concentrations showed a corresponding decrease with the lowest value being 4.1 mgl^{-1} which was measured on both the 6th and the 20th of July. On the 6th this value was measured at site M16 and on the 20th at site M12.

3) Oxygenator Assessment

Both oxygenator assessment exercises were carried out on the ebb tide.

i) 20th July - The upstream dissolved oxygen saturation was 54% and this increased to a maximum of 60% immediately downstream of the oxygenator returning to 54% within 20 metres.

ii) 15th September - The upstream dissolved oxygen saturation was 70% and this fell to 67.5% 10 metres downstream of the oxygenator, increasing slightly to 67.8% 20 metres downstream. The maximum dissolved oxygen concentration measured in the agitated water discharged by the oxygenator pump (the 'boil') was 90%.

The 'boil' was extremely localised covering a circular area approximately 1 metre in diameter. The grid of sample points which had been devised was not used due to the lack of any significant oxygen increases in the immediate proximity of the plant.

4) Telemetry

The telemetry system performed satisfactorily and provided data which was used to initiate oxygenation. The delay between data transmission and reception was typically 5-10 minutes. The battery life of the outstation was about 3 weeks. The large size of the aerial, which had been expected to cause problems, both with deployment and possible vandalism, was acceptable.

DISCUSSION

The potential applications for an effective direct oxygenation system are numerous and include estuarine barrage water quality improvement and medium term alleviation of water quality problems pending new sewage works construction. However, it has not been possible to demonstrate any significant improvement in dissolved oxygen concentrations in the Tywi estuary, due to operation of the 2 tonne per day BOC Vitox unit, either in this study or in previously reported work (Owen 1988). It should be noted that the plant was not operating correctly during the latter part of this years studies. It appears that the oxygenation capacity of the plant is inadequate to overcome the short-term oxygen demand which occurs as the flood tide enters the estuary. Calculation of the capacity required to oxygenate the flow on an incoming spring tide suggests that even the 12 tonne per day unit will be unable to increase the dissolved oxygen significantly. Based on a measured flood-tide flow of 200 cumecs (fig.12) the input required to raise the oxygen concentration by 3 mgl^{-1} would

be 0.6 kg s^{-1}. This would require a plant with a nominal capacity of 52 tonnes per day, assuming 100% efficiency. The assumption made by previous workers that dissolved oxygen concentrations could be built up over a number of tides (Owen 1988b) is not accepted. The proportion of water returning on any tide which has been in the river on the previous tide is likely to be very small. Therefore even the 12 tonne per day plant is unlikely to provide a significant increase in oxygen concentrations in the estuary.

It has been apparent this year that the two tonne per day unit is totally ineffective due to a combination of poor design and neglect. It has not been possible therefore to assess the technique of direct oxygen injection. Now that an operating agreement for the 12 tonne per day plant has been ratified it is essential that lessons are learnt from past mistakes. The unit must be deployed so that the pumps and sparge bars can easily be removed from the river for maintenance.

Experience obtained on the estuary during this summer (1989) suggests that the best method of evaluation of the oxygenation plant is by boat surveys in conjunction with continuous monitors. The numerous factors affecting dissolved oxygen concentrations will make the interpretation of continuous monitor data difficult, especially if increases due to oxygenation are small. However, if boat surveys are used to identify the magnitude of increases in the vicinity of the oxygenation plant and the extent of any increase is explored upstream or downstream, until continuous monitor sites are reached, it should be possible to identify increases in continuous monitor data due to oxygenation. If increases in the vicinity of the oxygenation plant are small then this will not be possible and the oxygenation plant will have to be considered as ineffective. A calculation of the probable increase gives a figure of approximately 0.5 mgl^{-1} at a tidal flow of 200 m^3s^{-1} which will be difficult to detect. At

lower tidal flows of 100 m^3s^{-1} the predicted increase of 1 mgl^{-1} may be sufficiently large to be identified and reliably measured. Dye releases in the vicinity of the oxygenator could be considered as they would allow identification of oxygenated water by means of a fluorometer.

Observations, over a number of years, have shown the involvement of marine and estuarine algae in some of the more severe dissolved oxygen sags. Although there is little detailed algal data available for this summer there was an apparent association between the severe sag which occurred on May 30th and an early bloom of the marine alga Phaeocystis. Any attempt to elucidate the causes of the Tywi estuary dissolved oxygen sag must include consideration of Coastal eutrophication. The funnel shape of the Carmarthen Bay, oriented to face prevailing winds, is an ideal collector of marine algae. The location of the Tywi estuary makes it the likely area where marine algae will accumulate. The change from high to low salinity causes the death of many marine algal species. The metabolism of the released nutrients by bacteria in the estuarine sediments appears to be a major factor in the more severe dissolved oxygen sags. On other occasions, where algae are tolerant of the salinity in the estuary, the effects of photosynthesis in the day, and respiration, at night, become apparent. Remote sensing data from earth orbiting satellites may be of value in investigating algal distribution.

The deployment of water quality monitors in the immediate vicinity of the Parc-y-Splotts outfall has demonstrated low dissolved oxygen events under freshwater flows. Any effect of these events on the passage of migratory fish should be apparent from the findings of the fish tracking project. High water spring tide sags would be expected to be significant to migratory fish and although the estuary would have probably have complied with the 5 mgl^{-1} (95 percentile) standard it would have failed the 3 mgl^{-1} (absolute) standard. (A system

of assessing compliance from continuous monitor data should be devised perhaps involving random selection of data points). The findings of the Tywi tracking project are therefore of particular interest in 1989 as they may indicate the validity of the estuarine Environmental Quality Standard for oxygen. More specifically any movement of migratory fish through the estuary during conditions worse than the standards, may suggest a need for their revision.

Although the summer of 1989 was particularly hot and dry, with prolonged low river flows, any dissolved oxygen sags were transient. There was no evidence of fish kills in the estuary although NRA personnel were frequently in the field. Migratory fish behaviour may ensure that they avoid potentially dangerous conditions in the estuary by remaining at sea until improvements occur. This may make them vulnerable to illegal netting.

CONCLUSIONS

1 Dissolved oxygen sags approaching 1 mgl^{-1} occurred on the Tywi Estuary in the summer of 1989 related to marine algal blooms.

2 Localised dissolved oxygen depletion occurs in the vicinity of Parc-y-Splotts STW under freshwater flows.

3 The metabolism of algae which survive in the estuary can significantly influence dissolved oxygen concentrations in limited parts of the estuary.

4 Even though the weather conditions during the summer of 1989 were extremely adverse there was no evidence of any fish mortalities in the estuary.

5 The 2 tonne per day oxygenation plant is totally ineffective due to lack of maintenance and calculations suggest that the 12 tonne per day plant may be of inadequate capacity.

REFERENCES

1 Owen, P.G. (1988a) "Investigations into dissolved oxygen levels in the Tywi Estuary 1985-86" Welsh Water Report No. SW/88/8.

2 Jones, F. and Boarer, J. (1986) "Investigation of the influences of algae on oxygen depletion in the Tywi Estuary" Welsh Water Report No. SW/86/25.

