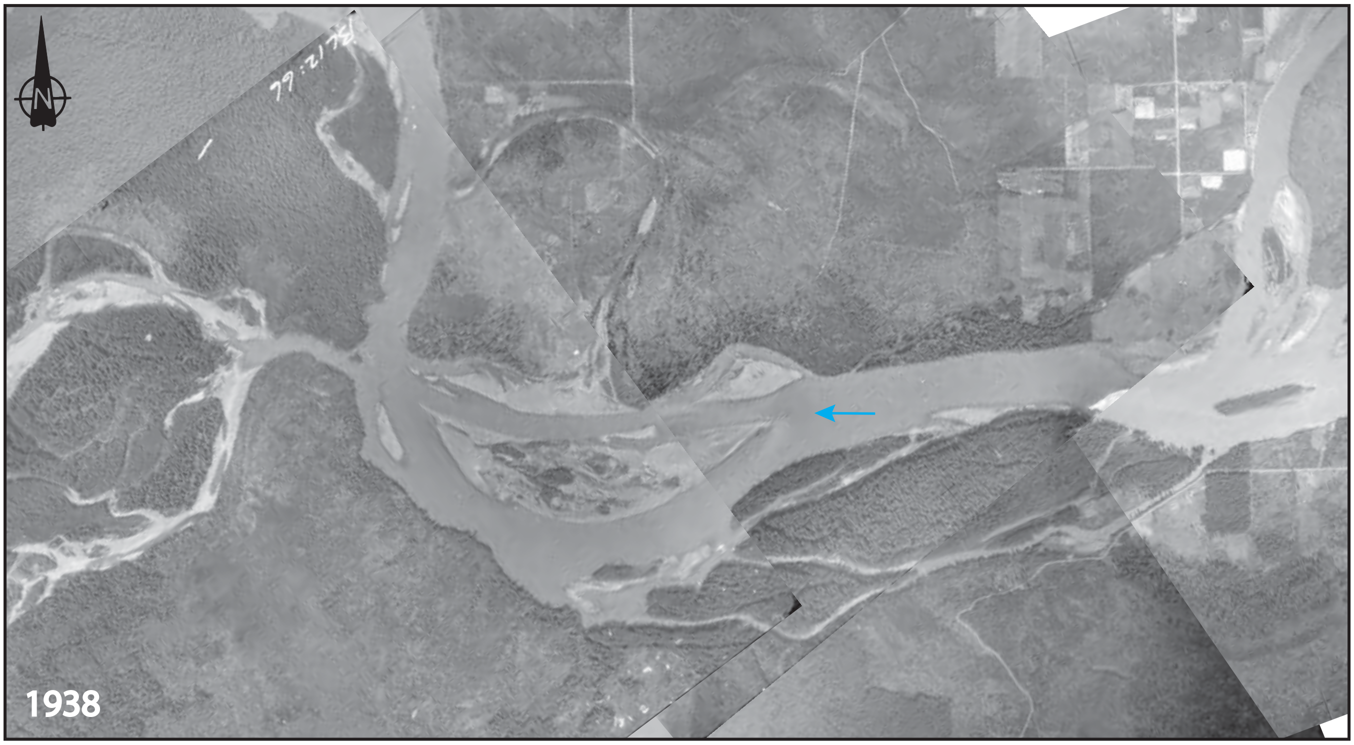
CHANNEL STABILITY ASSESSMENT: SKEENA AND KITSUMKALUM RIVERS IN THE VICINITY OF TERRACE



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EXECUTIVE SUMMARY

The City of Terrace [COT] and the Regional District of Kitimat-Stikine [RDKS] have requested M. Miles and Associates Ltd. to assess channel stability and associated river related hazards along Skeena River in the vicinity of Terrace and on the lower section of Kitsumkalum River.

This report:

1. Provides relevant background information on geological and hydrological conditions;
2. Reviews the results of various flood hazard studies;
3. Compiles a chronological series of air photos to document how Skeena and lower Kitsumkalum Rivers have changed over the last 70 years;
4. Uses the above information to identify or comment on issues of concern;
5. Discusses the morphologic effects of the river training works recently undertaken by COT and RDKS;
6. Identifies river-related stability issues relevant to the COT, the RDKS or the Kitsumkalum First Nation; and
7. Makes recommendations on what additional investigations are warranted to monitor developing hazards or prepare appropriate solutions.

The historical air photo analyses indicate that modest rates of channel shifting have been occurring in the vicinity of Thornhill and Queensway on the south side of Skeena River. Recently installed river training works should protect this area from further erosion hazard. A secondary river channel located immediately upstream of the RDKS sewage treatment plant has carried considerable flow during recent flood events and could readily become more active. Soil bioengineering and possibly deeper burial of the influent pipeline might provide sufficient protection over at least the short term.

The historical air photo analyses, channel surveys and interviews with long term residents indicate that gravel sized sediments are accumulating within the Skeena River channel in the vicinity of Braun's Island. An increased percentage of the total river flow may now be entering the Hells Gate Channel and, during flood events, overbank flow is being directed across the north bank flood plain where it enters the Braun's Island Slough. The instream gravel accumulation cannot be readily removed. Recently installed river training works in the vicinity of the COT sewage treatment plant will reduce the potential for bank erosion in this area but will not provide protection from flooding. Additional soil bioengineering might reduce overbank water velocities and decrease the potential for a channel relocation (or avulsion) through this area. Flood proofing and other adaptive responses to the existing flood hazard (including updating the flood plain mapping) are required.

The lower Kitsumkalum River was extensively modified to facilitate log driving in the middle of the last century. Overgrown rip-rap and a log storage pond now substantially affect the channel's ability to shift laterally or to accommodate sediment accumulation within the lowermost reach of Kitsumkalum River. Bridge construction has reduced the channel conveyance area. Unstable slopes and tributary channels are delivering significant coarse textured sediment loads to Kitsumkalum River and these materials are being preferentially deposited in the area downstream of the lower canyon at River Km 10. The downstream channel is both laterally and vertically unstable. Alluvial channel banks are subject to erosion and channel avulsion. Backwater effects from Skeena River, the reduced conveyance capacity under the CNR bridge, riparian clearing and flood waters delivered by tributary streams further complicate flooding and channel stability in this area. Site-specific investigations, which include updating the flood plain mapping, are required to better assess potential hydro-technical hazards and to develop remedial strategies. Appropriate land use zoning and flood proofing will be required to limit future flood damage in this area.

The report makes 20 recommendations which include further hydrological analyses, river surveys and site specific investigations, hydraulic and flood plain mapping studies, remedial works, monitoring and suggestions for how to better define priorities for future work.

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STATEMENT OF LIMITATIONS OF REPORT

This document has been prepared by M. Miles and Associates Ltd. [MMA], for the exclusive use and benefit of the City of Terrace. No other party is entitled to rely on any of the conclusions, data, opinions, or any other information contained in this document.

This document represents MMA's best professional judgement based on the information available at the time of its completion and as appropriate for the project scope of work. Services performed in developing the content of this document have been conducted in a manner consistent with that level and skill ordinarily exercised by scientists and engineers currently practising under similar conditions. No warranty, expressed or implied, is made.

CHANNEL STABILITY ASSESSMENT: SKEENA AND KITSUMKALUM RIVERS IN THE VICINITY OF TERRACE

1: INTRODUCTION AND OBJECTIVES

The City of Terrace [COT] requested M. Miles and Associates Ltd. [MMA] to prepare a channel stability assessment for Skeena River in the vicinity of Terrace. The study area for this project originally extended between the confluence of Zymoetz [aka Copper] River and the confluence with Kitsumkalum River. The secondary channel of Skeena River, which is locally referred to as 'Hell's Gate', is also included. This study area was subsequently extended (in late-March 2009) to include Kitsumkalum River downstream of Treston Lake. This region is illustrated on *Figure 1.1*.

The COT's interest in channel stability principally stems from on-going erosion issues in the vicinity of the Terrace Sewage Treatment Plant [STP]. Related issues include work being undertaken by the Regional District of Kitimat-Stikine [RDKS] to provide erosion protection in the vicinity of Queensway. The initial objective of this study was therefore to provide an assessment of how these works may affect a left bank *[1] sub-division located downstream of the Highway 16 Bridge over Skeena River. We prepared some initial comments for Mr. Colin Adams, P. Eng., of McElhanney Consulting Services Ltd. in Terrace on the proposed RDKS bank stabilization project on November 18, 2008 *(MMA, 2008a)*. MMA has also extensively worked with Mr. Mike Thompson, P. Eng and Mr. Ivo Von Bastelaere, P. Eng. of Worley Parsons Ltd. [WPL] to develop plans to stabilize the river bank and protect the influent pipeline to the COT STP.

The Kitsumkalum First Nation [KFN], the COT and the RDKS also have concerns regarding channel instability and flood hazard on the lower Kitsumkalum River. This area has been extensively modified by historic log driving activities, local land use and by both the CNR and the Highway 16 Bridges. These activities have altered the natural river conditions and have resulted in some interesting channel stability issues.

The Zymoetz River confluence (located 6 km upstream of the Highway 16 bridge) has also been investigated as this is an important source area for the coarse sediments which are being deposited in Skeena River in the vicinity of Terrace.

Given these geographically diverse interests, the present report:

i) provides relevant background information on geological and hydrological conditions;

ii) reviews the results of various flood hazard studies;

iii) compiles a chronological series of air photos to document how Skeena and lower Kitsumkalum Rivers have changed over the last 70 years;

iv) uses the above information to identify or comment on issues of concern;

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1 while looking downstream

v) discusses the morphologic effects of the river training works recently undertaken by COT and RDKS;

vi) identifies river-related stability issues relevant to the COT, the RDKS or the KFN; and

vii) makes recommendations on what additional investigations are warranted to monitor developing hazards or prepare appropriate solutions.

2: STUDY PROGRAM

Mr. Mike Miles, P. Geo. of MMA and Mr. Ivo Van Bastelaere, P. Eng of WPL undertook an initial site inspection on July 29, 2008. This work included a ground inspection of the COT STP site and a heli-copter overview of the area between the Zymoetz River Confluence and the Outlet of Hell's Gate. The lower Kitsumkalum was not inspected as we were not yet aware that this was an area of interest. Imagery and field notes obtained during this work are documented in *MMA (2008b).*

A second field trip was undertaken on April 2, 2009 with Mr. Mike Thompson, P. Eng of WPL to review 'as-built' conditions along the river training works constructed to protect the COT STP. Site photos and notes documenting this inspection are presented in *MMA (2009a)*.

A third field trip was undertaken on April 22/23, 2009 to document conditions on lower Kitsumkalum River. Imagery taken during this inspection is presented in *MMA (2009b)*.

Office analyses included compiling discharge data collected at the Water Survey of Canada [WSC] streamgauging stations *Skeena River at Usk, Kitsumkalum River near Terrace, Zymoetz River near Terrace* and *Zymoetz River above OK Creek*. Aerial photos flown in 2001 and orthophotos prepared from 2007 aerial imagery were used to prepare baseline mosaics illustrating the study area. These compilations are included as Appendices 1 and 2, respectively. A series of historical air photos were assembled to document channel changes over the period since 1938. Where possible, changes in river bed elevation were determined by comparing surveys undertaken in 2008 with those used by the BC Ministry of Environment [BC MOE] to prepare the 1982 Flood Plain Mapping Report *(see BC MOE, 1982)*. Current channel bathymetry was kindly provided by McElhanney Consulting Services Ltd.

3: PHYSICAL SETTING

Skeena River drains the Central Plateau, Interior Plateau and the Coast Mountain Ranges *(Holland, 1976)*. The city of Terrace is located on the western edge of the Hazelton Mountains approximately 125 kilometers east of Prince Rupert. Two major tributaries enter the Skeena River in the vicinity of Terrace. The Zymoetz River confluence is located approximately 6 km upstream of the Highway 16 Bridge in Terrace and the Kitsumkalum River confluence is situated approximately 9 kilometers down-stream. The watershed area at the WSC streamgauging station *Skeena River at Usk*, located 28 km upstream of the Zymoetz River confluence, is 42,200 km². The basin areas at the WSC gauges, *Zymoetz River near Terrace* and *Kitsumkalum River near Terrace* are 3,080 km² and 2,180 km², respectively.

Clague (1984) has mapped the surficial geology of the study area. A copy of this mapping is presented on *Figures 3.1A & B*. The associated legend is shown on *Table 3.1*. The valley bottom areas along both Skeena and Kitsumkalum Rivers is typically composed of recent fluvial sediments *(code Ap; see Figures 3.1A & B and Table 3.1)* which are subject to periodic flooding. Higher elevation areas include terrace deposits *(code At)*, terrace scarps *(code Us)*, glaciofluvial *(code A^G)*, glacio-lacustrine *(code L^G)* and deltaic sediments *(code $A^G d$)*. Glacial marine sediments *(code Wgm–V)* were deposited near the end of the last glaciation when this portion of the Skeena River valley was below sea level. These unstable, erosion susceptible, materials could underlie the fluvial sediments within both the Skeena and lower Kitsumkalum Rivers valley bottom.

There is one important error on *Clague (1984)* mapping. *Figure 3.1A* indicates the entrance to the Hell's Gate side channel complex is composed of river terrace deposits *(code At)*. This material is in fact erosion-resistant bedrock.

4: HYDROLOGY

4.1 AVAILABLE INFORMATION

The Water Survey of Canada [WSC] has operated four stream gauging stations near Terrace *(see Table 4.1)*. Two stations, *Skeena River at Usk* & *Zymoetz River above OK Creek* are currently active. The '*at Usk'* station is located approximately 28 km upstream from Terrace and is situated above the confluence with the Zymoetz [aka Copper] River. The station *Zymoetz River above OK Creek* is located on lower Zymoetz River, approximately 6 km upstream of Terrace. Two other stations, *Kitsumkalum River near Terrace* and *Zymoetz River Near Terrace*, operated from 1929 to 1951 and 1951 to 1964, respectively. Station locations are indicated on *Figure 1.1* and the available data is indicated on *Table 4.1*.

The distribution of stream gauging stations requires that streamflow values at Terrace must be estimated based on data from the gauge on *Skeena River at Usk* and the inflow data from Zymoetz River. There is also no operational gauge on Kitsumkalum River. As a consequence, streamflow values in the study area can be determined by a variety of techniques. The resulting variability in design flood estimates is summarized in Section 4.3.6 and some readers may wish to proceed directly to this text.

4.2 SEASONAL DISCHARGE REGIME

4.2.1 Skeena River at Usk

The seasonal variation in flow on *Skeena River at Usk* is shown on *Figure 4.2.1.1*. These data indicate that *Skeena River at Usk* can experience two periods of peak flow over the course of the year. The maximum flow typically occurs between mid-April and mid-July as a result of the snowmelt freshet. A second period of elevated discharge can occur as a result of rain or rain-on-snow events in the period between mid-September and mid-December. Minimum flows typically occur in late-winter or early-spring. A sizeable flood occurred in 2007 and this event is also shown on *Figure 4.2.1.1*. The peak flow of 7,550 m^3/s (or 0.178 $m^3/s/km^2$) occurred on June 7.

4.2.2 Zymoetz River Near Terrace and Zymoetz River Above OK Creek

Streamflow data from *Zymoetz River near Terrace (1951-1964)* and *Zymoetz River above OK Creek (1963 to present)* are shown on *Figures 4.2.2.1 & 4.2.2.2*, respectively. This tributary to Skeena River again experiences two periods of peak flow over the year. Thirteen years of data from the *'near Terrace'* station indicate that fall rain or rain-on-snow events in the 1952-1964 period are approximately equivalent in size to the spring snowmelt freshets. However, 46 years of data from the *'above OK Creek'* station indicate that fall rain floods in the 1963-2008 period can be substantially larger than the freshet flows. The increased magnitude of fall rain events on Zymoetz River reflects both the smaller basin area (in comparison to Skeena River) and its more exposed position to fall rainstorm events.

The 2007 flood caused the largest observed spring freshet discharge on *Zymoetz River above OK Creek* with the peak flow of 817 m^3/s (or 0.278 $m^3/s/km^2$) occurring on June 4^{th}. Discharge data from the discontinued gauge *Zymoetz River near Terrace* indicate the maximum observed spring freshet flow 968 m^3/s (0.314 $m^3/s/km^2$) occurred on June 9^{th} 1954. The maximum observed fall rain floods at *Zymoetz River above OK Creek* and *Zymoetz River near Terrace* are 1,980 m^3/s (0.681 $m^3/s/km^2$) on November 1, 1978 and 1,050 (0.341 $m^3/s/km^2$) on October 31, 1961, respectively.

4.2.3 Kitsumkalum River Near Terrace

A total of 22 years of discharge data were collected on *Kitsumkalum River near Terrace* in the period between 1929 and 1952. The seasonal variation in flow is illustrated on *Figure 4.2.3.1*. There are, again, two periods of peak flow with the maximum snowmelt freshet flows (883 m^3/s or 0.405 $m^3/s/km^2$), being somewhat larger that the largest observed fall rain or rain-on-snow flood (646 m^3/s or 0.296 $m^3/s/km^2$). No data are available from Kitsumkalum River in the post-1952 period.

4.2.4 Combined Flows, Skeena River at Usk, Zymoetz River above OK Creek and Zymoetz River near Terrace

Stream discharge at Terrace can be best estimated by adding values observed on *Skeena River at Usk* with those occurring on the same day at *Zymoetz River near Terrace (1951-1964)* or *Zymoetz River above OK Creek (1964-2008)*. The results of this analysis are shown on *Figure 4.2.4.1*. The spring freshet floods continue to be the dominant hydrological event of the year with the maximum combined flow of 8,232 m^3/s occurring on June 7, 2007. However, fall floods are still sizeable events reaching values of 6,360 m^3/s. The maximum flood of record on *Skeena River at Usk* is 9,340 m^3/s. This event, which occurred on May 26, 1948, is 899 m^3/s larger than any flow observed over the period when concurrent data from Zymoetz River is also available.

Winter instream construction activities on Skeena River at Terrace are typically scheduled to occur in January or February. The data on *Figure 4.2.4.1* indicate that flows in this period could be as low as 114 m^3/s and as large as 1,124 m^3/s.

4.3 FLOOD HISTORY AND MAGNITUDE

4.3.1 Skeena River at Usk

The historical variation in annual maximum daily and instantaneous discharges observed on *Skeena River at Usk* are illustrated on *Figure 4.3.1.1*. The results of flood frequency analyses undertaken using the BC Government flood frequency routine [FREQAN] *[1] are compiled on *Tables 4.3.1.1 and 4.3.1.2*. These results indicate that the largest annual maximum daily flow occurred in 1948 (9,340 m^3/s or 0.221 $m^3/s/km^2$). The second largest flood occurred in 1972 (7,790 m^3/s or 0.185 $m^3/s/km^2$) and the 2007 event was the third largest flood of record (7,550 m^3/s or 0.179 $m^3/s/km^2$). These three events have computed average return periods of >200, 40 and 30 years, respectively. *[2]

Annual maximum instantaneous discharges are somewhat larger than the associated daily discharge which is the average flow over a 24-hour period. On the basis of the instantaneous discharge data shown on *Figure 4.3.3.1b*, the 1972 and 2007 events have average return periods of 99 and 47 years, respectively.

The annual maximum instantaneous discharge record is 20 years shorter than the record of annual maximum daily discharges. As illustrated on *Figure 4.3.1.2*, there is a very strong correlation between these two parameters. *[3] The developed 'best fit' relationship has been used to estimate unmeasured instantaneous discharge values in the period between 1928 and 1956. The results are shown on *Figure 4.3.1.3* and a revised flood frequency analysis is presented on *Table 4.3.1.3*. On the basis of this analysis, the 1948, 1972 and 2007 floods have average return periods of >200, 50 and 28 years, respectively. The predicted 200-year return period daily and instantaneous discharges are 9,260 and 9,440 m^3/s, respectively.

As discussed in Section 4.2.1, Skeena River experiences both spring and fall floods. Each period comprises a distinct population of events and it is appropriate to statistically analyse each of these events separately *(see Watt, 1990)*. The historical variation in maximum daily discharges observed in the spring (April 1 to August 31) and fall (September 1 to March 31) is illustrated on *Figure 4.3.1.4*. Flood frequency analyses are compiled on *Table 4.3.1.4 & 4.3.1.5*. On this basis, the 200-year return period daily flow in the spring and fall periods are 9,300 and 5,950 m^3/s, respectively. The 1948, 1972 and 2007 'spring' floods have calculated return periods of 209, 42 and 33 years, respectively. This analytical procedure likely provides the most reliable estimates of flood return periods on *Skeena River at Usk*.

4.3.2 Zymoetz River Near Terrace and Zymoetz River Above OK Creek

The historical variation in annual maximum flood flows on the two Zymoetz River gauging stations is illustrated on *Figures 4.3.2.1 & 4.3.2.2*. Flood frequency analyses are summarized on *Tables 4.3.2.1*

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1 Data have been fitted using the Log Pearson Type II Distribution fitted by the Method of Moments.

2 The average return period provides an indication of how frequently a specific discharge may be equaled or exceeded. For example a 10-year return period flood has a 10% chance of being exceeded in any year; a 20-year flood has a 5% chance and a 100-year flood has a 1% chance of occurring.

3 The coefficient of determination or 'r^2' value is 0.99, indicating that 99% of the variability in instantaneous flows is explained by the developed 'best fit' relationship.

to 4.3.2.3. The predicted 2-year return period annual maximum daily discharge observed at the older station *Zymoetz River near Terrace* (813 m^3/s) is significantly larger than that predicted for *Zymoetz River above OK Creek* (579 m^3/s) which suggests that the earlier period was wetter as the 6% smaller basin area at the *'above OK Creek'* site (3,080 vs. 2,908) is not likely to result in this change in flow.

Given the similar area at these two stations, the data records have been amalgamated on *Figure 4.3.2.3*. A revised flood frequency analysis is compiled on *Table 4.3.2.4*. On this basis, the 2- and 200-year return period annual maximum daily flows are 625 m^3/s and 2,530 m^3/s, respectively.

Zymoetz River also experiences two periods of high flow each year. We have therefore separately analyzed spring and fall floods in a manner similar to that undertaken for *Skeena River at Usk*. These results are illustrated on *Figures 4.3.2.4 to 4.3.2.6* for the *'near Terrace', 'above OK Creek'* and combined periods of record. The associated flood frequency analyses are summarized on *Tables 4.3.2.5 to 4.3.2.10*. The results from the 'combined analyses' indicates that predicted 2 and 200-year return period flows are 530 m^3/s (approx. 0.177 $m^3/s/km^2$) and 1,120 m^3/s (approx. 0.373 $m^3/s/km^2$) in the spring and 460 m^3/s (approx. 0.153 $m^3/s/km^2$) and 2,770 m^3/s (approx. 923 $m^3/s/km^2$) in the fall, respectively. This indicates that the spring freshet is larger than the fall flood in most years, but that the fall flood is larger than the spring freshet during unusually large events. These events are approximately equal in size for a return period of 3 to 4 years.

4.3.3 Kitsumkalum River Near Terrace

The historical variation in annual maximum daily and instantaneous discharges observed on Kitsumkalum River in the period between 1928 and 1952 are shown on *Figure 4.3.3.1*. Flood frequency analyses are summarized on *Tables 4.3.3.1 & 4.3.3.2*. These calculations indicate that the 2 and 200-year return period annual maximum instantaneous discharges are 453 and 1,180 m^3/s, respectively. However the period of record is sufficiently short (18 years) that flood discharge estimates for return periods of >25 years (i.e. twice the period of record) are subject to considerable uncertainty.

We have tried to improve the reliability of the flood frequency analyses by using the annual maximum daily discharge data to estimate missing annual maximum instantaneous discharge values. The relationship between these two values is shown on *Figure 4.3.3.2*. The r^2 value is 0.99. The extended series of annual maximum instantaneous discharges is shown on *Figure 4.3.3.3* and the results of a revised flood frequency analysis are summarized on *Table 4.3.3.3*. On this basis the estimated 2 and 200-year flood flows are 454 m^3/s (0.298 $m^3/s/km^2$) and 1,130 m^3/s (0.518 $m^3/s/km^2$). Unfortunately there are no overlapping data records from regional streams of comparable size (e.g. Kitimat River, Little Wedeene River) which would allow flood magnitudes in the 1929 to 1952 periods to be compared with those that are presently occurring. Given this limitation, and the short period of record available from Kitsumkalum River, additional regional analyses are required to develop a reliable design flood estimate for this watershed.

The seasonal variation in discharge data shown on *Figure 4.2.3.1* indicates that both spring and fall floods occur on Kitsumkalum River. We have extracted the available annual maximum daily discharges in the April 1 to August 31 and September to March 31 periods to determine the comparative size of spring/summer and fall/winter flood events. The results are shown on *Figure 4.3.3.4*. Flood frequency analyses are shown on *Tables 4.3.3.4 & 4.3.3.5*. These calculations indicate the annual maximum 2-year return period daily discharge in the spring and fall is 393 m^3/s (0.180 $m^3/s/km^2$) and 322 m^3/s (0.148 $m^3/s/km^2$), respectively. Spring flood are also larger than fall floods for return periods of 50 and 100-year return periods (872 m^3/s vs. 815 m^3/s and 1010 m^3/s vs. 940 m^3/s, respectively). However, due to the short period of record, the reliability of the calculations for return periods of >25 years is uncertain.

4.3.4 Combined Flows, Skeena River at Usk, Zymoetz River near Terrace and Zymoetz River above OK Creek

The historical variation in flood flows in the vicinity of Terrace can be estimated by combining discharge data from *Skeena River at Usk* and streamflow data observed on Zymoetz River.

The historical variation in the annual maximum daily flows calculated by amalgamating data from *Skeena River at Usk* and *Zymoetz River above OK Creek* is illustrated on *Figure 4.3.4.1*. These data cover the 45 year period between 1964 and 1968. The associated flood frequency analysis is compiled on *Table 4.3.4.1*. The data record can be extended back an additional thirteen years by also including data from *Zymoetz River near Terrace*. This analysis is illustrated on *Figure 4.3.4.2*. These results indicate that the 2-year return period annual maximum discharge is in the range of 5,270 to 5,310 m^3/s (approx. 0.117 $m^3/s/km^2$). The 200-year return period flood is predicted to be 9,270 to 9,470 m^3/s (approx. 0.207 $m^3/s/km^2$).

As previously discussed, it is appropriate to separately analyze spring (April 1 to August 31) and fall (September 15 to March 31) events. This analysis has been undertaken on data from *Skeena River at Usk*, plus *Zymoetz River above OK Creek* and the results are illustrated on *Figure 4.3.4.3*. The spring floods are much larger in size, but significant fall floods can also occur. Flood frequency analyses are summarized on *Tables 4.3.4.3 & 4.3.4.4* for spring and fall floods, respectively. This analysis indicates the 2-year return period annual maximum daily discharge in the spring and fall is 5,130 m^3/s (0.113 $m^3/s/km^2$) and 2,150 m^3/s (0.048 $m^3/s/km^2$), respectively. The calculated 200-year return period spring and fall daily discharge is 9,790 m^3/s and 7,430 m^3/s, respectively. These calculations indicate that the June 7th, 2007 maximum daily discharge of 8,232 m^3/s has an average return period of approximately 40 years.

A similar analysis has been undertaken using data from both Zymoetz River stations. No correction has been made for the small (172 km^2) difference in basin area between the *'near Terrace'* and *'above OK Creek'* gauging sites. *Figure 4.3.4.4* illustrates the historical variation in combined spring and fall events. Flood frequency analyses are summarized on *Tables 4.3.4.5 & 4.3.4.6*. This extended data record increases the two-year return period annual maximum daily discharge in the spring to 5,230 m^3/s and to 2,170 m^3/s in the fall. The calculated spring and fall 200-year return period daily discharges are reduced to 9,180 m^3/s (0.203 $m^3/s/km^2$) and 6,880 m^3/s (0.152 $m^3/s/km^2$), respectively. On this basis, the June 7, 2007 maximum daily flow has an average return period of 50 years.

The analytical procedures investigated above produce slightly different results but indicate that the combined 200-year return period 'daily' flood is in the range of 9,200 to 9,800 m^3/s and that the 2007 flood has an average return period of 40 to 50 years.

4.3.5 Timing of Skeena River and Kitsumkalum River Discharges

The potential for flooding on lower Kitsumkalum River is increased when high flows on Skeena River occur at the same time as high flows on Kitsumkalum River. We have undertaken an initial data review to determine how frequently this occurred during the period of concurrent streamflow measurements on both rivers.

The daily discharges observed on *Skeena River at Usk* and *Kitsumkalum River near Terrace* in the period between 1929 and 1952 are compared in Appendix 3. This preliminary analysis indicates that concurrent floods occur in both the spring and fall periods.

4.3.6 Comparison of Flood Frequency Results

As previously discussed, predicting the potential magnitude of extreme floods in the vicinity of Terrace is a complicated task as:

i) flood events consist of both spring and fall events;

ii) the stream gauging records are of varying length; and

iii) stream gauging data from different sites must be combined to estimate the river discharge at Terrace.

The results of the flood frequency analyses undertaken on data from relevant WSC stations is summarized on *Table 4.3.6.1*. This analysis includes calculations based on annual maximum flows and peak flows observed in the spring and fall periods. Important conclusions include:

i) The station *Skeena River at Usk* has the longest data record (76 years) and the predicted 200-year return period annual maximum daily discharge is 9,240 m^3/s. The associated instantaneous discharge is 9,400 m^3/s. The ratio between these events is 1.02.

   The predicted 200-year return period annual maximum daily flow in the 'spring' period is 9,300 m^3/s. This value decreases to 5,950 m^3/s in the 'fall'.

ii) Zymoetz River is the principal tributary to Skeena River in the area between the Usk gauge and Terrace. Data analysis from two gauging stations indicate that the 200-year return period annual maximum daily discharge is approximately 2,500 m^3/s. However, this value varies considerably, depending on which station's data is used in the analysis. The 200-year return period annual maximum instantaneous discharge could range between 3,800 and 4,200 m^3/s.

   The 200-year return period daily discharges in the 'spring' and 'fall' periods are 1,120 m^3/s and 2,770 m^3/s, respectively.

iii) Analysis of concurrent data from Skeena River plus the two stations on Zymoetz River provides an estimate of Skeena River flows at Terrace. This analysis indicates the predicted 200-year return period annual maximum flow is 9,270 m^3/s. This value is only 30 m^3/s larger than the 200-year return period annual maximum discharge predicted at the Usk gauge. This result reflects the shorter period of record available from the combined stations (57 vs. 76 years).

The 200-year return period 'spring' flow calculated from the combined Skeena and Zymoetz Rivers data is 9.180 m^3/s which is less than the value predicted at the Usk gauge (9,300 m^3/s). This anomaly again reflects the varying periods of record used in these calculations.

The 200-year return period 'fall' discharge calculated from the combined data is 6,880 m^3/s which is larger than the 'fall' value at the Usk gauge (5,950 m^3/s).

iv) The smaller size of the spring flood estimate from the combined data record compared to the predicted size of the 'spring' flood at Usk is problematic. A variety of additional analyses could be undertaken to address this issue, but cannot be completed within the scope of the present assignment. A conservative approach would be to base the design flood estimate for Terrace on the sum of the predicted 200-year return period daily flows calculated using the 'spring' data at Usk (9,300 m^3/s) and Zymoetz River (1,120 m^3/s). This gives a combined mean daily flow of 10,420 m^3/s.

v) Stream discharge data from Kitsumkalum River indicate the 200-year return period annual maximum daily flow is 1,110 m^3/s. The 200-year return period event is computed to be 1,470 m^3/s in the spring and 1,080 m^3/s in the fall. These values are likely to be more reliable than those predicted from annual data.

Studies by *Coulson (1988)* recommend the use of the following formula to transpose flood flows from one basin area to another:

$$Q_1 = \left[\frac{A_1}{A_2}\right]^{0.785} \times Q_2 \qquad .....(i)$$

where Q_1 and Q_2 are discharge (in m^3/s) and A_1 and A_2 are the basin area (in km^2) for watersheds 1 and 2 respectively.

This procedure can be used to transpose predicted flood data from Zymoetz River (basin area 2,908 km^2 to 3,080 km^2) to Kitsumkalum River (basin area 2,180 km^2). On this basis, the predicted 200-year return period annual daily flow on Kitsumkalum River is predicted to be 1,970 m^3/s, which is 80% larger than the 1,110 m^3/s predicted on the basis of the WSC stream gauging data. The maximum daily spring and fall floods are predicted to be 879 m^3/s and 2,160 m^3/s. The spring value is 60% of that predicted by the WSC data and the fall value is double. This inconsistency may reflect the hydrologic effect of lake storage on Kitsumkalum River. Nevertheless, these results imply that additional streamflow data need to be collected on Kitsumkalum River in order to improve our ability to reliably estimate potential flood magnitudes.

vi) The results of the various flood frequency analyses have been used to estimate the return period of regionally significant floods. This analysis, which is summarized on *Table 4.3.6.2*, indicate that:

- the spring 1936 flood on Kitsumkalum River had a return period of 40 to 50 years. This event occurred simultaneously with the flood of record on Skeena River (see Section 4.4). Unconfirmed data in *Septer and Schwab (1995)* could indicate this event had a >500 year return period at Usk (Section 4.4);

- the spring 1948 flood had a return period of >200 years on *Skeena River at Usk* and 8 to 14 years on Kitsumkalum River;

- the spring 1964 flood had a return period of 30 years on *Skeena River at Usk*, 50 years on Zymoetz River and close to 50 years on the basis of combined Skeena River and Zymoetz River discharges; and

- the spring 2007 flood had a return period of approximately 30 years at Usk, 18 years on Zymoetz River and approximately 45 years based on combined Skeena and Zymoetz River discharges.

All of these events are sufficiently large that they can be expected to have resulted in considerable bank erosion in susceptible materials and coarse sediment (bed load) transport.

4.4 FLOOD DAMAGE

4.4.1 Flood Chronology

Septer and Schwab (1995) document 45 significant flood events on Skeena River in the period between 1891 and 1991 *(see Table 4.4.1.1)*. Only two of these floods (Spring 1936 and Fall 1978) were reported to have also simultaneously affected the Kitsumkalum and Zymoetz Rivers, while nine events were reported on both Skeena and Zymoetz Rivers. Brief descriptions of significant concurrent events are presented below to illustrate the dramatic affects of sizeable floods.

4.4.2 Flood Descriptions

The following descriptions of significant events are all from *Septer and Schwab (1995)*.

The Great Flood of 1894

"There is limited data on the 'Great Flood of 1894' which continued for 57 days (The Daily Alaska Empire, May 29, 1948), which may have been larger than the 1936 event. In a letter to the Omineca Herald and Terrace News, long-time Terrace resident Harry L. Frank recalled the "Great Flood of 1894" as being less than the 1936 flood, however, according to Wiggs O'Neill, the 1894 flood was much bigger than the flood of 1936: 'Our highwater of 1936 was a baby in comparison. There has never been a highwater to equal it since'."

The Flood of May 29 to June 3, 1936:

"A sudden rise in temperatures caused snow melt and flooding conditions province wide and in the Yukon Territories and Alaska. The Skeena, Columbia, and Thompson rivers reached the highest levels in 30 years. According to the Natives (sic), one would have to go back at least a hundred years to find

a flood as bad as that in 1936 (F. Frank, letter to The Herald, May 4, 1972). The rising water of the Skeena River at Usk was 360,000 cfs (10,194 m3/s). In Terrace, the main course of the Skeena River shifted from the south side of Ferry Island to the north of it. The slough north of the island tripled in size to 300 yd. (275 m). On June 3, the Kitsumkalum River near Terrace recorded a maximum daily discharge of 883 m3/s, setting an all-time record (Environment Canada, 1991). The Skeena River changed its course near Terrace and caused severe erosion (Gottesfeld, pers. comm.). In many places the Skeena River cut entirely new channels."

October 29-Nov 1, 1978

"*On October 31, Terrace recorded 114.8 mm of rain in 24 hours, setting an all-time record any time of the year, with 70-80 km/h winds. On November 1, another 89.1 mm of rain fell in a 24-hour period. The storm appears to have centred around the Terrace–Kitimat area.*

Flows on the coastal streams peaked on November 1. The instantaneous maximum daily discharges were: Zymagotitz River 18,700 cfs (530 m3/s), Exchamsiks River 30,500 cfs (863 m3/s), Kitimat River 99,900 cfs (3,000 m3/s), Hirsch Creek 23,500 cfs (681 m3/s), Little Wedeene River 13,500 cfs (382 m3/s), Zymoetz River (on November 2) 111,000 cfs (3,140 m3/s) (Environment Canada, 1991). Both the Zmagotitz and the Zymoetz Rivers overflowed their banks on November 2."

October 6 to 14, 1991

"A record rainfall was recorded in the Terrace area. According to the Terrace Weather Office, 242.4 mm (9.54 in) of rain fell between October 6 and 14, far more than the annual average for October. On Highway 16 east of Terrace, the bridges over the Copper River and St. Croix Creek were threatened by erosion. The rising Skeena River backed up side rivers, causing flooding in the smaller communities near Terrace. On October 15, the Skeena River at Usk recorded a maximum instantaneous discharge of 5,530 m3/s and a maximum daily discharge of 5,310 m3/s (Environment Canada, 1991).

The Regional District of Kitimat-Stikine [RDKS] website [http://rdks.bc.ca] also provides a useful summary of the effects of historic flood flows.

5: FLOOD PLAIN MAPPING

5.1 BC MINISTRY OF ENVIRONMENT MAPPING

The BC MOE surveyed river cross sections between 1975 and 1983 which were used to prepare floodplain maps for lower Zymoetz River, Skeena River in the vicinity of Terrace and lower Kitsumkalum River *(BC MOE, 1982 & 1985)*. The design flows adopted for the Zymoetz River study were as follows:

LOCATION	RETURN PERIOD (years)	DISCHARGE TYPE	FLOW (m^3/s)
Zymoetz River	20	Daily	1,410
	20	Instantaneous	2,320
	200	Daily	2,510
	200	Instantaneous	4,610

Source: BC Water Management Branch Design File Summary 0305030 - Hec-II, dated November 20, 1984

The BC MOE *(B. Kuhnke, pers. comm.)* is unable to confirm the design flows used in the 1982 flood-plain mapping studies on Skeena and Kitsumkalum Rivers. However, these values were typically provided by the former Water Investigations Branch. We located what we believe to be the relevant files and this information is summarized below:

LOCATION	RETURN PERIOD (years)	DISCHARGE TYPE	FLOW (m^3/s)
Skeena River at New Remo	20	Daily	8,300
	20	Instantaneous	8,550
	200	Daily	11,100
	200	Instantaneous	11,400

LOCATION	RETURN PERIOD (years)	DISCHARGE TYPE	FLOW (m^3/s)
Kitsumkalum River	20	Daily	760
	20	Instantaneous	775
	200	Daily	1,030
	200	Instantaneous	1,070

Source: R. R. Wyman, 1981.

Copies of the BC MOE mapping are presented in Appendix 4. These maps show the location of surveyed river cross-sections and the elevation of the 20-year and 200-year return period water levels.

The elevation of the 200-year return period flood construction level includes a ‘freeboard’ allowance above the predicted ‘daily’ or ‘instantaneous’ flood. These values are typically 0.6 m (2 ft.) above the high water levels predicted from the calculated daily discharge elevation or 0.3 m (1 ft.) above the calculated instantaneous discharge elevation, with the higher elevation being adopted. Project files provided by Ashfaque Ahmed and Lyle Larsen of the BC MOE indicate that the Zymoetz River flood construction level was calculated by adding 0.30 m to predicted 200-year return period instantaneous discharge flood elevations. Unfortunately the BC MOE *(B. Kuhnke, pers. comm.)* cannot presently determine what freeboard criteria were used to calculate flood construction levels on either the Skeena River or Kitsumkalum River floodplain mapping. Given the comparatively small ratio between instantaneous and daily discharges on Skeena River, it is likely that the flood construction level was compiled as 0.6 m above the predicted daily flow. Unfortunately it is not possible to guess which criterion was adopted on Kitsumkalum River.

5.2 WATER MANAGEMENT CONSULTANTS 2001 AND 2009 STUDIES

Water Management Consultants [WMC] (2001) undertook a study to update the *BC MOE (1982)* floodplain mapping for the area in the immediate vicinity of Terrace. The 200-year return period flow for Skeena River near Terrace was calculated by adding together the predicted 200-year snowmelt freshet flows for *Zymoetz River above OK Creek* and *Skeena River at Usk*. This results in a conservative design estimate as both flows may not occur synchronously. The *WMC (2001)* design flow of 11,200 m^3/s is very similar to the 11,100 to 11,400 m^3/s values which were used in the *BC MOE (1982)* floodplain mapping studies on Skeena River.

The results of the *WMC (2001)* analysis are shown on *Figure 5.2.1*. This map indicates areas exposed to high ground water levels and shows the depth of inundation which would occur during the design flood event, plus a 0.3 m freeboard allowance.

WMC revised their 2001 study in 2009 *(WMC, 2009)* at the request of the RDKS. This analysis, which is shown on *Figure 5.2.2*, includes model re-calibration based on observed high water levels during the 2007 flood and limited channel re-surveys on the mainstem of Skeena River. The adopted 200-year return period spring freshet flows on Skeena River near Terrace and Kitsumkalum River were 10,715 m^3/s and 1,216 m^3/s, respectively. The Skeena River value is very similar to that employed in the *WMC (2001)* study (11,200 vs. 10,715 m^3/s). The Kitsumkalum River value appears to be approximately 16% higher than that previously employed by the BC MOE (1,216 m^3/s vs. 1,030 to 1,070 m^3/s). There is only limited post-2007 survey data for Kitsumkalum River and the basis for the *WMC (2001)* calculations in this area need to be confirmed. These analyses indicate predicted 200-year return period flood elevations with no freeboard allowance. The *WMC (2009)* calculations also include predictions of average water velocity during the design flood. The results, which are shown on *Figure 5.2.3*, will underestimate mainstem water velocities as the “average value” includes overbank areas which will have much reduced velocities.

5.3 WATER SURFACE ELEVATION AND VELOCITY PROFILES

5.3.1 Skeena River

The *BC MOE (1982)* and *WMC (2001 & 2009)* analyses have been used to prepare profiles showing how water surface elevation and average water velocity varies in the area between the CNR railway bridge and the Kitsumkalum River confluence. The water surface profile data from these three studies is compared on *Figure 5.3.1.1*. This analysis indicates that the flood elevations predicted by *WMC (2001)* in the area between the Highway 16 Bridge and the sewage treatment plant are up to 1 m lower than those estimated by the BC MOE in 1982. However, the 2009 estimates are up to approximately 1 m higher than those predicted by MOE and would be 1.3 to 1.6 m higher if a freeboard allowance was included. Water surface elevations downstream of the sewage treatment plant have similar profiles on *Figure 5.3.1.1*. This implies that the 2009 elevations are 0.3 to 0.6 m higher than the previous estimates when the freeboard allowance is included.

The changing water surface elevations reflect changes in the design discharge, changes in channel roughness values used to calibrate the model and changes in river bed elevation. Changes in channel bed elevation will be discussed further in Section 5.4.

The WMC water velocity data are summarized on *Figure 5.3.1.2*. This analysis indicates how velocities decrease in the comparatively wide section of valley flat located near the COT STP and then increase in the more constricted area near Hell's Gate. These values are difficult to interpret as they include areas of overbank flow. One possible interpretation is that channel constriction in the Hell's Gate area could be causing backwater effects in the upstream channel. More detailed analyses of the WMC model results are needed to determine if this is occurring.

5.3.2 Kitsumkalum River

The predicted flood elevations compiled by the *BC MOE (1982) and WMC (2009)* are compared on *Figure 5.3.2.1*. This analysis indicates that the average water surface slope decreases downstream of River Km 2.5. This corresponds to the approximate location where the channel morphology changes from a single thread to multi-thread channel configuration. The lower gradient downstream section may also represent an area influenced by backwater effects from Skeena River.

The water elevations predicted by the BC MOE in 1982 range from 0.3 m to 1 m higher than those calculated by *WMC (2009)*. The BC MOE elevations will include 0.3 to 0.6 m of freeboard, which partially explains the increased elevations. *WMC (2009)* indicates their studies were based on updated river cross-sections in lower Kitsumkalum River, a 200-year return period flow on Kitsumkalum River of 1,216 m^3/s (which is approximately 16% larger than that employed by the BC MOE) and a coincident 200-year return period discharge of 9,630 m^3/s on Skeena River. The model was calibrated based on spring 2007 high water mark elevations. However, the WMC water level elevations may not reflect current river conditions given the limited amount of new survey data which appears to be available.

5.4 CHANGES IN CHANNEL MORPHOMETRY

5.4.1 Skeena River

River cross-section elevation data collected by the BC MOE *(1982)* and McElhanney Consulting Services Ltd. in 2008 have been compiled to determine how the river bed elevations have changed in the approximately 30 year period between the two surveys. The 2008 river surveys may not have been taken in exactly the same location as the previous cross-sections and the sections have been shifted laterally 'by eye' as there are no common control points which would allow a more accurate procedure to be adopted. The results of this analysis are compiled in Appendix 5. Cross-section locations are shown on the floodplain maps compiled in Appendix 4.

The channel thalweg is a line connecting the deepest point in a series of river cross-sections. *Figure 5.4.1.1* compares the channel thalweg elevations surveyed in 1975 and 2008 based on the data in Appendix 5. This analysis suggests that the channel thalweg elevation has generally increased in the area between Ferry Island and the Outlet of Braun's Slough. The magnitude of this change varies between less than 1 m near Ferry Island to possibly as much as 9 m in the vicinity of the entrance to Hell's Gate. Unfortunately, McElhanney was not able to re-survey all the MOE sections and this results in some uncertainty. However, the historical air photo analyses (discussed in Section 6) and observations by long term residents, such as Chief Don Roberts (pers. comm.), confirm that substantial volumes of sediment have been depositing in the vicinity of the STP and the mainstem channel of Skeena River upstream of the Kitsumkalum confluence.

5.4.2 Kitsumkalum River

River cross-section data was obtained by the BC MOE in 1978 on the Kitsumkalum River as part of their floodplain mapping program [Appendix 4, Sheet 6]. McElhanney Consulting Services Ltd. re-surveyed four cross-sections on the lower Kitsumkalum River in the vicinity of the Highway and railway bridges in 2009 *(Figure 5.4.2.1)*. This survey adopted the same datum used in 1978. UTM coordinates were not provided for the 1978 data and the precise location of these data points is unknown. The 1978 and 2009 data have therefore been shifted laterally by eye to facilitate analysis of bed elevation changes over the last approximately 30 years. The survey results are compiled in Appendix 6.

Figure 5.4.2.2 illustrates the thalweg elevations determined by the 1978 and 2009 cross-section surveys. This analysis indicates that the thalweg elevation has aggraded by 1.4 m upstream of the Highway 16 Bridge, stayed more or less the same under the highway bridge, downcut by 1.4 m between the highway and railway bridge and downcut by 2.1 m under the CNR railway bridge. This pattern suggests that general scour is occurring in the constricted area at the railway bridge and that backwater effects may be promoting sediment deposition upstream of the highway bridge. However, a more detailed review of the hydraulic analyses would be needed to confirm this interpretation.

6: HISTORICAL AIR PHOTO ANALYSIS AND RATES OF BANK EROSION

6.1 COMPILATION OF HISTORICAL AIR PHOTOS

Representative historical air photos or orthophotos of the study area were acquired from the province of BC, the Federal Government and private sources. Nine sets of aerial imagery dating from 1938 to 2007 were scanned and compiled at a common scale to document changes in channel conditions for Skeena River and the lower sections of Zymoetz and Kitsumkalum Rivers. The historical air photo compilations of Skeena and Kitsumkalum Rivers are presented in Appendices 7 and 8, respectively. These sheets are annotated to indicate significant events and the interested reader is referred to these Appendices for detailed information on site-specific locations. *[1] The following sections provide a brief summary of the results.

6.2 CHANNEL CHANGES ON SKEENA RIVER

6.2.1 Skeena River at the Zymoetz River Confluence [See Appendix 7, Sheets 2 and 3]

The Zymoetz River confluence is illustrated on *Plate 6.2.1.1*. The lower section of Zymoetz River is laterally unstable as significant amounts of bank erosion and gravel deposition or erosion have occurred throughout the photo record. Sizeable unvegetated instream gravel accumulations are evident in 1938 and these deposits persist through the whole period. A dyke was constructed on the right bank and rock rip-rap was placed on the left bank to stop bank erosion and channel shifting in the vicinity of the new Highway 16 river crossing. These works cut-off access to a side channel and significantly reduced the channel width. Significant bank erosion subsequently occurred upstream and

1 Reports by *Hogan and Schwab (1989)* and *Beaudry, et al., (1990)* provide some, now out of date, information on channel stability in the downstream section of Skeena River.

downstream of the crossing. Zymoetz River continues to transport large quantities of both fine and coarse sediment to the Skeena River.

6.2.2 Skeena River from the Zymoetz Confluence to the Highway 37 Bridge [See Appendix 7, Sheets 3 to 5]

Skeena River forms a single thread channel immediately downstream of Zymoetz River. A series of unvegetated bars and islands occur immediately upstream of the Highway 37 Bridge *(Plate 6.2.2.1)*. The bridge is located on a bedrock constriction in the channel.

Localized bank erosion is occurring on the islands upstream of the Highway 37 Bridge and erosion early in the last century required the construction of revetments to protect the CNR railway on the north bank of the river. There appears to have been little change in channel location on the south bank, however, recent (post-1983) valley flat clearing could result in increased instability in areas with reduced riparian vegetation.

6.2.3 Vicinity of Ferry Island [See Appendix 7, Sheets 5 and 6]

Ferry Island is located immediately downstream of the Highway 37 Bridge. The historical air photo analysis indicates that Ferry Island has enlarged and extended downstream over the period since 1938. This reflects increased deposition of sediment derived from the upstream channel. Only localized and modest erosion has occurred on the north (or right) bank of Skeena River opposite Ferry Island *(Plate 6.2.3.1a)*. More active, but still modest, rates of erosion have been occurring on the south (or left) bank of Skeena River opposite Ferry Island. This area, which is locally known as Thornhill and Queensway, contains a number of residential developments *(see Plate 6.2.3.1b)*. A series of bank stabilization projects (including one in the spring of 2009) have been undertaken to provide erosion protection for this area. The historic pattern of channel shifting is illustrated on *Figure 6.2.3.1*. This analysis indicates that there has been no detectable erosion in the post-1938 period in the section of Queensway that was protected by rip-rap in 2009. Some local erosion undoubtedly occurred, however, it is sufficiently small that it is within the accuracy of the air photo rectification procedure. This area consists of a low terrace which is more erosion resistant than the low flood plain which occurs downstream.

Transect 2 *(see Figure 6.2.3.1)* is near the RDKS STP located downstream of Queensway *(Plate 6.2.3.2)*. The average post-1938 rate of bank retreat has been 2.8 m/yr, with the highest amount of bank recession (4.3 to 4.5 m/yr) having occurred in the earlier part of the last century. This may reflect the effects of the sizeable floods which occurred in 1936 and 1948. There has been no detectable bank recession in the post-1988 period despite the occurrence of the large flood of June 2007.

The historical air photo analysis indicates that gravel accumulations at the downstream end of Ferry Island are enlarging and this might increase rates of future bank erosion opposite the RDKS STP *(Plate 6.2.3.3)*. However, these deposits isolate the area around the RDKS STP from the flow in the north bank channel and the incoming flow in the south channel is flowing parallel to the bank rather than directly impinging on it. Channel relocation (or avulsion) through the secondary channel, located south of the RDKS STP, appears to be a more immediate threat if the effluent pipeline is buried at shallow depth. Post-1983 clearing of this area has eliminated both the valley flat and riparian tree cover, which will increase the potential for channel instability.

A BC Hydro transmission line crosses Skeena River immediately upstream of the RDKS STP and one of the towers is being attacked by the river. A ring dyke has been constructed to protect the lower foundations *(Plate 6.2.3.4).* This structure now projects into the mainstem channel and significant local scour could pose a threat to its security.

6.2.4 Vicinity of COT STP and Braun's Slough [See Appendix 7, Sheets 6 to 7]

The COT's STP is located on the north (or right bank) of Skeena River immediately upstream of Braun's Slough. The present orientation of Skeena River directs the main flow into the upstream bank, as illustrated on *Plate 6.2.4.1*. The historical air photograph analysis indicates this bank has been progressively eroding over the post-1938 period. The pattern of bank erosion is indicated on *Figure 6.2.4.1*. Average erosion rates range between 0.7 and 4 m/yr. The maximum bank erosion between 2001 and 2007 was 105 m at Transect 1. This corresponds to an average recession rate of 15 m/yr, however, much of this erosion likely occurred in the June 2007 flood. This stability concern was previously recognized by the COT and local bank protection (consisting of short spurs, bank riprap and a buried set-back dyke) was installed around the STP prior to the 2007 flood. Additional riprap and spurs were installed in the early spring of 2009.

The June 2007 flood inundated sections of floodplain located upstream of the COT STP *(Plate 6.2.4.2)* and this water drained into Braun's Slough. The widespread deposition of sediment and debris on the floodplain attest to both the volume and velocity of overbank flow. Inspection of the floodplain maps [see Appendix 4 and *Figure 5.2.1*] indicates that the predicted 200-year return period water surface profile steepens on the north side of the floodplain opposite Braun's Island. This increased gradient could facilitate a channel relocation (or avulsion) through this area. This concern has also been recognized by the COT and soil bio-engineering was installed in the spring of 2009 to increase the hydraulic resistance to overbank flow through the establishment of a dense, quick growing, tree cover. The installed bank protection will reduce the erosion hazard, but will not prevent flooding.

The historical air photograph analyses indicate that sizeable gravel bars are forming in the mainstem of Skeena River between the inlet to Braun's Slough and the Kitsumkalum River confluence. This area is illustrated on *Plate 6.2.4.3*. The enlarging bars are likely responsible for increased flow through the 'Hell's Gate' sidechannel and for developing erosion concerns on the right bank. Post-1938 bank erosion is indicated on *Figure 6.2.4.2*. Widespread erosion, which locally exceeded 90 m, occurred between 1938 and 1960. Subsequent rates of bank recession have been reduced as much of this area is protected with variable quality rip-rap. The analyses on *Figure 6.2.4.2* indicate that average rates of erosion range from 1.1 m/yr to 2.4 m/yr. The largest erosion occurred at Transect 3, with approximately 90 m of recession between 1947 and 1960. More recently, bank erosion appears to have stabilized at this transect, with possibly small amounts of deposition occurring between 1988 and 2007. Transect 4 has also exhibited high rates of erosion between 1947 to 1960 (6.4 m/yr) but has also stabilized post-1988. Transect 1 is the only site that has shown small amounts of erosion post-1988.

6.2.5 Skeena River at the Kitsumkalum River Confluence [See Appendix 7, Sheet 8]

A series of bars and islands have developed opposite the mouth of Kitsumkalum River in the period since 1938. As illustrated on *Plate 6.2.5.1*, these structures now infill a significant portion of the 1938 channel width. Rates of bank erosion in this area have been constrained by bank protection located along the CNR railway alignment.

6.2.6 Hell's Gate Sidechannel [See Appendix 7, Sheet 9]

A number of secondary channels exist downstream of the entrance to Hell's Gate. These channels have become more active in recent years as the channels have enlarged significantly and the distribution of instream gravel accumulations has increased substantially *(see Plate 6.2.6.1)*. These changes in channel morphometry have increased the flow conveyance capacity and suggest that Hell's Gate sidechannel complex is transporting an increasing percentage of the total Skeena River flow.

This interpretation may be supported by stream discharge data collected by WPL prior to and following the 2007 flood. They measured the flows in both Hell's Gate channel and in the downstream section of Skeena River. Their results are shown below:

DATE	TOTAL FLOW (m^3/s)	FLOW SPLIT %	
		Hell's Gate	Main Channel
May 2003	3,400	35	65
December 2008	580	85	15

The flow distribution would be expected to vary with discharge and more data would therefore be required to monitor or assess changes in flow distribution over time.

6.3 CHANNEL CHANGES ON KITSUMKALUM RIVER

6.3.1 Treston Lake to Dalk-ka-gila-quoeux IR 2 [See Appendix 8, Sheets 1 to 8]

The 23 km section of Kitsumkalum River located between Treston Lake (at River Km 33) and IR 2 (at River Km 10.2) generally consists of a single thread channel. Canyons occur between River Kms 10 and 12.5 and Kms 14 and 14.5 where the river is confined by glacio-fluvial and terrace materials *(see Figure 3.1b)*. Some glacio-lacustrine sediments also occur immediately downstream of Treston Lake and contemporary fluvial sediments occur in non-confined areas.

Kitsumkalum, Redsand and Treston Lakes will trap the coarse sediment load being produced in the upstream watershed. However, there are a number of sizeable sediment sources between Treston Lake and IR 2. These include channels such as Star, Alice, Glacier and Lean-To Creeks, which appear to have been destabilized by logging activity *(Plate 6.3.1.1)*. Sizeable slope instabilities also occur at River Kms 28.5, 28.0, 27.5, 26.1, 24.6, 23.6, 16.5, 15.5, 14.5 and 10.5 *(see Plate 6.3.1.2)*. These failures, which are typically located in glaciofluvial materials, deliver both fine and coarser textured materials to Kitsumkalum River and these sediments are transported downstream.

The April 23, 2009 helicopter inspection located a recent channel avulsion in the area between River Kms 15.5 and 17.5. Vertical air photos of this area, which is located immediately downstream of Lean-To Creek, are compiled in Appendix 8, Sheets 5 & 6. The most recent conventional air photo was taken in 2001 and the river consisted of a single channel flowing around a large meander bend. A cut-off channel or ox-box lake is located on the left bank or east valley flat. The river has been progressively eroding towards this site over the period since 1938. Accelerated rapid bank recession occurred between 1974 and 2001. It is likely the channel avulsed into this area during the 2007 flood. The new channel is illustrated on *Plate 6.3.1.3*. This event triggered a number of slope instabilities on the adjacent valley wall. The combination of valley flat erosion to form the new channel and slope instabilities will have released a very sizeable sediment load to the downstream channel.

As discussed in *Lough and Whately (1984)* and *J & S Ventures Ltd (1996)*, the Kitsumkalum River was used to transport or 'drive' logs to a take out facility located near the Skeena River confluence. The historical air photo analysis indicates that the entrances to a number of secondary channels were blocked off in the period between 1947 and 1960. This work appears to have been undertaken to minimize the potential for logs to enter these areas. Channel blockage was documented on former side channels located at River Kms 24.5, 24.0, 18.5 and 16.0. These structures are now generally vegetated, as are many of the cut-off channel segments.

6.3.2 IR 2 to Dutch Valley [See Appendix 8, Sheets 8 to 10]

This 6 km section of channel extends between the exit of the lower canyon on Kitsumkalum River (River Km 10.2) and Dutch Valley (River Km 4.0). Coarse sediment delivered from the upper watershed begins to be deposited at the outlet of the lower canyon and the river adopts a more meandered configuration with a wider, more continuous valley flat, gravel bars, islands and secondary channels.

A sizeable area of sediment accumulation occurs between Kms 7.5 and 9. Some of the secondary channels in this area were blocked off between 1947 and 1960, presumably to facilitate log driving. The mainstem channel may also have been straightened, with the resulting loss of an extensive network of secondary channels (see Appendix 8, Sheet 9). Widespread channel shifting has subsequently occurred in this disturbed section of channel as a result of ongoing sediment deposition and the increased erosion potential associated with the pre-1960 shortening and steepening of this section of river. These processes are contributing to an elevated coarse textured sediment load being delivered to the downstream channel. Present river conditions in this area are illustrated on *Plate 6.3.2.1*.

The Nass River or west bank access road is located in close proximity to Kitsumkalum River between River Kms 5 and 6 *(see Plate 6.3.2.2)*. Chief Don Roberts (pers. comm.) indicates that the road was not overtopped at this location during the 2007 flood. However, he does have concerns over ongoing bank erosion in the vicinity of Km 5 (see Appendix 8, Sheet 10 and *Plate 6.3.2.2b)*. The historical air photos have been used to determine rates of bank erosion at this site *(see Figure 6.3.2.1)*. This analysis indicates that the total post-1938 bank recession is 83 m, or an average rate of 1.2 m/yr. Approximately 8 m of recession occurred as a result of the 2007 flood and the development of a mid-channel bar at this bend could result in rates of bank retreat which exceed the long term average. Field inspection indicates that an area of somewhat higher ground (indicated by the dark green coniferous tree cover on the 2009 air photos shown in Appendix 8, Sheet 10; also see *Plate 6.3.2.3)* is located inland from this bend. This low terrace may provide some additional erosion resistance. Fortunately, there are no high value structures located in the immediate vicinity of this bend.

A lengthy meander bend formerly occurred at River Km 4 just upstream of Dutch Valley. As indicated in Appendix 8, Sheet 10, this bend increased in length over the period between 1938 and 1988 and cut-off some time prior to 1993. Rates of erosion are summarized on *Figure 6.3.2.1* and indicate that over 150 m of bank recession occurred at this bend [Transect 2] between 1938 and 1988. The average annual rate of retreat was 9 m/yr between 1938 and 1947. This decreased to 1.4 m/yr between 1947 and 1988. Present site conditions are illustrated on *Plate 6.3.2.3*.

6.3.3 Dutch Valley to Skeena River Confluence [Appendix 8, Sheets 10 to 11]

The post-1988 meander cut-off described in Section 6.3.2 resulted in substantial re-organization of the downstream channel. As indicated in Appendix 8, Sheet 10, another meander cut-off occurred opposite Dutch Valley between August 2001 and August 2007. [This event may have been associated with the June 2007 flood.] The former mainstem channel was abandoned *(see Plate 6.3.3.1a)* and a new channel formed along a secondary channel which was located just west of the large field at Dutch Valley. The new channel is illustrated on *Figure 6.3.3.1b*. Field observations by Dave Gordon (pers. comm.) indicate that the river bed elevation in this area may have recently increased in elevation by more than 1 m due to sediment accumulation.

Air photograph analysis *(Figure 6.3.2.1)*, indicate that rates of bank erosion near the downstream end of Dutch Valley [Transect 4] have increased following the channel relocation. The lack of riparian vegetation will result in the area of bank along the cleared field being particularly erosion susceptible. A long storage shed is located within this area and future bank erosion could readily reach this structure. Fortunately, it would be possible to move this inexpensive structure. Soil bio-engineering techniques (described in *Polster 2001 & 2002; and Fischenich 2001)* could be used to provide an inexpensive means of increasing bank erosion resistance in this area.

The main channel was eroding towards the right bank opposite Dutch Valley prior to the post-2001 channel cut-off. As indicated on *Figure 6.3.2.1*, approximately 100 m of bank recession occurred [at Transect 3] in the post-1988 period prior to the bend being cut off, likely by the 2007 flood. This channel shifting exposed a sizeable industrial and residential waste disposal site on the right channel bank opposite the former Kalum Wood Products Limited Mill [River Km 3.5]. This site is illustrated on *Plate 6.3.3.2*. Sub-surface water was flowing from the base of the cut-bank into a residual pond located on the former mainstem channel on April 22, 2009 and a rust-coloured algal mat occurred along the base of the bank. This may be an indication that contaminated groundwater is entering the river from this site.

Substantial channel changes have occurred in the lower 3 km of Kitsumkalum River over the period since 1938. A log storage area was created in an area of low-lying flood plain in the period between 1947 and 1960 (see Appendix 8, Sheet 11). Extensive rip-rap protected revetments were constructed to stabilize the bank and direct logs into the storage facility. A rock-lined outlet channel was also constructed *(see Plates 6.3.3.3 & 6.3.3.4)*. These structures may have precipitated a meander bend cut-off at River Km 2 in the period between 1974 and 1988.

The historical air photo analysis has been used to quantify rates of progressive bank erosion in the lower river. As indicated on *Figure 6.3.2.1*, modest rates of bank erosion have recently occurred at both Transects 5 & 6. However, a secondary channel is enlarging immediately downstream of Dutch Valley at Transect 5 *(see Plates 6.3.3.5 & 6.3.3.6)* and the meander bend on which the now abandoned log storage area is situated on is sufficiently long that a channel cut-off is becoming increasingly likely. A complicating factor is that vegetated bank revetments surround the log storage area and extend along at least the right bank of the upstream abandoned river channel. These structures interfere with the river's ability to both shift laterally or store the coarse sediment load which is being moved through this section of channel. This may result in unexpected channel behaviour in the future, particularly if the river is able to outflank these structures. A buried industrial waste disposal site on the west side of the abandoned log storage area could also be another source of groundwater contamination.

The now abandoned railway grade located on the west side of Kitsumkalum River and the Nass River Road may provide some flood protection from mainstem high water levels. However, these structures may also impede local drainage from streams draining the valley wall. For example, *Plate 6.3.3.7* illustrates a tributary stream located near the abandoned Kalum Wood Products Limited mill which may have been diverted by the construction of the Nass River road. Flood discharges from this site could be diverted down the road to the Kalum Reserve and combine with the inflow from a channel adjacent to the reserve *(Plate 6.3.3.8)*. Chief Don Roberts (pers. comm.) suggests that water from either one or both of these sources entered the Reserve during the 2007 flood.

A variety of gravel borrow projects have been undertaken near the mouth of Kitsumkalum River. As illustrated on *Plate 6.3.3.9a*, the Ministry of Transportation maintenance yard is located in a former borrow pit located on the left bank of Kitsumkalum River immediately upstream of the Highway 16 Bridge. An active gravel borrow pit is located on the left bank approximately 1.3 km upstream. Recent clearing extends to the channel edge and a variety of revetments have been placed to reduce the likelihood of the river eroding or shifting into the pit *(see Plate 6.3.3.9b)*.

The CNR and BC Ministry of Transportation have both constructed bridges over Kitsumkalum River immediately upstream of the Skeena River confluence *(see Plates 6.3.3.10 & 6.3.3.11)*. The original CNR bridge consisted of two spans having a total width of approximately 125 m. One crossing the western mainstem channel and the other wider structure crossed an eastern secondary channel [see Appendix 8, Sheet 11]. The Department of Highways subsequently constructed an approximately 100 m wide bridge which more or less spanned the mainstem channel. However, the bridge alignment cut off the flow to the eastern opening on the CNR Bridge. This requires that all river flow now be conveyed through the western opening on the CNR Bridge which is approximately 50 m wide.

7: FUTURE CHANNEL BEHAVIOUR AND MANAGEMENT IMPLICATIONS

7.1 SKEENA RIVER

7.1.1 Zymoetz River Confluence

Previous investigations have indicated that high rates of sediment production from Zymoetz River reflect both valley wall and floodplain logging activity *(Miles and Associates Ltd., 1990)* and the effects of sizeable floods *(Weiland and Schwab, 1996a & 1996b)*. An up to date analysis of historical air photographs (similar to that undertaken for lower Kitsumkalum River) would be required to evaluate present sediment sources and determine how much material is still in transit within the river channel. Until such time as this analysis is undertaken, it would be prudent to assume Zymoetz River will continue to periodically produce morphologically significant quantities of coarse sediment.

The volume of logging-related sediment production is expected to decrease over time as vegetation develops on disturbed areas or presently mobile instream gravel accumulations. However, numerous slope instabilities occur naturally in the Zymoetz River watershed *(e.g. MMA, 2000a & b)* and unusual storm events would be expected to result in enlarged or additional instabilities.

Skeena River will periodically entrain any supplied material and the coarser fraction of these sediments will be preferentially deposited in lower gradient sections of the downstream channel (such as that which occurs in the vicinity of Braun's Island).

7.1.2 Skeena River from the Zymoetz Confluence to the Highway 37 Bridge

Localized channel shifting will continue to occur on Skeena River between Zymoetz River and Highway 25. Future rates of erosion may increase along the area of riparian and valley flat clearing located on the left bank upstream of the Highway 37 Bridge *(see Plate 6.2.2.1b)*. It would be useful to re-establish riparian vegetation in this area and restrict future riparian clearing. These actions could reduce future bank erosion as well as providing ecological benefit.

7.1.3 Vicinity of Ferry Island

The historical air photograph analysis *(Figure 6.2.3.1)* indicates that in the period since 1938 comparatively little erosion has occurred in the vicinity of Thornhill and up to approximately 75 m has occurred near the downstream section of Queensway. This corresponds to an average annual erosion rate of ≤1.1 m/yr. [Actual erosion rates are likely to be episodic.] Comparison of the 1993 and 2001 air photos [see Appendix 7, Sheets 5 & 6] indicates that approximately 500 m of rip-rap was constructed at Thornhill over this period, an additional 400 m ± had been added by September 2007 and an additional 900 m ± was constructed in the winter of 2008/2009. This rip-rap was installed along the existing bank and the width of the 'self launching apron' at the base of the revetment was approximately 5 m. This minor encroachment is unlikely to affect the distribution of flow around Ferry Island or affect bank stability on the opposing section of the north bank. Nevertheless this revetment will fix the orientation of the mainstem channel and direct it towards the right bank of Skeena River in the area upstream of the COT STP. However, due to the documented slow rates of bank erosion, the effect of bank hardening is not likely to significantly change rates of channel shifting in the near future.

