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November 20, 1984

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Dr. Larry Gilbertson
Harza-Ebasco Susitna Joint Venture
711 H Street
Anchorage, AK 99501

Dear Larry:

Attached is one copy of the technical memorandum on light extinction coefficients referenced in our FY85 Scope of Work under Task 12. This memorandum provides an analysis of data that EWT&A collected during September in the Susitna River and extracted from pertinent literature. The relationship between turbidity and penetration depth of light provided in the memo should be considered preliminary. We are continuing our work to provide a more definitive, Susitna-specific equation.

Sincerely,

E. Woody Trihey

E. Woody Trihey, P.E.

EWT/ds

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PRELIMINARY DATA
Subject to Revision
Date 11-20-84

Technical Memorandum

Preliminary Analysis of the Relationship between Turbidity and Light Penetration in the Susitna River, Alaska

by

Erwin Van Nieuwenhuyse

November, 1984

This memo presents an analysis of field data collected in the Susitna River drainage and elsewhere to provide a basis for estimating the depth to which photosynthetically active radiation (PAR) can penetrate turbid water. This knowledge will enable a better understanding of how the benthic algae community of the Talkeetna-to-Devil Canyon reach of the Susitna River (middle river) presently functions under the natural turbidity regime, and how it will likely respond to the very different seasonal turbidity regime anticipated under with-project conditions. The implications of an altered turbidity regime and the response of the benthic algae community are of considerable interest and concern regarding with-project rearing poential in habitats influenced by the mainstem.

PAR is defined as light that is useful to plants for photosynthesis. This portion of the electromagnetic spectrum ranges from 400 to 700 nanometers in wave length. Its intensity at depth z (I_z) is an exponential decay function of surface intensity (I_0), depth beneath the water surface (z), and the negative extinction coefficient (η):

$$I_z = I_0 e^{-\eta z} \qquad \text{Equation 1}$$

Strictly speaking, the extinction coefficients described in this document are "total vertical light extinction coefficients," i.e., (1) they incorporate the light attenuation and absorption properties of the water itself as well as those of all dissolved and particulate matter present in the water column, and (2) light at the surface and at depth are measured on parallel horizontal planes (Poole and Atkins 1926). By convention the extinction coefficient is expressed in metric units, but English units are used in our analysis to maintain consistency with other project studies.

Turbidity is an arbitrary measure of water "cloudiness," i.e., the extent to which suspended matter scatters and absorbs light as it crosses a fixed path length of water sample. Today it is most often expressed in nephelometric turbidity units (NTU) and is measured by nephelometry, i.e., using a turbidimeter which measures light scattered at a 90° angle to the incident beam.

Total vertical light extinction coefficient measurements were made during mid-September in accord with methodology described by Van Nieuwenhuyse (1983). Field measurements were obtained at four sites in the middle and lower Susitna River as well as three sites in the Chulitna and Talkeetna rivers under turbidities ranging from 4.4 to 130 NTU (Table 1).

Table 1. Extinction coefficients (η) and turbidities measured in the Susitna River drainage and Knik Arm, September 10-11, 1984.

SITE	TURBIDITY (NTU)	η (ft^{-1})
Chulitna River (LB)	120	4.03
Chulitna River (LB)	120	3.93
Lower Susitna River (LB)	130	4.21
Lower Susitna River (LB)	130	4.19
Lower Susitna River (RB)	45	1.53
Middle Susitna River (RB)	18	0.73
Talkeetna River (LB)	4.4	0.34
Knik Arm	50	1.63

LB = left bank, looking upstream

RB = right bank, looking upstream

Light extinction coefficients were plotted against turbidity and the resulting strong positive correlation ($r^2 = 0.99$, $n = 8$) was described well by the linear regression equation:

$$\eta = 0.181 + 0.0310\ T \qquad \text{Equation 2}$$

where η = extinction coefficient (ft^{-1}) and T = turbidity (NTU).

Although this model is adequate to describe light penetration for turbidities below 130 NTU, its predictions for higher turbidity levels can be improved substantially by combining the data points from which it was derived with data available from other studies. The resulting model based on pooled data could be applied to a broader range of turbidities with greater confidence than the model we developed with only eight data points collected during September.

Naturally-occurring turbidity levels for the middle Susitna River at Gold Creek range from 1 to 1,000 NTU; with-project turbidity conditions are estimated to range from approximately 25 to 250 NTU or more.

