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The Winter Hydrologic Regime of the Nechako River, British Columbia

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ABSTRACT

All historical winter hydrologic data for the Nechako River were compiled, and winter (November - April) has been the low flow period under both natural and regulated regimes. A sixty-six year record of air temperature data for Vanderhoof was used as an index of severity of winter, and found to correlate well with observed ice conditions. A simple water temperature model based on air temperature was used to predict cooling of river water to 0°C under different meteorological and hydrological conditions. The model indicates that the lower the discharge, then the faster the water temperature cools to 0°C. Anchor and frazil ice are generated in the zone of river at 0°C, prior to formation of a surface ice cover. Anchor ice can cause frost penetration into the substrate, diversion of flow, and can block the exchange of flow between a stream and the intragravel flow, possibly decreasing intragravel dissolved oxygen. A simple predictive model of the progression of surface ice, based on air temperature, was developed. In conjunction with the water temperature model, it indicated that the lower the flow, the earlier surface ice cover forms, the longer it persists, the deeper it penetrates and the further it extends upstream. Surface ice cover in a shallow river can: freeze to the bed allowing ice to penetrate into the substrate; divert flow away from shallow areas; decrease sub-ice water velocities and interchange with intragravel flow; and cause ice scour. Two years of water temperature and ice observations on the Nechako River were used to calibrate the models and document ice conditions in chinook spawning areas. The effects of winter hydrologic conditions on the intragravel environment and the risks to overwintering chinook eggs and alevins are assessed and risk is thought to increase with decreased flows.

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RÉSUMÉ

On a rassemblé toutes les données historiques sur le régime hydrologique de la rivière Nechako en hiver; on a ainsi observé le plus faible débit pendant cette saison (novembre-avril) en fonction d'un régime naturel ou régularisé. On a utilisé des données sur la température de l'air à Vanderhoof couvrant une période de 66 ans comme indice de la rigueur de l'hiver qui était en bonne corrélation avec les concentrations de glace observées. On s'est servi d'un simple modèle de la température de l'eau basé sur la température de l'air pour prédire le refroidissement de la rivière jusqu'à 0°C en fonction de diverses conditions météorologiques et hydrologiques. Le modèle révèle que plus le débit est faible, plus rapide est le refroidissement de l'eau jusqu'à 0°C. La glace de fond et la frasil se forment là où la température de l'eau se situe à 0°C et avant la formation de la surface gelée. La glace de fond peut être la cause de la pénétration du gel dans le substrat et du détournement du débit et peut bloquer l'échange aqueux entre les interstices du gravier et le cours principal, ce qui peut amener une baisse de la teneur en oxygène dissous dans les interstices du gravier. On a aussi mis au point un simple modèle de prédiction de la progression de la couverture de glace basé sur la température de l'air. De concert avec le modèle de la température de l'eau, ce dernier modèle a révélé que plus faible est le débit, plus tôt la couverture de glace se forme, plus longue est sa durée, plus profonde est sa pénétration et plus loin en amont son étendue. Dans une rivière peu profonde, la couverture de glace peut atteindre le lit et ainsi entraîner la pénétration de la glace dans le substrat, détourner le débit loin des zones peu profondes, réduire la vitesse du courant sous la glace et l'échange avec l'eau des interstices du gravier et entraîner l'érosion. On a utilisé des données sur la température de l'eau et les concentrations de glace recueillies pendant deux ans dans la rivière Nechako pour calibrer les modèles et mettre par écrit les concentrations de glace dans les frayères du saumon quinnat. On évalue l'incidence des conditions hydrologiques hivernales sur l'environnement constitué par les interstices du gravier et les risques pour les oeufs et les alevins hivernants du saumon quinnat; on croit que les risques augmentent en fonction d'une baisse du débit.

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D. Calkins acted as an external advisor to this study, and suggested many techniques for analysis, relevant references, participated in a winter on-site visit to the Nechako, and reviewed earlier drafts of the report.

1. INTRODUCTION

The Nechako River, a major tributary to the Fraser River, drains a catchment area of approximately 43,000 km^2 (Figure 1), including the 890 km^2 Nechako Reservoir. The Nechako Reservoir, impounded by Kenney Dam in 1952, is owned by Alcan Aluminium Ltd. (Alcan) and a variable 10 - 50% of the Nechako River flow has been diverted to the Kemano River system for power generation over the last 30 years. During the period 1980 - 1987, the Department and Alcan pursued various legal and technical routes to resolve the issue of the flows required to maintain fish stocks. The issue has since settled out of court (Alcan, Federal Crown and Provincial Crown; 1987) with prescribed short term and long term flows, and a staged program of remedial measures to maintain the salmon stocks.

The purpose of this report is to describe the winter regime of the Nechako River, summarizing historical winter data and reporting on observations made during recent years. Field data have been collected during the 1985 - 1986 and 1986 - 1987 winter field seasons. The impetus for this study was to gain an understanding of the physical processes, particularly ice formation, operating during the winter period. It was also intended to explore various predictive models of ice formation, and establish cause and effect links between physical processes and the biological resource. This description of the winter hydrology of the Nechako River provided the basis for an assessment of minimum flows necessary for overwinter survival of chinook eggs and alevins. Future study recommendations for continued monitoring of physical parameters, as well as suggested investigations of the linkages between physical and biological parameters are presented.

The data and analyses are presented in the chapters headed - winter hydrology, meteorology, water temperature, surface ice, anchor ice, water quality and recommendations.

Previous studies of winter habitat or conditions on the Nechako River have focused on overwinter survival of chinook eggs and alevins (Tutty, 1980; Envirocon, 1984; Johansen, 1985; Jaremovic and Johansen, 1986). Sample site selection for these studies was limited to the upper 10 km of the Nechako, which is usually ice free in winter and is therefore not representative of winter conditions on most of the river. Overwintering habitat for juvenile chinook and other species has not been studied explicitly on the Nechako. Studies of overwinter fish habitat are uncommon in ice-covered rivers (e.g. Swales et al., 1986; Emmett and McElderry, 1986; Reiser and White, 1981), primarily due to sampling difficulties. Very few studies attempt to integrate biological sampling with an understanding of the physical processes involved in winter hydrology (Walsh and Calkins, 1986).

2. WINTER HYDROLOGY

The Nechako River originates in the Nechako Reservoir located in the Coast Mountains, and flows north and then east to join the Fraser River at Prince George (Figure 1). Its total length, measured from the base of Cheslatta Falls below the reservoir to its confluence with the Fraser, is 277 km. Two major rivers are tributary to the Nechako, the Stuart River and the Nautley River, which drain Stuart Lake and Fraser Lake respectively.

The Water Survey of Canada, Environment Canada has collected streamflow data at a number of stations and for various periods of time on the Nechako and its tributaries over the past 70 years (Table 1). The two stations, Nechako River at Vanderhoof and Nechako River below Cheslatta Falls, will be used extensively in this report, to describe the winter flow regime of the Nechako River (Figure 2). To briefly describe pre-regulation (1952) conditions, a composite data set calculated by addition of two major pre-regulation Nechako tributaries will be referred to. Details on this calculated data set and discussion of the Nechako River flow regime during summer conditions are given by the Department of Fisheries and Oceans (1984).

Prior to regulation, the Nechako River fall and winter flows demonstrated a generally declining pattern, with the lowest flows of the year occurring in February and March (Table 2). The average of the mean monthly flows for the winter months of November to April was 102.7 m^3/s. There was a wide range of variability in winter flows, with some high flow events as late as December, and the lowest mean monthly value was 36.3 m^3/s. As part of the Settlement Agreement, the short term releases are similar to the injunction flows of the last 8 years, at an average of 31.1 m^3/s for the winter months. The long term settlement flows, which would not be implemented until after remedial measures are in place, would be 25.2 m^3/s in November dropping to 14.2 m^3/s from December to March.

Under the regulated flow regime since 1952, the average winter flow (based on November-April mean monthly flow) was 92.6 m^3/s, which is a slight reduction from natural conditions (Table 3). However, the 1952-1956 reservoir filling period which often involved no flow release into the Nechako River resulting in winter flows of 8 m^3/s or less, was not used to calculate the regulated flows given in Table 3. More significantly, the regulated flow regime increased the variability of mean monthly winter flows by approximately 60%. The minimum monthly flow recorded for the regulated (post-filling) period was 13.3 m^3/s, which is 36% less than the lowest recorded monthly mean for the natural regime of 36.6 m^3/s.

The regulated flow regime of the middle Nechako River can be described by the flow records for Vanderhoof at km 142 (Table 4). The lower Nechako River is gauged at km 217 (Isle Pierre), but as there is no known chinook incubation habitat below Vanderhoof, the regime of the lower Nechako will not be discussed in detail here. The middle and lower Nechako winter flows are augmented by the steady lake outflows from the Nautley and Stuart rivers and other tributaries. The average winter flow at Vanderhoof for the period 1956-1984 was 94.8 m^3/s, and the average Nautley River winter flow is 14.6 m^3/s. The wide range of variability in winter flows due to the reservoir release flow pattern is reflected in the Vanderhoof records, with monthly means of 9.5 m^3/s and 339 m^3/s bracketing the long term average.

Since 1980, flows in the upper Nechako under the injunction flow regime have been gauged at the Nechako River below Cheslatta Falls (Table 5). The mean monthly winter discharge has been 34.4 m^3/s, with a small ($\pm$10%) variation between maximum and minimum mean monthly values. The injunction flow regime represents an average 40% reduction from the natural flows, with a much reduced range of variability.

It should be noted that all data presented in Tables 2-5 are based on mean monthly values, and the daily flows will exhibit a wider range of variability than the monthly values. The implications of highly variable winter flows are that they can disrupt and destabilize an ice cover. Experience on other regulated rivers (Acres, 1980; Keenhan et al., 1982) with a significant ice cover such as the Peace River, has shown that stable winter flows help to maintain a solid ice cover. Stage fluctuations, particularly when the flow is significantly reduced below natural flows, risk exposure of the spawning areas or severely diminish the depth of water covering those areas. When flows are reduced to an extremely low level, it leaves very little margin for variability due to reservoir management requirements, extreme climatic events, unforeseen events, etc.

The changes in discharge under these various flow regimes can be discussed in terms of stage (or water level), which is the parameter of concern in determining overwintering fish habitat and can be presented in simple graphical format. Using the stage-discharge relationship, which defines a unique discharge for a given stage, the depth of water for various winter discharges can be calculated. Using the table for the Nechako River below Cheslatta Falls, stage values for the natural, regulated, injunction or short term settlement and long term settlement winter mean monthly flows have been calculated (Table 6). These data have also been plotted on a surveyed cross-section of the Nechako River at the gauging station (Figure 4), to demonstrate what the various discharges represent in terms of river depth. For comparative purposes, these stage data have been shown with the backwater effect on stage due to the presence of an ice cover ignored.

However, the backwater effect is a very significant physical phenomenon which radically alters the stage-discharge relationship under ice conditions. It is of particular importance in very shallow rivers or streams where the normal winter low flow period can result in very little depth of water remaining under the ice cover. The effect of ice on the open-water stage-discharge curve has been well documented (Rantz et al, 1982; Chin, 1966; Lavender, 1984; Rosenberg and Pentland, 1966), and results in the superimposition of a variably increased stage on the open water relationship (Figure 5). The backwater is caused by the formation of ice on the streambed (anchor ice), at the stream margins (shore ice) and/or in the water column (frazil ice). The ice physically occupies the channel thereby displacing the water, and also affects the stage by decreasing the hydraulic radius of the stream with a complete surface ice cover. The magnitude of a backwater is highly variable both spatially and temporally, and varies with type of ice as well as discharge.

On the Nechako River, the backwater effect has been documented for three sites: the Water Survey of Canada gauges at Nechako below Cheslatta Falls, Nechako at Vanderhoof, and at Diamond Island. For the Water Survey of Canada stations, the open water stage-discharge curves have been derived from the most recent stage-discharge tables (Peter Langford, Prince George; personal communication). The data points do not represent metered stage-discharge values, but rather they are points off the best-fit stage-discharge curve plotted by Water Survey of Canada. Superimposed on the open water stage - discharge curve are point stage readings under ice conditions. These values have been obtained from Water Survey of Canada meter notes or from the actual stage recorder charts (Figure 6). Interpretation of ice events are indicated on Figure 6, during a period of significant stage variation entirely due to ice. During this time period, Water Survey of Canada reported a steady discharge of 36-37 m^3/s, using the standard practice of estimating discharge during periods of ice effect. This procedure is relatively reliable on a regulated river such as the Nechako with stable flows and few tributaries.

The stage-discharge curves for Nechako below Cheslatta Falls are given in Figure 7, and the curves for Nechako at Vanderhoof are given in Figure 8. For the Nechako below Cheslatta station, the overwinter discharge under the injunction flow regime has been consistently between 30 and 37 m^3/s, resulting in a clustering of the data points on the ice rating curves (Figure 7). The clustering of data points also results in the ice rating curve being drawn parallel to the open water curve, due to lack of points to define the high and low ends of the curve. It is probable that the ice rating curve would converge with the open water curve at low stage - discharges. While there are insufficient data to accurately define the relationships, there appear to be two distinct populations of points. The more common, smaller magnitude backwater events can be attributed to the formation of frazil or anchor ice or the initiation of shore ice growth. These events are often transitory, occurring overnight in response to an overnight drop in air temperature. The range in stage rise from 0-50 cm above open water conditions, is due to variation in the amount or type of ice forming at or immediately downstream of the gauging station. The second cluster of points with a stage rise of 1.1 m is due to a full width surface ice cover progressing upstream of the gauging station. This infrequent event has apparently only occurred twice in the seven years of record. This site is located near the downstream end of the open water reach below Cheslatta Falls and the length of the reach fluctuates with weather conditions. As a result, the upper reach of the Nechako, approximately km 10 - km 35, experiences variable stage due to backwater, several ice events per winter and a fluctuating water temperature regime.

The rating curves for Nechako at Vanderhoof station (Figure 8) indicate a single ice condition curve, with an average stage rise of 60 cm. The range of points varies from 40 to 100 cm stage rise due to ice conditions, but is complicated by the fact that the cross-section (bed material) is more mobile at Vanderhoof than at Cheslatta, resulting in a revised rating curve at least once a year (personal communication, Peter Langford, Water Survey of Canada, Prince George). Some of the lower stage points may represent frazil and anchor ice conditions, and encroaching shore ice for the 1-2 week period prior to formation of a full channel width surface ice cover. Only a sample of data points from the 1980's period were used in Figure 8, and winter stage readings are not always recorded by Water Survey of Canada.

Water levels were recorded at Diamond Island (km 67) from November/86 to March/87 using a Montedoro-Whitney data logger. In addition to the pressure transducer probe used to measure stage, water temperature, intra-gravel temperature and dissolved oxygen probes were also attached to the data logger. The raw data are given in Appendix 1, and the stage data for the freeze-up period are plotted in Figure 9. The water levels are not tied to a known datum, but are accurate relative to a point near a chinook spawning dune. These data could eventually be linked to survey data of spawning dune positions and depths (Hamilton, 1987), and water level could be expressed as depth over spawning redds.

As indicated in Figure 9, water levels increased by approximately 50 cm during a 5 day (Nov. 11-15) and subsequent 7 day event (Nov. 19-25) of anchor and frazil ice formation. This interpretation of ice events from stage data is corroborated by the water temperature data, also given in Appendix 1 and on Figure 9. Following the data gap due to equipment malfunction (Nov. 28 - Dec. 10), the stage increased to 65 cm over open water conditions. This stage represents a full width surface ice cover, as was confirmed by a site visit on December 10. The stage declined gradually by 30 cm under the ice cover during December in response to slightly decreased reservoir outflows and gradual cessation of tributary inflows due to freezing. A solid ice cover was in place with a stable backwater stage of 45 cm until Feb. 21/87, when the ice cover was eroded by rising water temperatures. Stages dropped rapidly as the ice cover broke up and stages dropped to open water levels by February 24th. A brief period of frazil and/or anchor ice formation occurred between March 1 and 7, as indicated by stage rises of up to 40 cm above open water stage (Appendix 1).

3. Meteorology

In the absence of long term water temperature or ice data to characterize the severity of winter river conditions, the long term air temperature records at Vanderhoof have been used. Air temperature data are commonly available for a longer period of time and can be used as a quantitative index of the severity of winter and ice conditions (Michel and Berenger, 1972). The Vanderhoof station has the longest term record in the Nechako basin, and is located near the centre of the basin.

Atmospheric Environment Service of Environment Canada has maintained a meteorological station at Vanderhoof since 1916, continuously since 1952. Mean monthly temperatures for the period of record are given in Table 7. Using only those years with a complete record, 48 of the last 66 years, mean daily air temperatures at Vanderhoof were used to tabulate the seasonal total accumulated degree days below 0°C or freezing degree days (Table 8) (Atmospheric Environment Service, monthly).That is, starting on the first date in fall when mean daily temperatures drop below 0°C, the magnitude of the mean daily departure below zero is summed. The cumulation continues until spring when mean daily temperatures rise and remain above zero. The range of initiation dates for below freezing weather is September 22 to November 8th, with a mean date of October 10th. The end of freezing weather covers a similar range of time, from March 20 to May 6, with a mean date of April 9 (Table 8).

These seasonal totals give a quantitative index of the overall severity of winter and will be demonstrated in a later section to correlate well with the presence and duration of river ice. There have been several changes in station location within the local Vanderhoof area over the period of record, but the temperature differences between locations is thought to be less than 1°C on average (N. Green, personal communication, Atmospheric Environment Service observer, Vanderhoof).

The differences between the Vanderhoof area and the upper Nechako basin can be demonstrated by comparing the Vanderhoof data set with that collected at Irvine's for the common period 1983 - 1986. Air temperatures have been manually recorded as daily maximum and minimum values in a standard Stevenson screen near river level at Irvine's continuously since October 1984, with several other seasonal values for the period 1980-1984 (Table 9). Comparison of the mean monthly temperatures at Irvine's and Vanderhoof indicates that Irvine's is always colder than Vanderhoof, by a range of 0.5 to 3.7°C (Table 10). Based on 34 values, an average 2.0°C difference between the two stations can be demonstrated. The magnitude of difference is confirmed by correlation analysis, with an r value of 0.99 (B. James, Envirocon Pacific Ltd, personal communication). Therefore, the upper Nechako River valley is consistently cooler than the Vanderhoof area, and for modelling ice and water temperatures on the upper Nechako, a -2°C correction factor to the Vanderhoof air temperature records can be applied.

The total accumulated degree days below 0°C data from Table 8 were ranked and plotted as a probability of exceeding a given value (Table 11; Figure 10). Such frequency analyses are more commonly expressed in terms of return period, with the cumulation of 1700 degree days below 0°C having a 1 in 10 return period. The rankings indicate the severity of individual winters, with the last six years in relation to the long term record of particular interest. For instance, the winter of 1980-81, when Envirocon (1984) carried out their overwintering studies, was the mildest year in 48 years of record. The winters of Department of Fisheries and Oceans overwintering studies (1983-84, 1984-85) were ranked 43rd and 29th severest respectively, while the observations of frozen redds made by Tutty (1980) were made during the 17th severest winter.

4. Water Temperature

Water temperatures on regulated rivers can be quite drastically altered from the natural regime (Burt and Mundie, 1986; AEIDC, 1983) but the effects of reduced winter flows on reservoir outlet temperatures have rarely been studied. Under reduced winter flows, reservoir outlet temperatures of 3 - 4°C will usually cool to zero at some distance downstream, as a function of prevailing meteorological conditions and river hydraulics. This distance will vary throughout the winter, as meteorological and hydrological variables are transient (Ashton, 1986).

The natural pre-Kemano I Nechako River was lake fed, and with the much higher winter discharges, an open water reach probably persisted for most of the upper Nechako River (Figure 2). There are no year round water temperature data for the natural Nechako River, but water temperatures have been recorded at Irvine's (km 10) since 1980, and the mean monthly temperatures for the period of record are summarized in Table 12 (unpublished data, Fisheries and Oceans).

The mean daily temperatures for the months September to April are given in Tables 13 to 20. During the winter period, all those days when Water Survey of Canada indicated an ice condition at the gauge were assumed to have a water temperature of zero. This assumption was used to calibrate the temperatures near 0°C, and other daily values within that month were corrected appropriately. This is a conservative assumption, as water temperature may cool to zero for some time prior to substantial ice formation,due to antecedent ice conditions, air temperatures, water velocity, etc. (D. Calkins, personal communication). Based on the data from Irvine's (Table 12), the upper Nechako River had relatively warm mean monthly water temperatures of 13.6°C in September, 9.3°C in October and 3.8°C in November. These values are warmer than would be expected for this geographic location, and are attributable to the influence of the Nechako Reservoir. The low interannual variability (less than 10%) is similarly due to the large stable source of relatively warm water in the reservoir. The mean monthly temperatures decline steadily from 3.8°C in November to the minimum of 0.3°C in February. The interannual variability increases markedly to over 100% during the mid-winter period, due to the decreased flow volume and the greater effect of major changes in air temperature. The water temperatures on the upper Nechako River can drop to zero during extreme cold snaps, and ice of some type formed at Irvine's every year for some relatively short duration in the period 1980-86. It should be noted that the gauge site at Irvine's is located in the variable open water reach below Cheslatta Falls, which is not representative of winter temperature or ice conditions on the middle and lower Nechako. Water temperatures increase to above freezing by early March, with a March mean monthly temperature of 1.7°C.

While there are no continuous winter temperature records for the middle or lower reaches of the Nechako River, spot water temperatures were routinely collected by Water Survey of Canada (1977) at the Nechako River at Vanderhoof gauge. In conjunction with the record of ice cover at the gauge, where it can be assumed that the water temperature is zero, the lower Nechako cools faster and earlier, and is clearly colder than the upper river during the winter months. The mean monthly temperatures for November to March at Vanderhoof are 2.4°C, 0.2°C, 0.2°C, 0.2°C, 0.2°C respectively, based on a range of 8 to 20 spot measurements (Water Survey of Canada, 1977). As these data are reported to an accuracy of 0.5°C, and an ice cover persists at this site on average from late November to early April, the December to March temperatures should probably be corrected to zero.

In 1986 - 1987, water temperatures were monitored using a Montedoro-Whitney data logger at Diamond Island (km 67) for the period November 7, 1986 to March 24, 1987. The raw data are given in Appendix 1, and a plot of mean daily temperatures for the period of record is given as Figure 11. Temperatures at Diamond Island dropped rapidly from the 0.6°C peak recorded on November 8, 1986 to 0°C or slightly supercooled by November 9. (Note that the thermistor probes are only considered accurate to 0.1°C and not designed for accuracy at the freezing point. Any negative temperatures should be interpreted as 0°C or only transient supercooling conditions, as frazil ice formation raises temperatures to 0°C). Two periods of 0°C water temperature ensued (Nov. 11-15 and Nov. 19-25) with frazil and anchor ice occurring during these periods, as indicated by the simultaneous stage rises (Figure 9). The intervening periods (Nov. 15-19 and Nov. 25-28) saw daytime temperatures as high as 2.3 °C. Temperatures remained at zero beneath a stable ice cover until February 21st, when a brief warming spell (Feb. 21-27) brought daytime highs to 0.7°C. Zero temperatures with frazil/anchor ice formation persisted from March 1-7th, following by a steady rise in water temperatures to daytime highs of over 4°C by March 24 when the data logger was removed.

Water temperatures at Irvine's are continuously recorded with both a mechanical thermograph and a water temperature probe attached to the Water Survey of Canada DCP (Data Collection Platform) equipment. Raw thermograph data for Irvine's is given in Tables 19 and 20, and a summary comparison of mean monthly temperatures is given in Table 12. Water temperatures in the winter of 1986/87 were unusually mild by comparison to the previous 6 years (Table 12). All months from November to April reported mean monthly temperatures above the long term mean. Only two brief periods of 0°C temperatures were recorded in early January and early March, with all other months above 0.8°C.

To calculate water temperatures at other locations along the Nechako, as well as for different discharges, the following procedure was suggested (D. Calkins, personal communication). A simple temperature model (Ashton, 1979) allows water temperatures to be predicted for points upstream and downstream of a site where water temperatures are recorded. It also allows the point where water temperatures cool to 0°C (the 0°C isotherm, where an isotherm is defined as a line of equal temperature) to be calculated. The 0°C isotherm indicates the location where ice of some form starts to be generated, and will be used further in the sections describing ice formation. It should be noted that for short periods of time reaches of the river up to approximately 10 km long may be cooled to 0°C, without a surface ice cover. A more sophisticated energy budget model of heat loss (Ashton, 1986) was not considered possible without radiation and wind data from the immediate study area. An energy based water temperature model was used (Envirocon, 1984) to predict freezing water temperatures on the upper Nechako River using Prince George meteorological data. However, no calibration or verification of the model was presented and there appear to be numerous computational or modelling inconsistencies in the results (Calkins, 1987).

To describe the water temperature model used in this study, the water temperature decay function for open water, is defined by Ashton (1979):

$$\frac{Tw - Ta}{Tw,0 - Ta} = \exp\left[\frac{-h_{wa}\,(x - x_0)}{\rho\, C_p\, \overline{VD}}\right] \quad (1)$$

where:
- Ta = air temperature (°C)
- $Tw,0$ = upstream water temperature (°C)
- Tw = water temperature (°C)
- $x-x_0$ = distance between water temperature locations (m)
- V = velocity (m/s)
- D = flow depth (m)
- Cp = heat capacity (J/kg /°C)
- ρ = density of water (kg/m^3)
- h_{wa} = heat transfer coefficient for air/water (W/m^2/°C)

Based on field data from December 10 and 11, 1986 (Table 21 and Figure 12), a value for hw, the heat transfer coefficient for water, for the Nechako River was calculated, using several different reaches of river.

Using the reach Irvine's (km 10) to Big Valley (km 17), and the following values:

$x - x_0$ = 7000 m
T_w = 0.8
$T_{w,0}$ = 1.4
$\overline{VD}$ = 3.93 ft^2/s, based on IPSFC (1979) data (x0.0929 to convert to m^2/s)
ρ = 1000
C_p = 4215

and rewriting equation (1) to solve for hw gives:

$$hw = \frac{-\rho \, C_p \, \overline{VD}}{x - x_0} \, \ln \left[\frac{T_w - T_a}{T_{w,0} - T_a} \right] \quad (2)$$

$$hw = 13.06$$

Using the reach Cheslatta to Big Valley and equation (2) to solve for hw gives a value of hw = 17.41. These values fall within the range of 15-20 $W/m^2/°C$, typical winter values of hwa reported for other rivers (Calkins, 1982; 1984).

A value of 15 $W/m^2/°C$ for the heat transfer coefficient was used to calculate the water temperature decay rate below Cheslatta Falls for several different winters. The procedure for calculating the water temperature decay rate is to rewrite equation (1), to solve for Tw and $T_{w,0}$:

$$T_w = T_a + (T_{w,0} - T_a) \exp \left[\frac{-hw\,(x-x_o)}{\rho C_p \, \overline{VD}} \right] \quad (3)$$

and

$$T_{w,0} = T_a + (T_w - T_a) \, / \, \exp \left[\frac{-hw\,(x-x_o)}{\rho C_p \, \overline{VD}} \right] \quad (4)$$

where: C_p = 4215 J/kg/°C
hw = 15 $W/m^2/°C$
ρ = 1000 kg/m^3
$\overline{VD}$ = 4.26 ft^2/s for 1000 ft^3/s, and 2.92 ft^2/s for 500 ft^3/s, respectively (IPSFC, 1979).

The mean monthly water temperatures at Irvine's (T_{w10}) and the long-term meteorological record for Vanderhoof (Ta) with the -2.0°C correction factor for the upper Nechako basin were used to calculate various water temperature decay rates. Using equation (4), the upstream water temperature at Cheslatta Falls (Tw,0) was back-calculated for a discharge of 1000 ft^3/s. This starting temperature was then used to calculate water temperatures at 8, 12, 20, 35, 70 and 100 km downstream from Cheslatta Falls. The same data set was used to calculate what the water temperatures at the various points would have been at a discharge of 500 ft^3/s. Figure 13 was derived from the exponential decay function to facilitate extrapolation between discharges.

The calculations were performed for:

(1) The long-term average air temperatures at Vanderhoof minus the 2°C correction factor for the upper Nechako River area, and the six year average of water temperatures recorded at Irvine's (Table 22).

(2) 1980-81, as this year represents the warmest winter water temperatures for the 6 years of record, as well as the mildest winter in 48 years based on the Vanderhoof meteorological data (Table 23).

(3) 1984-85, represents a near average (rank 29th of 48 years of record) year based on air temperatures (Table 24).

(4) A composite extremely cold year, based on 1984-85 water temperatures, and the 1978-79 air temperature data which was ranked as the 2nd coldest year in 48 years of record at Vanderhoof (Table 25).

These data indicate that in general, the river temperature cools more rapidly at the lower discharge of 500 ft^3/s than at 1000 ft^3/s. The zero degree isotherm will advance further upstream, as indicated by Tables 22-25. Under long-term average conditions (Table 22) at 1000 ft^3/s, the 0°C isotherm moves upstream to a position between km 12 and 20 by mid-December, and is stable within that zone until late February. At 500 ft^3/s, the 0°C isotherm moves further upstream, to between km 8 and 12, by late December. This implies that the river approximately between km 10 and 20 will be cooled to 0°C at 500 ft^3/s, and therefore exposed to the risks of either surface or anchor ice formation (see sections on ice regime for further discussion). In an extremely mild year, such as 1980-81 (Table 23), the 0°C isotherm is positioned between km 35 and 70 at 1000 ft^3/s, whereas it progresses further upstream to between km 20 and 35 at 500 ft^3/s. Again, this exposes an additional 20 km of river to the risks associated with ice conditions at lower flows. In an average year such as 1984-85 (Table 24) the 0°C isotherm is located between km 12 and 20 at 1000 ft^3/s, whereas it progresses upstream to between km 8 and 12 at 500 ft^3/s. Under extremely cold conditions (Table 25), the 0°C isotherm progresses upstream of km 12 at 1000 ft^3/s, whereas at 500 ft^3/s, it progresses above 8 km from mid-December to mid-January. This circumstance would expose all of the key chinook spawning areas to the risks associated with ice conditions. The differences in the location of the zero degree isotherm at 500 and 1000 ft^3/s under the three sets of temperature conditions for a selected date are given in Figures 14, 15 and 16. These figures indicate the additional length and position of river sections cooled to 0°C at lower flows. The implications of these temperature changes in terms of ice conditions are described in subsequent sections.

Using the predicted water temperatures at km 12 and km 35 as a rough indication of the cumulative difference in water temperature at different discharges, the bimonthly average temperatures were multiplied by 120 days for the period November 15-March 1 (Table 26). These estimates indicate a 40-50% reduction in the accumulated heat units at the lower discharge of 500 ft^3/s. The difference between flows is less (20%) in a mild winter, and much greater in a very cold winter (75%). While these data cover too short a time period to accurately calculate accumulated thermal units (ATU), some indications of the implications for incubating eggs can be given. Water temperatures were modelled for proposed September flows of 56.6 m^3/s and 24.8 m^3/s, and no significant difference between the two flows was noted. These results can be explained by the closeness of the average September mean monthly air (9.5°C - Vanderhoof) and water (13.6°C - Irvine's) temperatures, as September is the month where mean air temperatures start to drop below mean water temperatures. The closeness of the two temperature records implies that a change in discharge will not result in a large change in water temperature. For October, the mean monthly water temperature (9.4°C at Irvine's) is already more than double the mean monthly air temperature (4.3°C at Vanderhoof), and water temperatures display a steady decline throughout the month. By extrapolation of the heat transfer coefficient calculated for November to March (15 $W/m^2/°C$), some water temperatures under long term average conditions have been estimated (Table 23). They indicate a lower October mean monthly temperature by approximately 0.7°C for 500 ft^3/s when compared to 1000 ft^3/s. The water temperature decay calculations described above could also be used to estimate daily or monthly water temperatures at 1000 and 500 ft^3/s for any site.

Accumulated thermal degree days (ATU) using surface water temperatures at Irvine's have been calculated for 1985-86 (Table 27) and could be calculated for other years 1980-85. ATU's at Irvine's from 1983-84 (Table 28) and 1984-85 (Table 29) were calculated using shallow intragravel probes (Johansen, 1985; Jaremovic, 1986). Where common data exist (1983-84, 84-85) ATU's using surface water temperatures and intragravel temperatures should be compared.

Interpretation of the results of the water temperature model must be qualified by the simplicity of the model, and the number of assumptions made in the computations. In particular, the calculation of the heat transfer coefficient using air temperature data alone in the absence of the other meteorological data required for a more accurate calculation of heat loss, may introduce some error. Simulation of the position of the zero degree isotherm will be more accurate when comparing relative differences (between two different flow regimes) than absolute position. Calculation of the position of the zero degree isotherm is particularly sensitive to the value of the heat transfer coefficient (hwa), and the simple decay function does not simulate isothermal or increasing water temperatures with distance downstream.

5. Anchor Ice Formation

When a fast flowing river such as the Nechako super-cools to temperatures slightly below zero (-0.01 to -0.03°C), very small ice crystals known as frazil ice are formed in suspension (Osterkamp, 1981). A river surface velocity of 0.6 m/s is sufficient to prevent the spontaneous formation of a surface ice cover and allow frazil ice to be generated (Tsang, 1982). Frazil ice is distributed throughout the water column by turbulence, and it adheres during its growth phase to the substrate when it comes in contact with the streambed, forming anchor ice. Anchor ice is thus formed in open turbulent water, and it can coalesce and increase in thickness to completely cover a streambed (Tsang, 1982). Anchor ice will form preferentially on coarser substrate, and on any elevated bed features (Figure 17). It can occupy the entire space between a bed feature and the underside of a surface ice cover (Michel, 1971). Anchor ice can build up in thickness to block and divert streamflow (Maciolek and Needham, 1952), and the ice can emerge at the water surface (Gilfilian et al., 1972). This allows frost to penetrate through the anchor ice, freezing it solid and then penetrating into the substrate (Reiser and Wesche, 1979; Walsh and Calkins, 1986). Surface streamflow is probably unable to penetrate through anchor ice (Calkins, 1987), effectively cutting off exchange of streamflow and intragravel flow, and possibly affecting the levels of intragravel dissolved oxygen. While no measurements of velocity under anchor ice have been reported, Beltaos and Dean (1981) have measured very low velocities (approximately 0.5 cm/s) through floating frazil ice. The relationship between surface and intragravel velocities is very complex (McNeil, 1962; Vaux, 1962) and a change in the water surface profile caused by anchor ice may be sufficient to disrupt intragravel flow. In constrast to the detailed predictive models developed for surface ice formation (see Chapter 6), the prediction of anchor ice formation, persistence and growth is at an elementary stage (Marcotte and Robert, 1986).

Therefore, the physical risks to chinook eggs and alevins associated with anchor ice are:

(1) blockage and diversion of streamflow away from portions of the streambed;

(2) build up and emergence at the water surface forming a solid ice mass and allowing frost penetration into the substrate;

(3) decrease or cessation of the exchange between streamflow and intragravel flow;

(4) possible decrease in the delivery of dissolved oxygen into the substrate.

Anchor ice has been observed in the Nechako River on several occasions, including November 1985 (Blachut, 1986a) and December 1986 (Blachut, 1987b). It has been observed blanketing the steambed for several kilometers, preferentially deposited on chinook spawning dunes, emergent at the water surface, and attached to the underside of the surface ice cover (Figures 18 & 19). This combined ice cover of surface ice and frazil and/or anchor ice underneath presents a greater risk, in that the whole mass could freeze solid and allow ice penetration into the substrate. These observations were made at discharges of 30-35 m^3/s (1060-1235 ft^3/s) indicating that risks associated with anchor ice can occur at the short term settlement flows. As anchor ice formation is not strongly depth dependent, it would have formed at the lower long term settlement flow assuming the same water temperature regime.

Interpretation of additional anchor ice events can be made from stage and/or water temperature records for the Nechako River. As described in Chapter 2 on the backwater effect of ice and in the literature (Rantz et al, 1982), characteristic frazil/ anchor ice events can be found on the Water Survey of Canada stage recorder charts for Nechako below Cheslatta Falls (Figure 6). These events can be as short as six hours duration overnight, with daytime water temperatures rising again to above 0°C allowing the anchor ice to release and melt. Longer events of up to seven days duration will be due to a combination of frazil and anchor ice formation concurrent with lateral shore ice growth. Two periods of this type of ice growth were documented by the datalogger at Diamond Island between November 11-15 and November 19-25, 1986 (Figure 9). A frazil/anchor ice event was also documented after the surface ice cover had gone out, between March 1 and 7th, 1987.

The major difference between the two flows (1100 and 500 ft^3/s) with respect to anchor ice, is the location of the zero degree isotherm. The zone of 0°C water is calculated to be longer and shifted further upstream at lower flows (Table 22). This would expose a greater area of streambed to anchor ice formation and its associated risks under the lower flow regime. A specific example based on the water temperature and surface ice models is given in Figure 14, which indicates 7 additional km of surface ice cover, and an additional 4 km of 0°C water in an area of concentrated chinook spawning (Jaremovic and Rowland, 1987). The variability of the location of the zero degree isotherm and the surface cover results in several periods per winter, depending on weather conditions, when anchor ice may form. An increase in the number of times that the zero degree isotherm passes a given point will result in potentially more periods of anchor ice formation.

6. Surface Ice Regime

Under natural flow conditions, a river in a cold climate will carry an implicit risk of ice effects, particularly when low flows coincide with extremely cold air temperatures (Killick and Weir, 1950). The effects of regulation on the surface ice regime of a river have often been very damaging and unpredictable and have therefore been documented extensively (e.g., Acres, 1980; Asvall, 1972; Keenhan et al, 1982). However, most hydroelectric projects other than diversions such as Kemano I, usually result in higher winter stages and flows, thicker ice cover downstream and ice jam flooding (Paschke and Coleman, 1986). A river such as the Nechako, with flows diverted out of the channel to another system, will have those ice conditions associated with a much lower winter discharge. In general, the lower the discharge, then the faster the water temperature cools and the earlier the ice cover forms. An ice cover which forms earlier will progress further upstream and its longer duration will allow a thicker ice cover to grow. This ice cover then persists over a shallow depth of water in the existing channel bed.

The data on the surface ice regime of the Nechako River which are available include: Water Survey of Canada data on ice occurrence and ice thickness for the two gauging stations at Irvine's and Vanderhoof, aerial photography from January 1975, satellite imagery for various dates between 1972 and 1985, and observations by Fisheries and Oceans employees between 1977 and 1986. Despite the lack of systematic data collection on ice conditions, it is possible to predict the location of the upstream ice front (leading edge), ice thickness and duration of ice cover at various locations. Extensive use is made of the water temperature record at Irvine's (Tables 12-20) and the long term air temperature record at Vanderhoof (Tables 7-11) in these calculations.

The Nechako River is typical of other similar sized rivers in central British Columbia, with an ice cover for approximately 5 months each year. However, the presence of several large lakes, Fraser and Stuart Lakes, and the Nechako Reservoir influences the winter water temperature regime and hence the ice regime of the Nechako River. In addition, the geomorphology of the river channel is a factor in considering the winter ice regime, in that cross-sectional shape influences water depth and extent of ice contact with the bed.

The middle and lower reaches of the Nechako River have a solid ice cover for an average 5 months a year, as documented at Vanderhoof. A long term record of the duration of ice cover can be demonstrated by the Water Survey of Canada observations of an ice condition at the Nechako River at Vanderhoof gauging station (Table 30). Ice conditions noted by the Water Survey of Canada are those where stage is significantly affected by the presence of ice of any type, as demonstrated in Section 2. The start of ice conditions will consist of frazil and anchor ice formation, and shore ice growth for a variable period of time (approximately one to two weeks, depending on weather) before a solid ice cover is formed. The formation and behavior of frazil and anchor ice have been briefly described in Chapter 5. The end of ice conditions affecting the stage-discharge relationship will occur when the river is clear of ice, usually a few days after the solid ice cover has broken up. Under the regulated flow regime, with no rapidly rising discharges in April, break-up is usually a slower, later thermal melt-out event rather than a mechanical break-up with associated ice jams and flooding.

The freeze-up dates for the Nechako River at Vanderhoof range quite widely, from October 27 to January 1, with a mean freeze-up date for 31 years of record of November 27 (Table 30). The discharge was plotted against the cumulative freezing degree days between the start of sub-zero mean daily air temperatures and the freeze-up date (Figure 20), to test the relationship between discharge and date of freeze-up. The wide scatter of points indicates that other variables in addition to discharge are significant in determining the date of freeze-up. However, there is a general relationship of later freeze-up with higher discharge.

