GREG UTZIG

– for your information. I have sent a copy of your report to T. Salway.

83/03/11

HYDROLOGY OF THE ARGENTA SLOPE

by

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DRAFT

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The work of Pat Luckey of Johnsons Landing, B.C., who diligently measured base station stage heights and collected sediment samples on the seven Argenta Slope creeks, from 1980-82, is gratefully acknowledged.

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PREFACE

This study and report was commissioned by the B.C. Ministry of Forests, as part of a complete ecological data gathering, mapping and interpretation program for the Argenta slope, an area bounded by the height of land on the south side of Clint creek and the height of land on the north side of Fry creek.

Streamflow was monitored on Kootenay Joe, Gar, Gardner, Bulmer and Carter creeks from May to October, 1981. Water Survey of Canada data on Argenta creek was also included in an analysis of the hydrographs. Several runoff relationships were developed. Differences in total annual streamflow and flow regime were investigated and mean September flows estimated.

Stream channels were inventoried "on foot" and the data tabulated and mapped (at 1:15,840). The data were analysed, interpreted and discussed and overall stability (hazard) ratings for channel reaches were developed.

Kutenai Nature Investigations Ltd. in co-operation with the B.C. Ministry of Forests was responsible for the ecological data acquisition and the production of a terrain, soils and vegetation, forest capability, erosion potential and an engineering interpretation map (at 1:15,840).

The final section of this report discusses, in general terms, the potential impacts of timber harvesting activities on streamflow and channel stability. Data requirements for the site specific application of the WRENSS(1980) or similar methodologies, within drainage areas, to the development of optimum harvesting plans is also discussed.

INTRODUCTION

The Argenta Slope is situated at the head of Kootenay Lake, rising from the east shoreline above and between the small communities of Argenta and Johnsons Landing to over 2500 m. above sea level on the east boundary of the study area, defined by the height of land. The approximate co-ordinates of the center of the slope are 50° 07'N and 117° 52'W. Five major creeks, with well-defined surface watershed areas, drain the slope into Kootenay Lake. The drainage boundaries of these creeks named Kootenay Joe, Gar, Salisbury, Bulmer and Argenta are as shown on the Hydrology map, (Appendix 1), together with the less well-defined drainage areas of Gardner and Carter creeks.

The geology of the area is complex but well described by Fyles(1964) and Reesor(1973). Utzig et al(1983) have produced a composite map, called "Bedrock Geology" for the area which combines the maps of Fyles and Reesor, along with some minor modifications. Complexly folded meta-sedimentary rocks, striking north-north westerly and dipping steeply are interrupted in the south portion of the study area, within the Kootenay Joe creek drainage, by the intrusion of the Fry creek batholith. The main channel of Kootenay Joe creek occurs over this contact zone. Glaciation has been extensive over the area and the glacial features and deposits are described by Utzig et al(1983) in their "Terrain" map of the area.

Vegetation above 1520 m. falls generally under the moist Engelmann Spruce-Subalpine Fir (ESSF) biogeoclimatic subzone classification and below 1520 m, into the moist Western Red Cedar-Western Hemlock (ICHa) subzone. Soils and vegetation are classified and described by Utzig et al (1983), in their "Soils and Vegetation" map of the area.

The climate of the study area is quite mild, with January temperatures (measured at Duncan Lake Dam, 50° 15'N, 116° 58'W, 549 m.), averaging -4.4° C and July temperatures, averaging 17.8° C (B.C. Dept. of Agriculture). Precipitation at Lardeau (50° 12'N, 116° 58'W, 550 m), at the north end of Kootenay Lake, averages 676 mm with about 30% falling as snow. The above figures are based on 30 years of data, from 1941-70. Snowpack water equivalents at the beginning of April and May, at Upper Gray creek (49° 37'N, 116° 39'W, 1910 m), that is probably representative of upper elevation snow conditions on the Argenta slope, averaged 824 and 876 mm respectively, from 1969-80. The figures for 1981, the year of the study, were 700 and 762 mm, at the end of April and May respectively. All West Kootenay snow courses had lower than average April and May snowpacks in 1981. Koch creek (49° 43'N, 117° 59'W, 1860 m.), that is more representative of conditions on Perry Ridge, experienced averages of 768 and 834 mm water equivalents of snow, at the beginning of April and May respectively, for the period 1959-80, and 633 and 751 mm in 1981. These figures are similar to those for Upper Gray creek.

