

**THE CDR MODEL APPLIED TO DATA FOR  
WHITEBURN BROOK BELOW POLLOCK LAKE,  
MEDWAY RIVER BASIN, NOVA SCOTIA, 1984**

**by  
Mary E. Thompson**

**LRTAP Project  
Rivers Research Branch  
National Water Research Institute  
Canada Centre for Inland Waters  
Burlington, Ontario L7R 4A6, Canada  
July 1987  
NWRI Contribution #87-114**

## ABSTRACT

The CDR model is successfully applied to data for Whiteburn Brook, a small stream draining a headwater lake near Kejimikujik National Park, Nova Scotia.

Dissolved organic carbon (DOC) concentrations are low, and the data indicate that the organic matter is not very reactive, perhaps due to in-lake processes.

## RÉSUMÉ

Le modèle du TAC est appliqué avec succès aux données du ruisseau Whiteburn, un petit cours d'eau qui draine les eaux d'un lac d'amont près du Parc national Kejimikujik, Nouvelle-Écosse.

Les concentrations de carbone organique dissous (COD) sont faibles et les données indiquent que les matières organiques ne sont pas très réactives, probablement à cause de processus inhérents au lac.

## **MANAGEMENT PERSPECTIVE**

This is a contribution to the LRTAP Project. It is another successful application of the CDR model, this time to a small stream draining a headwater lake near Kejimikujik National Park, Nova Scotia.

## **PERSPECTIVE - GESTION**

Le présent document constitue une contribution au projet TADPA. Il décrit une autre application réussie du modèle du TAC au ruisseau Rogers, un cours d'eau à très forte teneur en matières organiques au Parc national Kejimikujik, Nouvelle-Écosse.

## INTRODUCTION

Whiteburn Brook, which carries the outflow from Pollock Lake, a headwater lake in the watersheds of the Medway River, Nova Scotia, is a small stream with a drainage area of 9.49 km<sup>2</sup>. The sampling station (NAQUADAT code 00NS01EE0015) is at 44-21-07 N and 65-05-48 W. the Water Survey of Canada guage is at 44-21-10 N and 65-05-48 W (WSC code 01EE007). The basin is apparently underlain by slates and schists of the Halifax Formation, highly metamorphosed strata of Cambrian-Ordovician age.

The first year for which daily discharge data are available is 1984. Interestingly, the 1984 discharge data were not published in the annual compilation of discharge data for the Atlantic Provinces 1984 (Water Survey of Canada, 1985), but are present on a tape of discharge data for the Atlantic Provinces supplied by Water Survey of Canada. Runoff of Whiteburn Brook was 0.903 m yr<sup>-1</sup> for 1984.

Whiteburn Brook is a moderately softwater brook with moderate levels of DOC (range 2.7 to 12.0, discharge-weighted annual mean 5.2 mg L<sup>-1</sup>). The watershed receives a moderate amount of seasalt; Cl<sup>-</sup> concentrations in 1984 ranged from 4.8 to 8.9 mg L<sup>-1</sup>. The data are corrected for seasalt, using Cl<sup>-</sup> as the seawater indicator species, and assuming the same major ion ratios to Cl<sup>-</sup> in the marine aerosol as in open seawater (Thompson, 1982).

The annual cycle of events in this stream is similar to that observed in other streams in the same area. Flow and seasalt levels are higher in the winter, as are excess sulfate concentrations.

During summer and fall, flow is typically low, but cation and DOC concentrations rise. Sulfate concentrations are low in the summer, on occasion so low that the seasalt correction produces negative values. This phenomenon has been described by Kerekes et al. (1986).

CDRs and excess sulfate yields are calculated by summing the products of mean monthly seasalt-corrected discharge-weighted concentrations and mean monthly runoff. Data for pH are not discharge-weighted because it is felt that discharge-weighting biases the results toward low values; instead for pH and alkalinity, monthly arithmetic mean values are multiplied by the number of days in that month. The products are summed and divided by the number of days in the year.

The mean annual discharge-weighted sum of cations is obtained by dividing CDR by annual runoff. Mean discharge-weighted excess sulfate concentrations are obtained similarly. The alkalinity estimate is taken as the difference between the mean discharge-weighted sum of cations and the mean discharge-weighted excess sulfate concentration. MTB sulfate concentrations are generally higher than IC sulfate concentrations because of the presence of organic anions that affect the MTB sulfate measurement and must be considered in calculating charge balance. Because the CDR model requires charge balance, MTB sulfate data are used.

From the estimated alkalinity, pH is calculated from

$$\text{pH} = 7.8 + \text{p Pco}_2 - \text{p HCO}_3^-$$

in which  $p \text{ Pco}_2$  is commonly taken to be 2.5, for which the expression reduces to

$$\text{pH} = 10.3 - p \text{ HCO}_3^-$$

where  $p$  is used to denote the negative logarithms of the concentration of a species.

