PRELIMINARY DRAFT
IMPACT ASSESSMENT TECHNICAL MEMORANDUM

SUSPENDED SEDIMENT AND TURBIDITY

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METHODS FOR PREDICTING AND ASSESSING DOWNSTREAM IMPACTS RESULTING FROM IMPOUNDMENT OF THE UPPER SUSITNA RIVER

SUSPENDED SEDIMENT AND TURBIDITY

INTRODUCTION

This technical memorandum presents a discussion of the ways in which environmental impacts associated with an altered suspended sediment regime in the middle Susitna River can be predicted and assessed. It begins with a description of baseline suspended sediment transport and our present understanding of how it influences habitat quality and biological productivity in the middle Susitna River. This is followed by a discussion of how this and other information presently being gathered can best be used to make rational predictions regarding post-impoundment conditions and some methods available to test these predictions should the proposed project be licensed and built.

BASELINE CONDITIONS

Glaciers cover approximately ~~3.4~~ 4.0% of the Susitna River drainage area above the USGS gauging station at Gold Creek (RM 137). About 13% of the annual runoff measured at this station (over 150 miles downstream from the nearest glacier) is contributed by glacial wasting (~~Williamson~~ Harrison and R&M Consultants, Inc. 1982). The estimated mean annual suspended sediment discharge at Gold Creek was calculated by Harza-Ebasco as 7.26 x 10^6 t/yr (Harza-Ebasco 1984). Using data collected during 1952-1957, Borland (1961) estimated the mean annual sediment load at Gold Creek as 3.29 $\times 10^6$ t/yr with an average annual runoff of 7.00 x 10^6 ac-ft. Knott and Lipscomb (1983), on the basis of weekly sampling from May-September 1982, estimated the total suspended sediment load for that period in 1982 as 2.81 $\times 10^6$ tons with a water discharge of 6.2×10^6 ac-ft. The total suspended load during the 1983 water year (October 1982 - September 1983) was 3.46 $\times 10^6$ t[illegible]r at 6.45×10^6 ac-ft total discharge (Knott and Lipscomb 1985). Knott's figures compare well with Borland's estimates even though Knott's sampling transect was located 35 river miles downstream from the Gold Creek station.

Almost all (99.6%) of this suspended sediment transport takes place between May and September. During spring breakup and flood events throughout the open water season, the relative amount of sand transported exceeds the silt-clay particle size fraction transported. Typically, by late June the onset of glacial wasting in the headwaters, combined with higher summer flows, increases the proportion of silt-clay in the suspended sediment load. From late June to mid-September 1982, the proportion of silt-clay fluctuated around 78 ±8.5% of the total suspended load. The TSS concentration during this period averaged 372 ±160 mg/l (Knott and Lipscomb 1983), while turbidities ranged from 74 to 730 NTU (R&M Consultants, Inc. 1982). By late September or early October, TSS concentrations and turbidities typically drop below 20 and during the winter months (December-March), TSS concentrations are usually <3 mg/l and turbidities <1NTU (Knott and Lipscomb 1985, R&M Consultants, Inc. 1981).

The physical processes of flow and TSS transport during the open water season and of temperature and ice during the winter exert powerful limitations on the ability of the middle river to support fish production. Temperature and ice processes probably limit production in most streams throughout Alaska (clearwater as well as glacially influenced) and are not exceptional or particularly destructive in the middle river. From the standpoint of density-independent regulation, the two most distinctive limiting factors in the Susitna River are: 1) the highly erratic flow regime; and 2) the relatively high suspended sediment load during the open water season.

In our opinion of the two, sediment load (or more accurately, turbidity) is the more important in terms of limiting fish production principally because it limits fish food production in all areas affected by mainstem flow. In other words, if the flow regime were regulated to optimize fish habitat conditions, but turbidity levels remained unchanged, fish production would be enhanced far less (if at all) than if turbidity were substantially reduced or eliminated under the existing flow regime.

