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# Operation of the "Hydrolab" 8000 System for Collection of Water Quality Data

YUKON RIVER BASIN STUDY

This project was completed for the Yukon River Basin Study, an intergovernmental study funded by the governments of Canada, Yukon and British Columbia.

Water Quality Report No. 5

P.H. Whitfield



Inland Waters Directorate
Pacific and Yukon Region
Vancouver, B.C.

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Paul H. Whitfield
Water Quality Branch
Inland Waters Directorate
Environment Canada
502-1001 West Pender Street
Vancouver B.C. V6E 2M9

Yukon River Basin Study
Water Quality Work Group Report #5

## DISCLAIMER

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## ABSTRACT

This document describes our experience with the "Hydrolab" 8000 system and some of the operational enhancements that have been developed by Water Quality Branch Pacific and Yukon Region. The "Hydrolab" system has several features which are useful in field studies. It provides precise measurements of a limited number of water quality variables. It can operate as an unattended monitor or a survey instrument. The system components, aspects of the operation of each component, and details of the subsequent processing of logged water quality data are described.

## RESUME

Ce document décrit nos travaux effectués au moyen du système "Hydrolab" 8000 et quelques-unes des améliorations qui y ont été apportées par le personnel de la Direction de la qualité des eaux, région du Pacifique et du Yukon. Le système "Hydrolab" possède plusieurs caractéristiques très utiles pour les études sur le terrain. Il permet de mesurer précisément quelques variables sur la qualité des eaux; il peut être utilisé de façon automatique pour la surveillance continue, ou pour des relevés. La surveillance continue automatique est utile pour plusieurs types d'études sur le terrain, et elle est essentielle quand les conditions climatiques sont très dures (en hiver, la température de l'air du Yukon peut descendre jusqu'à -40°C). Quand des mesures à intervalles constants et courts sont requises (par exemple, pour des études de fluctuations diurnes ou quand les conditions changent rapidement), un système tel qu' "Hydrolab" 8000 laisse le personnel sur le terrain libre pour d'autres tâches essentielles.

Ce rapport décrit nos travaux avec les différentes composantes du système ainsi que la manipulation de celles-ci, et présente le traitement subséquent des données sur la qualité des eaux qu'il enregistre. Le protocole d'utilisation du système évolue constamment et des documents subséquents en décriront de nouvelles applications.

## INTRODUCTION

This document describes our experience with the "Hydrolab" 8000 system and some of the operational enhancements that have been developed by Water Quality Branch Pacific and Yukon Region. The "Hydrolab" system has several features which are useful in field studies. It provides precise measurements of a limited number of water quality variables. It can operate as an unattended monitor or a survey instrument.

Data is stored in a solid state memory and does not require moving parts as would a magnetic tape or other storage. Storage capacity is relatively large (e.g., six variables measured every 15 minutes for a week). Since the stored data is machine readable, further processing can be achieved without the conversions required when using analog strip charts. These properties are desirable for a variety of reasons, particularly where these properties enhance data gathering capabilities.

Data gathering in an unattended mode is useful in many field programs, but is critical in the situation where conditions are extreme (such as during the winter in the Yukon Territory where air temperatures reach -40 degrees Celsius). Where time series records at closely spaced intervals are required, such as studies of diurnal fluctuations or rapidly changing conditions, a system such as the "Hydrolab" 8000 frees the field crew to attend to other tasks concurrent to the collection of data.

However, like all new equipment or procedures there are inherent problems or difficulties which are faced. One of the major drawbacks to the "Hydrolab" system is its cost. The total system which is described here costs about $37,000. An additional limitation is, as for all electronic instrumentation the availability of service facilities. With the "Hydrolab" system any repairs that are required result in returning the unit to the manufacturer in Austin, Texas. This requires a longer period of time than would be needed if local service were available, as well as the additional problems associated with shipping equipment across the International Boundary.

Our system 8000 consists of the following components:

1. 8100-161 Data Transmitter equipped with sensors for determining depth, temperature, conductivity, dissolved oxygen, pH, and oxidation-reduction potential.
2. 8002-000 Data Control Unit with Digital Display Only.
3. 8002-031 Data Control Unit with Auto Data Logging with 4096 reading memory positions and an Interface for manual control unit.
4. 8300-005 Underwater Data Cable 5 meters.
5. 8300-050 Underwater Data Cable 50 meters.
6. 8400-010 Transmitter Carrier with Circulator.
7. 8700-510 Manual Controller for entry of station labels.
8. 5200-8002 Reader Processor (Data Management Unit).

The system can be used in a variety of configurations, as deemed appropriate to the situation. Of primary concern in this report is the operation of the 8000 system as a data capture and logging instrument, and the subsequent evaluation of the data.

This report describes our experience with the system components, aspects of the operation of each component, and details the subsequent processing of logged water quality data. Operation of the system is still developing and updates of this document will include additional information regarding further applications. For details of the operation of the "Hydrolab" system the reader should consult the "Hydrolab" Operations manual

The first operation of the system was undertaken as part of the study of dissolved oxygen under ice in the Yukon River basin reported in Whitfield and McNaughton (1984). Example data sets included herein were obtained in the course of that study. Funding for that study and for the purchase of the five meter cable and the data logging unit were provided by the Yukon River Basin Study Committee.

# DESCRIPTION OF SYSTEM COMPONENTS

## Data Transmitter

The data transmitter is the submersible measuring instrument of the system 8000. The transmitter, which Water Quality Branch acquired, measures six variables. The Transmitter is enclosed in a "lexan" (polycarbonate) housing which is pressure tested to an equivalent depth of 340 meters. The sensors that the transmitter was equipped with are:

1. TEMPERATURE - measured with a linear thermistor network. No calibration is required or allowed. Range of temperatures: -5 to +45 degrees Celsius. Precision +/- 0.2 degrees Celsius.
2. DEPTH - determined by strain gauge pressure transducer. User calibration of local zero required to accommodate local air pressure correction.
3. DISSOLVED OXYGEN - measured using a gold/silver polarographic cell (Clark). User calibration is required and can be done using ambient air as a standard. It is preferable to calibrate using Winkler analysis. Range of dissolved oxygen: 0 to 20 mg/l. Precision 0.2 mg/l.
4. CONDUCTIVITY - measured using a temperature-compensated, four electrode cell. Cell requires periodic cleaning but is easily disassembled for that purpose. Calibration of the electrode requires potassium-chloride standards.

Range of conductivity: 0 to 20 millisiemens/cm. Precision +/- 1 percent.

5. pH - measured using the glass electrode: silver/silver chloride reference electrode pair. Calibration using standard pH buffers. Temperature compensation is automatic. Range 0 to 14 units. Precision +/- 0.1 units.
6. OXIDATION REDUCTION POTENTIAL (ORP) - measured using a platinum electrode: silver/silver chloride electode pair. Range -2000 to +2000 millivolts. Precision +/- 1 percent.

Transmitter Carrier

The data transmitter is encased in the transmitter carrier which is constructed of high impact lexan. Attachments are provided to connect the carrier to data bus cable and to the transmitter. The transmitter carrier has an integral circulator necessary for effective measurement of dissolved oxygen. Attachment of weights for lowering and holding of the sensor assembly is provided.

Data Bus Cables

These polyurethane-jacketed cables contain the necessary communications wires between the sensor and the surface unit. A strength member is integral in the cable allowing it to be used for raising and lowering the sensor.

## Data Control Units

The two data control units are the data processors of the 8000 system. Both data control units display digital readouts. One of the units also provides analog output. The other unit can automatically log digital data. This memory is a CMOS type, requires low levels of current, and has a capacity of 4096 total observations. The sampling can be set at intervals of 15,30,60, or 120 minutes. This allows unattended monitoring of the six variables.

The unit with its batteries, both the internal and the external, has the capacity to gather data for one week sampling six variables at 15 minute intervals. Nevertheless when the unit becomes cooler than 10 degrees Celsius the active life of the power supply is seriously reduced. In practice we operated the unit within a 'hot-box' constructed specifically for the "Hydrolab" 8000 system (McNaughton, 1984). The 'hot-box' maintained the instrument at 15 to 20 degrees Celsius which greatly prolonged the life of the batteries of the unit.

## Manual Controller

This unit is used in conjunction with the data logging control unit. The manual controller is used to digitize data at the time of measurement, add labels, and store the data into the CMOS memory of the data control unit. This is particularly useful for doing profiling of a water column, or for storing large numbers of determinations in a machine readable form.

## Reader Processor (DMU)

This unit is used to transfer data from the data control unit CMOS memory. The unit may be used to recover data to a terminal, or to a computer. These applications are described in the manuals provided by "Hydrolab". Water Quality Branch has developed the necessary software support to allow the data to be transferred from the memory to an Osborne microcomputer (Whitfield, 1983).

## OPERATIONAL OBSERVATIONS

1. The instrument is very well constructed with only a few minor inconveniences. The user of this equipment must be aware that it is an electronic instrument and should be given the level of care that one would accord any other delicate electronics. We initially had problems with the memory function of this unit. The problem was a faulty board into which the memory chips were placed. The board was improperly manufactured allowing the memory chips to fall out under normal handling. "Hydrolab" replaced the board when they were alerted to the problem. The unit has several other design features which should be improved. Switching of the time interval to the desired interval requires removal of the electronics from the water-proof housing. This was also true of the internal batteries which power the CMOS memory. It is not advisable to open the housing except under controlled circumstances. The internal batteries should be changed prior to each use to ensure that sufficient battery life exists to maintain the memory in a 'live' state. Since there is no provision for determining the condition of the internal power supply of the CMOS memory replacing of the batteries prior to each use is a mandatory precaution.

2. Calibration of the instrument is, with the exception noted in 3 below, simple using the standards suggested by the manufacturer. Conductivity calibration, while simple, is somewhat confused by the manner in which the data control

unit offers a number of conductivity ranges. Care in the recovery of data where the range in use is specified is recommended. Software developed by us overcomes this problem, as discussed later.

3. The dissolved oxygen electrode is somewhat difficult to calibrate. The instructions provided are somewhat obscure. The calibration is performed in water saturated air with the end up, and the open end loosely capped. The instructions in the manual otherwise apply. If the electrode seems difficult to calibrate the membrane and the electrolyte within the probe sould be replaced. Calibration was more successful when the membrane was replaced before attempting to calibrate. The software described later allows for additional calibration of the results based on concurrent Winkler titrations.

   In addition, there are no instructions for replacing the electrode membrane. The following procedure is recommended:

   a. Provide KCl (saturated solution) in an eyedropper bottle.
   b. Remove the sensor guard from the top of the probe.
   c. Remove the "O" ring and the old membrane.
   d. Inspect the anode and the cathode surface for salt crystals or foreign material. Flush the probe with KCl or distilled water.
   e. Lift a new membrane out and place it within easy reach.
   f. Fill the probe and install the new membrane according to the following steps:
      1) grasp thread end of probe between thumb and forefinger.

2) secure one end of membrane under the thumb.

3) use the eyedropper to fill the electrode well.

4) create a meniscus large enough to cover the gold cathode.

5) with the other hand grasp the free end of the membrane.

6) in a continuous motion stretch the membrane up and over the electrode, and down the other side.

7) secure the membrane with forefingers

8) roll the "O" ring over the end of the probe, ensuring that there are no wrinkles or air bubbles under the membrane.

9) trim the edges of the membrane outside the "O" ring with scissors. CAREFULLY.

g. Allow 15 minutes for the electrode to polarize prior to any attempt to calibrate the electrode.

Although this procedure is relatively simple and can be performed in the field the electrode should be treated as carefully as possible.

4. The electrodes, particularly dissolved oxygen, were unstable when frazil ice was present in the water column. Frazil ice tended to collect on the electrode assembly and disturb the measurements during freeze-up.

5. The stirring device should be checked regularly to make certain it functions properly and is not collecting debris.

6. At low water temperatures the equilibration period set electronically is sometimes insufficient. Frequent anomalous

readings obtained at low temperatures are evident in plots of the data. It is believed that atypical readings result from inadequate equilibration, since at higher water temperatures (e.g.>0) where equilibration is more rapid the anomalous values occur with a much lower frequency.

## DATA RECOVERY

Each of the procedures for the recovery of data from the memory unit has limitations. Of the three available and described below, the procedure for transferring from the "Hydrolab" to the microcomputer developed by Water Quality Branch is preferred.

### "Hydrolab" to Terminal

This procedure is described in the manual which accompanies the Data Management Unit (DMU). The methodology is straight-forward and easily performed once the user has determined the properties of the particular terminal being used and adjusted them to the requirements of the DMU. The recovery procedure produces an acceptable report, but the data is not machine readable in this form.

### "Hydrolab" to Terminal to Computer

This procedure produces the same report as does the previous procedure. It also produces a machine readable version of the report on the computer to which it is attached. Since this version does not contain the headers present in the terminal report, it does not require any editing prior to processing. This method was found, however, to be unacceptable due to the sensitivity of the DMU and the CMOS memory to noise on the telephone lines used to establish communications between the DMU-terminal and the mainframe computer. Occurrence of line noise during transmission resulted in a serious disruption of the data in the memory. Line noise caused individual records and even blocks of records to be overwritten depending upon the severity of the noise.