The total revetment length along the Thornhill–Queensway area is approximately 1,800 m. It is important that local residents understand that this work does not provide protection in the flood susceptible areas indicated on the BC MOE floodplain maps [see Appendix 4, Sheet 8].

The RDKS STP and a BC Hydro Transmission Line Tower are both located on the south bank immediately downstream of an area which has experienced 195 m of erosion since 1938 *(see Figure 6.2.3.1)*. Recent rates of bank erosion have been reduced in the post-1988 period as the mainstem current is now flowing parallel to rather impinging on this bank. However, accelerated erosion could occur if the mid-channel gravel bars opposite this site expand. High water levels associated with the 2007 flood overtopped sections of this river bank. Debris and sediment deposits indicate water flowed through the field and secondary channel located south of the RDKS STP. Channel enlargement in this area is therefore a potential threat as it could expose influent pipelines.

Recent rates of bank erosion have been sufficiently small that additional bank revetments do not appear to be immediately required. The ring-dyke protecting the BC Hydro Transmission Tower appears to be under fairly severe attack and it may be desirable to ensure it is still capable of providing the required protection.

A cleared field with little or no riparian buffer is located upstream of the sewage treatment plant and was a preferred area of over bank flow during the 2007 flood.

Re-establishing riparian vegetation and preventing the further loss of forest cover in this area could reduce the potential for bank erosion or a channel relocation in this area.

7.1.4 Vicinity of COT STP and Braun's Slough

The preceding discussion indicates that substantial quantities of gravel have deposited in the section of Skeena River in the vicinity of Braun's Slough. This appears to have increased the percentage of flow being diverted into the Hell's Gate sidechannel and reduced the percentage of discharge flowing towards the Kitsumkalum Confluence. The north (or right bank) of Skeena River at and upstream of the COT STP has been severely attacked by the incoming flow and this has required the installation of extensive bank revetments. Extensive overbank flooding occurred in the vicinity of Braun's Slough in 2007 and the water surface profile suggests that a channel avulsion could occur in this area.

Preferential sediment deposition is expected to continue in this area and promote future channel instability. Further analyses of the *WMC (2009)* hydraulic modeling would be needed to quantify the effects of changes in channel bathymetry on flood levels and to assess the potential benefits of lowering the stream bed. From a morphologic perspective, dredging is unlikely to result in a long term solution as deepening the river bed will likely result in increased sediment transport from the upstream channel which will rapidly infill the excavation. Our initial recommendation is therefore to focus remedial efforts on measures to appropriately adapt to the future flooding and channel instability hazards.

The bank revetments installed adjacent to and upstream of the COT STP appear to be constructed on fluvial gravels which overlay readily erodible glacio-marine sediments. [These materials were exposed during construction of the upstream end of this project.] Significant local scour could occur if the glacio-marine sediments become exposed and this could require revetment repair or reconstruction. This hazard is particularly severe at the nose of the constructed spurs and at the upstream end of the project where the incoming river flow is oriented towards the upstream end of the bank revetment. The COT needs to ensure these bank protection works do not become outflanked.

Hydraulic calculations undertaken during the design of the COT STP bank protection works suggest that the river discharge which will cause overbank flow has a return period of approximately 5 years *(M. Thompson, pers. comm.)*. Floods of this magnitude or larger could cut off the COT STP from land access and divert flow into the vicinity of Braun's Slough. The recently completed bank protection works and soil bioengineering could reduce the potential for river bank erosion in this area, but is not intended to provide flood protection. Under very severe conditions it could be possible for a channel to develop into Braun's Slough despite having the bank protected with heavy rip-rap.

7.1.5 Skeena River at the Kitsumkalum River Confluence

Sediment accumulation is likely to continue in the section of Skeena River near the Kitsumkalum River confluence over the short term. Longer term behaviour will depend on what channel changes occur in the vicinity of Braun's Slough and Hell's Gate.

7.1.6 Hell's Gate Sidechannel

The Hell's Gate sidechannel has been progressively increasing in size and this trend is likely to continue to occur for at least the immediate future. The depth of the river bed between the bedrock outcrops which occur at the entrance to Hell's Gate will largely control the amount of water that can enter this constricted channel. It would therefore be desirable to determine the depth of the river bed and whether there is a bedrock sill which controls the river bed elevation.

7.2 KITSUMKALUM RIVER

7.2.1 Treston Lake to Dalk-ka-gila-quoeux IR 2

The section of Kitsumkalum River between Treston Lake and Dalk-ka-gila-quoeux IR 2 is expected to continue supplying a morphologically significant coarse sediment load to the lower Kitsumkalum River. Source areas include unstable tributary streams, valley wall slope instabilities and areas of eroding channel bank such as the recent avulsion between Kms 15.5 and 17.5. Rates or volumes of sediment production will vary with storm or flood magnitude and with land use effects such as fire or logging activity. As previously discussed, much of the coarse sediment originating in this reach will be transported downstream to wider and lower gradient sections of Kitsumkalum River.

7.2.2 IR 2 to Dutch Valley

The area of sediment accumulation between Kms 7.5 and 9 may become increasingly unstable as this is the first area where the upstream coarse sediment load (from sites such as the recent channel avulsion) can be deposited. Over time this material will continue to move downstream and could cause accelerated channel shifting in the area between the Nass access road [Km 6] and Dutch Valley.

7.2.3 Dutch Valley to Skeena River Confluence

Coarse sediment loadings from the upstream channel, combined with local land use impacts, including construction of lengthy training works and riparian clearing, are expected to result in ongoing meander progression and cut-offs in the lower Kitsumkalum River. The historical air photo analysis indicates that the location and magnitude of the channel shifting will be difficult to predict and a wide zone will be required to give the room the river needs to both regain channel slope (or length) and provide room to store the incoming sediment load.

Accelerated bank erosion should be expected in the vicinity of Dutch Valley and channel avulsions could readily occur on either side of the river in the vicinity of the former log driving storage area.

The channel constriction at the CNR railway has resulted in substantial local scour which has the potential to adversely affect the stability of the bridge footings. Sediment accumulation, unusual flood flows and/or backwater effects from Skeena River might raise water levels enough to threaten recent borrow pits on the left bank of Kitsumkalum River upstream of the Highway Bridge. Site inspection and more detailed hydraulic analyses would be needed to better evaluate this concern.

Flood hazards to the Kitsumkalum IR 1 community appears to arise from both the mainstem river [see Appendix 4, Sheet 6] and from the down valley movement of tributary inflow. A more detailed description of what happened during the 2007 flood could provide a better basis for deigning appropriate remedial actions.

As discussed in Section 6.3.3, the present waterway opening beneath the CNR railway bridge is approximately 50 m. *WMC (2009)* proposed a 200-year return period design flow on Kitsumkalum River of 1,216 m^3/s. The *Transportation Association of Canada (2001)* suggests that bridge approach embankments should not encroach into the channel and that a 'trial' waterway width can be computed using the following equation:

$$W_S = C\,Q^{0.5}$$

where W_S = water surface width at design discharge (m);
Q = design discharge (m³/s); and
C = coefficient with a value of 3.3 to 4.8

On this basis, the 'trial' opening width could be 115 to 167 m. The low value is appropriate for streams with scour resistant banks, while the larger value being appropriate for 'shifting alluvial channels'.

This rough calculation suggests that the residual waterway opening on the CNR bridge is small (unless the site is in heavy backwater during design flow conditions). Additional hydraulic analyses are required to further evaluate this concern.

8: RECOMMENDATIONS

8.1 HYDROLOGY

The hydrological analyses indicate that the design flood estimate for Skeena River near Terrace varies depending on the data set used for this calculation. It would be possible to refine this analysis through the following additional work:

1. Verify the unpublished streamflow data cited in *Septer and Schwab (1995)* which indicates a peak flow of ≥ 10,194 m³/s occurred on *Skeena River at Usk* during the 1936 flood. If confirmed, re-calculate the flood frequency analyses including this value.

2. Request the WSC to calculate the annual maximum instantaneous streamflow values for both spring and fall flood events on Skeena, Zymoetz and Kitsumkalum Rivers. [At present only one value is available per year.] The flood frequency analyses should be revised using this new information.

3. Obtain estimates of the June 2009 flood flows on Skeena and Zymoetz Rivers and update the flood frequency analyses. [Preliminary data indicate the maximum daily flow *'at Usk'* was 5,560 m³/s. The corresponding average return period is approximately 5 years for spring and annual flood flows.]

4. Water level and discharge data have not been collected on Kitsumkalum River since 1952. This gauge should be re-established as the data would assist in developing appropriate management plans for future activities in the lower Kitsumkalum Valley.

8.2 RIVER SURVEYS AND SITE-SPECIFIC INVESTIGATIONS

5. The historical air photograph analyses, river surveys and observations by long term residents indicate that sediment accumulation is occurring on Skeena River in the vicinity of the COT STP, along Skeena River at the entrance to Hell's Gate and in the vicinity of the Kitsumkalum River confluence. These deposits, which cannot be easily removed, appear to be affecting channel stability and flood elevations. It would be useful to undertake comprehensive bathymetric surveys of the study area using modern GPS/sounder techniques, such that the magnitude and location of on-going changes in river bed elevation can be monitored. Field observations and the sonar results should be used to determine if there is a rock sill at the inlet of Hell's Gate which would limit the extent of future channel downcutting. This information will assist in quantifying recent rates of sediment accumulations, identifying developing problem areas and in evaluating potential remedial strategies.

6. The location and volume of sediment deposition since the 1975, 1979, 1983 and 2008 surveys should be computed. Depending on the results of this analysis, it may be desirable to calculate potential bed material transport rates *(see Wilcock, 2001; Wilcock et al., 2006 and Pitlick et al., 2006)* and investigate how future bed material transport might affect river bed elevations along Skeena River *(e.g. US Department of the Interior, 2007)*.

7. A variety of bank protection works have been constructed on both Skeena and Kitsumkalum Rivers. These revetments were constructed to varying standards. Some are overgrown with vegetation (which makes them difficult to identify on air photographs) and others appear to be in need of repair. Many of these revetments appear to have been placed by local landowners using readily available material. It is recommended that the location, size class *(see BC Ministry of Transportation and Highways, 1991)* and condition of these structures be mapped and that any developing stability concerns be identified. This evaluation should consider the trends in channel stability documented in this report and future channel stability. Once available, this information should be used to priorize any remedial works.

A variety of studies have been undertaken to evaluate the effects of rip-rap on aquatic habit or organisms *(e.g. Knudsen and Dilley, 1987; Schmetterling, et al., 2001; Craig and Zale, 2001 and Quigley and Harper, 2004)*. These analyses commonly report that rip-rap had both positive and negative effects, with negative effects being predominant. Short sections of rip-rap are typically not a problem, however, the cumulative impacts of long expanses of rip-rap (such as those which occur on Skeena River) can be significant. In some circumstances, these negative effects can be mitigated through the use of large hydraulically rough rip-rap which provides low velocity micro-habitat for fish *(see Lister et al., 1993)* and by incorporating vegetation into the revetment *(see Polster, 2001)*. Opportunities for environmental improvements should therefore also be evaluated during the revetment assessment. This evaluation could usefully include all the log driving related revetments installed on Kitsumkalum River.

8. Field studies identified two industrial waste dumps in the lower Kitsumkalum River flood plain. The site near the abandoned Kalum Wood Products Mill could be exposed by future bank erosion (which is not presently an immediate concern) and appears to be delivering iron and nutrient rich water to a Kitsumkalum River sidechannel. Any relevant water quality data from these sites should be obtained and reviewed. Depending on the results, it may be desirable to retain a specialist to provide an opinion of the severity of this issue.

9. Limited discharge data suggests that the percentage of the total flow being transported by the Hell's Gate side channel could be increasing. It would be useful to measure the flow distribution between Hell's Gate and the mainstem channel to document how this value changes with discharge. Periodically repeating these measurements would allow any developing trends to be identified. These data would also be used as an indicator of changes in flood hazard in the vicinity of Braun's Island. Similar measurements could also be undertaken to document the flow distribution around Ferry Island.

10. Field surveys undertaken in 2009 indicate that the channel thalweg elevation under the CNR bridge over Kitsumkalum River has decreased by up to 2 m in comparison to conditions in 1975. These results should be forwarded to CNR as they may wish to determine if this downcutting poses a threat to their bridge.

8.3 HYDRAULIC ANALYSES AND FLOODPLAIN MAPPING

11. The BC MOE has been unable to determine the design discharge values used in their 1982 floodplain mapping studies on Skeena and Kitsumkalum Rivers. They are also unable to confirm how the freeboard allowance was calculated *(Bill Kuhnke, pers. comm.)*. The project files for this investigation are available in Victoria, but are not available for public inspection *(Ashfaque Ahmed, pers. comm.)*. This material should be obtained and the required information extracted. This would allow a more reliable comparison of the flood elevations predicted by *BC MOE (1982)* and *WMC (2001 & 2009)*.

12. The recent hydraulic studies by *Water Management Consultants (2001 & 2009)* indicate that potential flood levels on Skeena and Kitsumkalum Rivers have changed in the period since 1982 when the BC MOE completed their floodplain maps. Additional hydraulic studies appear to be required on at least the lower Kitsumkalum River (due to changes in river bed elevation and to reliably assess the effects of the various river training works and two bridges). Once this work is completed, new floodplain mapping should be prepared. These results could require that updated flood proofing measures (e.g. BC Ministry of Water, Land and Air Protection, 2004) be adopted in some areas and that appropriate emergency response plans be developed. It will be important to ensure local residents understand the implications of the flooding and channel stability hazards which have been identified on the basis of this work. The floodplain mapping studies should also include an evaluation of flood risks due to tributary streams which may affect the Kitsumkalum Reserve.

13. A recent investigation of flooding hazards on Nechako River in the vicinity of Prince George *(nhc, et al., 2009)* reviewed the freeboard allowance criteria used in other jurisdictions. They suggest that it may be appropriate to use values other than the BC MOE standards of 0.3 to 0.6 m, depending on site-specific conditions. It is therefore suggested that the criteria for estimating flood construction levels in the study area be evaluated during the floodplain mapping study.

8.4 REMEDIAL WORKS

14. This study has identified a number of areas where on-going channel instability threatens existing infrastructure. These sites include the RDKS STP on the south side of Skeena River, the Skeena River flood plain in the vicinity of Braun's Slough and a number of sites in the lower Kitsumkalum valley. Site-specific investigations are warranted to better define these threats and develop appropriate remedial strategies.

15. The historical air photo analysis indicates that riparian vegetation has been cleared to the channel edge, or bank erosion has extended into cleared areas, on both Skeena and Kitsumkalum Rivers. Studies by *Millar (2000)*, *Eaton et al. (2004)* and *Simon et al. (2007)* indicate that riparian vegetation (and particularly mature trees) plays an important role in controlling bank erosion. [In large rivers such as the Skeena, this effect may include providing log jams which deflect high velocity areas off shore.] Riparian vegetation also provides important ecological functions, including shade and nutrients. It is now common practice to include a 'riparian buffer' in southern municipalities *(BC Ministry of Water, Land and Air Protection, 2005)* and in all forestry activity. Northern areas and farms are currently exempt from this regulation. Nevertheless, it would be desirable to maintain existing riparian areas and undertake measures to re-establish vegetation where it has been cleared. *Polster (2001 & 2002)* provide guidance on how this might be achieved.

16. The bank erosion protection works which were recently installed adjacent to COT STP are not designed to modify the pattern of overbank flooding. However, soil bioengineering treatments, consisting of 'live gravel bar staking' and 'live palisades' were installed to provide a hydraulically rough floodplain surface and reduce overbank water velocities. These treatments could reduce (but not eliminate) the potential for a channel avulsion in the vicinity of Braun's Slough if the vegetation grows successfully. Budget and land acquisition constraints prevented installing soil bioengineering over all of the recommended area. It is recommended that the growth and survival rates for the soil bioengineering treatments be monitored and that any required supplemental planting be undertaken as the opportunity arises.

8.5 MONITORING

17. The effects of the June 2009 freshet on bank erosion and revetment stability should be evaluated once the water levels have dropped. If there are significant changes, the historical air photography analyses and computed rates of channel shifting maps should be updated when low water level photography is available.

18. The 'as-built' conditions along the revetments placed to protect the COT STP were documented through a combination of ground *(see MMA, 2009a)* and air *(see MMA, 2009b* and *Cambria Gordon, in press)* photographs. It is our understanding that the COT has or will undertake topographic surveys which can be used to track changes in revetment stability. It is recommended that these measurements be repeated during low water in the spring of 2010 and then either every 5 years or after a $\geq$5 year return period flood. Particular attention should be paid to the upstream end of the revetment and the uppermost spur, as the incoming flow directly impinges on this area and glaciomarine sediments were encountered at shallow depth. Local scour could undermine these structures and, if this occurs, remedial work should be instigated in a timely manner. A temporary measure might be to cable standing trees together such that any future bank recession would form an erosion resistant log jam. More aggressive measures, such as additional rock placement could also be appropriate if a significant amount of erosion were to occur or if the river showed signs of 'outflanking' the bank protection works.

A similar monitoring program to that described above could be usefully undertaken for the bank protection works recently installed in the vicinity of Thornhill and Queensway. Particular attention should be paid to the downstream end of the 2008/2009 revetment. Field observations on April 2 & 3, 2009 suggest that a portion of this work was constructed on ice and, as this melted, localized movement was occurring in the 'self-launching apron'. This upper portion of this revetment was also not revegetated. It would be useful to monitor natural recolinization and, if necessary, undertake measures to expedite this process.

19. The channel bathymetric survey discussed in Recommendation 5 should be repeated approximately every 5 years or after a ≥5 year return period flood has occurred. It may also be necessary to update the flood elevation levels if significant changes in bathymetry were to occur.

8.6 FUTURE PRIORITIES

20. This report and the results of the *WMC (2009)* hydraulic analyses should be reviewed with stakeholders. This group should include Mr. Lyle Larsen, the Regional Inspector of Dykes and Floodplain Technician working for the BC Ministry of Environment in Prince George. This process can be expected to refine the initial recommendations presented in this study and assist in defining priorities for future work.

9: CERTIFICATION

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10.2 PERSONAL COMMUNICATIONS

Lynne Campo	Water Survey of Canada, Vancouver
Dave Gordon, R.P. Bio.	Cambria Gordon Ltd., Terrace
Chief Don Roberts	Kitsumkalum First Nation, Terrace
Mike Thompson, P. Eng.	Worley Parsons Ltd., Victoria
Bill Kuhnke	BC Ministry of Environment, Victoria
Ashfaque Ahmed	BC Ministry of Environment, Victoria

FIGURES

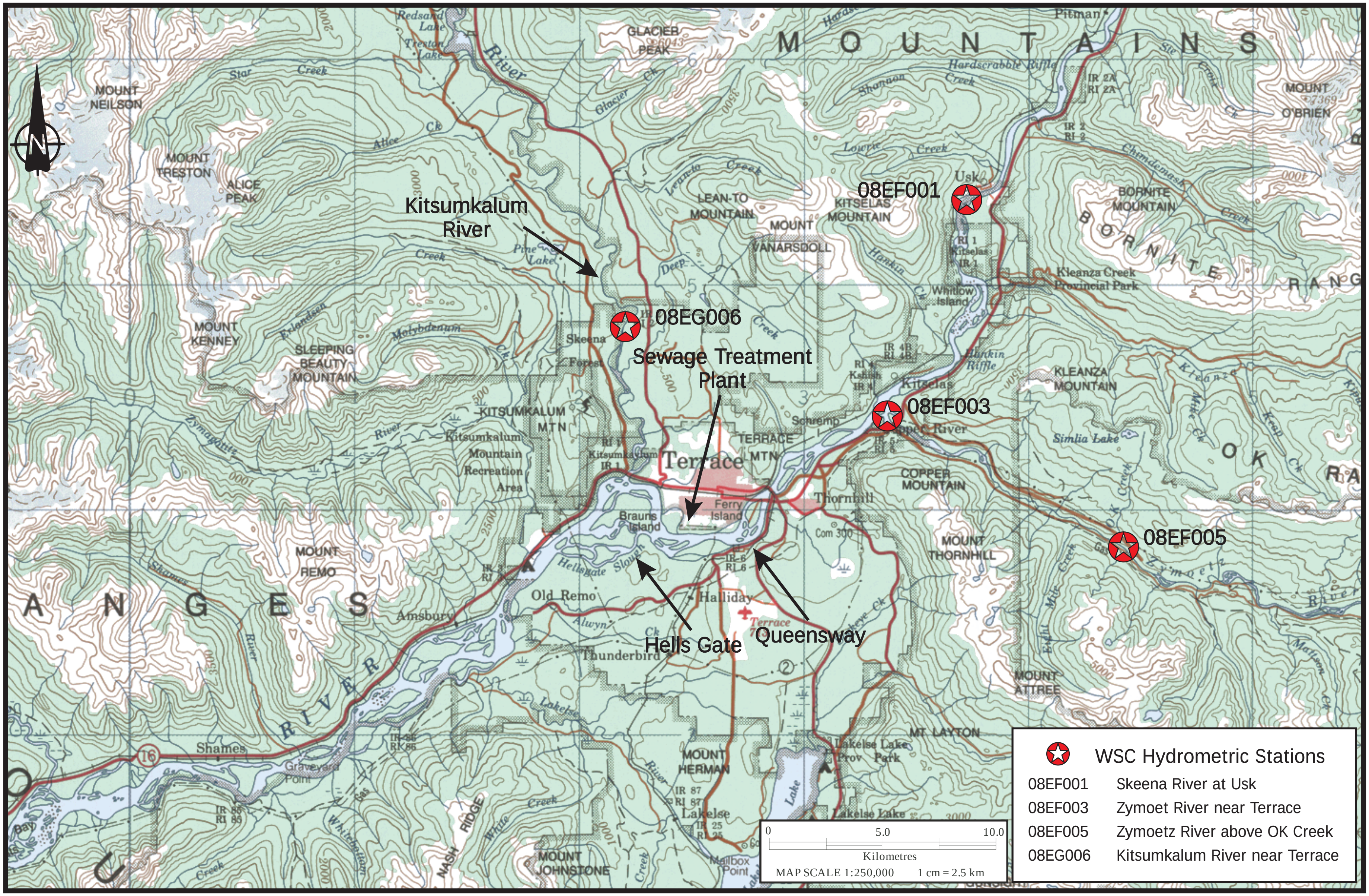
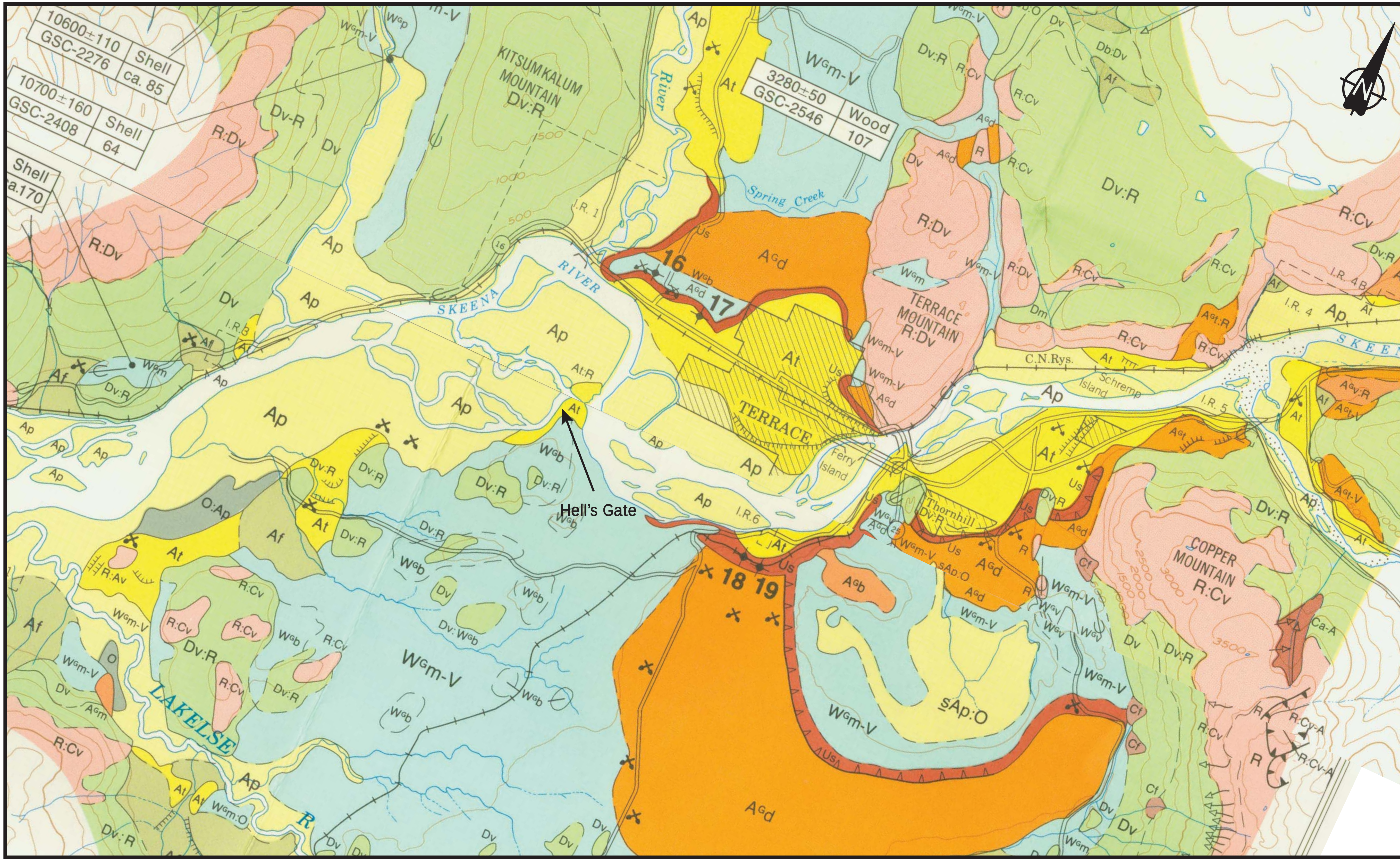
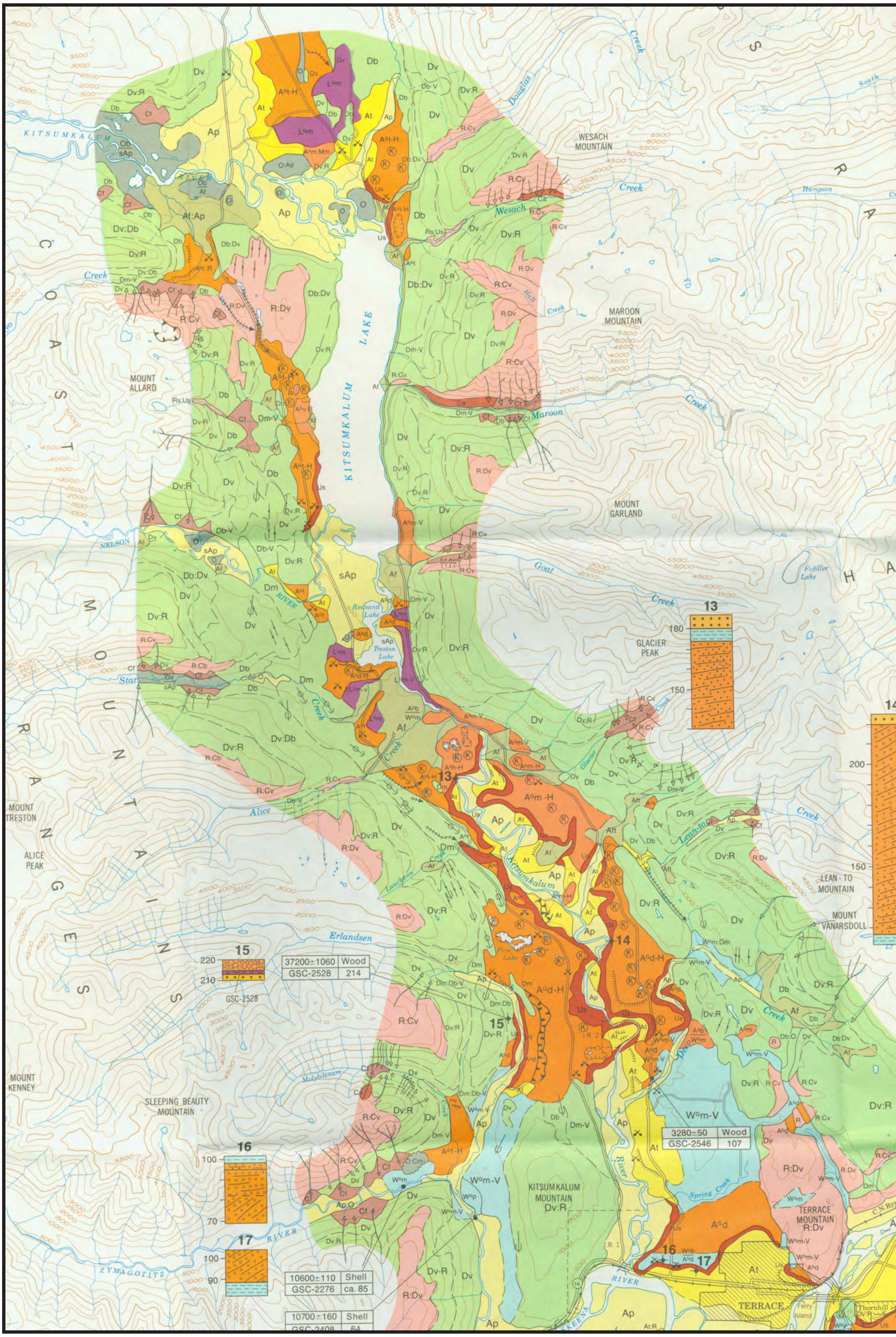


Figure 1.1: Location map.



See Table 2.1 for map legend

Figure 3.1a: Map showing surficial geology of the study area (from Clague, 1984).



See Table 2.1 for map legend

Figure 3.1b: Map showing surficial geology of the Kalum River (from Clague, 1984).

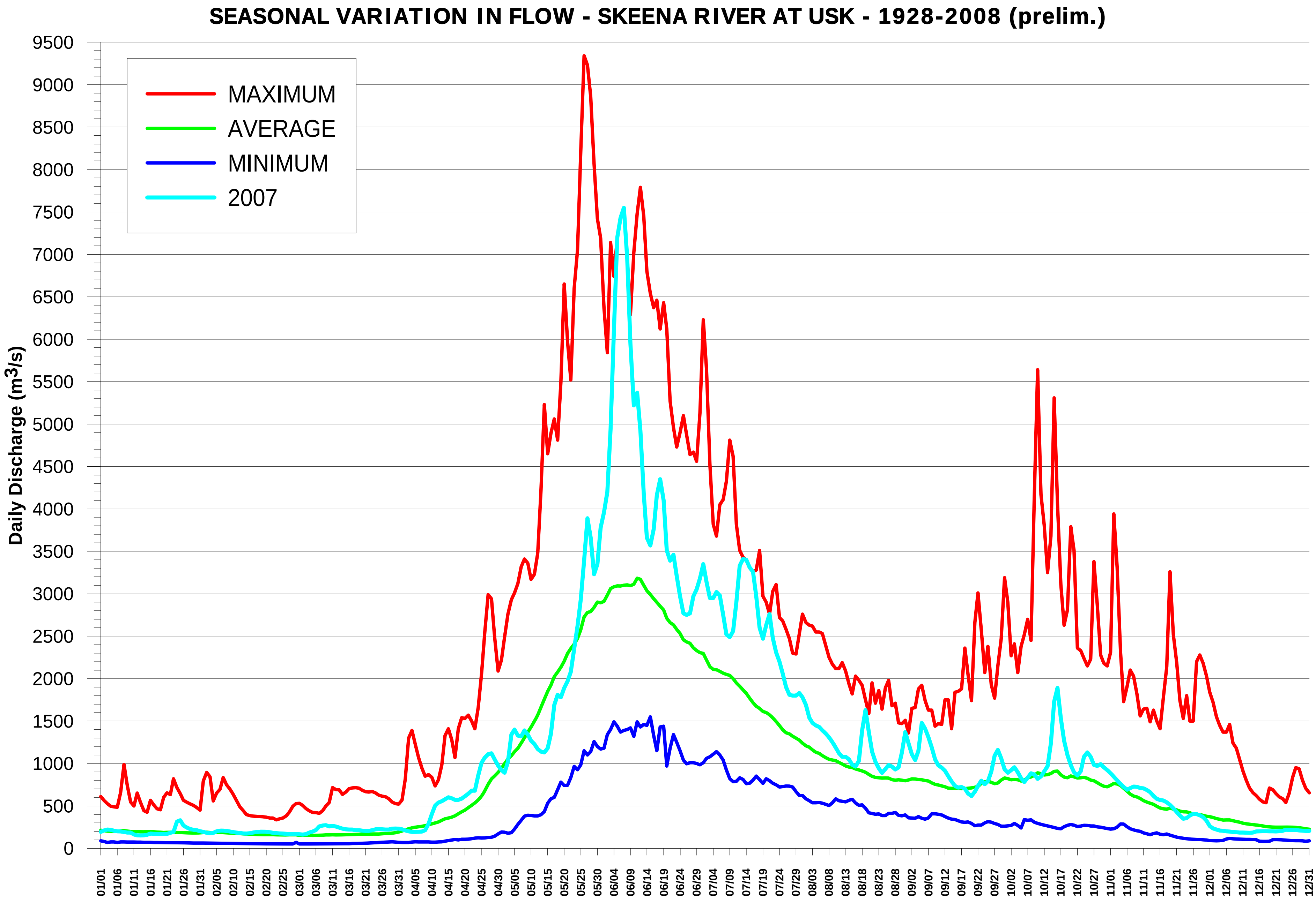


Figure 4.2.1.1: Maximum, average and minimum flows, Skeena River at Usk, 1928 to 2008 (prelim.).

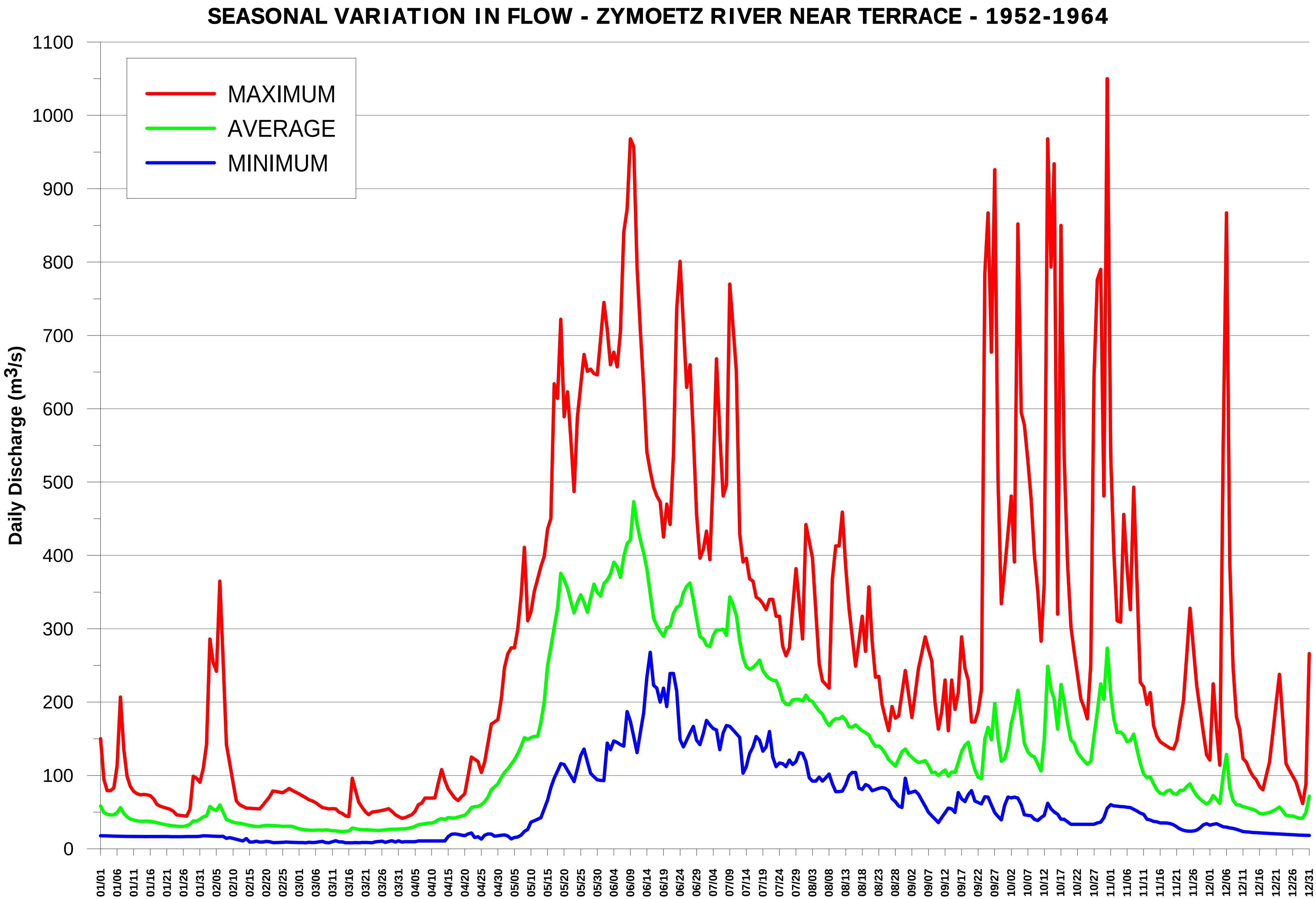


Figure 4.2.2.1: Maximum, average and minimum flows, Zymoetz River Near Terrace, 1952 to 1964.

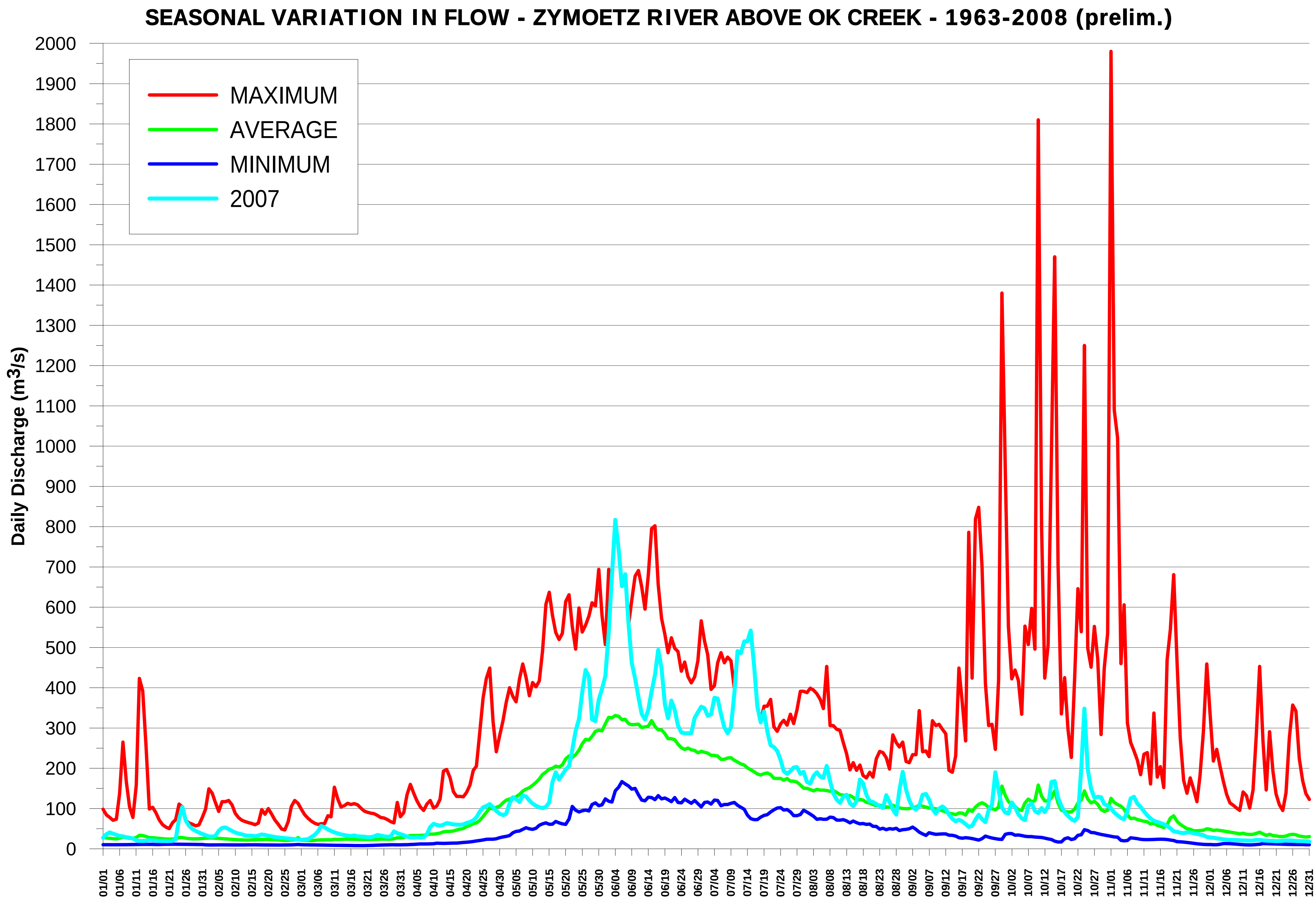


Figure 4.2.2.2 Maximum, average and minimum flows, Zymoetz River Above OK Creek, 1963 to 2008 (prelim.).

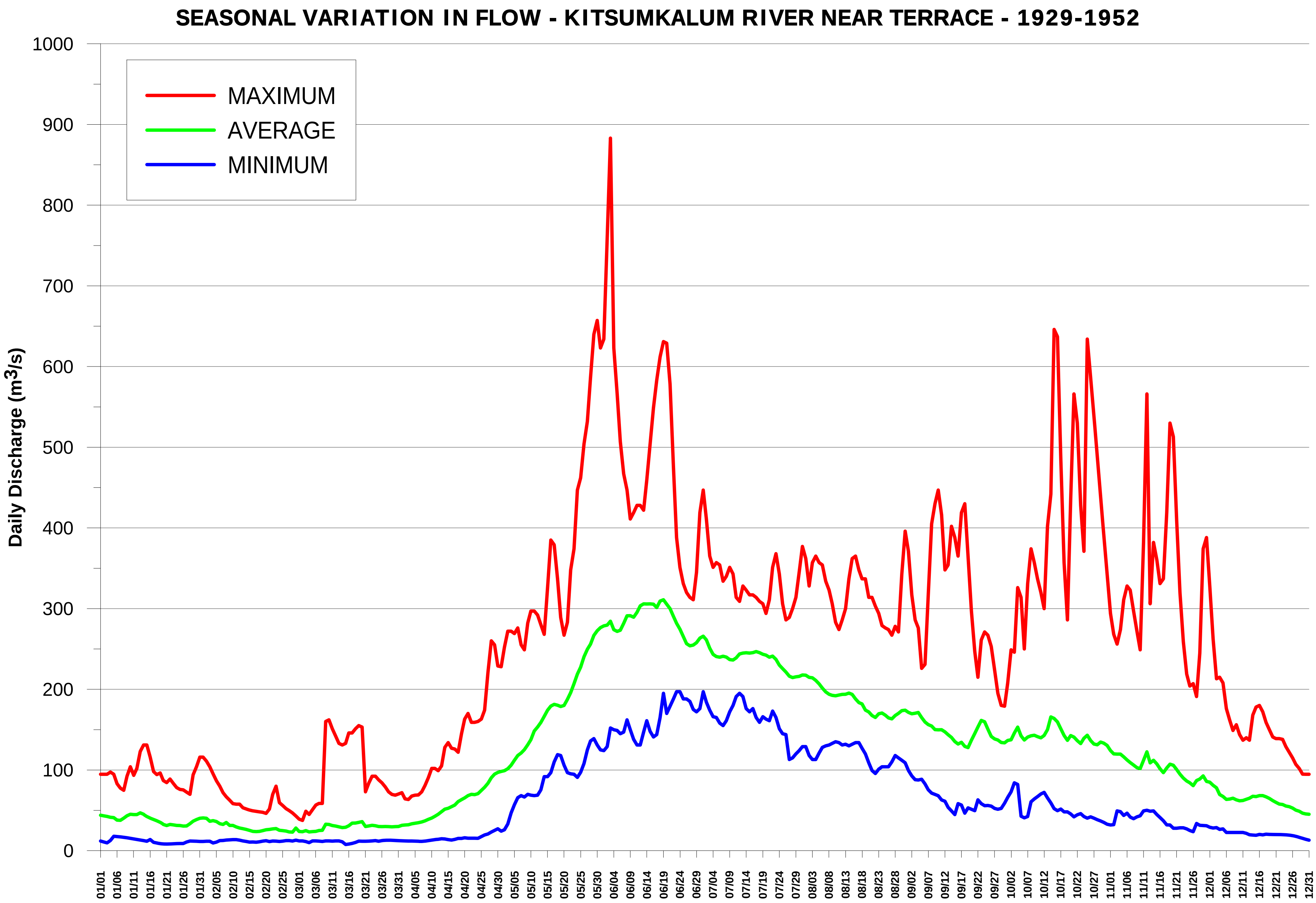


Figure 4.2.3.1: Maximum, average and minimum flows, Kitsumkalum River Near Terrace, 1929 to 1952.

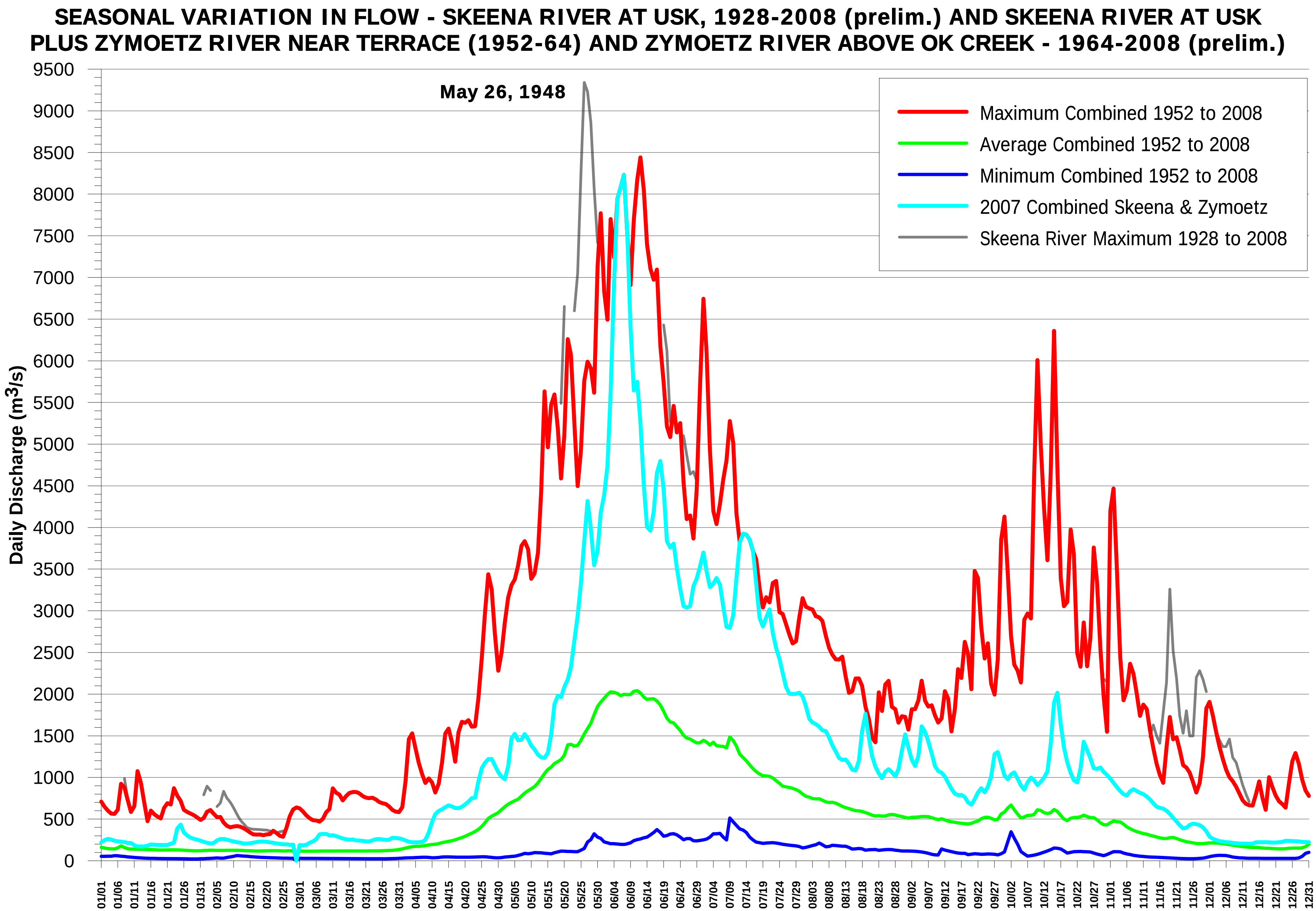
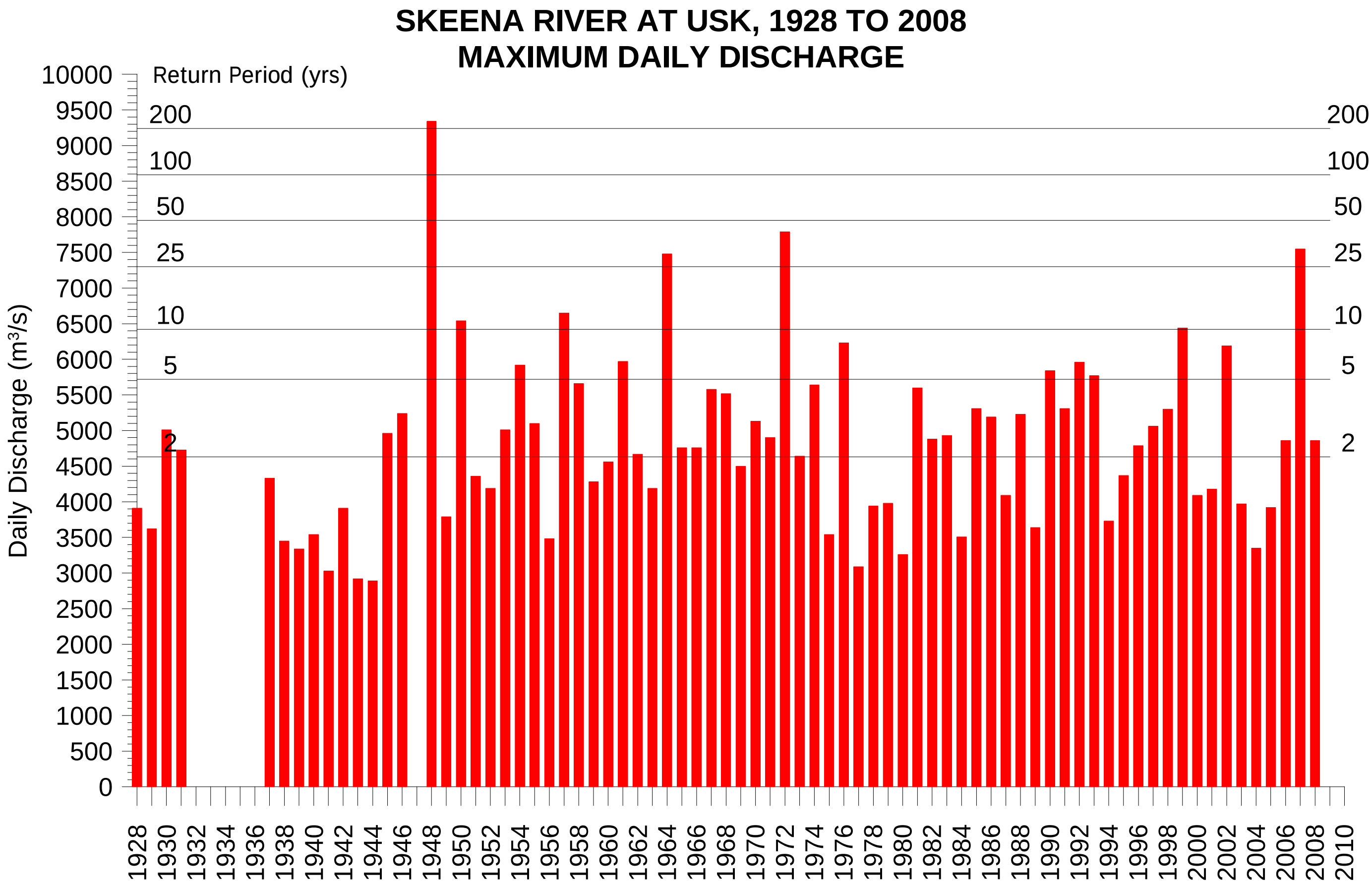


Figure 4.2.4.1: Maximum, average and minimum flows, Skeena River at Usk plus Zymoetz River near Terrace and Zymoetz River above OK Creek.



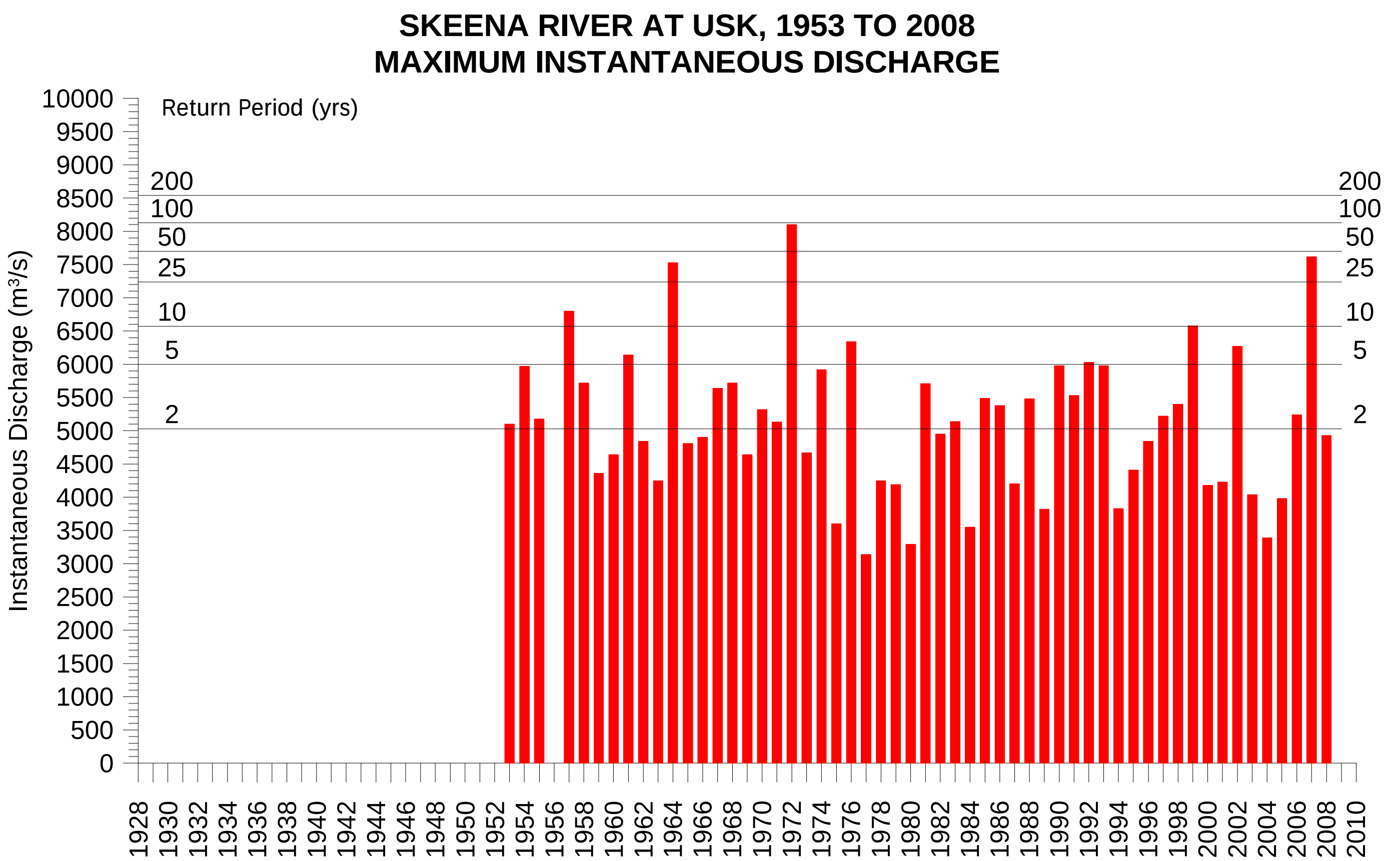


Figure 4.3.1.1: Historical variation in annual maximum daily and instantaneous discharge, Skeena River at Usk, 1928 to 2008.

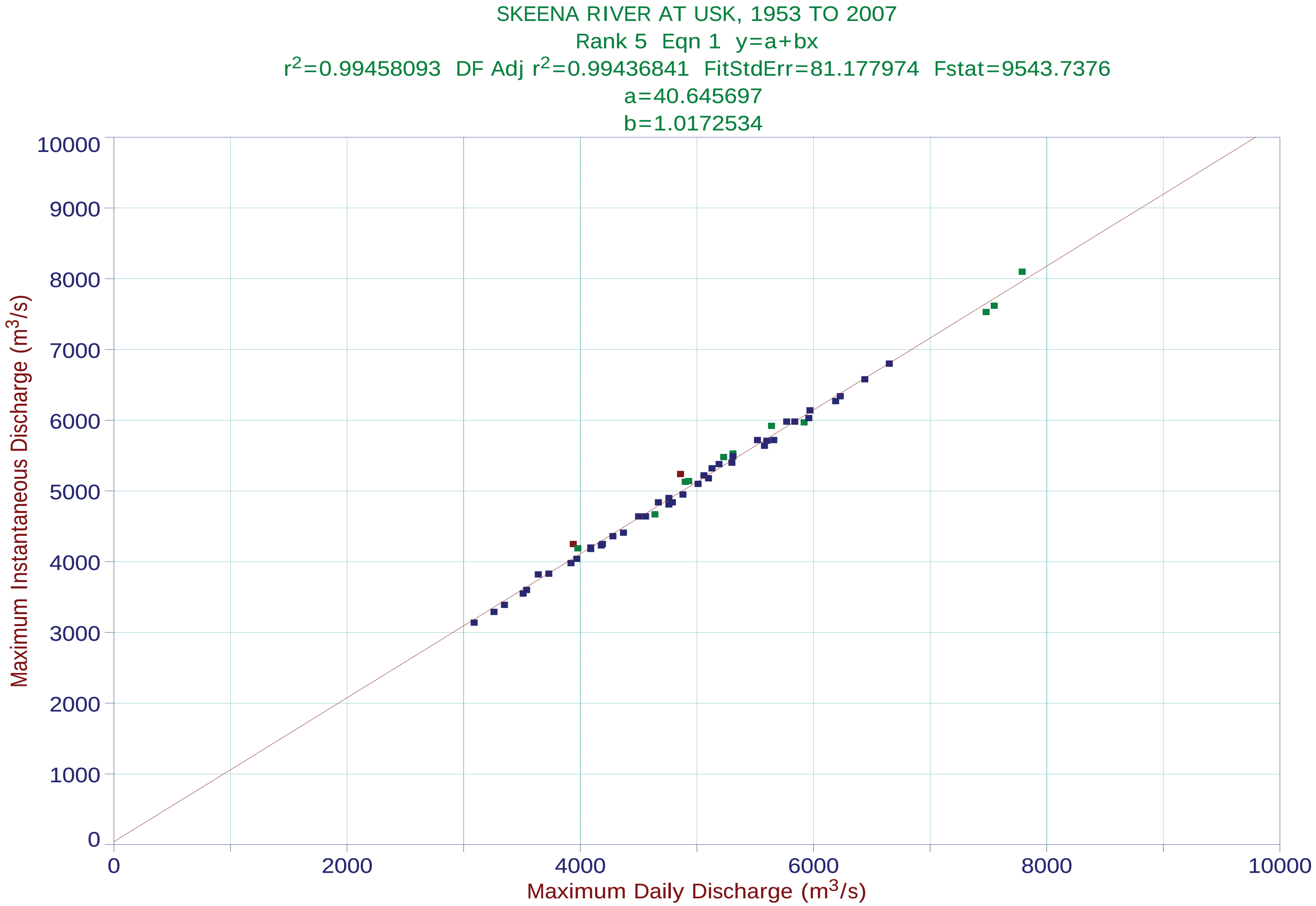
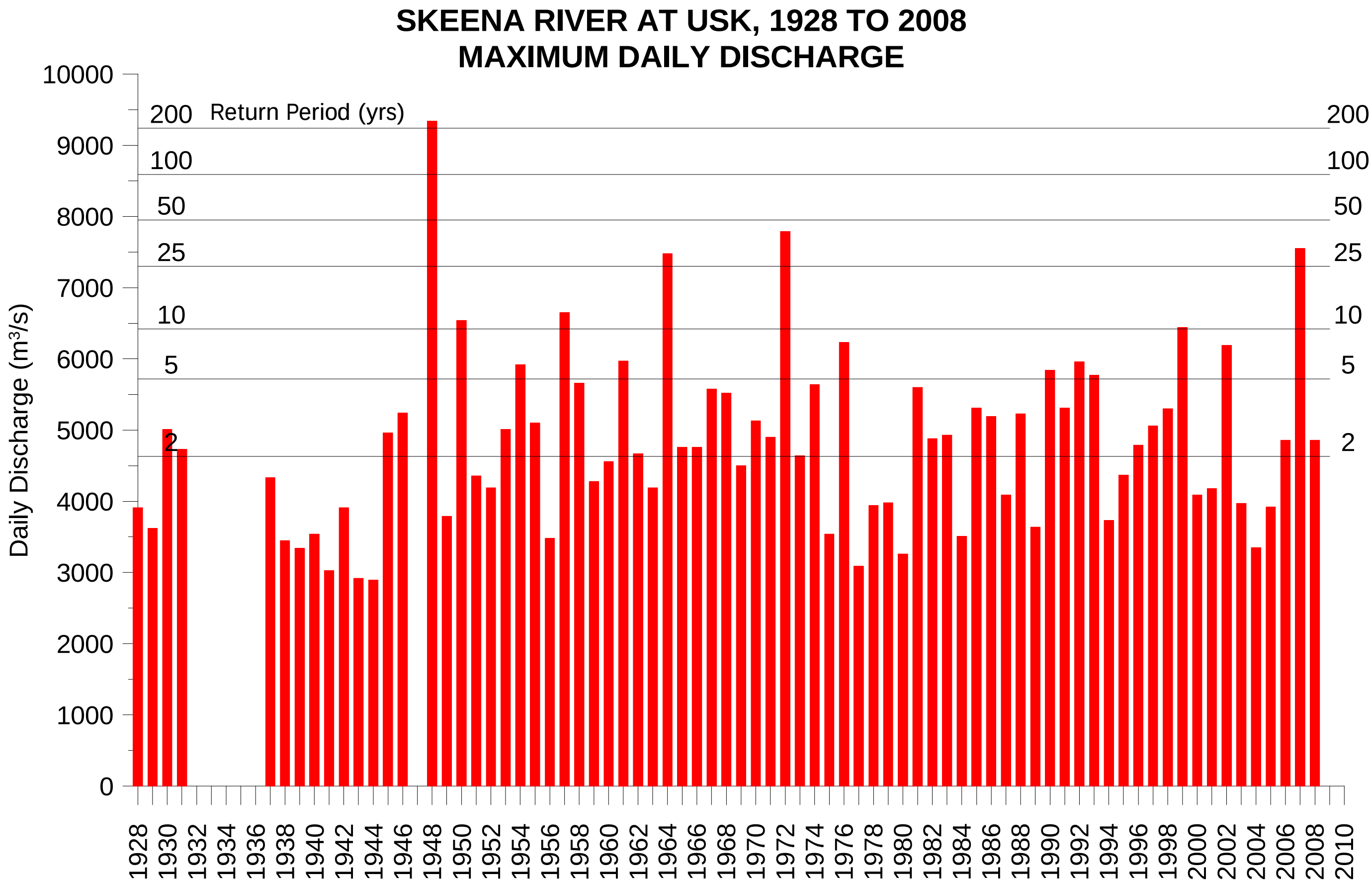


Figure 4.3.1.2: Relationship between annual maximum daily and instantaneous discharges observed on Skeena River at Usk.



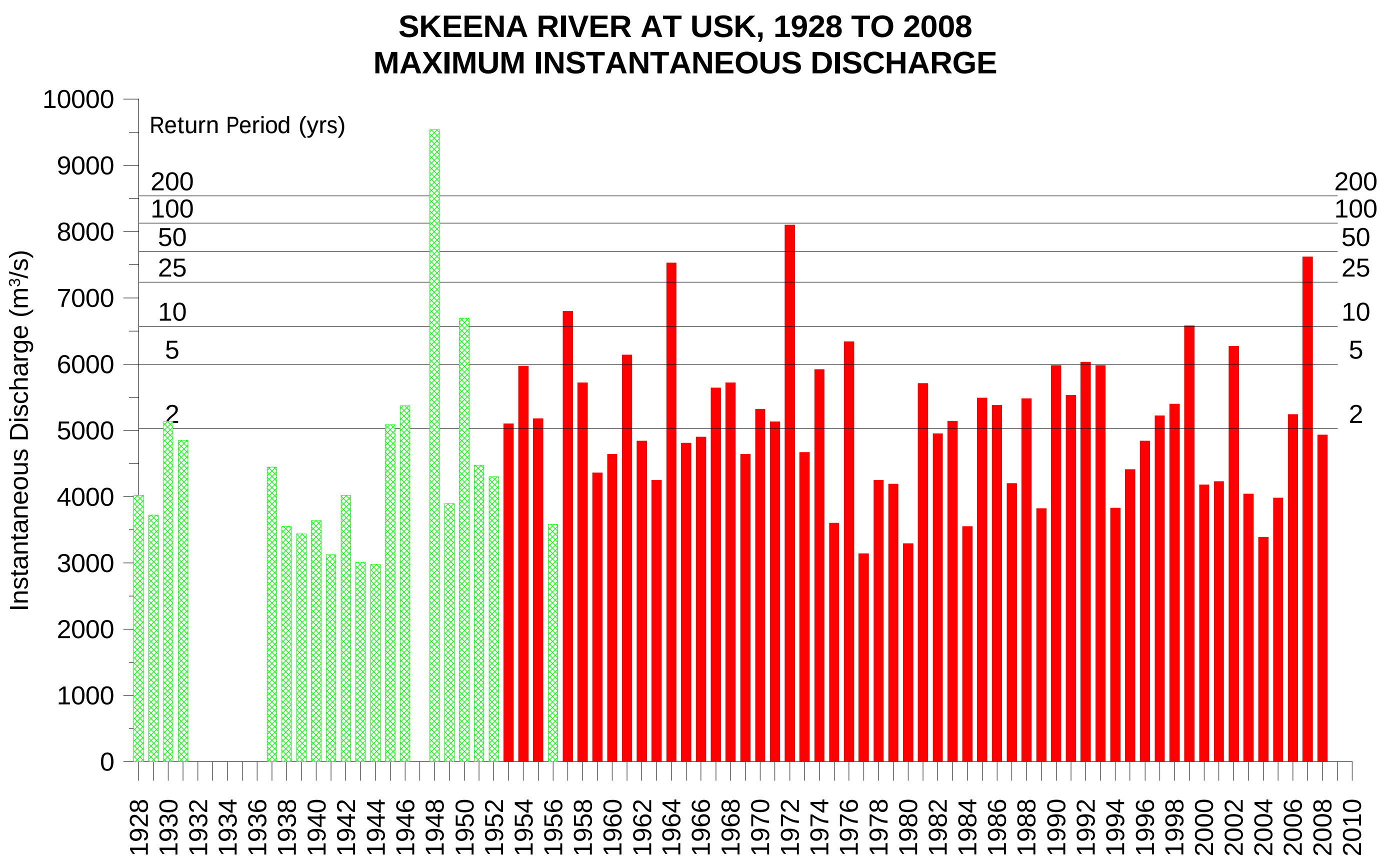
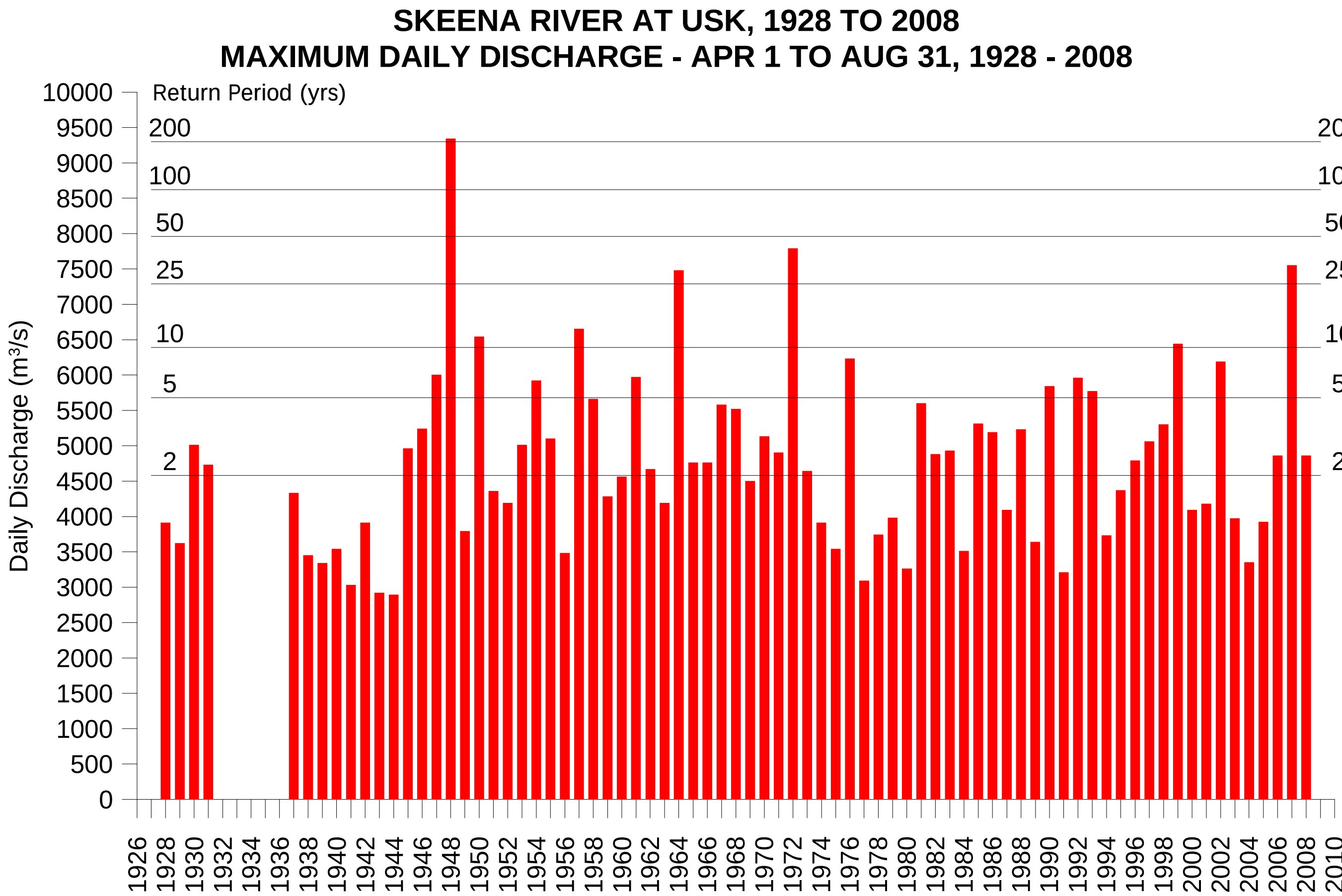


Figure 4.3.1.3: Historical variation in annual maximum daily and instantaneous discharge, Skeena River at Usk, 1928 to 2008, including synthesized data.



