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Deadman River Channel Stability Analysis

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DEADMAN RIVER
CHANNEL STABILITY ANALYSIS

by

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ABSTRACT

The Deadman River watershed is located in south central British Columbia fifty kilometres west of Kamloops. The federal Department of Fisheries and Oceans and the provincial Ministry of Environment, Lands and Parks have both expressed concerns over the channel instability which is occurring within a 30 km long area. This report summarizes relevant geological and hydrometric data; identifies changes in stream channel morphometry or stability over the period of air photo record; assesses the factors responsible for any identified changes in channel morphology; and recommends mitigation options and management practices.

Air photograph interpretation indicates that in 1948 Deadman River had a generally narrow and stable channel configuration. In subsequent years the river has become wider and more laterally unstable. The most significant changes have occurred in areas where post-1948 agricultural practices have eliminated the riparian vegetation. Air photograph measurements indicate that 28 km (or 44%) of the 64 km of stream bank in the study area presently has no woody riparian vegetation. An additional 15 km (or 23%) of the river bank has only a narrow riparian vegetation fringe less than one half the channel width wide. Approximately 20 km (or 31%) of the total river bank length is presently eroding and 92 per cent of this total is occurring in areas with reduced riparian vegetation. Unvegetated channel widths in three representative agricultural areas have increased by an average of 330 per cent. In one area the unvegetated channel width has increased from 18 m to 114 m. The wider and shallower river can be expected to have warmer water temperatures, a reduction in the number and size of pools, less undercut bank habitat and, possibly, smaller minimum flows (due to increased subsurface movement of water within the wider river bed). Rip-rap placement as well as ploughing of fields has also reduced the number of back channel and wetland areas.

The study area is located downstream of Mowich Lake and there is therefore no coarse-textured sediment transport from the upper watershed. With the exception of Criss Creek, tributary streams appear to be supplying little or no coarse-textured sediments. Two areas of local slope instability were identified which could be delivering sediment to the stream channel. However, the vast majority of the post-1948 increase in sediment load results from bank erosion in areas where grazing or agricultural clearing have reduced or eliminated woody riparian bank vegetation.

Approximately 4.5 km of rip-rap have been placed within the study area to control bank erosion. River training costs following a sizeable flood in 1990 are estimated at over \$150,000. Much of this cost was paid for through the BC Government Provincial Emergency Program. Field inspection indicates that, while these repairs may locally control bank erosion, they are frequently associated with sediment deposition and further bank erosion in the area immediately downstream.

The long term solution to channel instability problems along the Deadman River is to provide a vegetated riparian corridor. The width of the corridor must be sufficiently wide to allow shrubs and trees to grow to sufficient size that they can re-stabilize the channel banks. Corridor width should be determined by a site-specific assessment of the present channel instability. On the basis of morphological considerations, a corridor width of six to seven channel widths may be initially required in areas of low-lying, erosion-prone materials. This implies that a sizeable land area will be required and a methodology for obtaining this land will need to be developed. A number of research issues have been identified, however changing present attitudes toward the management of riparian areas is likely the most challenging aspect of the proposed work.

RÉSUMÉ

Le bassin hydrographique de la rivière Deadman se trouve dans le centre-sud de la Colombie-Britannique, 50 km à l'ouest de Kamloops. Le ministère des Pêches et des Océans et le ministère de l'Environnement, des Terres et des Parcs de la province ont tous deux fait état de leurs préoccupations concernant l'instabilité du chenal de cette rivière dans un secteur de 30 km de long. Ce rapport résume les données géologiques et hydrométriques pertinentes; décrit les changements dans la morphométrie ou la stabilité du chenal de la rivière survenus au cours de la période des relevés faits à l'aide de photographies aériennes; évalue les facteurs responsables de tous les changements signalés dans la morphologie du chenal; recommande des mesures d'atténuation et des pratiques de gestion.

L'interprétation des photographies aériennes indique qu'en 1948, la rivière Deadman avait un chenal généralement étroit et stable. Au cours des années qui ont suivi, la rivière s'est élargie et ses berges sont devenues instables. Les changements les plus importants se sont produits dans les zones où les pratiques agricoles de l'après 1948 ont éliminé la végétation riveraine. Les mesures par photographie aérienne indiquent que 28 (ou 44 %) des 64 km du chenal de la rivière dans le secteur à l'étude n'ont actuellement aucune végétation riveraine arborescente. Une section additionnelle de 15 km (ou 23 %) de la rivière n'a qu'une étroite lisière de végétation riveraine égale à moins de la moitié de la largeur du chenal. Environ 20 km (ou 31 %) de la longueur totale de la berge de la rivière s'érode actuellement, dont 92 % dans les zones à végétation riveraine réduite. La largeur du chenal non couverte de végétation dans les trois zones agricoles représentatives a augmenté en moyenne de 330 %. Dans une zone du chenal, la largeur de terrain non couvert de végétation est passée de 18 à 114 m. La rivière plus large et moins profonde devrait donner lieu à des températures de l'eau plus chaudes, à une réduction du nombre et de la taille des mares, à la réduction du nombre d'habitats de berges sapées et, potentiellement, à des débits minimums plus faibles (en raison du déplacement accru de l'eau de subsurface dans le lit plus large de la rivière). Les enrochements et le labourage des champs ont également réduit le nombre de bras de rivière et de milieux humides.

La zone à l'étude se trouve en aval du lac Mowich et il n'y a donc pas de transport de sédiments grossiers provenant de la partie supérieure du bassin hydrographique. À l'exception du ruisseau Criss, les affluents semblent fournir très peu de sédiments grossiers, voire aucun. Deux endroits en pente instable signalés pourraient déverser des sédiments dans le chenal de la rivière. Cependant, la grande majorité de l'augmentation de la charge en sédiments après 1948 est le résultat de l'érosion des berges aux endroits où le pâturage ou le déboisement agricole a réduit ou éliminé la végétation arborescente riveraine.

Environ 4,5 km d'enrochement ont été construits dans la zone à l'étude afin de lutter contre l'érosion des berges. Les travaux de correction de la rivière après une importante inondation en 1990 sont évalués à plus de 150 000 \$, payés en grande partie par le programme d'urgence du gouvernement provincial de la Colombie-Britannique. Une inspection sur le terrain indique que, bien que ces réparations permettent de lutter localement contre l'érosion des berges, elles sont fréquemment associées au dépôt de sédiments et à une érosion plus poussée de la berge immédiatement en aval des travaux.

La solution à long terme aux problèmes d'instabilité du chenal le long de la rivière Deadman consiste à mettre en place un corridor de végétation riveraine. Ce corridor doit être suffisamment large pour permettre aux arbustes et aux arbres d'atteindre une taille suffisante pour restabiliser les berges du chenal. La largeur du corridor devrait être déterminée à la suite d'une évaluation à chaque endroit où le chenal est actuellement instable. D'après les considérations morphologiques, il faudrait au départ une largeur de 6 à 7 fois la largeur du chenal dans les secteurs bas constitués de matériaux vulnérables à l'érosion. Cela signifie qu'il faudra une grande superficie de terrain et qu'il faudra trouver une façon d'obtenir ce terrain. On a déjà cerné plusieurs aspects de la question, mais l'aspect probablement le plus difficile consiste à changer les attitudes actuelles vis-à-vis de l'aménagement des zones riveraines.

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1.0 INTRODUCTION AND OBJECTIVES

The Deadman River watershed is located on the north side of Thompson River four kilometres west of Kamloops Lake (Figure 1.0.1). The federal Department of Fisheries and Oceans (DFO) and the provincial Ministry of Environment, Lands and Parks (MOELP) have both expressed concerns over the channel instability which is occurring throughout the area of ranch land located downstream of Mowich Lake. The author was therefore requested to prepare an "overview" level hydrotechnical assessment of stream channel conditions with the objectives of:

- i) providing a summary of relevant geological and hydrometric data;
- ii) identifying changes in stream channel morphometry or stability over the period of air photo record;
- iii) assessing the factors responsible for any identified changes in channel morphology; and
- iv) preparing recommendations on mitigation options and management practices.

This work was to be conducted on the basis of comparative air photo analysis supplemented by a short field trip. A draft version of this report was prepared in May 1994. Additional air photo interpretation and mapping was subsequently requested and this work was undertaken in the winter of 1994/5.

The principal study area consists of a 29 km section of river between the Deadman River bridge located 12 km upstream of the Thompson River confluence and Tobacco Creek (Figure 1.0.2). Air photos of the upper watershed were however also reviewed to identify potential sediment sources and assess how changes in land use may have affected sediment production and flood magnitude within the study area.

2.0 PHYSICAL SETTING

2.1 PHYSIOGRAPHY AND GEOLOGY

The Deadman River watershed is located within the Thompson and Fraser Plateau areas of the Interior Plateau Physiographic Region (Holland, 1976). This is an area of rolling uplands which have been dissected by fluvial and glacial erosion. The bedrock geology of the Deadman River watershed consists of both volcanic and sedimentary rocks. Much of the mainstem river valley is formed by andesite, basalt, limestone and argillite of the Mesozoic Age Nicola Group. Areas of sandstone, conglomerate and shale (of Cretaceous or Tertiary Age) occur on the eastern boundaries of the watershed. Dacite and basalts of the Kamloops Group (of Eocene and Oligocene Age) occur in the central and western portion of the watershed, while plateau lavas and basalt flows (of Miocene and Pliocene Age) occur in the headwaters (Duffel and McTaggart, 1952; Roddick *et al.*, 1979; Campbell and Tipper, 1972).

The entire Deadman River watershed has been glacially over-ridden and deposits of till blanket most upland surfaces. Extensive areas of exposed bedrock do however occur along the valley walls in the area downstream of Criss Creek. A large landslide has occurred 3 km upstream of the Criss Creek confluence and blocks and rubble extend from one side of the valley to the other. Large slides have also occurred further upstream and have resulted in the formation of Mowich and Snohoosh Lakes.

The valley bottom area consists of a mixture of glacio-fluvial terraces, fan deposits and contemporary fluvial deposits. A large fan has formed in the Thompson River Valley at the mouth of Deadman River and this appears to have resulted in the formation of Kamloops Lake (Fulton, 1975; Ryder, 1976; Gough *et al.*, (no date) and Young *et al.*, 1983).

2.2 WATERSHED CHARACTERISTICS

The Deadman River watershed is shown on Figure 1.0.2. The total basin area is approximately 1,490 km². Criss Creek is the largest tributary to the lower Deadman River and has a basin area of 490 km² (Table 2.2.1). Elevations range from approximately 350 m asl at the Thompson River confluence to 1,775 m asl in the headwaters of Criss Creek. The long profiles of Deadman River and Criss Creek¹ are shown on Figure 2.2.1. The average channel gradient through the Deadman River study area is approximately 0.007 m/m. Four lakes, Mowich Lake (regulated), Snohoosh Lake (regulated), Skookum Lake and Deadman Lake, occur along the mainstem of Deadman River upstream of the study area. [Basin areas are 0.3, 0.9, 0.2 and 0.5 km², respectively.] Numerous smaller lakes occur in the headwaters of Deadman River, Criss Creek and on Hamilton Creek (a west bank tributary which joins Deadman River upstream of Deadman Lake). These features serve to both naturally regulate streamflow and reduce the amount of coarse-textured sediments which are transported downstream to the study area.

2.3 CLIMATOLOGY

The Atmospheric Environment Service (AES) operates a number of climate stations in the vicinity of the proposed project (Table 2.3.1, Figure 2.3.1). Kamloops Airport is the closest station recording short duration rainfall data. Fourteen other sites provide information on the spatial

1 From 1:50,000 scale NTS mapping.

variability of daily temperatures and precipitation. The seasonal variation in monthly temperature and precipitation is shown on Figures 2.3.2 and 2.3.3 on the basis of data from *Kamloops A* (elev. 345 m) and the higher elevation station at *Mount Lolo* (elev. 1,727 m). These data indicate average monthly temperatures range between -4.8 and 20.8°C at *Kamloops A*, while values range from -9.9 to 12.4°C at *Mount Lolo*. Below freezing temperatures have occurred between September and May at *Kamloops A* and in every month of the year at *Mount Lolo*. The annual precipitation total at these two stations is 269.5 and 514.1 mm, respectively. Approximately 26 per cent of this total occurs as snow at *Kamloops A*. This value increases to 42 per cent at *Mount Lolo*.

The seasonal variation in snow accumulation at the Water Management Branch snow survey sites Deadman River (elev. 1,430 m) and Tranquille Lake (elev. 1,420 m) are shown on Figure 2.3.4. Station locations are shown on Figure 2.3.1. These data indicate that maximum accumulations generally occur around April 1st and snow remains on the ground until May or June. Maximum snow accumulations at an elevation of 1,400 m show substantial temporal and regional variation. April 1 snow water equivalent values at the Deadman River snow course range from 30 to 188 mm, while those at Tranquille Lake range from 116 and 381 mm.

The seasonal variation in maximum 24-hour rainfall and precipitation at *Kamloops A* and *Mount Lolo* is shown on Figures 2.3.5. In both locations the largest values occur as a result of mid-summer convective activity with the extreme values of record occurring in August. A frequency analysis of short-duration rainfall data and 1 to 10 day precipitation data observed at *Kamloops A* are shown on Table 2.3.2. The analytical technique is described in Hogg and Carr (1985). The results indicate that the predicted magnitude of extreme events at *Kamloops A* are of modest size in comparison to values which can commonly occur along coastal areas of British Columbia. These results must however be interpreted with care as regional analysis of 1 to 10-day precipitation totals in APPENDIX 1 indicate that the predicted 100-year, 1-day rainfall values at *Kamloops* and *Kamloops Airport* are substantially smaller than those predicted at all other stations investigated.

Inspection of Table 2.3.2 indicate that the maximum rainfall and precipitation events of record at *Kamloops Airport* occurred in 1990 for durations of five minutes to two hours and in 1976 for durations of six hours to ten days. The calculated return periods for both events exceed 100 years for some durations.

In order to look at the long term variations in climatic characteristics, the annual precipitation, annual rainfall, greatest 24-hour precipitation and greatest 24-hour rainfall observed at *Kamloops* were correlated with those observed at *Kamloops A* during the common observation period of 1951 to 1982. This analysis, which is summarized in APPENDIX 2, indicates that the data from these two sites are not well correlated (r^2 values range from 0.5 to 0.6). On the basis of the developed regression equations, the data from *Kamloops* has been extended to 1992 and the results are shown on Figures 2.3.6 to 2.3.9. Frequency analyses are summarized on Table 2.3.3.

The above analyses indicate that annual rainfall and precipitation in the period since approximately 1975 have been generally greater than average (Figures 2.3.6 and 2.3.7). For example, the average annual precipitation in the period between 1878 and 1974 was 257.7 mm, while the average value between 1975 and 1992 was 273.7 mm or 6 per cent larger. The 1981 annual precipitation value (375.7 mm) was the 3rd highest on record and had a calculated return period of 20 years. The 1927 and 1895 values were however substantially larger (458.6 and 503.6 mm, respectively) and have calculated return periods of 105 and 263 years.

Statistical tests (**Q**, **R**, and **W** statistics, described in Buishand (1982) were undertaken to determine if a significant shift in annual precipitation regime had occurred over the period of record. One of the three tests (the **W** statistic) did indicate that there was a 90 per cent probability that the trend shown on the residual mass curve, of generally less than average annual precipitation totals in the period up to 1974 and generally greater than average values in the period between 1975 and present, represents a statistically-significant shift in regime. However given the low significance level, and the fact that two other tests indicate that the trend is not statistically significant, this result must be viewed with caution.

Similar analyses were undertaken on synthesized annual maximum 24-hour precipitation and rainfall data (Figures 2.3.8 and 2.3.9). These analyses indicate that generally larger than average maximum 1-day precipitation and rainfall events occurred between 1878 and 1917, generally less than average values occurred between 1918 and 1975 and generally greater than average values have occurred since 1976. Average annual maximum 24-hour rainfall values in these three periods are 23.9, 16.9 and 21.0 mm, respectively which corresponds to values of 126 per cent, 85 per cent and 111 per cent of the average value for the entire period of record. Statistical tests indicate that these changes in regime are statistically significant. All tests on rainfall data were significant at the 95 (**Q** test) or 99 per cent (**R** and **W** test) levels. Tests on annual maximum 24-hour precipitation data were also significant at the 90 per cent (**Q** and **R** statistics) or 99 per cent (**W** statistic) levels.

The above analyses indicate that annual precipitation conditions may have been somewhat wetter than average in the post-1975 period and that annual maximum 24-hour rainfall and precipitation values in the post-1976 period were also higher than the long term average. Both these effects could possibly have contributed to larger than average streamflows in the post-1975 period.

2.4 HYDROLOGY

The Water Survey of Canada (WSC) operates water level and streamflow gauging sites at a variety of locations in the area around Deadman River (Table 2.4.1 and Figure 2.3.1). Data include measurements on *Deadman River above Criss Creek* and on a number of tributaries including *Criss Creek near Savona*, *Joe Ross Creek near the Mouth* and *Heller Creek above Diversions*. Bonaparte River, located immediately west of Deadman River, has also been gauged and may be relevant to the present study given its similar physiographic setting (it does however have a substantially larger basin area).

The seasonal variation in observed discharge on the four gauging stations in the Deadman River watershed are illustrated on Figures 2.4.1 to 2.4.4. The spring freshet can be seen to typically occur between April and July, while comparatively low flows occur during the period between October and March.

The historical variation in annual maximum daily and instantaneous discharge observed on the four gauges in the Deadman River watershed and on the Bonaparte River gauge are shown on Figures 2.4.5 to 2.4.9. Flood frequency analyses have been undertaken for each of these sites and the results are shown in APPENDIX 3. The largest discharges on record at all sites occurred in June of 1990. Return periods have been calculated on the basis of four frequency distributions and the results are summarized on Table 2.4.2. There is a wide variation between the return periods calculated on the basis of each of the four frequency distribution and this reflects the unavoidable uncertainties in this type of analysis. On the basis of experience and statistical parameters (such as the Kolmogorov-Smirnov goodness of fit test), the Log Pearson Type III distribution is thought to provide the most reasonable results. However, with four exceptions, all

of the calculated return periods exceed twice the period of record and are therefore potentially unreliable.

The above analyses indicate that the June 1990 flood occurred within both the Deadman and Bonaparte River watersheds. Return periods on the headwaters of Deadman River were approximately 30 years, while the gauge on *Deadman River above Criss Creek* reports a flood which has a calculated return period of at least "178" years. This return period is anomalously larger than that calculated for the same flood on Criss Creek or the other two headwater tributaries and on Bonaparte River.

A variety of studies were undertaken in order to investigate the reliability of the June 1990 flood discharge estimate. Daily discharge on Deadman River and Criss Creek during 1990 are shown on Figure 2.4.10. These graphs indicate that both sites experienced peaks during the spring and early summer with the maximum flow occurring on June 13 on Criss Creek and on June 14 on Deadman River. The June 14 flow on Deadman River was estimated on the basis of Rating Table 33 which was in use between June 13, 1990 and September 12, 1990 at which point the gauge was re-established as channel incision had lowered water levels below the gauge 0 elevation (Ken Barker, Pers. Comm.). The above analyses indicate that Rating Table 33 was in use for such a short period of time, and the river bed was sufficiently mobile, that the reliability of the June 14/94 discharge needed to be reviewed with the WSC district office in Kamloops. Discussions with Ken Barker, the officer in charge, indicate that streamflow was measured on June 14, 1990 as 60.6 m³/s and the daily discharge value of 58.5 m³/s therefore appears to be reliable.

The 2 and 200-year return period daily and instantaneous flood discharges calculated for the gauging stations on Bonaparte and Deadman Rivers are plotted on Figures 2.4.11 and 2.4.12. Envelope curves about these points have been plotted using the metric version of "Creager's Equation" (Creager *et al.*, 1945).

$$q = 0.503C [0.386 A]^{[0.936 A^{-0.045}] - 1}$$

where q is unit discharge (m³/s/km²), A is basin area (km²) and C is a coefficient which is calculated to have a value between 0.1 and 0.4 for the 2-year return period instantaneous discharge. Two hundred-year instantaneous discharge estimates correspond to C values of 0.8 to 2.0. This preliminary analysis has been used to estimate representative instantaneous flows for various locations within the study area. These estimates are summarized on Table 2.4.3.

2.5 VEGETATION COVER

Biogeoclimatic Mapping (BC Ministry of Forests, 1988) indicated that the Deadman River valley bottom and valley walls are located within the Bunchgrass and Ponderosa Pine Biogeoclimatic Zones, respectively. Most of the remainder of the watershed is within the Interior Douglas Fir Biogeoclimatic Zone.

The draft "Southern Interior Watershed Procedure" (Arkle *et al.*, 1993) indicates that hydrologic recovery¹ following logging begins when tree species reach 3 m in height and approximate pre-logging values when a height of 9 m is reached (Arkle *et al.*, page 11). Data presented in the

1 i.e. "when snowpack conditions following logging approximate those prior to logging" (Arkle *et al.*, page 10)

report by Sigma Engineering (1991) further indicates that the time required for trees to reach various heights is as follows:

BIOGEOCLIMATIC ZONE	TIME IN YEARS FOR:	
	3 m HEIGHT	7 m HEIGHT
Ponderosa Pine	18.0	33.2
Interior Douglas Fir	16.6	37.1

Thus hydrologic recovery is thought to begin 16 to 18 years following logging and complete recovery is estimated to take approximately 40 years.¹

A historical summary of logging activity was not available at the time this report was written (S. Maricle, Pers. Comm.). Some information of the amount of recent logging is however provided in SECTION 2.6.

2.6 LAND USE

The Deadman River valley is principally used as ranch land. Calves are usually born on valley-bottom pasturage in late-winter or early-spring and the herd spends its summer and fall on adjacent private or Crown rangelands. The valley bottom areas (which are frequently irrigated) are used to grow hay in the summer and serve as winter pasturage.

Forest harvesting also occurs within the Deadman watershed. Jack Cheng undertook a study in August 1990 to assess the possible effects of harvesting on the June 14/90 Deadman River flood event. This report, which is included in APPENDIX 4, indicates that:

- only 1.2 per cent (593.3 ha) of the Criss Creek watershed has been logged since 1985; and
- only 2.1 per cent of the watershed upstream of the WSC gauge *Deadman River above Criss Creek* has been logged since 1985.

and, on the basis of this analysis, it was concluded that:

"It is not likely that the current level of clearcut logging should cause a significant increase in snow and/or rain-generated peak flows at mainstem Deadman River or Criss Creek for the following reasons:

- a) the small percentage of either watershed that has been clearcut logged;*
- b) the relatively gentle terrain on which most cut blocks are located; and*
- c) there are some lakes that provide flow regulation."*

1 Sigma Engineering does not provide data for 9 m high trees; Arkle *et al.* indicates 7 m trees are at the 68% recovery level.

Additional reports by Mitchell (November 1, 1990) and Clarke (November 15, 1990) also indicate that logging had little effect on the June 1990 flood as:

- a) *"The quality of clearcut logging in the upper tributaries of Deadman Creek was good and post-harvesting rehabilitation was adequate to control most on-site erosion and off-site sedimentation"* Mitchell, Page 1.
- b) *"There is no evidence of any significant bank and/or slope failures in the upper and ever mid reaches of either the Deadman River or Criss Creek. No evidence of debris torrents or log jams was observed. The main problem seemed to be water volumes generated over the whole drainage area not just excess water from cut blocks.*

In discussions with Don Ignace of the Skeetchestn Indian Band it was determined that the spring snow melt had already taken place and high water had receded prior to the high water event in question. The other thing I learned was that the high flood waters of June 12 or 13 occurred in all the creeks at the same time. There was no differential levels which indicates that elevation and snow were not a factor and I could conclude that all the water came from the rainfall."

Clarke, Page 1.

Information provided by the Water Management Branch in Kamloops (Doyle, 1994) indicates that the June 1990 flood was entirely rainfall derived and the state of hydrologic recovery following logging, as discussed in SECTION 2.5, therefore probably had little effect on flood magnitude. If snow melt was however occurring, then the harvesting data presented in the letter by Jack Cheng may be misleading as forestry activity over a 40-year period (rather than the 5-year period between 1985 and 1990) should have been used in the analysis.

2.7 FLUVIAL GEOMORPHOLOGY

Air photograph interpretation indicates that there are a number of distinctive river reaches within the present study area. A brief description of each of these areas is presented on Table 2.7.1. This analysis indicates that there are comparatively long sections of river which have wide low-lying sections of valley flat. Intervening areas consist of narrower sections of valley flat where the river is confined by fluvial fans, terraces, or landslide deposits. Rates of channel shifting are generally highest within the wide valley flat reaches and, as a consequence, these areas contain numerous unvegetated river bars.

It is sometimes possible to detect the affects of sediment moving down a river channel by examining the historic variation in water levels associated with specific discharges at stream gauging stations. A specific gauge plot was therefore prepared for the Deadman River gauging site on the basis of mean annual flow of 1.65 m³/s and this information is shown on Figure 2.7.1. The analysis indicates that channel section at the gauging site was aggrading in the period between 1961 and 1976. Significant channel downcutting occurred in 1982 (of about 40 cm) and

again in 1990 (of about 70 cm). Discussion with Steve Maricle indicates that a weir was placed across Deadman River approximately 150 m downstream of the Criss Creek gauge in approximately 1920 to divert water into an irrigation channel. This weir washed out in approximately 1978. The documented channel aggradation and downcutting may therefore merely reflect channel readjustment following the loss of the downstream weir, rather than a more widespread phenomenon resulting from a change in sediment loading.

A useful method of comparing the energy available in a river is by calculating the stream power:

$$\Omega = Q \cdot S \cdot Y$$

where

- Ω is stream power (watts);
- Q is discharge (m^3/s);
- S is water surface slope (m/m); and
- Y is the weight density of water ($9799 N/m^3$)

The stream power associated with the 2 and 100-year daily flow has been calculated for the *Deadman River above Criss Creek* gauging station and for the section of Deadman River located downstream of Criss Creek (based on Table 2.4.3). The results are shown on Table 2.7.2, in comparison to other rivers on which stream improvement or assessment projects have been recently undertaken. This analysis indicates that the section of Deadman River located "above Criss Creek" has comparatively low stream power values. Stream power is somewhat larger downstream of Criss Creek due to the increased river flow. This analysis suggests that the rates of channel shifting and sediment transport on Deadman River can be expected to be larger than those generally occurring on the Salmon River near Salmon Arm, but are nevertheless modest in comparison to higher energy streams. Relatively simple measures can therefore likely be successfully used to control bank erosion in much of this system and the affect of destabilizing a river bank (by for example removing its vegetation cover) is likely to be less dramatic in comparison to what would occur as a result of a similar disturbance in a higher energy environment.

2.8 RIVER TRAINING WORKS

Measurements from 1990 and 1992 aerial photographs indicate that approximately 4.8 km of rip-rap have been placed between Mowich Lake and the Highway 1 bridge. The majority of these revetments are located within the Craig Ranch (1.4 km or 29 per cent)¹ and on the "Dockstader" Ranch (2.0 km or 43 per cent).

Many of the above structures were placed following the 1990 flood event (Rosenau, 1990) Information provided by Paul Doyle of the Provincial Water Management Branch (Doyle, 1994) indicates that:

¹ This does not include 440 m of rip-rap (9% of total) placed by Westcoast Energy.

"Water Management through P.E.P. spent \$92,000 on riprap on private properties and Indian Reserve after [the 1990] flood. Fish and Wildlife/Department of Fisheries and Oceans spent tens of thousands more on some Dockstader banks and on Indian Reserve Hatchery dyke. Pipeline company also spent some thousands on riprap in other areas. Steve Maricle may have some of these \$ figures which I've never known. I recall \$60,000 for hatchery but my recall is faulty."

Channel bank re-stabilization activities following the 1990 flood are thus likely to have cost over \$150,000 and, as will be discussed in SECTION 3.1.4, much of the river bank is still actively eroding.

3.0 CHANNEL STABILITY ASSESSMENT

3.1 AIR PHOTO ANALYSIS

3.1.1 Introduction

A wide selection of air photographs are available for the Deadman River watershed (Tables 3.1.1a, b and c). Photos from 1948, 1959, 1965, 1966, 1974, 1980, 1986, and 1992 were therefore obtained in order to investigate changes in stream channel location and morphology over time. The photos span the sizeable floods in 1969 and 1990 and therefore provide a basis for quantitatively assessing the effects of these events.

3.1.2 Case Studies

An initial review of the available air photos indicates that substantial changes in stream channel morphology and stability have occurred since 1948. These changes are of a similar nature throughout the study area. Three sites, all of which are located in channel reaches which have a wide valley flat, have been selected to illustrate these effects:

1. The Craig Ranch;
2. The Phillips Ranch;
3. The "Docksteader" Ranch.

The locations of these ranches are shown on Figure 3.1.1.

Figure 3.1.2 shows a historical series of air photos of the Craig Ranch. This site is located immediately upstream of the Criss Creek confluence. The 1948 photograph (Figure 3.1.2a) indicates that both banks of Deadman River above the Criss Creek fan were continuously vegetated, except where a right bank¹ ranch undertook some local clearing. The river consists of a narrow, single thread, sinuous channel and, except in the vicinity of the right bank ranch, the channel is devoid of any bar forms or other indications of significant bed material transport. There are also no patterns of vegetation succession, indicating that the channel is undergoing slow or negligible rates of lateral channel shifting.

By 1986 (Figure 3.1.2b), the left bank valley flat had been almost entirely cleared and sizeable portions had been ploughed. The river channel has widened and straightened. There are well-developed point bars, indicating that both significant channel shifting is occurring and that the rate of bedload transport to total sediment transport had increased. The 1992 photos (Figure 3.1.2c) indicate that the 1990 flood discharge resulted in substantial bank erosion, the further enlargement of most point bars and the loss of a considerable area of pasture.

A similar pattern occurs in the vicinity of the Phillips Ranch (Figure 3.1.3). In 1948 (Figure 3.1.3a), the stream bank areas were continuously vegetated despite the fact that much

1 while looking downstream

of the adjacent valley flat area was being used as pasture. The channel was single thread with a stable irregular to tortuously-meandering pattern. By 1986 (Figure 3.1.3b) most of the channel bank vegetation had been cleared and the channel had become both wider and straighter. A number of point bars had formed, indicating that rates of bank erosion and coarse-textured sediment transport had increased. The 1992 photos (Figure 3.1.3c) indicate that the 1990 flood resulted in extensive bank erosion, further channel straightening and extensive point bar development. The channel is substantially wider than in 1948 and is carrying a much increased coarse-textured sediment load.

The 1948 photos of the upper "Dockstader" Ranch (Figure 3.1.4a) indicate that the bank vegetation on this section of Deadman River was again intact despite the use of adjacent valley bottom areas as pasturage. As with the Craig and Phillips properties, the stream channel was narrow, had an irregularly to tortuously-meandering pattern, was undergoing low rates of channel shifting and was carrying only small amounts of coarse-textured sediment. By 1986 (Figure 3.1.4b) most of the valley bottom had been cleared, the channel had increased in width and was undergoing locally-significant rates of lateral channel shifting. The 1992 photos (Figure 3.1.4c) indicate that substantial channel shifting occurred following the 1990 flood despite the widespread placement of rip-rap along this section of river.

3.1.3 Changes in Channel Width

Measurements have been made at the three sites described above to illustrate the change in channel widths that has occurred over the period of air photo coverage. These results are summarized on Table 3.1.2 and indicate that the average channel width has increased from 9 to 10 m in 1949 to 30 to 48 m in 1992. The standard deviation about the average channel width has also increased from 1.9 to 4.1 m in 1948 to values of 15.6 to 28.8 m in 1992. Changes in maximum unvegetated channel width are even more extreme. For example, on the Craig Ranch the maximum unvegetated channel width has increased by almost 100 m. These increases in unvegetated width reflect both a change in channel morphology and the effect of recent bank erosion which has resulted in the formation of wide unvegetated point bars. These unvegetated bars are presently unsuitable for use as pasture or for other agricultural purposes. The change in average channel width is therefore indicative of the amount of pasture which has been lost due to river destabilization.

3.1.4 Channel Stability Mapping

The preceding case studies indicate that sizeable portions of the Deadman River valley flat have been cleared for agricultural, ranching or other activities. Within these areas much of the riparian zone has either no woody vegetation or only a narrow strip of vegetation bordering the stream. This reduction in streamside vegetation is morphologically significant as recent studies on Deadman, Salmon and Bonaparte Rivers (Beeson and Doyle - in preparation) indicate that rates of bank erosion are higher in areas which lack a well-developed riparian vegetation cover.

In order to determine the spatial extent of the loss in riparian vegetation, the 1992 air photos were examined in an enlarging mirror stereoscope and sections of river bank were classified on the basis of the following criteria:

- i) Woody bank vegetation absent or of limited extent; and
- ii) Woody bank vegetation less than 0.5 channel widths wide or severely reduced in density due to grazing activities.¹

All actively eroding sections of river bank were also identified, based on morphological characteristics such as the presence of prograding river bars. In some areas rip-rap or other measures have been taken to slow rates of bank retreat. In most cases these banks have still been classified as "eroding" as the effectiveness of the implemented measures cannot be determined on the basis of air photo interpretation. The resulting information was mapped on the 1:20,000 scale 1992 air photos and this information is presented in FOLIO 1. The 1992 air photos were also digitized and the lengths of the various mapped units are summarized on Table 3.1.3. Channel characteristics have been summarized by stream kilometre upstream of the Thompson River confluence.

The results of this analysis, which are displayed on Figure 3.1.5, indicate that 28 km (or 44 %) of the 64 km of river bank between the lower Deadman River Bridge at Km 12 and Tobacco Creek at Km 42 have little or no bank vegetation. An additional 15 km (or 23 %) has a woody bank vegetation which is less than approximately half a channel width wide. In total, 43 km (or 67 %) of the classified channel is either unvegetated or poorly vegetated.

The lengths of all actively eroding banks are summarized on Table 3.1.3 in relation to the amount of riparian vegetation. The distribution of eroding banks is shown on Figure 3.1.6. A total of 20 km, or 32 % of the channel banks, was actively eroding in 1992. Eighty-one per cent (or 16 km) of the total length of eroding banks is associated with unvegetated river banks and a total of ninety-two per cent (or 18.5 km) is associated with banks which have either no vegetation or only a narrow fringe of woody riparian vegetation. In contrast, only eight per cent (1.5 km) of the eroding sections of river bank have well-developed riparian vegetation (and in many cases, these areas have been destabilized by sediment accumulations derived from eroding unvegetated banks). This result confirms the work by Beeson and Doyle (in preparation) and M. Miles and Associates Ltd (1995) which indicates that unvegetated banks are more susceptible to bank erosion.

3.1.5 Discussion of Air Photo Analysis

The above analyses indicate that there is a widespread pattern of on-going loss in bank vegetation along Deadman River and a corresponding increase in channel width and rates of channel shifting. The 1990 flood, which was unquestionably an extreme and unusual event,

1 This criterion is difficult to apply along sections of valley wall where the amount of woody vegetation which existed prior to grazing is unknown. The length of river bank with reduced vegetation is however so large that any misclassifications will not significantly affect the results of the study

resulted in widespread channel shifting and erosion of valley bottom pasture lands. Nevertheless, the change from a laterally stable to a laterally unstable channel morphology pre-dates the 1990 flood event and thus the 1990 floods merely served to make an existing situation worse. Given the amount of sediment now stored within the Deadman River channel and the documented extensive loss in bank vegetation, accelerated rates of channel shifting must now be expected even under "normal" flood discharges. The time necessary to return to pre-flood conditions will depend upon the availability of areas to store the mobilized sediment and on the time necessary to re-establish bank vegetation.

3.2 FIELD INSPECTION

A field inspection was undertaken on April 19, 1994 and the area of Deadman River between the Highway 1 Bridge and Mowich Lake was inspected. The author was accompanied by Steve Maricle of the provincial Fisheries Branch and Bob Costerton, P.Eng. of the Water Management Branch, who were able to provide information on historic river behaviour and describe the various mitigation measures which have been undertaken. A number of local residents were interviewed, including Mr. and Mrs. Craig, Mrs. Phillips, Mr. Bob George (the present owner of the "Dockstader" Ranch) and Mr. Don Ignace. Telephone interviews were also undertaken with Don Bruce of Westcoast Energy and Barry Bomford of Numac to discuss how the pipeline route through the Deadman River watershed has been affected by channel shifting. A videotape of Deadman River prepared by the *Water Management Branch (1990)* on June 16, 1990 was also viewed to assess channel behaviour under flood conditions.

The field inspection confirmed that stream bank vegetation is generally absent from sections of the valley flat which have been used as pasture and that bank erosion is commonly occurring within these areas (Plates 3.2.1 to 3.2.3). In contrast, channel banks were generally stable along sections of stream with a well-developed vegetation cover (Plate 3.2.4). This pattern occurred throughout the study area.

A variety of techniques have been used to attempt to control channel shifting. These include:

- rip-rap placement
- spur construction
- tree revetments/tree retards
- fencing and vegetation planting.

Extensive amounts of rip-rap have been placed by the provincial Ministry of Environment, Lands and Parks (MOELP) either as part of a habitat maintenance program (e.g. the "Dockstader" Ranch) or as a response to the 1990 flood event (e.g. the Craig Ranch). Rip-rap was generally placed along eroding sections of channel bank in order to maintain an existing or desired channel location (e.g. Plate 3.2.5), rather than as set-back rip-rap.

Some of the placed rip-rap failed during the 1990 flood due to channel shifting associated with sediment deposition, as illustrated on Plate 3.2.6. A more widespread effect however is that rip-rap placement has been used to confine and straighten sections of river and, as a result,

sediment deposition frequently occurs immediately downstream of the rip-rap. When the channel attempts to shift around this material, more bank erosion occurs (e.g. Plate 3.2.7). This self-perpetuating cycle is exacerbated in many locations as the placed rip-rap confines the stream channel to a narrow area adjacent to the valley wall. Valley-wall erosion (e.g., Plate 3.2.8) then provides a source of coarse-textured sediment which the river cannot transport in a non-confined channel.

All of the interviewed ranchers felt that the present rip-rap protection on their properties was inadequate and that additional rip-rap should be placed to control bank erosion. The widespread adoption of such a policy might eventually result in the rip-rapping of at least one river bank along the approximately 20 km of unconfined channel located within the 29 km long study area (Table 2.7.1).

Rock spurs or groynes, such as that illustrated on Plate 3.2.9, have been placed at a small number of sites. These features can reduce bank erosion over a distance of 2 to 3 spur lengths and form scour holes which may provide useful fish habitat. Spurs or groynes are however subject to being "outflanked" by upstream bank erosion and numerous structures would be required to reduce bank erosion over an extended area.

Tree revetments, or "retards, such as illustrated on Plate 3.2.10, have been placed at a small number of locations in order to slow bank erosion and provide fisheries habitat. Paul Doyle, of the Water Management Branch in Kamloops (Doyle, 1992) has reviewed the performance of three tree revetment sites and found that they all failed within a few years, despite being exposed to only average flood peaks. Better design practice, including the use of substantial quantities of large bushy trees and the provision of a secure anchor (none of the studied trees were anchored) would likely improve performance. Even with these design modifications, tree revetments can be expected to have a limited lifetime. They appear to be best suited as a temporary measure to retard channel shifting and allow a dense vegetation growth to become established which will provide long term erosion protection.

Fencing, in conjunction with vegetation planting and rip-rap placement has been undertaken on extensive sections of the "Dockstader" Ranch, as well as at other locations. The 1990 flood however eroded some sections of the "Dockstader" fencing as it had been placed too close to eroding channel banks. Intact fencing has protected both planted and natural establishing wood vegetation from cattle grazing, while broken fencing has resulted in heavy browse damage (Plate 3.2.11). Vegetation planting has generally been undertaken along a narrow strip of land adjacent to the river channel and both bank erosion and a failure of cuttings and rooted stock to thrive appear to have locally reduced its effectiveness. Better planting techniques and/or other tree species (including willow and red osier dogwood) appear to be required to provide an effective means of stabilizing channel banks. A sufficient period of time to allow the establishment of a dense vegetation cover is also required. This necessitates the use of set-back fencing such that vegetation can grow outside the area subject to channel shifting over the period of the next 10 to 15 years. From the rancher's perspective set-back fencing is however undesirable as it reduces the available pasture area, allows the growth of weed species such as thistles or burdock (Plate 3.2.12) and tall trees, such as cottonwood, shade the adjacent pasture.

3.3 DISCUSSION OF FIELD RESULTS

Recent bank stabilization efforts on Deadman River have included a wide variety of measures ranging from traditional engineering approaches, such as rip-rap, to bio-engineering techniques, such as tree revetments and bank revegetation. Local success has been variable and, particularly in the case of rip-rap placement, has tended to merely relocate the problem downstream. General lessons which can be learned from this experience include:

- i) sediment production must be minimized, such that localized sediment deposition does not cause bank shifting;
- ii) channel length must be maintained as channel straightening increases stream gradient and velocity with a resulting increase in the stream's ability to shift laterally;
- iii) the presence of riparian vegetation makes the stream bank more difficult to erode and hence reduces sediment production;
- iv) artificially confining the stream channel against the edge of the valley results in erosion of coarse-textured sediment from the valley walls which are subsequently deposited in the river channel;
- v) stream channel stability at any site is affected by the amount of sediment being carried in from upstream areas; and
- vi) river training works can result in increased rates of downstream bank erosion.

In order to re-establish the stable channel configuration and low rates of channel shifting which were occurring in 1948, it will be necessary to

- i) re-establish bank vegetation; and
- ii) provide sufficient room to deposit the coarse-textured sediments now stored in the river channel. This implies that the river cannot be confined to a narrow area by dykes or other revetments.

Even with appropriate management strategies, and "normal" flood discharges, it will likely take decades to return the river to its formerly more stable condition.

4.0 SEDIMENT TRANSPORT

4.1 INTRODUCTION

The preceding discussion indicates that the erosion, transport and deposition of sediment is an important factor which affects the stability of Deadman River. Indeed sediment availability may be more important than flood magnitude in controlling a river's channel morphology and stability.

4.2 SEDIMENT SOURCES

A variety of natural sediment source areas occur in the Deadman River watershed, including talus slopes (Plate 4.2.1), earthflows (Plate 4.2.2) and eroding sections of valley wall (Plate 4.2.3). Sediment production from these areas will be episodic and considerable effort would be required to determine the quantities of sediment produced during various initiating conditions.

Air photo interpretation and ground inspection located areas where access and logging-road construction had locally increased sediment availability (e.g. Plate 4.2.4). Widespread slope disturbance has also occurred as a result of very poor logging practices (Plate 4.2.5), however in most areas there was little or no evidence that significant quantities of sediment were being transported across the valley flat to the stream channel. Additional studies would be required to thoroughly assess the effect of logging activities on sediment production. Such a study would however not be easily undertaken as rates of sediment production can be expected to change over time as roots rot out. Additionally, unusually heavy rain occurring during a period of wet ground conditions may be necessary to initiate significant sediment production. Two noteworthy areas were identified during the pair photo analyses. Both valley walls in the area between Km 24 to 26 and 27.5 to 28.5 (see FOLIO 1) are composed of erodible unstable sediments which have been disturbed. These areas deserve field inspection to determine if significant quantities of sediment are entering Deadman River, and if remedial efforts are warranted.

During the course of the field inspection (which was conducted during the early portion of the spring freshet) it appeared that suspended sediment concentrations and load was increasing downstream of Mowich Lake primarily as a result of river bank and valley wall erosion. Observations again suggest that the majority of this erosion was occurring along unvegetated pasture banks or in areas where the stream was artificially confined against the valley walls (Plates 3.2.1 to 3.2.2 and 3.2.8). This observation is supported in the 1990 letter from W. Mitchell to B. Read [see APPENDIX 4] which states that:

"Most of the bedload and suspended sediment initiation in Deadman Creek below the mouth of Criss Creek appears to be from extensive creek cutbank erosion in middle and lower Criss Creek and lower Deadman Creek." Mitchell, Page 2.