The use of pooled data to obtain general empirical models has been successful in numerous hydrologic and ecological applications in the past, e.g., the derivation of rearation coefficient models (Streeter and Phelps 1925, Churchill et al. 1962, O'Conner and Dobbins 1956), suspended sediment and bedload transport models (Dunne and Leopold 1978), and phosphorus loading models (Vollenweider and Kerekes 1980), and appears justified in this case as well.

To date we are aware of only two data bases that can be pooled with the measurements we obtained during September 1984; one collected for undisturbed and placer-mined streams in Interior Alaska (Van Nieuwenhuyse 1983) and the other for a glacial lake near Anchorage (R&M Consultants 1982). The first data base consists of measurements taken at very low turbidities (1.1 - 4.7 NTU) and very high turbidities (330 - 1,400 NTU) with no intermediate levels represented. This shortcoming is compensated to some extent by the range of turbidities examined in the glacial lake study (17 - 38 NTU) and by our September data set (4.4 - 130 NTU).

By pooling the three data sets and plotting light extinction coefficient against turbidity the following linear regression equation is obtained (R^2 = .98, n=30) which is applicable to turbidities ranging from approximately 5 to 1,400 NTU:

$$\eta = 0.543 + 0.0177\ (T) \qquad \text{Equation 3}$$

where η = extinction coefficient and T = turbidity (NTU).

The precision of the model is illustrated by the Working-Hotelling confidence bands (α = 0.05) which delimit the family of interval estimates of mean responses at all levels of the independent variable (Figure 1). The accuracy of the model, especially at very low and very high turbidities, is somewhat compromised by the inherent difficulties associated with accurately and precisely measuring turbidity. The extinction coefficient measurements on the other hand tend to be both very accurate and precise (Van Nieuwenhuyse 1983). Predictions from the light extinction model, however, are at least as realistic as those generated by the hydraulic