"Hydrolab" to Microcomputer

This procedure developed by Water Quality Branch is described in detail by Whitfield (1983). It requires a CP/M microcomputer which is relatively portable. The actual system upon which the procedure was implemented is an Osborne -1. This system, which is totally portable, can be operated in the field using a 12 volt power supply. Basically the procedure is an emulation of the "Hydrolab" to Terminal recovery procedure described above, with the recovered data being stored in a file on floppy disk. This file, which contains all the report headers can then be transferred to a mainframe using the communications available for the Osborne. Once the file has been placed on the mainframe computer it is a simple job to edit out the headers which were transferred. This procedure makes the process of recovery less sensitive to line noise during tranfers, since the disk files are unaffected by line troubles. In cases where transfers to the mainframe fail, a copy of the file remains on disk with the microcomputer for retransfer.

This method is preferable to those provided by "Hydrolab", although it requires additional equipment. It provides machine readable data in a much less volatile form than do the procedures supplied by "Hydrolab".

## DATA PROCESSING

Once the data has been transferred to the mainframe, and the extraneous header cards have been removed, there is a need to examine the data. One of the methods which best suits the time series which are gathered is a visual examination of plots of the data. We developed software which would perform the plotting of each of the variables on standard scales. A listing of the program developed is contained in the appendix to this report.

### Plotting Program

In order to produce the plots the user must compile a FORTRAN program, and then run the compiled program. The running program asks all the questions necessary to identify the plots. The following is a sample of the compilation and subsequent interaction with the program and system that produces a block of plots using MTS. Material in upper case is system generated, with user response in lower case or following the ?.

-------------------------------

```
#run *ftn scards=wqb5:hydrol.plot
#EXECUTION BEGINS
 NO ERROR IN MAIN
#EXECUTION TERMINATED
#r -load 5=h.datafile
#EXECUTION BEGINS
```

```
 PLOTTING OF HYDROLAB 8000 LOGGED DATA
WHAT IS THE RECORDING INTERVAL? I.E. 15
?15
WHAT IS THE STARTING DAY,MONTH,YEAR? AS 25,12,1975
?16,5,1983
WHAT IS THE STARTING HOUR,MIN? AS 10,50
?9,40
WHAT IS THE STATION NAME? LESS THAT 50 CHARACTERS IN LENGTH
---------|---------|---------|---------|--------|
?Takhini River at Old Dawson Road
FIRST FIVE CONDUCTIVITY VALUES ARE:
 11.0000 11.0000 11.0000 11.0000 11.000
INPUT SCALE FACTOR OR 1. TO STOP
?10.
FIRST FIVE CONDUCTIVITY VALUES ARE:
 110.0000 110.0000 110.0000 110.0000 110.0000
INPUT SCALE FACTOR OR 1. TO STOP
?1.
FIRST FIVE DO VALUES ARE:
 9.3090 10.3700 10.7800 10.8100 10.9500
INPUT CALIBRATION FACTOR OR 1. TO STOP
?1.
PDS: PLOT DESCRIPTION GENERATION BEGINS.
#EXECUTION TERMINATED
#r *ccqueue par=plotfile scale=.75
#EXECUTION BEGINS
```

```
 1 PLOTS; PLOTTING REQUIRES  340 SECONDS AND 49 IN.; $1.41
OK?
ok
"PLOTFILE  " HAS BEEN PERMITTED "R PKEY=*CCQUEUE".
PLOT ASSIGNED RECEIPT # 507921
#EXECUTION TERMINATED
-------------------------------
```

The printing of the first values of conductivity and dissolved oxygen allows the user to ensure that the appropriate scale of both variables is being used. The program has a number of error checking functions to ensure that input dates and times are within real bounds. Where errors are detected on input the program requests re-entry of the appropriate data.

Tabular Data

Table 1 shows (in part) the data gathered during April 1983. As can be seen, the readings are identified by time only. Records must be kept of the instruments use to allow identification of the data in terms of station and date. We use the form shown in Figure 1. This form is filled in as was appropriate for the data contained in Table 1. These forms comprise the major backup for the data being gathered and are filled in at every visit to the instrument.

Listing of H.TAK.APR at 10:54:31 on NOV 8, 1983 for CCid=WQB0



| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 2 | 09:40 | +002.5 | +000.0 | +0.010 | +12.36 | +07.72 | +0274. |
| 3 | 09:55 | +003.2 | +000.0 | +0.010 | +14.51 | +07.77 | +0288. |
| 4 | 10:10 | +003.5 | -000.0 | +0.010 | +14.42 | +07.78 | +0302. |
| 5 | 10:25 | +003.6 | +000.0 | +0.010 | +14.33 | +07.78 | +0313. |
| 6 | 10:40 | +003.6 | +000.0 | +0.010 | +14.23 | +07.78 | +0320. |
| 7 | 10:55 | +003.6 | +000.0 | +0.010 | +14.17 | +07.77 | +0327. |
| 8 | 11:10 | +003.7 | +000.0 | +0.010 | +14.12 | +07.77 | +0332. |
| 9 | 11:25 | +003.7 | +000.0 | +0.010 | +14.08 | +07.77 | +0336. |
| 10 | 11:40 | +003.6 | +000.0 | +0.010 | +14.00 | +07.77 | +0340. |
| 11 | 11:55 | +003.6 | +000.0 | +0.010 | +13.95 | +07.76 | +0343. |
| 12 | 12:10 | +003.6 | +000.0 | +0.010 | +14.00 | +07.76 | +0346. |
| 13 | 12:25 | +003.6 | +000.0 | +0.010 | +13.88 | +07.77 | +0348. |
| 14 | 12:40 | +003.6 | +000.0 | +0.010 | +13.83 | +07.77 | +0350. |
| 15 | 12:55 | +003.5 | +000.0 | +0.010 | +13.88 | +07.78 | +0352. |
| 16 | 13:10 | +003.5 | +000.1 | +0.011 | +13.80 | +07.79 | +0354. |
| 17 | 13:25 | +003.6 | +000.0 | +0.010 | +13.77 | +07.78 | +0355. |
| 18 | 13:40 | +003.6 | +000.0 | +0.010 | +13.81 | +07.79 | +0356. |
| 19 | 13:55 | +003.6 | +000.0 | +0.010 | +13.81 | +07.79 | +0357. |
| 20 | 14:10 | +003.6 | +000.0 | +0.010 | +13.73 | +07.80 | +0358. |
| 21 | 14:25 | +003.6 | +000.0 | +0.010 | +13.73 | +07.80 | +0359. |
| 22 | 14:40 | +003.6 | +000.0 | +0.010 | +13.70 | +07.80 | +0360. |
| 23 | 14:55 | +003.6 | +000.0 | +0.010 | +13.67 | +07.81 | +0360. |
| 24 | 15:10 | +003.6 | +000.0 | +0.010 | +13.69 | +07.81 | +0361. |
| 25 | 15:25 | +003.6 | +000.0 | +0.010 | +13.71 | +07.81 | +0362. |
| 26 | 15:40 | +003.6 | +000.1 | +0.010 | +13.72 | +07.81 | +0362. |
| 27 | 15:55 | +003.6 | +000.0 | +0.010 | +13.72 | +07.81 | +0363. |
| 28 | 16:10 | +003.6 | +000.0 | +0.010 | +13.66 | +07.81 | +0363. |
| 29 | 16:25 | +003.6 | +000.0 | +0.010 | +13.62 | +07.81 | +0364. |
| 30 | 16:40 | +003.6 | +000.0 | +0.010 | +13.67 | +07.82 | +0363. |
| 31 | 16:55 | +003.7 | +000.0 | +0.010 | +13.66 | +07.82 | +0363. |
| 32 | 17:10 | +003.5 | +000.0 | +0.010 | +13.64 | +07.81 | +0364. |
| 33 | 17:25 | +003.6 | +000.0 | +0.010 | +13.65 | +07.81 | +0364. |
| 34 | 17:40 | +003.6 | +000.0 | +0.010 | +13.64 | +07.81 | +0366. |
| 35 | 17:55 | +003.6 | +000.0 | +0.010 | +13.60 | +07.81 | +0367. |
| 36 | 18:10 | +003.6 | +000.1 | +0.010 | +13.57 | +07.81 | +0369. |
| 37 | 18:25 | +003.6 | +000.1 | +0.010 | +13.62 | +07.80 | +0371. |
| 38 | 18:40 | +003.7 | +000.1 | +0.010 | +13.59 | +07.80 | +0373. |
| 39 | 18:55 | +003.6 | +000.0 | +0.010 | +13.66 | +07.79 | +0374. |
| 40 | 19:10 | +003.7 | +000.0 | +0.010 | +13.60 | +07.79 | +0376. |
| 41 | 19:25 | +003.7 | +000.0 | +0.010 | +13.59 | +07.79 | +0377. |
| 42 | 19:40 | +003.7 | +000.0 | +0.010 | +13.60 | +07.78 | +0379. |
| 43 | 19:55 | +003.6 | +000.0 | +0.010 | +13.55 | +07.78 | +0380. |
| 44 | 20:10 | +003.8 | +000.0 | +0.010 | +13.58 | +07.78 | +0382. |
| 45 | 20:25 | +003.7 | +000.0 | +0.011 | +13.58 | +07.78 | +0383. |
| 46 | 20:40 | +003.5 | +000.0 | +0.010 | +13.57 | +07.77 | +0384. |
| 47 | 20:55 | +003.6 | +000.0 | +0.010 | +13.57 | +07.77 | +0385. |
| 48 | 21:10 | +003.6 | +000.0 | +0.010 | +13.56 | +07.77 | +0386. |
| 49 | 21:25 | +003.6 | +000.0 | +0.010 | +13.62 | +07.77 | +0387. |
| 50 | 21:40 | +003.6 | -000.0 | +0.010 | +13.51 | +07.77 | +0388. |
| 51 | 21:55 | +003.7 | +000.0 | +0.010 | +13.59 | +07.77 | +0389. |
| 52 | 22:10 | +003.7 | +000.0 | +0.010 | +13.52 | +07.77 | +0389. |
| 53 | 22:25 | +003.7 | +000.0 | +0.011 | +13.49 | +07.77 | +0390. |
| 54 | 22:40 | +003.6 | +000.0 | +0.010 | +13.50 | +07.77 | +0391. |
| 55 | 22:55 | +003.6 | +000.0 | +0.010 | +13.52 | +07.77 | +0391. |
| 56 | 23:10 | +003.6 | +000.0 | +0.010 | +13.47 | +07.77 | +0392. |
| 57 | 23:25 | +003.7 | +000.0 | +0.010 | +13.51 | +07.77 | +0392. |
| 58 | 23:40 | +003.6 | +000.0 | +0.010 | +13.46 | +07.77 | +0393. |
| 59 | 23:55 | +003.7 | +000.0 | +0.010 | +13.53 | +07.77 | +0393. |

Table 1
Sample Output Data

WATER QUALITY BRANCH - PACIFIC AND YUKON REGION

HYDROLAB FIELD NOTES

DATE 14 April 83

PROJECT Under Ice DO

| Station | Time | Depth | T°C | Cond | D.O. | pH | ORP |
|---|---|---|---|---|---|---|---|
| Check Standardization | | | | | | | |
| Takhini River at | | 2.1 | 0.1 | .010 | 12.45 | 7.65 | 268 |
| Old Dawson Road | | 2.1 | 0.1 | .010 | 12.45 | 7.66 | 269 |
| 15 min sequence | 0940 start. | | | | | | |
| | | | | | | | |
| Checkout | 1212 | 2.6 | 0.1 | .010 | 13.88 | 7.65 | 268 |
| | | 2.6 | 0.0 | .010 | 13.87 | 7.66 | 269 |

8-82w

Figure 1
Hydrolab Field Note Form for April 14, 1983

Plotted Data

Four sets of example plots are shown in Figures 2 through 21. These four sets show a number of things about the "Hydrolab" 8000 that are worth noting. The first set of five figures are from November. Figure 2 shows temperatures during the November sampling period and demonstrates the stability of this measurement under ice. All readings in the interval are zero, a fact reflected in the flat line exhibited in the plot. Figure 3 shows conductivity in the same period. The plot demonstrates the limits to precision of conductivity measurements. The electrode installed in the data transmission unit has a precision of +/- 10 microsiemens/cm. It is likely that conductivity measurements were affected by the presence of frazil ice during the early portion of the sampling period. November dissolved oxygens shown in Figure 4 demonstrates some of the limitations of this particular sensor. The early part of the record shows frazil ice interfering with the electrode, as reflected in the number of zero values obtained on November 12 and 13. Also evident during this period is some degree of upward drift during the initial period with concentrations becoming much more stable when frazil ceased to be a a problem. Figure 5 shows pH over this sampling period and shows an initial instability for the first few readings, and a subsequent stability. The electrode seems less affected by the presence of frazil than either the dissolved oxygen or conductivity electrodes.