The ice cover progresses upstream of Vanderhoof, as the zero degree isotherm moves upstream and the solid ice cover on the Nechako River probably reaches as far upstream as km 40, for at least 3 months every winter. This can be demonstrated by the predicted water temperatures which indicates that the zero degree isotherm progresses upstream of km 35 under long term average conditions (Table 22), and even under extremely mild conditions such as 1980-81 (Table 23) reaches close to km 35. The zone above km 35 is close enough to the warmer reservoir outlet flow that the upper river does not have a continuous surface ice cover for the entire winter. Rather, it is subjected to frequent fluctuations in water temperature and ice conditions in response to the fluctuating meteorological conditions. Ice conditions at the Water Survey of Canada gauge, Nechako River below Cheslatta Falls, located at km 10 gives a good indication of the incidence and duration of ice formation on the upper Nechako (Table 31). An interpretation of the presence, stage and shape of the backwater effect (see Chapter 2), and the air temperatures during the ice effect period indicate nine periods of anchor/frazil/shore ice growth and three progressions of the solid ice cover upstream of km 10. These three events, lasting for a minimum of 13 days, occurred during extremely cold air temperatures, when the total accumulated degree days for the winter season was at least 1000 degree days. Despite the short 6 year record at this station and the relatively mild winters during that period, the data indicate that under the present regime, an ice cover reaches as far upstream as km 10 once per winter in one of every two years.

The ice conditions along the large sections of the river at a given point in time are best documented by aerial observation. Three such flights were made (January 28, 1986; December 10, 1986 and March 26, 1987), with handheld photographs, a video film and 1:50,000 maps documenting the observations. The maps are attached in Appendix II and the video is available for viewing at the Nechako Project Office, Department of Fisheries and Oceans, Vancouver.

These observations document the spatial extent of ice cover, presence of open reaches, precise location of the leading edge, ice cover on side channels, tributary streams etc. The aerial flights indicate that numerous open water reaches persist downstream of the leading edge of surface ice cover. They are usually located in high velocity areas such as canyons and riffles, below tributary confluences and at possible ground water discharge sites. The December maps (Appendix 4, Figures 29-32) indicate that the Nechako River ice cover is initiated simultaneously at numerous locations, such as above a riffle or confined channel section or above a major tributary confluence. The typical pattern of a larger river such as the Peace or Mackenzie, is the systematic upstream progression of an ice cover, primarily as a function of meteorological parameters. The Nechako pattern of multiple ice bridging points and simultaneous ice cover initiation is more typical of smaller rivers (Michel, 1971), and has implications for modelling of ice cover formation.

To predict changes in the timing and extent of surface ice cover at different discharges the following procedure was suggested (Cunningham and Calkins, 1984). More complex ice progression models are available in the literature (e.g., Calkins, 1984; Paschke and Coleman, 1986), but they require considerably more hydraulic, meteorological and ice data than exist for the Nechako. Based on the limited observations of leading edge position for the Nechako (Table 32), a relationship between leading edge location and accumulated degree days to the date of observation was found (Figure 21). This allowed a simple equation to be written, using cumulative air temperature to predict leading edge (L.E.) position. The problem of multiple ice initiation points is ignored, and a continuous ice cover downstream of the leading edge is assumed. The equation is simply:

$$LE = a\,(\sum {}^{\circ}C\ \text{Days})^{b} \qquad (5)$$

with the values of the a and b coefficients derived from Nechako data as given in Figure 21.

Therefore for Nechako,

$$LE = 10\ (\textstyle\sum °C\ days)^{.364} \qquad (6)$$

using cumulative degree days of at least 100 to allow for cover initiation. To calibrate this simple model, the freezeup and leading edge progression data for 1985-86 were used (Table 33 and Figure 22). In Figure 22, the calculated water temperature decay rate is indicated by the open circles and the calculated leading edge progression values are indicated with closed circles. The movement of the zero degree isotherm downstream of km 40 at the start of January is due to a period of warmer weather, which increased water temperatures and melted the ice cover for approximately 10 km. This type of fluctuation of the leading edge cannot be modelled with the simple predictive equation given in equation (6). However, with the adjustment for the warm period in early January, the predicted leading edge position values fit reasonably well with field observations. Additional data sets to calibrate and verify the model are necessary to further test it's validity.

Therefore, progression of the leading edge was simulated using equation (6) for the near average (1984-85), extremely mild (1980-81) and composite extremely cold (1984-85 water temperatures; 1978-79 air temperatures) winters used in the water temperature calculations (Tables 34, 35 and 36). The procedure followed is to obtain bimonthly cumulative freezing degree days for individual years from Atmospheric Environment Service, calculate a leading edge position above Vanderhoof for a discharge of 1000 ft^3/s, subtract from 142 to obtain distance in km below Cheslatta Falls. The position of the zero degree isotherm for 1000 and 500 ft^3/s is obtained from Figure 13. In the absence of any data on rates of leading edge advancement at discharges of approximately 500 ft^3/s, it is assumed that the rate of advancement will be a function of the distance between the zero degree isotherm for 1000 and 500 ft^3/s. Therefore, the leading edge position for 500 ft^3/s is obtained by subtracting the difference in zero degree isotherm location. The simulated edge positions for 1000 and 500 ft^3/s are given in Table 37.

As an indication of the frequency of fluctuations of the zero degree isotherm, Envirocon (1984) calculated the number of times the "ice front" would pass Cutoff Creek (km 14). To check this number, equation (1) was rewritten to solve for the air temperature (Ta), to find when the 0°C isotherm would reach Cutoff Creek. The value of Ta = - 11°C was used, for a discharge of 1000 ft^3/s and an initial water temperature (Tw,0) of 1.5°C, and the years 1973-74, 1978-79 were searched for the number of days with air temperatures < - 11°C. On average, Envirocon's model appears to be underestimating the number of freezing degree days at Cutoff Creek by 20 - 25%.

For Irvine's, solving for Ta to obtain Tw = 0°C at km 10, an air temperature of -15°C is required. Checking the meteorological records, a total of 21 passes of the 0°C isotherm occurred in 1973-74, while 43 passes are predicted to have occurred in the extremely cold year of 1978-79. Envirocon (1984) predicted 6 and 12 passes of the zero degree isotherm for the years 1973-74 and 1978-79 respectively. These differences in model results indicate that fluctuation of the zero degree isotherm is a complex process and that further data collection and model development is required.

The physical risks to overwintering eggs and alevins associated with surface ice cover are:

(1) contact of the surface ice cover with the streambed and penetration of the freezing front into the substrate (Walsh and Calkins, 1986) (Figure 23)
(2) contact of the surface ice cover with the bed, in the shore zones, secondary channels, and over spawning dunes, so as to cause flow to be diverted away from these areas
(3) insufficient moving water beneath the surface ice cover to permit good intragravel flow, decreased velocities under a surface ice cover (Calkins, 1982; Lau, 1982)
(4) decreased levels of dissolved oxygen beneath a surface ice cover (Whitfield and McNaughton, 1986; Shallock and Lotspeich, 1974; Schreier et al, 1980)
(5) ice scour of the streambed during ice movement, resulting in disturbance of buried eggs and alevins.

While all five of the potential risks of a surface ice cover listed above are probably pertinent to the Nechako River, no field data for Nechako are available on risk 4. However, direct observation of the other risks of a surface ice cover on the Nechako River have been documented by the Department. As early as 1953 (weekly report, Fisheries Officer, J.P. Tuyttens, Week of February 7, 1953), anchor ice formation around upper Nechako River chinook redds and greater than 1 m of frost penetration into the redds was documented. Another investigation was carried out by Tutty (1980) at a winter discharge of approximately 14 m^3/s (500 ft^3/s). Tutty found that redds dewatered in December were subsequently inundated by the backwater effect, covered by anchor ice and a surface ice cover in January. The substrate of the redd was found to be frozen to a depth of 20 cm, and estimated to be frozen to a depth of 30 cm (Tutty, 1980). At a second site a 20 cm surface ice cover had 20 cm of frazil or anchor ice attached underneath and in contact with the crest of a chinook redd. The gravel under this ice cover was found to be unfrozen, but with sufficient cold temperatures, the freezing front will penetrate through the ice and into the substrate (Walsh and Calkins, 1986).

Johansen (1985) and Jaremovic (1986) conducted studies at Irvine's (km 10) at flows of approximately 1200 ft^3/s (34 m^3/s) which monitored overwinter survival of chinook eggs and measured intragravel temperatures at several depths. Their results document the penetration of frost 20-30 cm into an artifically constructed redd which had been exposed at freezeup, resulting in 100% mortality of chinook eggs (Figure 24). These redds were artificially constructed to be exposed at freezeup; they were subsequently inundated by a small backwater effect, covered by an estimated 13 cm of surface ice, resulting in penetration of the freezing front into the gravels. Blachut (1986a) documented surface and anchor ice formation, anchor ice depositing preferentially on spawning dunes, and anchor ice subsequently covered by surface ice growth to a total thickness of over 1 m. These ice conditions were observed as far upstream as km 25, and downstream to Diamond Island (km 70). Observations made by Blachut (1986b) include shore ice up to 25 cm thick, resting directly on the substrate with no running water underneath, and scour marks in nearshore areas made by moving ice. Velocities under an ice cover documented at Diamond Island (Figure 25) indicate a significant reduction in velocity in shallow nearshore areas under an ice cover. Ice thickness on the upper Nechako can reach up to 30 cm in a mild year (Blachut, 1986b), and depending on the magnitude of the backwater effect, this ice cover can grow to occupy most of the free water space. This will occur first in the shallow nearshore zones and over shallow features such as chinook redds. In a colder winter (1979-80), shore ice thicknesses of 40 cm were estimated (Figure 26), and the surface ice was observed to be frozen to the streambed at distances of approximately 10 m out from shore (K. Johansen, personal communication).

Given the number of freezing degree days experienced in the Nechako area, ice thicknesses can be roughly calculated to range from 50-70 cm in thickness (Shen and Yapa, 1985), depending on location along the river. The date of initiation of ice cover formation determines the maximum thickness reached, and the upper Nechako which forms an ice cover later and for a shorter duration than the middle and lower Nechako reaches, will achieve a thinner ice cover. The dynamic nature of the ice front in the upper reaches also complicates the predictability of the thickness of the ice cover in the upper Nechako. Ice thickness reached under different flows and under different meteorological regimes may be an important variable in determining overwinter fish survival, and should be incorporated in any future modelling or prediction studies.

8. Water Quality

Only two water quality parameters were of concern during winter on the undeveloped Nechako watershed: dissolved oxygen and total gas pressure (TGP). Dissolved oxygen levels were investigated due to a pattern of depressed dissolved oxygen under an ice cover in other northern areas (Whitfield and McNaughton, 1986; Shallock and Lotspeich, 1974; Schreier et al, 1980). If mainstream dissolved oxygen levels are low, then intragravel conditions for incubating eggs and alevins may become lethal when affected by other factors such as anchor ice. Total gas pressure, or the supersaturation of water with dissolved oxygen and nitrogen, has been documented to be a concern below Cheslatta Falls in summer months (Byres and Servizi, 1986). While incubating eggs are less susceptible to the effects of elevated TGP than juvenile or adult fish (Alderdice & Jensen, 1985), an elevated TGP may induce chronic gas bubble trauma (GBT). In addition, the presence of a continuous surface ice cover would theoretically prevent elevated TGP levels from re-aerating, and extend the risk of chronic GBT further downstream.

To investigate these possible additional risks to overwintering salmonids in the Nechako, spot dissolved oxygen and TGP measurements were made over the winters of 1985-86 and 1986-87. These data are summarized in Table 38, and generally indicate elevated TGP levels below Cheslatta Falls. One measurement above the falls indicated slightly undersaturated water coming out of the Murray-Cheslatta lake system, which was increased by 7% after its descent over Cheslatta Falls. In most instances, TGP levels declined with distance downstream as a result of re-aeration. However, the upper 30-35 km of the Nechako River appears to be subjected to super-saturated conditions throughout the winter. The possible effects of elevated TGP on overwintering fish or incubating eggs and alevins has not been investigated on the Nechako. The persistence of elevated TGP levels under an ice cover is unknown, but theoretically advance of an ice cover under cold conditions to within 10 km of Cheslatta Falls could result in elevated TGP levels for an extended distance downstream.

Spot measurements of dissolved oxygen (Table 38) have consistently indicated values of 10 mg/l or greater. Continuous monitoring of dissolved oxygen was carried out in 1986-87 at Irvine's, and values of dissolved oxygen were always above 11 mg/l (Appendix 2). Intragravel dissolved oxygen probes were tested, and found to give inaccurate readings due to insufficient flow velocities past the sensor. However, a continuous ice cover did not reach this location in the relatively mild winter of 1986-87. These samples give a preliminary indication that the serious dissolved oxygen depressions observed on other northern systems (Whitfield and McNaughton, 1986) do not occur on the upper Nechako. At Diamond Island, an intragravel dissolved oxygen probe gave an indication that oxygen levels are depressed under an ice cover (Appendix 1). While the absolute values can't be used due to sensor problems, in relative terms the data indicate significant drops in intragravel oxygen while an ice cover is present. However, a more rigorous sampling program under the ice cover should be carried out to confirm that winter dissolved oxygen levels under an ice cover are adequate for overwintering fish, eggs, and alevins.

9. Conclusions and Recommendations

Two years of field observations of winter ice conditions were combined with historical hydrology, water temperature and meteorology data to describe the winter regime of the Nechako River.

The following recommendations must be qualified by the purpose and timing of preparation of this report, and the present status of Nechako River studies. The original purpose of this study was to gain a better understanding of winter physical processes and to further develop the winter flow recommendation in preparation for the Supreme Court case. The data base on winter conditions, particularly ice regime was very limited and the selection of techniques to model water temperature and ice progression was predicated on data availability. This limitation should not affect future winter regime studies and the appropriate model type and data base requirements should be reviewed thoroughly. Winter studies to date have focused on physical conditions for incubating chinook eggs and alevins, and overwinter habitat requirements for chinook and trout juveniles have not been thoroughly assessed.

It is recommended that further monitoring of winter conditions is essential to improve the understanding of ice processes on the Nechako River, and to document the range of variability of conditions. This should be continued for several years to provide an adequate database on winter physical parameters, to permit either a qualitative description of the winter regime or quantitative modelling. The latter development would provide a predictive and management tool to assess the long term settlement flows. Implicit in many of the recommendations given below, is that linkages between physical processes, fish habitat and fish need to be studied. The suspicion that winter may be the limiting time period for chinook production from the Nechako must be explored. These types of interdisciplinary studies are vital to truly understanding the relationships between flow and fish populations.

Winter Hydrology

1. Ongoing stage and discharge measurements by Water Survey of Canada at Irvine's and Vanderhoof should be accessed routinely. Software to access and archive the DCP data needs final development, with assistance from Computer Services.

2. The need for additional sites (such as Diamond Island, Fort Fraser or Greer Creek) to describe site specific physical conditions should be reviewed, in conjunction with winter biological studies.
3. Review other winter minimum flow studies, such as those conducted in Montana (Montana Dept. of Fish, Wildlife and Parks, 1984) and Alaska (Van Haveren, 1987).
4. Comparison of winter stage data with surveyed depth of water over spawning redds, and further documentation of the range of backwater conditions at various sites.
5. A range of controlled winter flows could be released to monitor and test various physical parameter models.

Meteorology

1. Ongoing air temperature measurements by Atmospheric Environment Service (Vanderhoof) and Water Survey of Canada (Irvine's) should be accessed and archived routinely.
2. Additional stations and/or meteorological parameter requirements needed for water temperature and ice modelling should be identified.

Water Temperature

1. Ongoing data collection of water temperatures at Irvine's (Water Survey of Canada and Department of Fisheries & Oceans) should be accessed and archived routinely.
2. Additional station requirements should be identified, with Diamond Island and Vanderhoof as tentative new locations for temperature monitoring.
3. The simple water temperature model used in this study requires further refinement. Additional data sets for calibration of the heat transfer coefficient are required and verification of modelled results should be carried out. Continued use of the simple air-water temperature model rather than a more complex energy budget model (with its detailed meteorological data requirements) should be reviewed.

Anchor Ice

1. Additional field observations of the location, thickness, persistence and flow through anchor ice are required.
2. Flow through and under (through bed materials) anchor ice has rarely been measured or studied. This may be identified as an applied research problem.

Surface Ice

1. Additional field observation of the surface ice cover is required, including leading edge position, shore ice progression rates, ice thickness, occurrence and persistence of hanging dams, occurrence and extent of surface ice frozen to the bed, ice conditions in side channels and at tributary confluences. These observations can be obtained by the use of local observers at strategic locations on the river, aerial mapping during appropriate ice conditions and possibly time lapse photography at key sites.

2. The ice (leading edge progression) model used in this study requires review and further refinement. Other more sophisticated ice models (eg. ice continuity model - Calkins 1984; Paschke and Coleman, 1986) should be reviewed and compared to the progression model. Additional calibration and verification data sets are required to confirm the modelled results in this report. With a better data set, a daily leading edge progression model could be run to provide more detailed model results. A separate or integrated ice thickness prediction model based on air temperatures should be explored (e.g., Shen and Yapa, 1985).

Intragravel Conditions

1. The precise relationship between surface flow and intragravel flow, and the effects of surface and anchor ice on this relationship is currently unknown. Calkins (1987) identified this as an area requiring a major applied research effort, and a Canadian federal agency has the laboratory facilities and expertise to conduct this type of research. It is recommended that this applied research project be conducted, which would involve a detailed lab analysis of the structure of fluid flow in both the stream and its bed, under open water and various ice conditions.

2. Following on the results of this study, further development of equipment to monitor and sample the intragravel environment is necessary. Durable, non-invasive dissolved oxygen and flow rate probes compatible with data loggers have yet to be designed.

3. Subsequent to successful completion of the two above items, a well-designed and instrumented monitoring program on intragravel conditions should be carried out. It will require several years to document natural variability, and before and after flow reduction conditions should be monitored.

Water Quality

1. Continue spot measurements of dissolved oxygen and TGP in conjunction with other sampling trips. In particular dissolved oxygen levels at the time of freeze-up and under an ice cover have not been accurately monitored.

Winter Remedial Measures

1. In anticipation of the reduced long term settlement flows and assuming that impacts on overwintering eggs, alevins and juveniles is a possibility, then winter remedial measures should be researched and tested. Identification of problem areas through the monitoring of habitat use will predetermine the type of mitigation potential. Ice booms to enhance development of a surface ice cover (Ashton, 1986) are a possibility if sufficient depth of water remains under the ice cover. Local hydraulic structures such as gabions may be useful to increase backwater stage, encourage surface ice growth and provide overwintering pool habitat.

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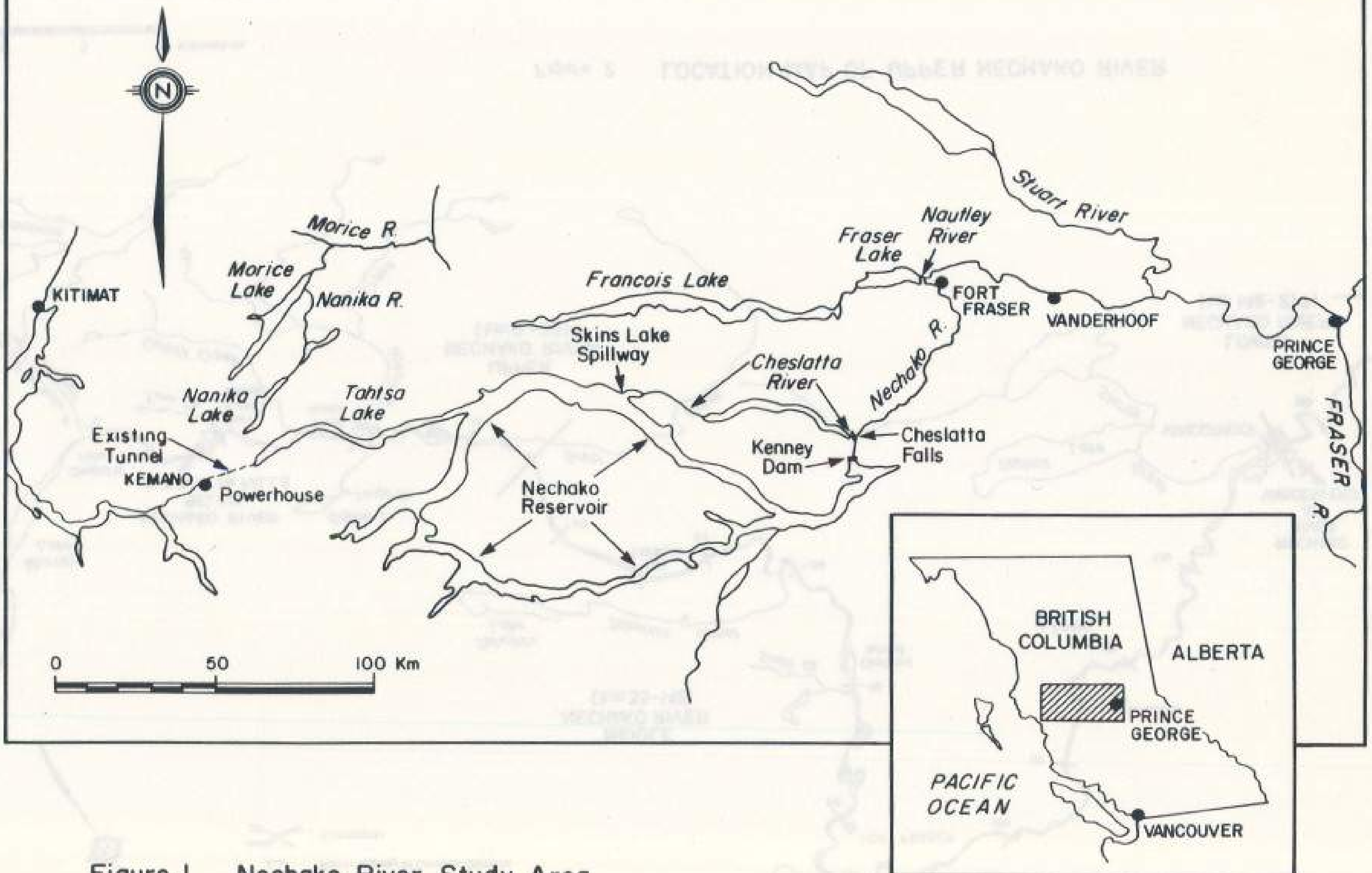


Figure I Nechako River Study Area

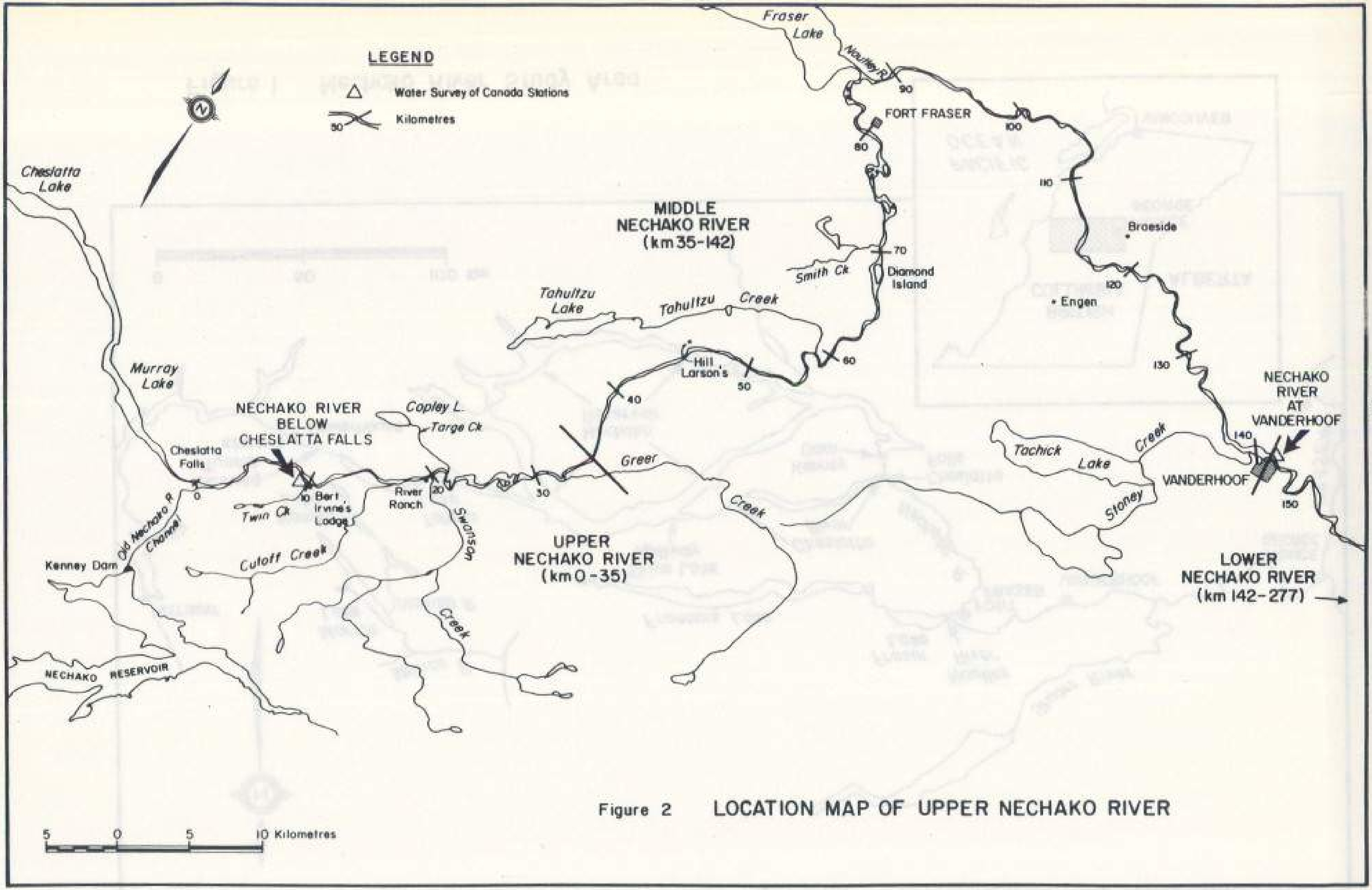
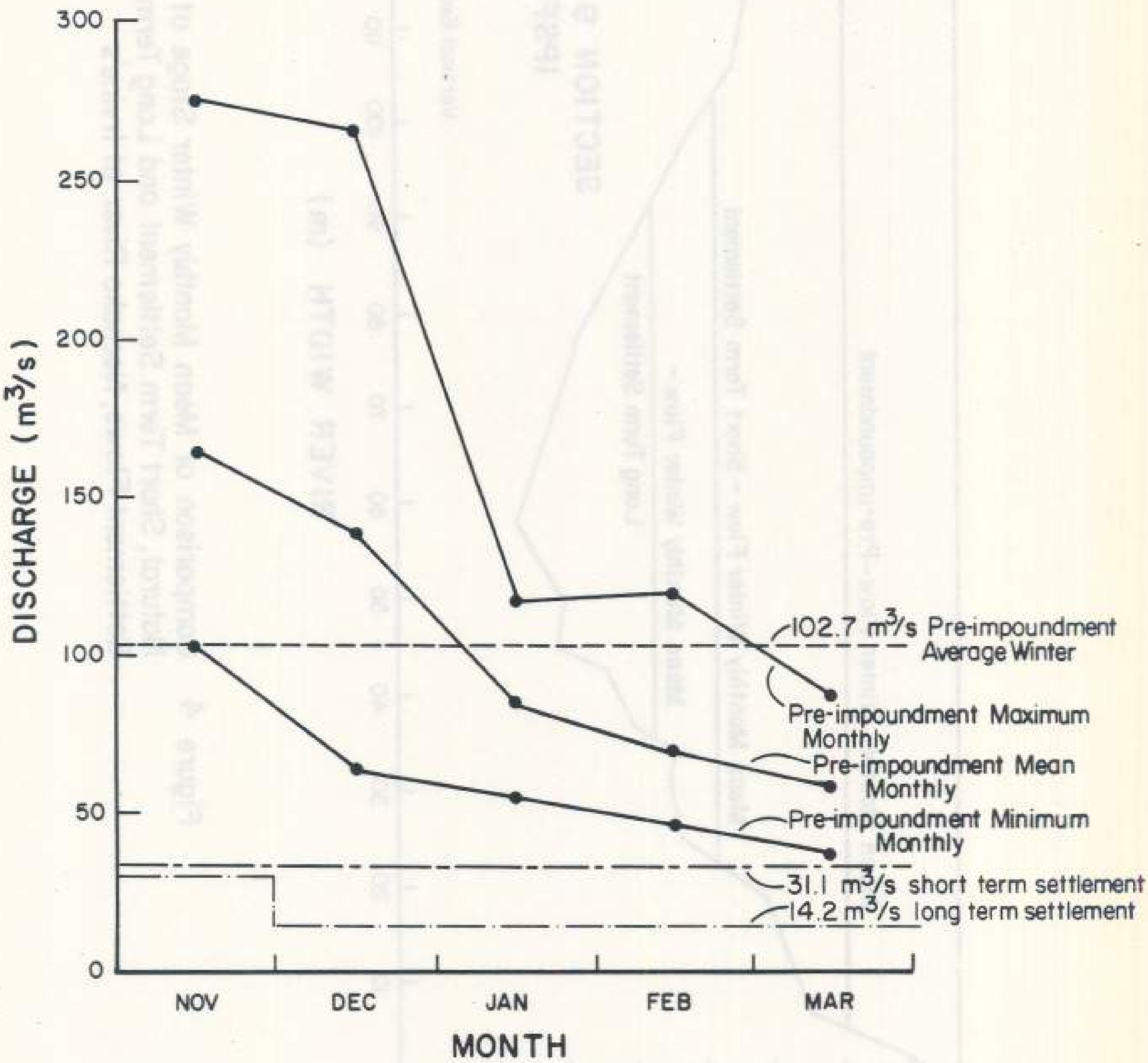


Figure 2 LOCATION MAP OF UPPER NECHAKO RIVER

Figure 3 Comparison of Pre-impoundment and Regulated Mean Monthly Flows, Upper Nechako River



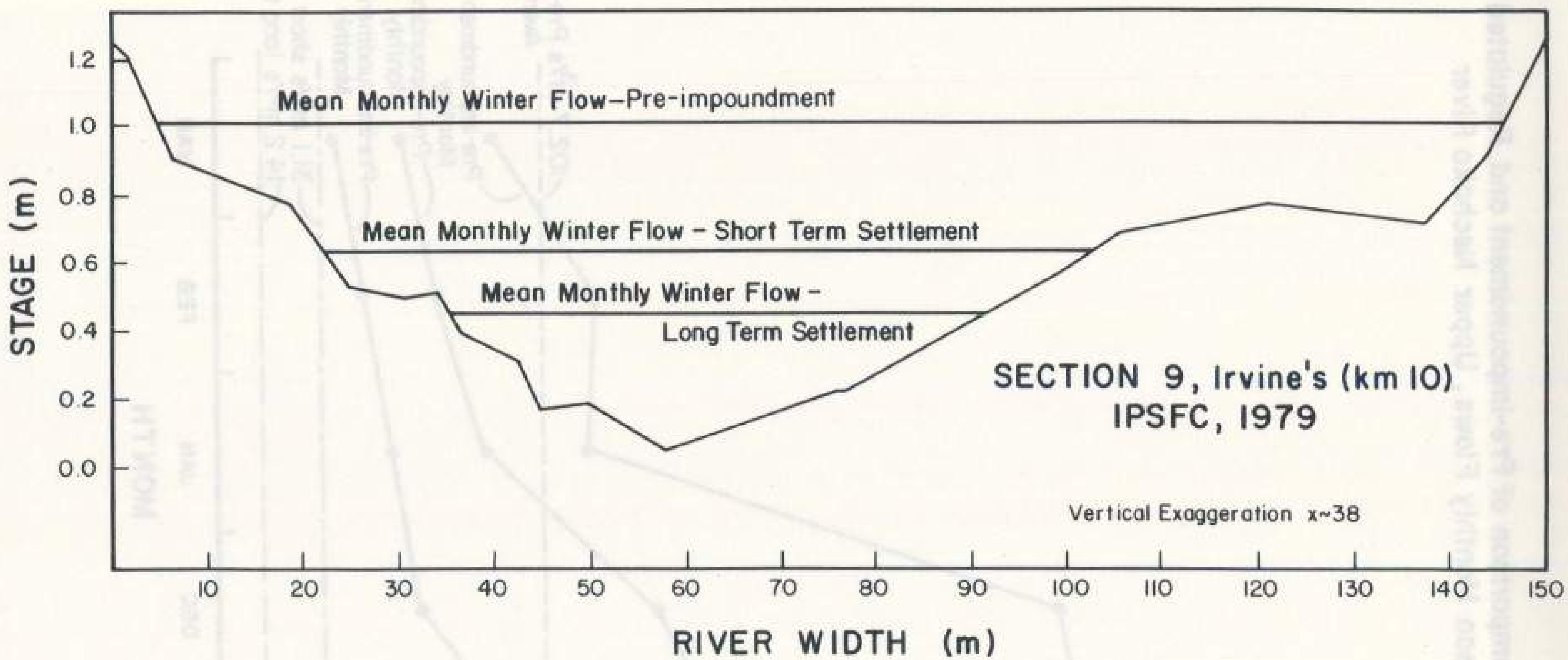


Figure 4 Comparison of Mean Monthly Winter Stage at Natural, Short Term Settlement and Long Term Settlement Flows, Nechako River at Irvine's

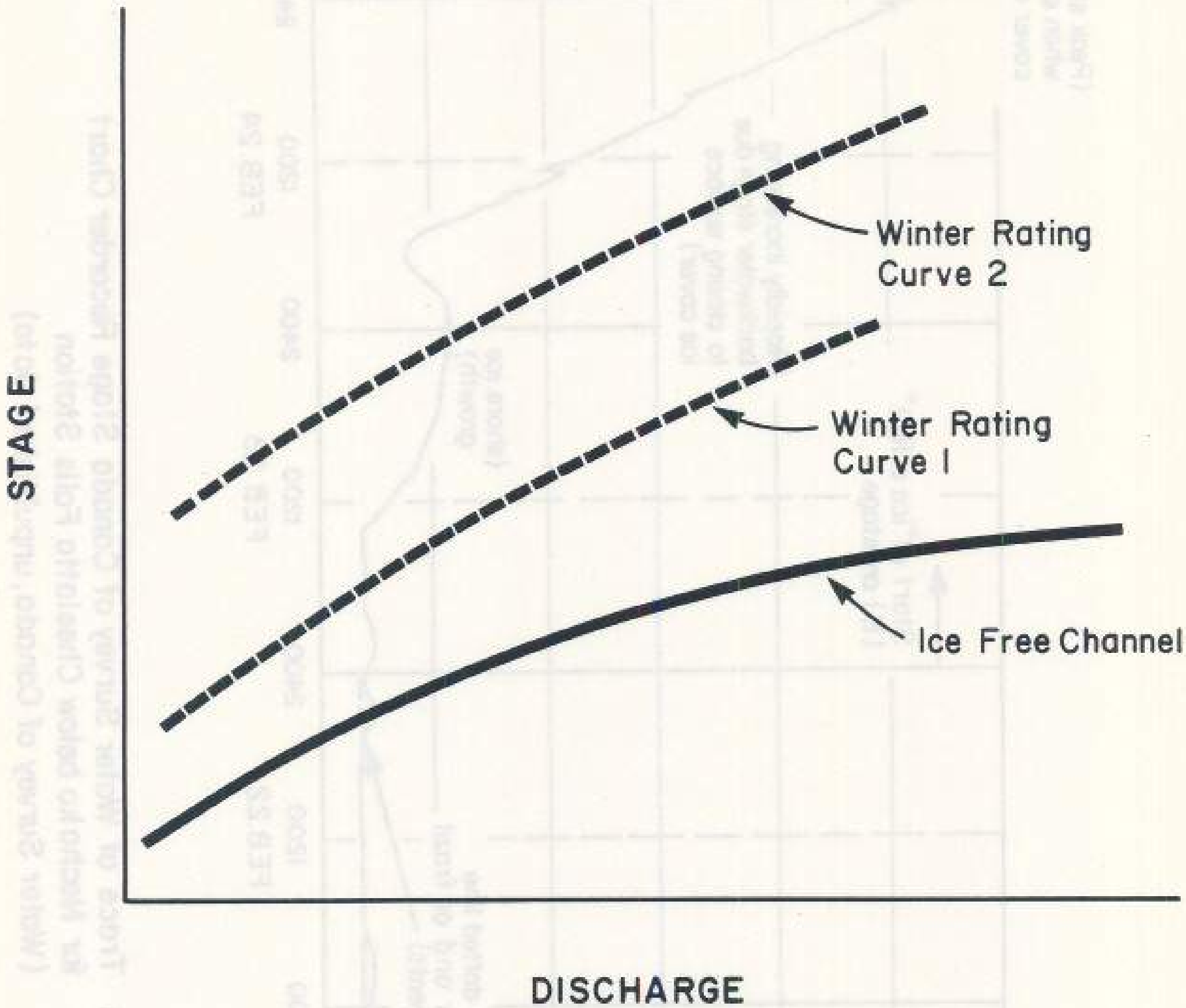


Figure 5 Winter Stage Discharge Relationship
(after Lavender, 1984)

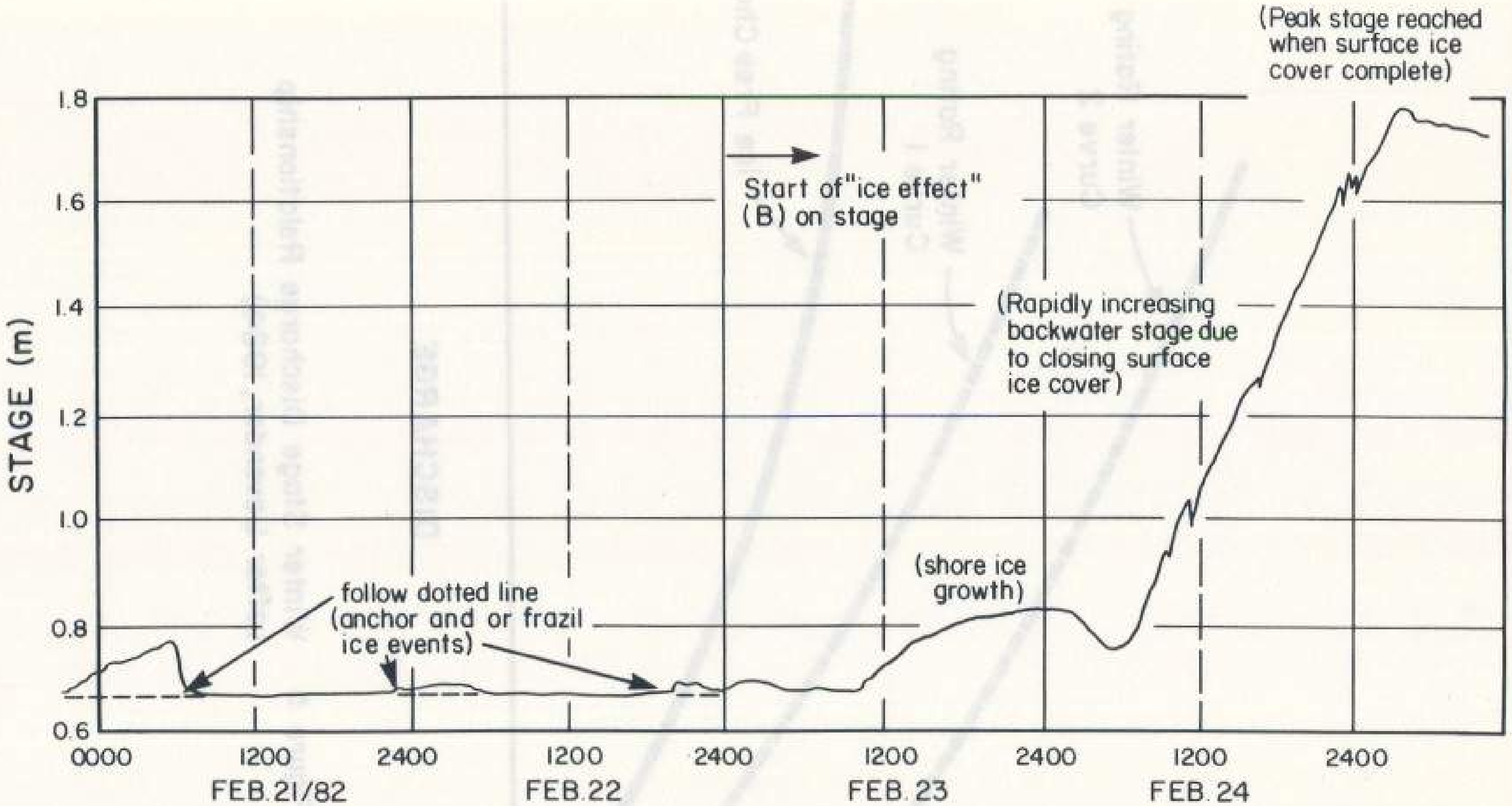


Figure 6 Trace of Water Survey of Canada Stage Recorder Chart for Nechako below Cheslatta Falls Station (Water Survey of Canada, unpublished data)