## DISCUSSION

The data used for the CDR model are given in Table 1, and the results are plotted on Figure 1. Day-weighted arithmetic mean pH, calculated by weighting the arithmetic mean pH for each month by the number of days in that month, summing the results and dividing by 366, is used because that result best fits the model. Discharge-weighting of pH or of the antilogs of pH give lower mean pH results by about 0.2 pH units. However, the model estimate of alkalinity,  $34.5 \mu\text{eq L}^{-1}$ , is similar to the day-weighted arithmetic mean alkalinity,  $32.7 \mu\text{eq L}^{-1}$ . Here again, discharge-weighting the alkalinity produces a lower mean,  $21.0 \mu\text{eq L}^{-1}$ , and a lower estimate of mean pH by about 0.2 pH units.

Because it gives charge balance, MTB sulfate, which incorporates some organic anions, is used for the model. This stream, however, is not especially influenced by organic anions. The difference between the mean MTB sulfate and the mean IC sulfate, referred to as delta sulfate by Howell and Pollock (1982), and as  $\text{SRA}^-$  (for soluble



reactive  $A^-$ ) by Thompson (1986), is only 11-3  $\mu\text{eq L}^{-1}$ . The term  $SRA^-$  is preferred to delta sulfate because, although it is obtained by subtracting IC sulfate from MTB sulfate, the species we are evaluating is not sulfate but rather an organic anion.

The mean annual DOC concentration is 5.2  $\text{mg L}^{-1}$ . The organic anion,  $A^-$ , calculated by the method of Oliver et al. (1983), from the mean DOC and the mean pH (5.84) is 47  $\mu\text{eq L}^{-1}$ , considerably larger than  $SRA^-$ . As Oliver et al. worked with purified organic matter, the difference between  $A^-$  and  $SRA^-$ , which is always positive, has been attributed to complexation in nature of some of the  $A^-$  with Fe and Al (Thompson, 1986). On a mean annual basis, however, there is not enough Fe (9.6  $\mu\text{eq L}^{-1}$ ) or Al (8.2  $\mu\text{eq L}^{-1}$ ) to account for the difference between  $A^-$  and  $SRA^-$ , 35.5  $\mu\text{eq L}^{-1}$ . It may be that, because Whitburn Creek drains Pollock Lake, some in-lake process has indurated the organic matter, making it less reactive. Fe and Al do correlate with DOC, however, Fe over the year, and Al from January to July, and the correlations are highly significant:

$$\begin{aligned}n &= 12 & R^2 &= 0.83 \\(\text{Fe}) &= -0.299 + 0.093 (\text{DOC}) \\F &= 48.3 & P &= 0.0000\end{aligned}$$

$$\begin{aligned}n &= 7 & R^2 &= 0.94 \\(\text{Al}) &= 0.027 + 0.009 (\text{DOC}) \\F &= 82.6 & P &< 0.001\end{aligned}$$

Figure 2 shows the monthly mean values of DOC, Fe and Al. The figure shows that Fe and DOC follow a similar annual pattern, but that Al which follows DOC to July, abruptly deviates in August. Again, the causative reason is not known, but is presumed to be due to some altered property of the organic matter.

#### SUMMARY AND CONCLUSIONS

The CDR model has been applied to data for Whiteburn Brook, a small stream that drains Pollock Lake, a headwater lake in the watershed of the Medway River, a few kilometers east of Kejimikujik National Park, Nova Scotia. The model predicts the day-weighted arithmetic mean pH exactly.

Using mean annual data,  $A^-$  calculated from DOC and pH by the method of Oliver et al. (1983) is greater than  $SRA^-$ , the difference between MTB and IC sulfates, and the difference between  $A^-$  and  $SRA^-$  is greater than the sum of Fe and Al. It is presumed that in-lake processes may have rendered the organic matter less reactive.

#### REFERENCES

- Howell, G.D. and Pollock, T.L. 1986. Sulphate, water colour and dissolved organic carbon relationships in organic waters of Atlantic Canada. In Statistical Aspects of Water Quality Monitoring, Developments in Water Science, Vol. 27, El-Shaarawi, A.H. and Kwiatkowski, R.E., eds., Elsevier Science Publishers, pp 53-63.

