# FIELD EVALUATION OF HYDROLAB® DATASONDE® 2000

by

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Abstract

A Hydrolab[1] DataSonde 2000[1,2], a commercially available water quality monitor, was installed at two sites in Canagagigue Creek for three one-week periods during 1987. Independent water quality measurements were taken at regular intervals. The Hydrolab systems performed well during the field tests and the data show close agreement with the independent measurements. An analysis of the conductivity data gives a time of travel between the selected sites of four hours under high flow and eight hours under low flow.

[1] Hydrolab and DataSonde are both registered trademarks of Hydrolab Corporation, Austin, Texas.

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Résumé

L'Hydrolab[1] Datasonde 2000[1,2], un moniteur de la qualité de l'eau disponible dans le commerce, a été installé pour trois périodes d'une semaine à deux endroits à Canagagigue Creek au cours de 1987. Des mesures indépendantes de la qualité de l'eau ont été prises à intervalles réguliers. L'Hydrolab a bien fonctionné au cours des essais sur le terrain, et les résultats obtenus sont en étroite corrélation avec les mesures indépendantes. Une analyse des données de la conductivité donne un temps de transit entre les sites choisis de quatre heures à débit élevé et de huit heures à faible débit.

[1] Hydrolab et Datasonde sont des marques déposées de Hydrolab Corporation, Austin (Texas).

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## Executive Summary

A commercially available water quality monitor was used to acquire one-week time series for temperature, dissolved oxygen, pH and conductivity in a small, southern Ontario river. This self-contained instrument is reliable, easy to deploy, and sufficiently accurate for many limnological and water quality applications. This work should be of interest to Water Quality Regional Branch Chiefs, provincial and federal water resource managers, and water quality modellers.

# Résumé à l'intention de la direction

On a utilisé un moniteur de la qualité de l'eau disponible dans le commerce pour obtenir des séries chronologiques hebdomadaires de mesures de la température, de l'oxygène dissous, du pH et de la conductivité dans un petit cours d'eau du sud de l'Ontario. Il s'agit d'un appareil autonome fiable, facile à utiliser et suffisamment précis pour diverses applications limnologiques et ayant trait à la qualité de l'eau. Cet appareil pourrait intéresser les chefs des directions régionales de la qualité de l'eau, les gestionnaires provinciaux et fédéraux des ressources aquatiques et les modélisateurs de la qualité de l'eau

## Introduction

The purpose of this study is to evaluate the performance of the Hydrolab water quality monitor under field conditions. The Hydrolab DataSonde is a self-contained logging device which measures and records in-situ, various water quality parameters. The Hydrolab systems were designed for continuous monitoring and the use of these instruments for environmental studies could provide an efficient means of obtaining water quality data. Accurate and reliable data are necessary for monitoring programs and for time series modelling. Two Hydrolab DataSondes were installed in a small creek for three one-week periods during 1987. Independant water quality measurements were also taken at selected intervals for comparison with the in-situ monitors.

## Methods

The Hydrolab DataSonde system is a submersible automated water quality data system developed by Hydrolab Corporation, Austin, Texas. The unit consists of a battery powered datalogger enclosed in a light weight durable housing and equipped with probes installed within the unit. The DataSonde is 52 cm long and weighs 4.8 kg and is submersible to a depth of 300 m. The system is shown in Figure 1. The DataSonde RAM memory stores over 3600 parameter readouts during any deployment period. Access to the memory is attained through the Hydrolab 5200-20XX Data Management Unit (DMU) via a RS-232-C cable connected to an IBM compatible computer with communication software. Sampling intervals can be programmed in multiples of five minutes and start and stop times can be pre-programmed. Data is downloaded to a printer for immediate printout or to a memory file for storage. This version of the DataSonde has capabilities for temperature, pH, dissolved oxygen, and conductivity. The manufacturer's performance specifications for each parameter are shown in Table 1.

Table 1. DataSonde 2000 series performance specifications

| SPECIFICATIONS | TEMPERATURE | CONDUCTIVITY | DIS. OXYGEN | pH |
|---|---|---|---|---|
| Range | 2 to 5 C° | 0-1500 uS/cm | 0-20 mg/L | 0-14 pH |
| Accuracy | ±0.1 C° | ±1% of range | ±0.2 mg/L | ±0.1 pH |
| Resolution | ±0.025 C° | 0.1% of range | 0.01 mg/L | 0.01 pH |
| Temperature Compensation | N/A | Automatic 25 C° | Automatic | Automatic |
| Sensor Type | Linear Thermistor | 6-electrode cell | Polargraphic cell | Glass electrode |

Source: Hydrolab brochure

Two Hydrolab DataSondes (serial numbers 5000 and 5001) were installed in Canagagigue Creek for an one-week period during

June, July, and October, 1987. Canagagigue Creek is a minor tributary of the Grand River and flows through the town of Elmira. The creek receives effluent from the Elmira Water Pollution Control Plant and the flow in the Creek is controlled by the Woolwich Dam and Reservoir. Two sites along Canagagigue Creek were selected for Hydrolab evaluation. CN-3 is located 1.67 km from the Control Plant and represents the portion of the creek that is affected by the effluent; CN-4 is 5.48 km downstream and represents the recovery zone. Figure 2 shows the study region and sampling sites. This area was selected for several reasons. Canagagigue Creek was the study site for previous research projects (Carey et al 1983) and information on water quality parameters was available. The high conductivity levels and the easily observed diurnal changes in dissolved oxygen and pH made this location ideal. The creek is also easily accessible and installation of the monitors was relatively simple.

Prior to field installation, each instrument was calibrated and start and stop times pre-programmed. A sampling interval of 15 minutes was chosen. Calibration was performed by the Calibration Unit, NWRI, according to their standards (Cooper 1987, Peer 1985). A list of the calibration points for each parameter is shown in Table 2. A conductivity range of 0-1500 uS and a high flow regime for the dissolved oxygen sensor were selected. The alkaline batteries in each unit were replaced prior to calibration.

Table 2. Calibration points for Hydrolab DataSonde

| | | | |
|---|---|---|---|
| TEMPERATURE | 0° C | 15° C | 25° C |
| OXYGEN | 10% $O_2$ in $N_2$ | 15% $O_2$ in $N_2$ | 21% $O_2$ in $N_2$ |
| pH | 4 | 7 | 10 |
| CONDUCTIVITY | 744 uS | 996 uS | 1454 uS |

Each Hydrolab was attached to a cement block and placed on the creek bottom with the probes facing downstream to minimize contamination. The unit 5000 was installed at CN-3 and 5001 installed at CN-4. The water depth at each site was at least 50 cm (depending on flow) and the monitors remained in the creek for eight days.

Independent measurements of the water quality parameters were taken at each site on five occasions during each monitoring period. Stream water temperature was measured with a standard mercury thermometer with a range of 0-50° C. pH measurements were made with a Corning digital pH meter and an Orion Research ROSS combination pH electrode. The probe was calibrated in the laboratory with Fisher buffer solutions of pH 4, 7, and 10 and the calibration was checked on-site with pH 7 buffer.

A one-liter water sample was collected from each site and returned to the laboratory for conductivity analysis. A YSI model 32 conductivity meter and probe were used for these determinations and the temperature was recorded simultaneously.