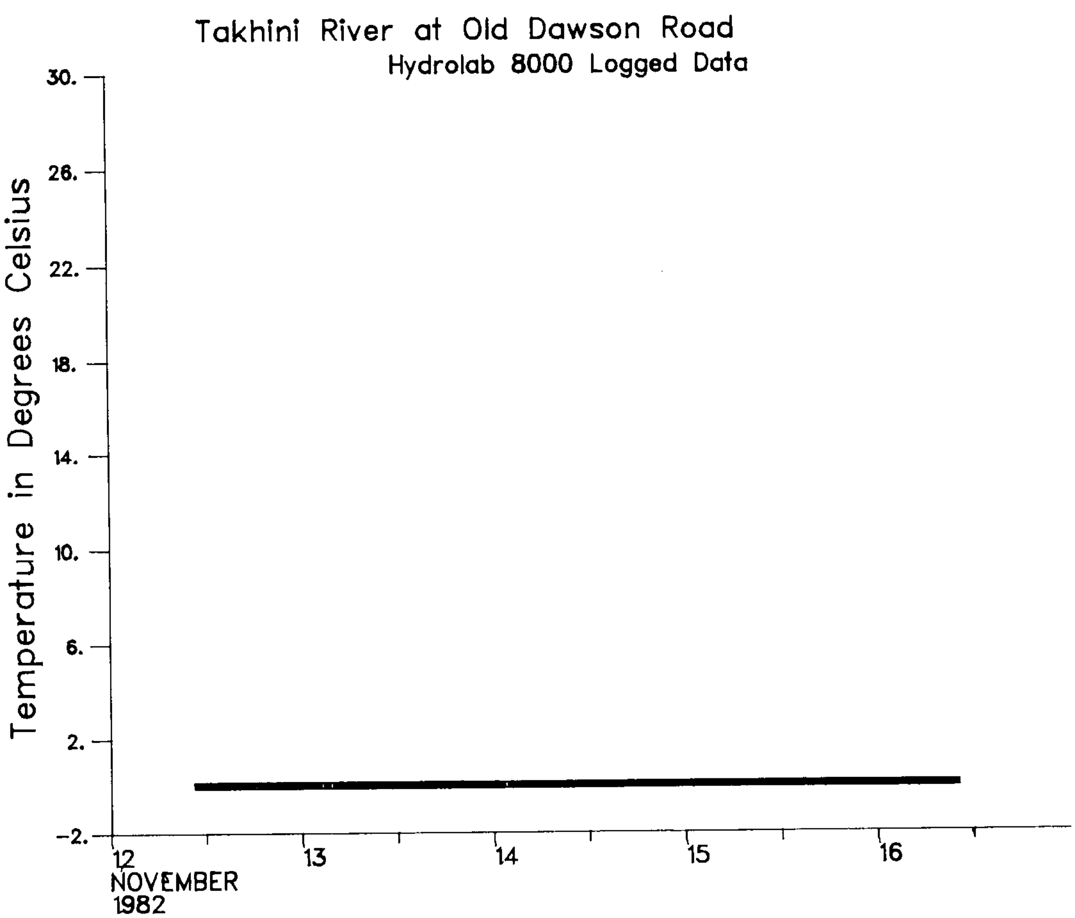


Figure 2
Water Temperature During November Sampling Period

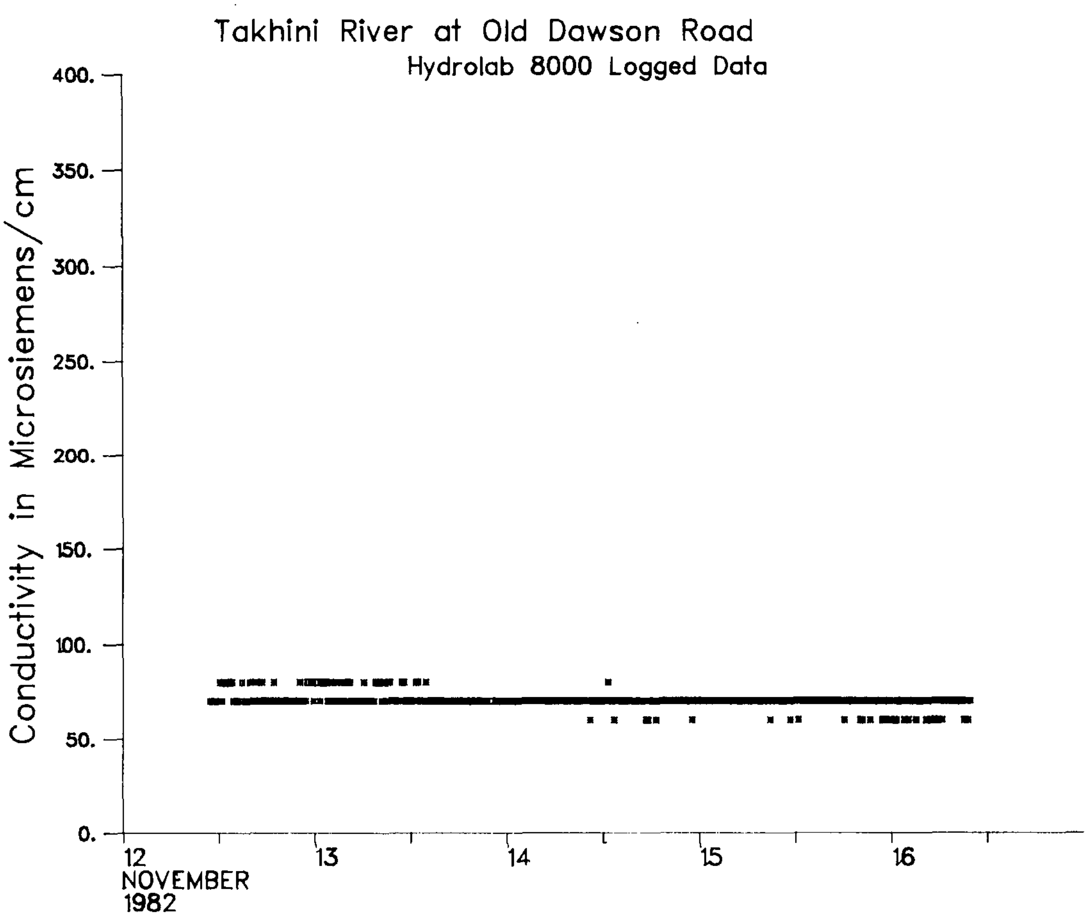


Figure 3
Conductivity During November Sampling Period

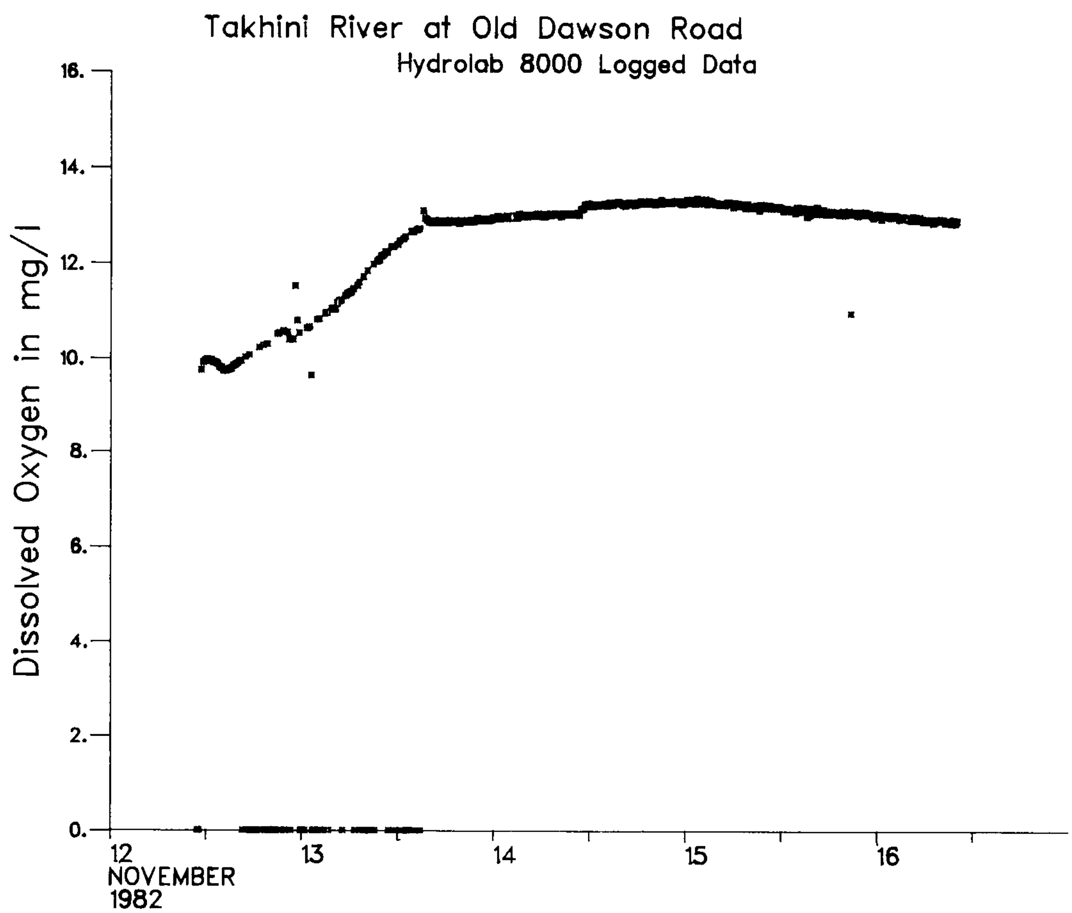


Figure 4
Dissolved Oxygen During November Sampling Period

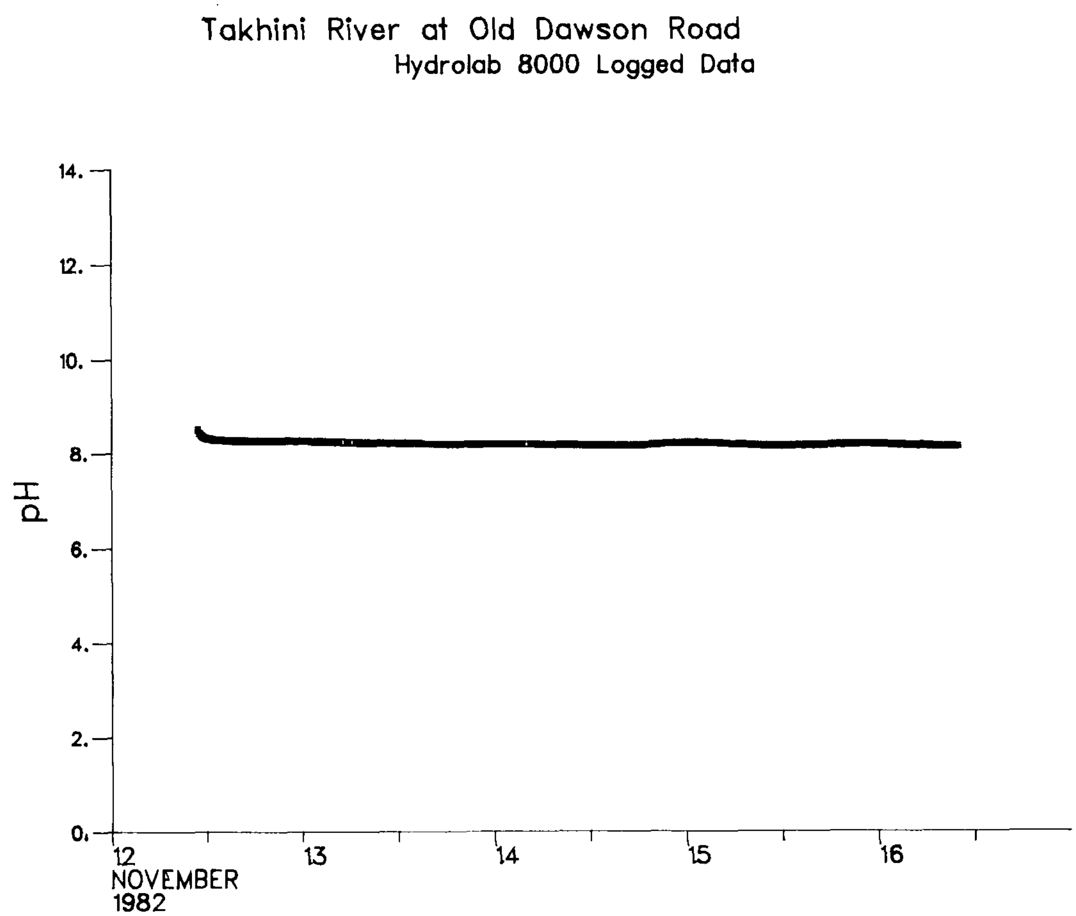


Figure 5
pH During November Sampling Period

Oxidation-reduction potential (Figure 6) shows a somewhat longer period of instability than does the pH readings. This problem seems abate after the first five to six hours. The upward drift of the subsequent readings reflects the downward trend of the dissolved oxygen readings.

The same variables for the sampling period during March are shown in Figures 7 through 11. Once again temperature was stable at zero degrees Celsius (Figure 7). Conductivity, again, is constant the limits of precision in the latter portion of the sampling period (Figure 8). Conductivity was substantially greater than during November. The dissolved oxygen data (Figure 9) shows a few anomalous values. These anomalies are likely the result of insufficient time being allowed (electronically) for the electrode to reach equilibrium. Generally, when frazil ice is not present, the electrode behaves in a more acceptable fashion. Figure 10 shows the pH instability at the start of a measuring period and Figure 11 shows the same for ORP. ORP readings were substantially greater in March than in November, while dissolved oxygen was substantially lower in March than was observed previously.