The June 16, 1990 videotape of the Deadman River (Water Management Branch, 1990), which was taken during the receding stage of the June 15 flood (Figure 2.4.10), also indicates that

fluvial erosion of the river bank and the valley wall was occurring throughout the study area, with many of the most active sites being located in areas of cleared pasture.

4.3 SEDIMENT LOADINGS FROM TRIBUTARY STREAMS

There are eight sizeable tributaries which enter Deadman River over the length of the study area. The lower reaches of each of these streams was examined on the available aerial photography to assess sediment loadings on the basis of channel size and morphology. The results of this analysis are summarized on Table 4.3.1.

The Deadman River at the upper end of the study area contains small unvegetated gravel bars. The river has entrained this bed load in the area downstream of Mowich Lake. This appears to result from a combination of bank erosion in an area of cleared valley bottom farm land and from valley wall erosion at sites such as those illustrated on Plates 4.2.1 to 4.2.4.

With the exception of Criss Creek, all tributary streams appear to be carrying either small or very small quantities of coarse-textured sediments. Criss Creek has built a coarse-textured fan onto the Deadman River valley flat and recently abandoned channels are evident on the fan surface. Unvegetated bar forms are also evident in the lower reach of this tributary and are an indication of periodically-significant rates of bed load transport.

The above observations indicate that coarse-textured sediments are being imported into the study area from the upstream channel and from the Criss Creek watershed. All other tributaries appear to be carrying comparatively small quantities of coarse-textured sediments. The overall impression from this analysis is that the principal source of coarse-textured sediment is from river bank and valley wall erosion from within the study area.

5.0 IMPACTS ON FISHERIES HABITAT

Air photo interpretation and ground inspection of Deadman River indicates that within the last 50 years there has been a decrease in river channel length, a loss in bank vegetation and an increase in the rate of coarse-textured sediment transport. A sizeable reduction in the extent of backchannel or wetland area (such as illustrated on Plate 5.0.1) has also occurred as the river channel has been progressively forced towards the edge of the valley and riparian channel areas infilled to increase the area of productive pasture (e.g., Plate 5.0.2). Channel width appears to have generally increased as has the distribution of sediment deposits. Reduction in stream-side vegetation, along with a more shallow channel cross-section, can be expected to have increased summer water temperatures, among other factors. Ranching practices appear to be the principal cause of most, if not all, of these impacts.

It is beyond the scope of the present report to determine the biological results of these changes in channel habitat conditions. Numerous studies have however been undertaken to determine the affects of similar physical changes on other systems and the results are not beneficial to the fisheries resources (For example see papers presented in Johnson *et al.*, 1985; Chaney *et al.*, 1990; Armour *et al.*, 1991). Impacts include loss of habitat (particularly undercut banks), deterioration of bed material (substrate) suitability for spawning, elevated water temperatures, loss of benthic organisms and food supplies from stream bank areas, etc. In the present circumstance, the loss of backchannel and wetland areas are also likely to adversely affect juvenile coho and possibly rainbow trout which rear in this type of habitat.

6.0 RECOMMENDATIONS

6.1 ESTABLISHMENT OF RIPARIAN CORRIDOR

The analyses undertaken in this report indicate that the loss of riparian vegetation is the single most important cause of increased bank erosion, sediment transport, sediment accumulation and loss of ranch land within the study area. Loss of streamside shade is likely increasing summer water temperatures. Bank erosion could also be exacerbating water shortages during the summer irrigation period, as streamflow may be locally flowing within sediment deposited on the stream bed.

Habitat restoration activities should focus on restoring bank vegetation over the approximately 43 km of unvegetated or poorly vegetated stream banks. Approximately 18.5 km or 43 per cent of the inadequately-vegetated banks are presently eroding and therefore the rehabilitation of these areas should be a high priority. It may be necessary to locally stabilize some of these actively eroding sites through the use of bio-engineering or more traditional approaches. However, the cost of these structures is high and, considering the length of river that could be treated, it may be prohibitively expensive to undertake this work in all areas. Restoration work should however not just focus on the sections of eroding banks as the 24.5 km of presently-stable, unvegetated or poorly vegetated, banks can be expected to become future erosion problems. It is therefore recommended that a suitably wide riparian corridor be established along all presently unvegetated or sparsely vegetated areas and that fencing be constructed to prevent browsing damage. Measures should also be undertaken to maintain and protect areas of existing riparian vegetation. Over the long term, the establishment or growth of a variety of woody shrub and tree species within a riparian corridor will eventually reduce rates of channel shifting, stabilize sediment deposits and reduce the channel width. The establishment and maintenance of a vegetated riparian corridor is thus the long term solution to channel instability problems on the Deadman River.

6.2 RIPARIAN CORRIDOR WIDTH

The width of the required riparian corridor should ideally be determined on a site-specific basis as a function of present channel stability and an assessment of how this may change over time as a result of upstream bank erosion or other factors. As a general objective it would be desirable to establish a riparian corridor on each bank which has a width of at least three times the channel width. This recommendation is based on channel morphology relationships which indicate that the average radius of a meander bend is approximately 2½ times the river width. Providing a corridor with a total width of approximately 6 to 7 times the channel width would thus allow the river to migrate in a relatively natural manner without unduly disturbing adjacent property.

Channel width should be determined in nearby sections of the river which have well-developed woody vegetation on both banks. In areas of active erosion, the corridor width will have to be increased such that vegetation has the time necessary to develop sufficiently that it can stabilize

the river. Once the river has stabilized, it may be possible to reduce the corridor width to the values described above. In some presently stable areas, such as those adjacent to erosion resistant materials, it may be possible to reduce the riparian corridor to one channel width wide. However, this is a minimum criterion which should not be reduced without just cause.

6.3 LAND ACQUISITION

In some cases it may be necessary to rent or buy the land required for a streamside management corridor (as is being done in Alberta ¹) or to provide some other form of compensation to the riparian land owners. However land owners may choose to voluntarily set aside the required riparian areas if it is possible to demonstrate that establishing a vegetated streamside corridor is in their best long term interest. Specifically, if the present trend of channel destabilization continues, bank erosion and increased river width will result in a loss of land which could locally exceed that required to establish a vegetated corridor.

6.4 FENCING AND PLANTING

The streamside riparian corridor will need to be fenced to prevent grazing damage by livestock. Cattle access to the stream for drinking water or to cross to the other bank should be limited to a small number of locations. In areas of active erosion it would be desirable to plant the fenced area with native shrubs and trees. The optimum species mix and planting techniques need to be determined. The intent should be to provide some tall trees (such as cottonwood or poplar) to shade the river and shrubs (such as willow and red osier dogwood) which will increase the stability of the channel banks. In non-eroding or slowly eroding areas, natural revegetation may be sufficient to re-stabilize the stream banks.

6.5 BANK STABILIZATION

In general, the river should be allowed to migrate within the established riparian corridor. It may however be necessary to initially control local areas of rapid erosion through the use of tree retards or other appropriate bio-engineering techniques. The use of rip-rap should generally be avoided for the reasons discussed in SECTION 3.2. If the recommended corridor width is established and suitably vegetated, the need for future bank stabilization projects should be greatly reduced. It may however be periodically necessary to either use bioengineering or other techniques to keep the river within the established corridor or to re-establish the corridor as required. If rip-rap is required to protect an expensive pre-existing structure which cannot be moved, it should be keyed-in below potential scour depths and ideally placed as "set-back rip-rap" along the edge of the defined corridor.

1 see Makowecki, 1980 and Konyonenbelt, 1994.

6.6 PRIORITY FOR UNDERTAKING RESTORATION WORK

Mapping developed for this project shows the location of areas which are unvegetated or sparsely vegetated, as well as those areas which are actively eroding. From the perspective of reducing downstream sediment production, it would be desirable to initially undertake work in those areas which are unvegetated and eroding. However, these sites will likely be expensive to repair and, from a benefit-cost perspective, it may be desirable to spend a substantial portion of the available funding acquiring and fencing poorly vegetated areas which could otherwise be destabilized. The optimum rehabilitation plan probably consists of three components, with the relative emphasis varying over time and with the availability of funding.

- 1: Rehabilitate severely disturbed sites, including bioengineering efforts to stabilize eroding banks and planting to expedite the re-establishment of a riparian vegetation;
2. Acquire and fence areas which are presently poorly vegetated. Allow revegetation to occur naturally; and
- 3: Take measures to prevent the loss of riparian vegetation in areas which are presently vegetated.

River reaches containing sections of low-lying flat likely deserve high priorities and it would be desirable to work in a downstream direction, such that upstream sediment production does not destabilize rehabilitated sections of stream channel.

6.7 INSPECTION AND MAINTENANCE OF RIPARIAN CORRIDOR

The establishment of a vegetated corridor could have some negative affects on nearby property owners, due to an initial increase in the incidence of weed species, shading fields and beaver activity. An on-going program to address these issues should therefore be undertaken, as required. It should however be noted that over the long term the formation of beaver dams, or log jams, could be beneficial as these structures will reduce water velocity, trap sediment and provide fish habitat. Once bank vegetation is established there will also be a reduced tendency for these structures to re-direct the river channel and cause bank erosion. Fencing will need to be maintained and areas of future erosion will need to be evaluated and appropriate rehabilitation procedures recommended.

7.0 FUTURE WORK

7.1 ADDITIONAL CHANNEL STABILITY MAPPING

The present project addresses channel stability in the 29 km study area located 12 km upstream of the Thompson River confluence. Air photo interpretation and the field inspection indicate that channel stability concerns also occur in the area upstream to Mowich Lake and downstream to the Thompson River confluence. Undertaking additional channel stability mapping in these areas is therefore desirable in order to prepare consistent recommendations and restoration priorities for the entire lower Deadman River.

7.2 SYNOPTIC SEDIMENT TRANSPORT INVESTIGATION

The Deadman River field inspection of April 19, 1994 suggested that suspended sediment concentrations and total sediment load was increasing in a downstream direction as a result of bank and valley wall erosion within or adjacent to areas affected by cattle grazing or associated river training efforts. It was therefore proposed that a number of suspended sediment samples be collected to determine if this impression was true. This study, which is briefly described in APPENDIX 4, should be undertaken and, depending upon the results, it may be desirable to repeat this work to determine how the results vary at different times of the year. Once available, these data should be used to modify the presently proposed recommendations, as required.

7.3 ON-SITE INSPECTIONS

The channel stability mapping presented in this report identifies the location of eroding river banks and those areas with little or no riparian vegetation. On-site inspections will be required to develop site-specific remedial plans, such as establishing corridor width requirements, locating fencing boundaries and planning measures to reduce rates of bank erosion. Ideally this work should be undertaken by a multi-disciplinary team consisting of a fluvial geomorphologist, a river engineer, a fisheries biologist and a plant ecologist or bioengineer. It may also be desirable to include a range agrologist, as experience in Alberta indicates that providing recommendations to improve general range conditions increases rancher co-operation and results in improved riparian conditions.

7.4 UPLAND SEDIMENT SOURCES

The present project has identified a number of areas where slope instability or disturbance may be increasing sediment loads in Deadman River (see SECTION 4.2). Recent large scale air photos of the Criss Creek watershed and the Deadman River watershed downstream of Mowich Lake should be reviewed and all areas of significant sediment production should be identified. This should include an assessment of all access roads. All potentially problematic areas should be inspected in the field and remedial measures to control sediment production should be

undertaken as required. It makes little sense to propose an extensive valley bottom riparian management program if it can be adversely affected by upland sediment production.

7.5 REVEGETATION TRIALS

A variety of projects have been undertaken on Deadman River to promote the re-establishment of bank vegetation. These include both transplanting rooted plants and cuttings. These projects appear to have been generally unsuccessful. Recent work on Salmon River indicates that success rates can be increased by watering and by the use of protective collars to prevent damage by small mammals. Given the extensive length of channel banks which need to be revegetated, it would be desirable to set up some well-controlled experiments to determine the optimum techniques for rehabilitating the various types of river banks found within the comparatively dry conditions of the study area. For example, what is the difference in rates of revegetation at sites with transplanted vegetation versus sites which have been merely fenced? Can bio-engineering techniques such as "spiling", "bush mattresses", "live shore fascines", and "live wooden baffles", as described in Schiechl (1980) and Coppin and Richards (1990) be used to promote rapid revegetation of actively eroding areas? Operational trials should be conducted by experienced personnel and the tests should be conducted in a manner which will provide the information needed to develop design guidelines and estimate costs for future projects.

7.6 TREE RETARD DESIGN SPECIFICATIONS

A number of tree retard sites were inspected in the field and they generally appeared to be of limited success. Both inadequate anchors and insufficient material appeared to be important factors which adversely affected performance. More substantive designs have recently been employed on the Salmon River (see M. Miles and Associates Ltd., 1995) and this experience should be utilized in future projects on the Deadman River. Additional design investigation however appears to be warranted. The long term effectiveness of these structures needs to be monitored to determine the optimum design. For example, is rock on the upstream and downstream end of tree retard sites beneficial? How thick do the anchoring cables need to be? What sized anchors are required and how far back should they be placed?

7.7 RIPARIAN CORRIDOR WIDTH REQUIREMENTS

The recommendations on the required riparian corridor width presented in this report are based on typical channel geometry relationships and observations of channel stability in the 1948 to 1992 period at sites on Deadman River with varying amounts of bank vegetation. The effects of canopy height and width on stream shading have however not been considered (e.g. Barton *et al.*, 1985).

Corridor width requirements will significantly affect the amount of riparian land that must be acquired. This topic therefore deserves more careful consideration and controlled experiments

to determine the optimum corridor widths in various river settings. The process of acquiring land and creating a riparian corridor should not be held back until such time as this work can be completed. The performance of completed sites should however be monitored in a manner which will allow corridor width recommendations to be revised as required.

7.8 BENEFIT COST

A benefit-cost analysis of various bank protection measures needs to be undertaken. Ranchers will likely protest that set-back fencing results in a financial loss (due to removing pasture land from production) while rip-rap placement maximizes their productive capacity. However if the rancher, rather than the government, had to pay for this protection the benefit-cost ratio may justify taking some land out of production. The paper by Kovalchik and Elmore (1991) provides some guidance as studies in central Oregon indicate that set-back fencing caused a loss of eight animal-unit-months per mile of channel, which was deemed to be "an insignificant loss of available forage from grazing allotments". The issue may however be more complicated and deserves a thorough investigation.

7.9 PUBLIC PARTICIPATION

If carried out, the recommendations proposed in this study will alter the way ranching is currently undertaken in the study area. Some form of these recommendations may also serve as a basis for remedial actions on other watersheds which are experiencing similar problems. The affected ranchers deserve the opportunity to comment on or modify these recommendations and assist in the implementation processes. Changing present attitudes towards the management of riparian areas is likely the most challenging aspect of the proposed work.

7.10 GOVERNMENT POLICY

If implemented, the proposed recommendations will alter the traditional relationship between land owners and regulatory agencies. Specifically, the Water Management Branch or the Provincial Emergency Program will no longer finance the widespread placement of rip-rap along eroding river banks. This will undoubtedly have numerous "policy implications" which will need to be addressed prior to the next flood event. In order to maintain consistency and fairness, it may be necessary to expand the area covered by the proposed recommendations to include other watersheds which are experiencing similar problems.

7.11 MONITORING AND REVIEW

The effectiveness of all mitigation efforts needs to be monitored regularly and periodically critically assessed. These analyses should be undertaken by someone not previously involved with the project and used to modify future practices (on both Deadman River and other watersheds) as appropriate.

8.0 CERTIFICATION

This report has been prepared by:



A handwritten signature in cursive script, appearing to read "M. J. Miles", is written over a horizontal line.

Mike Miles, M.Sc., P.Geol March 22, 1995



9.0 SOURCES OF INFORMATION

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9.2 PERSONAL COMMUNICATIONS

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FIGURES



From: 1:5,000,000 scale map

Figure 1.0.1: Study area location.

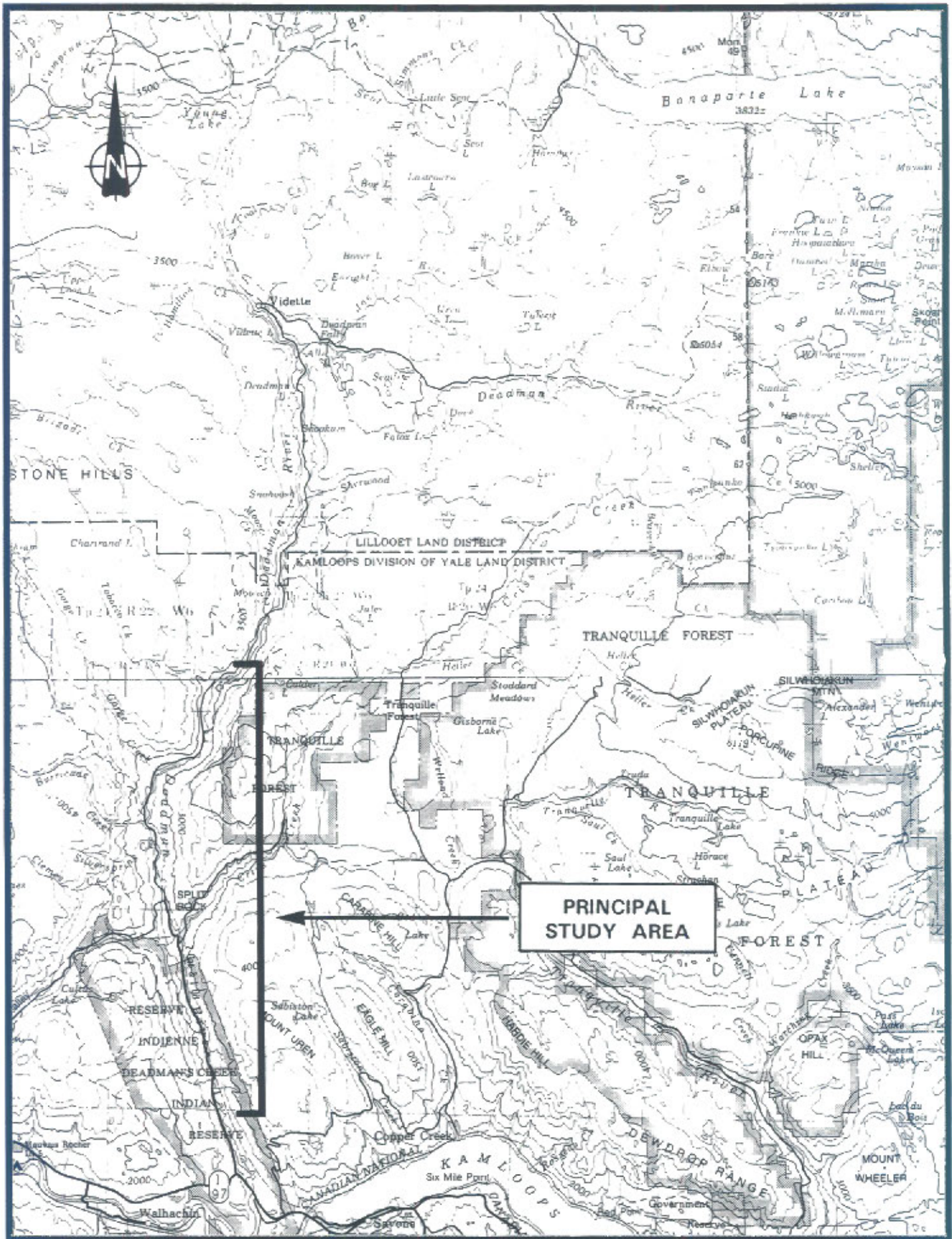


Figure 1.0.2: The Deadman River watershed.

From: 1:250,000 scale map

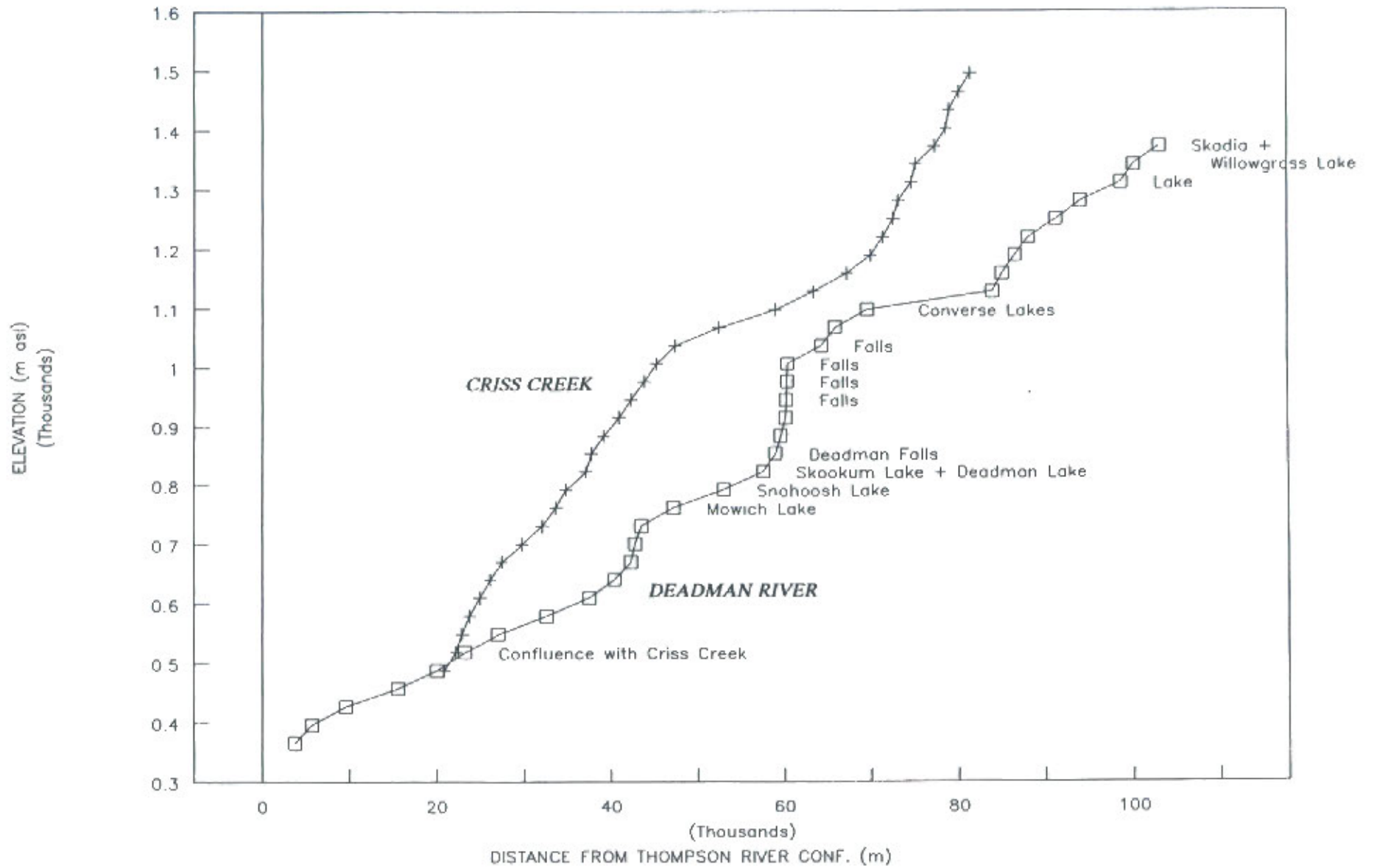
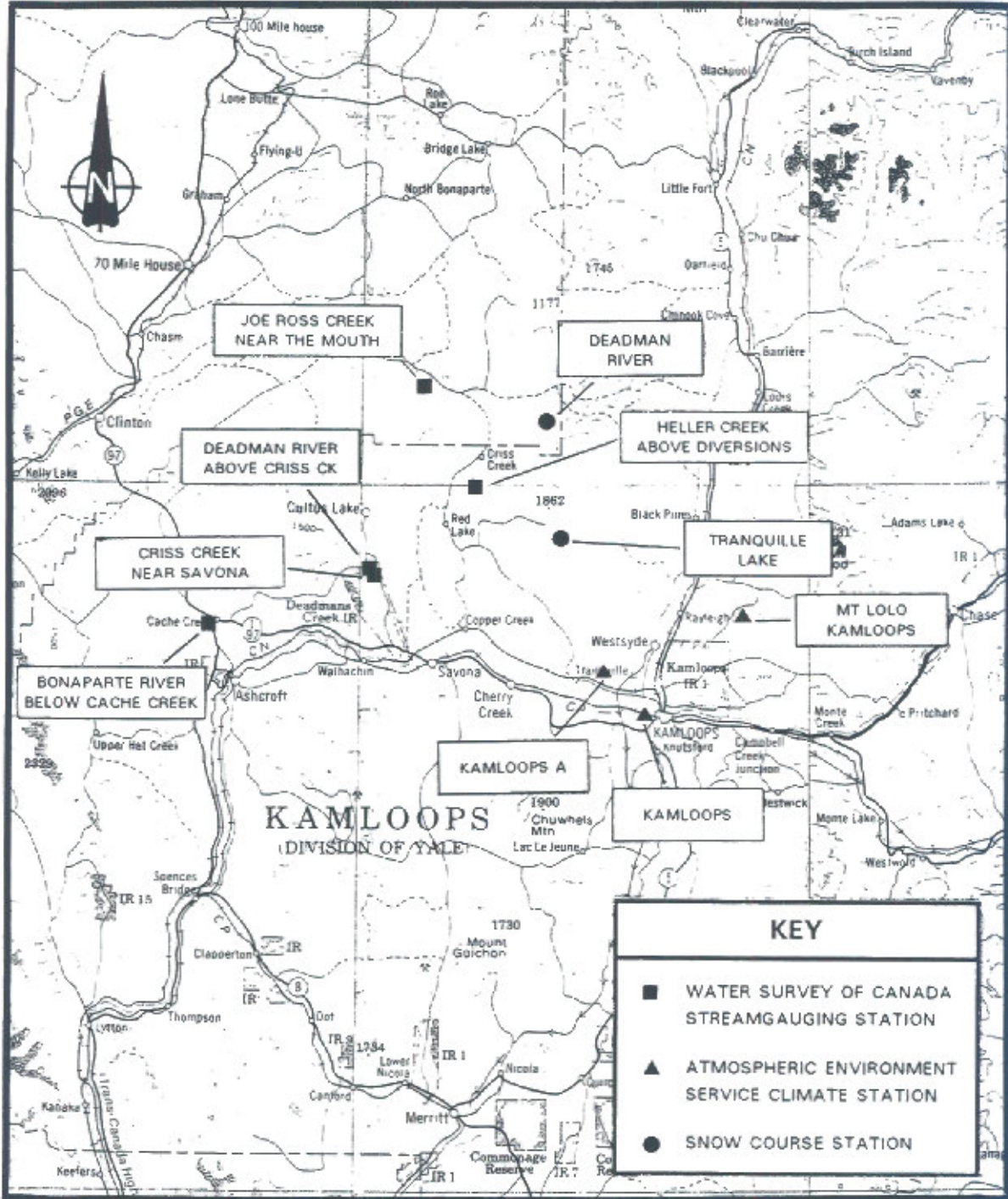


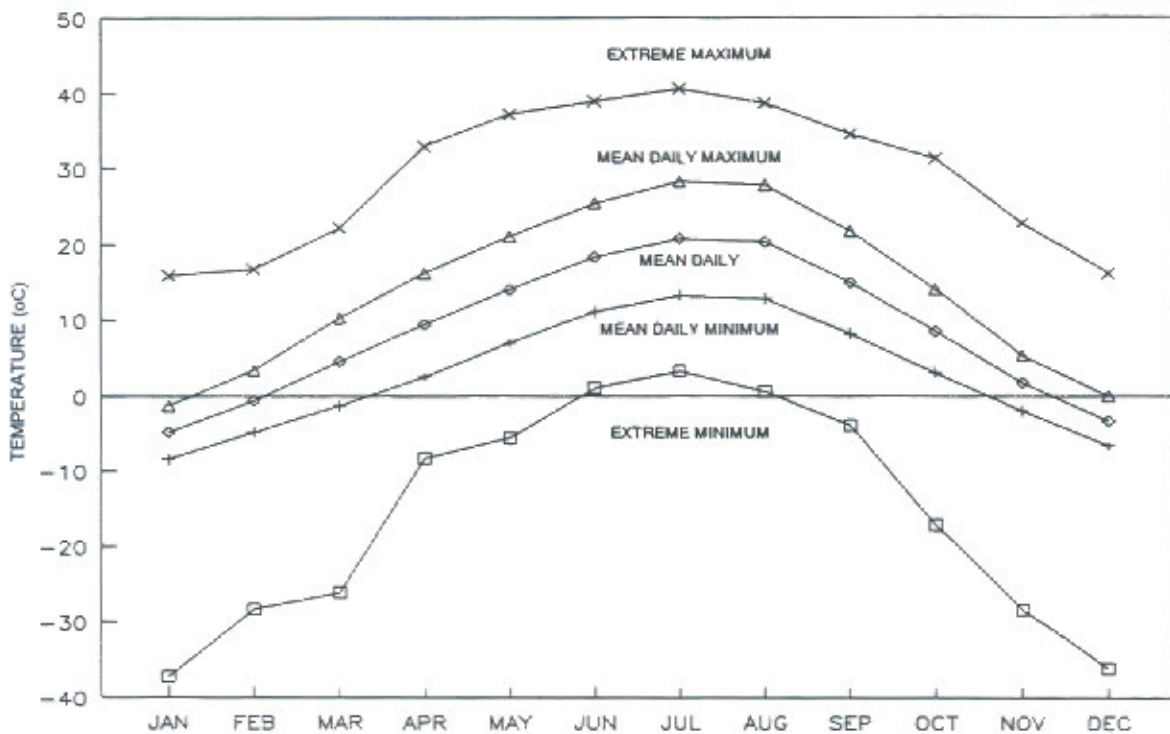
Figure 2.2.1: Long profile of Deadman River, Criss Creek and their principal tributaries



From: 1:1,000,000 scale map

Figure 2.3.1: Location of selected climate and streamgauging stations.

KAMLOOPS A, 1951-90



KAMLOOPS A, 1951-90

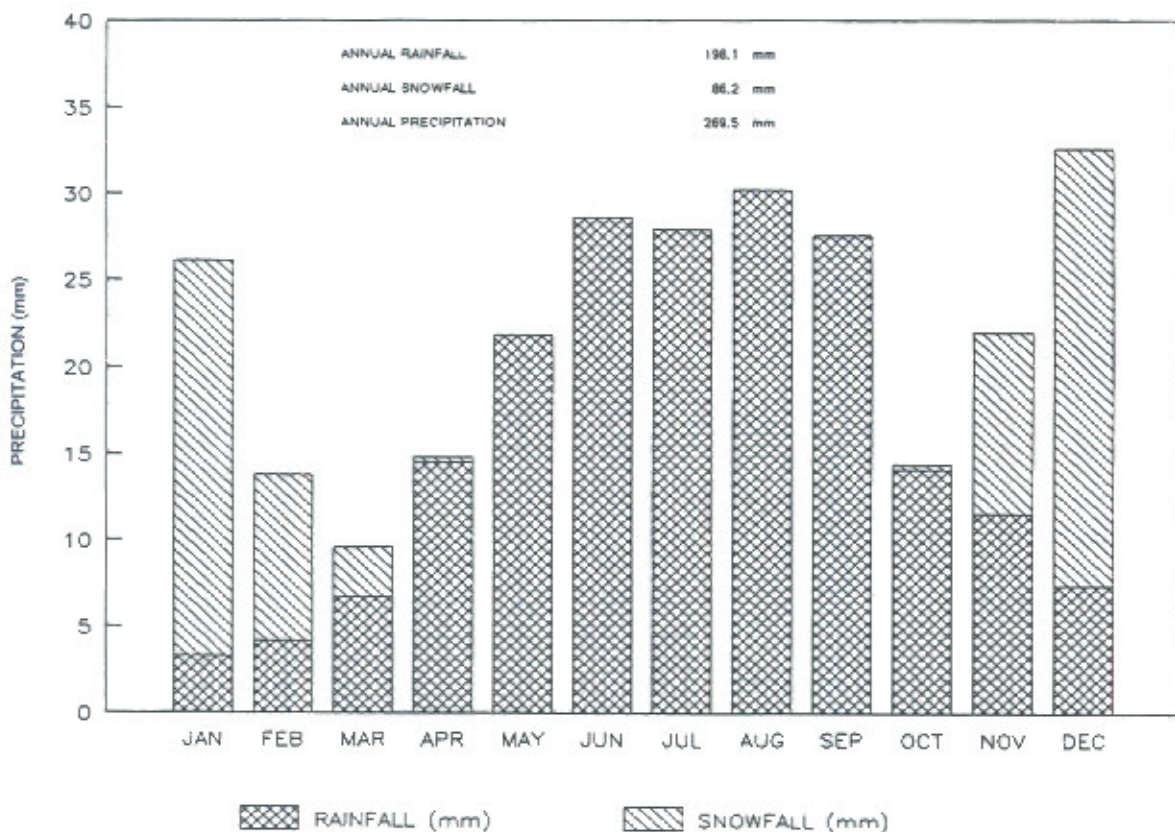
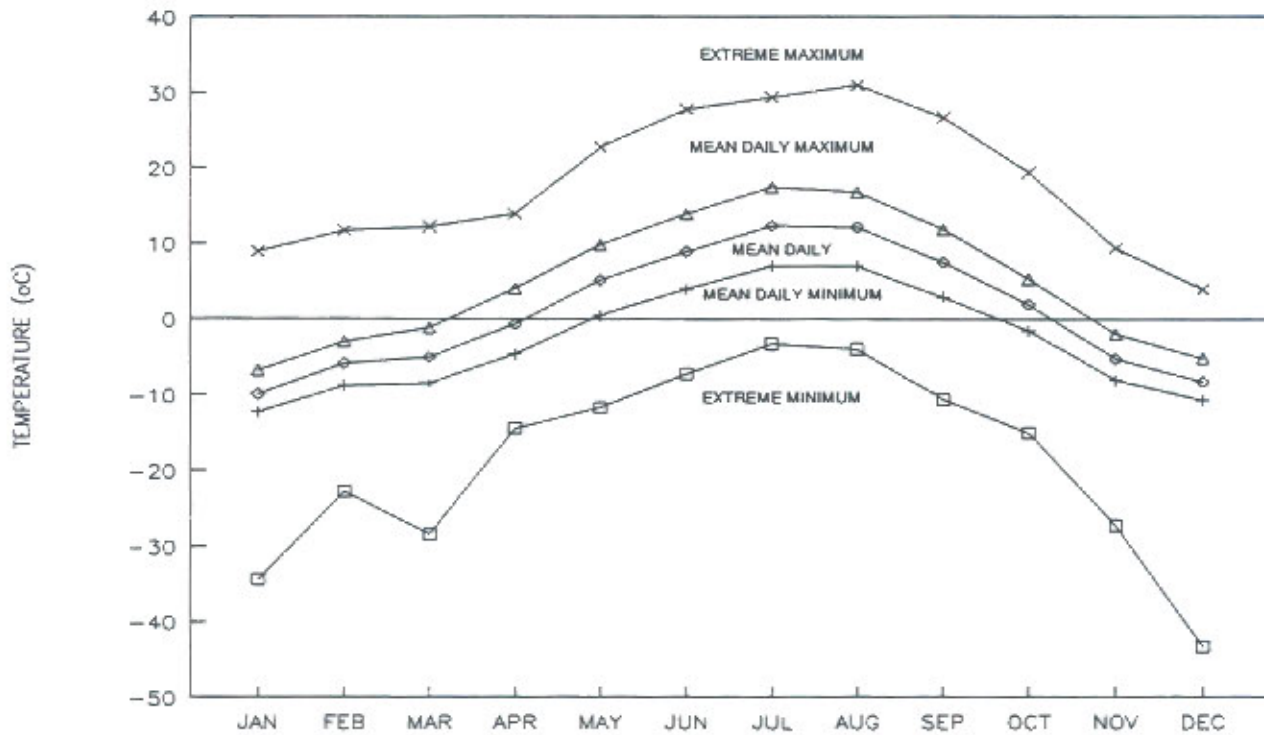


Figure 2.3.2: Seasonal variation in temperature and precipitation normals, Kamloops A, 1951-1993

MT LOLO, KAMLOOPS, 1951-80



MT. LOLO, KAMLOOPS, 1951-80

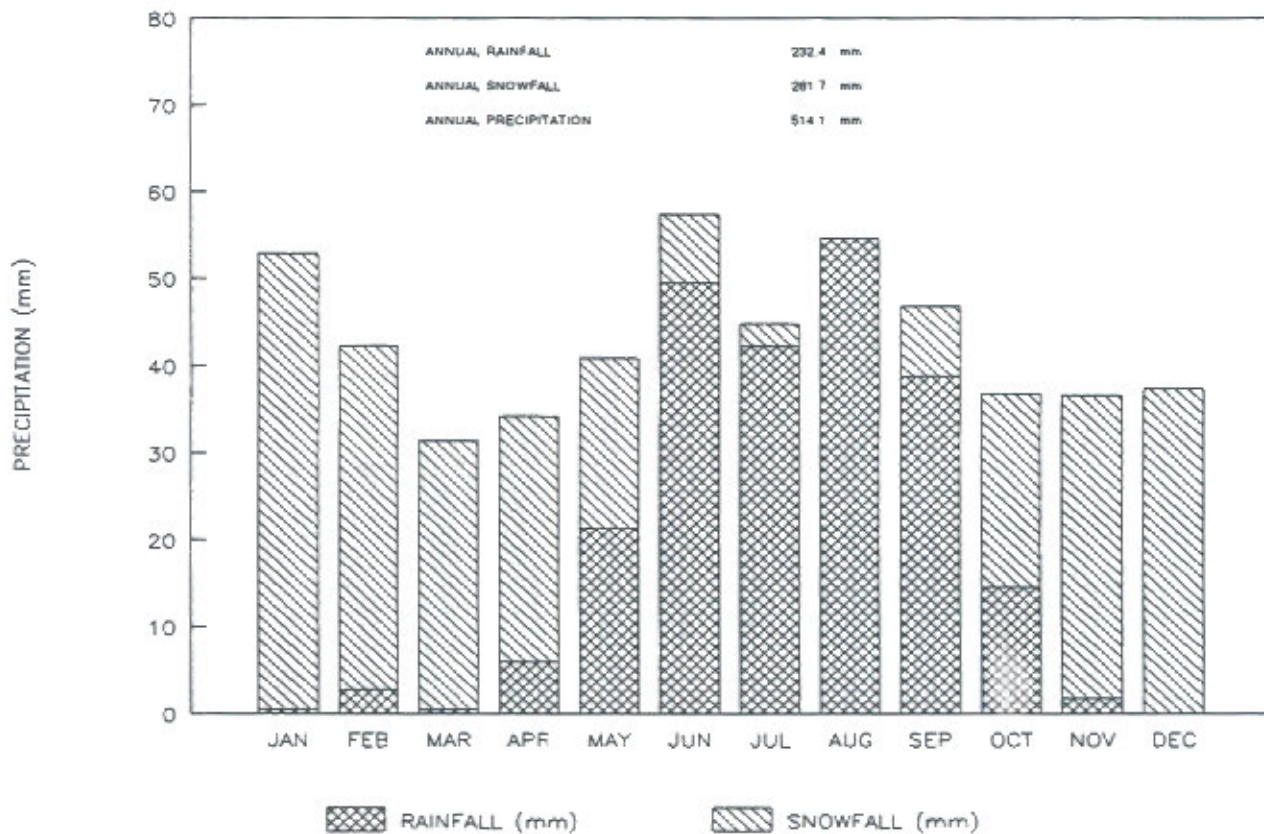
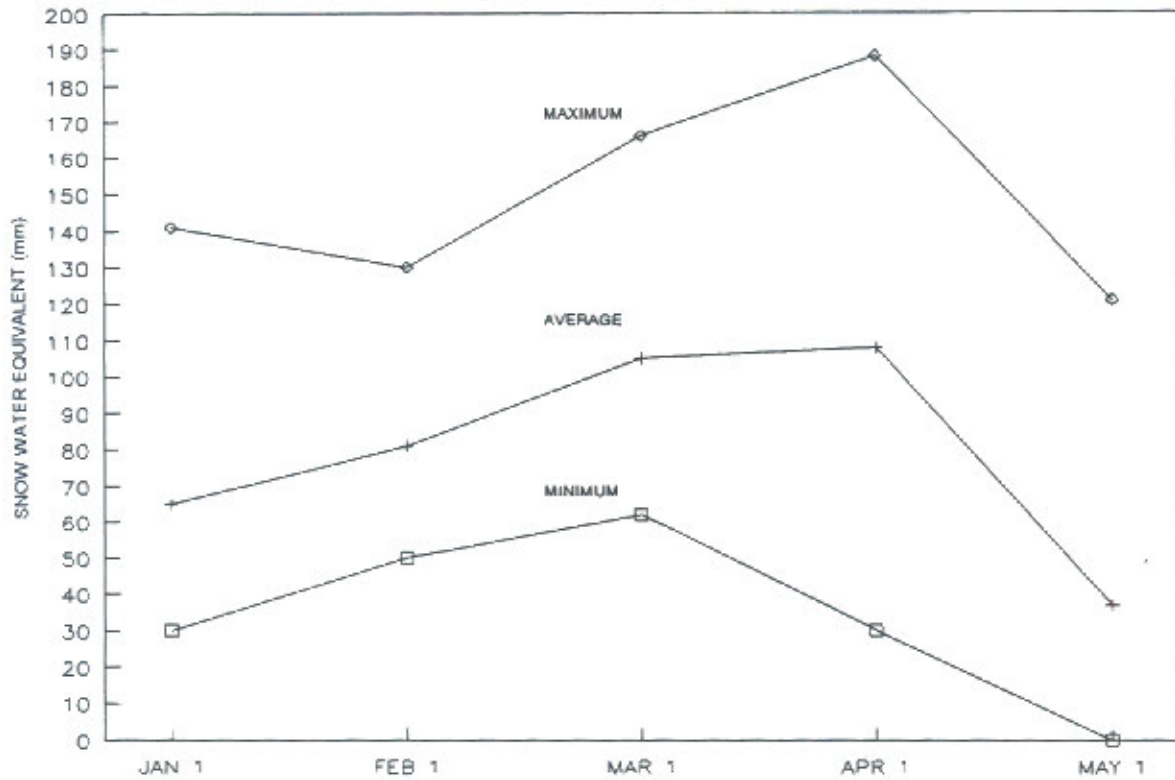


Figure 2.3.3: Seasonal variation in temperature and precipitation normals, Mt. Lolo Kamloops - 1951-1977

DEADMAN RIVER, 1984-1993

ELEVATION 1,430 m



TRANQUILLE LAKE, 1950-1993

ELEVATION 1,420 m

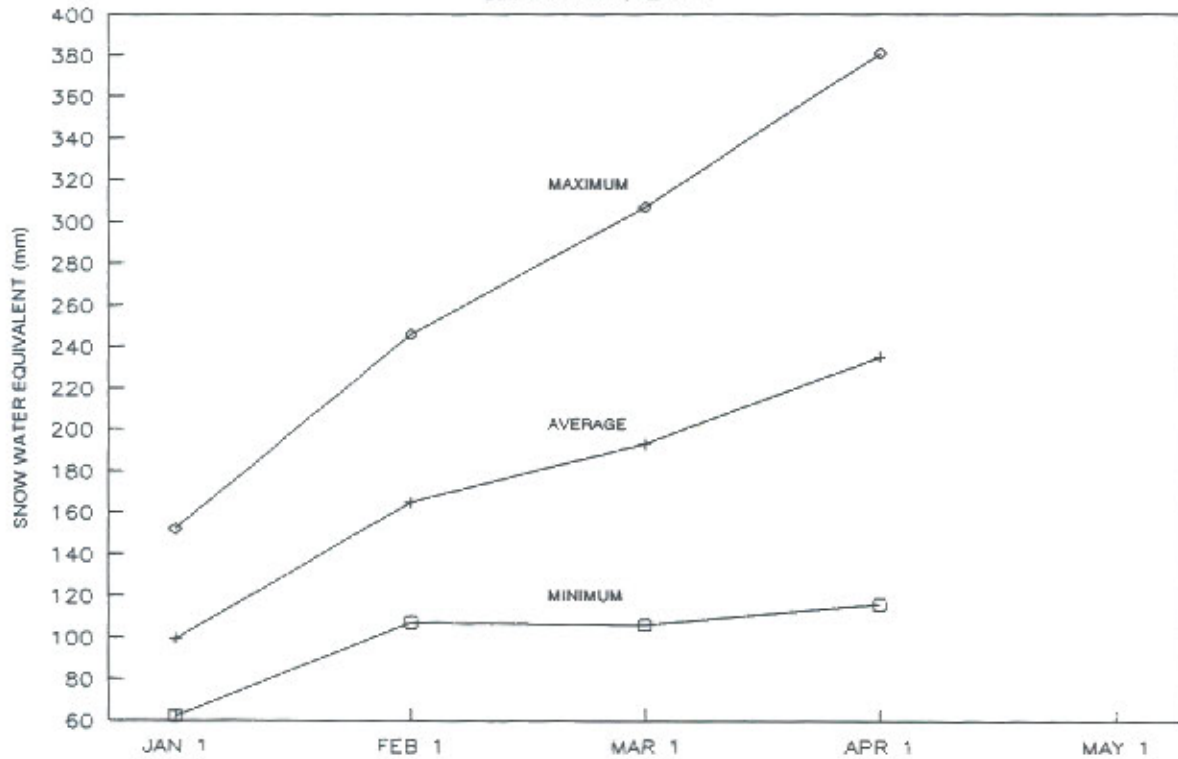
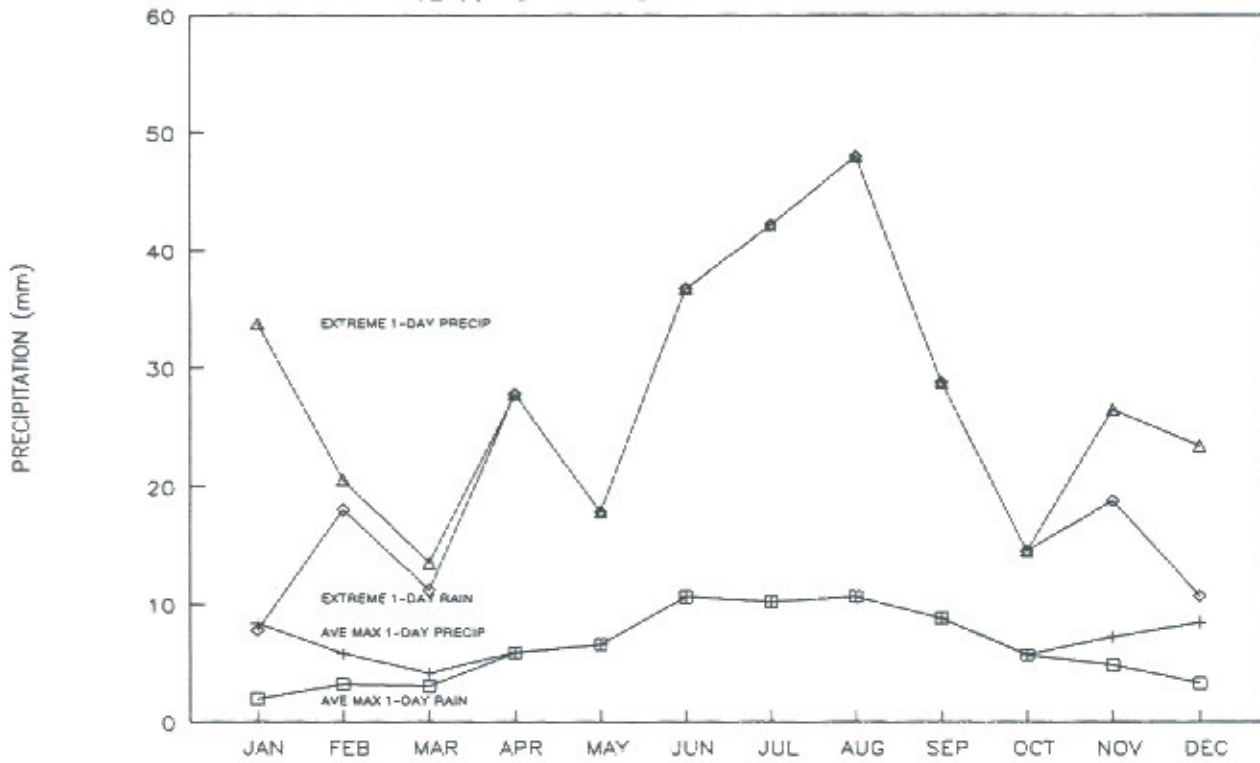


Figure 2.3.4: Seasonal variation in snow cover

KAMLOOPS A, 1951-1993

SEASONAL VAR. IN 24-HOUR RAIN & PRECIP.