3 Owen, P.G. (1988b) "An assessment of direct oxygenation of the River Tywi Estuary" Welsh Water Report No. SW/88/21.

Fig. 1 TYWI ESTUARY - MONITORS AND SAMPLING POINTS

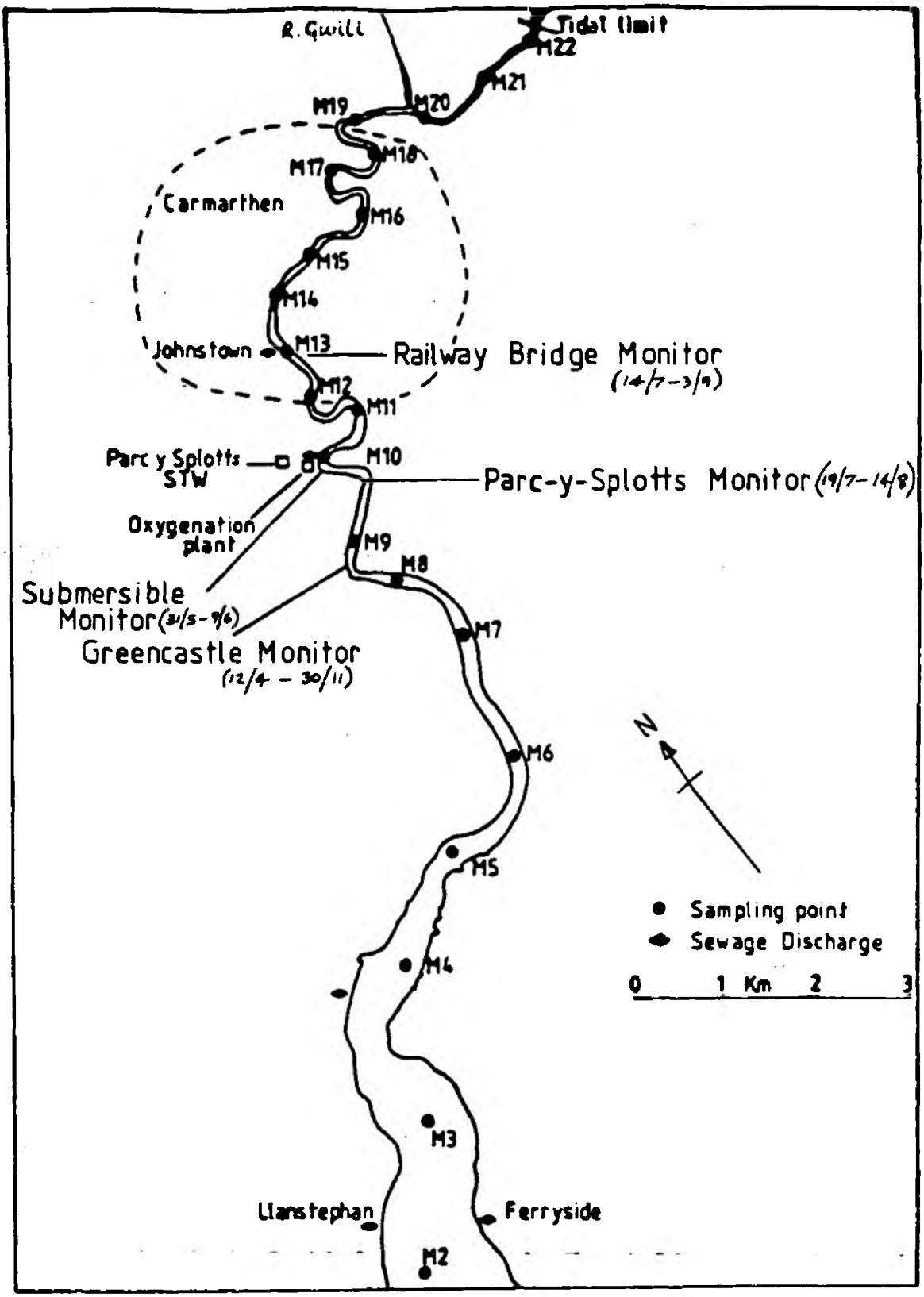


Fig.2d TWI ESTUARY

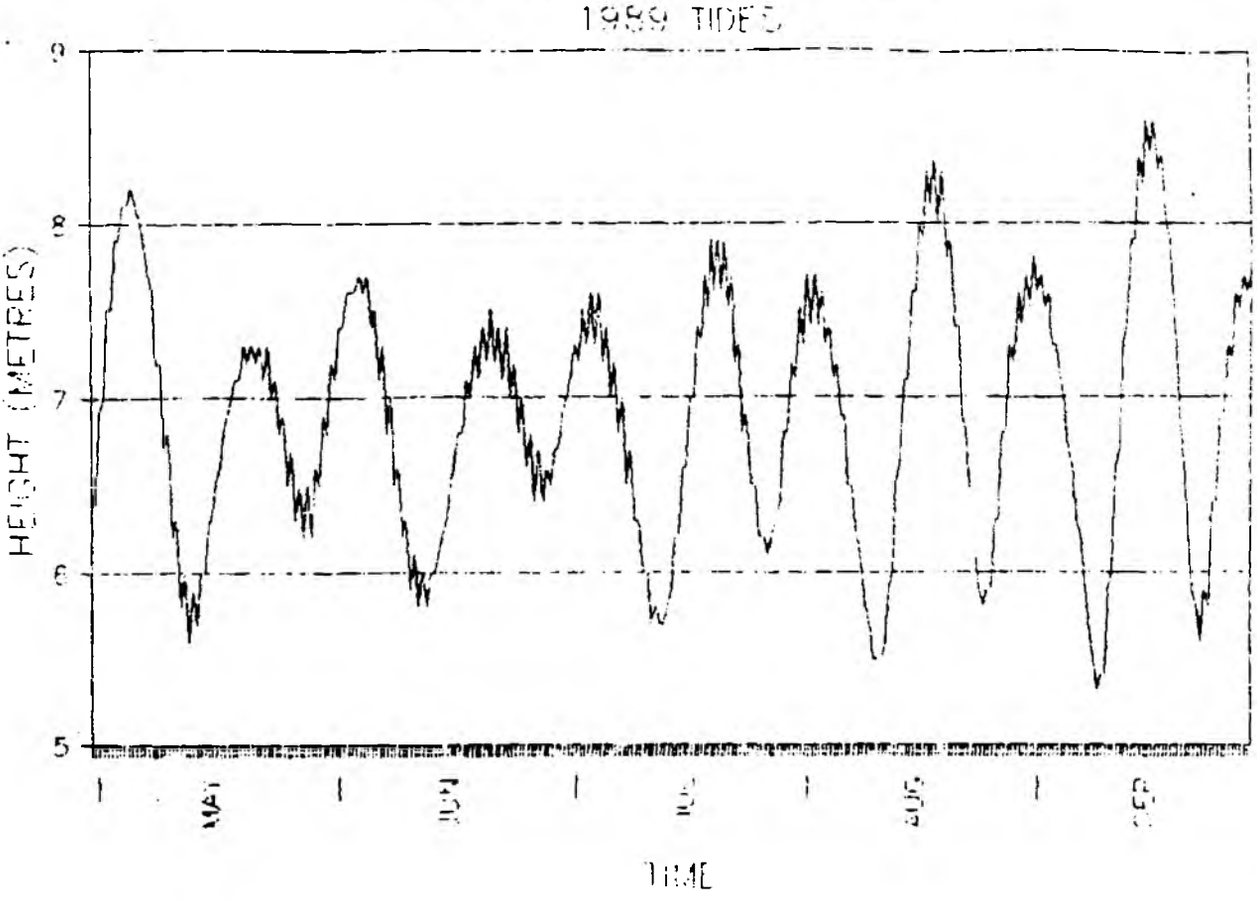
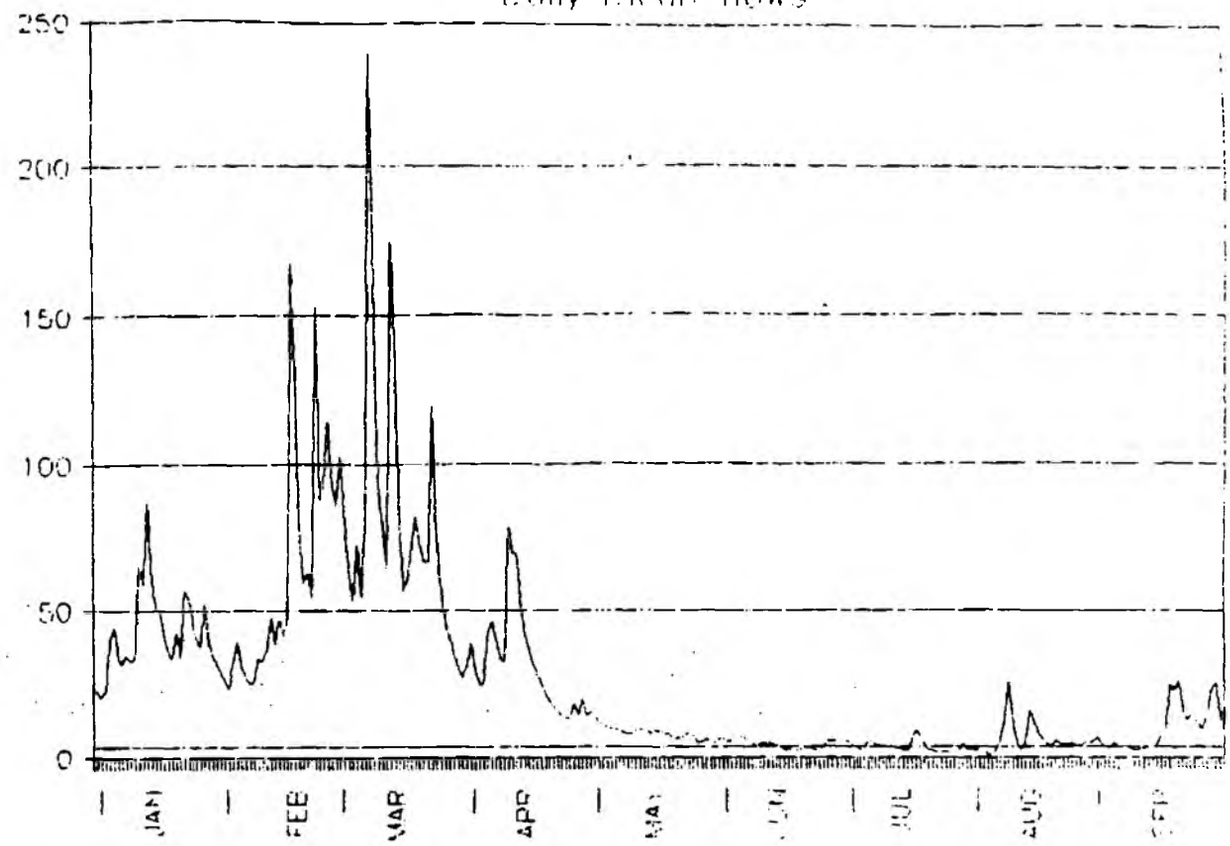


Fig.2b FLOW TO LOWER ESTUARY 1989



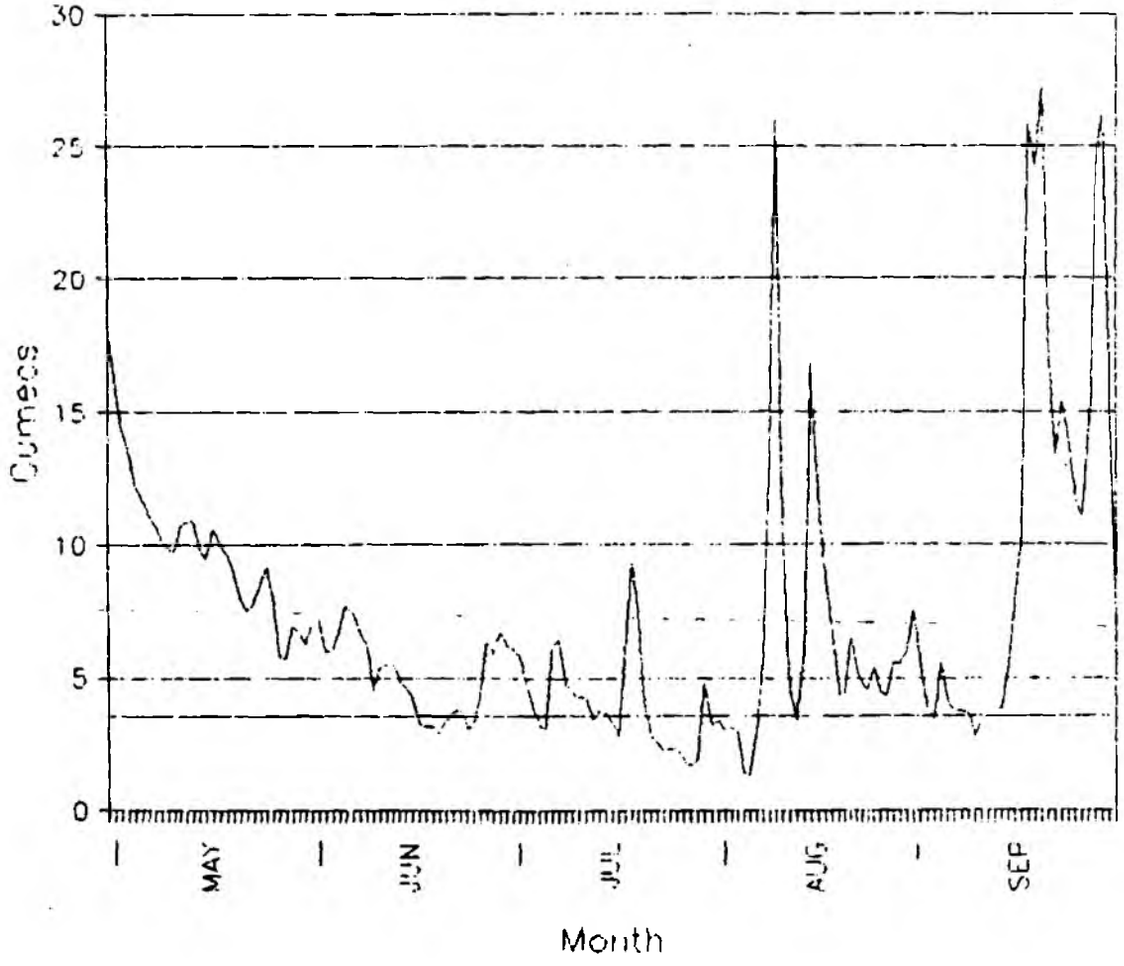
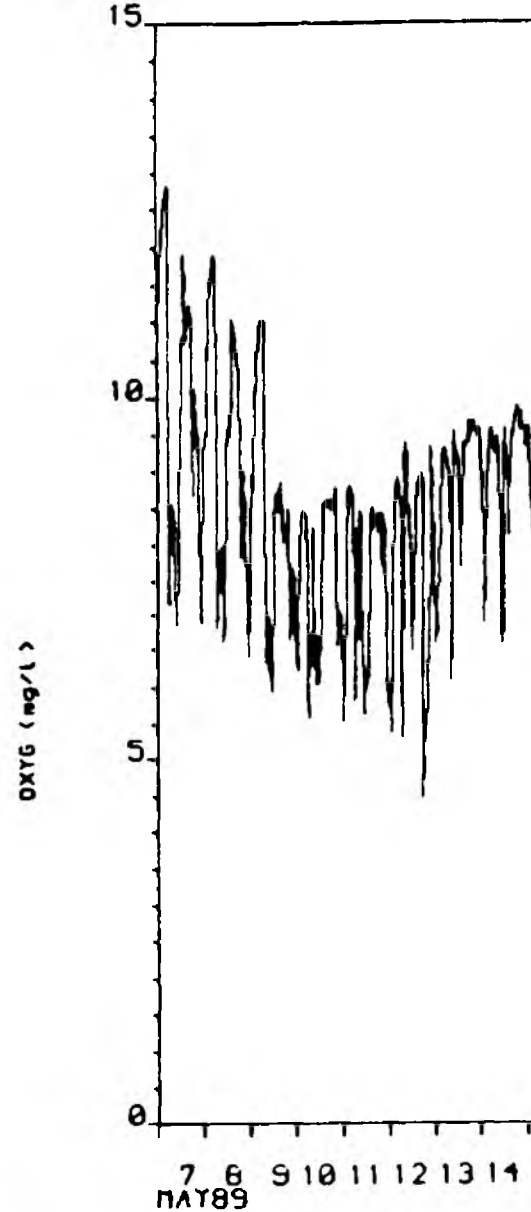