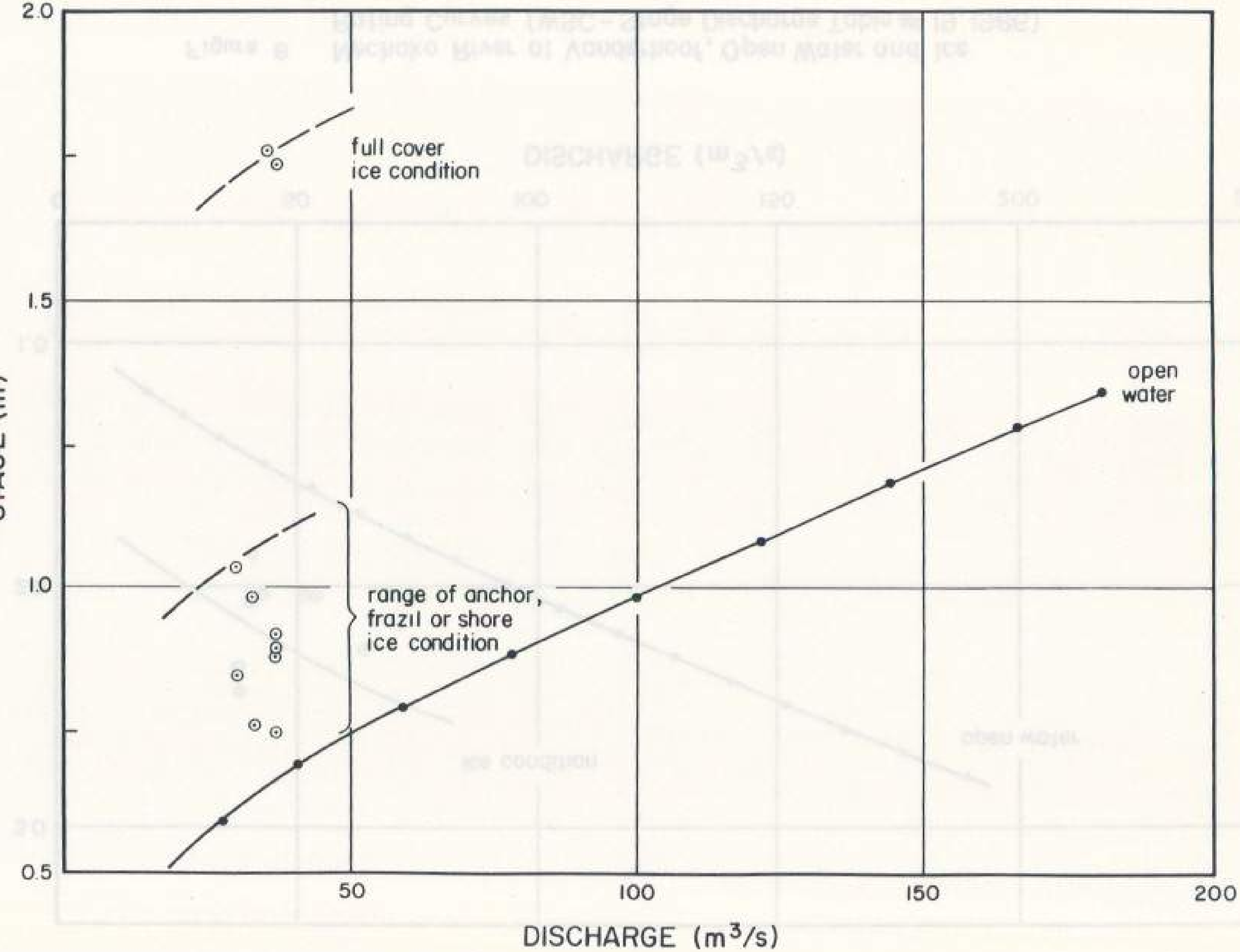


Figure 7 **Nechako River Below Cheslatta Falls (WSC - Stage Discharge Table # 1, 1985), Open Water and Ice Rating Curves**

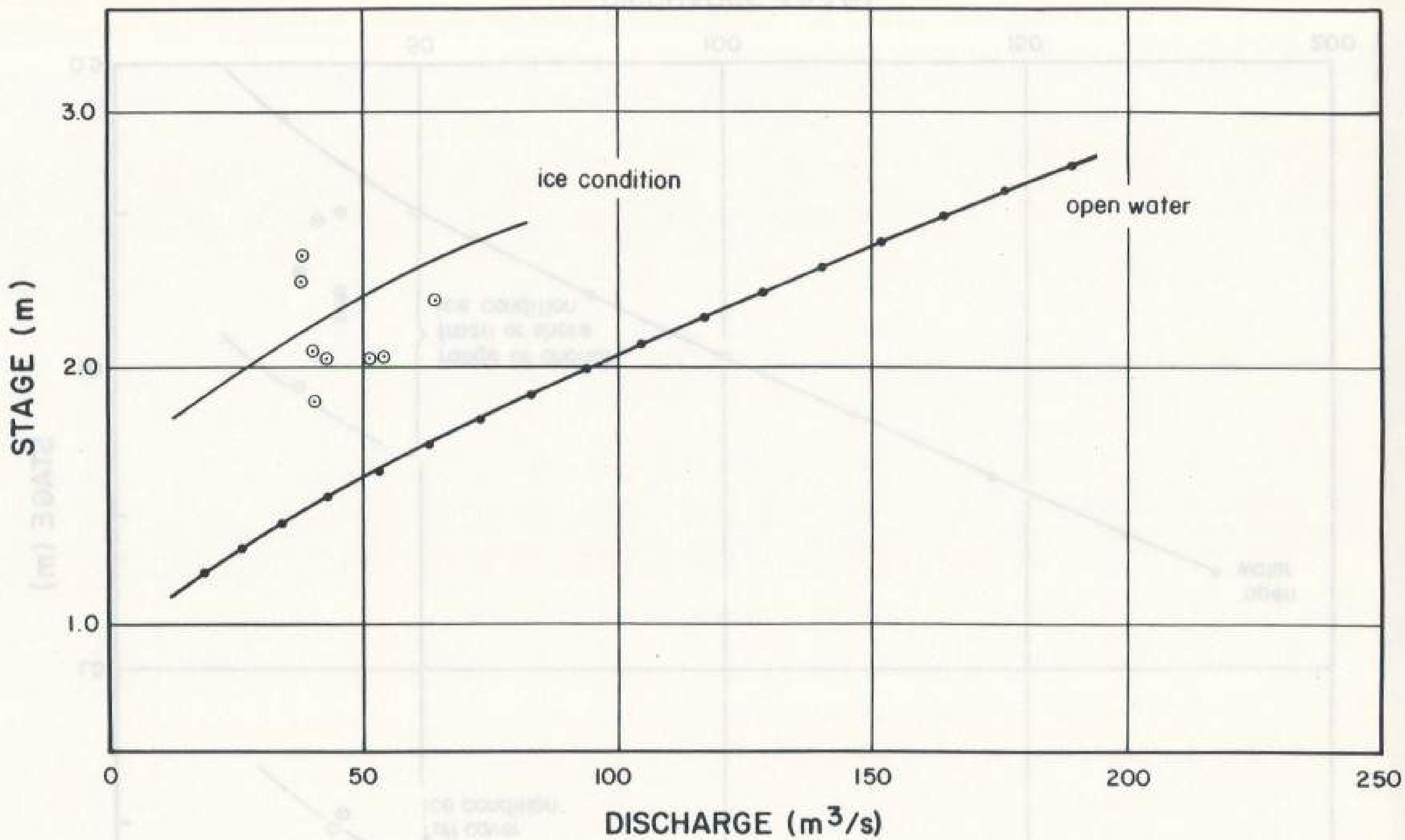


Figure 8 Nechako River at Vanderhoof, Open Water and Ice Rating Curves (WSC - Stage Discharge Table # 19, 1986)

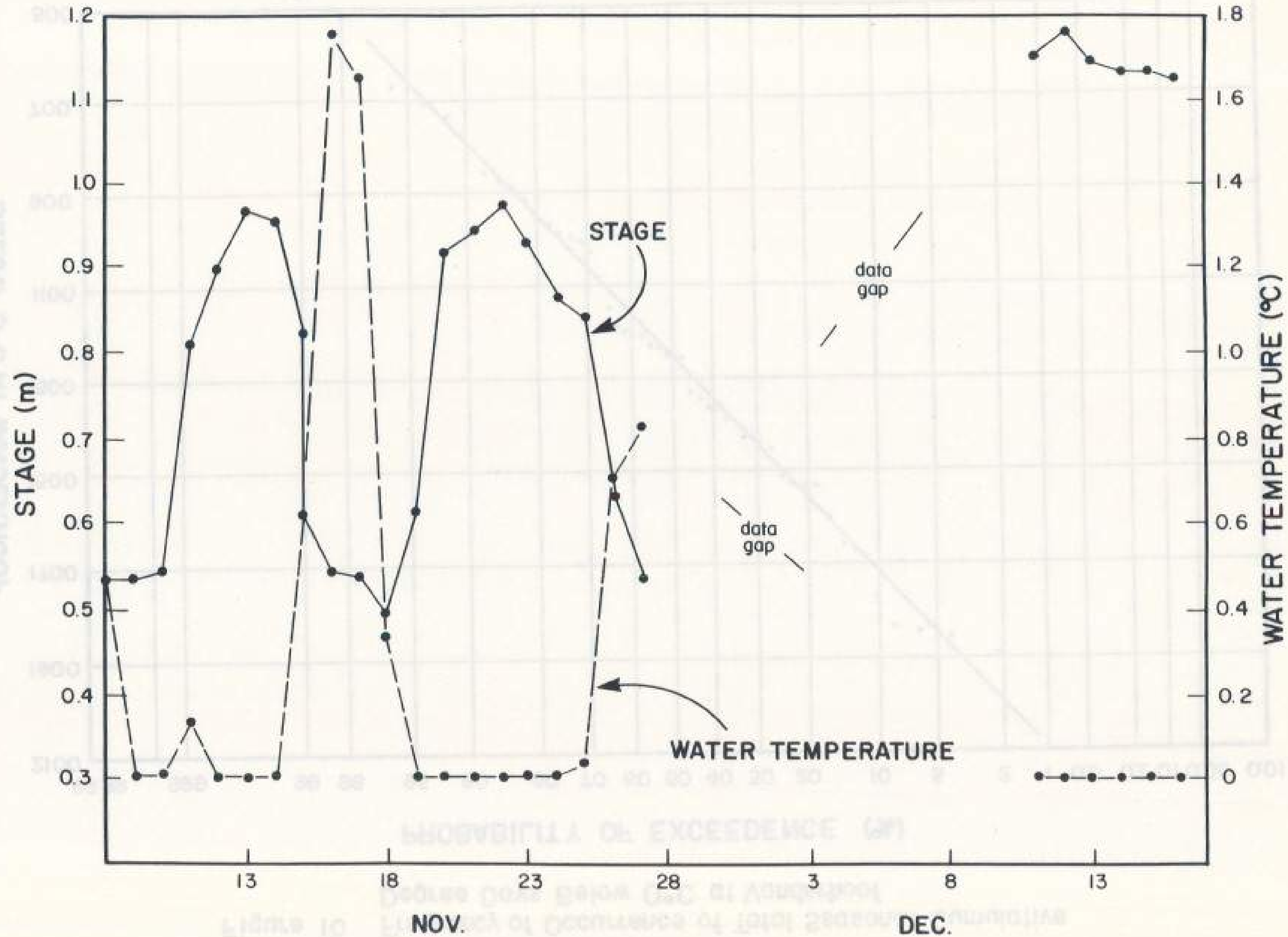
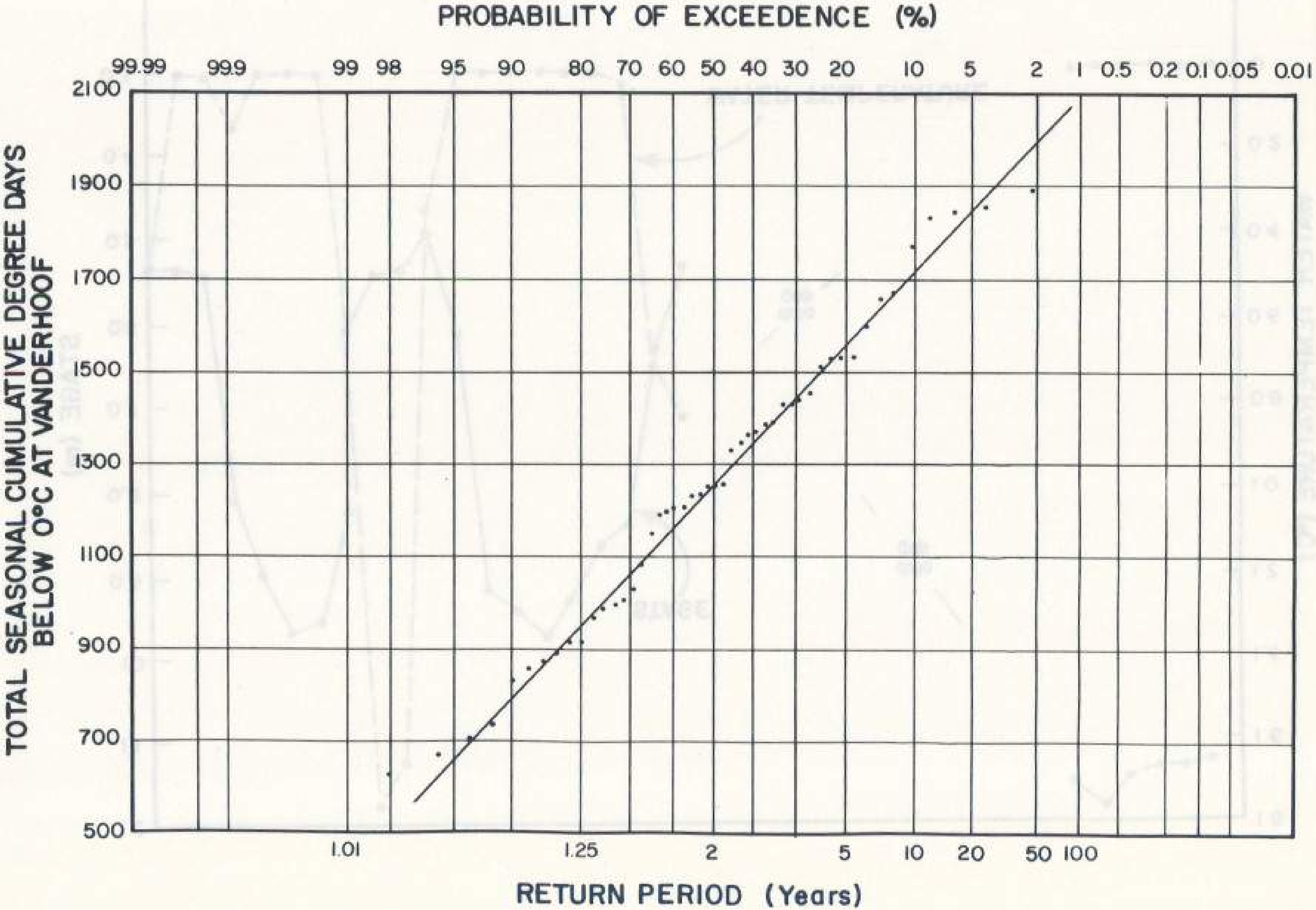


Figure 9 Mean Daily Stage and Water Temperature, Diamond Island, Nechako River, 1986

Figure 10 Frequency of Occurrence of Total Seasonal Cumulative Degree Days Below 0°C at Vanderhoof



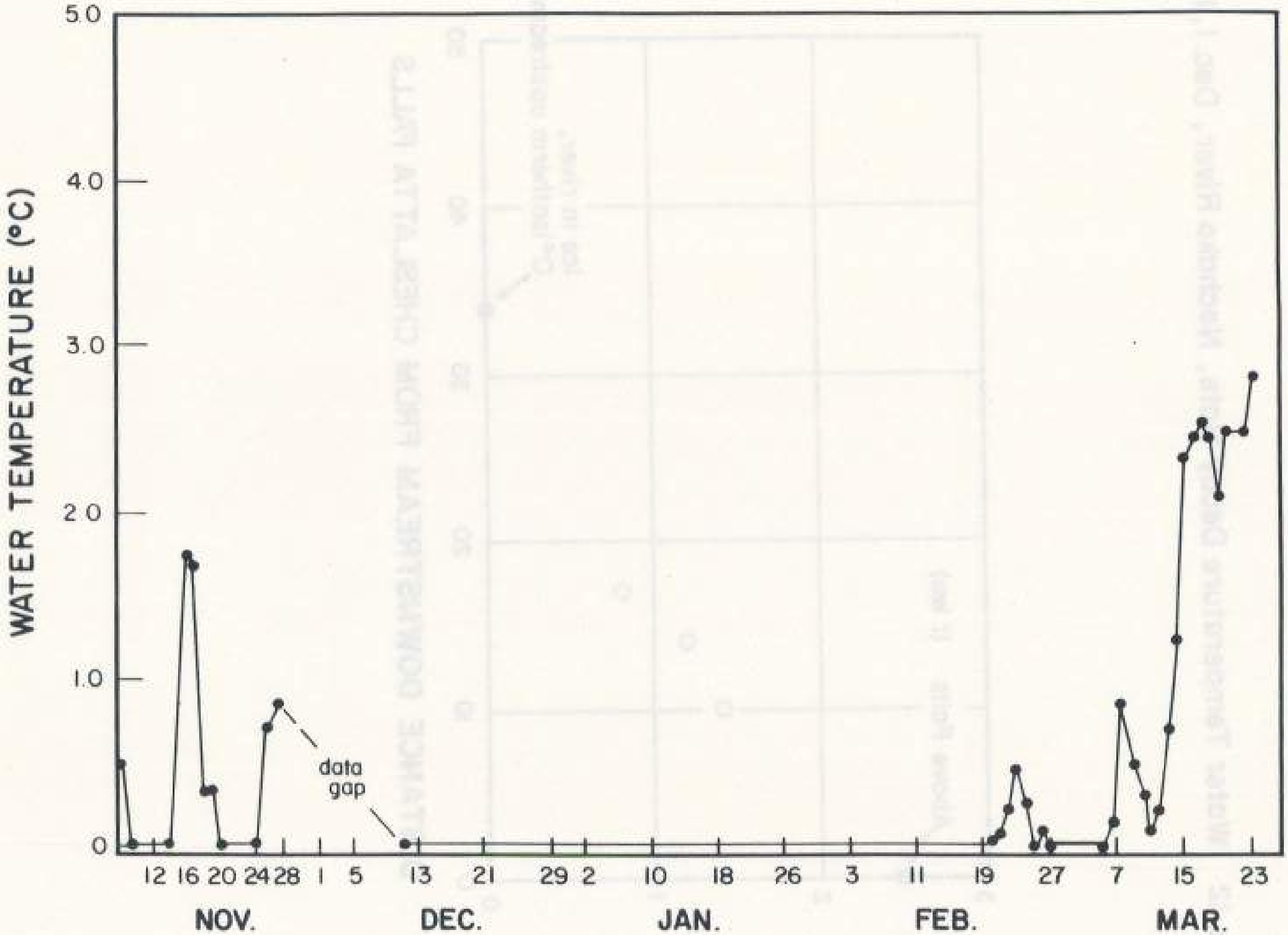


Figure 11 Mean Daily Water Temperature, Diamond Island, Nechako River, 1986-87

Figure 12 Water Temperature Decay Rate, Nechako River, Dec. 1, 1986

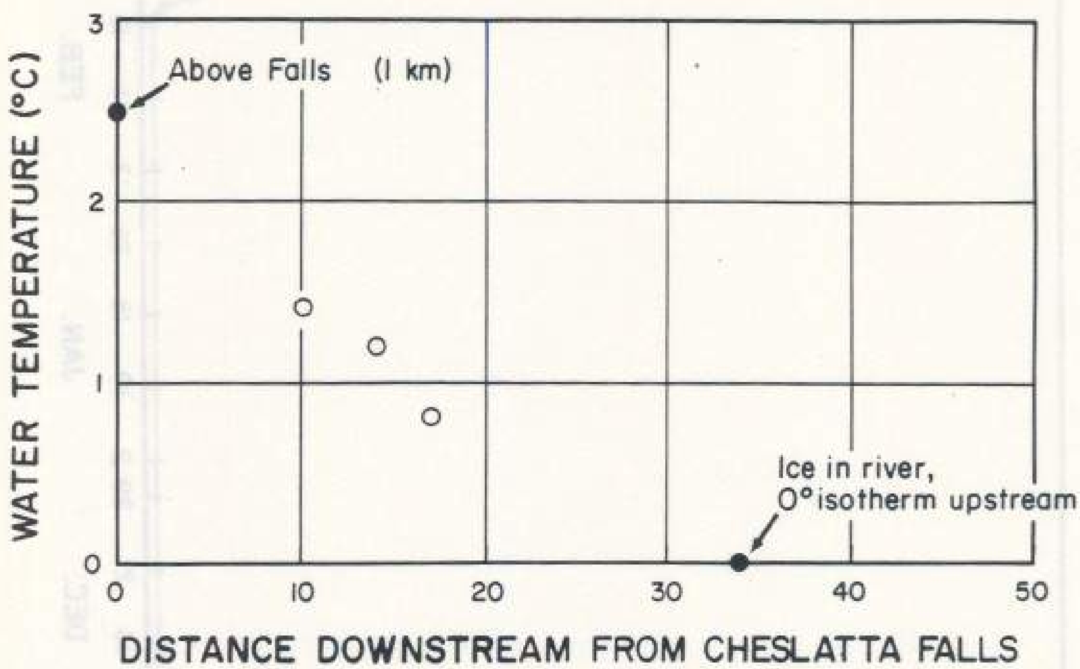
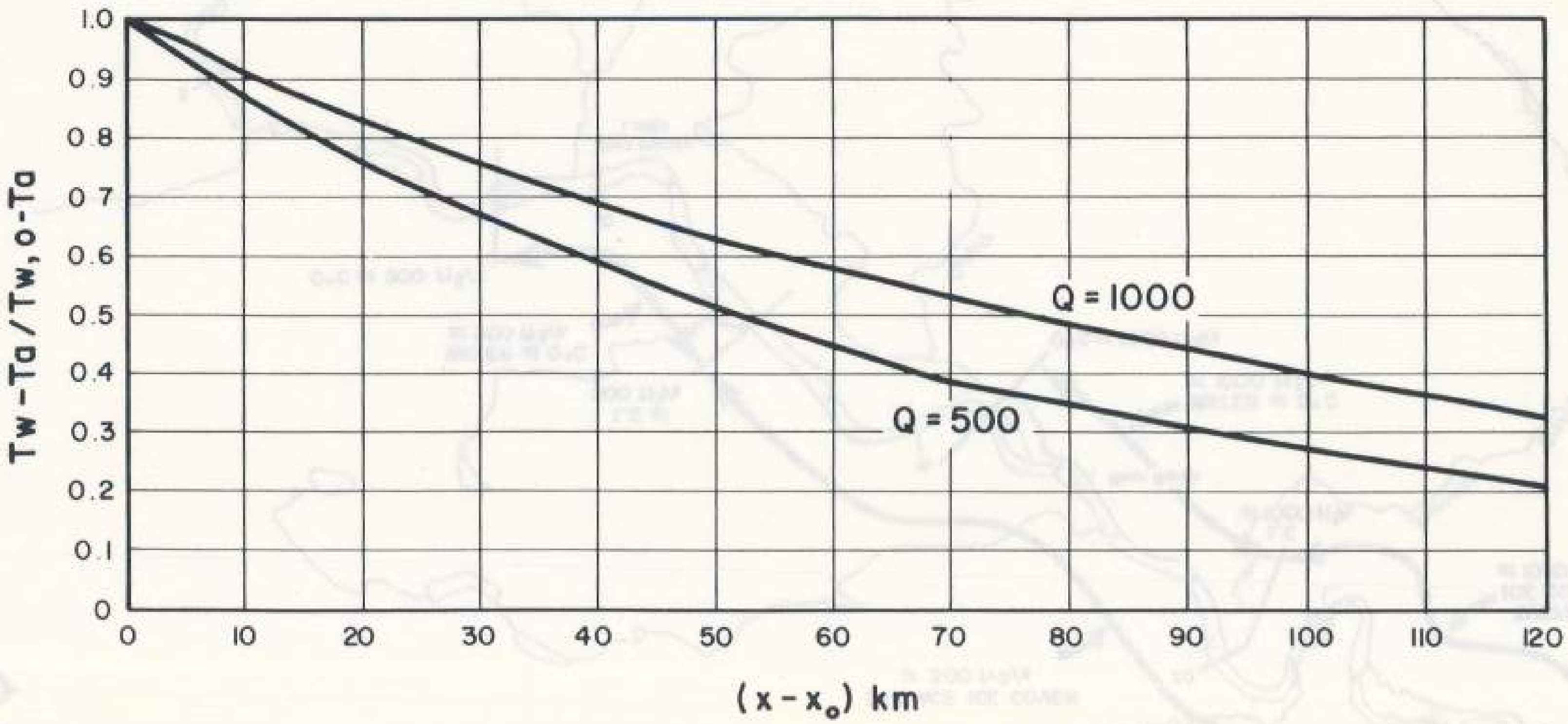


Figure 13 Decay of Water Temperature with Distance Downstream, Nechako River - for open water, where $hw = 15\ w/m^2\text{-}°C$



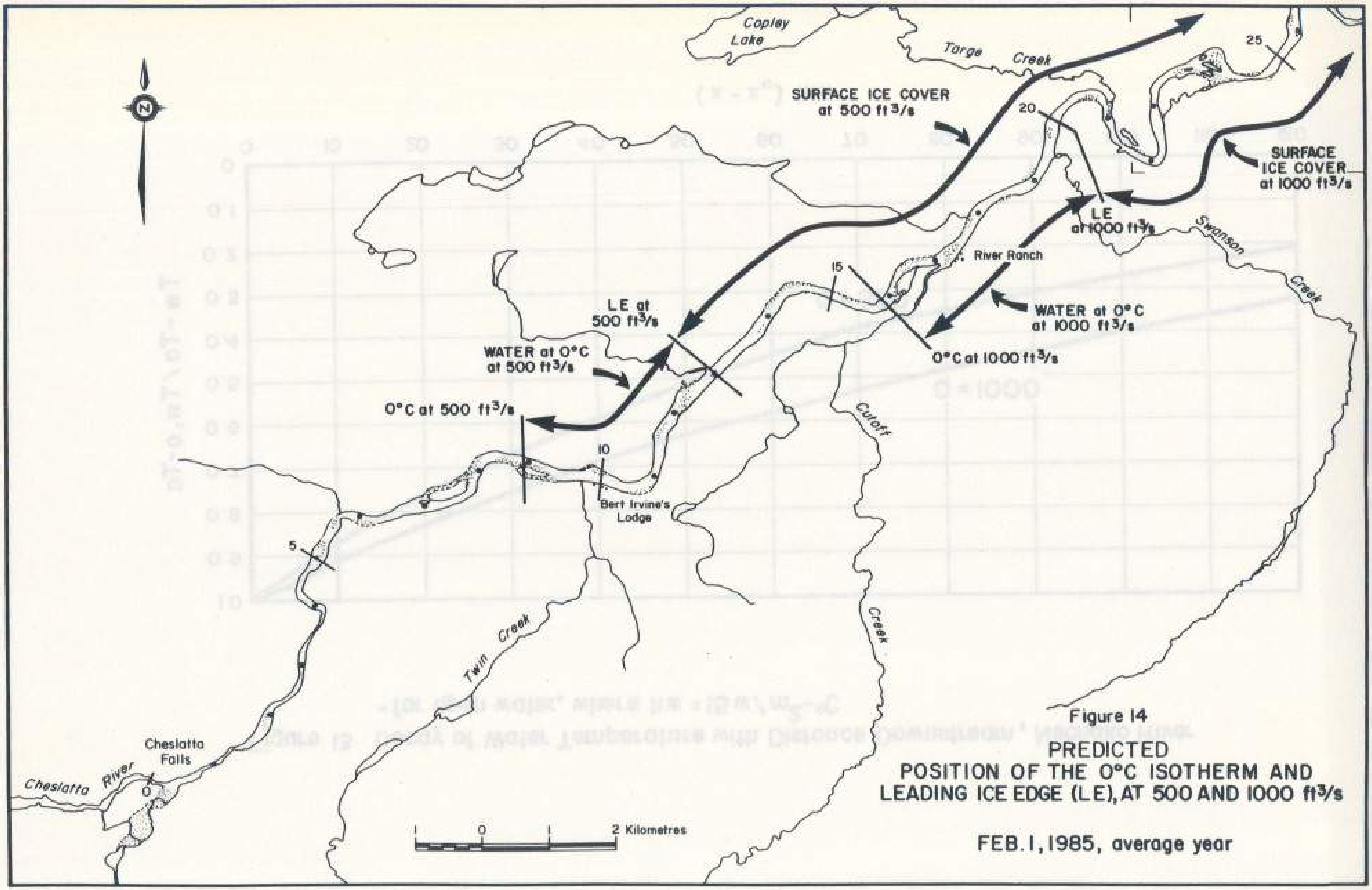


Figure 14
PREDICTED
POSITION OF THE 0°C ISOTHERM AND
LEADING ICE EDGE (LE), AT 500 AND 1000 ft³/s

FEB. 1, 1985, average year

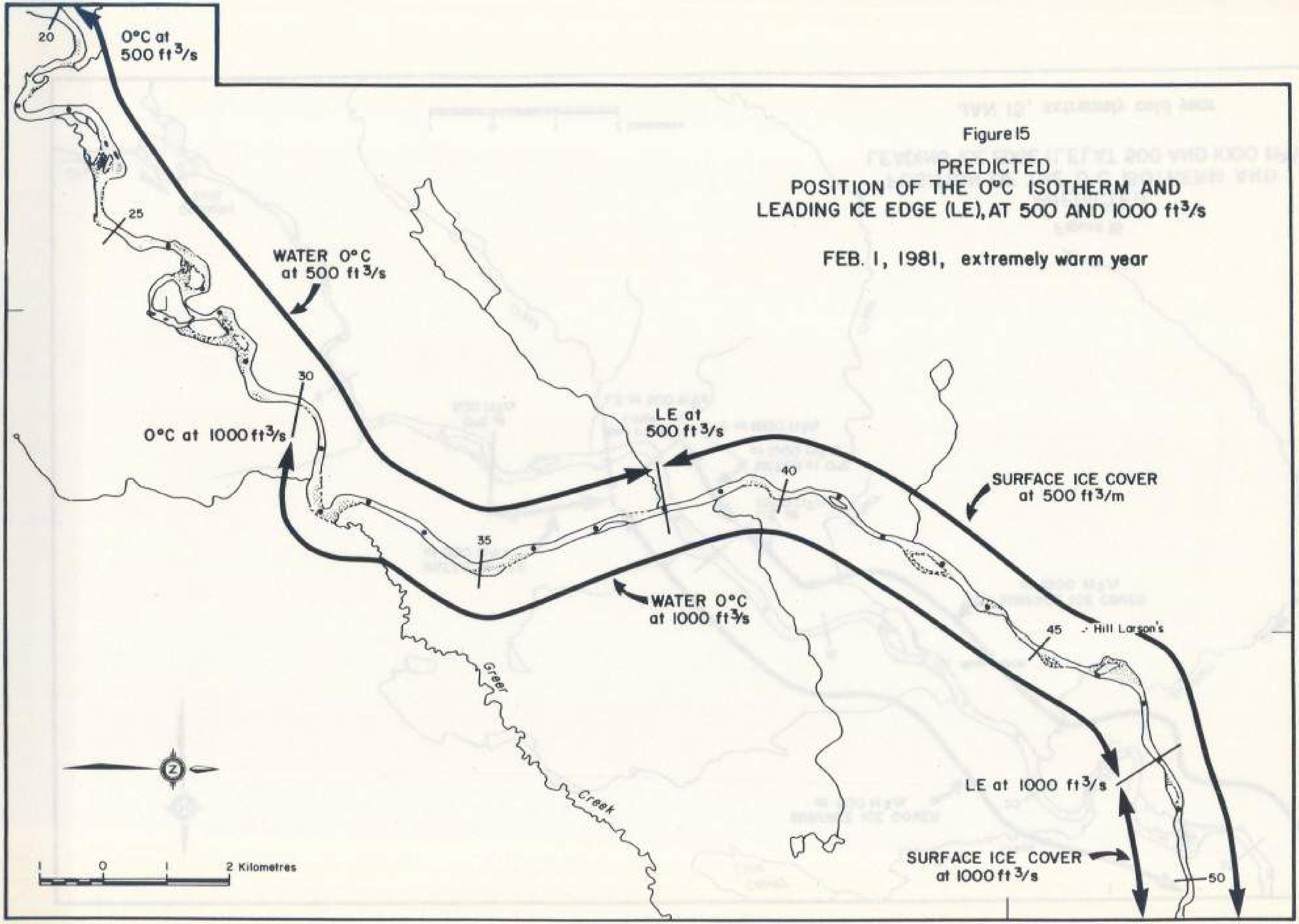


Figure 15

PREDICTED POSITION OF THE 0°C ISOTHERM AND LEADING ICE EDGE (LE), AT 500 AND 1000 ft³/s

FEB. 1, 1981, extremely warm year

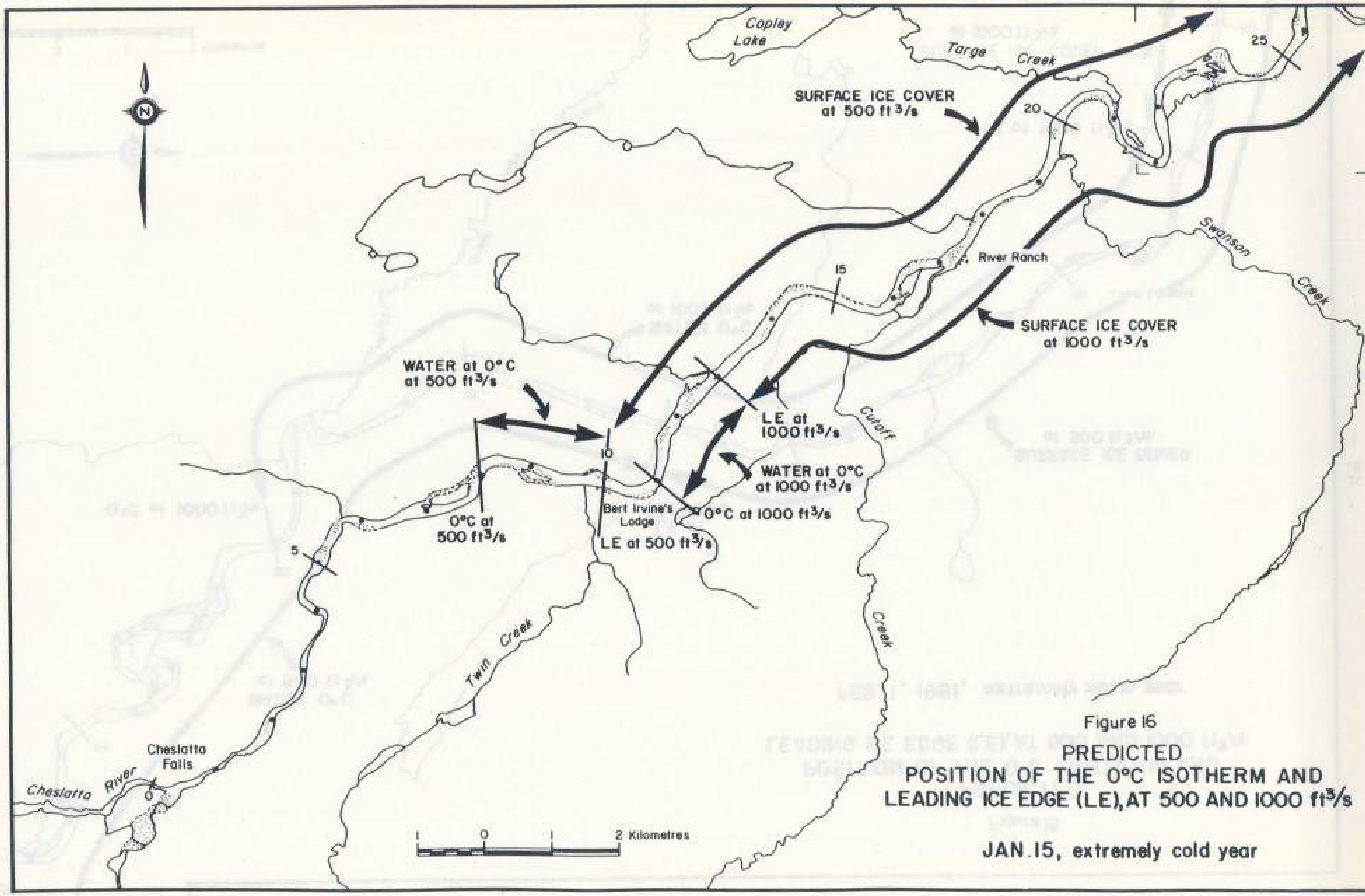


Figure 16
PREDICTED
POSITION OF THE 0°C ISOTHERM AND LEADING ICE EDGE (LE), AT 500 AND 1000 ft^3/s

JAN. 15, extremely cold year

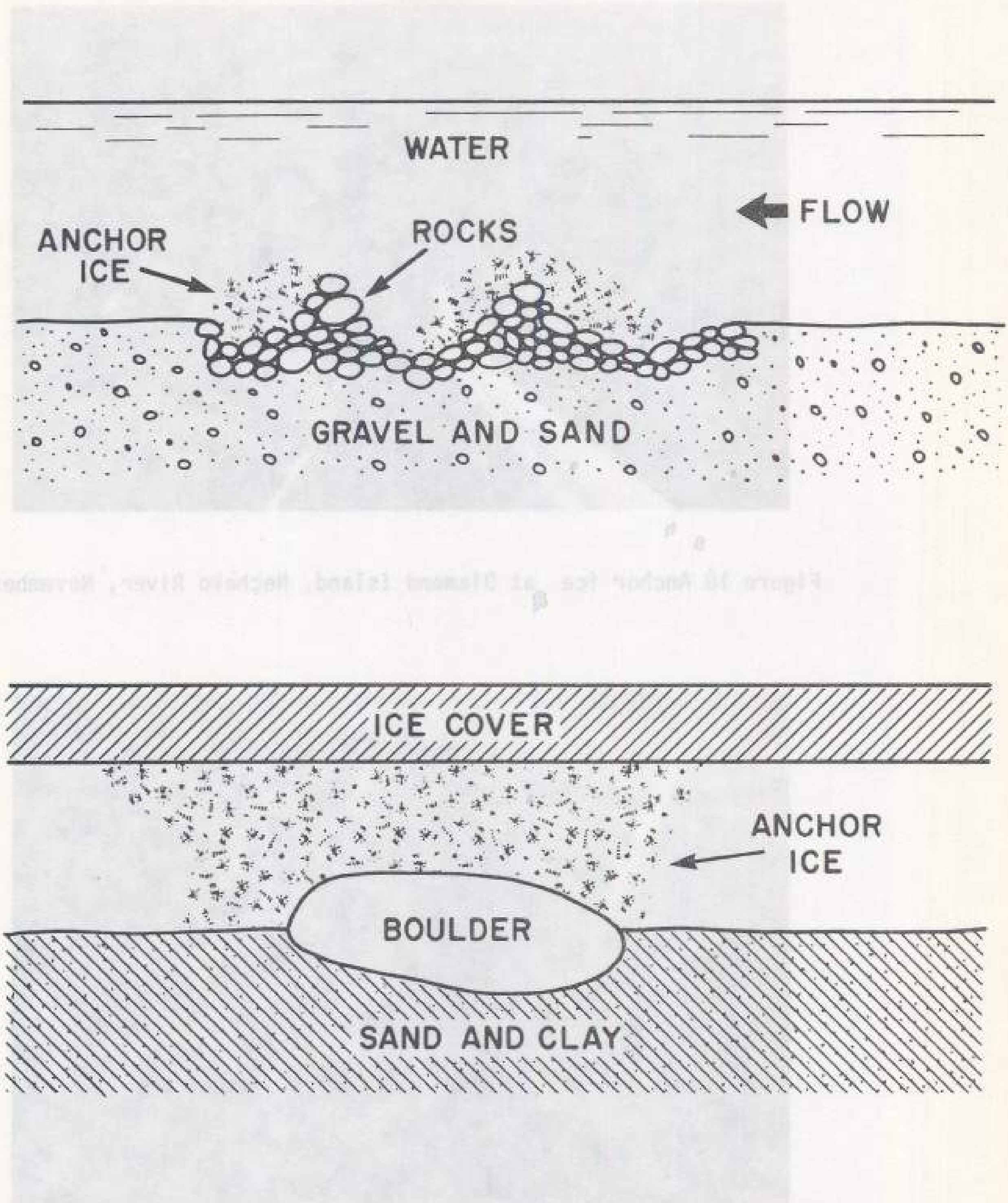


Figure 17 Various Types of Anchor Ice Deposition (adapted from Michel, 1971)