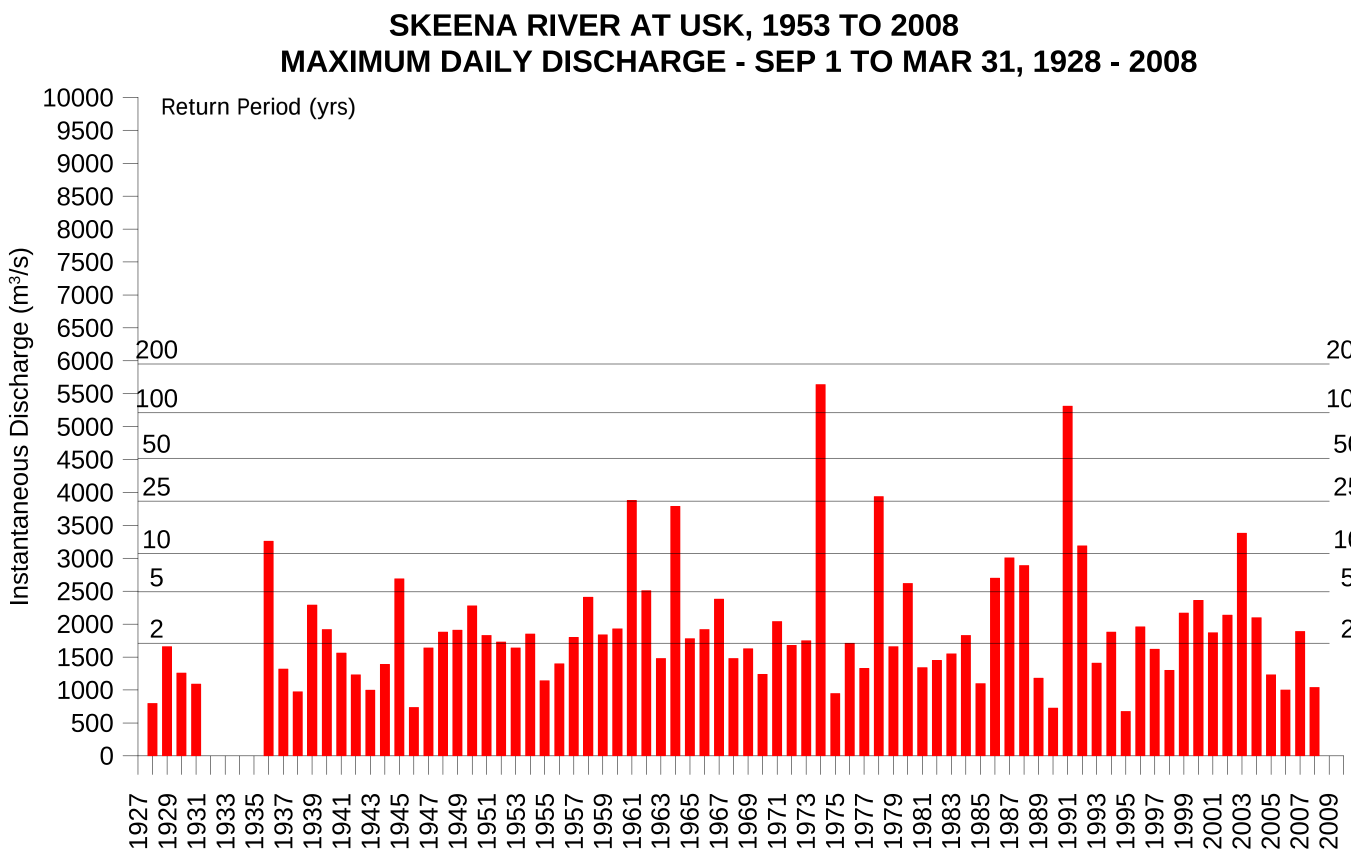


Figure 4.3.1.4: Historical variation in annual maximum daily discharge, Skeena River at Usk, April 1 to August 31 and September 1 to March 31, 1928 to 2008.

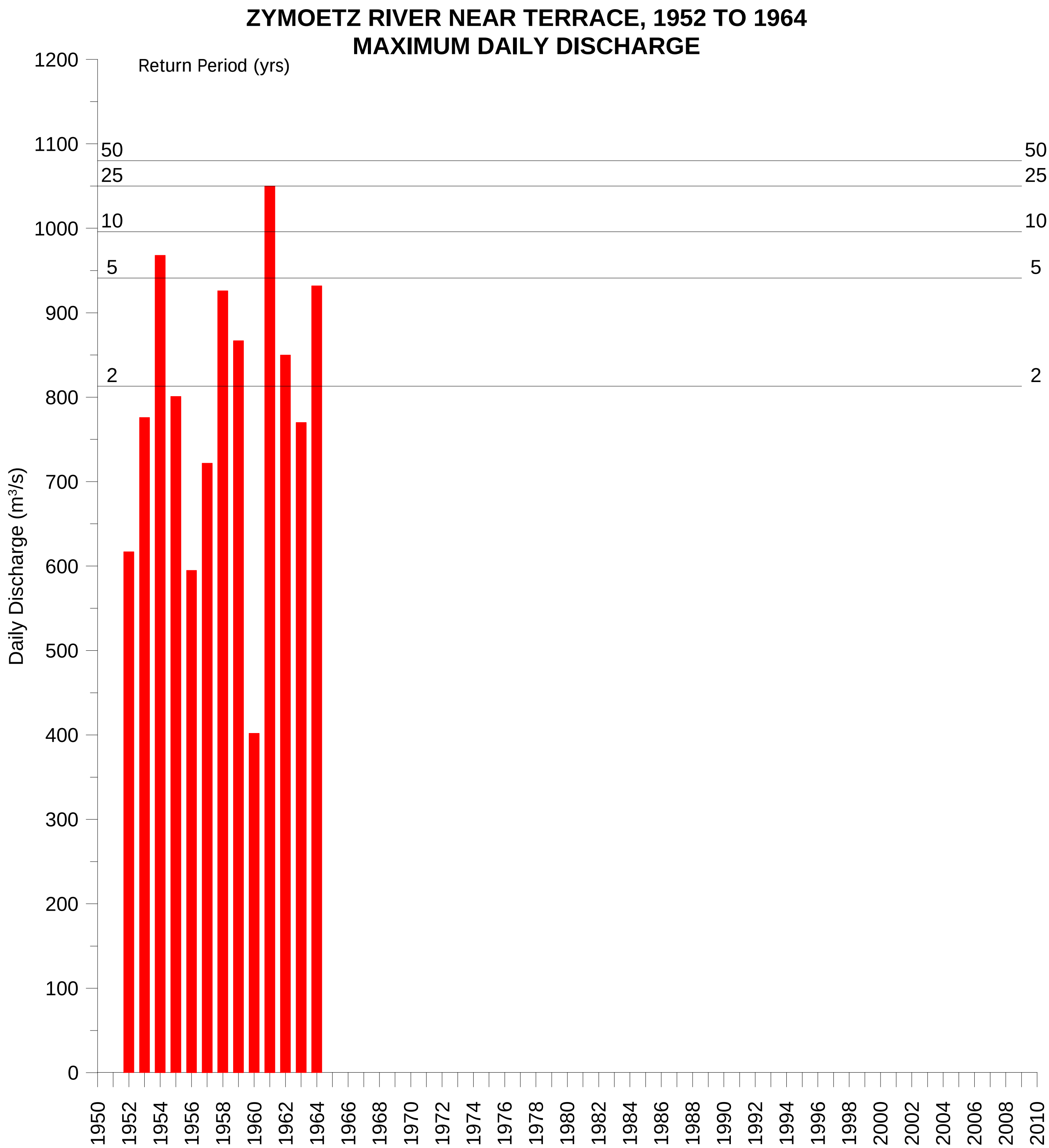
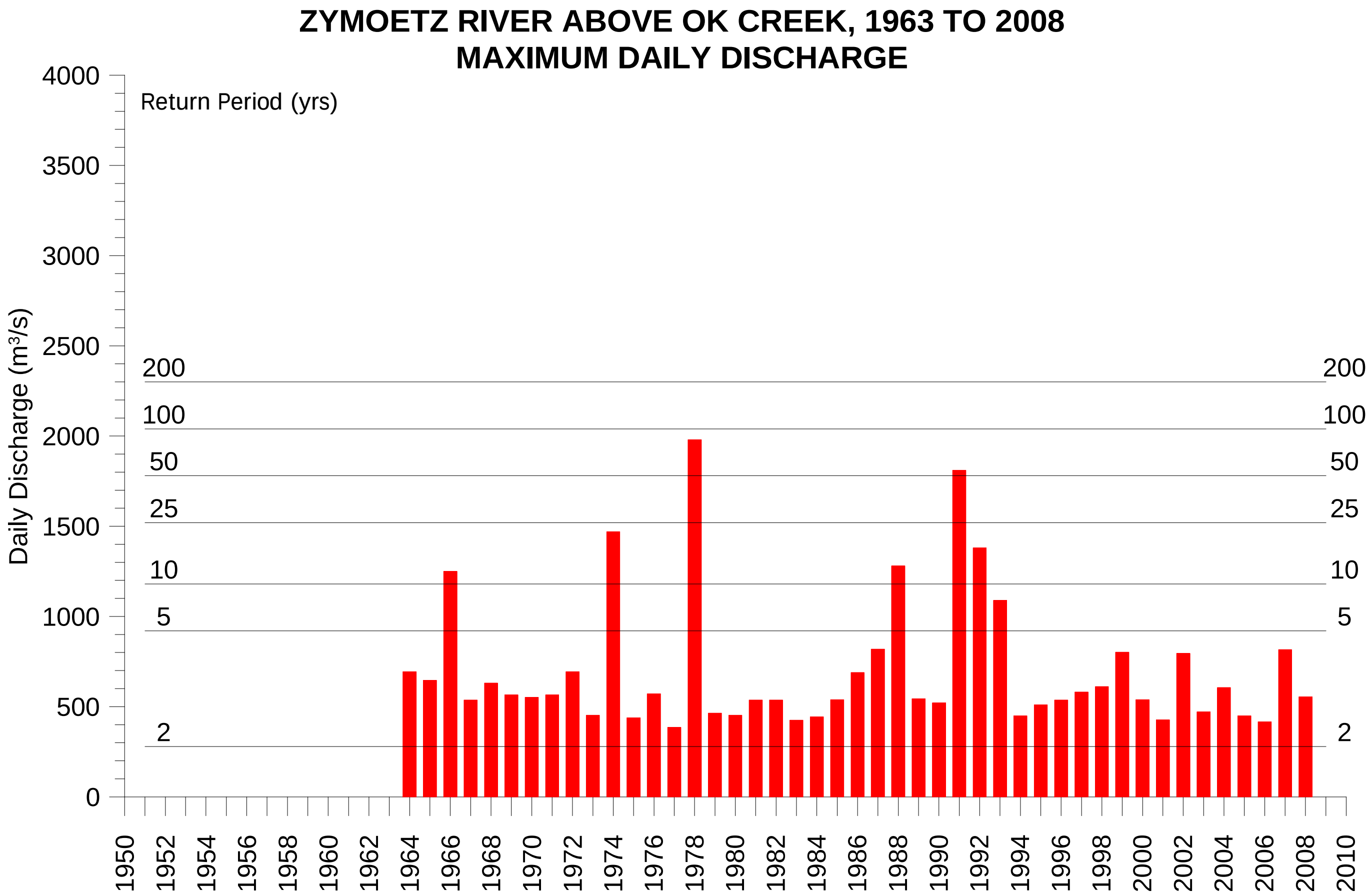


Figure 4.3.2.1: Historical variation in annual maximum daily discharge, Zymoetz River near Terrace, 1952 to 1964.



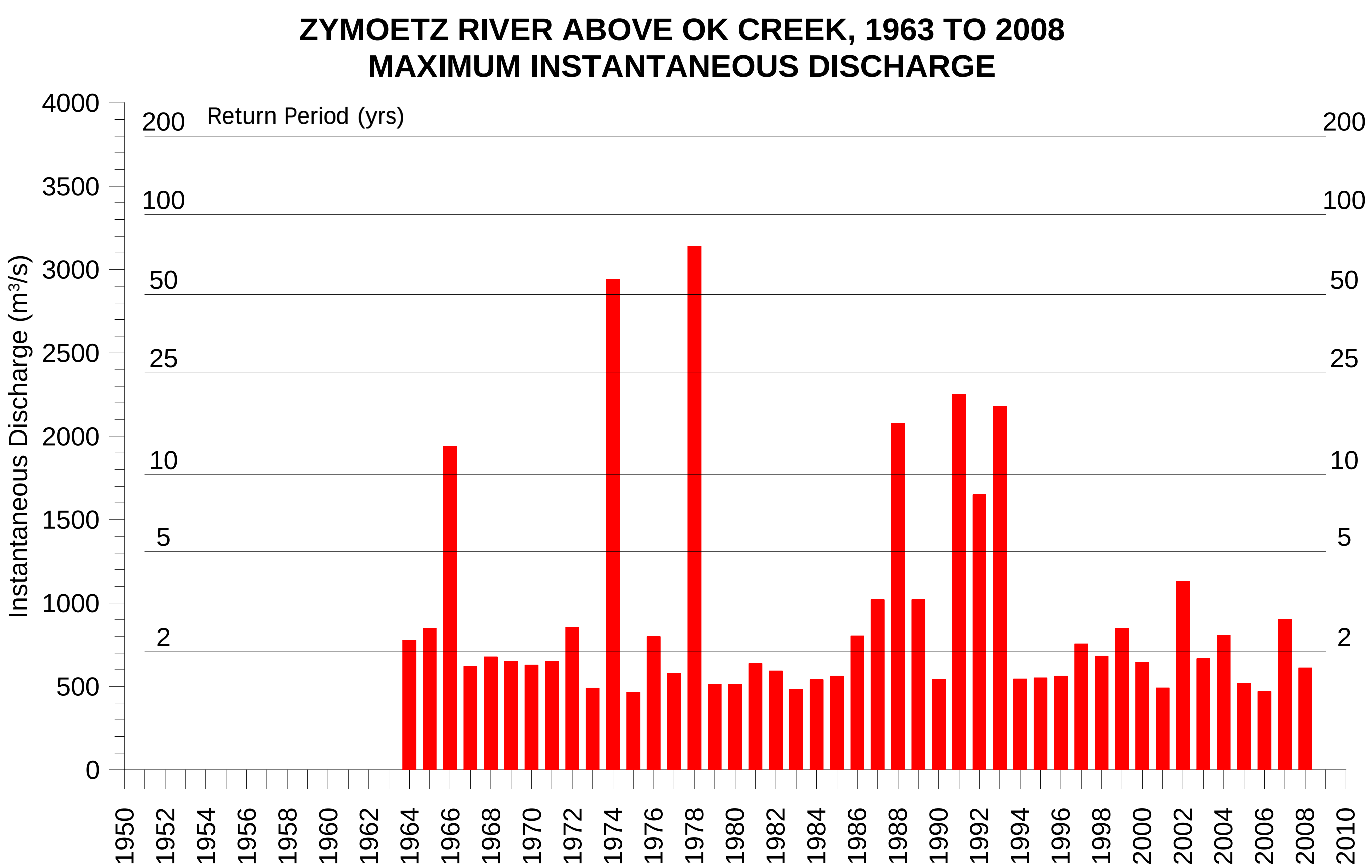


Figure 4.3.2.2: Historical variation in annual maximum daily and instantaneous discharge, Zymoetz River above OK Creek, 1963 to 2008.

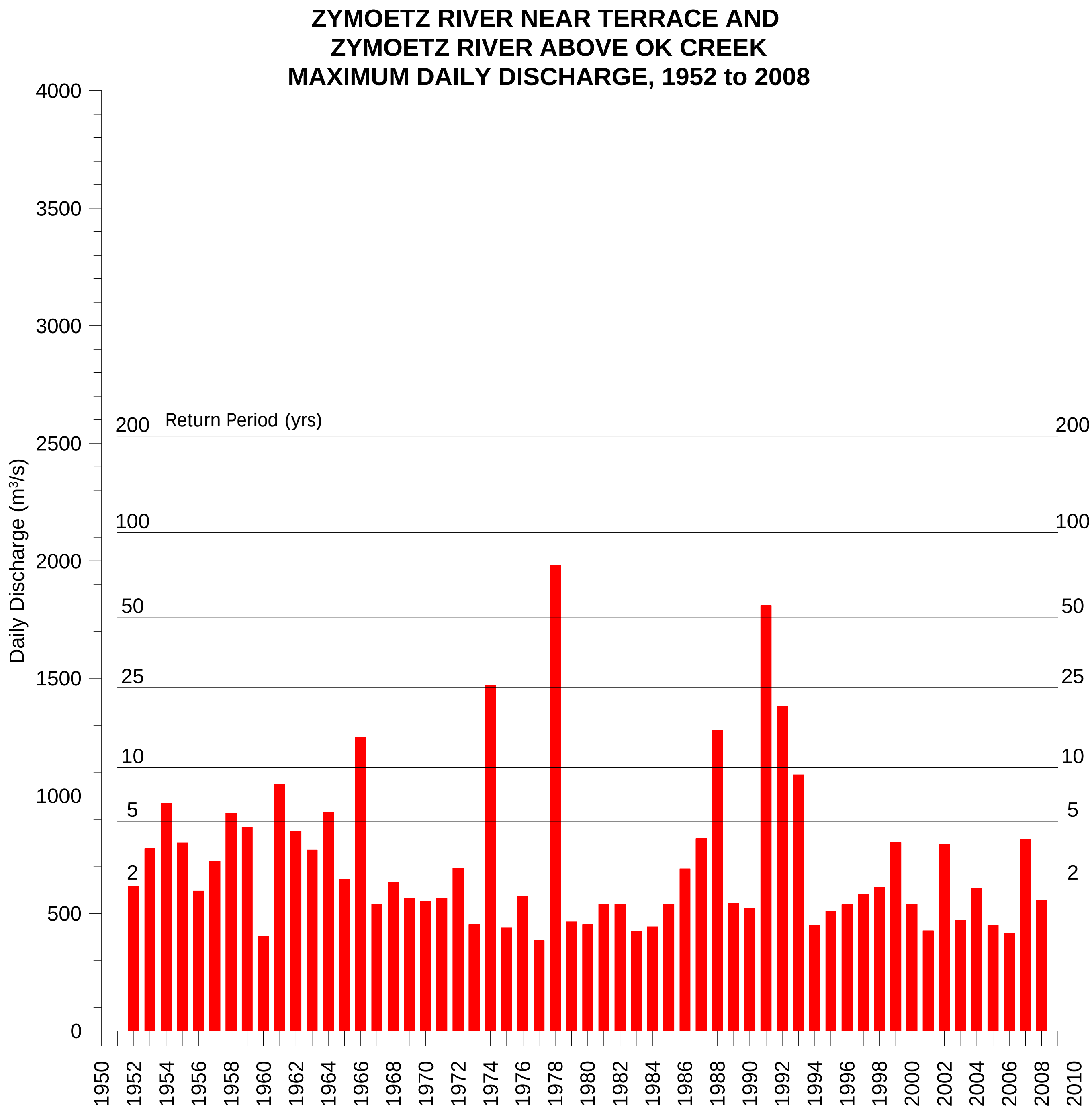
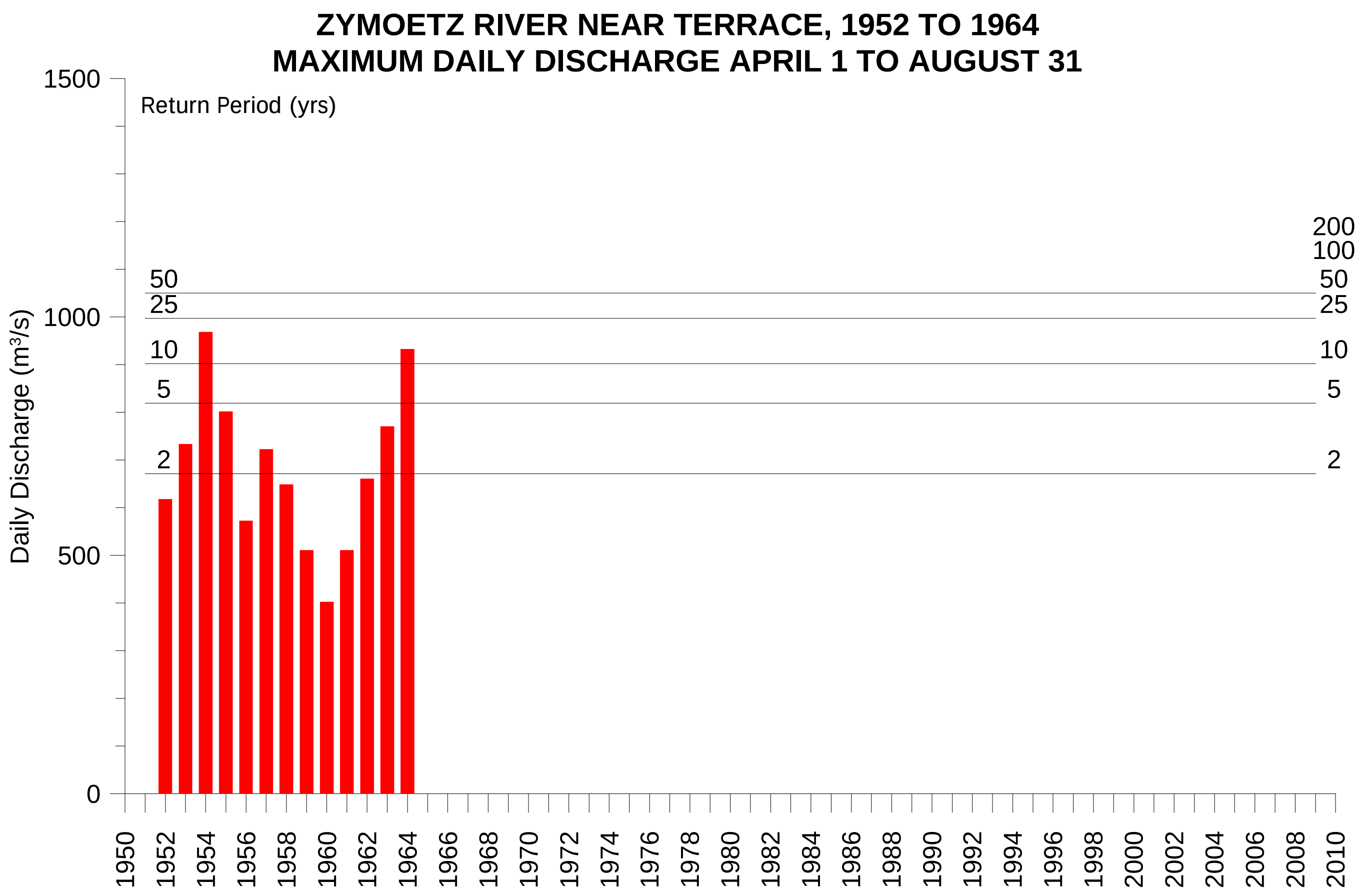


Figure 4.3.2.3: Historical variation in annual maximum daily discharge, Zymoetz River near Terrace and Zymoetz River above OK Creek, 1952 to 2008.



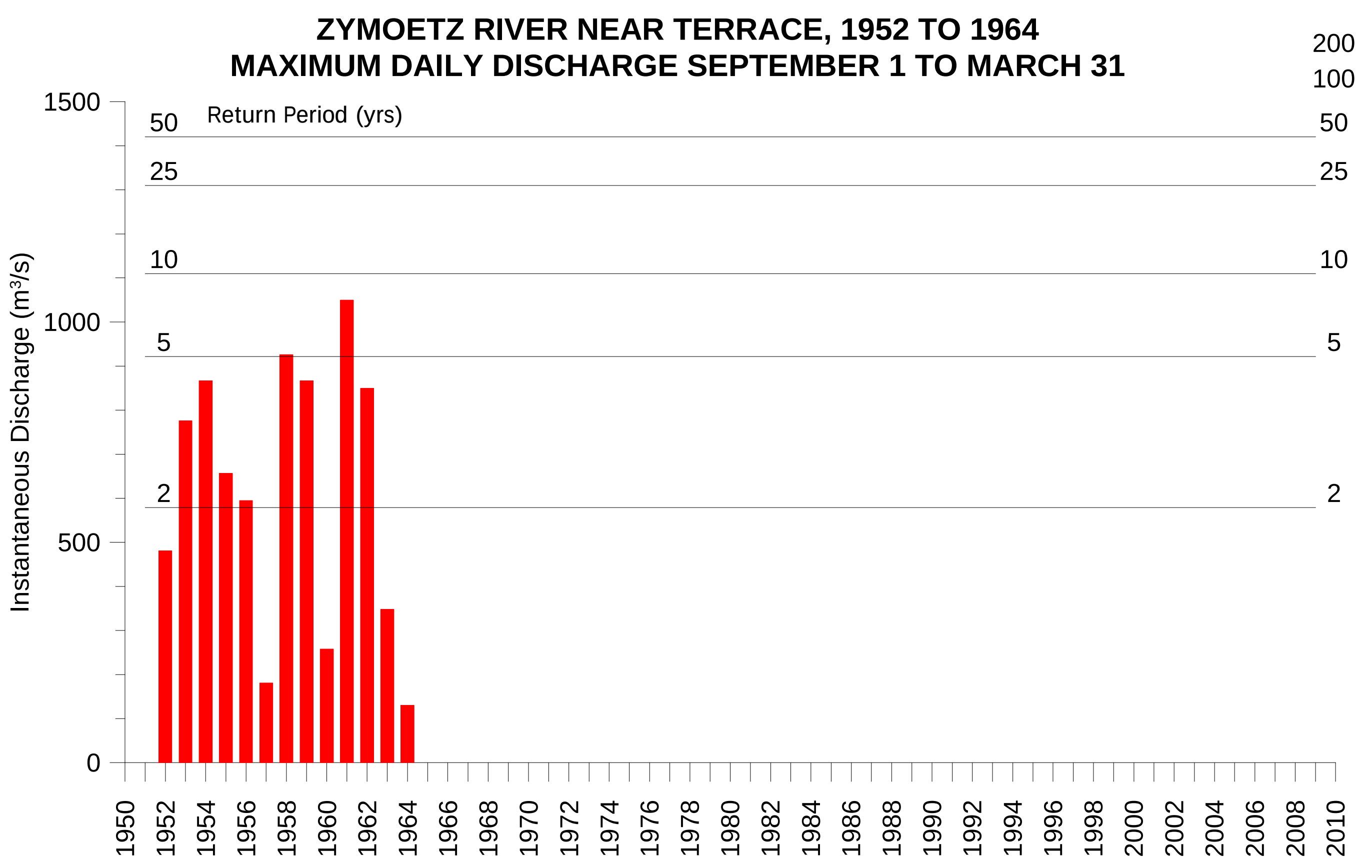
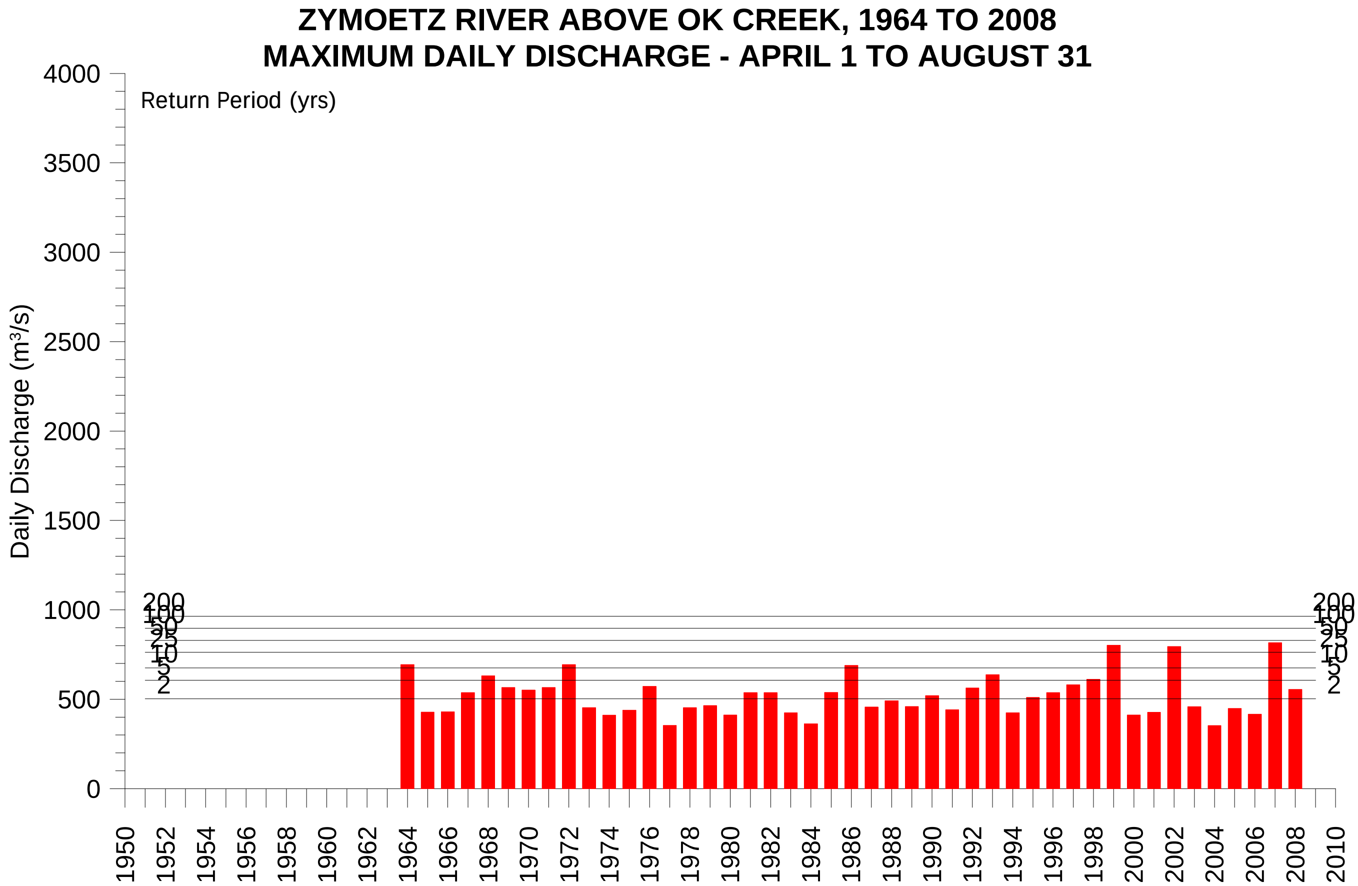


Figure 4.3.2.4: Historical variation in annual maximum daily discharge, Zymoetz River near Terrace
April 1 to August 31 and September 1 to March 31, 1952 to 1964



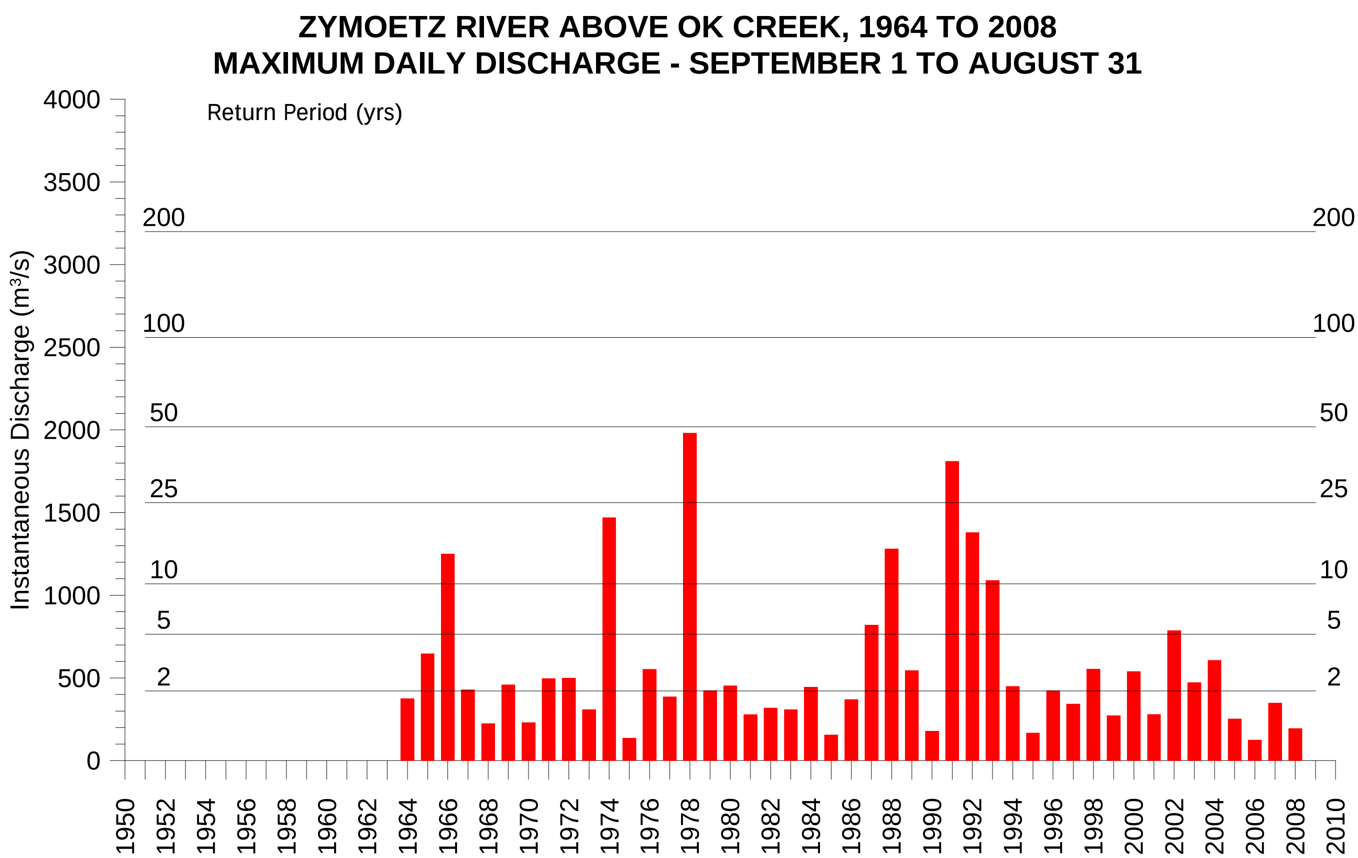
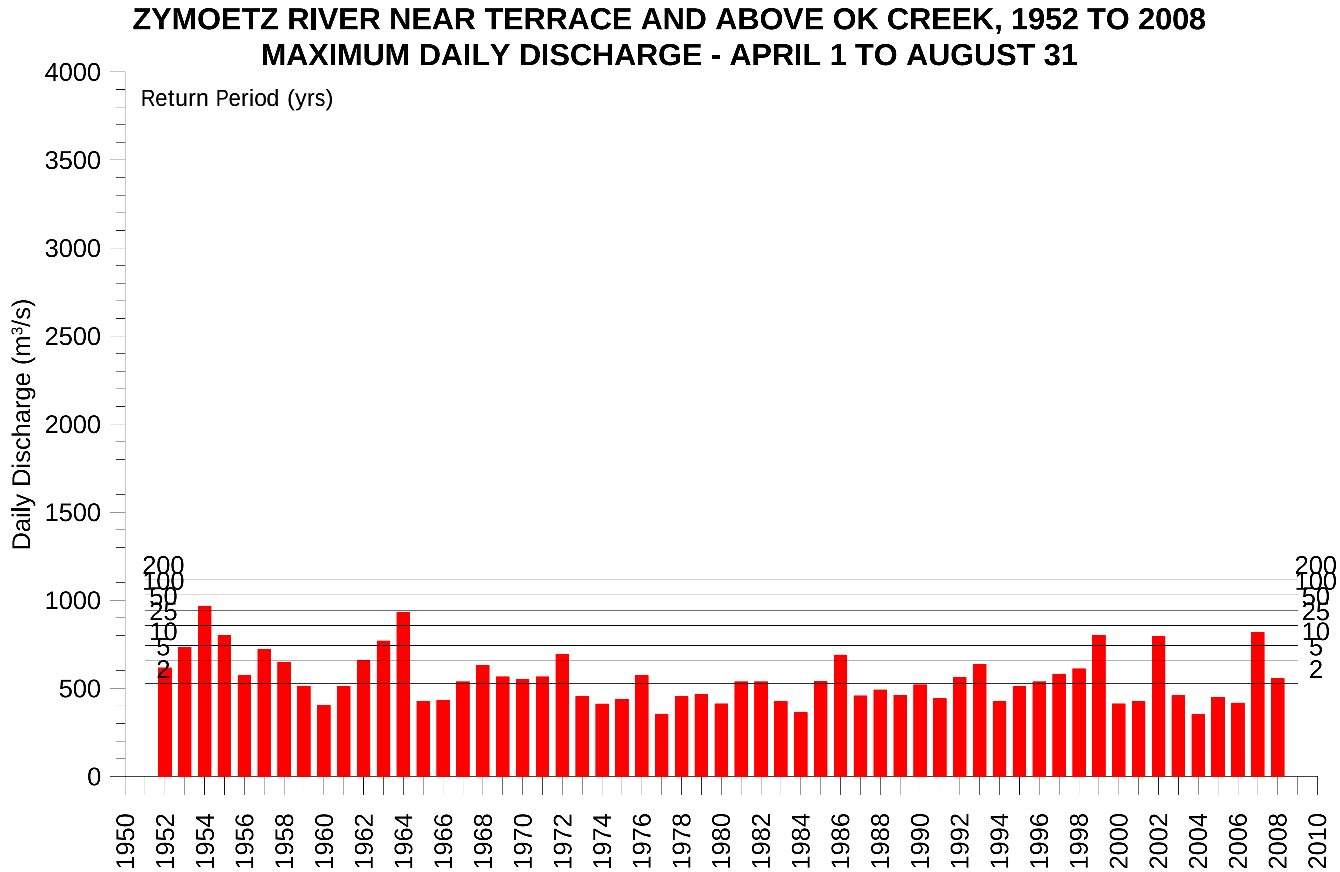


Figure 4.3.2.5: Historical variation in annual maximum daily discharge, Zymoetz River above OK Creek April 1 to August 31 and September 1 to March 31, 1964 to 2008.



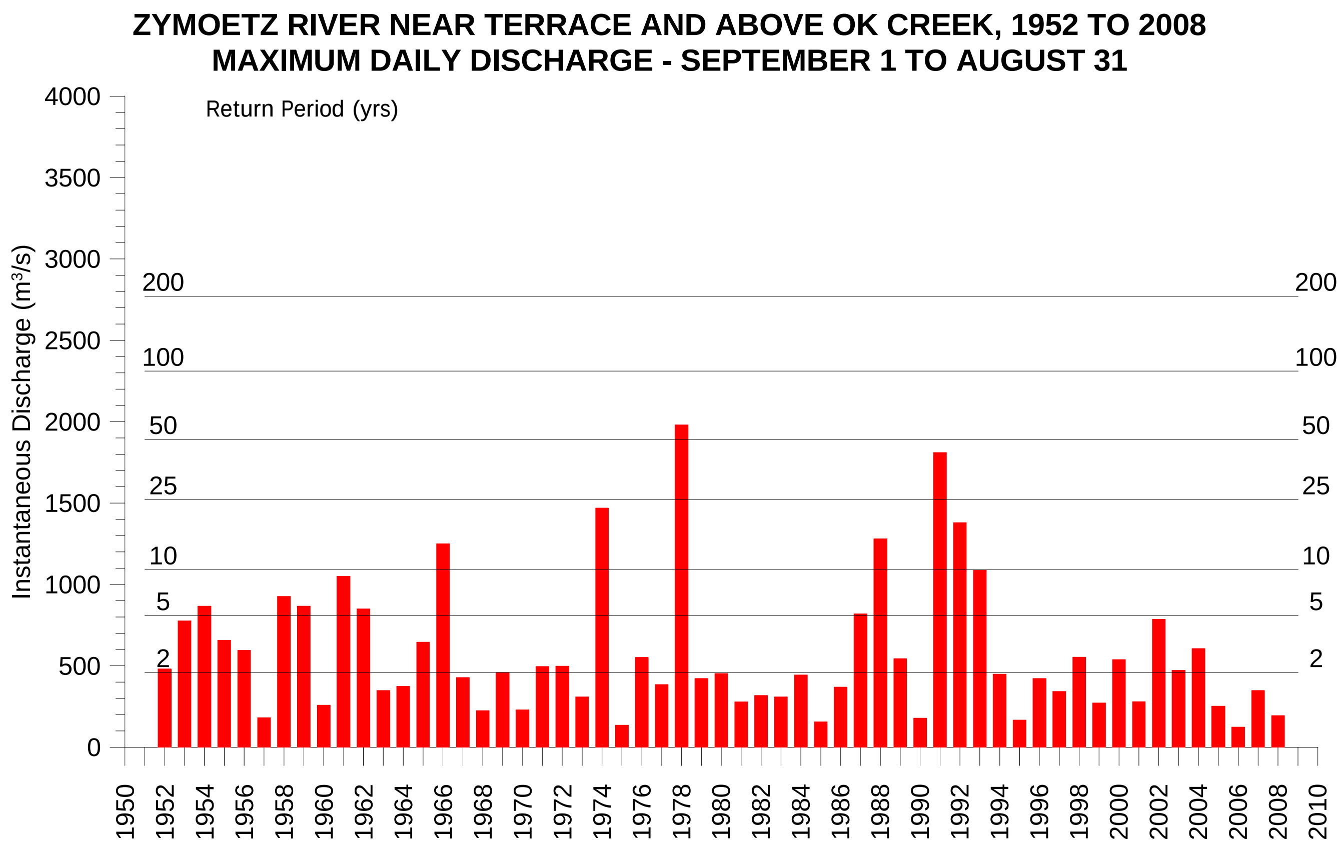
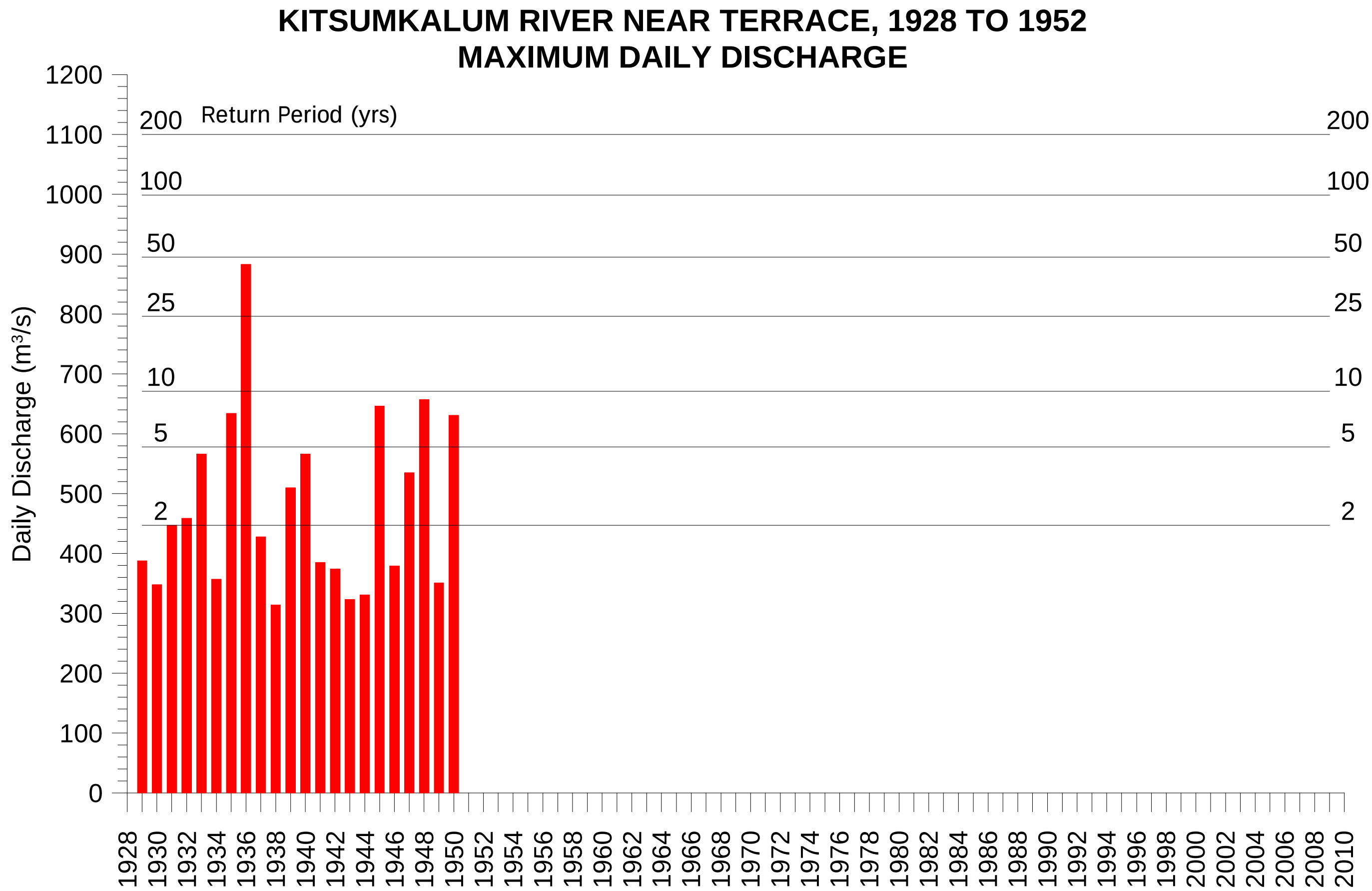


Figure 4.3.2.6: Historical variation in annual maximum daily discharge, Zymoetz River near Terrace and Zymoetz River above OK Creek, April 1-August 31 & September 1-March 31, 1952-2008.



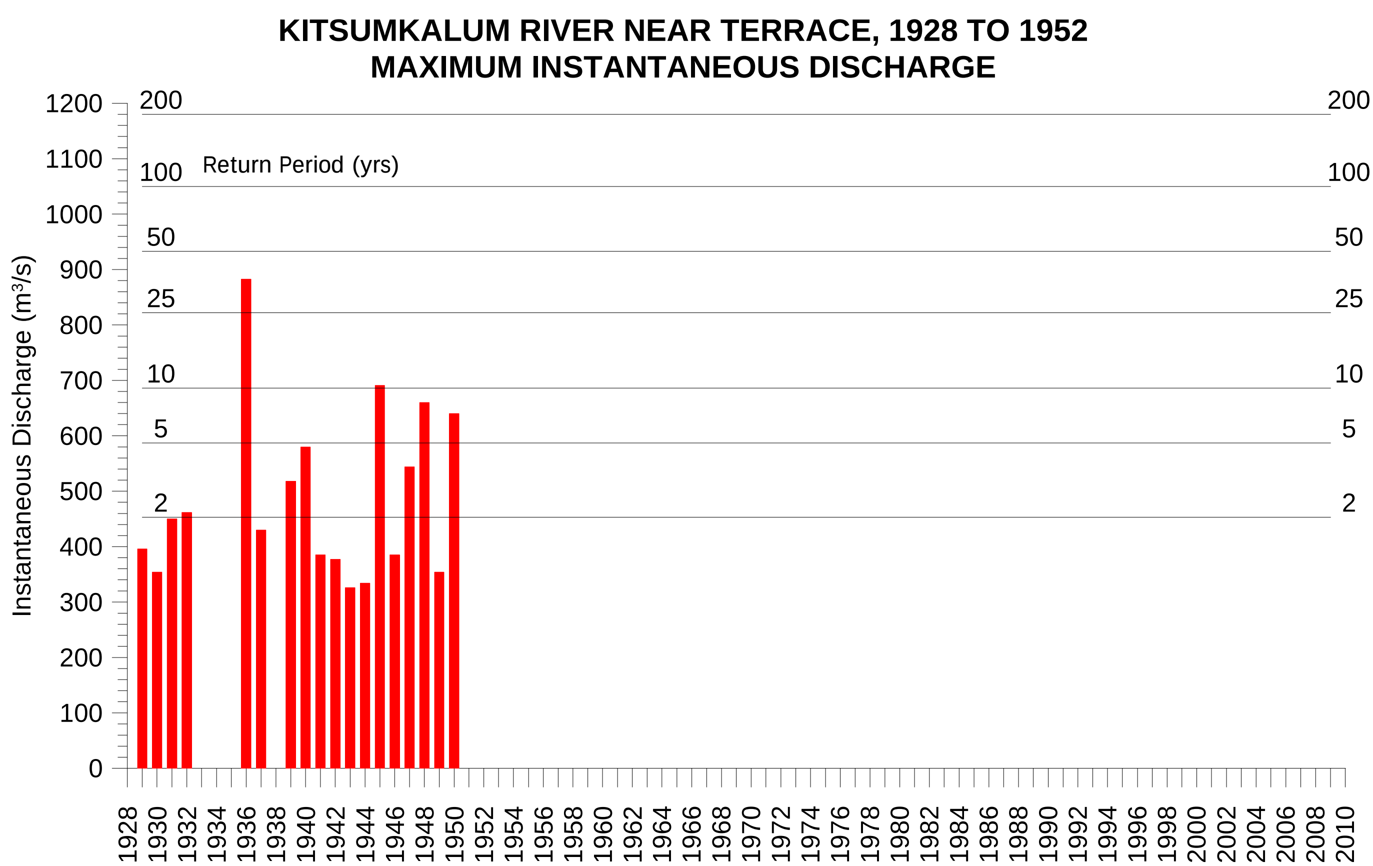


Figure 4.3.3.1: Historical variation in annual maximum daily and instantaneous discharge, Kitsumkalum River near Terrace, 1928 to 1952.

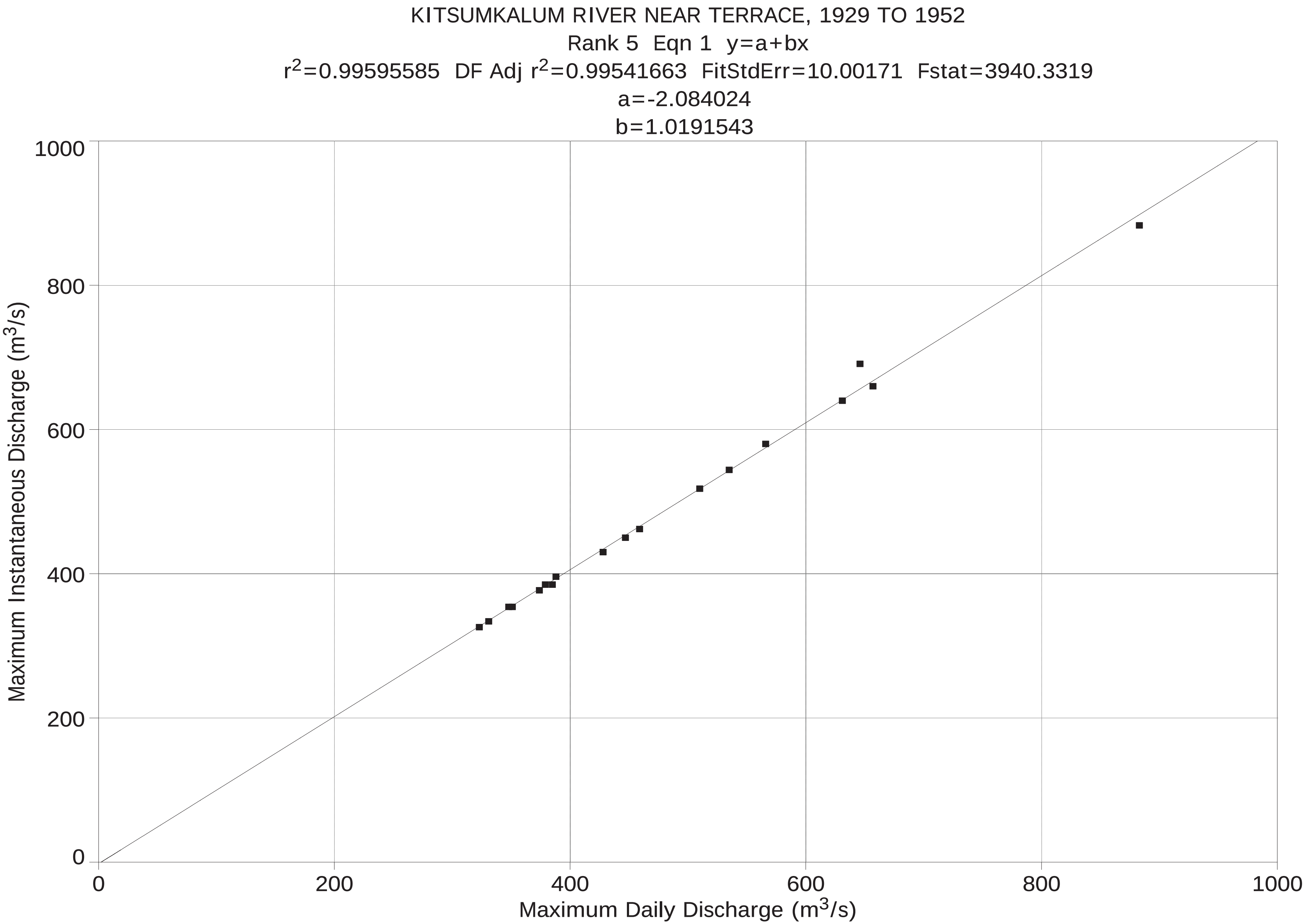
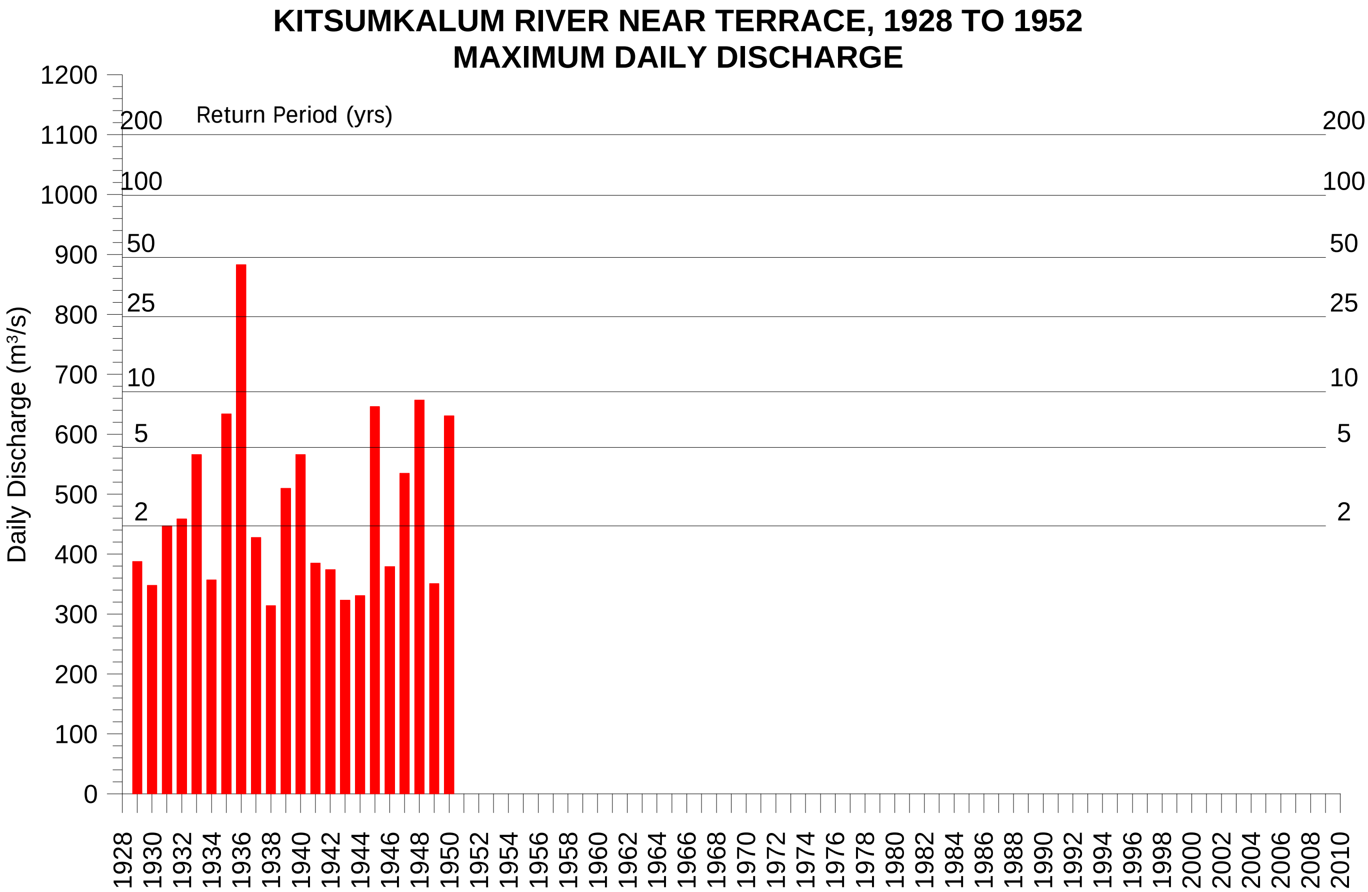


Figure 4.3.3.2: Relationship between annual maximum daily and instantaneous discharges observed on Kitsumkalum River near Terrace.



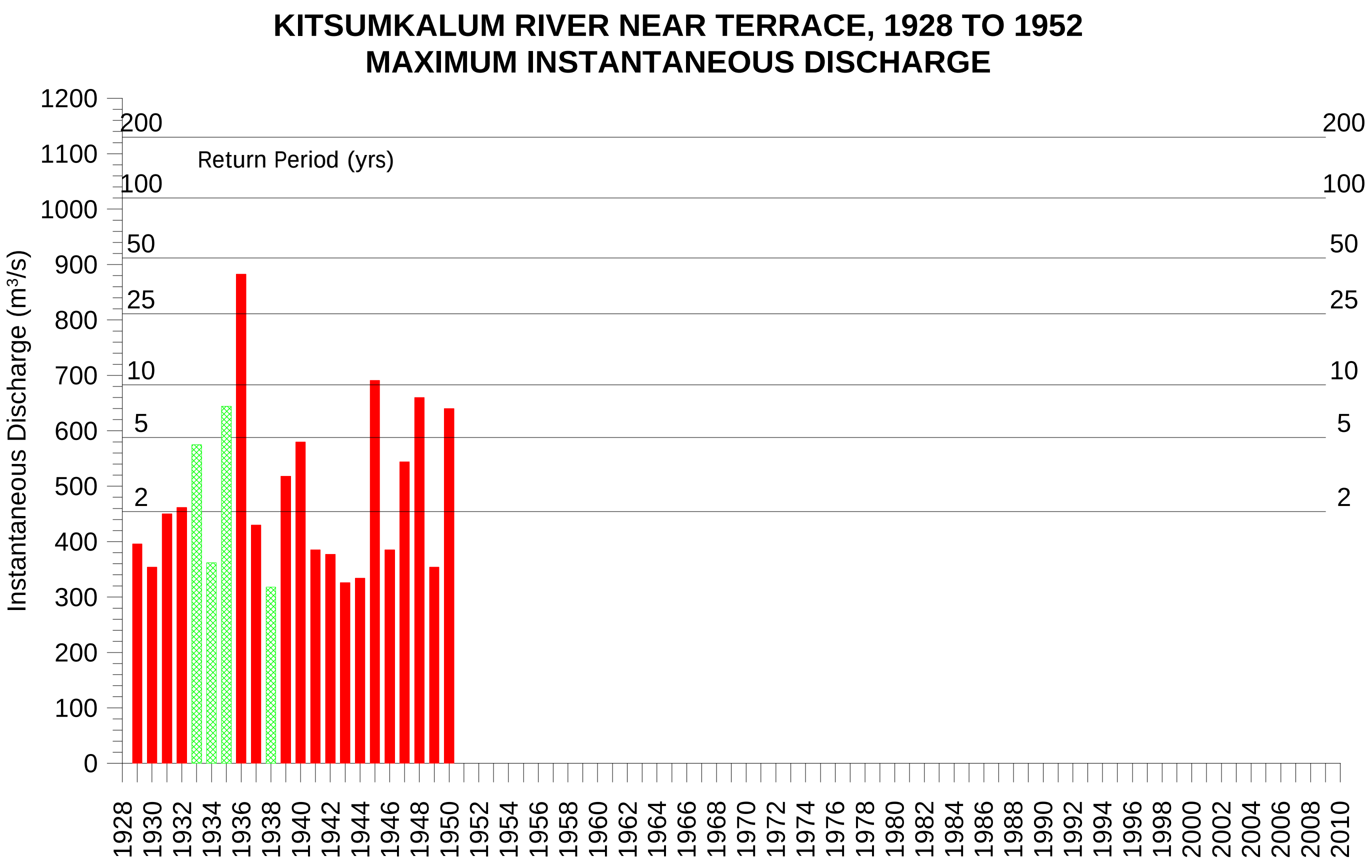
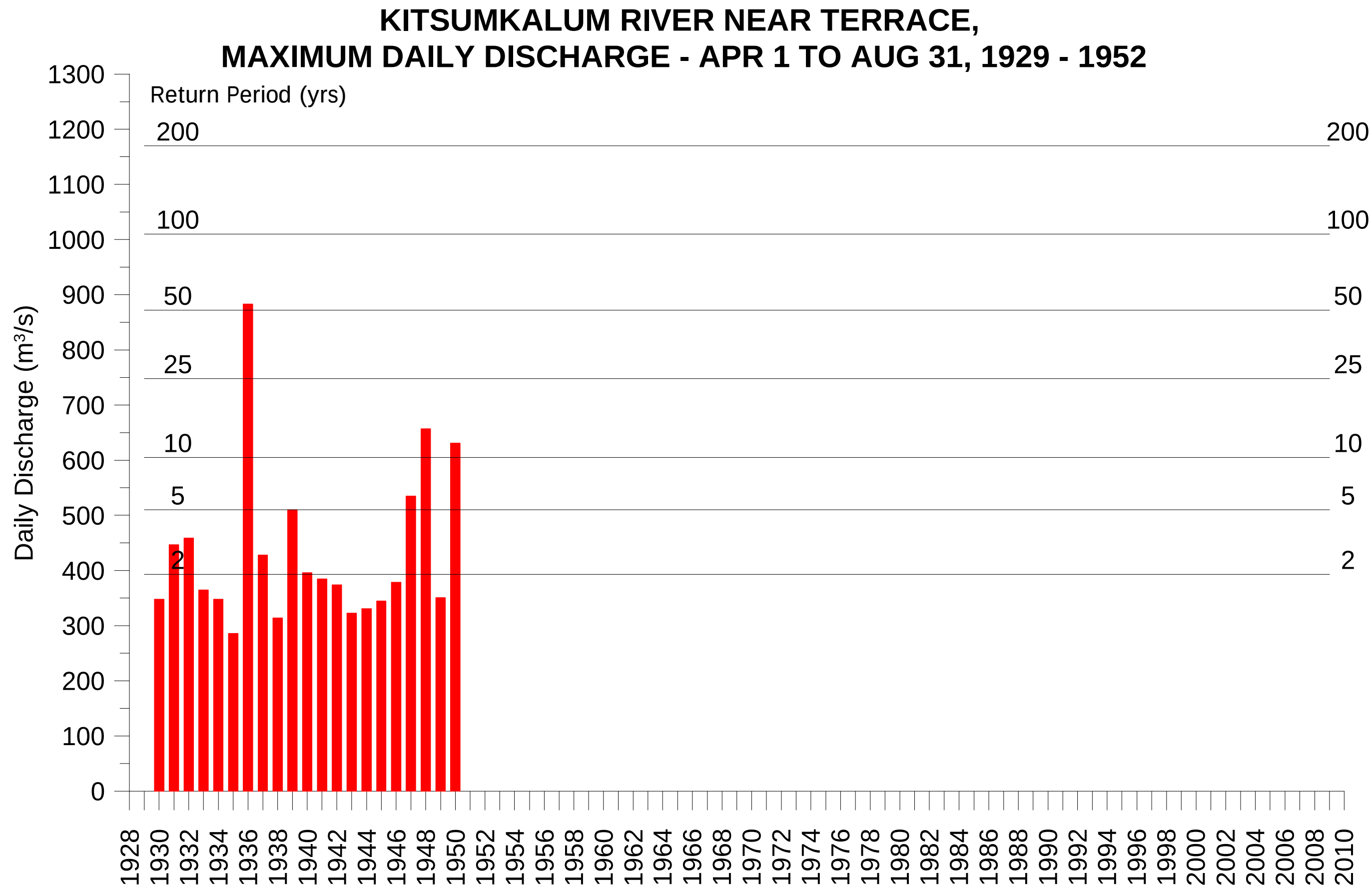


Figure 4.3.3.3: Historical variation in annual maximum daily and instantaneous discharge, Kitsumkalum River near Terrace, 1928 to 1952, including synthesized data.