Fig. 2c Greencastle -



Summary Oxygen Data

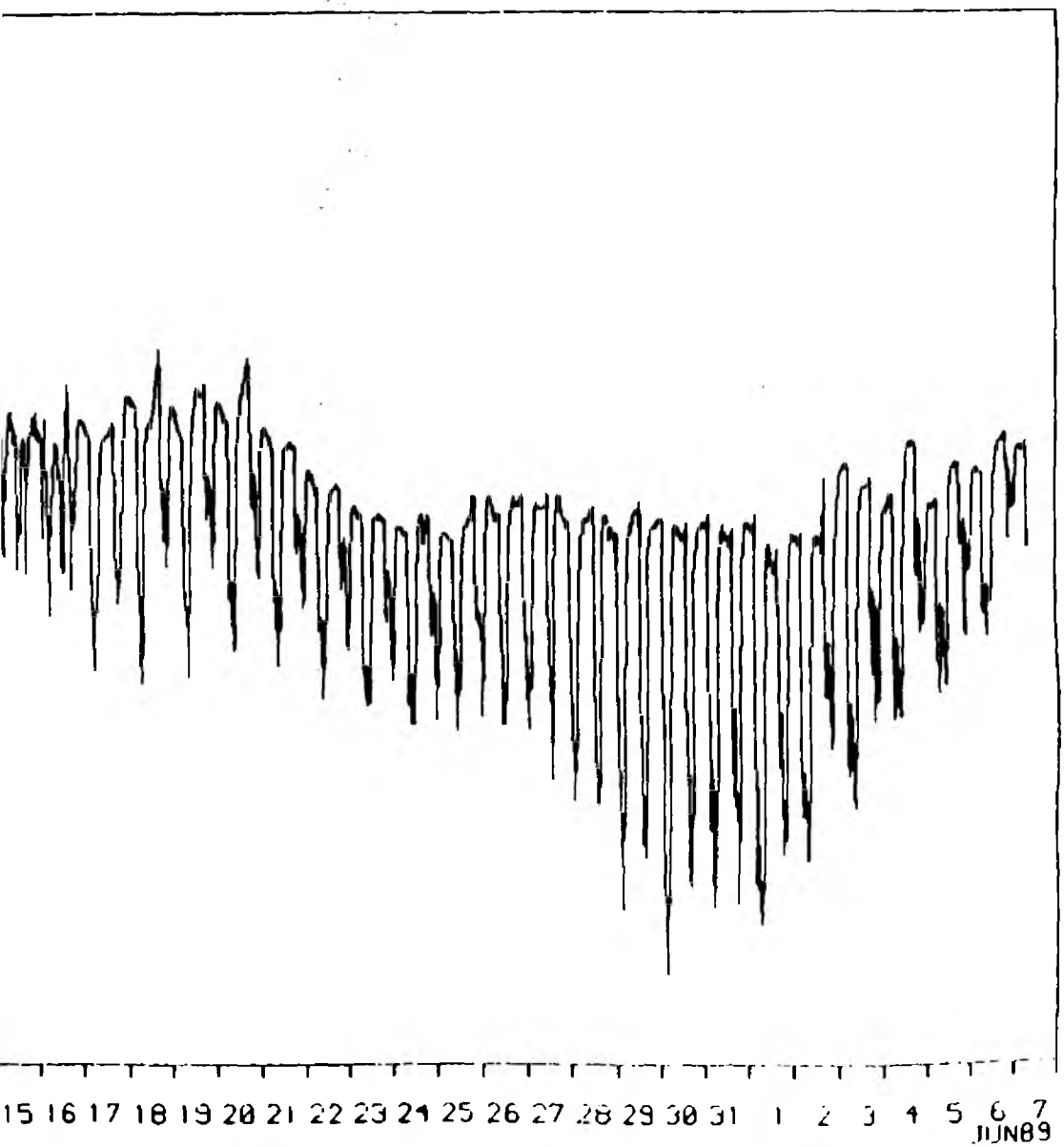
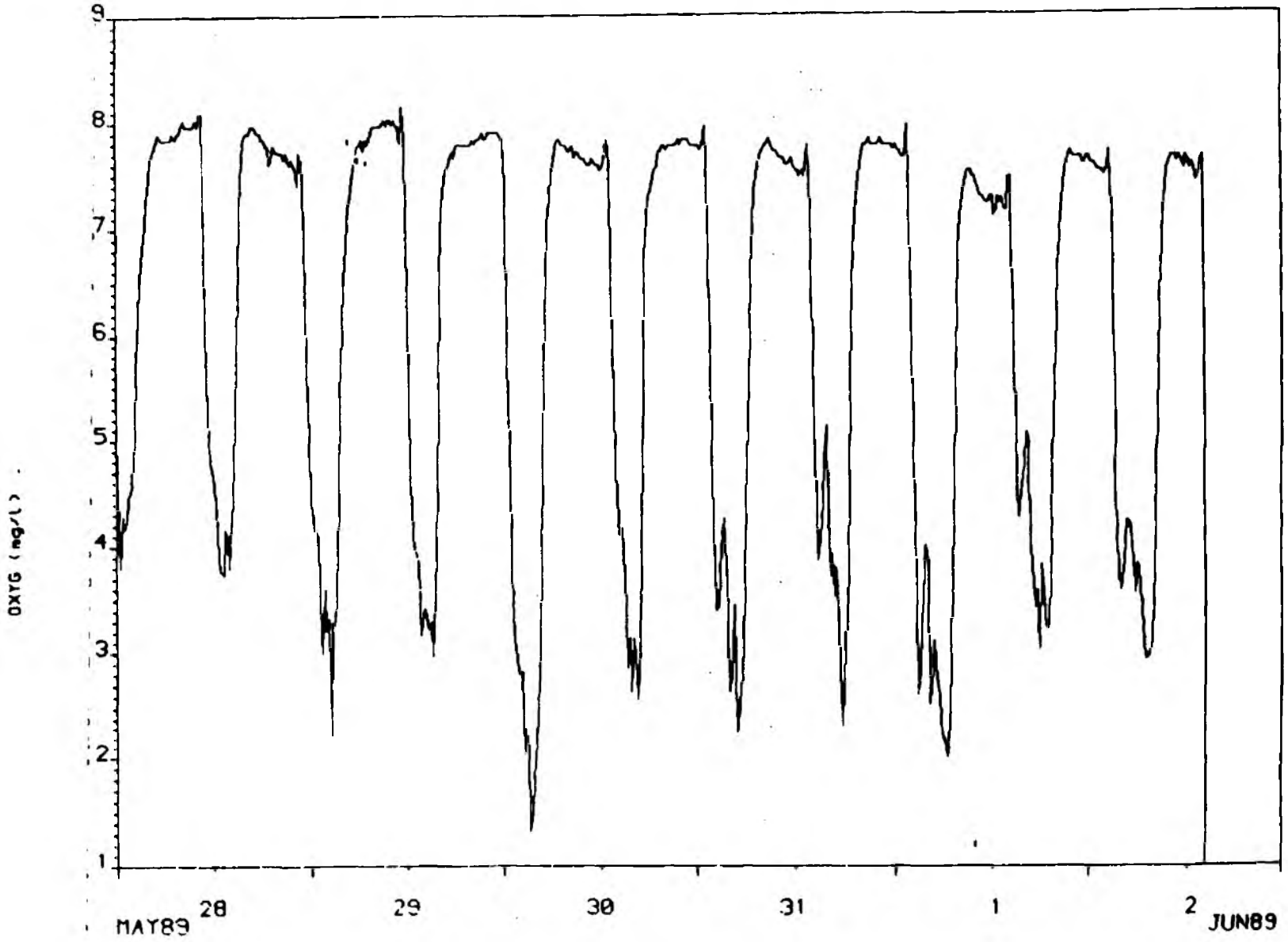


fig. 3a Greencastle - Oxygen data (28/5/89 - 3/6/89)