MT LOLO KAMLOOPS, 1964-1977

SEASONAL VAR. IN 24-HOUR RAIN & PRECIP.

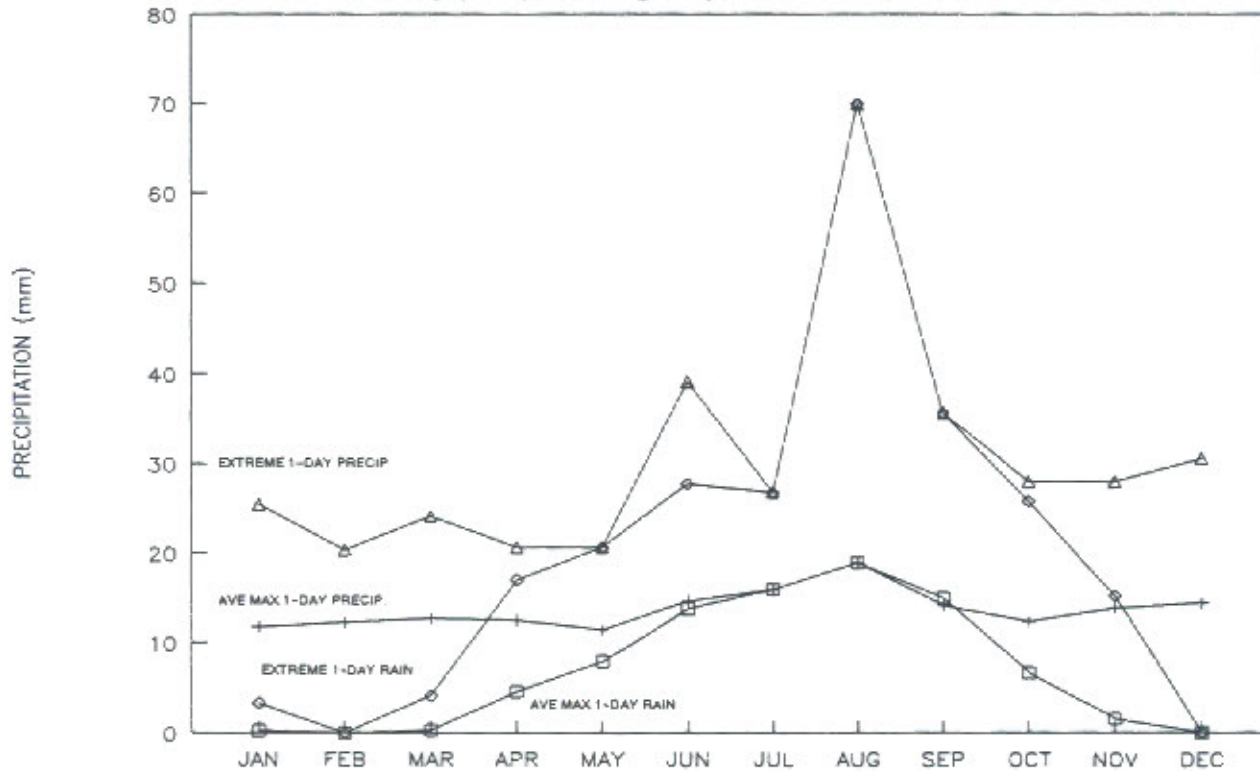


Figure 2.3.5: Seasonal variation in maximum and average 24-hour rainfall and precipitation at Kamloops A and Mt Lolo Kamloops

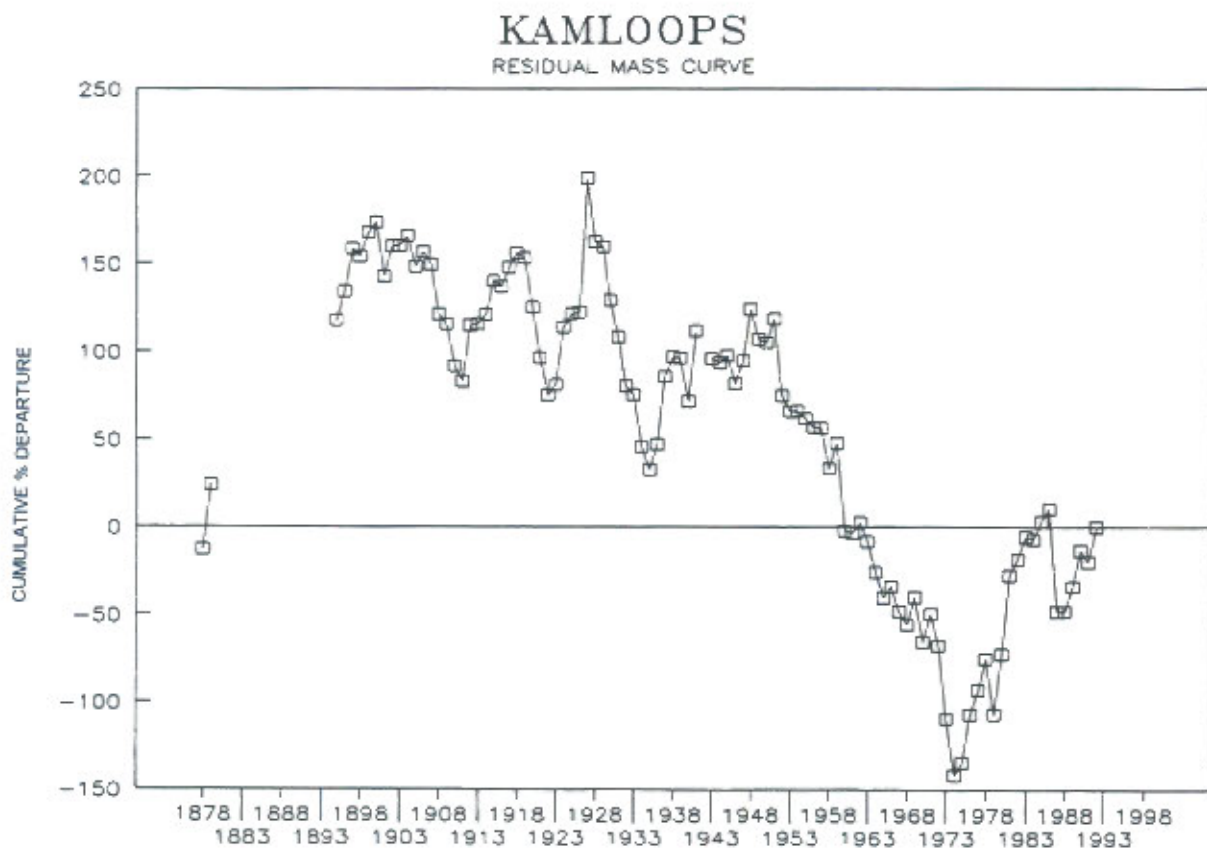
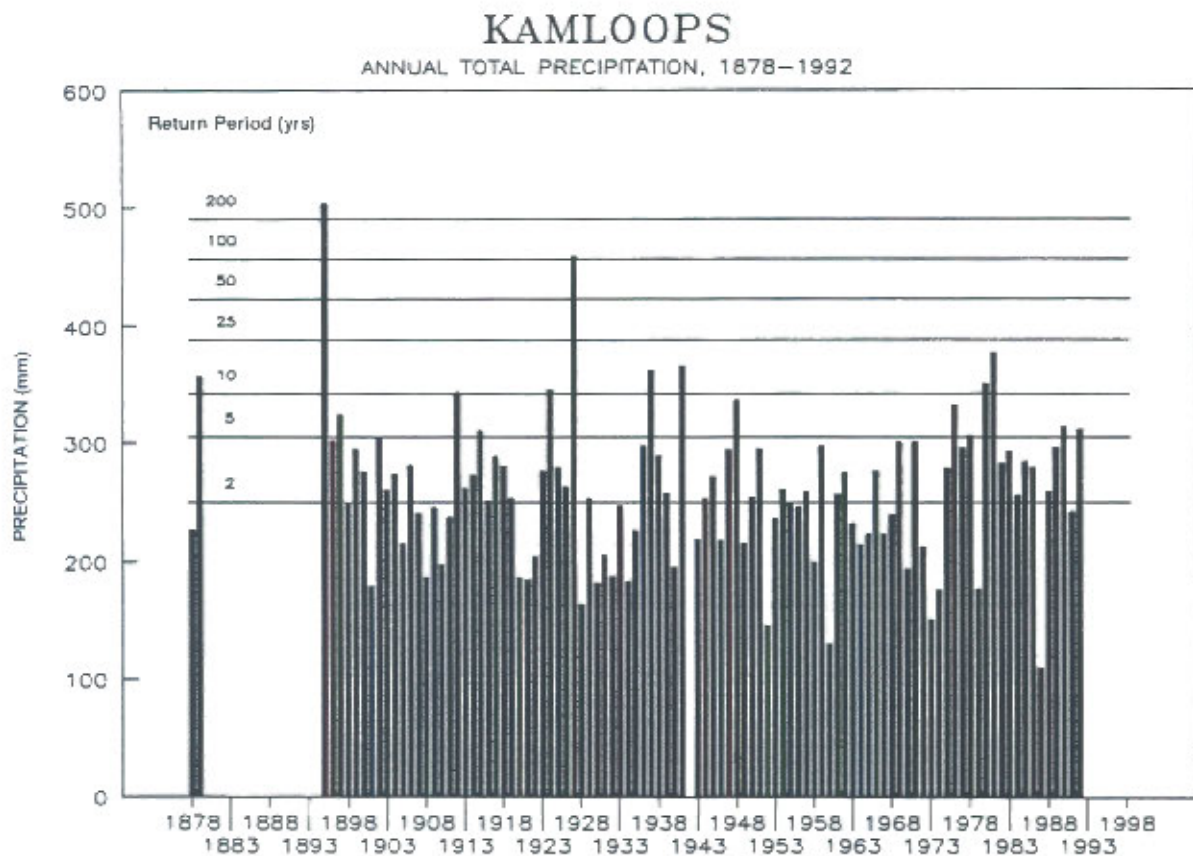


Figure 2.3.6: Historical variation in annual precipitation (synthesized data) at Kamloops, 1878-1992

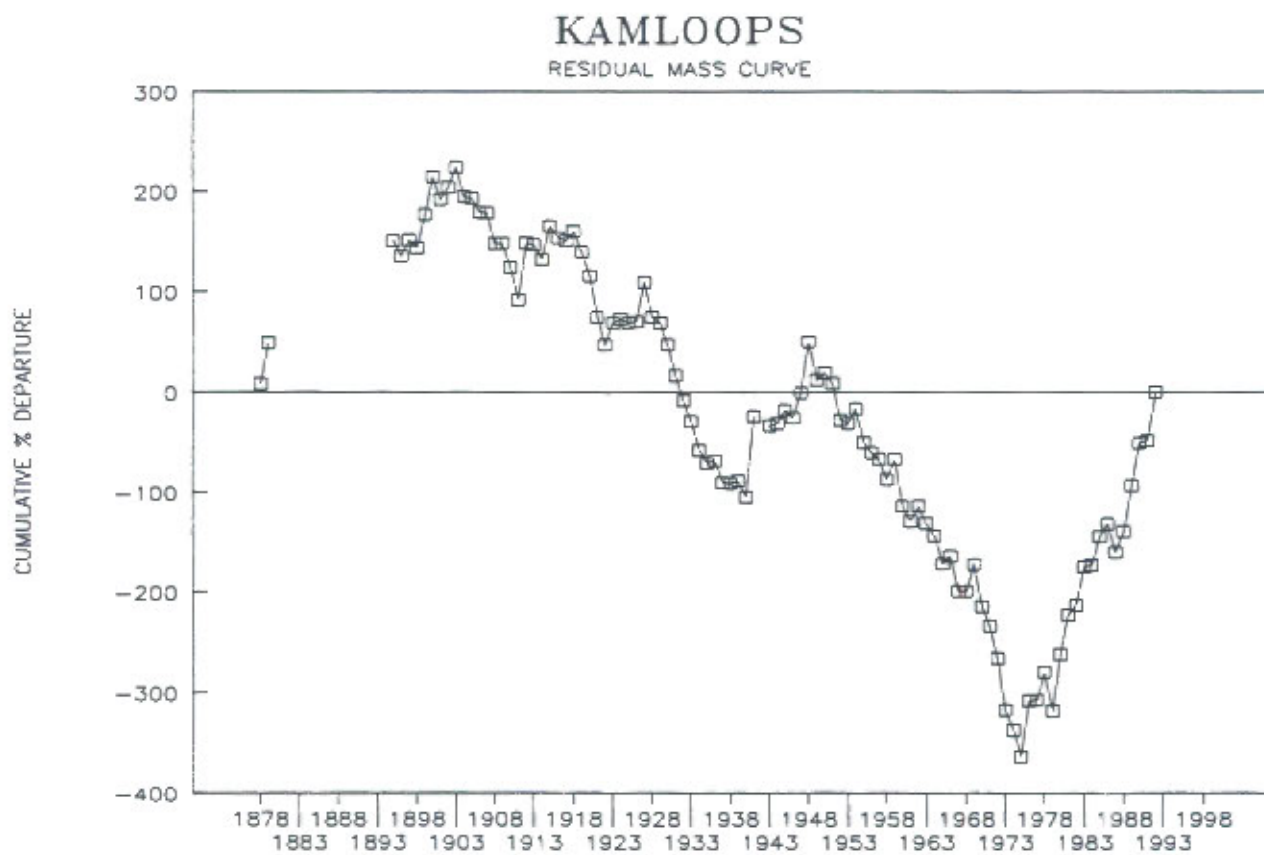
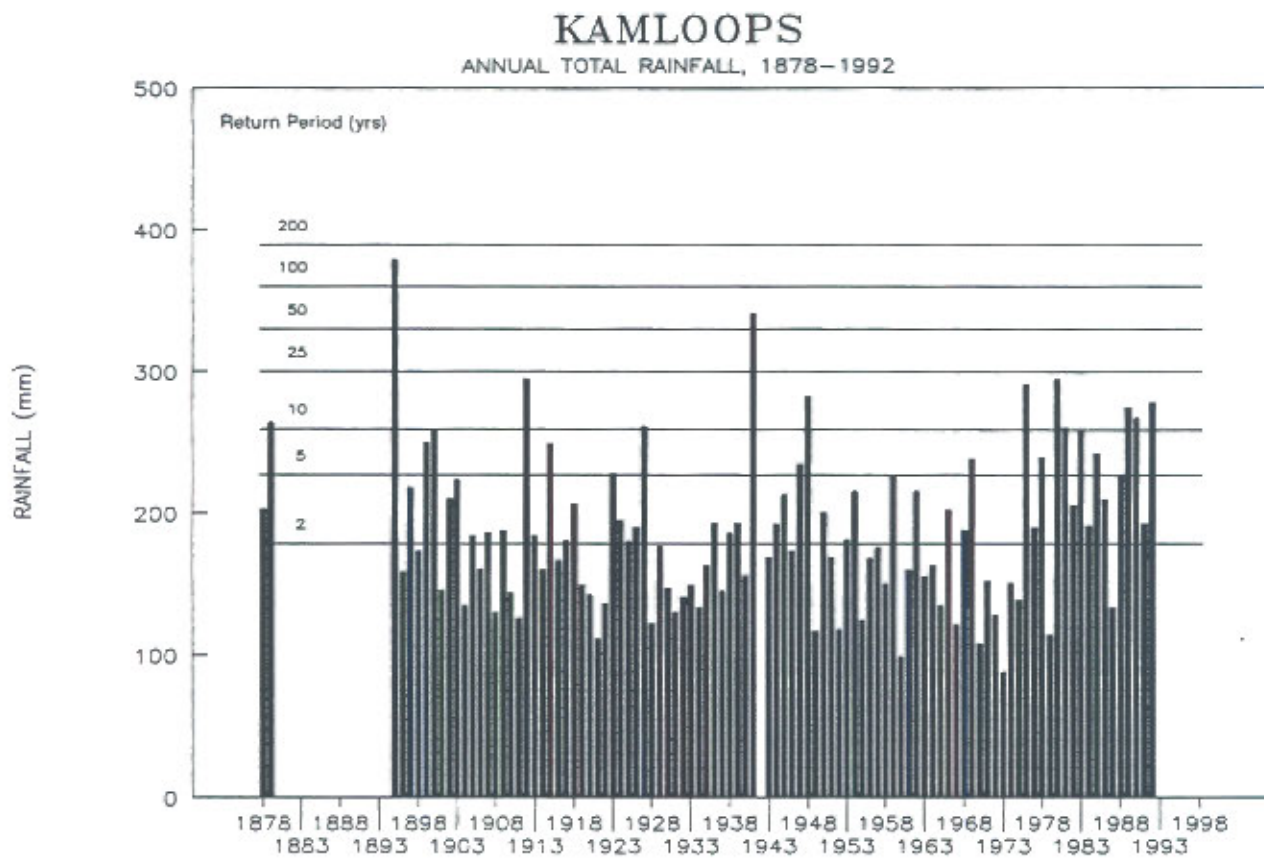
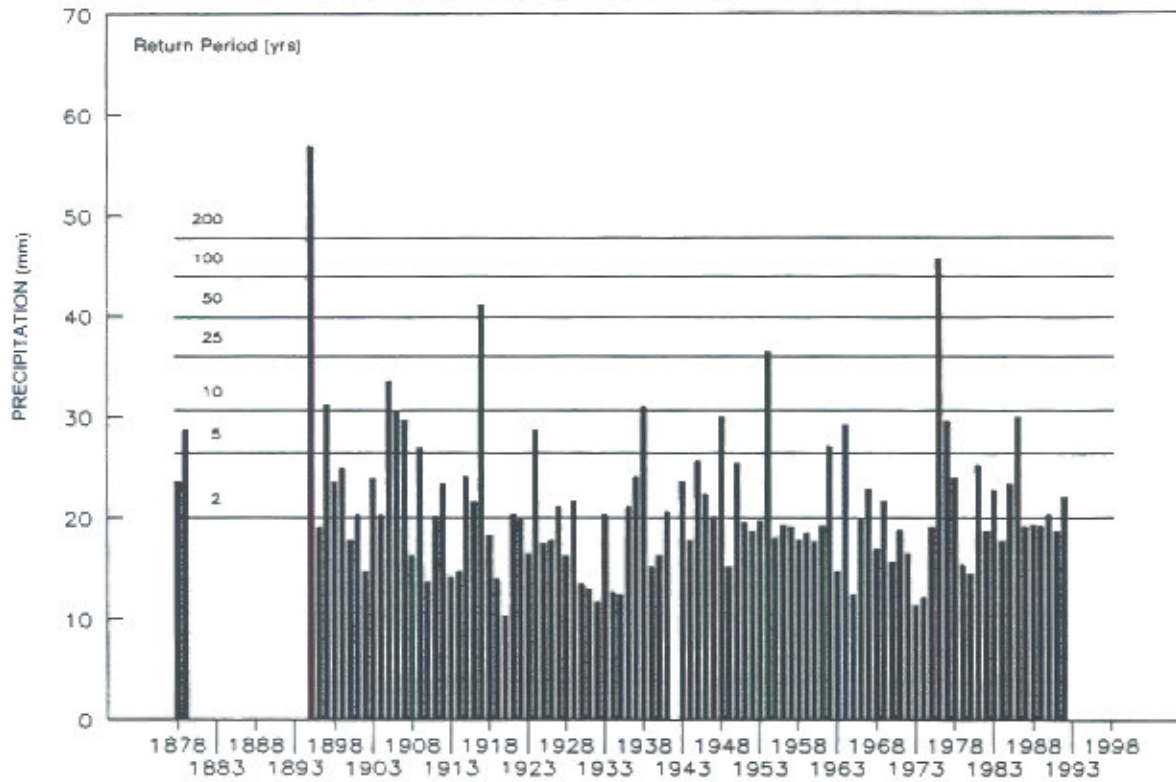


Figure 2.3.7: Historical variation in annual rainfall (synthesized data) at Kamloops, 1878-1992

KAMLOOPS, 1878-1992

ANNUAL MAXIMUM 24-HOUR PRECIPITATION



KAMLOOPS 1878-1992

RESIDUAL MASS CURVE

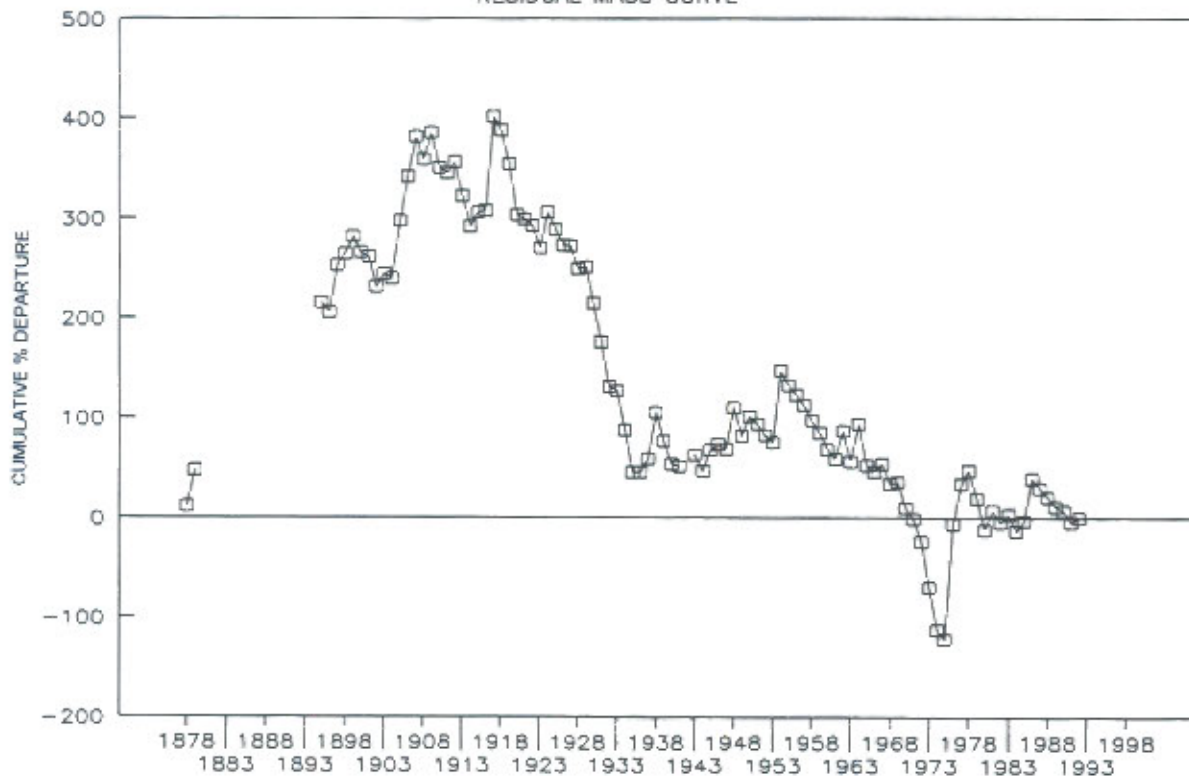
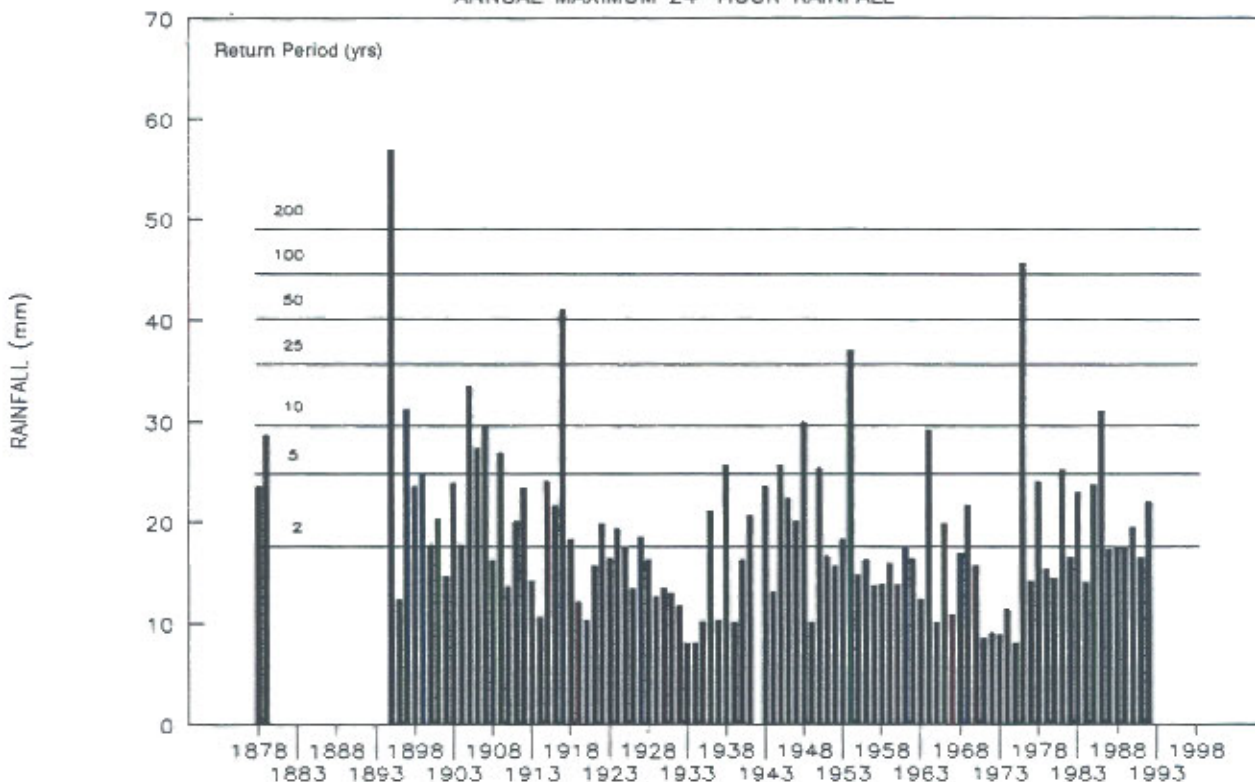


Figure 2.3.8: Historical variation in annual maximum 24-hour precipitation (synthesized data) at Kamloops, 1878-1992

KAMLOOPS, 1878-1992

ANNUAL MAXIMUM 24-HOUR RAINFALL



KAMLOOPS, 1878-1992

RESIDUAL MASS CURVE

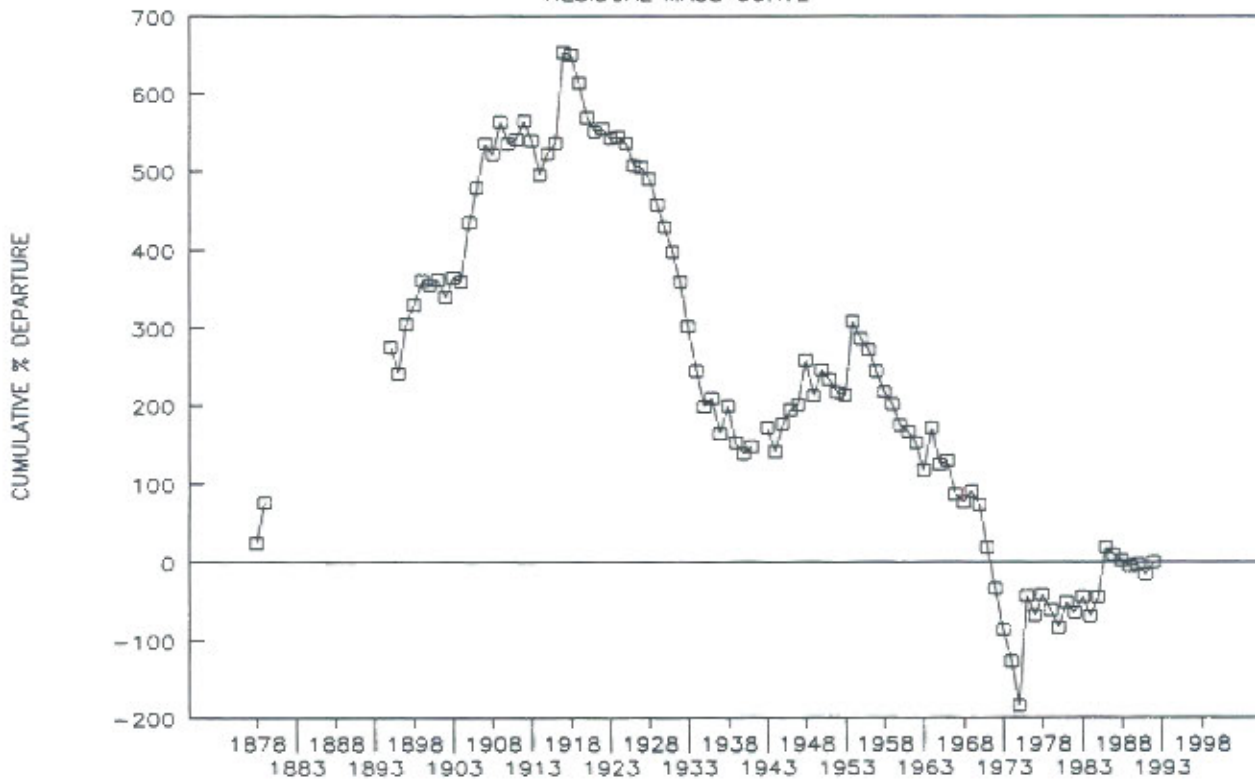


Figure 2.3.9: Historical variation in annual maximum 24-hour rainfall (synthesized data) at Kamloops, 1878-1992

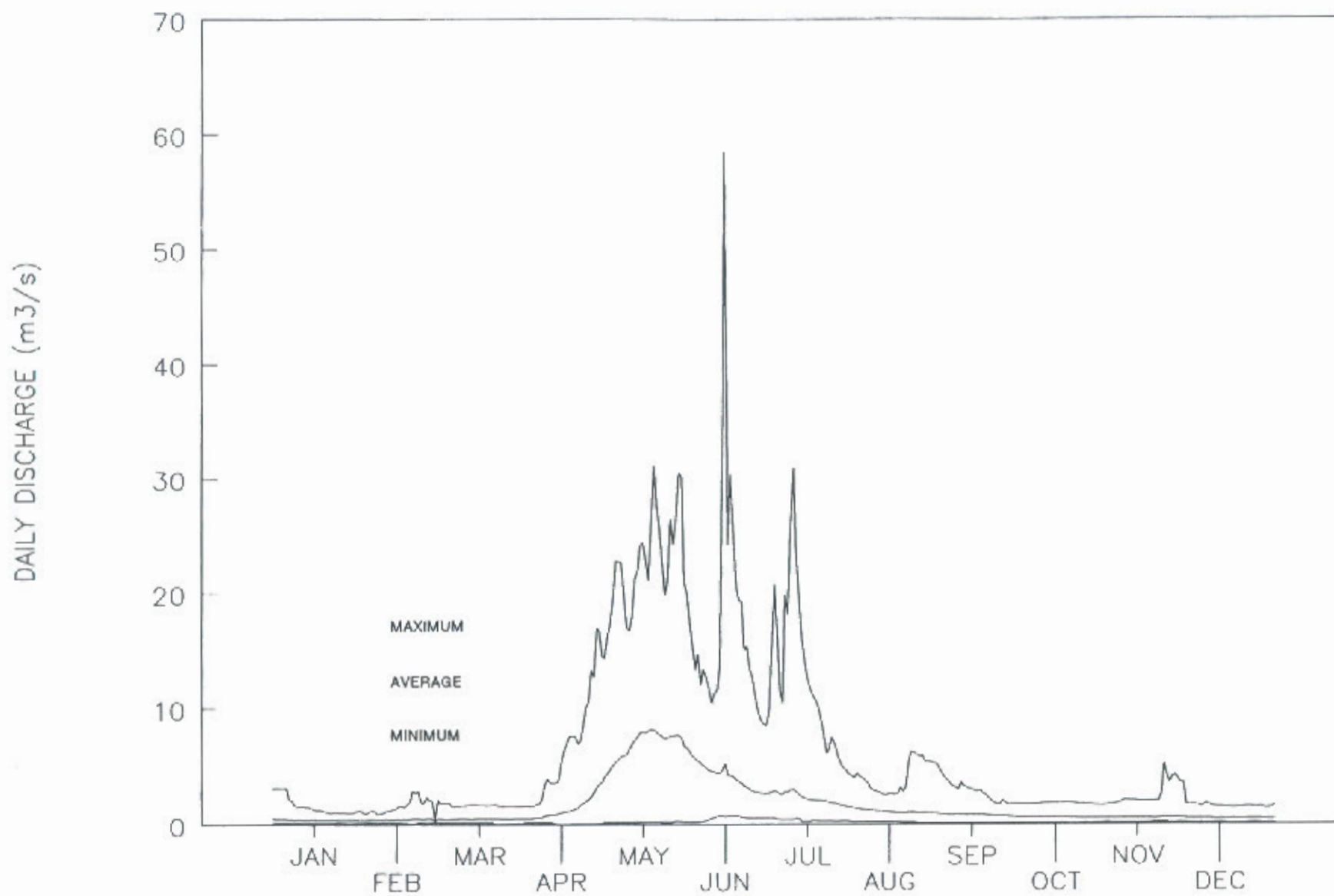
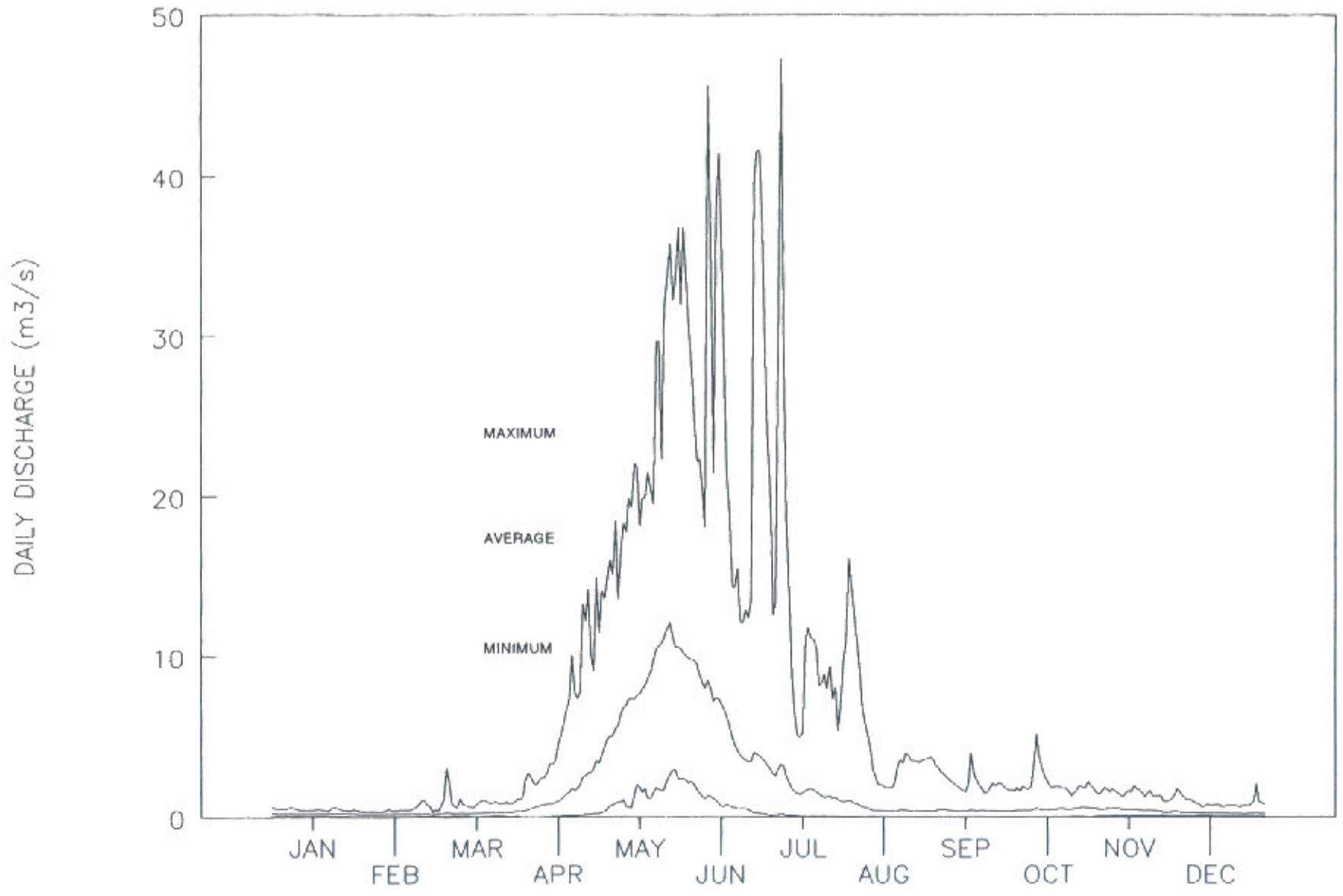