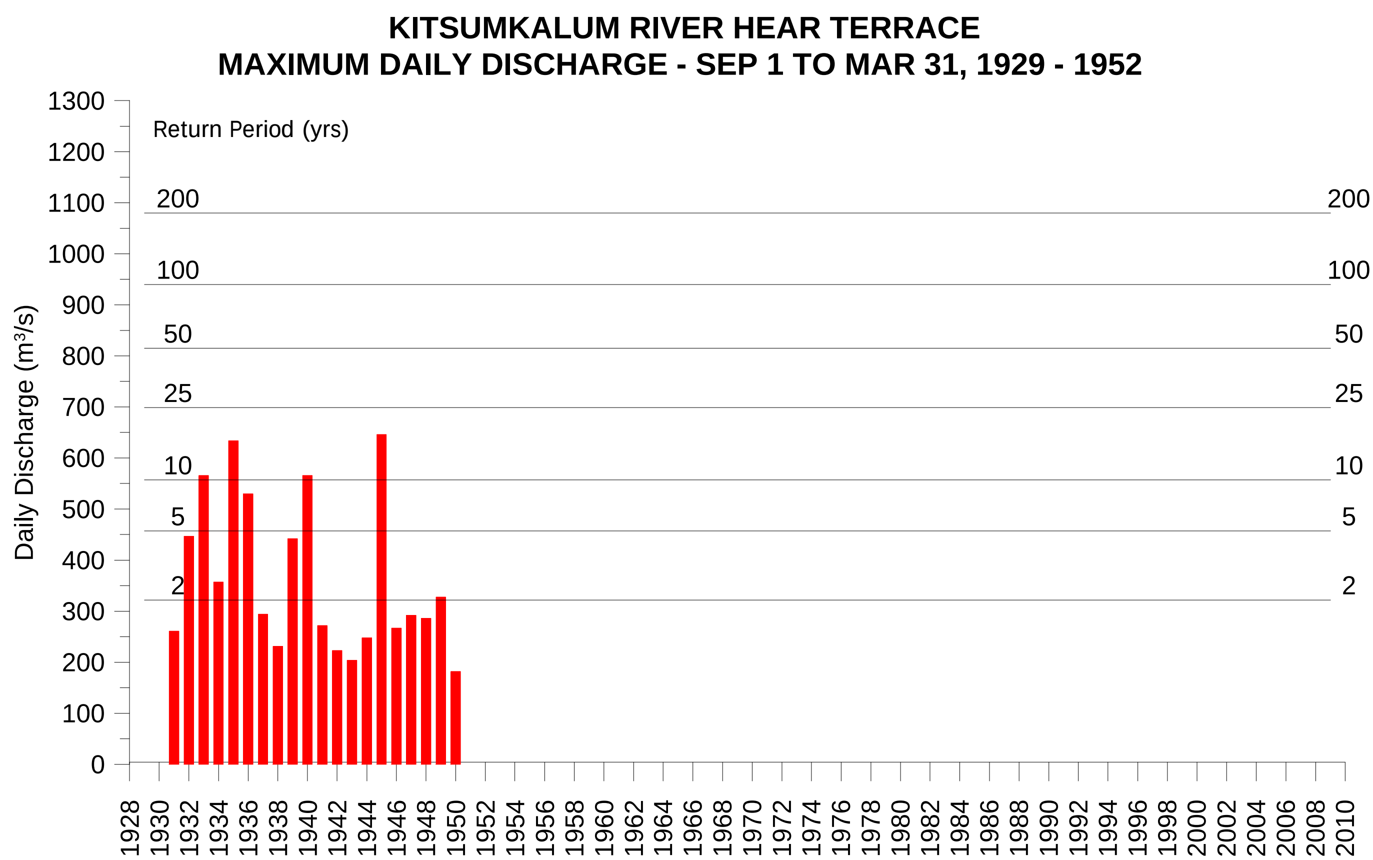


Figure 4.3.3.4: Historical variation in annual maximum daily discharge, Kitsumkalum River near Terrace April 1 to August 31 and September 1 to March 31, 1929 - 1952.

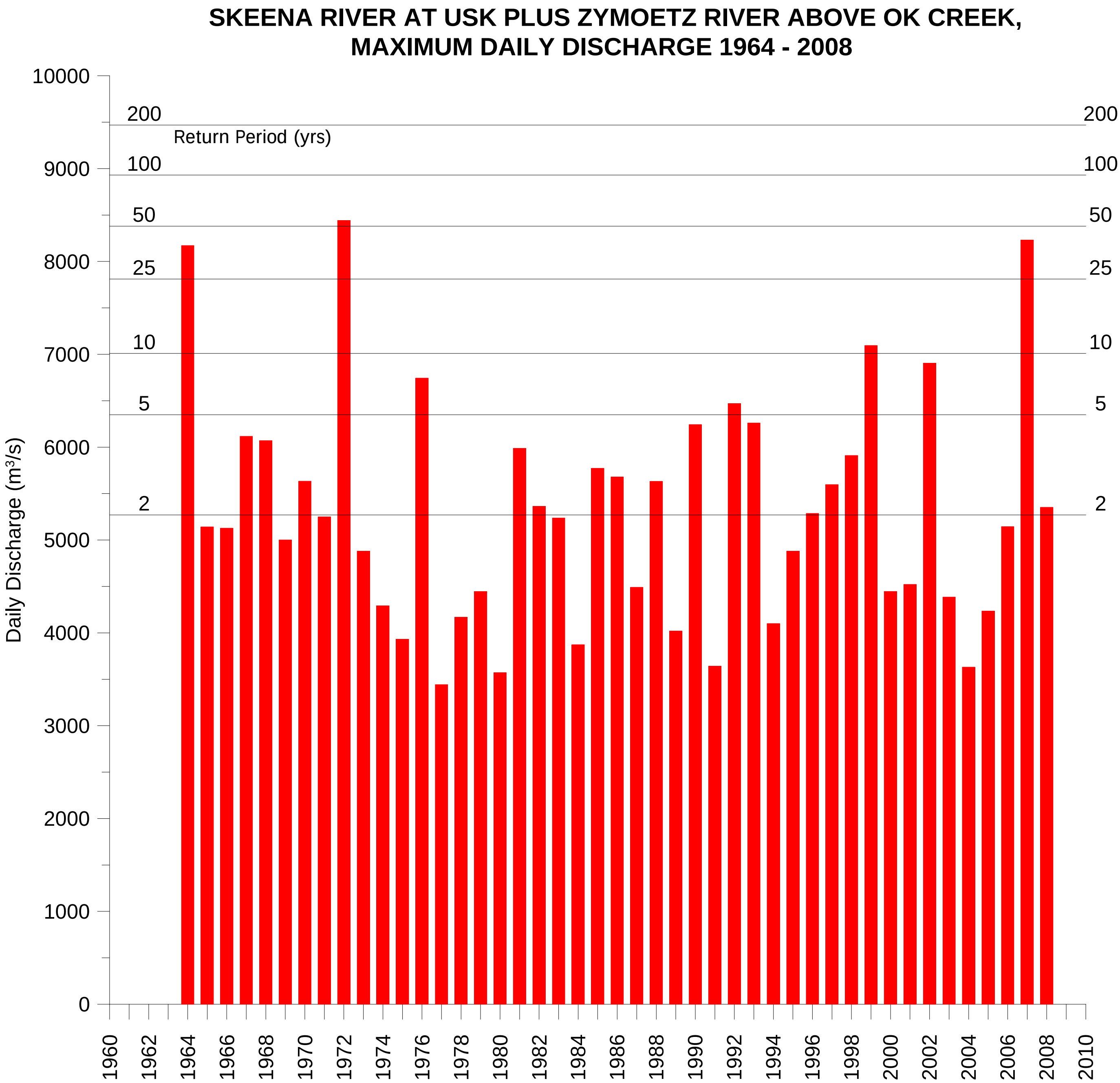


Figure 4.3.4.1: Historical variation in annual maximum daily discharge, Skeena River at Usk and Zymoetz River above OK Creek, 1964 - 2008.

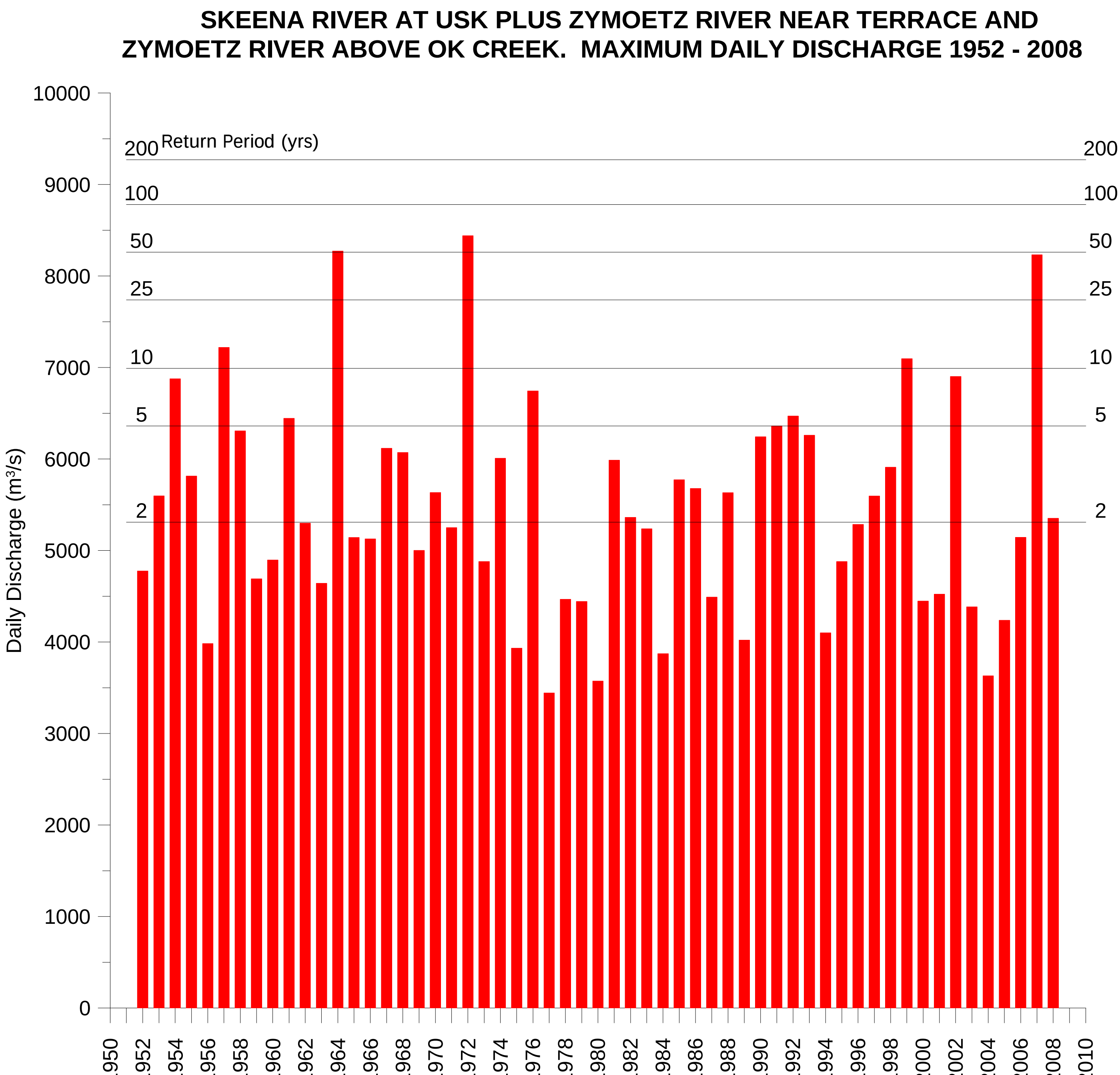
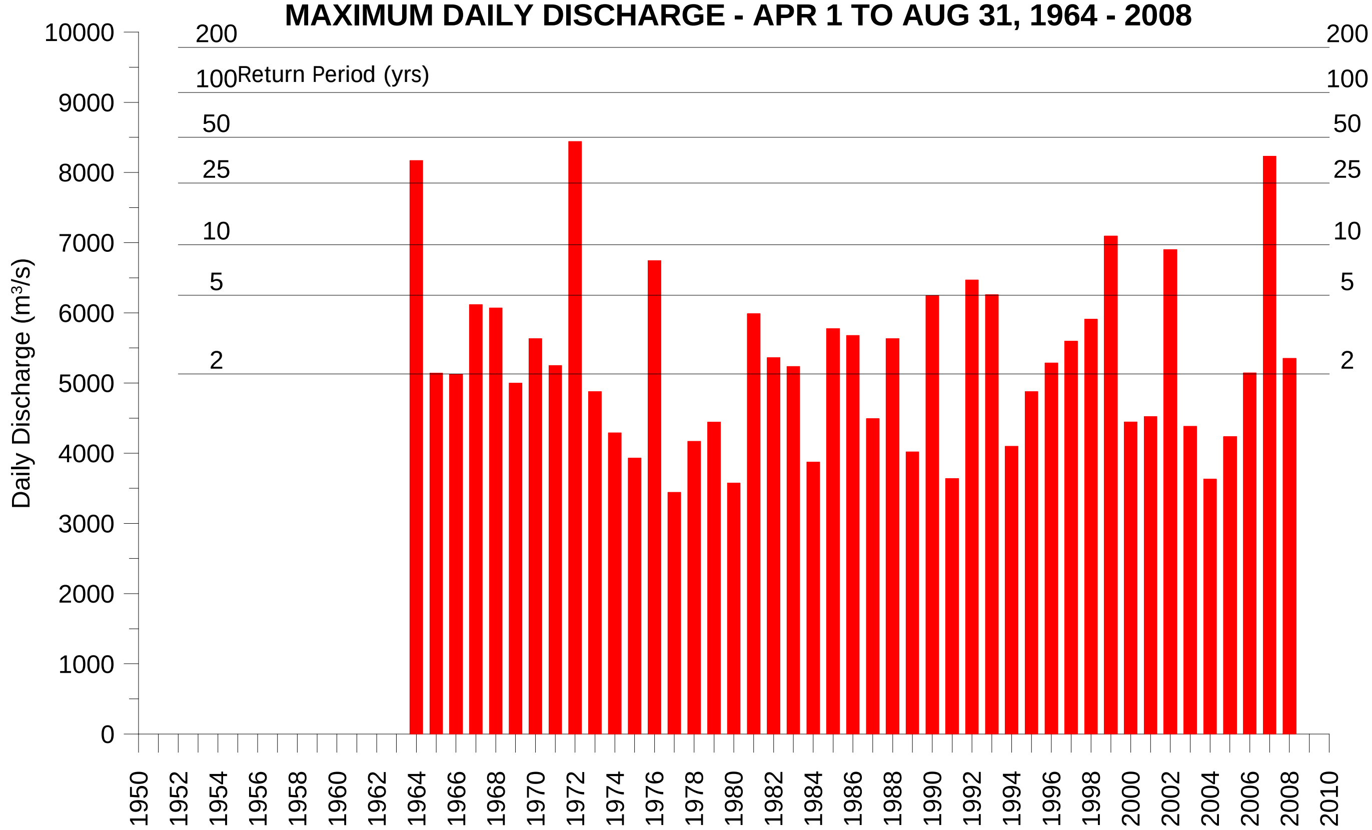


Figure 4.3.4.2: Historical variation in annual maximum daily discharge, Skeena River at Usk, plus Zymoetz River near Terrace and Zymoetz River above OK Creek, 1952 - 2008.

SKEENA RIVER AT USK PLUS ZYMOETZ RIVER ABOVE OK CREEK, MAXIMUM DAILY DISCHARGE - APR 1 TO AUG 31, 1964 - 2008



SKEENA RIVER AT USK PLUS ZYMOETZ RIVER ABOVE OK CREEK, MAXIMUM DAILY DISCHARGE - SEP 1 TO MAR 31, 1964 - 2008

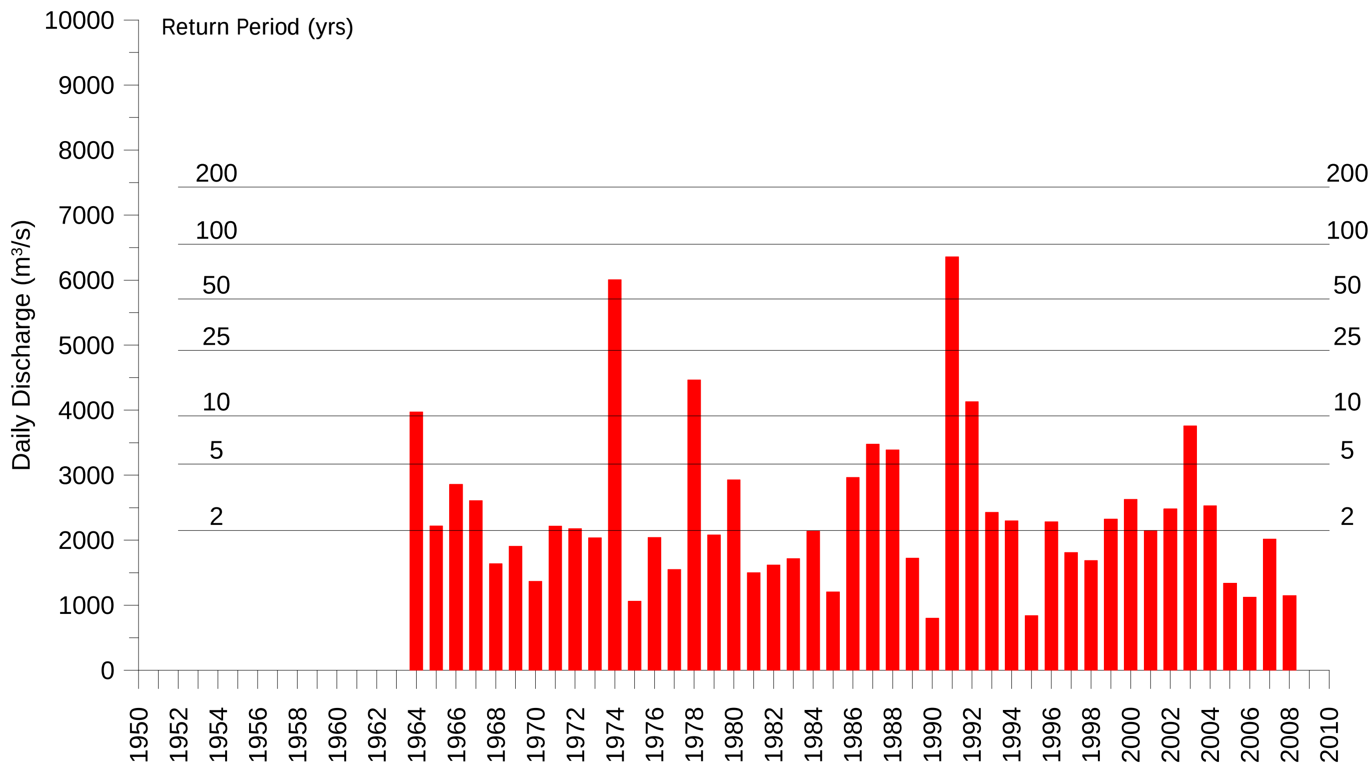
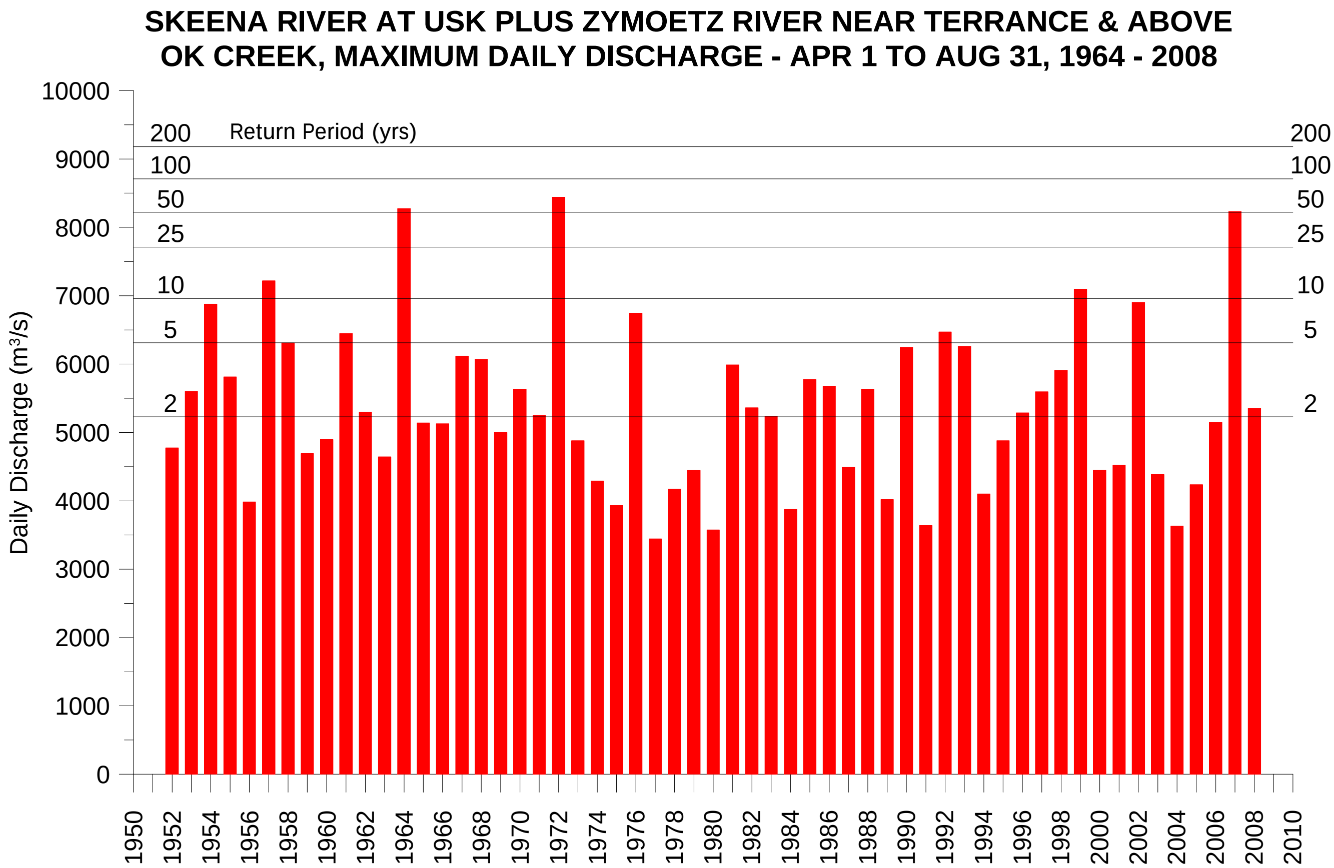


Figure 4.3.4.3: Historical variation in annual maximum daily discharge, Skeena River at Usk and Zymoetz River above OK Creek, April 1 to August 31 and September 1 to March 31, 1964 - 2008.



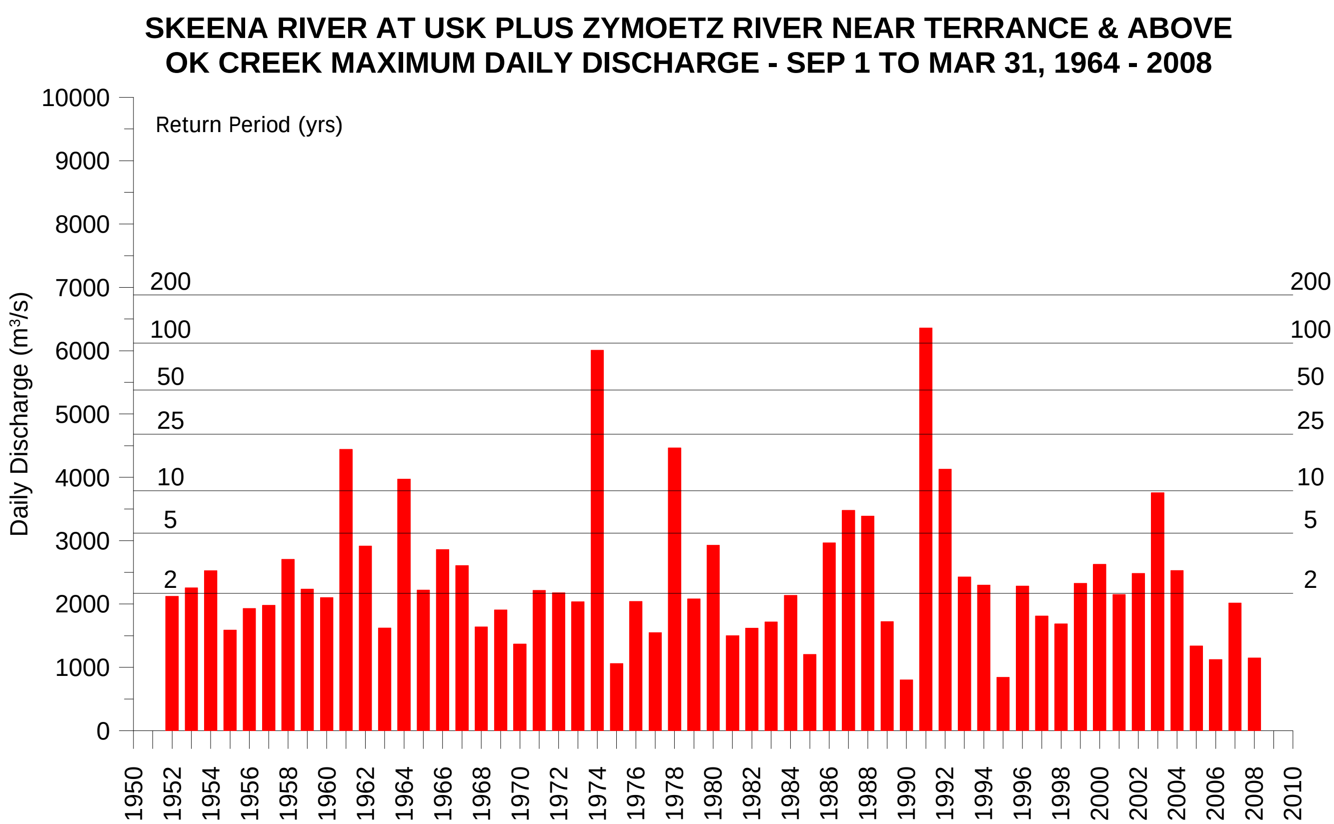


Figure 4.3.4.4: Historical variation in annual maximum daily discharge, Skeena River at Usk, Zymoetz River Near Terrace & Above OK Creek, April 1-August 31 & September 1-March 31, 1952-2008.

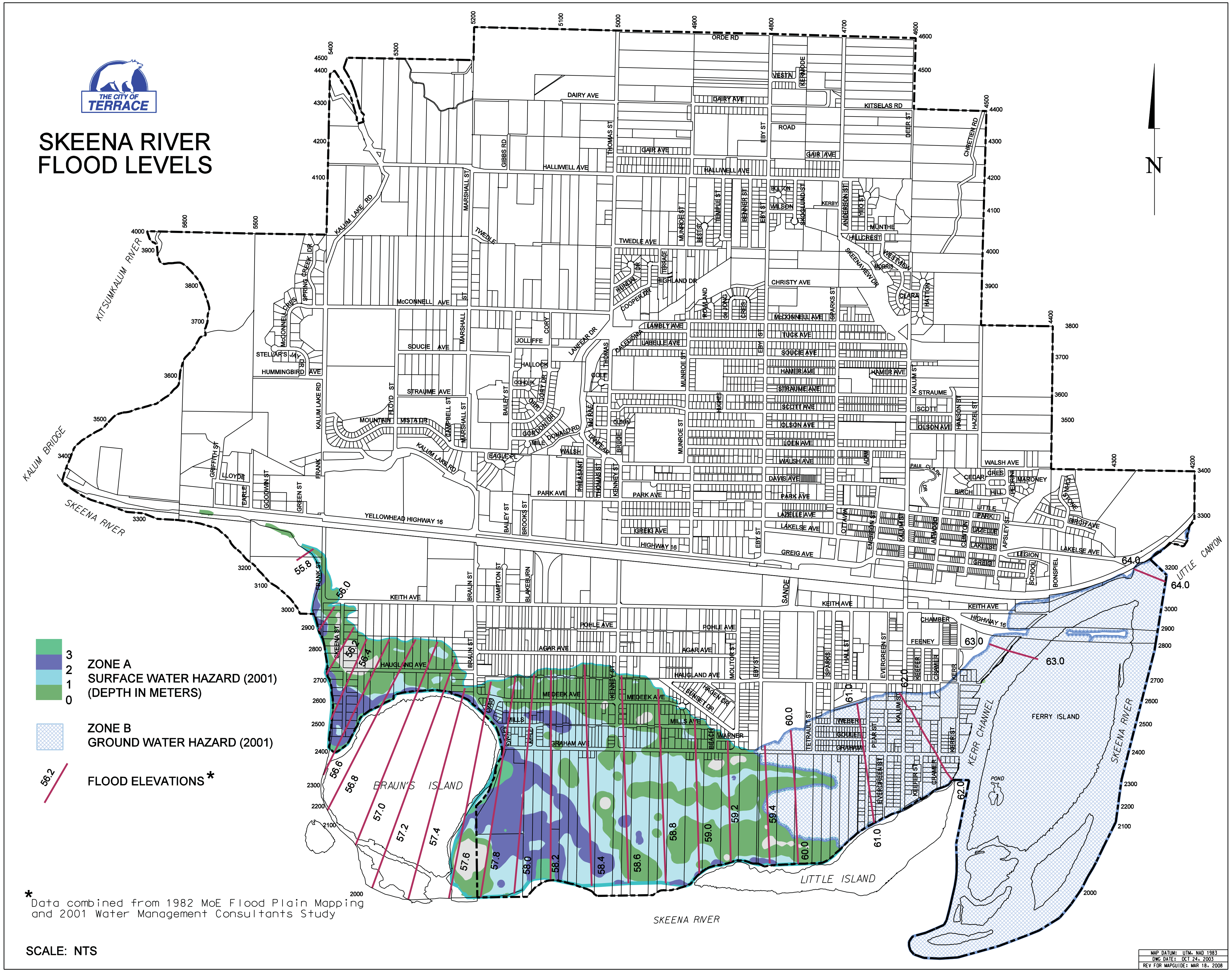


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Figure 5.2.1: Map showing revised flood levels in the vicinity of Terrace prepared by Water Management Consultants (2001).

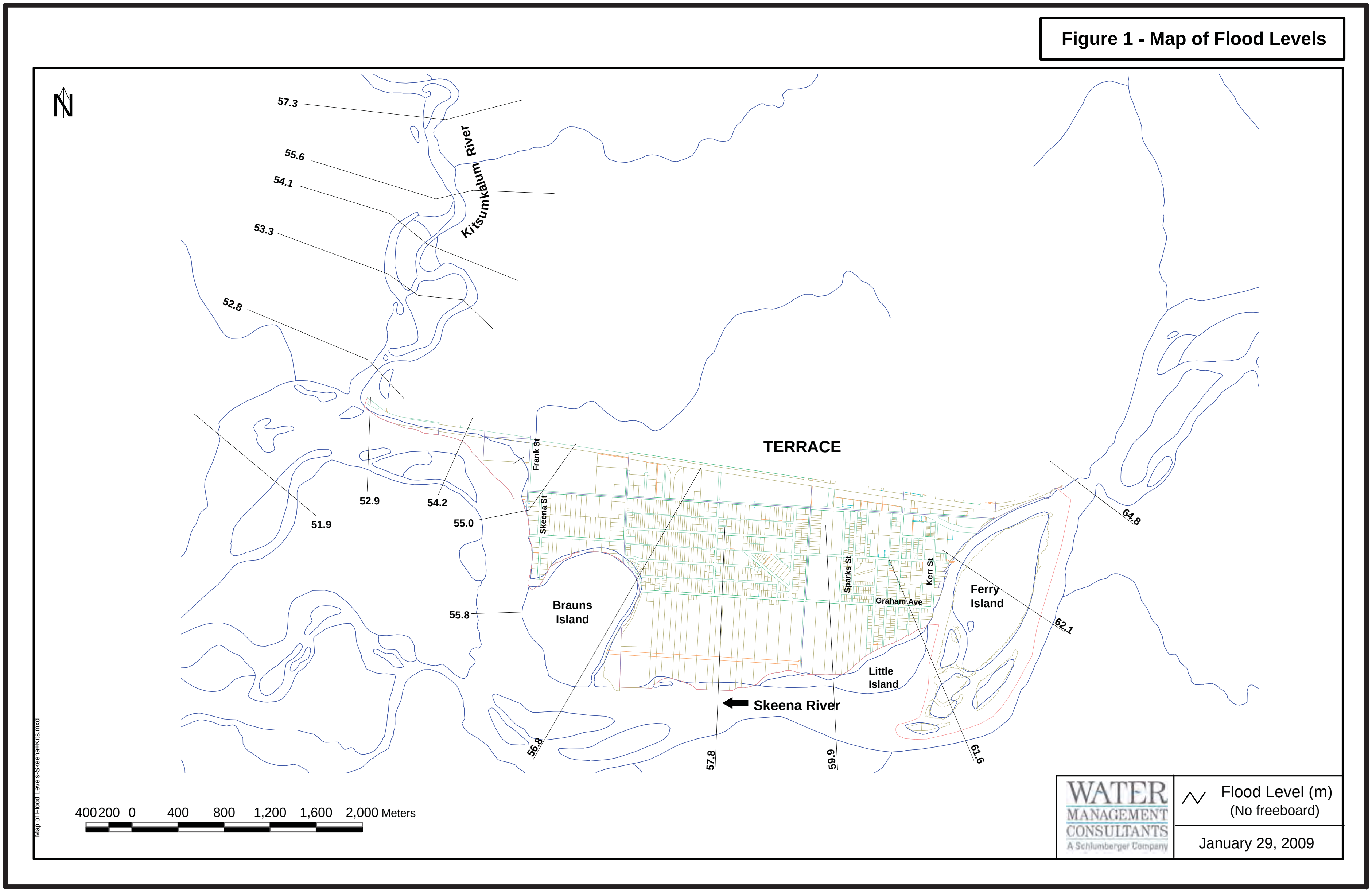


Figure 5.2.2: Revised map of predicted water elevations during the 200-year flood prepared by Water Management Consultants (2009).

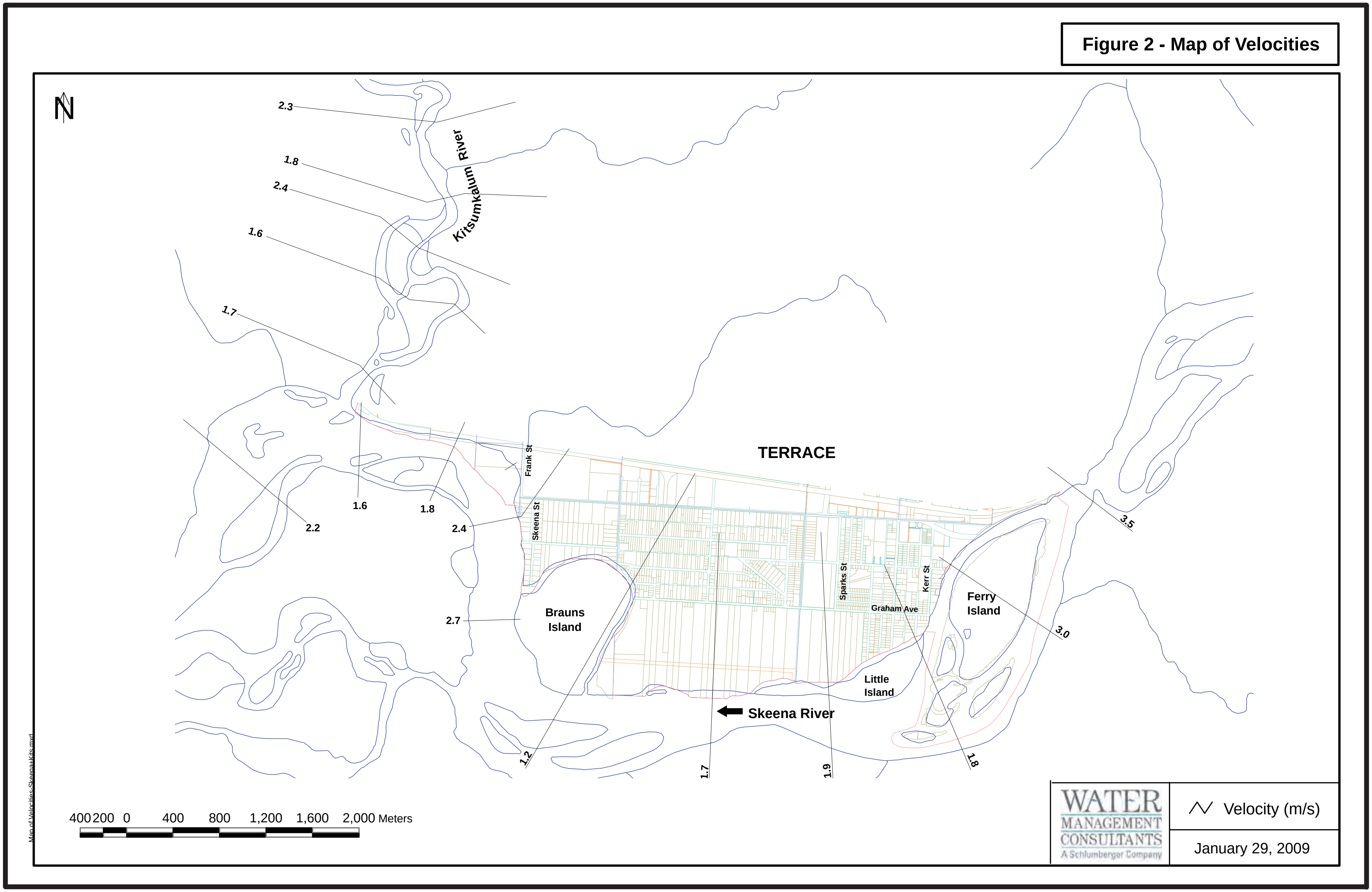


Figure 5.2.3: Map of average water velocities during the 200-year flood, prepared by Water Management Consultants, 2009.

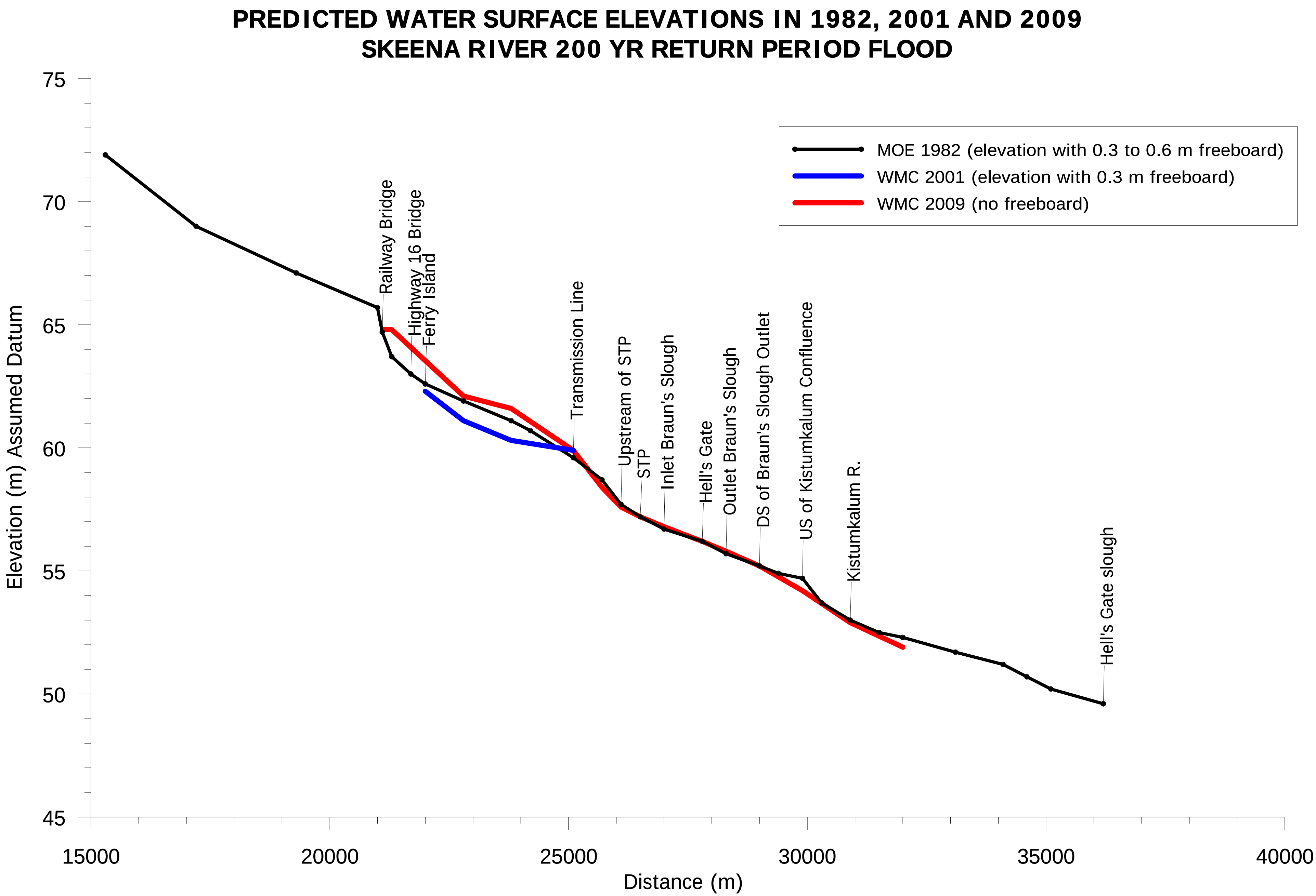


Figure 5.3.1.1: Comparison of predicted 200 year return period flood elevations on Skeena River.

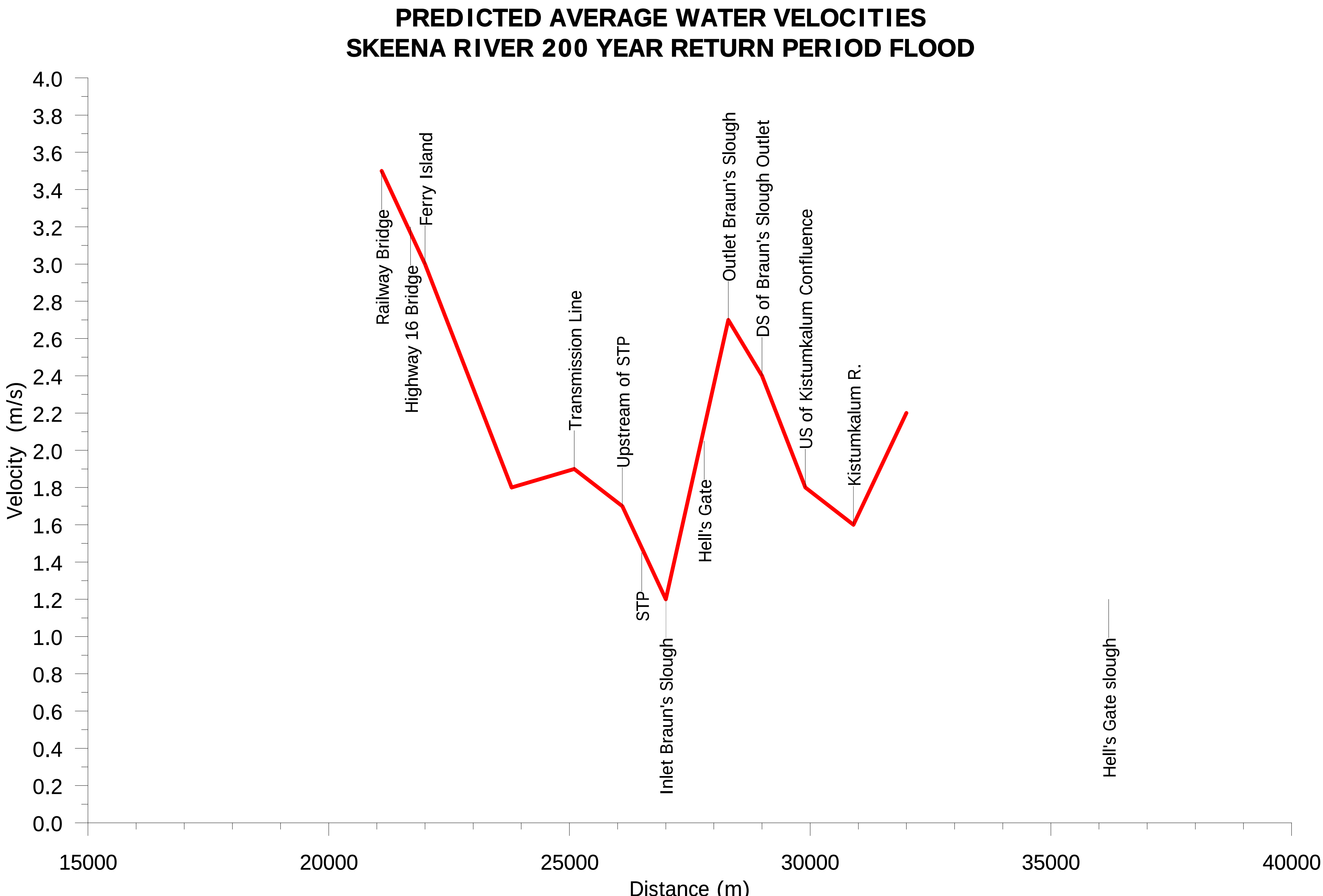


Figure 5.3.1.2: Downstream variation in average water velocities on Skeena River during a 200-year return period flood (WMC, 2009).

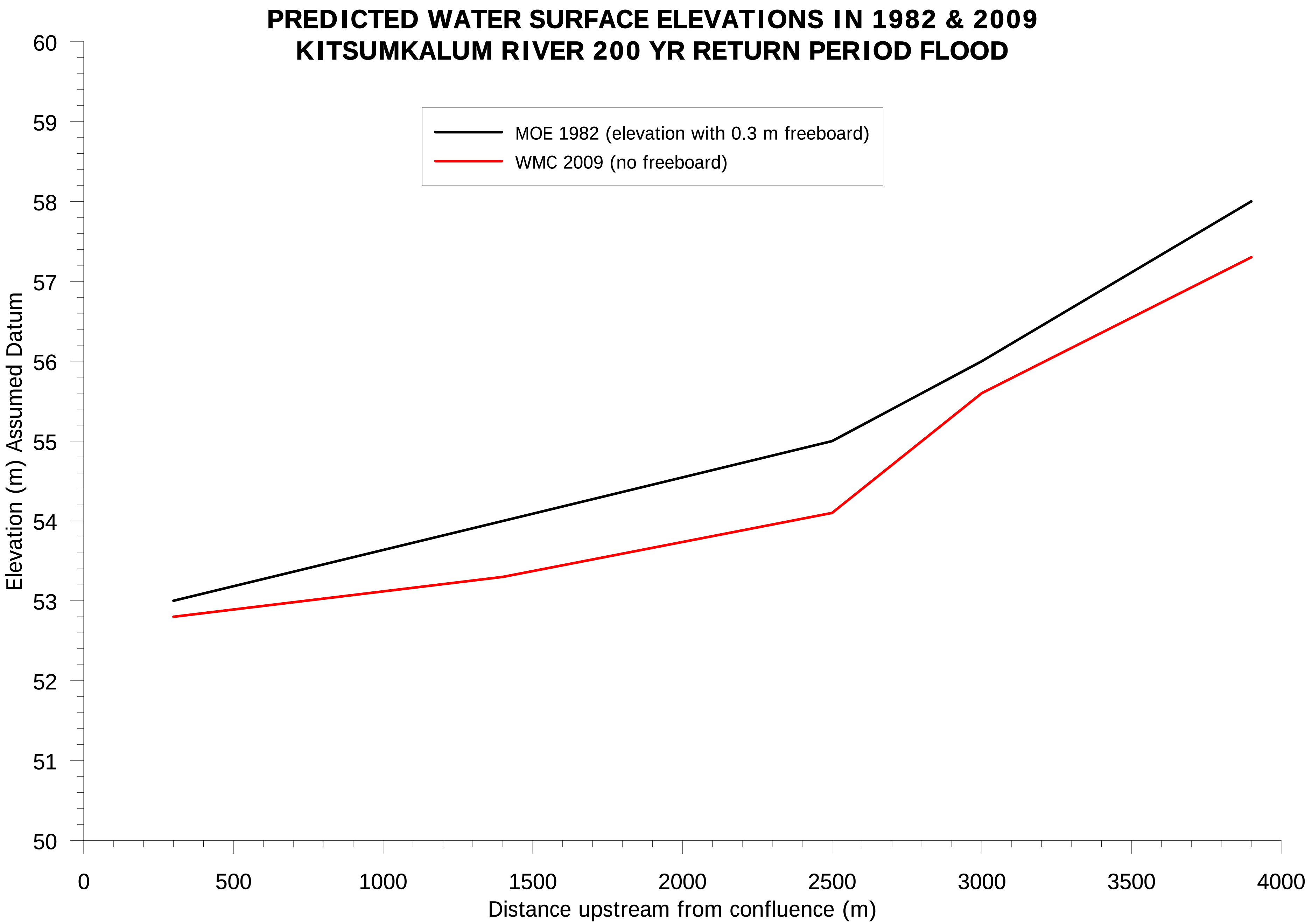


Figure 5.3.2.1: Comparison of predicted 200 year return period flood elevations on Kitsumkalum River.

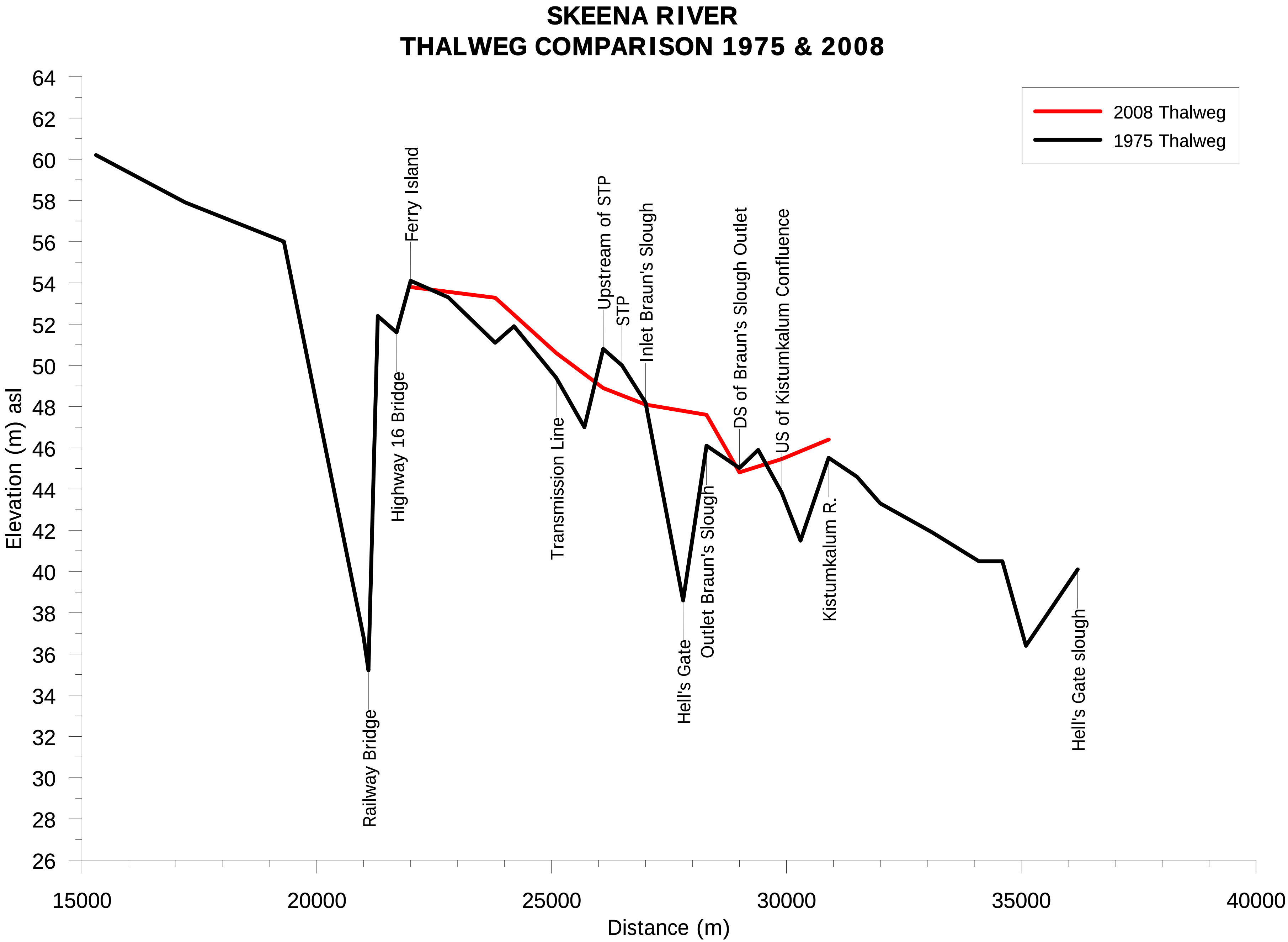


Figure 5.4.1.1: Comparison of Skeena River channel thalweg elevations surveyed in 1975 and 2008.

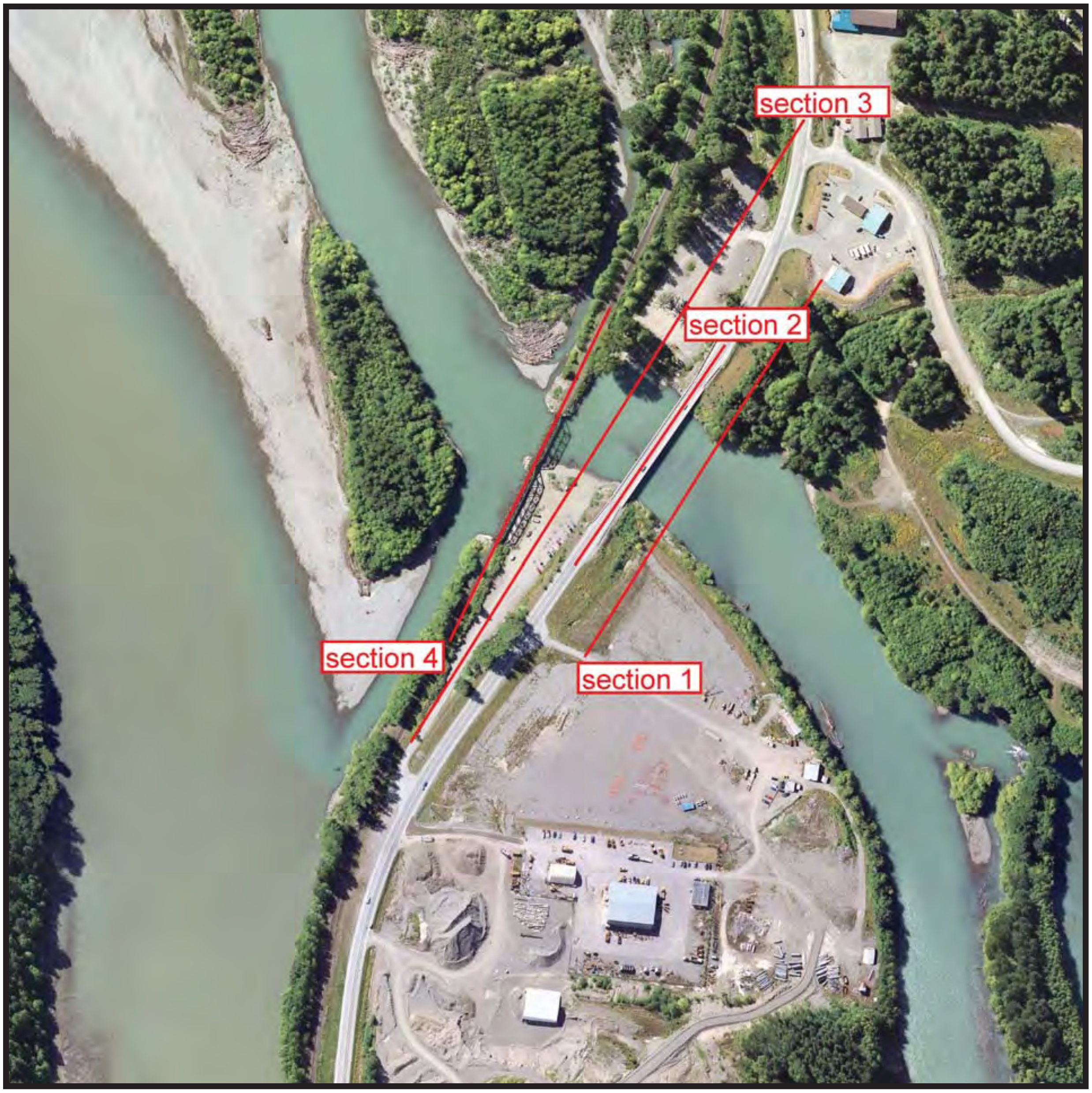


Figure 5.4.2.1: Location of McElhanney's 2009 river cross-section surveys on lower Kitsumkalum River.

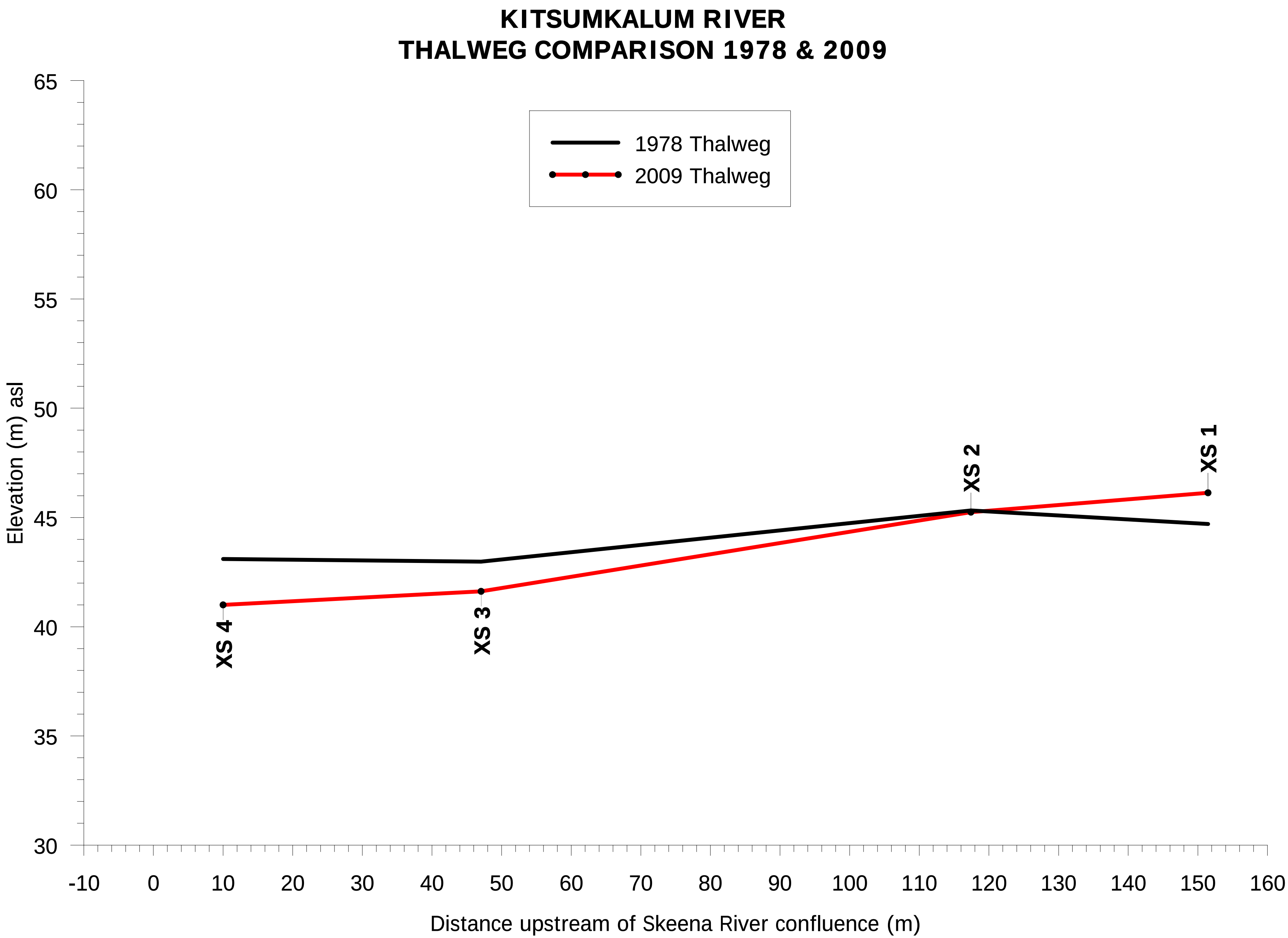
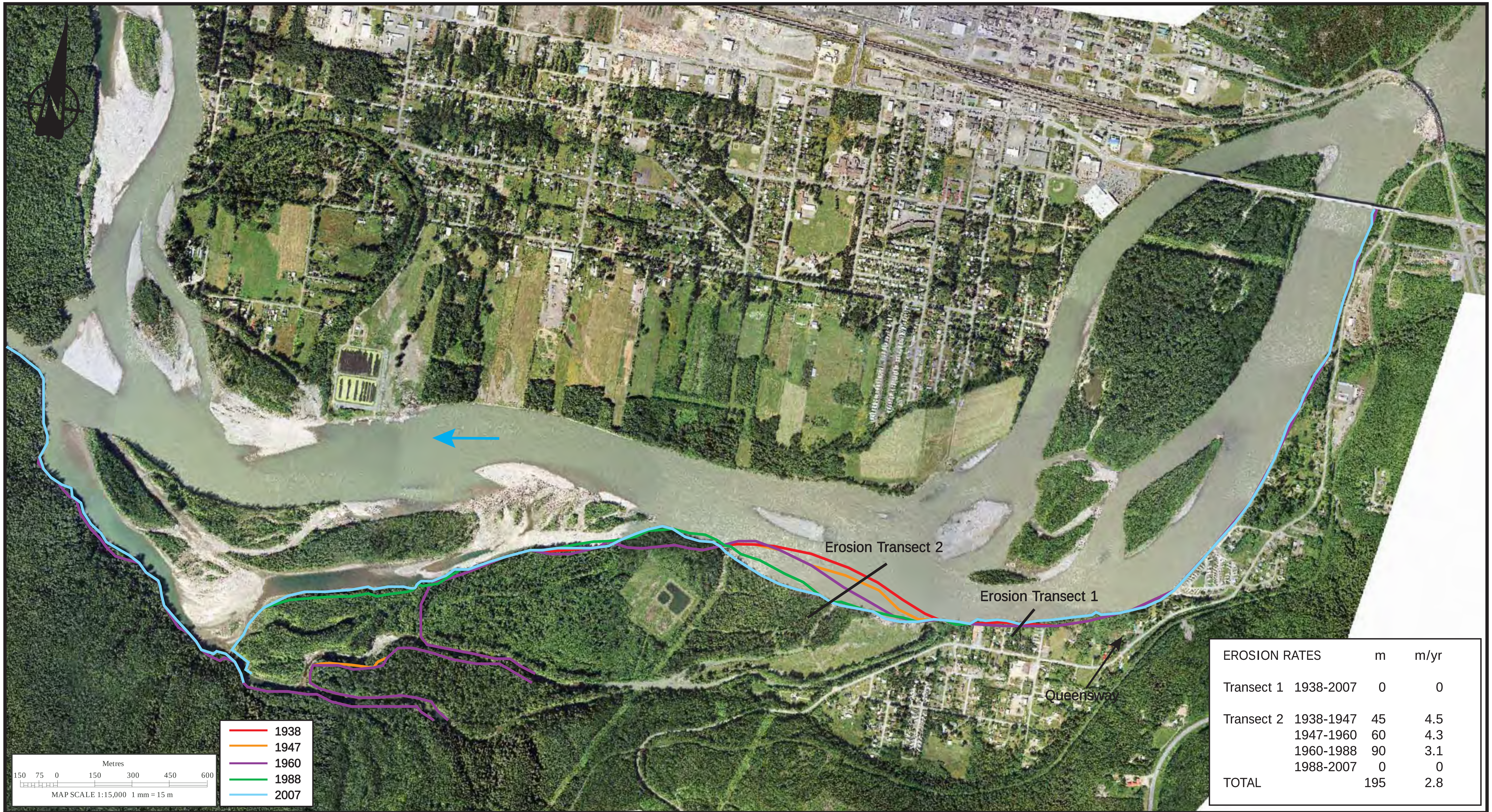


Figure 5.4.2.2: Comparison of 1978 and 2009 channel thalweg elevations on lower Kitsumkalum River.