- Kerekes, J., Beauchamp, S., Tordon, R. and Pollock, T. 1986. Sources of sulphate and acidity in wetlands and lakes in Nova Scotia. *Water, Air and Soil Pollution*, 31: 207-214.
- Oliver, B.G., Thurman, E.M. and Malcolm, R.L. 1983. The contribution of humic substances to the acidity of coloured natural waters. *Geoch. Cosmoch. Acta*. 47: 2031-2035.
- Thompson, M.E. 1982. Exchange of marine sodium for calcium during chemical weathering in the Isle aux Morts River Basin, Newfoundland. *Geoch. Cosmoch. Acta*. 46: 361-365.
- Thompson, M.E. 1986. The cation denudation rate model - its continued validity. *Water, Air and Soil Pollution* 31: 17-26.
- Water Survey of Canada. 1986. Surface water data Atlantic Provinces 1984. Environment Canada, Inland Waters Directorate, Water Resources Branch, Ottawa.

**Table 1. Summary of data used to apply the CDR model to Whiteburn Creek, 1984.**

Discharge-weighted sum of cations		83.3 $\mu\text{eq L}^{-1}$
Discharge-weighted excess MTB sulfate		48.8 $\mu\text{eq L}^{-1}$
Alkalinity estimate		34.5 $\mu\text{eq L}^{-1}$
	Model pH	5.84
Arithmetic mean	pH	5.84
Runoff		0.903 $\text{m yr}^{-1}$
CDR	CDR	75.2 $\text{meq m}^{-2} \text{yr}^{-1}$
Excess MTB sulfate yield		44.1 $\text{meq m}^{-2} \text{yr}^{-1}$

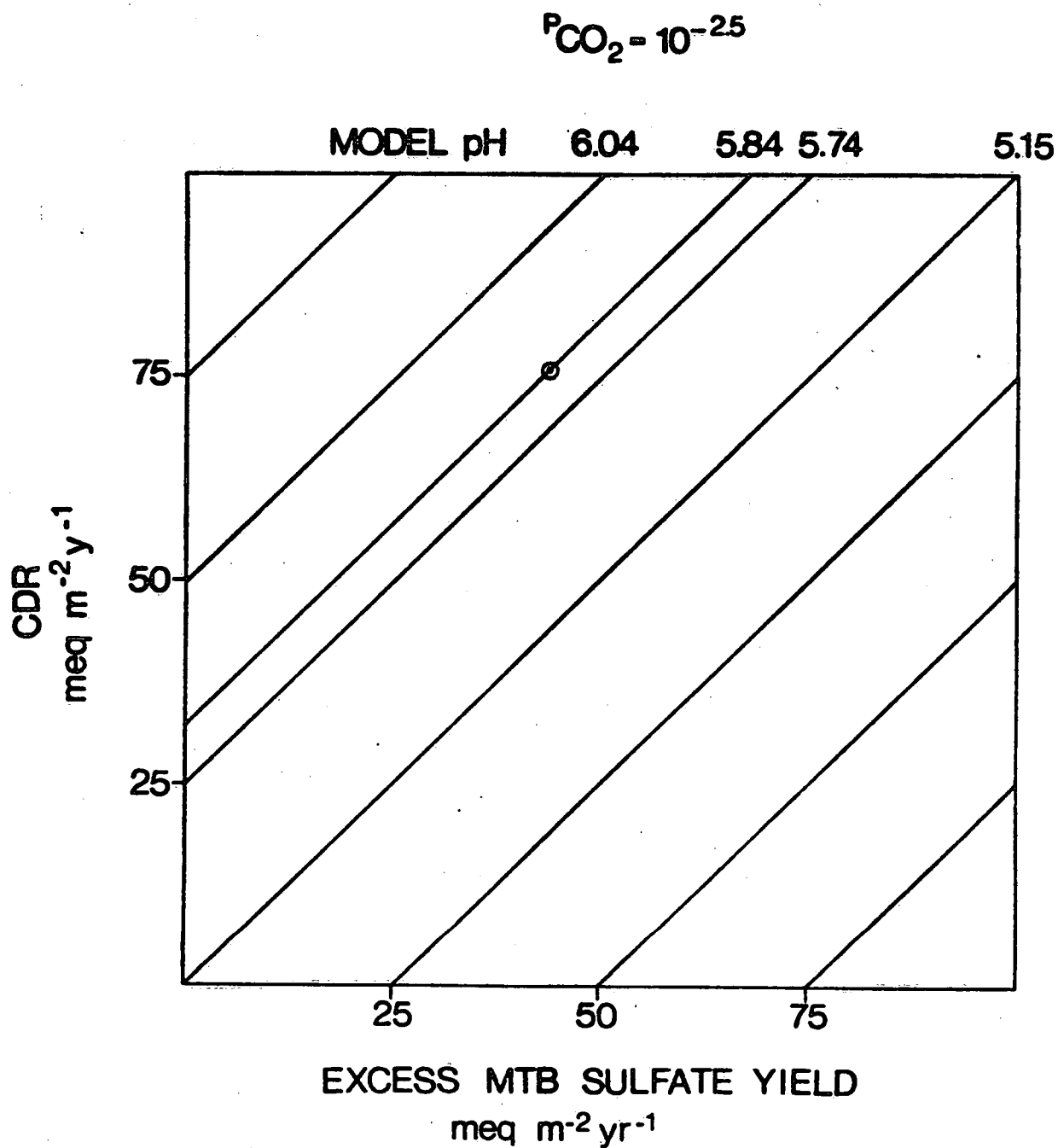


Figure 1. The CDR model drawing for data from Whiteburn Brook,  
Nova Scotia, 1984.