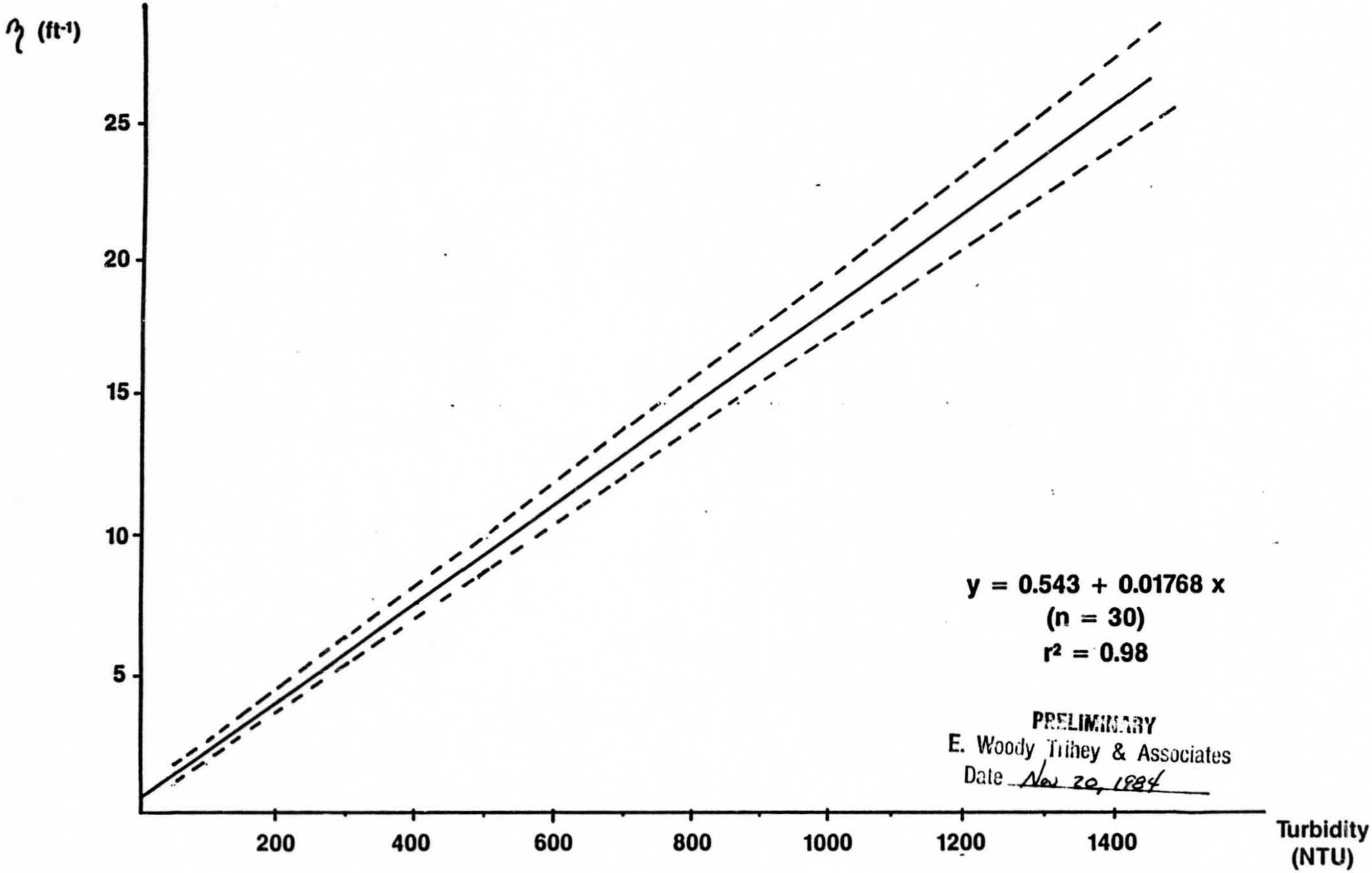

Figure 1. Pooled linear regression model of extinction coefficient v. turbidity showing 95% Working-Hotelling confidence band.

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models and the with-project turbidity forecasts with which it will be linked to assess impact on rearing potential.

One example of an application for the light extinction model can be given by deriving the relationship between turbidity and "compensation depth," i.e., the depth at which only 1% of the PAR striking the water's surface is available to the benthic algae community. While the use of this concept--which was developed for lakes--is somewhat arbitrary in the context of streams and rivers, it is a convenient (if not conservative) indicator variable for defining the lower limit of the euphotic zone in rivers and will be used here until a more appropriate limit can be developed.

Thus, by combining equations 1 and 3 and by setting $I_z = 0.01\ (I_o)$, one obtains:

$$I_{z_c} = 0.01\ (I_o) = I_o e^{-(0.543\ +\ 0.0177T)z_c}$$

$$= -\ 4.605 = -(0.543 + 0.1077T)z_c$$

$$z_c = \frac{4.605}{(0.543 + 0.0177T)} \qquad \text{Equation 4}$$

where z_c = "compensation depth" (ft) and as before T = turbidity (NTU). Thus, at a turbidity of 500 NTU, the estimated (95% confidence interval) lower limit of useful light penetration would be approximately 0.49 + 0.03 ft below the surface. At 300, 100, 50, and 10 NTU, it would be 0.80 + 0.05, 2.1 + 0.3, 3.5 + 1.20, and 9.2 + 5.4 ft, respectively.

Another use for the model would be to estimate the amount of light energy available for photosynthesis at any particular depth (e.g., a channel's mean depth) given the amount of light striking the surface and the turbidity.

While the model presented here is probably the best general model available at this time, a more accurate, Susitna-specific model, applicable to a broad range of naturally-occurring turbidity levels will become available by this time next year as extinction coefficients and turbidities are measured in conjunction with primary production studies which we will initiate in March or April of 1985.

REFERENCES

Churchill, M.A., H.L. Elmore, and R.A. Buckingham. 1962. Prediction of stream rearation rates. J. Sanit. Eng. Div., Proc. ASCE, 88, SA4:1-46.

Dunne, T. and L.B. Leopold. 1978. Water in environmental planning. W.H. Freeman and Co. San Francisco. 818 p.

O'Conner, D.J. and W.E. Dobbins. 1956. The mechanism of rearation in natural streams. J. Sanit.Eng. Div., Proc. ASCE, 82, SA6:1-30.

Poole, H.H. and W.R.G. Atkins. 1926. On the penetration of light into sea-water. J. Mar. Biol. Ass., U.K., 14:177-198.

R&M Consultants. 1982. Glacial lake studies interim report. Prepared for Acres American Inc., Anchorage, Alaaska.

Streeter, H.W. and E.B. Phelps. 1925. A study of the pollution and natural purification of the Ohio River: U.S. Public Health Service, Public Health Bull. 146. 75 p.

Van Nieuwenhuyse, E.E. 1983. The effects of placer mining on the primary productivity of Interior Alaska streams. M.S. Thesis, University of Alaska, Fairbanks. 120 p.

Vollenweider, R.A. and J. Kerekes. 1980. The loading concept as basis for controlling eutrophication philosophy and preliminary results of the OECD Programme on eutrophication. Prog. Wat. Tech. 12:5-18.