Dissolved oxygen was measured by two methods. Measurements were taken on site with a YSI model 54 oxygen meter equipped with a YSI model 5739 sensor. This system was calibrated with air saturated water each day prior to use. The second method for dissolved oxygen determinations was a modification of the classical Winkler procedure (Strickland and Parsons 1972). Triplicate samples were taken at each site and fixed immediately by adding manganous sulphate and alkaline iodide solutions. The samples were returned to the laboratory and titrations were conducted the same day.

At the end of each monitoring period the DataSondes were recovered from the field sites and returned to the Calibration Laboratory for data retrieval and post-field calibration. Data was obtained both as a printout and as a computer memory file which was easily transferred to a spreadsheet file for data analysis.

## Results

Post-field calibration of the DataSondes was conducted one week (on average) after return from the field. Table 3 shows the variation for each parameter during the June field test. In all cases the changes are less than one per cent with the exception of pH at CN-3. This sensor also showed poor repeatability during the pre-field calibration.

The dissolved oxygen sensor in this model of Hydrolab are continuously powered by two 2.7 volt cells mounted inside the unit which allows relatively quick readings to be taken after activating the main unit. During July, these batteries failed in both units; 5001 during the field test and 5000 after recovery but before post-field calibration. However, the field data for both DataSondes appear reliable with the exception of dissolved oxygen at CN-4 (unit 5001).

The post-field calibration in October gave results similiar to those found in June for the 5000 unit. A memory failure during calibration of the CN-4 unit resulted in loss of the calibration coefficients and inability to compare calibrations.

Table 3. Differences between pre- and post-field calibrations of DataSondes - June

| PARAMETER | CALIBRATION POINTS | DEVIATION UNIT 5000 | DEVIATION UNIT 5001 |
|---|---|---|---|
| TEMPERATURE | 5.00 | -0.09 | 0.01 |
| (° C) | 15.00 | 0.04 | 0.13 |
| | 25.00 | -0.03 | 0.02 |
| DIS. OXYGEN | 10 % | -0.26 | 0.26 |
| (mg/L) | 15 % | -0.44 | 0.17 |
| | 21 % | -0.61 | 0.20 |
| pH | 7 | 0.20 | 0.02 |
| (pH units) | 10 | 0.37 | 0.04 |
| CONDUCTIVITY (uS/cm) | 1408 | 4 | 6 |

Independent measurements for each water quality parameter were taken for comparison with the Hydrolab data as a means of determining the accuracy of the monitors. The time of each independent reading was recorded and compared with those taken at comparable times by the in-situ instruments. Table 4 shows a comparison of the pH values for each station. Although the response time for each pH sensor may vary, particularly in low ionic strength water, the comparisons at the CN-4 site are very close. The values for station CN-3 are more variable; however, this Hydrolab probe gave repeatability problems during calibration.

Temperature comparisons are shown in Table 5. The accuracy in reading the standard thermometer is ca. 0.2° C and in most cases agreement is achieved between the two methods.

The Hydrolab dissolved oxygen values were compared with the YSI 54 readings and with the Winkler titrations. This data is presented in Table 6. Concentrations of dissolved oxygen between all methods show minor variations. The low Hydrolab value on June 12 at CN-3 may be a result of algae buildup on the sensor. Both YSI 54 readings for October 2 are unusually high and believed to be operator error.

The temperature-corrected conductivity measurements are shown in Table 7. Although the number of samples is smaller, the correspondence between the two systems is very good.

Table 4. Comparison of Hydrolab and independent pH measurements

| DATE | pH CN-3 (pH units) HYDROLAB | pH CN-3 (pH units) CORNING | pH CN-4 (pH units) HYDROLAB | pH CN-4 (pH units) CORNING |
|---|---|---|---|---|
| 870605 | 8.55 | 8.12 | 8.44 | 8.48 |
| 870608 | 8.54 | 8.24 | 8.11 | 8.57 |
| 870609 | 8.47 | 8.17 | 8.34 | 8.50 |
| 870610 | 8.64 | 8.48 | 8.44 | 8.46 |
| 870612 | 8.23 | 8.08 | 8.04 | 8.20 |
| 870717 | 9.04 | 8.61 | 8.60 | 8.68 |
| 870720 | 8.30 | 8.01 | 8.07 | 8.22 |
| 870721 | 8.90 | 8.55 | 8.61 | 8.86 |
| 870722 | 8.87 | 8.54 | 8.47 | 8.67 |
| 870724 | 8.57 | 8.27 | 8.13 | 8.27 |
| 871002 | 8.36 | 8.49 | 8.54 | 8.64 |
| 871005 | 8.52 | 8.63 | 8.66 | 8.89 |
| 871006 | 8.28 | 8.38 | 8.42 | 8.59 |
| 871007 | 8.26 | 8.30 | 8.07 | 8.17 |
| 871009 | 8.41 | 8.49 | 8.21 | 8.43 |

Table 5. Comparison of Hydrolab and independent temperature measurements

| DATE | TEMPERATURE CN-3 (°C) HYDROLAB | TEMPERATURE CN-3 (°C) THERMOMETER | TEMPERATURE CN-4 (°C) HYDROLAB | TEMPERATURE CN-4 (°C) THERMOMETER |
|---|---|---|---|---|
| 870605 | 17.28 | 17.8 | 16.77 | 17.0 |
| 870608 | 20.70 | 21.1 | 20.78 | 21.2 |
| 870609 | 17.70 | 17.7 | 16.60 | 16.9 |
| 870610 | 16.01 | 16.5 | 14.28 | 14.5 |
| 870612 | 18.54 | 19.0 | 17.19 | 17.8 |
| 870717 | 24.12 | 25.0 | 23.19 | 24.0 |
| 870720 | 24.20 | 24.8 | 24.46 | 25.0 |
| 870721 | 26.57 | 27.0 | 28.30 | 29.0 |
| 870722 | 25.77 | 26.5 | 25.34 | 26.0 |
| 870724 | 25.22 | 25.8 | 24.12 | 24.5 |
| 871002 | 14.19 | 14.7 | 13.85 | 14.2 |
| 871005 | 13.18 | 13.1 | 13.31 | 13.6 |
| 871006 | 13.77 | 13.6 | 13.43 | 13.0 |
| 871007 | 11.53 | 11.1 | 11.02 | 10.8 |
| 871009 | 9.97 | 9.8 | 9.63 | 9.5 |

Table 6. Comparison of Hydrolab and independent dissolved oxygen measurements

| | OXYGEN CN-3 (mg/L) | | | OXYGEN CN-4 (mg/L) | | |
|---|---|---|---|---|---|---|
| DATE | HYDROLAB | WINKLER | YSI 54 | HYDROLAB | WINKLER | YSI 54 |
| 870605 | 8.79 | 9.61 | 9.7 | 10.92 | 10.85 | 11.0 |
| 870608 | 8.98 | 9.73 | 10.0 | 12.59 | 12.48 | 12.8 |
| 870609 | 8.68 | | 10.1 | 11.68 | | 11.4 |
| 870610 | 9.63 | 11.19 | 11.7 | 13.24 | 12.89 | 13.4 |
| 870612 | 6.55 | 8.54 | 8.8 | 9.69 | 9.51 | 10.0 |
| 870717 | 13.93 | 13.63 | 13.6 | | 13.55 | 13.4 |
| 870720 | 8.04 | 7.31 | 8.2 | | 9.06 | 9.2 |
| 870721 | 13.44 | 12.73 | 13.0 | | 12.31 | 12.7 |
| 870722 | 12.23 | 13.29 | 11.2 | | 13.54 | 11.4 |
| 870724 | 10.96 | 11.11 | 11.3 | | 9.80 | 10.0 |
| 871002 | 11.14 | 11.20 | 14.7 | 11.00 | 12.10 | 14.2 |
| 871005 | 12.07 | 12.40 | 12.4 | 12.76 | 13.70 | 13.4 |
| 871006 | 10.89 | 11.40 | 11.6 | 11.70 | 12.70 | 12.8 |
| 871007 | 9.31 | 9.70 | 9.6 | 8.97 | 9.90 | 9.8 |
| 871009 | 10.14 | 10.60 | 10.2 | 9.49 | 10.60 | 10.2 |