The results from the April period are shown in Figures 12 to 16. Temperature was somewhat less stable that earlier observed reflecting a slight warming of the water (Figure 12). Conductivity (Figure 13) shows somewhat more scatter between values of 100 and 110 microsiemens/cm than was evident in March. Dissolved oxygen again shows some initial

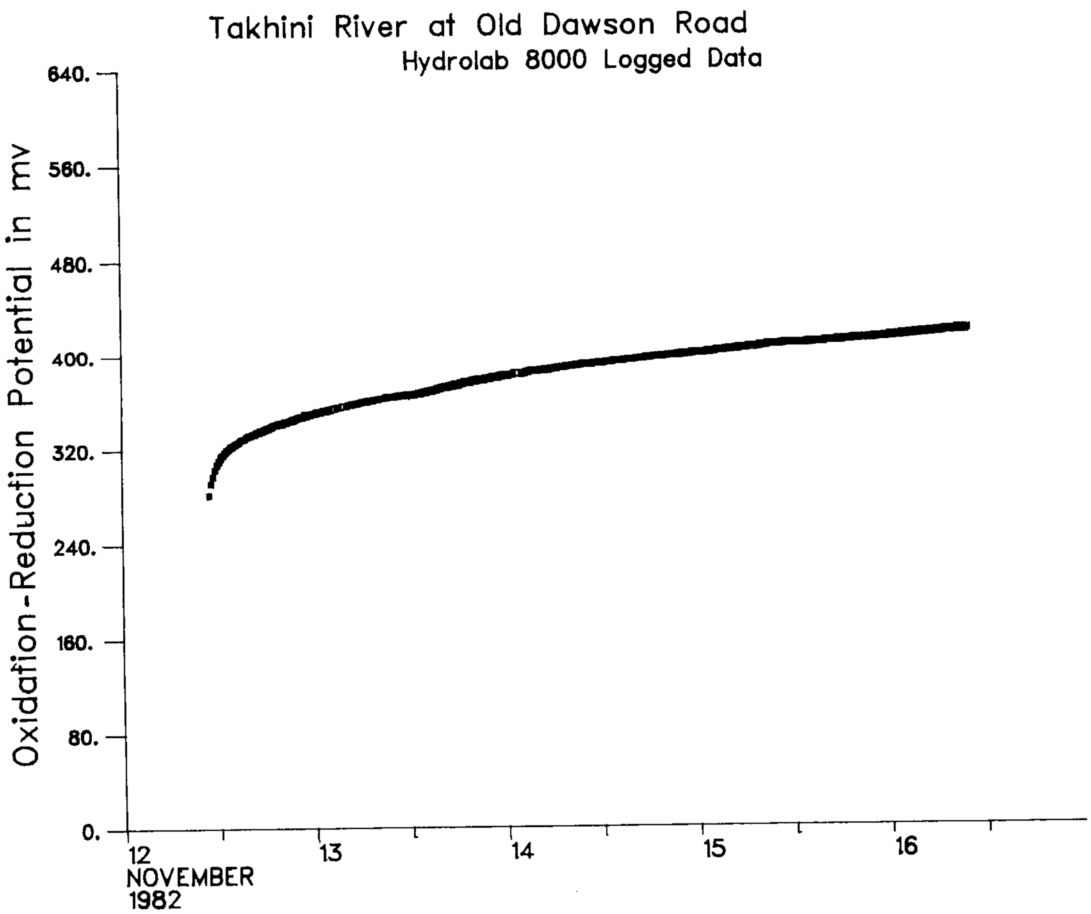


Figure 6
Oxidation-Reduction Potential During November Sampling Period

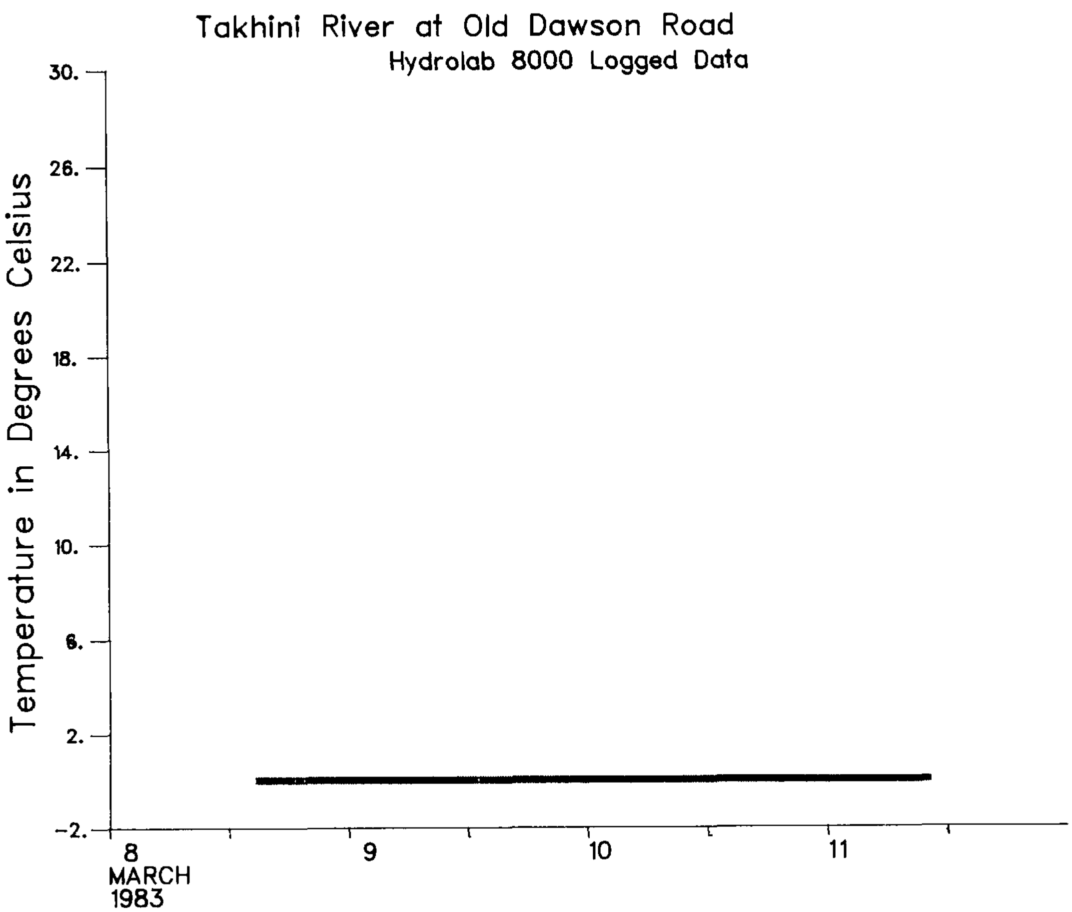


Figure 7
Water Temperature During March Sampling Period

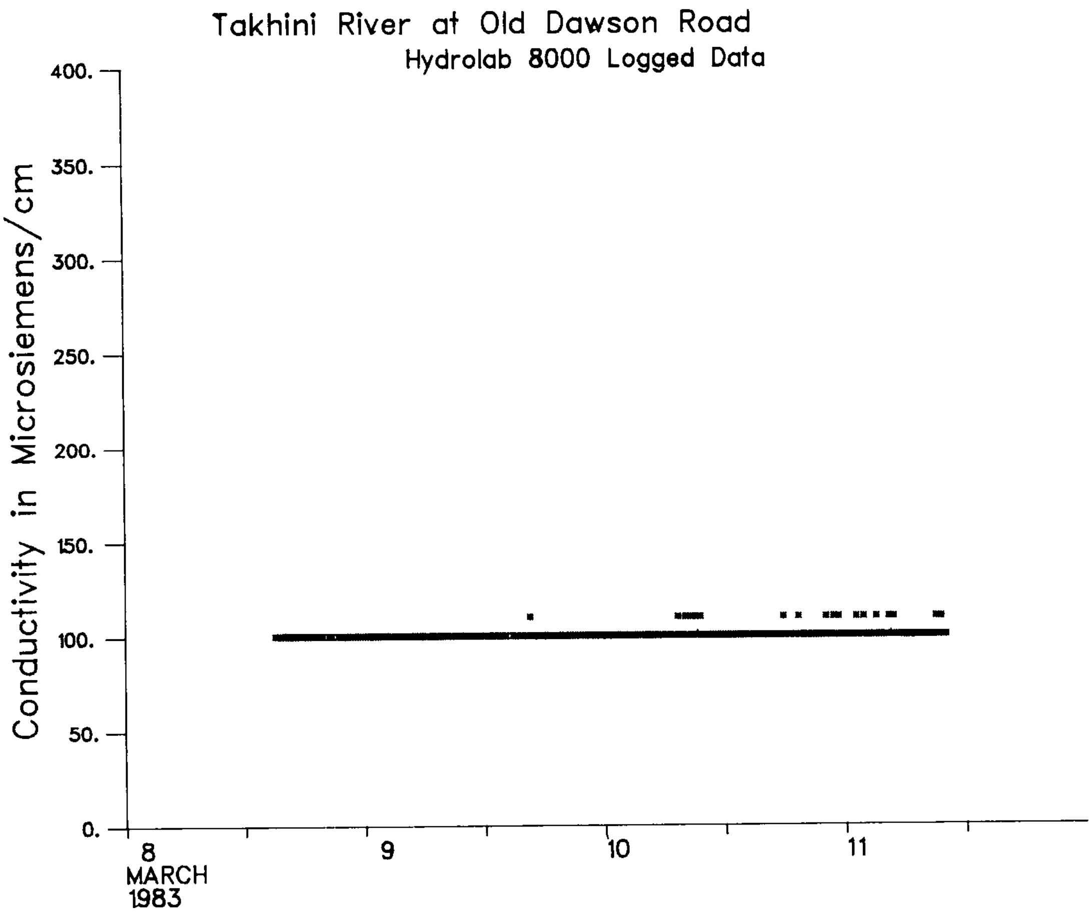


Figure 8
Conductivity During March Sampling Period

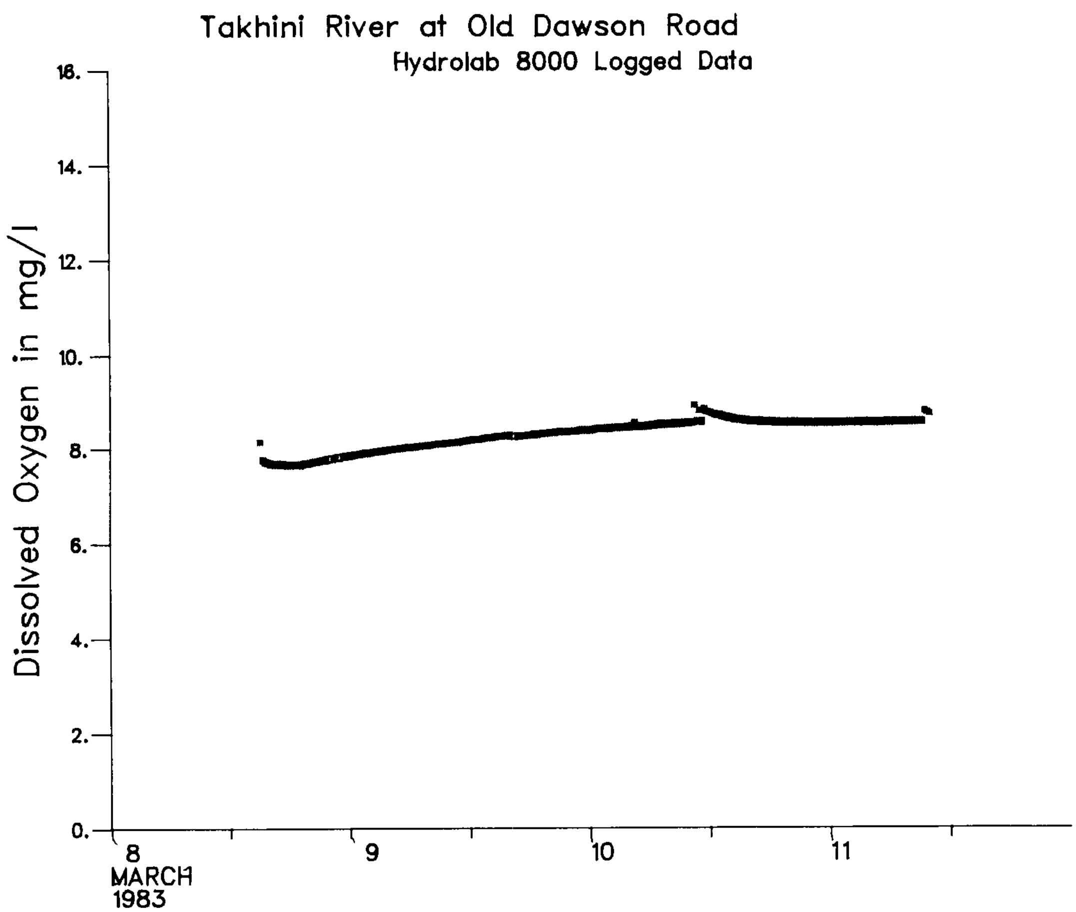


Figure 9
Dissolved Oxygen During March Sampling Period

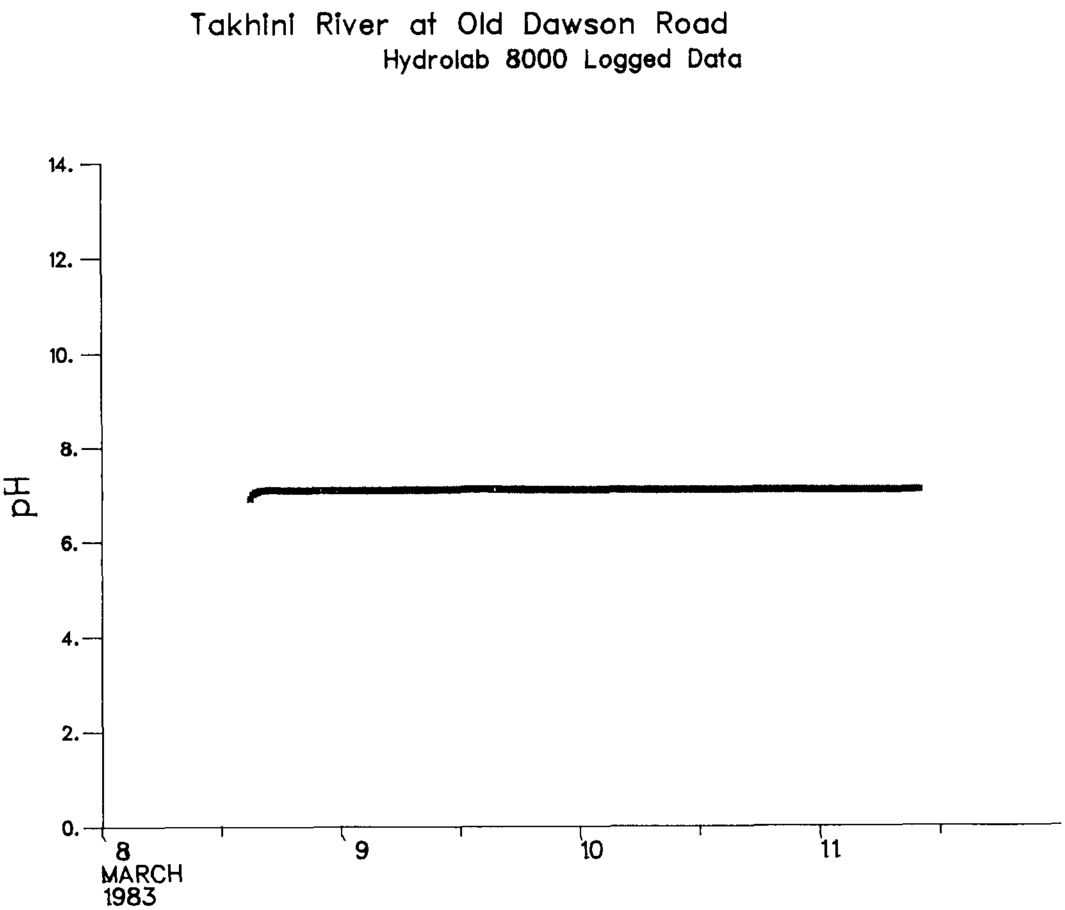


Figure 10
pH During March Sampling Period

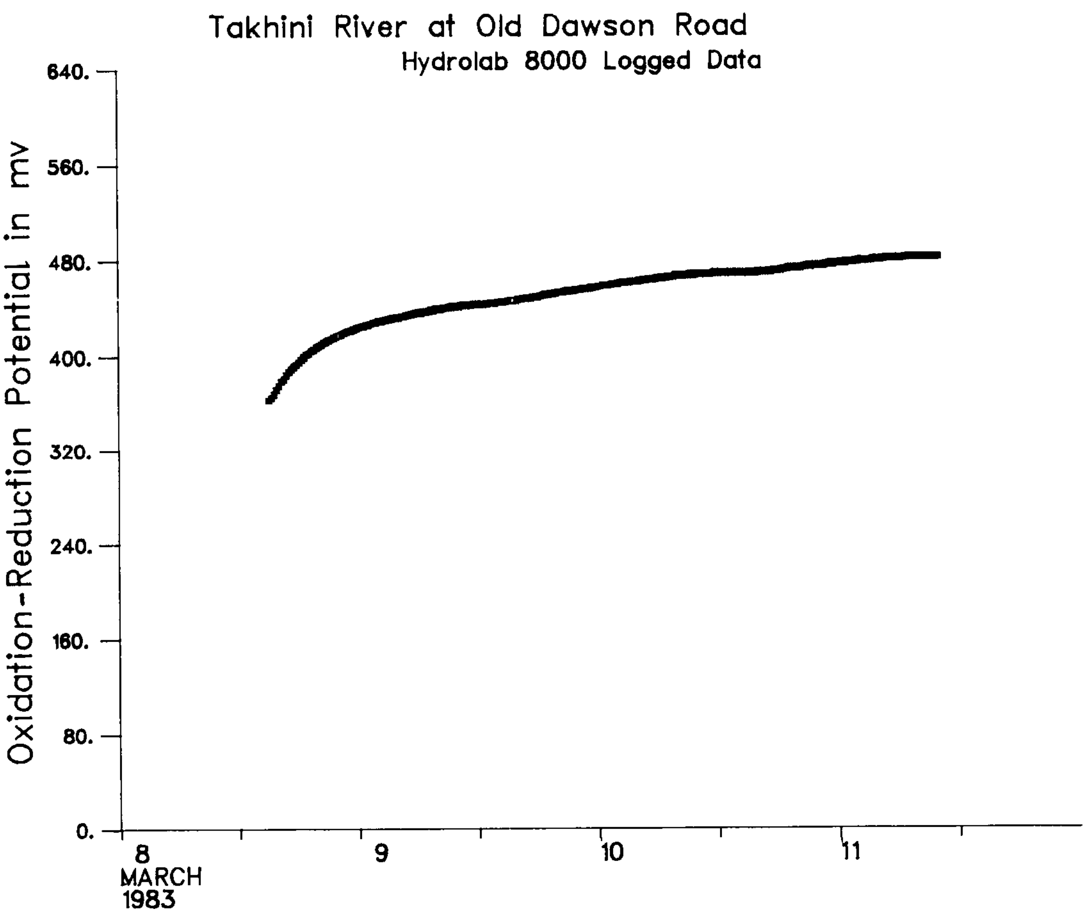


Figure 11
Oxidation-Reduction Potential During March Sampling Period

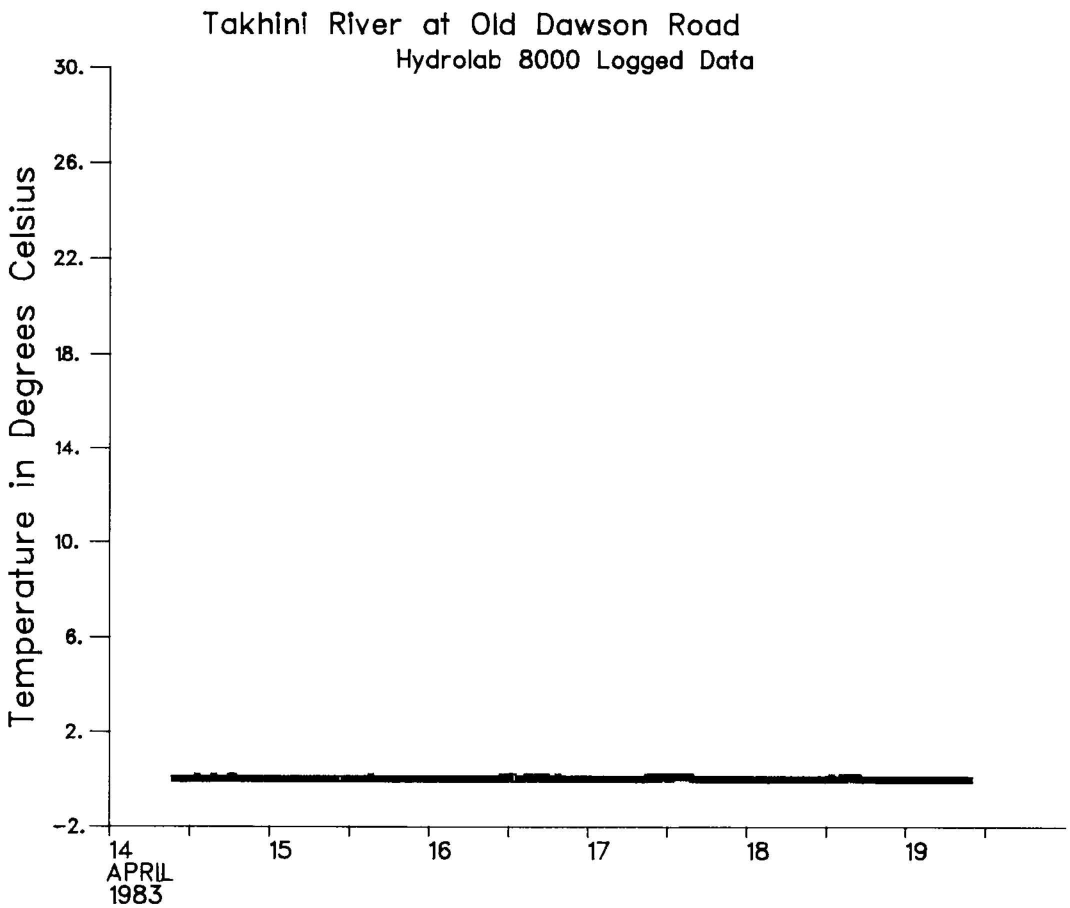


Figure 12
Water Temperature During April Sampling Period

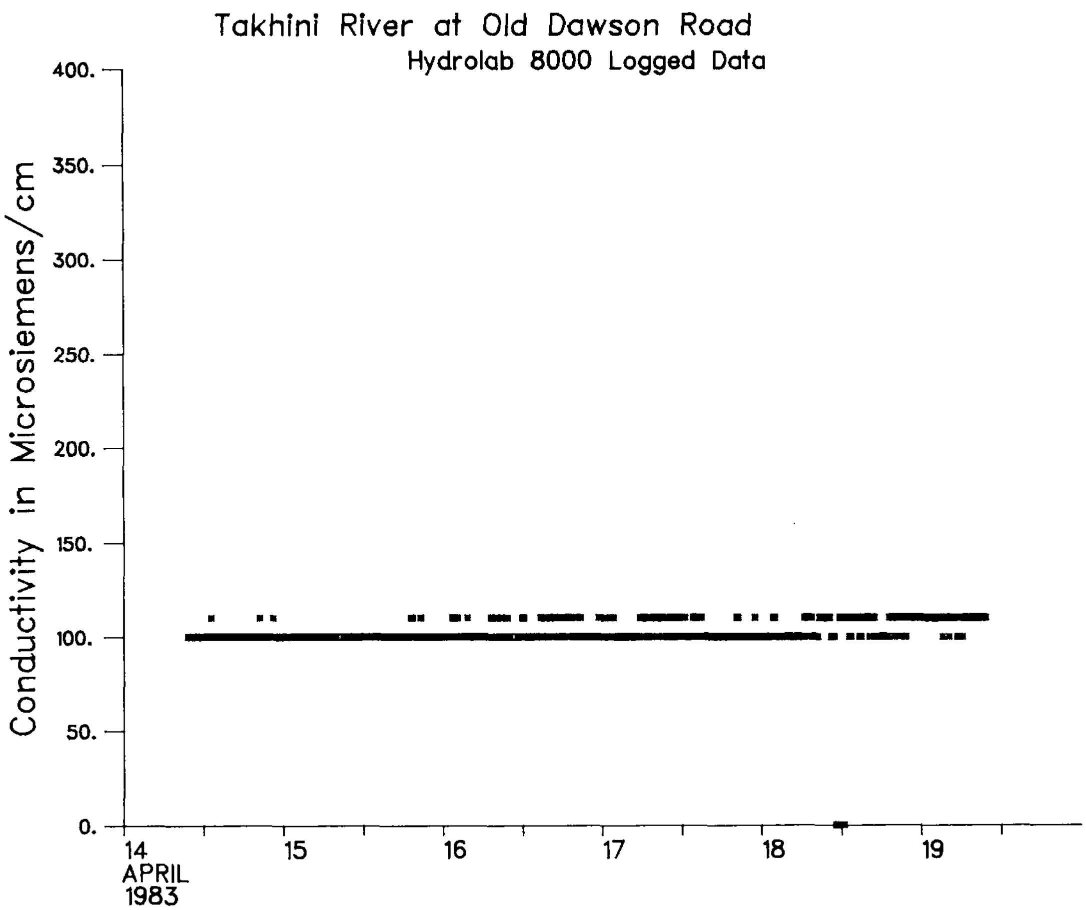


Figure 13
Conductivity During April Sampling Period

instability and some anomalous values (Figure 14). The frequency of the anomalies is somewhat reduced compared to the March sampling period. A second period of instability is evident on the afternoon of April 15th. This anomaly is the result of replacement of the electrode membrane. The values recorded after the membrane was changed were also affected. The dissolved oxygen concentrations were higher than observed in March. Figure 15 shows pH measurements during the same interval. The values indicate some diurnal fluctuations after a brief period of initial instability. ORP shown in Figure 16 also reflects a diurnal pattern. The disturbance of the instrument on the afternoon of the 15th coincides with the discontinuity of ORP. The section following briefly describes the importance of oxidation-reduction potential as a desirable measurement. The evidence of a diurnal pattern under ice of ORP measurements suggests that it may be useful in examinations of biological activity under ice, since this phenomenon appears during a period of much higher biological activity than the previous periods. The presence of a diurnal cycle also suggests that ORP changes relatively rapidly in a productive situation when there is no exchange with the atmosphere.