Figure 18 Anchor ice at Diamond Island, Nechako River, November,1985

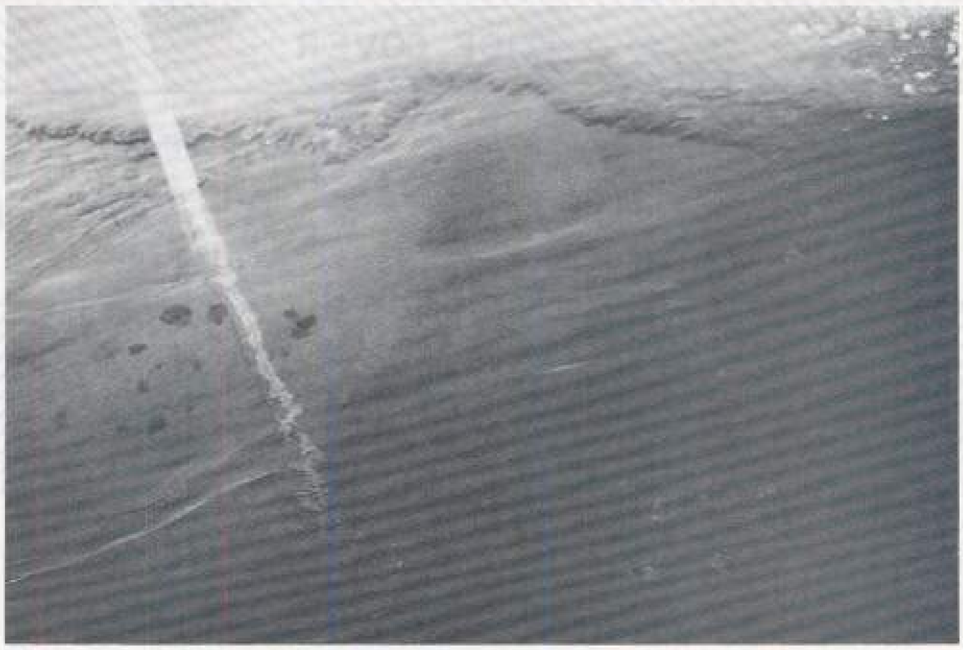


Figure 19 Anchor ice attached to the underside of the surface ice cover at Diamond Island, Nechako River, November, 1985

Figure 20 Vanderhoof - Freeze-up
Mean Monthly Flow Versus Cumulative Degree Days

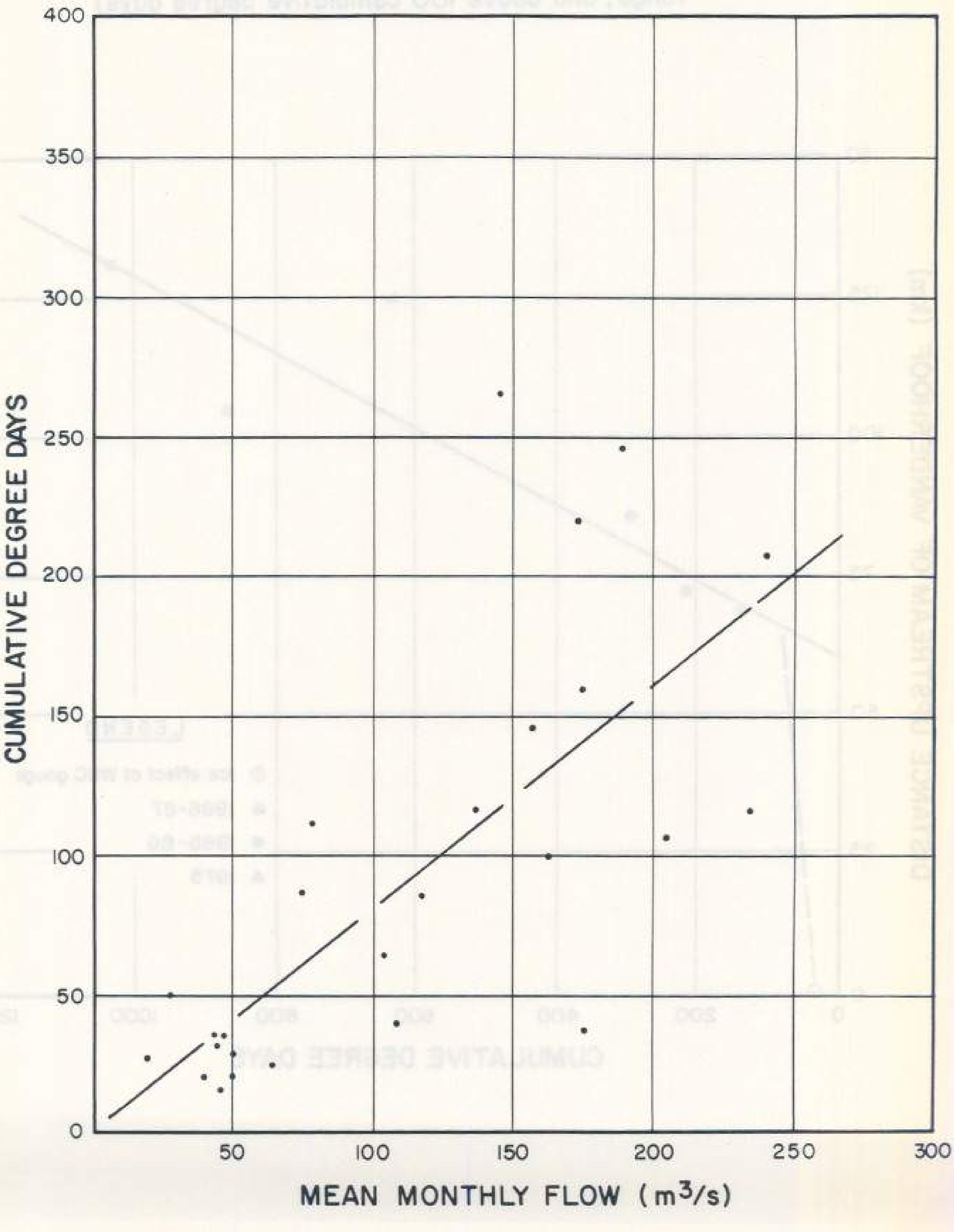


Figure 21 Relationship Between Leading Ice Edge Location and Cumulative Freezing Degree Days, Nechako River (relationship only holds for discharges in 30-35 m^3/s range, and above 100 cumulative degree days)

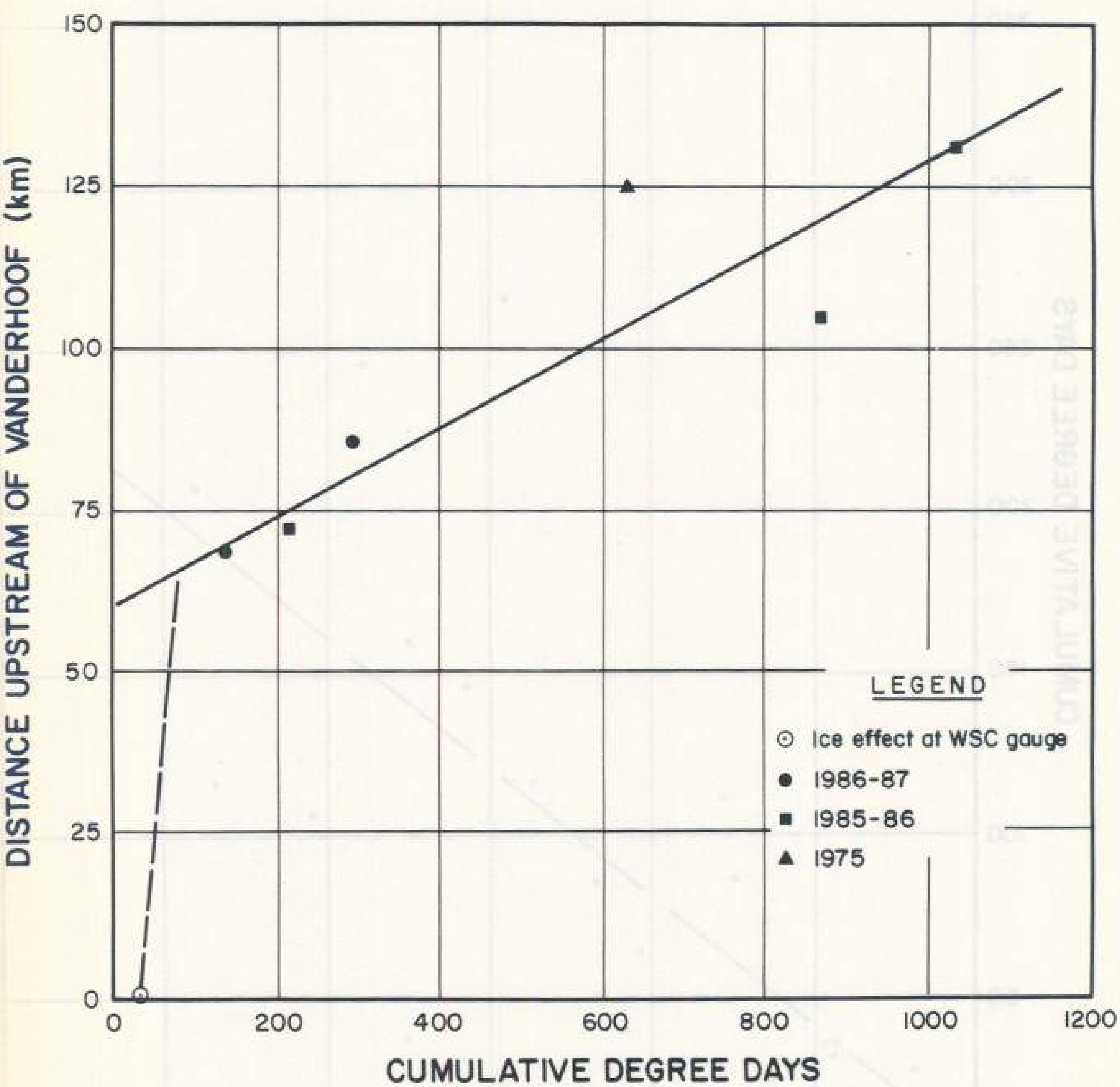
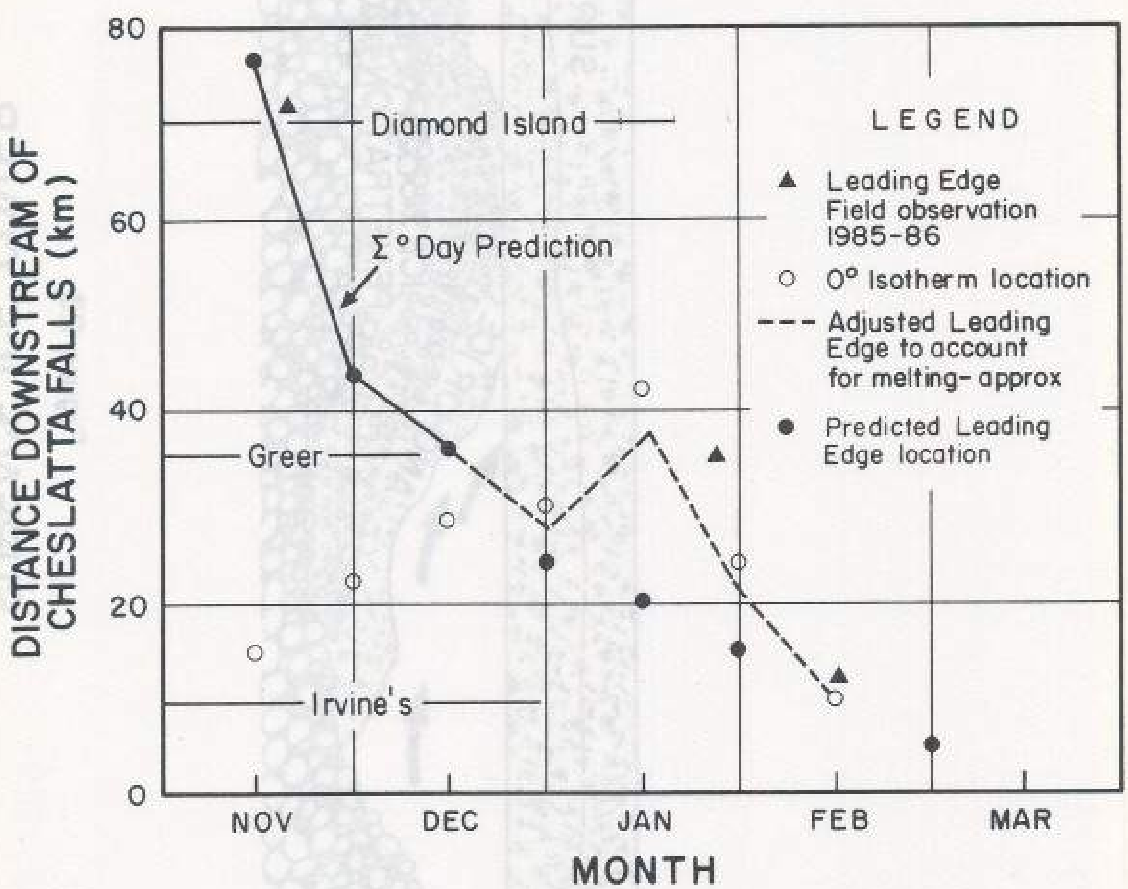


Figure 22 Calibration of Leading Edge Position Model



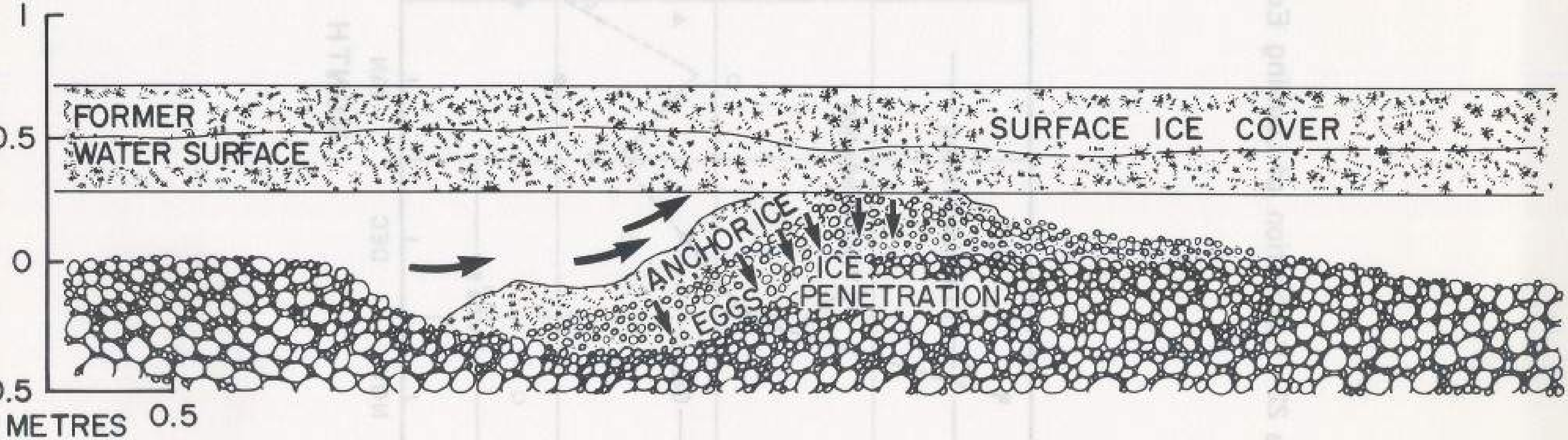


Figure 23

SURFACE ICE COVER
OVER A SALMON REDD

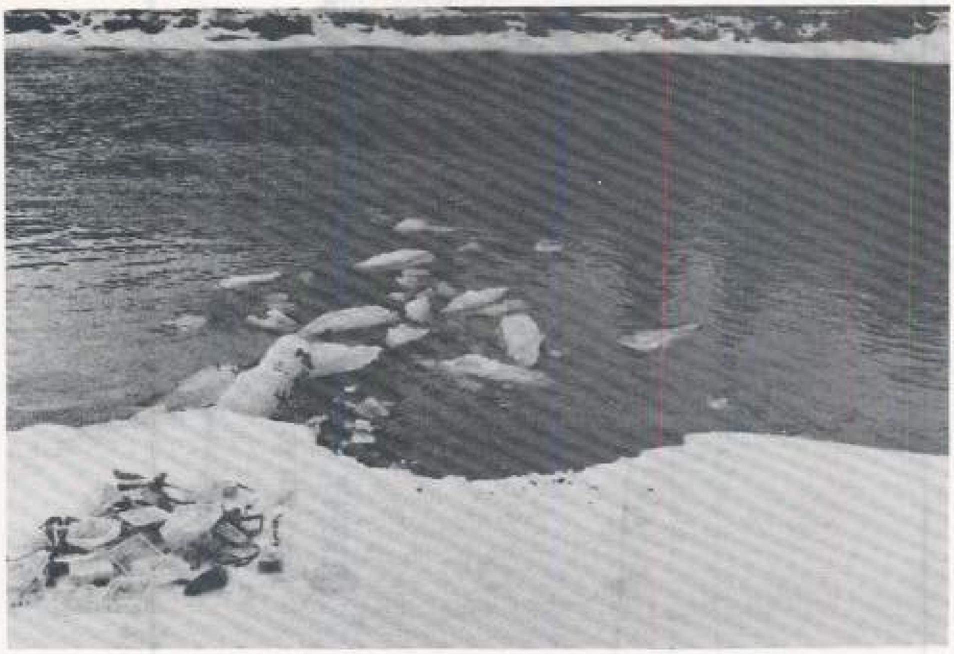


Figure 24 Surface ice cover over artificial dune, upper Nechako River

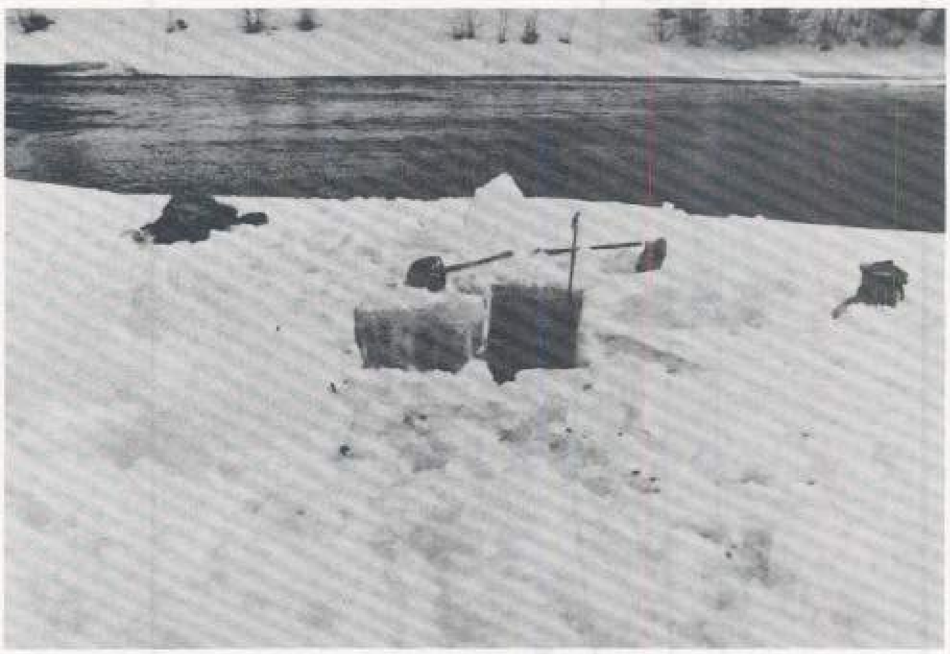


Figure 26 Shore ice over 40 cm thick, frozen to the streambed, upper Nechako River

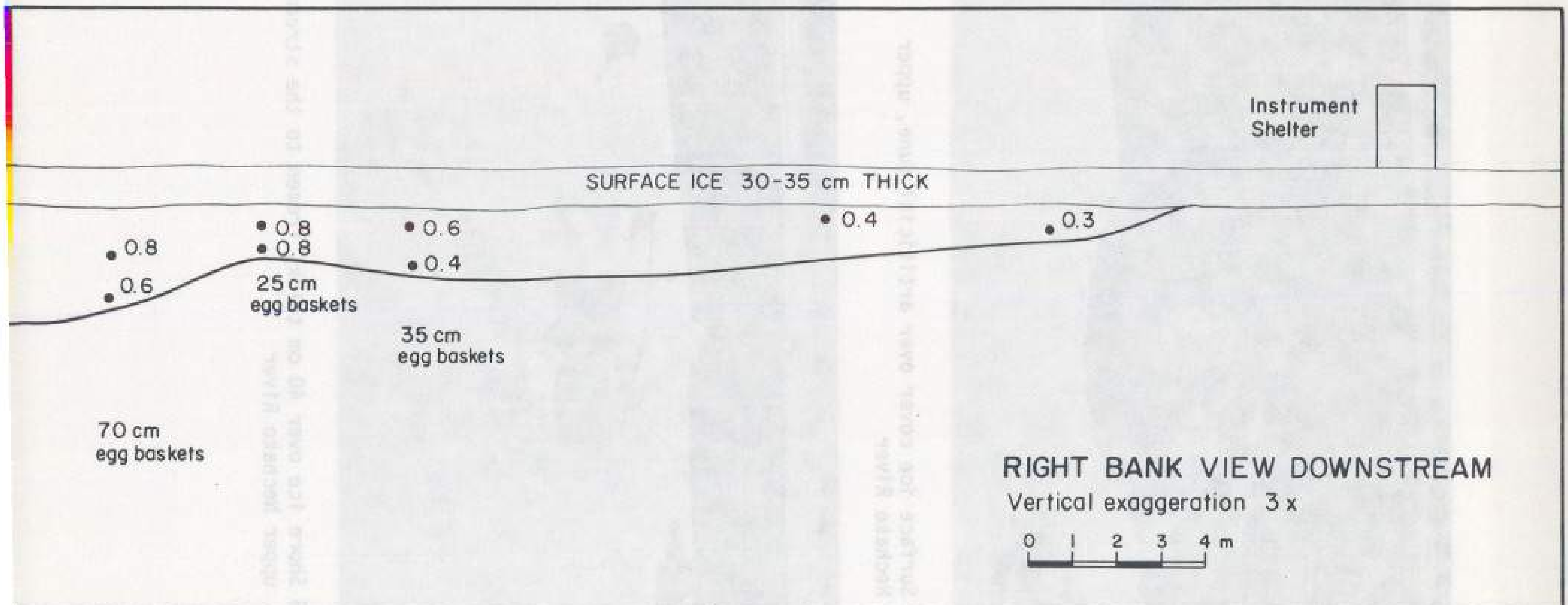


Figure 25 Velocity Under Ice Cover, Nechako River at Diamond Island, February, 1987 (velocity in m/s)

TABLE 1 - WATER SURVEY OF CANADA HYDROMETRIC STATIONS, NECHAKO RIVER

Station Name	Period of Record
Nechako River at Fort Fraser	1915-1953*
Nechako River at Isle Pierre	1950
Nechako River at Vanderhoof	1948- present*
Nechako River below Cheslatta Falls	1980- present
Nautley River near Fort Fraser	1950- present
Ootsa River at Ootsa Lake	1929-1952
Stuart River near Fort St. James	1929- present
Tetachuck River near Ootsa Lake	1930-1952

* Denotes presence of some gaps in the record

TABLE 2 - COMPOSITE MONTHLY PRE-IMPOUNDMENT NECHAKO RIVER FLOW SUMMARY, 1930-1942* (m^3/s)
(Water Survey of Canada, 1985)

	JAN.	FEB.	MAR.	NOV.	DEC.	Winter Mean
Maximum Recorded Mean Monthly	117.4	119.2	86.4	274.0	266.0	172
Mean Monthly	83.9	69.3	58.0	163.4	138.8	102.7
Minimum Recorded Mean Monthly	53.8	45.8	36.6	102.9	62.9	60.4

* Values based on Ootsa River at Ootsa Lake plus Tetachuck River near Ootsa Lake, the two major tributaries of the pre-regulated Nechako River.

TABLE 3 - MONTHLY FLOW SUMMARY - UPPER NECHAKO RIVER, 1957-1981* (m^3/s)

	JAN.	FEB.	MAR.	NOV.	DEC.	Winter Mean
Maximum Recorded Mean Monthly	274.9	249.3	293.1	319.3	239.5	275.2
Mean Monthly	79.9	79.3	81.4	133.0	89.3	92.6
Minimum Recorded Mean Monthly	13.3	14.9	16.3	24.9	14.9	16.9

* From Envirocon (1984), calculated discharges for Reach 1 (km 0-10).

TABLE 4 - MONTHLY FLOW SUMMARY - NECHAKO RIVER AT VANDERHOOF, 1956-1984 (m^3/s)
(Water Survey of Canada, 1985)

	JAN.	FEB.	MAR.	NOV.	DEC.	Winter Mean
Maximum Recorded Mean Monthly	292.0	259.0	314.0	339.0	282.0	297.2
Mean Monthly	82.8	81.1	86.4	131.0	92.7	94.8
Minimum Recorded Mean Monthly	16.9	13.2	16.8	10.8	9.5	13.4

TABLE 5 - MONTHLY FLOW SUMMARY - NECHAKO RIVER BELOW CHESLATTA FALLS, 1980-1985 (m^3/s)
(Water Survey of Canada 1985; 1986)

	JAN.	FEB.	MAR.	NOV.	DEC.	Winter Mean
Maximum Recorded Mean Monthly	38.6	37.4	37.9	41.5	36.4	38.4
Mean Monthly	34.8	34.4	34.2	34.9	33.6	34.4
Minimum Recorded Mean Monthly	30.7	31.8	31.6	31.4	31.0	31.3

TABLE 6 - STAGE AT NECHAKO RIVER BELOW CHESLATTA FALLS STATION, FOR VARIOUS FLOW REGIMES

	Minimum Recorded Mean Monthly	Mean Monthly	Maximum Recorded Mean Monthly
Natural Flows (1930-1942)	Q = 36.6 m^3/s S = 0.669 m	Q = 102.7 S = 1.004	Q = 274.0 S = 1.687
Regulated Flows (1957-1981)	Q = 13.3 S = 0.466	Q = 92.6 S = 0.961	Q = 345.8 S = 1.934
Injunction Flows (1980-1985)	Q = 31.0 S = 0.626	Q = 34.4 S = 0.653	Q = 60.6 S = 0.803
Short term Settlement			Q = 31.1 S = 0.627
Long term Settlement Flow			Q = 14.2 S = 0.476

TABLE 7 - MEAN MONTHLY AIR TEMPERATURE AT VANDERHOOF
(Atmospheric Environment Service, Monthly)

YEAR	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
1916	-	-11.2	-2.3	4.8	8.0	12.6	12.6	13.8	8.6	4.0	-4.9	-14.1
1917	-16.1	-12.8	-6.6	2.3	8.4	11.4	12.8	13.1	7.9	3.8	1.9	-17.9
1918	-11.1	-12.2	-6.7	2.6	6.9	10.5	14.2	12.5	10.9	3.8	-1.6	-8.5
1919	-8.5	-14.3	-7.7	4.4	6.5	9.5	13.6	13.3	11.3	-0.5	-8.5	-14.6
1920	-17.2	-8.5	-5.6	-1.2	6.5	10.4	15.6	12.0	10.3	6.0	-2.2	-7.1
1921	-11.3	-4.5	-4.1	2.9	7.8	11.5	11.6	12.3	10.6	8.2	-9.4	-13.4
1922	-14.9	-18.2	-6.0	2.4	7.4	12.3	13.9	14.4	11.0	4.8	-1.8	-11.0
1923	-14.3	-11.5	-4.8	3.5	9.2	13.6	14.4	15.1	9.4	9.3	0.3	-6.6
1924	-10.7	-5.5	-7.9	-0.1	8.8	13.0	14.6	13.3	10.7	2.8	-6.2	-17.4
1925	-12.1	-9.3	-4.4	2.5	10.1	12.6	15.1	12.8	9.4	-0.1	-2.3	-3.1
1926	-4.9	-0.5	-	-	-	-	14.4	13.5	0.1	-0.2	-4.1	-9.4
1927	-14.9	-6.9	-5.9	-	-	-	-	-	-	-	-	-19.7
1928	-12.0	-7.3	-2.4	2.4	10.2	14.6	15.1	13.3	9.9	3.2	-0.6	-9.0
1929	-14.0	-9.6	2.3	1.0	8.1	12.1	12.6	13.4	11.7	4.7	-1.1	-10.7
1930	-21.5	-5.8	-2.0	4.4	7.3	10.8	12.4	15.8	9.1	4.7	-	-0.5
1931	-5.2	-5.0	-3.3	5.0	5.0	11.0	12.9	13.2	9.8	3.1	-6.3	-
1932	-	-	-	-	-	-	-	-	-	-	-	-12.1
1933	-	-	-	-	-	-	-	-	-	-	-	-3.8
1934	-	-	-	-	-	-	-	-	-	-	-	-
1935	-17.1	-4.2	-6.0	-0.9	9.4	12.2	15.6	13.1	10.0	2.9	-6.0	-3.8
1936	-12.2	-24.6	-3.0	3.7	11.3	13.9	13.7	-	8.8	6.0	-1.8	-9.5
1937	-21.1	-12.2	-0.3	4.3	9.5	13.8	14.2	11.6	10.5	5.9	-4.5	-10.3
1938	-9.2	-11.4	-1.9	4.6	8.4	12.3	14.8	13.3	12.7	6.3	-3.7	-9.9
1939	-7.3	-12.1	-4.5	3.8	9.3	12.0	14.6	13.5	9.5	4.6	2.6	-2.2
1940	-10.8	-7.4	2.5	5.9	10.1	12.0	14.8	13.6	11.6	5.1	-7.8	-6.3
1941	-6.3	-5.8	0.3	8.9	9.0	14.1	16.5	15.7	10.1	6.8	-	-10.8
1942	-7.8	-6.3	-1.1	5.4	11.1	-	-	-	-	-	-	-
1943	-	-	-	-	-	-	-	-	-	-	-	-
1944	-	-	-	-	-	-	-	-	-	-	-	-
1945	-	-	-	-	-	-	-	-	-	-	-	-
1946	-	-	-	-	-	-	-	-	-	-	-	-
1947	-	-	-	-	-	-	-	-	-	-	-	-
1948	-	-	-	-	-	-	-	-	-	-	-	-
1949	-	-	-	-	-	-	-	-	-	-	-	-
1950	-	-	-	-	-	-	-	-	-	-	-	-

TABLE 7 - (Cont'd)

YEAR	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
1951	-	-	-	-	-	13.7	16.0	13.6	9.4	1.6	-3.1	-14.2
1952	-13.7	-8.2	-2.7	3.5	9.4	11.2	14.8	14.2	10.9	6.8	-1.8	-5.6
1953	-15.0	-3.0	-1.1	3.1	10.3	12.2	14.3	13.5	9.3	5.9	1.3	-5.1
1954	-17.6	-6.1	-5.6	-2.3	8.2	10.9	12.1	13.3	8.9	3.8	2.7	-6.6
1955	-8.3	-8.2	-8.4	1.9	6.6	11.8	14.2	11.2	9.0	3.1	-13.4	-16.8
1956	-17.5	-12.0	-3.6	3.6	10.0	11.0	14.8	14.3	9.5	2.2	-2.4	-9.9
1957	-22.2	-12.7	-1.9	4.1	10.6	12.0	12.2	11.0	11.0	1.3	0.1	-6.8
1958	-3.4	-7.6	-2.6	4.7	11.4	16.1	17.5	13.3	8.4	5.7	-4.8	-8.3
1959	-14.0	-10.4	0.4	3.8	8.1	11.7	13.8	10.5	8.6	3.3	-7.6	-3.9
1960	-11.1	-5.1	-3.0	5.0	7.2	11.2	15.1	12.3	8.5	5.0	-2.9	-9.8
1961	-8.2	-5.1	-0.4	4.2	9.1	13.8	15.8	15.0	7.6	3.9	-7.0	-12.1
1962	-11.3	-9.9	-4.8	-	7.3	10.3	14.5	13.2	9.1	5.4	0.3	-
1963	-11.3	-1.1	-0.6	3.9	8.5	11.7	-	15.3	11.8	5.7	-5.5	-8.5
1964	-7.5	-1.6	-3.7	-	-	12.7	13.4	-	8.2	5.1	-5.2	-17.3
1965	-12.0	-7.3	-4.2	3.8	8.7	11.8	15.8	15.5	8.9	5.7	-5.0	-9.5
1966	-16.0	-4.7	-	-	-	-	14.4	12.9	10.4	3.4	-6.0	-9.3
1967	-12.3	-4.3	-6.5	1.4	8.0	13.7	13.5	15.3	11.0	4.3	-1.6	-10.5
1968	-11.2	-9.7	0.3	3.2	8.5	10.2	14.6	12.2	8.6	3.4	-2.0	-15.8
1969	-26.4	-10.5	-1.4	5.0	9.7	15.9	13.8	11.5	9.7	3.2	0.8	-3.5
1970	-	-	-	-	7.6	13.2	13.1	12.8	7.8	4.1	-7.2	-14.8
1971	-14.0	-7.9	-5.5	3.5	8.7	12.0	15.6	14.1	7.5	2.3	-3.4	-18.5
1972	-20.1	-12.5	-1.4	1.2	9.6	11.7	13.5	13.6	7.0	3.0	-1.4	-13.3
1973	-13.0	-9.7	-1.6	3.8	8.8	10.7	13.1	11.1	8.6	2.8	-11.1	-9.2
1974	-18.3	-6.3	-3.9	4.2	7.0	11.0	12.3	14.0	10.3	4.9	-5.4	-6.4
1975	-13.7	-13.7	-5.0	2.0	7.8	11.2	15.7	11.9	9.5	3.6	-5.6	-10.0
1976	-10.2	-9.6	-4.0	3.7	7.9	10.3	13.0	13.3	9.6	3.5	-1.6	-5.5
1977	-9.2	-2.4	-1.4	5.6	8.2	12.1	13.4	15.2	8.1	4.0	-5.1	-17.4
1978	-12.6	6.4	-1.5	5.0	7.1	13.8	14.0	13.1	8.4	5.1	-7.0	-14.3
1979	-21.1	-15.4	-1.7	3.4	8.0	10.9	15.0	14.4	10.4	5.3	-5.1	-9.8
1980	-17.3	-7.7	-4.4	5.5	9.9	13.1	13.6	-	10.6	6.5	0.6	-8.8
1981	-3.2	-4.1	2.5	4.1	11.6	11.6	16.9	17.4	11.8	5.4	0.5	-9.2
1982	-17.5	-11.5	-4.0	1.8	9.5	17.3	16.8	14.4	12.3	5.5	-5.9	-9.0
1983	-6.7	-2.2	-0.4	6.3	12.5	12.9	15.3	15.2	9.1	5.1	-0.9	-18.0
1984	-5.2	0.1	2.4	5.2	8.0	12.8	15.4	15.0	8.1	2.1	-5.9	-15.3
1985	-7.1	-6.0	0.1	4.5	11.1	12.9	16.6	15.1	9.2	3.7	-14.9	-9.3
1986	-4.0	-10.5	2.1	4.3	9.2	13.5	15.4	16.2	9.3	7.2	-4.7	-7.2
$\bar{X}$	-12.5	-8.3	-2.8	3.5					9.5	4.3	-3.8	-10.2
n	57	58	56	53					58	58	56	59

TABLE 8 - SEASONAL TOTAL ACCUMULATED DEGREE DAYS BELOW 0°C AT VANDERHOOF (Atmospheric Environment Service, Monthly)

YEAR	START DATE	°DAYS Until Dec. 31	+	°DAYS After Jan. 1	END DATE	TOTAL
1916-17	OCT 1	598.1		1075.7	MAY 2	1673.8
17-18	OCT 14	609.2		924.1	APR 16	1533.3
18-19	NOV 5	334.5		918.1	APR 13	1252.6
19-20	OCT 13	792.9		1041.1	APR 14	1834.0
20-21	NOV 8	303.9		678.1	MAY 6	982.0
21-22	NOV 7	712.6		1172.5	APR 16	1885.1
22-23	OCT 26	411.0		920.5	MAR 29	1331.5
23-24	NOV 4	234.5		763.6	APR 27	998.1
24-25	OCT 17	732.6		798.4	APR 15	1531.0
28-29	OCT 10	331.7		815.1	APR 11	1146.8
29-30	OCT 27	384.4		958.2	MAR 23	1342.6
35-36	OCT 8	396.2		1262.6	APR 4	1658.8
36-37	OCT 30	392.5		1039.4	MAR 28	1431.9
37-38	OCT 28	491.2		715.7	APR 1	1206.9
38-39	NOV 5	443.5		791.1	APR 5	1234.6
39-40	OCT 5	140.1		560.6	MAR 23	700.7
40-41	OCT 26	447.5		468.5	MAR 25	916.0
52-53	OCT 25	258.9		630.1	APR 14	889.0
53-54	OCT 23	173.7		789.6	APR 30	963.3
54-55	NOV 6	228.7		776.4	APR 25	1005.1
55-56	OCT 18	937.7		488.8	APR 6	1426.5
56-57	OCT 18	467.1		1129.5	APR 12	1596.6
57-58	OCT 2	282.5		448.7	MAR 25	731.2
58-59	OCT 8	411.0		776.6	MAY 1	1187.6
59-60	OCT 7	386.9		643.6	MAR 29	1030.5
60-61	OCT 17	417.7		495.8	APR 14	913.5
61-62	OCT 9	611.8		827.6	MAR 28	1439.4
63-64	OCT 26	452.8		426.0	MAR 26	878.8
64-65	OCT 25	716.9		740.4	APR 20	1457.3
66-67	OCT 10	506.1		733.6	APR 19	1239.7
67-68	OCT 28	396.1		685.6	APR 12	1081.7
68-69	OCT 10	573.8		1195.2	APR 2	1769.0
70-71	OCT 5	691.5		842.8	APR 16	1534.3
71-72	OCT 15	728.0		1117.5	APR 17	1845.5

TABLE 8 - (Cont'd)

YEAR	START DATE	°DAYS	+	°DAYS	END DATE	TOTAL
1972-73	SEP 22	500.1		748.5	MAR 28	1248.6
73-74	OCT 19	618.6		893.8	APR 26	1512.4
74-75	OCT 28	366.6		994.1	APR 08	1360.7
75-76	OCT 25	506.2		749.9	APR 03	1256.1
76-77	OCT 14	246.7		424.0	MAR 30	670.7
77-78	OCT 19	711.3		671.1	APR 14	1382.4
78-79	OCT 26	682.9		1166.0	APR 13	1848.9
79-80	OCT 17	474.7		914.2	APR 08	1388.9
80-81	OCT 26	340.5		282.3	APR 12	622.8
81-82	OCT 21	325.7		1044.5	APR 15	1370.2
82-83	OCT 19	468.9		355.2	MAR 25	824.1
83-84	NOV 5	621.5		237.1	MAR 20	858.6
84-85	OCT 17	738.8		463.0	MAR 29	1201.8
85-86	OCT 7	738.5		460.9	APR 12	1199.4
Earliest	SEP 22				MAR 20	
Mean	OCT 20				APR 09	1258.2
Latest	NOV 08				MAY 06	

- based on mean daily temperature, using years with complete record
- based on analysis from Atmospheric Environment Service

TABLE 9 - MEAN MONTHLY AIR TEMPERATURE FOR NECHAKO RIVER AT IRVINE'S
(Unpublished Department of Fisheries and Oceans Data)

YEAR	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sept	Oct	Nov	Dec
1981								15.8				
1982												-9.5
1983	-8.2									4.0	-1.6	
1984	-7.1*	-0.8								0.3	-7.8	-18.2
1985	-10.5	-8.4	-2.0	2.3	8.4	10.6	15.0	13.2	8.0	2.1	-18.2	-12.8
1986	-7.5	-14.2	0.4	2.5	6.8	11.5	13.8	14.8	7.7	6.0	-6.8	-9.6

* indicates a data gap of more than 3 days in the daily record.