Table 7. Comparison of Hydrolab and independent conductivity measurements

| DATE | CONDUCTIVITY CN-3 (uS/cm) | | CONDUCTIVITY CN-4 (uS/cm) | |
|---|---|---|---|---|
| | HYDROLAB | YSI 32 | HYDROLAB | YSI 32 |
| 870608 | 1228 | 1176 | 1204 | 1196 |
| 870609 | 1336 | 1274 | 1245 | 1227 |
| 870612 | 1355 | 1352 | 1241 | 1251 |
| 870721 | 1103 | 1071 | | |
| 871005 | 1202 | 1106 | 1085 | 1155 |

The evaluation of the Hydrolabs also provided an opportunity to assess the water quality conditions in Canagagigue Creek following the installation of tertiary treatment at the Elmira Water Pollution Control Plant. The diurnal changes in pH, temperature, and dissolved oxygen are shown in Figure 3-5. Conductivity measurements varies with changes in flow, and a Figure 6 shows the diurnal changes for eight days under very low flow. Figure 7 shows the changes in conductivity with an increase in flow at mid-week. The flow manipulation was provided by the Grand River Conservation Authority in conjunction with another NWRI study on the Creek (Carey and Lau).

The time of travel between CN-3 and CN-4 was determined from analysis of the conductivity measurements. For each 24 hour period, the sum of the absolute differences in conductivity between the two stations at different lag times was plotted against lag time. The minimum of this sum can be considered a first approximation for the time of travel between the two sites (for more detail see the Appendix). The time of travel under low flow is shown in Figure 8 and under high flow in Figure 9. This information is useful for calculating disappearance rates of nutrients and organic compounds in the creek.

## Discussion

The Hydrolab water quality monitors performed well under field conditions for a one week period. These instruments have a number of features which make them useful as monitoring devices. Installation is simple as there are no cables or external power supply and data is recorded without additional equipment. Data retrieval is easy and compatible with other computer software. The sensors appear reliable for stream monitoring applications. Prior laboratory testing of these instruments provide specifications for each sensor with expected ranges under field conditions (Ford 1987).

Several considerations are important before using the Hydrolab monitors. Accurate calibration of the sensors is essential. Access to the Calibration Unit, NWRI, is a valuable asset although calibration could be achieved by individual laboratories. Independent measurements provide reference points during the deployment period as the DataSonde is not readily interrogated in the field. Regular battery replacement before use is advisable. Battery life is dependent on the number and frequency of parameter readings and may vary, especially during long-term monitoring programs. The drift in calibration may also be greater with longer monitoring times.

## Acknowledgments

We wish to thank L. Peer and J. Cooper, Calibration Unit, NWRI, for their work in calibrating the Hydrolab monitors. The assistance of the Technical Operations Division, NWRI, for field support is also appreciated.

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Strickland, J. D. H. and T. R. Parsons. 1972. A Practical Handboook of Seawater Analysis. Fisheries Research Board of Canada, Bulletin 167, pp. 21-26.