The data for the last group of plots were gathered in May, after the ice cover had disappeared (Figures 17 to 21). Water temperature shows a regular diurnal pattern of warmer temperatures during the afternoon, with lower temperatures in the evening and early morning (Figure 17). This pattern

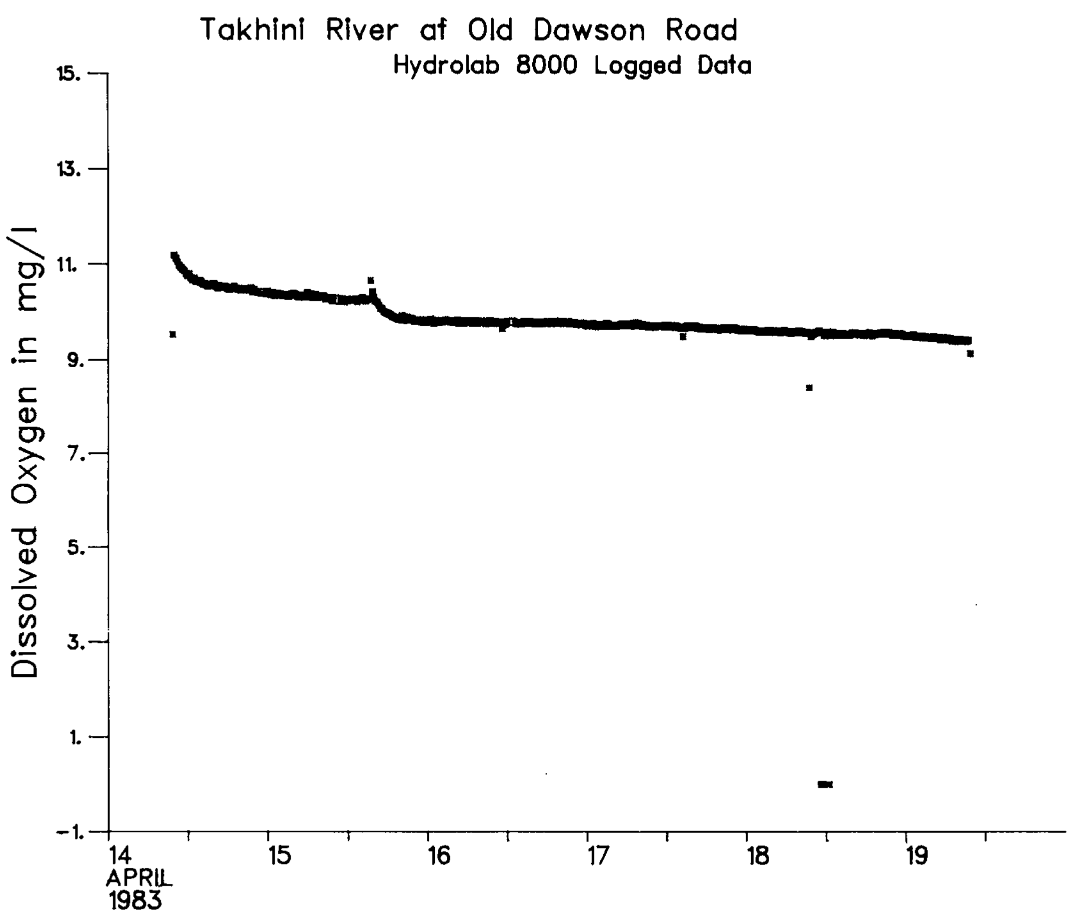


Figure 14
Dissolved Oxygen During April Sampling Period

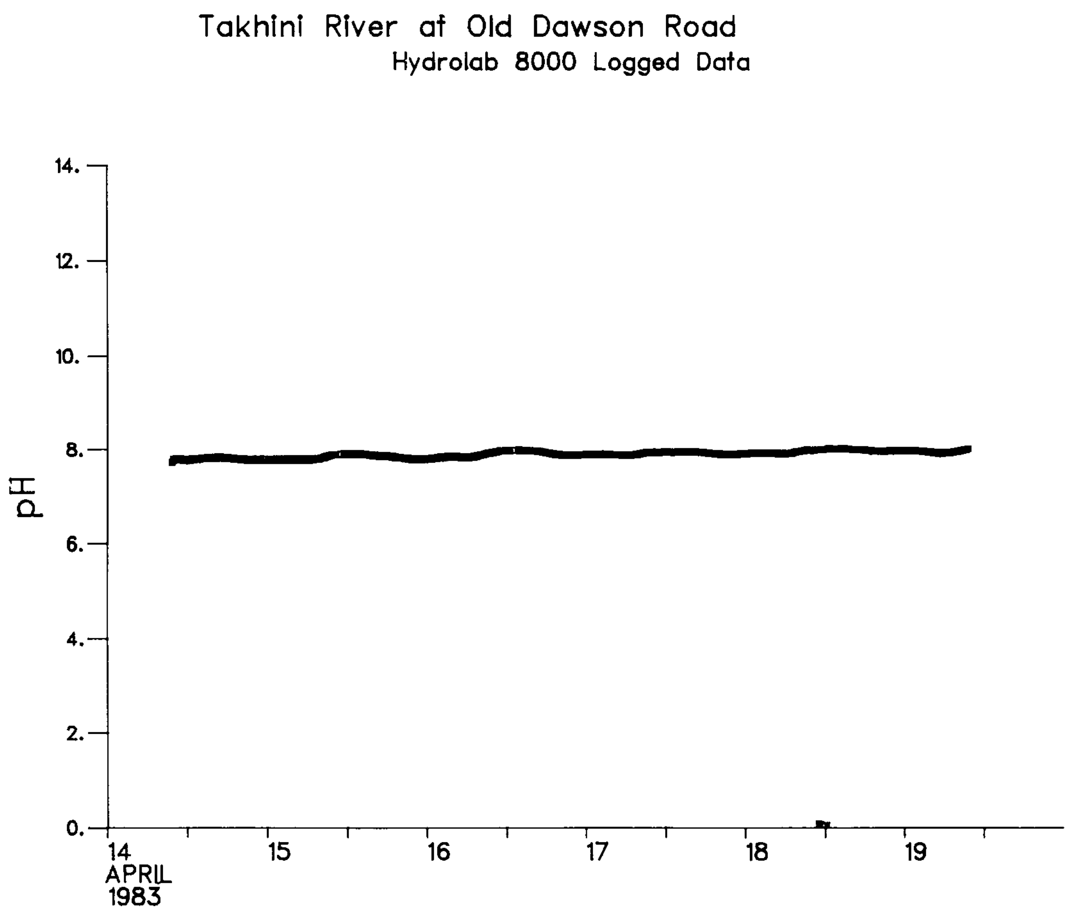


Figure 15
pH During April Sampling Period

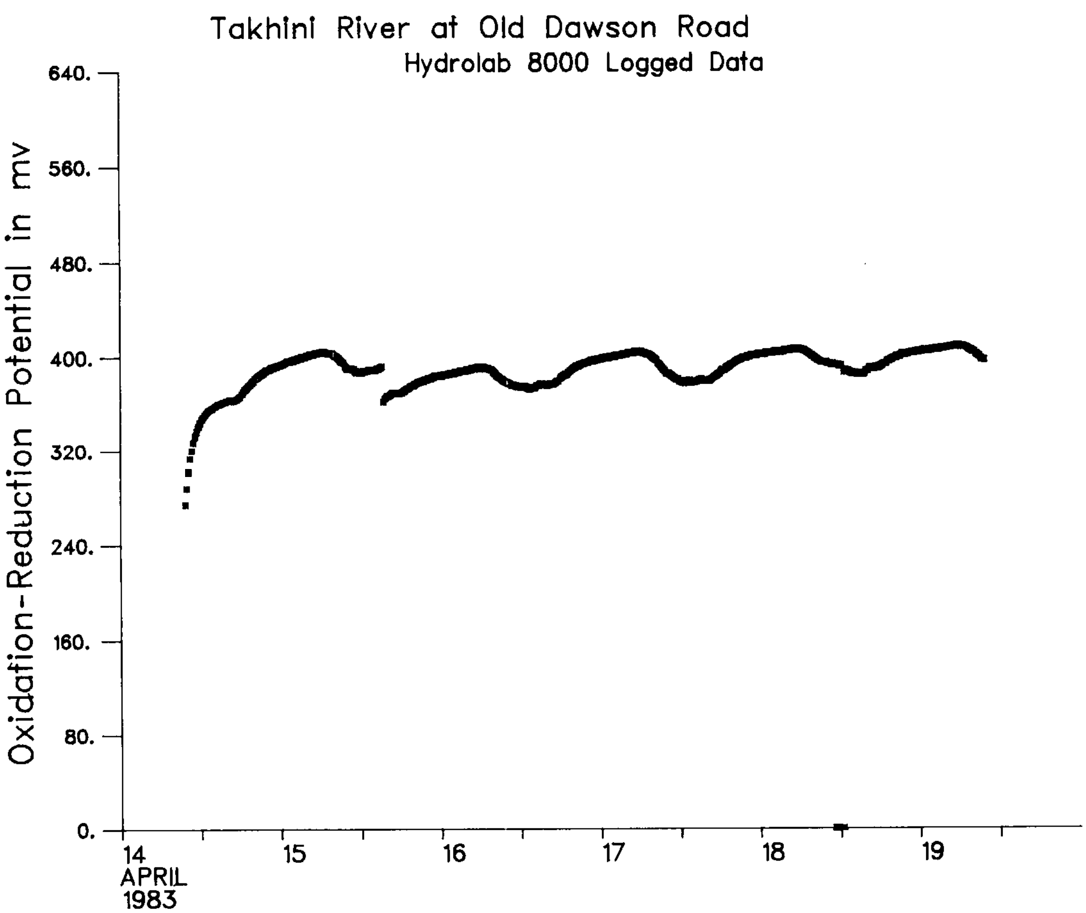


Figure 16
Oxidation-Reduction Potential During April Sampling Period

reflects solar heating of the water. Conductivity demonstrates (Figure 18) the same pattern reflected in previous plots of conductivity. Dissolved oxygen shows a diurnal pattern with some scatter (Figure 19). Figure 20 again demonstrates the initial instability of pH measurements. Subsequently the pH measurements remain very stable. ORP also shows the initial instability described previously and a diurnal pattern during the remainder of the period (Figure 21). The diurnal nature appears to be 'smoothed' relative to the April observations.

Plots of these data are a valuable tool for examining the data and for establishing some of the limitations of the measuring electrodes.