Figure 2.4.1: Seasonal variation in flow, Deadman above Criss Creek, 1913-93

Figure 2.4.2: Seasonal variation in flow, Criss Creek near Savona, 1912-1992



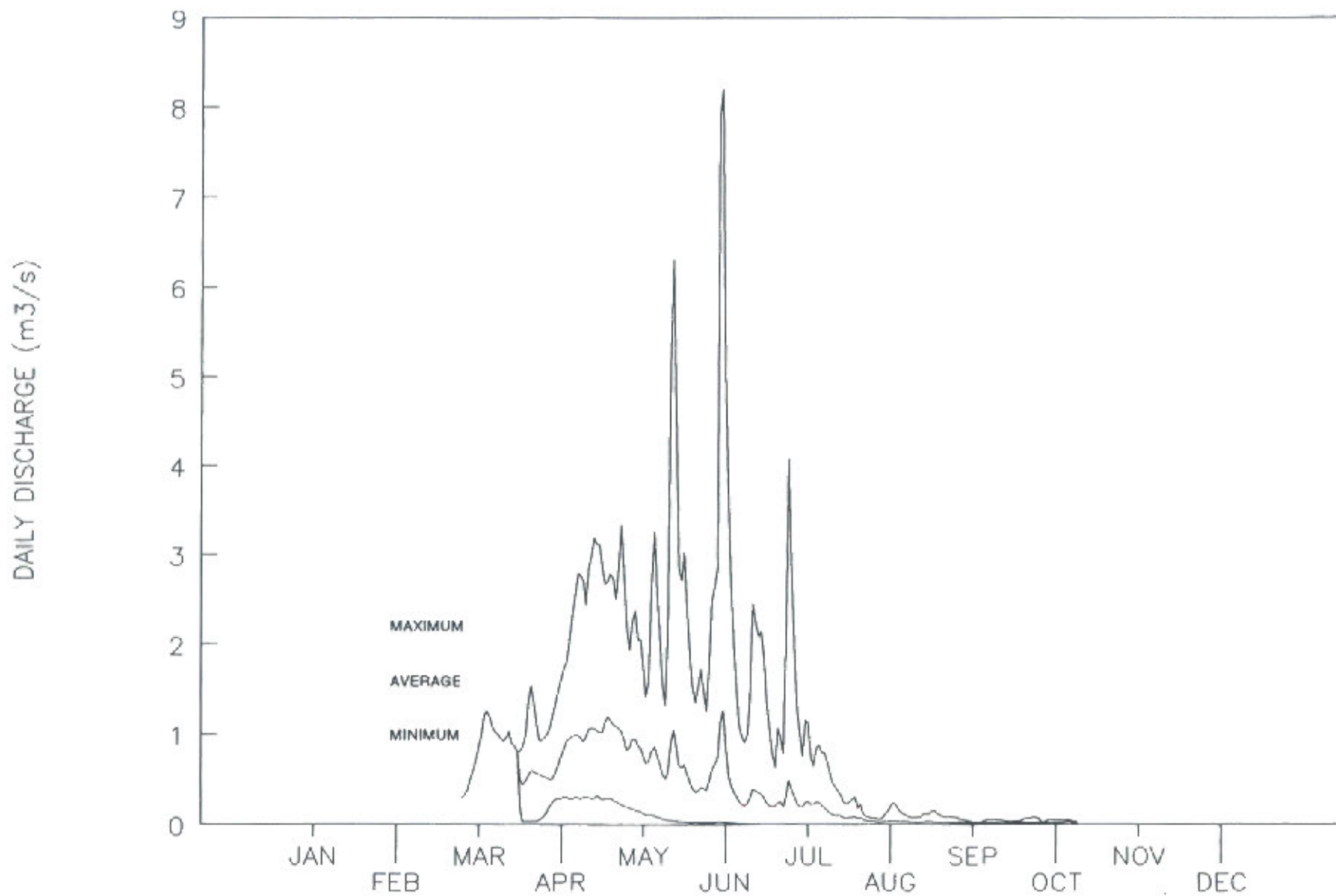
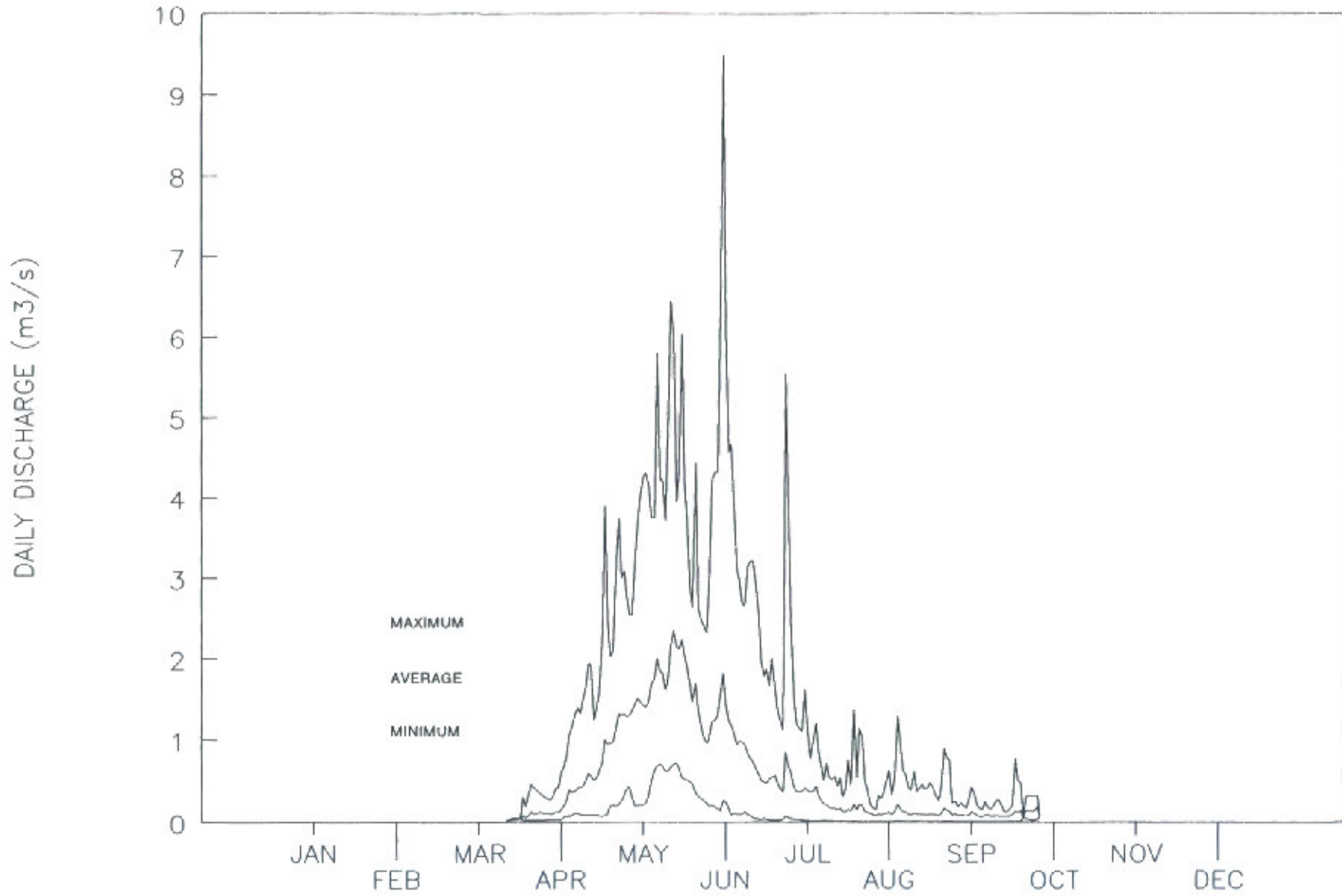


Figure 2.4.3: Seasonal variation in flow, Joe Ross Creek near the mouth, 1984-93

Figure 2.4.4: Seasonal variation in flow, Heller Creek above diversions, 1982-93



DEADMAN RIVER ABOVE CRISS CREEK

ANNUAL MAXIMUM DAILY DISCHARGE, 1912-93

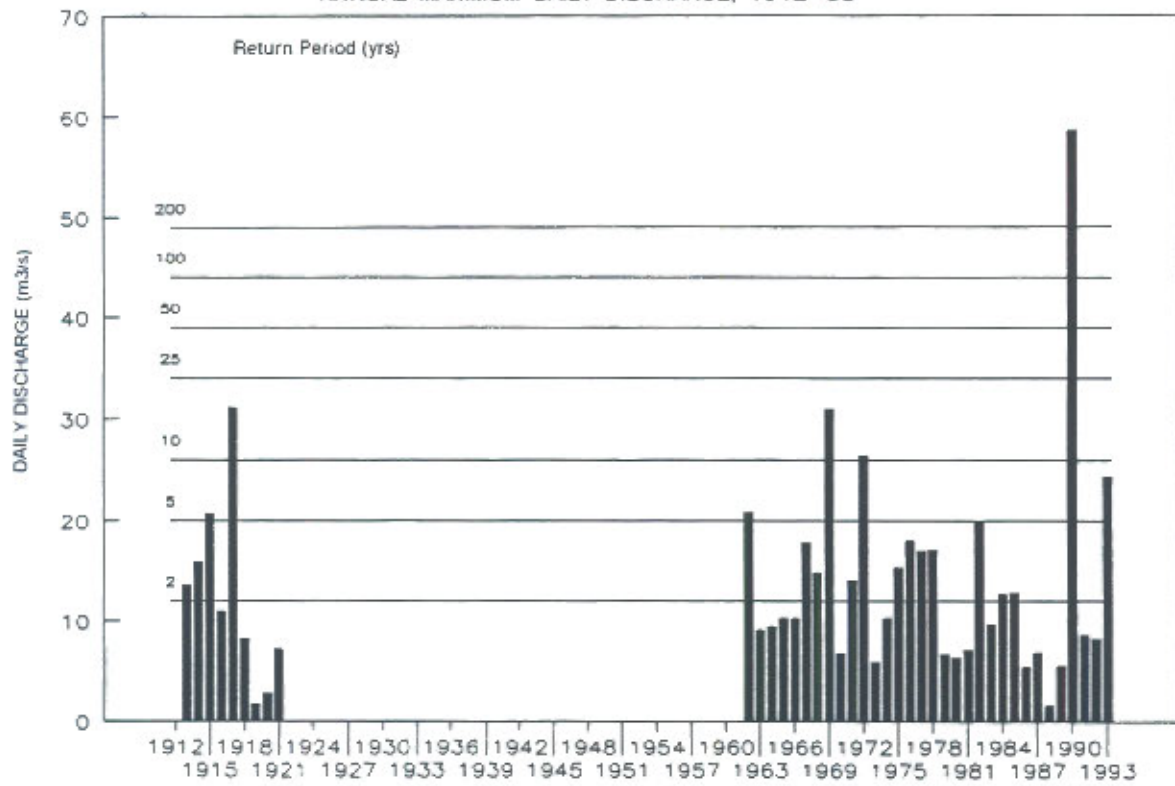


Figure 2.4.5: Historical variation in annual maximum daily discharge, Deadman River above Criss Creek

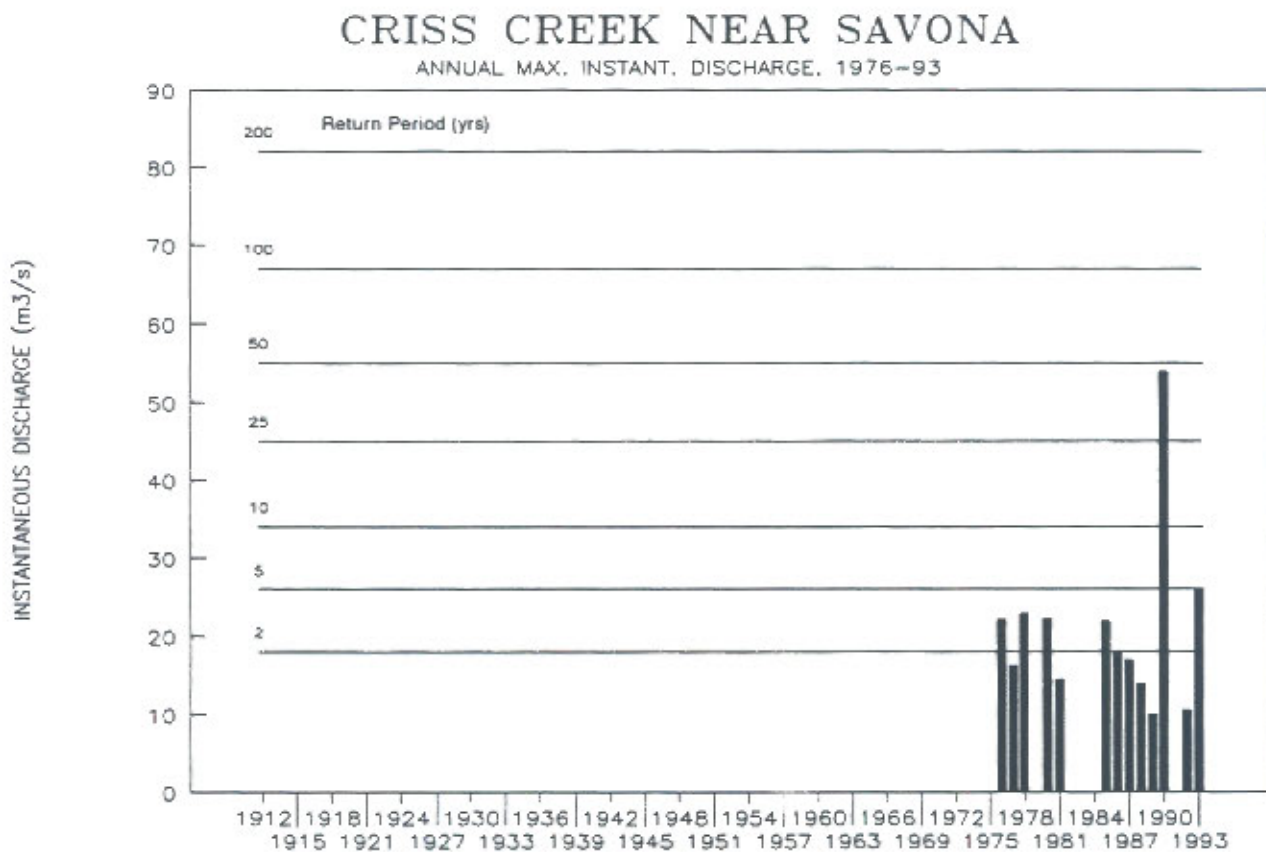
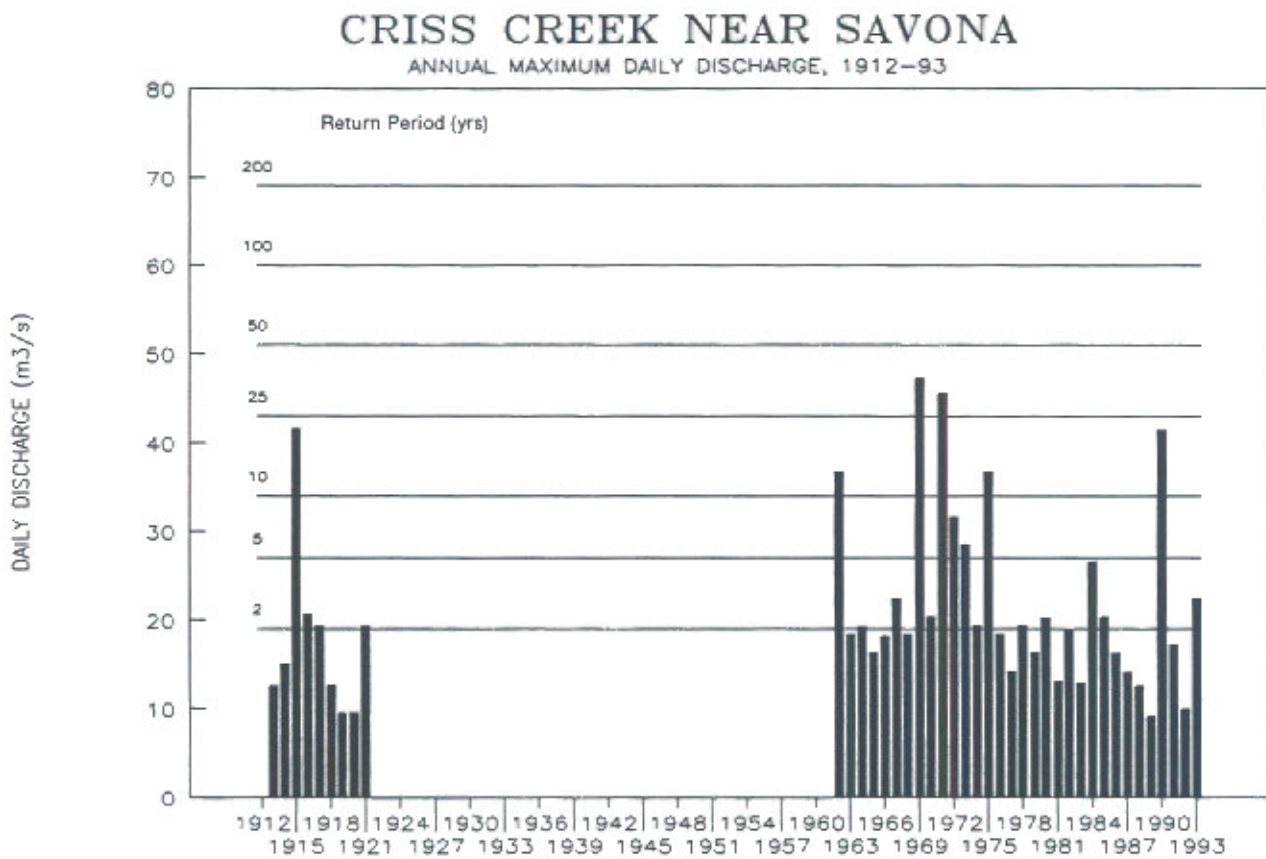


Figure 2.4.6: Historical variation in annual maximum daily and instantaneous discharge, Criss Creek near Savona

HELLER CREEK ABOVE DIVERSIONS

ANNUAL MAXIMUM DAILY DISCHARGE, 1983-93

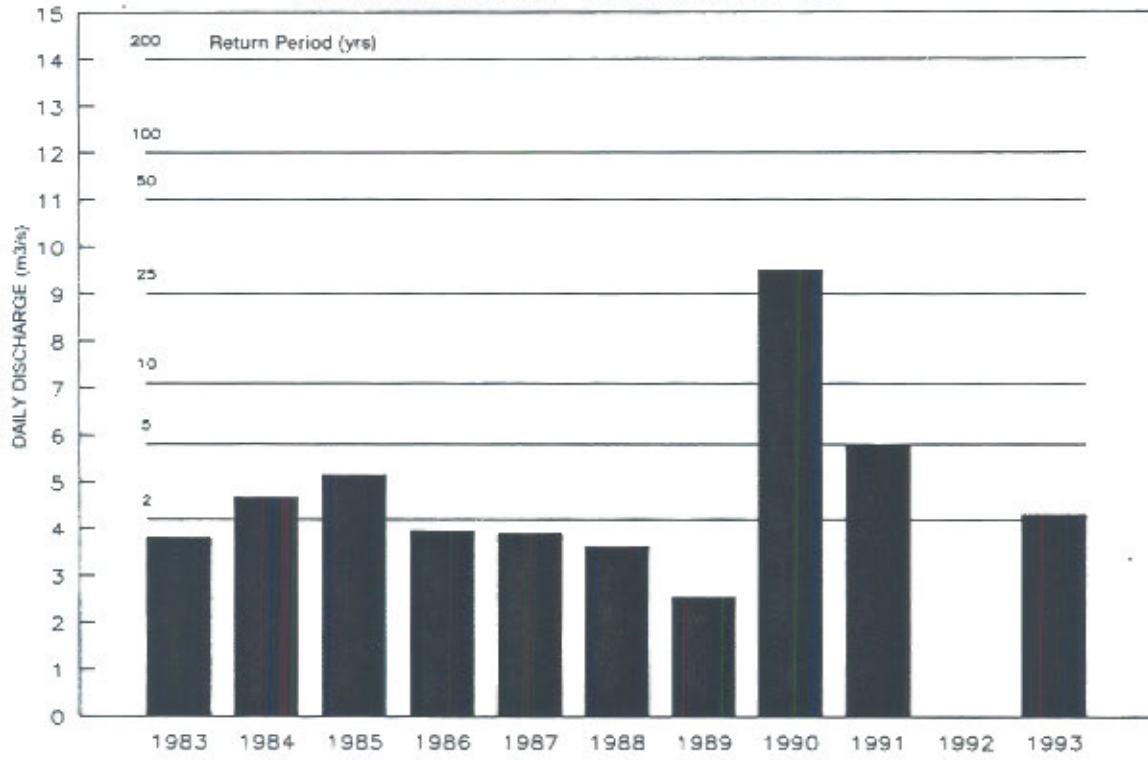
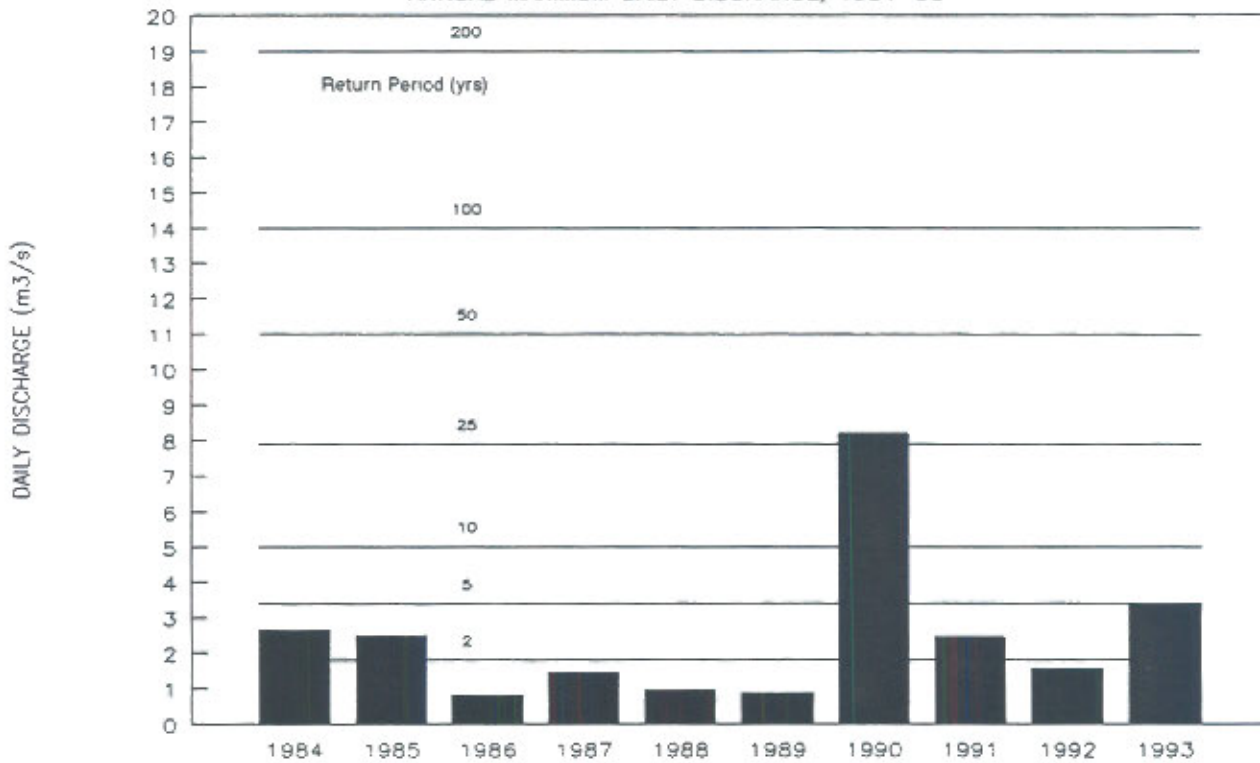


Figure 2.4.7: Historical variation in annual maximum daily discharge, Heller Creek above diversions

JOE ROSS CREEK NEAR THE MOUTH

ANNUAL MAXIMUM DAILY DISCHARGE, 1984-93



JOE ROSS CREEK NEAR THE MOUTH

ANNUAL MAX. INSTANT. DISCHARGE, 1984-93

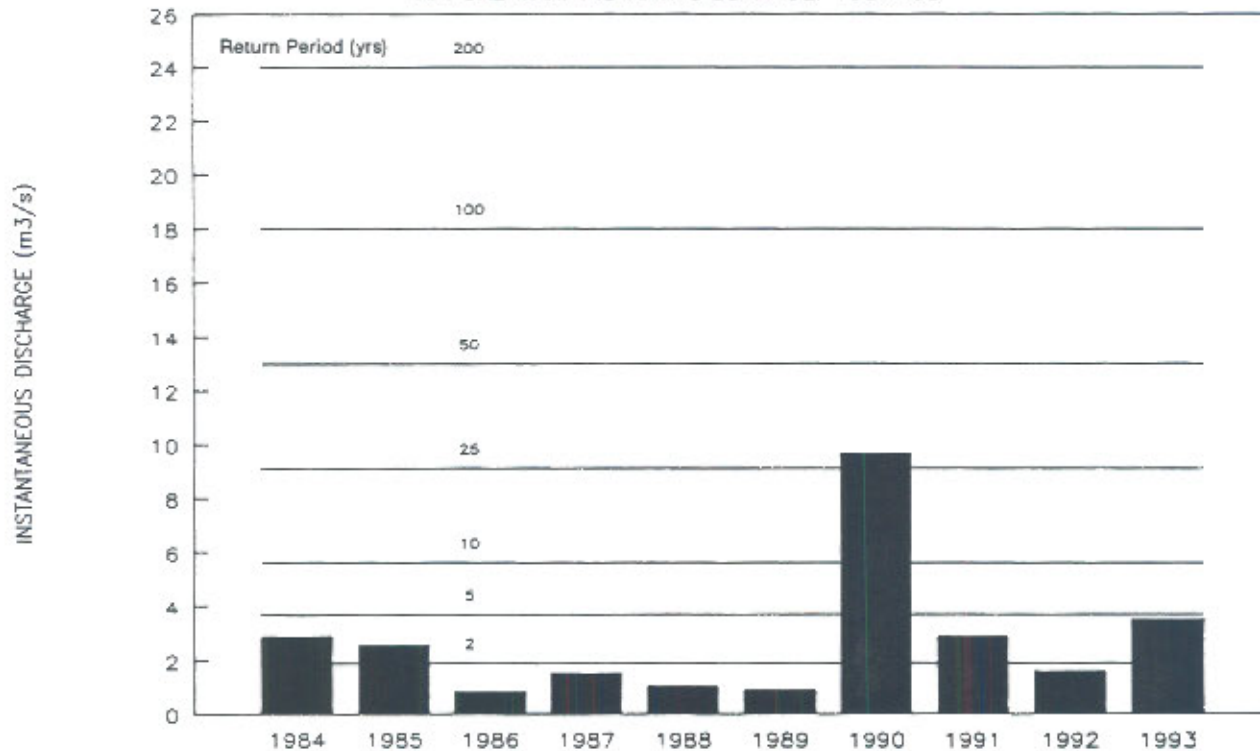
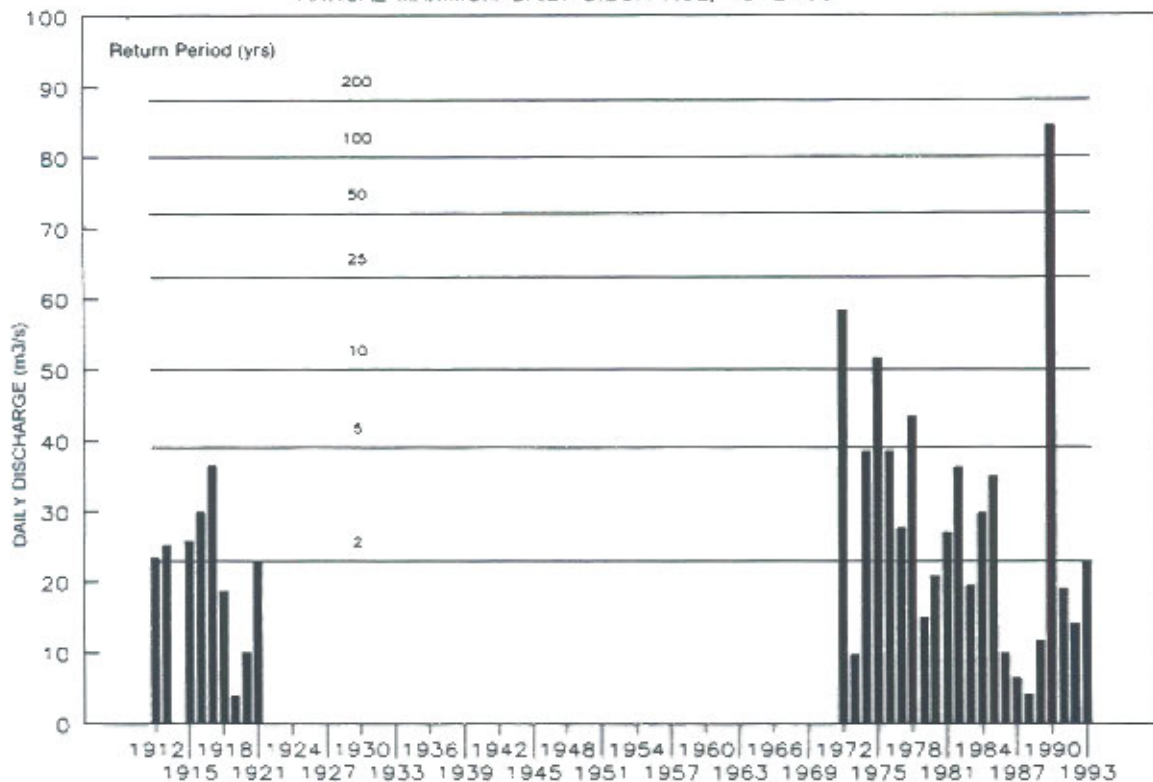


Figure 2.4.8: Historical variation in annual maximum daily and instantaneous discharge, Joe Ross Creek near the mouth

BONAPARTE RIVER BELOW CACHE CREEK

ANNUAL MAXIMUM DAILY DISCHARGE, 1912-93



BONAPARTE RIVER BELOW CACHE CREEK

ANNUAL MAX. INSTANT. DISCHARGE, 1976-93

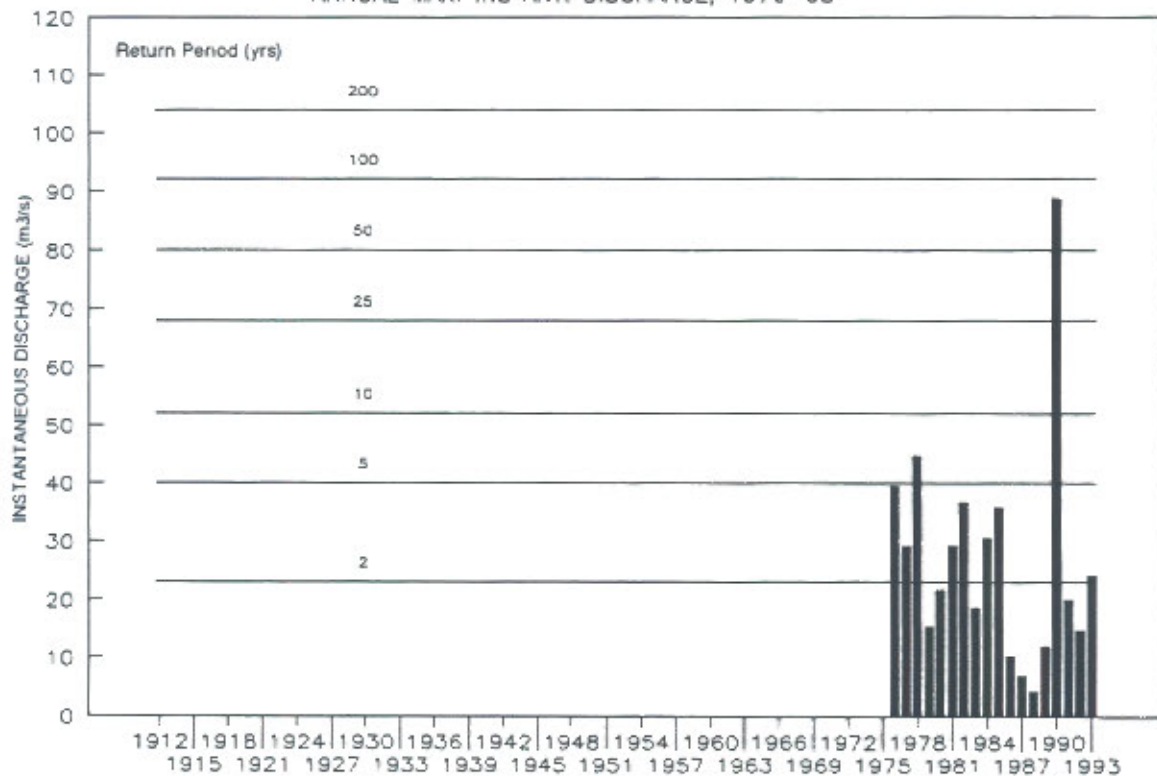
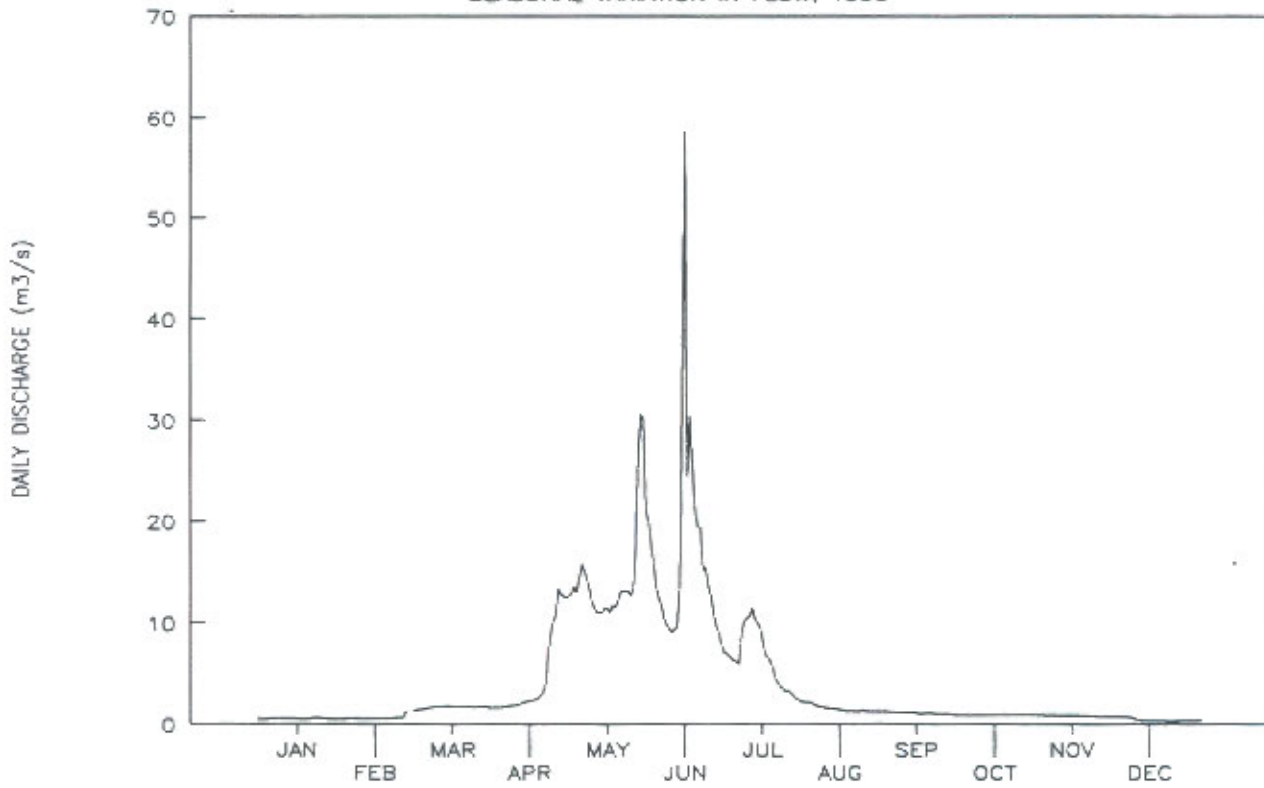


Figure 2.4.9: Historical variation in annual maximum daily and instantaneous discharge, Bonaparte River below Cache Creek

DEADMAN RIVER ABOVE CRISS CREEK

SEASONAL VARIATION IN FLOW, 1990



CRISS CREEK NEAR SAVONA

SEASONAL VARIATION IN FLOW 1990

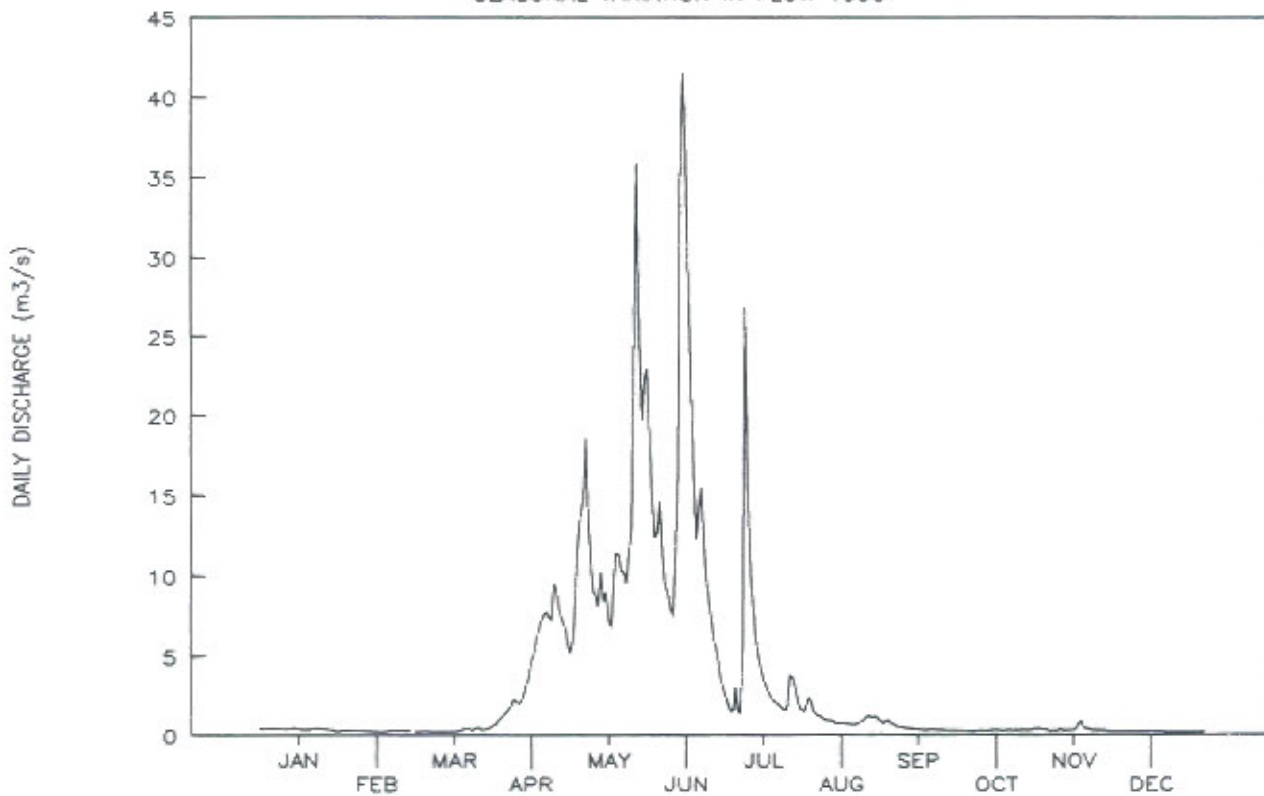


Figure 2.4.10: Seasonal variation in flow, Deadman River above Criss Creek and Criss Creek near Savona during 1990

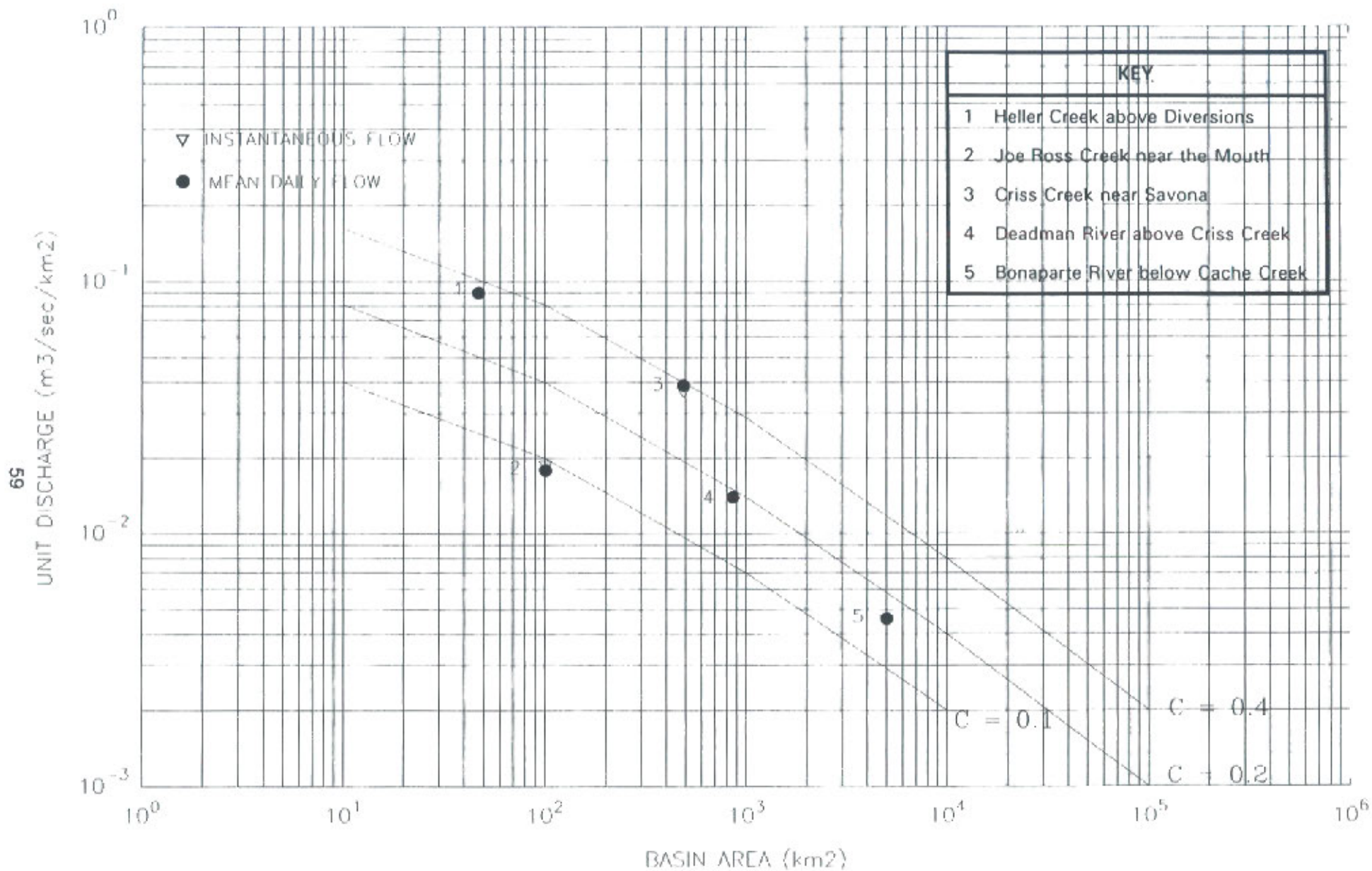
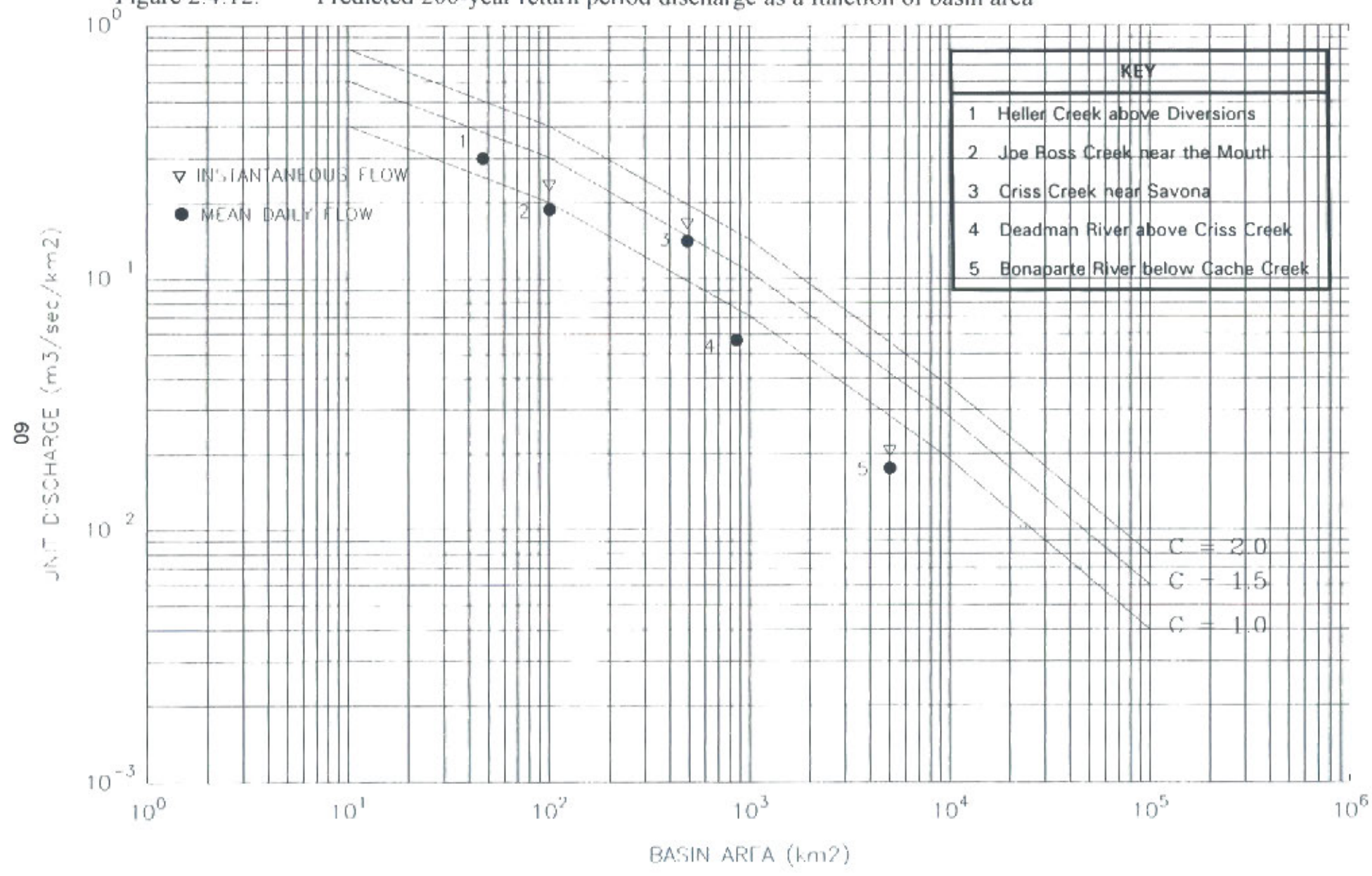