5/89 - 3.6/89

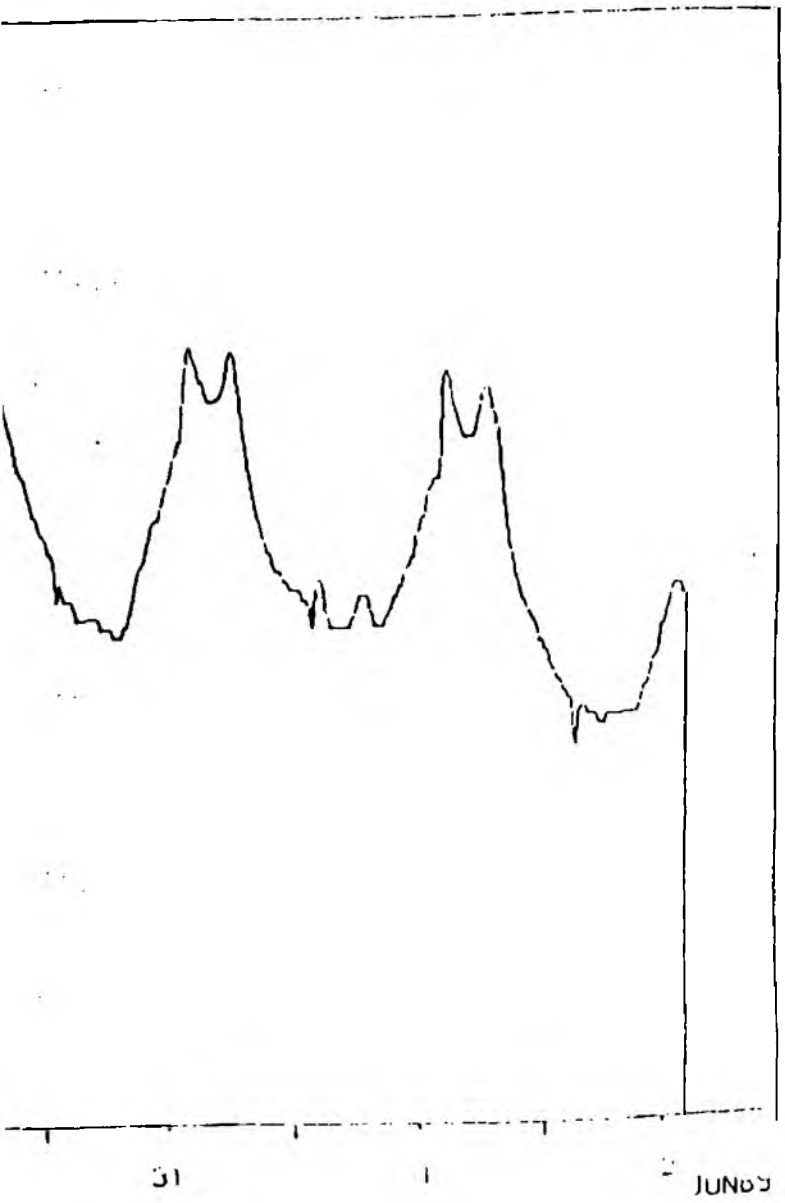


Fig. 36 Greencastle - Temperature data (28

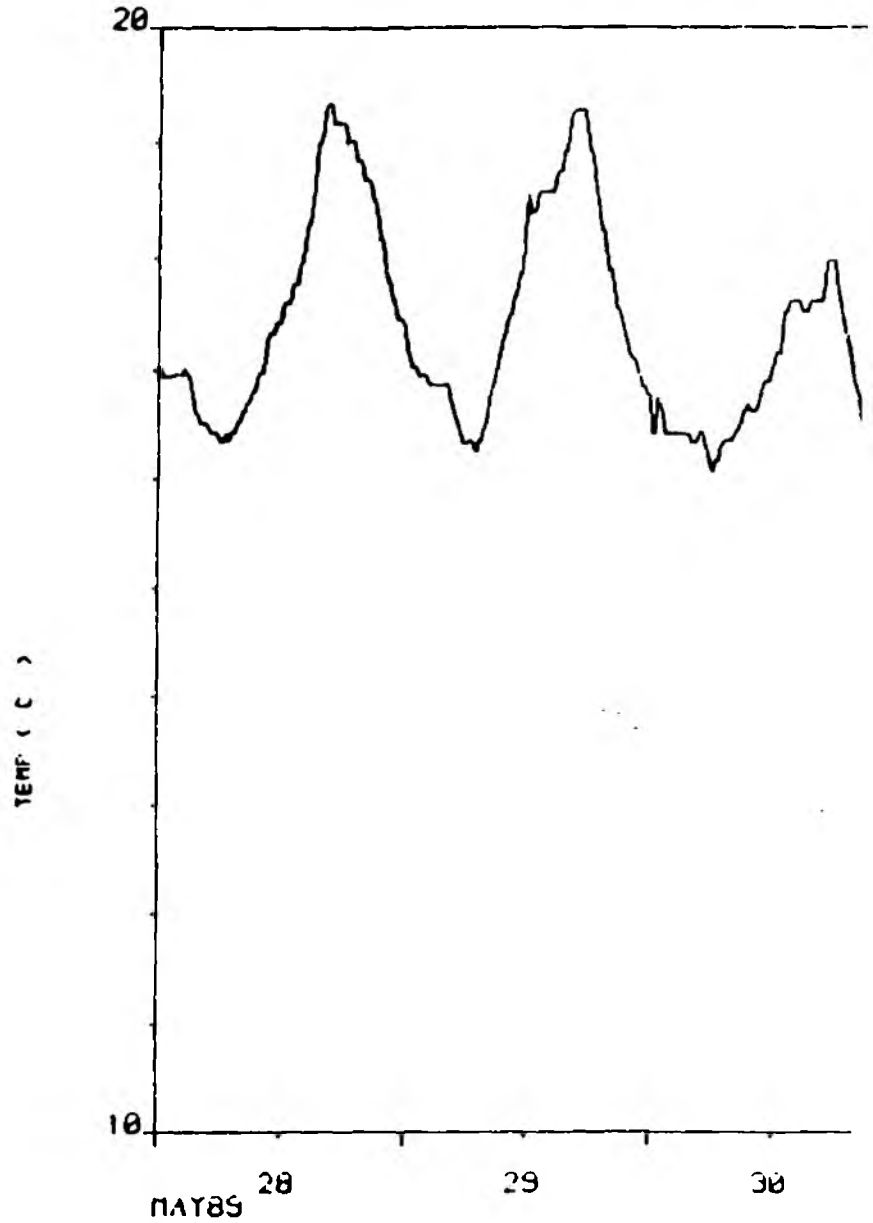


fig. 3c Greencastle - Conductivity data (28/5/89 - 3/6/89)

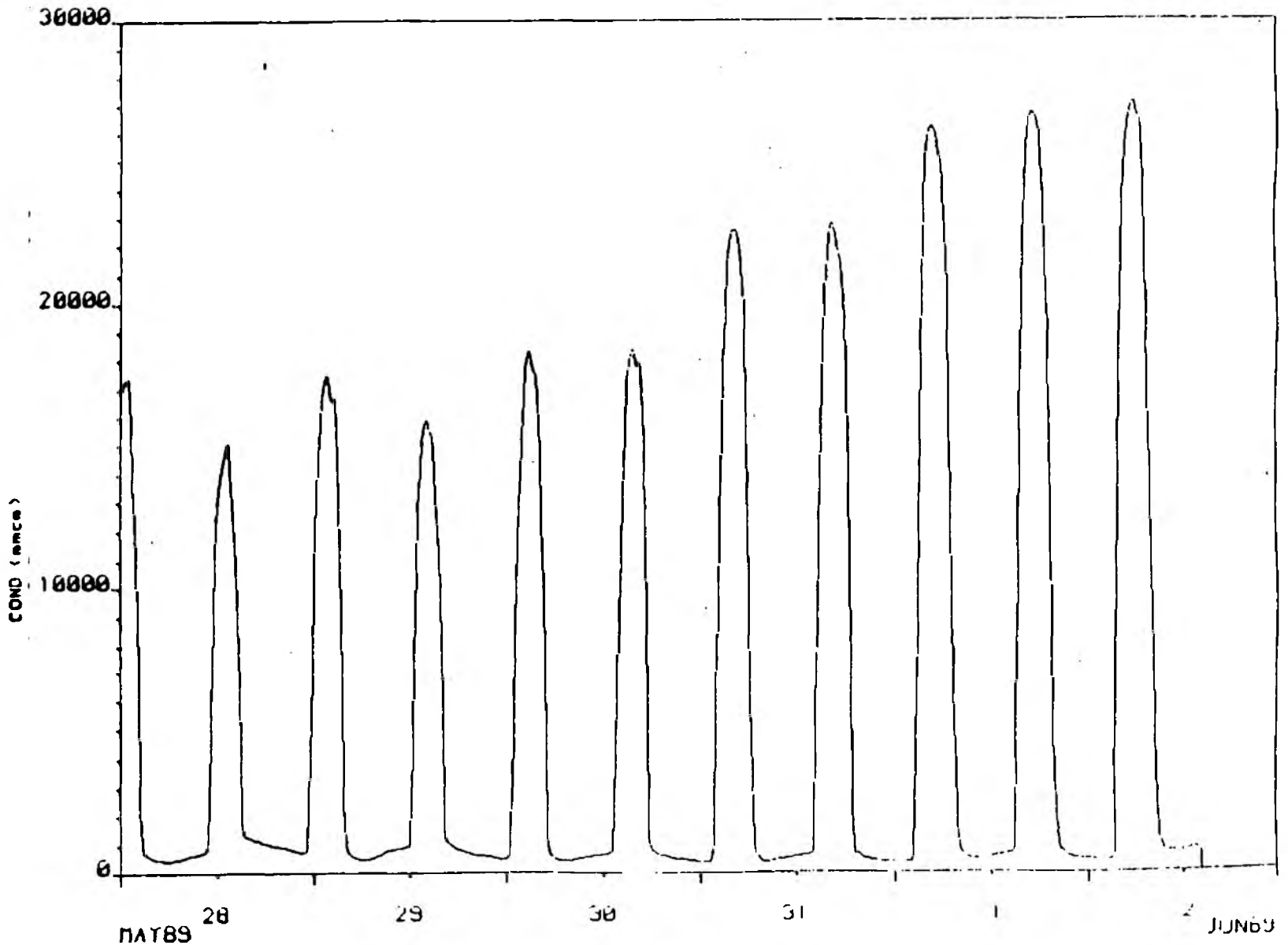


fig. 4a Submersible - Oxygen data (31/5/89 - 9/6/89)

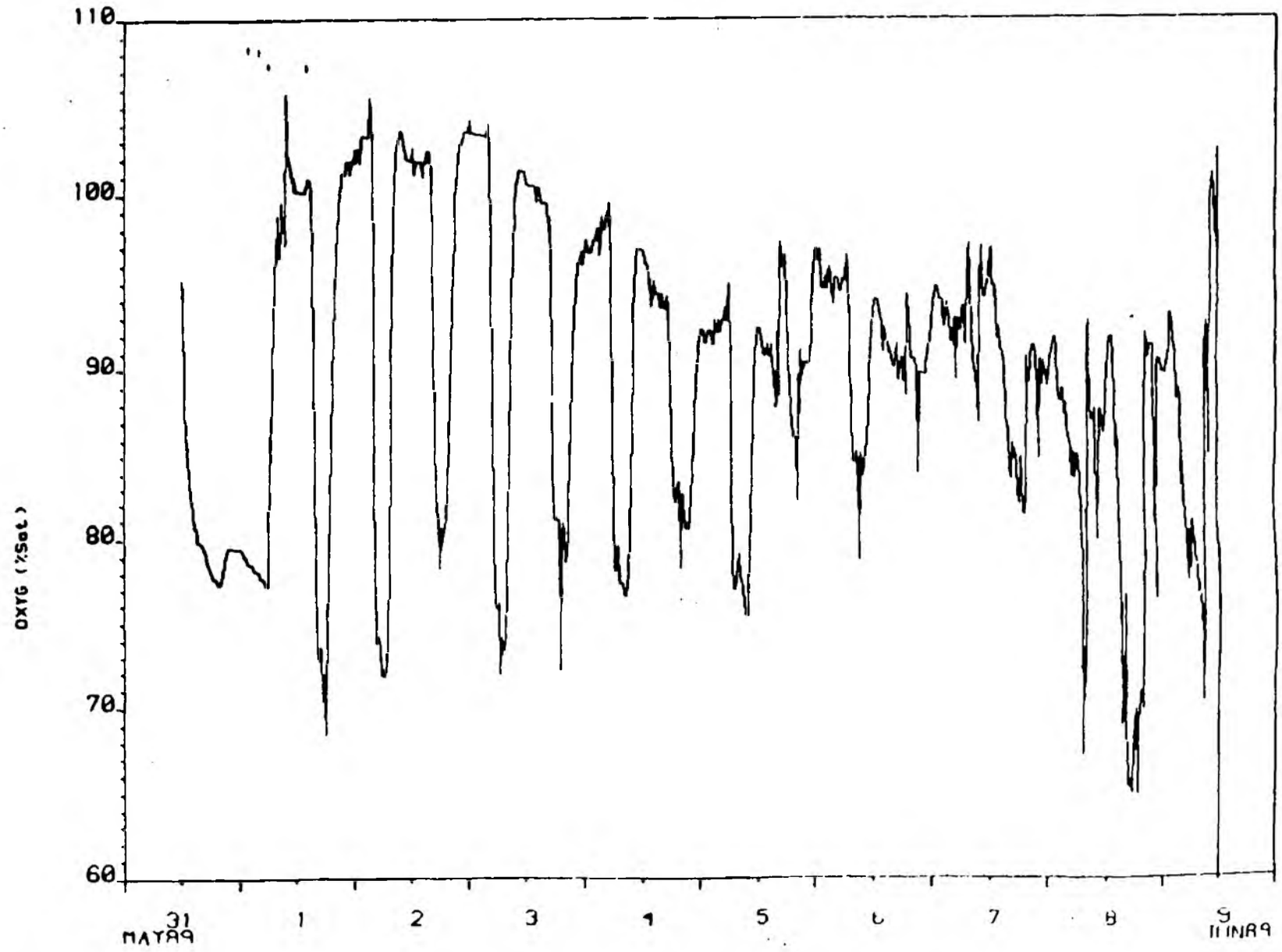


fig. 4b Submersible - Conductivity data (31/5/89 - 9/6/89)