Most of the biological studies conducted to date have been directed toward the goal of describing the relationship between fish habitat and mainstem flow in the middle river. This information can be used to define the with-project flow regime best suited to maintain or enhance existing fish habitat conditions in the middle river. This emphasis on flow and fish habitat stems not only from the important role flow plays in fish production, but also from the fact that the amount of flow released by the proposed project is negotiable. The quantity and particle size distribution of suspended sediment transported by the regulated flow, as well as the turbidity it will exert, are not negotiable; they are simply the inevitable consequences of damming a glacial river. Thus, from the standpoint of predicting the potential harmful or beneficial effects associated with reducing and redistributing the annual transport of suspended sediment throughout the middle river, the question of how turbidity exerts its influence on the basic biological productivity of a lotic system requires a quantitative answer. This quantitative response must be analyzed in the context of both prevailing natural conditions and the anticipated with-project TSS regime.

Based on 1984 field observations and preliminary data collected before breakup (1985), it is clear that the natural TSS regime just described exerts a strong influence on both the seasonal timing and the extent of primary and secondary production in the middle river. The large numbers of emerging aquatic insect (especially clinonomid and plecopteran) adults observed from mid March to mid-May 1985 throughout the middle river, indicate that substantial secondary production takes place during the winter months (Van Nieuwenhuyse 1985). This insect growth appears to have been based largely on the algae production which took place during the previous fall transition period (i.e., when turbidities fell to below 20 NTU). March-May is also the period when recently emerged chum fry feed in preparation for outmigration and that chinook juveniles display a significant growth spurt (ADF&G/Su-Hydro 1982, 1985a).

Most of the chum and 1+ chinook have migrated out of the middle river by mid summer. At this time, substantial numbers of 0+ chinook juveniles begin to migrate out of their natal tributary streams (most notably Indian River and Portage Creek) and redistribute themselves principally in turbid side channels. As autumn approaches, juvenile chinook densities in the tributaries decline and densities in sloughs increase (ADF&G/Su-Hydro 1982). During the summer, aquatic insect densities in turbid Susitna River habitats are two orders of magnitude lower than in clearwater habitats during spring (ADF&G/Su-Hydro 1985b; Van Nieuwenhuyse 1985). During the fall, when 0+ chinook are preparing to overwinter in slough and tributary mouth habitats, the mainstem and peripheral channels along the entire length of the middle river display a large pulse of primary production which is estimated to exceed the spring pulse by at least two orders of magnitude on a daily systemwide basis (Van Nieuwenhuyse 1985). The task of processing this large quantity of organic carbon (an educated guess would conservatively place the figure somewhere between 100,000-500,000 tons) falls primarily on the cold-adapted chironomid larvae. Thus, the fall appears to be the major period of insect food production, while much of the winter is characterized by food processing.

This basic pattern is not significantly different form the patterns displayed by many clearwater streams elsewhere in Alaska or in temperate latitude streams in general (Anderson 1984, Ball and Barn 1975, Lowe and Gale 1980, and Tett et al. 1978). What is distinctive about the middle river is that the bulk of the primary production it supports is restricted to a very brief period in autumn when turbidity levels fall below 20 NTU. The 20 NTU figure characterized the fall transition period of 1984 and does not necessarily represent the maximum turbidity level at which substantial primary production may take place in the middle river. If the period between glacial melt "shutdown" and river freezeup had been characterized instead by a higher turbidity level (e.g., 50 or even 100 NTU), it is conceivable that a substantial increase in primary production over summer levels would still have occurred. This is because the rate of primary production is largely a function of the amount of useful light energy available to the benthic algae community.

With reasonably accurate forecasts of with-project turbidity levels and a quantitative understanding of the relationship between algae production and light energy at depth, it will be possible to objectively predict the impacts associated with impoundment. With-project turbidity levels will be deduced on the basis of output from the DYRESM modeling effort currently under way. This task will require a model which will predict turbidity on the basis of forecasted suspended sediment concentrations generated by the DYRESM model.