Figure 2.4.11: Predicted 2-year return period discharge as a function of basin area

Figure 2.4.12: Predicted 200-year return period discharge as a function of basin area



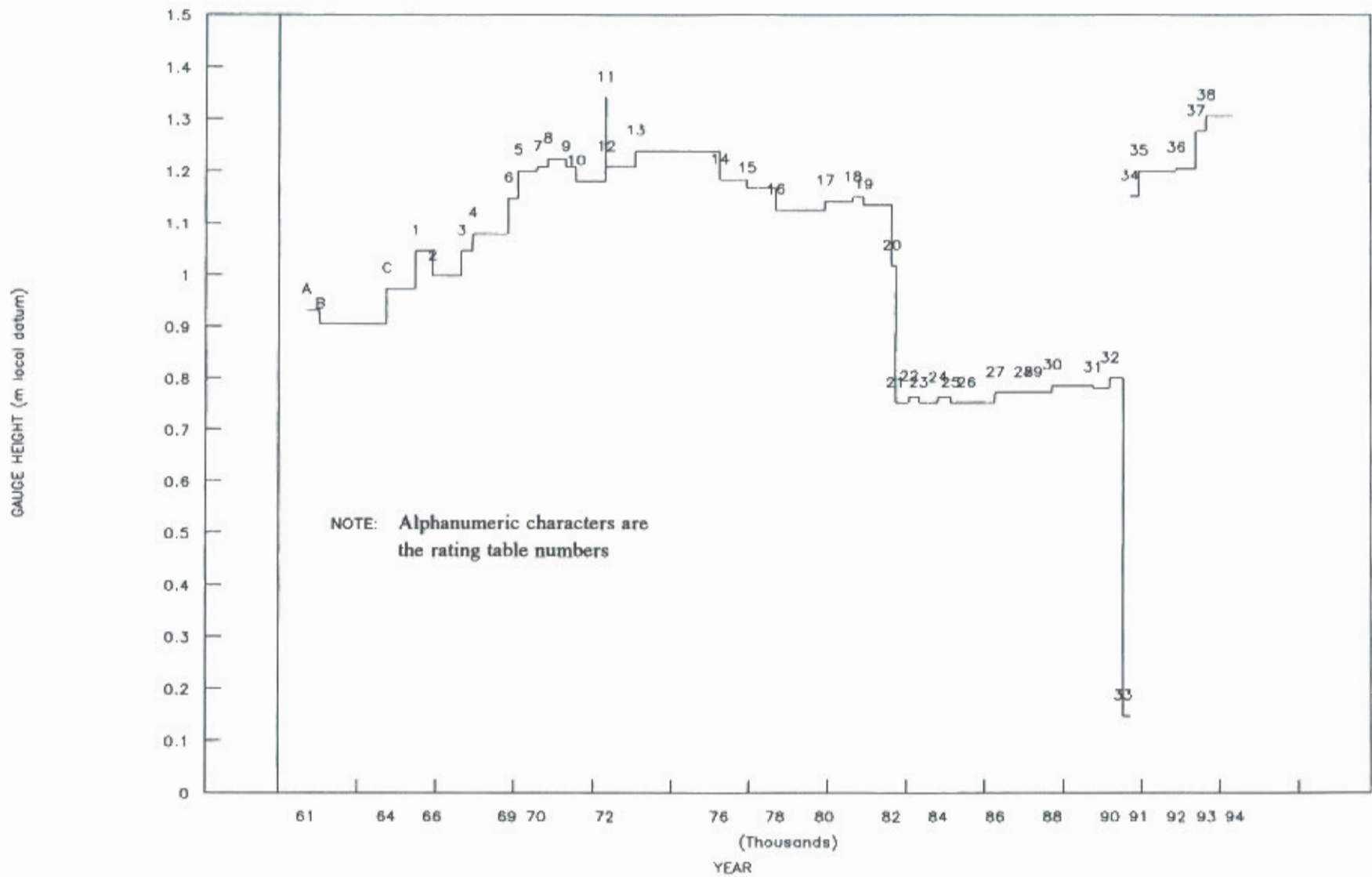
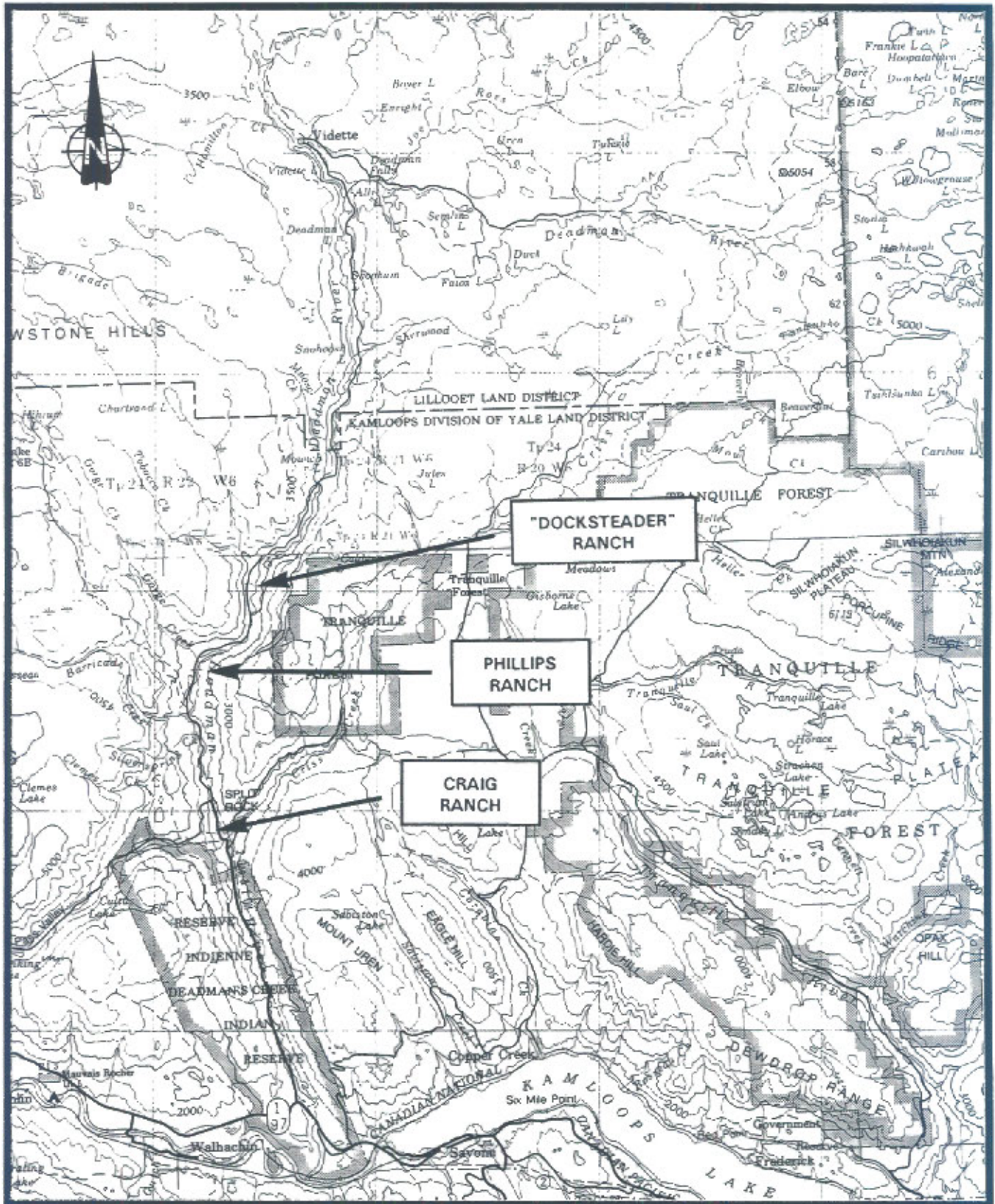


Figure 2.7.1: Specific gauge plot for Deadman Creek above Criss Creek showing the historical variation in the gauge elevation for a discharge of 1.65 m³/s.



From: 1:250,000 scale mapping

Figure 3.1.1: Location of air photo study sites.



3.1.2a

September 13, 1948

BC 646 #23

Discharge: not available



3.1.2b

June 26, 1986

BC 86034 #155 & 310

Deadman River above Criss Creek

Discharge: 0.928 m³/s



3.1.2c

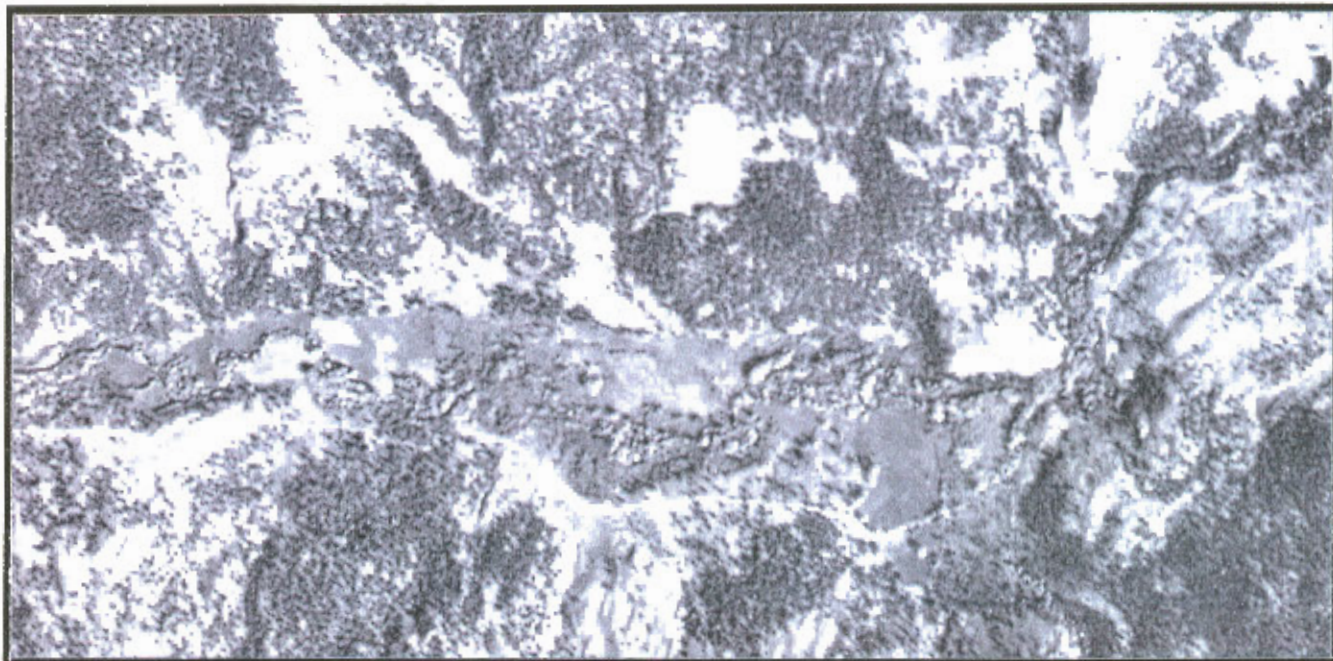
May 24, 1992

BCC 92002 #55 & 99

Deadman River above Criss Creek

Discharge: 3.12 m³/s

Figure 3.1.2: Historical changes in channel morphology, Craig Ranch.

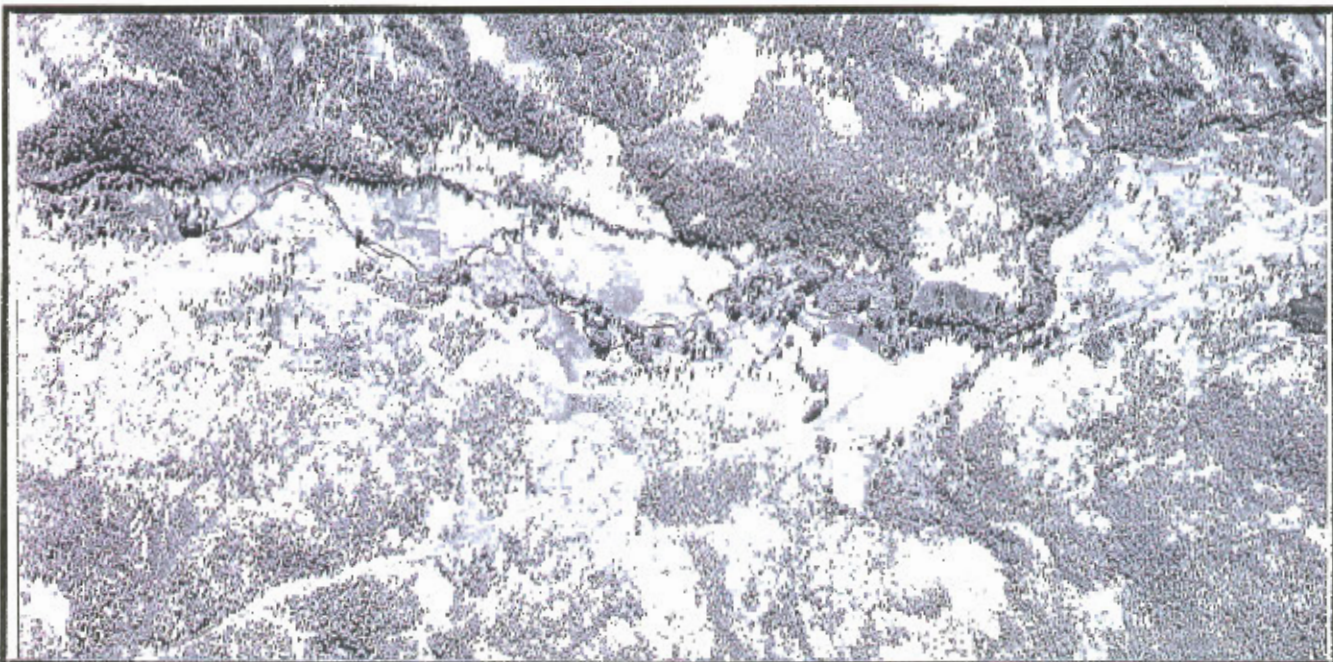


3.1.3a

September 13, 1948

BC 646 #22

Discharge: not available



3.1.3b

June 27, 1986

BC 86035 #137

Deadman River above Criss Creek

Discharge: 0.928 m³/s



3.1.3c

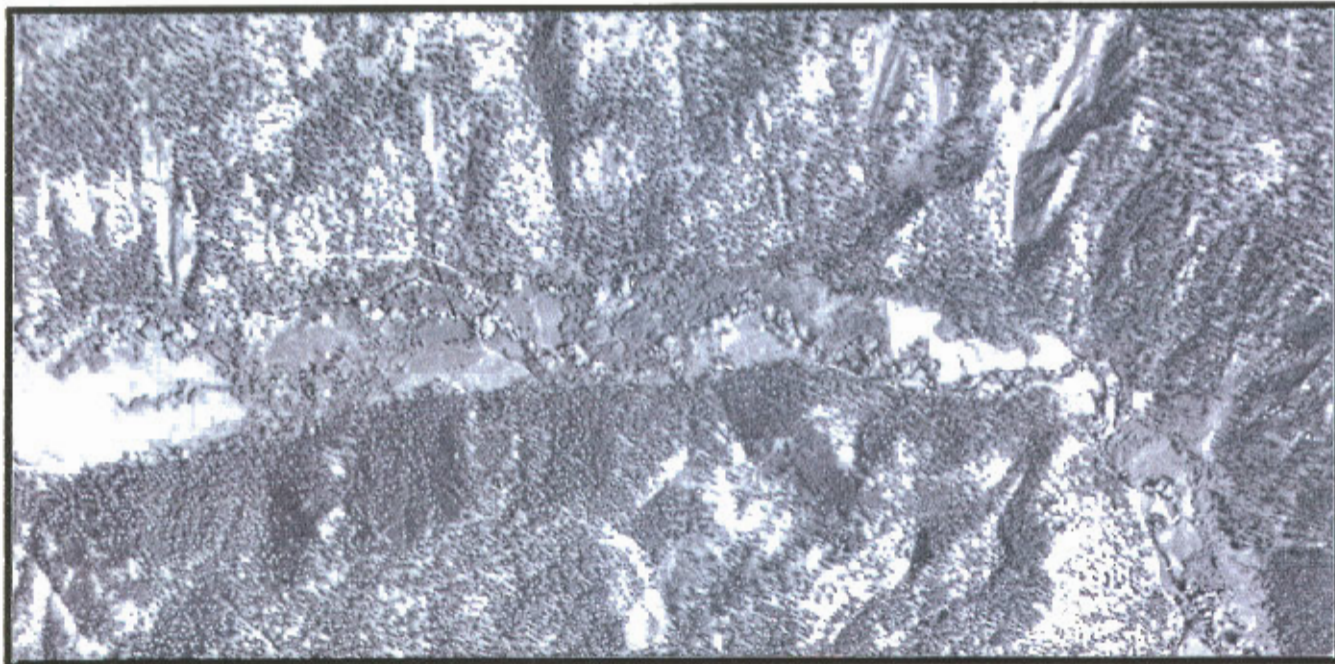
June 23, 1992

BCC 92015 #223

Deadman River above Criss Creek

Discharge: $0.994 \text{ m}^3/\text{s}$

Figure 3.1.3: Historical changes in channel morphology, Phillips Ranch.

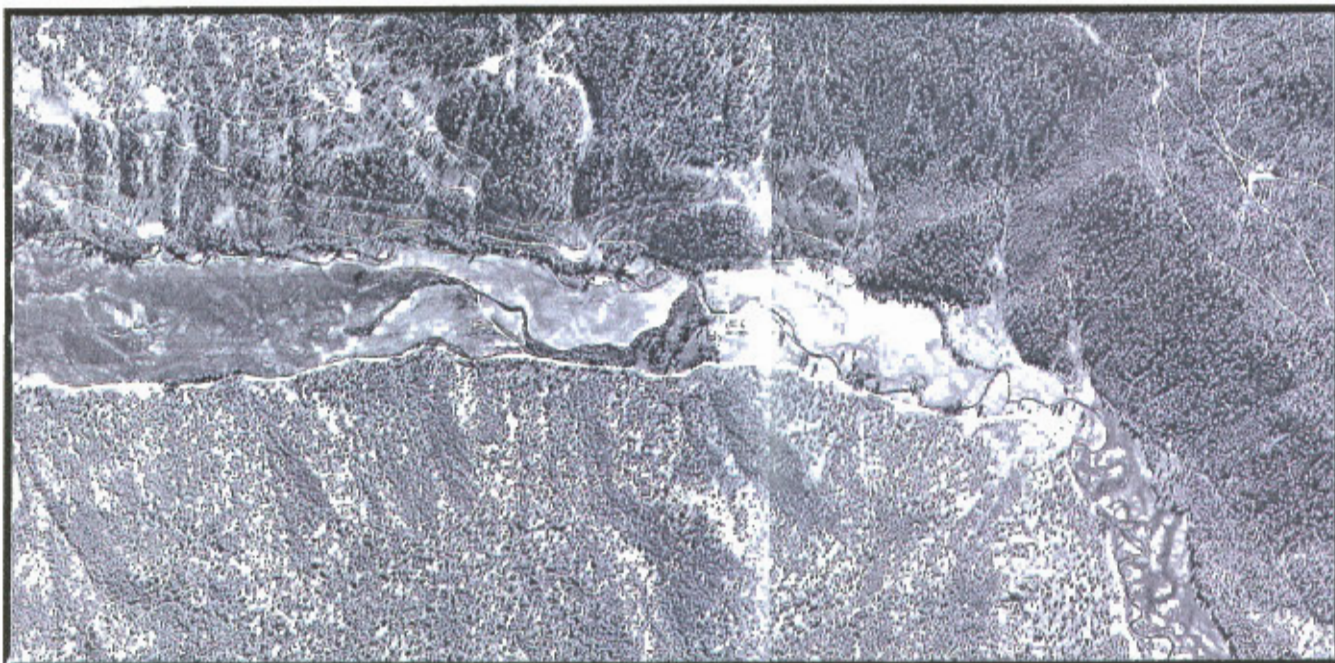


3.1.4a

September 13, 1948

BC 646 #20

Discharge: not available



3.1.4b

June 27, 1986

BC 86041 #80

BC 86068 #170

Deadman River above Criss Creek

Discharge: 0.928 m³/s



3.1.4c

June 23, 1992

BCC 92016 #23

Deadman River above Criss Creek

Discharge: 0.994 m³/s

Figure 3.1.4: Historical changes in channel morphology, Upper "Dockstader" Ranch.

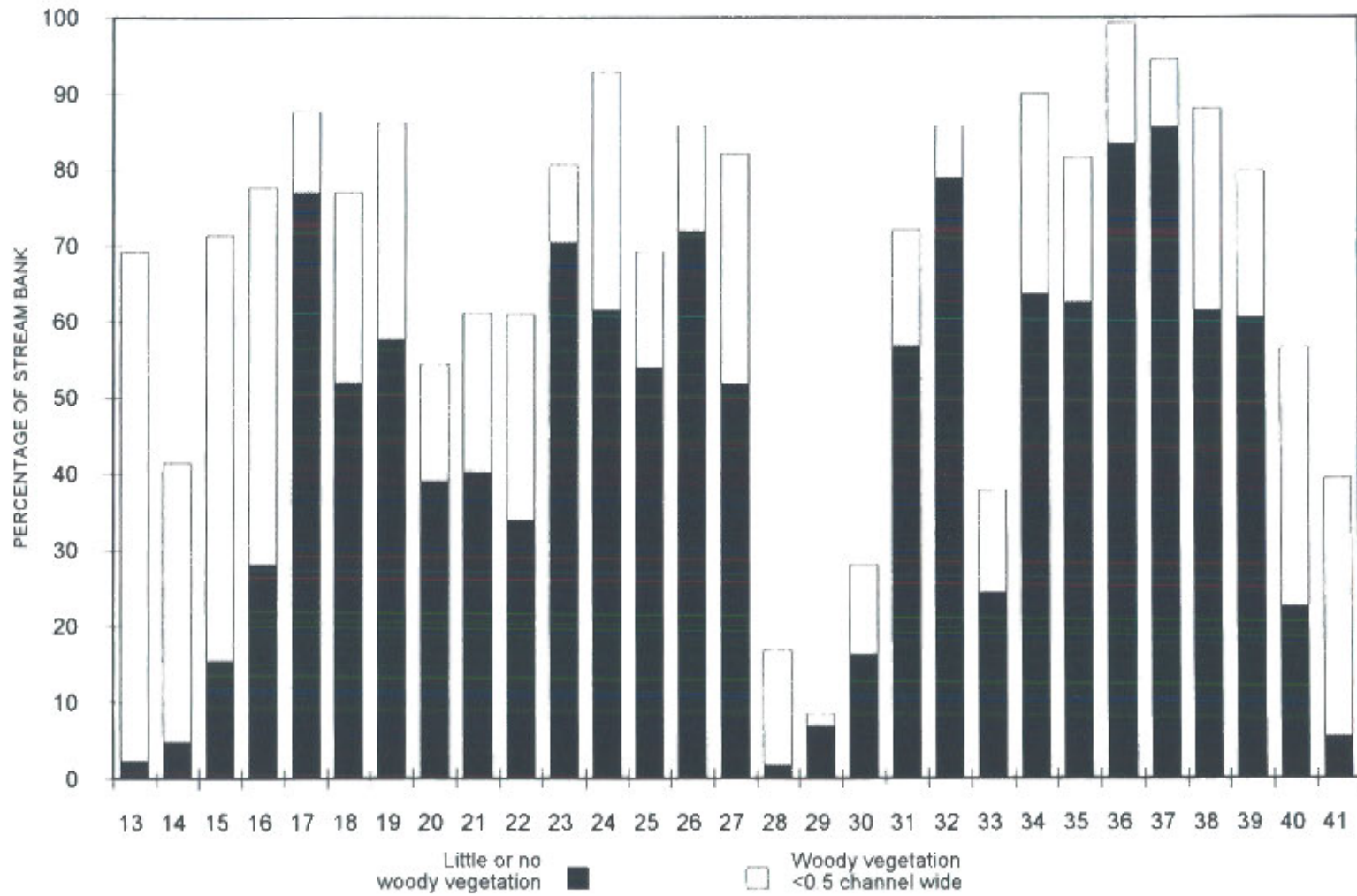


Figure 3 1.5: Distribution of unvegetated or poorly vegetated banks on Deadman River between Km 12 and Km 41

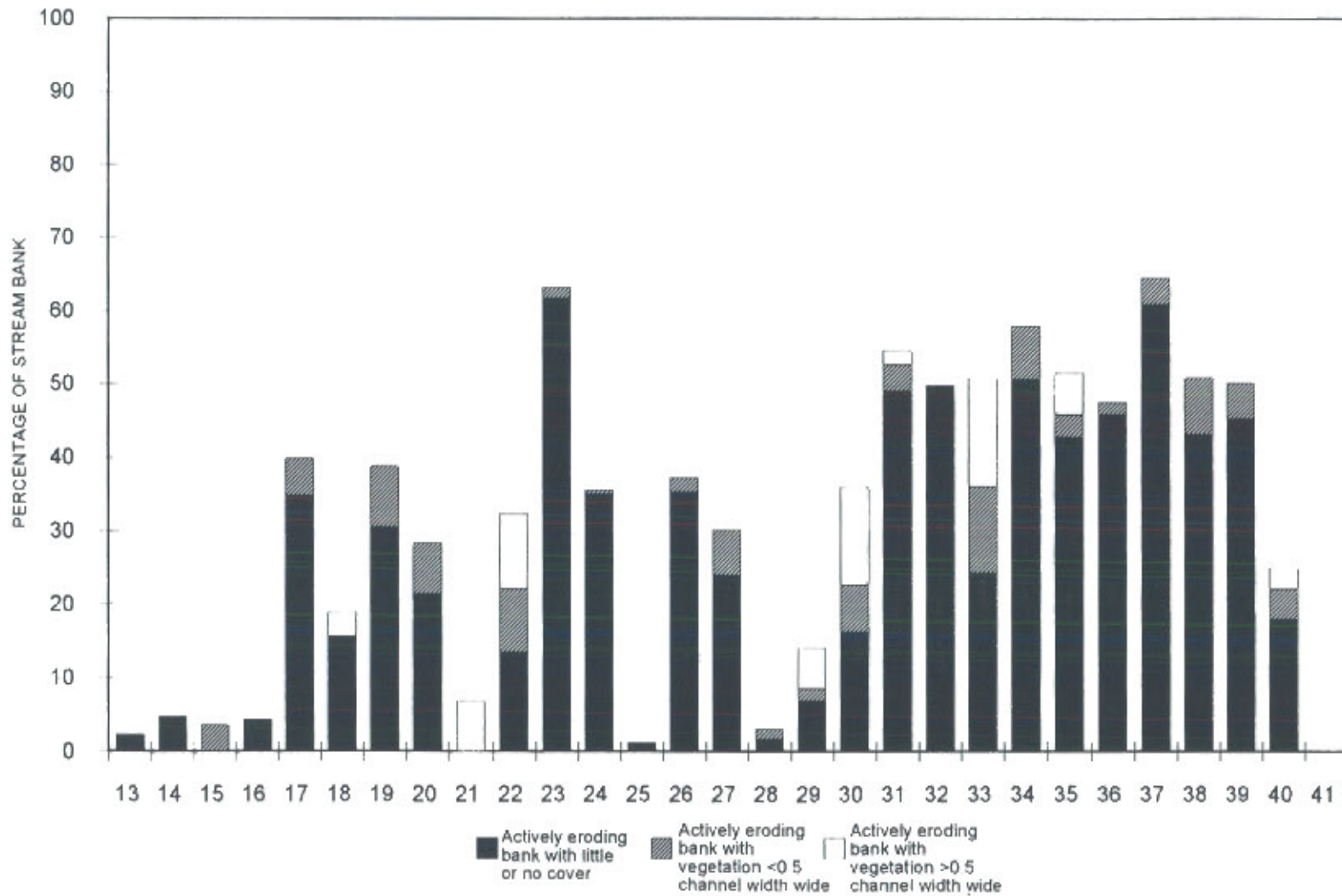


Figure 3.1.6: Distribution of actively eroding stream banks on Deadman River between Km 12 and Km 41

TABLES

TABLE 2.2.1: REPRESENTATIVE BASIN AREAS AND CHANNEL SLOPES

LOCATION	AREA (km ²)	ELEVATION			CHANNEL LENGTH (km)	AVERAGE CHANNEL SLOPE (m/m)
		MAX (m asl)	MIN (m asl)	DIF (m)		
Deadman River below Mowich Lake	615	1,640	750	890	64	0.014
Deadman River above Criss Creek	862	1,640	530	1,110	85	0.013
Criss Creek at the Mouth	490	1,775	530	1,245	56	0.022
Deadman River below Criss Creek	1,352	1,640	530	1,110	85	0.013
Deadman River at the Mouth	1,489	1,640	350	1,290	104	0.012

NOTE: All measurements from 1:100,000 scale mapping

TABLE 2.3.1: SUMMARY OF AVAILABLE DATA AT SELECTED ATMOSPHERIC ENVIRONMENT SERVICE CLIMATE STATIONS

AES STATION NUMBER	AES STATION NAME	ELEVATION (m)	PERIOD OF RECORD	YEARS * OF RECORD	AVAILABLE DATA							
					TEMP	PRECIP	RATE OF PRECIP	WIND	SUN	EVAP.	NIPHER	
1123468	HIGHLAND VALLEY BCCL	1,463	66-93	28	X	X					X	
1123469	HIGHLAND VALLEY LORNEX	1,276	67-93	27	X	X						
1160510	ASHCROFT	305	12-69	45	X	X						
1160511	ASHCROFT	366	73-80	7	X	X						
1160670	BARRIERE	375	55-62	36	X	X						
1160673	BARRIERE NORTH	389	70-84	15		X						
1161590	CHINOOK COVE	404	13-55	43	X	X						
1162265	DARFIELD	390	56-93	38	X	X						
1163779	KAMLOOPS	349	1878-1982	100	X	X						
1163780	KAMLOOPS A	346	51-93	43	X	X	X	X	X			X
1164717	LOON LAKE	823	68-93	26	X	X						
1165030	McCLURE	381	67-93	27	X	X						
1165225	MT LOLO KAMLOOPS	1,737	64-77	14	X	X						
1167191	70 MILE HOUSE	1,080	74-87	14	X	X						
1168667	VINSULLA	357	62-66	4		X						

FROM: Atmospheric Environment Service, 1989

Abbreviations:

TEMP	Temperature
PRECIP	Precipitation
RATE OF PRECIP	Rate of Precipitation
SUN	Sunshine
EVAP	Evaporation
NIPHER	Nipher Snow Gauge

* Approximate number for temperature and/or precipitation parameters only

TABLE 2.3.2: ANALYSIS OF RAINFALL INTENSITY-DURATION-FREQUENCY DATA, KAMLOOPS AIRPORT

STATION NAME	PERIOD OF RECORD	TOTAL PRECIPITATION						OBSERVED VALUE			SPECIFIED RETURN PERIOD PRECIPITATION (mm)						PROBABLE MAXIMUM PRECIPITATION (mm)
		DURATION			YEARS OF RECORD	MEAN VALUE (mm)	STANDARD DEVIATION (mm)	YEAR	VALUE (mm)	RETURN PERIOD (yrs)	2 YEARS	5 YEARS	10 YEARS	25 YEARS	50 YEARS	100 YEARS	
		(mins)	(hrs)	(days)													
KAMLOOPS A	1965-1990	5			26	3.5	2.3	1990	12.0	204.3	3.1	5.2	6.5	8.2	9.5	10.7	41.8
		10			26	5.0	3.1	1990	16.0	169.2	4.5	7.2	9.0	11.3	13.0	14.7	56.4
		15			26	5.9	3.4	1990	17.8	159.1	5.3	8.3	10.3	12.8	14.7	16.6	62.5
		30			26	7.0	3.5	1990	18.0	100.8	6.4	9.5	11.6	14.2	16.1	18.0	66.5
			1		26	8.3	3.7	1990	19.0	73.2	7.7	11.0	13.1	15.9	17.9	19.9	72.3
			2		26	10.1	4.3	1990	22.8	79.2	9.4	13.2	15.7	18.9	21.2	23.6	85.4
			6		26	14.0	5.1	1976	28.2	63.8	13.2	17.7	20.7	24.4	27.2	30.0	104.5
			12		26	17.4	7.7	1976	41.7	102.5	16.1	22.9	27.4	33.1	37.4	41.6	155.3
	24		26	20.6	10.4	1976	53.1	98.5	18.9	28.1	34.2	41.9	47.6	53.2	209.4		
KAMLOOPS A	1951-1992			1	42	20.3	8.3	1976	48.0	129.2	18.9	26.3	31.1	37.3	41.8	46.3	171.0
				2	42	24.9	9.7	1976	53.8	81.8	23.3	31.9	37.6	44.7	50.0	55.3	201.5
				3	42	27.6	9.9	1976	54.1	55.7	26.0	34.7	40.5	47.8	53.3	58.7	208.5
				4	42	29.5	10.7	1976	56.9	48.0	27.7	37.2	43.5	51.4	57.2	63.1	225.7
				5	42	31.6	10.8	1976	58.7	45.0	29.8	39.4	45.7	53.7	59.6	65.5	230.8
				6	42	33.3	10.7	1976	59.9	43.7	31.5	41.0	47.3	55.2	61.0	66.9	231.0
				7	42	34.6	11.1	1976	62.8	46.8	32.8	42.6	49.1	57.3	63.4	69.4	239.7
				8	42	37.2	11.1	1976	62.8	34.8	35.4	45.2	51.7	59.9	66.0	72.0	242.9
				9	42	28.8	11.5	1976	65.8	110.9	26.9	37.1	43.8	52.3	58.6	64.9	251.0
				10	42	40.5	11.8	1976	71.8	54.0	38.6	49.0	55.9	64.6	71.1	77.5	257.7

NOTE: Shaded values exceed twice the period of record and are therefore potentially unreliable

TABLE 2.3.3:

FREQUENCY ANALYSIS OF PRECIPITATION DATA FROM KAMLOOPS

PARAMETER	PERIOD OF RECORD	YEARS OF RECORD	MEAN VALUE (mm)	STANDARD DEVIATION (mm)	OBSERVED VALUE			SPECIFIED RETURN PERIOD PRECIPITATION (mm)						
					YEAR	VALUE (mm)	RETURN PERIOD (yrs)	2 YEARS	5 YEARS	10 YEARS	25 YEARS	50 YEARS	100 YEARS	200 YEARS
TOTAL ANNUAL RAINFALL	1878-1992	99	187.846	54.909	1895	378.8	155	178.8	227.3	259.5	300.1	330.2	360.1	389.9
	1878-1992	99	187.846	54.909	1941	341.1	64	178.8	227.3	259.5	300.1	330.2	360.1	389.9
	1878-1992	99	187.846	54.909	1981	278.1	15	178.8	227.3	259.5	300.1	330.2	360.1	389.9
TOTAL ANNUAL PRECIPITATION	1878-1992	99	259.944	62.591	1895	503.6	263	249.7	304.9	341.6	387.9	422.2	456.3	490.2
	1878-1992	99	259.944	62.591	1927	458.6	105	249.7	304.9	341.6	387.9	422.2	456.3	490.2
	1878-1992	99	259.944	62.591	1981	375.7	20	249.7	304.9	341.6	387.9	422.2	456.3	490.2
MAXIMUM 24-HR RAINFALL	1878-1992	99	18.982	8.158	1895	56.9	692	17.6	24.8	29.6	35.7	40.1	44.6	49.0
	1878-1992	99	18.982	8.158	1976	45.7	119	17.6	24.8	29.6	35.7	40.1	44.6	49.0
MAXIMUM 24-HR PRECIPITATION	1878-1992	99	21.188	7.237	1895	56.9	999	20.0	26.4	30.6	36.0	39.9	43.9	47.8
	1878-1992	99	21.188	7.237	1976	45.7	138	20.0	26.4	30.6	36.0	39.9	43.9	47.8

NOTE: Shaded values exceed twice the period of record and are therefore potentially unreliable

TABLE 2.4.1: SUMMARY OF AVAILABLE DATA AT SELECTED WATER SURVEY OF CANADA (WSC) STREAM GAUGING STATIONS

STATION NUMBER 08LF	STATION NAME	BASIN AREA (km ²)	TYPE OF RECORD	TYPE OF FLOW	PARAMETER	YEARS OF RECORD
002	BONAPARTE RIVER BELOW CACHE CREEK	5,020	11-21 MS; 26-29 M#; 69-71 M#; 72 MS 73-74 mc; 75 MS; 76-93 RC	REG	1	31
					2	18
007	CRISS CREEK NEAR SAVONA	490	12-20 MS; 61-65 MC; 76-78 RC; 79 MC 80-93 RC	REG	1	41
					2	13
009	DEADMAN RIVER ABOVE WALHACHIN FLUME	1,170	11-12 MS	NAT	1	-
					2	-
010	DEADMAN RIVER (WALHACHIN FLUME)	?	12 M#; 13 MS; 15 M#; 22 M#	REG	1	-
					2	-
011	DEADMAN RIVER BELOW WALHACHIN FLUME	?	11 MS	REG	1	-
					2	-
027	DEADMAN RIVER ABOVE CRISS CREEK	862	13-21 MS; 61-93 MC	REG	1	41
					2	-
087	MOOSE CREEK ABOVE DIVERSIONS	?	81 #	NAT	1	-
					2	-
091	HELLER CREEK ABOVE DIVERSIONS	46.6	82-93 MS	NAT	1	10
					2	-
094	JOE ROSS CREEK NEAR THE MOUTH	101	84 - 93 RS	NAT	1	10
					2	10

FROM: Inland Waters Directorate, 1992

NOTES:

* stage only
 # miscellaneous measurements
 M manual gauge
 R recording gauge
 S seasonal operation
 C continuous operation
 numbers refer to years (e.g. 09 is 1909)

REV Data to 19 .
 have been reviewed
 NAT Natural Flow
 REG Regulated Flow with
 date of regulation
 if known
 NA Not Available

(i) Data not published
 1 Daily Flows
 2 Instantaneous Flows
 7 Satellite D.C.P.
 10 Minimum Flows

TABLE 2.4.2: CALCULATED RETURN PERIODS FOR THE JUNE, 1990 FLOOD

WSC STATION	YEARS OF RECORD		RETURN PERIOD (yrs) FOR JUNE, 1990 FLOOD BASED ON ASSUMED FREQUENCY DISTRIBUTION							
	DAILY	INST.	LOG NORMAL		GUMBEL		PEARSON TYPE III		LOG PEARSON TYPE III	
			MAX. DAILY	MAX INST.	MAX. DAILY	MAX INST.	MAX. DAILY	MAX INST.	MAX. DAILY	MAX INST.
DEADMAN RIVER ABOVE CRISS CREEK	41	-	259		2,320		178		823	
CRISS CREEK NEAR SAVONA	41	13	20	47	42	366	23	48	22	46
HELLER CREEK ABOVE DIVERSIONS	10	-	39		111		34		32	
JOE ROSS CREEK NEAR THE MOUTH	10	10	45	50	273	372	35	36	27	28
BONAPARTE RIVER BELOW CACHE CREEK	31	18	89	66	194	263	112	68	148	84

NOTE: Shaded values exceed twice the period of record and are therefore potentially unreliable

TABLE 2.4.3: FLOOD ESTIMATES FOR VARIOUS LOCATIONS WITHIN THE STUDY AREA

LOCATION	BASIN AREA (km ²)	FLOOD MAGNITUDE (m ³ /s) FOR A RETURN PERIOD OF:			
		2-YEARS		200-YEARS	
		DAILY	INSTANT.	DAILY	INSTANT.
DEADMAN RIVER BELOW MOWICH LAKE	615	11	17	34	57
DEADMAN RIVER ABOVE CRISS CREEK	862	12	20	49	65
CRISS CREEK NEAR SAVONA	490	19	25	69	82
DEADMAN RIVER BELOW CRISS CREEK	1,352	26	34	126	168
DEADMAN RIVER AT THE MOUTH	1,489	28	36	130	171

NOTE: These are preliminary estimates which are not suitable for engineering design

TABLE 2.7.1: DEADMAN RIVER REACH CHARACTERISTICS IN THE AREA BETWEEN KM 12 AND KM 41

REACH LOCATION (km)		LENGTH (km)	STREAM CHANNEL DESCRIPTION
FROM	TO		
41.3	40.5	0.8	A narrow, laterally stable, single thread channel confined between a right bank road and the left bank valley wall.
40.5	39.5	1.0	A straight, single thread channel flowing within a section of wide valley flat containing sediments from the Tobacco Creek fan
39.5	32.7	6.8	An irregularly meandering channel flowing within a wide valley flat. The channel is actively shifting and there are large unvegetated bar forms, particularly in the upstream section of this reach.
32.7	32.0	0.7	An irregular channel which is partially confined between the Gorge Creek fan and the left bank valley wall.
32.0	29.5	2.5	An irregularly meandering channel flowing within a wide low-lying valley flat. The channel is actively shifting and there are numerous large unvegetated bar forms
29.5	27.5	2.0	A narrow irregular channel which is nearly continuously confined against the left bank valley wall by the fan of Barricade Creek and by a large right bank landslide.
27.5	26.0	1.5	A generally laterally stable channel which is frequently confined by large fluvial fans which extend into the moderately wide valley flat
26.0	25.3	0.7	A single thread, irregularly meandering channel flowing within a wide valley flat.
25.3	23.6	1.7	A single thread, irregular channel frequently confined by the valley walls or fans which extend into the valley flat.
23.6	22.0	1.6	A single thread, irregularly meandering channel flowing within a wide valley flat. The channel is actively shifting and has formed large unvegetated bar forms
22.0	20.8	1.2	An irregular channel flowing between fans formed by Criss Creek and Clemes Creek.
20.8	14.0	6.8	An irregularly meandering channel flowing within a wide valley flat. The channel is occasionally confined by large fans.
14.0	12.0	2.0	A single thread, irregular channel flowing within a discontinuous valley flat. The channel is frequently confined by large fluvial fans, terraces or the valley wall. Rates of channel shifting are low.