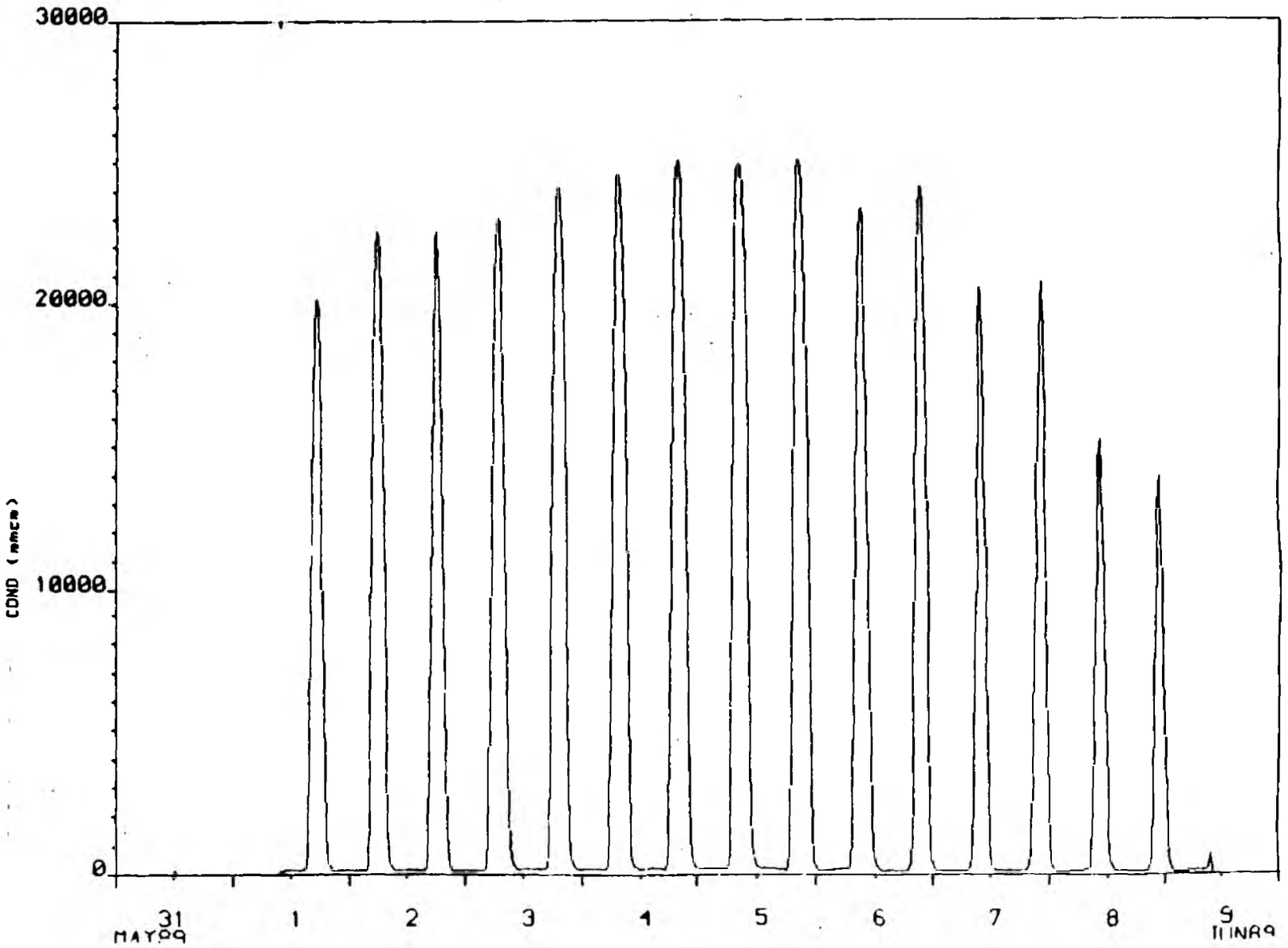


fig. 5a Parc-y-Splotte - Oxygen data (26/7/89 - 1/8/89)

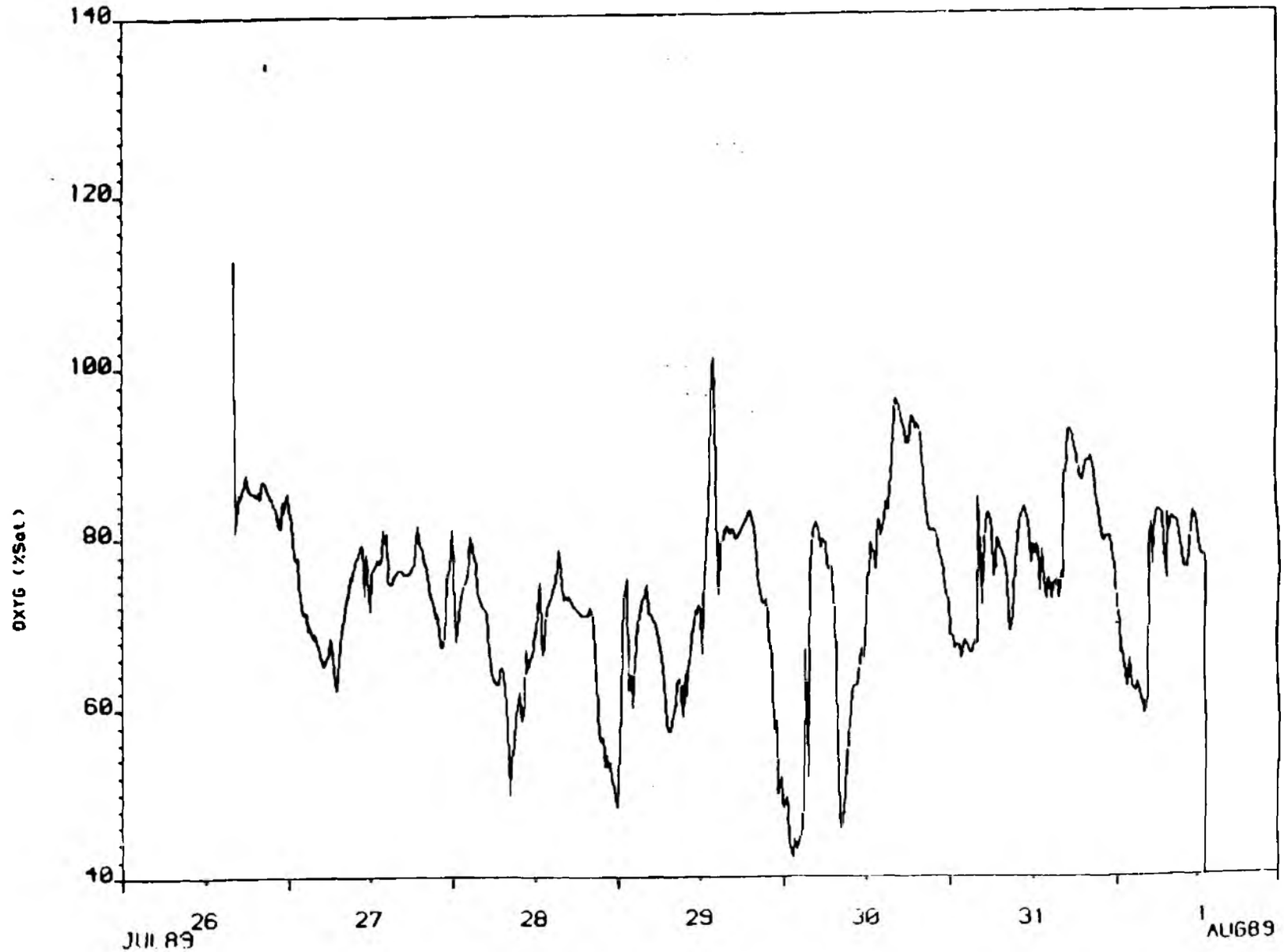


fig. 5b Parc-y-Splotts - Conductivity data (26/7/89 - 1/8/89

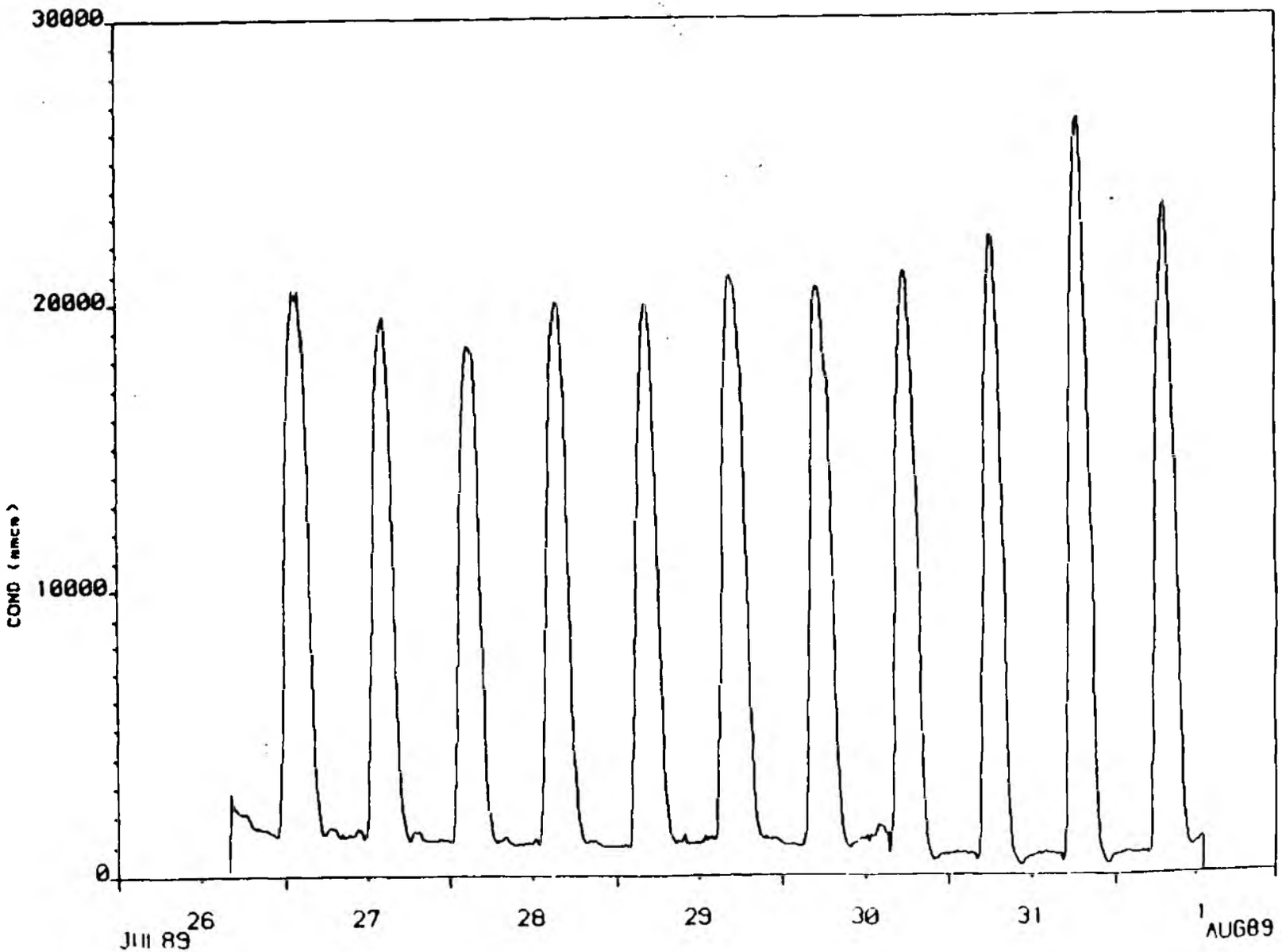
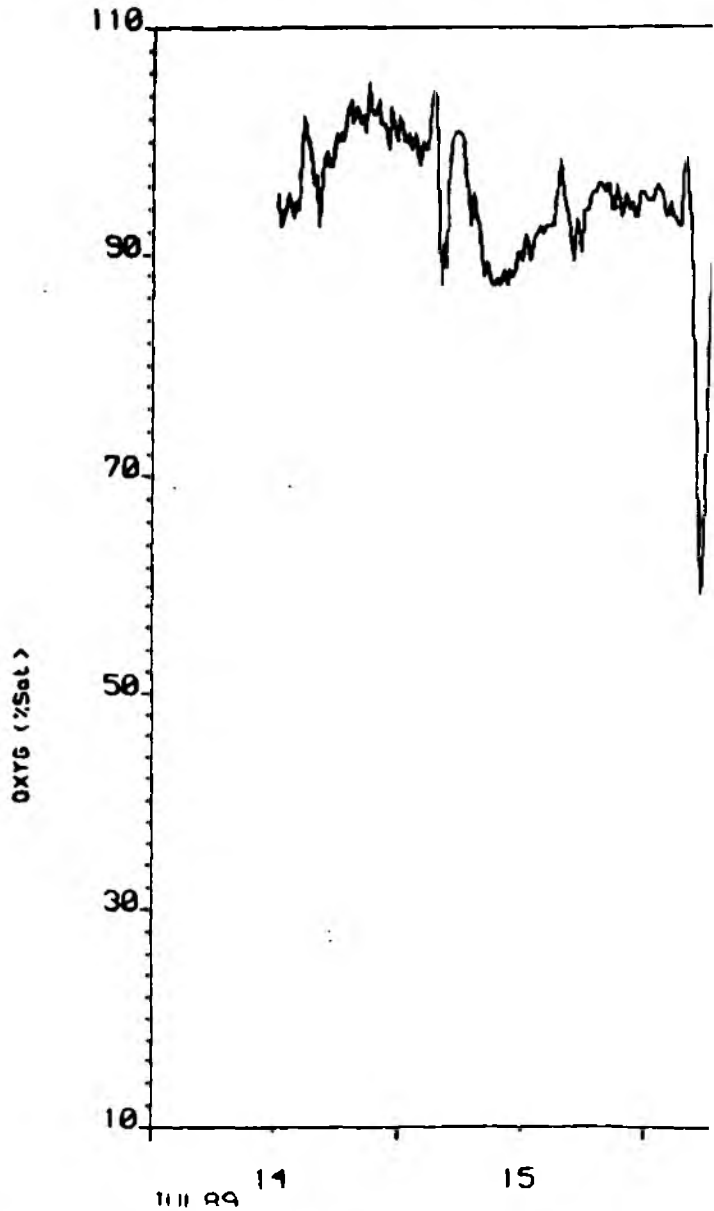