TABLE 10 - DIFFERENCE BETWEEN MEAN MONTHLY AIR TEMPERATURES RECORDED AT VANDERHOOF (Atmospheric Environment Service) AND AT IRVINE'S (Department of Fisheries and Oceans, Unpublished Data)

YEAR	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sept	Oct	Nov	Dec
1981								1.2				
1982												0.5
1983	1.5									1.1	0.7	-
1984	1.9	0.9								1.8	1.9	2.9
1985	3.4	2.4	2.1	2.2	2.7	2.3	1.6	1.9	1.2	1.6	3.3	3.5
1986	3.5	3.7	1.7	1.8	2.4	2.0	1.6	1.4	1.6	1.2	2.1	2.4

$\bar{x}$ = 2.0, range 0.7 to 3.7

n = 34

Note that temperatures are always lower at Irvine's.

TABLE 11 - RANK AND PLOTTING POSITION OF SEASONAL TOTAL ACCUMULATED DEGREE DAYS BELOW 0°C AT VANDERHOOF

RANK	PLOTTING POSITION	°DAYS	YEARS
1	.021	1885.1	1921-22
2	.041	1848.9	1978-79
3	.061	1845.5	1971-72
4	.082	1834.0	1919-20
5	.102	1769.0	1968-69
6	.122	1673.8	1916-17
7	.143	1658.8	1935-36
8	.163	1596.6	1956-57
9	.184	1534.3	1970-71
10	.204	1533.3	1917-18
11	.224	1531.0	1924-25
12	.245	1512.0	1973-74
13	.265	1457.3	1964-65
14	.286	1439.4	1961-62
15	.306	1431.9	1936-37
16	.326	1426.5	1955-56
17	.347	1388.9	1979-80
18	.367	1382.4	1977-78
19	.388	1370.2	1981-82
20	.408	1360.7	1974-75
21	.429	1342.6	1929-30
22	.449	1331.5	1922-23
23	.469	1256.1	1975-76
24	.490	1252.6	1918-19
25	.510	1248.6	1972-73
26	.531	1239.7	1966-67
27	.551	1234.6	1938-39
28	.571	1206.9	1937-38
29	.592	1201.8	1984-85
30	.612	1199.4	1985-86
31	.633	1187.6	1958-59
32	.653	1146.8	1928-29
33	.673	1081.7	1967-68
34	.694	1030.5	1959-60
35	.714	1005.1	1954-55
36	.735	998.1	1923-24

TABLE 11 (Cont'd)

RANK	PLOTTING POSITION	°DAYS	YEARS
37	.755	982.0	1920-21
38	.775	963.3	1953-54
39	.796	916.0	1940-41
40	.816	913.5	1960-61
41	.837	889.0	1952-53
42	.857	878.8	1963-64
43	.878	858.6	1983-84
44	.898	824.1	1982-83
45	.918	731.2	1957-58
46	.939	700.7	1939-40
47	.959	670.7	1976-77
48	.980	622.8	1980-81

Based on the Weibull plotting position formula N+1/m, from Chow (1964).

TABLE 12 - MEAN MONTHLY WATER TEMPERATURE - NECHAKO RIVER AT IRVINE'S
(Unpublished Department of Fisheries and Oceans Data)

YEAR	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
1980	-	-	-	-	-				13.4	10.0	5.7	1.7
1981	1.5*	0.9*	2.7	4.1	8.3				14.7	9.2	-	-
1982	0	0.1	0.3	1.8	5.4				14.2	9.9	4.4*	1.5*
1983	0.4	0.4	1.6	-	8.8				13.4	8.9	5.1	0.9*
1984	0	0.1	-	-	-				12.4	8.8	0.7*	0 *
1985	0.5	0.3	1.9	4.0*	8.6				13.0	8.6	2.5	0.5
1986	1.1	0.0	1.3	3.9	6.8				14.1	9.4	4.2	1.5
1987	1.2	1.2	2.1	4.3*	8.3				14.8*	10.0	6.0	2.0*
$\bar{x}$	0.7	0.4	1.7	3.6	7.7				13.8	9.4	4.1	1.2

Note: May - Aug temperatures recorded but not tabulated here.

* indicates a data gap of more than 3 days in daily record.

TABLE 13 - 1980 MEAN DAILY WATER TEMPERATURE -
NECHAKO RIVER AT IRVINE'S
(Unpublished Department of Fisheries and Oceans data)

	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
1									14.7	11.7	7.9	1.6
2									14.6	11.8	7.5	1.4
3									13.9	11.8	7.3	1.3
4									13.6	12.1	7.3	1.6
5									13.9	11.9	7.6	1.5
6									13.9	11.7	7.6	1.3
7									13.8	11.7	7.3	1.4
8									14.1	11.3	7.1	1.8
9									14.4	10.8	6.6	2.3
10									14.6	10.6	6.4	2.4
11									14.4	10.5	6.2	2.4
12									13.9	10.7	6.2	2.3
13									13.6	10.8	6.3	2.4
14									13.6	10.4	6.4	2.7
15									14.1	10.2	5.8	2.6
16									14.2	10.2	5.9	2.3
17									14.1	10.2	5.6	1.6
18									13.4	10.2	5.4	1.0
19									13.6	10.2	5.2	1.0
20									12.9	9.8	5.4	1.1
21									12.6	9.1	4.9	1.1
22									12.8	8.6	4.1	1.3
23									12.3	8.3	-	1.4
24									12.7	8.4	4.0	1.4
25									12.7	8.5	4.2	1.4
26									12.7	8.0	4.2	1.8
27									12.3	7.6	4.0	2.0
28									12.0	8.1	3.6	1.7
29									12.3	8.0	2.9	1.6
30									11.8	7.8	2.0	1.6
31										8.1	-	-
$\bar{x}$									13.4	10.0	5.7	1.7

- start of recording period - September

TABLE 14 - 1981 MEAN DAILY WATER TEMPERATURE -
NECHAKO RIVER AT IRVINE'S
(Unpublished Department of Fisheries and Oceans data)

	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
1	-	1.3	1.0	3.6					16.1	11.5	6.7	
2	-	1.4	1.9	3.6					15.9	11.2	6.4	
3	-	1.5	1.9	3.4					15.7	11.0	6.8	
4	-	1.3	1.7	3.4					15.9	11.0	6.3	
5	-	1.4	1.5	3.6					15.5	10.3	-	
6	-	1.6	2.1	3.3					16.4	10.6	-	no
7	-	1.4	2.1	3.8					16.6	10.8	-	data
8	-	1.5	1.9	3.8					17.1	10.4	-	
9	-	-	2.1	3.8					16.9	9.7	-	
10	-	0 B	2.1	3.6					16.0	10.1	-	
11	-	0 B	2.1	2.9					15.6	9.8	-	
12	1.6	-	2.2	3.4					15.3	9.7	-	
13	1.5	-	2.2	3.5					15.3	9.2	-	
14	1.6	-	2.8	3.9					14.6	9.6	-	
15	1.4	-	2.6	3.9					15.2	9.7	-	
16	1.5	-	2.6	3.9					15.3	9.4	-	
17	1.0	-	2.6	4.2					15.2	9.4	-	
18	1.3	-	2.5	4.2					15.1	9.2	-	
19	1.6	-	2.6	4.2					14.6	8.8	-	
20	1.7	-	2.6	4.2					14.3	7.9	-	
21	1.6	-	2.4	4.1					14.1	7.8	-	
22	1.6	-	2.8	4.7					13.9	7.9	-	
23	1.4	0 B	2.8	4.2					13.6	8.1	-	
24	1.4	0.3	2.9	4.3					13.2	8.8	-	
25	1.2	0.8	3.3	4.3					13.3	8.3	-	
26	1.4	0.6	3.3	4.9					12.5	7.8	-	
27	1.8	0.6	3.6	4.4					12.5	7.8	-	
28	1.9	0.8	3.6	5.1					12.5	7.8	-	0
29	2.0		3.5	5.1					12.5	7.1	-	0
30	1.4		3.2	5.1					12.2	6.9	-	0
31	1.1		3.8	5.3					12.2	7.2	-	0
$\bar{x}$	1.5*	0.9*	2.7	4.0					14.7	9.2	-	-

* indicates average including a data gap of more than 3 days

B - ice condition on adjacent Water Survey of Canada gauge

TABLE 15 - 1982 MEAN DAILY WATER TEMPERATURE -
NECHAKO RIVER AT IRVINE'S
(Unpublished Department of Fisheries and Oceans data)

	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
1	0B	0	0B	0.9					15.0	13.1	6.4	-
2	0B	0.3	0B	0.7					15.3	12.2	6.1	-
3	0B	0.3	0B	0.7					15.0	12.2	6.4	-
4	0B	0.1	0B	1.2					14.7	11.9	6.4	-
5	0B	0.3	0B	1.0					15.3	11.7	6.0	-
6	0B	0.1	0B	1.2					15.8	11.4	5.4	-
7	0B	0.3	0B	1.4					14.7	11.3	5.3	
8	0B	0	0	1.4					14.8	10.7	5.4	1.7
9	0B	0.3	0.1	1.0					14.6	11.4	5.3	1.7
10	0B	0	0.3	1.2					13.6	11.3	5.3	1.7
11	0B	0	0	1.4					13.4	10.8	4.7	1.5
12	0B	0B	0.2	1.6					13.3	10.7	4.7	1.4
13	0B	0B	0	1.6					13.6	11.0	4.2	1.4
14	0B	0B	0.3	1.4					13.3	11.1	4.2	1.5
15	0B	0B	0.3	1.6					13.9	10.8	4.4	1.5
16	0B	0B	0.3	1.8					14.1	10.4	4.3	1.8
17	0B	0	0.4	1.5					14.3	9.4	4.2	1.4
18	0B	0	0.5	1.9					14.3	9.0	3.6	1.7
19	0B	0	0.5	1.8					14.1	8.8	3.3	1.3
20	0B	0	0.6	2.1					14.4	8.8	2.5	1.4
21	0B	0	0.6	2.2					14.4	8.6	2.2	1.4
22	0B	0	0.7	1.9					14.3	8.6	1.7	1.4
23	0B	0B	0.6	2.2					14.1	8.2	1.5	1.1
24	0B	0B	0.5	2.6					13.9	8.3	1.8	1.1
25	0B	0B	0.5	2.8					-	8.6	-	1.4
26	0B	0B	0.7	2.9					-	8.6	-	1.1
27	0B	0B	0.6	2.3					-	7.9	-	
28	0B	0B	0.6	2.9					-	7.5	-	
29	0B		0.7	2.7					13.2	6.9	-	
30	0		1.0	2.9					12.9	7.2	-	
31	0		0.2							7.2	-	
$\bar{x}$	0	0.1	0.3	1.8					14.2	9.9	4.4*	1.5*

* indicates average including a data gap of more than 3 days

B - ice conditions on adjacent Water Survey of Canada gauge

TABLE 16 - 1983 MEAN DAILY WATER TEMPERATURE -
NECHAKO RIVER AT IRVINE'S
(Unpublished Department of Fisheries and Oceans data)

	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
1	-	0.6	1.0						16.5	11.3	6.9	-
2	-	0.3	0.7						16.0	10.6	6.9	2.8
3	0.8	0.3	0.5						16.0	11.0	6.7	2.8
4	0.8	0.3	1.0						15.3	10.7	6.9	2.5
5	0.7	0.3	1.0						14.3	10.4	6.4	2.5
6	0.7	0.3	1.0						14.2	10.4	6.4	2.5
7	0.6	0	0.8						14.0	10.0	6.7	1.4
8	0.6	0	0.8						14.0	10.0	6.7	1.1
9	0.4	0.1	1.5						14.0	9.6	5.6	1.4
10	0.3	0.3	1.4						13.8	9.4	5.3	1.7
11	0.4	0.3	1.7						13.8	9.6	5.7	1.9
12	0.8	0.3	1.7						13.9	9.7	5.8	1.7
13	0.4	0.3	1.7						14.3	9.6	5.8	1.9
14	0.6	0.3	1.7						14.2	8.9	5.6	2.5
15	0.4	0.3	1.9						13.9	8.3	5.3	1.1
16	0.4	0.3	1.5						13.5	-	5.3	0.3
17	0.6	0.6	1.7						12.8	-	5.3	0 B
18	0.7	0.6	1.7						12.5	8.3	5.3	0 B
19	0.7	0.3	1.8						12.4	8.3	4.7	0 B
20	0.6	0.4	1.7						12.9	8.2	4.7	0 B
21	0.3	0.3	1.4						13.1	8.5	3.9	0 B
22	0	0.6	1.4						12.9	8.1	3.8	0 B
23	0	0.8	1.5						12.9	7.4	3.9	0 B
24	0	1.0	1.8						12.6	7.4	3.9	0 B
25	0	0.7	1.9						12.6	7.5	3.9	0 B
26	0	0.7	1.9						12.1	7.8	3.6	0 B
27	0	0.7	2.4						11.3	7.2	3.6	0 B
28	0	0.7	2.2						11.3	7.5	3.1	0 B
29	0.1		2.4						11.1	7.2	3.3	0 B
30	0.4		2.9						11.0	7.5	3.1	0 B
31	0.4		2.8							7.5		0 B
$\overline{x}$	0.4	0.4	1.6	4.0					13.4	8.9	5.1	0.9*

* indicates average including a data gap of more than 3 days

B - ice conditions on adjacent Water Survey of Canada gauge

TABLE 17 - 1984 MEAN DAILY WATER TEMPERATURE -
NECHAKO RIVER AT IRVINE'S
(Unpublished Department of Fisheries and Oceans data)

	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
1	0 B	0							13.5	11.5	-	0 B
2	0 B	0.3							13.2	11.1	-	0 B
3	0 B	0.3							13.3	11.0	-	0
4	0 B	0							13.3	-	-	0
5	0	0							-	-	-	0
6	0	0.3							-	10.8	1.9	0
7	0	0.6							13.1	10.7	1.9	0
8	0	0.3							13.9	10.6	1.7	0
9	0	0.3							13.9	10.1	1.7	0
10	0	0							13.5	9.9	1.4	0
11	0	0.3							13.1	9.7	1.4	0 B
12	0	0.3							13.1	9.4	0.8	0 B
13	0	0							13.2	8.9	0.6	0 B
14	0	0							13.2	8.5	0.6	0 B
15	0 B	0							12.8	8.5	0.3	0 B
16	0 B	0							13.1	8.2	0.3	0 B
17	0 B	0							13.3	7.5	0.3	0 B
18	0 B	0							13.2	7.2	0.6	0 B
19	0 B	0.3							12.8	7.5	0.6	0 B
20	0 B	0							12.6	7.8	0.3	0 B
21	0 B	0							12.1	-	0	0 B
22	0 B	0							11.3	8.6	0.8	0 B
23	0	0							11.1	8.3	0.8	0 B
24	0	0							10.8	-	0.8	0 B
25	0	0							10.8	8.2	0.6	0 B
26	0	0							10.7	8.1	0.3	0 B
27	0	0.3							10.4	6.4	0.3	0 B
28	0	0.3							11.0	5.6	0 B	0 B
29	0	0.3							10.7	4.6	0 B	0 B
30	0								10.7	-	0 B	0 B
31	0											
$\bar{x}$	0	0.1							12.4	8.8*	0.7*	0 *

* indicates average including a data gap of more than 3 days

B - ice conditions on adjacent Water Survey of Canada gauge

TABLE 18 - 1985 MEAN DAILY WATER TEMPERATURE -
NECHAKO RIVER AT IRVINE'S
(Unpublished Department of Fisheries and Oceans data)

	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
1	0 B	0.3	1.1	2.8					15.3	11.7	6.4	0 B
2	0 B	0.6	1.4	2.8					15.3	11.4	6.4	0 B
3	0 B	0.6	1.1	2.5					15.6	11.1	5.8	0 B
4	0 B	0.3	1.1	2.8					15.0	10.8	5.6	0 B
5	0 B	0.3	1.1	3.3					13.9	11.1	5.3	0.8
6	0 B	0 B	1.4	3.3					13.1	10.3	5.6	0.8
7	0.3	0 B	1.4	3.3					13.6	9.7	5.3	0.8
8	0.6	0 B	1.4	3.6					13.6	9.4	4.4	0.6
9	0.6	0 B	1.7	-					13.6	9.7	3.1	0.6
10	0.6	0 B	1.7	-					13.6	9.7	3.1	0.6
11	0.6	0 B	1.4	-					13.6	9.7	3.1	0.8
12	0.6	0 B	1.7	-					13.6	9.4	3.1	0.6
13	0.6	0 B	1.7	-					13.6	9.4	3.1	0.6
14	0.6	0 B	1.4	-					13.3	9.4	3.1	0.6
15	0.6	0 B	1.7	-					13.1	8.9	3.1	0.8
16	0.8	0 B	2.2	-					12.8	8.6	2.5	0.8
17	0.6	0 B	2.5	-					12.8	8.6	1.4	0.8
18	0.6	0 B	2.2	4.4					12.5	8.6	1.4	0.8
19	1.1	0.3	2.5	4.2					12.5	8.3	1.4	0.8
20	0.8	0.3	2.2	4.4					12.5	8.1	-	0.8
21	0.8	0.6	2.5	4.4					11.9	8.3	0 B	0.8
22	1.1	0.6	2.2	4.7					11.9	8.3	0 B	0.8
23	0.8	0.8	1.4	4.7					11.9	7.8	0 B	0.8
24	0.8	0.6	2.5	4.7					11.9	7.5	0 B	0.3
25	0.3	0.6	2.2	4.7					11.9	7.2	0 B	0.3
26	0.8	0.8	2.5	4.7					11.7	7.2	0 B	0
27	0.8	1.1	2.5	4.7					11.4	6.9	0 B	0
28	0.3	0.8	2.5	4.7					11.4	6.7	0 B	0
29	0.3		2.2	5.0					11.4	6.7	0 B	0.3
30	0.3		2.2	4.4					-	6.7	0 B	0.3
31	0.3		2.2	5.0						6.4		0.3
$\bar{x}$	0.5	0.3	1.9	4.0*					13.0	8.6	2.5	0.5

* indicates average including a data gap of more than 3 days

B - ice conditions on adjacent Water Survey of Canada gauge

TABLE 19 - 1986 MEAN DAILY WATER TEMPERATURE -
NECHAKO RIVER AT IRVINE'S
(Unpublished Department of Fisheries and Oceans data)

	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
1	1.4	0.3	0 B	2.1					16.9	11.7	7.8	1.7
2	1.1	0	0 B	3.1					16.9		8.1	1.4
3	1.1	0B	0 B	3.3					16.4		8.3	1.4
4	1.1	0B	0 B	3.9					16.1		8.1	1.4
5	1.1	0B	0.9	3.3					16.1		7.8	1.4
6	1.1	0B	0.6	3.9					15.6		7.2	1.4
7	1.1	0B	0.6	3.9					15.6		5.6	1.4
8	1.1	0B	0.9	3.9					15.8		4.4	1.4
9	1.4	0B	0.5	3.9					15.3		4.2	1.4
10	1.4	0B	0.5	3.9					15.0	10.6	3.9	1.4
11	1.4	0B	0.5	3.1					14.7	10.6	3.9	1.4
12	1.1	0B	1.4	3.3					14.2		3.6	1.9
13	1.1	0B	1.4	3.9					13.9		4.2	2.2
14	1.1	0B	0.5	4.2					13.6	10.6	4.2	2.5
15	1.1	0B	1.4	4.2					13.6	10.0	4.2	1.7
16	1.1	0B	1.4	3.9					13.3	9.7	4.2	1.4
17	1.1	0B	1.4	4.2					13.3	9.4	3.3	1.4
18	1.1	0B	1.7	3.9					13.3	8.9	1.7	1.1
19	1.1	0B	1.7	3.6					12.8	9.4	2.2	1.1
20	0.8	0B	2.0	3.9					13.3	9.2	2.2	1.1
21	1.1	0B	1.7	3.9					13.3	8.9	2.8	1.4
22	1.1	0B	1.7	3.9					13.3	8.9	2.8	1.4
23	1.1	0B	1.7	3.6					13.3	8.6	3.3	1.4
24	1.1	0B	2.3	3.9					12.8	8.6	2.8	1.4
25	1.1	0B	1.7	4.2					12.8	8.9	2.8	1.4
26	1.1	0B	2.0	3.9					12.3	8.9	2.5	1.4
27	1.1	0B	2.6	4.4					12.3	8.6	2.5	1.4
28	1.1	0B	2.3	4.7					12.2	8.6	2.2	1.7
29	1.1		2.0	5.0					12.3	8.6	2.2	1.4
30	-		2.0	5.0					11.9	8.3	2.5	1.1
31	-		1.4							-		1.1
$\bar{x}$	1.1	0	1.3	3.9					14.1	9.4*	4.2	1.5

* indicates average including a data gap of more than 3 days

B - ice conditions on adjacent Water Survey of Canada gauge

TABLE 20 - 1987 MEAN DAILY WATER TEMPERATURE -
NECHAKO RIVER AT IRVINE'S
(Unpublished Department of Fisheries and Oceans data)

	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
1	1.4	0.8	1.4	3.6					15.0	-	7.5	3.6
2	1.7	0.8	1.1	3.6					15.3	13.3	6.9	3.3
3	1.4	0.8	0.8	3.6					15.0	13.1	7.5	3.3
4	1.1	0.8	1.4	3.6					15.6	12.5	7.5	3.1
5	0.8	1.1	1.7	3.6					15.6	12.5	7.8	3.1
6	0.8	1.4	1.9	3.9					15.6	12.2	7.5	3.1
7	0.8	1.4	1.9	3.1					15.3	12.2	7.2	2.8
8	1.4	1.4	1.9	-					15.8	11.7	7.5	2.8
9	1.9	1.4	1.4	-					16.1	11.4	7.2	3.1
10	1.7	1.4	1.1	-					15.8	11.4	7.2	2.5
11	1.4	1.4	1.4	-					16.1	11.4	6.9	2.2
12	1.4	1.7	1.4	-					15.6	10.8	6.7	1.7
13	1.7	2.2	1.7	-					14.7	10.8	6.7	1.4
14	1.7	1.1	2.2	-					14.7	10.6	6.4	1.4
15	1.7	1.1	2.5	3.1					13.9	10.3	6.1	1.4
16	1.1	1.1	2.2	3.6					14.2	10.3	5.0	1.4
17	1.1	1.1	2.2	3.6					13.9	9.7	5.0	1.4
18	1.7	1.1	1.9	3.6					13.9	9.7	5.3	1.4
19	1.4	1.4	1.9	3.6					13.9	9.7	5.3	1.7
20	1.4	1.4	2.2	3.9					13.9	9.7	5.6	1.7
21	1.4	1.1	2.2	4.7					13.9	9.2	5.6	1.4
22	1.1	1.4	2.2	4.7					13.9	8.6	5.3	0.8
23	0.8	1.1	2.5	4.7					14.2	8.9	4.7	-
24	0.8	0.8	2.8	4.7					13.9	8.9	4.7	-
25	0.8	1.1	2.8	4.7					13.6	8.6	4.4	-
26	0.8	1.1	2.5	4.7					-	8.3	4.7	-
27	0.8	0.8	2.8	5.3					-	8.6	4.7	-
28	0.8	-	2.5	5.0					-	8.6	4.4	-
29	0.8	-	3.1	5.6					-	8.9	4.4	-
30	-		3.6	5.3					-	8.9	3.9	0
31	-		3.3	-					-	8.6	-	0
$\bar{x}$	1.2	1.2	2.1	4.3*					14.8*	10.0	6.0	2.0*

* indicates average including a data gap of more than 3 days

B ice conditions on adjacent Water Survey of Canada gauge

TABLE 21 - WATER TEMPERATURE DECAY DATA

1400-1500 hrs, Dec 11/86 Overcast, no wind $Q = 34\ m^3/s$

	Ta	Tw		
Greer Creek (34 km)	-8.3	0°C	80' of shore ice	Some frazil slush flowing "but not much"
Big Valley Ranch (17 km)	-9.6	0.8°C	No shore ice	
Cutoff Creek (14 km)	-9.6	1.2°C	No shore ice	
Irvine's (10 km)	-8.6	1.3-1.4°C	No shore ice	
	$\overline{Ta} = -9.0$			
Above Cheslatta Falls 200-300' above highway bridge over Nechako		2.5°C	(1700 hrs)	

TABLE 22 - CALCULATION OF WATER TEMPERATURE DECAY
RATE FOR AVERAGE CONDITIONS

Date	Air Temp*	Recorded° Water Temp (km 10)	Reservoir Outlet Water Temp	Water Temperature at Distances Downstream of Cheslatta Falls: 8	12	20	35	70	100
							for Q = 1000 ft^3/s ($28.3\ m^3/s$)		
15 Oct	2.3	9.3	10.0	9.4	9.2	8.7	7.9	6.4	5.4
1 Nov	-2.2	6.6	7.4	6.8	6.4	5.8	4.8	2.9	1.7
15 Nov	-5.8	3.8	4.7	4.0	3.6	3.0	1.9	0	0
1 Dec	-9.0	2.4	3.5	2.6	2.2	1.4	0.1	0	0
15 Dec	-12.2	1.0	2.2	1.2	0.8	0	0	0	0
1 Jan	-13.4	0.8	2.1	1.1	0.5	0	0	0	0
15 Jan	-14.5	0.6	2.0	0.9	0.3	0	0	0	0
1 Feb	-12.4	0.5	1.7	0.7	0.3	0	0	0	0
15 Feb	-10.3	0.3	1.3	0.5	0.1	0	0	0	0
1 Mar	-7.6	1.0	1.8	1.2	0.8	0.3	0	0	0
							for Q = 500 ft^3/s ($14.2\ m^3/s$)		
15 Oct	2.3		10.0	9.2	8.9	8.2	7.2	5.4	4.4
1 Nov	-2.2		7.4	6.4	6.0	5.2	3.9	1.6	0.4
15 Nov	-5.8		4.7	3.6	3.2	2.3	0.8	0	0
1 Dec	-9.0		3.5	2.3	1.7	0.6	0	0	0
15 Dec	-12.2		2.2	0.8	0.1	0	0	0	0
1 Jan	-13.4		2.1	0.6	0	0	0	0	0
15 Jan	-14.5		2.0	0.4	0	0	0	0	0
1 Feb	-12.4		1.7	0.3	0	0	0	0	0
15 Feb	-10.3		1.3	0.1	0	0	0	0	0
1 Mar	-7.6		1.8	0.9	0.4	0	0	0	0
							for Q = 375 ft^3/s ($10.6\ m^3/s$)		
15 Oct	2.3		10.0	9.1	8.7	8.0	6.8	4.9	4.0
1 Nov	-2.2		7.4	6.3	5.8	4.9	3.4	1.1	0
15 Nov	-5.8		4.7	3.5	2.9	1.9	0.3	0	0
1 Dec	-9.0		3.5	2.1	1.4	0.2	0	0	0
15 Dec	-12.2		2.2	0.5	0	0	0	0	0
1 Jan	-13.4		2.1	0.3	0	0	0	0	0
15 Jan	-14.5		2.0	0.1	0	0	0	0	0
1 Feb	-12.4		1.7	0.1	0	0	0	0	0
15 Feb	-10.3		1.3	0	0	0	0	0	0
1 Mar	-7.6		1.8	0.7	0.2	0	0	0	0

* Based on long term average air temperture at Vanderhoof, -2°C correction for upper Nechako basin.

° Based on average water temperature for Nechako River at Irvine's, 1980-86.

TABLE 23 - CALCULATION OF WATER TEMPERATURE DECAY RATE FOR 1980-81

Date	Air Temp*	Recorded° Water Temp (km 10)	Reservoir Outlet Water Temp	Water Temperature at Distances Downstream of Cheslatta Falls 8	12	20	35	70	100
							for Q = 1000 ft^3/s (28.3 m^3/s)		
15 Nov	-1.4	5.6	6.3	5.7	5.5	5.0	4.2	2.7	1.7
1 Dec	-6.1	3.7	4.6	3.9	3.5	2.9	1.7	0	0
15 Dec	-10.8	1.7	2.9	1.9	1.5	0.6	0	0	0
1 Jan	-8.0	1.6	2.5	1.8	1.4	0.8	0	0	0
15 Jan	-5.2	1.5	2.1	1.6	1.4	0.9	0.2	0	0
1 Feb	-5.7	1.2	1.8	1.3	1.1	0.6	0	0	0
15 Feb	-6.1	0.9	1.6	1.0	0.8	0.3	0	0	0
1 Mar	-2.8	1.3	1.7	1.4	1.2	0.9	0.5	0	0
							for Q = 500 ft^3/s (14.2 m^3/s)		
15 Nov	-1.4		6.3	5.5	5.2	4.5	3.5	1.7	0.7
1 Dec	-6.1		4.6	3.5	3.0	2.1	0.7	0	0
15 Dec	-10.8		2.9	1.5	0.9	0	0	0	0
1 Jan	-8.0		2.5	1.5	1.0	0.1	0	0	0
15 Jan	-5.2		2.1	1.4	1.0	0.4	0	0	0
1 Feb	-5.7		1.8	1.1	0.7	0.1	0	0	0
15 Feb	-6.1		1.6	0.8	0.5	0	0	0	0
1 Mar	-2.8		1.7	1.3	1.0	0.7	0	0	0
							for Q = 375 ft^3/s (10.6 m^3/s)		
15 Nov	-1.4		6.3	5.4	5.0	4.3	3.1	1.2	0.3
1 Dec	-6.1		4.6	3.4	2.8	1.8	0.2	0	0
15 Dec	-10.8		2.9	1.3	0.6	0	0	0	0
1 Jan	-8.0		2.5	1.3	0.7	0	0	0	0
15 Jan	-5.2		2.1	1.3	0.9	0.2	0	0	0
1 Feb	-5.7		1.8	0.9	0.5	0	0	0	0
15 Feb	-6.1		1.6	0.7	0.3	0	0	0	0
1 Mar	-2.8		1.7	1.2	0.9	0.5	0	0	0

* Based on long term average air temperture at Vanderhoof, -2°C correction for upper Nechako basin.

° Based on average water temperature for Nechako River at Irvine's, 1980-86.

TABLE 24 - CALCULATION OF WATER TEMPERATURE DECAY RATE FOR 1984-85

Date	Air Temp*	Recorded Water Temp (km 10)	Reservoir Outlet Water Temp	Water Temperatures at Distances Downstream of Cheslatta Falls 8	12	20	35	70	100
						for Q = 1000 ft^3/s (28.3 m 3/5)			
15 Nov	-7.9	0.7	1.5	0.9	0.5	0	0	0	0
1 Dec	-12.6	0.4	1.6	0.6	0.2	0	0	0	0
15 Dec	-17.3	0	1.6	0.3	0	0	0	0	0
1 Jan	-13.2	0.3	1.6	0.5	0.1	0	0	0	0
15 Jan	-9.1	0.5	1.4	0.7	0.3	0	0	0	0
1 Feb	-8.6	0.4	1.2	0.6	0.2	0	0	0	0
15 Feb	-8.0	0.3	1.1	0.5	0.2	0	0	0	0
1 Mar	-5.0	1.1	1.7	1.2	1.0	0.6	0	0	0
						for Q = 500 $ft^3\$s$ (14.2 m^3/s)			
15 Nov	-7.9		1.5	0.6	0.1	0	0	0	0
1 Dec	-12.6		1.6	0.2	0	0	0	0	0
15 Dec	-17.3		1.6	0	0	0	0	0	0
1 Jan	-13.2		1.6	0.1	0	0	0	0	0
15 Jan	-9.1		1.4	0.4	0	0	0	0	0
1 Feb	-8.6		1.2	0.2	0	0	0	0	0
15 Feb	-8.0		1.1	0.2	0	0	0	0	0
1 Mar	-5.0		1.7	1.0	0.7	0.2	0	0	0
						for Q = 375 ft^3/s (10.6 m^3/s)			
15 Nov	-7.9		1.5	0.4	0	0	0	0	0
1 Dec	-12.6		1.6	0	0	0	0	0	0
15 Dec	-17.3		1.6	0	0	0	0	0	0
1 Jan	-13.2		1.6	0	0	0	0	0	0
15 Jan	-9.1		1.4	0.2	0	0	0	0	0
1 Feb	-8.6		1.2	0.1	0	0	0	0	0
15 Feb	-8.0		1.1	0.1	0	0	0	0	0
1 Mar	-5.0		1.7	0.9	0.6	0	0	0	0

* Based on long term average air temperture at Vanderhoof, -2°C correction for upper Nechako basin.

° Based on average water temperature for Nechako River at Irvine's, 1980-86.

TABLE 25 - CALCULATION OF WATER TEMPERATURE DECAY RATE FOR EXTREMELY COLD WINTER

Date	Air Temp*	Recorded° Water Temp (km 10)	Reservoir Outlet Water Temp	Water Temperature at Distances Downstream of Cheslatta Falls: 8	12	20	35	70	100
							for Q = 1000 ft^3/s ($28.3\ m^3/s$)		
15 Nov	-9.0	0.7	1.6	0.9	0.5	0	0	0	0
1 Dec	-12.7	0.4	1.6	0.6	0.2	0	0	0	0
15 Dec	-16.3	0	1.5	0.3	0	0	0	0	0
1 Jan	-19.7	0.3	2.2	0.7	0	0	0	0	0
15 Jan	-23.1	0.5	2.7	0.9	0.1	0	0	0	0
1 Feb	-20.3	0.4	2.3	0.8	0	0	0	0	0
15 Feb	-17.4	0.3	2.0	0.6	0	0	0	0	0
1 Mar	-10.6	1.1	2.2	1.3	0.9	0.1	0	0	0
							for Q = 500 ft^3/s ($14.2\ m^3/s$)		
15 Nov	-9.0		1.6	0.5	0.1	0	0	0	0
1 Dec	-12.7		1.6	0.2	0	0	0	0	0
15 Dec	-16.3		1.5	0	0	0	0	0	0
1 Jan	-19.7		2.2	0	0	0	0	0	0
15 Jan	-23.1		2.7	0.1	0	0	0	0	0
1 Feb	-20.3		2.3	0.1	0	0	0	0	0
15 Feb	-17.4		2.0	0.1	0	0	0	0	0
1 Mar	-10.6		2.2	0.9	0.3	0	0	0	0
							for Q = 375 ft^3/s ($10.6\ m^3/s$)		
15 Nov	-9.0		1.6	0.4	0	0	0	0	0
1 Dec	-12.7		1.6	0	0	0	0	0	0
15 Dec	-16.3		1.5	0	0	0	0	0	0
1 Jan	-19.7		2.2	0	0	0	0	0	0
15 Jan	-23.1		2.7	0	0	0	0	0	0
1 Feb	-20.3		2.3	0	0	0	0	0	0
15 Feb	-17.4		2.0	0	0	0	0	0	0
1 Mar	-10.6		2.2	0.7	0.1	0	0	0	0

* Based on long term average air temperture at Vanderhoof, -2°C correction for upper Nechako basin.

° Based on average water temperature for Nechako River at Irvine's, 1980-86.

TABLE 26 - COMPARISON OF MODELLED ACCUMULATED DEGREE DAYS (°C) AT DIFFERENT DISCHARGES FOR THE PERIOD NOV. 15 - MAR. 1

km 12

Discharge (cfs)	Long Term Avg. Conditions	Extremely Mild Conditions (1980-81)	Average Conditions (1984-85)	Extreme Cold Conditions
1000	132	252	36	24
500	81	204	12	6
375	68	180	10	1

km 35

Discharge (cfs)	Long Term Avg. Conditions	Extremely Mild Conditions (1980-81)	Average Conditions (1984-85)	Extreme Cold Conditions
1000	30	96	0	0
500	12	60	0	0
375	5	48	0	0

TABLE 27

Accumulated degree days or thermal units at Irvine's (ATU) 1985-86. Assumed peak spawning date: September 11/85 (Jaremovic and Rowland, 1987). Based on water temperatures Nechako River at Irvines's.

September 1985			October 1985			November 1985		
Date	°C	ATU	Date	°C	ATU	Date	°C	ATU
1			1	11.7	258.9	1	6.4	527.2
2			2	11.4	270.3	2	6.4	533.6
3			3	11.1	281.4	3	5.8	539.4
4			4	10.8	292.2	4	5.6	545.0
5			5	11.1	303.3	5	5.3	550.3
6			6	10.3	313.6	6	5.6	555.9
7			7	9.7	323.3	7	5.3	561.2
8			8	9.4	332.7	8	4.4	565.9
9			9	9.7	342.4	9	3.1	569.0
10			10	9.7	352.1	10	3.1	572.1
11	13.6	13.6	11	9.7	361.8	11	3.1	575.2
12	13.6	27.2	12	9.4	371.2	12	3.1	578.3
13	13.6	40.8	13	9.4	380.6	13	3.1	581.4
14	13.3	54.1	14	9.4	390.0	14	3.1	584.5
15	13.1	67.2	15	9.4	398.9	15	3.1	587.6
16	12.8	80	16	8.9	407.5	16	2.5	590.1
17	12.8	92.8	17	8.6	416.1	17	1.4	591.5
18	12.5	105.3	18	8.6	424.7	18	1.4	592.9
19	12.5	117.8	19	8.3	433.0	19	1.4	594.3
20	12.5	130.3	20	8.1	441.1	20	1.4	594.3
21	11.9	142.2	21	8.3	449.4	21	0	594.3
22	11.9	154.1	22	8.3	457.7	22	0	594.3
23	11.9	166.0	23	7.8	465.5	23	0	594.3
24	11.9	177.9	24	7.5	473.0	24	0	594.3
25	11.9	189.8	25	7.2	480.2	25	0	594.3
26	11.7	210.5	26	7.2	487.4	26	0	594.3
27	11.4	212.9	27	6.9	494.3	27	0	594.3
28	11.4	224.3	28	6.7	501.0	28	0	594.3
29	11.4	235.7	29	6.7	507.7	29	0	594.3
30	11.5E	247.2	30	6.7	514.4	30	0	594.3
			31	6.4	520.8			

TABLE 27 (Continued)

Accumulated degree days (ATU). Nechako River at Irvine's.

December 1985			January 1986			February 1986		
Date	°C	ATU	Date	°C	ATU	Date	°C	ATU
1	0	594.3	1	1.4	611.2	1	0.6	645.4
2	0	594.3	2	1.1	612.3	2	0	645.4
3	0	594.3	3	1.1	613.4	3	0.3	645.7
4	0	594.3	4	1.1	614.5	4	0.3	646.0
5	0.8	595.1	5	1.1	615.6	5	0	646.3
6	0.8	595.9	6	1.1	616.7	6	0.3	646.3
7	0.8	596.7	7	1.1	617.8	7	0.3	646.6
8	0.6	597.3	8	1.1	618.9	8	0	646.9
9	0.6	597.9	9	1.4	620.3	9	0	646.9
10	0.6	598.5	10	1.4	621.7	10	0	646.9
11	0.8	599.3	11	1.4	623.1	11	0	646.9
12	0.6	599.9	12	1.1	624.2	12	0	646.9
13	0.6	600.5	13	1.1	625.3	13	0	646.9
14	0.6	601.1	14	1.1	626.4	14	0	646.9
15	0.8	601.9	15	1.1	627.5	15	0	646.9
16	0.8	602.7	16	1.1	628.6	16	0	646.9
17	0.8	603.5	17	1.1	629.7	17	0	646.9
18	0.8	604.3	18	1.1	630.8	18	0	646.9
19	0.8	605.1	19	1.1	631.9	19	0	646.9
20	0.8	605.9	20	0.8	632.7	20	0	646.9
21	0.8	606.7	21	1.1	633.8	21	0	646.9
22	0.8	607.5	22	1.1	634.9	22	0	646.9
23	0.8	608.3	23	1.1	635.0	23	0	646.9
24	0.3	608.6	24	1.1	637.1	24	0	646.9
25	0.3	608.9	25	1.1	638.2	25	0	646.9
26	0	608.9	26	1.1	639.3	26	0	646.9
27	0	608.9	27	1.1	640.4	27	0	646.9
28	0	608.9	28	1.1	641.5	28	0.3	650.2
29	0.3	609.2	29	1.1	642.6			
30	0.3	609.5	30	1.1	643.7			
31	0.3	609.8	31	1.1	644.8			

TABLE 27 (Continued)

Accumulated degree days (ATU). Nechako River at Irvine's.