NOTE: - Terminology follows *Kellerhals, Church and Bray, 1976*
 - See FOLIO 1 for the location of these reaches

TABLE 2.7.2: COMPARISON OF STREAM POWER VALUES

STREAM	LOCATION	BASIN AREA (km ²)	SLOPE (m/m)	2-YEAR DAILY FLOOD		100-YEAR DAILY FLOOD	
				DISCHARGE (m ³ /s)	STREAM POWER (W)	DISCHARGE (m)	STREAM POWER (W)
Salmon River	near Salmon Arm	1,510	0.0007	28	192	55	377
Crowsnest River	at Frank	404	0.0027	30	794	80	2,117
Salmon River	above Salmon Lake	143	0.0140	7.2	988	16	2,195
Deadman River	above Criss Creek	862	0.0097	12	1,141	44	4,182
Carnation Creek	at the Mouth	10.1	0.0100	15	1,470	29	2,842
Deadman River	below Criss Creek	1,352	0.0058	26	1,478	N/A	N/A
Hluhill Creek	above Diversions	69	0.0195	8.4	1,606	25	4,778
Salmon River	at Falkland	1,040	0.0160	17	2,665	49	7,682
Castle River	at Ranger Station	155	0.0054	70	3,704	210	11,112
Coldwater River	near Brookmere	316	0.0065	60	3,822	120	7,643
Oldman River	near Brocket	4,400	0.0018	240	4,233	1,500	26,457
Louis Creek	at the Mouth	515	0.0193	24	4,531	47	8,874
Oldman river	near Waldron's Corner	1,440	0.0050	100	4,900	400	19,598
Oldman River	near Lethbridge	17,000	0.0009	570	5,027	3,100	27,339
Castle River	at Beaver Mines	823	0.0043	130	5,478	420	17,697
Coquihalla River	near Hope	741	0.0110	210	22,636	800	86,231

TABLE 3.1.1a: SUMMARY OF AIR PHOTOGRAPHS AVAILABLE FOR DEADMAN RIVER

YEAR	DATE	AIR PHOTO INDEX	FLIGHT LINE B.C.	PHOTO NUMBER	FLYING HEIGHT (ft)	CAMERA FOCAL LENGTH (mm)	FILM FORMAT (")	SCALE 1:	DISCHARGE (m ³ /s)	DISCHARGE (m ³ /s)
									DEADMAN RIVER AB CRISS CK	CRISS CREEK NEAR SAVONA
1947	JUL 22	SP 12/58	378	68-81	17300	148.590	5	32,111		
1948	SEP 13	92 I-1	646	18-27	17,300	148.590	5	32,111	n/a	n/a
				38-45	17,800	148.590	5	33,137		
1958	JUN 19	92 I-3	2435	51-61	18,000	148.590	5	33,547	n/a	n/a
	AUG 27	92 I/E-1	2562	81-84	19,200	320.040	5	16,719	n/a	n/a
1959	JUL 22	92 I/E-1	2646	81-86	18,900	320.040	5	16,433	n/a	n/a
				20-21	19,000	320.040	5	16,528		
				26-28						
				35-40						
1959	JUL 22	92 I/E-1	2649	85-87	19,100	320.040	5	16,623	n/a	n/a
				110-112	19,000	320.040	5	16,528		
	JUL 21		2651	44-46	19,000	320.040	5	16,528		
				79-80	18,950	320.040	5	16,480		
	JUL 22		2652	57-59	19,000	320.040	5	16,528		
				81-83						
2654	43-44	18,940	320.040	5	16,471					
66-67										
1965	SEP 16	92 I-5	5167	230-236	19,000	152.260	9	34,741	0.481	0.804
1966	MAY 18	92 I-5	5185	176-184	20,000	152.260	9	36,743	7.87	13.70
				185-187						
1974	SEP 14	92 I NE-1	5629	24-27	39,000	153.410	9	74,227	0.408	0.071
1974	JUL 26	92 P/E-2	7592	11-12	20,200	305.570	9	18,508	0.646	0.354
				211	20,000	305.570	9	18,308		
	JUL 27	92 I/W-2	7595	54-56	20,000	305.570	9	18,308	0.629	0.320
				78-80						
	92 I/W-2	7595	159-162	20,000	305.570	9	18,308	0.629	0.320	
			181-183							
235-237										
260-263										
92 I/E-4	7596	23-24	20,000	305.570	9	18,308				
52-53										
93-95										
101-104										
143-144										
AUG 26	92 I/E-4	7643	107	20,500	305.560	9	18,808	0.453	0.108	
1976	SEP 01	92 I-6	5739	184-185	24,500	152.433	9	45,702	4.47	3.26
				218-219						
	5740	13-15	24,500	152.433	9	45,702				
48-51										
SEP 08	92 I-6	5742	115-120	24,500	152.937	9	45,551	3.62	2.07	
1979	JUN 18	SP 82/79	C 210	01-06	7,200	305.090	9	5,546	1.70	2.34
				96-232						

NOTE: 1: An average groundheight of 500 m (1,650 ft.) amsl has been used to compute photo scale
 2: S.P. indicates Special Project
 3: Camera focal length on 5 inch negative photos has been increased by a factor of 1.80 to compensate for 9 inch print size

TABLE 3.1.1b: SUMMARY OF AIR PHOTOGRAPHS AVAILABLE FOR DEADMAN RIVER

YEAR	DATE	AIR PHOTO INDEX	FLIGHT LINE B.C.	PHOTO NUMBER	FLYING HEIGHT (FLASL)	CAMERA FOCAL LENGTH (mm)	FILM FORMAT (*)	SCALE 1:	DISCHARGE (m ³ /s) DEADMAN RIVER AB CRISS CK	DISCHARGE (m ³ /s) CRISS CREEK NEAR SAVONA
1980	SEP 09	92 I/E-6	80125	49-51	25,000	305.090	9	23,334	1.11	1.95
	SEP 10	92 I/E-6	80125	144-146 263-266	25,000	305.090	9	23,334	1.25	1.78
			80126	33-36 159-160 234-235	25,000	305.090	9	23,334		
	SEP 09	92 I/E-6	80128	106-107 229-231	25,000	305.090	9	23,334	1.11	1.26
	SEP 10	92 I/E-6	80134	87-89	25,000	305.090	9	23,334	1.25	1.26
1982	AUG 22	92 NE-4	82030	43-54 100-110 119-133	31,500	152.260	9	59,770	1.50	0.702
	AUG 24	92 NE-4	82034	99-100 148-149 150-155 182-185	33,500	152.260	9	63,775	1.45	0.486
1984	JUL 10	92 NE-3	84023	178-179 248-250	36,000	152.250	9	68,785	2.16	2.65
	JUL 15	92 NE-3	84030	01-02 85-93 135-144 170-175	36,000 34,500 36,000	152.250 152.250 152.250	9 9 9	68,785 65,782 68,785		
1986	JUN 26	92 I/E-7	86033	028 211 158	19,000	304.490	9	17,372	0.928	0.847
			86034	96-99 310 153-155	19,000	304.490	9	17,372		
	JUN 27	92 I/E-7	86035	078 137	19,000	304.490	9	17,372	0.928	0.694
	JUN 26	92 I/E-7	86038	151 276	19,000	304.490	9	17,372	0.928	0.847
	JUN 27	92 I/E-7	86041	080	19,000	304.490	9	17,372	0.928	0.694
	AUG 02	92 I/E-7	86068	171	19,000	304.490	9	17,372	1.71	1.46
			86069	80 168	19,000	304.490	9	17,372		
			86070	043	19,000	304.490	9	17,372		
	AUG 06	92 I/E-7	86091	074	19,000	304.490	9	17,372	0.898	0.881
	1987	SEP 07	92 I/E-8	C 744	01-03 05-07 79-81 84-85 87-92	21,000	305.000	9	19,342	0.618

NOTE: 1: An average groundheight of 500 m (1,650 ft.) asl has been used to compute photo scale
 2: S.P. indicates Special Project
 3: Camera focal length on 5 inch negative photos has been increased by a factor of 1.80 to compensate for 9 inch print size

TABLE 3.1.1c: SUMMARY OF AIR PHOTOGRAPHS AVAILABLE FOR DEADMAN RIVER

YEAR	DATE	AIR PHOTO INDEX	FLIGHT LINE B.C.	PHOTO NUMBER	FLYING HEIGHT (FASL)	CAMERA FOCAL LENGTH (mm)	FILM FORMAT (*)	SCALE 1:	DISCHARGE (m ³ /s) DEADMAN RIVER AB CRISS CK	DISCHARGE (m ³ /s) CRISS CREEK NEAR SAVONA
1987	SEP 27	92 VE-8	C 774	15-17	20,000	305.000	9	18,343	0.415	0.005
				80-81						
				86-88						
				96-97						
				147-151						
1988	AUG 23	92 VE&W	C 877	56-58	18,500	303.980	9	16,900	0.570	0.102
				70-71						
				149-151						
1989	JUN 05	92 VE&W	C 947	204-207	15,000	305.113	9	13,340	2.96	3.28
	SEP 12	92 VE&W	C 1030	25-28	15,000	305.000	9	13,345	0.970	0.733
1990	JUL 08	92 I-15	C 90031	75-111	6,500	305.000	9	4,848	10.4	15.8
				112-145	7,000	305.000	9	5,348		
				207-220						
	JUL 09	92 I-15	C 90032	01-22	7,500	305.000	9	5,848	10.7	10.3
	AUG 04	92 I	C 90063	138	20,000	303.805	9	18,415	1.78	1.20
				152						
	AUG 05	92 I	C 90064	63	20,000	303.805	9	18,415	1.68	1.19
				80						
C 90076				18						
				36						
				40-42						
				78-83						
				86-88						
AUG 07	92 I	C 90059	206-207	20,000	304.490	9	18,373	1.61	0.923	
			247							
1992	MAY 24	92 VE&W	C 92002	05-06	19,500	305.644	9	17,805	3.12	3.65
				54-56						
				96-100						
				169-171						
				174-175						
				C 92003						
	C 92006	25-26	19,500	305.644	9	17,805				
				69-71						
				128-139	20,000	305.644	9	18,304		
				212-214	20,500	305.644	9	18,803		
JUN 23	92 VE&W	C 92015	223-224	19,500	305.133	9	17,835	0.994	0.612	
			C 92016	23-25	20,500	305.133	9			18,834
				91-92						

NOTE: 1: An average groundheight of 500 m (1,650 ft.) asl has been used to compute photo scale
 2: S.P. Indicates Special Project
 3: Camera focal length on 5 inch negative photos has been increased by a factor of 1.80 to compensate for 9 inch print size

TABLE 3.1.2: CHANGES IN UNVEGETATED CHANNEL WIDTH BETWEEN 1948 AND 1992

LOCATION (km)		RANCH	FIGURE	AVERAGE UNVEGETATED CHANNEL WIDTH (m)		CHANNEL WIDTH STANDARD DEVIATION (m)		CHANGE IN UNVEGETATED CHANNEL WIDTH		MAXIMUM UNVEGETATED CHANNEL WIDTH (m)		CHANGE IN MAXIMUM CHANNEL WIDTH	
FROM	TO			1948	1992	1948	1992	(m)	(%)	1948	1992	(m)	(%)
35.7	38.7	UPPER "DOCK-STEADER"	3.1.4	9.8	30.3	4.1	16.6	20.5	209	25.6	87.4	61.8	241
29.9	31.7	PHILLIPS	3.1.3	8.8	42.9	1.9	15.6	34.1	388	12.8	82.2	69.4	542
22.0	23.3	CRAIG	3.1.2	9.7	48.3	2.9	28.8	38.6	398	18.2	114.4	96.2	529

TABLE 3.1.3: DEADMAN RIVER CHANNEL CLASSIFICATION IN THE AREA BETWEEN KM 12 AND KM 41

BOC FLIGHT LINE #	PHOTO #	STREAM KM	THALWEG LENGTH (m)	CUM. THALWEG LENGTH (km)	TOTAL BANK LENGTH (m)	LENGTH OF BANK WITH:						LENGTH OF ACTIVELY ERODING BANK WITH					
						NO WOODY VEGETATION		WOODY VEG. < 0.5 CHANNEL WIDTH		WOODY VEG. > 0.5 CHANNEL WIDTH		NO WOODY VEGETATION		WOODY VEG. < 0.5 CHANNEL WIDTH		WOODY VEG. > 0.5 CHANNEL WIDTH	
						(m)	(%)	(m)	(%)	(m)	(%)	(m)	(%)	(m)	(%)	(m)	(%)
92006	25	12 13	1,053	1.1	2,105	48	2	1,411	67	647	31	48	2	0	0	0	0
92003	150	13 14	1,106	2.2	2,211	105	5	812	37	1,295	59	105	5	0	0	0	0
		14 15	956	3.1	1,913	294	15	1,073	56	546	29	0	0	69	4	0	0
		15 16	1,134	4.2	2,268	637	28	1,125	50	507	22	98	4	0	0	0	0
92002	5	16 17	772	5.0	1,545	1,188	77	167	11	189	12	537	35	80	5	0	0
		17 18	1,019	6.0	2,038	1,057	52	514	25	467	23	319	16	0	0	67	3
		18 19	966	7.0	1,932	1,113	58	556	29	264	14	588	30	162	8	0	0
		19 20	1,171	8.2	2,343	912	39	365	16	1,065	45	502	21	164	7	0	0
	55	20 21	1,068	9.2	2,135	859	40	448	21	828	39	0	0	0	0	147	7
		21 22	1,135	10.4	2,270	771	34	614	27	885	39	305	13	198	9	232	10
		22 23	1,118	11.5	2,236	1,573	70	231	10	431	19	1,380	62	35	2	0	0
	99	23 24	1,192	12.7	2,384	1,465	61	750	31	169	7	834	35	16	1	0	0
		24 25	1,023	13.7	2,046	1,103	54	315	15	628	31	25	1	0	0	0	0
		25 26	1,253	15.0	2,506	1,801	72	349	14	356	14	864	35	50	2	0	0
170	26 27	1,154	16.1	2,308	1,193	52	703	30	412	18	554	24	142	6	0	0	
	27 28	1,219	17.3	2,437	41	2	373	15	2,023	83	41	2	34	1	0	0	
	28 29	1,132	18.5	2,264	154	7	40	2	2,070	91	154	7	40	2	125	6	
92015	223	29 30	1,264	19.7	2,528	410	16	300	12	1,817	72	410	16	164	6	336	13
		30 31	999	20.7	1,999	1,131	57	310	16	557	28	979	49	74	4	39	2
		31 32	1,184	21.9	2,368	1,867	79	164	7	336	14	1,179	50	0	0	0	0
		32 33	1,247	23.2	2,495	606	24	340	14	1,549	62	606	24	294	12	367	15
		33 34	1,104	24.3	2,208	1,403	64	587	27	218	10	1,117	51	163	7	0	0
92016	23	34 35	1,149	25.4	2,298	1,435	62	441	19	422	18	982	43	70	3	132	6
		35 36	1,067	26.5	2,134	1,778	83	341	16	15	1	976	46	38	2	0	0
		36 37	1,062	27.5	2,124	1,817	86	191	9	116	5	1,293	61	78	4	0	0
		37 38	1,057	28.6	2,114	1,298	61	565	27	252	12	912	43	164	8	0	0
92016	92	38 39	1,134	29.7	2,268	1,371	60	442	20	455	20	1,024	45	113	5	0	0
		39 40	1,051	30.8	2,102	473	23	716	34	912	43	378	18	87	4	62	3
		40 41	1,008	31.8	2,016	110	5	686	34	1,221	61	0	0	0	0	0	0
TOTAL					63,594	28,012	44	14,928	23	20,654	32	16,229	26	2,237	4	1,505	2

TABLE 4.3.1: ASSESSMENT OF SEDIMENT LOADS IN TRIBUTARY STREAMS TO DEADMAN RIVER

TRIBUTARY	APPROX. BASIN AREA (km ²) *1	APPROX. STREAM LOCATION (km) *2	1990 AIR PHOTO		CHANNEL CHARACTERISTICS NEAR CONFLUENCE WITH DEADMAN RIVER	RELATIVE BEDLOAD CONTRIBUTION
			FLIGHT LINE BCC	PHOTO #		
Upper Deadman River	--	41	92016	92	Single thread irregular channel containing small point bars.	MODERATE
Tobacco Creek	37.4	40.1	92016	92	Small, well-vegetated channel. Channel is incised in a small fan. No indications of significant sediment transport.	VERY SMALL
Gorge Creek	61.8	32.4	92015	223	Small, well-vegetated channel. Some slope disturbance on valley walls and small bar form evident near highway bridge	SMALL
Barricade Ck	68.5	29.2	92015	223	Small, generally well-vegetated channel. No bar forms evident on air photos	SMALL
Silverspring Creek	7.6	26.9	92002	170	A very small creek which flows over a disturbed section of valley wall. The channel across the valley flat consists of a narrow, stable ditch	VERY SMALL
Criss Creek	490	21.6	92002	55	A large gravel and cobble bedded stream which has an active fan on the Deadman Creek valley flat. Channel contains unvegetated bar forms	MODERATE
Clemes Creek	70.6	21.4	92002	55	A small incised channel which has generally well-vegetated banks	SMALL
Sedge Creek	10.7	17.6	92002	5	A very small stream which flows over a large unvegetated fan. There is no well-defined channel between the valley flat and the mainstem Deadman River	VERY SMALL
Unnamed Creek	2.5	15	92003	150	A very small stream which does not have a well-defined channel across the valley flat	VERY SMALL

*1 From: 1:50,000 scale mapping

*2 Upstream of the Thompson River confluence

PLATES

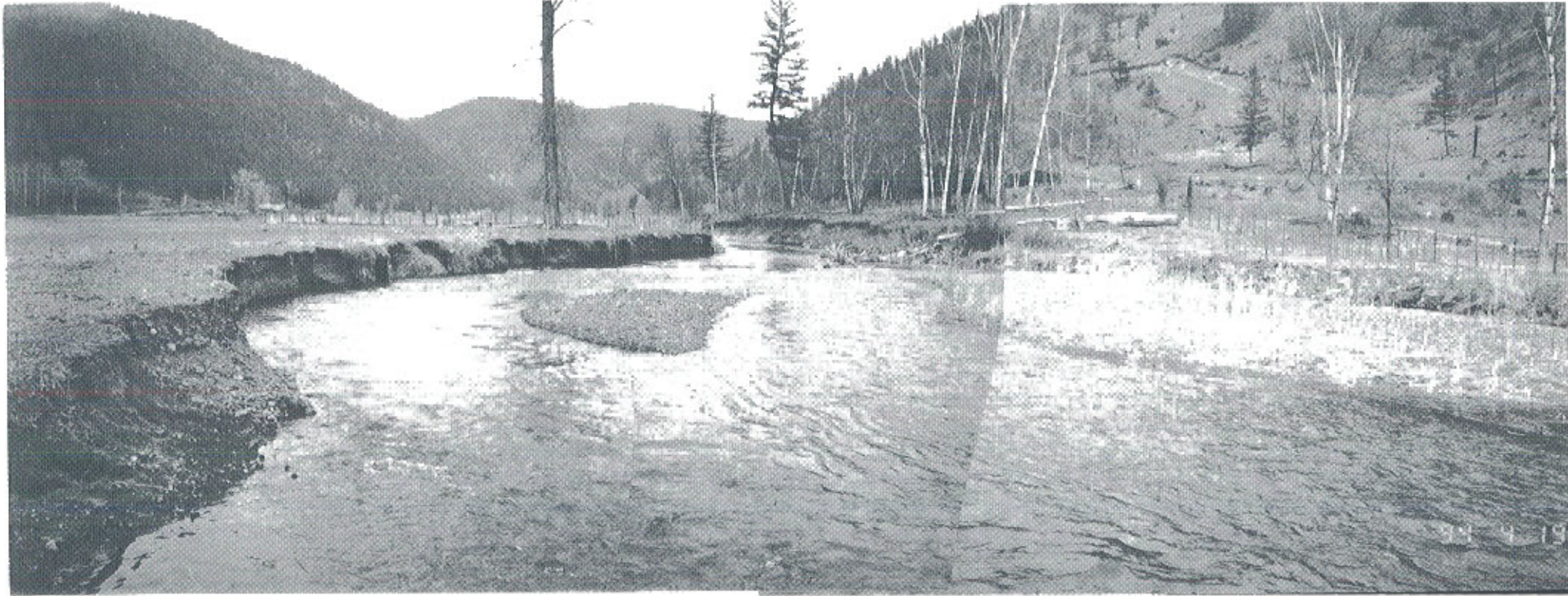
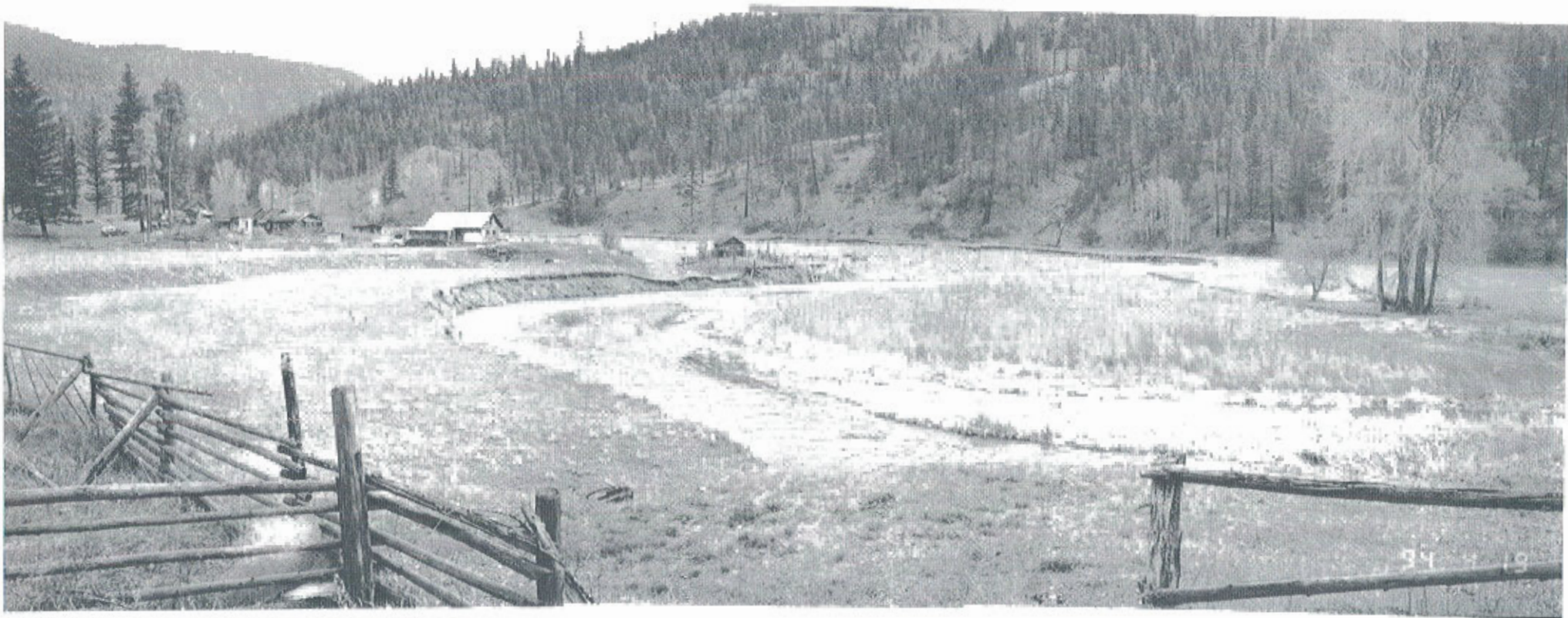


Plate 3.2.1: Looking upstream to an eroding section of pasture located on the "Dockstader" Ranch.

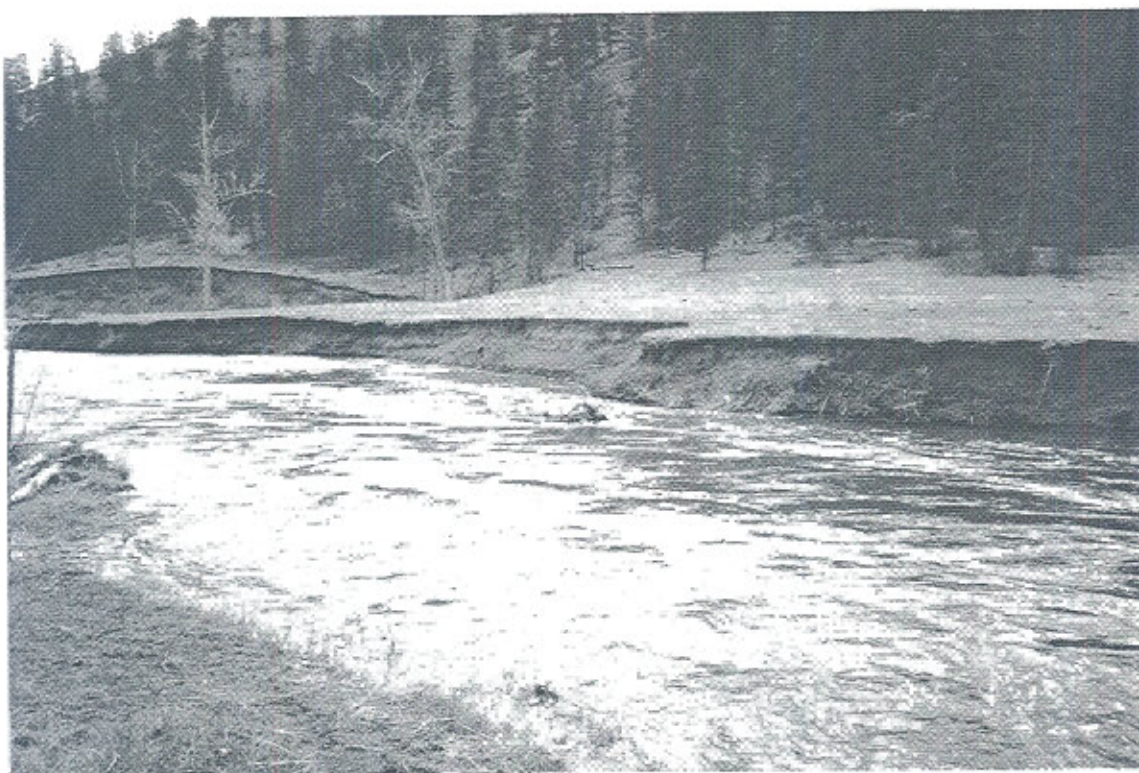


06

MM 94-03-27 to 29

Plate 3.2.2: Looking upstream to prograding point bars and eroding banks on the Phillips Ranch.

Date of Photography: April 19, 1994



Date of Photography: April 19, 1994

MM 94-06-12

Plate 3.2.3: Looking downstream onto eroding pasture on the Craig Ranch,
located just upstream of the Criss Creek confluence

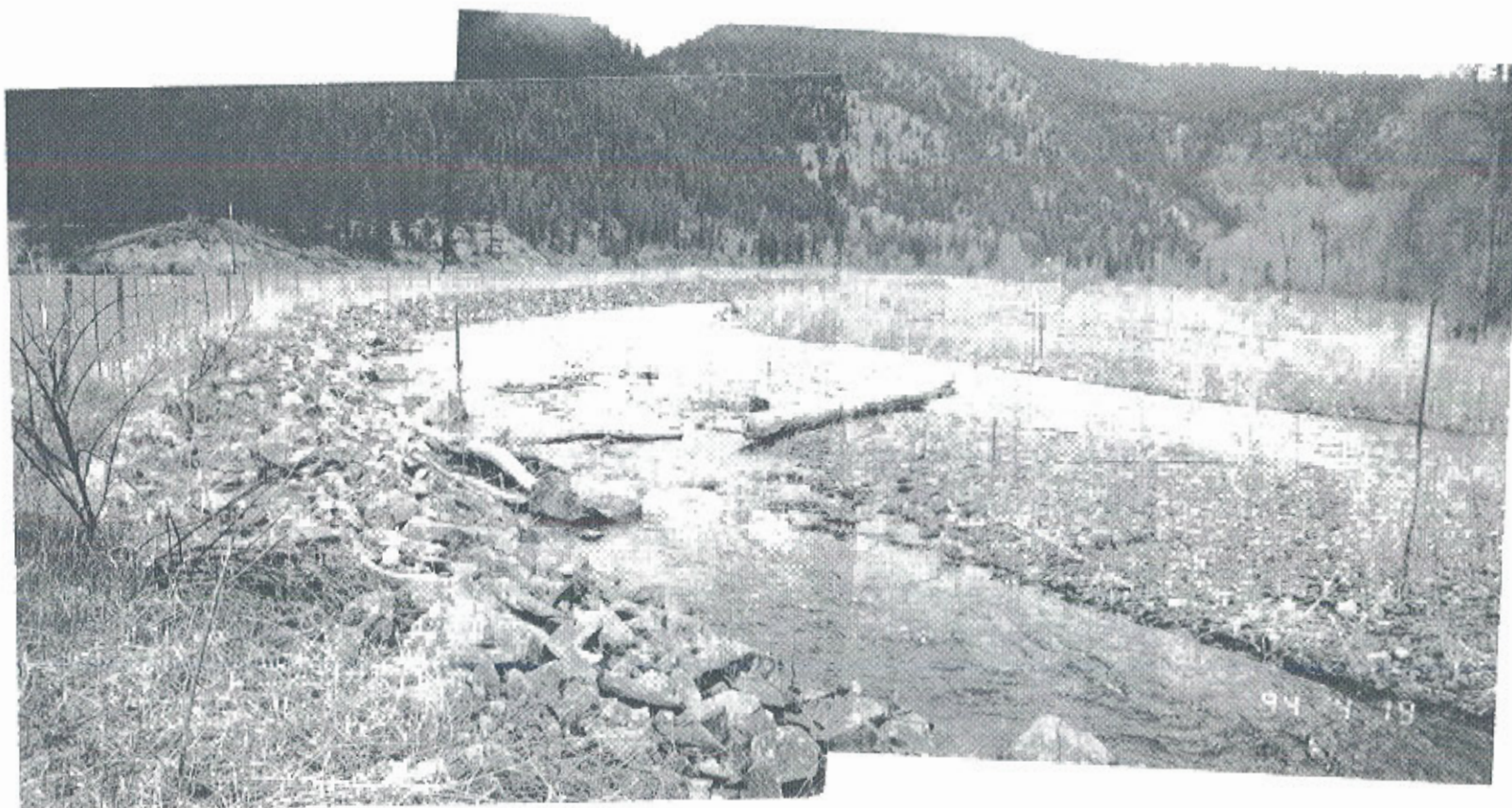


MM 94-03-18

Plate 3.2.4: Looking upstream on Deadman River below Gorge Creek, showing the stable character of well-vegetated banks.

92

Date of Photography: April 19, 1994.



MM 94-05-14 to 15

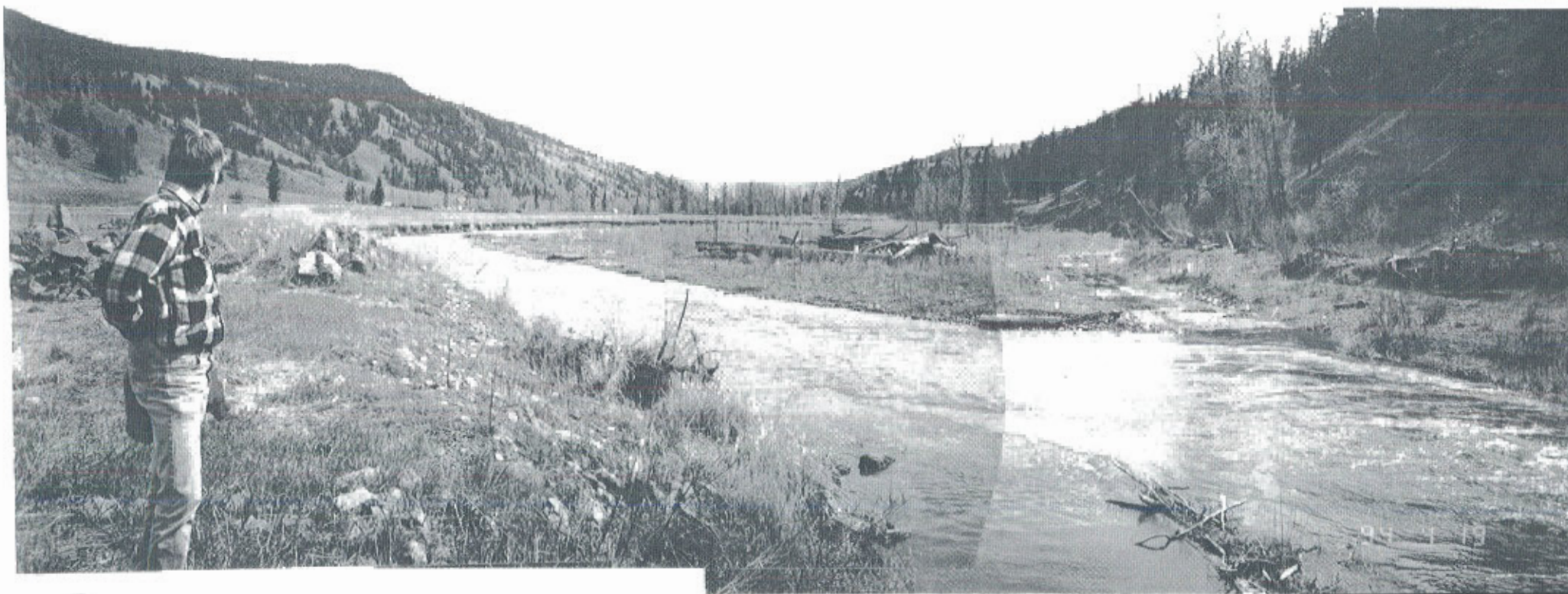
Plate 3.2.5: Looking upstream on rip-rap placed in the "Dockstader" Ranch. Note the single boulders used to enhance fisheries habitat values.

Date of Photography: April 19, 1994



MM 94-05-0

Plate 3.2.6: Looking along a breached and by-passed section of rip-rap on the "Dockstader" Ranch.



96

MM 94-06-28 to 30

Plate 3.2.7: Looking downstream towards an area of sediment accumulation which occurs immediately downstream of a rip-rapped section of channel on the Craig Ranch, showing the resulting erosion of pasture land.

Date of Photography: April 19, 1994



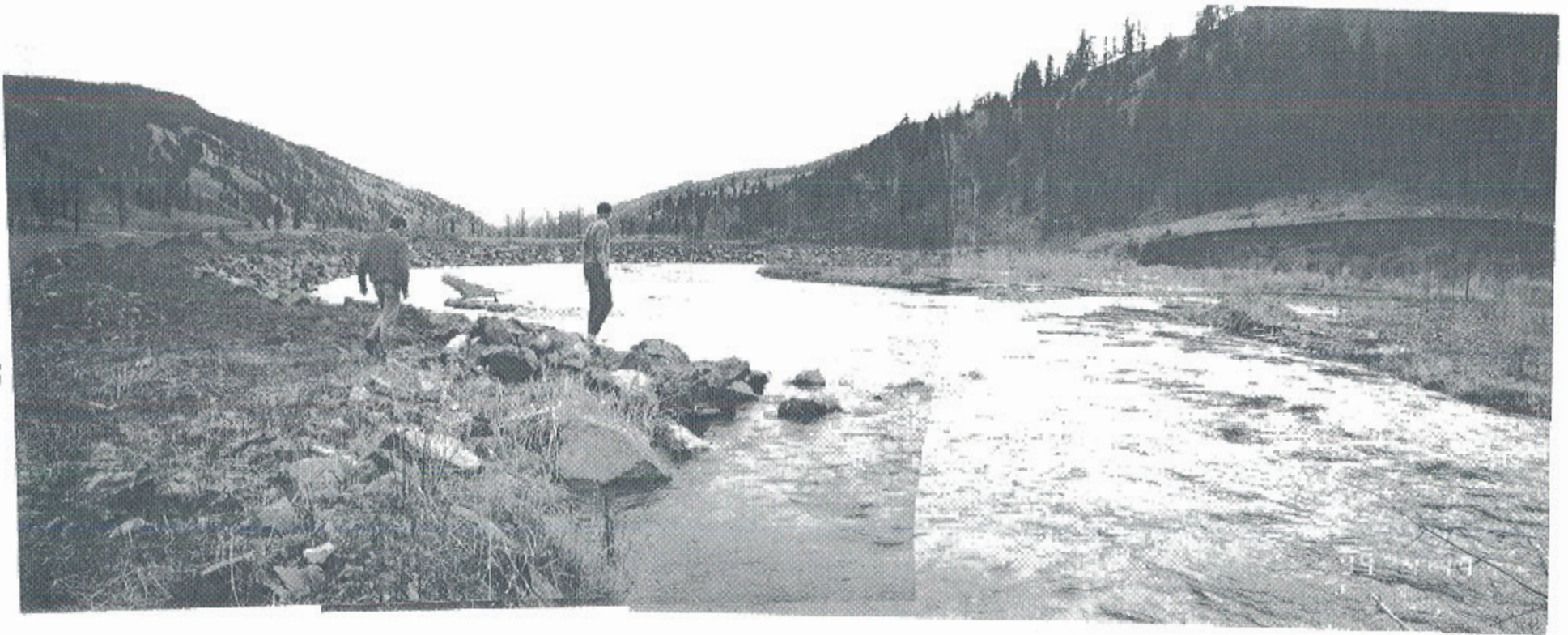
MM 94-06-18 to 22

8

Plate 3.2.8:

Looking downstream on Deadman River to an eroding section of valley wall located immediately downstream of a rip-rapped section of channel on the Craig Ranch.

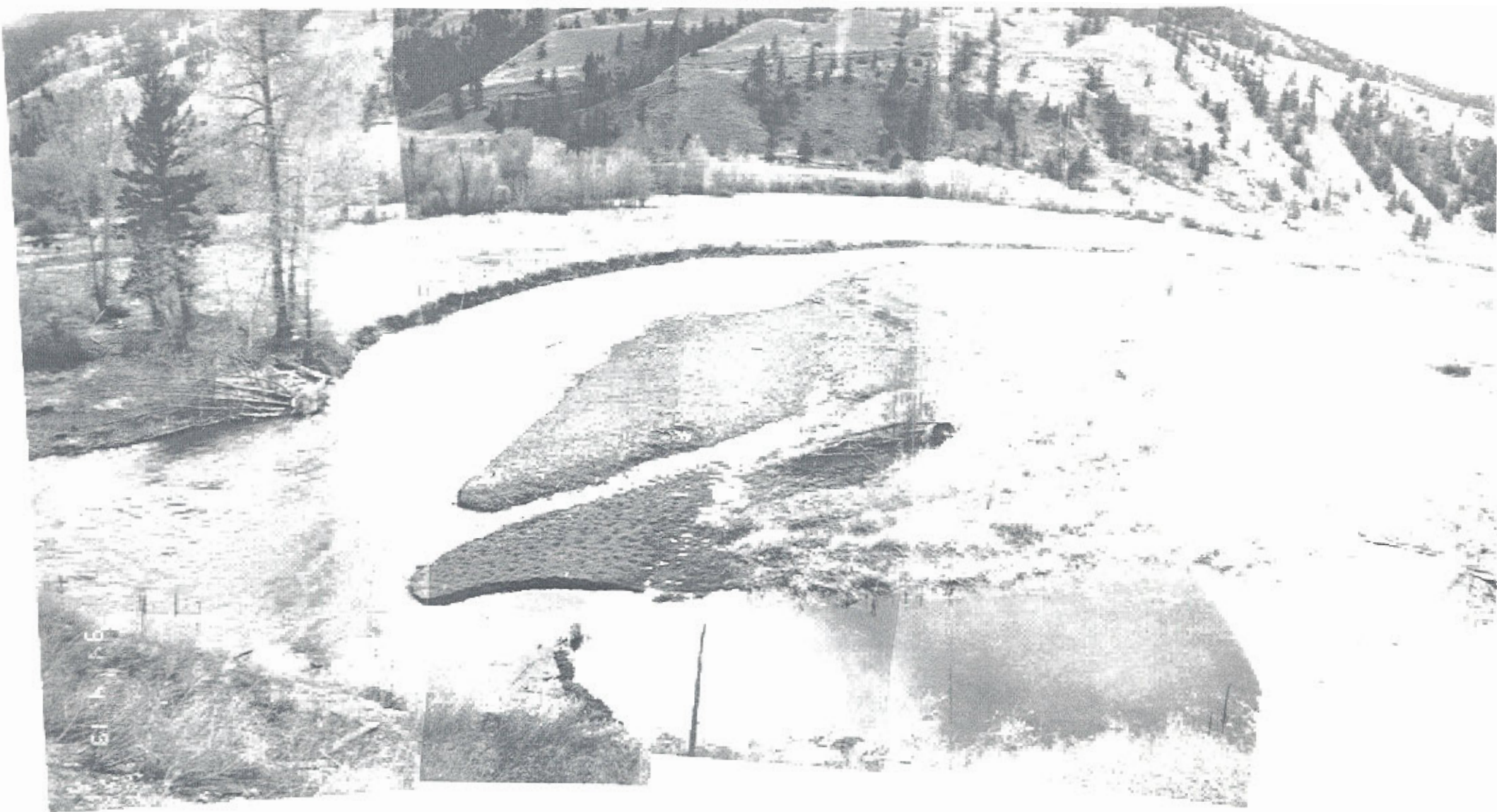
Date of Photography: April 19, 1994



MM 94-06-14 to 16

Plate 3.2.9: Looking downstream to a short spur placed on Deadman River in an attempt to direct the stream back into a former channel on the Craig Ranch.

Date of Photography: April 19, 1994



MM 94-06-33 - 37

Plate 3.2.10: Looking upstream to an eroding section of pasture and a large point bar on lower Deadman River. Note fencing and cabled debris.

98

Date of Photography: April 19, 1994.



Date of Photography: April 19, 1994

MM 94-04-16A

Plate 3.2.11: Broken fencing allowed cattle to heavily damage establishing woody vegetation, on the "Docksteader" Ranch.



