ENVIRONMENT CANADA
INLAND WATERS DIRECTORATE

PROVINCE OF BRITISH COLUMBIA
MINISTRY OF ENVIRONMENT
WATER MANAGEMENT BRANCH

# FLOODPLAIN MAPPING PROGRAM

# STUART LAKE AND RIVER

# DESIGN BRIEF

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# 1 INTRODUCTION

Hay & Company Consultants were engaged by the B.C. Ministry of Environment to undertake studies and prepare floodplain maps for Stuart River, Necoslie River, Nahounli Creek and the Stuart Lake Shoreline near Fort St. James. This work is covered under the 1987 joint Federal/Provincial Agreement on Floodplain Mapping.

The watershed of the Stuart River and its aforementioned tributaries is part of the Fraser River drainage basin and is located in the interior plateau of British Columbia northwest of Prince George, Figure 1. Nahounli Creek drains into Stuart Lake which is the headwaters for the Stuart River. The Necoslie River joins the Stuart River a few hundred metres below the outlet from Stuart Lake. The Stuart River flows south to join the Nechako River which then joins the Fraser at Prince George. The Stuart River drains a total area of 14,600 $km^2$ with an elevation range of 680 m to 2079 m. Necoslie River drains 595 $km^2$ with an elevation range of 680 m to 1240 m and Nahounli Creek drains approximately 149 $km^2$ with an elevation range of 680 m to 1400 m.

The floodplain mapping studies described herein cover approximately the first 4 km of the Stuart River downstream of Stuart Lake as well as the first 8 km of the Necoslie River above the Stuart River confluence. The studies also cover approximately 1.8 km of Nahounli Creek and 20 km of the Stuart Lake shoreline.

Representative photographs of the study areas are included with locations referenced to the survey cross sections or principal features.

# 2 SOURCES OF INFORMATION

This study made use of river and lakeshore survey information supplied by Mr. P.J. Woods of the Water Management Branch, B.C. Environment. The information package included cross section data, thalweg and water surface profiles, photographs of river cross sections, notes on Water Survey of Canada gauge descriptions, bridge drawings plus 1:5000 base mapping. Mr. G.W. Davidson, Water Management Branch (Prince George), provided a background report dealing with flooding in Fort St. James. In addition, Water Survey of Canada streamflow and water level records were utilized along with 1:50,000 and 1:250,000 topographic mapping. A complete listing of data sources and references is included in Appendix D.

## 3 FIELD INSPECTIONS

A field inspection was conducted by Mr. R.J. Wallwork, on September 25-26, 1990, prior to preparation of the HEC-2 backwater models. This reconnaissance inspection was conducted to familiarize Hay & Company staff with the study area and to ascertain if any changes had occurred subsequent to preparation of the river survey package.

## 4 HYDROLOGY

### 4.1 Flood Frequency Studies - Methodology

The Water Survey of Canada CFA-88 computer program was utilized for the frequency estimates of both the Stuart Lake levels and Stuart River flows. Frequency distributions utilized by the computer program included:

1. Generalized Extreme Value Distribution (Types 1,2 or 3).
2. Three Parameter Lognormal Distribution
3. Log Pearson Type III Distribution

### 4.2 Stuart River Floods

Water Survey of Canada have operated a stream gauge (Sta. No. 08JE001) on the Stuart River near the lake outlet since 1929. The station was operated as a manual gauge until 1986 after which a continuous recording gauge was installed. Consequently there are 59 years of annual maximum daily records but only 3 years of maximum instantaneous flow records.

Frequency estimates from the three distributions are summarized below. The mean flood was 317 $m^3/s$.

**Table 1 - Stuart River Flood Frequency Estimates ($m^3/s$)**
**Sta. 08JE001**

| | Return Period - Years | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Distribution | 500 | 200 | 100 | 50 | 20 | 10 | 5 | 2 |
| GEV (EV3) | 651 | 607 | 571 | 533 | 479 | 435 | 386 | 306 |
| 3-Par Lognormal | 691 | 634 | 590 | 546 | 486 | 438 | 387 | 305 |
| Log Pearson Type III | 665 | 615 | 576 | 536 | 480 | 436 | 386 | 306 |

There were no high or low outliers identified in the record. The 3-parameter lognormal estimates were adopted for this study on the basis of their being slightly more conservative than the other estimates. The associated flood frequency plot is enclosed, Appendix A. The adopted flood estimates are therefore as follows:

200 year maximum daily flood = 634 $m^3/s$
20 year maximum daily flood = 486 $m^3/s$

The ratio of instantaneous to daily flood peaks was taken to be 1.02 based on the limited instantaneous records available and regional I/D ratios. Instantaneous flood estimates are therefore as follows:

200 year instantaneous flood = 647 $m^3/s$
20 year instantaneous flood = 496 $m^3/s$

### 4.3 Stuart Lake Flood Levels

A water level recording station has been operated near the outlet of Stuart Lake since 1956 (WSC Sta. 08JE003). Initially operated as a manual gauge, the station was converted to a continuous recorder in 1979, but since 1986 has reverted to manual operation. As such there are 32 years of maximum daily water levels and seven years of maximum instantaneous water levels. Lake levels peak between June 22 and July 31 with July 4 being the average date for annual peak water levels.

In addition to the recorded lake levels, there are the 59 years of discharge records at the Stuart River gauge located about 1.5 km downstream of the lake outlet. Necoslie River enters the Stuart River between the lake outlet and the gauge, however, it peaks earlier than the Stuart River and therefore has little or no effect on flood levels in Stuart Lake. Consequently, there is a very strong correlation between Stuart Lake levels and Stuart River flows. A rating curve, Figure 2, was developed from the 32 years of concurrent records. The 1972 flood was the recorded extreme event for both the Stuart Lake and Stuart River stations.

In light of the above, three frequency analysis methods were considered in the estimation of Stuart Lake flood levels:

**Method 1** — frequency analysis of 32 years of Stuart Lake stage records

**Method 2** — as above with historic information: treat 1972 flood level as the largest in 60 years (1930-1990 excluding 1932).

**Method 3** frequency analysis of 59 years of Stuart River floods with conversion to lake level by means of the rating curve, Figure 2.

Results from the lake level frequency analyses using methods 1 and 2 are listed below with the historic estimates in brackets:

**Table 2 - Stuart Lake Flood Frequency Estimates - Stage in metres**
**Sta. 08JE003**

| | Return Period - Years | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Distribution | 500 | 200 | 100 | 50 | 20 | 10 | 5 | 2 |
| GEV (EV3) | 4.87 | 4.70 | 4.55 | 4.39 | 4.15 | 3.94 | 3.69 | 3.26 |
| | (4.69) | (4.56) | (4.44) | (4.30) | (4.09) | (3.90) | (3.67) | (3.25) |
| 3-Par | 5.09 | 4.85 | 4.66 | 4.46 | 4.18 | 3.95 | 3.69 | 3.25 |
| Lognormal | (4.89) | (4.69) | (4.53) | (4.35) | (4.11) | (3.90) | (3.67) | (3.25) |
| Log Pearson | 5.04 | 4.81 | 4.62 | 4.43 | 4.16 | 3.94 | 3.69 | 3.26 |
| Type III | (4.86) | (4.66) | (4.50) | (4.33) | (4.09) | (3.89) | (3.66) | (3.25) |

The mean annual maximum lake stage is 3.30 m which corresponds to a lake elevation of 680.81 m (WSC gauge zero = 677.512 m). There were no outliers identified in the record. The 3-parameter lognormal estimates were selected for further consideration as they are slightly more conservative than the other estimates. Lake stage frequency plots are included in Appendix B.

The previously derived flood estimates for the Stuart River (3-parameter lognormal) were converted to lake stage by means of the rating curve, Figure 2.

Stuart Lake flood elevations determined by the three methods are tabulated below for comparison.

**Table 3 - Stuart Lake Flood Levels - (Elevation - metres GSC)**

| Return Period Years | Method 1 Stage analysis | Method 2 Stage analysis (historic) | Method 3 Flood analysis /rating curve |
|---|---|---|---|
| 500 | 682.60 | 682.40 | 682.50 |
| 200 | 682.36 | 682.20 | 682.26 |
| 100 | 682.17 | 682.04 | 682.06 |
| 50 | 681.97 | 681.86 | 681.87 |
| 20 | 681.69 | 681.62 | 681.60 |
| 10 | 681.46 | 681.41 | 681.38 |
| 5 | 681.20 | 681.18 | 681.15 |
| 2 | 680.76 | 680.76 | 680.73 |

Adjusting the stage record with the historic data resulted in a reduction in the extreme flood level estimates obtained from the stage analysis. These estimates (Method 2) were also in closer agreement with estimates derived from the rating curve approach (Method 3). The rating curve estimates(*) will be adopted for this study as they are slightly more conservative and are based on actual records as opposed to historic adjustments on a shorter record base. Stuart Lake flood levels are therefore as follows:

200 year lake level = 682.26 m (GSC)
20 year lake level = 681.60 m (GSC)

No adjustment will be made for the difference between maximum instantaneous and maximum daily water levels as the difference is small, the seven year average being only 17 mm.

### 4.4 Regional Flood Studies - Nahounli Creek and Necoslie River

Nahounli Creek and Necoslie River both drain ungauged catchments characterized by generally low relief, numerous small lakes and swampy ground. Drainage areas and elevation ranges derived from 1:50000 topographic mapping are as follows:

**Table 4 - Nahounli Ck. and Necoslie R. Catchments**

| | Drainage Area $km^2$ | Elevation Range m |
|---|---|---|
| Nahounli Creek | 149 | 680-1400 |
| Necoslie River | 595 | 680-1240 |

A regional flood frequency analysis was conducted based on station records for the following WSC stations:

**Table 5 - Regional Analysis - Stations Used**

| WSC Sta. | Name | Drainage Area $km^2$ | Elev. Range m | Flood Peaks years |
|---|---|---|---|---|
| 08JE001 | Stuart R. | 14600 | 680-2079 | 59 |
| 07ED001 | Nation R. | 4350 | 850-2079 | 34 |
| 08KC001 | Salmon R. | 4300 | 610-1580 | 37 |
| 08JC005 | Chilako R. | 3390 | 610-1322 | 13 |
| 08JE005 | Kazchek Ck. | 881 | 690-1344 | 5 |
| 08JE004 | Tsilcoh R. | 414 | 720-1123 | 14 |
| 07EE009 | Chuchinka Ck. | 311 | 760-1220 | 14 |
| 08KC003 | Muskeg R. | 303 | 820- 980 | 12 |
| 08KC002 | Wright Ck. | 181 | 610-1000 | 9 |
| 08JC007 | Clear Ck. | 52.1 | 670- 976 | 4 |
| 08JC008 | Murray Ck. | 20.2 | 640- 920 | 8 |

Snowmelt floods appear exclusively at all of these stations with flood peaks in all but the largest catchments occurring in the months of April and May.

Frequency analyses were conducted on stations with 9 or more years of records. Preliminary estimates were made utilizing Creager's method of regional analysis, relating flows to catchment area. However this method, which was established for rainfall events, gave unrealistically high flood estimates.

A standard index flood approach was then followed whereby the mean unit flood discharge and ratios of extreme flood events to the mean are calculated and plotted against catchment drainage area on log-log paper, Figures 3 and 4. The procedure used was essentially the same as that followed by the Water Management Branch (References 1 and 2).

In this analysis, greatest weight was given to the data for the Tsilcoh and Salmon Rivers due to their close proximity to the site and length of record. Results of the regional frequency analyses are summarized below:

**Table 6 - Flood Estimates: Nahounli Creek (D.A. = 149 $km^2$)**

| Return Period Years | Daily | | | Instantaneous | | Inst./daily estimated |
|---|---|---|---|---|---|---|
| | $m^3/s$ | $l/s/km^2$ | Ratio to mean | $m^3/s$ | $l/s/km^2$ | |
| mean | 11.5 | 77 | 1.0 | 13.1 | 87.8 | 1.14 |
| 20 | 20.5 | 138 | 1.79 | 23.4 | 157 | 1.14 |
| 200 | 29.3 | 196 | 2.55 | 33.4 | 224 | 1.14 |

**Table 7 - Flood Estimates: Necoslie River (D.A. = 595 $km^2$)**

| Return Period Years | Daily | | | Instantaneous | | Inst./daily estimated |
|---|---|---|---|---|---|---|
| | $m^3/s$ | $l/s/km^2$ | Ratio to mean | $m^3/s$ | $l/s/km^2$ | |
| mean | 38.1 | 64 | 1.0 | 39.6 | 66.6 | 1.04 |
| 20 | 64.7 | 109 | 1.70 | 67.3 | 113 | 1.04 |
| 200 | 89.5 | 150 | 2.35 | 93.1 | 156 | 1.04 |

Flood frequency plots for Nahounli Creek and Necoslie River are shown on Figures 5 and 6, respectively.

### 4.5 Historical Data

There are reports of recent flooding on Nahounli Creek (Reference 3) in the vicinity of the Douglas Avenue Bridge. The creek has been known to freeze up solid to bank full stage with ice spreading over the banks in places. Flooding occurred in May 1974 and April 1976 and potential flooding situations were mentioned in April 1982 and the winter of 1985-86. Due to the relatively frequent occurrence of these events, assessments were made of the hydraulic capacity of the bridge culverts on Nahounli Creek. It was determined that the 3890 x 2690 mm arch culvert at the Highway 27 road crossing, Photo 16, (Stuart Drive West) would pass approximately 28 $m^3/s$ under inlet control prior to overtopping the road. This capacity corresponds to a flood return period of approximately 60 years, Figure 5, supporting the absence of reported flooding for this culvert.

The twin culverts at the Ash Road crossing, Photos 20 and 21, just upstream of the wooden Douglas Avenue Bridge, were estimated to be 2690 x 2080 mm arch culverts from site photos (Reference 11). These culverts have little cover and in fact the culvert crowns are actually about 0.9 m above the level of the nearby Douglas Road. Flow escapement at the right bank culvert entrance is possible for flows as little as 7.2 $m^3/s$ and would definitely occur for discharges of 16 $m^3/s$ and higher. The latter flow corresponds to a flood return period of only 4.3 years, Figure 5, and is in agreement with the relatively frequent flood reports. If the right embankment at the culvert entrance were raised, culvert capacity would increase to 22 $m^3/s$ (return period = 16 years) prior to overtopping the concrete deck of the Ash Road Bridge. It therefore appears that flooding in the vicinity of the Douglas Avenue Bridge may be linked to underutilized culvert capacity at the Ash Road crossing.

Areas at risk along the shoreline of Stuart Lake were identified by Mr. Lyle Larsen, Water Management Branch (Prince George) during a field inspection June 20, 1988. Stuart Lake water levels were 681.364 m during the inspection or approximately 0.9 m below the 200 year flood level (zero

freeboard). Mr. Larsen visited 4 sites along the shoreline and reported that residents would be affected if water levels were to rise a further 0.3 m to 0.5 m. It should be noted that the 1972 flood level was 682.07 m (4.557 m on gauge) or 0.7 m above the level during Mr. Larsen's inspection. Therefore all of the sites he identified would have suffered flood damage in 1972. Based on the frequency analysis presented herein, the 1972 flood has a return period of approximately 100 years.

# 5 HYDRAULIC ANALYSIS - STUART RIVER

## 5.1 Model Calibration

The HEC-2 water surface profile model of the Stuart River was developed from the 18 river cross sections supplied by the Ministry plus an additional 10 sections developed either from the 1:5000 topographic mapping or interpolated from the given sections. These additional sections were added as refinements to the model to ensure that the upstream model limit reflected static lake levels and to fulfill data requirements which could not be foreseen at the time of the original survey. The back channel sections 17 and 18 were used as extensions to the main channel section 15 and 14 respectively. Some of the surveyed cross section points for section 15 were dropped in order to limit the combined section to the model limit of 100 points. The bridge was modelled using the normal bridge method and additional sections were also developed on either side of the old bridge piers.

The HEC-2 model was calibrated using the river survey profile taken May 27, 1989 which corresponds to a discharge of 174 $m^3/s$. Initial estimates of Manning's "n" values were based on reference 9 in conjunction with the May 1989 river survey photographs. Adjustments were made to the roughness values until the computed profile was within 0.03 m of the surveyed profile. Channel roughness values varied from n=0.026 near the lake outlet to n=0.070 at XS-3.5. Overbank areas were assigned n values of 0.060 to 0.100.

It should be noted that XS-10.9 (downstream face of the bridge) corresponds to WSC Sta 08JE001 and XS-20 (Stuart Lake) corresponds to WSC Sta 08JE003. Flood elevations derived from the rating curves for these stations were used as target levels during subsequent HEC-2 flood runs with the calibrated model. Starting water levels at XS-1 were adjusted so as to minimize the differences between the computed and target water levels. These differences were limited to a maximum of 0.05 m for the 200 year and 20-year flood runs.