March 1986			April 1986		
Date	°C	ATU	Date	°C	ATU
1	1.1	651.3	1	3.1	710.3
2	0.8	652.1	2	3.1	713.4
3	1.4	653.5	3	3.3	716.7
4	1.4	654.9	4	3.9	720.6
5	1.4	656.3	5	3.3	723.9
6	1.1	657.4	6	3.9	727.8
7	1.1	658.5	7	3.9	731.7
8	1.4	659.9	8	3.9	735.6
9	1.0	660.9	9	3.9	739.5
10	1.0	661.9	10	3.9	743.4
11	1.0	662.9	11	3.1	747.5
12	1.9	664.8	12	3.3	750.8
13	1.9	666.7	13	3.9	754.7
14	1.0	667.7	14	4.2	758.9
15	1.9	669.6	15	4.2	763.1
16	1.9	671.5	16	3.9	767.0
17	1.9	673.4	17	4.2	771.2
18	2.2	675.6	18	3.9	775.1
19	2.2	677.8	19	3.6	778.7
20	2.5	680.3	20	3.9	782.6
21	2.2	682.5	21	3.9	786.5
22	2.2	684.7	22	3.9	790.4
23	2.2	686.9	23	3.6	794.0
24	2.8	689.7	24	3.9	797.9
25	2.2	691.9	25	4.2	802.1
26	2.5	694.4	26	3.9	806.0
27	3.1	697.5	27	4.4	810.4
28	2.8	700.3	28	4.7	915.1
29	2.5	702.8	29	5.0	820.1
30	2.5	705.3	30	5.0	825.1
31	1.9	707.2			

TABLE 28

Accumulated degree days at Irvine's, 1983-84 (Johansen, 1985)

September 1983			October 1983			November 1983		
Date	°C	ATU	Date	°C	ATU	Date	°C	ATU
1			1	10.4	188	1	6.8	419
2			2	10.1	198	2	4.9	424
3			3	8.9	207	3	5.8	430
4			4	9.7	216	4	6.2	436
5			5	9.5	226	5	4.9	441
6			6	9.5	234	6	3.8	445
7			7	8.3	243	7	4.6	449
8			8	8.9	252	8	5.0	454
9			9	8.9	260	9	4.3	459
10			10	7.6	268	10	3.1	463
11			11	8.3	276	11	2.7	466
12			12	10.1	285	12	4.2	470
13			13	9.3	294	13	4.4	474
14			14	7.5	302	14	4.3	479
15			15	5.9	309	15	3.5	482
16	12.6	12.6	16	6.9	315	16	4.1	487
17	12.8	25	17	5.7	321	17	3.5	490
18	12.1	37	18	8.4	329	18	4.2	495
19	12.4	49	19	6.0	336	19	3.7	499
20	12.7	61	20	6.5	343	20	2.4	501
21	13.3	75	21	7.3	350	21	2.3	504
22	14.3	89	22	6.8	357	22	1.5	506
23	14.7	103	23	6.5	364	23	0.6	507
24	13.8	116	24	5.3	369	24	0.6E	508
25	12.2	128	25	6.2	375	25	0.7E	509
26	13.3	141	26	5.9	381	26	0.8	511
27	9.0	150	27	4.9	387	27	1.0	512
28	9.3	160	28	5.8	393	28	0.5	513
29	8.8	169	29	6.2	399	29	1.1	514
30	9.4	178	30	5.8	405	30	0.6	515
			31	7.3	412			

* note that mean daily temperatures were rounded off before calculating ATU's.

TABLE 28 (con't)

Accumulated degree days at Irvine's, 1983-84 (Johansen, 1985)

December 1983			January 1984			February 1984		
Date	°C	ATU	Date	°C	ATU	Date	°C	ATU
1	0.2	516	1	-	526	1	0	533
2	0.3	516	2	-	526	2	0	533
3	0.3	517	3	-	526	3	0	533
4	0.3	518	4	-	527	4	0.1	533
5	0.3	519	5	-	527	5	0.1	533
6	0.3	519	6	-	527	6	0.1	533
7	0.1	519	7	-	528	7	0.2	533
8	0.1	519	8	0	528	8	0.4	533
9	0.1E	519	9	0	528	9	0.4	533
10	0.1	520	10	0	529	10	0.3	534
11	0.1	520	11	0	529	11	0.3	534
12	0.1	520	12	0	529	12	0.5	535
13	0.1	520	13	0	529	13	0.6	535
14	0.1	521	14	0	530	14	0.6	536
15	0.1	521	15	0	530	15	0.6	537
16	0.1	522	16	0	530	16	0.9	538
17	0.1	522	17	0	530	17	0.7	538
18	0.1	522	18	0	530	18	0.4	539
19	0.2	522	19	0	530	19	0.7	539
20	0.2	522	20	0	530	20	1.1	541
21	0.1	523	21	0	531	21	1.0	542
22	0	523	22	0	531	22	0.8	542
23	0	523	23	0	531	23	0.8	543
24	0.1	523	24	0	531	24	1.0	544
25	-	524	25	0	531	25	0.6	544
26	-	524	26	0	531	26	0.7	545
27	-	524	27	0	531	27	0.8	545
28	-	525	28	0	532	28	0.9	546
29	-	525	29	0	532	29	0.9	547
30	-	525	30	0	533	30		
31	-	526	31	0	533			

TABLE 28 (con't)

Accumulated degree days at Irvine's, 1983-84 (Johansen, 1985)

	March 1984	
Date	°C	ATU
1	1.2	548
2	1.1	550
3	1.2	551
4	1.0	552
5	1.9	554
6	1.7	555
7	1.8	557
8		
9		
10		
11		
12		
13		
14		
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16		
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21		
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24		
25		
26		
27		
28		
29		
30		
31		

TABLE 29

Accumulated degree days at Irvine's, 1984-85 (Jaremovic, 1986)

September 1984			October 1984			November 1984		
Date	°C	ATU	Date	°C	ATU	Date	°C	ATU
1			1	10.9	206.6	1	-	
2			2	11.1	217.7	2	-	
3			3	11.8	229.5	3	-	
4			4	11.2	240.7	4	-	
5			5	10.9	251.6	5	-	
6			6	10.9	262.5	6	-	
7			7	11.5	274.0	7	-	
8			8	11.0	285.0	8	-	
9			9	10.5	295.5	9	-	
10			10	10.3	305.8	10	-	
11			11	10.3	316.1	11	-	
12			12	9.8	325.9	12	-	
13			13	10.0	335.9	13	-	
14			14	9.0	344.9	14	-	531.7*
15	13.2	13.2	15	8.7	353.6	15	2.4	534.1
16	13.0	26.2	16	8.8	362.4	16	2.3	536.4
17	13.1	39.3	17	8.3	370.7	17	2.2	538.6
18	13.5	52.8	18	7.9	378.6	18	2.2	540.8
19	13.2	66.0	19	7.5	386.1	19	2.7	534.5
20	13.2	79.2	20	7.5	393.6	20	2.5	546.0
21	13.0	92.2	21	7.6	401.2	21	2.1	548.1
22	12.0	104.2	22	7.8	409.0	22	2.2	550.3
23	-		23	8.0	417.0	23	2.9	553.2
24	-		24	7.7	424.7	24	2.7	555.9
25	-		25	7.0	431.7	25	2.6	558.5
26	-		26	-		26	2.3	560.8
27	-		27	-		27	2.2	563.0
28	-		28	-		28	2.3	565.3
29	-	184.7*	29	-		29	2.2	567.5
30	11.0	195.7	30	-		30	2.0	569.5
31	-		31	-				

* estimated

TABLE 29 (cont'd)

December 1984			January 1985			February 1985		
Date	°C	ATU	Date	°C	ATU	Date	°C	ATU
1	2.3	571.8	1	0.2		1	0.5	622.8
2	2.1	573.9	2	0.2		2	-	
3	1.9	575.8	3	0.2	600.2	3	-	
4	1.6	577.4	4	0.3	600.3	4	-	
5	1.4	578.8	5	0.2	600.3	5	-	
6	1.7	580.5	6	0.4	600.5	6	-	
7	2.1	582.6	7	0.6	600.9	7	-	624.6
8	1.7	584.3	8	0.8	601.5	8	0.4	624.8
9	1.4	585.7	9	0.8	602.1	9	0.2	624.8
10	1.6	587.3	10	0.9	602.8	10	-	
11	1.4	588.7	11	0.7	603.3	11	0.3	624.9
12	1.7	590.4	12	0.8	603.9	12	0.2	624.9
13	1.5	591.9	13	0.9	604.6	13	0.4	625.1
14	1.4	593.3	14	1.1	605.7	14	0.6	625.5
15	1.2	594.5	15	1.2	606.9	15	0.9	626.2
16	0.3	594.6	16	1.3	608.2	16	0.6	626.6
17	0.4	594.8	17	1.3	609.5	17	0.6	627.2
18	0.3	594.9	18	0.9	610.2	18	0.9	627.9
19	0.4	595.1	19	1.3	611.5	19	1.3	629.2
20	0.8	595.7	20	1.3	612.8	20	1.1	630.3
21	0.8	596.3	21	1.2	644.0	21	1.0	631.3
22	0.7	596.8	22	1.4	615.4	22	1.7	633.0
23	0.7	597.3	23	1.4	616.8	23	1.5	634.5
24	0.6	597.7	24	1.3	618.1	24	1.4	635.9
25	1.4	599.1	25	0.9	618.8	25	1.1	637.0
26	1.0	600.1	26	0.8	619.4	26	1.3	638.3
27	0.3	600.2	27	0.9	620.1	27	1.9	640.2
28	0.2	600.2	28	0.9	620.8	28	2.0	642.2
29	0.2		29	0.9	621.5	29		
30	0.2		30	0.8	622.1	30		
31	0.2		31	0.6	622.5			

TABLE 29 (cont'd)

	March 1985			April 1985	
Date	°C	ATU	Date	°C	ATU
1	1.5	643.7	1	2.9	703.8
2	1.7	645.4	2	2.6	706.4
3	1.4	646.8	3	2.9	709.3
4	1.4	648.2	4	2.7	712.0
5	1.3	649.5	5	2.8	714.8
6	1.1	650.5	6	3.2	718.0
7	1.4	652.0	7	3.5	721.5
8	1.5	653.5	8	3.6	725.1
9	-	655.2*	9	3.8	728.9
10	-	657.0*			
11	2.0	659.0			
12	-	660.8			
13	-	662.9*			
14	1.8	664.7			
15	1.7	666.4			
16	1.9	668.3			
17	-	670.3*			
18	-	672.3*			
19	-	674.3*			
20	-	676.3*			
21	-	678.3*			
22	-	680.3*			
23	2.0	682.3			
24	1.6	683.9			
25	2.3	686.2			
26	2.3	688.5			
27	2.7	691.2			
28	2.7	693.9			
29	2.3	696.2			
30	2.0	698.2			
31	2.7	700.9			

* estimated

TABLE 30

ICE EFFECTS ON THE WATER SURVEY OF CANADA GAUGE - NECHAKO RIVER AT VANDERHOOF

	WSC ("Ice Conditions")* Start	End
1986-87	Nov. 8	Mar.31
1985-86	Nov. 6	Apr. 6
1984-85	Oct.27	Apr. 9
1983-84	Nov.16	Mar.29
1982-83	Nov.17	Apr.12
1981-82	Nov.28	Apr.24
1980-81	Nov.22	Mar.25
1979-80	Nov. 8	Apr.10
1978-79	Nov.11	Apr.11
1977-78	Nov.17	Apr. 7
1976-77	Jan. 1	Feb.20
1975-76	Nov.27	Apr.14
1974-75	Nov.22	Apr.18
1973-74	Nov. 3	Apr.12
1972-73	Nov.28	Apr. 6
1971-72	Nov.29	Apr.11
1970-71	Nov.20	Apr.22
1969-70	Dec.14	Apr. 3
1968-69	Dec. 4	Apr. 8
1967-68	Nov.25	Apr. 9
1966-67	Nov.27	Apr.16
1965-66	Nov.24	Apr. 1
1964-65	Nov.27	Apr.10
1963-64	Nov.17	Apr.20
1962-63	Dec.24	Apr. 7
1961-62	Nov.16	Apr.17
1960-61	Dec.15	Apr. 8
1959-60	Jan. 1	Apr. 6
1958-59	Dec. 6	Apr.12
1957-58	Dec.21	Mar.11
1956-57	Oct.29	Apr. 2
1955-56	-	Apr.20
Earliest	Oct.27	Feb.20
Mean	Nov.27	Apr. 7
Latest	Jan. 1	Apr.24

* Water Survey of Canada "ice conditions" indicates a station where the presence of ice has affected the stage-discharge relationship. The start of ice conditions will be frazil and border ice growth for a variable period of time before freeze up. End of ice conditions will occur when the river is clear of ice usually some period of time after actual breakup. These dates are interpreted qualitatively by Water Survey of Canada technicians from the stage recorder charts.

TABLE 31 - ICE EFFECTS AT WATER SURVEY OF CANADA GAUGE, NECHAKO RIVER BELOW CHESLATTA FALLS

Year	Dates	∑° Days for dates indicated	Ice Effect Postulated	Duration Days	
1980-81	Feb. 10 - 11	562.8 - 576.6	?	2	
	23 - 26	592.7 - 599	?	4	
1981-82	Dec. 28 - Jan. 29	247 - 855	Anchor/shore ice	32	
	Feb. 12 - 16	1007.6 - 1075.2	Full width	5	
	Feb. 23 - Mar. 6	1118 -	"	13	5
1982-83	Jan. 22 - Jan. 29	611 - 674	Anchor ice/shore ice	5	
1983-84	Dec. 17 - Dec. 31	286 - 621	Anchor ice/shore ice	15	
	Jan. 1 - 4	624 - 625	"	4	
	15 - 22	697 - 791	"	8	2
1984-85	Nov. 28 - Dec. 2	240 - 279.8	"	5	
	Dec. 11 - Dec. 31	345 - 738	Anchor/shore	21	
	Jan. 1 - 6	738 - 818	Shore ice	6	
	Feb. 6 - 18	1030 - 1157.2	Full width	13	4
1985-86	Nov. 21 - Dec. 4	212 - 520	Anchor/shore	13	
	Feb. 15 - 27	1010.8 - 1181.5	Full width	13	2

TABLE 32 - NECHAKO RIVER ICE COVER EXTENT OBSERVATIONS

Date	Position of Leading Edge (Km.)	Source	Vanderhoof $\sum°$ Days	Distance Above Vanderhoof Km.
Jan. 14/75	17	B.C. Gov't Aerial Photo	614.5	125
Dec. 19/79	10	Field Obs - K. Johansen		132
Feb. 12/82	10+	WSC Records	1008	132
Feb. 6/85	10+	WSC Records	1030	132
Nov. 21/85	72	Field Obs - S.P. Blachut	212.3	72
Jan. 28/86	35	Field Obs - S.P. Blachut	867.8	105
Feb. 15/86	10+	WSC Records	1030	132
Nov. 28/86	74	Field Obs - S.P. Blachut	164.3	68
Dec. 10/86	56	Aerial Obs - D. Calkins & S.P. Blachut	290.3	86

TABLE 33 - CALIBRATION OF NECHAKO RIVER FREEZE-UP 1985-86

Date	Tw	$\bar{T}a$	0°C Isotherm	°C Days	Leading Edge (Graph)	Adjusted Due to Melting (Approx.)
Nov. 1	5.0	-6.7	73			
15	1.0	-23.1	15	105	77	
Dec. 1	1.3	-12.0	22	451	43	
15	1.3	-6.7	29	631	36	
Jan. 1	1.2	-5.8	30	738	24*	28
15	1.1	-3.3	42	825	20*	38
Feb. 1	1.1	-8.8	24	878	15*	22
15	0.1	-13	12	1010	10	10
Mar. 1	1.00 1.8	-1	-	1181	5	10

* indicates melting of cover 0° isotherm not in correct location nor will the leading edge be correct.

TABLE 34 - PREDICTED PROGRESSION OF LEADING EDGE FOR 1984-85, POSITIONS IN KM BELOW CHESLATTA FALLS

Date	∑ °C Days	Leading Edge for Q = 1000	0°C Isotherm for Q = 1000	0°C Isotherm for Q = 500	Difference in 0°C Isotherm	Leading Edge for Q = 500
1 Nov.	101	88	-	-	-	-
15 Nov.	200	73	19	16	3	70
1 Dec.	273	65	13	11	2	63
15 Dec.	383	55	10	7	3	52
1 Jan.	761	31	9	6	3	28
15 Jan.	871	24	15	10	5	19
1 Feb.	974	20	16	9	7	13
15 Feb.	1147	18	16*	9*	7	11
1 Mar.	1163	25	31*	22*	9	16

TABLE 35 - PREDICTED PROGRESSION OF LEADING EDGE FOR 1980-81, POSITIONS IN KM BELOW CHESLATTA FALLS

Date	°C Days	Leading Edge for Q = 1000	0°C Isotherm for Q = 1000	0°C Isotherm for Q = 500	Difference in 0°C Isotherm	Leading Edge for Q = 500
1 Nov.	1	-				
15 Nov.	10	-	120	-	-	-
1 Dec.	60	-	60	42	18	-
15 Dec.	189	75	25?	18	7	68
1 Jan.	343	58	30	21	9	49
15 Jan.	407	53	38	26	14	39
1 Feb.	472	48	30	20	10	38
15 Feb.	588	40	25	17	8	32
1 Mar.	603	46	51*	36*	15	34

* melting of ice cover indicated when 0° Isotherm is downstream of leading edge

TABLE 36 - PREDICTED PROGRESSION OF LEADING EDGE
FOR EXTREMELY COLD WINTER

Date	∑ °C Days	Δ Leading Edge for Q = 1000	0°C Isotherm for Q = 1000	0°C Isotherm for Q = 500	Difference in 0°C Isotherm	Leading Edge for Q = 500
1 Nov.	4					
15 Nov.	63	-	-	-	-	
1 Dec.	257	67	13	8	5	62
15 Dec.	376	55	10	7	3	52
1 Jan.	712	33	11	8	3	30
15 Jan.	1136	13	11	8	3	10
1 Feb.	1357	13	11	8	3	10
15 Feb.	1582	13	11	8	3	10
1 Mar.	1779	17	20*	14*	6	12

Δ using 1978-79 air temperatures, 1984-85 water temperatures (see Table 26).

* melting of ice cover indicated when 0°C isotherm is downstream of leading edge

TABLE 37 - POSITION OF LEADING EDGE AT DIFFERENT DISCHARGES
DOWNSTREAM OF CHESLATTA FALLS

River Km - Position of Leading Edge $Q = 1000\ ft^3/s$

Date	1980-81	1984-85	Extremely Cold
Dec. 1	-	65	67
15	75	55	55
Jan. 1	58	31	33
15	53	24	13
Feb. 1	48	20	13
15	40	18	13
Mar. 1	46	25	17

River Km - Position of Leading Edge $Q = 500\ ft^3/s$

Date	1980-81	1984-85	Extremely Cold
Dec. 1	-	63	62
15	68	52	52
Jan. 1	49	28	30
15	39	19	10
Feb. 1	38	13	10
15	32	11	10
Mar. 1	34	19	12

TABLE 38 - WINTER/WATER QUALITY DATA, NECHAKO RIVER

SAMPLE LOCATION	DATE	TIME	WATER TEMP. (°C)	DISSOLVED OXYGEN (MG/L)	TOTAL GAS SATURATION (%)
Cheslatta Flats	18.11.85	1520	3.3	-	106.4
Cutoff Creek	18.11.85	1400	1.5	-	102.4
Above Cheslatta Falls	28.1.86	1350	1.0	-	98.2
Cheslatta Flats	28.1.86	1255	0.9	-	105.3
Irvine's	29.1.86	1450	1.0	-	104.0
Cutoff Creek	27.1.86	1455	1.4	-	103.2
Greer Creek	29.1.86	1630	0.5	-	100.0
Vanderhoof (Bond Bros.)	30.1.86	0950	0	-	98.6
Irvine's	4.11.86	1215	8.6	11.6	103.4
Cheslatta Flats	5.11.86	1730	6.5	-	103.4
Greer Creek	27.11.86	0945	1.5	11.7	100.3
Irvine's	27.11.86	1530	3.1	12.4	103.2
Irvine's	11.12.86	1510	1.7	10.0	104.4
Vanderhoof (Bond Bros.)	11.12.86	0900	0	10.5	-
Vanderhoof (Bond Bros.)	9.2.87	1530	0	11.0	-
Greer Creek	10.2.87	0920	1.6	10.8	101.1
Cheslatta Flats	25.3.87	1705	2.5	10.5	105.4
Irvine's	25.3.87	1400	3.1	12.5	105.9
Greer Creek	25.3.87	1210	2.7	10.5	102.4

APPENDIX 1

Data Recorded at Diamond Island, November, 1986 - March, 1987.

NOTE: These data were collected using a Montedoro-Whitney data logger. Depths were measured with a pressure transducer probe, with a 0 - 10 foot sensitivity range. Water temperatures were measured with thermistor probes, accurate to 0.1°C. The Temp 1 probe monitored bulk stream temperatures and the Temp 2 probe monitored shallow intragravel temperatures, 20 cm below the gravel surface in a chinook spawning dune. The dissolved oxygen probe was a Sensitron electrochemical sensor with temperature compensation. However, the sensor membrane is flow dependent and a minimum 0.5 ft/s is required for an accurate reading, and this high a flow rate was not experienced in the intragravel environment. Consequently, the absolute dissolved oxygen values appear to be inaccurate, but they can be interpreted in relative terms.

DATAMATE : Data Processing System : by Montedoro - Whitney : Page 2
Data from : WDM-8, Inst# 1, November 08, 1986
NECHAKO

Time	Depth m	Temp1 degC	Temp2 degC	dOxy1 mg/l
November 08, 1986				
00:00	0.540	0.367	0.244	10.397
06:00	0.534	0.244	0.611	7.013
12:00	0.531	0.000	0.611	8.483
18:00	0.515	-0.122	0.366	7.448
November 09, 1986				
00:00	0.519	-0.122	-0.122	8.057
06:00	0.523	-0.244	-0.244	6.689
12:00	0.534	-0.244	-0.244	8.989
18:00	0.528	-0.122	-0.122	7.489
November 10, 1986				
00:00	0.512	-0.122	-0.122	6.760
06:00	0.529	-0.122	0.000	6.892
12:00	0.541	-0.122	-0.122	5.878
18:00	0.556	-0.122	0.000	5.270
November 11, 1986				
00:00	0.548	-0.122	0.000	5.675
06:00	0.819	0.122	0.244	4.865
12:00	1.000	0.122	0.366	4.419
18:00	0.857	0.000	-0.122	5.057
November 12, 1986				
00:00	0.877	0.000	-0.122	4.945
06:00	0.900	0.000	-0.122	5.290
12:00	0.901	0.000	-0.122	5.199
18:00	0.930	0.000	-0.122	5.017
November 13, 1986				
00:00	0.944	0.000	-0.122	4.651
06:00	0.959	0.000	-0.122	4.419
12:00	0.962	0.000	-0.122	4.408
18:00	0.955	0.000	-0.122	4.358
November 14, 1986				
00:00	0.944	0.000	-0.122	4.561
06:00	0.956	0.000	-0.122	4.611
12:00	0.951	0.000	-0.122	4.509
18:00	0.947	0.000	-0.122	4.561

DATAMATE : Data Processing System : by Montedoro - Whitney : Page 3
Data from : WDM-8, Inst# 1, November 15, 1986
NECHAKO

Time	Depth m	Temp1 degC	Temp2 degC	dOxy1 mg/l
November 15, 1986				
00:00	0.931	0.122	0.000	5.017
06:00	0.887	0.244	0.244	5.290
12:00	0.823	0.733	0.733	5.300
18:00	0.661	1.588	1.465	6.881
November 16, 1986				
00:00	0.543	1.710	1.587	6.831
06:00	0.539	1.588	1.465	7.429
12:00	0.539	1.832	1.709	7.854
18:00	0.540	2.442	2.320	7.742
November 17, 1986				
00:00	0.539	2.320	2.320	7.550
06:00	0.539	2.076	1.954	6.851
12:00	0.526	1.466	1.465	7.063
18:00	0.524	0.977	0.977	7.256
November 18, 1986				
00:00	0.527	0.000	0.000	7.287
06:00	0.522	-0.122	-0.122	7.024
12:00	0.495	0.367	0.733	2.929
18:00	0.408	0.489	0.611	2.888
November 19, 1986				
00:00	0.426	0.244	0.733	3.030
06:00	0.366	0.244	0.611	2.959
12:00	0.735	0.122	0.122	2.200
18:00	0.903	-0.122	0.000	2.959
November 20, 1986				
00:00	0.873	0.000	0.000	2.625
06:00	0.945	0.000	-0.122	3.608
12:00	0.947	0.000	0.000	3.030
18:00	0.923	0.000	0.000	3.000
November 21, 1986				
00:00	0.935	0.000	0.000	2.918
06:00	0.959	0.000	0.000	2.797
12:00	0.941	0.000	0.000	2.848
18:00	0.917	0.000	0.000	2.929

Time	Depth m	Temp1 degC	Temp2 degC	dOxy1 mg/l
November 22, 1986				
00:00	0.951	0.000	0.000	2.868
06:00	0.984	0.000	0.000	2.766
12:00	0.984	0.000	0.000	2.756
18:00	0.959	0.000	0.000	2.777
November 23, 1986				
00:00	0.964	0.000	0.000	2.777
06:00	0.959	0.000	0.000	2.756
12:00	0.911	0.000	0.000	2.665
18:00	0.867	0.000	0.000	2.756
November 24, 1986				
00:00	0.855	0.000	0.000	2.777
06:00	0.881	0.000	0.000	2.777
12:00	0.869	0.000	0.000	2.766
18:00	0.838	0.000	0.000	2.726
November 25, 1986				
00:00	0.846	0.000	0.000	2.747
06:00	0.848	0.000	0.000	2.675
12:00	0.843	0.000	0.000	2.595
18:00	0.831	0.000	0.122	2.422
November 26, 1986				
00:00	0.769	0.367	0.366	2.523
06:00	0.644	0.489	0.489	3.638
12:00	0.547	0.977	0.855	7.783
18:00	0.535	1.221	1.099	10.053
November 27, 1986				
00:00	0.533	0.855	0.855	9.749
06:00	0.528	0.733	0.733	9.800
12:00	0.529	0.855	0.733	9.901
18:00	0.530	1.099	0.977	9.759
November 28, 1986				
00:00	0.530	1.099	0.977	9.111
06:00	0.522	0.733	0.611	9.364
12:00	%99999.00	999.999	%99999.00	999.999
18:00	%99999.00	999.999	%99999.00	999.999

Data from : WDM-8, Inst# 1, December 08, 1986
NECHAKO

Time	Depth m	Temp1 degC	Temp2 degC	dOxy1 mg/l
December 08, 1986				
00:00	%99999.00	999.999	%99999.00	999.999
06:00	%99999.00	999.999	%99999.00	999.999
12:00	%99999.00	999.999	%99999.00	999.999
18:00	%99999.00	999.999	%99999.00	999.999
December 09, 1986				
00:00	%99999.00	999.999	%99999.00	999.999
06:00	%99999.00	999.999	%99999.00	999.999
12:00	%99999.00	999.999	%99999.00	999.999
18:00	%99999.00	999.999	%99999.00	999.999
December 10, 1986				
00:00	%99999.00	999.999	%99999.00	999.999
06:00	%99999.00	999.999	%99999.00	999.999
12:00	%99999.00	999.999	%99999.00	999.999
18:00	1.170	0.000	-0.122	1.905
December 11, 1986				
00:00	1.163	0.000	-0.122	2.118
06:00	1.158	0.000	-0.122	2.159
12:00	1.144	0.000	0.000	2.280
18:00	1.133	0.000	-0.122	2.219
December 12, 1986				
00:00	1.160	0.000	-0.122	2.280
06:00	1.175	0.000	-0.122	2.138
12:00	1.161	0.000	-0.122	2.037
18:00	1.163	0.000	0.000	2.037
December 13, 1986				
00:00	1.159	0.000	-0.122	2.027
06:00	1.130	0.000	0.000	2.017
12:00	1.120	0.000	0.000	2.017
18:00	1.125	0.000	0.000	1.895
December 14, 1986				
00:00	1.133	0.000	0.000	1.905
06:00	1.125	0.000	-0.122	1.875
12:00	1.123	0.000	-0.122	1.774
18:00	1.134	0.000	0.000	1.794

DATAMATE : Data Processing System : by Montedoro - Whitney : Page 8
Data from : WDM-8, Inst# 1, December 15, 1986
NECHAKO

Time	Depth m	Temp1 degC	Temp2 degC	dOxy1 mg/l
December 15, 1986				
00:00	1.159	0.000	-0.122	1.875
06:00	1.128	0.000	0.000	1.885
12:00	1.114	0.000	0.000	1.926
18:00	1.121	0.000	0.000	1.936
December 16, 1986				
00:00	1.105	0.000	0.000	2.007
06:00	1.085	0.000	-0.122	2.239
12:00	1.071	0.000	-0.122	2.341
18:00	1.078	0.000	0.000	2.270
December 17, 1986				
00:00	1.073	0.000	-0.122	2.432
06:00	1.054	0.000	-0.122	2.493
12:00	1.047	0.000	0.000	2.523
18:00	1.053	0.000	-0.122	2.544
December 18, 1986				
00:00	1.055	0.000	-0.122	2.585
06:00	1.036	0.000	-0.122	2.645
12:00	1.018	0.000	0.000	2.777
18:00	1.023	0.000	0.000	2.898
December 19, 1986				
00:00	1.025	0.000	0.000	2.980
06:00	1.069	0.000	0.000	2.756
12:00	1.005	0.000	0.000	2.777
18:00	0.997	0.000	0.000	2.635
December 20, 1986				
00:00	0.993	0.000	0.000	2.787
06:00	0.982	0.000	0.000	2.726
12:00	0.973	0.000	0.000	2.544
18:00	0.984	0.000	0.000	2.371
December 21, 1986				
00:00	0.982	0.000	0.000	2.331
06:00	0.981	0.000	0.000	2.128
12:00	0.966	0.000	0.000	2.088
18:00	0.970	0.000	0.000	2.239

Time	Depth m	Temp1 degC	Temp2 degC	dOxy1 mg/l
December 22, 1986				
00:00	0.969	0.000	0.000	2.068
06:00	0.970	0.000	0.000	2.128
12:00	0.971	0.000	0.000	2.027
18:00	0.983	0.000	0.000	2.118
December 23, 1986				
00:00	1.022	0.000	0.000	2.210
06:00	0.990	0.000	0.000	2.260
12:00	0.973	0.000	0.000	2.229
18:00	0.980	0.000	0.000	2.078
December 24, 1986				
00:00	0.978	0.000	0.000	2.149
06:00	0.969	0.000	0.000	2.210
12:00	0.953	0.000	0.000	2.351
18:00	0.967	0.000	0.000	2.229
December 25, 1986				
00:00	0.955	0.000	0.000	2.422
06:00	0.948	0.000	0.000	2.371
12:00	0.943	0.000	0.000	2.392
18:00	0.955	0.000	0.000	2.341
December 26, 1986				
00:00	0.939	0.000	0.000	2.585
06:00	0.929	0.000	0.000	2.371
12:00	0.936	0.000	0.000	2.210
18:00	0.937	0.000	0.000	2.189
December 27, 1986				
00:00	0.920	0.000	0.000	2.443
06:00	0.912	0.000	0.000	2.453
12:00	0.917	0.000	0.000	2.068
18:00	0.925	0.000	0.000	2.097
December 28, 1986				
00:00	0.917	0.000	0.000	2.108
06:00	0.912	0.000	0.000	2.007
12:00	0.913	0.000	0.000	1.844
18:00	0.920	0.000	0.000	1.844

Time	Depth m	Temp1 degC	Temp2 degC	dOxy1 mg/l
December 29, 1986				
00:00	0.915	0.000	0.000	2.128
06:00	0.910	0.000	0.000	2.138
12:00	0.903	0.000	0.000	2.149
18:00	0.907	0.000	0.000	1.895
December 30, 1986				
00:00	0.900	0.000	0.000	2.138
06:00	0.897	0.000	0.000	2.280
12:00	0.886	0.000	0.000	2.270
18:00	0.875	0.000	0.000	2.412
December 31, 1986				
00:00	0.829	0.000	0.000	2.513
06:00	0.771	0.000	0.000	2.321
12:00	0.742	0.000	0.000	2.331
18:00	0.759	0.000	0.000	2.280

Time	Depth m	Temp1 degC	Temp2 degC	dOxy1 mg/l
January 01, 1987				
00:00	0.876	0.000	0.000	2.301
06:00	0.879	0.000	0.000	2.229
12:00	0.881	0.000	0.000	2.229
18:00	0.901	0.000	0.000	2.270
January 02, 1987				
00:00	0.911	0.000	0.000	2.381
06:00	0.875	0.000	0.000	2.513
12:00	0.860	0.000	0.000	2.463
18:00	0.820	0.000	0.000	2.371
January 03, 1987				
00:00	0.884	0.000	0.000	2.341
06:00	0.846	0.000	0.000	2.239
12:00	0.895	0.000	0.000	2.210
18:00	0.906	0.000	0.000	2.260
January 04, 1987				
00:00	0.936	0.000	0.000	2.432
06:00	0.901	0.000	0.000	2.523
12:00	0.895	0.000	0.000	2.503
18:00	0.917	0.000	0.000	2.513
January 05, 1987				
00:00	0.883	0.000	0.000	2.523
06:00	0.864	0.000	0.000	2.453
12:00	0.861	0.000	0.000	2.443
18:00	0.812	0.000	0.000	2.371
January 06, 1987				
00:00	0.826	0.000	0.000	2.443
06:00	0.787	0.000	0.000	2.371
12:00	0.808	0.000	0.000	2.412
18:00	0.846	0.000	0.000	2.473
January 07, 1987				
00:00	0.871	0.000	0.000	2.625
06:00	0.838	0.000	0.000	2.564
12:00	0.811	0.000	0.000	2.554
18:00	0.822	0.000	0.000	2.564

Data from : WDM-8, Inst# 1, January 08, 1987
NECHAKO

Time	Depth m	Temp1 degC	Temp2 degC	dOxy1 mg/l
January 08, 1987				
00:00	0.843	0.000	0.000	2.665
06:00	0.852	0.000	0.000	2.747
12:00	0.829	0.000	0.000	2.696
18:00	0.817	0.000	0.000	2.605
January 09, 1987				
00:00	0.863	0.000	0.000	2.675
06:00	0.850	0.000	0.000	2.747
12:00	0.853	0.000	0.000	2.635
18:00	0.869	0.000	0.000	2.625
January 10, 1987				
00:00	0.891	0.000	0.000	2.605
06:00	0.881	0.000	0.000	2.513
12:00	0.880	0.000	0.000	2.443
18:00	0.897	0.000	0.000	2.280
January 11, 1987				
00:00	0.918	0.000	0.000	2.301
06:00	0.929	0.000	0.000	2.402
12:00	0.929	0.000	0.000	2.321
18:00	0.932	0.000	0.000	2.138
January 12, 1987				
00:00	0.945	0.000	0.000	2.260
06:00	0.911	0.000	0.000	2.229
12:00	0.923	0.000	0.000	2.189
18:00	0.921	0.000	0.000	2.108
January 13, 1987				
00:00	0.933	0.000	0.000	2.159
06:00	0.904	0.000	0.000	2.260
12:00	0.902	0.000	0.000	2.311
18:00	0.911	0.000	0.000	2.311
January 14, 1987				
00:00	0.899	0.000	0.000	2.381
06:00	0.889	0.000	0.000	2.422
12:00	0.887	0.000	0.000	2.463
18:00	0.884	0.000	0.000	2.473

Time	Depth m	Temp1 degC	Temp2 degC	dOxy1 mg/l
January 15, 1987				
00:00	0.875	0.000	0.000	2.544
06:00	0.865	0.000	-0.122	2.523
12:00	0.849	0.000	0.000	2.422
18:00	0.853	0.000	0.000	2.371
January 16, 1987				
00:00	0.882	0.000	0.000	2.371
06:00	0.882	0.000	0.000	2.250
12:00	0.913	0.000	0.000	2.210
18:00	0.929	0.000	0.000	2.210
January 17, 1987				
00:00	0.934	0.000	0.000	2.200
06:00	0.925	0.000	0.000	2.159
12:00	0.922	0.000	0.000	2.027
18:00	0.931	0.000	0.000	1.844
January 18, 1987				
00:00	0.951	0.000	0.000	1.916
06:00	0.931	0.000	0.000	1.946
12:00	0.921	0.000	0.000	1.885
18:00	0.923	0.000	0.000	1.905
January 19, 1987				
00:00	0.915	0.000	0.000	2.058
06:00	0.900	0.000	0.000	2.159
12:00	0.889	0.000	0.000	2.149
18:00	0.861	0.000	0.000	2.128
January 20, 1987				
00:00	0.892	0.000	0.000	2.138
06:00	0.899	0.000	0.000	2.027
12:00	0.913	0.000	0.000	1.996
18:00	0.937	0.000	0.000	1.986
January 21, 1987				
00:00	0.937	0.000	0.000	2.159
06:00	0.917	0.000	0.000	2.169
12:00	0.920	0.000	0.000	2.068
18:00	0.924	0.000	0.000	2.037

Time	Depth m	Temp1 degC	Temp2 degC	dOxy1 mg/l
January 22, 1987				
00:00	0.909	0.000	0.000	2.169
06:00	0.915	0.000	0.000	2.189
12:00	0.912	0.000	0.000	2.169
18:00	0.916	0.000	0.000	2.138
January 23, 1987				
00:00	0.911	0.000	0.000	2.200
06:00	0.909	0.000	0.000	2.210
12:00	0.909	0.000	0.000	2.250
18:00	0.911	0.000	0.000	2.189
January 24, 1987				
00:00	0.909	0.000	0.000	2.179
06:00	0.906	0.000	0.000	2.250
12:00	0.900	0.000	0.000	2.290
18:00	0.903	0.000	0.000	2.200
January 25, 1987				
00:00	0.923	0.000	0.000	2.270
06:00	0.900	0.000	0.000	2.331
12:00	0.886	0.000	0.000	2.341
18:00	0.842	0.000	0.000	2.290
January 26, 1987				
00:00	0.902	0.000	0.000	2.432
06:00	0.855	0.000	0.000	2.443
12:00	0.859	0.000	0.000	2.402
18:00	0.885	0.000	0.000	2.331
January 27, 1987				
00:00	0.928	0.000	0.000	2.402
06:00	0.892	0.000	0.000	2.341
12:00	0.885	0.000	0.000	2.301
18:00	0.895	0.000	0.000	2.321
January 28, 1987				
00:00	0.897	0.000	0.000	2.301
06:00	0.897	0.000	0.000	2.270
12:00	0.894	0.000	0.000	2.108
18:00	0.905	0.000	0.000	2.159

Data from : WDM-8, Inst# 1, January 29, 1987
NECHAKO

Time	Depth m	Temp1 degC	Temp2 degC	dOxy1 mg/l
January 29, 1987				
00:00	0.949	0.000	0.000	2.331
06:00	0.939	0.000	0.000	2.290
12:00	0.927	0.000	0.000	2.270
18:00	0.940	0.000	0.000	2.169
January 30, 1987				
00:00	0.977	0.000	0.000	2.250
06:00	0.949	0.000	0.000	2.280
12:00	0.927	0.000	0.000	2.229
18:00	0.956	0.000	0.000	2.229
January 31, 1987				
00:00	0.977	0.000	0.000	2.361
06:00	0.945	0.000	0.000	2.402
12:00	0.946	0.000	0.000	2.290
18:00	0.949	0.000	0.000	2.311