Horizontally projected drainage areas, above the gauging stations on each creek, were carefully measured using the 1:15,840 topographic base map. The areas are 651 ha for Kootenay Joe, 317 ha for Gar, 108 ha for Gardner, 1271 ha for Salisbury, 855 ha for Bulmer, 570 ha for Argenta and 314 ha for Carter creeks. Stream channel longitudinal profiles for each of the seven study creeks indicate that average channel gradients are 28% for Kootenay Joe (main channel plus north fork), 34% for Gar (main channel plus north fork), 41% for

Gardner (main channel plus south gully), 26% for Salisbury (main channel plus north fork), 29% for Bulmer, 30% for Argenta (main channel plus north fork) and 11% for Carter. Such average gradients (except the figure for Carter creek) are typical of small first and second order steep mountain creeks. In terms of sediment movement, they are generally regarded as "source limiting", since high energy flows during peak runoff are capable of moving all but the coarsest material. In their stable states, channel bottoms and bank compositions show a marked lack of material, finer tha~~t~~n fine gravels (< 2.5 mm).

STREAMFLOW

Streamflow was monitored on Kootenay Joe, Gar, Gardner, Bulmer and Carter creeks, on a frequent basis from May 19* through to October 1, 1981 (Appendix 2). Suitable stream gauging stations were carefully chosen and staff gauges inserted in the channel bottom material, prior to monitoring. These site locations are shown on the Hydrology map (Appendix 1). A Marsh McBirney portable water current meter, model 201, was used to obtain accurate discharge measurements and stage/discharge relationships. Approximately fifty per cent of the streamflow data was obtained from stage heights, observed by a local technician, after conversion using the appropriate stage/discharge curves. During the monitoring program stage heights were frequently checked against actual flow measurements and corrections made where necessary (due to staff gauge displacements and replacements and certain methods

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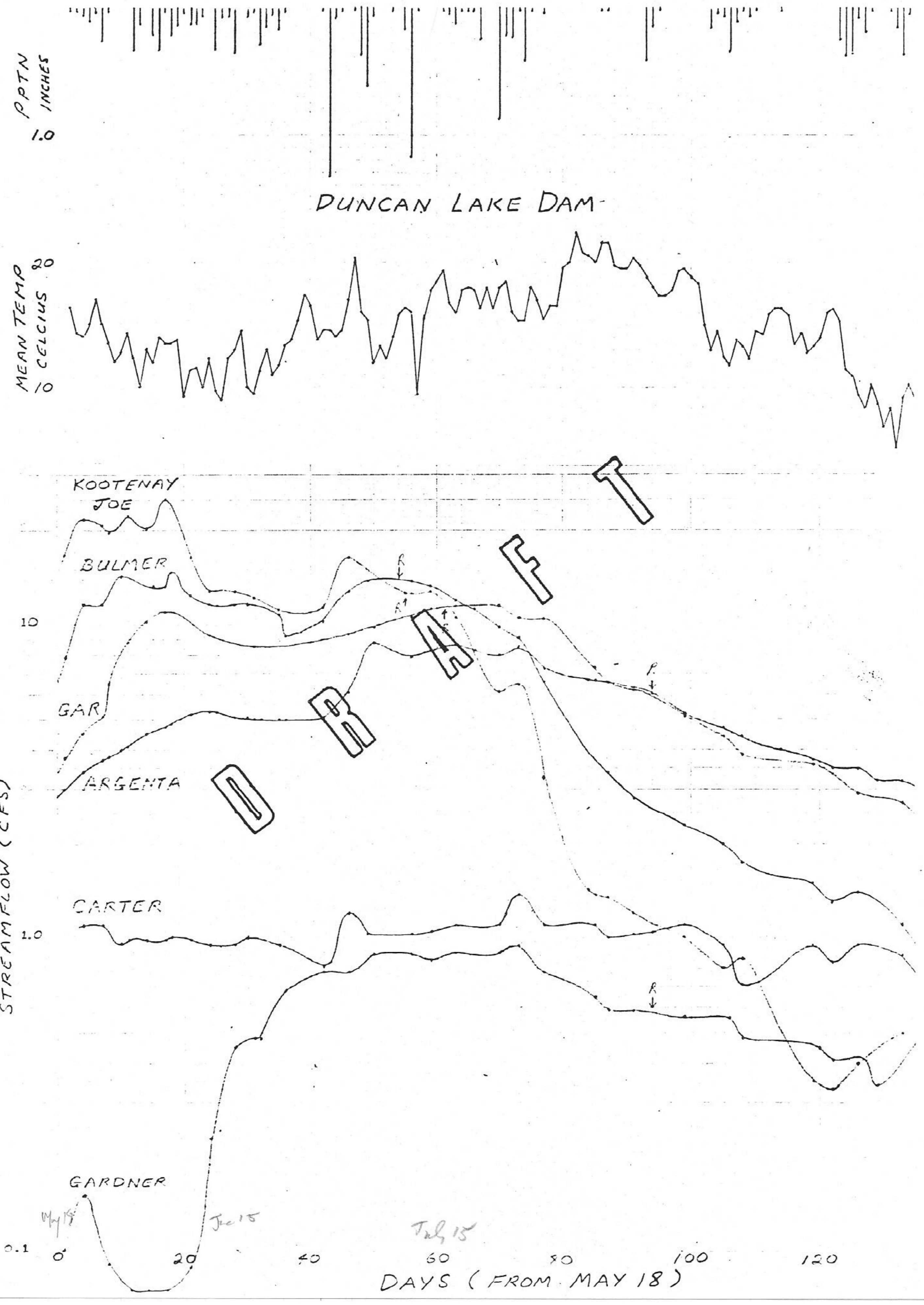
* The delayed start to the program was caused by late approval for the project. Fortunately, the main hydrograph peaks did not occur until shortly after that date, so that they were not missed.