### 5.2 Sensitivity Studies

The sensitivity of the calibrated model to variations in discharge was investigated by means of a multiple flow run in which the 200-year instantaneous discharge was increased by 10, 20 and 30% (see Study File: Vol.1 - Stuart River). Starting water levels were derived using the slope-area option (ES = 0.001). A 30% increase in discharge resulted in stage increases ranging from 0.51 m at XS-2 to 0.72 m at XS-14.

Similar sensitivity studies were conducted to determine the effects of changes to the bed roughness (multiple "n" run). The calibrated model roughness values were increased by 20 and 40% with the 200-year mean daily discharge. A 40% increase in roughness resulted in stage increases ranging from 0.68 m at XS-20 to 0.82 m at XS-2.

It should be noted that no attempt was made, during the above sensitivity studies, to match target levels at the WSC gauges. The sensitivity studies therefore overstate the potential uncertainities with the model as large variations in roughness would result in unrealistic water levels in Stuart Lake.

The results from the sensitivity studies were used to evaluate the adequacy of the freeboard allowance used for the designated flood level.

### 5.3 Designated Flood Level and Freeboard Requirements

The designated flood level generally consists of the computed 200-year instantaneous peak profile plus 0.3 m of freeboard or the computed 200-year mean daily peak profile plus 0.6 m of freeboard, whichever level is higher; or as deemed advisable if special conditions are apparent. Stated another way, unless the instantaneous profile is 0.3 m or more above the maximum daily profile, the maximum daily profile plus 0.6 m freeboard allowance will govern. For the Stuart River there is only about 0.05 m difference between the two profiles so the 200-year mean daily flood profile plus 0.6 m freeboard will govern. Tabulated values for the Stuart River flood profile (freeboard included) are given in Appendix C. The freeboard allowance used for the designated flood level therefore appears adequate to accommodate about a 25% flow increase or a 30% increase in roughness.

Interpolated flood levels at a 0.2 m interval spacing were derived from the designated flood profile, Figure 7, and used to draw flood level isograms on the enclosed floodplain maps. The interval spacing was increased to 0.4 m for the steep reach downstream of the gas pipeline crossing. Similarly, 20-year flood levels, including freeboard, were derived and noted on the floodplain maps.

# 6 HYDRAULIC ANALYSIS - NECOSLIE RIVER

## 6.1 Model Calibration

The HEC-2 model of the Necoslie River was developed from the 22 river cross sections supplied by the Ministry with extensions to the limit of the floodplain according to the 1:5000 topographic mapping. Modifications were made to XS-16 to reflect a more realistic alignment of the left half of the section. Also the station chainages for XS-8 were factored by 0.9 to allow for the row of dolphins across the river. The bridge was modelled using the special bridge method.

As there were no high watermark data available, attempts were made to calculate Manning's "n" values from the surveyed water surface profile and an assumed discharge. This approach proved futile as there were several flat reaches which yielded unrealistic roughness values. Consequently, Manning's "n" values were estimated based on reference 9 used in conjunction with the May 1989 river survey photographs. The chosen roughness values resulted in flow into the overbank areas for most of the cross sections upstream of XS-12 when the flow equalled the mean annual flood of 38.1 $m^3/s$ (mean daily flow). The Manning's "n" values adopted for the channel varied from 0.030 in the lower reaches to 0.050 in the upper reaches of the river. Overbank areas were given "n" values of 0.050 to 0.125.

## 6.2 Sensitivity Studies

The sensitivity of the calibrated model to variations in discharge and roughness was investigated by means of multiple flow and multiple n runs (see Study File: Vol.2 - Necoslie River) using the same procedures followed for the Stuart River (Section 5.2) with the exception that starting water levels were held constant for each sensitivity study. It was determined that a 30% flow increase would result in a maximum stage increase of 0.33 m at XS-18. Likewise, a 40% roughness increase resulted in a maximum stage increase of 0.48 m at XS-17.

## 6.3 Designated Flood Level and Freeboard Requirements

Based on the discussion of freeboard criteria presented in Section 5.3, it was determined that the designated flood level for the Necoslie River would consist of the 200-year maximum daily profile plus 0.6 m freeboard. The designated flood level also translates into 0.54 m or more freeboard on top of the 200-year peak instantaneous flood profile. This freeboard allowance would therefore be adequate to accommodate about a 50% increase in either flow or roughness. The Necoslie River is therefore less sensitive than the Stuart River to flow and roughness changes and consequently the adopted freeboard allowance can accommodate the higher degree of uncertainity in the hydrological estimates and model calibration on the Necoslie River.

The designated flood profile (freeboard included) is shown on Figure 8 and tabulated values for the profile are listed in Appendix C. Even numbered interpolated flood levels were derived from this profile and used to draw flood level isograms on the enclosed floodplain maps. Also shown are the 20-year flood levels (freeboard included).

The Necoslie River is subject to freeze up, however, it is believed that due to the relative breadth of the floodplain, overbank channel capacity may limit ice related flooding. The flood profiles presented in this report are for open water conditions only as noted on the mapping.

## 7 HYDRAULIC ANALYSIS - NAHOUNLI CREEK

### 7.1 Model Calibration

The HEC-2 model of Nahounli Creek was developed from the 16 river cross sections supplied by the Ministry plus one interpolated cross section. Sections were extended to the limit of the floodplain according to the 1:5000 topographic mapping. The three bridge/culvert crossings were modelled by the special bridge method.

Once again, there were no high watermark data available so Manning's n values were estimated from the May 1989 river survey photographs and reference 9. The chosen roughness values resulted in flow into the overbank areas for many of the cross sections when flow equalled the mean annual flood of 11.5 $m^3/s$ (mean daily flow). The Manning's n values adopted for the channel varied from 0.045 at the mouth to 0.075 at XS-15. Overbank areas were assigned n values of 0.050 to 0.125.

### 7.2 Sensitivity Studies

The sensitivity of the calibrated model to variations in discharge and roughness was investigated by means of multiple flow and multiple n runs (see Study File: Vol. 3 - Nahounli Creek) using the same procedures followed for the Necoslie River (Section 6.2). Results from these tests indicated that a 30% flow increase would result in a maximum stage increase of 0.22 m at XS-3 and a 40% roughness increase would result in a maximum stage increase of 0.29 m at XS-14.

Nahounli Creek is therefore the least sensitive of the three streams to changes in either flow or roughness.

### 7.3 Designated Flood Level and Freeboard Requirements

Application of the standard freeboard criteria to Nahounli Creek resulted in selection of the 200-year mean daily profile plus 0.6 m of freeboard.

There is a maximum difference of 0.14 m between the 200-year peak instantaneous and 200-year mean daily flood profiles which translates into 0.46 m or more freeboard on top of the 200-year peak instantaneous flood profile. This freeboard could accommodate about a 60% increase in either flow or roughness.

Nahounli Creek is subject to freeze up, as mentioned in Section 4.5, which has the potential to increase flood levels. Also, the culverts and bridge crossings are subject to debris blockages which could also increase flood levels. These flood related factors are noted on the mapping. The designated flood profile (freeboard included) is shown on Figure 9 and tabulated values for the profile are listed in Appendix C. Even numbered interpolated flood levels were then derived from this profile and used to draw flood level isograms on the enclosed floodplain maps. The 20-year flood levels (freeboard included) are also shown on the maps.

## 8 WIND/WAVE ANALYSIS - STUART LAKE

### 8.1 Wave Runup

Flood levels in Stuart Lake are based on the assumed concurrence of high lake levels and common seasonal winds. High lake levels generally occur in June or July so winds during the months of May to September were analyzed using wind data for the Fort St. James airport. The maximum fetch is 39 km for winds from the northwest. In the runup analysis, a beach slope of approximately 7 degrees (1V:8H) was used based on estimates of the slope at Paarens Beach Park (photo 2). Results of the wave runup analysis are tabulated below.

**Table 8 - Stuart Lake - Wave Runup**

| Return Period Years | Wave Height m | Wave Period s | Wave Runup m |
|---|---|---|---|
| 1 | 1.3 | 4.8 | 0.7 |
| 5 | 1.8 | 5.2 | 0.9 |
| 10 | 2.0 | 5.4 | 1.0 |
| 25 | 2.2 | 5.6 | 1.0 |

An additional analysis was conducted to ensure that uncommon high winds coincident with lower lake levels do not exceed the high water case. The results of this analysis are tabulated below.

**Table 9 - Stuart Lake - Flood Level/Runup Combinations**

| Return Period - Lake Level Years | Lake Level m | Return Period - Wave Runup years | Wave Runup m | Combined Level m |
|---|---|---|---|---|
| 200 | 682.26 | 1 | 0.7 | 682.96 |
| 40 | 681.81 | 5 | 0.9 | 682.71 |
| 20 | 681.60 | 10 | 1.0 | 682.60 |
| 8 | 681.31 | 25 | 1.0 | 682.31 |

The above analysis shows that the highest flood levels will result from the combination assuming common seasonal winds.

In the above analysis it should be noted that wave runup is a dynamic effect apparent only at the shore edge or beach and does not imply still water levels in the backshore area unless overtopping of a berm could result in ponding.

### 8.2 Wind Setup

A wind setup analysis was conducted based on a long duration wind speed of 32 km/h acting over a 10 hour period. Using bathystrophic theory and bathymetry data obtained from the Department of Fisheries, a total wind setup of 0.06 m was obtained. This value was rounded up to 0.1 m to be conservative.

### 8.3 Designated Flood Level and Freeboard Requirements

The designated flood level for Stuart Lake is recommended to be 683.1 m. This value (rounded up) is the combination of the 200-year lake level of 682.26 m (Section 4.3) plus 0.8 m freeboard allowance for wave runup and wind setup.

The Ministry currently uses a value of 683.5 m (includes 3.0 feet freeboard) for the Stuart Lake flood level. This value is understood to have been based on a stage - frequency analsis conducted in 1975 by hydrological staff of the Water Management Branch (reference 3). The record base was only 19 years at that time and included the 1972 flood which appears to have a return period of approximately 100 years. The recommended level has the benefit of an additional 13 years of record plus an analysis of wave runup and wind setup for freeboard determination. It is thus recommended the 200 year flood level for Stuart Lake, including freeboard, be lowered from the current value of 683.5 m to 683.1 m.

## 9 SPECIAL FLOOD CONDITIONS

There do not appear to be any special flood conditions for the Stuart River, however, it should be noted that flood levels in the uppermost reach of the river (above XS-16) may be governed by the still water flood level in the lake plus wind

effects such as setup and surface waves. Stuart Lake freezes in winter but the river remains relatively free of ice according to one of the local float plane pilots.

Necoslie River is highly meandering and could be subject to channel shifting during extreme flood events. There is evidence of extensive bank erosion (see photos 12-14) which could undermine trees during flood conditions. Consequently there is some danger of log jams forming although these are not expected to have much of an effect on flood levels due to the width of the floodplain in most areas. Ice conditions could also result in elevated flood levels above the open water conditions depicted on the maps.

Nahounli Creek is subject to freeze up as previously mentioned. Ice related flooding is of particular concern because of the close proximity of houses along the watercourse and the potential for culvert blockages at the three bridge crossings. There is also a risk from debris blockages at these culverts. These flood risks have been noted on the mapping.

## 10 FLOODPLAIN MAPS

The floodplain maps for Stuart Lake, Stuart River, Necoslie River and Nahounli Creek are enclosed, Drawing nos. 89-42-1 to 89-42-7 (7 sheets). The limits of the respective floodplains are shown together with flood level isograms showing approximate lines of equal 200-year flood water level to the edge of the floodplain.

As noted on the drawings, the floodplain limits have not been established on the ground by legal survey and the maps depict open water conditions only.

## 11 CONCLUSIONS AND RECOMMENDATIONS

On the basis of our investigations for this study, we make the following recommendations:

1. That the floodplain maps prepared for Stuart River and Lake at Fort St. James (includes Necoslie River and Nahounli Creek), as presented herein, be interim designated under the terms of the joint Federal/Provincial Floodplain Mapping Agreement.

2. That the floodplain maps be reviewed and updated as required on the basis of future flood data or information relating to major physical changes in the floodplain.

3. That the hydraulic features at the Ash Road culvert entrance be reviewed to see if hydraulic performance can be improved, particularly with respect to flow escapement at the right abutment.

Prepared by: R.J. Wallwork.
R.J. Wallwork, P.Eng.

Approved by: D.D. McConnell
D.D. McConnell, P.Eng.

# Appendix A

# Flood Frequency Analysis - Stuart River

WSC STATION NO=08JE001
WSC STATION NAME=STUART RIVER NEAR FORT ST. JAMES

| MONTH | YEAR | DATA | ORDERED | RANK | PROB. | RET. PERIOD |
|---|---|---|---|---|---|---|
| (1) | (2) | (3) (CMS) | (4) (CMS) | (5) | (6) (%) | (7) (YEARS) |
| 7 | 1930 | 177.000 | 592.000 | 1 | 1.01 | 98.667 |
| 7 | 1931 | 272.000 | 501.000 | 2 | 2.70 | 37.000 |
| 7 | 1933 | 385.000 | 453.000 | 3 | 4.39 | 22.769 |
| 6 | 1934 | 343.000 | 450.000 | 4 | 6.08 | 16.444 |
| 7 | 1935 | 279.000 | 447.000 | 5 | 7.77 | 12.870 |
| 7 | 1936 | 320.000 | 433.000 | 6 | 9.46 | 10.571 |
| 7 | 1937 | 218.000 | 432.000 | 7 | 11.15 | 8.970 |
| 7 | 1938 | 218.000 | 428.000 | 8 | 12.84 | 7.789 |
| 6 | 1939 | 377.000 | 428.000 | 9 | 14.53 | 6.884 |
| 6 | 1940 | 306.000 | 428.000 | 10 | 16.22 | 6.167 |
| 6 | 1941 | 215.000 | 422.000 | 11 | 17.91 | 5.585 |
| 6 | 1942 | 261.000 | 419.000 | 12 | 19.59 | 5.103 |
| 7 | 1943 | 212.000 | 391.000 | 13 | 21.28 | 4.698 |
| 7 | 1944 | 180.000 | 385.000 | 14 | 22.97 | 4.353 |
| 7 | 1945 | 204.000 | 382.000 | 15 | 24.66 | 4.055 |
| 6 | 1946 | 309.000 | 377.000 | 16 | 26.35 | 3.795 |
| 7 | 1947 | 278.000 | 364.000 | 17 | 28.04 | 3.566 |
| 6 | 1948 | 391.000 | 354.000 | 18 | 29.73 | 3.364 |
| 7 | 1949 | 300.000 | 345.000 | 19 | 31.42 | 3.183 |
| 7 | 1950 | 309.000 | 343.000 | 20 | 33.11 | 3.020 |
| 6 | 1951 | 328.000 | 340.000 | 21 | 34.80 | 2.874 |
| 7 | 1952 | 428.000 | 336.000 | 22 | 36.49 | 2.741 |
| 7 | 1953 | 334.000 | 334.000 | 23 | 38.18 | 2.619 |
| 7 | 1954 | 428.000 | 328.000 | 24 | 39.86 | 2.508 |
| 7 | 1955 | 219.000 | 321.000 | 25 | 41.55 | 2.407 |
| 7 | 1956 | 215.000 | 320.000 | 26 | 43.24 | 2.312 |
| 6 | 1957 | 286.000 | 314.000 | 27 | 44.93 | 2.226 |
| 6 | 1958 | 422.000 | 309.000 | 28 | 46.62 | 2.145 |
| 7 | 1959 | 453.000 | 309.000 | 29 | 48.31 | 2.070 |
| 6 | 1960 | 433.000 | 306.000 | 30 | 50.00 | 2.000 |
| 6 | 1961 | 297.000 | 300.000 | 31 | 51.69 | 1.935 |
| 7 | 1962 | 232.000 | 299.000 | 32 | 53.38 | 1.873 |
| 6 | 1963 | 265.000 | 297.000 | 33 | 55.07 | 1.816 |
| 7 | 1964 | 501.000 | 297.000 | 34 | 56.76 | 1.762 |
| 6 | 1965 | 354.000 | 289.000 | 35 | 58.45 | 1.711 |
| 6 | 1966 | 382.000 | 286.000 | 36 | 60.14 | 1.663 |
| 6 | 1967 | 447.000 | 284.000 | 37 | 61.82 | 1.617 |
| 7 | 1968 | 428.000 | 280.000 | 38 | 63.51 | 1.574 |
| 7 | 1969 | 280.000 | 279.000 | 39 | 65.20 | 1.534 |
| 6 | 1970 | 289.000 | 278.000 | 40 | 66.89 | 1.495 |
| 7 | 1971 | 345.000 | 272.000 | 41 | 68.58 | 1.458 |
| 6 | 1972 | 592.000 | 265.000 | 42 | 70.27 | 1.423 |
| 7 | 1973 | 340.000 | 261.000 | 43 | 71.96 | 1.390 |
| 7 | 1974 | 419.000 | 258.000 | 44 | 73.65 | 1.358 |
| 7 | 1975 | 258.000 | 249.000 | 45 | 75.34 | 1.327 |
| 6 | 1976 | 450.000 | 232.000 | 46 | 77.03 | 1.298 |
| 6 | 1977 | 314.000 | 231.000 | 47 | 78.72 | 1.270 |
| 7 | 1978 | 209.000 | 225.000 | 48 | 80.41 | 1.244 |