Data from : WDM-8, Inst# 1, February 01, 1987
NECHAKO

Time	Depth m	Temp1 degC	Temp2 degC	dOxy1 mg/l
February 01, 1987				
00:00	0.934	0.000	0.000	2.544
06:00	0.920	0.000	0.000	2.645
12:00	0.919	0.000	0.000	2.635
18:00	0.895	0.000	0.000	2.564
February 02, 1987				
00:00	0.914	0.000	0.000	2.493
06:00	0.873	0.000	0.000	2.615
12:00	0.861	0.000	0.000	2.574
18:00	0.873	0.000	0.000	2.503
February 03, 1987				
00:00	0.934	0.000	0.000	2.635
06:00	0.941	0.000	0.000	2.696
12:00	0.915	0.000	0.000	2.665
18:00	0.903	0.000	0.000	2.615
February 04, 1987				
00:00	0.940	0.000	0.000	2.706
06:00	0.931	0.000	0.000	2.817
12:00	0.907	0.000	0.000	2.706
18:00	0.902	0.000	0.000	2.554
February 05, 1987				
00:00	0.948	0.000	0.000	2.605
06:00	0.952	0.000	0.000	2.635
12:00	0.939	0.000	0.000	2.483
18:00	0.945	0.000	0.000	2.422
February 06, 1987				
00:00	0.974	0.000	0.000	2.443
06:00	0.959	0.000	0.000	2.432
12:00	0.959	0.000	0.000	2.412
18:00	0.974	0.000	0.000	2.361
February 07, 1987				
00:00	0.982	0.000	0.000	2.392
06:00	0.968	0.000	0.000	2.392
12:00	0.967	0.000	0.000	2.381
18:00	0.982	0.000	0.000	2.351

Time	Depth m	Temp1 degC	Temp2 degC	dOxy1 mg/l
February 08, 1987				
00:00	0.981	0.000	0.000	2.402
06:00	0.971	0.000	0.000	2.321
12:00	0.967	0.000	0.000	2.200
18:00	0.967	0.000	0.000	2.361
February 09, 1987				
00:00	0.961	0.000	0.000	2.432
06:00	0.963	0.000	0.000	2.412
12:00	0.962	0.000	0.000	2.381
18:00	0.967	0.000	0.000	2.270
February 10, 1987				
00:00	0.970	0.000	0.000	2.412
06:00	0.000	0.000	0.000	2.432
12:00	0.970	0.000	0.000	2.381
18:00	0.967	0.000	0.000	2.392
February 11, 1987				
00:00	0.967	0.000	0.000	2.422
06:00	0.969	0.000	0.000	2.432
12:00	0.966	-0.122	-0.122	1.743
18:00	0.971	0.000	0.000	2.128
February 12, 1987				
00:00	0.965	0.000	0.000	2.189
06:00	0.966	0.000	0.000	2.219
12:00	0.962	0.000	0.000	2.290
18:00	0.967	0.000	0.000	2.371
February 13, 1987				
00:00	0.964	0.000	0.000	2.422
06:00	0.962	0.000	0.000	2.392
12:00	0.962	0.000	0.000	2.229
18:00	0.962	0.000	0.000	2.270
February 14, 1987				
00:00	0.972	0.000	0.000	2.341
06:00	0.976	0.000	0.000	2.361
12:00	0.975	0.000	0.000	2.331
18:00	0.977	0.000	0.000	2.402

Data from : WDM-8, Inst# 1, February 15, 1987
NECHAKO

Time	Depth m	Temp1 degC	Temp2 degC	dOxy1 mg/l
February 15, 1987				
00:00	0.971	0.000	0.000	2.503
06:00	0.968	0.000	0.000	2.523
12:00	0.967	0.000	0.000	2.422
18:00	0.979	0.000	0.000	2.290
February 16, 1987				
00:00	0.969	0.000	0.000	2.270
06:00	0.971	0.000	0.000	2.301
12:00	0.971	0.000	0.000	2.280
18:00	0.976	0.000	0.000	2.331
February 17, 1987				
00:00	0.976	0.000	0.000	2.290
06:00	0.970	0.000	0.000	2.392
12:00	0.974	0.000	0.000	2.402
18:00	0.974	0.000	0.000	2.341
February 18, 1987				
00:00	0.974	0.000	0.000	2.432
06:00	0.970	0.000	0.000	2.432
12:00	0.969	0.000	0.000	2.381
18:00	0.974	0.000	0.000	2.270
February 19, 1987				
00:00	0.973	0.000	0.000	2.229
06:00	0.967	0.000	0.000	2.250
12:00	0.975	0.000	0.000	2.179
18:00	0.993	0.000	0.000	2.007
February 20, 1987				
00:00	0.983	0.000	0.000	2.007
06:00	0.984	0.000	0.000	2.108
12:00	0.987	0.122	0.122	2.047
18:00	0.982	0.244	0.122	1.824
February 21, 1987				
00:00	0.951	0.122	0.122	1.794
06:00	0.931	0.244	0.122	1.794
12:00	0.847	0.244	0.122	1.946
18:00	0.705	0.244	0.122	1.541

Data from : WDM-8, Inst# 1, February 22, 1987
NECHAKO

Time	Depth m	Temp1 degC	Temp2 degC	dOxy1 mg/l
February 22, 1987				
00:00	0.644	0.244	0.122	1.611
06:00	0.627	0.244	0.122	1.510
12:00	0.615	0.244	0.244	1.480
18:00	0.605	0.489	0.366	1.418
February 23, 1987				
00:00	0.594	0.489	0.366	1.936
06:00	0.589	0.122	0.244	2.270
12:00	0.588	0.489	0.366	2.371
18:00	0.575	0.855	0.733	2.402
February 24, 1987				
00:00	0.564	0.367	0.366	2.828
06:00	0.592	0.000	0.000	3.851
12:00	0.597	0.122	0.122	2.756
18:00	0.552	0.489	0.489	2.645
February 25, 1987				
00:00	0.562	0.000	0.000	2.777
06:00	0.609	0.000	0.000	3.709
12:00	0.586	0.122	0.000	3.030
18:00	0.567	0.367	0.244	3.060
February 26, 1987				
00:00	0.553	0.122	0.000	2.959
06:00	0.555	0.000	0.000	2.868
12:00	0.553	0.244	0.122	2.828
18:00	0.559	0.367	0.366	2.787
February 27, 1987				
00:00	0.551	0.000	0.000	3.344
06:00	0.602	0.000	0.000	3.932
12:00	0.567	0.244	0.122	4.966
18:00	0.539	0.122	0.122	4.672
February 28, 1987				
00:00	0.555	0.000	0.000	3.132
06:00	0.563	0.000	0.000	3.324
12:00	0.562	0.122	0.000	3.243
18:00	0.564	0.244	0.122	3.152

Time	Depth m	Temp1 degC	Temp2 degC	dOxy1 mg/l
March 01, 1987				
00:00	0.593	0.000	-0.122	3.486
06:00	0.600	0.000	-0.122	3.567
12:00	0.567	0.244	0.122	3.537
18:00	0.576	0.000	0.000	3.435
March 02, 1987				
00:00	0.564	0.000	-0.122	3.395
06:00	0.536	0.000	0.000	3.841
12:00	0.779	0.122	0.000	2.523
18:00	0.869	0.000	0.000	2.260
March 03, 1987				
00:00	0.788	0.000	0.000	2.544
06:00	0.767	0.000	0.000	2.189
12:00	0.699	0.000	0.000	2.402
18:00	0.684	0.000	0.000	2.402
March 04, 1987				
00:00	0.807	0.000	0.000	2.493
06:00	0.803	0.000	0.000	2.463
12:00	0.829	0.122	0.000	2.381
18:00	0.942	0.000	0.000	2.179
March 05, 1987				
00:00	0.925	0.000	0.000	2.088
06:00	0.868	0.000	0.000	2.108
12:00	0.864	0.000	0.000	2.068
18:00	0.922	0.000	0.000	1.996
March 06, 1987				
00:00	0.859	0.000	0.000	2.047
06:00	0.780	0.000	0.000	2.219
12:00	0.806	0.000	0.000	2.229
18:00	0.725	0.000	0.000	2.311
March 07, 1987				
00:00	0.693	0.000	0.000	2.463
06:00	0.694	0.000	0.000	2.544
12:00	0.677	0.122	0.122	2.544
18:00	0.570	0.977	0.611	2.756

Time	Depth m	Temp1 degC	Temp2 degC	dOxy1 mg/l
March 08, 1987				
00:00	0.561	0.855	0.733	2.990
06:00	0.559	0.244	0.366	3.142
12:00	0.555	0.977	0.733	3.132
18:00	0.550	1.710	1.465	2.959
March 09, 1987				
00:00	0.547	0.733	0.733	3.192
06:00	0.548	0.000	0.122	3.517
12:00	0.569	0.489	0.366	3.415
18:00	0.540	0.977	0.855	3.233
March 10, 1987				
00:00	0.545	0.367	0.366	3.284
06:00	0.586	0.000	0.000	3.649
12:00	0.556	0.367	0.244	3.912
18:00	0.539	0.733	0.611	3.719
March 11, 1987				
00:00	0.544	0.244	0.244	3.608
06:00	0.533	0.000	0.000	3.598
12:00	0.546	0.122	0.122	3.679
18:00	0.540	0.122	0.122	3.649
March 12, 1987				
00:00	0.536	0.000	0.000	3.537
06:00	0.528	0.000	0.000	3.820
12:00	0.552	0.244	0.122	3.628
18:00	0.547	0.855	0.733	3.537
March 13, 1987				
00:00	0.545	0.611	0.489	3.385
06:00	0.542	0.733	0.611	3.303
12:00	0.546	1.099	0.855	3.202
18:00	0.544	0.977	0.855	3.182
March 14, 1987				
00:00	0.545	1.221	0.977	3.152
06:00	0.542	0.855	0.855	3.213
12:00	0.542	1.588	1.343	3.132
18:00	0.542	1.954	1.709	3.152

Data from : WDM-8, Inst# 1, March 15, 1987
NECHAKO

Time	Depth m	Temp1 degC	Temp2 degC	dOxy1 mg/l
March 15, 1987				
00:00	0.546	1.588	1.465	3.192
06:00	0.542	1.466	1.343	3.253
12:00	0.545	2.442	2.076	3.264
18:00	0.548	3.053	2.808	3.091
March 16, 1987				
00:00	0.542	2.320	2.198	3.233
06:00	0.542	1.832	1.832	3.405
12:00	0.543	2.687	2.320	3.355
18:00	0.541	3.663	3.297	3.274
March 17, 1987				
00:00	0.549	2.809	2.686	3.334
06:00	0.542	2.320	2.320	3.375
12:00	0.542	2.931	2.686	3.415
18:00	0.547	3.297	3.175	3.476
March 18, 1987				
00:00	0.544	2.442	2.442	3.679
06:00	0.540	1.588	1.832	3.830
12:00	0.540	2.687	2.320	3.912
18:00	0.544	3.419	3.175	3.739
March 19, 1987				
00:00	0.542	2.076	2.198	3.801
06:00	0.539	1.099	1.221	3.943
12:00	0.542	2.198	1.954	3.932
18:00	0.541	3.541	3.175	3.669
March 20, 1987				
00:00	0.544	2.564	2.564	3.709
06:00	0.539	1.832	1.954	3.841
12:00	0.541	2.442	2.198	3.902
18:00	0.540	3.663	3.419	3.628
March 21, 1987				
00:00	0.542	2.564	2.564	3.669
06:00	0.533	1.343	1.587	3.851
12:00	0.539	2.442	2.198	3.871
18:00	0.537	3.908	3.663	3.537

Data from : WDM-8, Inst# 1, March 22, 1987
NECHAKO

Time	Depth m	Temp1 degC	Temp2 degC	dOxy1 mg/l
March 22, 1987				
00:00	0.539	2.442	2.442	3.750
06:00	0.531	1.221	1.587	3.912
12:00	0.539	2.564	2.320	3.943
18:00	0.539	4.030	3.663	3.587
March 23, 1987				
00:00	0.542	2.687	2.808	3.649
06:00	0.538	1.588	1.832	3.801
12:00	0.541	2.809	2.442	3.801
18:00	0.539	4.518	4.152	3.496
March 24, 1987				
00:00	0.539	3.053	3.175	3.598
06:00	0.542	1.954	2.198	3.791
12:00	0.541	3.175	2.931	3.791

End of data

APPENDIX 2

Data Recorded at Irvine's, November 1986 - March, 1987.

NOTE: These date were collected using a Terrascience Ltd. Terra-8 datalogger. The dissolved oxygen data were collected using a sensitron probe (described on page 102), and an Ingold oxygen electrode probe with temperature compensation and little or no flow dependency. Therefore the consistently low (4-5 mg/l) values recorded by the Sensitron probe reflect the flow-dependency problem rather than low intragravel dissolved oxygen. Calibration checks of the Sensitron probe at the time of installation revealed intragravel dissolved oxygen values slightly less than bulk stream values. Water temperatures were measured with thermistor probes accurate to 0.1°C, with the two channels monitoring intragravel temperatures at 20 cm below the gravel surface in 35 and 55 cm of water respectively.

DATE	TIME	DISSOLVED OXYGEN (mg/l)	TEMPERATURE (deg C)	TEMPERATURE (deg C)	DISSOLVED OXYGEN (mg/l)
11/05/86	1800	5.5	9.2	9.2	11.8
11/06/86	0000	5.4	8.9	9.1	11.3
11/06/86	0600	5.4	8.9	9.0	11.4
11/06/86	1200	5.4	9.0	9.1	12.1
11/06/86	1800	5.2	8.9	9.0	11.8
11/07/86	0000	5.3	8.3	8.5	11.3
11/07/86	0600	5.6	7.5	7.6	11.3
11/07/86	1200	5.8	7.5	7.6	12.0
11/07/86	1800	5.7	7.5	7.7	11.8
11/08/86	0000	5.7	7.2	7.3	11.5
11/08/86	0600	5.9	7.0	7.0	11.6
11/08/86	1200	5.9	6.9	7.0	12.2
11/08/86	1800	5.9	7.0	7.0	12.0
11/09/86	0000	5.7	6.6	6.7	11.7
11/09/86	0600	5.7	6.5	6.6	11.7
11/09/86	1200	5.9	6.6	6.6	12.4
11/09/86	1800	5.8	6.6	6.7	12.1
11/10/86	0000	5.7	6.5	6.5	11.7
11/10/86	0600	5.8	6.5	6.5	11.7
11/10/86	1200	5.6	6.1	6.2	12.0
11/10/86	1800	5.6	6.0	6.0	11.8
11/11/86	0000	5.7	5.6	5.7	11.6
11/11/86	0600	5.6	6.0	6.0	11.7
11/11/86	1200	5.7	6.3	6.3	12.4
11/11/86	1800	5.8	6.2	6.3	12.2
11/12/86	0000	5.7	6.0	6.0	11.9
11/12/86	0600	5.6	5.9	6.0	11.8
11/12/86	1200	5.5	5.8	6.0	12.1
11/12/86	1800	5.6	5.7	5.7	11.8
11/13/86	0000	5.5	6.1	6.1	11.7
11/13/86	0600	5.5	6.2	6.3	11.7
11/13/86	1200	5.7	6.5	6.4	12.4
11/13/86	1800	5.5	6.3	6.4	12.0
11/14/86	0000	5.5	6.1	6.1	11.7
11/14/86	0600	5.4	5.9	6.0	11.8
11/14/86	1200	5.8	6.2	6.2	12.5
11/14/86	1800	5.6	6.3	6.3	12.1
11/15/86	0000	5.6	6.2	6.2	11.7
11/15/86	0600	5.4	6.1	6.1	11.7
11/15/86	1200	5.5	6.2	6.1	12.2
11/15/86	1800	5.4	6.5	6.4	12.0
11/16/86	0000	5.4	6.2	6.3	11.6
11/16/86	0600	5.5	6.2	6.2	11.6
11/16/86	1200	5.6	6.2	6.2	12.2
11/16/86	1800	5.5	6.2	6.2	12.0
11/17/86	0000	5.4	6.0	6.0	11.6
11/17/86	0600	5.5	5.9	5.9	11.6

DATE	TIME	DISSOLVED OXYGEN (mg/l)	TEMPERATURE (deg C)	TEMPERATURE (deg C)	DISSOLVED OXYGEN (mg/l)
11/17/86	1200	5.7	5.7	5.7	12.2
11/17/86	1800	5.7	5.3	5.3	11.9
11/18/86	0000	5.6	4.5	4.6	11.6
11/18/86	0600	5.6	3.8	3.9	11.4
11/18/86	1200	5.6	4.1	4.2	11.8
11/18/86	1800	5.5	4.0	4.1	11.4
11/19/86	0000	5.7	4.1	4.2	11.4
11/19/86	0600	5.7	4.4	4.5	11.5
11/19/86	1200	6.0	4.5	4.5	12.1
11/19/86	1800	5.8	4.1	4.2	11.7
11/20/86	0000	5.6	4.2	4.3	11.5
11/20/86	0600	5.7	4.2	4.3	11.4
11/20/86	1200	5.9	4.2	4.3	12.0
11/20/86	1800	5.7	4.7	4.7	11.8
11/21/86	0000	5.6	4.6	4.7	11.5
11/21/86	0600	5.7	4.8	4.8	11.6
11/21/86	1200	5.9	4.9	4.9	12.3
11/21/86	1800	5.7	5.1	5.1	12.0
11/22/86	0000	5.7	5.1	5.0	11.7
11/22/86	0600	5.6	4.9	4.9	11.7
11/22/86	1200	5.8	4.8	4.8	12.2
11/22/86	1800	5.7	5.0	5.0	11.9
11/23/86	0000	5.5	5.1	5.1	11.7
11/23/86	0600	5.5	5.1	5.1	11.6
11/23/86	1200	5.4	5.1	5.0	12.0
11/23/86	1800	5.4	5.1	5.1	11.8
11/24/86	0000	5.2	4.9	4.9	11.6
11/24/86	0600	5.3	4.7	4.7	11.6
11/24/86	1200	5.4	4.7	4.7	12.2
11/24/86	1800	5.5	4.5	4.6	12.0
11/25/86	0000	5.4	4.6	4.6	11.8
11/25/86	0600	5.3	4.6	4.6	11.7
11/25/86	1200	5.4	4.8	4.8	12.2
11/25/86	1800	5.4	4.8	4.8	11.8
11/26/86	0000	5.0	4.6	4.6	11.5
11/26/86	0600	5.2	4.3	4.3	11.6
11/26/86	1200	5.4	4.4	4.4	12.3
11/26/86	1800	5.4	4.4	4.4	12.0
11/27/86	0000	5.3	4.3	4.3	11.7
11/27/86	0600	5.2	4.2	4.2	11.6
11/27/86	1200	5.2	4.2	4.3	12.2
11/27/86	1800	5.2	4.3	4.3	11.9
11/28/86	0000	5.2	4.2	4.2	11.7
11/28/86	0600	5.2	4.2	4.2	11.7
11/28/86	1200	5.5	4.2	4.2	12.3
11/28/86	1800	5.5	4.2	4.2	12.1
11/29/86	0000	5.5	4.2	4.2	11.8

DATE	TIME	DISSOLVED OXYGEN (mg/l)	TEMPERATURE (deg C)	TEMPERATURE (deg C)	DISSOLVED OXYGEN (mg/l)
11/29/86	0600	5.4	4.2	4.2	11.9
11/29/86	1200	5.4	4.2	4.2	12.3
11/29/86	1800	5.3	4.3	4.3	12.1
11/30/86	0000	5.2	4.3	4.3	11.8
11/30/86	0600	5.4	4.2	4.3	11.8
11/30/86	1200	5.5	4.4	4.4	12.4
11/30/86	1800	5.1	4.5	4.5	12.1
12/01/86	0000	5.1	4.3	4.3	11.8
12/01/86	0600	5.3	4.0	4.1	11.8
12/01/86	1200	5.4	3.9	3.9	12.4
12/01/86	1800	5.4	3.9	3.9	12.2
12/02/86	0000	5.3	3.6	3.7	11.9
12/02/86	0600	5.3	3.5	3.6	12.0
12/02/86	1200	5.4	3.5	3.6	12.4
12/02/86	1800	5.3	3.6	3.6	12.2
12/03/86	0000	5.3	3.4	3.4	11.9
12/03/86	0600	5.3	3.2	3.3	11.9
12/03/86	1200	5.4	3.3	3.3	12.4
12/03/86	1800	5.3	3.4	3.4	12.2
12/04/86	0000	5.2	3.5	3.5	11.9
12/04/86	0600	5.3	3.5	3.5	11.9
12/04/86	1200	5.4	3.6	3.6	12.3
12/04/86	1800	5.3	3.6	3.7	12.0
12/05/86	0000	5.2	3.4	3.4	11.8
12/05/86	0600	5.4	3.5	3.5	11.8
12/05/86	1200	5.4	3.6	3.7	12.3
12/05/86	1800	5.6	3.6	3.6	12.0
12/06/86	0000	5.5	3.3	3.4	11.8
12/06/86	0600	5.6	3.2	3.3	11.9
12/06/86	1200	5.6	3.4	3.4	12.4
12/06/86	1800	5.4	3.6	3.6	12.0
12/07/86	0000	5.4	3.6	3.5	11.7
12/07/86	0600	5.4	3.6	3.6	11.8
12/07/86	1200	5.6	3.6	3.6	12.2
12/07/86	1800	5.5	3.8	3.8	12.1
12/08/86	0000	5.5	3.5	3.6	11.9
12/08/86	0600	5.5	3.4	3.4	11.9
12/08/86	1200	5.6	3.5	3.6	12.4
12/08/86	1800	5.5	3.6	3.6	12.2
12/09/86	0000	5.6	3.7	3.8	11.9
12/09/86	0600	5.5	3.5	3.5	11.9
12/09/86	1200	5.7	3.5	3.5	12.4
12/09/86	1800	5.5	3.6	3.6	12.1
12/10/86	0000	5.5	3.4	3.5	11.8
12/10/86	0600	5.5	3.4	3.4	11.8
12/10/86	1200	5.7	3.3	3.4	12.2
12/10/86	1800	5.5	3.5	3.5	11.9

DATE	TIME	DISSOLVED OXYGEN (mg/l)	TEMPERATURE (deg C)	TEMPERATURE (deg C)	DISSOLVED OXYGEN (mg/l)
12/11/86	0000	5.5	3.4	3.4	11.7
12/11/86	0600	5.5	3.3	3.4	11.7
12/11/86	1200	5.5	3.5	3.6	12.2
12/11/86	1800	5.6	3.8	3.8	11.9
12/12/86	0000	5.5	3.7	3.7	11.7
12/12/86	0600	5.5	3.8	3.8	11.7
12/12/86	1200	5.5	4.0	4.0	12.2
12/12/86	1800	5.4	4.2	4.2	12.0
12/13/86	0000	5.4	4.0	4.0	11.7
12/13/86	0600	5.4	3.9	3.9	11.7
12/13/86	1200	5.4	3.9	3.9	12.0
12/13/86	1800	5.4	3.8	3.9	11.9
12/14/86	0000	5.4	3.9	3.9	11.7
12/14/86	0600	5.4	3.8	3.8	11.7
12/14/86	1200	5.5	3.9	3.8	12.2
12/14/86	1800	5.5	3.9	3.9	12.0
12/15/86	0000	5.4	3.8	3.8	11.7
12/15/86	0600	5.3	3.8	3.8	11.8
12/15/86	1200	5.4	3.8	3.7	12.3
12/15/86	1800	5.4	3.7	3.6	12.0
12/16/86	0000	5.4	3.7	3.7	11.8
12/16/86	0600	5.4	3.7	3.7	11.8
12/16/86	1200	5.5	3.7	3.7	12.3
12/16/86	1800	5.2	3.7	3.7	12.0
12/17/86	0000	5.4	3.5	3.5	11.8
12/17/86	0600	5.5	3.6	3.6	11.8
12/17/86	1200	5.4	3.6	3.6	12.2
12/17/86	1800	5.4	3.7	3.7	11.9
12/18/86	0000	5.4	3.5	3.6	11.7
12/18/86	0600	5.5	3.4	3.4	11.7
12/18/86	1200	5.5	3.6	3.6	12.2
12/18/86	1800	5.5	3.5	3.6	11.9
12/19/86	0000	5.4	3.5	3.6	11.7
12/19/86	0600	5.4	3.5	3.6	11.7
12/19/86	1200	5.5	3.6	3.6	12.1
12/19/86	1800	5.4	3.6	3.6	11.8
12/20/86	0000	5.4	3.5	3.6	11.6
12/20/86	0600	5.4	3.5	3.5	11.6
12/20/86	1200	5.4	3.7	3.7	12.0
12/20/86	1800	5.4	3.7	3.7	11.8
12/21/86	0000	5.3	3.7	3.7	11.6
12/21/86	0600	5.3	3.7	3.7	11.6
12/21/86	1200	5.4	3.7	3.7	12.1
12/21/86	1800	5.3	3.6	3.7	11.9
12/22/86	0000	5.3	3.7	3.6	11.6
12/22/86	0600	5.2	3.4	3.4	11.5
12/22/86	1200	5.2	3.7	3.7	11.9

DATE	TIME	DISSOLVED OXYGEN (mg/l)	TEMPERATURE (deg C)	TEMPERATURE (deg C)	DISSOLVED OXYGEN (mg/l)
12/22/86	1800	5.3	3.9	3.9	11.7
12/23/86	0000	5.2	3.7	3.8	11.5
12/23/86	0600	5.2	3.7	3.7	11.5
12/23/86	1200	5.2	3.7	3.7	12.1
12/23/86	1800	5.1	3.8	3.8	11.8
12/24/86	0000	5.2	3.7	3.7	11.6
12/24/86	0600	5.1	3.5	3.5	11.5
12/24/86	1200	5.2	3.4	3.4	11.9
12/24/86	1800	5.0	3.6	3.6	11.8
12/25/86	0000	5.0	3.7	3.7	11.6
12/25/86	0600	5.0	3.6	3.6	11.5
12/25/86	1200	5.0	3.5	3.5	11.9
12/25/86	1800	4.9	3.4	3.5	11.7
12/26/86	0000	5.0	3.4	3.5	11.4
12/26/86	0600	4.9	3.5	3.5	11.5
12/26/86	1200	5.0	3.8	3.7	11.9
12/26/86	1800	4.8	3.7	3.7	11.8
12/27/86	0000	4.9	3.4	3.5	11.5
12/27/86	0600	5.1	3.3	3.3	11.5
12/27/86	1200	5.0	3.6	3.5	12.0
12/27/86	1800	4.8	3.7	3.7	11.8
12/28/86	0000	4.7	3.8	3.8	11.6
12/28/86	0600	4.8	3.7	3.7	11.6
12/28/86	1200	4.8	3.8	3.8	12.1
12/28/86	1800	4.8	3.8	3.7	11.8
12/29/86	0000	4.8	3.6	3.6	11.5
12/29/86	0600	4.8	3.5	3.5	11.4
12/29/86	1200	4.8	3.7	3.6	11.9
12/29/86	1800	4.8	3.8	3.8	11.8
12/30/86	0000	4.9	3.6	3.7	11.5
12/30/86	0600	5.0	3.5	3.5	11.6
12/30/86	1200	5.2	3.5	3.5	12.2
12/30/86	1800	5.1	3.6	3.6	11.9
12/31/86	0000	5.2	3.5	3.6	11.6
12/31/86	0600	5.1	3.5	3.5	11.6
12/31/86	1200	5.2	3.6	3.6	12.0
12/31/86	1800	5.0	3.7	3.7	11.7
02/10/87	1800	5.0	3.3	3.3	12.3
02/11/87	0000	4.7	3.2	3.2	11.7
02/11/87	0600	4.4	3.1	3.1	11.7
02/11/87	1200	4.6	3.2	3.2	12.4
02/11/87	1800	4.5	3.2	3.2	12.2
02/12/87	0000	4.6	3.0	3.1	11.8
02/12/87	0600	4.4	3.0	3.0	11.8
02/12/87	1200	4.5	3.1	3.1	12.4
02/12/87	1800	4.4	3.3	3.2	12.4

DATE	TIME	DISSOLVED OXYGEN (mg/l)	TEMPERATURE (deg C)	TEMPERATURE (deg C)	DISSOLVED OXYGEN (mg/l)
02/13/87	0000	4.6	3.2	3.2	11.7
02/13/87	0600	4.6	3.1	3.1	11.7
02/13/87	1200	4.6	3.1	3.2	12.4
02/13/87	1800	4.6	3.3	3.3	12.2
02/14/87	0000	4.8	3.1	3.1	11.6
02/14/87	0600	4.8	3.0	3.0	11.6
02/14/87	1200	5.0	3.2	3.2	12.4
02/14/87	1800	4.9	3.4	3.3	12.3
02/15/87	0000	5.0	2.9	3.0	11.7
02/15/87	0600	4.8	2.9	2.9	11.7
02/15/87	1200	5.1	3.2	3.1	12.4
02/15/87	1800	5.0	3.4	3.4	12.3
02/16/87	0000	4.9	3.1	3.1	11.7
02/16/87	0600	4.8	2.9	3.0	11.6
02/16/87	1200	5.1	3.3	3.2	12.3
02/16/87	1800	5.1	3.3	3.3	12.1
02/17/87	0000	4.9	3.0	3.0	11.7
02/17/87	0600	5.0	2.8	2.9	11.7
02/17/87	1200	5.0	3.0	2.9	12.4
02/17/87	1800	5.0	3.3	3.2	12.4
02/18/87	0000	5.2	3.0	3.0	11.8
02/18/87	0600	5.0	2.8	2.9	11.7
02/18/87	1200	5.2	3.1	3.1	12.3
02/18/87	1800	5.0	3.3	3.2	12.3
02/19/87	0000	5.1	3.1	3.1	11.8
02/19/87	0600	5.2	3.0	3.0	11.8
02/19/87	1200	5.2	3.4	3.3	12.6
02/19/87	1800	5.0	3.7	3.6	12.4
02/20/87	0000	5.0	3.1	3.1	11.8
02/20/87	0600	5.0	3.0	3.0	11.8
02/20/87	1200	5.1	3.4	3.3	12.5
02/20/87	1800	4.9	3.6	3.6	12.4
02/21/87	0000	4.8	3.2	3.2	11.8
02/21/87	0600	5.0	2.9	2.9	11.7
02/21/87	1200	5.1	3.1	3.1	12.4
02/21/87	1800	5.0	3.3	3.3	12.3
02/22/87	0000	5.0	3.1	3.1	11.8
02/22/87	0600	4.8	3.0	3.0	11.7
02/22/87	1200	4.9	3.0	3.0	12.3
02/22/87	1800	4.8	3.3	3.3	12.3
02/23/87	0000	4.8	3.0	3.0	11.8
02/23/87	0600	4.8	2.7	2.7	11.7
02/23/87	1200	5.0	2.9	2.8	12.4
02/23/87	1800	4.9	3.2	3.2	12.4
02/24/87	0000	4.8	2.8	2.9	11.8
02/24/87	0600	5.0	2.5	2.6	11.8
02/24/87	1200	4.9	2.8	2.8	12.4

DATE	TIME	DISSOLVED OXYGEN (mg/l)	TEMPERATURE (deg C)	TEMPERATURE (deg C)	DISSOLVED OXYGEN (mg/l)
02/24/87	1800	4.8	3.4	3.3	12.3
02/25/87	0000	4.8	2.9	2.9	11.7
02/25/87	0600	4.8	2.7	2.7	11.7
02/25/87	1200	4.9	3.3	3.1	12.4
02/25/87	1800	4.8	3.6	3.5	12.2
02/26/87	0000	4.6	3.2	3.2	11.7
02/26/87	0600	5.0	3.1	3.1	11.6
02/26/87	1200	5.0	3.2	3.1	12.0
02/26/87	1800	4.9	3.2	3.3	12.1
02/27/87	0000	4.9	2.7	2.8	11.6
02/27/87	0600	4.9	2.5	2.5	11.5
02/27/87	1200	4.9	2.9	2.9	12.2
02/27/87	1800	5.0	3.4	3.4	11.9
02/28/87	0000	4.9	2.8	2.8	11.6
02/28/87	0600	5.0	2.5	2.5	11.6
02/28/87	1200	5.0	2.9	2.9	12.2
02/28/87	1800	4.8	3.5	3.5	12.0
03/01/87	0000	5.0	2.9	2.9	11.4
03/01/87	0600	5.2	2.6	2.6	11.4
03/01/87	1200	5.1	3.0	3.0	12.0
03/01/87	1800	5.0	3.4	3.4	12.0
03/02/87	0000	4.8	2.9	2.9	11.4
03/02/87	0600	4.9	2.5	2.6	11.4
03/02/87	1200	5.0	2.8	2.8	12.0
03/02/87	1800	4.9	3.0	3.0	11.9
03/03/87	0000	4.9	2.5	2.5	11.5
03/03/87	0600	4.8	2.1	2.2	11.4
03/03/87	1200	5.0	2.6	2.6	11.9
03/03/87	1800	5.0	3.1	3.1	11.8
03/04/87	0000	4.9	3.0	3.0	11.4
03/04/87	0600	5.0	3.0	2.9	11.4
03/04/87	1200	5.1	3.5	3.4	12.0
03/04/87	1800	4.9	3.7	3.7	11.9
03/05/87	0000	4.9	3.3	3.3	11.4
03/05/87	0600	4.7	3.1	3.1	11.4
03/05/87	1200	4.8	3.5	3.5	12.1
03/05/87	1800	4.6	3.7	3.6	11.8
03/06/87	0000	4.8	3.2	3.2	11.4
03/06/87	0600	4.8	3.0	3.0	11.5
03/06/87	1200	4.8	3.6	3.5	12.2
03/06/87	1800	4.8	3.8	3.7	12.1
03/07/87	0000	4.6	3.3	3.3	11.7
03/07/87	0600	4.7	2.9	3.0	11.7
03/07/87	1200	4.7	3.4	3.3	12.4
03/07/87	1800	4.4	3.9	3.8	12.2
03/08/87	0000	4.6	3.0	3.1	11.7
03/08/87	0600	4.9	2.7	2.8	11.7

DATE	TIME	DISSOLVED OXYGEN (mg/l)	TEMPERATURE (deg C)	TEMPERATURE (deg C)	DISSOLVED OXYGEN (mg/l)
03/08/87	1200	4.9	3.1	3.1	12.3
03/08/87	1800	4.7	3.7	3.6	12.1
03/09/87	0000	4.8	3.0	3.1	11.6
03/09/87	0600	5.1	2.7	2.8	11.6
03/09/87	1200	5.2	3.2	3.1	12.2
03/09/87	1800	4.9	3.6	3.6	12.1
03/10/87	0000	4.8	3.0	3.0	11.6
03/10/87	0600	4.9	2.6	2.7	11.6
03/10/87	1200	5.0	3.0	3.0	12.2
03/10/87	1800	5.0	3.3	3.2	12.0
03/11/87	0000	4.9	3.0	3.0	11.6
03/11/87	0600	4.9	2.6	2.7	11.5
03/11/87	1200	4.8	3.2	3.1	12.2
03/11/87	1800	4.8	3.2	3.2	11.8
03/12/87	0000	5.0	3.0	3.1	11.6
03/12/87	0600	5.0	3.1	3.1	11.5
03/12/87	1200	5.1	3.7	3.5	12.2
03/12/87	1800	4.6	4.1	4.0	12.1
03/13/87	0000	4.8	3.5	3.5	11.6
03/13/87	0600	4.6	3.3	3.2	11.5
03/13/87	1200	4.6	3.4	3.3	11.9
03/13/87	1800	4.7	3.6	3.6	11.9
03/14/87	0000	4.7	3.3	3.3	11.5
03/14/87	0600	4.7	3.2	3.2	11.5
03/14/87	1200	4.7	3.8	3.7	12.2
03/14/87	1800	4.7	4.3	4.3	12.0
03/15/87	0000	4.6	3.6	3.6	11.6
03/15/87	0600	4.7	3.3	3.3	11.6
03/15/87	1200	4.9	4.1	3.8	12.3
03/15/87	1800	4.8	4.2	4.1	12.0
03/16/87	0000	4.8	3.4	3.4	11.5
03/16/87	0600	4.9	3.1	3.1	11.6
03/16/87	1200	4.9	3.9	3.7	12.3
03/16/87	1800	4.8	4.0	3.9	12.0
03/17/87	0000	4.7	3.4	3.4	11.5
03/17/87	0600	4.7	3.2	3.2	11.4
03/17/87	1200	4.9	3.8	3.6	12.1
03/17/87	1800	4.8	4.0	4.0	11.9
03/18/87	0000	4.8	3.2	3.3	11.4
03/18/87	0600	4.9	2.9	3.0	11.4
03/18/87	1200	4.9	3.8	3.6	12.1
03/18/87	1800	5.0	4.2	4.0	11.9
03/19/87	0000	4.9	3.5	3.5	11.4
03/19/87	0600	4.8	3.0	3.1	11.4
03/19/87	1200	5.0	3.7	3.6	12.2
03/19/87	1800	5.0	4.3	4.2	12.0
03/20/87	0000	4.8	3.5	3.5	11.4

DATE	TIME	DISSOLVED OXYGEN (mg/l)	TEMPERATURE (deg C)	TEMPERATURE (deg C)	DISSOLVED OXYGEN (mg/l)
03/20/87	0600	4.9	3.1	3.2	11.3
03/20/87	1200	4.8	3.8	3.7	12.3
03/20/87	1800	4.6	4.3	4.2	12.0
03/21/87	0000	4.8	3.4	3.4	11.4
03/21/87	0600	4.9	3.0	3.1	11.5
03/21/87	1200	4.7	3.9	3.7	12.3
03/21/87	1800	4.5	4.6	4.5	12.0
03/22/87	0000	4.8	3.5	3.6	11.4
03/22/87	0600	4.8	3.1	3.2	11.4
03/22/87	1200	4.6	3.9	3.7	12.3
03/22/87	1800	4.6	4.6	4.5	12.0
03/23/87	0000	4.5	3.6	3.6	11.4
03/23/87	0600	4.6	3.2	3.2	11.4
03/23/87	1200	4.7	4.0	3.8	12.3
03/23/87	1800	4.4	4.8	4.7	12.1
03/24/87	0000	4.5	3.7	3.8	11.5
03/24/87	0600	4.6	3.2	3.3	11.5
03/24/87	1200	4.6	4.1	3.9	12.5
03/24/87	1800	4.3	4.8	4.6	12.2
03/25/87	0000	4.2	3.8	3.9	11.5
03/25/87	0600	4.4	3.6	3.6	11.4
03/25/87	1200	4.4	3.8	3.8	12.1

APPENDIX 3

GLOSSARY

Accumulated Degree Days - the sum or accumulation of the departure of mean daily temperature from a given temperature. In this report, it refers to accumulated water temperature above 0°C.

Anchor Ice - submerged ice formed on or frozen to the bed of a stream.

Backwater Effect - an increase in water level, without any change in discharge, due to the presence of ice (of any type) in the stream channel.

Channel Hydraulics - the geometry of a stream channel and its relationship to discharge.

Dessication - the drying out of streambed gravels and therefore any eggs or alevins contained.

Dewatering - removal of water from streambed gravels, either by a drop in water level or the freezing solid of all available water.

Discharge - the quantity of water passing down a stream, depending on its volume and velocity. Measured in cubic meters per second (m^3/s) or cubic feet per second (ft^3/s).

Frazil - fine ice crystals formed in turbulent water which is super cooled, to slightly below 0°C.

Freezing Degree Days - the sum of mean daily air temperatures below 0°C, as an indicator of freezing conditions.

Freezing Front - the downward movement of the zero degree isotherm in soil or gravel. Indicates the depth of freezing.

Intragravel Flow - movement of water between the particles of a streambed (synonym - intergravel).

Leading Edge - the furthest upstream edge of a solid surface ice cover, where it adjoins open water (synonym - ice front).

Seasonal Total Accumulated Degree Days Below 0°C - the summation of mean daily air temperature below 0°C, from the start of negative temperatures until spring when mean daily temperatures remain above 0°C.

Shore Ice - growth of ice in-situ attached to the river banks.

Spawning Redd - nest dug in gravel of streambed by a spawning fish.

Stage - the height of the surface of a stream, a measure of a stream depth or water level.

State-Discharge Relationship - a mathematical or graphical relationship which allows an accurate estimate of discharge to be obtained from a measurement of stage.

Stranding - the abandonment of objects due to dewatering or a drop in water level. Can refer to either ice or fish.

Substrate - the particles (can range from silt to boulders) which make up the bed of a stream.

Supercooling - the temporary drop in water temperature of a fast flowing river to very slightly below 0°C (-0.01 to -0.03°C), which allows frazil and anchor ice to form.

Surface Ice Cover - a continuous, solid cover of ice from bank to bank on the surface of a stream. Various types of ice (i.e., frazil, shore) can make up the cover.

Zero Degree Isotherm - an imaginary line across a stream where the water temperature is uniformly at 0°C.