of observation, e.g. "rooster tail" corrections during high flows). The wooden weir on Carter creek provided some useful check measurements using Francis' formula. Argenta creek was monitored on a continuous basis by Water Survey of Canada, at their permanent gauging station (Stn No. 08NH051, 50° 09'50"N, 116° 54'01"W) and their published results are incorporated into this study. Several check measurements were however, carried out on Argenta creek, using the Marsh McBirney meter and good agreement was obtained. Streamflow was not measured on Salisbury creek, until September 1981, since it was not possible to use the portable wading rod and metering equipment on such a large creek during high flows. Its flow was estimated at > 100 cfs (2.83 m^3/s) for the early season. For further details on the operation and use of the Marsh McBirney meter, see Salway (1982, pp 28-29). Besides base station flow measurements, other flow measurements were obtained at a high elevation on Kootenay Joe and at several locations, above and below the main P.O.D. (point of diversion for domestic and irrigation water) on Gardner creek.

Figure II-1 is a composite graph of all the hydrographs obtained in this study program. Total precipitation and mean daily temperatures, at Duncan Lake Dam climatological station are shown at the top of the figure.

Kootenay Joe creek exhibits the quickest response of all the creeks to the high temperatures, precipitation and rapid snowmelt patterns, from May 18 to June 6, 1981. It has the highest peak flow (25.02 cfs, 0.7085 m^3/s) on June 4 and the most rapid recession from July 16, falling

FIGURE II-1 : 1981 HYDROGRAPHS (ARGENTA SLOPE.



to the lowest value of all the creeks (0.33 cfs, 0.0093 m^3/s) on September 17. The flow regime of Kootenay Joe creek resembles that of McFayden creek, at the SE end of Perry Ridge, during the same period (Salway, 1982,pp. 33-4). Both creeks are supplied predominantly by storage areas, generally consisting of well-drained soils, with a high percentage of coarse fragments, overlying acid intrusives, see Wittneben (1980), Jungen (1980) and Utzig et al. (1983). Kootenay Joe actually flows over an intrusive contact zone, between quartz monzonite and deformed schists, quartzites and limestones (Reesor, 1973).

Bulmer creek possesses a similar regime to that of Kootenay Joe, with well-defined peaks, but a somewhat less rapid recession. The soils in Bulmer creek watershed are also generally well-drained, with a high coarse fragment content. Bulmer creek flows predominantly over schists and quartzites (Fyles, 1964).

The flow regime of Gar creek exhibits a damped, smoothed, delayed response to climatological factors, without any sharp peaks and a very gradual recession. Deeper storage for melt water is postulated from the form of the Gar creek hydrograph for 1981, possibly within fractured saprolitic rock and/or limestone aquifers.

Gardner creek, just north of Gar creek, has an even slower response, rising from springs at about 770 m.a.s.l., apparently from a limestone aquifer (Reesor, 1973).