EROSION RATES		m	m/yr
Transect 1	1938-2007	0	0
Transect 2	1938-1947	45	4.5
	1947-1960	60	4.3
	1960-1988	90	3.1
	1988-2007	0	0
TOTAL		195	2.8

Orthophoto	August 14, 2007				
Skeena River at Usk 1,050 m³/s Zymoetz R. (Copper Cr.) above OK Cr. 113 m³/s					
REFERENCED DRAWING NO.	REFERENCED DRAWING DESCRIPTION				
A	Dec. 10, 2008	Issued for discussion			
F - 35					

APPROXIMATE SCALE:	1:15,000
DATE:	December 12, 2008
DRAWN:	S. Allegretto
DESIGNED:	S. Allegretto
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SKEENA RIVER

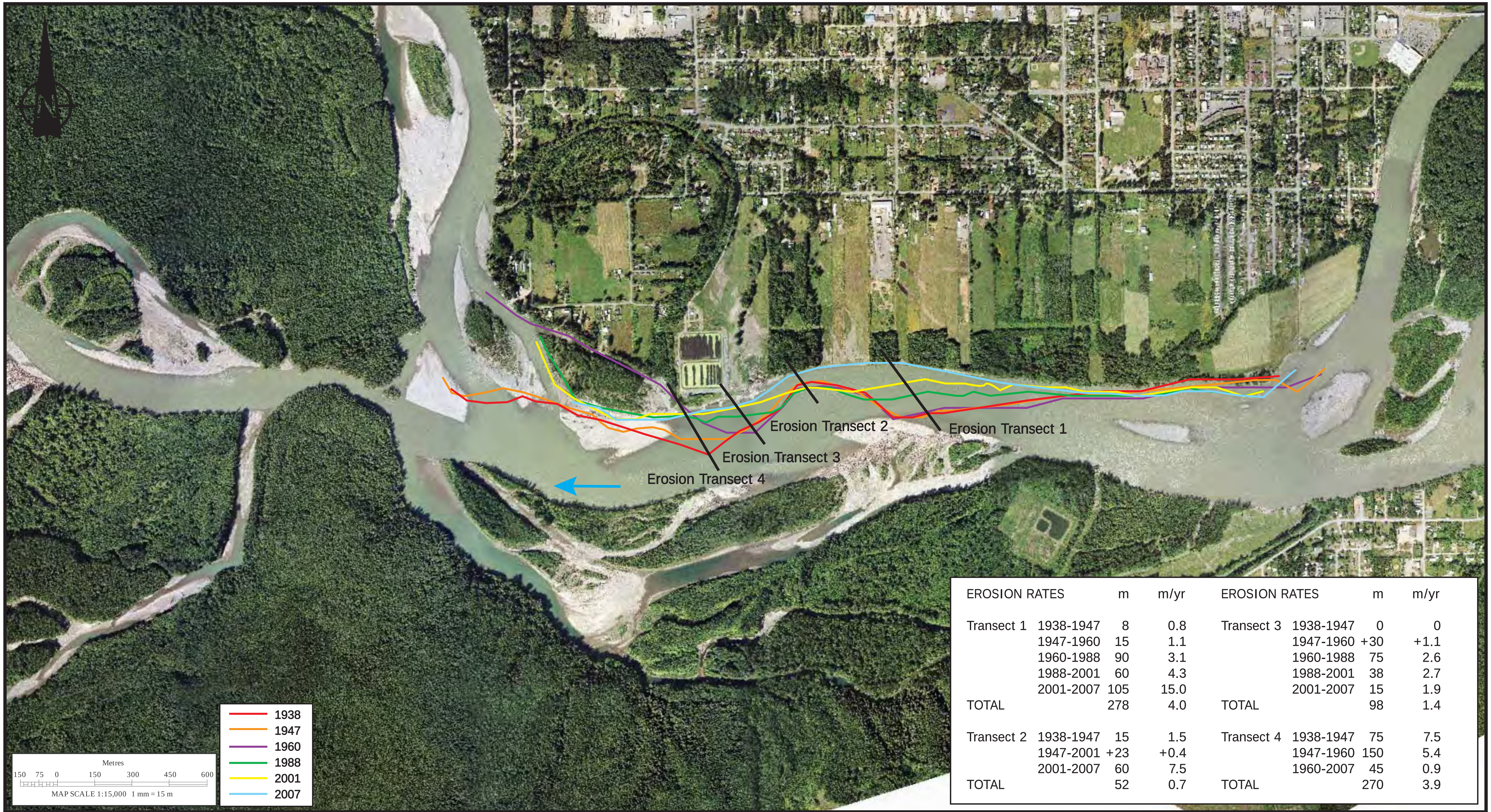
1938 to 2007 erosion rates on Skeena River in the vicinity of Queensway and the Regional District of Terrace, Sewage Treatment Plant

FIGURE 6.2.3.1

PROJECT # 330

Km #

REV: A



EROSION RATES		m	m/yr	EROSION RATES		m	m/yr
Transect 1	1938-1947	8	0.8	Transect 3	1938-1947	0	0
	1947-1960	15	1.1		1947-1960	+30	+1.1
	1960-1988	90	3.1		1960-1988	75	2.6
	1988-2001	60	4.3		1988-2001	38	2.7
	2001-2007	105	15.0		2001-2007	15	1.9
TOTAL		278	4.0	TOTAL		98	1.4
Transect 2	1938-1947	15	1.5	Transect 4	1938-1947	75	7.5
	1947-2001	+23	+0.4		1947-1960	150	5.4
	2001-2007	60	7.5		1960-2007	45	0.9
TOTAL		52	0.7	TOTAL		270	3.9

Orthophoto	August 14, 2007				
Skeena River at Usk 1,050 m³/s Zymoetz R. (Copper Cr.) above OK Cr. 113 m³/s					
REFERENCED DRAWING NO.	REFERENCED DRAWING DESCRIPTION				
A	Dec. 10, 2008	Issued for discussion			
F - 36					

APPROXIMATE SCALE: 1:15,000
DATE: December 10, 2008
DRAWN: S. Allegretto
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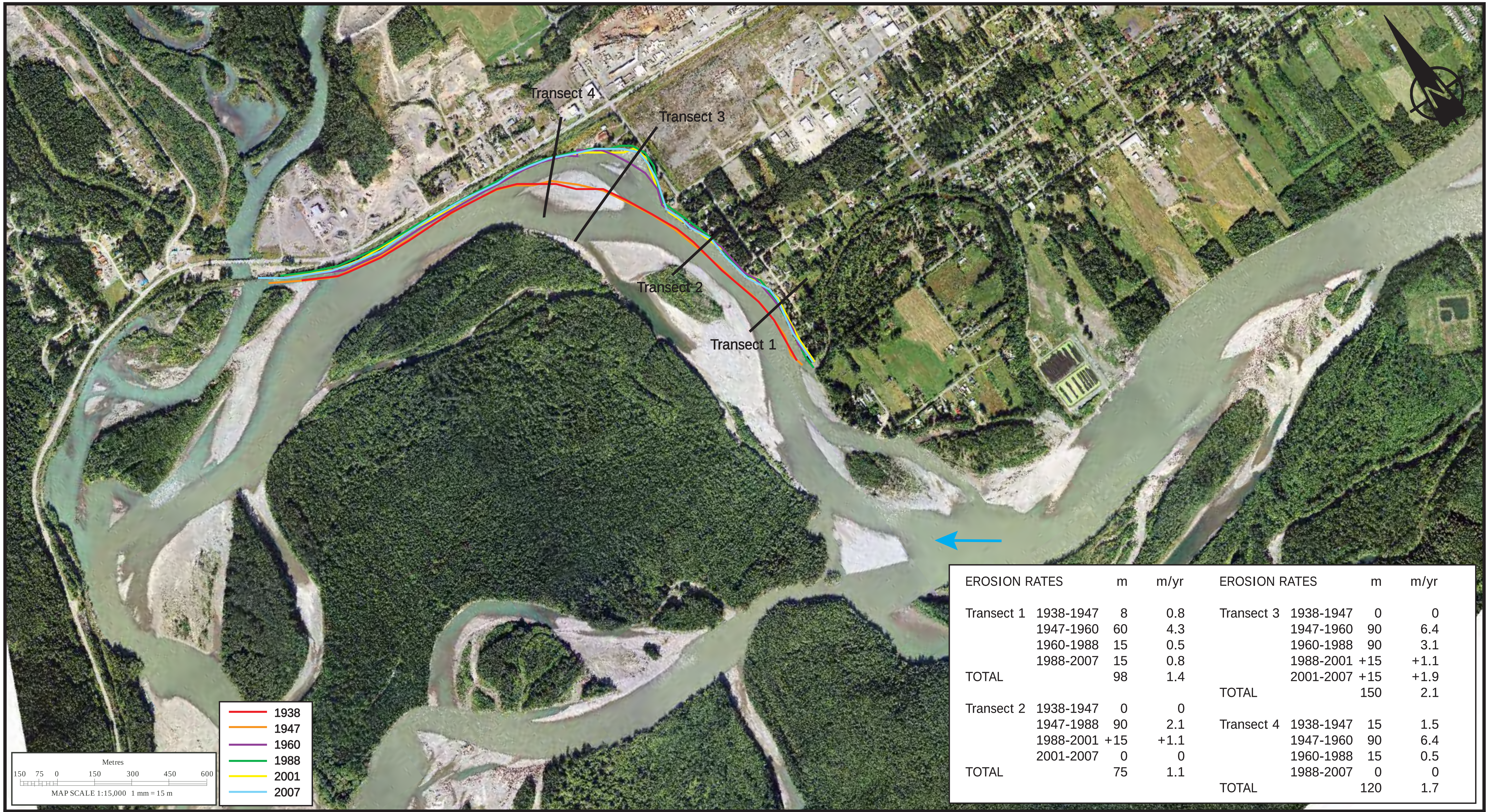
SKEENA RIVER

1938-2007 erosion rates on Skeena River near the City of Terrace, Sewage Treatment Plant

FIGURE 6.2.4.1

PROJECT # 330
Km #
REV: A



EROSION RATES		m	m/yr
Transect 1	1938-1947	8	0.8
	1947-1960	60	4.3
	1960-1988	15	0.5
	1988-2007	15	0.8
TOTAL		98	1.4
Transect 2	1938-1947	0	0
	1947-1988	90	2.1
	1988-2001	+15	+1.1
	2001-2007	0	0
TOTAL		75	1.1

EROSION RATES		m	m/yr
Transect 3	1938-1947	0	0
	1947-1960	90	6.4
	1960-1988	90	3.1
	1988-2001	+15	+1.1
	2001-2007	+15	+1.9
TOTAL		150	2.1
Transect 4	1938-1947	15	1.5
	1947-1960	90	6.4
	1960-1988	15	0.5
	1988-2007	0	0
TOTAL		120	1.7

Orthophoto | August 14, 2007

Skeena River at Usk 1,050 m³/s Zymoetz R. (Copper Cr.) above OK Cr. 113 m³/s

REFERENCED DRAWING NO.	REFERENCED DRAWING DESCRIPTION				
A	Dec. 10, 2008	Issued for discussion			
F - 37					

APPROXIMATE SCALE:	1:15,000
DATE:	December 10, 2008
DRAWN:	S. Allegretto
DESIGNED:	S. Allegretto
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V8G 1B3

SKEENA RIVER

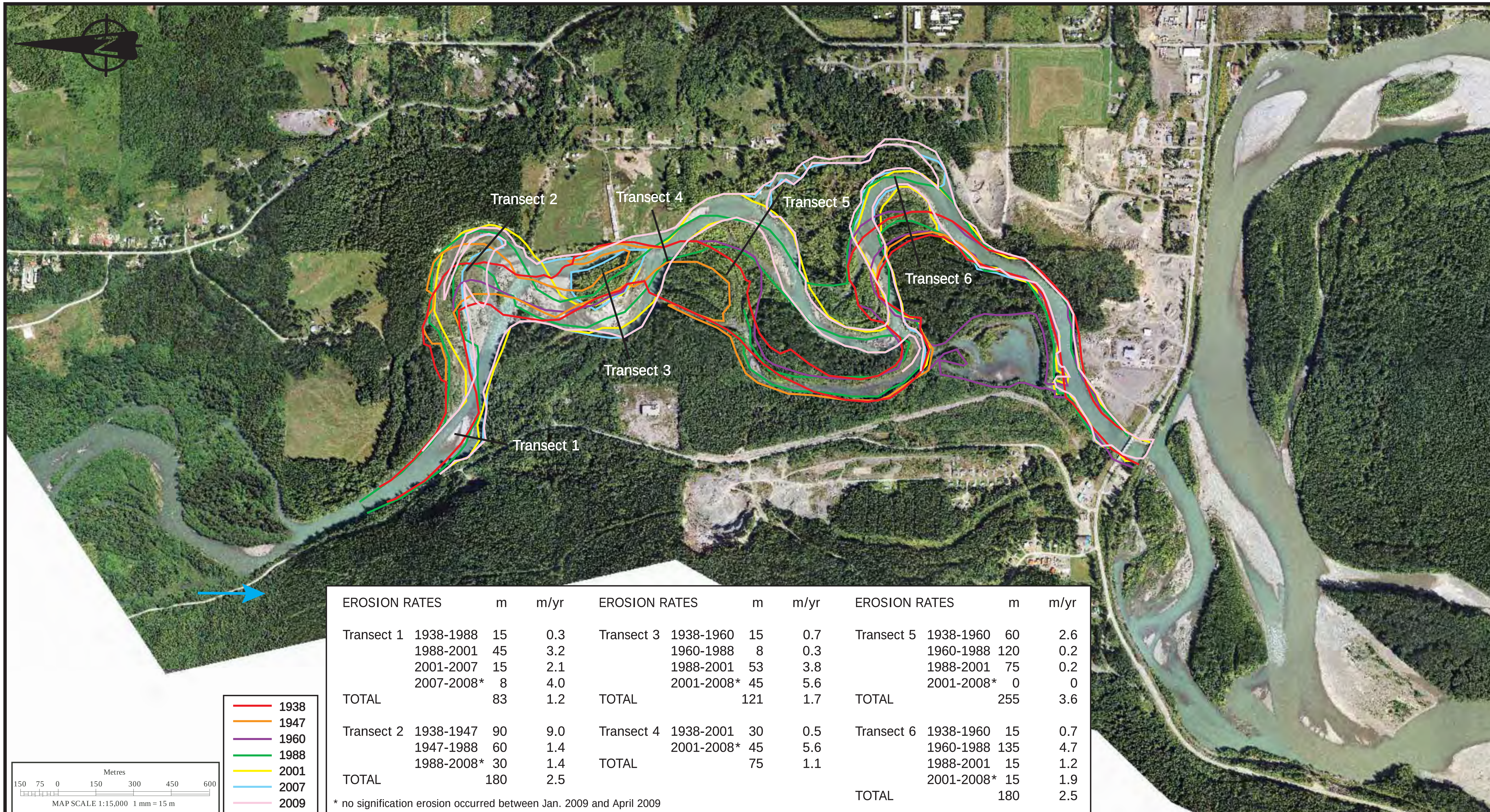
1938 to 2007 erosion rates on Skeena River downstream of Braun's Slough

FIGURE 6.2.5.1

PROJECT # 330

Km #

REV: A



EROSION RATES		m	m/yr
Transect 1	1938-1988	15	0.3
	1988-2001	45	3.2
	2001-2007	15	2.1
	2007-2008*	8	4.0
TOTAL		83	1.2
Transect 2	1938-1947	90	9.0
	1947-1988	60	1.4
	1988-2008*	30	1.4
TOTAL		180	2.5

EROSION RATES		m	m/yr
Transect 3	1938-1960	15	0.7
	1960-1988	8	0.3
	1988-2001	53	3.8
	2001-2008*	45	5.6
TOTAL		121	1.7
Transect 4	1938-2001	30	0.5
	2001-2008*	45	5.6
TOTAL		75	1.1

EROSION RATES		m	m/yr
Transect 5	1938-1960	60	2.6
	1960-1988	120	0.2
	1988-2001	75	0.2
	2001-2008*	0	0
TOTAL		255	3.6
Transect 6	1938-1960	15	0.7
	1960-1988	135	4.7
	1988-2001	15	1.2
	2001-2008*	15	1.9
TOTAL		180	2.5

* no signification erosion occurred between Jan. 2009 and April 2009

Orthophoto	August 14, 2007
Skeena River at Usk 1,050 m³/s	Zymoetz R. (Copper Cr.) above OK Cr. 113 m³/s
REFERENCED DRAWING NO.	REFERENCED DRAWING DESCRIPTION
A	Dec. 10, 2008 — Issued for discussion
F - 38	

APPROXIMATE SCALE: 1:15,000
DATE: December 10, 2008
DRAWN: S. Allegretto
DESIGNED: S. Allegretto
CHECKED: M. Miles
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KITSUMKALUM RIVER

1938-2009 EROSION RATES ON LOWER KITSUMKALUM RIVER

FIGURE 6.3.2.1

PROJECT # 330
Km #
REV: A

TABLES

TABLE 3.1: SURFICIAL GEOLOGY MAP LEGEND (from Clague, 1984)

SYMBOL		NAME	SURFICIAL DEPOSITS		LANDFORM		COMMENTS
			MATERIAL	THICKNESS (metres)	TOPOGRAPHY	SLOPES (degrees)	
X		man-made terrain	diamicton, rubble, gravel, sand	>2	plain	0-3	landfill
I		glacier ice	ice and snow	>20	rolling, sloping, crevassed	1-30	steep slopes occur in areas of ice falls
O	O	organic terrain	peat, muck	<15	plain	0-3	bogs, fens, swamps
	Ob	organic blanket	peat, muck	>1	takes form of underlying surface	0-10	
	* Ov	organic veneer	peat, muck	0.5-1	takes form of underlying surface	0-15	
C	Ch Cm	landslide	diamicton; blocks and rubble of local bedrock	>3	hummocky, rolling	0-35 0-15	includes landslides involving bedrock and landslides involving unconsolidated Quaternary sediments
	Cf	avalanche fan, debris-flow fan	gravel, diamicton	>5	fan	5-30	includes fans with entrenched channels and fans close to local base level
	Ca	talus	blocks and rubble of local bedrock	>2	apron, sheet	25-35	little or no vegetation on presently active slopes
	Cb	colluvial blanket	colluvium	>1	takes form of underlying surface	1-35	includes slopewash, minor talus, talus stabilized by vegetation
	Cv	colluvial veneer	colluvium	0.5-1	takes form of underlying surface	1-40	includes slopewash, minor talus, talus stabilized by vegetation
A	Af	alluvial fan	gravel and sand	>5	fan	1-20	includes terraced fan remnants (Aft), fans with entrenched channels, and fans close to local base level
	Ap	floodplain	gravel and sand	>2	plain with shallow channels	0-3	includes low benches subject to occasional flooding
	Ax	valley floor complex	alluvium and colluvium	>2	plain, fan, terraces, lower valley walls	0-35	includes Ap, At, Af, and Cf; differentiation of these units is not possible at scale of map
	Av	alluvial veneer	gravel and sand	0.5-1	takes form of underlying surface	0-20	
	At	river terrace	gravel and sand	>2	terrace and scarp	0-3	generally one to several metres of sand overlying gravel
	Ad	delta	gravel and sand	>5	terrace	0-5	marine delta
A^G	A^Gm A^Gh	kames, ice stagnation terrain	gravel and sand	>10	rolling, hummocky	0-15 0-30	unit deposited in contact with stagnant glacier ice; interbeds of diamicton commonly present in unit
	* A^Gr	esker	gravel and sand	>10	ridge	0-30	unit deposited beneath and within stagnant glacier ice
	A^Gb	glaciofluvial blanket	gravel and sand	>1	takes form of underlying surface	0-20	
	A^Gv	glaciofluvial veneer	gravel and sand	0.5-1	takes form of underlying surface	0-20	
	* A^Gf	glaciofluvial fan	gravel and sand	>10	fan	1-20	ice-contact feature, commonly with kettles
	A^Gt	kame terrace	gravel and sand	>10	terrace and scarp	0-3	ice-contact feature, commonly with kettles
	A^Gd	delta	gravel and sand	>10	terrace, fan	0-20	proglacial and ice-contact lacustrine and marine deltas
L^G	* L^Gm	rolling glaciolacustrine terrain	silt, clay, minor sand (locally with dropstones)	>2	rolling	0-10	ice-marginal depositional environment; relict lake floor
	* L^Gt	glaciolacustrine terrace	silt, clay, minor sand (locally with dropstones)	>2	terrace	0-3	
	* L^Gb	glaciolacustrine blanket	silt, clay, minor sand (locally with dropstones)	>1	takes form of underlying surface	0-10	
	* L^Gv	glaciolacustrine veneer	silt, clay, minor sand (locally with dropstones)	0.5-1	takes form of underlying surface	0-15	
W^G	W^Gm	rolling glaciomarine terrain	silt, clay (locally with dropstones)	>2	rolling	0-10	proglacial depositional environment; relict seafloor
	* W^Gp	glaciomarine plain	silt, clay (locally with dropstones)	>2	plain	0-2	proglacial depositional environment
	W^Gb	glaciomarine blanket	silt, clay (locally with dropstones)	>1	takes form of underlying surface	0-15	
	W^Gv	glaciomarine veneer	silt, clay (locally with dropstones)	0.5-1	takes form of underlying surface	0-20	
M	* Mm	ground moraine	till	>2	rolling	0-15	constructional morainic topography (not controlled by form of underlying unit)
	* Mb	till blanket	till	>1	takes form of underlying surface	0-20	
	* Mv	till veneer	till	0.5-1	takes form of underlying surface	0-25	
D	Dr Dm	drift	till, gravel, and colluvium	>2	ridged, rolling	0-15	constructional drift topography (not controlled by form of underlying unit)
	Db	drift blanket	till, gravel, and colluvium	>1	takes form of underlying surface	0-25	
	Dv	drift veneer	till, gravel, and colluvium	0.5-1	takes form of underlying surface	0-30	
Us		terrace scarps, river banks	all types of unconsolidated Quaternary sediments	>20 (scarp height)	steep erosional slopes	>30	unit consists of several stratigraphic units of contrasting lithologies, in places with a blanket or veneer of colluvium
R	R	bedrock			rolling, sloping, hummocky, ridged	0-60	thin (<0.5 m) or no cover of unconsolidated Quaternary sediments
	* Rs	canyon walls, river banks			steep slopes	>45	Rs used mainly in conjunction with Us for canyon walls

* Does not occur as a dominant unit on this sheet

TABLE 4.1: SUMMARY OF AVAILABLE DATA AT SELECTED STREAM GAUGING STATIONS IN THE VICINITY OF SKEENA RIVER

STATION NUMBER 08...	STATION NAME	BASIN AREA (km2)	PERIOD OF RECORD	TYPE OF RECORD	TYPE OF FLOW	PARAMETER	YEARS OF RECORD
EG006	KITSUMKALUM RIVER NEAR TERRACE	2,180	1929 - 1952	1928-29 RM; 30-31 RC; 32-34 RS; 35-35 RC; 36-47 RS; 48-50 RC; 51-52 RS	NAT	Daily	22
						Instantaneous	18
EF001	SKEENA RIVER AT USK	42,200	1928-2008	1928-31 MC; 36-38 MS; 39-49 MC; 50-96 RC; 97-2009 RC	NAT	Daily	74
						Instantaneous	54
EF003	ZYMOETZ RIVER NEAR TERRACE	3,080	1952-1964	1951-M#; 52-64 MC	NAT	Daily	13
						Instantaneous	n/a
EF005	ZYMOETZ RIVER ABOVE O.K. CREEK	2,908	1963 - 2009	1963-2009 RC	NAT	Daily	45
						Instantaneous	45

Inland Waters Directorate, HYDAT CDRom 2000 & http://scitech.pyr.ec.gc.ca/waterweb/formNav.asp

NOTES:

*	stage only	REV	Data to 19__ have been reviewed	(i)	Data not published
#	miscellaneous measurements	NAT	Natural Flow	1	Daily Flows
M	manual gauge	REG	Regulated Flow with date of regulation if known	2	Instantaneous Flows
R	recording gauge			7	Satellite D.C.P.
S	seasonal operation	NA	Not Available	10	Minimum Flows
C	continuous operation				
	numbers refer to years (e.g. 09 is 1909)				

TABLE 4.3.1.1: FREQUENCY ANALYSIS OF ANNUAL MAXIMUM DAILY DISCHARGE - SKEENA RIVER AT USK, 1928 - 2008

SKEENA RIVER AT USK
MAXIMUM DAILY DISCHARGE, 1928 to 2008 Skew: 1.01

Frequency Distribution	Estimate of Specified Recurrence Interval Discharge in m3/second							Goodness of fit 1	Goodness of fit 2 (See NOTES below)
	2 years	5 years	10 years	25 years	50 years	100 years	200 years	1	2
Log Normal (Maximum Likelihood)	4,620	5,720	6,450	7,350	8,010	8,680	9,340	.0594	.0195
Gumbel (Maximum Likelihood)	4,620	5,710	6,430	7,350	8,020	8,700	9,370	.0607	.0185
Pearson Type III (By Moments)	4,610	5,740	6,460	7,320	7,930	8,520	9,090	.0591	.0198
Log Pearson Type III (By Moments)	4,630	5,720	6,420	7,300	7,950	8,590	9,240	.0550	.0172
Average	4,620	5,720	6,440	7,330	7,980	8,620	9,260		
Adopted Value	4,630	5,720	6,420	7,300	7,950	8,590	9,240		

95% Confidence Limits for Specified Recurrence Interval in m3/second

Frequency Distribution	2 years		5 years		10 years		25 years		50 years		100 years		200 years	
	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper
Log Normal (Maximum Likelihood)	4360	4890	5330	6150	5920	7030	6630	8170	7130	9030	7620	9900	8110	10800
Gumbel (Maximum Likelihood)	4350	4880	5310	6110	5910	6950	6680	8010	7240	8810	7790	9600	8350	10400
Pearson Type III (By Moments)	4350	4880	5320	6170	5890	7020	6580	8050	7070	8790	7530	9500	7980	10200
Log Pearson Type III (By Moments)	4380	4900	5330	6140	5910	6980	6600	8070	7100	8890	7590	9720	8070	10600
Average	4360	4890	5320	6140	5910	6990	6620	8080	7130	8880	7630	9680	8130	10500
Adopted Value	4350	4900	5310	6170	5890	7030	6580	8170	7070	9030	7530	9900	7980	10800

1 Modified Kolmogorov-Smirnov goodness of fit test based on unbiased plotting positions for all points.

2 Modified Kolmogorov-Smirnov goodness of fit test based on unbiased plotting positions for 5 largest points.

Analytical procedures used to prepare this summary were made available by the River Forecast Centre, Water Management Branch, B.C. Ministry of Environment. This assistance is gratefully acknowledged.

TABLE 4.3.1.2: FREQUENCY ANALYSIS OF ANNUAL MAXIMUM INSTANTANEOUS DISCHARGE - SKEENA RIVER AT USK, 1928 - 2008

SKEENA RIVER AT USK
MAXIMUM INSTANTANEOUS DISCHARGE, 1953 TO 2008 — *Skew: .491*

Frequency Distribution	Estimate of Specified Recurrence Interval Discharge in m3/second							Goodness of fit (See NOTES below)	
	2 years	5 years	10 years	25 years	50 years	100 years	200 years	1	2
Log Normal (Maximum Likelihood)	5,020	6,000	6,570	7,240	7,710	8,150	8,580	.0563	.0217
Gumbel (Maximum Likelihood)	4,950	6,020	6,730	7,620	8,290	8,950	9,600	.0809	.0312
Pearson Type III (By Moments)	5,030	6,010	6,570	7,210	7,640	8,050	8,440	.0519	.0239
Log Pearson Type III (By Moments)	5,030	6,000	6,570	7,240	7,700	8,130	8,540	.0554	.0221
Average	5,010	6,010	6,610	7,330	7,830	8,320	8,790		
Adopted Value	5,030	6,000	6,570	7,240	7,700	8,130	8,540		

95% Confidence Limits for Specified Recurrence Interval in m3/second

Frequency Distribution	2 years		5 years		10 years		25 years		50 years		100 years		200 years	
	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper
Log Normal (Maximum Likelihood)	4740	5320	5610	6410	6090	7090	6620	7920	6980	8510	7320	9070	7640	9620
Gumbel (Maximum Likelihood)	4650	5250	5560	6490	6130	7320	6850	8400	7380	9190	7910	9990	8430	10800
Pearson Type III (By Moments)	4740	5330	5610	6410	6080	7060	6600	7810	6960	8330	7290	8810	7600	9280
Log Pearson Type III (By Moments)	4740	5330	5600	6430	6070	7130	6590	7950	6940	8540	7260	9100	7570	9650
Average	4720	5310	5590	6430	6090	7150	6670	8020	7060	8640	7440	9240	7810	9830
Adopted Value	4650	5330	5560	6490	6070	7320	6590	8400	6940	9190	7260	9990	7570	10800

1 Modified Kolmogorov-Smirnov goodness of fit test based on unbiased plotting positions for all points.

2 Modified Kolmogorov-Smirnov goodness of fit test based on unbiased plotting positions for 5 largest points.

Analytical procedures used to prepare this summary were made available by the River Forecast Centre, Water Management Branch, B.C. Ministry of Environment. This assistance is gratefully acknowledged.

TABLE 4.3.1.3: FREQUENCY ANALYSIS OF ANNUAL MAXIMUM INSTANTANEOUS (plus generated) DISCHARGE - SKEENA RIVER AT USK, 1929 - 2008

SKEENA RIVER AT USK (including generated data)
MAXIMUM INSTANTANEOUS DISCHARGE (1928 to 2008) *Skew: .979*

Frequency Distribution	Estimate of Specified Recurrence Interval Discharge in m3/second							Goodness of fit (See NOTES below)	
	2 years	5 years	10 years	25 years	50 years	100 years	200 years	1	2
Log Normal (Maximum Likelihood)	4,740	5,870	6,600	7,510	8,180	8,840	9,510	.0643	.0201
Gumbel (Maximum Likelihood)	4,740	5,860	6,600	7,540	8,230	8,920	9,610	.0677	.0204
Pearson Type III (By Moments)	4,740	5,890	6,610	7,480	8,090	8,690	9,260	.0625	.0203
Log Pearson Type III (By Moments)	4,760	5,870	6,580	7,460	8,110	8,750	9,400	.0609	.0178
Average	4,740	5,870	6,600	7,500	8,150	8,800	9,440		
Adopted Value	4,760	5,870	6,580	7,460	8,110	8,750	9,400		

95% Confidence Limits for Specified Recurrence Interval in m3/second

Frequency Distribution	2 years		5 years		10 years		25 years		50 years		100 years		200 years	
	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper
Log Normal (Maximum Likelihood)	4480	5020	5470	6300	6070	7190	6780	8330	7290	9200	7790	10100	8270	11000
Gumbel (Maximum Likelihood)	4470	5000	5440	6270	6070	7130	6850	8220	7430	9040	8000	9850	8560	10700
Pearson Type III (By Moments)	4470	5010	5450	6320	6040	7180	6740	8220	7230	8960	7700	9680	8150	10400
Log Pearson Type III (By Moments)	4500	5030	5470	6290	6060	7140	6760	8240	7260	9060	7750	9890	8230	10700
Average	4480	5020	5460	6300	6060	7160	6780	8250	7300	9060	7810	9870	8310	10700
Adopted Value	4470	5030	5440	6320	6040	7190	6740	8330	7230	9200	7700	10100	8150	11000

1 Modified Kolmogorov-Smirnov goodness of fit test based on unbiased plotting positions for all points.

2 Modified Kolmogorov-Smirnov goodness of fit test based on unbiased plotting positions for 5 largest points.

Analytical procedures used to prepare this summary were made available by the River Forecast Centre, Water Management Branch, B.C. Ministry of Environment. This assistance is gratefully acknowledged.

TABLE 4.3.1.4: FREQUENCY ANALYSIS OF ANNUAL MAXIMUM DAILY DISCHARGE - SKEENA RIVER AT USK, APRIL 1 TO AUGUST 31, 1928 - 2008

SKEENA RIVER AT USK
Maximum Daily Discharge April 1 to August 31, 1928 to 2008 *Skew: 1.02*

Frequency Distribution	Estimate of Specified Recurrence Interval Discharge in m3/second							Goodness of fit 1	Goodness of fit 2 (See NOTES below)
	2 years	5 years	10 years	25 years	50 years	100 years	200 years	1	2
Log Normal (Maximum Likelihood)	4,560	5,680	6,420	7,370	8,070	8,770	9,490	.0637	.0202
Gumbel (Maximum Likelihood)	4,570	5,660	6,380	7,290	7,960	8,630	9,300	.0612	.0160
Pearson Type III (By Moments)	4,570	5,710	6,430	7,300	7,920	8,510	9,090	.0588	.0193
Log Pearson Type III (By Moments)	4,580	5,680	6,390	7,290	7,960	8,620	9,300	.0571	.0168
Average	4,570	5,680	6,410	7,310	7,980	8,640	9,290		
Adopted Value	4,580	5,680	6,390	7,290	7,960	8,620	9,300		

95% Confidence Limits for Specified Recurrence Interval in m3/second

Frequency Distribution	2 years		5 years		10 years		25 years		50 years		100 years		200 years	
	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper
Log Normal (Maximum Likelihood)	4320	4830	5290	6120	5890	7020	6620	8220	7150	9140	7670	10100	8190	11000
Gumbel (Maximum Likelihood)	4320	4830	5270	6060	5870	6890	6630	7940	7190	8730	7750	9520	8300	10300
Pearson Type III (By Moments)	4310	4830	5280	6130	5870	6990	6560	8030	7050	8780	7530	9500	7980	10200
Log Pearson Type III (By Moments)	4340	4850	5290	6100	5880	6960	6580	8070	7100	8920	7600	9780	8100	10700
Average	4320	4840	5280	6100	5880	6960	6600	8070	7120	8890	7640	9720	8140	10600
Adopted Value	4310	4850	5270	6130	5870	7020	6560	8220	7050	9140	7530	10100	7980	11000

[1] *Modified Kolmogorov-Smirnov goodness of fit test based on unbiased plotting positions for all points.*

[2] *Modified Kolmogorov-Smirnov goodness of fit test based on unbiased plotting positions for 5 largest points.*

Analytical procedures used to prepare this summary were made available by the River Forecast Centre, Water Management Branch, B.C. Ministry of Environment. This assistance is gratefully acknowledged.

TABLE 4.3.1.5: FREQUENCY ANALYSIS OF ANNUAL MAXIMUM DAILY DISCHARGE - SKEENA RIVER AT USK, SEPTEMBER 1 TO MARCH 31, 1928 - 2008

SKEENA RIVER AT USK
Maximum Daily Discharge September 1 to March 31, 1928 to 2008 (prelim.) *Skew: 1.81*

Frequency Distribution	Estimate of Specified Recurrence Interval Discharge in m3/second							Goodness of fit See NOTES below	
	2 years	5 years	10 years	25 years	50 years	100 years	200 years	1	2
Log Normal (Maximum Likelihood)	1,720	2,510	3,070	3,830	4,430	5,040	5,690	.0790	.0176
Gumbel (Maximum Likelihood)	1,770	2,470	2,940	3,530	3,960	4,400	4,830	.0954	.0332
Pearson Type III (By Moments)	1,660	2,520	3,150	3,960	4,580	5,180	5,790	.0952	.0121
Log Pearson Type III (By Moments)	1,710	2,490	3,070	3,870	4,520	5,210	5,950	.0734	.0159
Average	1,720	2,500	3,060	3,800	4,370	4,960	5,560		
Adopted Value	1,710	2,490	3,070	3,870	4,520	5,210	5,950		

95% Confidence Limits for Specified Recurrence Interval in m3/second

Frequency Distribution	2 years		5 years		10 years		25 years		50 years		100 years		200 years	
	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper
Log Normal (Maximum Likelihood)	1560	1900	2220	2830	2670	3550	3230	4550	3660	5360	4090	6230	4530	7160
Gumbel (Maximum Likelihood)	1600	1930	2220	2730	2610	3260	3110	3950	3470	4460	3830	4970	4190	5470
Pearson Type III (By Moments)	1490	1830	2160	2880	2610	3680	3190	4730	3630	5530	4050	6310	4480	7100
Log Pearson Type III (By Moments)	1550	1890	2200	2820	2650	3560	3240	4630	3700	5520	4170	6500	4670	7570
Average	1550	1890	2200	2810	2640	3510	3190	4470	3610	5220	4040	6000	4470	6830
Adopted Value	1490	1930	2160	2880	2610	3680	3110	4730	3470	5530	3830	6500	4190	7570

[1] Modified Kolmogorov-Smirnov goodness of fit test based on unbiased plotting positions for all points.
[2] Modified Kolmogorov-Smirnov goodness of fit test based on unbiased plotting positions for 5 largest points.

Analytical procedures used to prepare this summary were made available by the River Forecast Centre, Water Management Branch, B.C. Ministry of Environment. This assistance is gratefully acknowledged.

TABLE 4.3.2.1: FREQUENCY ANALYSIS OF ANNUAL MAXIMUM DAILY DISCHARGE - ZYMOETZ RIVER NEAR TERRACE, 1952 - 1964

ZYMOETZ RIVER NEAR TERRACE
MAXIMUM DAILY DISCHARGE, 1952 TO 1964 — *Skew: -.770*

Frequency Distribution	Estimate of Specified Recurrence Interval Discharge in m3/second							Goodness of fit (See NOTES below)	
	2 years	5 years	10 years	25 years	50 years	100 years	200 years	1	2
Log Normal (Maximum Likelihood)	817	939	990	1,040	1,060	1,090	1,100	.0458	.0437
Gumbel (Maximum Likelihood)	769	980	1,120	1,300	1,430	1,560	1,690	.153	.0963
Pearson Type III (By Moments)	813	941	996	1,050	1,080	1,100	1,120	.0555	.0404
Log Pearson Type III (By Moments)	816	951	1,000	1,040	1,060	1,070	1,080	.0586	.0448
Average	804	953	1,030	1,110	1,160	1,200	1,250		
Adopted Value	813	941	996	1,050	1,080	1,100	1,120		

95% Confidence Limits for Specified Recurrence Interval in m3/second

Frequency Distribution	2 years		5 years		10 years		25 years		50 years		100 years		200 years	
	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper
Log Normal (Maximum Likelihood)	705	908	839	1020	888	1070	932	1110	957	1140	977	1160	994	1180
Gumbel (Maximum Likelihood)	637	901	777	1180	859	1380	959	1630	1030	1820	1100	2010	1170	2200
Pearson Type III (By Moments)	701	925	784	1100	816	1180	844	1250	859	1290	872	1330	882	1350
Log Pearson Type III (By Moments)	679	979	726	1250	741	1360	752	1450	757	1490	760	1520	762	1540
Average	681	928	782	1140	826	1250	872	1360	901	1440	928	1500	953	1570
Adopted Value	637	979	726	1250	741	1380	752	1630	757	1820	760	2010	762	2200

1 Modified Kolmogorov-Smirnov goodness of fit test based on unbiased plotting positions for all points.
2 Modified Kolmogorov-Smirnov goodness of fit test based on unbiased plotting positions for 5 largest points.

Analytical procedures used to prepare this summary were made available by the River Forecast Centre, Water Management Branch, B.C. Ministry of Environment. This assistance is gratefully acknowledged.

TABLE 4.3.2.2: FREQUENCY ANALYSIS OF ANNUAL MAXIMUM DAILY DISCHARGE - ZYMOETZ RIVER ABOVE OK CREEK, 1963 - 2008

ZYMOETZ RIVER ABOVE OK CREEK
MAXIMUM DAILY DISCHARGE, 1963 TO 2008 Skew: 2.02

Frequency Distribution	Estimate of Specified Recurrence Interval Discharge in m3/second							Goodness of fit	
	2 years	5 years	10 years	25 years	50 years	100 years	200 years	1	2
								See NOTES below	
Log Normal (Maximum Likelihood)	600	875	1,090	1,400	1,660	1,950	2,250	.119	.0447
Gumbel (Maximum Likelihood)	627	858	1,010	1,200	1,350	1,490	1,630	.170	.0741
Pearson Type III (By Moments)	579	920	1,180	1,520	1,780	2,040	2,300	.166	.0252
Log Pearson Type III (By Moments)	581	859	1,110	1,510	1,880	2,330	2,880	.0912	.0363
Average	597	878	1,100	1,410	1,670	1,950	2,270		
Adopted Value	579	920	1,180	1,520	1,780	2,040	2,300		

95% Confidence Limits for Specified Recurrence Interval in m3/second

Frequency Distribution	2 years		5 years		10 years		25 years		50 years		100 years		200 years	
	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper
Log Normal (Maximum Likelihood)	533	681	742	1040	890	1360	1090	1840	1240	2260	1400	2740	1570	3280
Gumbel (Maximum Likelihood)	556	699	748	968	869	1150	1020	1390	1130	1560	1240	1740	1350	1910
Pearson Type III (By Moments)	495	664	727	1110	882	1480	1080	1960	1230	2340	1380	2710	1530	3080
Log Pearson Type III (By Moments)	518	652	707	1040	851	1440	1060	2140	1250	2840	1450	3750	1680	4910
Average	525	674	731	1040	873	1360	1060	1830	1210	2250	1370	2730	1530	3300
Adopted Value	495	699	707	1110	851	1480	1020	2140	1130	2840	1240	3750	1350	4910

1 Modified Kolmogorov-Smirnov goodness of fit test based on unbiased plotting positions for all points.

2 Modified Kolmogorov-Smirnov goodness of fit test based on unbiased plotting positions for 5 largest points.

Analytical procedures used to prepare this summary were made available by the River Forecast Centre, Water Management Branch, B.C. Ministry of Environment. This assistance is gratefully acknowledged.

TABLE 4.3.2.3: FREQUENCY ANALYSIS OF ANNUAL MAXIMUM INSTANTANEOUS DISCHARGE - ZYMOETZ RIVER ABOVE OK CREEK, 1963 - 2008

ZYMOETZ RIVER ABOVE OK CREEK
MAXIMUM INSTANT DISCHARGE, 1963 to 2008 — *Skew: 2.12*

Frequency Distribution	Estimate of Specified Recurrence Interval Discharge in m3/second							Goodness of fit	
	2 years	5 years	10 years	25 years	50 years	100 years	200 years	1	2 (See NOTES below)
Log Normal (Maximum Likelihood)	726	1,170	1,550	2,140	2,670	3,260	3,940	.121	.0580
Gumbel (Maximum Likelihood)	797	1,170	1,420	1,730	1,960	2,190	2,420	.192	.0878
Pearson Type III (By Moments)	708	1,310	1,770	2,380	2,850	3,330	3,800	.224	.0426
Log Pearson Type III (By Moments)	700	1,140	1,580	2,360	3,150	4,170	5,500	.101	.0482
Average	733	1,200	1,580	2,150	2,660	3,240	3,910		
Adopted Value	708	1,310	1,770	2,380	2,850	3,330	3,800		

95% Confidence Limits for Specified Recurrence Interval in m3/second

Frequency Distribution	2 years		5 years		10 years		25 years		50 years		100 years		200 years	
	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper
Log Normal (Maximum Likelihood)	630	850	946	1460	1190	2050	1540	3030	1830	3960	2140	5070	2470	6380
Gumbel (Maximum Likelihood)	681	914	992	1350	1190	1650	1430	2030	1610	2310	1790	2590	1970	2870
Pearson Type III (By Moments)	563	854	963	1650	1230	2300	1580	3190	1840	3860	2110	4540	2370	5230
Log Pearson Type III (By Moments)	608	806	890	1470	1120	2220	1490	3730	1820	5450	2210	7880	2680	11300
Average	620	856	948	1480	1180	2050	1510	3000	1780	3900	2060	5020	2370	6440
Adopted Value	563	914	890	1650	1120	2300	1430	3730	1610	5450	1790	7880	1970	11300

1 Modified Kolmogorov-Smirnov goodness of fit test based on unbiased plotting positions for all points.
2 Modified Kolmogorov-Smirnov goodness of fit test based on unbiased plotting positions for 5 largest points.

Analytical procedures used to prepare this summary were made available by the River Forecast Centre, Water Management Branch, B.C. Ministry of Environment. This assistance is gratefully acknowledged.

TABLE 4.3.2.4: FREQUENCY ANALYSIS OF ANNUAL MAXIMUM DAILY DISCHARGE - ZYMOETZ RIVER NEAR TERRACE AND ZYMOETZ RIVER ABOVE OK CREEK, 1952 - 1964

ZYMOETZ RIVER NEAR TERRACE & ABOVE OK CREEK
Maximum Daily Discharge 1952 to 2008 — *Skew: 1.93*

Frequency Distribution	Estimate of Specified Recurrence Interval Discharge in m3/second							Goodness of fit	
	2 years	5 years	10 years	25 years	50 years	100 years	200 years	1	2 (See NOTES below)
Log Normal (Maximum Likelihood)	608	889	1,140	1,550	1,920	2,350	2,850	.0805	.00839
Gumbel (Maximum Likelihood)	661	887	1,040	1,230	1,370	1,510	1,640	.130	.0528
Pearson Type III (By Moments)	621	932	1,160	1,470	1,700	1,930	2,160	.0912	.0232
Log Pearson Type III (By Moments)	625	892	1,120	1,460	1,760	2,120	2,530	.0665	.0238
Average	629	900	1,110	1,430	1,690	1,980	2,300		
Adopted Value	625	892	1,120	1,460	1,760	2,120	2,530		

95% Confidence Limits for Specified Recurrence Interval in m3/second

Frequency Distribution	2 years		5 years		10 years		25 years		50 years		100 years		200 years	
	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper
Log Normal (Maximum Likelihood)	556	675	761	1060	929	1440	1180	2100	1390	2730	1620	3510	1880	4440
Gumbel (Maximum Likelihood)	598	723	791	982	914	1160	1070	1380	1180	1550	1290	1720	1400	1890
Pearson Type III (By Moments)	551	690	778	1090	931	1400	1130	1810	1270	2120	1420	2440	1570	2750
Log Pearson Type III (By Moments)	568	688	765	1040	913	1360	1120	1890	1300	2390	1500	3000	1710	3740
Average	568	694	774	1040	922	1340	1120	1800	1290	2200	1460	2670	1640	3200
Adopted Value	551	723	761	1090	913	1440	1070	2100	1180	2730	1290	3510	1400	4440

1 Modified Kolmogorov-Smirnov goodness of fit test based on unbiased plotting positions for all points.

2 Modified Kolmogorov-Smirnov goodness of fit test based on unbiased plotting positions for 5 largest points.

Analytical procedures used to prepare this summary were made available by the River Forecast Centre, Water Management Branch, B.C. Ministry of Environment. This assistance is gratefully acknowledged.

TABLE 4.3.2.5: FREQUENCY ANALYSIS OF ANNUAL MAXIMUM DAILY DISCHARGE - ZYMOETZ RIVER NEAR TERRACE, APRIL 1 TO AUGUST 31, 1952 - 1964

ZYMOETZ RIVER NEAR TERRACE
Maximum Daily Discharge April 1 to August 31, 1952 to 1964 — *Skew: .206*

Frequency Distribution	Estimate of Specified Recurrence Interval Discharge in m3/second							Goodness of fit (See NOTES below)	
	2 years	5 years	10 years	25 years	50 years	100 years	200 years	1	2
Log Normal (Maximum Likelihood)	672	817	898	988	1,050	1,110	1,160	.0493	.0493
Gumbel (Maximum Likelihood)	655	818	925	1,060	1,160	1,260	1,360	.0713	.0298
Pearson Type III (By Moments)	675	817	895	980	1,040	1,090	1,140	.0527	.0527
Log Pearson Type III (By Moments)	671	819	902	994	1,050	1,110	1,160	.0480	.0460
Average	668	818	905	1,010	1,080	1,140	1,210		
Adopted Value	671	819	902	994	1,050	1,110	1,160		

95% Confidence Limits for Specified Recurrence Interval in m3/second

Frequency Distribution	2 years		5 years		10 years		25 years		50 years		100 years		200 years	
	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper
Log Normal (Maximum Likelihood)	576	775	695	948	751	1060	807	1190	843	1280	875	1370	905	1450
Gumbel (Maximum Likelihood)	554	757	662	974	725	1130	802	1320	857	1470	912	1610	966	1760
Pearson Type III (By Moments)	575	774	694	940	749	1040	805	1160	841	1230	873	1300	903	1370
Log Pearson Type III (By Moments)	576	782	673	997	718	1130	765	1290	794	1400	819	1500	842	1600
Average	570	772	681	965	736	1090	795	1240	834	1350	870	1450	904	1550
Adopted Value	554	782	662	997	718	1130	765	1320	794	1470	819	1610	842	1760

1 *Modified Kolmogorov-Smirnov goodness of fit test based on unbiased plotting positions for all points.*

2 *Modified Kolmogorov-Smirnov goodness of fit test based on unbiased plotting positions for 5 largest points.*

Analytical procedures used to prepare this summary were made available by the River Forecast Centre, Water Management Branch, B.C. Ministry of Environment. This assistance is gratefully acknowledged.

TABLE 4.3.2.6: FREQUENCY ANALYSIS OF ANNUAL MAXIMUM DAILY DISCHARGE - ZYMOETZ RIVER NEAR TERRACE, SEPTEMBER 1 TO MARCH 31, 1952-1964

ZYMOETZ RIVER NEAR TERRACE
Maximum Daily Discharge September 1 to March 31, 1952 to 1964 *Skew: -.334*

Frequency Distribution	Estimate of Specified Recurrence Interval Discharge in m3/second							Goodness of fit (See NOTES below)	
	2 years	5 years	10 years	25 years	50 years	100 years	200 years	1	2
Log Normal (Maximum Likelihood)	672	883	967	1,040	1,080	1,120	1,140	.103	.103
Gumbel (Maximum Likelihood)	566	886	1,100	1,360	1,560	1,760	1,960	.144	.125
Pearson Type III (By Moments)	631	877	996	1,120	1,190	1,250	1,310	.120	.120
Log Pearson Type III (By Moments)	579	922	1,110	1,310	1,420	1,520	1,600	.115	.0981
Average	612	892	1,040	1,210	1,310	1,410	1,500		
Adopted Value	579	922	1,110	1,310	1,420	1,520	1,600		

95% Confidence Limits for Specified Recurrence Interval in m3/second

Frequency Distribution	2 years		5 years		10 years		25 years		50 years		100 years		200 years	
	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper
Log Normal (Maximum Likelihood)	467	831	712	1010	798	1090	872	1160	913	1190	946	1220	974	1240
Gumbel (Maximum Likelihood)	366	766	579	1190	704	1490	854	1870	964	2160	1070	2450	1180	2730
Pearson Type III (By Moments)	444	819	636	1120	717	1270	795	1440	841	1540	880	1630	915	1710
Log Pearson Type III (By Moments)	370	904	483	1760	532	2330	576	2970	600	3370	619	3730	635	4030
Average	412	830	602	1270	688	1540	774	1860	829	2070	879	2260	925	2430
Adopted Value	366	904	483	1760	532	2330	576	2970	600	3370	619	3730	635	4030

1 Modified Kolmogorov-Smirnov goodness of fit test based on unbiased plotting positions for all points.

2 Modified Kolmogorov-Smirnov goodness of fit test based on unbiased plotting positions for 5 largest points.

Analytical procedures used to prepare this summary were made available by the River Forecast Centre, Water Management Branch, B.C. Ministry of Environment. This assistance is gratefully acknowledged.

TABLE 4.3.2.7: FREQUENCY ANALYSIS OF ANNUAL MAXIMUM DAILY DISCHARGE - ZYMOETZ RIVER ABOVE OK CREEK, APRIL 1 TO AUGUST 31, 1964-2008

ZYMOETZ RIVER ABOVE OK CREEK
Maximum Daily Discharge April 1 to August 31, 1964 to 2008 — *Skew: .933*

Frequency Distribution	Estimate of Specified Recurrence Interval Discharge in m3/second							Goodness of fit	
	2 years	5 years	10 years	25 years	50 years	100 years	200 years	1	2 (See NOTES below)
Log Normal (Maximum Likelihood)	498	605	679	775	849	924	1,000	.0923	.0243
Gumbel (Maximum Likelihood)	502	601	667	750	811	872	933	.110	.0335
Pearson Type III (By Moments)	504	611	677	757	814	868	920	.101	.0323
Log Pearson Type III (By Moments)	502	606	675	763	829	897	965	.103	.0289
Average	501	606	674	761	826	890	955		
Adopted Value	502	606	675	763	829	897	965		

95% Confidence Limits for Specified Recurrence Interval in m3/second

Frequency Distribution	2 years		5 years		10 years		25 years		50 years		100 years		200 years	
	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper
Log Normal (Maximum Likelihood)	469	532	556	663	610	761	677	896	726	1000	775	1120	823	1240
Gumbel (Maximum Likelihood)	471	532	553	648	606	727	671	828	719	904	766	979	813	1050
Pearson Type III (By Moments)	471	537	559	662	610	745	670	845	712	916	751	984	790	1050
Log Pearson Type III (By Moments)	471	534	556	659	608	748	672	866	718	958	763	1050	809	1150
Average	470	534	556	658	609	745	672	859	719	945	764	1030	809	1120
Adopted Value	469	537	553	663	606	761	670	896	712	1000	751	1120	790	1240

1 Modified Kolmogorov-Smirnov goodness of fit test based on unbiased plotting positions for all points.

2 Modified Kolmogorov-Smirnov goodness of fit test based on unbiased plotting positions for 5 largest points.

Analytical procedures used to prepare this summary were made available by the River Forecast Centre, Water Management Branch, B.C. Ministry of Environment. This assistance is gratefully acknowledged.

TABLE 4.3.2.8: FREQUENCY ANALYSIS OF ANNUAL MAXIMUM DAILY DISCHARGE - ZYMOETZ RIVER ABOVE OK CREEK, SEPTEMBER 1 TO MARCH 31, 1964-2008

ZYMOETZ RIVER ABOVE OK CREEK
Maximum Daily Discharge September 1 to March 31, 1964 to 2008 *Skew: 1.79*

Frequency Distribution	Estimate of Specified Recurrence Interval Discharge in m3/second							Goodness of fit	
	2 years	5 years	10 years	25 years	50 years	100 years	200 years	1	2 (See NOTES below)
Log Normal (Maximum Likelihood)	416	776	1,100	1,600	2,050	2,570	3,160	.0902	.0317
Gumbel (Maximum Likelihood)	477	766	958	1,200	1,380	1,560	1,730	.146	.0724
Pearson Type III (By Moments)	434	841	1,140	1,520	1,810	2,090	2,380	.129	.0606
Log Pearson Type III (By Moments)	421	764	1,070	1,560	2,020	2,560	3,200	.0892	.0357
Average	437	787	1,070	1,470	1,810	2,200	2,620		
Adopted Value	421	764	1,070	1,560	2,020	2,560	3,200		

95% Confidence Limits for Specified Recurrence Interval in m3/second

Frequency Distribution	2 years		5 years		10 years		25 years		50 years		100 years		200 years	
	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper
Log Normal (Maximum Likelihood)	339	516	595	1020	797	1520	1090	2370	1330	3180	1600	4160	1880	5340
Gumbel (Maximum Likelihood)	388	567	628	904	781	1130	970	1430	1110	1650	1250	1870	1380	2080
Pearson Type III (By Moments)	329	539	618	1060	805	1470	1040	2000	1220	2400	1390	2790	1570	3190
Log Pearson Type III (By Moments)	344	514	587	995	778	1470	1060	2310	1300	3140	1570	4180	1880	5470
Average	350	534	607	996	790	1400	1040	2030	1240	2590	1450	3250	1680	4020
Adopted Value	329	567	587	1060	778	1520	970	2370	1110	3180	1250	4180	1380	5470

1 Modified Kolmogorov-Smirnov goodness of fit test based on unbiased plotting positions for all points.

2 Modified Kolmogorov-Smirnov goodness of fit test based on unbiased plotting positions for 5 largest points.

Analytical procedures used to prepare this summary were made available by the River Forecast Centre, Water Management Branch, B.C. Ministry of Environment. This assistance is gratefully acknowledged.

TABLE 4.3.2.9: FREQUENCY ANALYSIS OF ANNUAL MAXIMUM DAILY DISCHARGE - ZYMOETZ RIVER NEAR TERRACE AND ZYMOETZ RIVER ABOVE OK CREEK, APRIL 1 TO AUGUST 31, 1952-2008

ZYMOETZ RIVER NEAR TERRACE & ABOVE OK CREEK
Maximum Daily Discharge, April 1 to August 31, 1952 - 2008 — *Skew: .974*

Frequency Distribution	Estimate of Specified Recurrence Interval Discharge in m3/second							Goodness of fit (See NOTES below)	
	2 years	5 years	10 years	25 years	50 years	100 years	200 years	1	2
Log Normal (Maximum Likelihood)	522	655	751	880	980	1,090	1,190	.0763	.0168
Gumbel (Maximum Likelihood)	530	650	730	830	905	979	1,050	.100	.0280
Pearson Type III (By Moments)	532	664	747	847	918	987	1,050	.0822	.0245
Log Pearson Type III (By Moments)	528	656	743	856	943	1,030	1,120	.0889	.0178
Average	528	656	743	853	937	1,020	1,110		
Adopted Value	528	656	743	856	943	1,030	1,120		

95% Confidence Limits for Specified Recurrence Interval in m3/second

Frequency Distribution	2 years		5 years		10 years		25 years		50 years		100 years		200 years	
	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper
Log Normal (Maximum Likelihood)	491	558	600	720	672	846	763	1020	831	1170	900	1320	970	1490
Gumbel (Maximum Likelihood)	497	563	599	701	664	795	746	915	806	1000	865	1090	924	1180
Pearson Type III (By Moments)	496	567	607	721	673	822	750	945	804	1030	856	1120	907	1200
Log Pearson Type III (By Moments)	496	563	602	715	669	826	752	975	814	1090	876	1210	939	1340
Average	495	563	602	714	669	822	753	965	814	1070	874	1190	935	1300
Adopted Value	491	567	599	721	664	846	746	1020	804	1170	856	1320	907	1490

1 Modified Kolmogorov-Smirnov goodness of fit test based on unbiased plotting positions for all points.
2 Modified Kolmogorov-Smirnov goodness of fit test based on unbiased plotting positions for 5 largest points.

Analytical procedures used to prepare this summary were made available by the River Forecast Centre, Water Management Branch, B.C. Ministry of Environment. This assistance is gratefully acknowledged.

TABLE 4.3.2.10: FREQUENCY ANALYSIS OF ANNUAL MAXIMUM DAILY DISCHARGE - ZYMOETZ RIVER NEAR TERRACE AND ZYMOETZ RIVER ABOVE OK CREEK, SEPTEMBER 1 TO MARCH 31, 1952-2008

ZYMOETZ RIVER NEAR TERRACE & ABOVE OK CREEK
Maximum Daily Discharge, September 1 to March 31, 1952 - 2008 — *Skew: 1.59*

Frequency Distribution	Estimate of Specified Recurrence Interval Discharge in m3/second							Goodness of fit 1	Goodness of fit 2
	2 years	5 years	10 years	25 years	50 years	100 years	200 years	See NOTES below	
Log Normal (Maximum Likelihood)	451	813	1,120	1,580	1,990	2,440	2,940	.0500	.00969
Gumbel (Maximum Likelihood)	504	801	997	1,250	1,430	1,610	1,790	.0955	.0453
Pearson Type III (By Moments)	474	856	1,120	1,470	1,720	1,970	2,220	.0752	.0360
Log Pearson Type III (By Moments)	459	808	1,090	1,520	1,890	2,310	2,770	.0467	.0142
Average	472	819	1,080	1,450	1,760	2,080	2,430		
Adopted Value	459	808	1,090	1,520	1,890	2,310	2,770		

95% Confidence Limits for Specified Recurrence Interval in m3/second

Frequency Distribution	2 years		5 years		10 years		25 years		50 years		100 years		200 years	
	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper
Log Normal (Maximum Likelihood)	377	541	652	1020	862	1460	1160	2170	1400	2830	1660	3590	1940	4480
Gumbel (Maximum Likelihood)	423	586	676	926	837	1160	1040	1450	1190	1670	1330	1890	1480	2110
Pearson Type III (By Moments)	383	565	676	1040	865	1390	1100	1830	1280	2170	1450	2490	1620	2820
Log Pearson Type III (By Moments)	385	547	654	999	853	1400	1130	2050	1360	2640	1600	3320	1870	4110
Average	392	559	664	994	854	1350	1110	1880	1310	2330	1510	2820	1730	3380
Adopted Value	377	586	652	1040	837	1460	1040	2170	1190	2830	1330	3590	1480	4480

1 Modified Kolmogorov-Smirnov goodness of fit test based on unbiased plotting positions for all points.

2 Modified Kolmogorov-Smirnov goodness of fit test based on unbiased plotting positions for 5 largest points.

Analytical procedures used to prepare this summary were made available by the River Forecast Centre, Water Management Branch, B.C. Ministry of Environment. This assistance is gratefully acknowledged.

TABLE 4.3.3.1: FREQUENCY ANALYSIS OF ANNUAL MAXIMUM DAILY DISCHARGE - KITSUMKALUM RIVER NEAR TERRACE, 1928 - 1952

KITSUMKALUM RIVER NEAR TERRACE
MAXIMUM DAILY DISCHARGE, 1928 to 1952 — *Skew: 1.07*

Frequency Distribution	Estimate of Specified Recurrence Interval Discharge in m3/second							Goodness of fit	
	2 years	5 years	10 years	25 years	50 years	100 years	200 years	1	2 (See NOTES below)
Log Normal (Maximum Likelihood)	423	575	715	944	1,150	1,400	1,690	.0988	.0593
Gumbel (Maximum Likelihood)	451	568	646	744	817	889	961	.154	.0925
Pearson Type III (By Moments)	452	588	675	780	856	929	1,000	.127	.0722
Log Pearson Type III (By Moments)	447	578	671	796	895	999	1,110	.133	.0725
Average	443	577	677	816	930	1,050	1,190		
Adopted Value	447	578	671	796	895	999	1,110		

95% Confidence Limits for Specified Recurrence Interval in m3/second

Frequency Distribution	2 years		5 years		10 years		25 years		50 years		100 years		200 years	
	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper
Log Normal (Maximum Likelihood)	380	488	468	746	537	1030	633	1540	712	2060	797	2720	889	3550
Gumbel (Maximum Likelihood)	398	505	486	651	540	752	607	881	655	978	704	1070	751	1170
Pearson Type III (By Moments)	392	512	488	687	543	807	606	955	651	1060	693	1160	734	1260
Log Pearson Type III (By Moments)	395	506	486	686	543	830	612	1040	663	1210	715	1400	767	1610
Average	391	503	482	693	540	854	614	1100	670	1330	727	1590	785	1900
Adopted Value	380	512	468	746	537	1030	606	1540	651	2060	693	2720	734	3550

1 Modified Kolmogorov-Smirnov goodness of fit test based on unbiased plotting positions for all points.

2 Modified Kolmogorov-Smirnov goodness of fit test based on unbiased plotting positions for 5 largest points.

Analytical procedures used to prepare this summary were made available by the River Forecast Centre, Water Management Branch, B.C. Ministry of Environment. This assistance is gratefully acknowledged.

TABLE 4.3.3.2: FREQUENCY ANALYSIS OF ANNUAL MAXIMUM INSTANTANEOUS DISCHARGE - KITSUMKALUM RIVER NEAR TERRACE, 1928 - 1952

KITSUMKALUM RIVER NEAR TERRACE
MAXIMUM INSTANTANEOUS DISCHARGE, 1928 to 1952 — *Skew: 1.18*

Frequency Distribution	Estimate of Specified Recurrence Interval Discharge in m3/second							Goodness of fit (See NOTES below)	
	2 years	5 years	10 years	25 years	50 years	100 years	200 years	1	2
Log Normal (Maximum Likelihood)	429	584	732	979	1,210	1,490	1,810	.0761	.0489
Gumbel (Maximum Likelihood)	460	576	654	751	824	896	967	.141	.0846
Pearson Type III (By Moments)	458	599	692	805	887	966	1,040	.103	.0796
Log Pearson Type III (By Moments)	453	587	686	822	933	1,050	1,180	.110	.0599
Average	450	587	691	839	963	1,100	1,250		
Adopted Value	453	587	686	822	933	1,050	1,180		

95% Confidence Limits for Specified Recurrence Interval in m3/second

Frequency Distribution	2 years		5 years		10 years		25 years		50 years		100 years		200 years	
	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper
Log Normal (Maximum Likelihood)	383	505	465	793	528	1130	617	1760	691	2440	770	3320	855	4450
Gumbel (Maximum Likelihood)	399	520	484	669	535	772	598	905	644	1000	689	1100	733	1200
Pearson Type III (By Moments)	390	526	481	717	532	851	592	1020	634	1140	674	1260	714	1370
Log Pearson Type III (By Moments)	394	520	480	718	533	883	598	1130	647	1340	696	1580	746	1860
Average	391	518	478	724	532	908	601	1200	654	1480	707	1810	762	2220
Adopted Value	383	526	465	793	528	1130	592	1760	634	2440	674	3320	714	4450

1 *Modified Kolmogorov-Smirnov goodness of fit test based on unbiased plotting positions for all points.*

2 *Modified Kolmogorov-Smirnov goodness of fit test based on unbiased plotting positions for 5 largest points.*

Analytical procedures used to prepare this summary were made available by the River Forecast Centre, Water Management Branch, B.C. Ministry of Environment. This assistance is gratefully acknowledged.

TABLE 4.3.3.3: FREQUENCY ANALYSIS OF ANNUAL MAXIMUM INSTANTANEOUS DISCHARGE - KITSUMKALUM RIVER NEAR TERRACE, OBSERVED AND SYNTHESIZED DATA, 1928 - 1952

KITSUMKALUM RIVER NEAR TERRACE
MAXIMUM INSTANTANEOUS DISCHARGE, OBSERVED PLUS SYNTHESIZED DATA (1928 to 1952) Skew: .997

Frequency Distribution	Estimate of Specified Recurrence Interval Discharge in m3/second							Goodness of fit 1	2
	2 years	5 years	10 years	25 years	50 years	100 years	200 years	See NOTES below	
Log Normal (Maximum Likelihood)	428	584	731	972	1,190	1,460	1,760	.100	.0558
Gumbel (Maximum Likelihood)	458	578	657	758	832	906	980	.143	.0905
Pearson Type III (By Moments)	460	599	686	791	866	938	1,010	.121	.0777
Log Pearson Type III (By Moments)	454	588	683	811	912	1,020	1,130	.122	.0704
Average	450	587	689	833	951	1,080	1,220		
Adopted Value	454	588	683	811	912	1,020	1,130		

95% Confidence Limits for Specified Recurrence Interval in m3/second

Frequency Distribution	2 years		5 years		10 years		25 years		50 years		100 years		200 years	
	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper
Log Normal (Maximum Likelihood)	384	495	474	763	545	1060	645	1610	727	2170	817	2890	914	3790
Gumbel (Maximum Likelihood)	403	513	493	662	549	766	617	899	667	998	716	1100	765	1190
Pearson Type III (By Moments)	399	522	499	698	555	817	619	963	665	1070	708	1170	749	1270
Log Pearson Type III (By Moments)	400	515	494	699	552	845	623	1060	676	1230	728	1420	781	1630
Average	396	511	490	706	550	872	626	1130	684	1370	742	1640	802	1970
Adopted Value	384	522	474	763	545	1060	617	1610	665	2170	708	2890	749	3790

1 Modified Kolmogorov-Smirnov goodness of fit test based on unbiased plotting positions for all points.

2 Modified Kolmogorov-Smirnov goodness of fit test based on unbiased plotting positions for 5 largest points.

Analytical procedures used to prepare this summary were made available by the River Forecast Centre, Water Management Branch, B.C. Ministry of Environment. This assistance is gratefully acknowledged.

TABLE 4.3.3.4: FREQUENCY ANALYSIS ANNUAL MAXIMUM DAILY DISCHARGE - KITSUMKALUM RIVER NEAR TERRACE, APRIL 1 TO AUGUST 31, 1929-1952

KITSUMKALUM RIVER NEAR TERRACE
Maximum Daily Discharge April 1 to August 31 (1929 to 1952) *Skew: 1.89*

Frequency Distribution	Estimate of Specified Recurrence Interval Discharge in m3/second							Goodness of fit	
	2 years	5 years	10 years	25 years	50 years	100 years	200 years	1	2
								See NOTES below	
Log Normal (Maximum Likelihood)	391	508	607	758	889	1,040	1,200	.0748	.0370
Gumbel (Maximum Likelihood)	407	502	565	644	703	762	820	.143	.0759
Pearson Type III (By Moments)	391	523	621	749	846	942	1,040	.103	.0295
Log Pearson Type III (By Moments)	393	510	605	748	872	1,010	1,170	.0815	.0387
Average	396	511	600	725	828	938	1,060		
Adopted Value	393	510	605	748	872	1,010	1,170		

95% Confidence Limits for Specified Recurrence Interval in m3/second

Frequency Distribution	2 years		5 years		10 years		25 years		50 years		100 years		200 years	
	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper
Log Normal (Maximum Likelihood)	353	445	426	632	477	817	546	1130	599	1430	655	1790	714	2210
Gumbel (Maximum Likelihood)	363	452	434	571	477	653	530	758	569	837	608	916	646	994
Pearson Type III (By Moments)	340	442	412	634	453	789	504	995	541	1150	579	1310	616	1460
Log Pearson Type III (By Moments)	350	440	417	623	460	796	518	1080	563	1350	610	1680	660	2080
Average	352	445	422	615	467	764	524	991	568	1190	613	1420	659	1690
Adopted Value	340	452	412	634	453	817	504	1130	541	1430	579	1790	616	2210

1 Modified Kolmogorov-Smirnov goodness of fit test based on unbiased plotting positions for all points.

2 Modified Kolmogorov-Smirnov goodness of fit test based on unbiased plotting positions for 5 largest points.

Analytical procedures used to prepare this summary were made available by the River Forecast Centre, Water Management Branch, B.C. Ministry of Environment. This assistance is gratefully acknowledged.

TABLE 4.3.3.5: FREQUENCY ANALYSIS OF ANNUAL MAXIMUM DAILY DISCHARGE - KITSUMKALUM RIVER NEAR TERRACE, SEPTEMBER 1 TO MARCH 31, 1929 - 1952

KITSUMKALUM RIVER NEAR TERRACE
Maximum Daily Discharge September 1 to March 31 (1929 to 1952) *Skew: .826*

Frequency Distribution	Estimate of Specified Recurrence Interval Discharge in m3/second							Goodness of fit (See NOTES below)	
	2 years	5 years	10 years	25 years	50 years	100 years	200 years	1	2
Log Normal (Maximum Likelihood)	310	455	579	767	931	1,120	1,320	.101	.0866
Gumbel (Maximum Likelihood)	330	448	526	625	698	770	843	.172	.120
Pearson Type III (By Moments)	338	474	557	656	725	792	855	.172	.0904
Log Pearson Type III (By Moments)	322	457	557	699	815	940	1,080	.141	.0965
Average	325	458	555	687	792	904	1,020		
Adopted Value	322	457	557	699	815	940	1,080		

95% Confidence Limits for Specified Recurrence Interval in m3/second

Frequency Distribution	2 years		5 years		10 years		25 years		50 years		100 years		200 years	
	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper
Log Normal (Maximum Likelihood)	263	377	353	610	417	841	502	1230	569	1610	639	2060	712	2600
Gumbel (Maximum Likelihood)	275	386	363	533	417	636	483	766	531	864	579	962	626	1060
Pearson Type III (By Moments)	273	402	376	572	431	683	494	818	538	913	579	1000	619	1090
Log Pearson Type III (By Moments)	270	384	360	578	418	744	491	996	546	1220	602	1470	660	1760
Average	270	387	363	573	421	726	492	954	546	1150	600	1370	654	1630
Adopted Value	263	402	353	610	417	841	483	1230	531	1610	579	2060	619	2600

1 Modified Kolmogorov-Smirnov goodness of fit test based on unbiased plotting positions for all points.
2 Modified Kolmogorov-Smirnov goodness of fit test based on unbiased plotting positions for 5 largest points.

Analytical procedures used to prepare this summary were made available by the River Forecast Centre, Water Management Branch, B.C. Ministry of Environment. This assistance is gratefully acknowledged.