METHODOLOGIES

Predicting Impacts. The previous discussion of baseline conditions provides a reasonably accurate description of natural patterns of suspended sediment transport and juvenile fish distribution in the middle river. Less accurate is our quantification of the relationships between TSS and turbidity and between turbidity and light extinction. We have essentially no hard data on primary and secondary production during spring and fall.

While we know that chironomid dipterans constitute the single most numerous food item in the diet of juvenile chum, chinook, and coho salmon (ADF&G/Su-Hydro 1982), we are only now collecting data on the density, distribution, and species composition of these and other aquatic insect communities during the spring when juvenile salmonid growth rates appear to be at their highest. Previous efforts have been limited to only part of the open water season (ADF&G/Su-Hydro 1982, 1985b). Likewise, baseline data collection on benthic algae biomass, species composition, and productivity began for the first time in March 1985 (Van Nieuwenhuyse 1985). This monitoring effort (Task 31) will continue until freezeup and should yield the information required to fill the most critical gaps in our knowledge of the basic biological processes currently supporting fish production in the middle river.

Considerable effort has been devoted to modelling the "weighted usable area (WUA) responses" of selected channels throughout the length of the middle river to mainstem discharge according to the Instream Flow Incremental Methodology. Rather than address fish production per se, this methodology provides a relative index of how much preferred habitat a given flow creates in a given channel for a given fish species and lifestage. The WUA response for a given channel is derived from empirical relationships between hydraulic and structural features of the channel and catch statistics. The means by which the information gleaned from these site-specific models will be applied to the entire middle river will be described in forthcoming reports by E. Woody Trihey and Associates.

The resulting integrated model will not, however, take into account the effects of mainstem flow and TSS concentration on lower trophic levels (i.e., the food base for fish production). The positive effect of increased algae productivity on fish production is well documented (LeCren 1972). To make objective predictions about how impoundment will effect middle river salmonid production will thus require the following additional information:

1. DYRESM model forecasts of weekly (or monthly) reservoir outflow TSS concentrations and particle size distributions;

2. a model relating suspended sediment concentration to turbidity;

3. baseline patterns of algae biomass, macroinvertebrate densities, and community composition during at least one annual cycle;

4. quantification of the relationship between light at depth and gross primary productivity in glacial systems; and

5. refined quantification of the relationship between turbidity and light extinction.

A field monitoring program (Task 31) designed by AEIDC to meet two of these information needs (3 and 4 above) has been underway since March 1985. Some preliminary data collected to date are reported in Van Nieuwenhuyse

(1985). Until now, the search for a reliable method to predict TSS concentration on the basis of turbidity (or vice versa) (2 above) has been hampered by a failure to consider the particle size distribution of the suspended sediment load. Since clay and silt-sized particles ($<62\mu$), impart a proportionally greater cloudiness to water than sand-sized or larger particles ($>62\mu$), a simple linear regression model relating turbidity and TSS concentration will not explain an acceptably high percentage of the variance between these two parameters (especially in a glacial system). By incorporating a second independent variable (e.g., the percentage of TSS $<62\mu$ in diameter) and by using a multiple regression model, a much greater degree of reliability is attained.

This approach was used to relate the TSS and particle size distribution data presented in Knott and Lipscomb (1983) with simultaneous turbidity measurements made by R&M Consultants (R&M Consultants 1982) for the Susitna River at Talkeetna, the Talkeetna River, the Chulitna River, and the Susitna River at Sunshine. The simple linear regression model yielded the following equation:

$$\log y = -1.2147 + 1.351 \log x_1 \quad (n=58;\ r^2=0.65) \qquad \text{Equation 1.}$$

where y = turbidity (NTU) and x_1 = TSS (mg/l).

Using the same data, the multiple regression method yielded the equation:

$$\log y = -1.226 + 0.9884 \log x_1 + 0.0161\, x_2 \quad (n=58;\ r^2=0.93) \qquad \text{Equation 2.}$$

where x_2 = proportion (%) of TSS concentration $<62\mu$ in diameter.