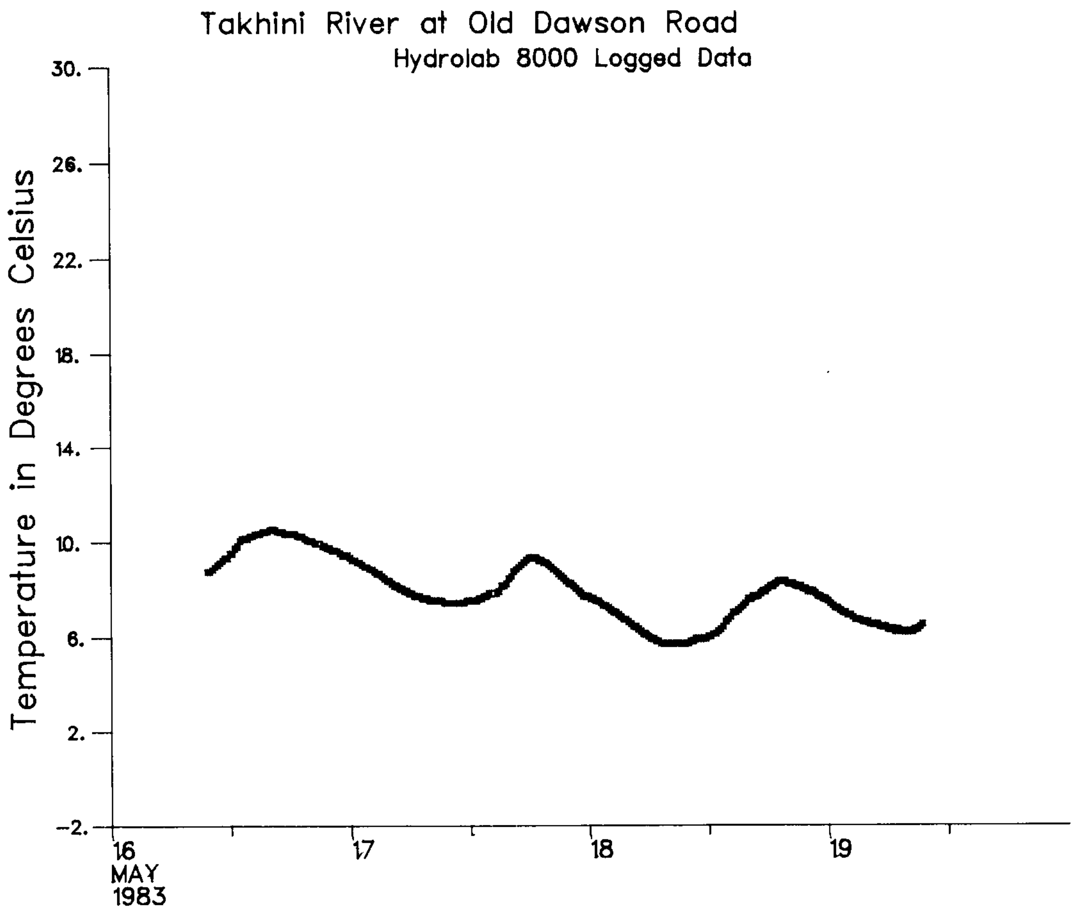


Figure 17
Water Temperature During May Sampling Period

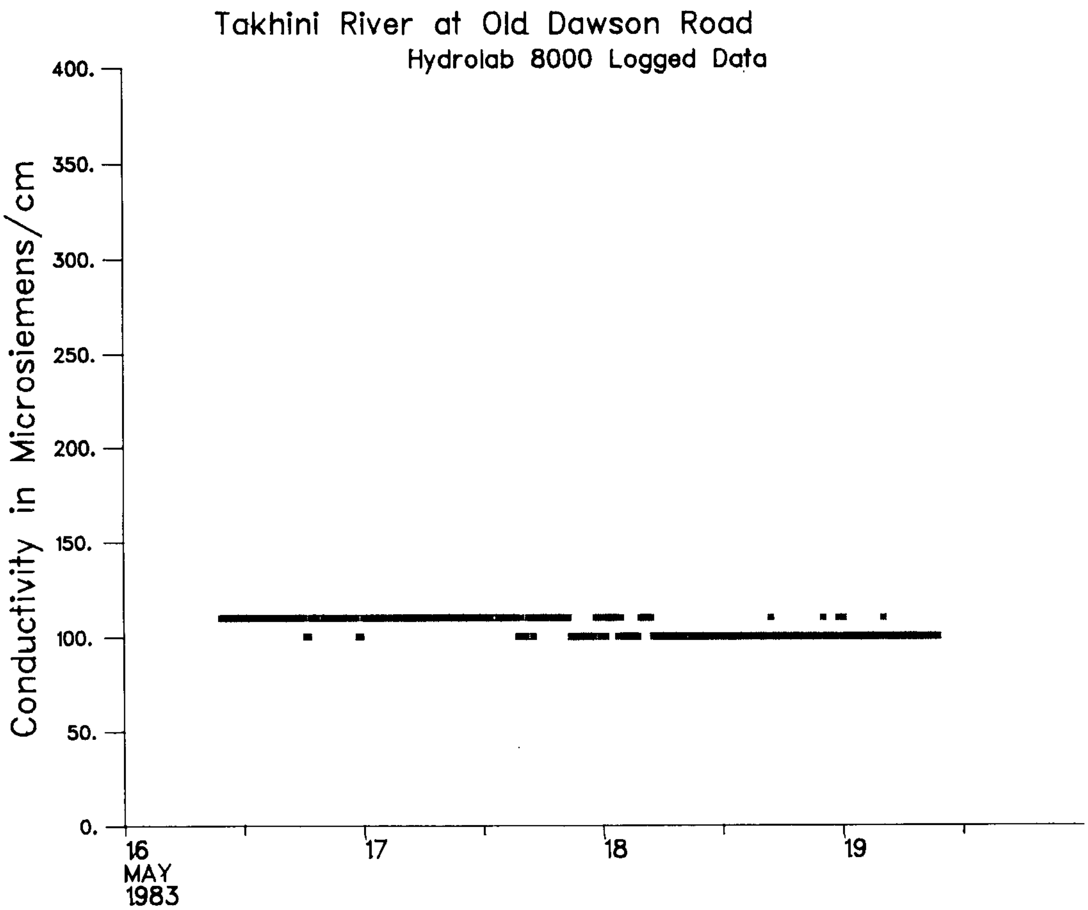


Figure 18
Conductivity During May Sampling Period

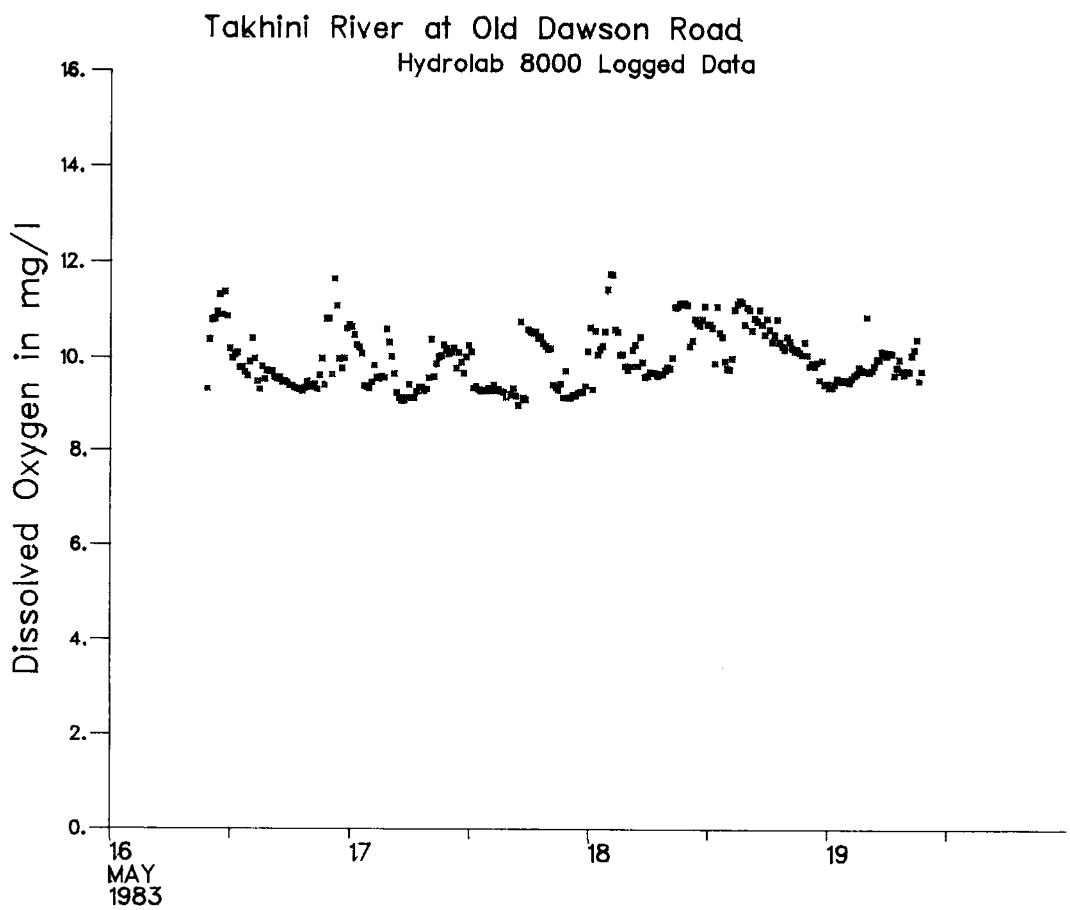


Figure 19
Dissolved Oxygen During May Sampling Period

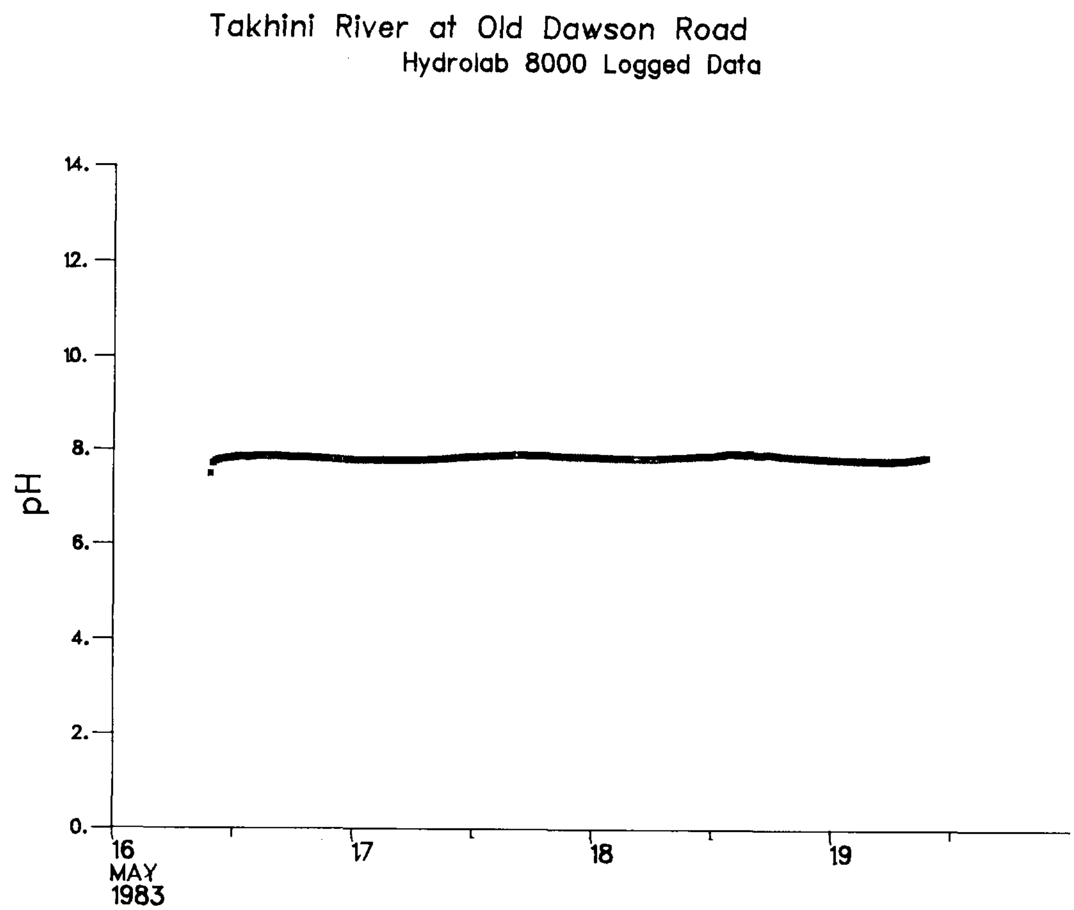


Figure 20
pH During May Sampling Period

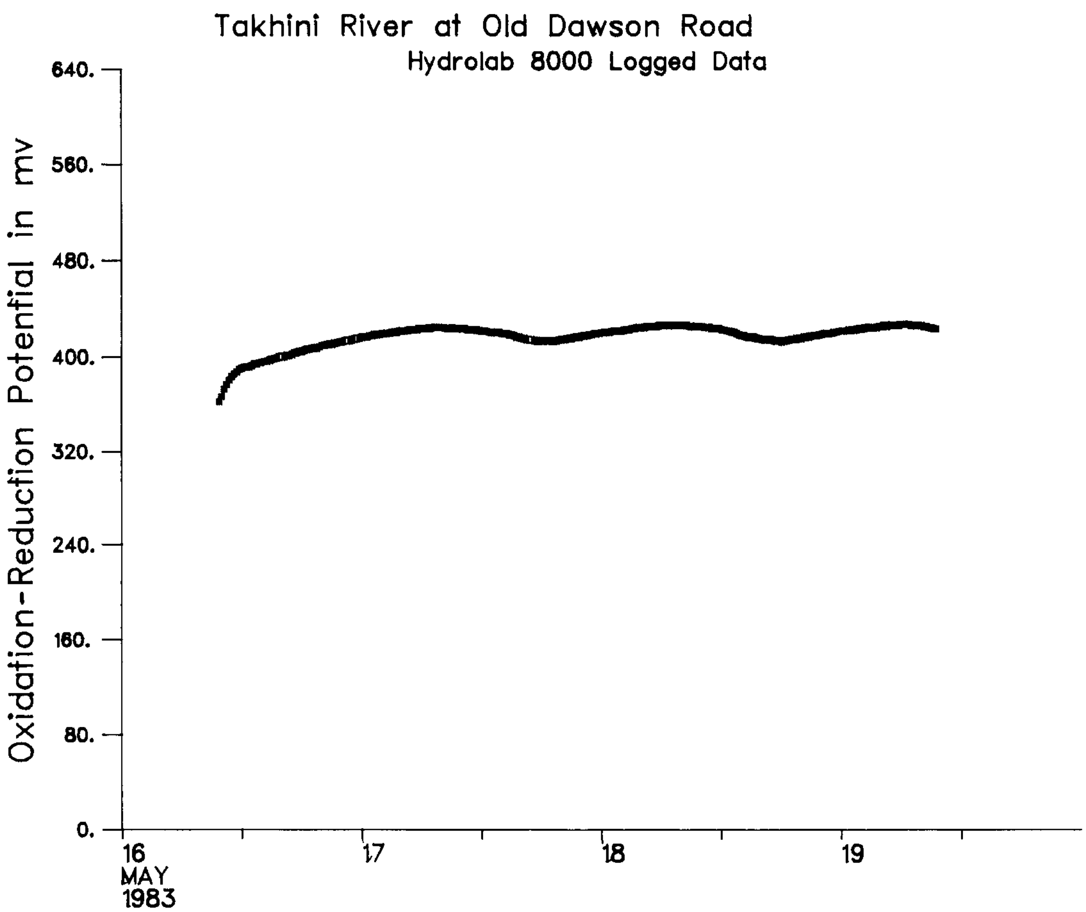


Figure 21
Oxidation-Reduction Potential During May Sampling Period

## OXIDATION-REDUCTION POTENTIAL

Oxidation-reduction potential is a measure of the aqueous electron concentration, while pH is a measure of the aqueous proton or hydrogen ion concentration. Since electrons neutralize protons, a great many natural reactions are dependent upon oxidation-reduction potential (ORP) and pH (Langmuir, 1971). However, interpretation of the ORP is limited to a descriptive tool because several redox reactions will usually contribute to the measured potential.