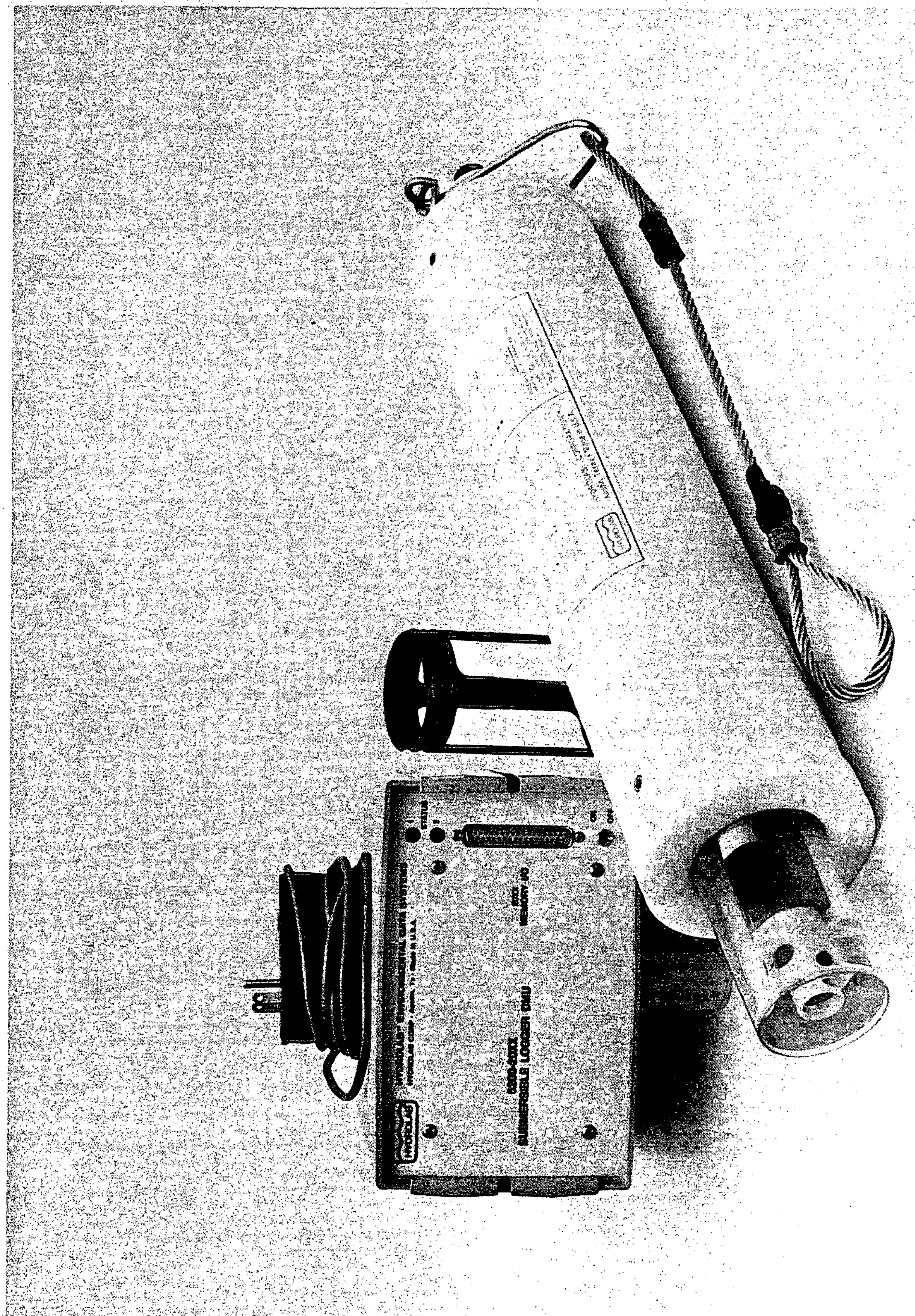

Figure 1. Hydrolab DataSonde 2000 Series

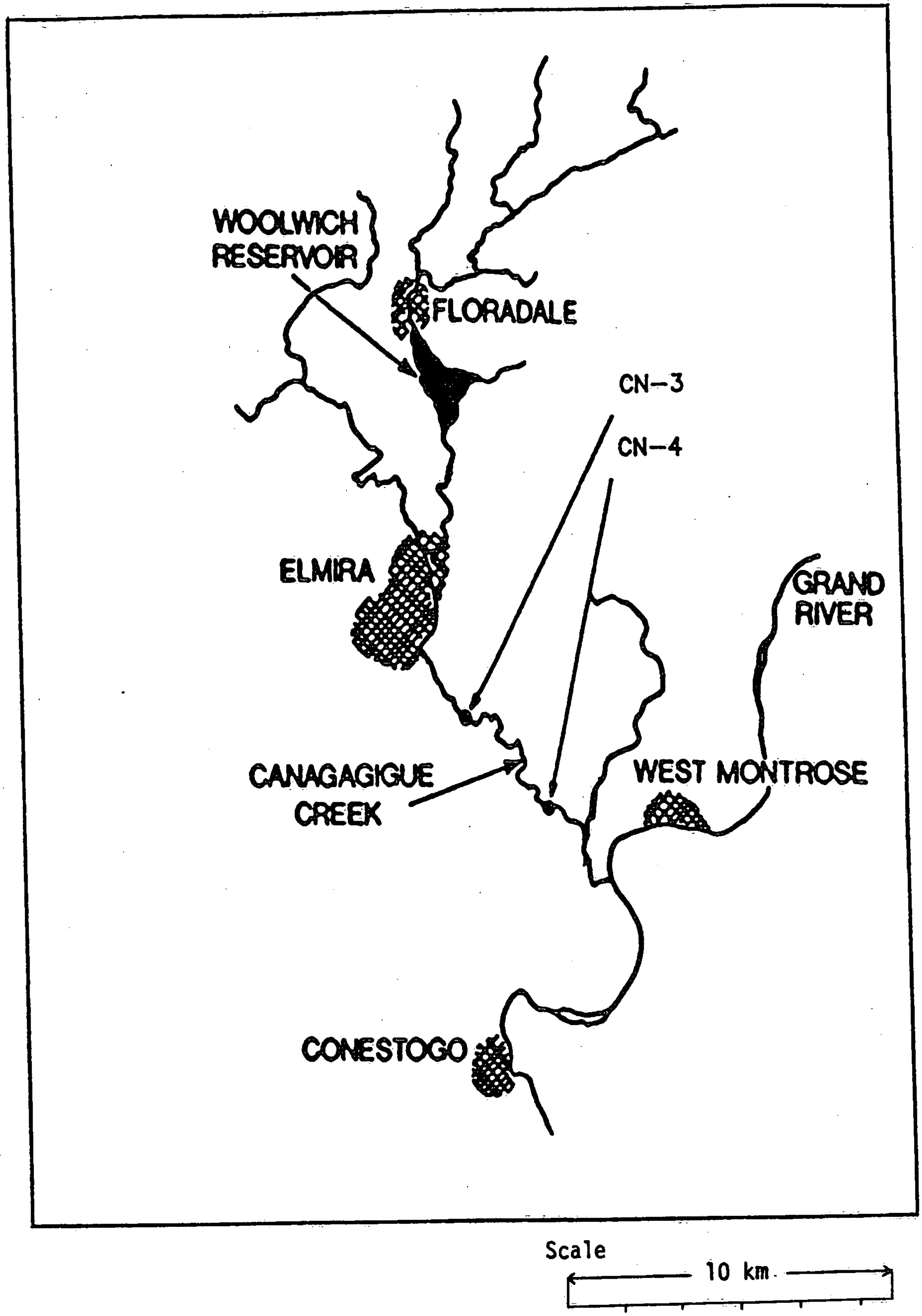


Figure 2. Map of study area and sampling sites

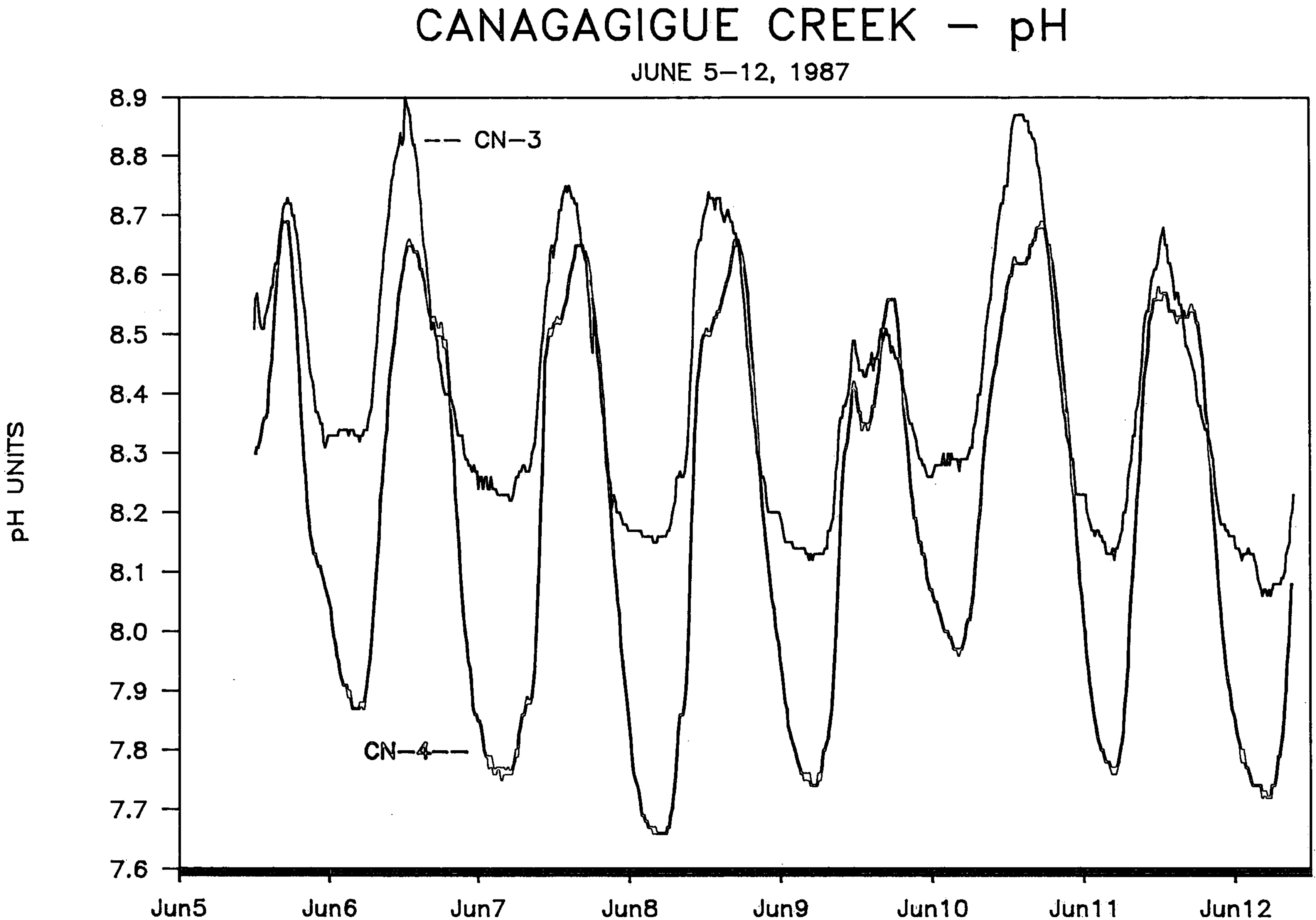


Figure 3. Hydrolab pH measurements at sites CN-3 and CN-4.