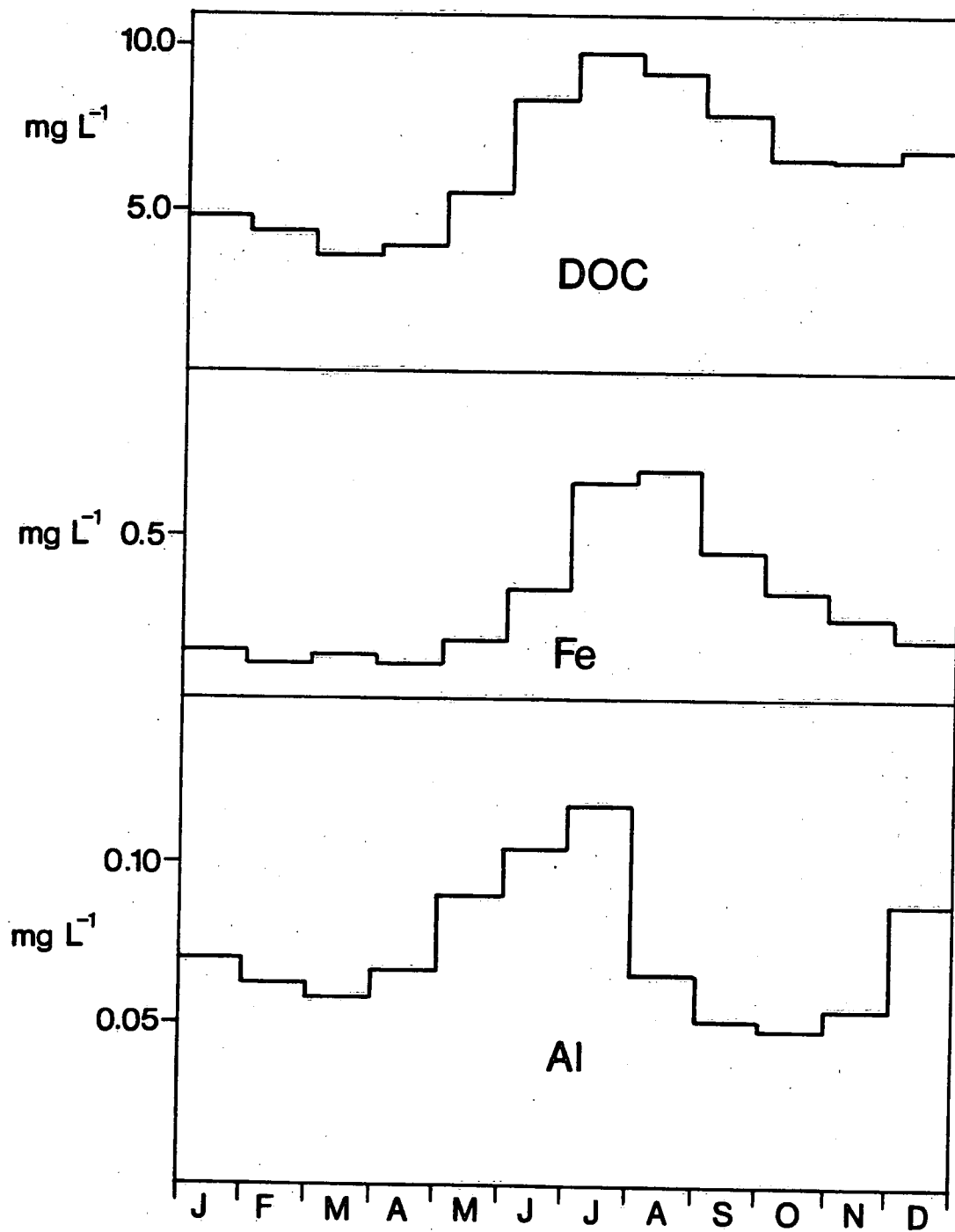


Figure 2. Monthly mean values of DOC, Fe, and Al for Whiteburn Brook, Nova Scotia, 1984.