MM 94-05-06

Plate 3.2.12: Looking upstream along fencing on the "Docksteader" Ranch, showing the establishment of burdock



Date of Photography: April 19, 1994

MM 94-05-26

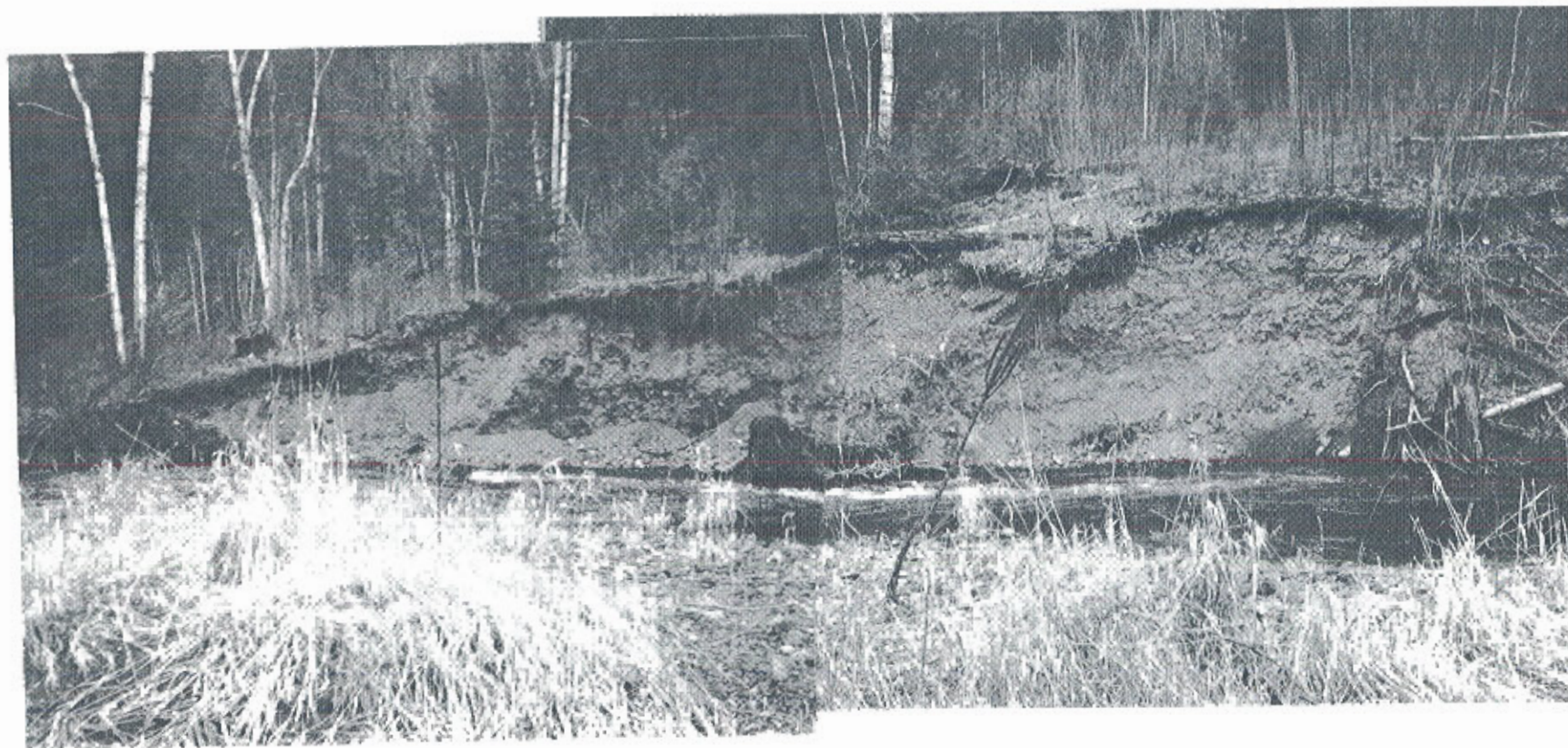
Plate 4.2.1: Looking downstream on Deadman River to an active talus slope located 200 m downstream from the outlet of Mowich Lake.



MM 94-05-35 to 37

Plate 4.2.2: Looking upstream to the terminus of an earth flow located approximately 700 m downstream of Mowich Lake.

Date of Photography: April 19, 1994



MM 94-05-19 to 20

Plate 4.2.3: Looking upstream to an eroding area on the left bank valley wall. Location is below Vern Bullwinger's property and 2 km upstream of the "Dockstader" Ranch.

Date of Photography: April 19, 1994



MM 94-05-28

Plate 4.2.4: Looking downstream from the 1st bridge below Mowich Lake showing an area where sidecast material (foreground) from skid road construction has entered Deadman River.



Date of Photography: April 19, 1994

MM 94-05-01

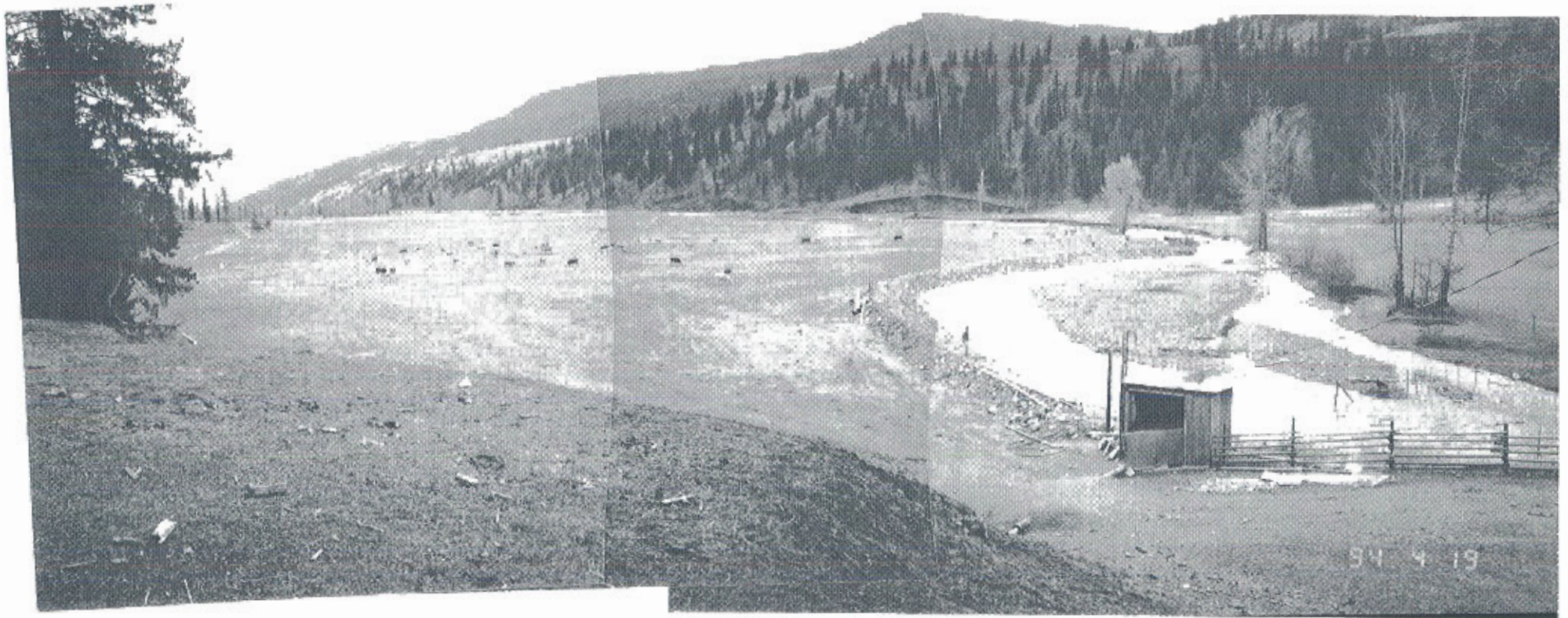
Plate 4.2.5. Logging skid trails on the left bank valley wall opposite
"Dockstader's" pasture



Date of Photography: April 19, 1994

MM 94-05-02

Plate 5.0.1: Looking upstream to a remnant back channel on the "Dockstader" Ranch. The channel was observed to contain considerable numbers of juvenile salmonids.



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MM 94-06-08 to 10

Plate 5.0.2: Looking downstream over the Craig Ranch showing river training works which force the river towards the right bank valley wall.

Date of Photography: April 19, 1994

APPENDIX 1

ANALYSIS OF ONE TO TEN-DAY PRECIPITATION TOTALS

(note: See Table 2.3.2 for *Kamloops A*)

TABLE A1-1: ANALYSIS OF PRECIPITATION INTENSITY-DURATION-FREQUENCY DATA

STATION NAME	PERIOD OF RECORD	TOTAL PRECIPITATION				OBSERVED VALUE			SPECIFIED RETURN PERIOD PRECIPITATION (mm)						PROBABLE MAXIMUM PRECIPITATION (mm)
		DURATION (days)	YEARS OF RECORD	MEAN VALUE (mm)	STANDARD DEVIATION (mm)	YEAR	VALUE (mm)	RETURN PERIOD (yrs)	2 YEARS	5 YEARS	10 YEARS	25 YEARS	50 YEARS	100 YEARS	
HIGHLAND VALLEY BCCL	1967-1988	1	14	21.2	5.5	1977	35.0	45.0	20.3	25.2	28.4	32.4	35.5	38.5	121.4
		2	14	27.9	8.2	1982	40.8	13.9	26.6	33.8	38.6	44.7	49.2	53.6	177.4
		3	14	32.5	11.0	1982	55.2	25.6	30.7	40.4	46.9	55.0	61.0	67.0	233.2
		4	14	35.4	12.0	1982	61.4	29.2	33.4	44.0	51.1	59.9	66.5	73.0	254.7
		5	14	37.5	12.9	1982	64.2	25.8	35.4	46.8	54.3	63.9	70.9	78.0	274.5
		6	14	38.9	13.3	1982	64.2	20.9	36.7	48.5	56.3	66.1	73.4	80.6	283.7
		7	14	40.0	14.0	1982	69.4	26.8	37.7	50.1	58.3	68.6	76.3	83.9	296.9
		8	14	43.9	16.7	1982	86.4	47.1	41.2	55.9	65.7	78.0	87.2	96.3	349.9
		9	14	46.6	16.8	1982	86.4	37.7	43.8	58.7	68.5	80.9	90.1	99.3	354.5
		10	14	47.8	17.2	1982	86.4	32.2	45.0	60.2	70.2	83.0	92.4	101.8	364.0
HIGHLAND VALLEY LOREX	1968-1992	1	23	24.7	6.8	1985	50.5	231.7	23.6	29.6	33.6	38.6	42.3	46.0	146.7
		2	23	33.7	12.1	1985	64.0	44.7	31.7	42.4	49.5	58.4	65.1	71.7	251.5
		3	23	38.4	13.4	1985	67.5	29.4	36.2	48.0	55.9	65.8	73.1	80.4	280.6
		4	23	42.9	16.5	1991	86.6	53.7	40.2	54.8	64.4	76.6	85.7	94.7	341.5
		5	23	47.2	16.9	82&91	88.6	41.7	44.4	59.4	69.3	81.7	91.0	100.2	353.5
		6	23	48.5	17.8	1982	97.7	62.2	45.6	61.3	71.7	84.9	94.6	104.3	371.6
		7	23	50.0	18.3	1982	102.7	72.1	47.0	63.2	73.9	87.4	97.4	107.4	382.8
		8	23	53.1	18.7	1982	105.2	64.0	50.0	66.5	77.5	91.3	101.6	111.8	393.3
		9	23	55.0	18.2	1982	107.4	72.0	52.0	68.1	78.8	92.2	102.2	112.1	386.9
		10	23	57.8	18.6	1982	110.4	67.5	54.7	71.2	82.1	95.8	106.0	116.1	397.8

NOTE: Shaded values exceed twice the period of record and are therefore potentially unreliable

TABLE A1-2: ANALYSIS OF PRECIPITATION INTENSITY-DURATION-FREQUENCY DATA

STATION NAME	PERIOD OF RECORD	TOTAL PRECIPITATION				OBSERVED VALUE			SPECIFIED RETURN PERIOD PRECIPITATION (mm)						PROBABLE MAXIMUM PRECIPITATION (mm)
		DURATION (days)	YEARS OF RECORD	MEAN VALUE (mm)	STANDARD DEVIATION (mm)	YEAR	VALUE (mm)	RETURN PERIOD (yrs)	2 YEARS	5 YEARS	10 YEARS	25 YEARS	50 YEARS	100 YEARS	
DARFIELD	1957-1992	1	35	23.1	7.4	1957	43.2	58.5	21.9	28.4	32.8	38.2	42.3	46.3	156.6
		2	35	29.5	10.3	1957	55.9	48.2	27.8	36.9	42.9	50.6	56.2	61.8	215.7
		3	35	33.5	10.4	1957	58.7	40.3	31.8	41.0	47.1	54.8	60.5	66.1	222.2
		4	35	36.1	11.5	1982	71.3	90.8	34.2	44.4	51.1	59.6	65.9	72.2	246.2
		5	35	39.4	13.5	1982	82.5	107.4	37.2	49.1	57.0	67.0	74.4	81.7	285.6
		6	35	43.1	15.0	1982	95.1	152.4	40.6	53.9	62.7	73.8	82.0	90.2	316.4
		7	35	46.8	15.8	1982	105.6	211.2	44.2	58.2	67.4	79.1	87.8	96.4	335.7
		8	35	49.5	16.5	1982	111.4	219.4	46.8	61.4	71.0	83.2	92.3	101.3	350.8
		9	35	51.9	17.8	1982	116.9	193.1	49.0	64.7	75.1	88.3	98.0	107.7	377.6
		10	35	53.5	18.2	1982	118.3	171.8	50.5	66.6	77.3	90.7	100.7	110.6	385.9
KAMLOOPS	1896-1981	1	73	20.5	6.8	1976	45.7	207.0	19.4	25.4	29.4	34.4	38.1	41.8	143.8
		2	73	25.3	8.2	1924	48.5	67.6	24.0	31.2	36.0	42.1	46.6	51.0	174.7
		3	73	27.8	8.9	1924	49.3	40.0	26.3	34.2	39.4	46.0	50.9	55.7	190.2
		4	73	29.7	9.3	1912	53.6	48.6	28.2	36.4	41.8	48.7	53.8	58.9	201.2
		5	73	31.8	10.0	1912	57.7	49.9	30.2	39.0	44.9	52.2	57.7	63.2	216.6
		6	73	34.2	11.1	1976	71.7	136.2	32.4	42.2	48.7	56.9	63.0	69.0	238.2
		7	73	36.1	11.8	1976	72.2	90.6	34.2	44.6	51.5	60.2	66.7	73.1	252.8
		8	73	37.9	11.9	1976	72.7	76.3	35.9	46.5	53.4	62.2	68.7	75.2	256.7
		9	73	39.8	12.4	1976	80.8	124.2	37.8	48.7	56.0	65.1	71.9	78.7	267.7
		10	73	42.2	13.2	1976	80.8	76.3	40.0	51.7	59.4	69.2	76.4	83.6	286.5

NOTE: Shaded values exceed twice the period of record and are therefore potentially unreliable

TABLE A1-3: ANALYSIS OF PRECIPITATION INTENSITY-DURATION-FREQUENCY DATA

STATION NAME	PERIOD OF RECORD	TOTAL PRECIPITATION				OBSERVED VALUE			SPECIFIED RETURN PERIOD PRECIPITATION (mm)						PROBABLE MAXIMUM PRECIPITATION (mm)
		DURATION (days)	YEARS OF RECORD	MEAN VALUE (mm)	STANDARD DEVIATION (mm)	YEAR	VALUE (mm)	RETURN PERIOD (yrs)	2 YEARS	5 YEARS	10 YEARS	25 YEARS	50 YEARS	100 YEARS	
LOON LAKE	1970-1989	1	15	22.2	12.7	1972	61.0	90.1	20.1	31.3	38.8	48.2	55.1	62.0	252.6
		2	15	28.2	12.1	1972	61.0	58.1	26.2	36.9	44.0	52.9	59.6	66.2	248.5
		3	15	32.0	11.3	1972	61.0	48.4	30.1	40.1	46.7	55.1	61.3	67.4	238.8
		4	15	34.6	11.8	1972	61.0	31.9	32.7	43.1	50.0	58.7	65.2	71.6	251.4
		5	15	36.3	12.0	1980	63.2	32.1	34.3	44.9	52.0	60.8	67.4	73.9	257.0
		6	15	37.5	12.8	1980	70.8	50.6	35.4	46.7	54.2	63.7	70.7	77.7	272.4
		7	15	38.6	13.8	1980	75.4	55.0	36.3	48.5	56.6	66.8	74.4	81.9	291.7
		8	15	42.4	14.7	1980	80.4	49.5	40.0	53.0	61.6	72.4	80.5	88.5	311.8
		9	15	44.8	15.5	1980	88.0	64.0	42.3	55.9	65.0	76.5	85.0	93.4	329.9
		10	15	46.1	15.6	1980	91.6	75.5	43.5	57.3	66.5	78.0	86.5	95.0	333.3
MCLURE	1968-1992	1	23	20.9	5.3	1992	34.6	49.5	20.0	24.7	27.8	31.7	34.6	37.5	117.6
		2	23	26.4	5.9	1969	37.3	19.5	25.4	30.6	34.1	38.5	41.7	44.9	134.1
		3	23	29.3	5.8	1985	40.8	23.2	28.3	33.5	36.9	41.2	44.3	47.5	135.0
		4	23	33.0	6.7	1992	56.8	170.0	31.9	37.8	41.7	46.7	50.4	54.0	156.1
		5	23	36.5	8.2	1992	58.2	53.6	35.2	42.4	47.2	53.3	57.8	62.2	187.3
		6	23	39.2	9.8	1976	63.2	41.7	37.6	46.2	52.0	59.2	64.6	69.9	219.0
		7	23	41.7	9.8	1976	66.2	44.5	40.1	48.7	54.5	61.7	67.1	72.4	221.1
		8	23	44.6	10.1	1976	66.2	28.2	42.9	51.9	57.8	65.2	70.8	76.3	229.1
		9	23	47.6	11.1	1976	71.0	27.1	45.8	55.6	62.1	70.3	76.4	82.4	251.2
		10	23	50.7	12.3	1971	75.1	23.2	48.7	59.5	66.8	75.8	82.6	89.3	276.1

NOTE: Shaded values exceed twice the period of record and are therefore potentially unreliable

TABLE A1-4: ANALYSIS OF PRECIPITATION INTENSITY-DURATION-FREQUENCY DATA

STATION NAME	PERIOD OF RECORD	TOTAL PRECIPITATION				OBSERVED VALUE			SPECIFIED RETURN PERIOD PRECIPITATION (mm)						PROBABLE MAXIMUM PRECIPITATION (mm)
		DURATION (days)	YEARS OF RECORD	MEAN VALUE (mm)	STANDARD DEVIATION (mm)	YEAR	VALUE (mm)	RETURN PERIOD (yrs)	2 YEARS	5 YEARS	10 YEARS	25 YEARS	50 YEARS	100 YEARS	
MT LOLO KAMLOOPS	1965-1976	1	12	30.5	14.5	1976	69.9	58.6	28.1	40.9	49.4	60.1	68.1	76.0	287.4
		2	12	38.2	14.2	1976	71.9	37.9	35.9	48.4	56.7	67.2	75.0	82.7	292.2
		3	12	43.7	16.1	1976	85.1	48.7	41.1	55.3	64.7	76.6	85.4	94.2	333.5
		4	12	47.9	16.3	1976	89.4	47.1	45.2	59.6	69.2	81.2	90.1	99.0	342.0
		5	12	50.5	15.6	1976	91.4	51.9	47.9	61.7	70.9	82.4	90.9	99.4	332.7
		6	12	55.8	21.4	1976	117.3	71.5	52.3	71.2	83.7	99.5	111.3	122.9	441.8
		7	12	57.8	21.9	1976	119.3	65.8	54.2	73.5	86.4	102.6	114.6	126.5	453.3
		8	12	61.2	21.9	1976	119.3	54.0	57.6	76.9	89.8	106.0	118.0	129.9	458.3
		9	12	63.9	24.9	1976	131.0	57.0	59.8	81.8	96.4	114.8	128.4	142.0	515.5
		10	12	67.7	25.7	1976	135.3	52.5	63.5	86.2	101.2	120.2	134.3	148.3	532.8

NOTE: Shaded values exceed twice the period of record and are therefore potentially unreliable

APPENDIX 2

**RELATIONSHIP BETWEEN CLIMATOLOGICAL PARAMETERS
AT *KAMLOOPS* AND *KAMLOOPS A* DURING THE
PERIOD BETWEEN 1951 AND 1982**

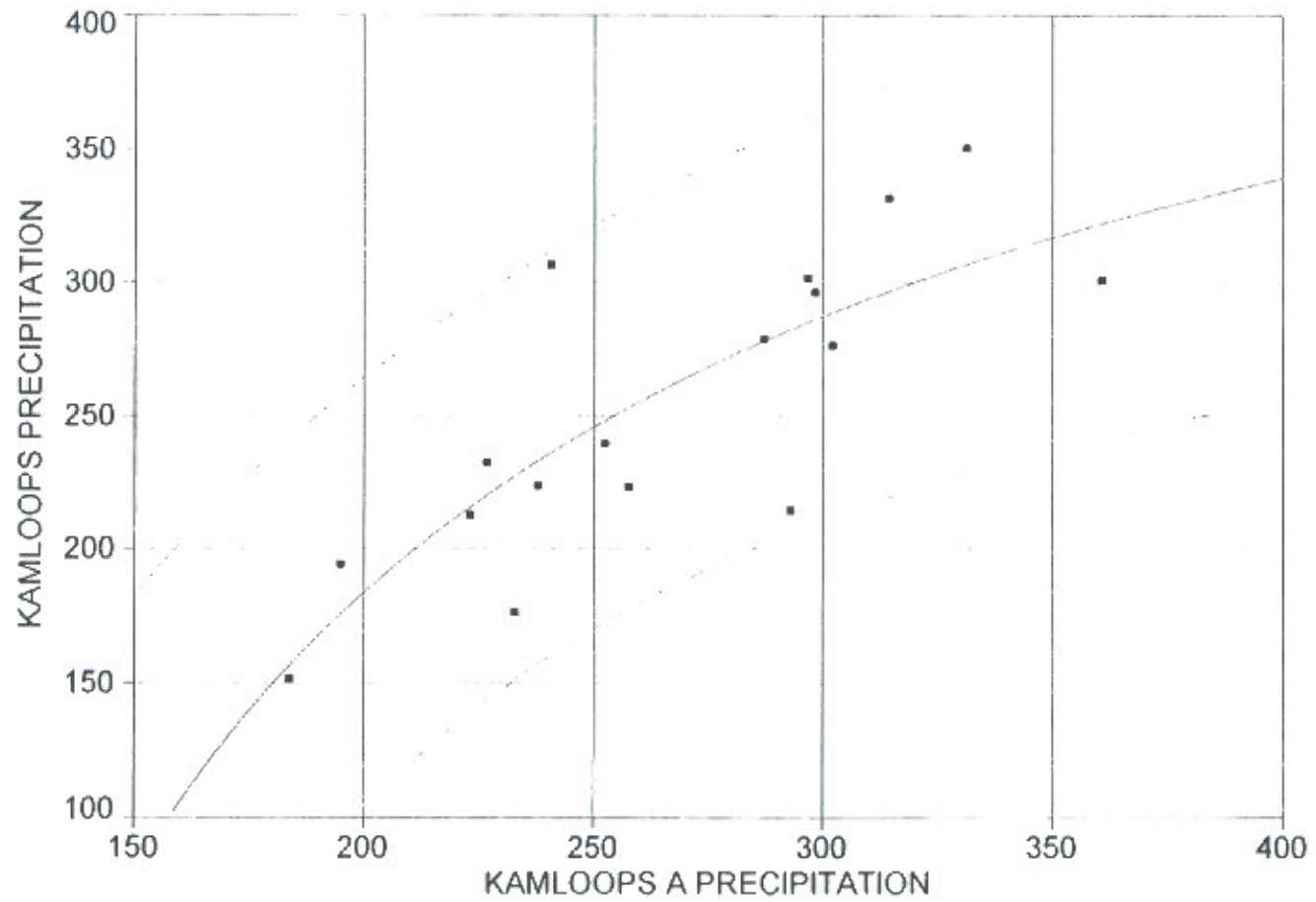
KAMLOOPS vs KAMLOOPS A TOTAL PRECIPITATION

Rank 6 Eqn 17 $y=a+b/x$

$r^2=0.652582731$ DF Adj $r^2=0.602951693$ FitStdErr=34.5190092 Fstat=28.1757467

a=494.10618

b=-62111.651



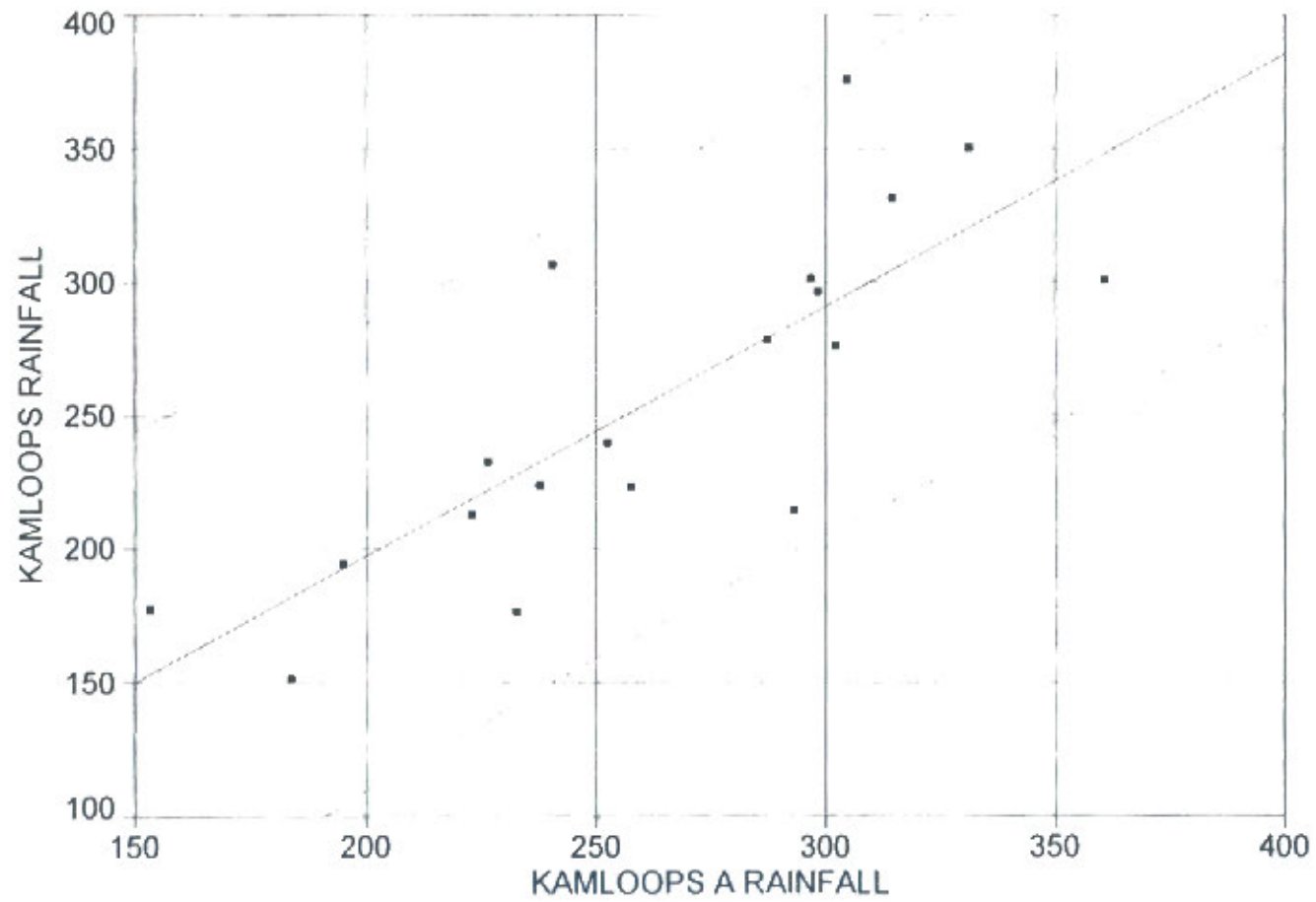
KAMLOOPS vs KAMLOOPS A TOTAL RAINFALL

Rank 1 Eqn 1 $y=a+bx$

$r^2=0.63830224$ DF Adj $r^2=0.59309002$ FitStdErr=39.1698981 Fstat=30.0005676

$a=8.8101691$

$b=0.94048166$



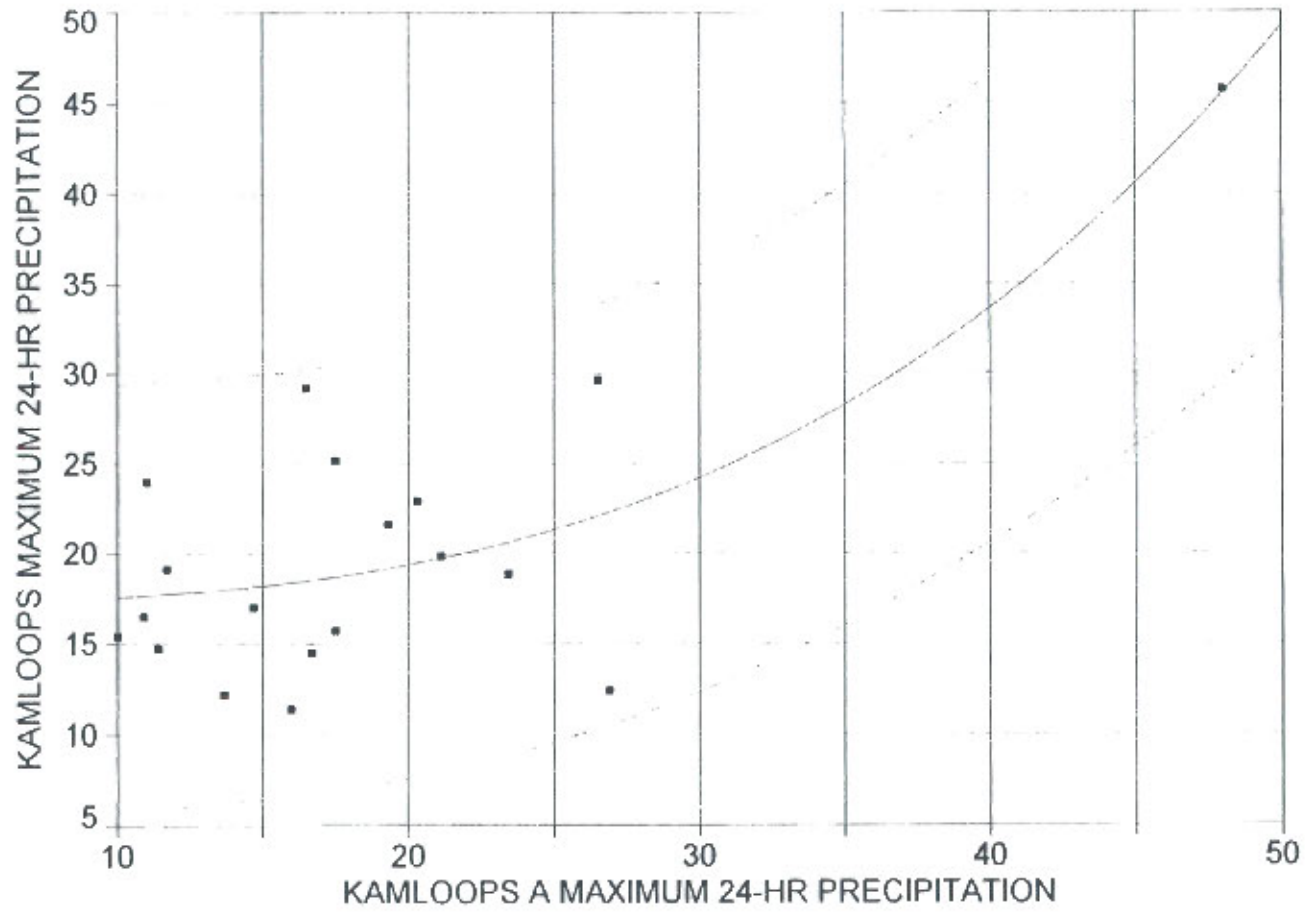
KAMLOOPS vs KAMLOOPS A MAXIMUM 24-HR PRECIPITATION

Rank 1 Eqn 7 $y=a+bx^3$

$r^2=0.585892725$ DF Adj $r^2=0.534129315$ FitStdErr=5.41486323 Fstat=24.0521645

a=17.310864

b=0.00025485177

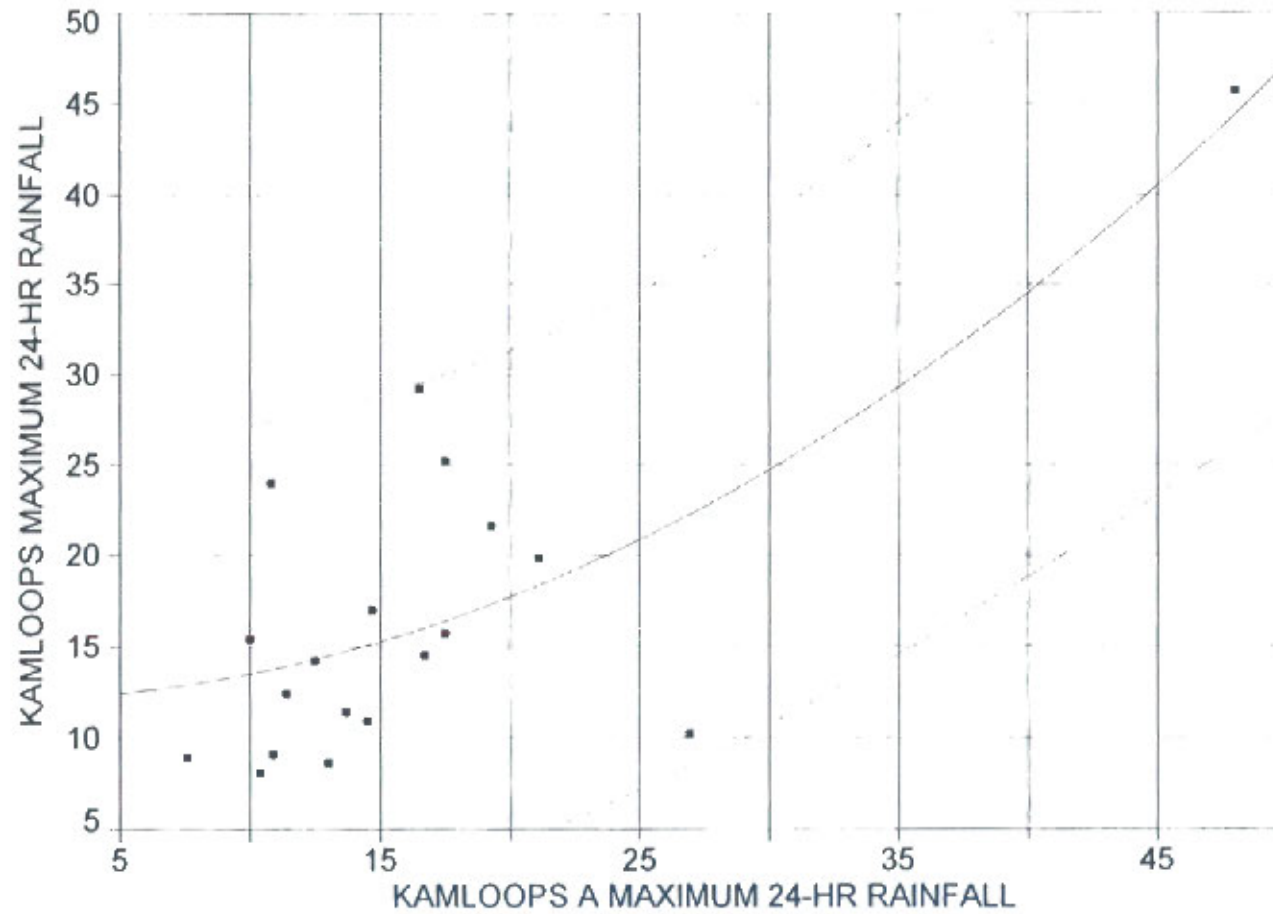


KAMLOOPS vs KAMLOOPS A MAXIMUM 24-HR RAINFALL

Rank 1 Eqn 4 $y=a+bx^2$ $r^2=0.567842092$ DF Adj $r^2=0.513822353$ FitStdErr=6.27675945 Fstat=22.3374729

a=12.087915

b=0.014017597



APPENDIX 3

FLOOD FREQUENCY ANALYSES

TABLE A3-1: BONAPARTE RIVER BELOW CACHE CREEK

PERIOD OF RECORD:		1912 to 1993										BASIN AREA:		5,020 km ²	
YEARS OF RECORD:		31		FREQUENCY ANALYSIS OF ANNUAL MAXIMUM DAILY DISCHARGE								COEFFICIENT OF SKEW:		1.42	
FREQUENCY DISTRIBUTION	PREDICTED DISCHARGE (m ³ /s) FOR A RETURN PERIOD OF:														
	2 Yrs		5 Yrs		10 Yrs		25 Yrs		50 Yrs		100 Yrs		200 Yrs		
LOG NORMAL (Maximum Likelihood)	23		38		49		64		75		86		98		
GUMBEL (Maximum Likelihood)	24		38		47		59		67		76		85		
PEARSON TYPE III (By Moments)	23		39		49		63		73		83		92		
LOG PEARSON TYPE III (By Moments)	23		39		50		63		72		80		88		
ADOPTED VALUE	23		39		50		63		72		80		88		
FREQUENCY DISTRIBUTION	95% CONFIDENCE LIMITS (m ³ /s) FOR A RETURN PERIOD OF:														
	2 Yrs		5 Yrs		10 Yrs		25 Yrs		50 Yrs		100 Yrs		200 Yrs		
	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	
LOG NORMAL (Maximum Likelihood)	18	29	30	49	37	64	46	87	53	105	59	124	66	145	
GUMBEL (Maximum Likelihood)	18	29	30	46	37	58	45	72	51	83	58	94	64	105	
PEARSON TYPE III (By Moments)	17	28	28	49	35	64	43	83	49	97	55	110	61	124	
LOG PEARSON TYPE III (By Moments)	18	30	27	58	33	77	39	103	42	121	46	139	49	156	
ADOPTED VALUE	17	30	27	58	33	77	39	103	42	121	46	139	49	156	
NOTES:															
Analytical procedures used to prepare this summary were made available by the Surface Water Section, Water Management Branch, B.C. Ministry of Environment. This assistance is gratefully acknowledged.															

TABLE A3-2: BONAPARTE RIVER BELOW CACHE CREEK

PERIOD OF RECORD:	1976 to 1993		BASIN AREA:	5,020 km ²										
YEARS OF RECORD:	18		FREQUENCY ANALYSIS OF ANNUAL MAXIMUM INSTANTANEOUS DISCHARGE	COEFFICIENT OF SKEW: 1.984										
FREQUENCY DISTRIBUTION	PREDICTED DISCHARGE (m ³ /s) FOR A RETURN PERIOD OF:													
	2 Yrs		5 Yrs		10 Yrs		25 Yrs		50 Yrs		100 Yrs		200 Yrs	
LOG NORMAL (Maximum Likelihood)	22		39		52		69		83		98		114	
GUMBEL (Maximum Likelihood)	24		38		47		59		68		77		85	
PEARSON TYPE III (By Moments)	21		39		52		70		83		96		109	
LOG PEARSON TYPE III (By Moments)	23		40		52		68		80		82		104	
ADOPTED VALUE	23		40		52		68		80		92		104	
FREQUENCY DISTRIBUTION	95% CONFIDENCE LIMITS (m ³ /s) FOR A RETURN PERIOD OF:													
	2 Yrs		5 Yrs		10 Yrs		25 Yrs		50 Yrs		100 Yrs		200 Yrs	
	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper
LOG NORMAL (Maximum Likelihood)	16	31	27	56	34	78	42	112	48	141	54	174	61	212
GUMBEL (Maximum Likelihood)	16	31	27	49	33	62	41	78	46	90	52	102	57	114
PEARSON TYPE III (By Moments)	14	28	22	55	27	77	32	107	37	129	41	152	45	174
LOG PEARSON TYPE III (By Moments)	16	32	25	64	30	90	36	127	41	157	45	189	48	223
ADOPTED VALUE	14	32	22	64	27	90	32	127	37	157	41	189	45	223
NOTES:														
Analytical procedures used to prepare this summary were made available by the Surface Water Section, Water Management Branch, B.C. Ministry of Environment. This assistance is gratefully acknowledged.														

TABLE A3-3: CRISS CREEK NEAR SAVONA

PERIOD OF RECORD:		1913 to 1993						BASIN AREA:		490 km ²					
YEARS OF RECORD:		41		FREQUENCY ANALYSIS OF ANNUAL MAXIMUM DAILY DISCHARGE						COEFFICIENT OF SKEW:		1.315			
FREQUENCY DISTRIBUTION		PREDICTED DISCHARGE (m ³ /s) FOR A RETURN PERIOD OF:													
		2 Yrs		5 Yrs		10 Yrs		25 Yrs		50 Yrs		100 Yrs		200 Yrs	
LOG NORMAL (Maximum Likelihood)		18		27		34		44		52		61		71	
GUMBEL (Maximum Likelihood)		19		27		32		38		43		47		52	
PEARSON TYPE III (By Moments)		19		28		34		42		48		53		59	
LOG PEARSON TYPE III (By Moments)		19		27		34		43		51		60		69	
ADOPTED VALUE		19		27		34		43		51		60		69	
FREQUENCY DISTRIBUTION		95% CONFIDENCE LIMITS (m ³ /s) FOR A RETURN PERIOD OF:													
		2 Yrs		5 Yrs		10 Yrs		25 Yrs		50 Yrs		100 Yrs		200 Yrs	
		Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper
LOG NORMAL (Maximum Likelihood)		16	21	23	33	28	43	34	59	38	72	43	87	48	104
GUMBEL (Maximum Likelihood)		17	22	23	31	27	37	32	44	35	50	39	56	42	62
PEARSON TYPE III (By Moments)		16	22	23	33	28	41	33	52	37	59	40	66	44	73
LOG PEARSON TYPE III (By Moments)		16	21	23	32	27	42	33	56	38	69	43	83	48	100
ADOPTED VALUE		16	22	23	33	27	43	32	59	35	72	40	87	42	104
NOTES:															
Analytical procedures used to prepare this summary were made available by the Surface Water Section, Water Management Branch, B.C. Ministry of Environment. This assistance is gratefully acknowledged.															

TABLE A3-4: CRISS CREEK NEAR SAVONA

PERIOD OF RECORD:		1976 to 1993						BASIN AREA:		490 km ²				
YEARS OF RECORD:		13		FREQUENCY ANALYSIS OF ANNUAL MAXIMUM INSTANTANEOUS DISCHARGE						COEFFICIENT OF SKEW:		2.421		
FREQUENCY DISTRIBUTION	PREDICTED DISCHARGE (m ³ /s) FOR A RETURN PERIOD OF:													
	2 Yrs		5 Yrs		10 Yrs		25 Yrs		50 Yrs		100 Yrs		200 Yrs	
LOG NORMAL (Maximum Likelihood)	18		27		34		45		55		65		77	
GUMBEL (Maximum Likelihood)	19		26		31		37		41		46		50	
PEARSON TYPE III (By Moments)	17		27		35		46		54		63		72	
LOG PEARSON TYPE III (By Moments)	18		26		34		45		55		67		82	
ADOPTED VALUE	18		26		34		45		55		67		82	
FREQUENCY DISTRIBUTION	95% CONFIDENCE LIMITS (m ³ /s) FOR A RETURN PERIOD OF:													
	2 Yrs		5 Yrs		10 Yrs		25 Yrs		50 Yrs		100 Yrs		200 Yrs	
	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper
LOG NORMAL (Maximum Likelihood)	14	24	19	40	22	56	26	84	29	111	32	143	35	182
GUMBEL (Maximum Likelihood)	14	23	19	33	22	40	25	48	28	55	30	61	33	68
PEARSON TYPE III (By Moments)	12	21	15	38	15	54	16	76	16	93	16	110	16	128
LOG PEARSON TYPE III (By Moments)	14	23	18	39	20	55	24	86	26	119	29	158	32	211
ADOPTED VALUE	12	24	15	40	15	56	16	86	16	119	16	158	16	211
NOTES:														
Analytical procedures used to prepare this summary were made available by the Surface Water Section, Water Management Branch, B.C. Ministry of Environment. This assistance is gratefully acknowledged.														