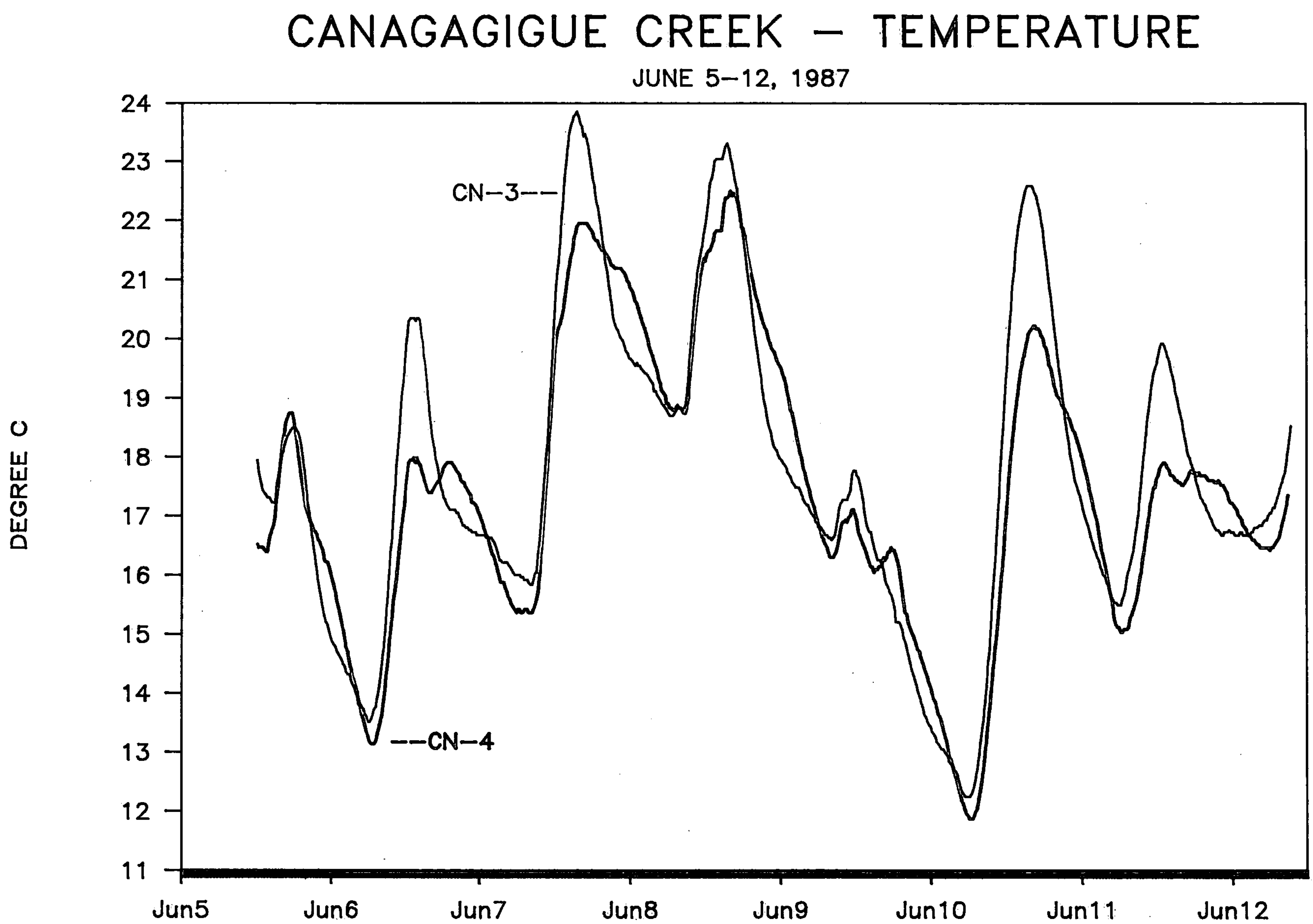


Figure 4. Hydrolab temperature measurements at sites CN-3 and CN-4.