WSC STATION NO=08JE001
WSC STATION NAME=STUART RIVER NEAR FORT ST. JAMES

| MONTH | YEAR | DATA | ORDERED | RANK | PROB. | RET. PERIOD |
|---|---|---|---|---|---|---|
| (1) | (2) | (3) (CMS) | (4) (CMS) | (5) | (6) (%) | (7) (YEARS) |
| 7 | 1979 | 321.000 | 219.000 | 49 | 82.09 | 1.218 |
| 7 | 1980 | 167.000 | 218.000 | 50 | 83.78 | 1.194 |
| 6 | 1981 | 364.000 | 218.000 | 51 | 85.47 | 1.170 |
| 7 | 1982 | 336.000 | 215.000 | 52 | 87.16 | 1.147 |
| 7 | 1983 | 249.000 | 215.000 | 53 | 88.85 | 1.125 |
| 7 | 1984 | 299.000 | 212.000 | 54 | 90.54 | 1.104 |
| 7 | 1985 | 231.000 | 209.000 | 55 | 92.23 | 1.084 |
| 7 | 1986 | 297.000 | 204.000 | 56 | 93.92 | 1.065 |
| 6 | 1987 | 284.000 | 180.000 | 57 | 95.61 | 1.046 |
| 6 | 1988 | 432.000 | 177.000 | 58 | 97.30 | 1.028 |
| 6 | 1989 | 225.000 | 167.000 | 59 | 98.99 | 1.010 |

FREQUENCY ANALYSIS - THREE-PARAMETER LOGNORMAL DISTRIBUTION
08JE001 STUART RIVER NEAR FORT ST. JAMES

## SAMPLE STATISTICS

| | MEAN | S.D. | C.V. | C.S. | C.K. |
|---|---|---|---|---|---|
| X SERIES | 317.068 | 89.651 | 0.283 | 0.595 | 3.356 |
| LN X SERIES | 5.720 | 0.283 | 0.049 | -0.047 | 2.635 |
| LN(X-A) SERIES | 5.700 | 0.288 | 0.051 | -0.059 | 2.636 |

X(MIN)= 167.000
X(MAX)= 592.000
LOWER OUTLIER LIMIT OF X= 137.058

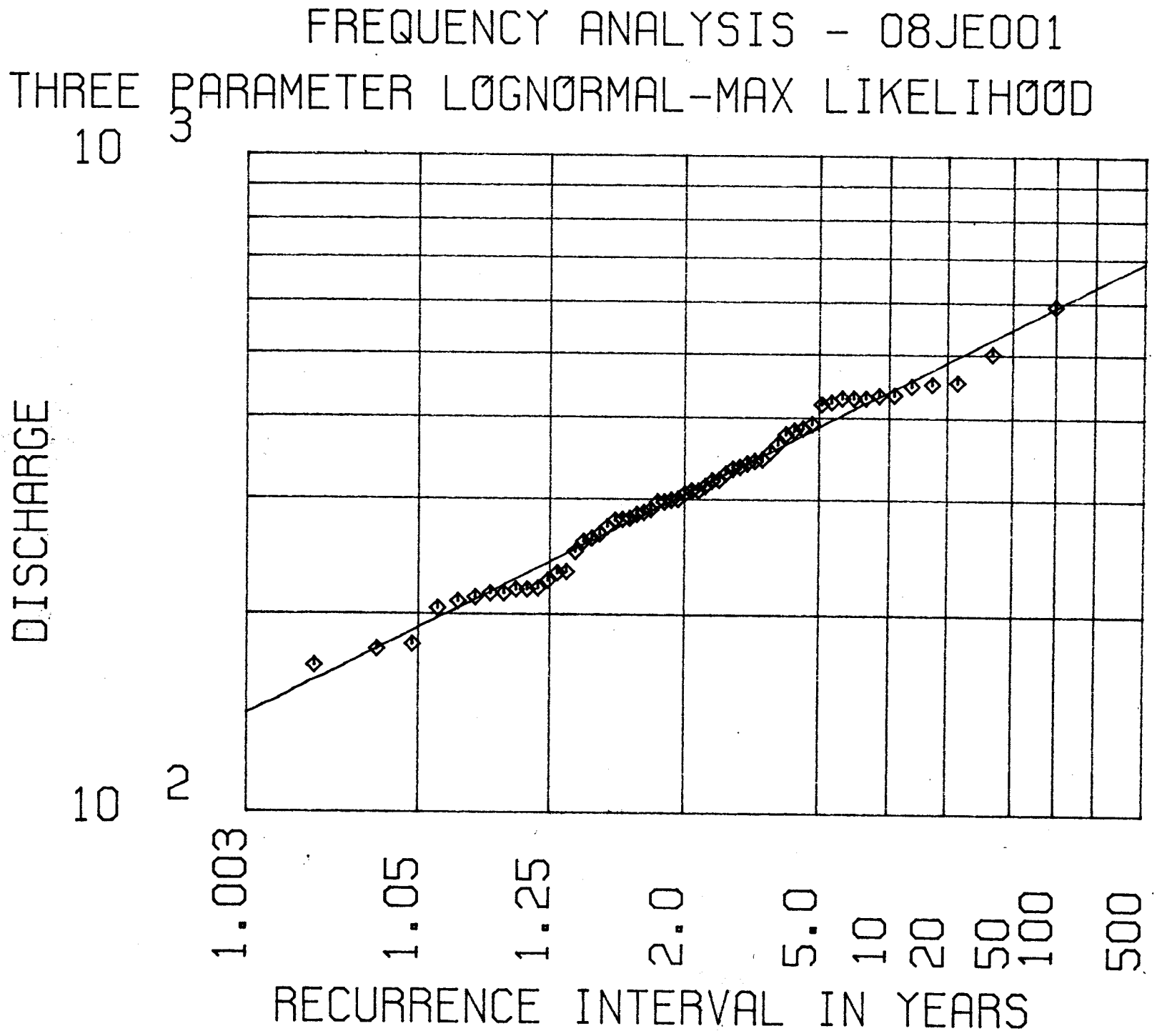
TOTAL SAMPLE SIZE= 59
NO. OF LOW OUTLIERS= 0
NO. OF ZERO FLOWS= 0

## SOLUTION OBTAINED VIA MAXIMUM LIKELIHOOD

3LN PARAMETERS: A= 5.799 M= 5.700 S= 0.288

## FLOOD FREQUENCY REGIME

| RETURN PERIOD | EXCEEDANCE PROBABILITY | FLOOD |
|---|---|---|
| 1.003 | 0.997 | 141.00 |
| 1.050 | 0.952 | 191.00 |
| 1.250 | 0.800 | 240.00 |
| 2.000 | 0.500 | 305.00 |
| 5.000 | 0.200 | 387.00 |
| 10.000 | 0.100 | 438.00 |
| 20.000 | 0.050 | 486.00 |
| 50.000 | 0.020 | 546.00 |
| 100.000 | 0.010 | 590.00 |
| 200.000 | 0.005 | 634.00 |
| 500.000 | 0.002 | 691.00 |


FREQUENCY ANALYSIS - 08JE001
THREE PARAMETER LØGNØRMAL-MAX LIKELIHØØD
10 3
10 2
DISCHARGE
1.003
1.05
1.25
2.0
5.0
10
20
50
100
500
RECURRENCE INTERVAL IN YEARS

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# Appendix B

## Stage Frequency Analysis - Stuart Lake

WSC STATION NO=08JE003
WSC STATION NAME=STUART LAKE NEAR FORT ST. JAMES

---

TOTAL TIME SPAN, YT= 60 YRS. FLOW THRESHOLD = 4557.000
OBSERVED PEAKS, N= 32 HISTORIC PEAKS ABOVE THRESHOLD, NHA= 1

OBSERVED PEAKS ABOVE THRESHOLD, NA= 1
OBSERVED PEAKS BELOW THRESHOLD, NB= 31
MISSING PEAKS BELOW THRESHOLD, NC= 28

| MONTH | YEAR | FLOOD STAGE $\times 10^3$ | DESCENDING ORDER | RANK M | RANK ADJ. | CUM. PROB. | RET.PERIOD YEARS |
|---|---|---|---|---|---|---|---|
| (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
| 7 | 1956 | 2679.000 | 4557.000 | 1 | 1.00 | 1.00 | 100.33 |
| | | | THRESHOLD | | | | |
| 6 | 1957 | 3063.000 | 4066.000 | 2 | 2.90 | 4.16 | 24.05 |
| 6 | 1958 | 3673.000 | 3923.000 | 3 | 4.81 | 7.32 | 13.66 |
| 6 | 1960 | 3764.000 | 3871.000 | 4 | 6.71 | 10.48 | 9.54 |
| 6 | 1961 | 3103.000 | 3868.000 | 5 | 8.61 | 13.64 | 7.33 |
| 7 | 1962 | 2752.000 | 3786.000 | 6 | 10.52 | 16.80 | 5.95 |
| 6 | 1963 | 2947.000 | 3764.000 | 7 | 12.42 | 19.97 | 5.01 |
| 7 | 1964 | 4066.000 | 3761.000 | 8 | 14.32 | 23.13 | 4.32 |
| 6 | 1965 | 3408.000 | 3673.000 | 9 | 16.23 | 26.29 | 3.80 |
| 7 | 1966 | 3527.000 | 3527.000 | 10 | 18.13 | 29.45 | 3.40 |
| 6 | 1967 | 3868.000 | 3453.000 | 11 | 20.03 | 32.61 | 3.07 |
| 7 | 1968 | 3761.000 | 3448.000 | 12 | 21.94 | 35.77 | 2.80 |
| 6 | 1969 | 2938.000 | 3408.000 | 13 | 23.84 | 38.93 | 2.57 |
| 7 | 1970 | 3112.000 | 3371.000 | 14 | 25.74 | 42.10 | 2.38 |
| 7 | 1971 | 3453.000 | 3355.000 | 15 | 27.65 | 45.26 | 2.21 |
| 7 | 1972 | 4557.000 | 3237.000 | 16 | 29.55 | 48.42 | 2.07 |
| 7 | 1973 | 3371.000 | 3225.000 | 17 | 31.45 | 51.58 | 1.94 |
| 7 | 1974 | 3786.000 | 3191.000 | 18 | 33.35 | 54.74 | 1.83 |
| 7 | 1975 | 2905.000 | 3112.000 | 19 | 35.26 | 57.90 | 1.73 |
| 7 | 1976 | 3923.000 | 3111.000 | 20 | 37.16 | 61.07 | 1.64 |
| 6 | 1977 | 3225.000 | 3103.000 | 21 | 39.06 | 64.23 | 1.56 |
| 7 | 1978 | 2655.000 | 3063.000 | 22 | 40.97 | 67.39 | 1.48 |
| 6 | 1979 | 3237.000 | 2947.000 | 23 | 42.87 | 70.55 | 1.42 |
| 7 | 1980 | 2374.000 | 2938.000 | 24 | 44.77 | 73.71 | 1.36 |
| 6 | 1981 | 3448.000 | 2921.000 | 25 | 46.68 | 76.87 | 1.30 |
| 7 | 1982 | 3355.000 | 2905.000 | 26 | 48.58 | 80.03 | 1.25 |
| 7 | 1983 | 2921.000 | 2756.000 | 27 | 50.48 | 83.20 | 1.20 |
| 7 | 1984 | 3191.000 | 2752.000 | 28 | 52.39 | 86.36 | 1.16 |
| 7 | 1985 | 2756.000 | 2717.000 | 29 | 54.29 | 89.52 | 1.12 |
| 6 | 1987 | 3111.000 | 2679.000 | 30 | 56.19 | 92.68 | 1.08 |
| 6 | 1988 | 3871.000 | 2655.000 | 31 | 58.10 | 95.84 | 1.04 |
| 6 | 1989 | 2717.000 | 2374.000 | 32 | 60.00 | 99.00 | 1.01 |

HISTORICAL FREQUENCY ANALYSIS - THREE-PARAMETER LOGNORMAL DISTRIBUTION
08JE003 STUART LAKE NEAR FORT ST. JAMES

## SAMPLE STATISTICS

| | MEAN | S.D. | C.V. | C.S. | C.K. |
|---|---|---|---|---|---|
| X SERIES | 3297.406 | 490.596 | 0.149 | 0.414 | 3.259 |
| LN X SERIES | 8.090 | 0.148 | 0.018 | 0.061 | 2.964 |
| LN(X-A) SERIES | 8.095 | 0.147 | 0.018 | 0.063 | 2.964 |

X(MIN)= 2374.000
X(MAX)= 4557.000
LOWER OUTLIER LIMIT OF X= 2224.562

TOTAL SAMPLE SIZE= 32
NO. OF LOW OUTLIERS= 0
NO. OF ZERO FLOWS= 0

## SOLUTION OBTAINED VIA MAXIMUM LIKELIHOOD

3LN PARAMETERS: A= -15.765 M= 8.092 S= 0.141

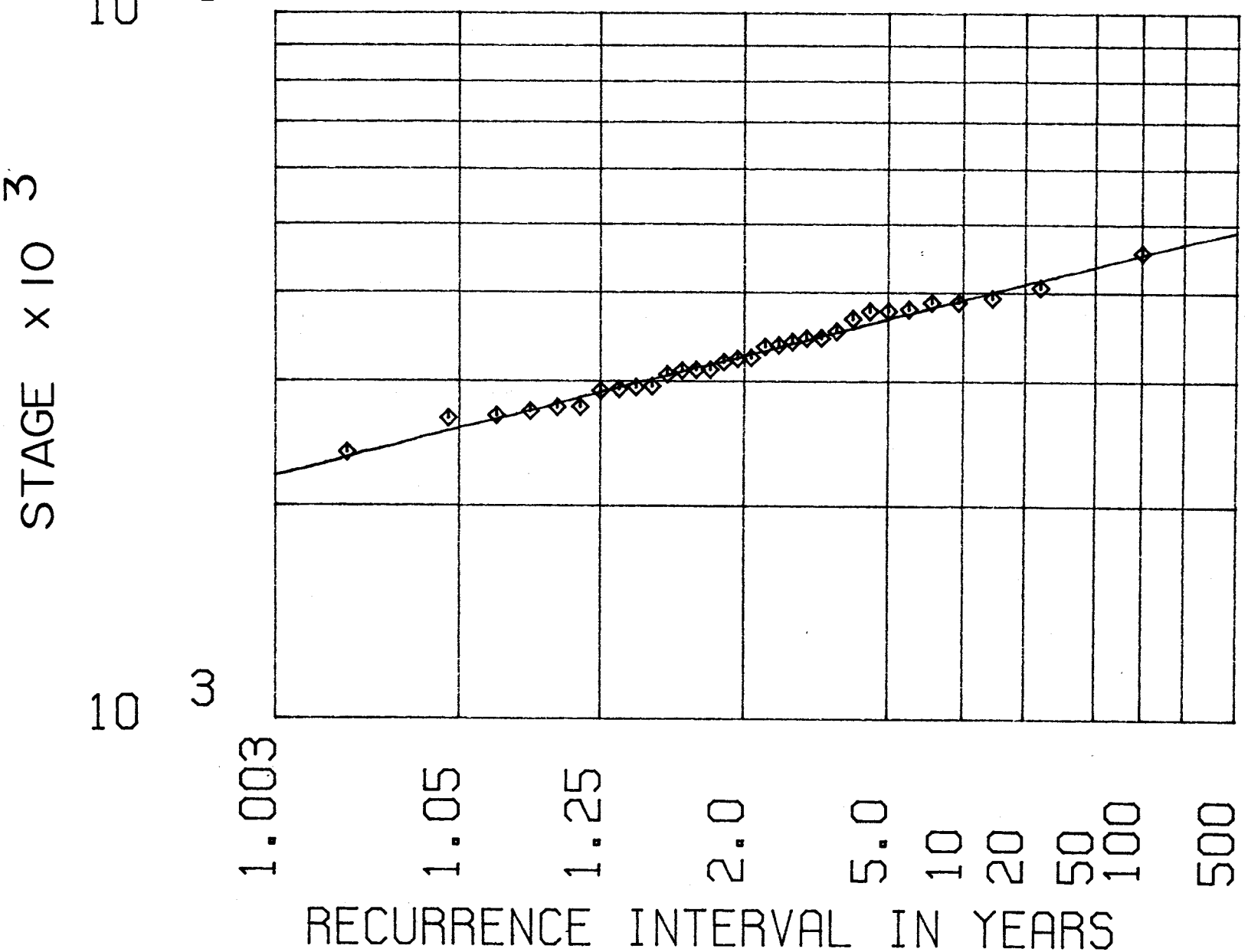
## FLOOD FREQUENCY REGIME

| RETURN PERIOD | EXCEEDANCE PROBABILITY | FLOOD STAGE $\times 10^3$ |
|---|---|---|
| 1.003 | 0.997 | 2200.00 |
| 1.050 | 0.952 | 2570.00 |
| 1.250 | 0.800 | 2890.00 |
| 2.000 | 0.500 | 3250.00 |
| 5.000 | 0.200 | 3670.00 |
| 10.000 | 0.100 | 3900.00 |
| 20.000 | 0.050 | 4110.00 |
| 50.000 | 0.020 | 4350.00 |
| 100.000 | 0.010 | 4530.00 |
| 200.000 | 0.005 | 4690.00 |
| 500.000 | 0.002 | 4890.00 |