fig. 6a Railway Bridge - Oxygen data



(14/7/89 - 19/7/89)

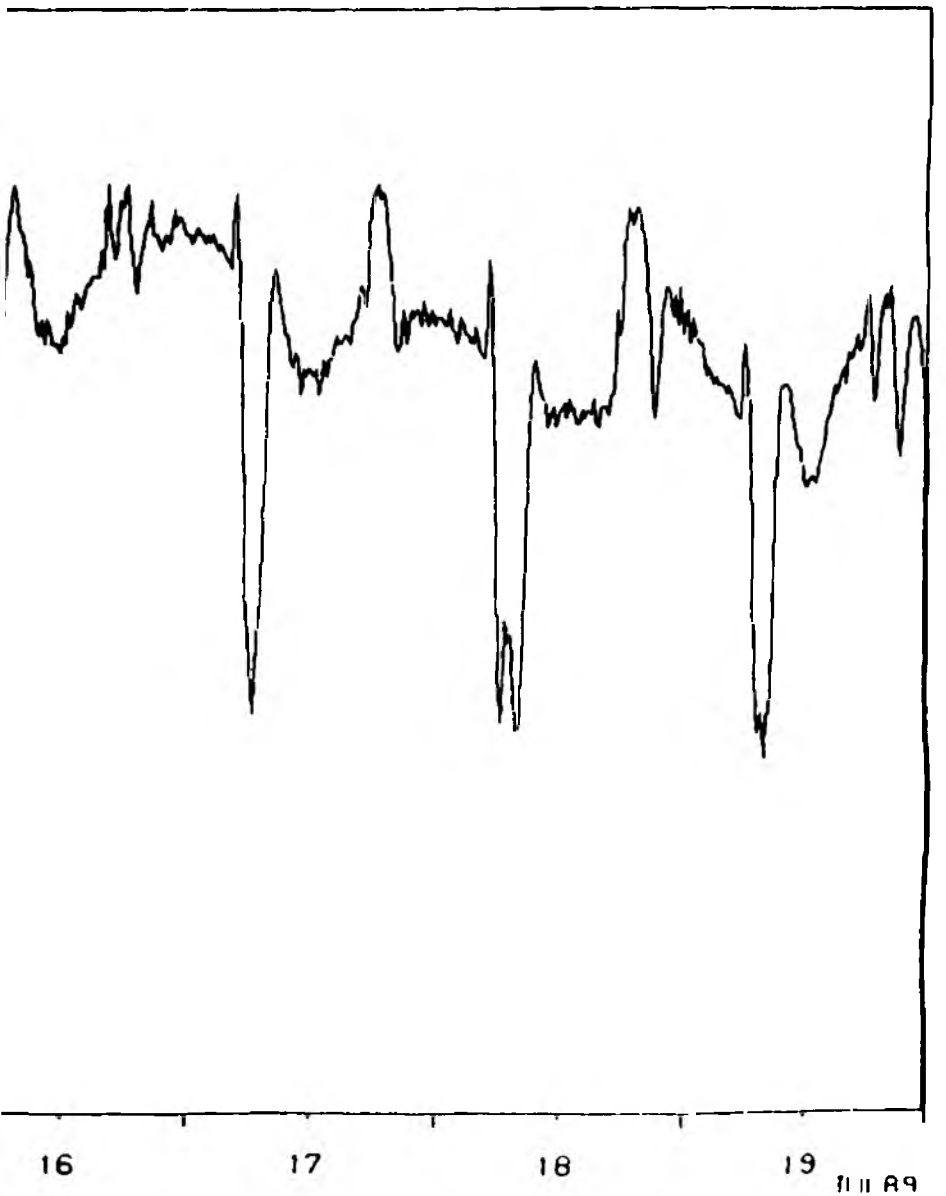


fig. 6b Railway Bridge - Conductivity data (14/7/89 - 19/7/8

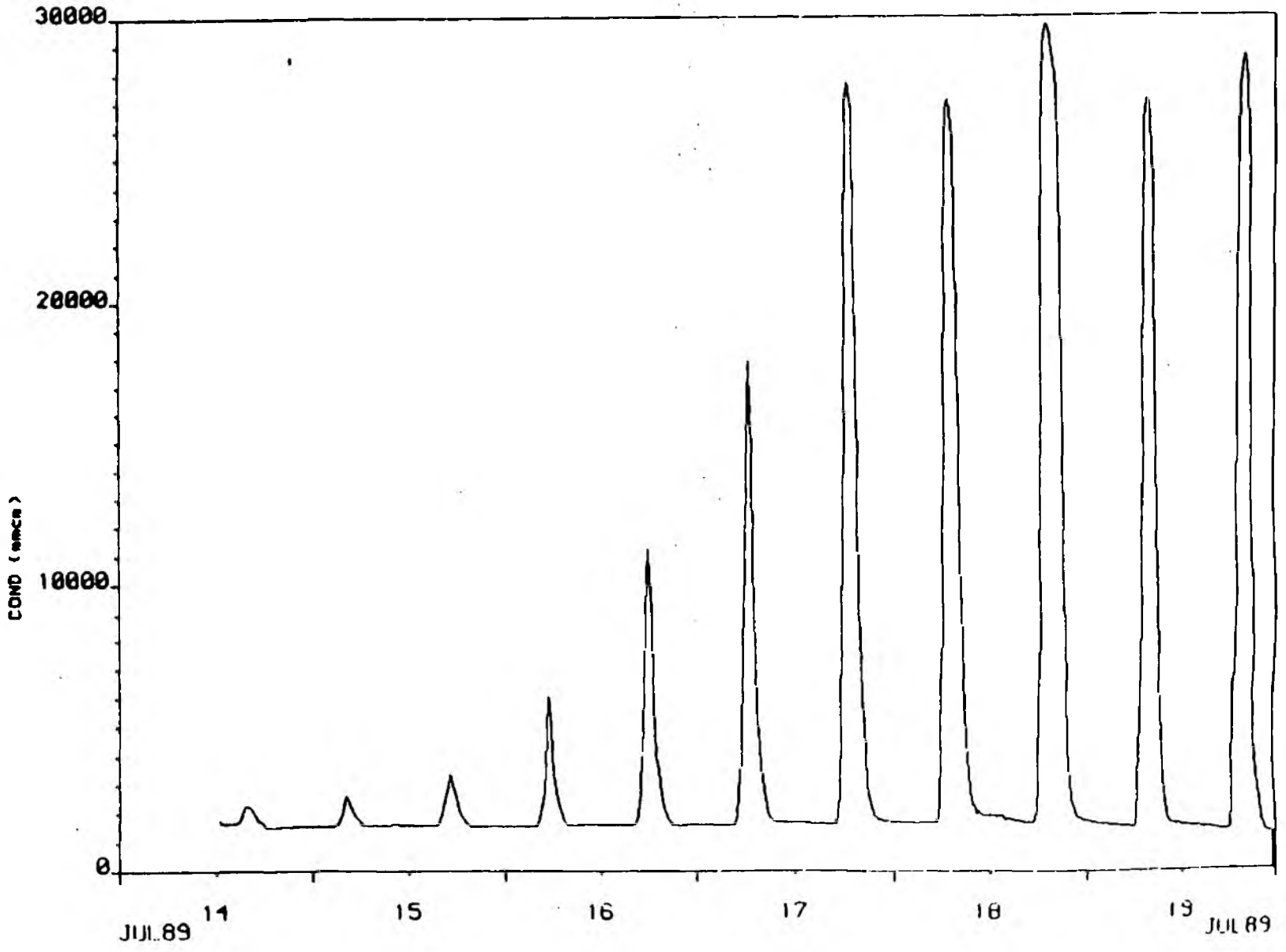
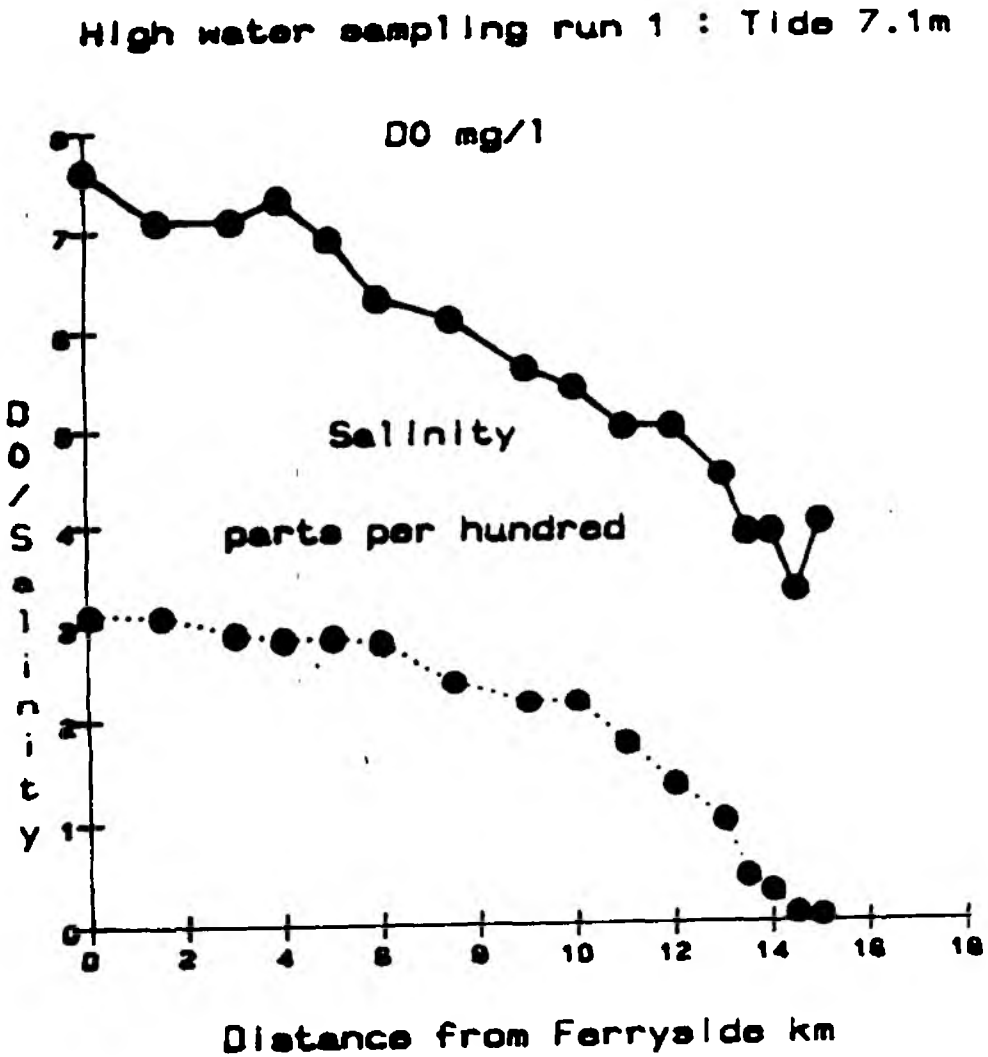