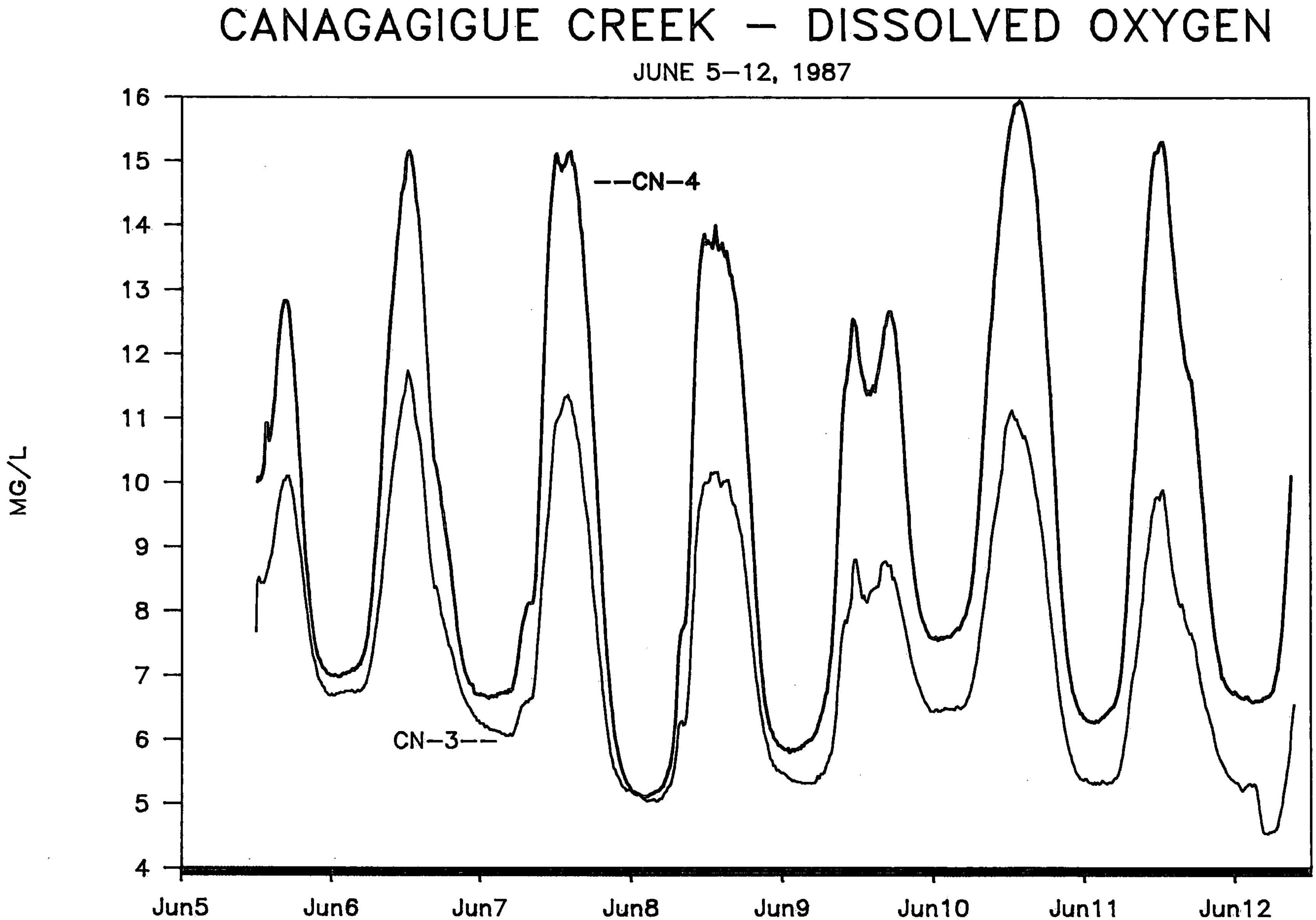


Figure 5. Hydrolab dissolved oxygen measurements at sites CN-3 and CN-4.

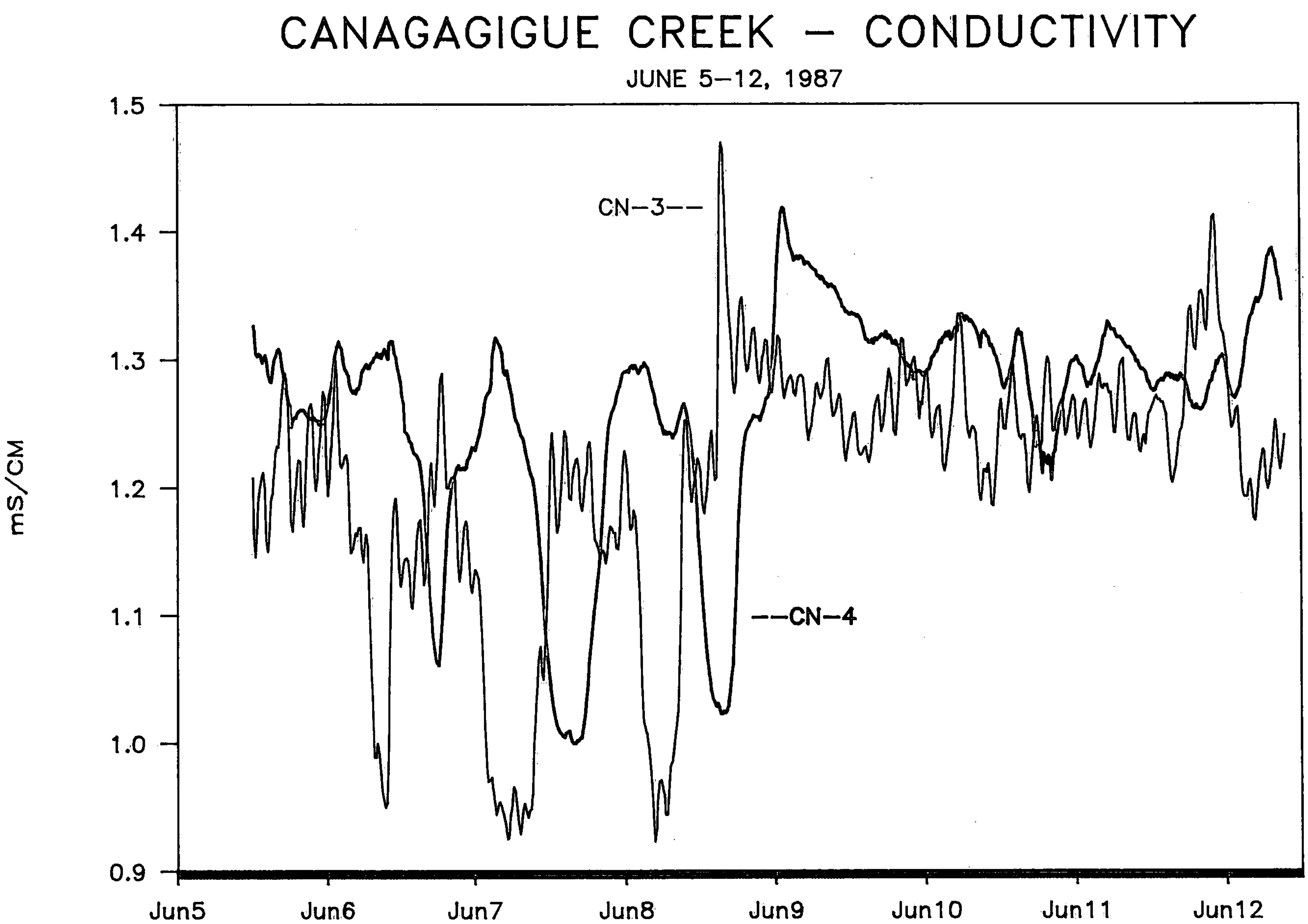


Figure 6. Hydrolab conductivity measurements at sites CN-3 and CN-4 - low flow.