Incorporating the second parameter results in a 28% increase in the amount of variation explained. Perhaps by adding other parameters to represent smaller particle sizes, the amount of variation explained could be increased further, but the fit for Equation 2 is adequate to demonstrate the utility of the multiple regression approach.

A recent technical memorandum (Reub and Wilkinson 1985) provides preliminary site-specific models relating mainstem discharge and turbidity to euphotic area models in six middle river channels representing a broad spectrum of morphological and hydraulic characteristics. These models operate similarly to the IFG models and are also capable of describing the photic energy available for photosynthesis at any given depth in a channel given the mainstem discharge, turbidity, and incident light intensity. As more data on productivity at different underwater light levels become available from the Task 31 monitoring effort, these models will be refined to yield estimates of expected primary production rates under a given flow and TSS/turbidity regime. Thus, the regression equation derived for the relationship between the quantity of useful light energy received by the benthic algae community of a stream and the community's metabolism will be analogous to the "suitability criteria curves" used in IFG analyses. The principal difference will be that light at depth alone will very likely explain 60-90% of the variation in productivity, whereas suitability criteria curves developed for fish spawning or rearing are often fit by eye and display considerable variation about the expected mean value.

Until reasonably well circumscribed forecasts of with-project seasonal TSS outflow concentrations are available, current educated guesses regarding with-project downstream trophic status must be couched in terms of hypothetical ranges and must rely on the very limited amount of information presently available (e.g., Harza-Ebasco 1985, EWT&A and Woodward Clyde 1985).

Predictions regarding the trophic status of Watana and Devil Canyon Reservoirs were made by Peterson (1982) based on the Vollenweider phosphorus loading model. For a discussion of the methods used and their limitations, the reader is referred to this report.

Assessing Impacts. If the proposed project is licensed and built, impacts on downstream trophic status can be assessed by one or more of the following methods:

1. Monitoring community metabolism of the middle river through continuous measurements of dissolved oxygen (DO) concentration, and water temperature at a mainstem site in the lower portion of the middle river (i.e, just upstream of the confluence area at Talkeetna).

2. Monitoring community metabolism by tracking pH, alkalinity (or perhaps conductivity), and water temperature at the Gold Creek bridge.

3. Periodic sampling of the benthos in selected habitats to estimate algae and macroinvertebrate biomass and species composition.

Monitoring community metabolism rates could be accomplished with a minimum of labor using equipment already owned by the Alaska Power Authority. Given the lower amplitude of discharge fluctuations expected after impoundment, a suitable site for placing two dissolved oxygen/temperature probes could be found well below the reach of the middle river which will still bear oxygen-supersaturated water under with-project conditions. These data, combined with data from nearby weather stations and a program to monitor incident light, water quality (e.g., TSS, particle size distribution, turbidity, conductivity, pH, alkalinity, macronutrient concentrations, trace metal concentrations, etc.), salmonid smolt outmigration, and adult escapements, would provide a basis for comparing with-project conditions to baseline conditions. This program would be required until at least three brood years of chinook outmigrants had returned to spawn.

Theoretically, community metabolism rates could be monitored even in oxygen-supersaturated water using simultaneous measurements of pH, alkalinity, and water temperature, but this method has yet to be applied in Alaska and has been used far less frequently than the dissolved oxygen method elsewhere.

Periodic benthic sampling in habitats selected on the basis of use by rearing fish or some other set of criteria, would be far more labor-intensive and less reliable than the community metabolism approach if alone it had to serve as the basis for impact assessment. It would, however, provide a way to detect any substantial shifts in community structure or in the seasonal pattern of algae and macroinvertebrate production caused by impoundment and would complement the community metabolism approach very well.

The application of any one of these techniques, combined with long-term monitoring of smolt outmigration or some other index of fish production, would do much to further our understanding of lotic ecosystems.

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