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# HISTØRICAL FREQUENCY ANALYSIS - 08JE003

## THREE PARAMETER LØGNØRMAL-MAX LIKELIHØØD




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# Appendix C

# Tabulated Flood Level Profiles (Freeboard Included)

**Stuart River: Flood Level Profile (Freeboard Included)***

| Cross Section No. | Flood Level (Freeboard Included) m |
|---|---|
| 1 | 681.17 |
| 2 | 681.22 |
| 3 | 681.76 |
| 3.5 | 682.13 |
| 4 | 682.22 |
| 5 | 682.34 |
| 6 | 682.38 |
| 7 | 682.43 |
| 7.5 | 682.47 |
| 7.75 | 682.49 |
| 8 | 682.51 |
| 8.5 | 682.49 |
| 8.9 | 682.43 |
| 9 | 682.43 |
| 9.1 | 682.47 |
| 10 | 682.63 |
| 10.9 | 682.63 |
| 11 | 682.63 |
| 11.1 | 682.65 |
| 12 | 682.71 |
| 13 | 682.79 |
| 14 | 682.84 |
| 15 | 682.85 |
| 16 | 682.86 |
| 19 | 682.87 |
| 20 | 682.87 |

* Refer to Study File: Vol.1 - Stuart River
Test 12 - 200-Year Flood (Daily) + 0.6 m Freeboard

**Necoslie River : Flood Level Profile (Freeboard Included)***

| Cross Section No. | Flood Level (Freeboard Included) m |
|---|---|
| 1 | 682.86 |
| 2 | 682.86 |
| 3 | 682.86 |
| 4 | 682.86 |
| 5 | 682.86 |
| 6 | 682.86 |
| 7 | 682.85 |
| 8 | 682.87 |
| 9 | 682.88 |
| 10 | 682.88 |
| 11 | 682.91 |
| 12 | 682.96 |
| 13 | 683.13 |
| 14 | 685.31 |
| 15 | 686.16 |
| 16 | 686.60 |
| 17 | 687.67 |
| 18 | 689.53 |
| 19 | 690.36 |
| 20 | 691.00 |
| 21 | 691.61 |
| 22 | 692.72 |

* Refer to Study File: Vol. 2 - Necoslie River
Test 8 - 200-Year Flood (Daily) + 0.6 m Freeboard.

**Nahounli Creek : Flood Level Profile (Freeboard Included)***

| Cross Section No. | Flood Level (Freeboard Included) m |
|---|---|
| 1 | 683.1 |
| 2 | 683.1 |
| 3 | 684.04 |
| 4 | 684.30 |
| 4.5 | 684.32 |
| 5 | 684.54 |
| 6 | 685.97 |
| 7 | 686.96 |
| 8 | 688.98 |
| 9 | 690.65 |
| 10 | 690.91 |
| 11 | 690.97 |
| 12 | 691.15 |
| 13 | 691.67 |
| 14 | 694.37 |
| 15 | 694.89 |
| 16 | 696.67 |

* Refer to Study File: Vol. 3 - Nahounli Creek
Test 6 - 200-Year Flood (Daily) + 0.6 m Freeboard.
Flood level at XS-1 and XS-2 governed by the flood level in Stuart Lake.

# Appendix D

# Data Sources and References

## Data Sources and References

Information Supplied by the Water Management Branch:

1. River Survey - Project 89 09 F029

   Binder (Volume 1 of 1) containing:

   a. Uncontrolled mosaic of Stuart River, Necoslie River and Nahounli Creek at Fort St. James, Drawing No. 90-4-1, scale 1:10,000.

   b. Work sheets of 6 topographic maps, Project No. 82-024 T and 83-137 T, showing cross section locations, thalwegs, bench marks and gauges.

   c. Nahounli Creek water level and thalweg written profiles and plots.

      - Nahounli Creek GR data listing, cross sections 1 to 16.
      - Nahounli Creek written cross sections (left to right), plots and photographs for cross sections 1 to 16.

   d. Necoslie River water level and thalweg written profiles and plots.

      - Necoslie River GR data listing, cross sections 1 to 22.
      - Necoslie River written cross sections (left to right), plots and photographs for cross sections 1 to 22.

   e. Water Survey of Canada gauge description forms for stations 08JE001 and 08JE003, and Water Management Branch background information regarding establishment of the Stuart Lake flood level (freeboard included).

   f. Stuart River water level and thalweg written profiles and plots including Stuart River back channel.

- o Stuart River GR data listing, cross sections 1 to 18.

- o Stuart River written cross sections (left to right), plots and photographs for cross sections 1 to 18.

g. Stuart Lake water level data, June 1988, and related water level information and photographs.

h. Floppy disk containing GR data in HEC-2 format.

2. Drawings

   a. Prints of Drawings Nos. 89-42-1 to 89-42-7, base mapsheets for floodplain mapping titled "Stuart River and Lake at Fort St. James," scale 1:5000.

   b. Ministry of Highways

      - o Stuart River Bridge - General Arrangement, Dwg. No. 84-53-B.

      - o Necoslie River Bridge - General Arrangement, Dwg. No. 930-4.

3. The Stuart Lake flood level (freeboard included) presently used for administrative purposes is 683.5 m. This level is subject to review by the consultant.

**Other Data Sources and References**


1. Water Management Branch, February 1987, "A Procedure for Regionalization of Peak Flows in B.C.", D.E. Reksten, Senior Hydrological Engineer.

2. Water Management Branch, February 1987, "Guide to Peak Flow Estimation of Ungauged Watersheds in the Omineca - Peace Region (Prince George)".

3. Water Management Branch, March 1988, "Village of Fort St. James - Floodplain Bylaw Requirements - Background Report", P.A. Campbell, Prince George Regional Office.

4. Water Survey of Canada, Surface Water Data - Reference Index - Canada 1988.

5. Water Survey of Canada, Historical Streamflow Summary - British Columbia - to 1988.

6. Water Survey of Canada, Historical Water Levels Summary - British Columbia - to 1987.

7. FAXCOM from Mr. Oliver Nagy, Water Survey of Canada, re Streamflow and Water Level data to 1989.

8. Water Resources Branch, Inland Waters Directorate, Environment Canada, July 1985, "Consolidated Frequency Analysis Package - CFA-User Manual For Version 1 - Dec Pro Series", by Paul J. Pilon, Robert Condie, K. David Harvey.

9. U.S. Geological Survey, Water-Supply Paper 1849, "Roughness Characteristics of Natural Channels", by Henry H. Barnes, Jr.

10. Hay & Company, October 3, 1990 letter to Water Management Branch re Survey Data Base - Stuart Lake and River - Floodplain Mapping Program.

11. Hay & Company, October 17, 1990 letter report to Water Management Branch re Flood Frequency Studies - Stuart Lake and River - Floodplain Mapping Program.

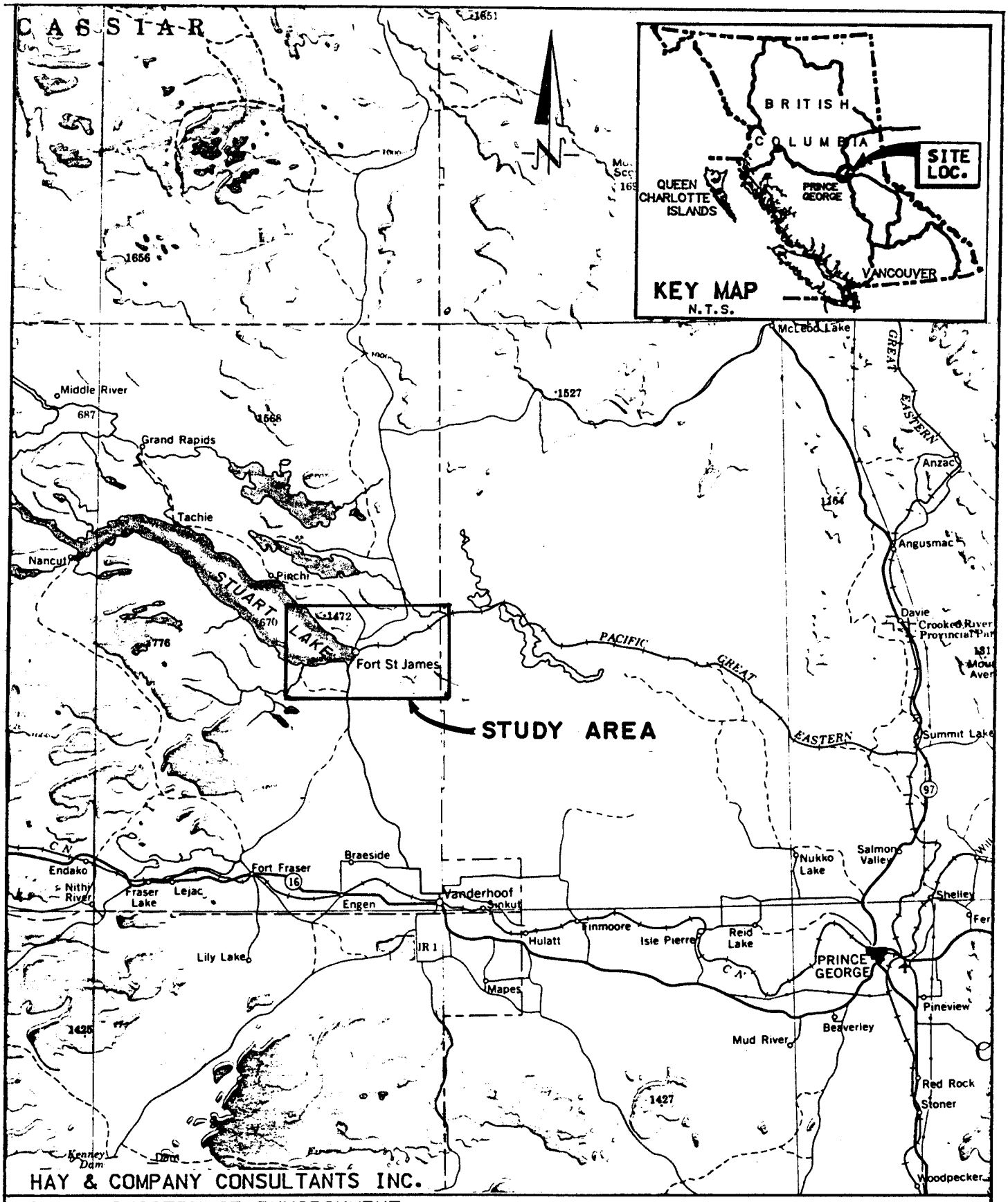
12. National Topographic Mapping, Energy, Mines and Resources, Canada.

**1:250,000 Maps**

| | | |
|---|---|---|
| Nechako River | 93F | Edition 2 |
| Prince George | 93G | Edition 1 |
| Fort Fraser | 93K | Edition 2 |
| McLeod Lake | 93J | Edition 2 |
| Manson River,B.C. | 93N | First Status Edition |
| Pine Pass | 93O | Edition 2 |

**1:50,000 Maps**

| | | |
|---|---|---|
| Knight Creek | 93J/4 | Edition 2 |
| Great Beaver Lake | 93J/5 | Edition 2 |
| Fort St. James | 93K/8 | Edition 2 |
| Pinchi Lake | 93K/9 | Edition 2 |



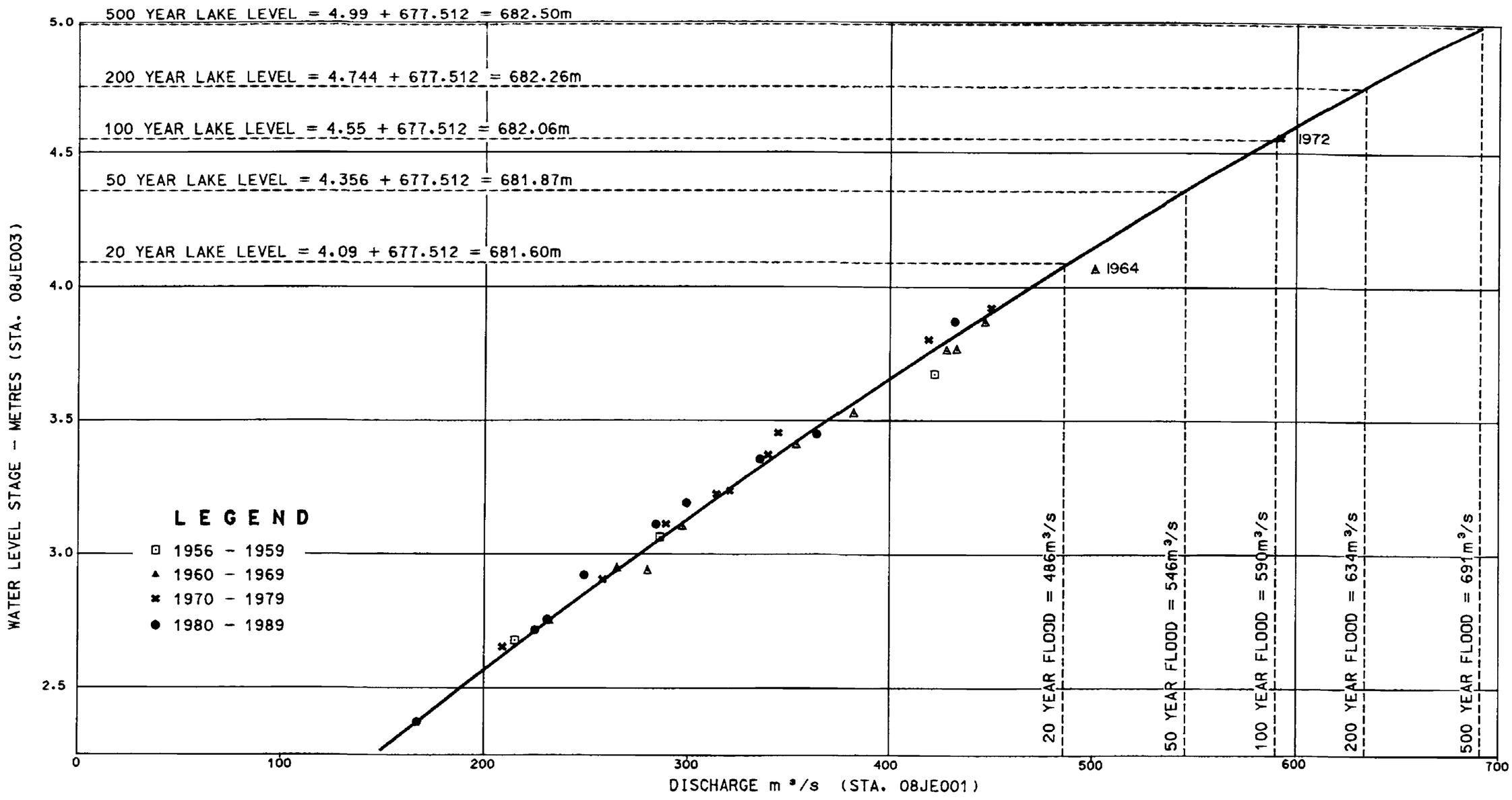

HAY & COMPANY CONSULTANTS INC.

B.C. MINISTRY OF ENVIRONMENT

# FLOODPLAIN MAPPING STUART LAKE AND RIVER

## LOCATION MAP

FIG. 1




HAY & COMPANY CONSULTANTS INC.