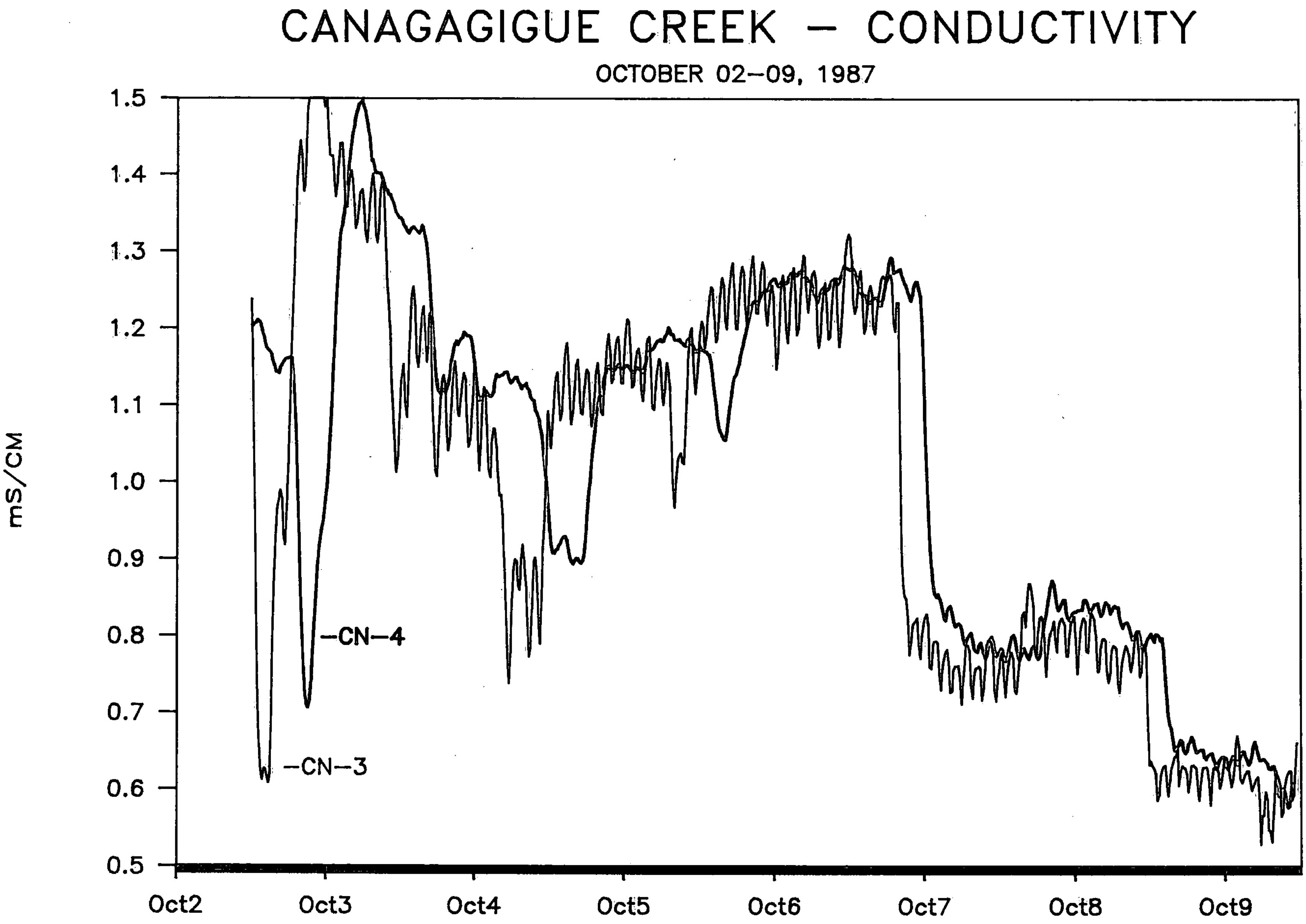


Figure 7. Hydrolab conductivity measurements at sites CN-3 and CN-4 - high flow.