Natural waters are in a highly dynamic state with regard to oxidation-reduction potential, rather than in or near equilibrium. Langmuir (1971) and others have used plots of ORP against pH to describe the characteristics of natural waters. Comparison of pH and ORP (Eh) results from the Takhini River with Langmuir's results (Figure 22) suggests that the under-ice environment is transitional. However, care must be taken in the interpretation of these ORP results because of thermodynamic limitations of the measuring system (Whitfield, 1974). Further discussion of the interpretation of oxidation-reduction potentials in estuaries may be found in Whitfield (1969).

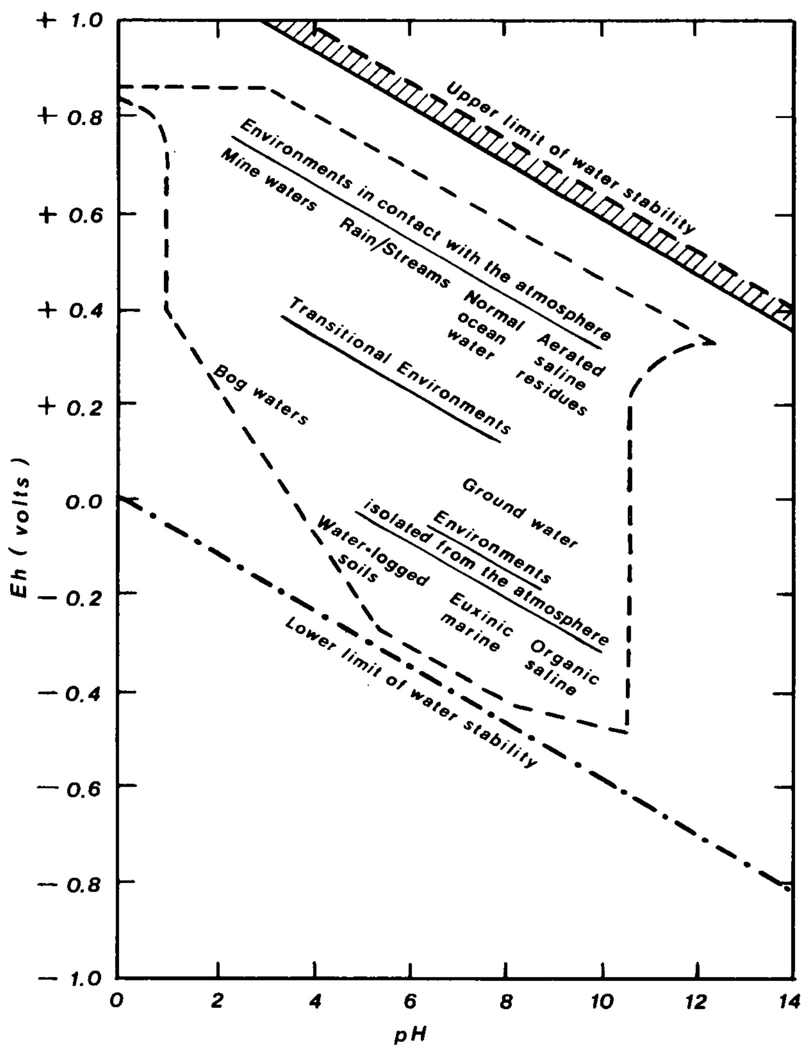


Figure 22
Approximate Positions of Some Natural Environments in Terms of Eh and pH

## LIMITATIONS

The "Hydrolab" 8000 is a useful device for obtaining closely spaced measurements of those water quality variables that the instrument has the capability of measuring. At colder water temperatures the dissolved oxygen electrode at times takes longer to equilibrate than the time delay prior to reading allows. It also tends to be relatively unstable during the first few hours of reading at cold temperatures. At higher water temperatures the response is much better. A severe problem exists with this electrode when frazil ice is present in the water column. The conductivity electrode behaves quite well in most circumstances, with some problems noted when frazil ice is present. It would be preferable to have a greater precision that 10 microsiemens/cm. Temperature measuring system offers no limitations. ORP and pH electrodes consistently show an initial drift period. The length of this period appears to be related to the ambient water temperature, with the lag period being somewhat greater at low temperature. Subsequent to this period, about three hours on average, both electrodes perform well and provide useful information.

## REFERENCES

Langmuir, D. 1971. Eh-pH Determination. In: Carver, R.E. Procedures in Sedimentary Petrology. Chapter 26.

McNaughton, B. 1984. Field equipment for water quality measurements under ice. Inland Waters Directorate, Pacific and Yukon Region. Yukon River Basin Study. Water Quality Work Group Report #4.

Whitfield, M. 1969. Eh as an operational parameter in estuarine studies. Limnology and Oceanography 14:547-58.

Whitfield, M. 1974. Thermodynamic limitations on the use of the platinum electrode in Eh measurements. Limnol. Oceanogr. 19:857-865.

Whitfield, P.H. 1983. Interfacing the Osborne 1 to the "Hydrolab" 8000 and to Simon Fraser University's MTS Service. Water Quality Branch. Inland Waters Directorate. Pacific and Yukon Region. Osborne Support Document

#1.

Whitfield, P.H. and B. McNaughton. 1984. Comparison of Dissolved Oxygen Processes Under Ice in Two Southern Yukon Rivers. Inland Waters Directorate. Pacific and Yukon Region. Yukon River Basin Study. Water Quality Work Group Report #3.

# APPENDIX

Listing of the FORTRAN source program used to produce the plots shown in Figures 2 through 21.

Listing of HYDROL.PLOT at 09:14:15 on NOV  9, 1983 for CCid=WQBC

```
C************************************************************
C
C PLOTTING OF HYDROLAB LOGGED DATA
C
C INPUT FORMAT IS 5G16.7 - HYDROLAB RECOVERY FORMAT
C DATA READ FROM UNIT 5 & FILE HPLOT MUST EXIST.
C
C************************************************************
      LOGICAL*1 STATN(50), TITLE(25)
      REAL INT, ANG(5) /5*90./
      INTEGER DAY, MONTH, YEAR, HR, MIN
      DIMENSION T(1000), C(1000), D(1000), P(1000), O(1000), TIME(1000)
C ASSIGN NECESSARY I/O FILES
      CALL FTNCMD('ASSIGN 9=HPLOT', 14)
      CALL FTNCMD('ASSIGN 3=*MSOURCE*', 18)
      CALL FTNCMD('ASSIGN 2=*MSINK*', 16)
      CALL EMPTYF(9)
C GET NEEDED INPUT INFORMATION
      WRITE (6,80)
      WRITE (2,90)
      CALL FREAD(3, 'R:', INT)
      WRITE (2,100)
      CALL FREAD(3, '3I:', DAY, MONTH, YEAR)
   10 WRITE (2,110)
      CALL FREAD(3, '2I:', HR, MIN)
      IF (HR .LE. 23) GO TO 20
      WRITE (2,120) HR
      GO TO 10
   20 WRITE (2,130)
      CALL FREAD(-2, 'DELIMITERS', '/?/ /')
      CALL FREAD(3, 'S:', STATN, 50)
      CALL FREAD(-1, 'DELI')
      CALL MOVEC(25, 'Hydrolab 8000 Logged Data', TITLE)
      TSTART = FLOAT(60*HR) + FLOAT(MIN)
      I = 1
C READ IN THE REAL DATA
   30 READ (5,140,END=40) T(I), C(I), D(I), P(I), O(I)
      TIME(I) = TSTART + (I - 1) * INT
      C(I) = C(I) * 1000
      I = I + 1
      GO TO 30
C CHECK THE SCALING OF CONDUCTIVITY AND DO
   40 WRITE (2,150) (C(K),K=1,5)
      WRITE (2,160)
      CALL FREAD(3, 'R:', CFACT)
C
      DO 50 J = 1, I
   50 C(J) = C(J) * CFACT
C
      IF (CFACT .NE. 1) GO TO 40
   60 WRITE (2,170) (D(K),K=1,5)
      WRITE (6,160)
      CALL FREAD(3, 'R:', DFACT)
C
      DO 70 J = 1, I
   70 D(J) = D(J) * DFACT
C
      IF (DFACT .NE. 1.) GO TO 60
```

```
C ADD THE INTERNAL MINIMUM AND MAXIMUM VALUES FOR SCALING
      T(I) = -2.
      C(I) = 0.
      D(I) = 0.
      O(I) = 0.
      P(I) = 0.
      I = I + 1
      T(I) = 24.
      C(I) = 400.
      D(I) = 14.
      P(I) = 14.
      O(I) = 400.
      N = I
C SCALE ALL THE DATA
      CALL PSCALE(8., 1., TMIN, TV, T, N, 1)
      CALL PSCALE(8., 1., CMIN, CV, C, N, 1)
      CALL PSCALE(8., 1., DMIN, DV, D, N, 1)
      CALL PSCALE(8., 1., PMIN, PV, P, N, 1)
      CALL PSCALE(8., 1., OMIN, OV, O, N, 1)
C DROP THE INTERNAL VALUES FROM THE ARRAYS
      N = N - 2
      CALL TSCALE(10., TICK, XMIN, XV, NDAYS, TIME, N)
      X = 2.
      Y = 1.
C SET UP DEFAULT VALUES
      CALL PLTXMX(70.)
      CALL PALPHA('SANSERIF.2 ', 0)
      CALL PINSYM(0.05)
C DRAW THE PLOTS
      CALL YAXIS(X, Y, 'Degrees Celsius', 15, 8., ANG(1), TMIN, TV, 1.)
      CALL TAXIS(X, Y, TICK, DAY, MONTH, YEAR, 10., NDAYS)
      CALL PLTOFS(XMIN, XV, TMIN, TV, X, Y)
      CALL PLINE(TIME, T, N, 1, -1, 11, 1)
      CALL PSYM(X + 3., 9.0, .18, TITLE, 0., 25, 0)
      CALL PSYM(X + 1., 9.35, .22, STATN, 0., 50, 0)
      X = X + 12.
      CALL YAXIS(X, Y, 'Microsiemens/cm', 15, 8., ANG(2), CMIN, CV, 1.)
      CALL TAXIS(X, Y, TICK, DAY, MONTH, YEAR, 10., NDAYS)
      CALL PLTOFS(XMIN, XV, CMIN, CV, X, Y)
      CALL PLINE(TIME, C, N, 1, -1, 11, 1)
      CALL PSYM(X + 3., 9.0, .18, TITLE, 0., 25, 0)
      CALL PSYM(X + 1., 9.35, .22, STATN, 0., 50, 0)
      X = X + 12.
      CALL YAXIS(X, Y, 'Dissolved Oxygen in mg/l', 24, 8., ANG(3), DMIN,
     1     DV, 1.)
      CALL TAXIS(X, Y, TICK, DAY, MONTH, YEAR, 10., NDAYS)
      CALL PLTOFS(XMIN, XV, DMIN, DV, X, Y)
      CALL PLINE(TIME, D, N, 1, -1, 11, 1)
      CALL PSYM(X + 3., 9.0, .18, TITLE, 0., 25, 0)
      CALL PSYM(X + 1., 9.35, .22, STATN, 0., 50, 0)
      X = X + 12.
      CALL YAXIS(X, Y, 'pH', 2, 7., ANG(4), PMIN, PV, 1.)
      CALL TAXIS(X, Y, TICK, DAY, MONTH, YEAR, 10., NDAYS)
      CALL PLTOFS(XMIN, XV, PMIN, PV, X, Y)
      CALL PLINE(TIME, P, N, 1, -1, 11, 1)
      CALL PSYM(X + 3., 9.0, .18, TITLE, 0., 25, 0)
      CALL PSYM(X + 1., 9.35, .22, STATN, 0., 50, 0)
      X = X + 12.
```

```
      CALL YAXIS(X, Y, 'Oxidation Reduction Potential in mv', 35, 8.,
     1     ANG(5), OMIN, OV, 1.)
      CALL TAXIS(X, Y, TICK, DAY, MONTH, YEAR, 10., NDAYS)
      CALL PLTOFS(XMIN, XV, OMIN, OV, X, Y)
      CALL PLINE(TIME, O, N, 1, -1, 11, 1)
      CALL PSYM(X + 3., 9.0, .18, TITLE, 0., 25, 0)
      CALL PSYM(X + 1., 9.35, .22, STATN, 0., 50, 0)
C ALL PLOTS DONE FINISH THE PLOT
      CALL PLTEND
      STOP
   80 FORMAT ('0', //'    PLOTTING OF HYROLAB 8000 LOGGED DATA', ///)
   90 FORMAT ('What is the recording interval? IE. 15')
  100 FORMAT ('What is the starting day,month,year? AS 25,12,1975')
  110 FORMAT ('What is the starting hour,min? as 10,50')
  120 FORMAT ('Invalid number of hours  ', I5, '  Misplaced Comma?')
  130 FORMAT ('What is the station name? Less that 50 characters in leng
     1th'/' ---------|---------|---------|---------|---------|')
  140 FORMAT (14X, 5F9.3)
  150 FORMAT ('0', 'First five conductivity values are:'/' ',
     1      5(2X,F8.4))
  160 FORMAT (' ', 'Input scale factor or 1. to stop')
  170 FORMAT ('0', 'First five DO values are:'/' ', 5(2X,F8.4))
      END
```