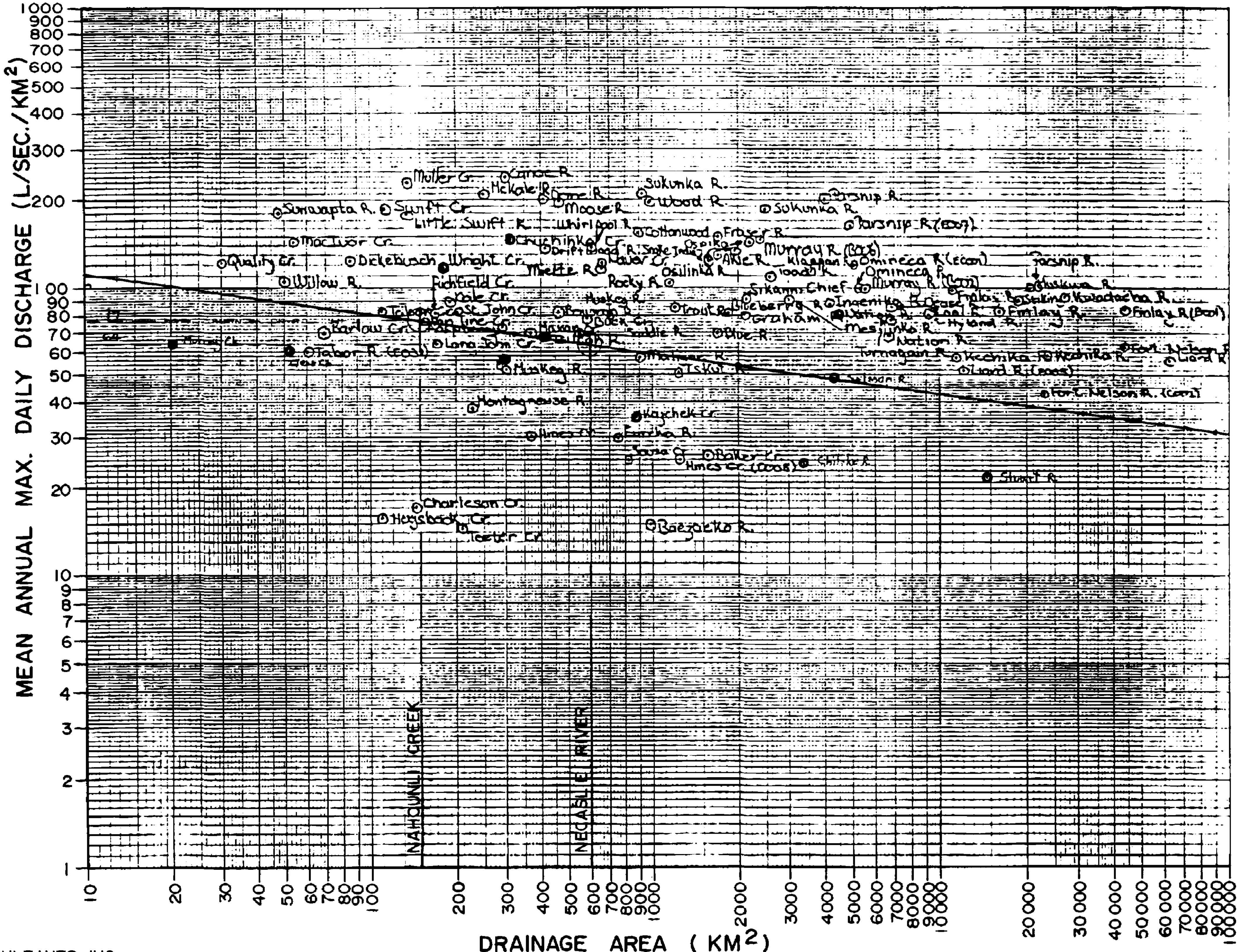
B.C. MINISTRY OF ENVIRONMENT

**FLOODPLAIN MAPPING**
**STUART LAKE AND RIVER**

# STUART LAKE LEVELS
# RATING CURVE AT OUTLET OF STUART LAKE

FIG. 2

MENV-10/FIG1.DGN/90-10-16




ADAPTED FROM REFERENCE 2
FIG. OPI

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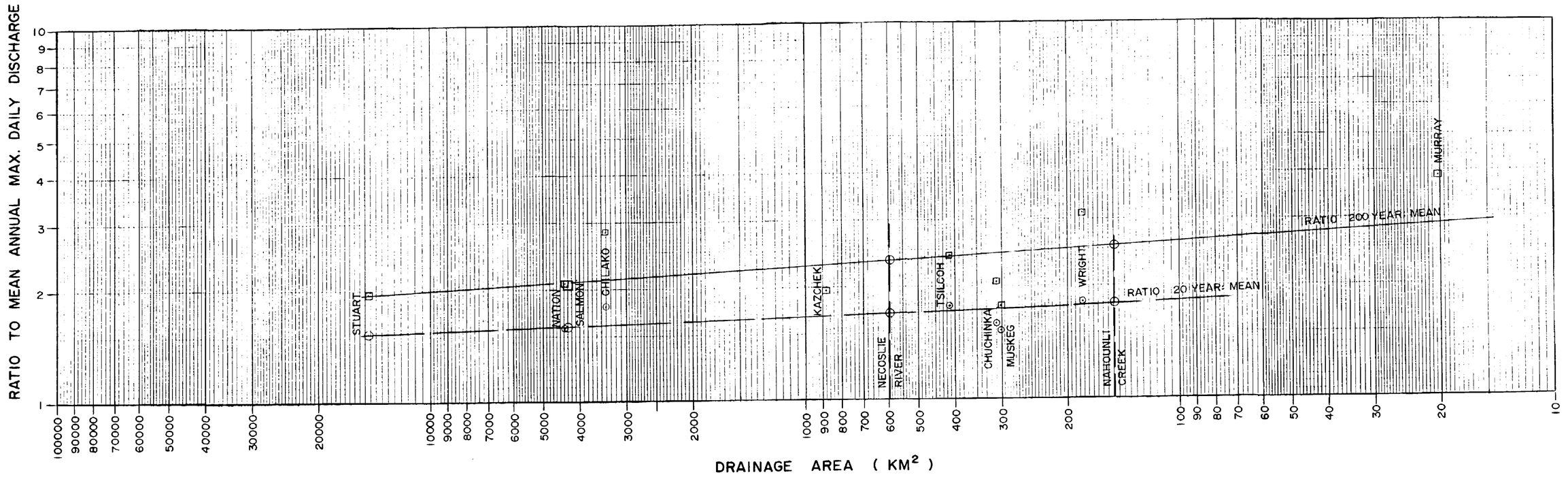
B. C. MINISTRY OF ENVIRONMENT

# FLOODPLAIN MAPPING
# STUART LAKE AND RIVER

## MEAN ANNUAL MAXIMUM DAILY DISCHARGE Vs. DRAINAGE AREA (PRINCE GEORGE REGION)

FIG.
3

MENV-10/DWG.DGN/90-10-16




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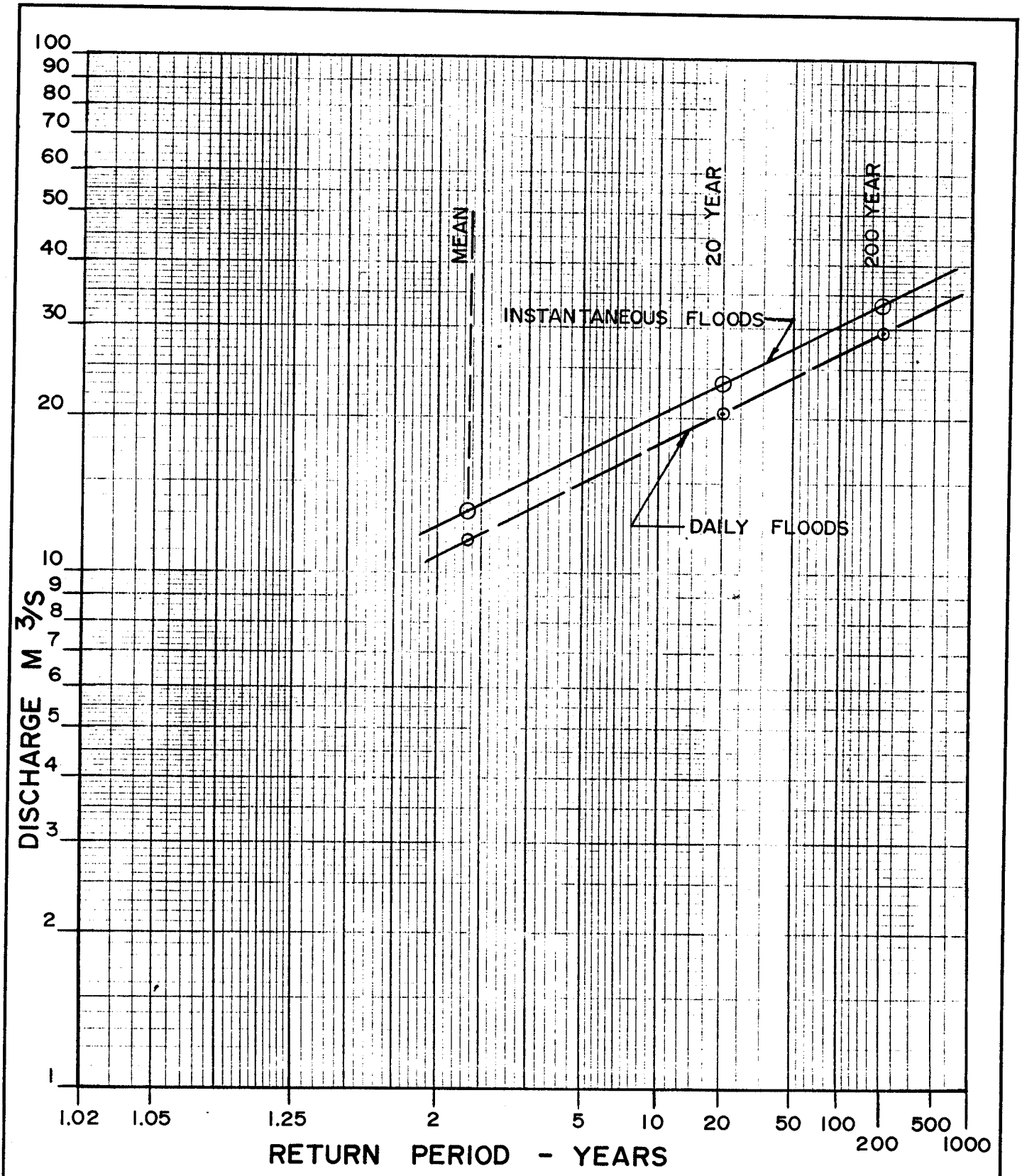
B. C. MINISTRY OF ENVIRONMENT

FLOODPLAIN MAPPING
STUART LAKE AND RIVER

RATIO RETURN PERIOD FLOODS TO MEAN FLOOD Vs. DRAINAGE AREA
FORT ST. JAMES REGION

FIG. 4

MENV-10/DWG.DGN/90-10-15




HAY & COMPANY CONSULTANTS INC.

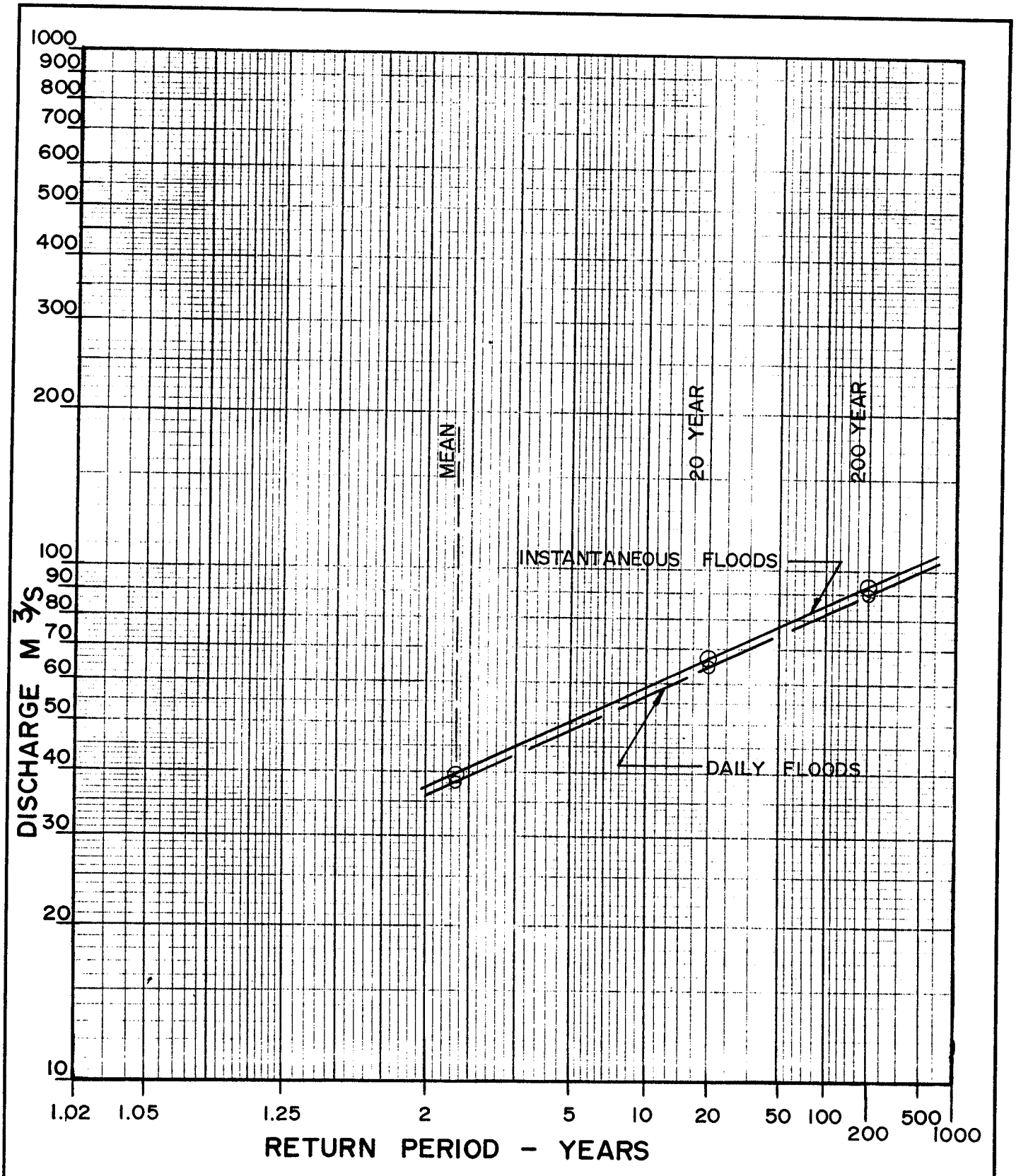
B. C. MINISTRY OF ENVIRONMENT

# FLOODPLAIN MAPPING
# STUART LAKE AND RIVER

## NAHOUNLI CREEK
## FLOW Vs. RETURN PERIOD

FIG. 5

MENV-10/DWG.DGN/90-10-15




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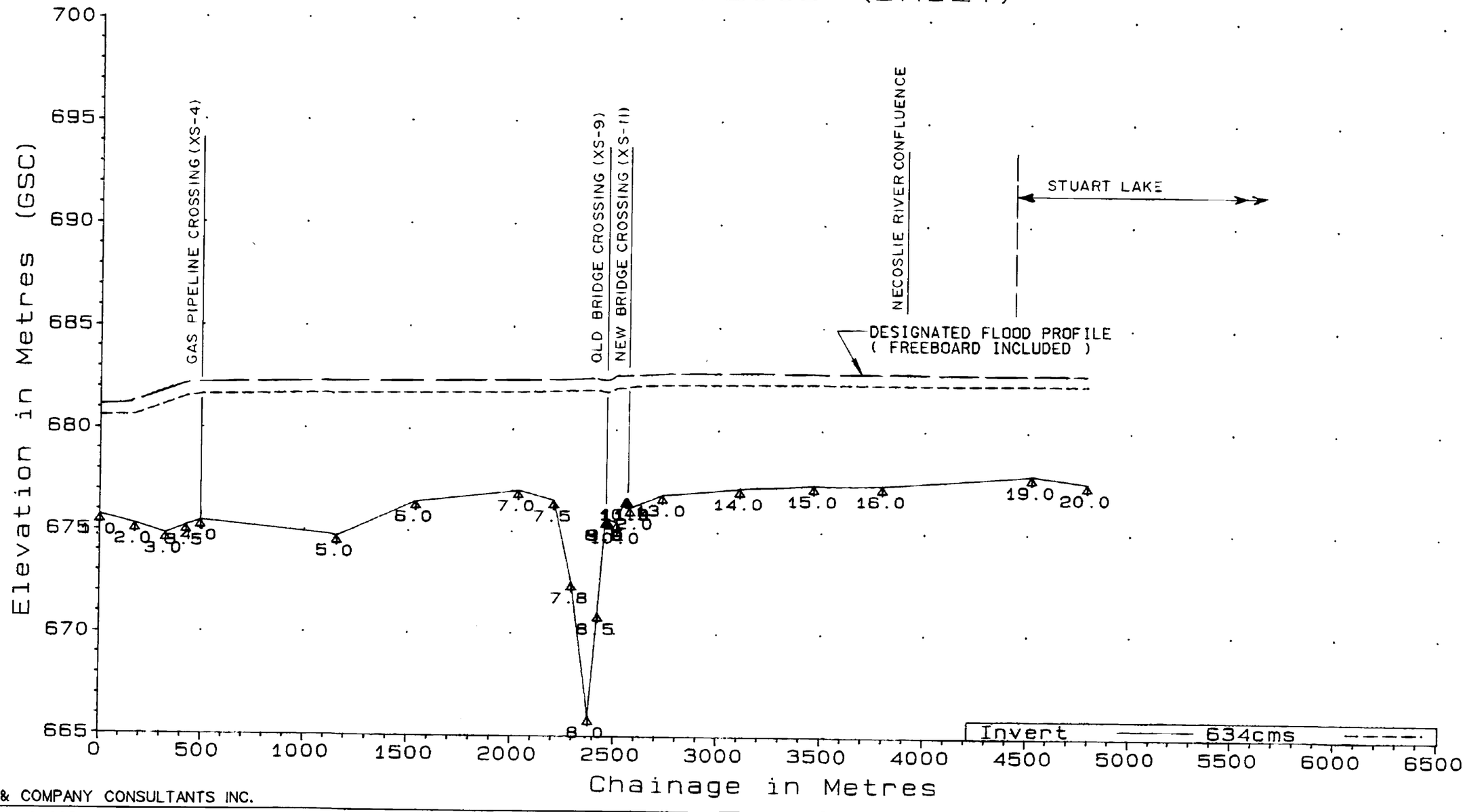
# FLOODPLAIN MAPPING
# STUART LAKE AND RIVER