fig. 7 Boat Surveys (20/6/89.6/7/89)



High water sampling run 2 : Tide 7.2m

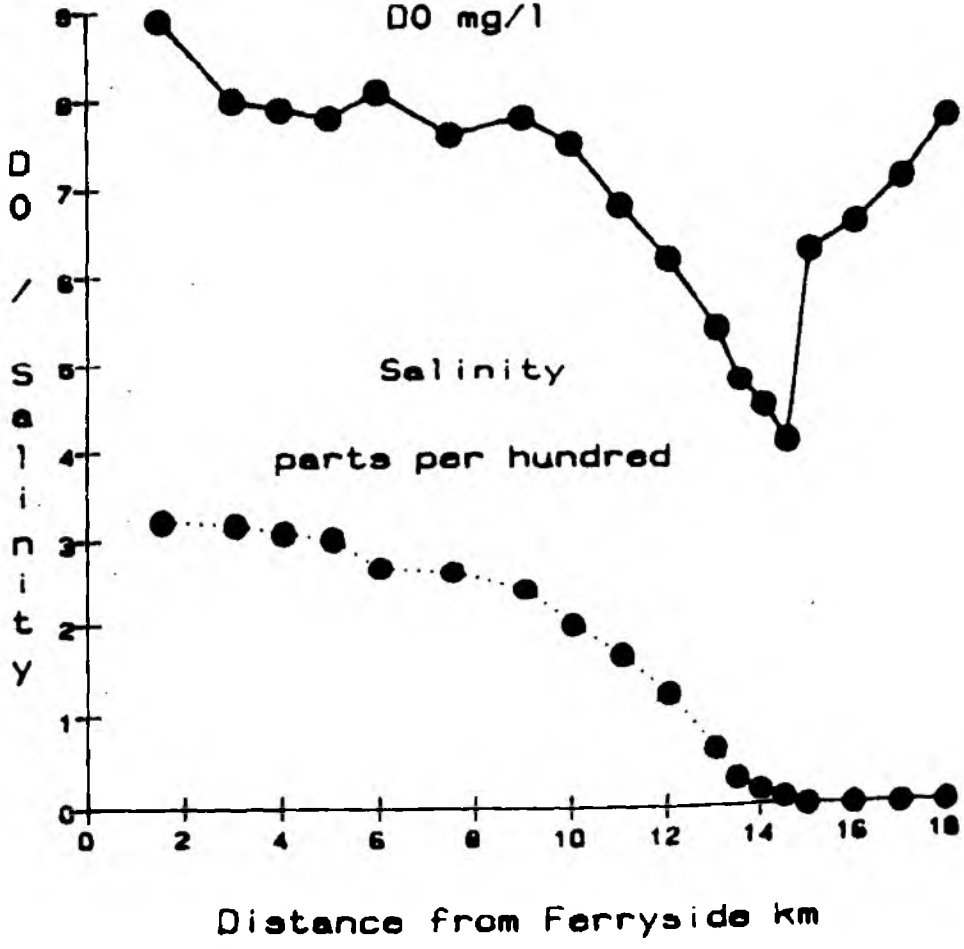
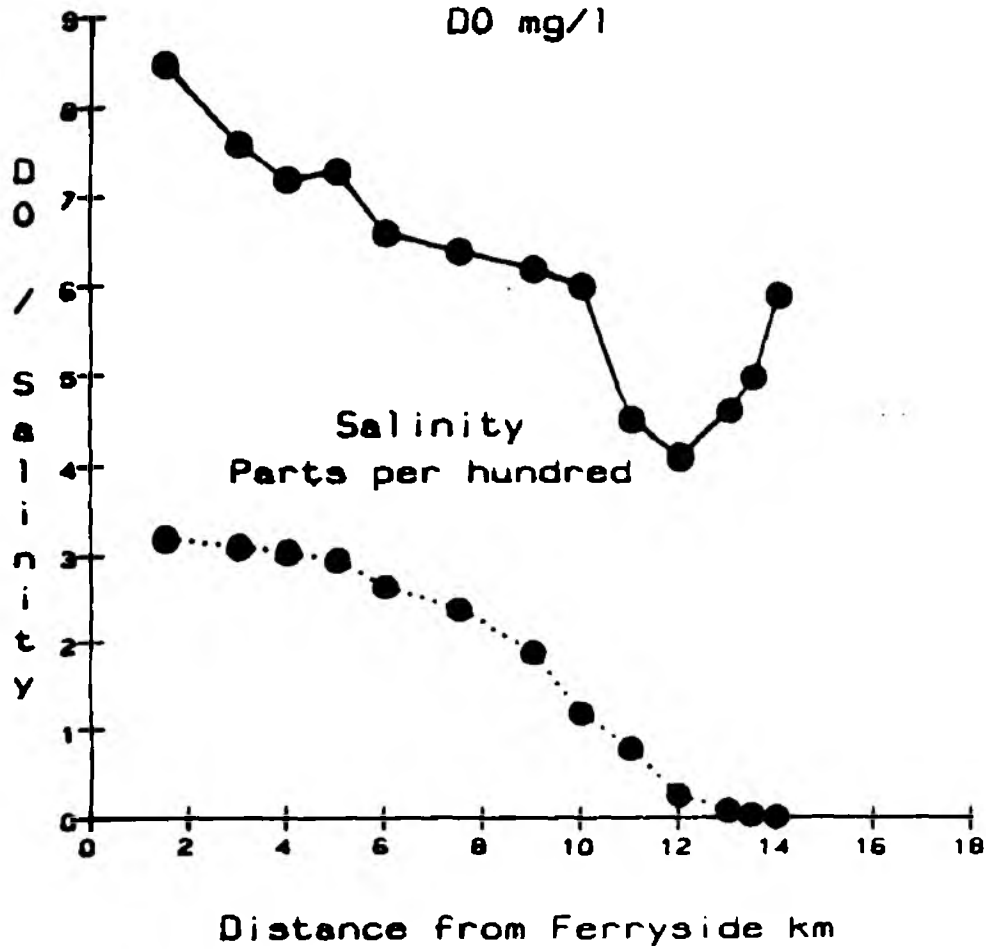


fig. 8 Boat Surveys (20/7/89, 15/9/89)