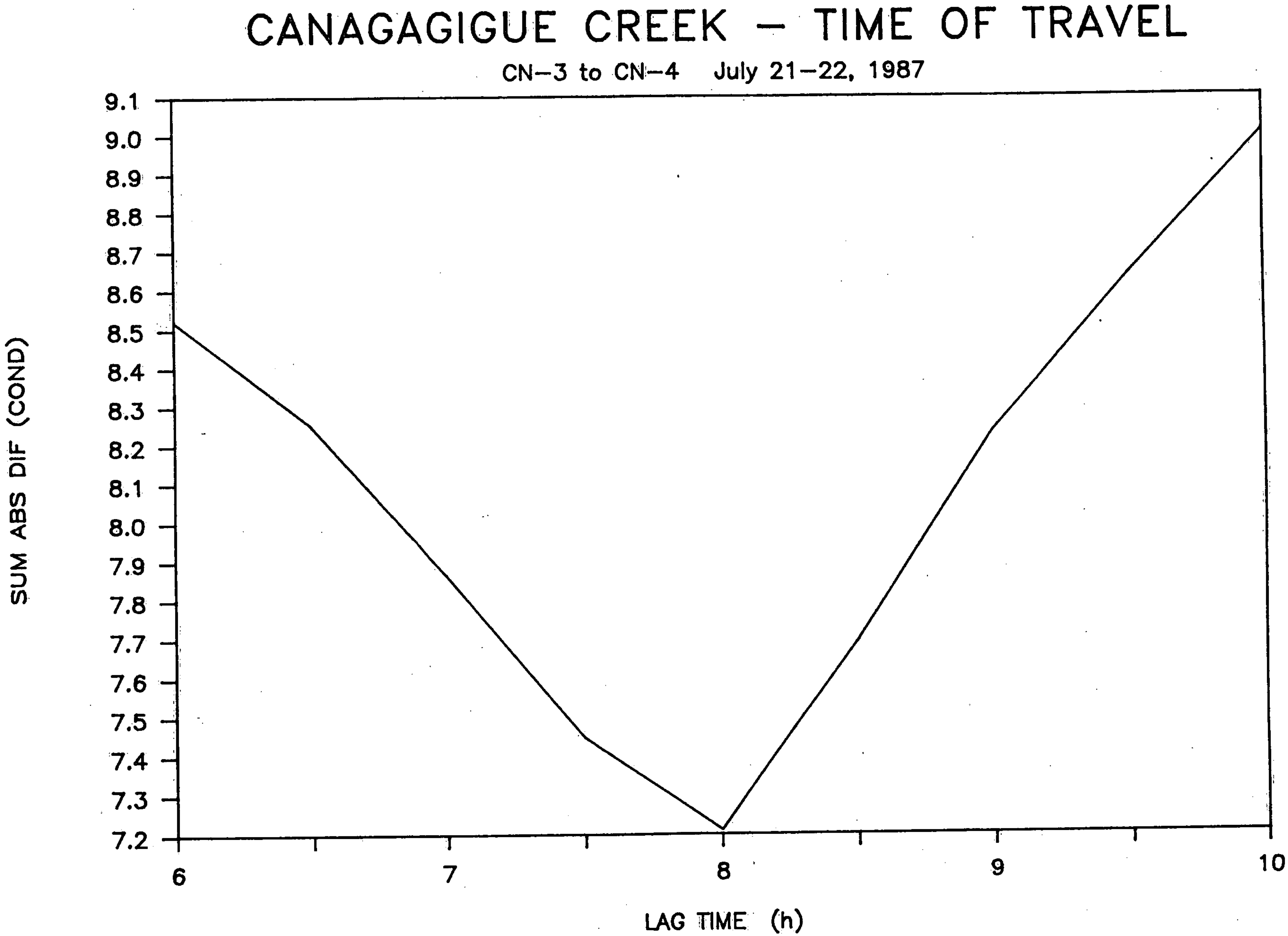


Figure 8. Canagagigue Creek : Time of travel - low flow

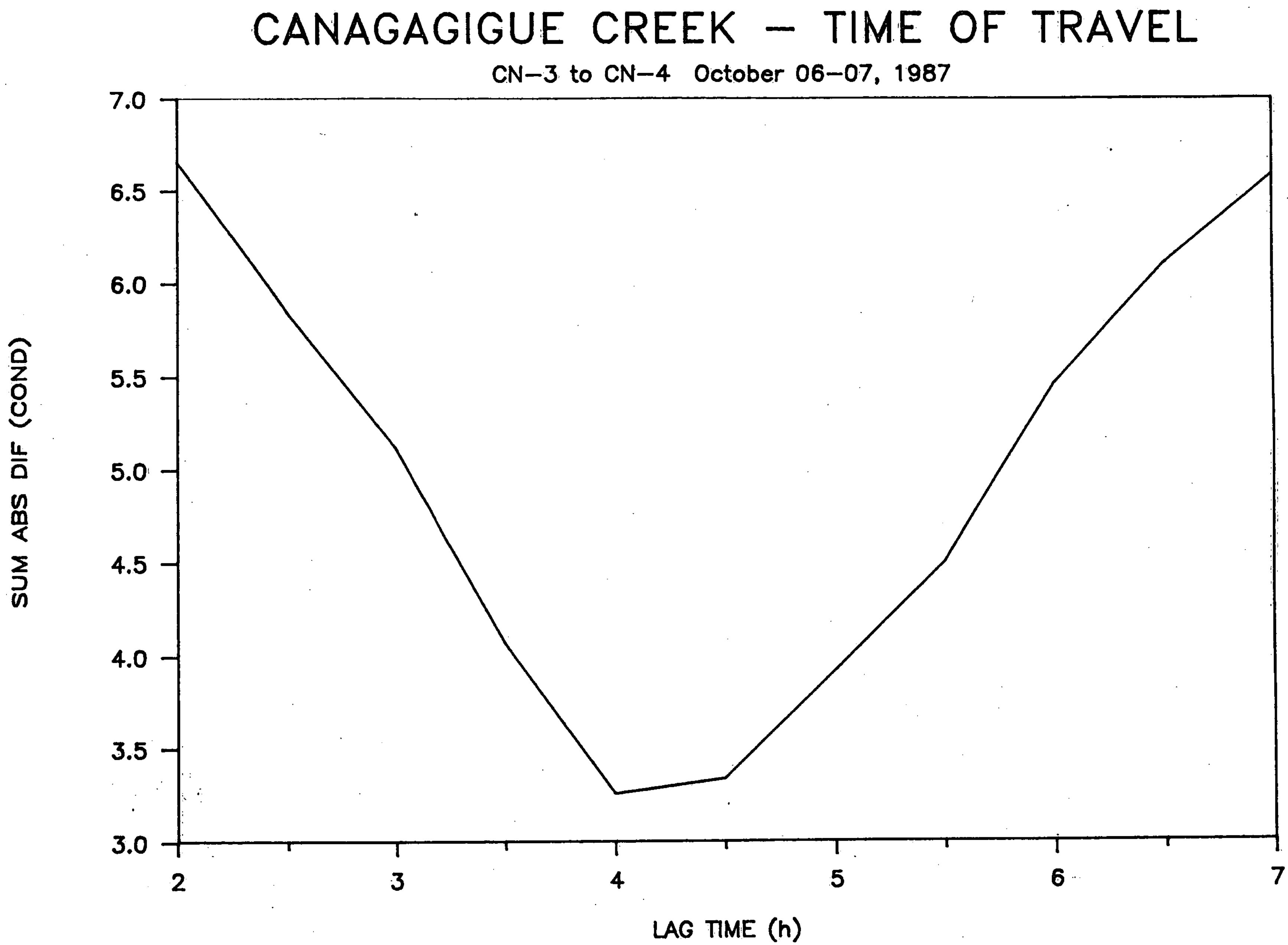


Figure 9. Canagagigue Creek : Time of travel - high flow

## Appendix

Canagagigue Creek receives a time-varying input from the Water Pollution Control Plant. This input contains major ions which increase the conductivity within the creek. Previously, we had collected hourly samples with automatic samplers and measured their conductivity in the laboratory. These hourly time series showed trends but had little fine detail. By using the Hydrolab monitors we obtained time series with 0.25 hour resolution, sufficient to show fine detail. By analyzing the relationship between the upstream and downstream time series it is possible to get an estimate for the time of travel between the two sites (longitudinal dispersion is not taken into account).

Strictly speaking, this data analysis problem is one of bivariate time series analysis where the two time series are not on a similar footing, i.e., they are causally related (Jenkins and Watts, 1968, p. 322). The time lag between the series can be examined by the cross correlation function (Jenkins and Watts, 1968, pp. 322-326; STSC, 1986, pp. 19.14-19.16). Furthermore, it is not likely that these time series are stationary, i.e., having constant mean and variance (Jenkins and Watts, 1968, pp. 147-152). Thus some form of smoothing should be used (STSC, 1986, p. 19.15). Commercially available statistics programs such as Statgraphics[1] can be used to smooth the time series and compute the cross correlation function. However, the user has little control over the way in which the lagging is done. Because of this, time series analysis was compared with two manual approaches using a spreadsheet (Lotus[2] 1-2-3[2]), and a graphical estimate by inspection of the plots. The results are given in Table A.1 for the October conductivity values.

In the spreadsheet calculations, a 24 hour subset of conductivity values (96 data points) for the upstream site (CN-3) was used. From this was subtracted a subset of 96 data points for the downstream site (CN-4) offset by a lag time, l. The sum of the absolute values of these differences is a measure of the "match" between the two subsets. The offset or lag which gives the minimum of this sum is the best estimate of the time of travel between upstream and downstream sites. This is similar to the $L_1$ norm approximation (Handscomb et al., 1966, p. 70; A. El-Shaarawi, personal communication). If COND is the conductivity, then we are minimizing the quantity:

sum of $|COND_{CN-3,t} - COND_{CN-4,t+l}|$
where t=0 to 95 for October 2-3, for example,
and l is the various lags; l=28 is a 7 hour lag.

Using the spreadsheet method, it is also possible to minimize the squares of these differences, i.e., to minimize:

sum of $(COND_{CN-3,t} - COND_{CN-4,t+l})^2$

This is similar to the $L_2$ norm approximation and is better suited to normally distributed data, whereas the $L_1$ norm is more robust where the data are not normally distributed (A. El-Shaarawi, personal communication).

Finally, because of the excellent fine feature in the time series, it is possible to estimate times of travel by inspection of the plots of upstream and downstream conductivity (Fig. 3). This has the advantage of being the simplest method of all, but is somewhat subjective.

Table A.1 gives the times of travel for each of the seven days estimated graphically, and by the absolute value and squares of the differences. For the cross correlation function, data were grouped and smoothed for the first two, second two, and last three days after inspection of Figure 3. The longer time periods were used to minimize any effects due to shortening the effective length of the series due to lagging in the cross correlation.

The agreement between all of the methods is very good. The small differences can be attributed to errors inherent to each method: e.g., too few lag times used in the spreadsheet method, inaccuracies in the graphical method, and grouping of two or three days' data for the cross correlation method. For the last day, October 6-7, both spreadsheet methods gave an indeterminate result, whereas it was possible to estimate a value for time of travel by the graphical method, albeit, very subjectively.

In summary, all of these methods are of comparable value for estimating time of travel in rivers from upstream/downstream time series. The graphical method is the most straightforward. Of the numerical methods, the two spreadsheet methods are more intuitive than the cross correlation method and can be done with software which is more commonly available.

Table A.1 Times of travel (h) estimated by four methods from the conductivity time series for October 2-9, 1987.

| Date | Graphical | $L_1$ Norm | $L_2$ Norm | Cross Correlation |
|---|---|---|---|---|
| 10/2-3 | 7.5 | 7.0 | 7.0 | |
| 10/3-4 | 7.5 | 7.0 | 7.0 | |
| 10/2-4 | | | | 6.75 |
| 10/4-5 | 7.5 | 7.0 | 7.0 | |
| 10/5-6 | 7.5 | 6.5 | 6.5 | |
| 10/4-6 | | | | 6.5 |
| 10/6-7 | 4.5 | 4.0 | 4.0 | |
| 10/7-8 | 4.0 | 3.5 | 3.5 | |
| 10/8-9 | 3.5 | undefined | | |
| 10/6-9 | | | | 3.75 |

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