## NECOSLIE RIVER
## FLOW Vs. RETURN PERIOD

FIG. 6

MENV-10/DWG.DGN/90-10-15

# STUART RIVER: TEST 12
# 200-YR FLOOD (DAILY)




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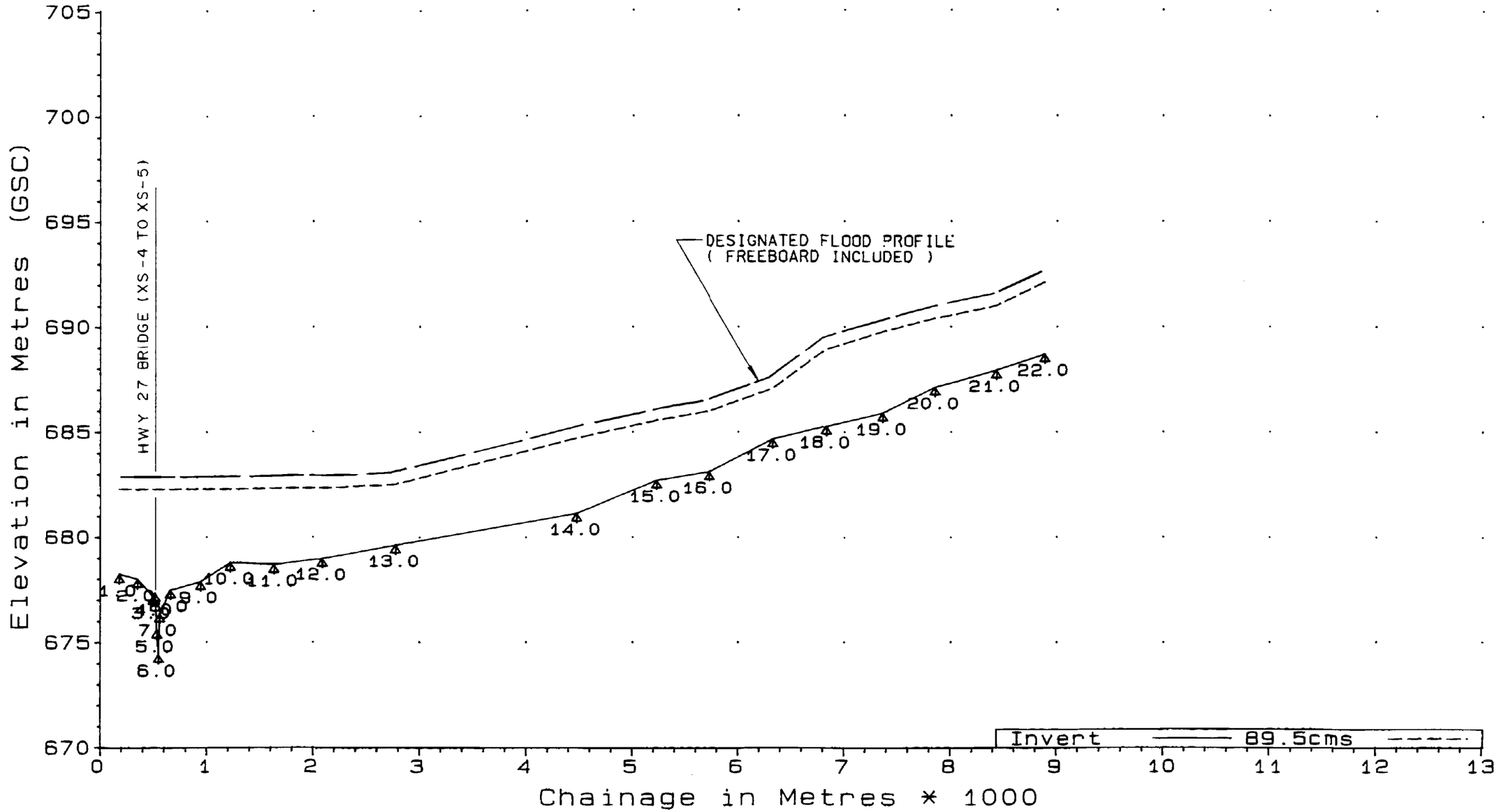
**FLOODPLAIN MAPPING**
**STUART LAKE AND RIVER**

**STUART RIVER**
**DESIGNATED FLOOD PROFILE**

FIG. 7

MENV-10/FIG.DGN/30-11-90

# NECOSLIE RIVER: TEST 8
# 200-YR FLOOD (DAILY)




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B. C. MINISTRY OF ENVIRONMENT

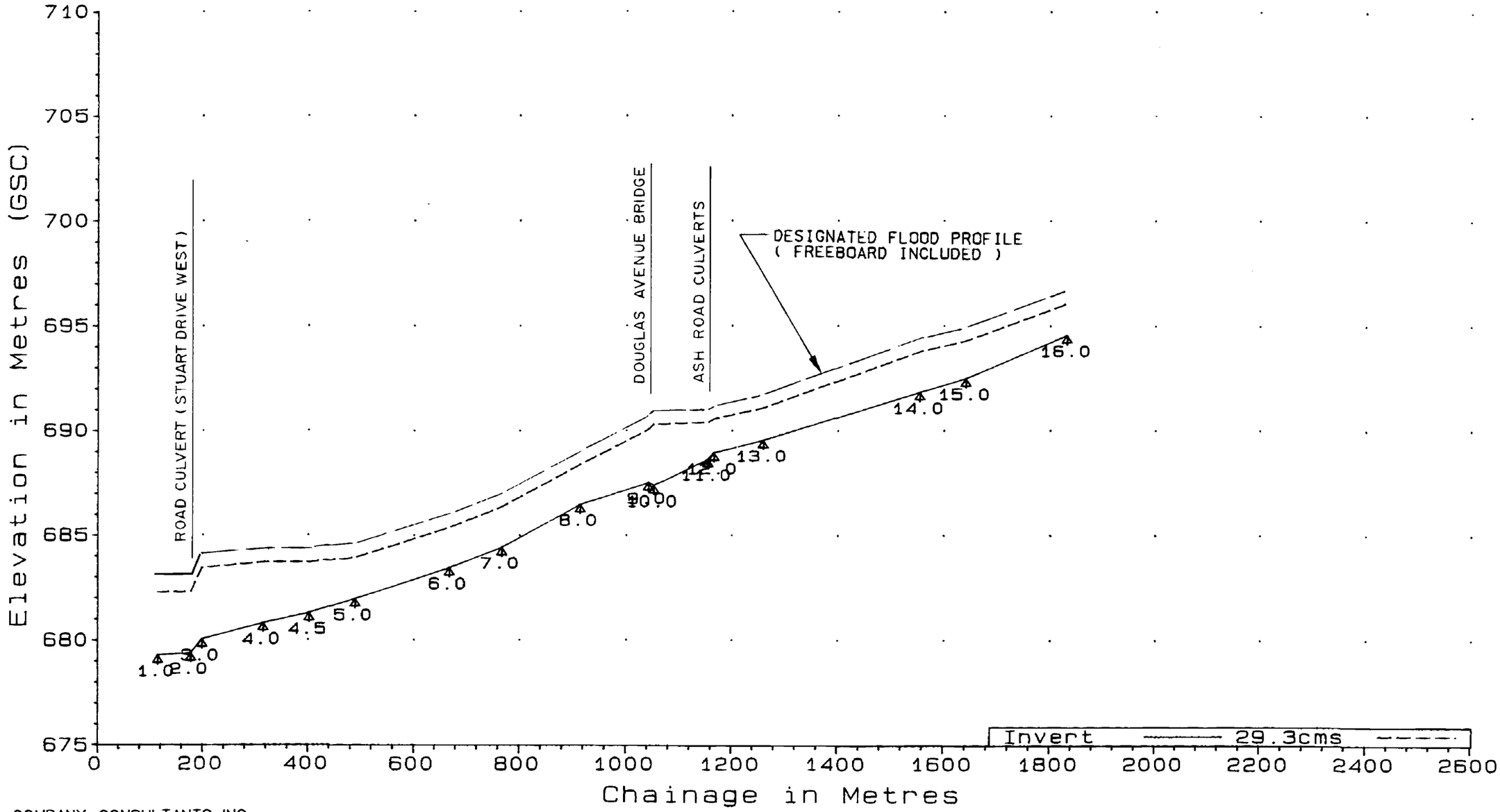
## FLOODPLAIN MAPPING
## STUART LAKE AND RIVER

## NECOSLIE RIVER
## DESIGNATED FLOOD PROFILE

FIG. 8

NENV-10/FIG.DGN/30-11-90

# NAHOUNLI CREEK: TEST 6
# 200-YR FLOOD (DAILY)




HAY & COMPANY CONSULTANTS INC.

B. C. MINISTRY OF ENVIRONMENT

**FLOODPLAIN MAPPING**
**STUART LAKE AND RIVER**

**NAHOUNLI CREEK**
**DESIGNATED FLOOD PROFILE**

FIG. 9

MENV-10/FIG.DGN/30-11-90



PHOTO 1 ▪ STUART LAKE LOOKING NORTHWEST FROM PITKA BAY MARINA



PHOTO 2 ▪ STUART LAKE SHORELINE NEAR PAARENS BEACH PARK

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# FLOODPLAIN MAPPING STUART LAKE AND RIVER

## PHOTOS 1 & 2

MENV-10/PHOTOS.DGN/11/27/90



PHOTO 3 - STUART RIVER LOOKING DOWNSTREAM AT SECTION 17 (BACK CHANNEL)

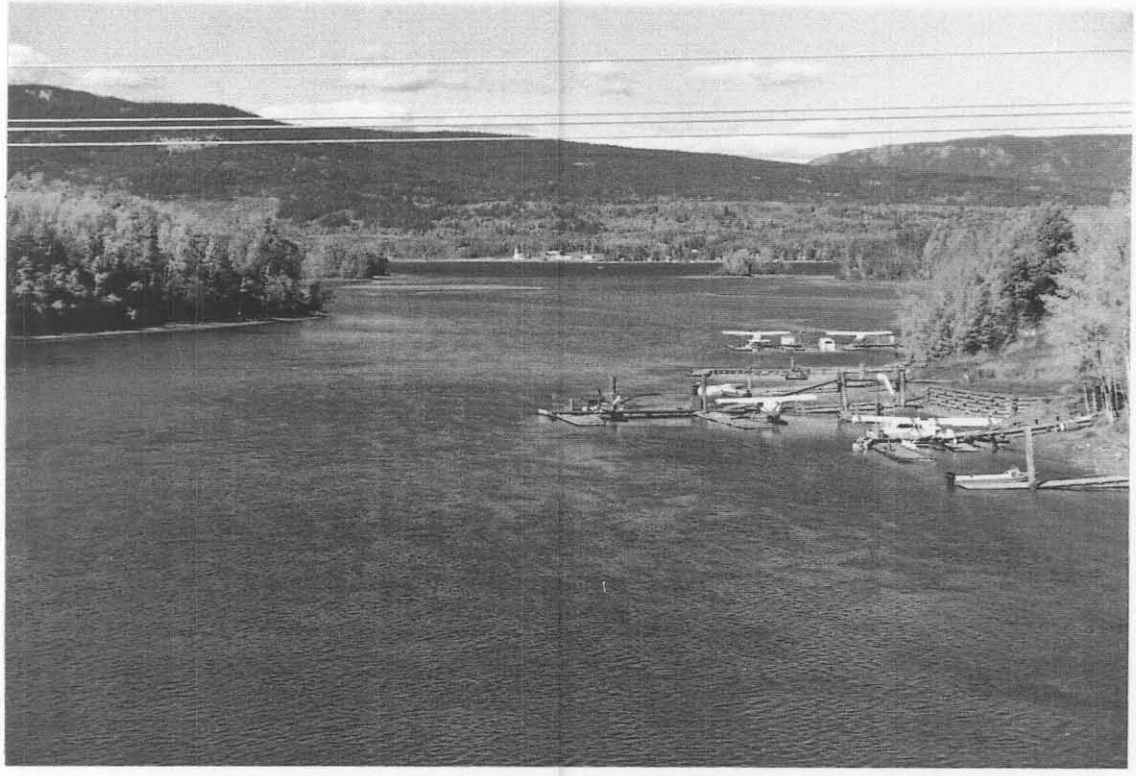


PHOTO 4 - STUART RIVER LOOKING UPSTREAM FROM BRIDGE (MAIN CHANNEL)

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# FLOODPLAIN MAPPING STUART LAKE AND RIVER