TABLE A3-5: DEADMAN RIVER ABOVE CRISS CREEK

PERIOD OF RECORD: 1913 to 1993		BASIN AREA: 862 km ²												
YEARS OF RECORD: 41		FREQUENCY ANALYSIS OF ANNUAL MAXIMUM DAILY DISCHARGE										COEFFICIENT OF SKEW: 2.371		
FREQUENCY DISTRIBUTION	PREDICTED DISCHARGE (m ³ /s) FOR A RETURN PERIOD OF:													
	2 Yrs		5 Yrs		10 Yrs		25 Yrs		50 Yrs		100 Yrs		200 Yrs	
LOG NORMAL (Maximum Likelihood)	11		20		26		34		41		48		56	
GUMBEL (Maximum Likelihood)	12		19		24		30		35		39		43	
PEARSON TYPE III (By Moments)	10		19		27		37		44		52		60	
LOG PEARSON TYPE III (By Moments)	12		20		26		34		39		44		49	
ADOPTED VALUE	12		20		26		34		39		44		49	
FREQUENCY DISTRIBUTION	95% CONFIDENCE LIMITS (m ³ /s) FOR A RETURN PERIOD OF:													
	2 Yrs		5 Yrs		10 Yrs		25 Yrs		50 Yrs		100 Yrs		200 Yrs	
	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper
LOG NORMAL (Maximum Likelihood)	9.1	14	16	25	20	33	25	46	29	57	34	69	38	82
GUMBEL (Maximum Likelihood)	9.7	14	16	23	19	29	24	36	27	42	31	47	34	53
PEARSON TYPE III (By Moments)	7.9	12	14	25	17	36	22	51	26	63	30	75	34	86
LOG PEARSON TYPE III (By Moments)	9.1	15	15	28	18	38	22	51	25	61	28	71	30	81
ADOPTED VALUE	8	15	14	28	17	38	22	51	25	63	28	71	30	82
NOTES:														
Analytical procedures used to prepare this summary were made available by the Surface Water Section, Water Management Branch, B.C. Ministry of Environment. This assistance is gratefully acknowledged.														

TABLE A3-6: HELLER CREEK ABOVE DIVERSIONS

PERIOD OF RECORD: 1983 to 1993		BASIN AREA: 46.6 km ²												
YEARS OF RECORD: 10		FREQUENCY ANALYSIS OF ANNUAL MAXIMUM DAILY DISCHARGE								COEFFICIENT OF SKEW: 1.961				
FREQUENCY DISTRIBUTION	PREDICTED DISCHARGE (m ³ /s) FOR A RETURN PERIOD OF:													
	2 Yrs		5 Yrs		10 Yrs		25 Yrs		50 Yrs		100 Yrs		200 Yrs	
LOG NORMAL (Maximum Likelihood)	4.33		5.92		7.09		8.69		9.96		11		13	
GUMBEL (Maximum Likelihood)	4.42		5.74		6.62		7.73		8.56		9.37		10	
PEARSON TYPE III (By Moments)	4.15		5.89		7.20		8.93		10		12		13	
LOG PEARSON TYPE III (By Moments)	4.24		5.82		7.09		8.95		11		12		14	
ADOPTED VALUE	4.2		5.8		7.1		9		11		12		14	
FREQUENCY DISTRIBUTION	95% CONFIDENCE LIMITS (m ³ /s) FOR A RETURN PERIOD OF:													
	2 Yrs		5 Yrs		10 Yrs		25 Yrs		50 Yrs		100 Yrs		200 Yrs	
	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper
LOG NORMAL (Maximum Likelihood)	3.44	5.63	4.34	8.40	4.84	11	5.41	15	5.81	18	6.18	22	6.55	27
GUMBEL (Maximum Likelihood)	3.43	5.40	4.23	7.25	4.69	8.6	5.22	10	5.61	12	5.99	13	6.36	14
PEARSON TYPE III (By Moments)	3.11	5.19	3.56	8.23	3.64	11	3.69	14	3.71	17	3.73	19	3.74	22
LOG PEARSON TYPE III (By Moments)	3.35	5.36	4.05	8.37	4.43	11	4.89	16	5.23	21	5.56	27	5.90	35
ADOPTED VALUE	3.1	3.2	3.6	8.4	3.6	11	3.7	16	3.7	21	3.7	27	3.7	35
NOTES:														
Analytical procedures used to prepare this summary were made available by the Surface Water Section, Water Management Branch, B.C. Ministry of Environment. This assistance is gratefully acknowledged.														

TABLE A3-7: JOE ROSS CREEK NEAR THE MOUTH

PERIOD OF RECORD:		1984 to 1993										BASIN AREA:		101 km ²	
YEARS OF RECORD:		10		FREQUENCY ANALYSIS OF ANNUAL MAXIMUM DAILY DISCHARGE								COEFFICIENT OF SKEW:		2.291	
FREQUENCY DISTRIBUTION		PREDICTED DISCHARGE (m ³ /s) FOR A RETURN PERIOD OF:													
		2 Yrs		5 Yrs		10 Yrs		25 Yrs		50 Yrs		100 Yrs		200 Yrs	
LOG NORMAL (Maximum Likelihood)		1.90		3.50		4.82		6.78		8.45		10		12	
GUMBEL (Maximum Likelihood)		2.09		3.41		4.29		5.39		6.21		7.03		7.84	
PEARSON TYPE III (By Moments)		1.72		3.69		5.27		7.40		9.04		11		12	
LOG PEARSON TYPE III (By Moments)		1.76		3.38		5.00		7.85		11		14		19	
ADOPTED VALUE		1.8		3.4		5		7.9		11		14		19	
FREQUENCY DISTRIBUTION		95% CONFIDENCE LIMITS (m ³ /s) FOR A RETURN PERIOD OF:													
		2 Yrs		5 Yrs		10 Yrs		25 Yrs		50 Yrs		100 Yrs		200 Yrs	
		Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper
LOG NORMAL (Maximum Likelihood)		1.13	3.19	1.91	6.41	2.39	10	2.96	16	3.38	21	3.79	28	4.19	36
GUMBEL (Maximum Likelihood)		1.11	3.07	1.91	4.91	2.36	6.2	2.89	7.9	3.28	9.2	3.66	10	4.03	12
PEARSON TYPE III (By Moments)		0.603	2.84	0.95	6.43	0.842	10	0.624	14	0.44	18	0.25	21	0.05	25
LOG PEARSON TYPE III (By Moments)		1.06	2.91	1.64	6.97	2.052	12	2.52	25	2.92	40	3.34	62	3.78	97
ADOPTED VALUE		1.1	3.2	1.6	7.0	2.1	12	2.5	25	2.9	40	3.3	62	3.8	97
<p>NOTES:</p> <p>Analytical procedures used to prepare this summary were made available by the Surface Water Section, Water Management Branch, B.C. Ministry of Environment. This assistance is gratefully acknowledged.</p>															

TABLE A3-8: JOE ROSS CREEK NEAR THE MOUTH

PERIOD OF RECORD:		1984 to 1993						BASIN AREA:		101 km ²				
YEARS OF RECORD:		10		FREQUENCY ANALYSIS OF ANNUAL MAXIMUM INSTANTANEOUS DISCHARGE						COEFFICIENT OF SKEW:		2.427		
FREQUENCY DISTRIBUTION	PREDICTED DISCHARGE (m ³ /s) FOR A RETURN PERIOD OF:													
	2 Yrs		5 Yrs		10 Yrs		25 Yrs		50 Yrs		100 Yrs		200 Yrs	
LOG NORMAL (Maximum Likelihood)	2.05		3.87		5.4		7.69		9.66		12		14	
GUMBEL (Maximum Likelihood)	2.29		3.79		4.79		6.05		6.98		7.91		8.83	
PEARSON TYPE III (By Moments)	1.81		4.12		6.02		8.63		11		13		15	
LOG PEARSON TYPE III (By Moments)	1.87		3.72		5.61		9.1		13		18		24	
ADOPTED VALUE	1.9		3.7		5.6		9.1		13		18		24	
FREQUENCY DISTRIBUTION	95% CONFIDENCE LIMITS (m ³ /s) FOR A RETURN PERIOD OF:													
	2 Yrs		5 Yrs		10 Yrs		25 Yrs		50 Yrs		100 Yrs		200 Yrs	
	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper
LOG NORMAL (Maximum Likelihood)	1.20	3.52	2.07	7.25	2.61	11	3.26	18	3.73	25	4.20	34	4.67	44
GUMBEL (Maximum Likelihood)	1.17	3.40	2.08	5.51	2.60	6.99	3.20	8.89	3.64	10	4.07	12	4.49	13
PEARSON TYPE III (By Moments)	0.519	3.11	0.859	7.39	0.627	11	0.219	17	n/a	21	n/a	26	n/a	30
LOG PEARSON TYPE III (By Moments)	1.12	3.15	1.73	7.98	2.13	15	2.67	31	3.10	52	3.56	86	4.06	140
ADOPTED VALUE	1.1	3.5	1.7	8.0	2.1	15	2.7	31	3.1	52	3.6	86	4.1	140
NOTES:														
Analytical procedures used to prepare this summary were made available by the Surface Water Section, Water Management Branch, B.C. Ministry of Environment. This assistance is gratefully acknowledged.														

APPENDIX 4

**GOVERNMENT REPORTS DISCUSSING THE EFFECTS OF FOREST
HARVESTING ON THE JUNE 1990 FLOOD**

KAMLOOPS FOREST DISTRICT

From:

KAMLOOPS REGION

Attention: Martin Lindberg
Operations Manager

Date: August 17, 1990

Our File: 08LF027 985-5-K

Your File:

RE: HYDROLOGIC EFFECTS OF CLEARCUT LOGGING IN THE
DEADMAN RIVER WATERSHED

Based on information supplied by your District, the following comments are made on the hydrologic effects of clearcut logging in the Deadman River Watershed, including the Criss Creek sub-watershed.

1. The watershed area of Deadman River above Criss Creek at the Water Survey of Canada (WSC) hydrometric station #08LF027 is 862 km² (336 mi²), with elevation ranging from 600 m to 1590 m and above the sea level (Fig. 1) median elevation of 1150 m. Since 1985, a total of 1802 ha or approximately 2.1 percent of the watershed has been clearcut logged.
2. The drainage area of Criss Creek above the WSC hydrometric station (#08LF007) is 490 km². Since 1985, a total of 593.3 ha or 1.2 percent of this watershed has been clearcut logged.
3. The peak flows in the Region within which the Deadman River watershed is located, normally occur from Mid-May to Mid-June as a result of snowmelt plus rain fall. Flows measured at both Dead River and Criss Creek hydrometric stations are regulated. The only nearby hydrometric station with natural flow data is at Watching Creek WSC station (1962-74). This station has a maximum recorded peak flow of 10.1 m³/s on May 30, 1972.
4. It is not likely that the current level of clearcut logging should cause a significant increase in snow and/or rain generated peak flows at main stem Deadman River or Criss Creek for the following reasons.

...2

Copy to DSR.

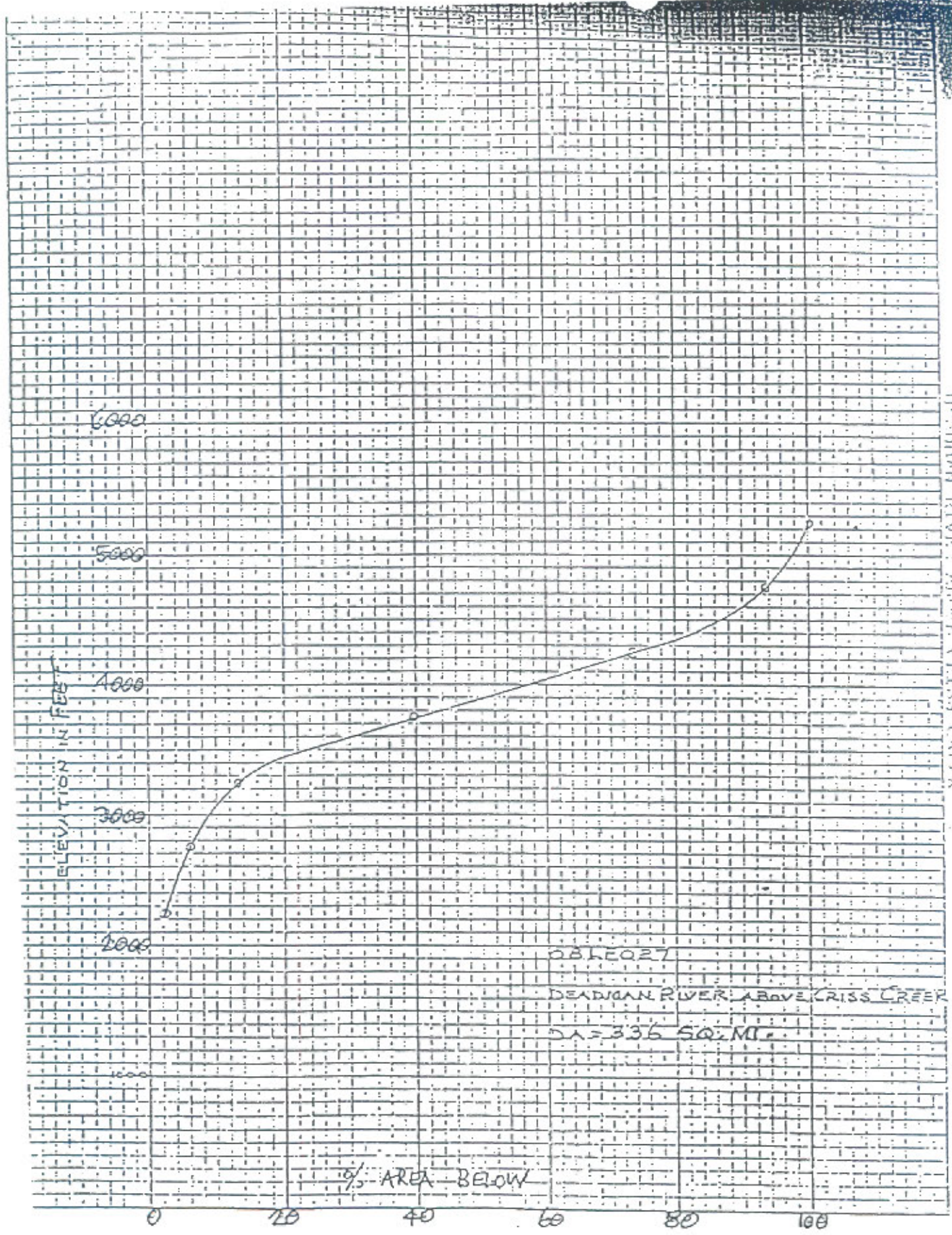
- a. The small percentage of either watershed that has been clearcut logged.
 - b. The relatively gentle terrain on which most cut blocks are located.
 - c. There are some lakes that provide flow regulation effects.
5. For future logging in the drainage, efforts should be made to avoid site specific problems by not causing logged blocks to exceed 30 percent of any major sub-watershed and by not creating large cut blocks. Preferably, cut blocks should be limited to less than 20 ha in size.



J.D. Cheng
Regional Hydrologist

JC/lr/1183r

DEADMAN RIVER ABOVE CRISS CREEK



081E027
DEADMAN RIVER ABOVE CRISS CREEK
DA = 336 SQ. MI.

To: KAMLOOPS FOREST DISTRICT

ATTENTION: B. Read,
Operations Manager, Harvesting

From: Kamloops Region
Sedimentation in Deadman Cr.

Date: November 1, 1990

Our File: 985-5-K

Your File:

Re: Site Investigation of Clearcut Logging in Deadman Creek Watershed

On October 30, 1990 an investigation was made of the clearcut logging in the Deadman Creek watershed. The purpose to determine the quality of the clearcut harvesting and effectiveness of the post harvest rehabilitation to control water erosion and downstream sedimentation. The hydrologic effects (peak flows, etc.) of clearcut logging was adequately addressed by J. Cheng's memorandum (August 17, 1990).

Results/Observations

- 1) Most of the cutblocks on Crown lands are located in the upper tributaries of the Deadman Creek watershed (e.g. Tsintsunko, Criss, Silverspring Creeks) and, as indicated in J. Cheng's memo, occupy less than 2.2 percent of the area in the watershed.
- 2) The cutblocks in most instances are on gentle slopes (less than 30%) with a couple on moderately steep (30 to 45%) slopes. Water erosion was minimal on most cutblocks and no evidence of off-site sedimentation into major creeks such as Criss, Tsintsunko or upper Deadman was evident.
- 3) Most of the cutblocks have been planted to trees or site prepared with a disc-trencher for planting in 1991.
- 4) Considerable creek bank erosion and flooding was observed in our helicopter investigation of the lower parts of Criss and Deadman Creeks.

Conclusion

- 1) The quality of clearcut logging in the upper tributaries of Deadman Creek was good and post harvesting rehabilitation was adequate to control most on-site erosion and off-site sedimentation.

...2

- 2) Most of the bedload and suspended sedimentation in Deadman Creek below the mouth of Criss Creek appears to be from extensive creek cutbank erosion in middle and lower Criss Creek and lower Deadman Creek.

W.R. Mitchell

W.R. Mitchell
Regional Research Pedologist

WRM/wt/1195r

4c
P. Van Noo
A. Vyse

~~Bob Read, Operations Manager~~
~~Harvesting~~
KAMLOOPS FOREST DISTRICT

From: Paul W. Clarke
Kamloops Forest Region
Date: Nov. 15, 1990
Our File: 942-7529.01
Your File: 985-5-K

RE: DEADMAN CREEK WATERSHED - LOGGING & DRAINAGE REVIEW

This memo relates to the observations that I made following our Oct 30 flight of the Deadman drainage area. I will not repeat what Bob Mitchell wrote in his memo of Nov 1 as I concur with all the memo contains. This memo will cover some additional observations that I made during the day.

1. There is no evidence of any significant bank and/or slope failures in the upper and ever mid reaches of either the Deadman River or Criss Creek. No evidence of debris torrents or log jams was observed. The main problem seemed to be water volumes generated over the whole drainage area not just excess water from cut blocks.
2. In discussions with Don Ignace of the Skeetchestn Indian Band it was determined that the spring snow melt had already taken place and high water had receded prior to the high water event in question. The other thing I learned was that the high flood waters of June 12 or 13 occurred in all the creeks at the same time. There was no differential levels which indicates that elevation and snow were not a factor and I could conclude that all the water came from the rainfall.
3. The bridge washed out on Criss Creek was the victim of high water and scour and not from debris in the creek.



Paul W. Clarke, P.Eng.
Regional Engineering Officer
Kamloops Forest Region

APPENDIX 5

**PROPOSED SUSPENDED SEDIMENT
MONITORING PROGRAM**

M. MILES AND ASSOCIATES LTD.

Consultants in Hydrology, Geomorphology and Environmental Impact Mitigation

645 ISLAND ROAD
VICTORIA, B.C., CANADA
V8S 2T7
TELEPHONE: (604) 595-0653
FAX: (604) 595-7367

Mr Steve Mericle,
Fisheries Technician,
B.C. Fisheries,
B.C. Ministry of Environment, Lands and Parks,
Southern Interior Region,
1259 Dalhousie Drive,
Kamloops, B.C.
V2C 5Z5

April 22, 1994

Dear Steve:

RE: DEADMAN RIVER CHANNEL STABILITY STUDY

- 1: As discussed on April 19/94 it would be desirable to take a series of depth-integrated suspended sediment samples along Deadman River to document the observed trend of increasing suspended sediment concentration downstream of Mowich Lake. The objective of the sampling program would be to verify our perception that significant erosion is occurring within the areas of valley bottom which have been cleared for ranching.

I am enclosing a photo mosaic of Deadman River downstream of Mowich Lake. I have indicated 19 sites where it would be desirable to take suspended sediment samples. Sample locations are listed on *Table 1*. Ideally these samples should be taken as near mid-channel as possible using a hand-held depth-integrated suspended sediment sampler (e.g. a "DH-81" or "DH-48" sampler). Where possible, sites are located on bridges or road crossings. Sampling should be undertaken in a downstream direction to minimize changes in river flow over the sampling period.

If possible, stream discharge measurements should also be undertaken at the two indicated sites, such that total sediment loads could be calculated. The staff gauges at the Water Survey of Canada gauging sites on Criss Creek and Deadman River should also be read prior to, during the site measurements, and after the sampling program.

If you decide to collect the water samples yourself I can provide a "DH-81" sampler (for a rental of \$10/day). However, you might also consider getting the Water Survey of Canada staff in Kamloops to assist in the sampling program. I discussed this with Bruno Tassone, Coordinator, Environmental

Monitoring Division of Environment Canada in Vancouver (phone number 666-6207) and he indicated they would likely be willing to assist on a "cost recovery" basis. Please give either Bruno or myself a phone call if you decide to proceed with this approach.

The collected water samples should be analyzed for total suspended solids (TSS) and turbidity. Ideally this should be done in the Environmental Monitoring Division's Lab in Vancouver. Bruno Tassone is again the appropriate contact. The normal pricing policy is to charge \$10 to \$15 per turbidity sample and \$14 per suspended sediment sample. Bruno may however be able to give you "a deal" given that DFO has initiated this study. Please give me a call if you need instruction in how to take or "fix" the required samples.

- 2: Could you possibly check your files for some additional 1992 air photos. I am missing coverage for:
- i) The Deadman River/Thompson River confluence; and
 - ii) Deadman River between Mowich Lake and "upper Docksteads".
- 3: Please don't hesitate to call me if there is anything I can do to help.

With best personal wishes,

Respectfully,



Mike Miles, M.Sc., P.Geo.

cc: Mike Romaine, DFO, Vancouver
Bruno Tassone, EMD, Vancouver

TABLE 1: RECOMMENDED LOCATIONS FOR SUSPENDED SEDIMENT SAMPLES

SITE #	LOCATION	MEASURE FROM	DISCHARGE MEASUREMENT
1	Outlet of Mowich Lake	small dam	yes
2	downstream of earth flow	right bank, as feasible	no
3	small tributary	road crossing	no
4	Deadman River downstream of small tributary	right bank	no
5	small tributary	road crossing	no
6	upper Docksteaders	right bank	no
7	below Docksteaders	right bank	no
8	Mrs. Phillips' property	right bank	no
9	tributary	road crossing	no
10	Deadman River	right bank	no
11	Deadman River	bridge	no
12	Deadman River	WSC gauge above Criss Creek	yes (read staff gauge)
13	Criss Creek	WSC gauge near Savona	yes (read staff gauge)
14	Deadman River	bridge	no
15	Deadman River	bridge	no
16	Deadman River	bridge	no
17	Deadman River	bridge	yes
18	Deadman River	right bank at former bridge	no
19	Deadman River	Thompson confluence, as feasible	no

FOLIO 1

CHANNEL STABILITY MAPPING OF DEADMAN RIVER
BETWEEN KM 12 AND KM 41



30BCC92003 No. 150

INFO
INTL



FOLIO 1

CHANNEL STABILITY MAPPING DEADMAN RIVER BETWEEN Km 12 AND Km 41

SHEET: 1 OF 8

Km: 12 TO 16

The air photos were taken on May 24 and June 23, 1992

MAPPED BY: Mike Miles

DRAWN BY: Wynne Miles

CHECKED BY: Mike Miles

DATE: Mar. 1995

DATE: Mar. 1995

DATE: Mar. 1995

M. MILES AND ASSOCIATES LTD.

KEY



UNVEGETATED OR SPARSELY
VEGETATED CHANNEL BANK



WOODY VEGETATION LESS THAN
0.5 CHANNEL WIDTH WIDE



ACTIVELY ERODING BANK



DISTANCE IN
KILOMETRES UPSTREAM
OF THOMPSON RIVER



FOLIO 1

CHANNEL STABILITY MAPPING DEADMAN RIVER BETWEEN Km 12 AND Km 41

SHEET: 2 OF 8

Km: 16 TO 20

The air photos were taken on May 24 and June 23, 1992

MAPPED BY: Mike Miles

DRAWN BY: Wynne Miles

CHECKED BY: Mike Miles

DATE: Mar. 1995

DATE: Mar. 1995

DATE: Mar. 1995

M. MILES AND ASSOCIATES LTD.

KEY



UNVEGETATED OR SPARSELY
VEGETATED CHANNEL BANK



WOODY VEGETATION LESS THAN
0.5 CHANNEL WIDTH WIDE

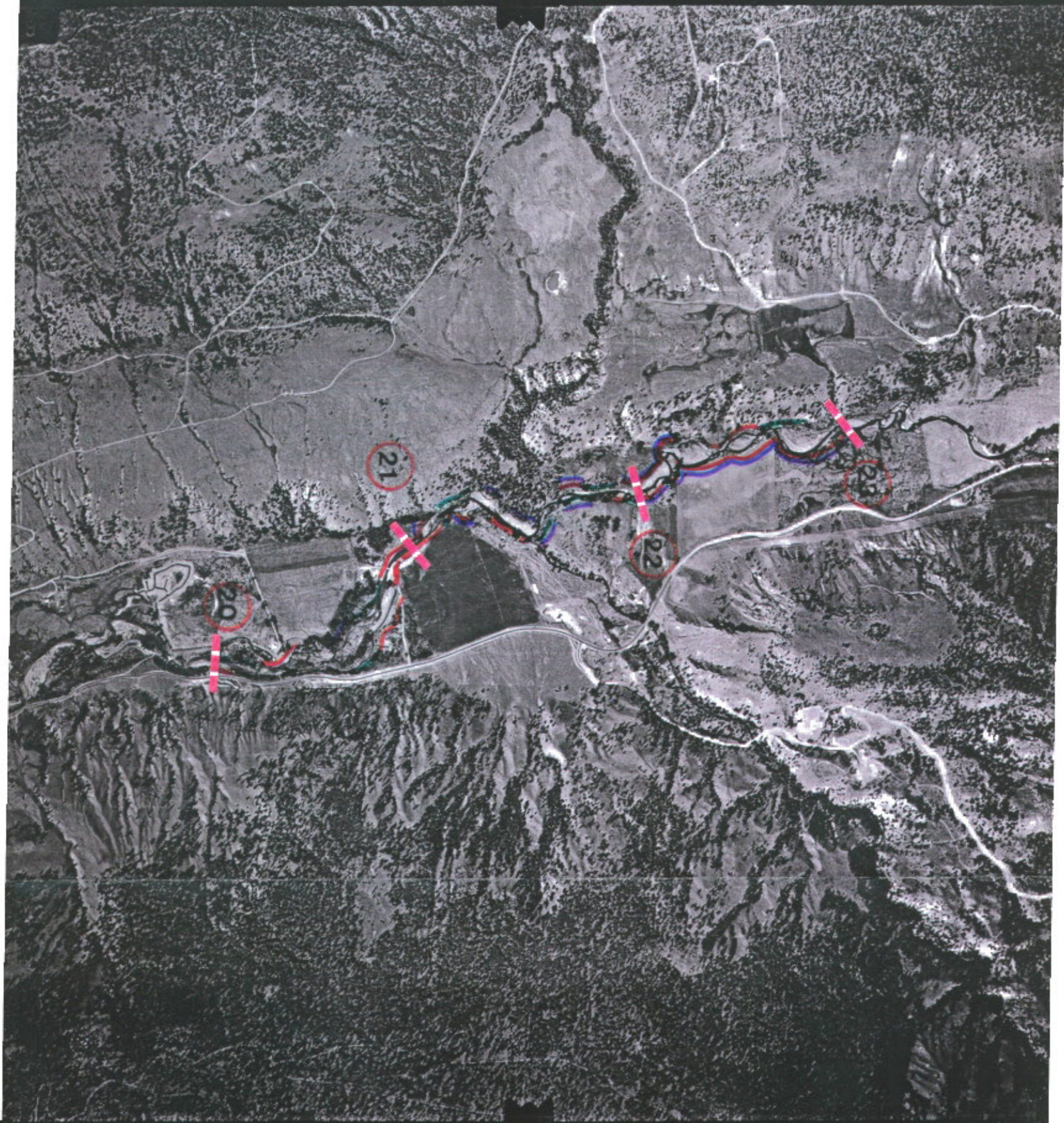


ACTIVELY ERODING BANK



16

DISTANCE IN
KILOMETRES UPSTREAM
OF THOMPSON RIVER



FOLIO 1

CHANNEL STABILITY MAPPING DEADMAN RIVER BETWEEN Km 12 AND Km 41

SHEET: 3 OF 8

Km: 20 TO 23

The air photos were taken on May 24 and June 23, 1992

MAPPED BY: Mike Miles

DRAWN BY: Wynne Miles

CHECKED BY: Mike Miles

DATE: Mar. 1995

DATE: Mar. 1995

DATE: Mar. 1995

M. MILES AND ASSOCIATES LTD.

KEY



UNVEGETATED OR SPARSELY
VEGETATED CHANNEL BANK



WOODY VEGETATION LESS THAN
0.5 CHANNEL WIDTH WIDE



ACTIVELY ERODING BANK



21

DISTANCE IN
KILOMETRES UPSTREAM
OF THOMPSON RIVER



308CC92002 No. 99

FOLIO 1

CHANNEL STABILITY MAPPING DEADMAN RIVER BETWEEN Km 12 AND Km 41

SHEET: 4 OF 8

Km: 23 TO 26

The air photos were taken on May 24 and June 23, 1992

MAPPED BY: Mike Miles

DRAWN BY: Wynne Miles

CHECKED BY: Mike Miles

DATE: Mar. 1995

DATE: Mar. 1995

DATE: Mar. 1995

M. MILES AND ASSOCIATES LTD.

KEY



UNVEGETATED OR SPARSELY
VEGETATED CHANNEL BANK



WOODY VEGETATION LESS THAN
0.5 CHANNEL WIDTH WIDE

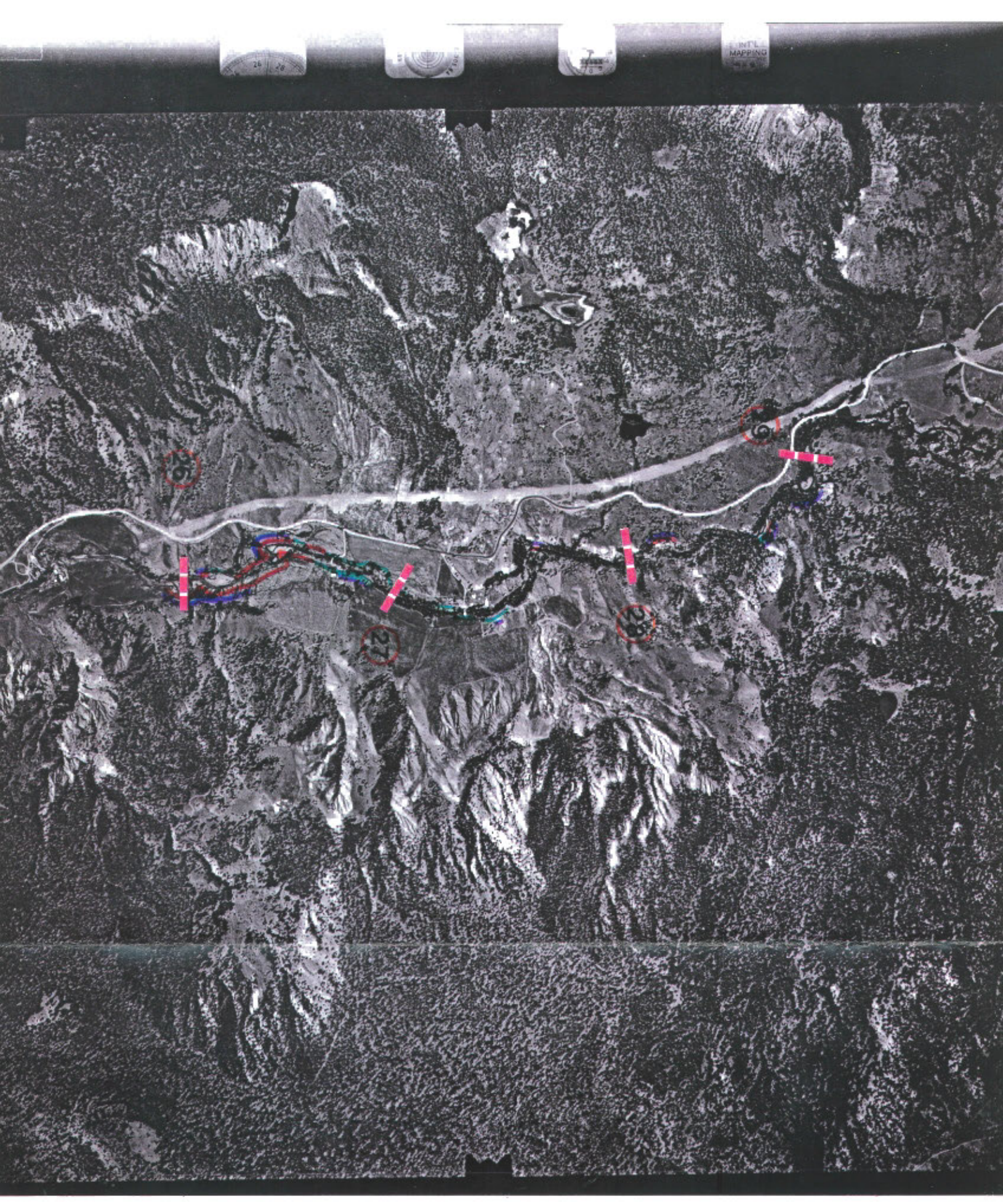


ACTIVELY ERODING BANK



24

DISTANCE IN
KILOMETRES UPSTREAM
OF THOMPSON RIVER



FOLIO 1

CHANNEL STABILITY MAPPING DEADMAN RIVER BETWEEN Km 12 AND Km 41

SHEET: 5 OF 8

Km: 26 TO 29

The air photos were taken on May 24 and June 23, 1992

MAPPED BY: Mike Miles

DRAWN BY: Wynne Miles

CHECKED BY: Mike Miles

DATE: Mar. 1995

DATE: Mar. 1995

DATE: Mar. 1995

M. MILES AND ASSOCIATES LTD.

KEY



UNVEGETATED OR SPARSELY
VEGETATED CHANNEL BANK



WOODY VEGETATION LESS THAN
0.5 CHANNEL WIDTH WIDE

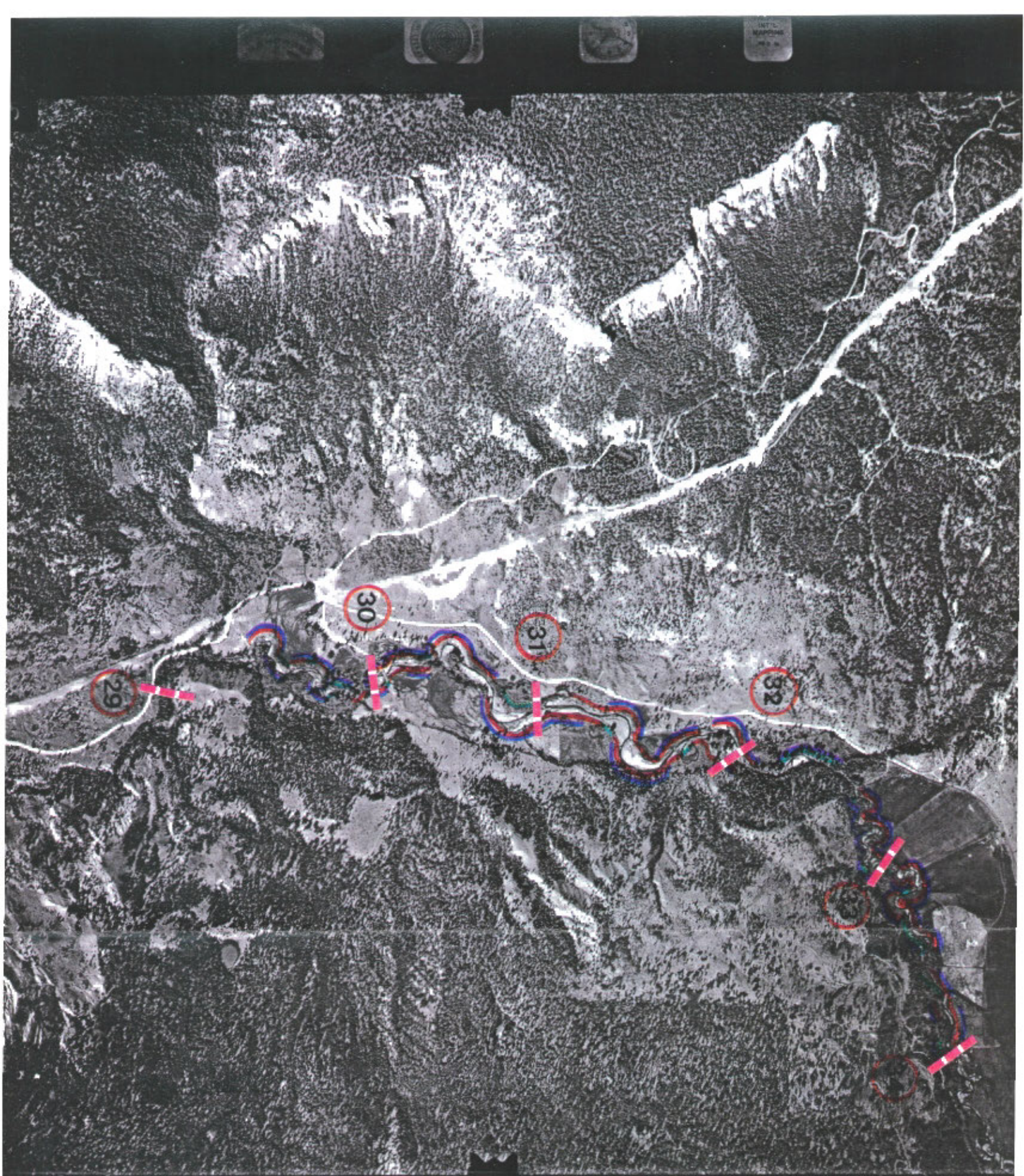


ACTIVELY ERODING BANK



27

DISTANCE IN
KILOMETRES UPSTREAM
OF THOMPSON RIVER



FOLIO 1

CHANNEL STABILITY MAPPING DEADMAN RIVER BETWEEN Km 12 AND Km 41

SHEET: 6 OF 8

Km: 29 TO 34

The air photos were taken on May 24 and June 23, 1992

MAPPED
BY: Mike Miles

DRAWN
BY: Wynne Miles

CHECKED
BY: Mike Miles

DATE: Mar. 1995

DATE: Mar. 1995

DATE: Mar. 1995

M. MILES AND ASSOCIATES LTD.

KEY



UNVEGETATED OR SPARSELY
VEGETATED CHANNEL BANK



WOODY VEGETATION LESS THAN
0.5 CHANNEL WIDTH WIDE

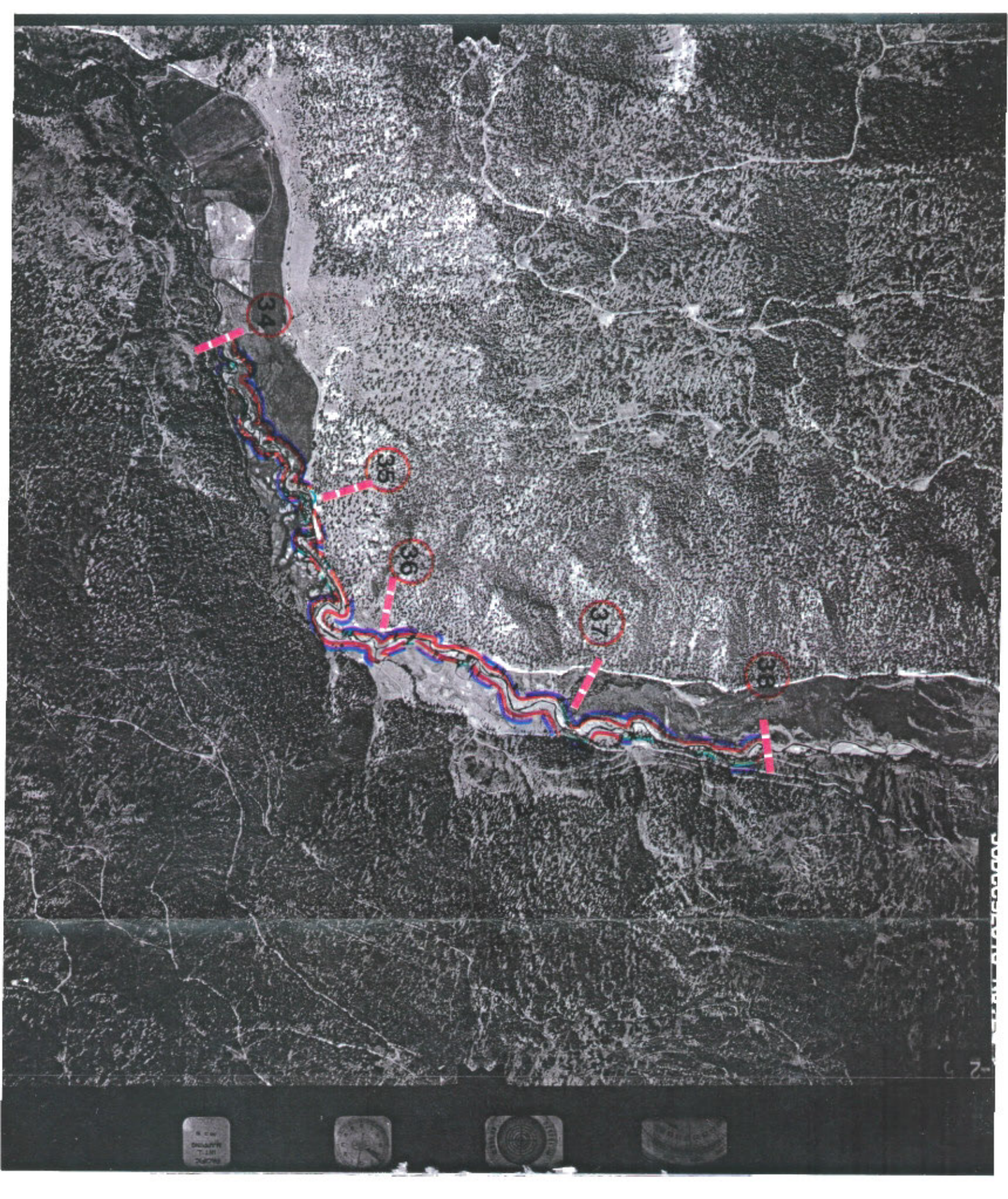


ACTIVELY ERODING BANK



30

DISTANCE IN
KILOMETRES UPSTREAM
OF THOMPSON RIVER



AERIAL PHOTOGRAPHING UNIT



FOLIO 1

CHANNEL STABILITY MAPPING DEADMAN RIVER BETWEEN Km 12 AND Km 41

SHEET: 7 OF 8

Km: 34 TO 38

The air photos were taken on May 24 and June 23, 1992

MAPPED BY: Mike Miles

DRAWN BY: Wynne Miles

CHECKED BY: Mike Miles

DATE: Mar. 1995

DATE: Mar. 1995

DATE: Mar. 1995

M. MILES AND ASSOCIATES LTD.

KEY



UNVEGETATED OR SPARSELY
VEGETATED CHANNEL BANK



WOODY VEGETATION LESS THAN
0.5 CHANNEL WIDTH WIDE



ACTIVELY ERODING BANK



DISTANCE IN
KILOMETRES UPSTREAM
OF THOMPSON RIVER



FOLIO 1

CHANNEL STABILITY MAPPING DEADMAN RIVER BETWEEN Km 12 AND Km 41

SHEET: 8 OF 8

Km: 38 TO 41

The air photos were taken on May 24 and June 23, 1992

MAPPED BY: Mike Miles

DRAWN BY: Wynne Miles

CHECKED BY: Mike Miles

DATE: Mar. 1995

DATE: Mar. 1995

DATE: Mar. 1995

M. MILES AND ASSOCIATES LTD.

KEY



UNVEGETATED OR SPARSELY
VEGETATED CHANNEL BANK



WOODY VEGETATION LESS THAN
0.5 CHANNEL WIDTH WIDE



ACTIVELY ERODING BANK



DISTANCE IN
KILOMETRES UPSTREAM
OF THOMPSON RIVER