TABLE 4.3.4.1: FREQUENCY ANALYSIS OF ANNUAL MAXIMUM DAILY DISCHARGE - SKEENA RIVER AT USK AND ZYMOETZ RIVER ABOVE OK CREEK, 1964 TO 2008

SKEENA RIVER AT USK PLUS ZYMOETZ RIVER ABOVE OK CREEK
Annual Maximum Daily Discharge, 1964 to 2008 (45 years record) *Skew: .647*

Frequency Distribution	Estimate of Specified Recurrence Interval Discharge in m3/second							Goodness of fit (See NOTES below)	
	2 years	5 years	10 years	25 years	50 years	100 years	200 years	1	2
Log Normal (Maximum Likelihood)	5,250	6,350	7,030	7,860	8,450	9,020	9,590	.0662	.0298
Gumbel (Maximum Likelihood)	5,220	6,340	7,090	8,030	8,730	9,420	10,100	.0792	.0227
Pearson Type III (By Moments)	5,280	6,370	7,010	7,760	8,280	8,770	9,230	.0583	.0343
Log Pearson Type III (By Moments)	5,270	6,350	7,010	7,810	8,380	8,930	9,470	.0611	.0318
Average	5,260	6,350	7,040	7,860	8,460	9,040	9,600		
Adopted Value	5,270	6,350	7,010	7,810	8,380	8,930	9,470		

95% Confidence Limits for Specified Recurrence Interval in m3/second

Frequency Distribution	2 years		5 years		10 years		25 years		50 years		100 years		200 years	
	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper
Log Normal (Maximum Likelihood)	4920	5620	5860	6880	6400	7740	7020	8810	7440	9610	7850	10400	8240	11200
Gumbel (Maximum Likelihood)	4870	5570	5810	6880	6400	7780	7140	8930	7680	9780	8220	10600	8750	11500
Pearson Type III (By Moments)	4930	5630	5870	6870	6390	7640	6970	8550	7370	9180	7750	9780	8110	10400
Log Pearson Type III (By Moments)	4930	5630	5870	6870	6400	7690	7000	8710	7420	9460	7810	10200	8200	10900
Average	4910	5610	5850	6880	6400	7710	7030	8750	7480	9510	7910	10300	8320	11000
Adopted Value	4870	5630	5810	6880	6390	7780	6970	8930	7370	9780	7750	10600	8110	11500

[1] Modified Kolmogorov-Smirnov goodness of fit test based on unbiased plotting positions for all points.

[2] Modified Kolmogorov-Smirnov goodness of fit test based on unbiased plotting positions for 5 largest points.

Analytical procedures used to prepare this summary were made available by the River Forecast Centre, Water Management Branch, B.C. Ministry of Environment. This assistance is gratefully acknowledged.

TABLE 4.3.4.2: FREQUENCY ANALYSIS OF ANNUAL MAXIMUM DAILY DISCHARGE - SKEENA RIVER AT USK, PLUS ZYMOETZ RIVER NEAR TERRACE AND ZYMOETZ RIVER ABOVE OK CREEK, 1952 TO 2008

Skeena River at Usk, plus Zyloetz River near Terrace and Above OK Creek, 1952 to 2008
Annual Maximum Daily Discharge (57 years record) *Skew: .589*

Frequency Distribution	Estimate of Specified Recurrence Interval Discharge in m3/second							Goodness of fit See NOTES below	
	2 years	5 years	10 years	25 years	50 years	100 years	200 years	1	2
Log Normal (Maximum Likelihood)	5,300	6,350	7,000	7,770	8,320	8,850	9,370	.0477	.0231
Gumbel (Maximum Likelihood)	5,250	6,360	7,090	8,010	8,700	9,370	10,100	.0617	.0250
Pearson Type III (By Moments)	5,330	6,370	6,990	7,690	8,180	8,630	9,070	.0382	.0270
Log Pearson Type III (By Moments)	5,310	6,360	6,990	7,740	8,260	8,780	9,270	.0445	.0246
Average	5,300	6,360	7,010	7,800	8,360	8,910	9,440		
Adopted Value	5,310	6,360	6,990	7,740	8,260	8,780	9,270		

95% Confidence Limits for Specified Recurrence Interval in m3/second

Frequency Distribution	2 years		5 years		10 years		25 years		50 years		100 years		200 years	
	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper
Log Normal (Maximum Likelihood)	5010	5610	5940	6800	6470	7580	7070	8540	7490	9250	7880	9940	8260	10600
Gumbel (Maximum Likelihood)	4950	5560	5890	6820	6490	7680	7240	8780	7790	9600	8330	10400	8870	11200
Pearson Type III (By Moments)	5030	5630	5950	6790	6460	7510	7040	8340	7430	8920	7800	9470	8150	9990
Log Pearson Type III (By Moments)	5020	5620	5950	6790	6470	7550	7060	8480	7470	9150	7850	9810	8220	10500
Average	5010	5600	5930	6800	6470	7580	7100	8540	7540	9230	7970	9910	8380	10600
Adopted Value	4950	5630	5890	6820	6460	7680	7040	8780	7430	9600	7800	10400	8150	11200

1 *Modified Kolmogorov-Smirnov goodness of fit test based on unbiased plotting positions for all points.*

2 *Modified Kolmogorov-Smirnov goodness of fit test based on unbiased plotting positions for 5 largest points.*

Analytical procedures used to prepare this summary were made available by the River Forecast Centre, Water Management Branch, B.C. Ministry of Environment. This assistance is gratefully acknowledged.

TABLE 4.3.4.3: FREQUENCY ANALYSIS OF ANNUAL MAXIMUM DAILY DISCHARGE - SKEENA RIVER AT USK PLUS ZYMOETZ RIVER ABOVE OK CREEK - APRIL 1 TO AUGUST 31, 1964-2008

SKEENA RIVER AT USK PLUS ZYMOETZ RIVER ABOVE OK CREEK
Maximum Daily Discharge April 1 to August 31, 1964 to 2008 *Skew: .748*

Frequency Distribution	Estimate of Specified Recurrence Interval Discharge in m3/second							Goodness of fit	
	2 years	5 years	10 years	25 years	50 years	100 years	200 years	1 (See NOTES below)	2
Log Normal (Maximum Likelihood)	5,080	6,250	7,020	8,000	8,740	9,480	10,200	.0716	.0247
Gumbel (Maximum Likelihood)	5,100	6,220	6,960	7,900	8,590	9,280	9,970	.0677	.0283
Pearson Type III (By Moments)	5,150	6,290	6,970	7,780	8,340	8,870	9,380	.0643	.0341
Log Pearson Type III (By Moments)	5,130	6,250	6,970	7,850	8,500	9,140	9,780	.0656	.0304
Average	5,110	6,250	6,980	7,880	8,540	9,190	9,840		
Adopted Value	5,130	6,250	6,970	7,850	8,500	9,140	9,780		

95% Confidence Limits for Specified Recurrence Interval in m3/second

Frequency Distribution	2 years		5 years		10 years		25 years		50 years		100 years		200 years	
	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper
Log Normal (Maximum Likelihood)	4750	5460	5710	6860	6290	7870	6990	9220	7490	10300	7980	11400	8460	12500
Gumbel (Maximum Likelihood)	4740	5450	5680	6760	6260	7660	7000	8800	7540	9650	8070	10500	8600	11300
Pearson Type III (By Moments)	4790	5520	5750	6830	6290	7660	6910	8650	7330	9340	7740	10000	8120	10600
Log Pearson Type III (By Moments)	4780	5490	5730	6810	6290	7720	6940	8880	7400	9760	7850	10600	8290	11500
Average	4770	5480	5720	6810	6280	7730	6960	8890	7440	9760	7910	10600	8370	11500
Adopted Value	4740	5520	5680	6860	6260	7870	6910	9220	7330	10300	7740	11400	8120	12500

1 Modified Kolmogorov-Smirnov goodness of fit test based on unbiased plotting positions for all points.

2 Modified Kolmogorov-Smirnov goodness of fit test based on unbiased plotting positions for 5 largest points.

Analytical procedures used to prepare this summary were made available by the River Forecast Centre, Water Management Branch, B.C. Ministry of Environment. This assistance is gratefully acknowledged.

TABLE 4.3.4.4: FREQUENCY ANALYSIS OF ANNUAL MAXIMUM DAILY DISCHARGE - SKEENA RIVER AT USK PLUS ZYMOETZ RIVER ABOVE OK CREEK - SEPTEMBER 1 TO MARCH 31, 1964-2008

SKEENA RIVER AT USK PLUS ZYMOETZ RIVER ABOVE OK CREEK
Maximum Daily Discharge September 1 to March 31, 1964 to 2008 — *Skew: 1.60*

Frequency Distribution	Estimate of Specified Recurrence Interval Discharge in m3/second							Goodness of fit (See NOTES below)	
	2 years	5 years	10 years	25 years	50 years	100 years	200 years	1	2
Log Normal (Maximum Likelihood)	2,150	3,180	3,910	4,890	5,650	6,430	7,250	.0708	.0217
Gumbel (Maximum Likelihood)	2,210	3,130	3,740	4,510	5,080	5,650	6,220	.0761	.0297
Pearson Type III (By Moments)	2,100	3,210	3,990	4,980	5,720	6,440	7,160	.0900	.0211
Log Pearson Type III (By Moments)	2,150	3,170	3,910	4,920	5,710	6,550	7,430	.0690	.0206
Average	2,150	3,170	3,890	4,820	5,540	6,270	7,010		
Adopted Value	2,150	3,170	3,910	4,920	5,710	6,550	7,430		

95% Confidence Limits for Specified Recurrence Interval in m3/second

Frequency Distribution	2 years		5 years		10 years		25 years		50 years		100 years		200 years	
	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper
Log Normal (Maximum Likelihood)	1880	2480	2700	3760	3230	4750	3890	6150	4370	7300	4860	8520	5360	9830
Gumbel (Maximum Likelihood)	1920	2500	2680	3580	3170	4310	3770	5250	4210	5950	4650	6650	5090	7350
Pearson Type III (By Moments)	1800	2400	2610	3810	3120	4850	3760	6200	4230	7200	4700	8180	5150	9160
Log Pearson Type III (By Moments)	1870	2470	2680	3750	3210	4760	3890	6220	4390	7420	4910	8730	5440	10200
Average	1870	2460	2670	3720	3180	4670	3830	5960	4300	6970	4780	8020	5260	9120
Adopted Value	1800	2500	2610	3810	3120	4850	3760	6220	4210	7420	4650	8730	5090	10200

1 Modified Kolmogorov-Smirnov goodness of fit test based on unbiased plotting positions for all points.
2 Modified Kolmogorov-Smirnov goodness of fit test based on unbiased plotting positions for 5 largest points.

Analytical procedures used to prepare this summary were made available by the River Forecast Centre, Water Management Branch, B.C. Ministry of Environment. This assistance is gratefully acknowledged.

TABLE 4.3.4.5: FREQUENCY ANALYSIS OF ANNUAL MAXIMUM DAILY DISCHARGE - SKEENA RIVER AT USK PLUS ZYMOETZ RIVER NEAR TERRACE AND ABOVE OK CREEK - APRIL 1 TO AUGUST 31, 1952 - 2008

SKEENA RIVER AT USK PLUS ZYMOETZ RIVER NEAR TERRACE AND ABOVE OK CREEK
Maximum Daily Discharge April 1 to August 31, 1952 - 2008 *Skew: .655*

Frequency Distribution	Estimate of Specified Recurrence Interval Discharge in m3/second							Goodness of fit See NOTES below	
	2 years	5 years	10 years	25 years	50 years	100 years	200 years	1	2
Log Normal (Maximum Likelihood)	5,180	6,280	6,990	7,860	8,500	9,140	9,760	.0559	.0194
Gumbel (Maximum Likelihood)	5,160	6,270	7,000	7,920	8,610	9,290	9,970	.0621	.0169
Pearson Type III (By Moments)	5,230	6,310	6,960	7,710	8,220	8,710	9,180	.0388	.0265
Log Pearson Type III (By Moments)	5,200	6,280	6,960	7,770	8,360	8,930	9,500	.0489	.0230
Average	5,190	6,290	6,980	7,820	8,420	9,020	9,600		
Adopted Value	5,230	6,310	6,960	7,710	8,220	8,710	9,180		

95% Confidence Limits for Specified Recurrence Interval in m3/second

Frequency Distribution	2 years		5 years		10 years		25 years		50 years		100 years		200 years	
	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper
Log Normal (Maximum Likelihood)	4880	5500	5840	6770	6400	7650	7060	8780	7530	9630	7990	10500	8430	11400
Gumbel (Maximum Likelihood)	4850	5470	5800	6740	6390	7600	7140	8710	7690	9530	8240	10300	8780	11200
Pearson Type III (By Moments)	4920	5540	5870	6760	6400	7520	7000	8410	7410	9030	7800	9620	8170	10200
Log Pearson Type III (By Moments)	4910	5520	5850	6750	6390	7570	7030	8590	7470	9350	7900	10100	8310	10900
Average	4890	5510	5840	6760	6400	7590	7060	8620	7530	9390	7980	10100	8420	10900
Adopted Value	4850	5540	5800	6770	6390	7650	7000	8780	7410	9630	7800	10500	8170	11400

1 Modified Kolmogorov-Smirnov goodness of fit test based on unbiased plotting positions for all points.
2 Modified Kolmogorov-Smirnov goodness of fit test based on unbiased plotting positions for 5 largest points.

Analytical procedures used to prepare this summary were made available by the River Forecast Centre, Water Management Branch, B.C. Ministry of Environment. This assistance is gratefully acknowledged.

TABLE 4.3.4.6: FREQUENCY ANALYSIS OF ANNUAL MAXIMUM DAILY DISCHARGE - SKEENA RIVER AT USK PLUS ZYMOETZ RIVER NEAR TERRACE AND ABOVE OK CREEK - SEPTEMBER 1 TO MARCH 31, 1952-2008

SKEENA RIVER AT USK PLUS ZYMOETZ RIVER NEAR TERRACE AND ABOVE OK CREEK
Maximum Daily Discharge September 1 to March 31, 1952 - 2008 — *Skew: 1.67*

Frequency Distribution	Estimate of Specified Recurrence Interval Discharge in m3/second							Goodness of fit 1	2
	2 years	5 years	10 years	25 years	50 years	100 years	200 years	See NOTES below	
Log Normal (Maximum Likelihood)	2,190	3,130	3,780	4,620	5,270	5,930	6,610	.0741	.0192
Gumbel (Maximum Likelihood)	2,220	3,080	3,650	4,380	4,910	5,450	5,980	.0842	.0273
Pearson Type III (By Moments)	2,110	3,130	3,870	4,800	5,500	6,190	6,870	.0973	.0165
Log Pearson Type III (By Moments)	2,170	3,120	3,790	4,680	5,380	6,120	6,880	.0679	.0174
Average	2,170	3,110	3,770	4,620	5,270	5,920	6,590		
Adopted Value	2,170	3,120	3,790	4,680	5,380	6,120	6,880		

95% Confidence Limits for Specified Recurrence Interval in m3/second

Frequency Distribution	2 years		5 years		10 years		25 years		50 years		100 years		200 years	
	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper
Log Normal (Maximum Likelihood)	1950	2450	2740	3570	3230	4410	3850	5560	4300	6470	4740	7420	5190	8420
Gumbel (Maximum Likelihood)	1980	2460	2710	3450	3180	4130	3770	4990	4200	5630	4620	6270	5040	6910
Pearson Type III (By Moments)	1870	2350	2640	3630	3140	4590	3780	5830	4250	6750	4710	7670	5170	8570
Log Pearson Type III (By Moments)	1940	2430	2720	3570	3220	4450	3860	5680	4340	6670	4830	7740	5330	8890
Average	1930	2420	2700	3560	3200	4390	3810	5510	4270	6380	4730	7280	5180	8200
Adopted Value	1870	2460	2640	3630	3140	4590	3770	5830	4200	6750	4620	7740	5040	8890

1 Modified Kolmogorov-Smirnov goodness of fit test based on unbiased plotting positions for all points.

2 Modified Kolmogorov-Smirnov goodness of fit test based on unbiased plotting positions for 5 largest points.

Analytical procedures used to prepare this summary were made available by the River Forecast Centre, Water Management Branch, B.C. Ministry of Environment. This assistance is gratefully acknowledged.

TABLE 4.3.6.1: COMPARISON OF PREDICTED 200-YEAR RETURN PERIOD DISCHARGES BASED ON VARIOUS DATA SETS

DATA SOURCE	PERIOD OF RECORD		ANNUAL DATA					SPRING (April 1 to August 31)				FALL (September 1 to March 31)			
						PREDICTED 200-YEAR DISCHARGE (m^3/s)									
	FROM	TO	YEARS OF RECORD	PARAMETER	REFERENCE	DAILY	INSTANTANEOUS	YEARS OF RECORD	PARAMETER	REFERENCE	PREDICTED 200-YEAR DISCHARGE (m^3/s)	YEARS OF RECORD	PARAMETER	REFERENCE	PREDICTED 200-YEAR DISCHARGE (m^3/s)
SKEENA RIVER AT USK (including generated instantaneous data)	1928	2008	76	Daily	Table 4.3.1.1	9,240	–	76	Daily	Table 4.3.1.4	9,300	76	Daily	Table 4.3.1.5	5,950
			77	Inst.	Table 4.3.1.3	–	9,400	77	Inst.	N/A	N/A	77	Inst.	N/A	–
ZYMOETZ RIVER NEAR TERRACE	1952	1964	13	Daily	Table 4.3.2.1	1,120	–	46	Daily	Table 4.3.2.5	1,160	46	Daily	Table 4.3.2.6	1,600
			N/A	Inst.	N/A	–	N/A (1)	N/A	Inst.	N/A	–	N/A	Inst.	N/A	–
ZYMOETZ RIVER ABOVE O.K. CREEK	1964	2008	45	Daily	Table 4.3.2.2	2,300	–	45	Daily	Table 4.3.2.7	965	45	Daily	Table 4.3.2.8	3,200
			45	Inst.	Table 4.3.2.3	–	3,800	45	Inst.	N/A	–	45	Inst.	N/A	–
ZYMOETZ RIVER NEAR TERRACE AND ZYMOETZ RIVER ABOVE OK CREEK	1952	2008	57	Daily	Table 4.3.2.4	2,530	–	57	Daily	Table 4.3.2.9	1,120	57	Daily	Table 4.3.2.10	2,770
			57	Inst	N/A	–	N/A (1)	N/A	Inst.	N/A	–	N/A	Inst.	N/A	–
KITSUMKALUM RIVER NEAR TERRACE	1928	1952	22	Daily	Table 4.3.3.1	1,110	–	21	Daily	Table 4.3.3 4	1,470	21	Daily	Table 4.3.3.5	1,080
			18	Inst.	Table 4.3.3.3	–	1,130	N/A	Inst.	N/A	–	N/A	Inst.	N/A	–
SKEENA RIVER AT USK, PLUS ZYMOETZ RIVER ABOVE OK CREEK	1964	2008	45	Daily	Table 4.3.4.1	9,470	–	45	Daily	Table 4.3.4.3	9,780	45	Daily	Table 4.3.4.4	7,430
			N/A	Inst.	N/A	–	N/A (2)	N/A	Inst.	N/A	–	N/A	Inst.	N/A	–
SKEENA RIVER AT USK, PLUS ZYMOETZ RIVER NEAR TERRACE AND ZYMOETZ RIVER ABOVE OK CREEK	1952	2008	57	Daily	Table 4.3.4.2	9,270	–	57	Daily	Table 4.3.4.5	9,180	57	Daily	Table 4.3.4.6	6,880
			N/A	Inst.	N/A	–	N/A (2)	N/A	Inst.	N/A	–	N/A	Inst.	N/A	–

NOTES:

1: The ratio of the predicted 200-year return period instantaneous to daily discharge calculated for the station Zymoetz River above OK Creek is 1.65 (3,800÷2,300). Using this ratio, the 200-year return period instantaneous discharge on Zymoetz River near Terrace would be 1,850 m^3/s and 4,180 m^3/s for the combined Zymoetz River data.

2: The ratio of the predicted 200-year return period instantaneous to daily discharge calculated for the Skeena River at Usk is 1.02. This ratio provides a minimum estimate of the potential 200-year return period instantaneous discharge on the combined Skeena River plus Zymoetz River above OK Creek of 9,660 m^3/s and 9,460 m^3/s for Skeena River plus both Zymoetz River stations.

3: The predicted 200-year flood return period discharges are based on varying periods of record. A common 'rule of thumb' is that flood predictions are potentially unreliable if the computed return period exceeds twice the period of record. This criteria is exceeded at all gauging stations. The data record on Kitsumkalum River is only 18 to 22 years and the 200-year return period discharge estimate for this site is subject to considerable uncertainty.

TABLE 4.3.6.2: COMPARISON OF CALCULATED RETURN PERIODS FOR REGIONALLY SIGNIFICANT FLOODS

DATA SOURCE	FLOW TYPE	PREDICTED RETURN PERIOD (years)									
		May 29-June 3, 1936		May 25-June 10, 1948		June 9-11, 1964		June 12, 1972		June 4-7, 2007	
		Spring	Annual	Spring	Annual	Spring	Annual	Spring	Annual	Spring	Annual
SKEENA RIVER AT USK (including generated instantaneous data)	Daily	*1	*1	209	235	31	31	42	44	33	34
	Inst.		*1		246		28		51		30
ZYMOETZ RIVER NEAR TERRACE	Daily	–	–	–	–	13	4	–	–	–	–
	Inst.	–	–	–	–	–	–	–	–	–	–
ZYMOETZ RIVER ABOVE O.K. CREEK	Daily	–	–	–	–	12	3	12	3	44	6
	Inst.	–	–	–	–		2	–	3		3
ZYMOETZ RIVER NEAR TERRACE AND ZYMOETZ RIVER ABOVE OK CREEK	Daily	–	–	–	–	46	6	7	3	18	4
	Inst	–	–	–	–	–	–	–	–	–	–
KITSUMKALUM RIVER NEAR TERRACE (including generated instantaneous data)	Daily	53	46	14	9	–	–	–	–	–	–
	Inst.		41		8	–	–	–	–	–	–
SKEENA RIVER AT USK, PLUS ZYMOETZ RIVER ABOVE OK CREEK	Daily	–	–	–	–	35	39	47	54	38	42
	Inst.	–	–	–	–	–	–	–	–	–	–
SKEENA RIVER AT USK, PLUS ZYMOETZ RIVER NEAR TERRACE AND ABOVE OK CREEK	Daily	–	–	–	–	47	51	58	63	45	48
	Inst.	–	–	–	–	–	–	–	–	–	–

Notes: ***1** Unpublished data cited in *Septer and Schwab (1995)* indicate discharges at Usk were ≥10,194 m^3/s in 1936. This flow, which needs to be confirmed would have an approximately 500 year return period.

TABLE 4.4.1.1: CHRONOLOGY OF SIGNIFICANT FLOOD EVENTS ON SKEENA, ZYMOETZ AND KITSUMKALUM RIVERS *(from Septer and Schwab, 1995)*

Skeena River	Date	Zymoetz (Copper) River	Date	Kitsumkalum River	Date
May-June	1894				
May-June	1898				
May-June	1916				
October 28-November 19	1917			October 28-November 19	1917
May-June	1928				
June 17-19	1931				
December 14-16	1931				
November 16-18	1932				
November 9-13	1933				
November 17-24	1933				
November 23-December 2	1933				
January 24-27	1934				
October 21-26	1935	October 21-26	1935		
November 5-8	1935				
May 29-June 3	1936	May 29-June 3	1936	May 29-June 3	1936
November 9-19	1936	November 9-19	1936		
December 1-5	1939				
October 17-20	1940				
May 25-26	1942				
October 13-15	1945				
		November 2	1945	November 2	1945
May-June	1947				
May 25-June 10	1948				
June 14-18	1950	June 14	1950		
October 26-28	1951	October 26-28	1951		
December 10	1951				
April 15-18	1952				
January 30-February 3	1954	January 30-February 3	1954		
June 10	1954				
October 11-16	1954				
		October 29-31	1961		
		October 15-17	1962		
May 31-June 8	1964				
June 8-11	1964				
October 16-20	1964	October 16-20	1964		
October 21-24	1966	October 21-24	1966		
January 21-23	1968				
May 20-23	1968				
May 31-June 2	1972				
June 12	1972				
October 5-9	1974				
October 13-15	1974	October 13-15	1974		
October 29-November 1	1978	October 29-November 1	1978	October 29-November 1	1978
November 4-7	1978				
January 5-12	1982				
		September 17-21	1987		
		September 26-29	1988		
October 20-22	1988				
June	1990				
October 6-14	1991		1991		
Number of Events	**45**		**16**		**4**

PLATES

July 29, 2008 MM Cam 2732

a) Looking upstream to the large fan located at the confluence of Zymoetz River and Skeena River

July 29, 2008 MM Cam 2769

b) Looking downstream to the Zymoetz River confluence showing the extent of instream gravel accumulations.

Plate 6.2.1.1: Oblique aerial photos of the Zymoetz River confluence.

July 29, 2008 MM Cam 2791

a) Looking downstream showing instream gravel accumulations and islands located downstream of the Zymoetz River.

July 29, 2008 MM Cam 2708

b) Looking upstream from the Highway 37 Bridge showing a locally eroding island, instream gravel storage and a cleared field with intermittent riparian vegetation.

Plate 6.2.2.1: Oblique aerial photos of Skeena River in the area between Zymoetz River and the Highway 37 Bridge.

July 29, 2008 MM Cam 2826

a) Looking downstream on the north chnnel around Ferry Island.

July 29, 2008 MM Cam 2691

b) Looking upstream along the south bank of Skeena River opposite Ferry Island.

Plate 6.2.3.1: Oblique aerial photos of Skeena River in the vicinity of Ferry Island.

April 23, 2009 MM Nikon 9064

a) Looking downstream to the Regional District Sewage Treatment Plant on the south side of Skeena River.

April 23, 2009 MM Nikon 9060

b) Looking upstream showing overbank debris deposited in the secondary channel which flows around the Regional District STP.

Plate 6.2.3.2: Oblique aerial photos of Skeena River in the vicinity of the Regional District Sewage Treatment Plant.

April 23, 2009 MM Nikon 9047

a) Looking upstream illustrating the enlarging gravel bars which are forcing the south channel of Skeena River towards the Regional District STP.

April 02, 2009 MM Pentax 09-5337

b) Looking north to the gravel bar at the downstream end of Ferry Island illustrating colinizing vegetation and recent erosion.

Plate 6.2.3.3: Oblique aerial photos illustrating instream gravel accumulations in the vicinity of the Regional District Sewage Treatment Plant.

April 23, 2009 MM Cam 6928

a)

April 223, 2009 MM Cam 6931

b)

Plate 6.2.3.4: Looking downstream to the ring dyke which protects a BC Hydro transmission tower, located immediately downstream of the Regional District STP.

July 29, 2008 MM Cam 3317

a) conditions prior to bank protection

April 23, 2009 MM Cam 6850

b) conditions following bank protection

Plate 6.2.4.1: Looking upstream on Skeena River illustrating how the mainstem flow is directed into the north bank upstream of the City of Terrace STP.

July 29, 2008 Photo provided by COT

a) Looking west

July 29, 2008 Photo provided by COT

b) Looking south

Plate 6.2.4.2: Photographs showing the extent of June 2007 over-bank flooding in the vicinity of the City of Terrace STP.

July 29, 2008 MM Cam 3269

a) Looking south

April 23, 2009 MM Cam 6408

b) Looking north

Plate 6.2.4.3: Oblique photographs of the enlarging gravel bars located between Braun's Slough and the Kitsumkalum Confluence.

April 23, 2009 MM Nikon 8364

a) Looking downstream showing the bars and islands opporite the Kitsumkalum River confluence

April 23, 2009 MM Nikon 8367

b) Looking downstream to the bars and islands at the mouth of Kitsumkalum River

Plate 6.2.5.1: Oblique aerial photographs of Skeena River in the vicinity of the Kitsumkalum River confluence.

July 29, 2008 MM Cam 2927

a) Looking upstream showing sediment deposits at the outlet of the Hell's Gate secondary channel

July 29, 2008 MM Cam 2943

b) Looking upstream showing the bedrock controlled inlet to the Hell's Gate secondary channel

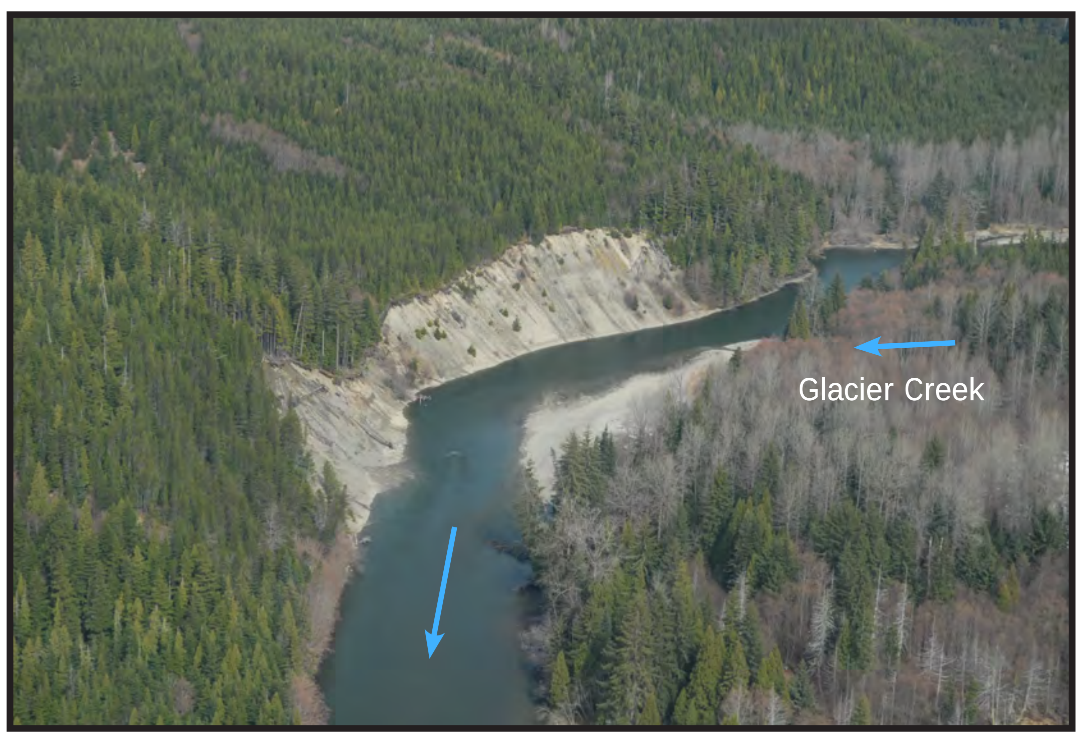
Plate 6.2.6.1: Oblique aerial photographs of a developing secondary channel below Hell's Gate.

April 23, 2009 MM Nikon 8649

a) Looking upstream showing the fan on Star Creek

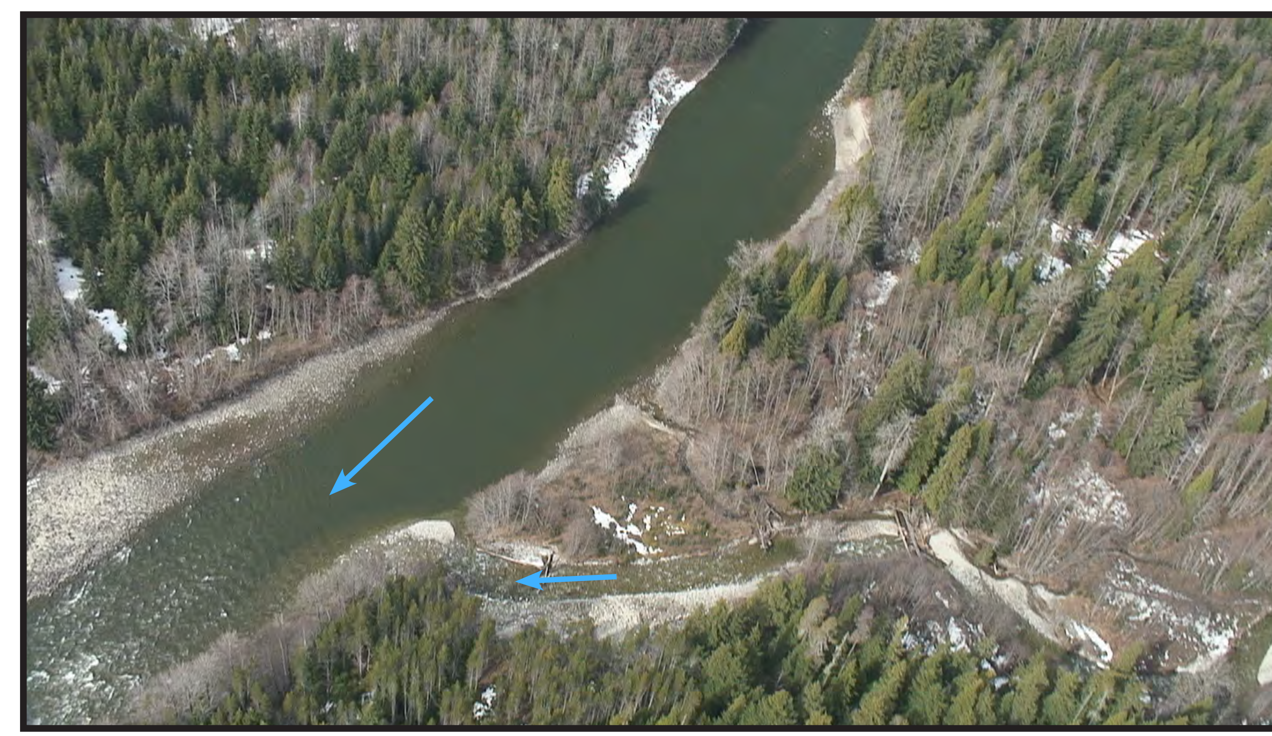
April 23, 2009 MM Cam 6592

b) Looking upstream showing the substantial sediment loads on Alice Creek



April 23, 2009 MM Nikon 8614

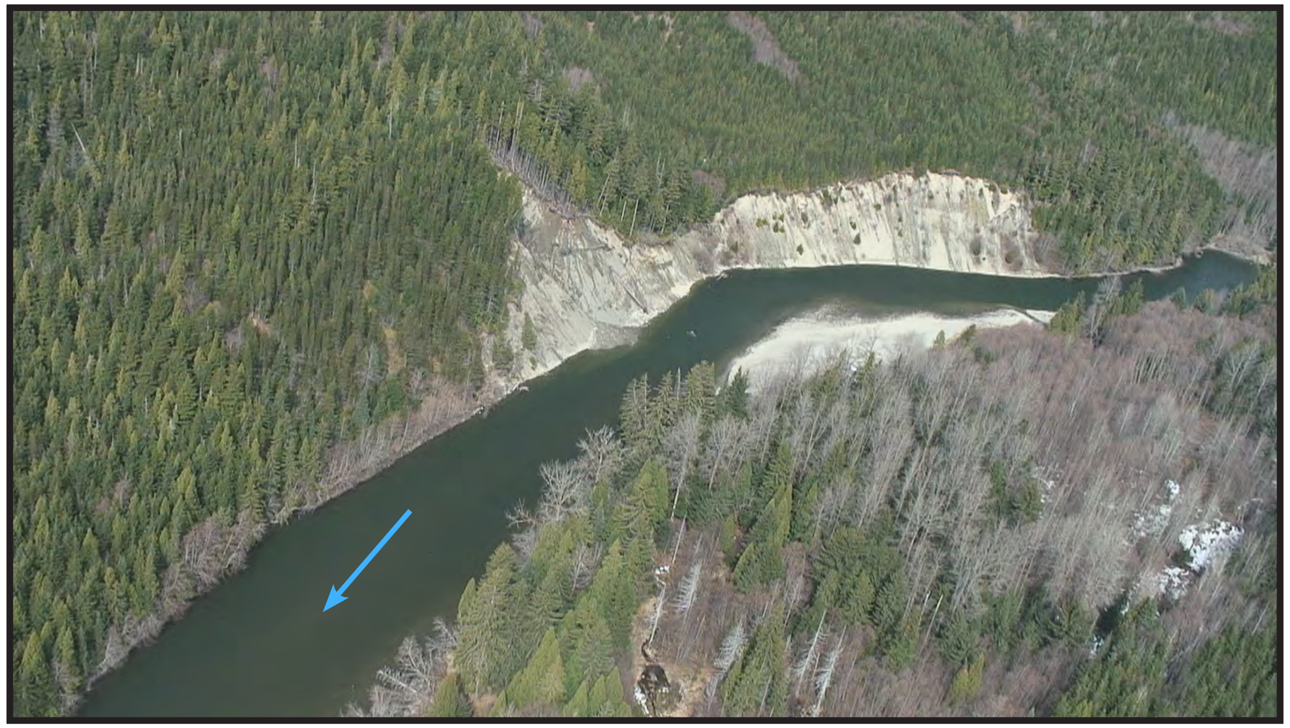
c) Looking upstream to the fan at the outlet of Glacier Creek



April 23, 2009 MM Cam 6523

d) Looking upstream to the confluence with Lean-to Creek

Plate 6.3.1.1: Oblique aerial photos illustrating the sediment loads being delivered to Kitsumkalum River by tributary streams.



April 23, 2009 MM Cam 6568

a) River Km 28.0

April 23, 2009 MM Cam 6559

b) River Km 26.1

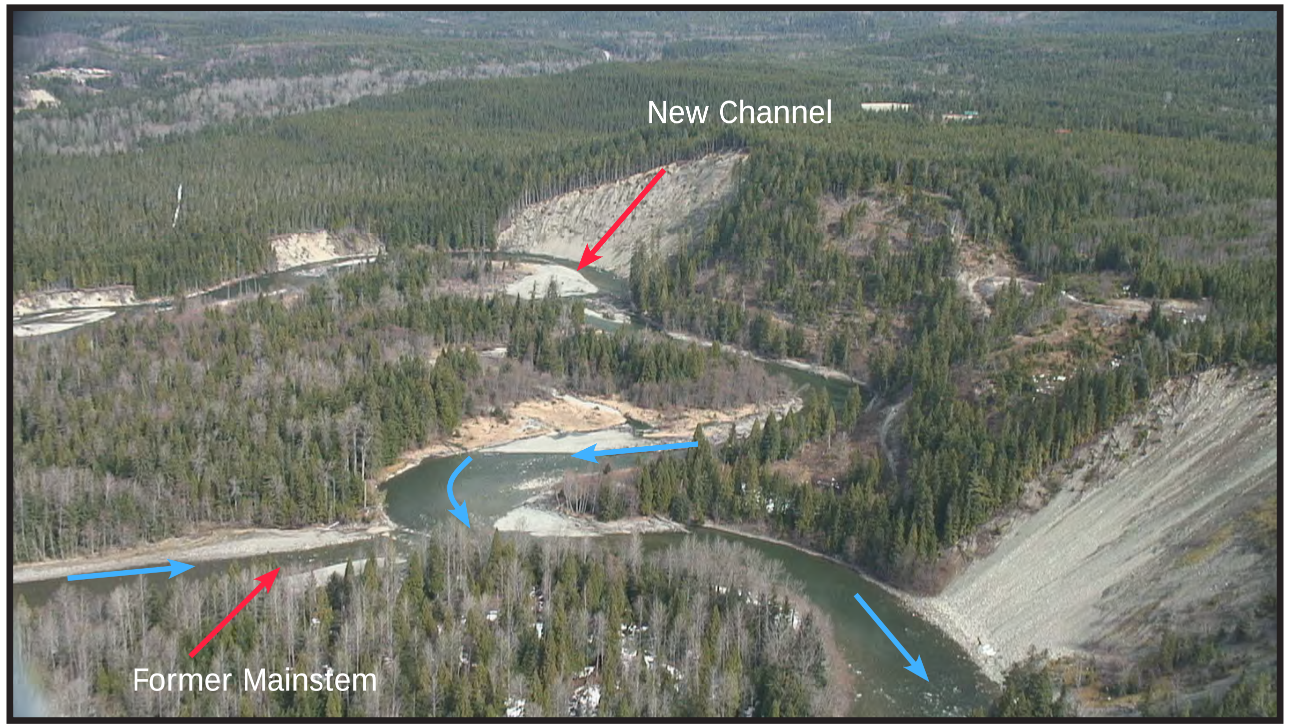
April 23, 2009 MM Cam 6546

c) River Km 23.6

April 23, 2009 MM Cam 6516

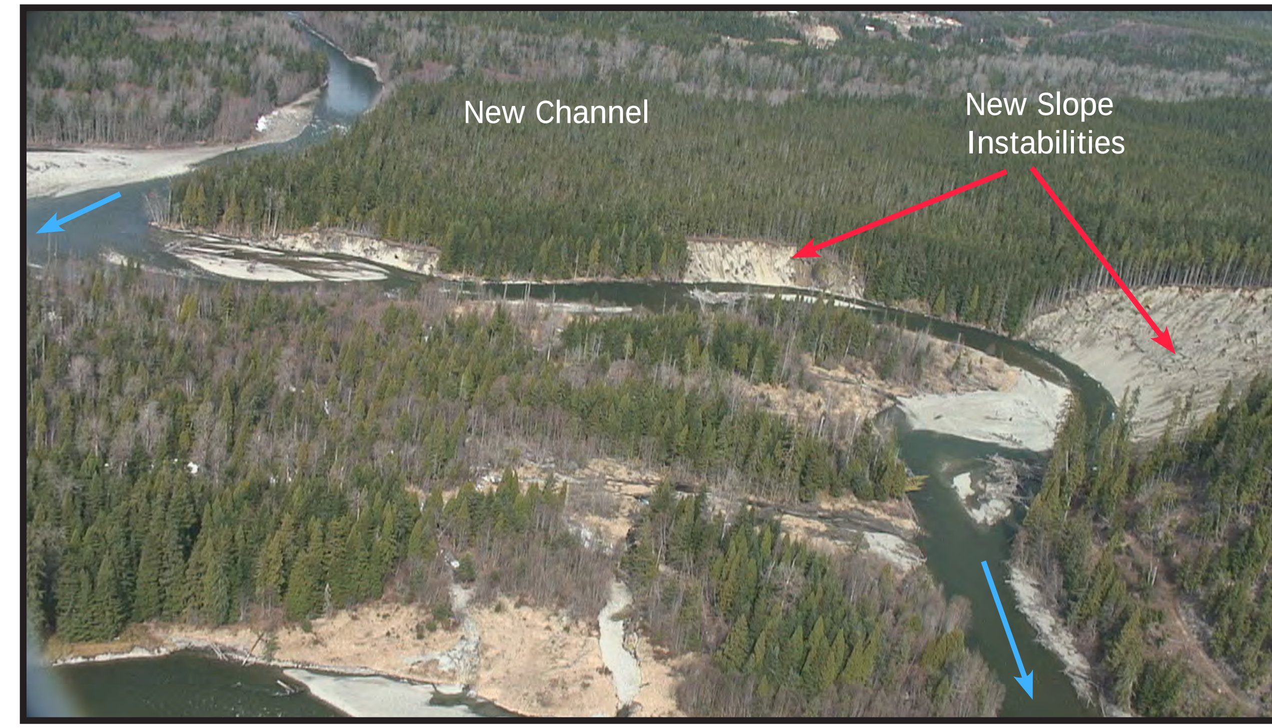
d) River Km 15.5

Plate 6.3.1.2: Oblique aerial photos illustrating the sediment loads being delivered to Kitsumkalum River from valley wall instabilities.



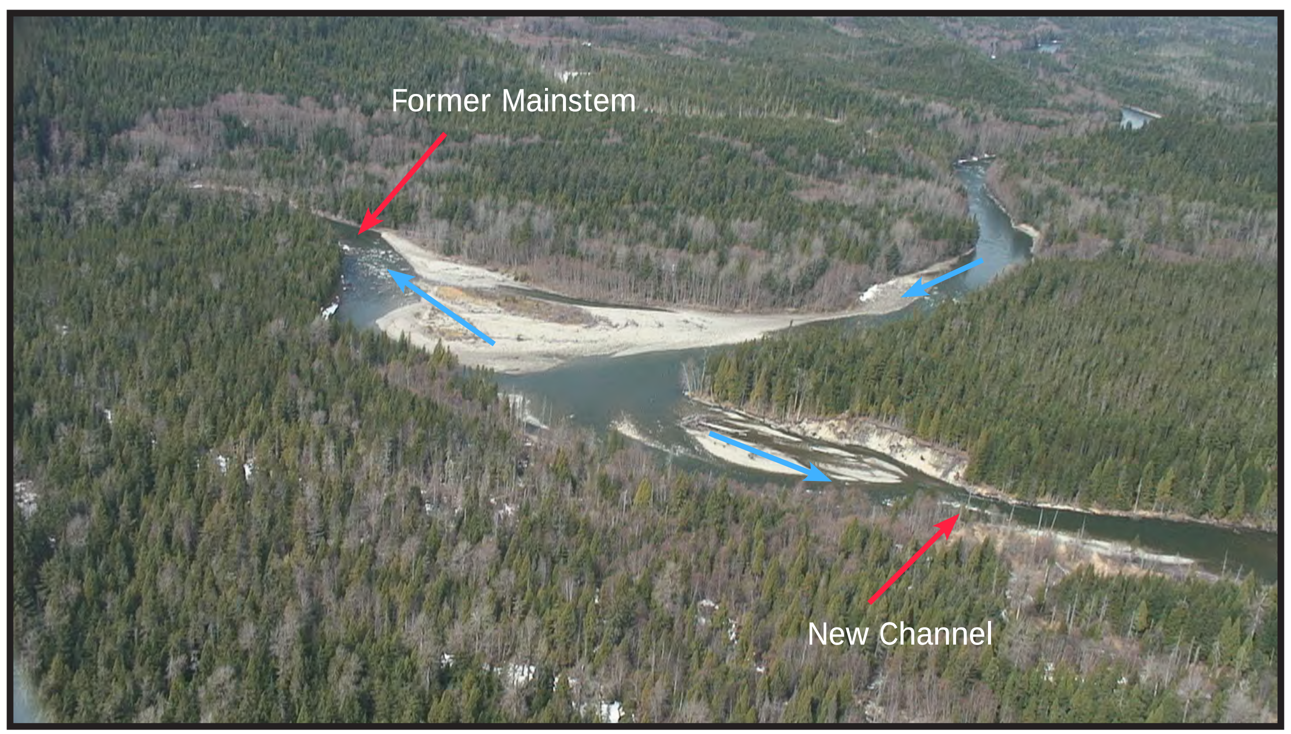
April 23, 2009 MM Cam 6517

a) Looking upstream to the outlet of the new channel.



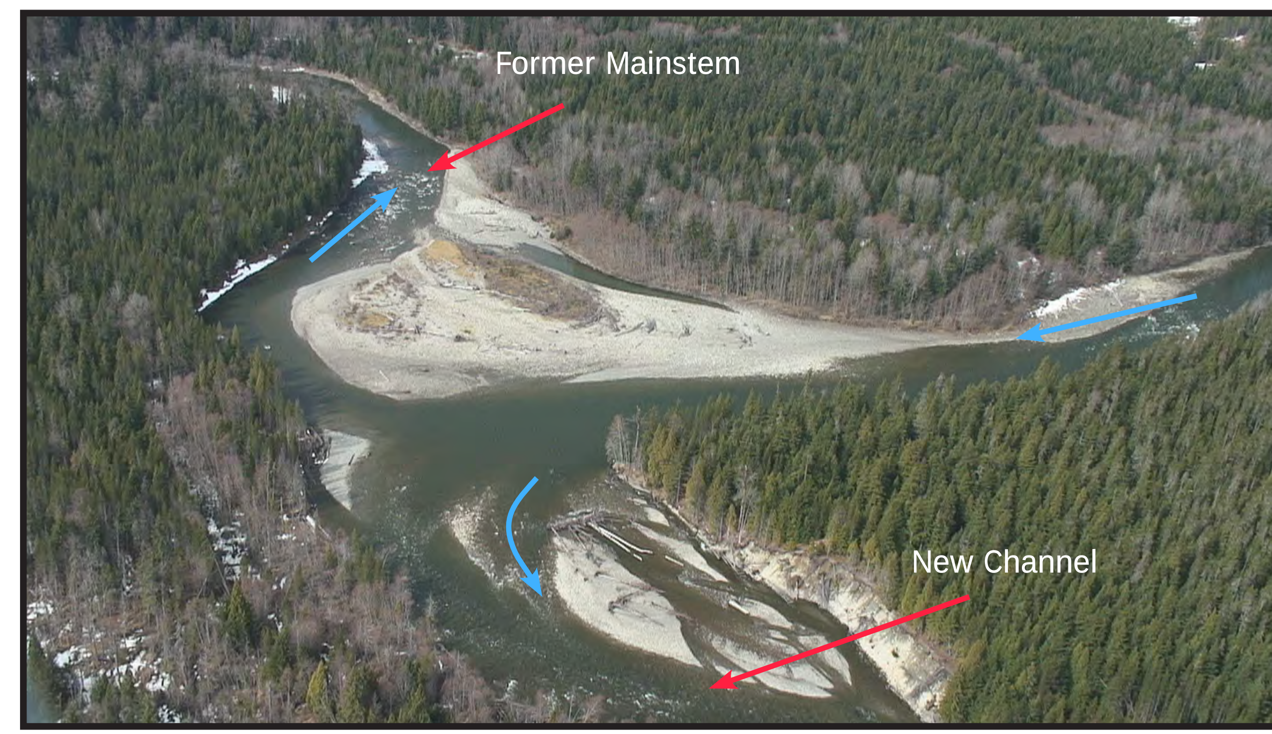
April 23, 2009 MM Cam 6518

b) Looking upstream along the new channel.



April 23, 2009 MM Cam 6519

c) Looking upstream to the inlet of the new channel.



April 23, 2009 MM Cam 6521

d) Looking upstream showing sediment accumulation opposite the channel inlet.

Plate 6.3.1.3: Oblique aerial photos illustrating the new river channel which has developed between River Kms 15.5 and 17.5 in the period since 2001.

April 23, 2009 MM Cam 6474

a) Looking upstream to the islands and bars located downstream of the lower Canyon outlet.

April 23, 2009 MM Nikon 8456

b) Looking towards the section of channel that may have been ‘straightened’ prior to 1960 to facilitate log driving.

Plate 6.3.2.1: Oblique aerial photos of the multi-thread channel located downstream of the lower Canyon outlet

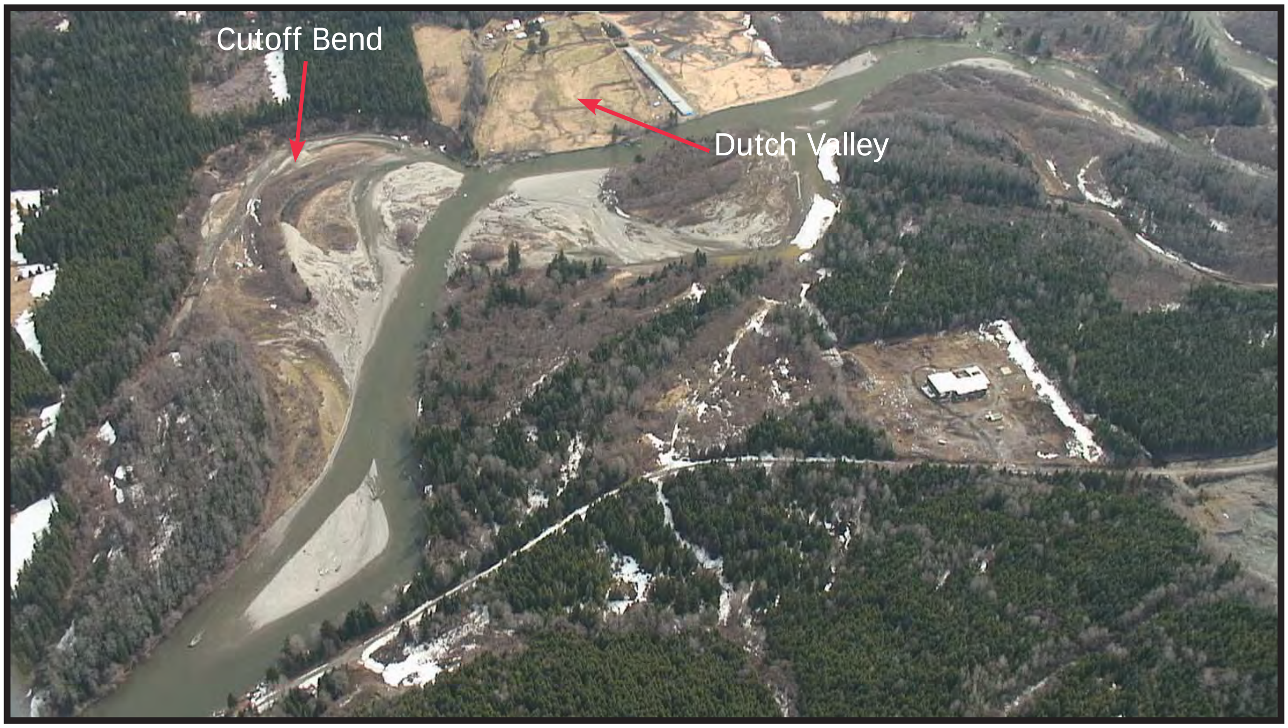
April 23, 2009 MM Cam 6735

a) Looking downstream along the road.

April 23, 2009 MM Cam 6736

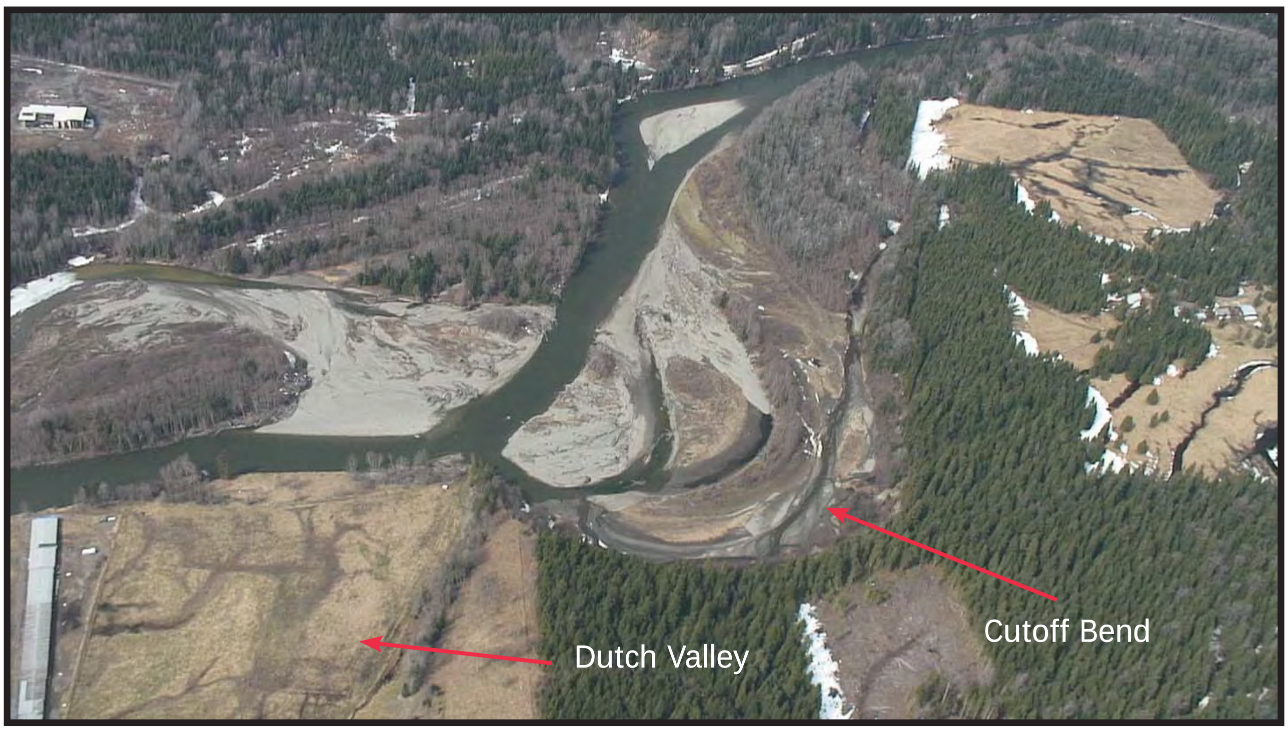
b) Looking downstream to the developing bar and eroding bend.

Plate 6.3.2.2: Oblique aerial photos of the area below Kms 5 and 6 where Kitsumkalum River is located in close proximity to the left bank (Nass River) access road.



April 23, 2009 MM Cam 6675

a) Looking east or downstream.



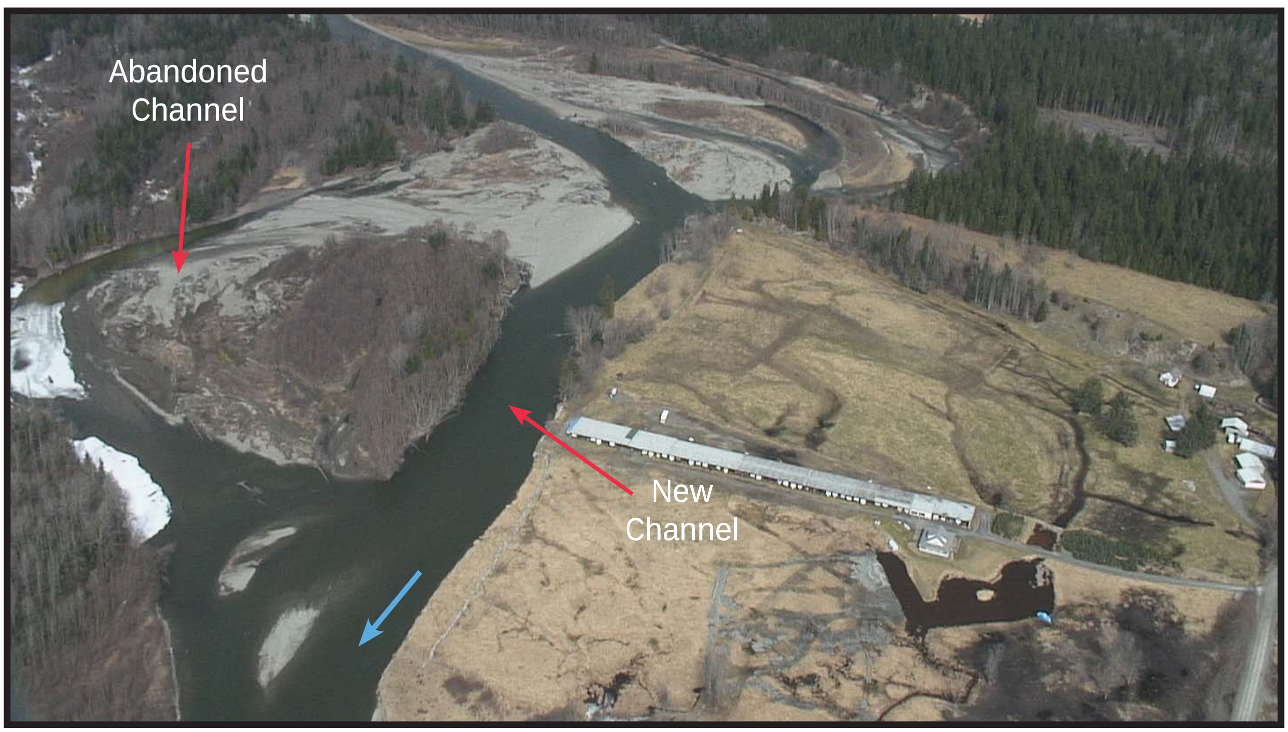
April 23, 2009 MM Cam 6722

b) Looking west or upstream

Plate 6.3.2.3: Oblique aerial photos of the pre-1993 meander bend cutoff at River Km 4 (near Dutch Valley).

April 23, 2009 MM Cam 6789

a) Looking downstream over the former mainstem channel.



April 23, 2009 MM Cam 6780

b) Looking upstream over the new channel and cleared field in Dutch Valley.

Plate 6.3.3.1: Oblique aerial photos of the recent channel changes opposite Dutch Valley.

April 22, 2009 MM Pentax 5424

a) Looking upstream showing the capped and seeded industrial waste disposal site with recent additions.

April 22, 2009 MM Pentax 5410

b) Ground water seepage and rust coloured algal mats at the base of the cut slope.

Plate 6.3.3.2: Photographs illustrating a potential groundwater contaminant site opposite the abandoned Kalum Wood Products Mill at River Km 3.5.

April 23, 2009 MM Cam 6792

a) Looking downstream to the abandoned channel located upstream of the log storage area. At least portions of the right bank are armoured.

April 23, 2009 MM Cam 6799

b) Looking downstream to the log storage area. The entire perimeter is armoured.

Plate 6.3.3.3: Oblique aerial photographs of abandoned log storage structures on lower Kitsumkalum River.

April 22, 2009 a) Looking upstream showing sediment and debris accumulations in the log storage area. MM Pentax 5450 to 5458

April 22, 2009 b) Looking upstream to the rock lined channel at the outlet of the storage area. MM Pentax 5460 to 5465

Plate 6.3.3.4: Ground photos of the log storage area on lower Kitsumkalum River.

Plate 6.3.3.5: Pre-2007 oblique aerial photograph of the lower Kalum River. [Photo provided by Cambria Gordon Ltd.]

April 23, 2009 MM Cam 6770

a) Looking upstream from the channel outlet.

April 23, 2009 MM Cam 6772

b) Looking upstream to Dutch Valley.

April 23, 2009 MM Cam 6775

c) Looking upstream over a local access bridge.

April 23, 2009 MM Cam 6777

d) Looking upstream to the channel inlet.

Plate 6.3.3.6: Oblique aerial photographs of a cut-off channel which is developing across the meander bend located downstream of Dutch Valley.

April 22, 2009 MM Pentax 5425 to 5430

Plate 6.3.3.7: Panorama looking upstream on a right bank tributary channel located opposite the abandoned Kalum Wood Products Limited Mill. The Nass River Road could divert flood waters from this site to the Kalum Reserve

April 23, 2009 MM Cam 6751

a) Looking downstream from the Nass River Quarry.

April 23, 2009 MM Cam 6754

b) Looking downstream showing the road and railway grade.

April 23, 2009 MM Cam 6757

c) Looking downstream to IR 1

April 23, 2009 MM Cam 6759

d) Looking downstream showing IR 1 in relation to a local stream channel.

Plate 6.3.3.8: Oblique aerial photographs showing the relationship between the Nass River road, the former railway grade and Kitsumkalum IR 1.

April 23, 2009 MM Nikon 8856

a) Looking upstream to the MOT maintenance yard.

April 23, 2009 MM Cam 6768

b) Looking upstream to the borrow pit.

Plate 6.3.3.9 : Oblique aerial photos looking upstream to developments on the left bank of lower Kitsumkalum River.

April 23, 2009 MM Nikon 8376

a) Looking downstream to bridges.

April 23, 2009 MM Nikon 8400

b) Looking upstream to bridges.

Plate 6.3.3.10: Oblique aerial photos of the railway and highway bridges over lower Kitsumkalum River.

April 22, 2009 a) Looking downstream to the Highway 16 Bridge. MM Pentax 5470

April 22, 2009 b) Looking downstream to the CNR Railway Bridge. MM Pentax 5511 to 5513

Plate 6.3.3.11: Ground photos of the Highway 16 and CNR bridges on lower Kitsumkalum River.

APPENDIX 3

Comparison of Daily Discharges on Skeena River at Usk and Kitsumkalum River near Terrrace 1929 to 1952

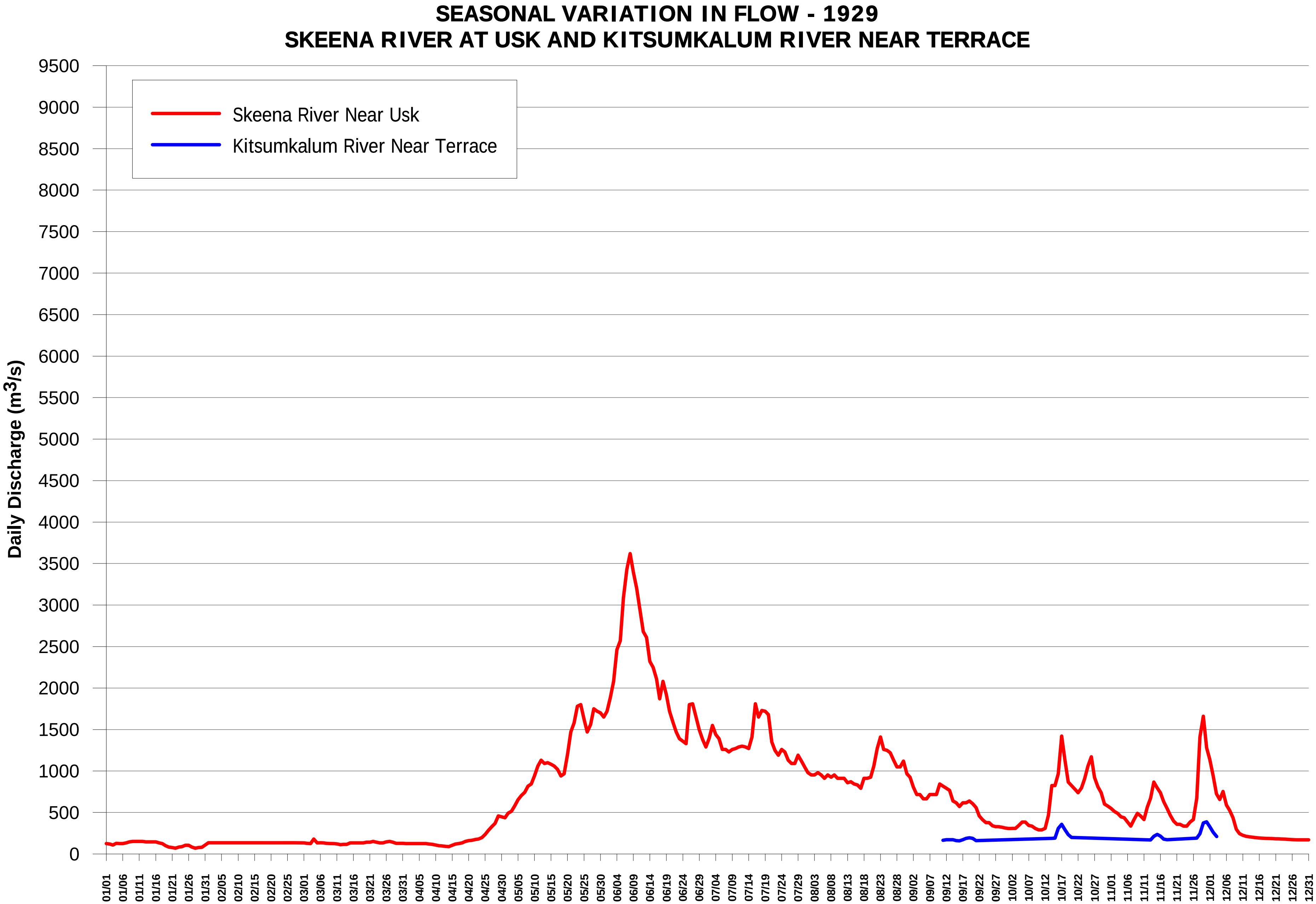


Figure A3-1: Seasonal variation in flow observed in 1929 at Kitsumkalum River Near Terrace and Skeena River at Usk.