## PHOTOS 3 & 4

MENV-10/PHOTOS.DGN/11/27/90

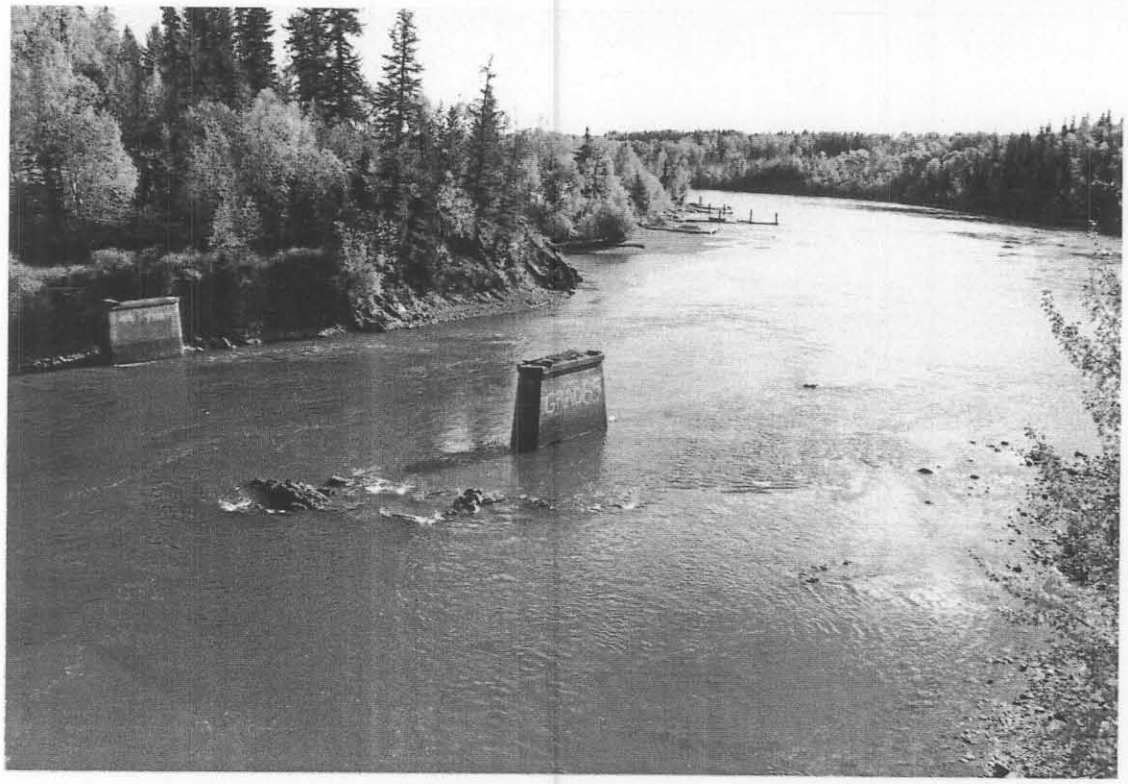


PHOTO 5 - STUART RIVER LOOKING DOWNSTREAM FROM BRIDGE

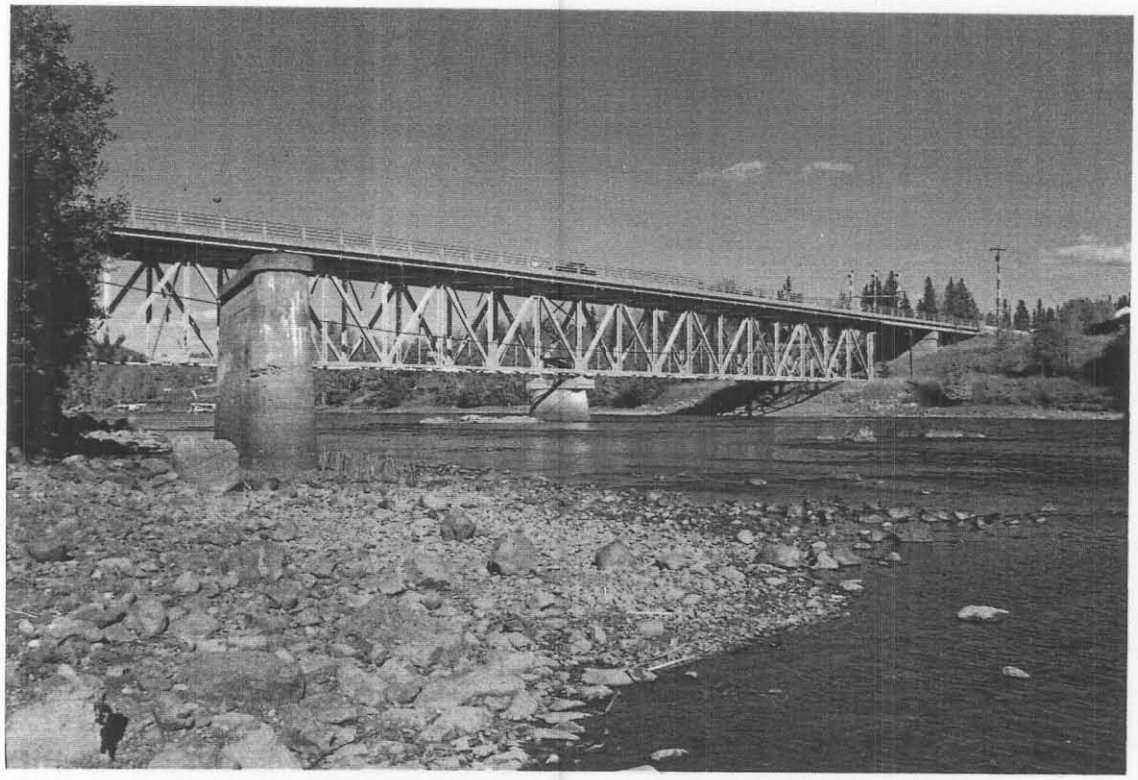


PHOTO 6 - STUART RIVER LOOKING UPSTREAM AT BRIDGE

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# FLOODPLAIN MAPPING STUART LAKE AND RIVER

## PHOTOS 5 & 6

MENV-10/PHOTOS.DGN/11/27/90



PHOTO 7 : STUART RIVER LOOKING UPSTREAM FROM GAS PIPELINE CROSSING (SECTION 4)

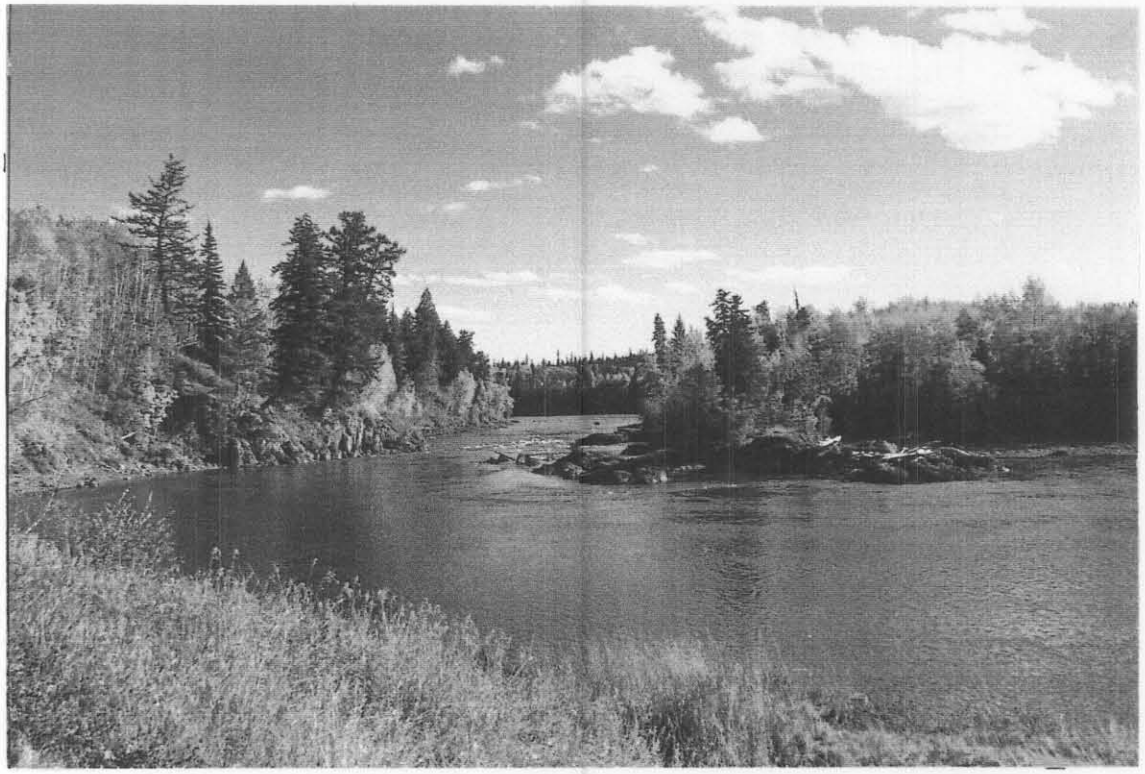


PHOTO 8 : STUART RIVER LOOKING DOWNSTREAM AT SECTION 3

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# FLOODPLAIN MAPPING STUART LAKE AND RIVER

## PHOTOS 7 & 8

MENV-10/PHOTOS.DGN/11/27/90

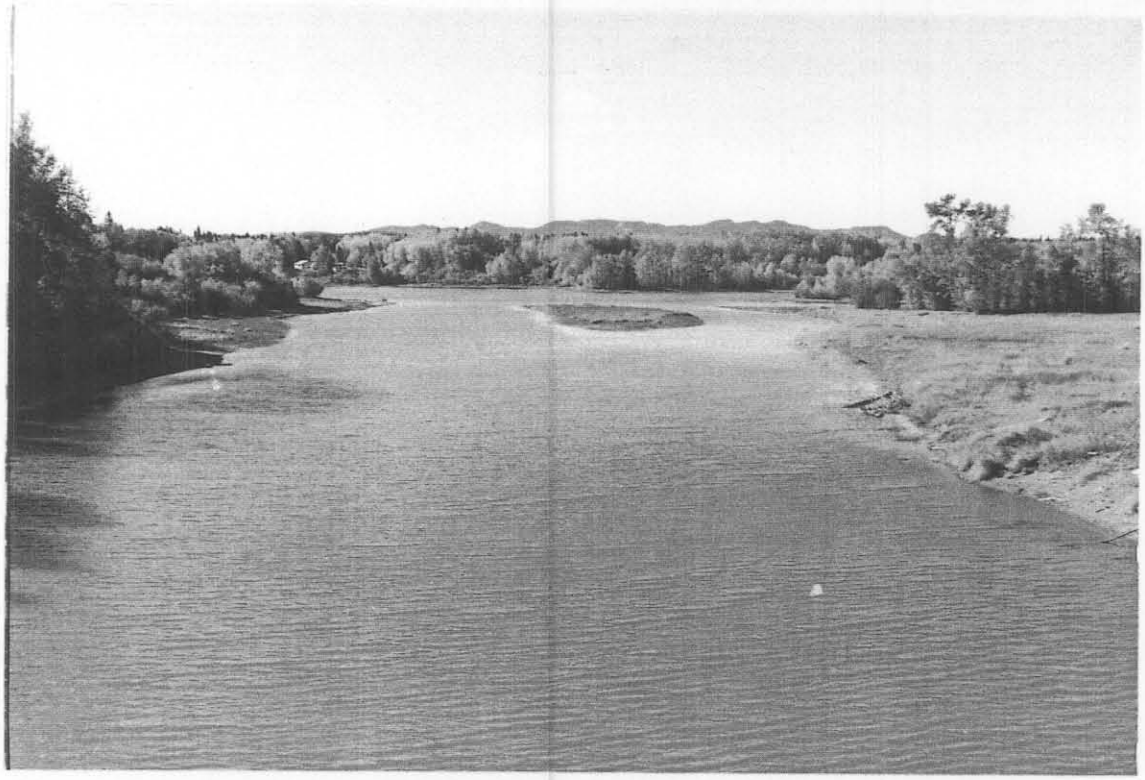


PHOTO 9 : NECOSLIE RIVER LOOKING DOWNSTREAM FROM BRIDGE

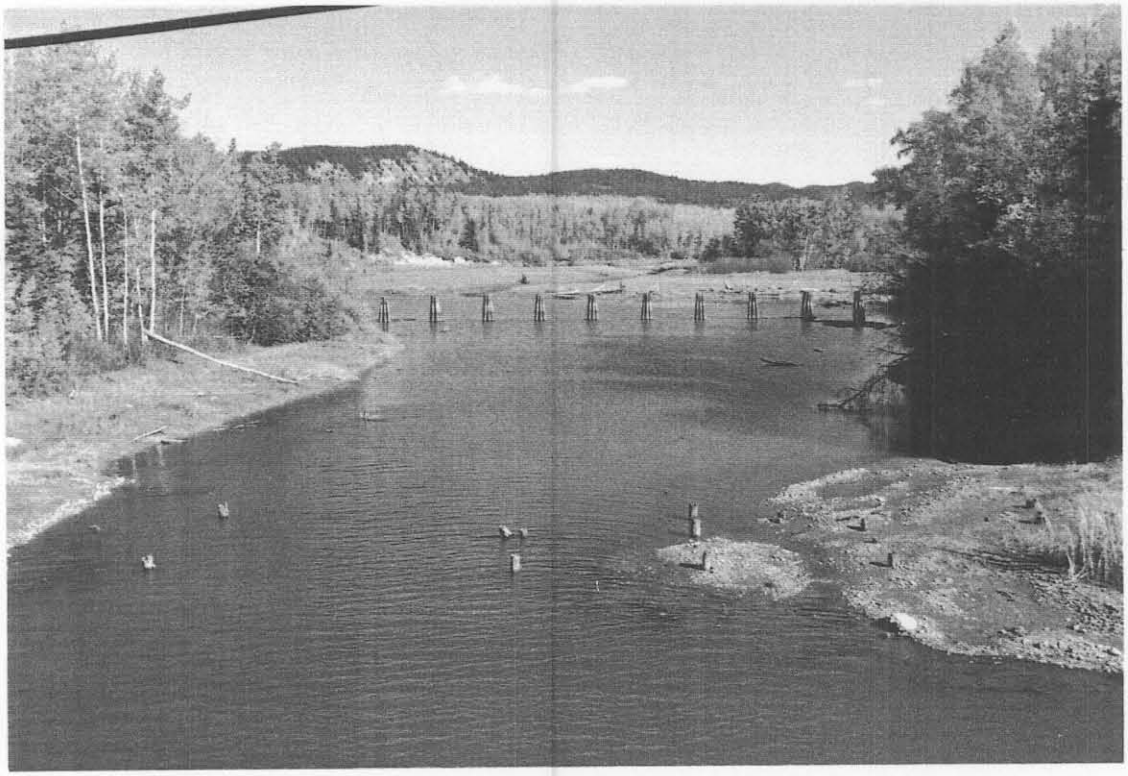


PHOTO 10 : NECOSLIE RIVER LOOKING UPSTREAM FROM BRIDGE

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# FLOODPLAIN MAPPING STUART LAKE AND RIVER

## PHOTOS 9 & 10

MENV-10/PHOTOS.DGN/11/27/90

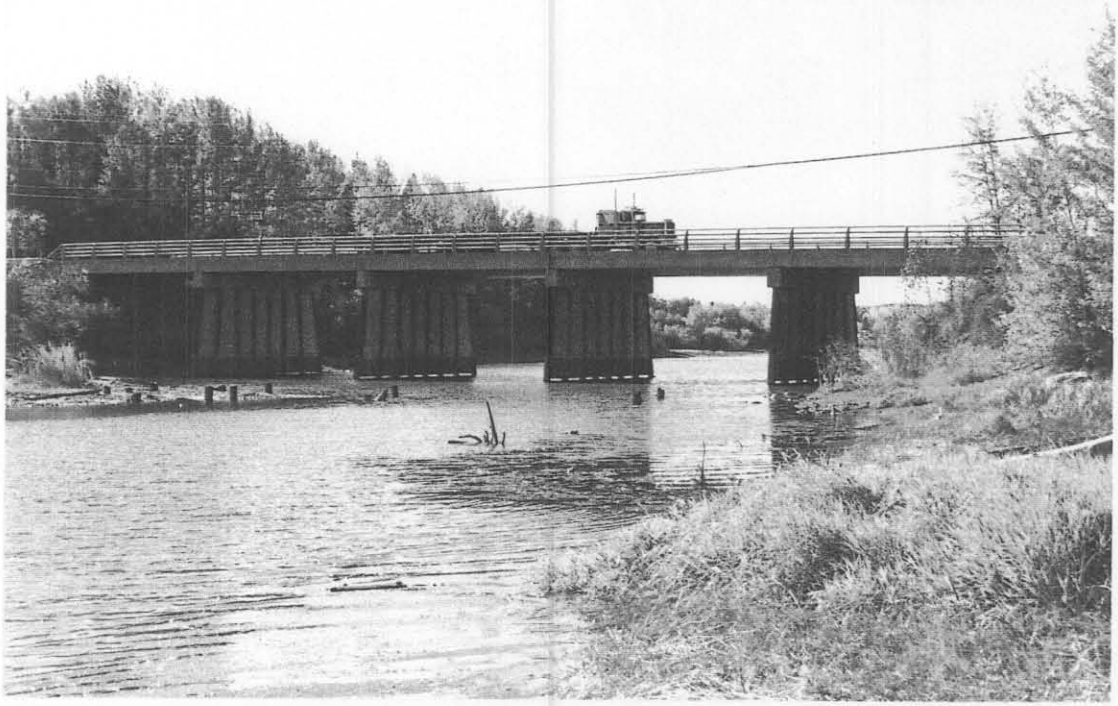


PHOTO 11 - NECOSLIE RIVER LOOKING DOWNSTREAM AT BRIDGE



PHOTO 12 - NECOSLIE RIVER LOOKING DOWNSTREAM NEAR SECTION 15

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# FLOODPLAIN MAPPING STUART LAKE AND RIVER

## PHOTOS 11 & 12

MENV-10/PHOTOS.DGN/11/27/90



PHOTO 13 : NECOSLIE RIVER LOOKING DOWNSTREAM AT SECTION 15

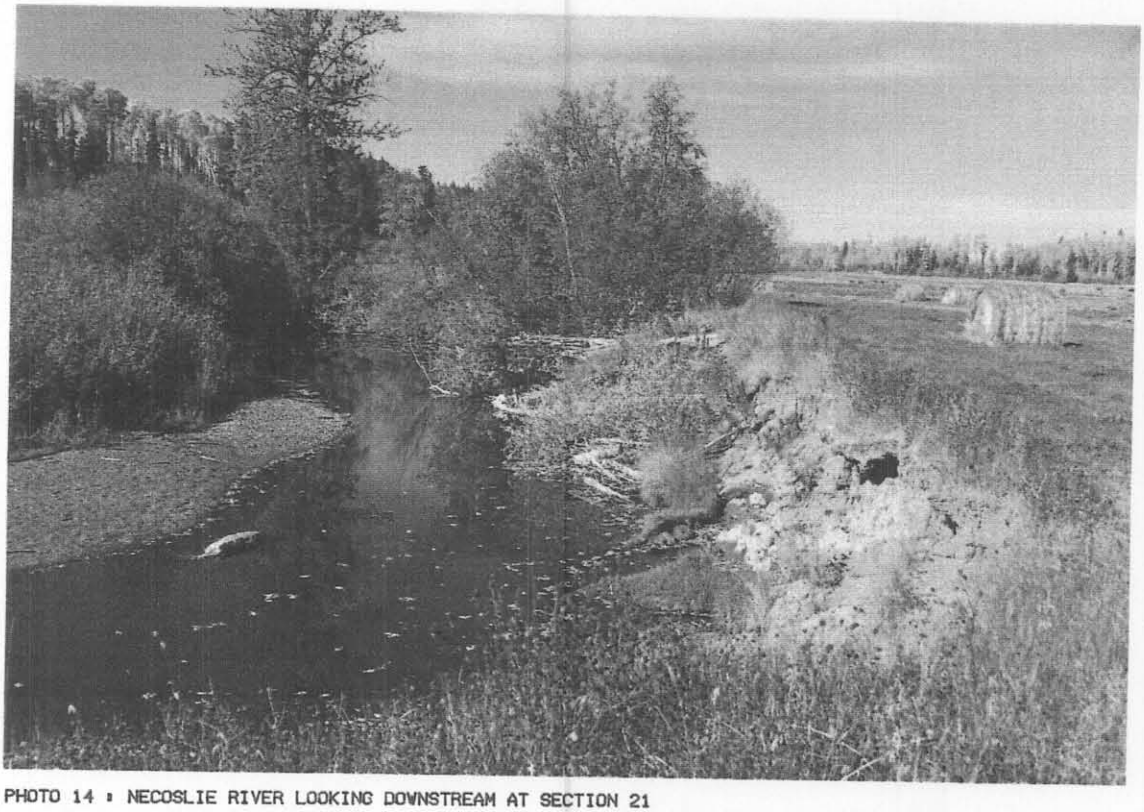


PHOTO 14 : NECOSLIE RIVER LOOKING DOWNSTREAM AT SECTION 21

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# FLOODPLAIN MAPPING STUART LAKE AND RIVER