High water sampling run 3 : Tide 7.5m



High water sampling run 4 : Tide 6.5m

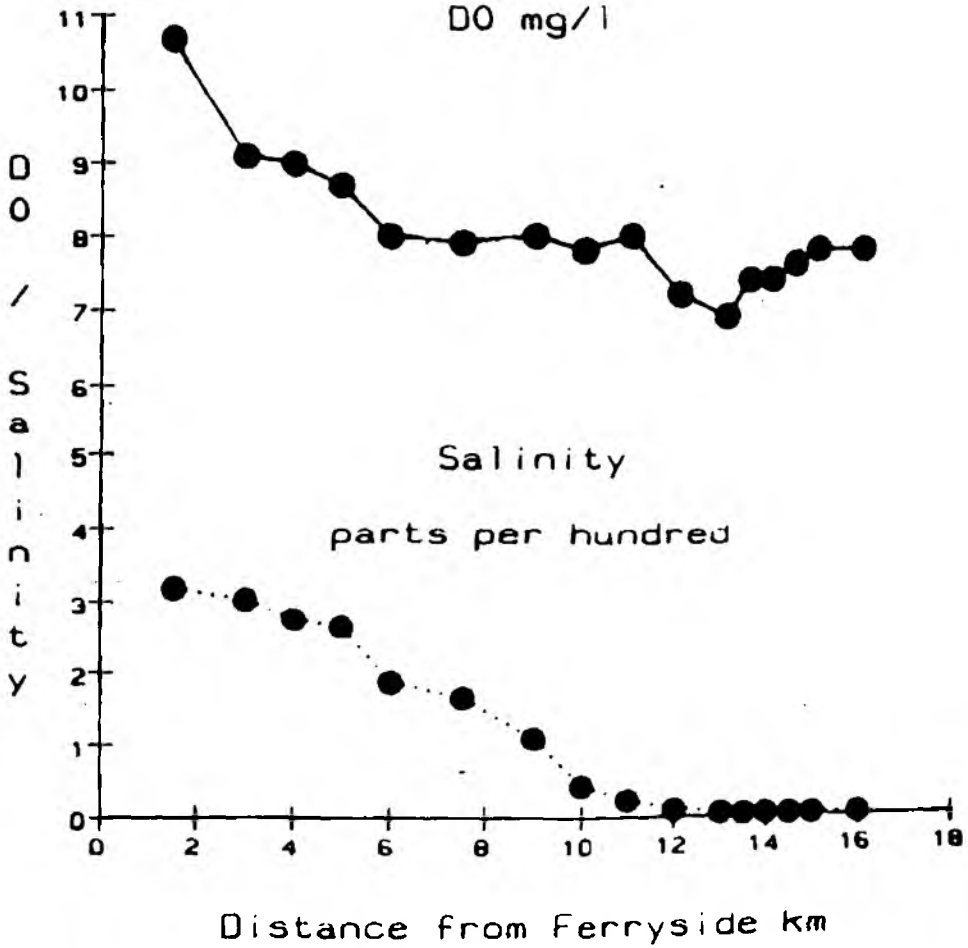
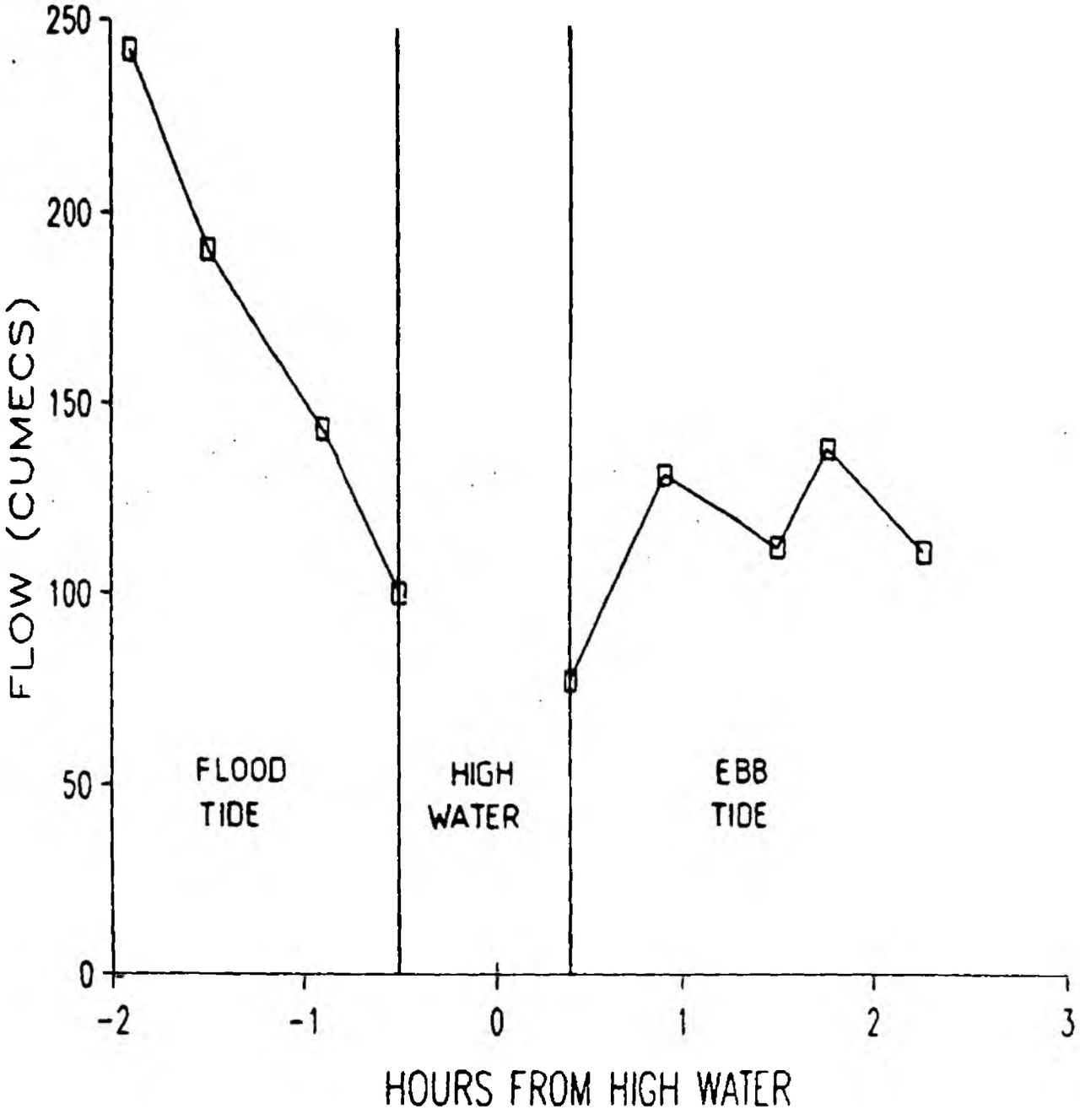


FIG. 9 TIDAL FLOW AT PARC-Y-SPLOTTS

11 AUGUST 1987



DATED 4 September 1989

Welsh Water PLC (1)

National Rivers Authority (2)

AGREEMENT

Re: Operation of the Tywi Oxygenation System

AGREEMENT for the operation of the Tywi Oxygenation System

1. Parties

Welsh Water PLC whose registered office is situate at Cambrian Way Brecon in the County of Powys (herein called 'the Company') under the hand of its Divisional Director South West Division Gordon Jones (1) and The National Rivers Authority Welsh Region whose Regional Office is situate at Plas Yr Afon St Mellons Business Park Cardiff (herein called 'the Authority') under the hand of its South Western Divisional Scientist Roger Thomas (2)

IT IS HEREBY AGREED AS FOLLOWS:

1. The Company will provide and maintain in working order for the duration of the agreement an experimental estuarine system together with the necessary oxygen supply (hereinafter called 'the System') at its Parc Y Splotts Sewage Treatment Works (hereinafter called 'the works') capable of injecting ten tonnes per day maximum of oxygen into the estuary of the River Tywi at Ordnance Survey Grid Reference SN401178

2. The Company will provide the system as an alternative to the provision of additional sewage treatment processes at Parc Y Splotts Sewage Treatment Works until such time as the principle and operation of the system is proven to be satisfactory under the terms of the assessment detailed in clause 9 or until the date of revision or termination of the agreement whichever is the sooner

3. In the event that the system is considered by the Authority to be an unsatisfactory alternative to additional sewage treatment processes then at the Authority's discretion the Company may be required to provide

   i) enchancement to the oxygen system so that the efficiency of the

oxygen transfer is improved to a satisfactory level or

ii) a combination of the system together with limited additional treatment at the works

iii) additional sewage treatment processes at the works such that the conditions of a positively determined long term discharge consent are satisfied

or

iv) an extended outfall to discharge at a location specified by the Authority during the design construction and implementation phases of any of the aforementioned requirements the Authority to have the right to require the Company to continue to maintain and operate the system

4. The system shall be operated when estuarine dissolved oxygen levels as measured by an automatic monitor (hereinafter called 'the monitor') located at Greencastle fall below 5mgl^{-1}

5. Oxygen injection shall be undertaken by the Company on a continuous basis under the direction of the Authority until the estuarine oxygen levels return to above 5mgl^{-1} except that the Authority may at its sole discretion restrict oxygen injection to defined periods of the tidal cycle

6. Nominated officers of the Company and the Authority will be responsible for effective liaison over the operation of the oxygenation system and such nominations shall be notified by each of the parties to this Agreement to the other by notice in writing addressed to the Divisional Director at Hawthorn Rise Haverfordwest Dyfed SA61 2BH or the Divisional Scientist at Llys Afon Hawthorn Rise Haverfordwest Dyfed SA61 2BQ as appropriate A nominated officer of the Authority shall

have specific responsibility for instructing the Company of any requirement to oxygenate which may be done by contacting the Company nominee or if such nominee cannot be contacted by contacting the Company Control Centre at Felindre

7. A second continuous water quality monitor shall be deployed during the period of the Agreement at or near the tidal limit of the River Tywi in order that any sudden and/or exceptional oxygen demand emanating from the freshwater river is identified If operation of the system is required wholly or partially because of an exceptional oxygen demand in the freshwater river and not associated with the demands of discharges from the works then the Authority shall pay to the Company the costs of oxygen required to be injected in respect thereof and reasonable staff costs associated with treating the freshwater river input

8. The Authority shall provide and maintain at its own cost the continuous monitoring equipment in the River Tywi at the sites specified in clauses 4 and 7 herein

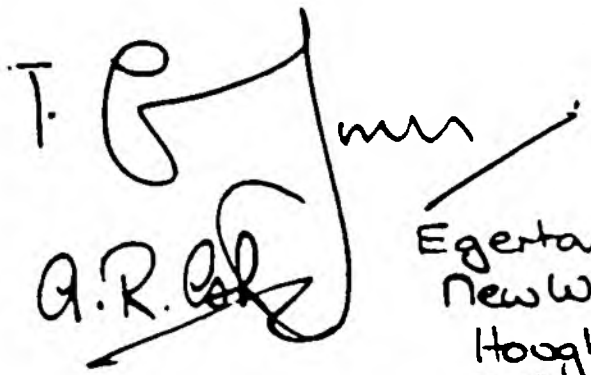
9. a) The efficacy of oxygen injection as a means of maintaining dissolved oxygen levels in the Tywi estuary above an absolute minimum of $3mgl^{-1}$ and to conform with the Environmental Quality Standard of $5mgl^{-1}$ as a 95 percentile will be assessed by the Authority without recharge to the Company and the Authority will make available to the Company all data analysis and conclusions arising from this work

b) This assessment will be undertaken over a minimum of five separate periods of operation each of which must cover at least a 48 hour period The Authority will then determine the degree

of success attained by oxygen injection in remedying the estuarine water quality problem and will determine whether the oxygen injection system on its own or in conjuction with additional sewage treatment processes may be retained as a long term solution

11. This Agreement shall be reviewed in five years from the date hereof if during that five year period weather conditions have been such that the system has in the opinion of the Authority not been fully assessed

Signed on behalf of the Company by Gordon Jones in the presence of:



Egerton Hous
New Wells R
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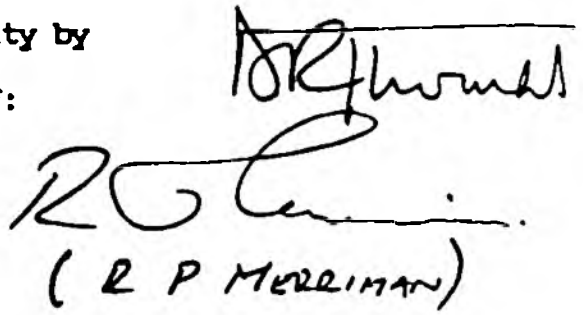
Milford Hav

Signed on behalf of the Authority by Roger Thomas in the presence of:



(R P MERRIMAN)

REPORT FEED BACK SHEET

The purpose of this form is to provide information which will enable the EAU to improve its service and help to ensure that resources are used appropriately. Comments are welcomed from any reader of the report. Please photocopy this page and return the completed form to the appropriate Senior Environmental Appraisal Officer/Scientist.

REPORT TITLE: _____

_____

REF. NO: _____

DATE OF REPORT: _____

MANAGER: _____ SPONSOR: _____

DATE OF COMMENTS: _____

COMMENTATOR: _____

DESIGNATION: _____

HOW WELL DOES THE WORK REPORTED FULFILL THE OBJECTIVES OF THE PROJECT?

_____

_____

WAS THE REPORT EASY TO COMPREHEND? _____

_____

WAS THE REPORT OF APPROPRIATE LENGTH? _____

_____

WAS THE STYLE OF THE REPORT ACCEPTABLE? _____

_____

WERE DIAGRAMS AND GRAPHS CLEAR? _____

_____

LIST ANY OMISSIONS IN THE FIELDWORK UNDERTAKEN _____

_____

_____

LIST ANY DEFICIENCIES IN THE STRUCTURE OF THE REPORT _____

_____

ARE THE CONCLUSIONS VALID? _____

ARE THE RECOMMENDATIONS OF VALUE? _____

ARE THE RECOMMENDATIONS ACHIEVABLE? _____

ANY OTHER COMMENTS _____

_____