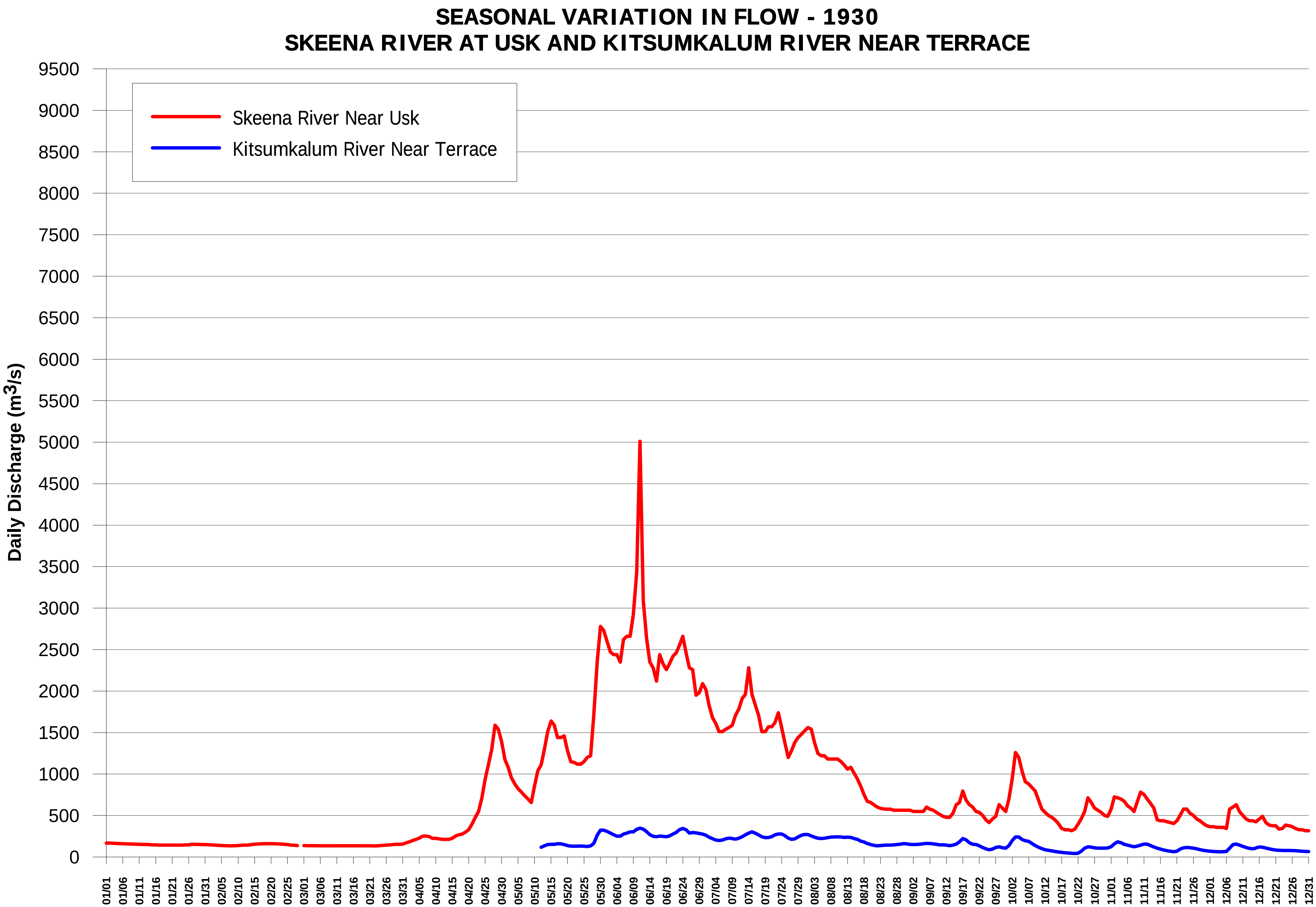


Figure A3-2: Seasonal variation in flow observed in 1930 at Kitsumkalum River Near Terrace and Skeena River at Usk.

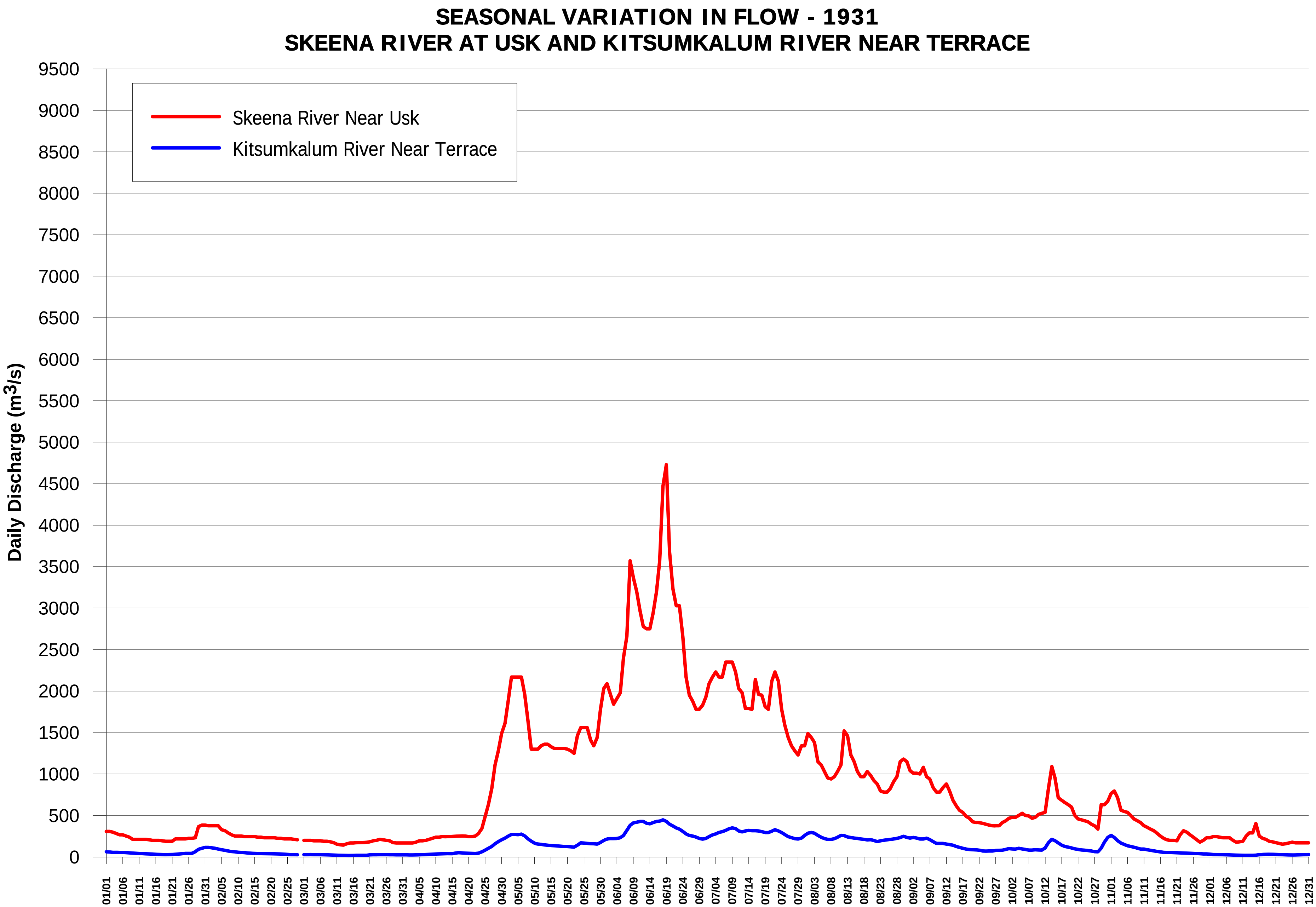


Figure A3-3: Seasonal variation in flow observed in 1931 at Kitsumkalum River Near Terrace and Skeena River at Usk.

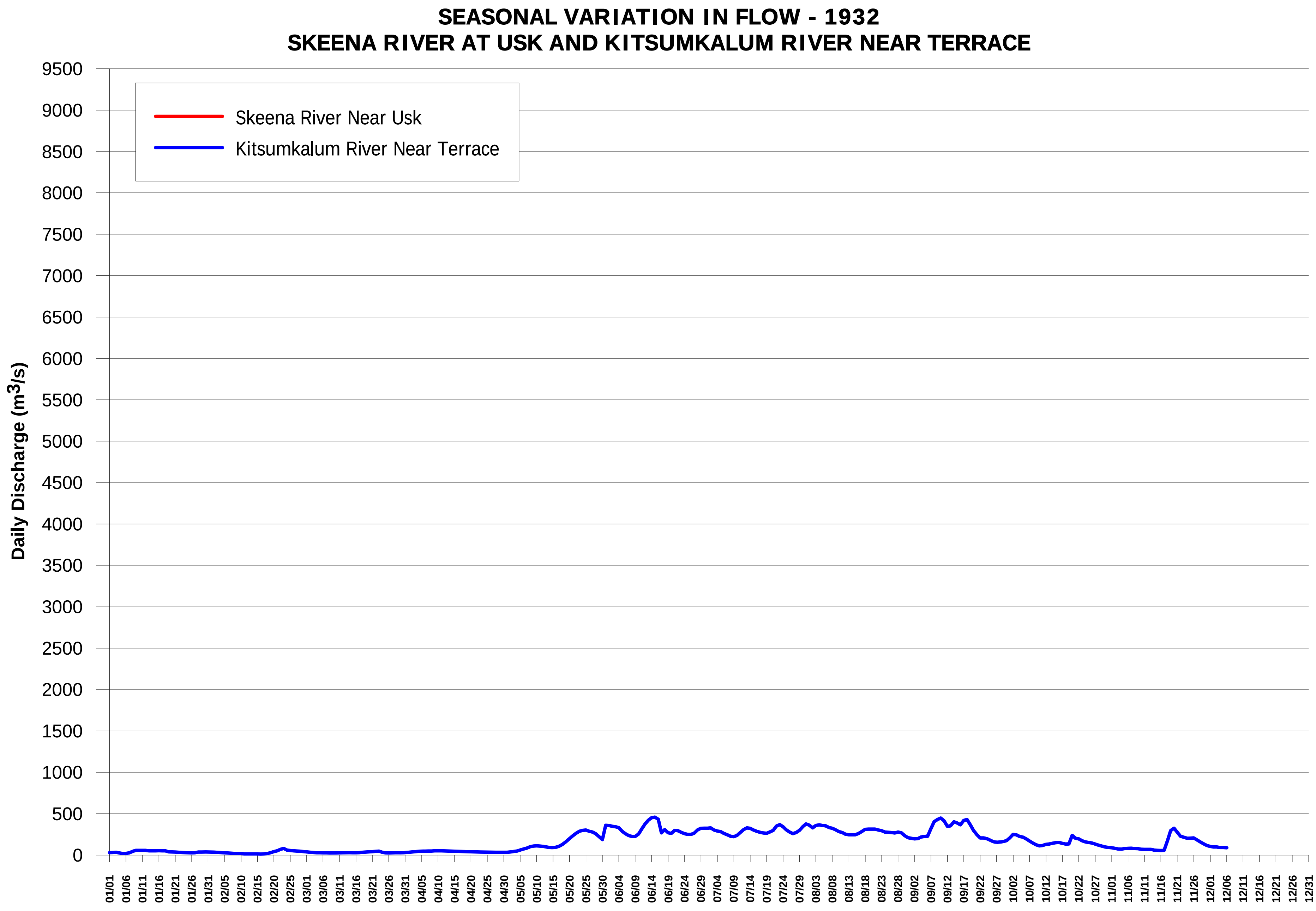


Figure A3-4: Seasonal variation in flow observed in 1932 at Kitsumkalum River Near Terrace and Skeena River at Usk.

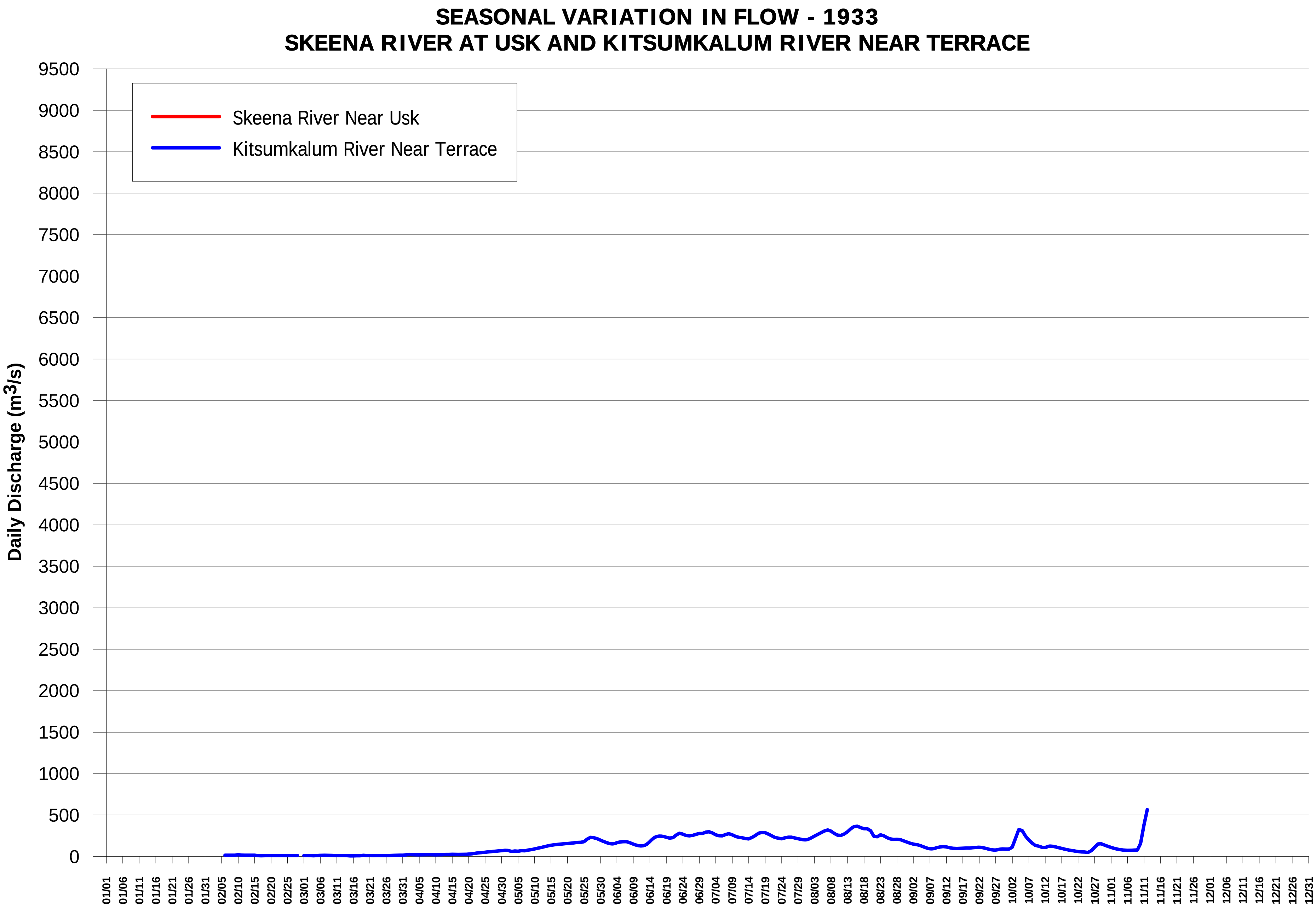


Figure A3-5: Seasonal variation in flow observed in 1933 at Kitsumkalum River Near Terrace and Skeena River at Usk.

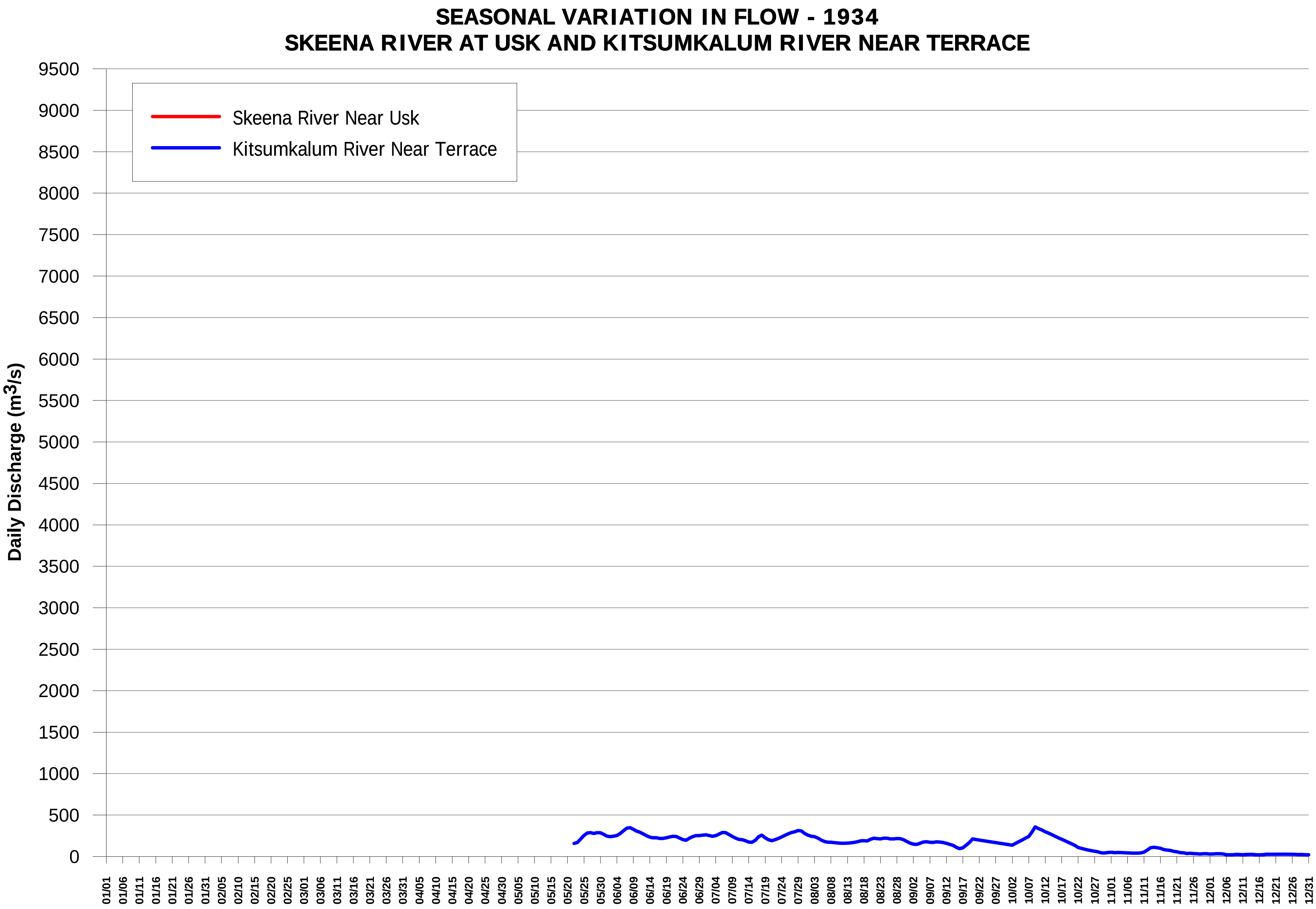


Figure A3-6: Seasonal variation in flow observed in 1934 at Kitsumkalum River Near Terrace and Skeena River at Usk.

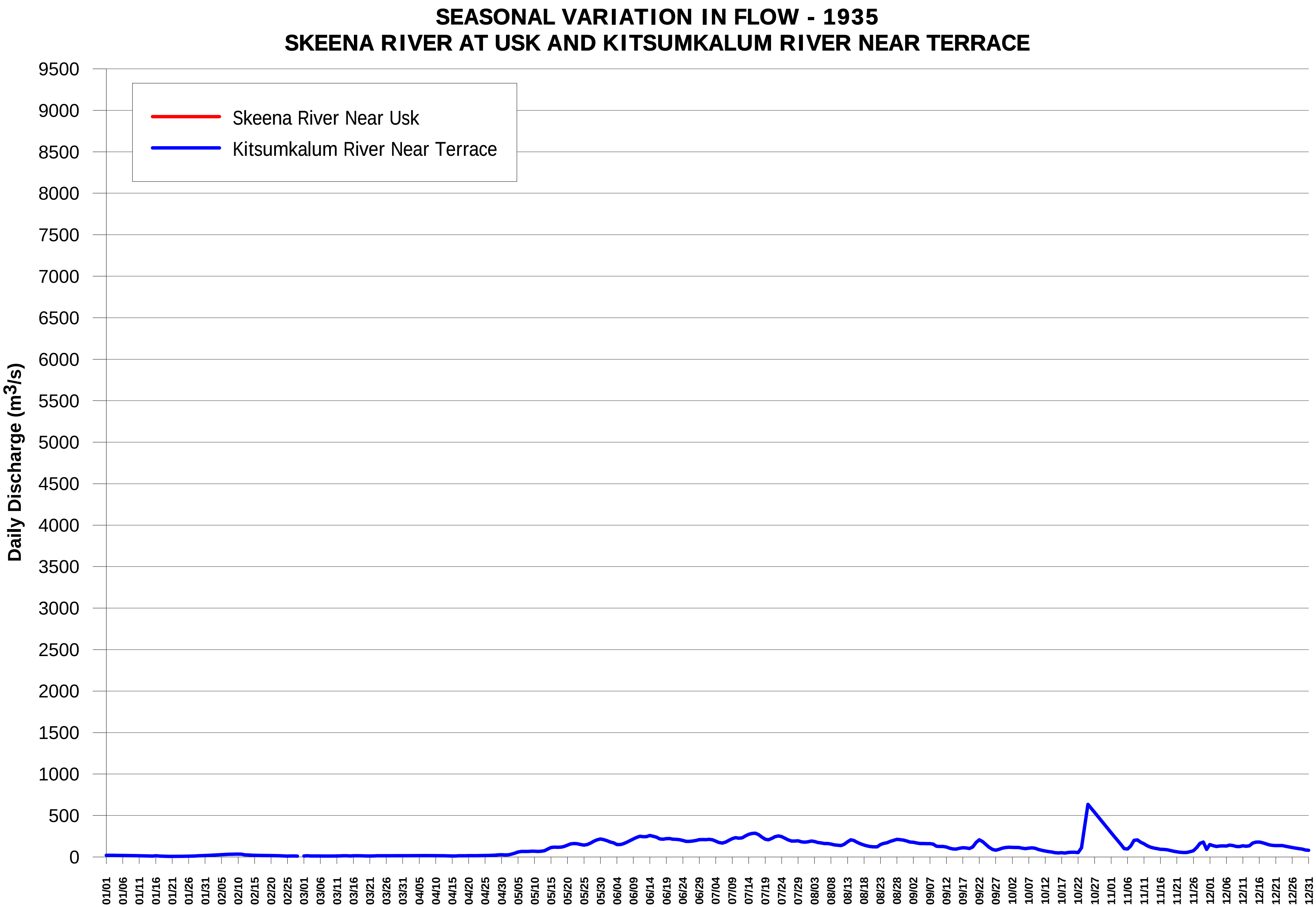


Figure A3-7: Seasonal variation in flow observed in 1935 at Kitsumkalum River Near Terrace and Skeena River at Usk.

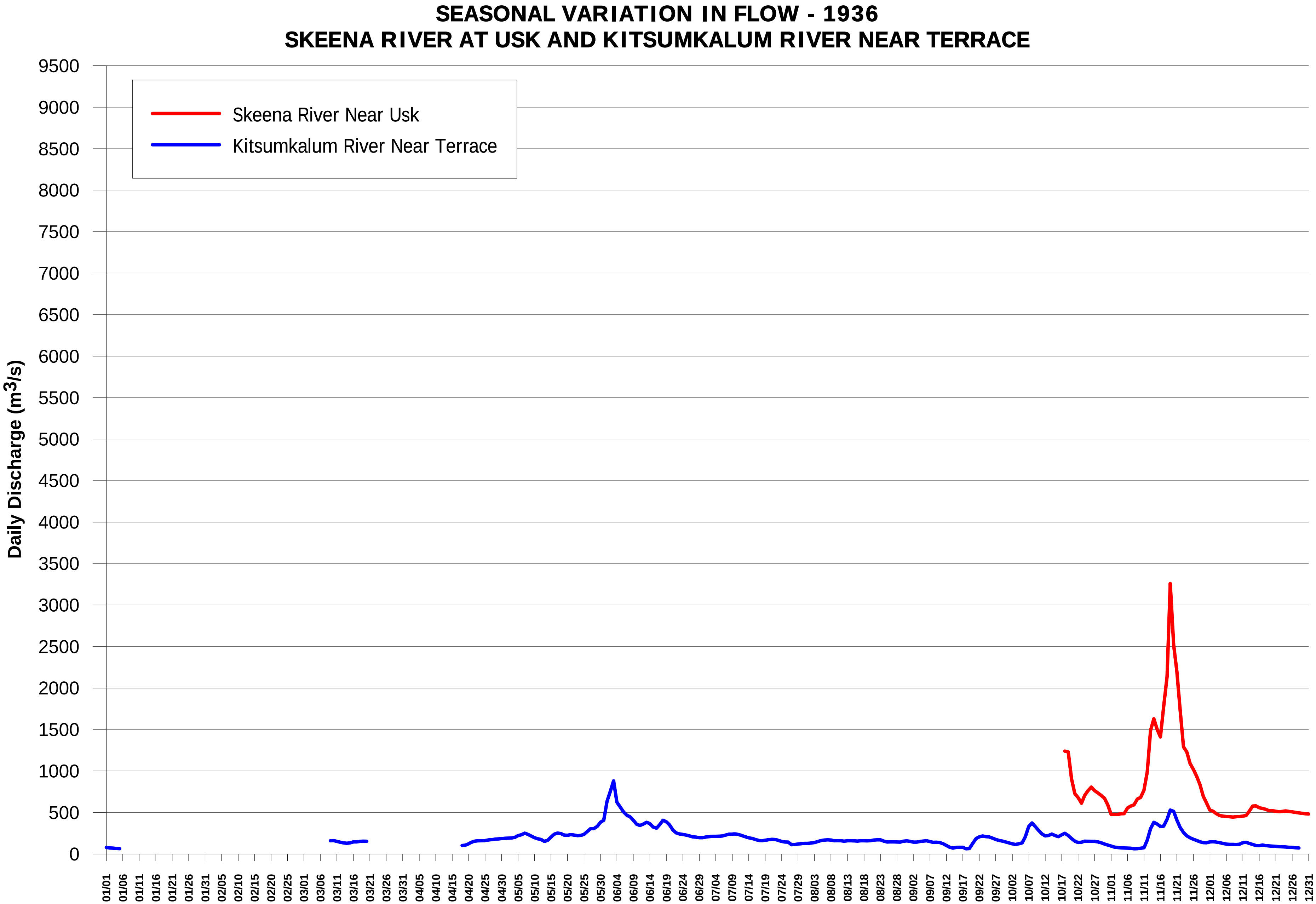


Figure A3-8: Seasonal variation in flow observed in 1936 at Kitsumkalum River Near Terrace and Skeena River at Usk.

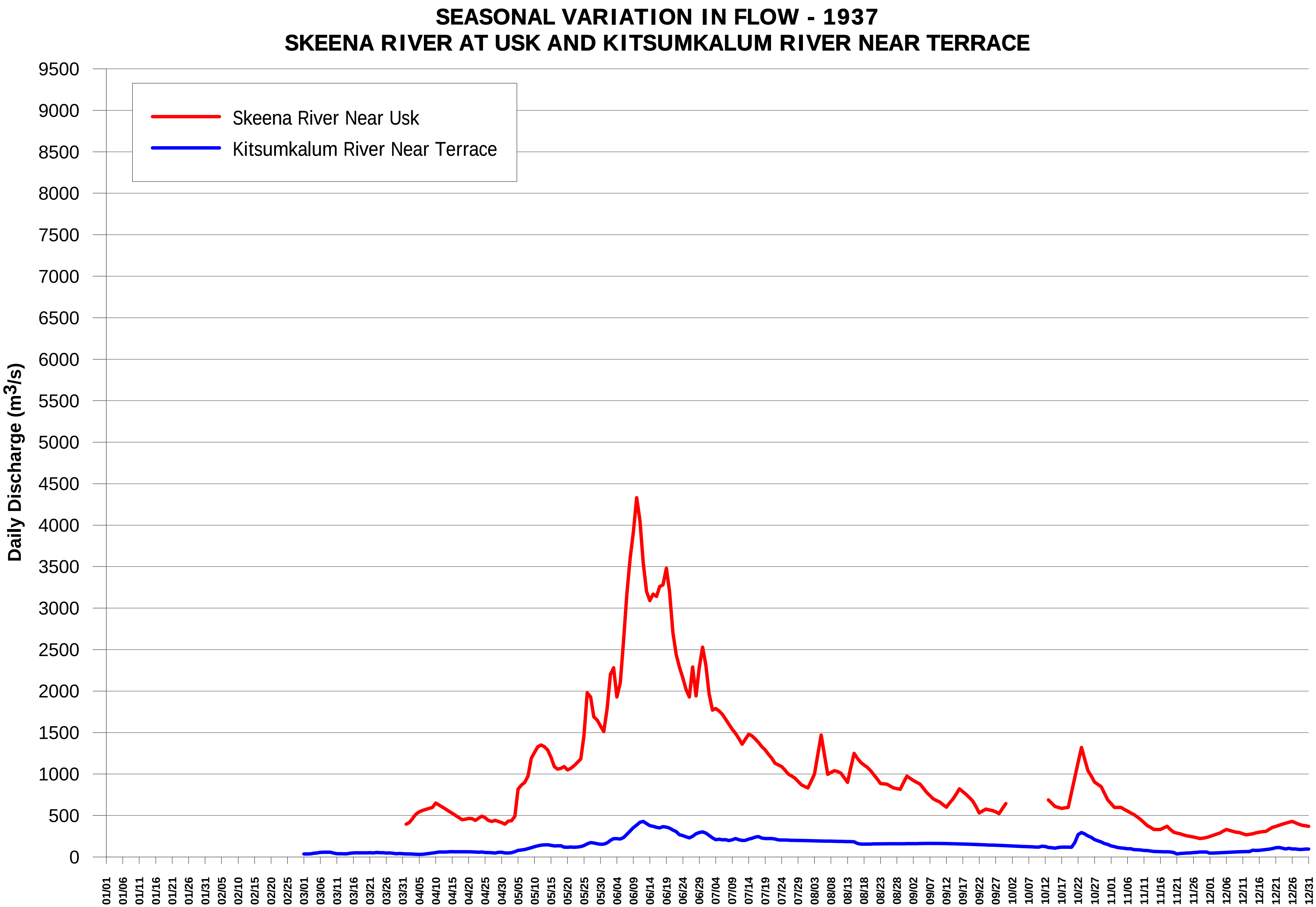


Figure A3-9: Seasonal variation in flow observed in 1937 at Kitsumkalum River Near Terrace and Skeena River at Usk.

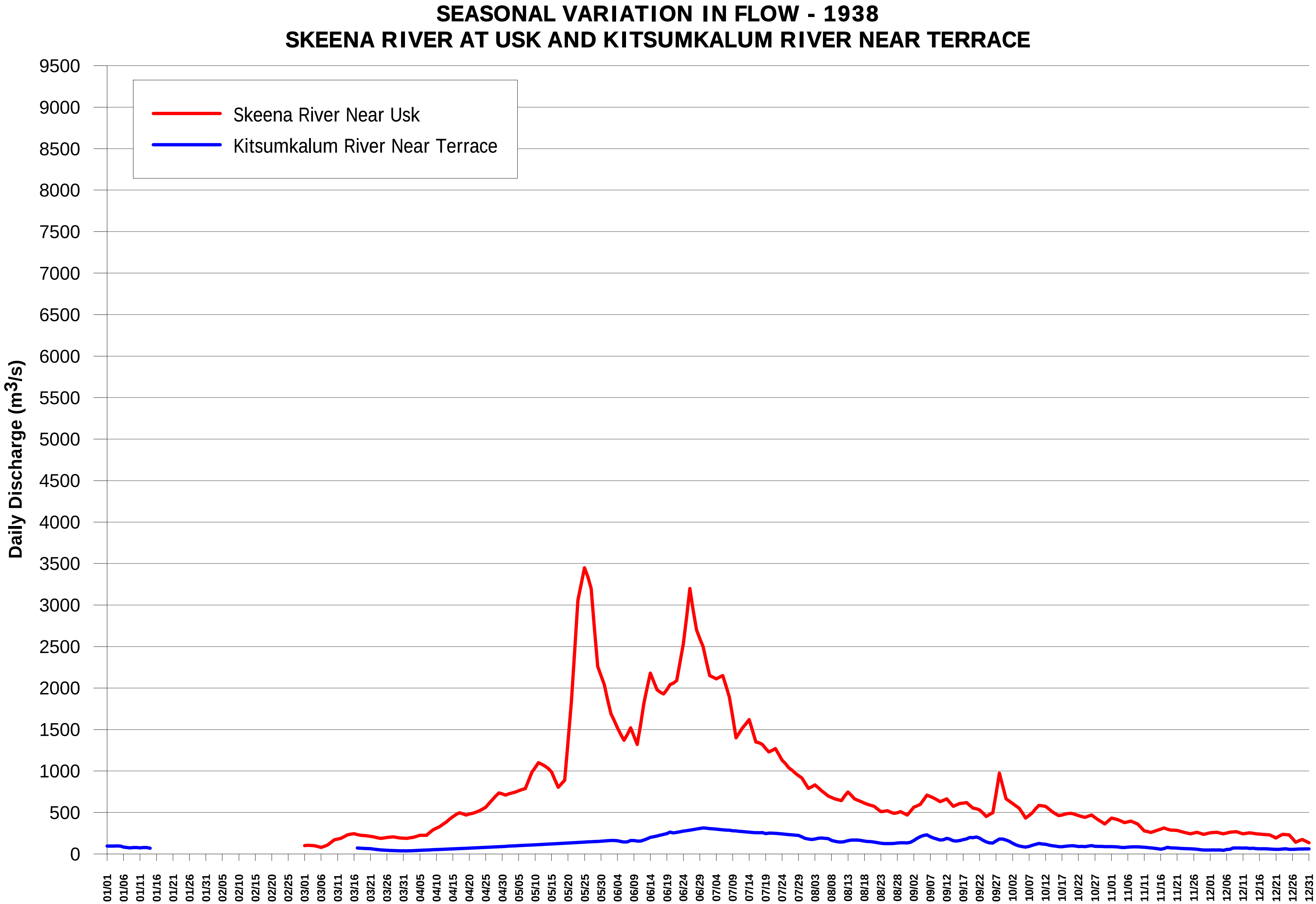


Figure A3-10: Seasonal variation in flow observed in 1938 at Kitsumkalum River Near Terrace and Skeena River at Usk.

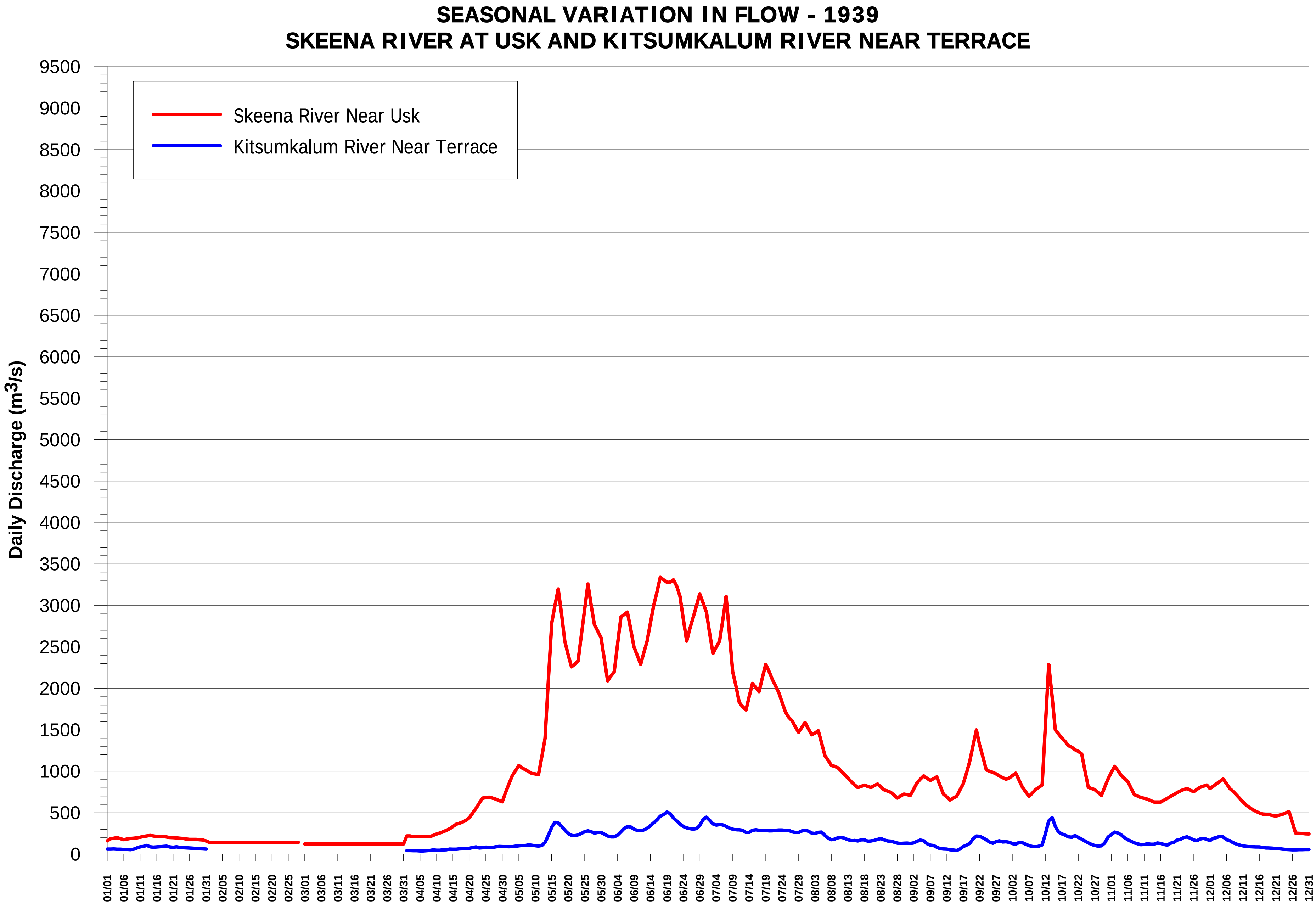


Figure A3-11: Seasonal variation in flow observed in 1939 at Kitsumkalum River Near Terrace and Skeena River at Usk.

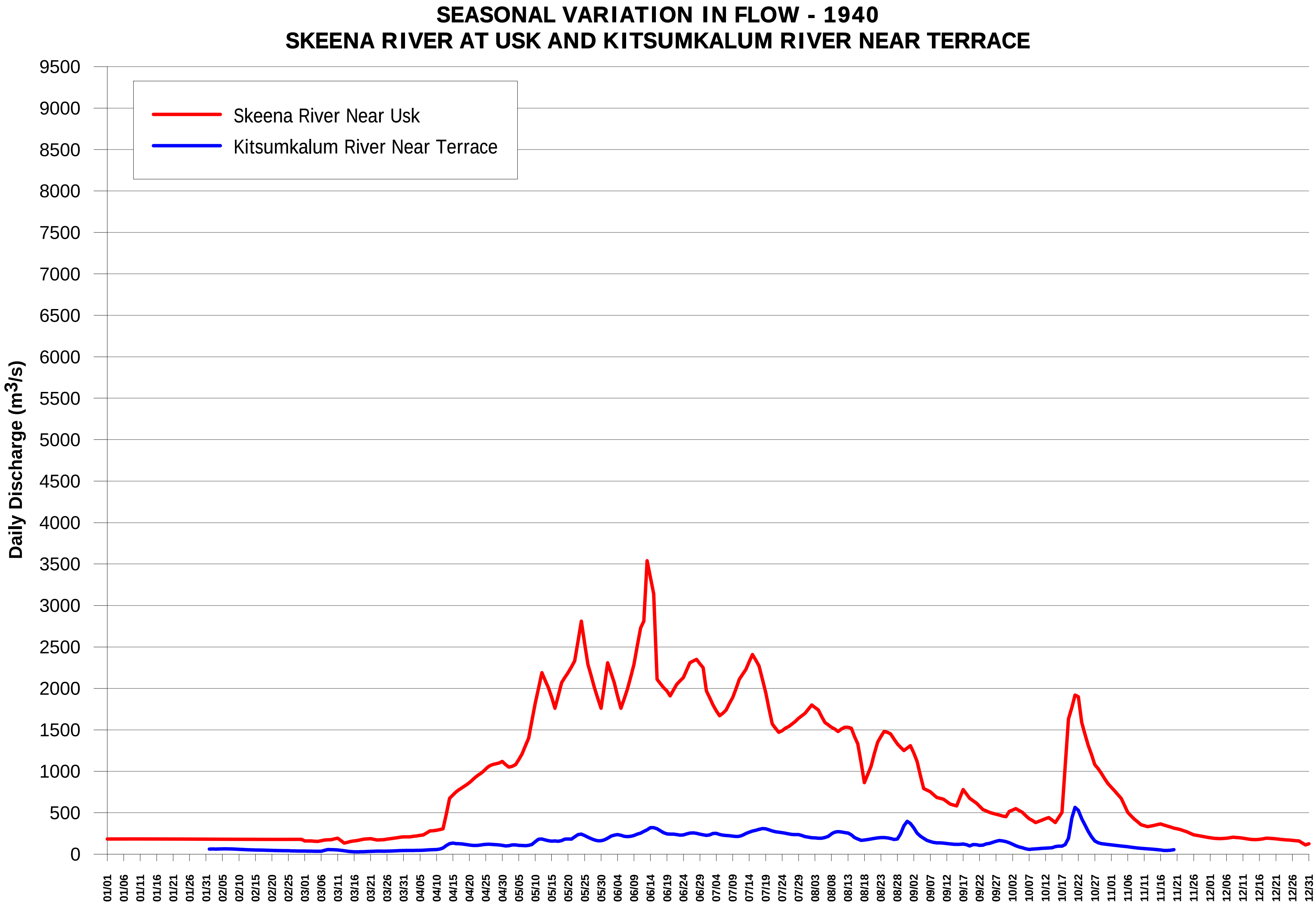


Figure A3-12: Seasonal variation in flow observed in 1940 at Kitsumkalum River Near Terrace and Skeena River at Usk.

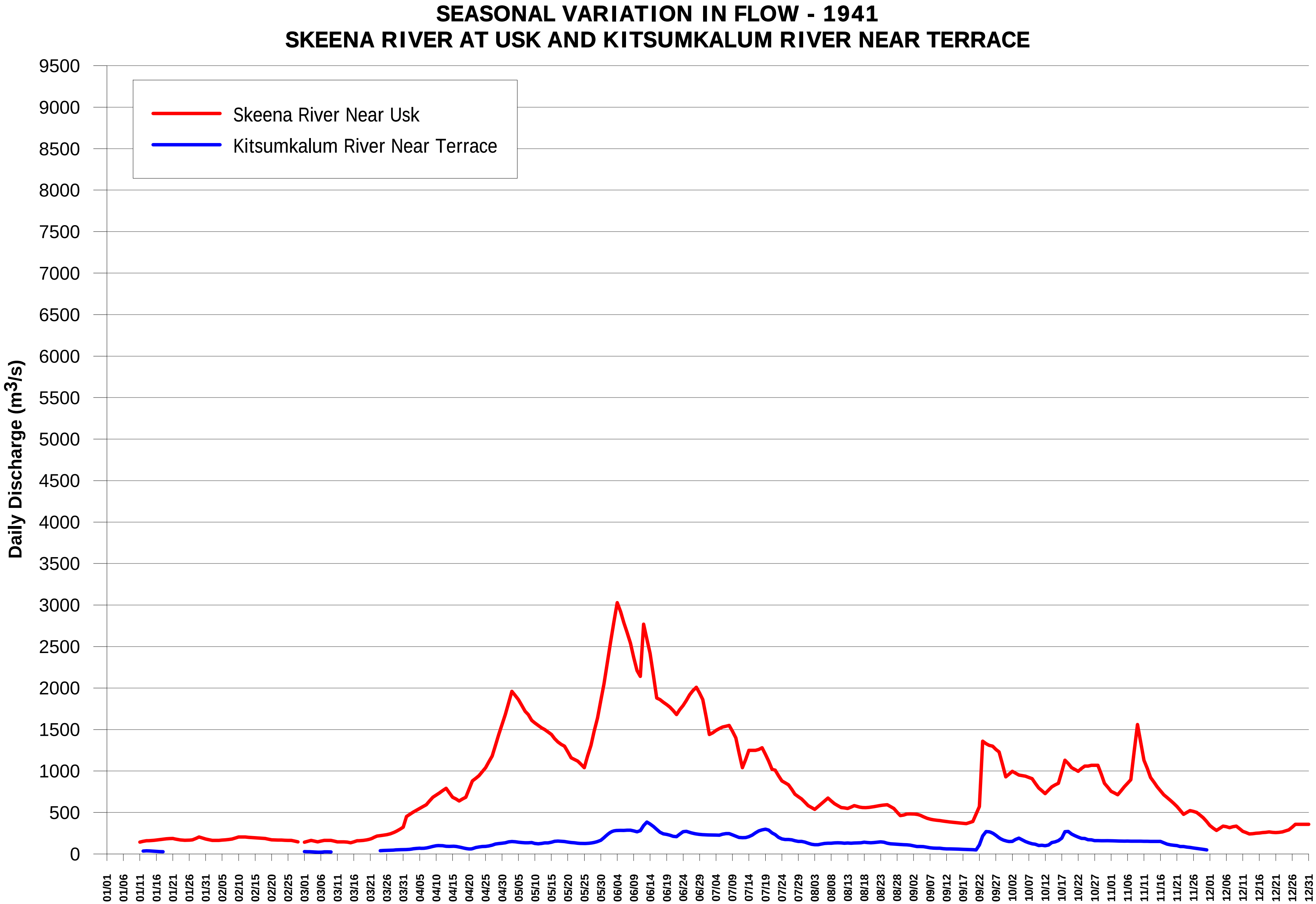


Figure A3-13: Seasonal variation in flow observed in 1941 at Kitsumkalum River Near Terrace and Skeena River at Usk.

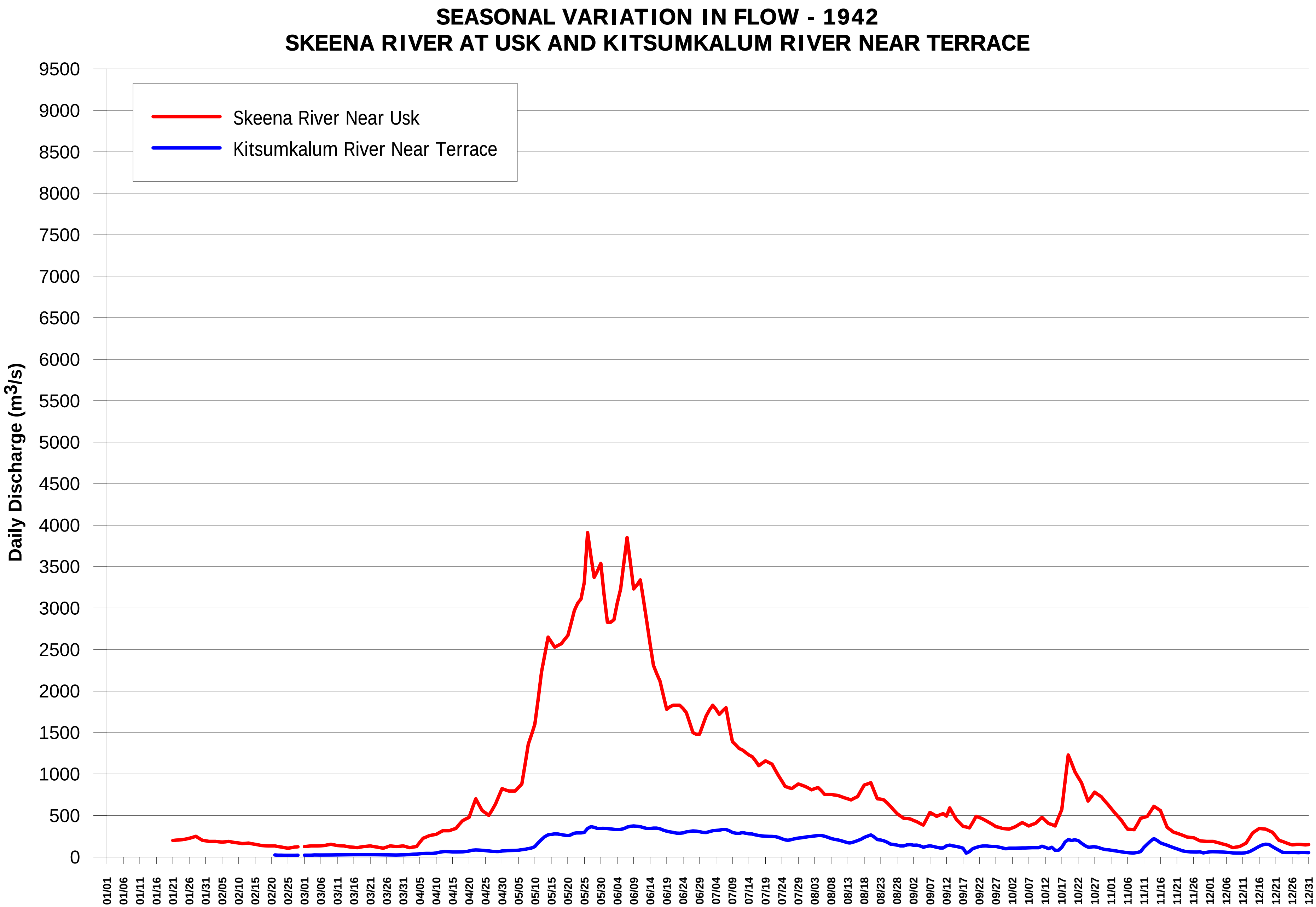


Figure A3-14: Seasonal variation in flow observed in 1942 at Kitsumkalum River Near Terrace and Skeena River at Usk.

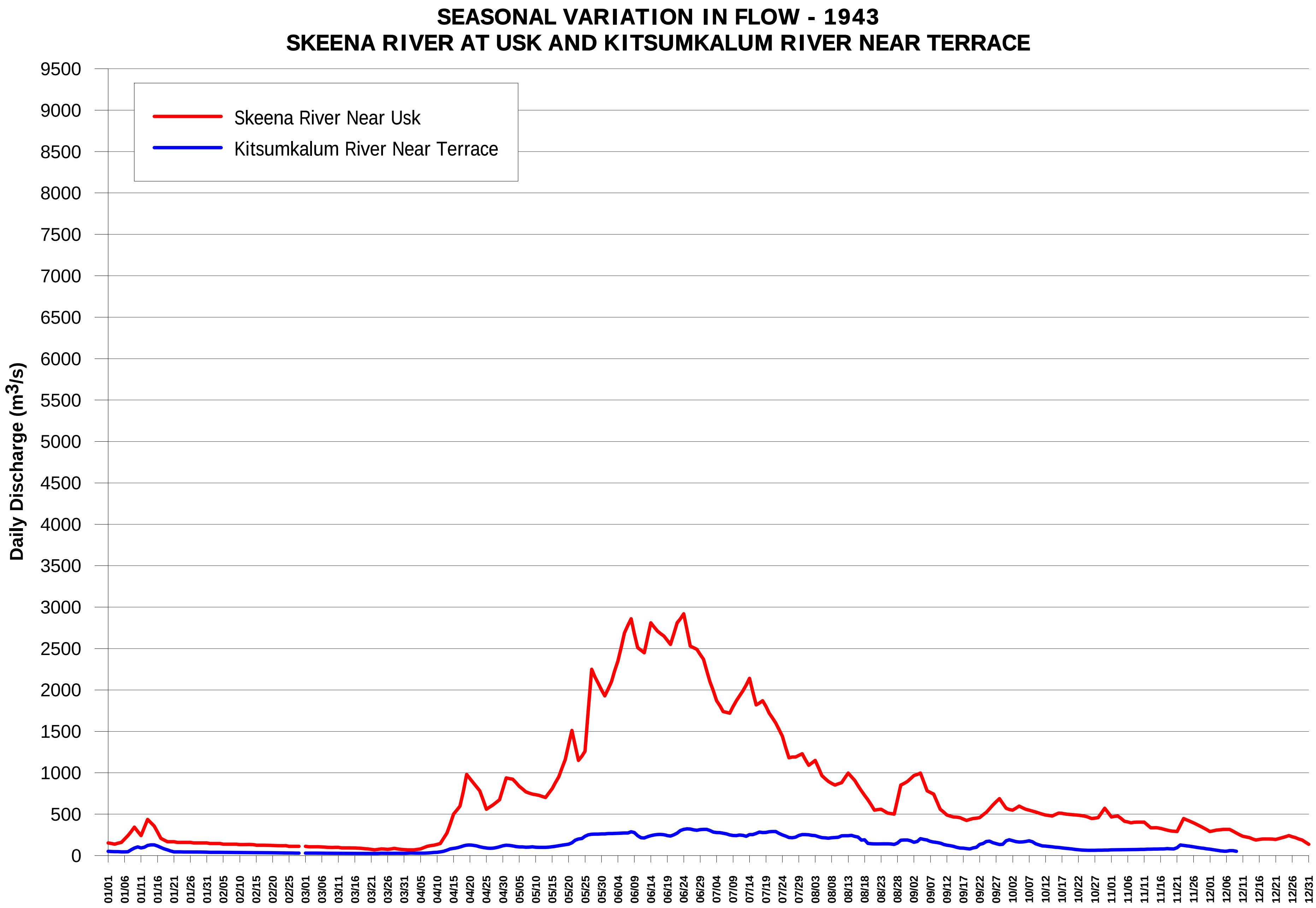


Figure A3-15: Seasonal variation in flow observed in 1943 at Kitsumkalum River Near Terrace and Skeena River at Usk.

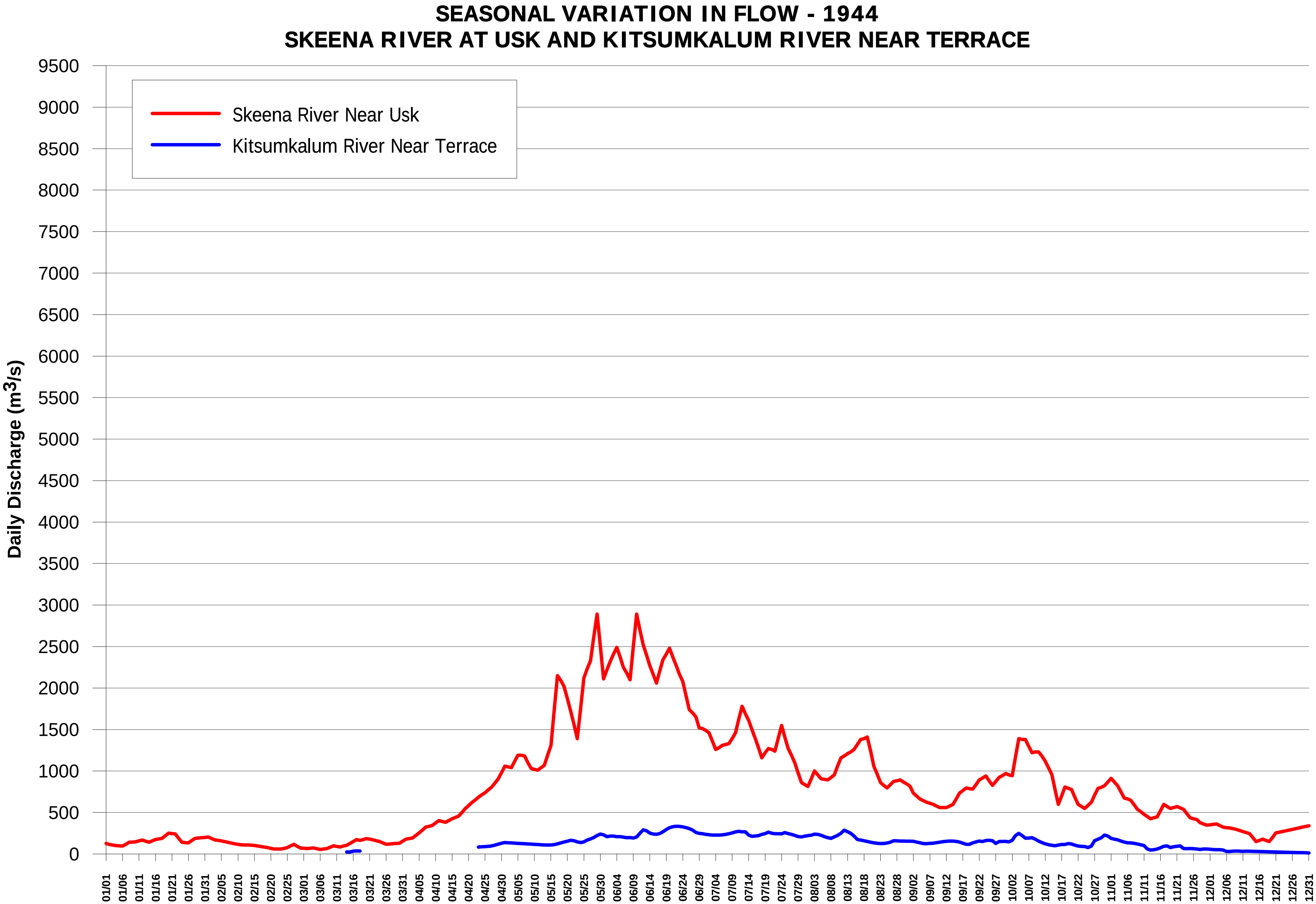


Figure A3-16: Seasonal variation in flow observed in 1944 at Kitsumkalum River Near Terrace and Skeena River at Usk.

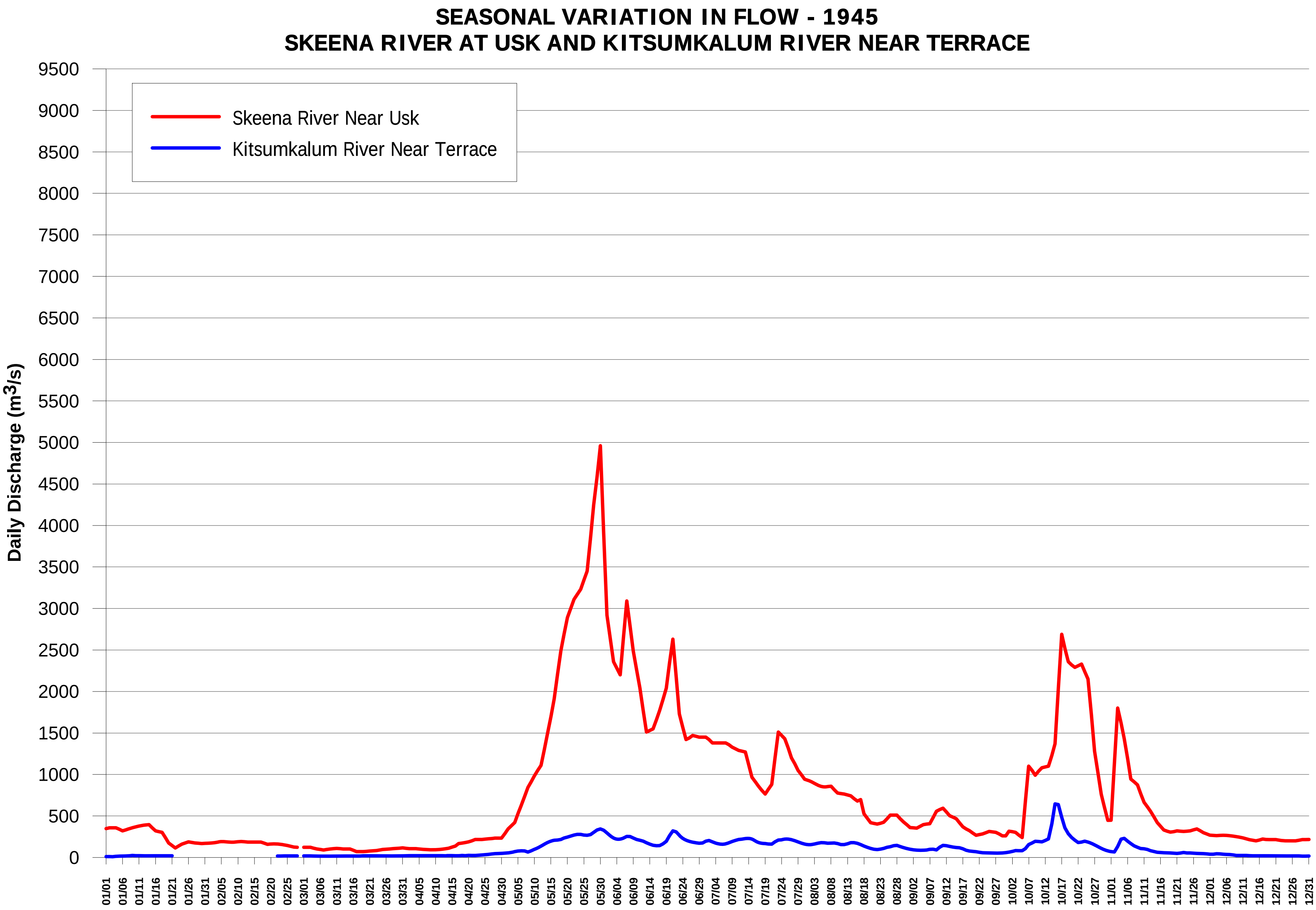


Figure A3-17: Seasonal variation in flow observed in 1945 at Kitsumkalum River Near Terrace and Skeena River at Usk.

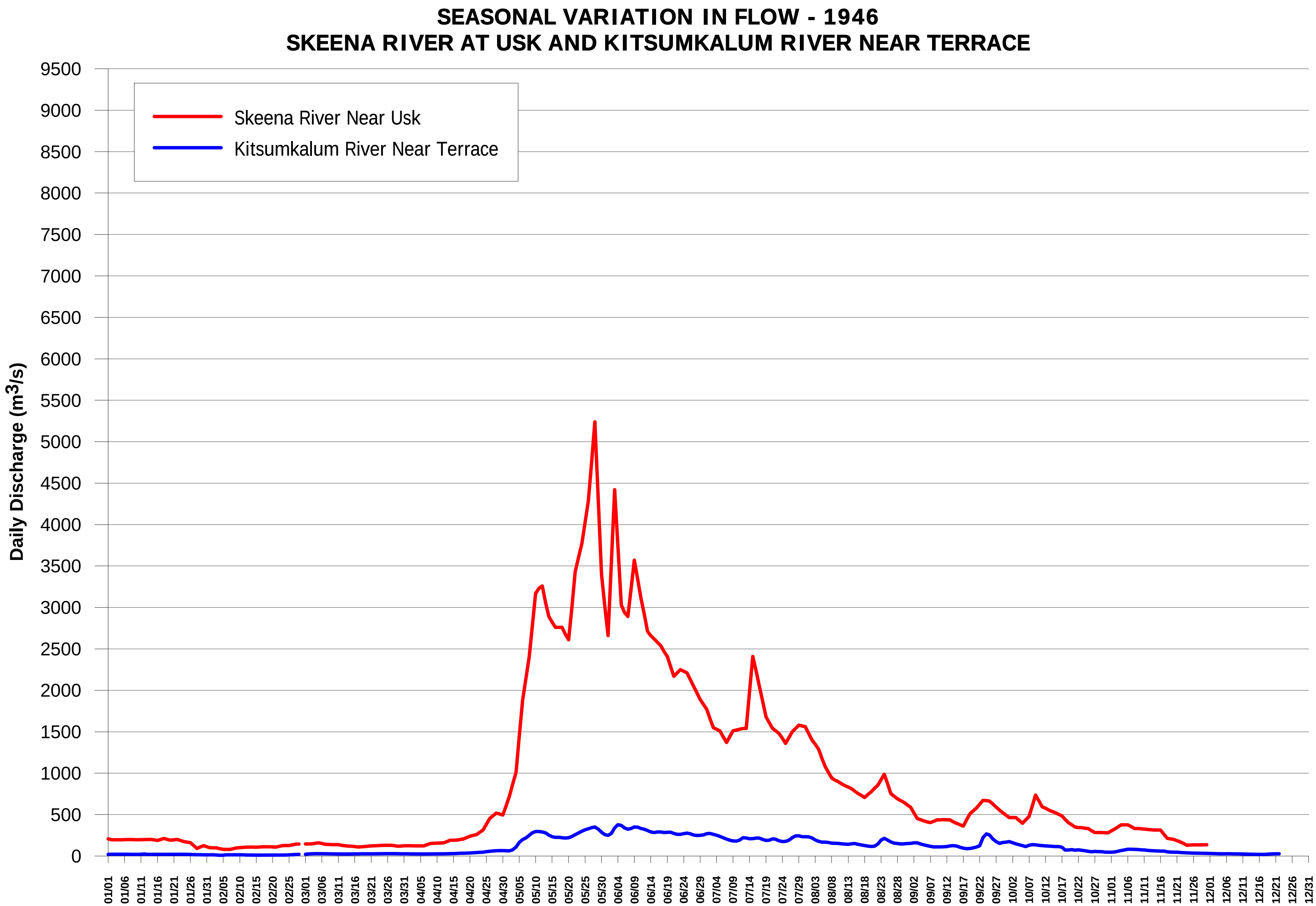


Figure A3-18: Seasonal variation in flow observed in 1946 at Kitsumkalum River Near Terrace and Skeena River at Usk.

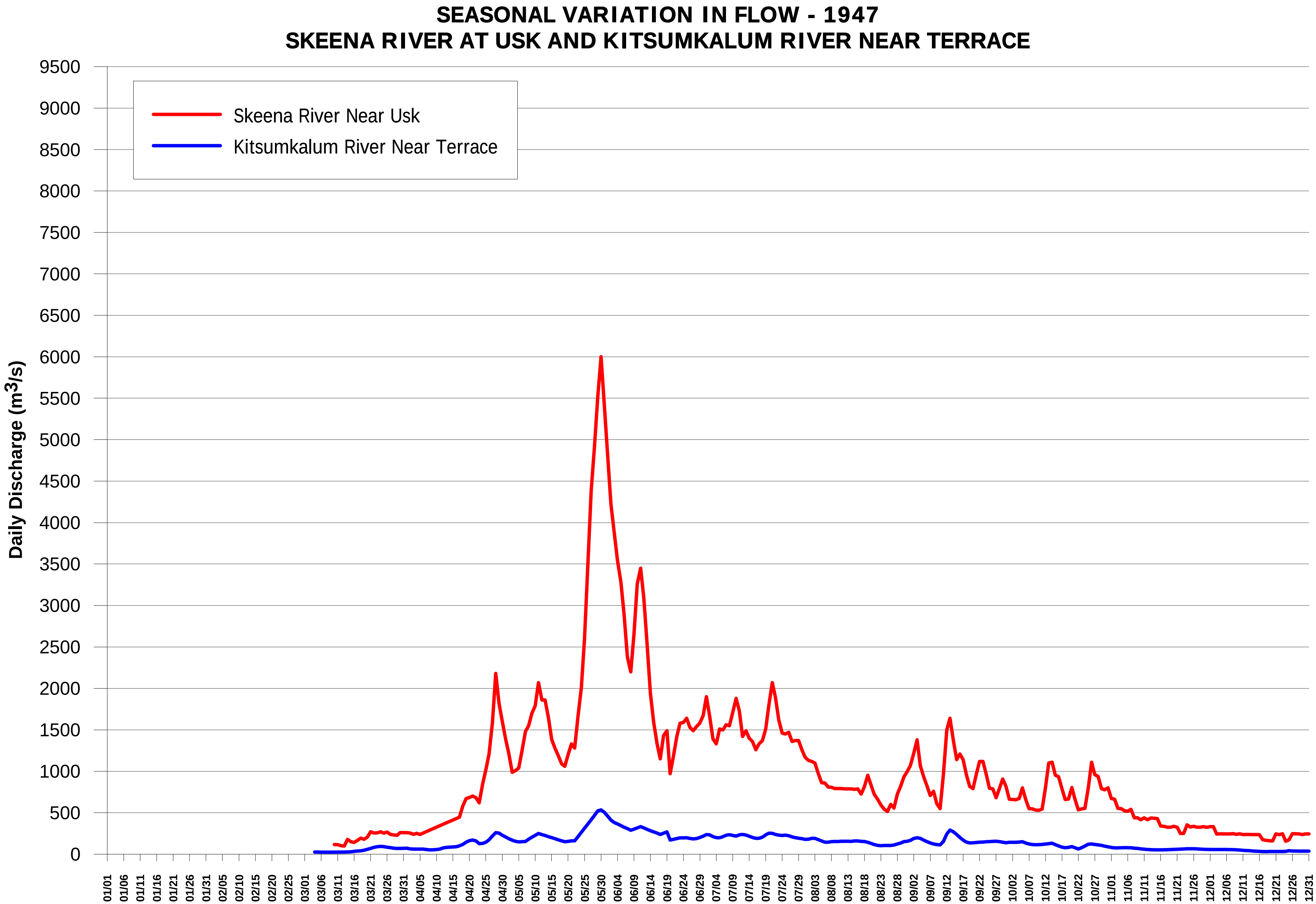


Figure A3-19: Seasonal variation in flow observed in 1947 at Kitsumkalum River Near Terrace and Skeena River at Usk.