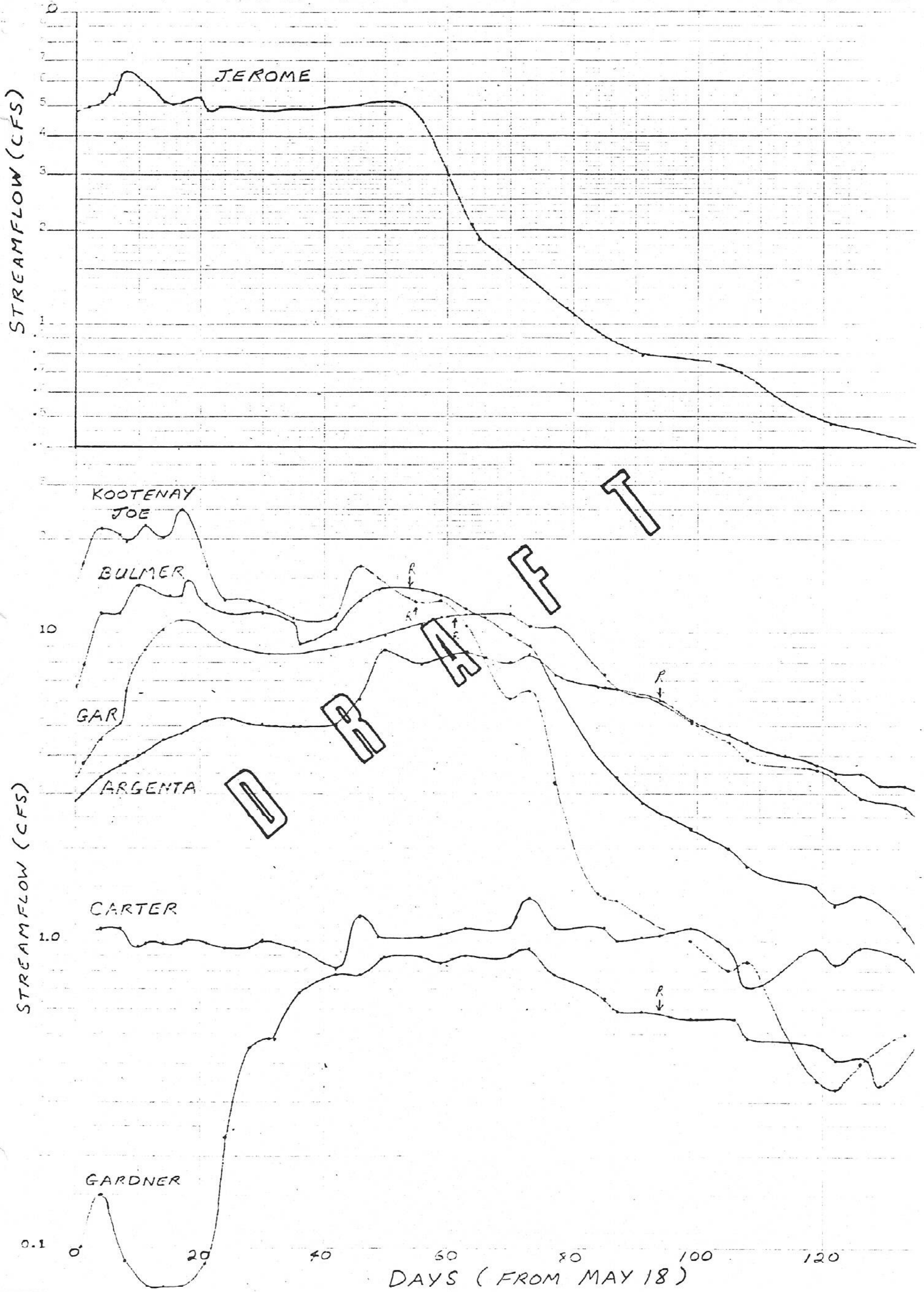
Argenta creek exhibits a similar delayed response to that of Gardner, but does not rise from low elevation springs. Instead, Argenta creek is probably supplied by melt water held in soil and ground-water storage, that is deeper and more slowly draining than storage conditions for Bulmer and Salisbury creeks to the south.

Carter creek, just north of Argenta creek, maintained an almost constant flow of 1.0 cfs (0.028 m^3/s), during the entire monitoring program. It actually flows through a large area of deep unconsolidated materials (Fyles, 1964).

It is worth noting that the high rainfall events of June 30, July 13 and July 27, 1981, as indicated on Duncan Lake Dam precipitation record (Figure II-1), produced three small but definite peaks, on the Kootenay Joe hydrograph, each three days later than the rainfall event. Only a slight inflexion on the Bulmer creek hydrograph, on July 30, appears as a consequence of the third event. The Gar creek hydrograph shows a slight inflexion on this date and the Argenta, Carter and Gardner creek hydrographs all exhibit small peaks on July 30. The Carter creek hydrograph also displays a definite small peak on July 3, in response to the first rainfall event of June 30.