APPENDIX 4 - ICE COVER MAPS OF THE NECHAKO RIVER

Figures 27 - 28	January 28, 1986
Figures 29 - 32	December 10, 1986
Figure 33 - 36	March 26, 1987

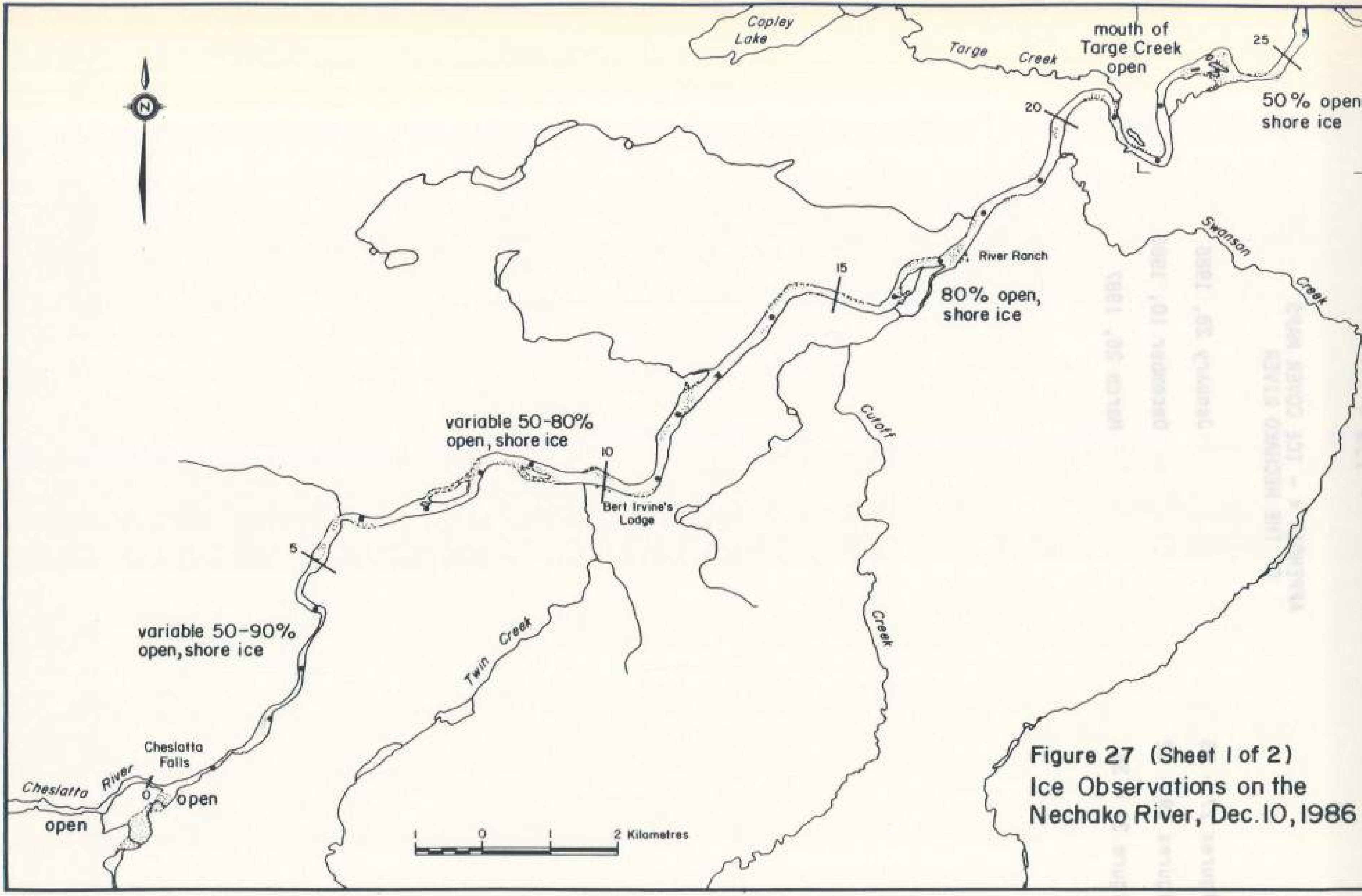

Figure 27 (Sheet 1 of 2)
Ice Observations on the Nechako River, Dec.10,1986

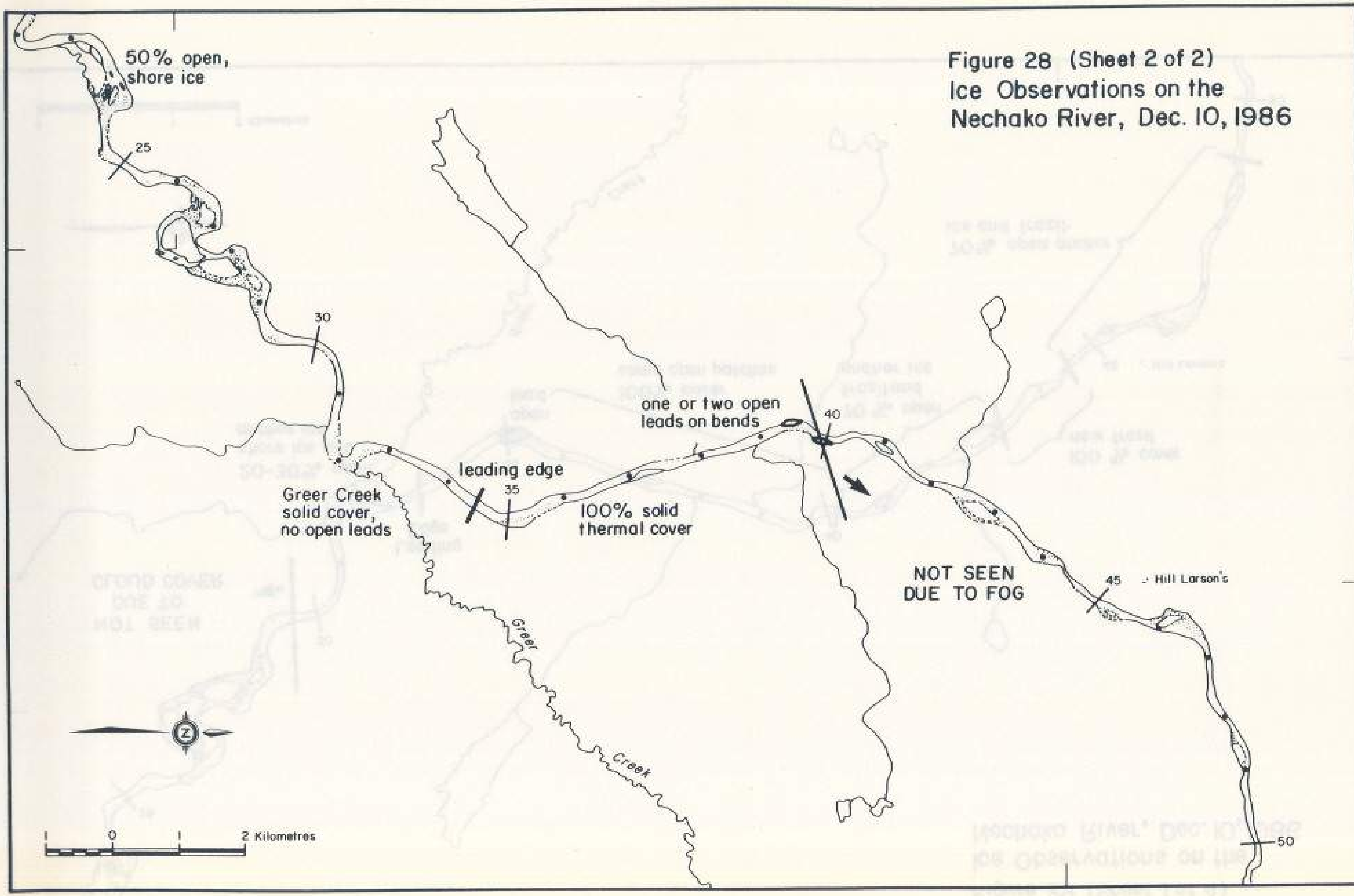
Figure 28 (Sheet 2 of 2)
Ice Observations on the
Nechako River, Dec. 10, 1986
50% open,
shore ice
25
30
35
40
45
50
one or two open
leads on bends
leading edge
Greer Creek
solid cover,
no open leads
100% solid
thermal cover
NOT SEEN
DUE TO FOG
Hill Larson's
Greer
Creek
0
1
2 Kilometres

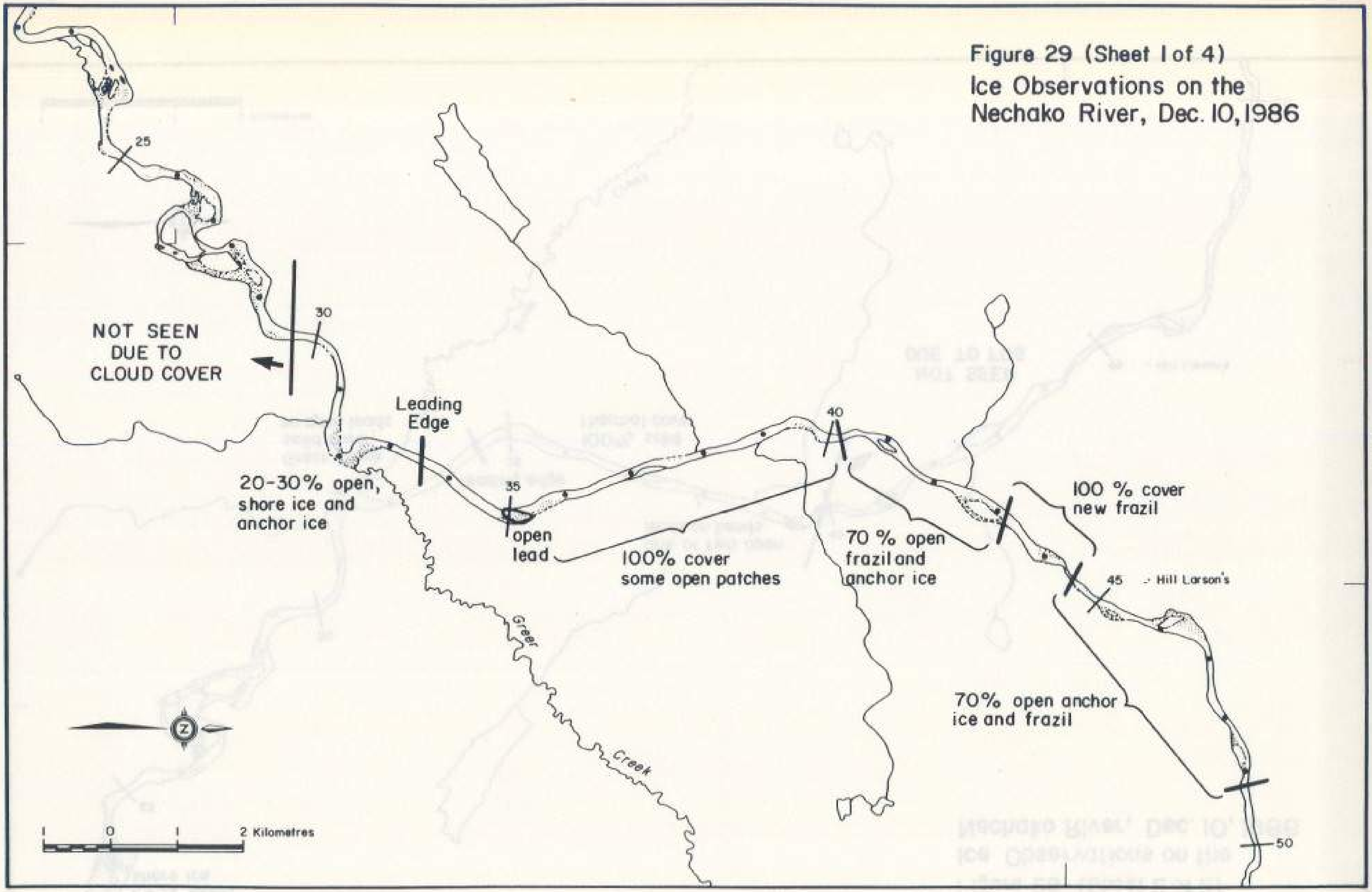

Figure 29 (Sheet 1 of 4)
Ice Observations on the
Nechako River, Dec. 10, 1986
25
30
NOT SEEN
DUE TO
CLOUD COVER
Leading
Edge
20-30% open,
shore ice and
anchor ice
35
open
lead
100% cover
some open patches
40
70 % open
frazil and
anchor ice
100 % cover
new frazil
45
Hill Larson's
70% open anchor
ice and frazil
50
Greer
Creek
1
0
1
2 Kilometres

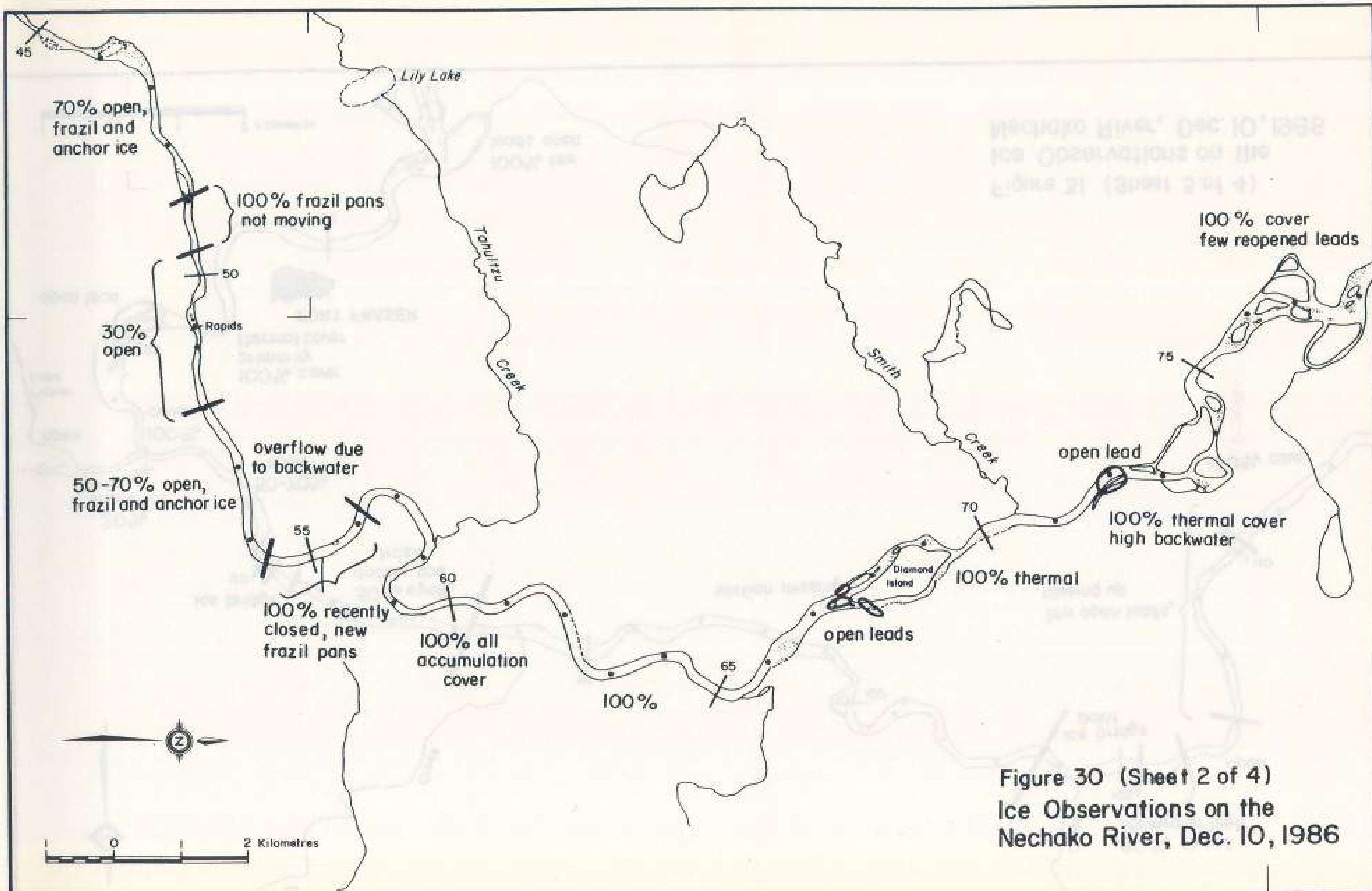

Figure 30 (Sheet 2 of 4)
Ice Observations on the Nechako River, Dec. 10, 1986

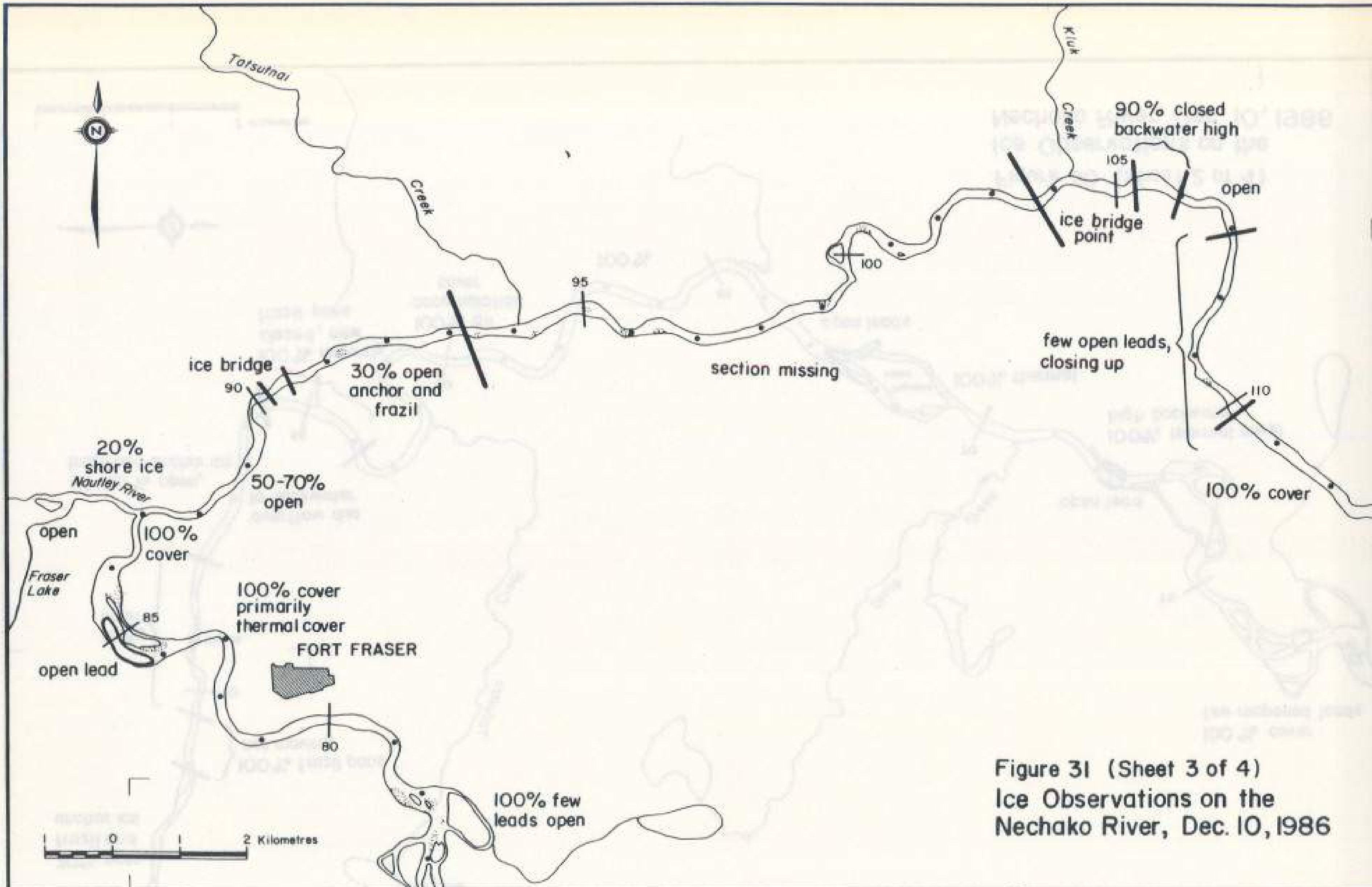

Figure 31 (Sheet 3 of 4)
Ice Observations on the
Nechako River, Dec. 10, 1986

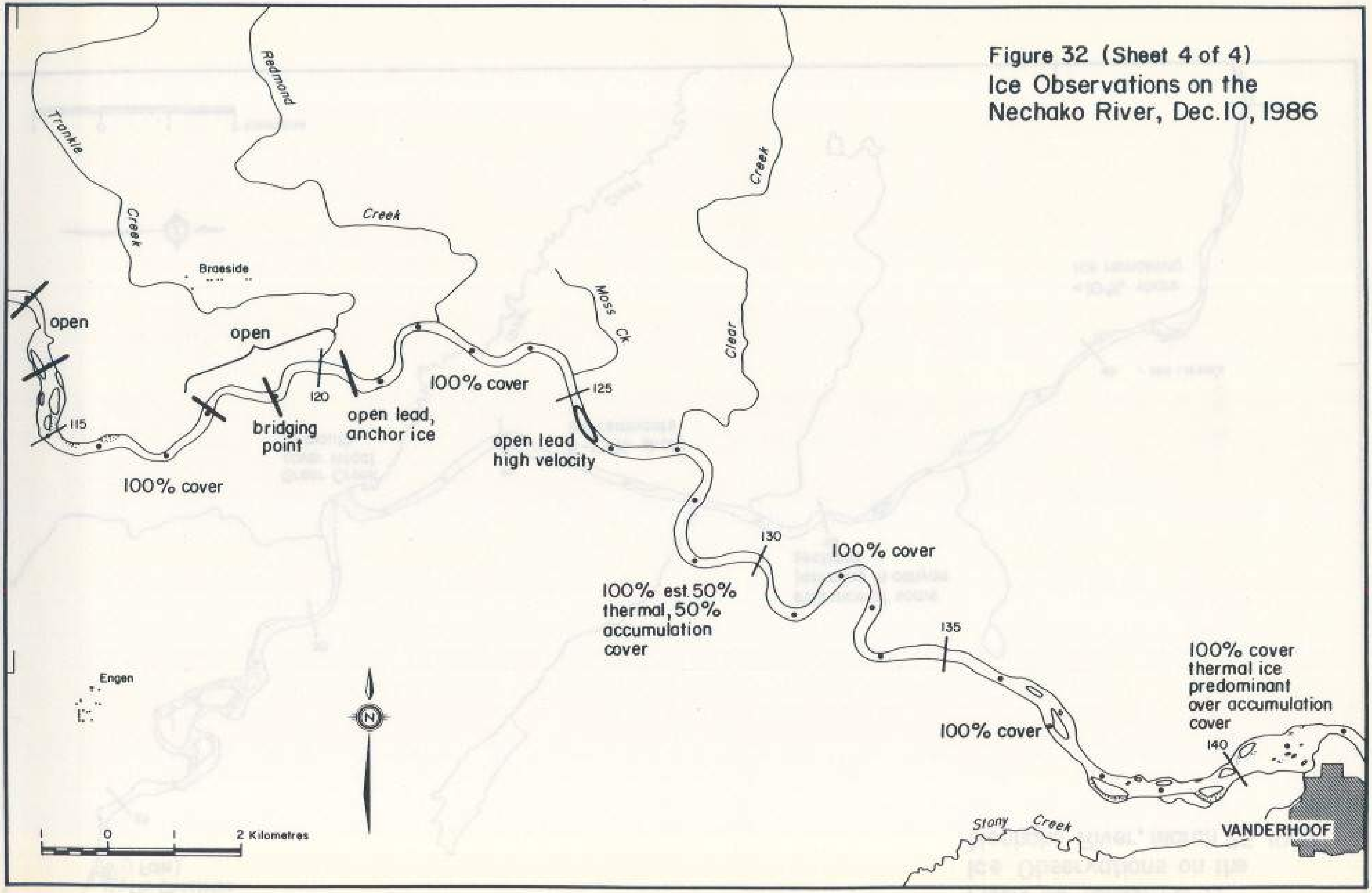
Figure 32 (Sheet 4 of 4)
Ice Observations on the
Nechako River, Dec.10, 1986
Redmond
Creek
Trankle
Creek
Clear
Creek
Moss Ck
Braeside
open
open
115
120
125
130
135
140
bridging
point
open lead,
anchor ice
100% cover
open lead
high velocity
100% cover
100% est.50%
thermal, 50%
accumulation
cover
100% cover
100% cover
thermal ice
predominant
over accumulation
cover
100% cover
Engen
Stony Creek
VANDERHOOF
1 0 1 2 Kilometres

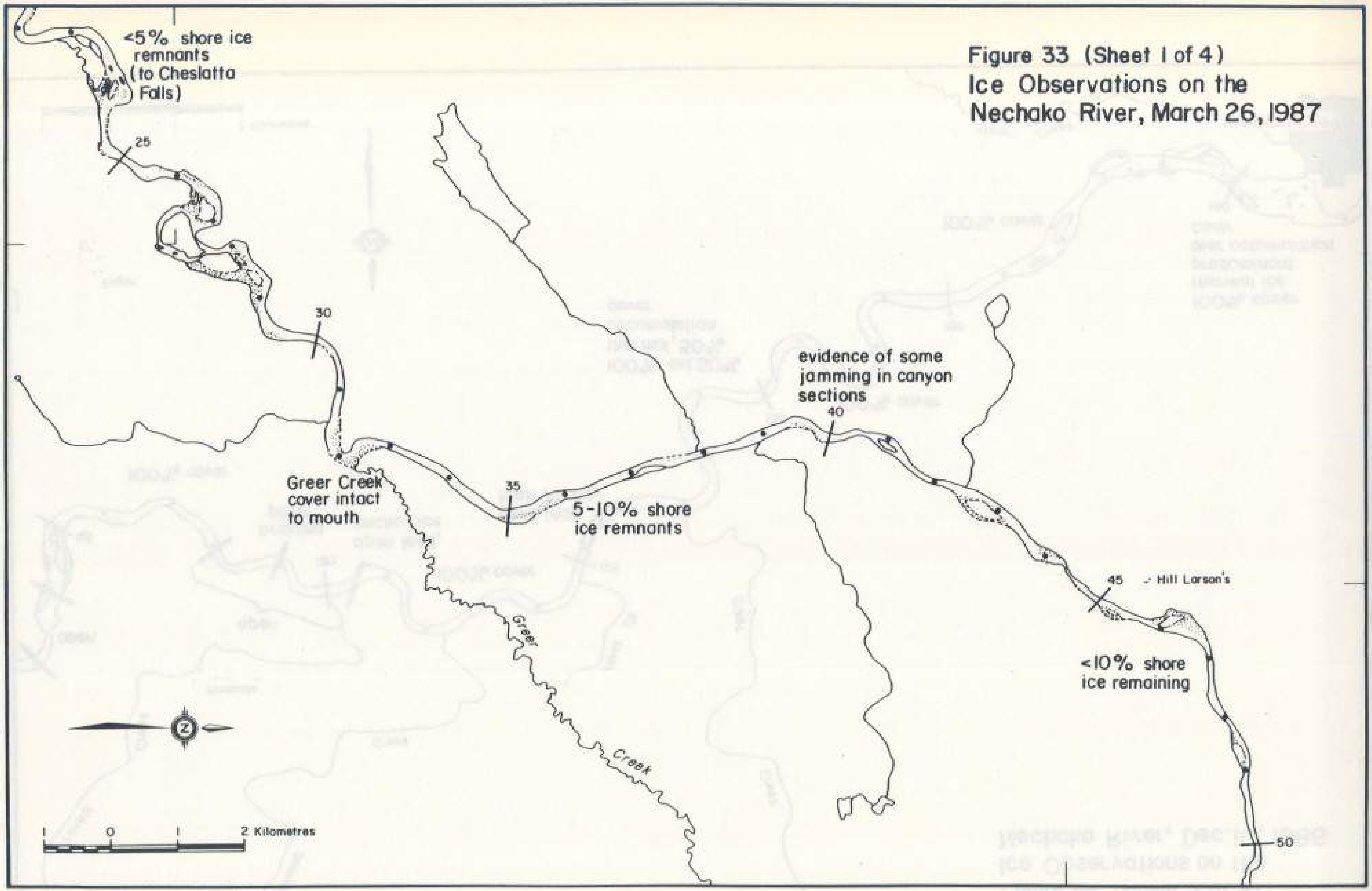
Figure 33 (Sheet 1 of 4)
Ice Observations on the
Nechako River, March 26, 1987
<5% shore ice remnants (to Cheslatta Falls)
25
30
35
40
45
50
evidence of some jamming in canyon sections
Greer Creek cover intact to mouth
5-10% shore ice remnants
Hill Larson's
<10% shore ice remaining
Greer
Creek
0
1
2 Kilometres

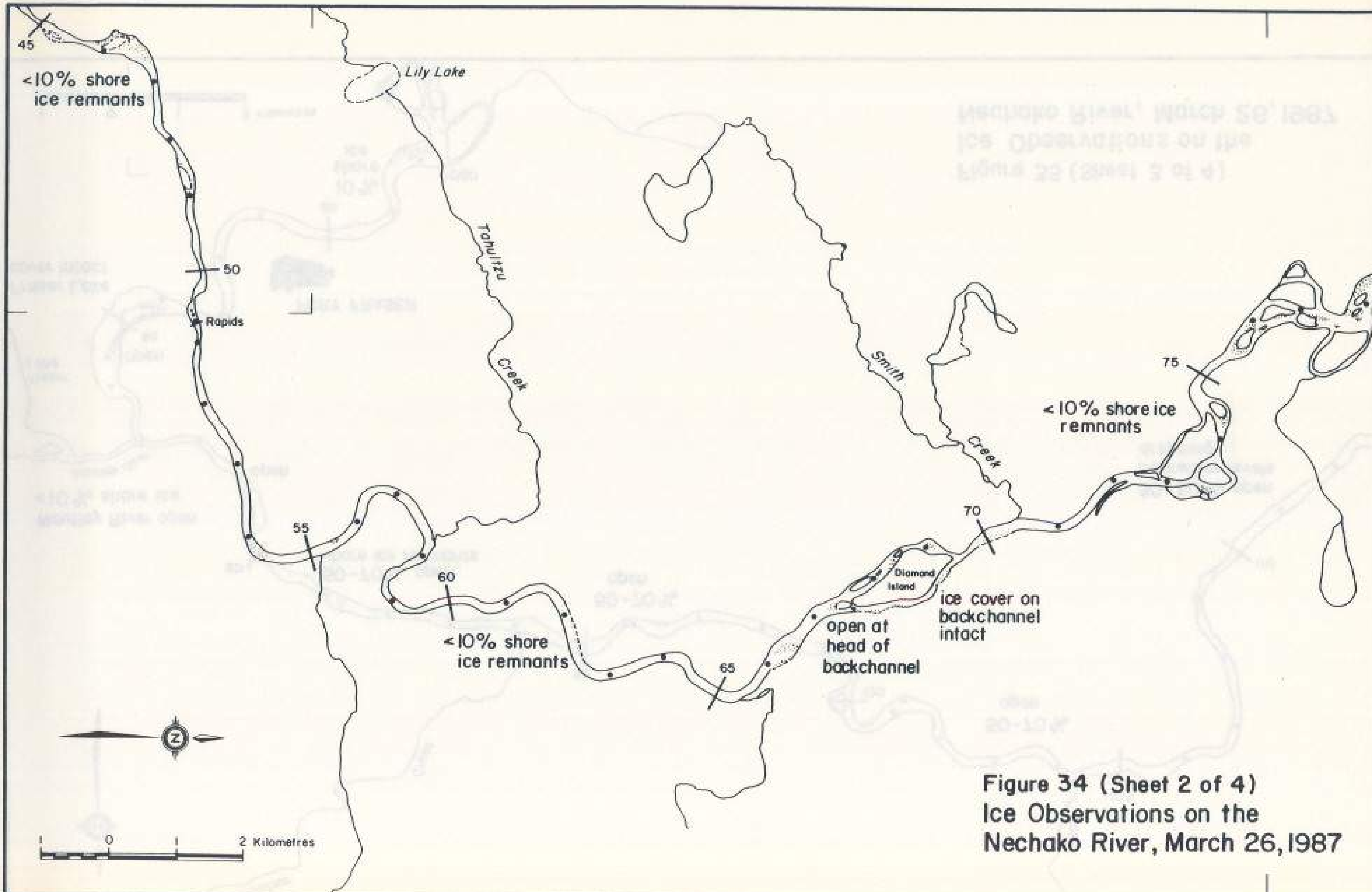

Figure 34 (Sheet 2 of 4)
Ice Observations on the
Nechako River, March 26, 1987

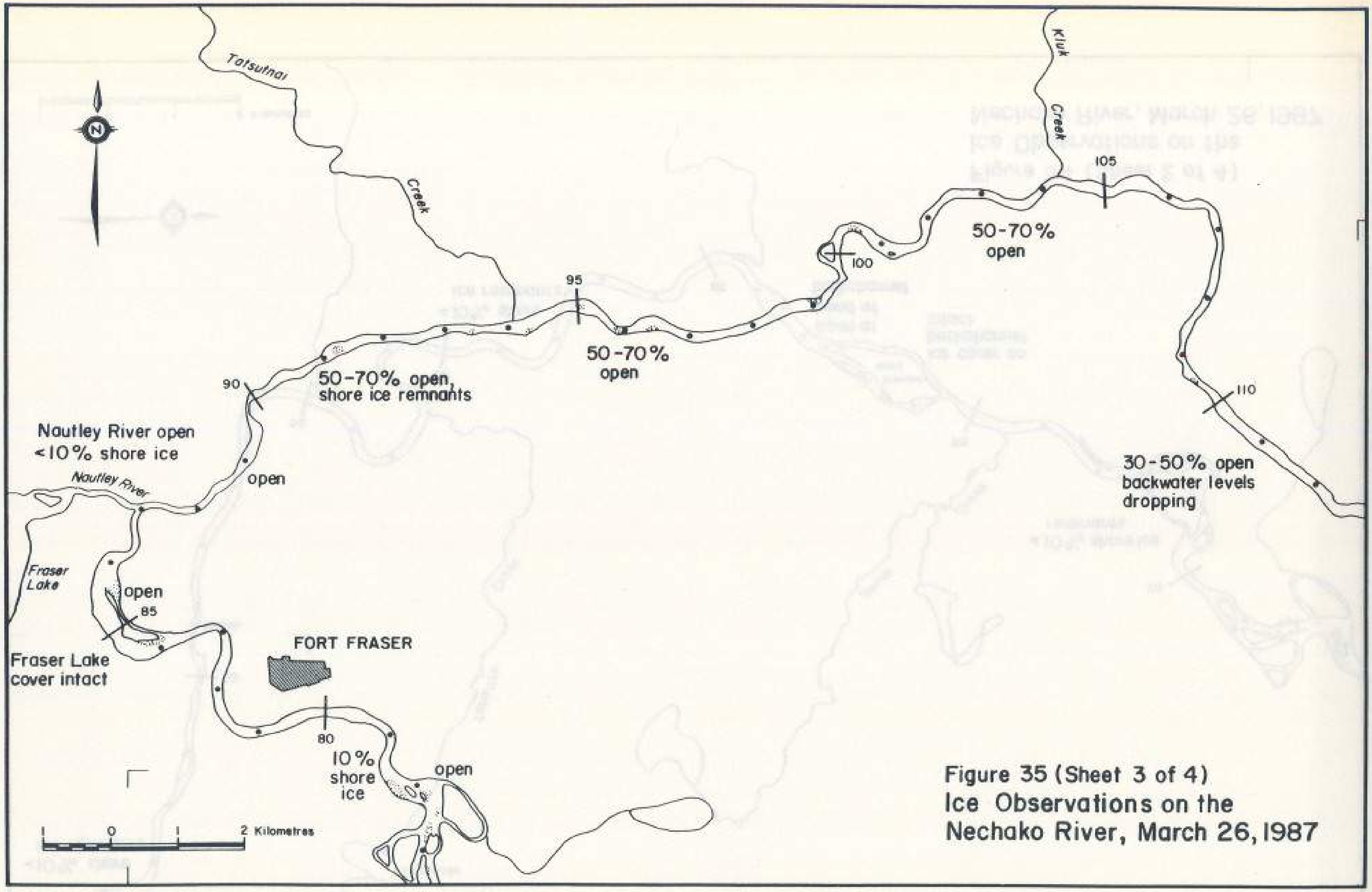

Figure 35 (Sheet 3 of 4)
Ice Observations on the
Nechako River, March 26, 1987

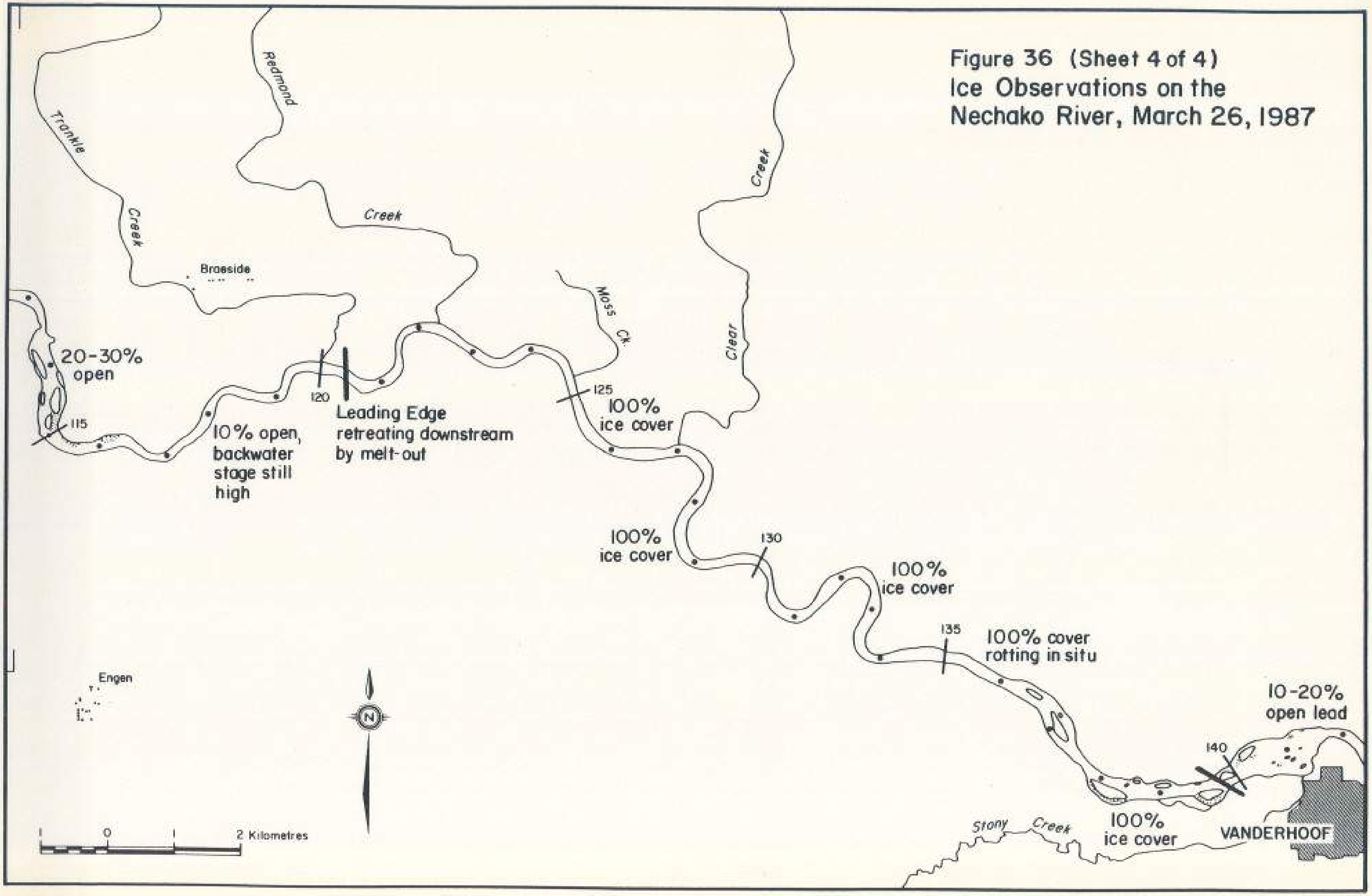

Figure 36 (Sheet 4 of 4)
Ice Observations on the
Nechako River, March 26, 1987