## PHOTOS 13 & 14

MENV-10/PHOTOS.DGN. 11/27/90



PHOTO 15 : NAHOUNLI CREEK LOOKING DOWNSTREAM FROM BRIDGE (STUART DRIVE WEST)

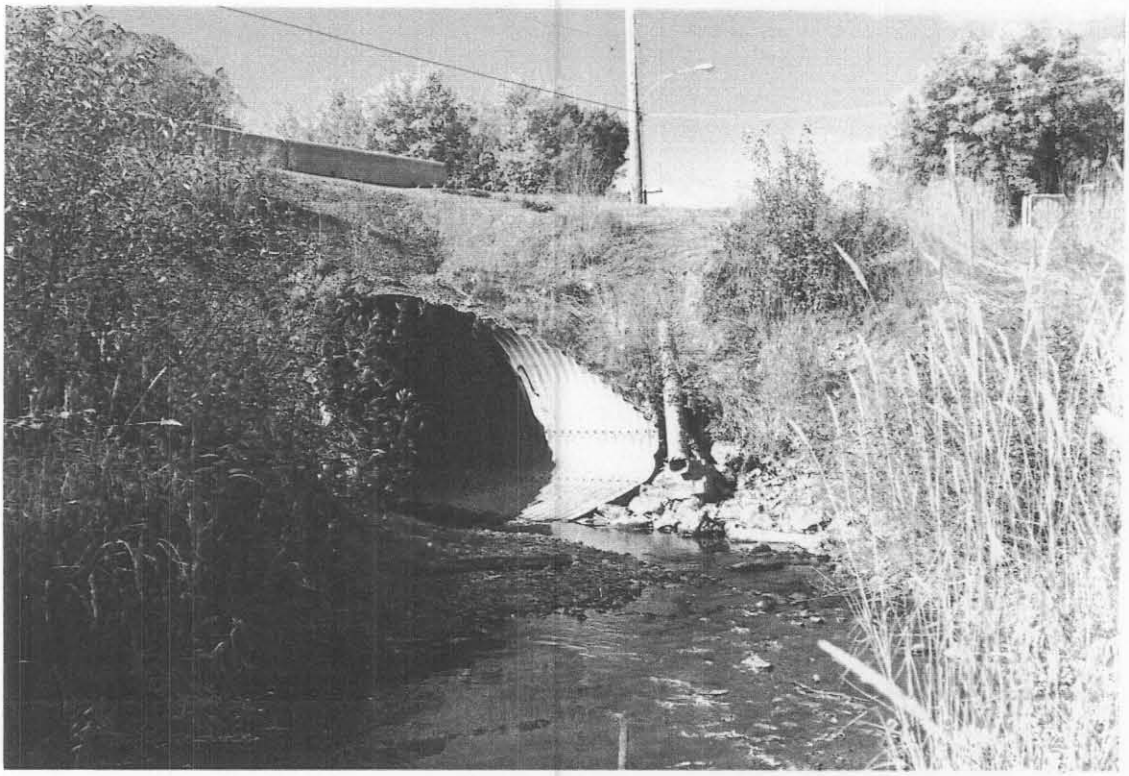


PHOTO 16 : NAHOUNLI CREEK LOOKING DOWNSTREAM AT CULVERT ENTRANCE (SECTION 3)

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# FLOODPLAIN MAPPING STUART LAKE AND RIVER

## PHOTOS 15 & 16

MENV-10/PHOTOS.DGN/11/27/90



PHOTO 17 - NAHOUNLI CREEK LOOKING DOWNSTREAM FROM ABOVE SECTION 5

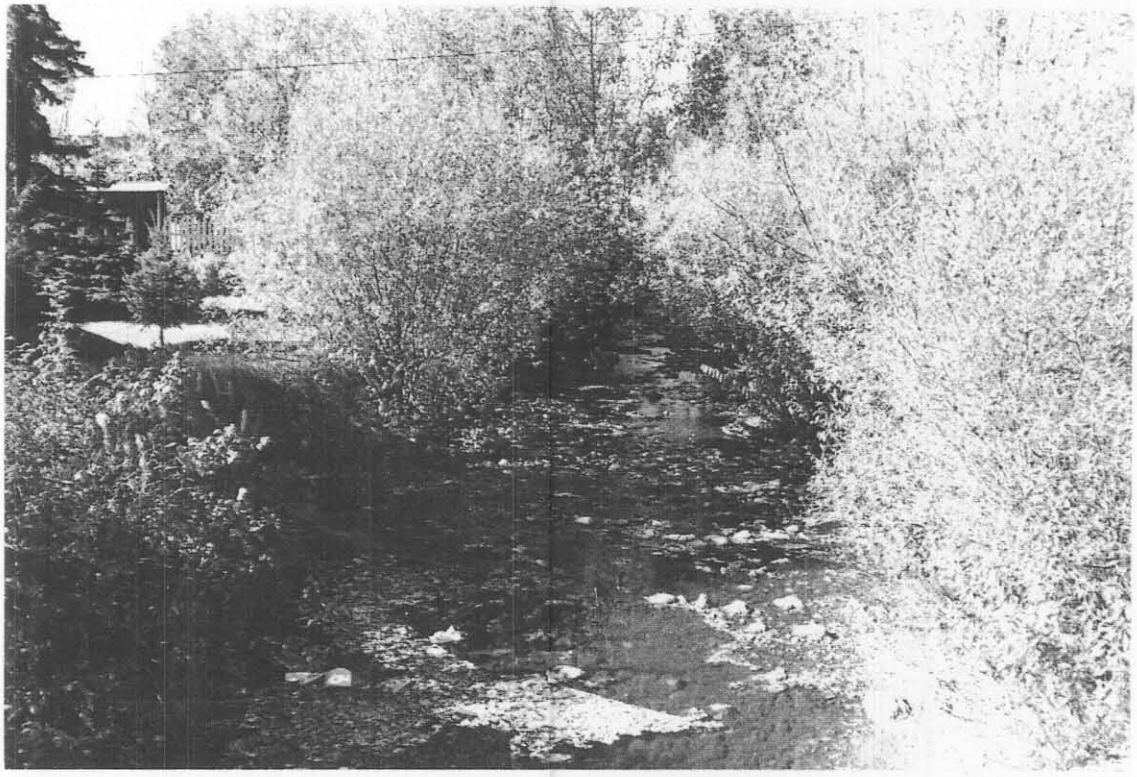


PHOTO 18 - NAHOUNLI CREEK LOOKING DOWNSTREAM FROM DOUGLAS AVENUE BRIDGE

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# FLOODPLAIN MAPPING STUART LAKE AND RIVER

## PHOTOS 17 & 18

MENV-10/PHOTOS.DGN/11/27/90

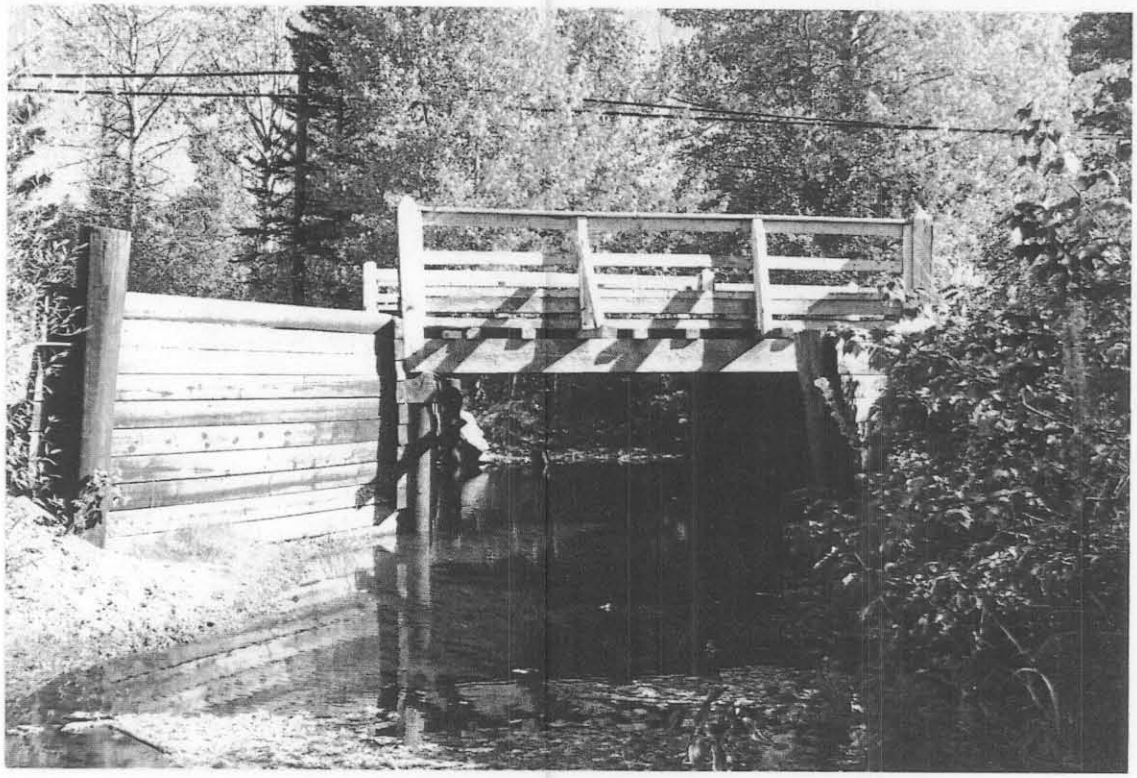


PHOTO 19 : NAHOUNLI CREEK LOOKING UPSTREAM AT DOUGLAS AVENUE BRIDGE (SECTION 9)

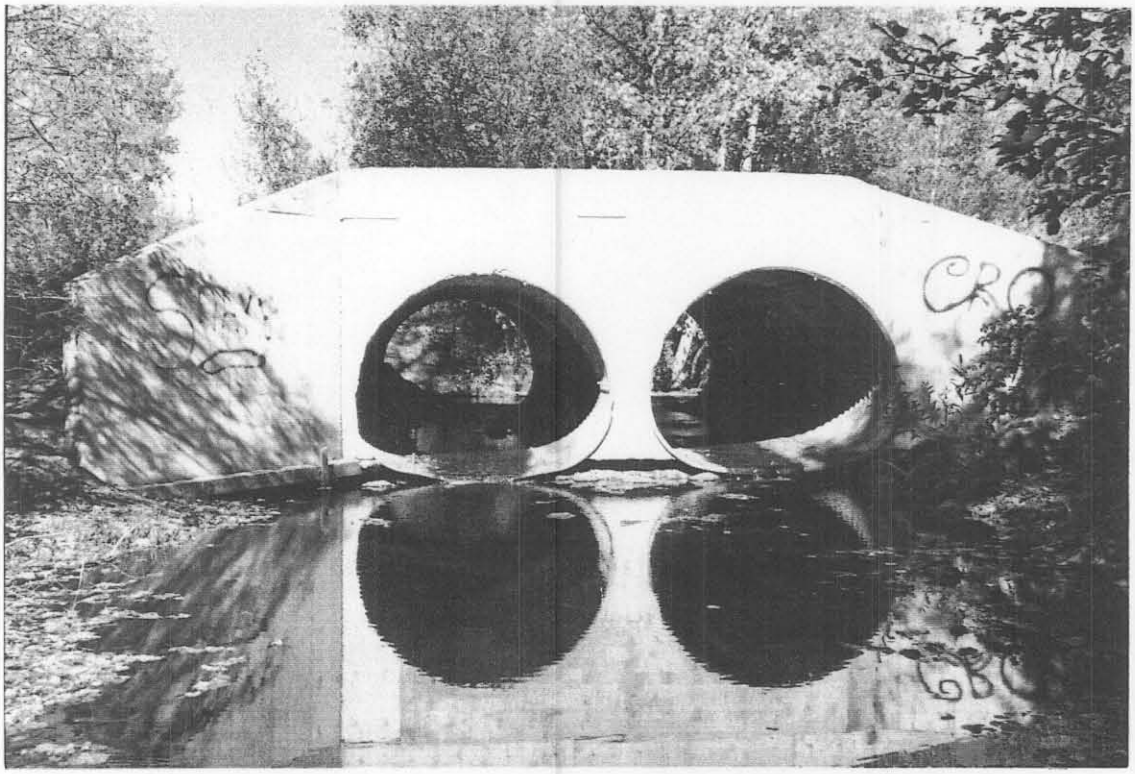


PHOTO 20 : NAHOUNLI CREEK LOOKING UPSTREAM AT ASH ROAD BRIDGE CULVERTS (SECTION 11)

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# FLOODPLAIN MAPPING STUART LAKE AND RIVER

## PHOTOS 19 & 20

MENV-10/PHOTOS.DGN/11/27/90

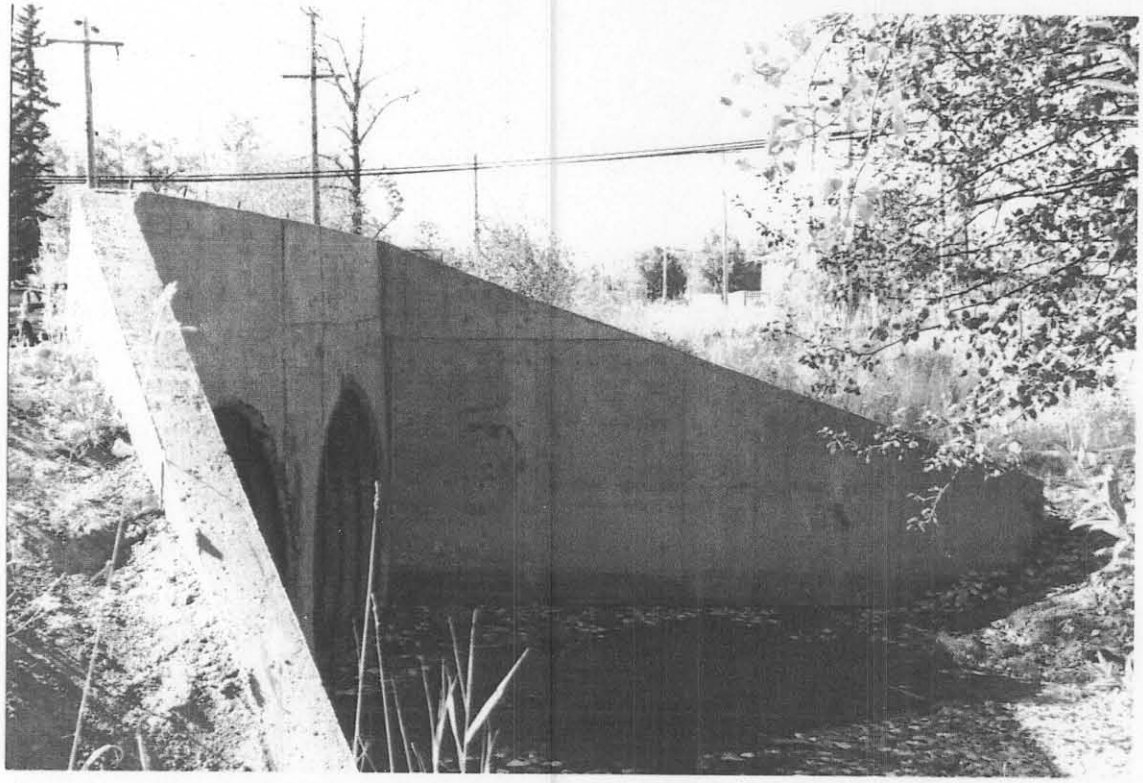


PHOTO 21 : NAHOUNLI CREEK AT ASH ROAD CULVERT ENTRANCE (SECTION 12)



PHOTO 22 : NAHOUNLI CREEK LOOKING UPSTREAM NEAR SECTION 13

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# FLOODPLAIN MAPPING STUART LAKE AND RIVER

## PHOTOS 21 & 22

MENV-10/PHOTOS.DGN/11/27/90