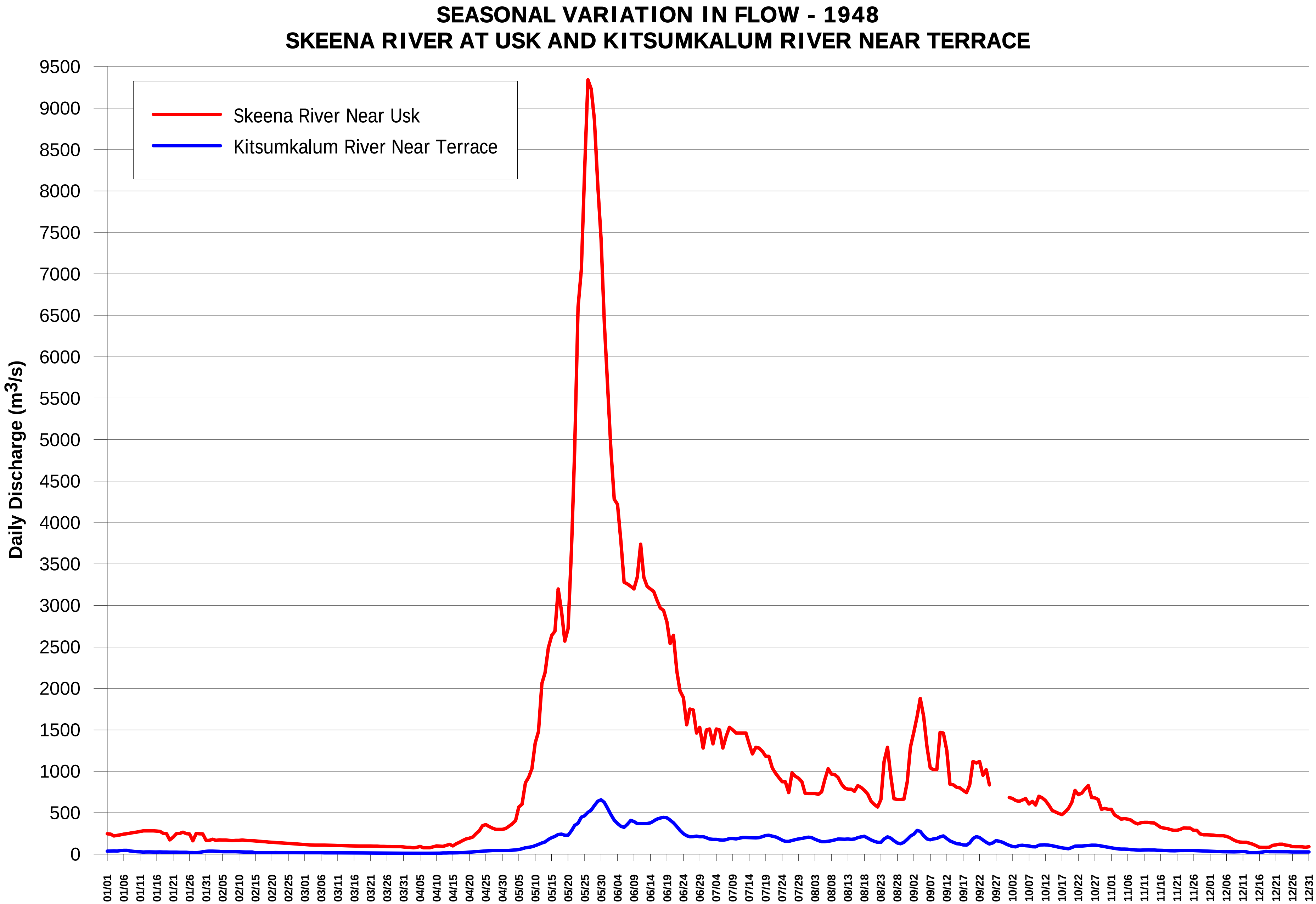


Figure A3-20: Seasonal variation in flow observed in 1948 at Kitsumkalum River Near Terrace and Skeena River at Usk.

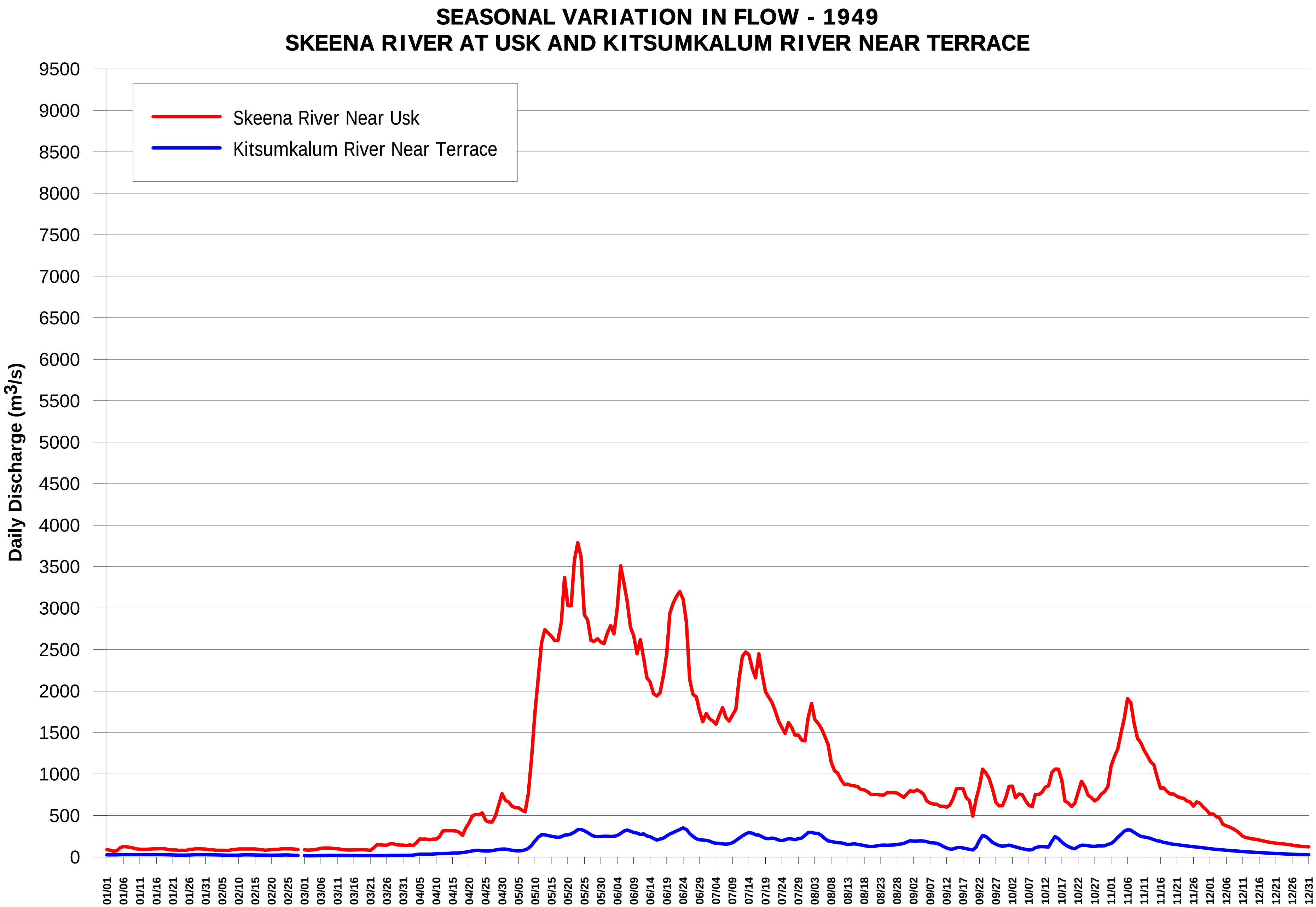


Figure A3-21: Seasonal variation in flow observed in 1949 at Kitsumkalum River Near Terrace and Skeena River at Usk.

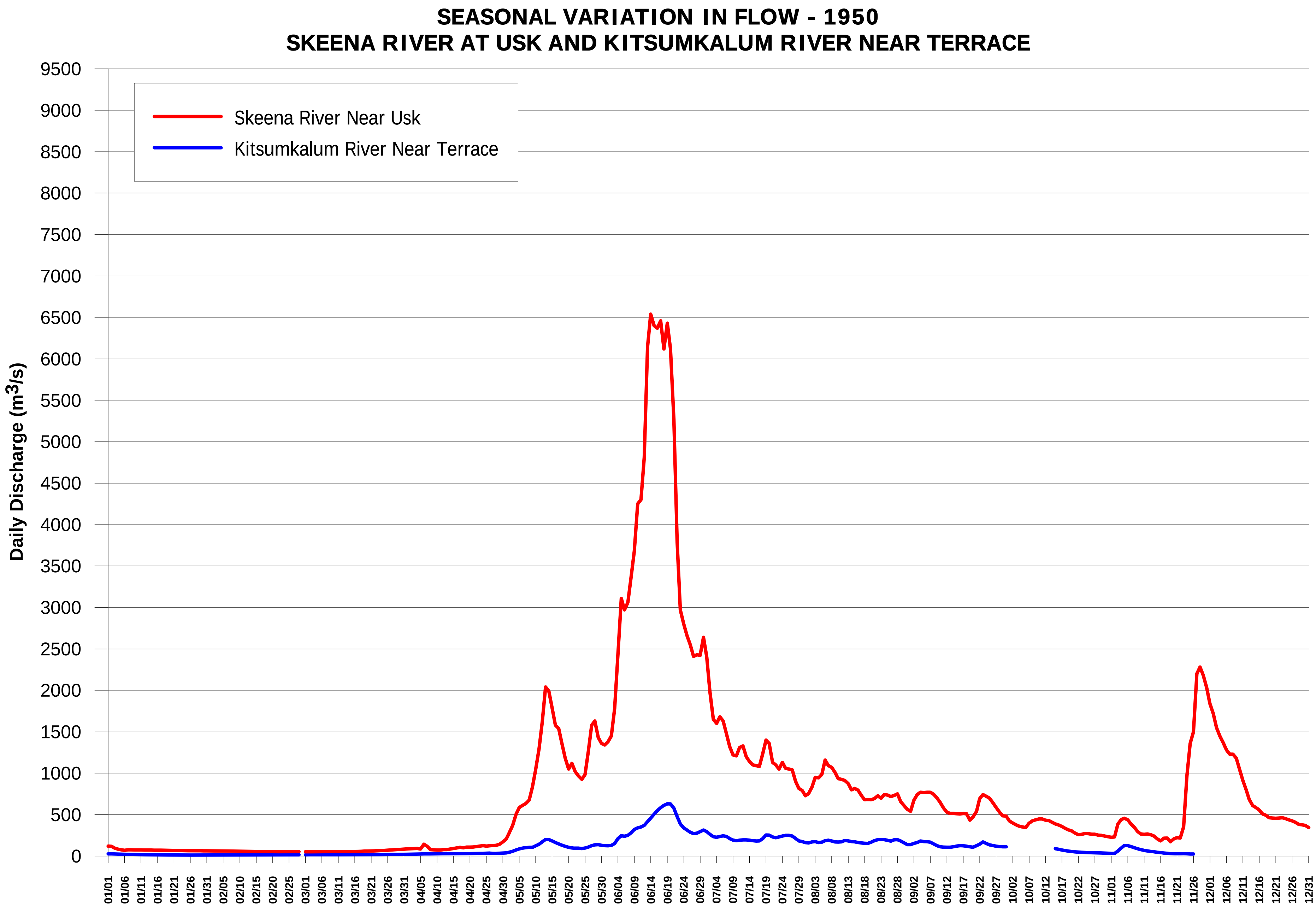


Figure A3-22: Seasonal variation in flow observed in 1950 at Kitsumkalum River Near Terrace and Skeena River at Usk.

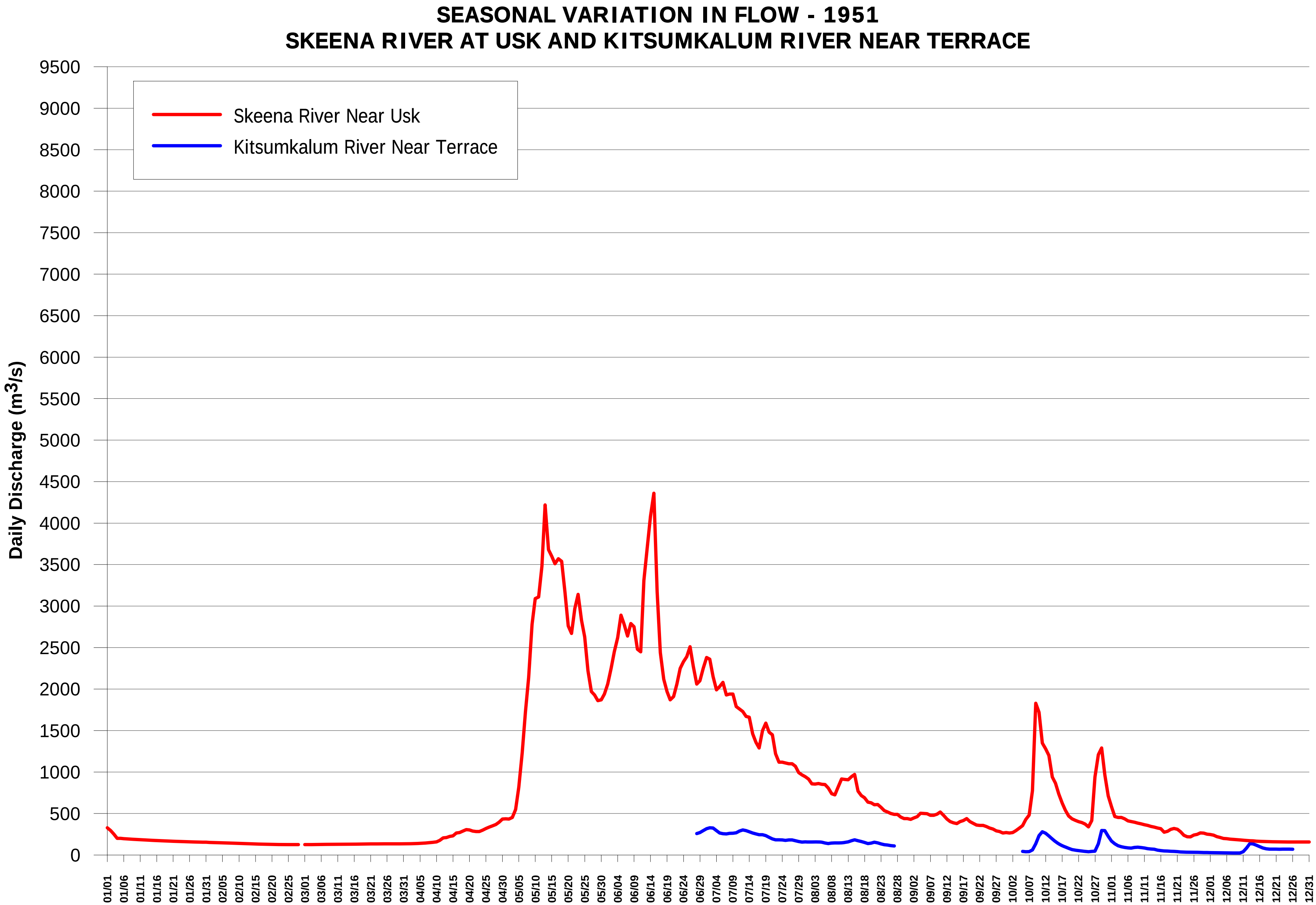


Figure A3-23: Seasonal variation in flow observed in 1951 at Kitsumkalum River Near Terrace and Skeena River at Usk.

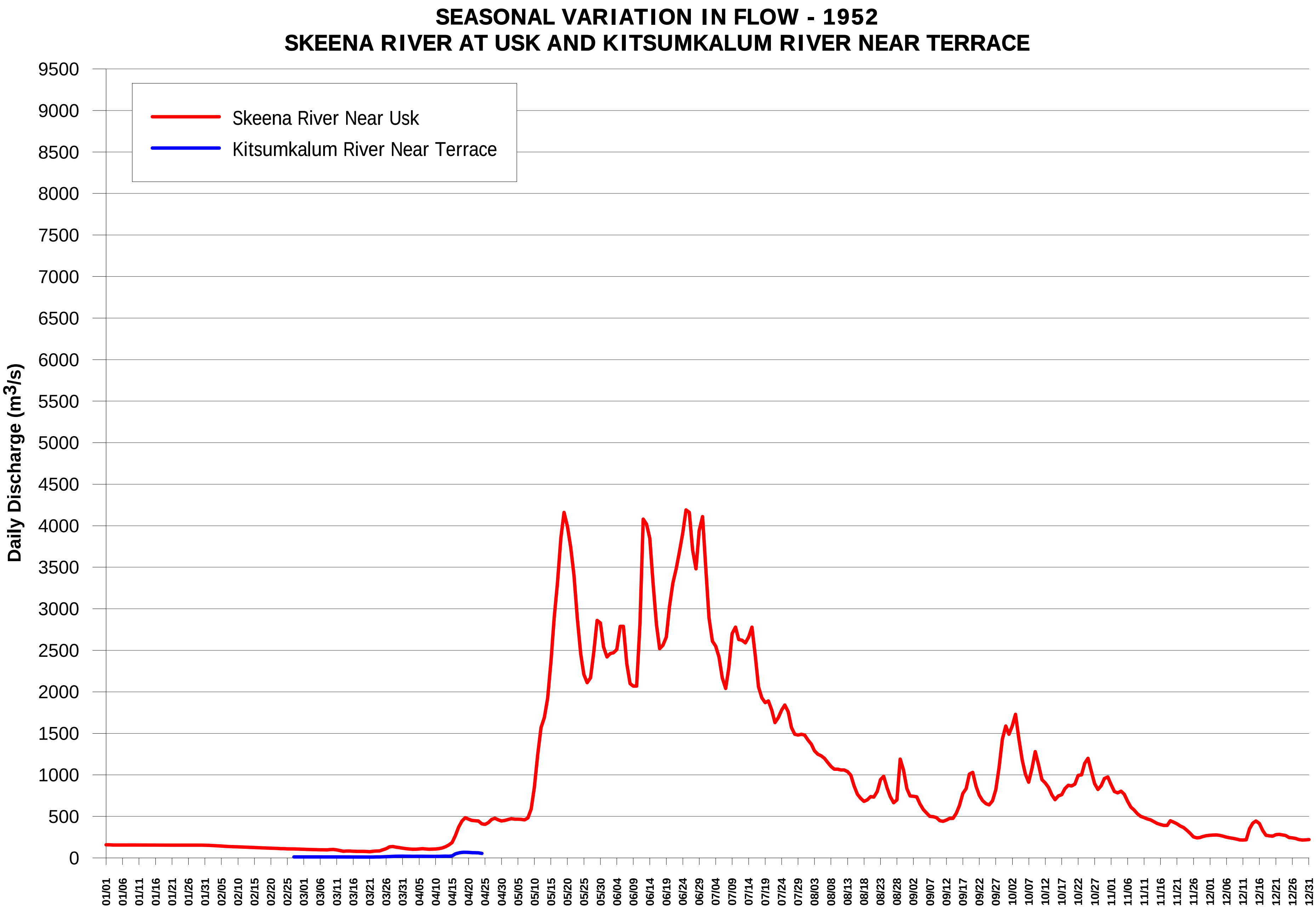


Figure A3-24: Seasonal variation in flow observed in 1952 at Kitsumkalum River Near Terrace and Skeena River at Usk.

APPENDIX 5

Comparison of BC MOE and McElhanney Consulting Services Ltd. River Cross-Section Surveys on Skeena River

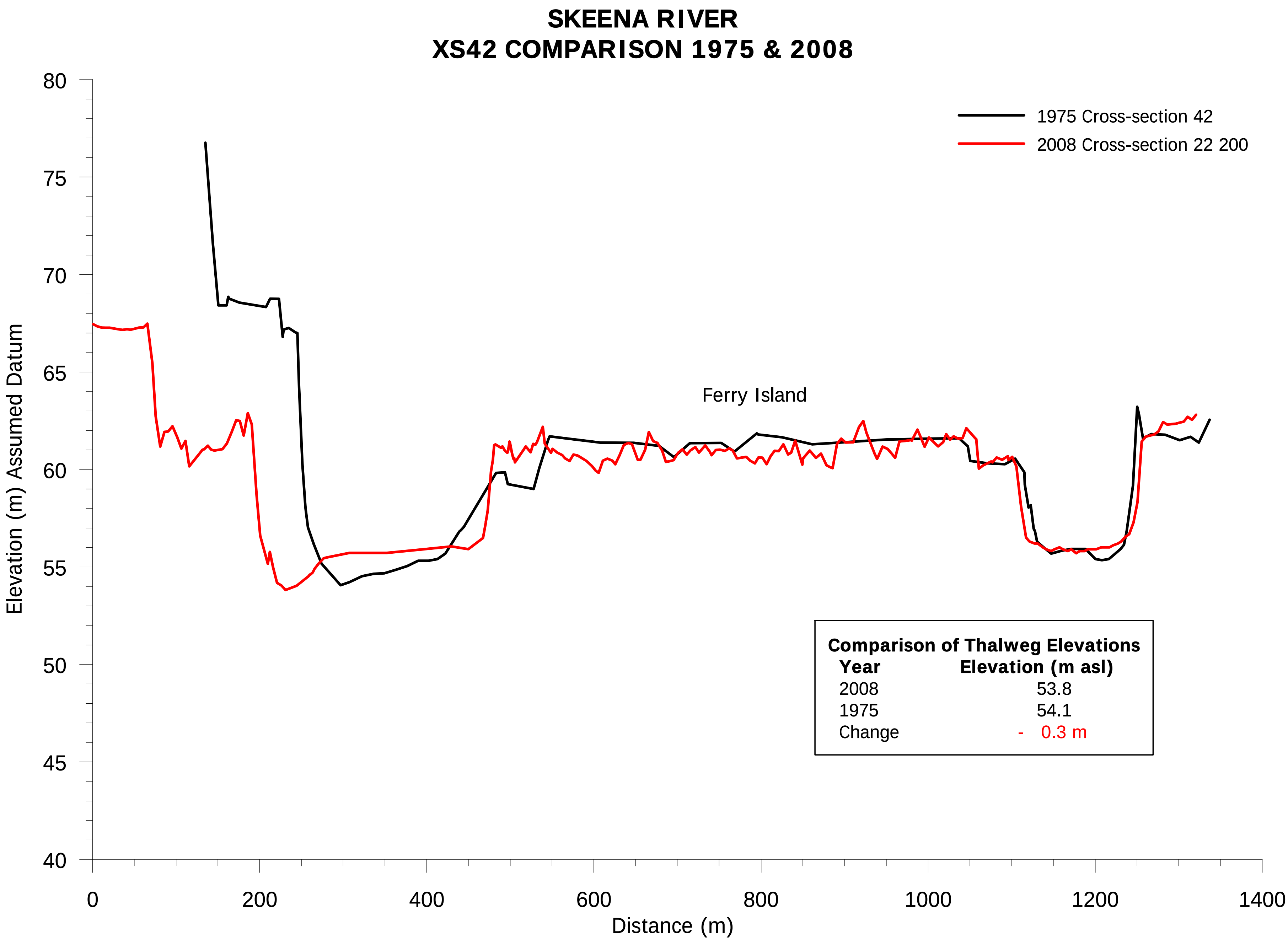


Figure A5-1: Cross-section 42

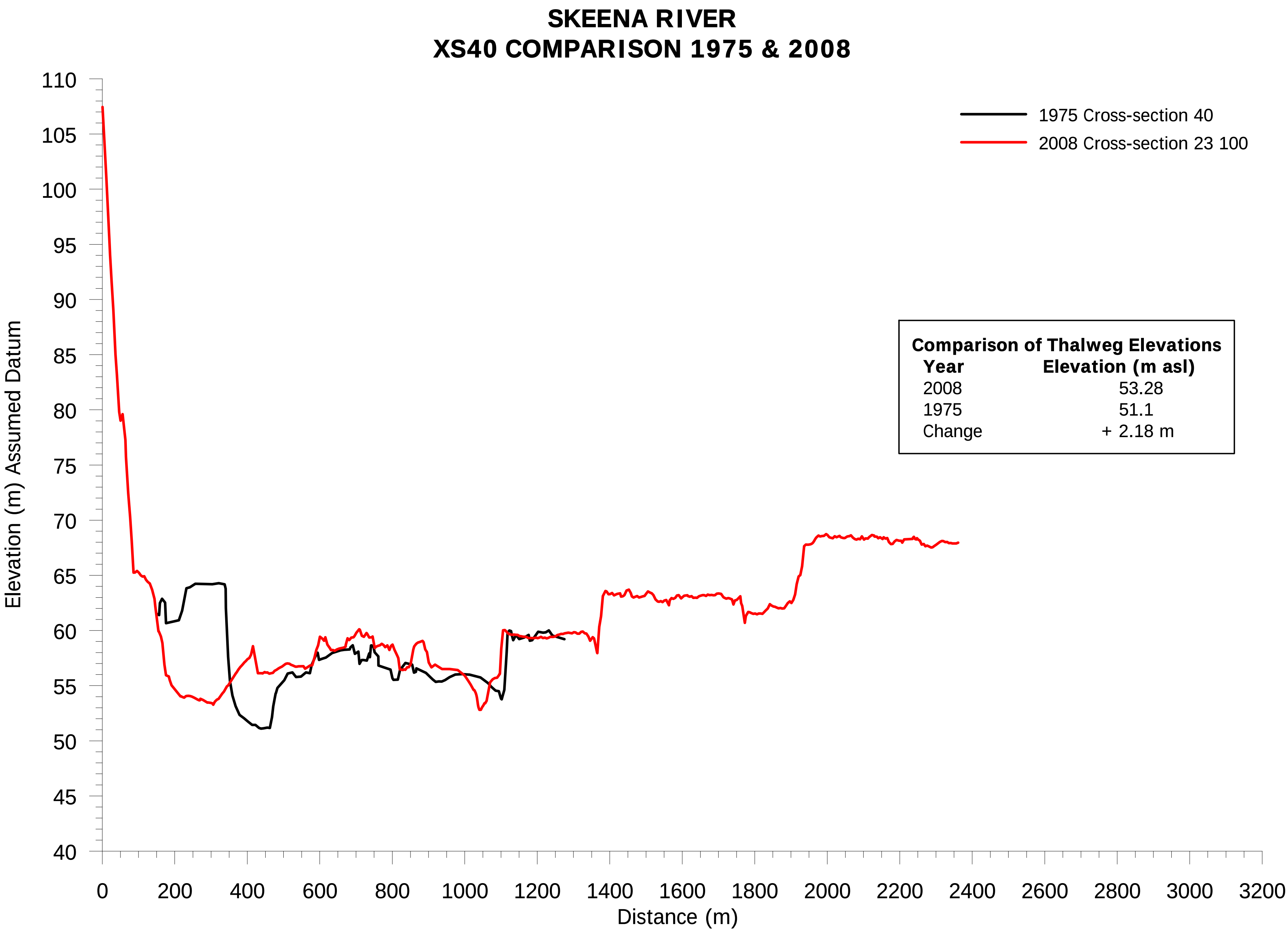


Figure A5-2: Cross-section 40

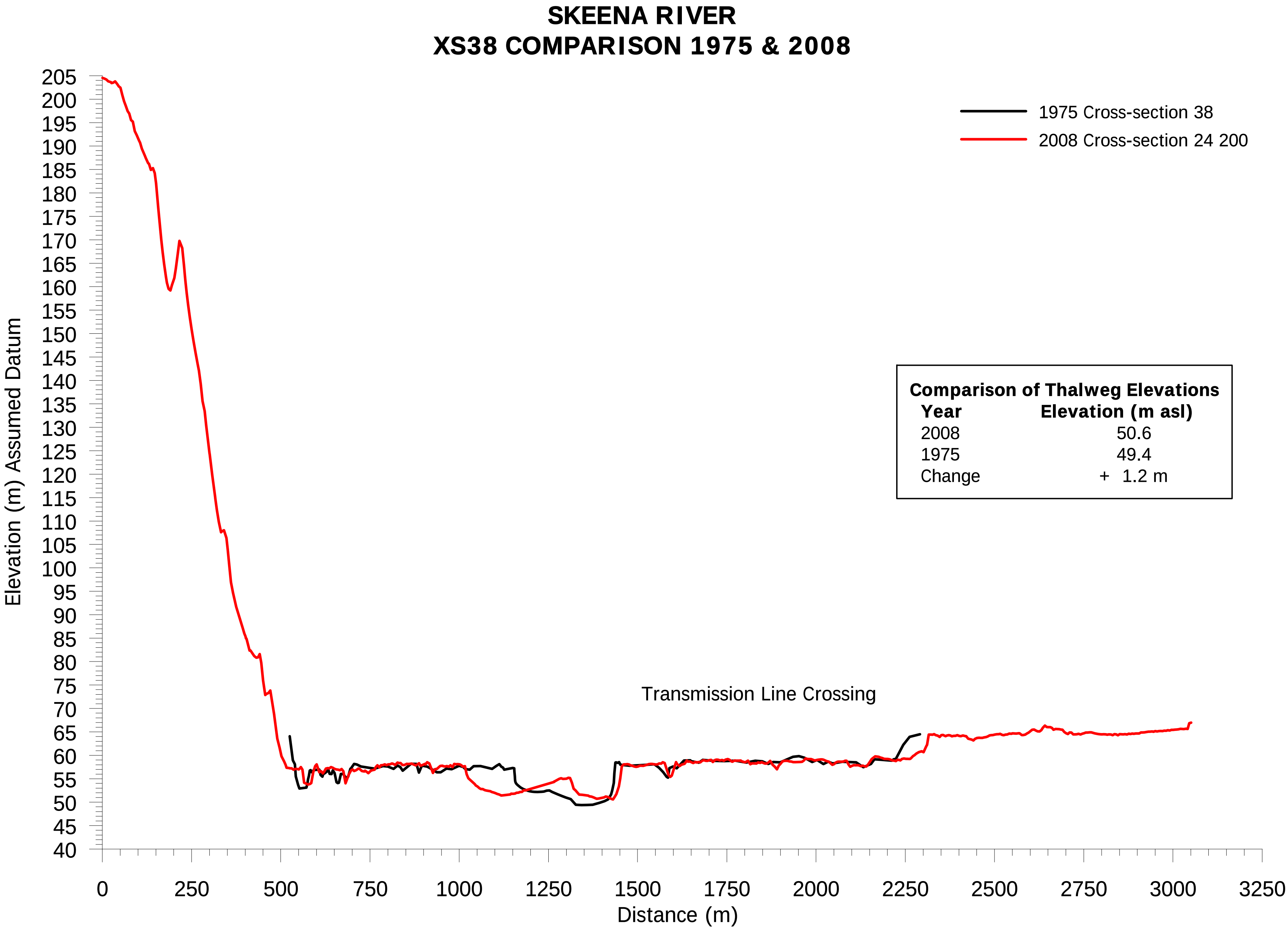


Figure A5-3: Cross-section 38

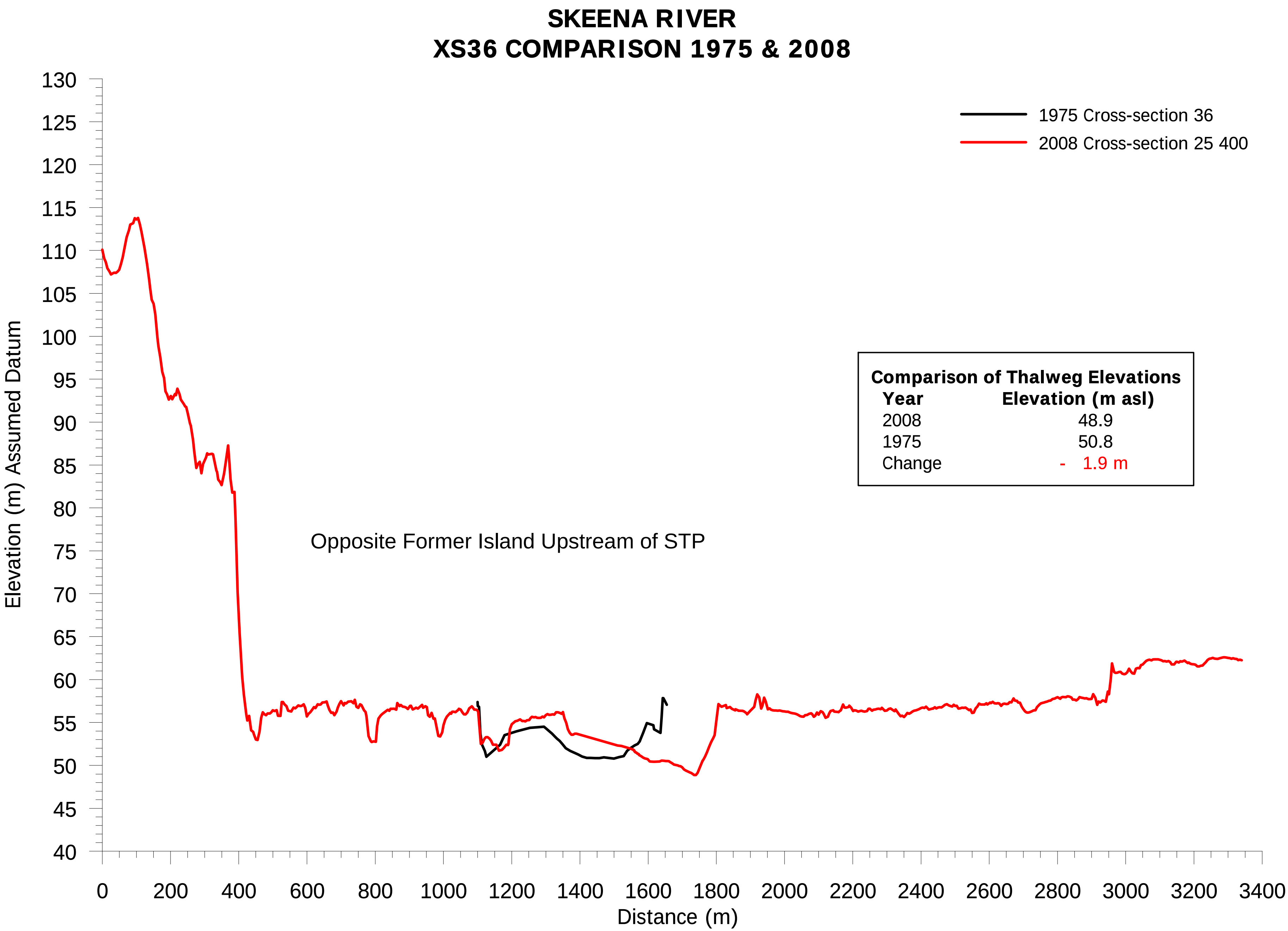
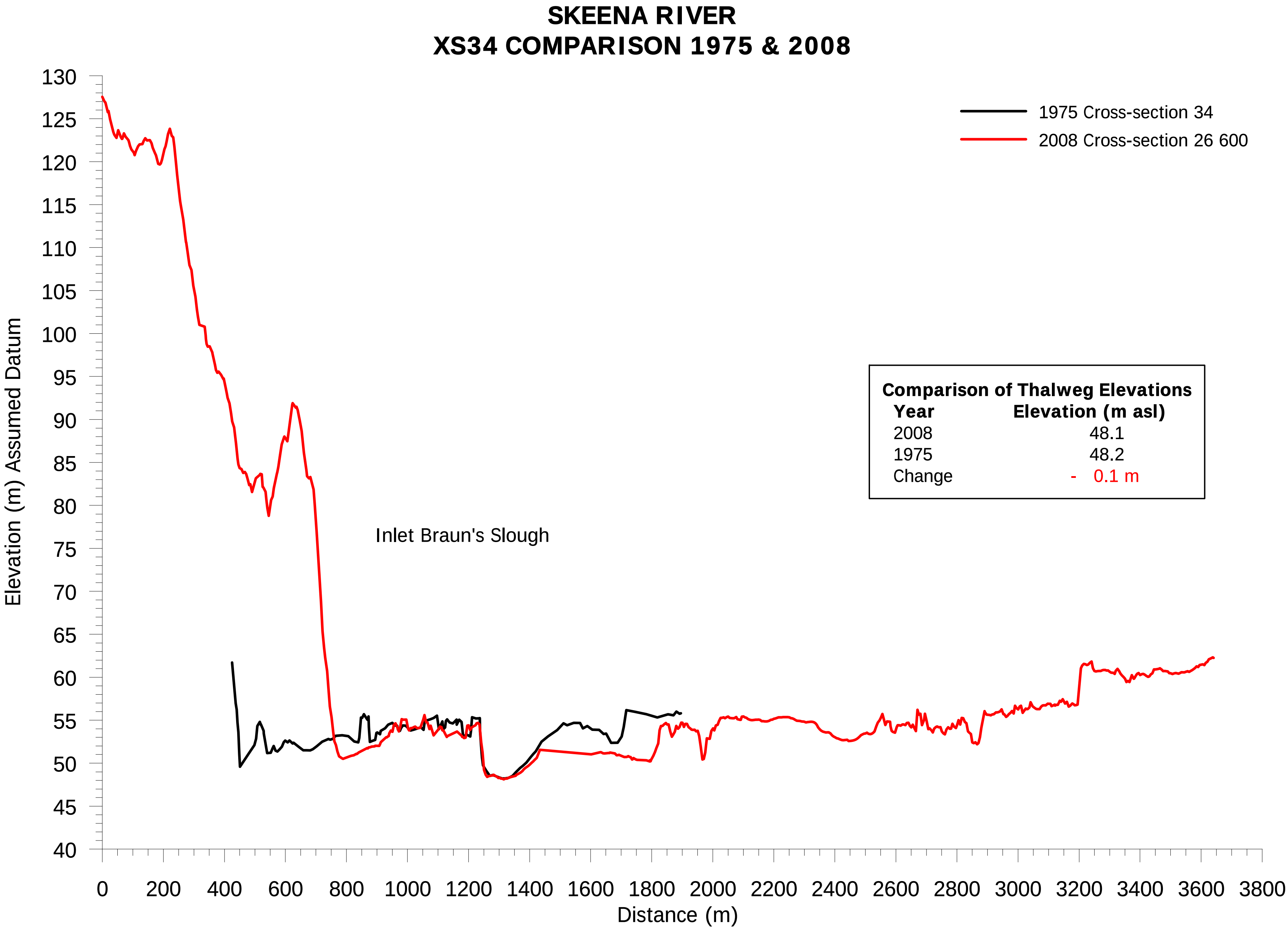


Figure A5-4: Cross-section 36



Comparison of Thalweg Elevations

Year	Elevation (m asl)
2008	48.1
1975	48.2
Change	- 0.1 m

Figure A5-5: Cross-section 34

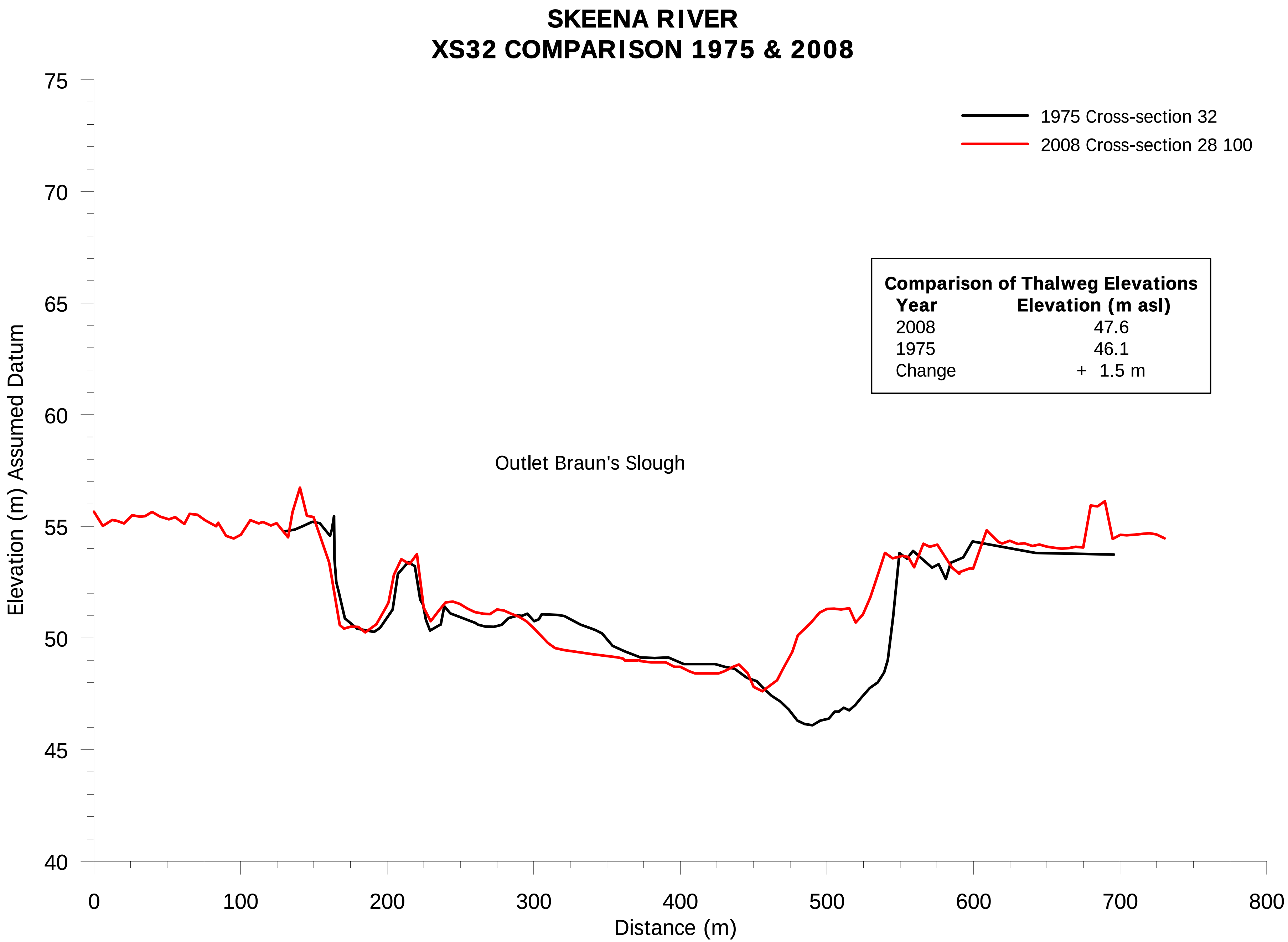


Figure A5-6: Cross-section 32

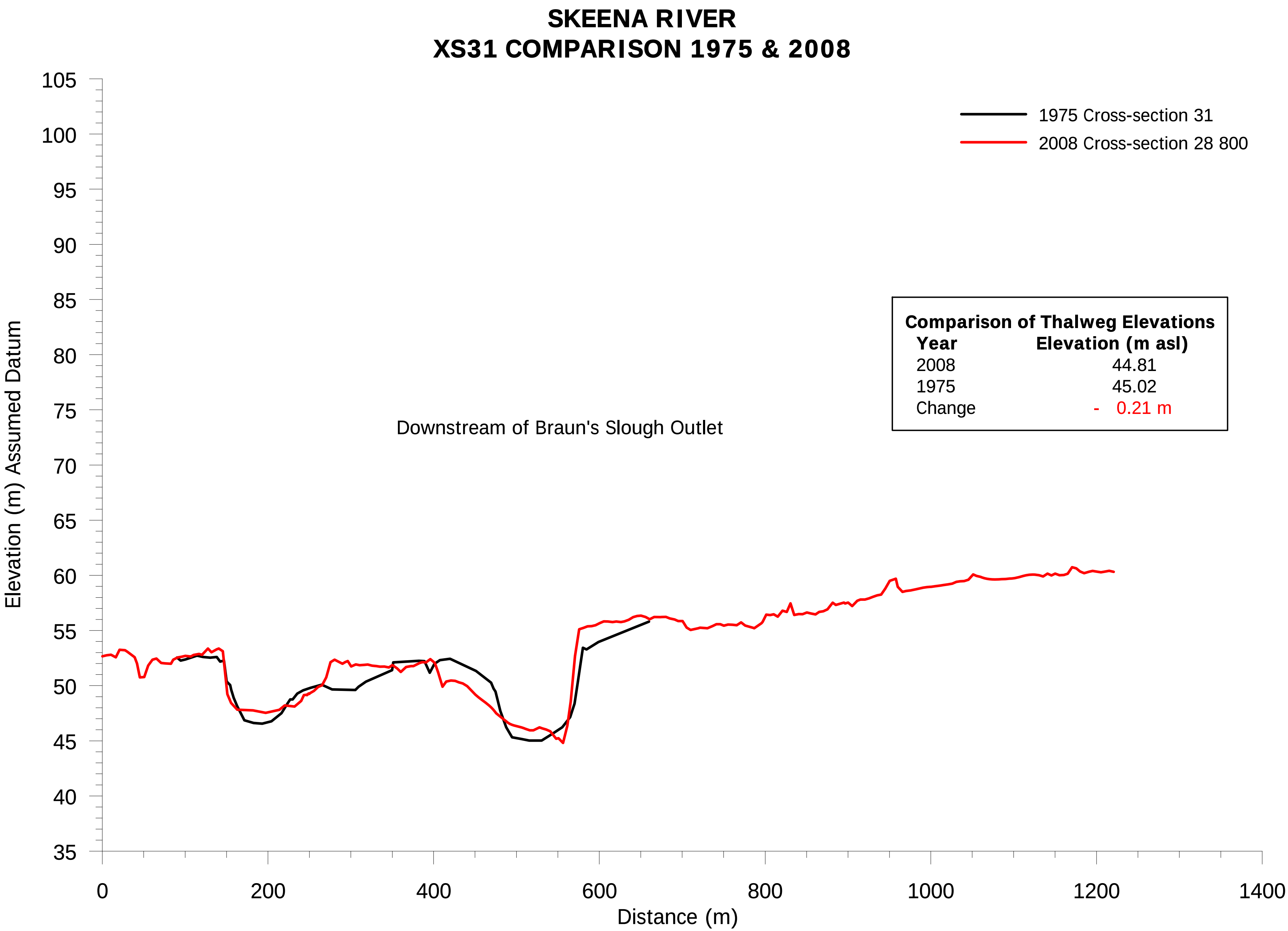


Figure A5-7: Cross-section 31

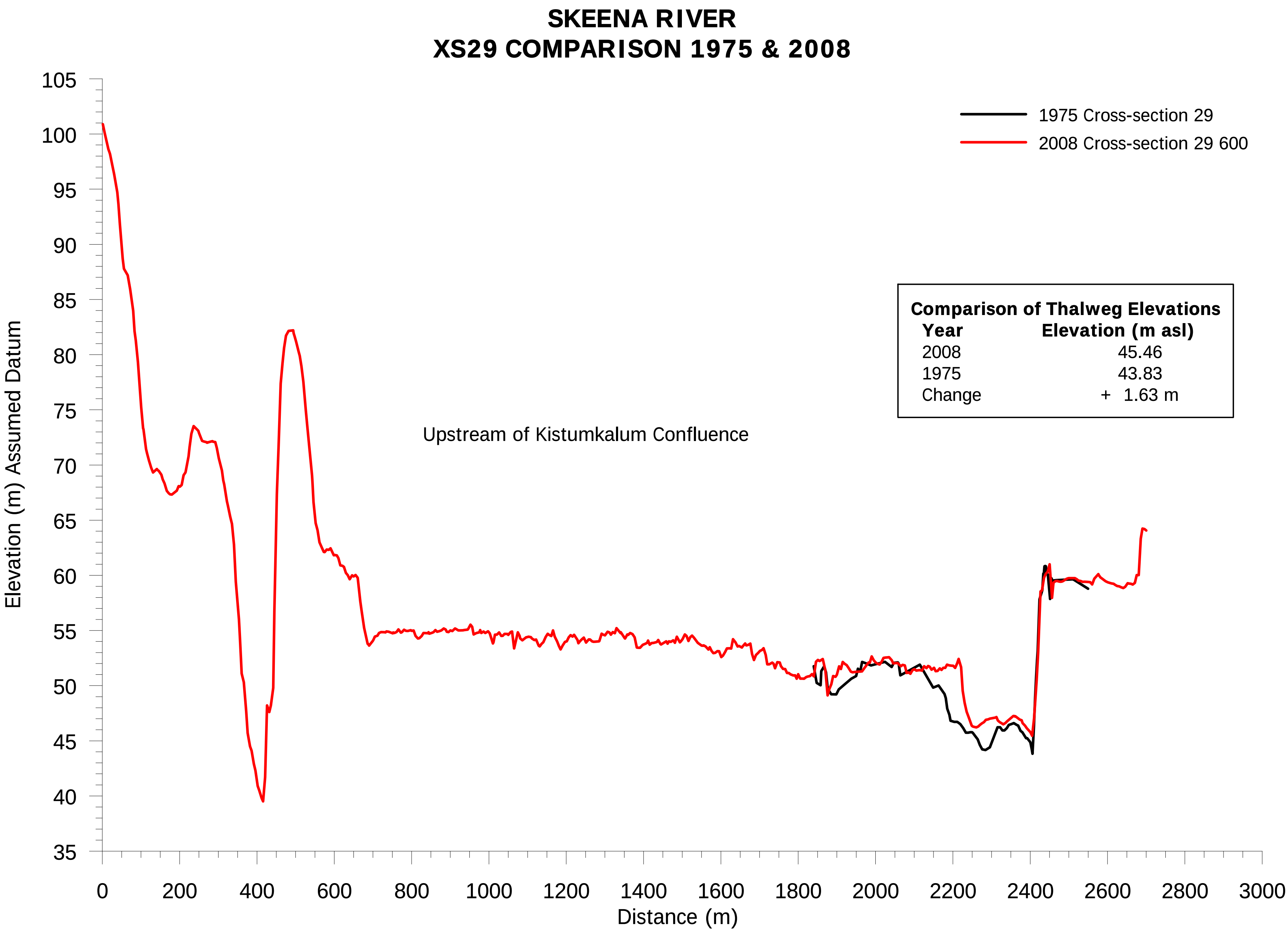


Figure A5-8: Cross-section 29

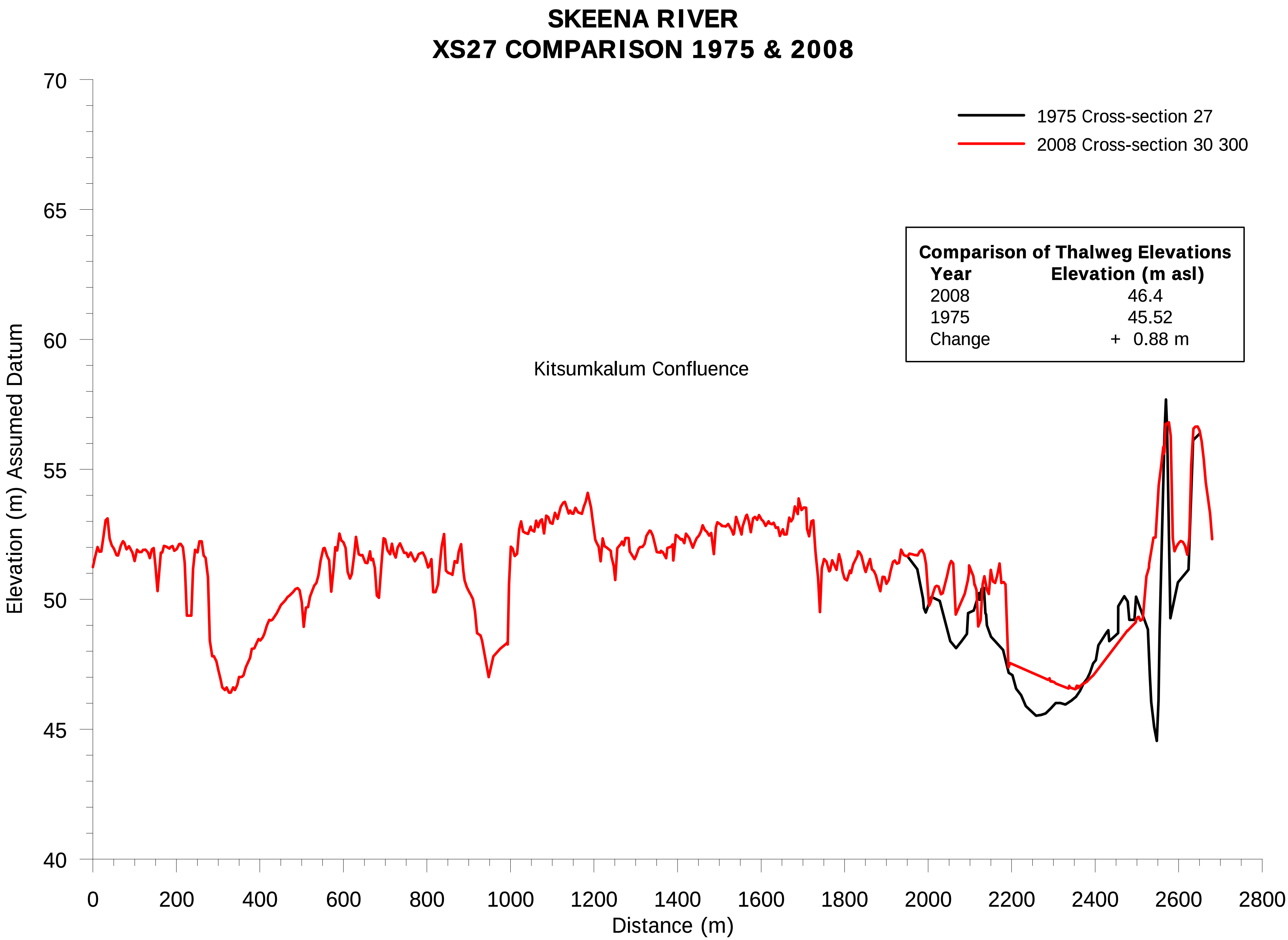


Figure A5-9: Cross-section 27

APPENDIX 6

Comparison of BC MOE (1978) and McElhanney Consulting Services Ltd. (2009) River Cross-Section Surveys on Kitsumkalum River

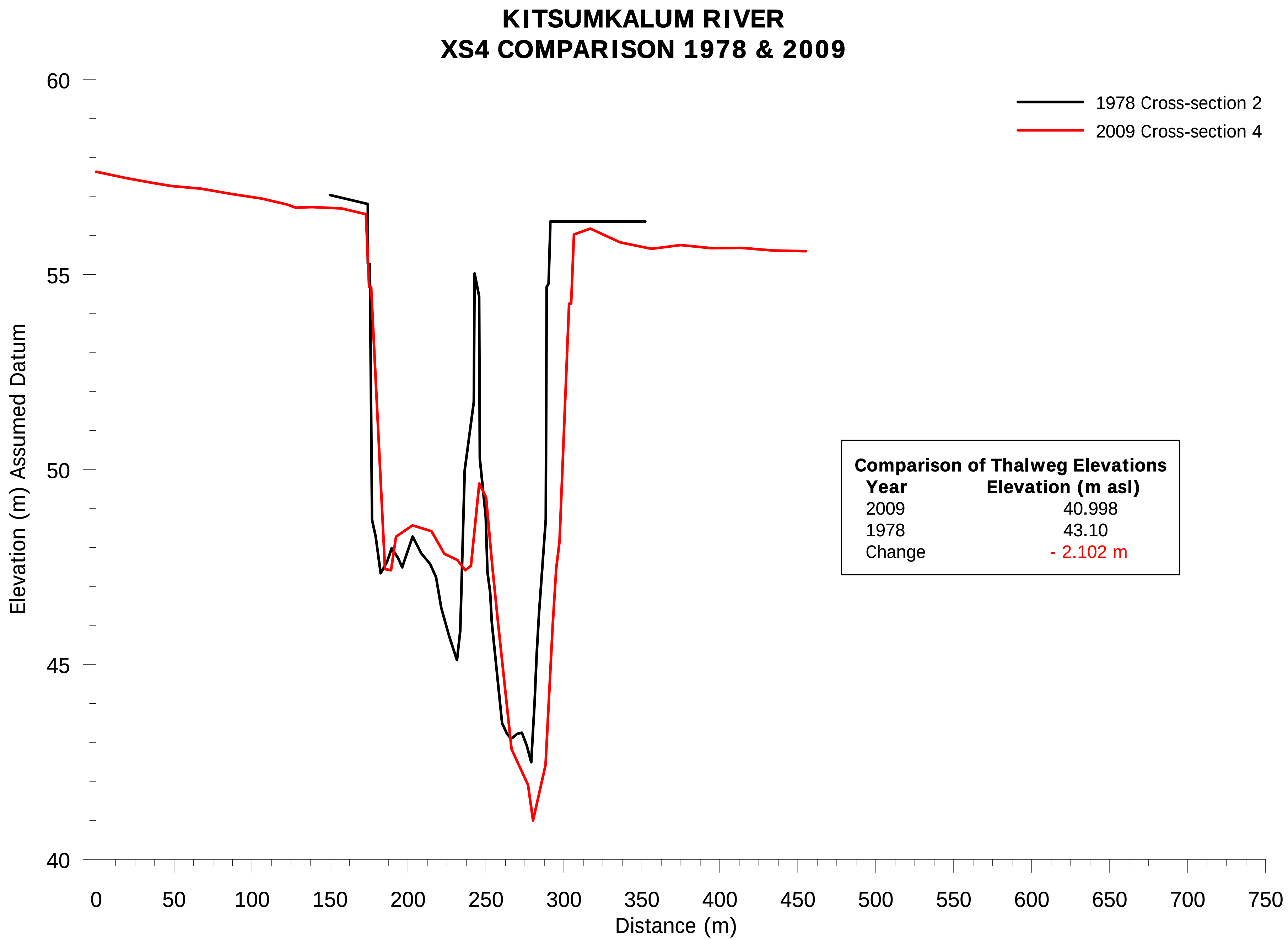


Figure A6-1: Cross-section 4

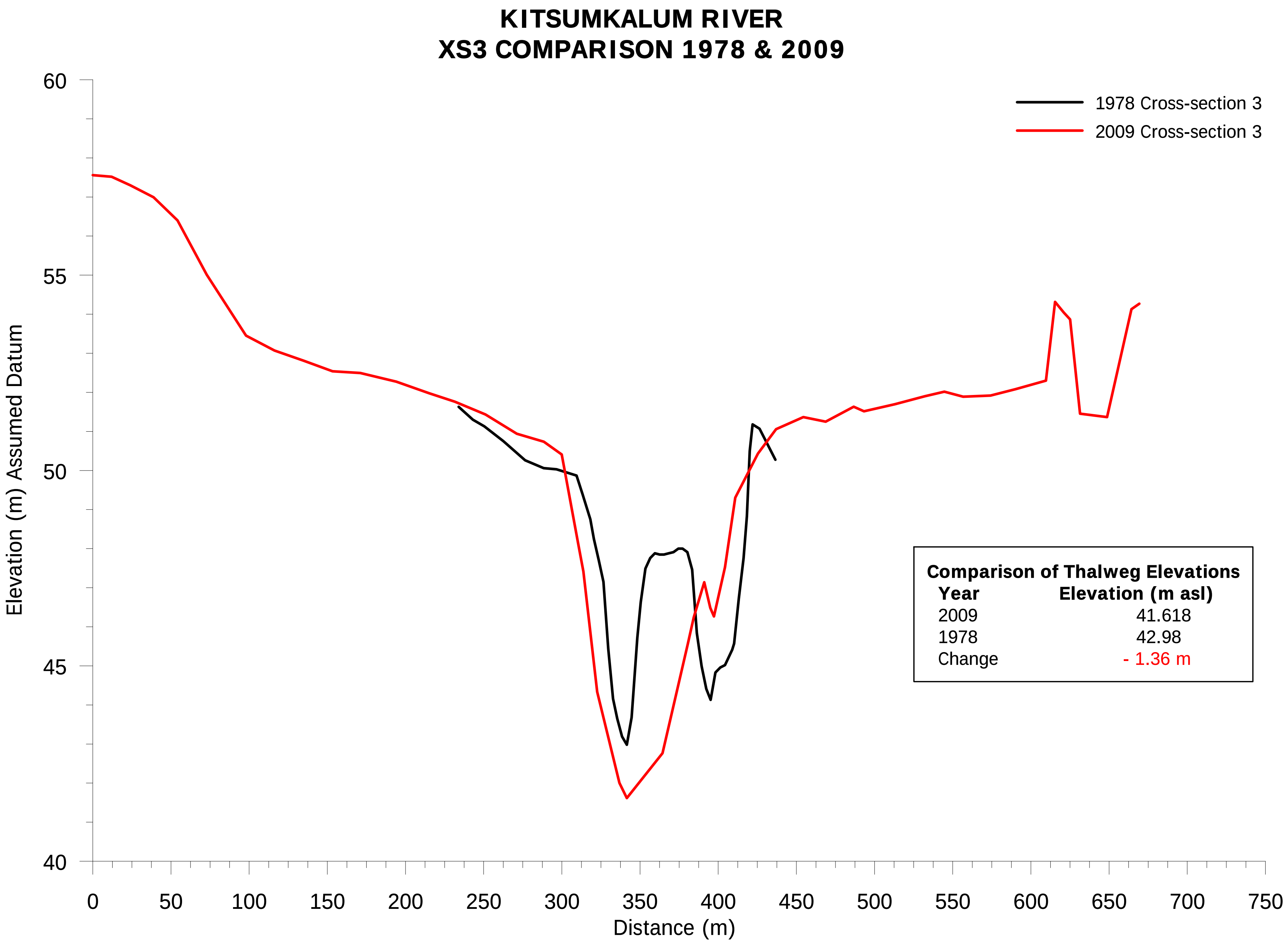


Figure A6-2: Cross-section 3

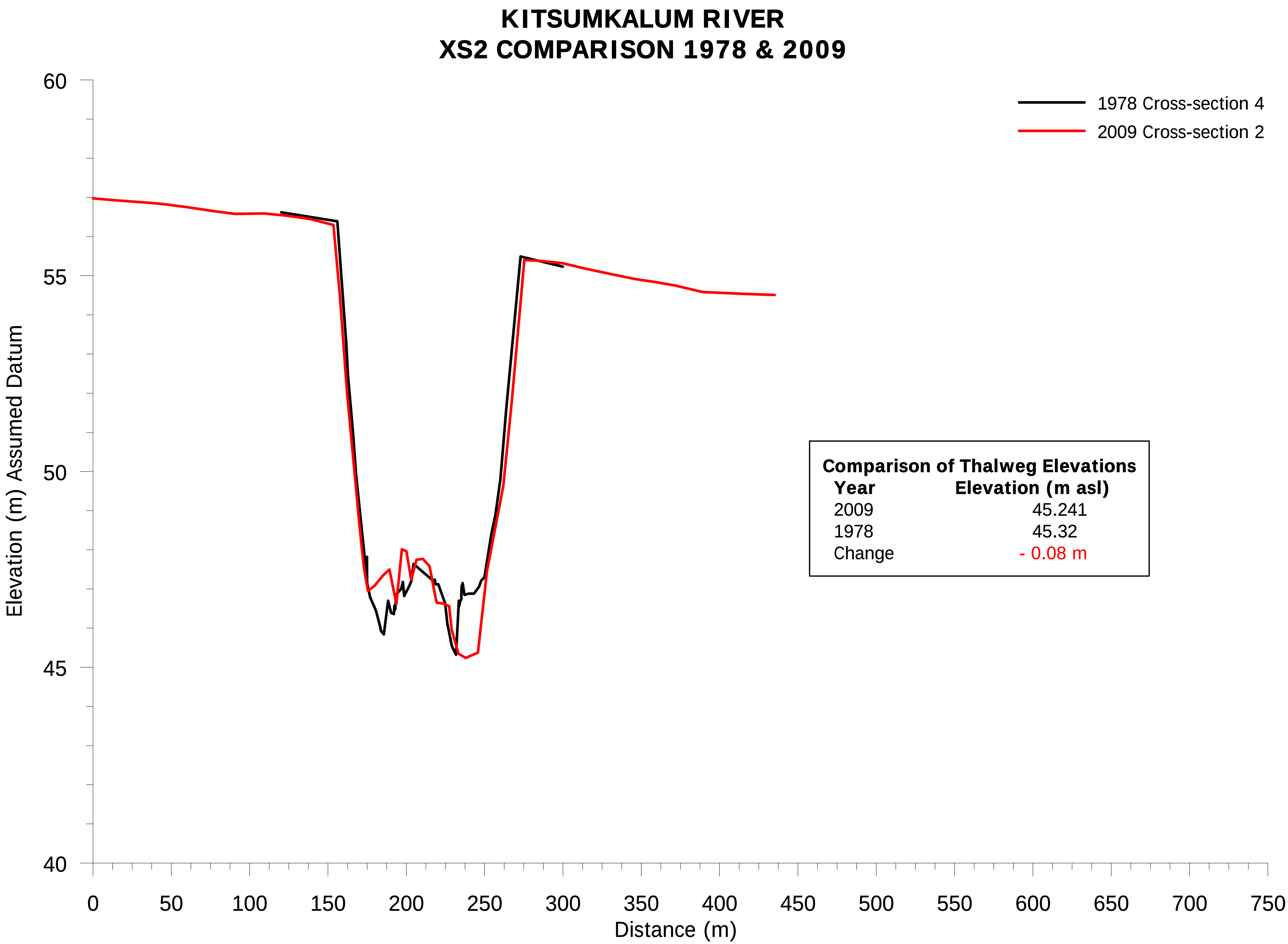
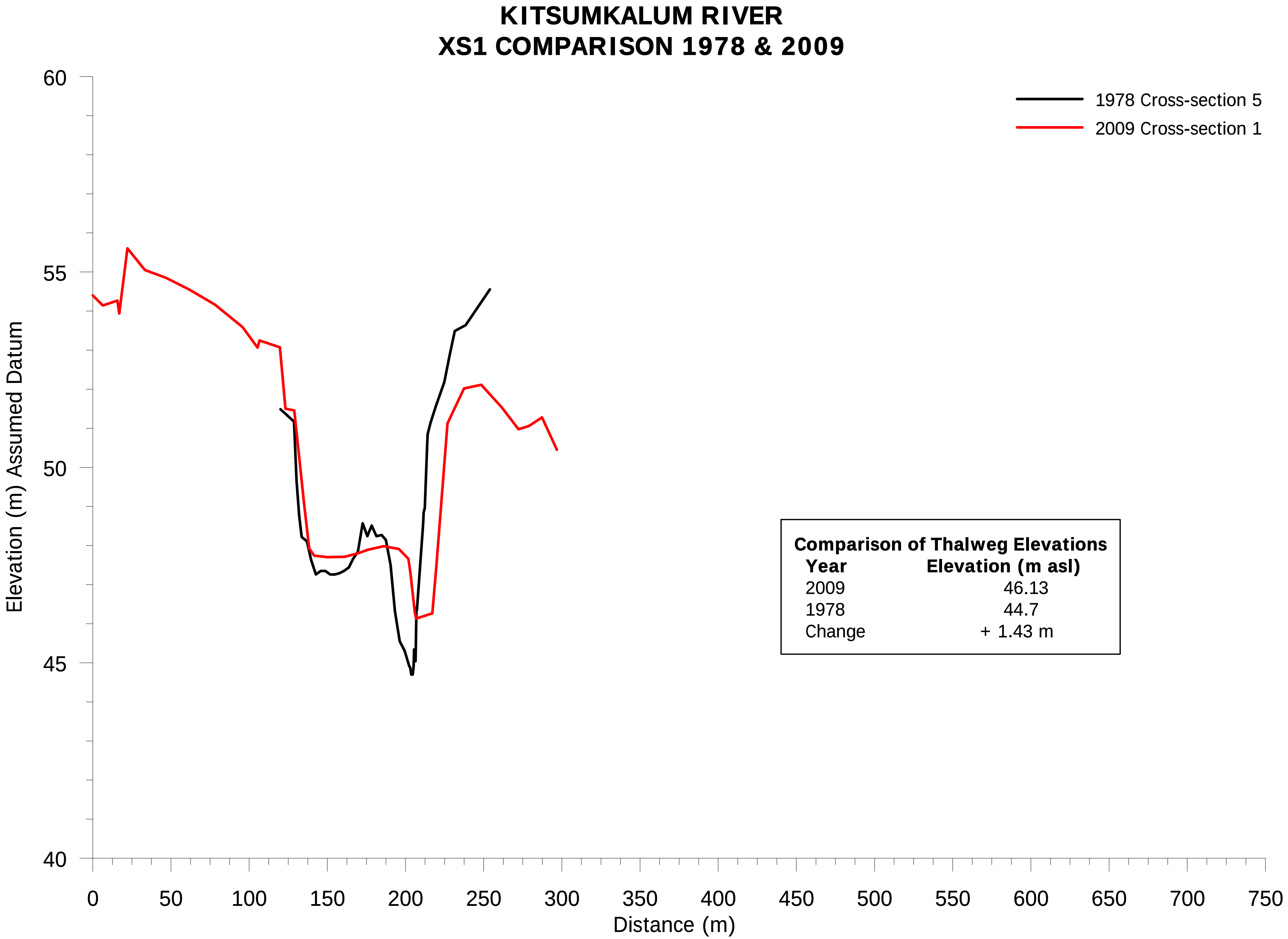


Figure A6-3: Cross-section 2



Comparison of Thalweg Elevations

Year	Elevation (m asl)
2009	46.13
1978	44.7
Change	+ 1.43 m

Figure A6-4: Cross-section 1