Figure II-2 displays the same information as Figure II-1, except that the Duncan Lake Dam meteorological data has been replaced by the Jerome creek hydrograph, for the same period. Jerome creek flows down the SE flank of Perry Ridge above Appledale, just north of Winlaw, in the Slocan Valley. Possessing thirteen years of daily seasonal streamflow record, between 1921 and 1977, this creek provided an accurate method of estimating mean September flows on Hird, Benninger and Watson creeks, as described by Salway (1982, pp. 32-43), as well as enabling other relationships to be developed. Jerome creek low flows

FIGURE II-2 : HYDROGRAPHS (JEROME AND ARGENTA SL



were found to be well correlated with those of McFayden creek, for 1981. Later, it will be shown that similar relationships exist between Jerome and Kootenay Joe creeks, and Jerome and Bulmer creeks.

It is useful to compare total discharges for the period of record (May 18 to October 1, 1981) for the Argenta Slope creeks. Each hydrograph was manually integrated over time and the results are displayed in Table II-1.

Table II-1

Total Discharge, May 18 to October 1, 1981

Creek	Total Discharge Decameters^3	Drainage Area Hectares	Unit Area Discharge Dam^3/Ha	Equivalent Depth Meters
Kootenay Joe	2763	651	4.244	0.4244
Bulmer	2541	855	2.972	0.2972
Gar	2462	317	7.767	0.7767
Argenta	1842	570	3.232	0.3232
Carter	331	314	1.054	0.1054
Gardner	180	108	1.667	0.1667
Jerome	919	285	3.225	0.3225

Surface drainage areas are also included along with unit area discharge and equivalent depths. Unit area discharge is defined as the total discharge per unit area, averaged over the drainage and the equivalent depth is the depth of water, assuming that the total discharge was uniformly spread over the entire drainage area. Jerome, Bulmer and Argenta creek watersheds generate almost identical flows, in proportion to their drainage areas.

Snowpack water equivalents at Koch creek (49° 43'N, 117° 59'W, 1860 m.) and Upper Gray Creek (49° 37'N, 116° 39'W, 1910 m.) at the beginning of May, 1981 were 751 and 700 mm, and the averages over 21 and 12 years respectively, were 834 and 876 mm. Total precipitation at South Slocan (49° 28'N, 117° 32'W, 457 m.) and Duncan Lake Dam (50° 15'N, 116° 58'W, 549 m.) from April 1 to September 30, 1981, was 490 and 598 mm, respectively. Average total annual precipitation over 30 years for South Slocan and Lardeau (50° 12'N, 116° 58'W, 550 m.) was 790 and 676 mm respectively (long-term Duncan Lake records are not available), and from April 1 to September 30, over 30 years was 284 and 254 mm. Hence, precipitation inputs for Perry Ridge and Argenta Slope watersheds appear similar, as suggested by the similar unit area discharges of Jerome, Bulmer and Argenta creeks for the period, May to October, 1981.

Carter and Gardner generate about 30% and 50% respectively (both are springs and Gardner rises substantially below the gauging station). Kootenay Joe watershed generates about 35% more than the Jerome, Bulmer, Argenta unit area discharge average and Gar generates more than double the amount. Gar creek is anomalous and appears to receive much more water, than its surface drainage area would suggest. Since its median elevation and area-elevation distribution does not indicate a substantially greater snowpack, than the other drainages would receive on the Slope, an externally-supplied aquifer (outside the surface watershed boundary) seems to be a strong possibility.

Total discharges for Jerome and Argenta creeks may be compared, from historical streamflow data for the period April 1 to September 30. Table II-2 shows the results of such a comparison.

Table II-2

Total Discharge for Jerome and Argenta Creeks

Year	Jerome Total Discharge Dam^3	Argenta Total Discharge Dam^3	Jerome/Argenta Discharge Ratio
1973	495.9	1100.3	0.4507
1974	1282.8	2492.9	0.5146
1975	784.5	1116.3	0.7028
1976	1043.5	1805.8	0.5779
Average	901.7	1628.8	0.562
1981	1187.1	2014.3	0.5893

From 1973 to 1976, there was considerable variation in absolute total discharge of each creek, due to climatological factors, but relative discharges remained remarkably similar (average discharge ratio was 0.562 with a sample standard deviation of 0.108). The drainage area ratio of Jerome over Argenta is 0.500, hence confirming that unit area discharges for both creeks have been similar over the years. For 1981, total discharges were substantially higher, indicating that 1981 was "wetter" than the average of 1973-76. For Jerome creek, the average total discharge for the period, April 1 to September 30, 1972-77 was 856.0 dam^3 (S.D.$\pm$ 373.0), compared to 1187.1 dam^3 for 1981.

In the study of four creeks on Perry Ridge (Salway, 1982), it was found that useful relationships existed between streamflows, both during saturated and unsaturated soil/groundwater discharge periods. Simple linear regressions were developed to describe these relationships, between small samples of time series, based on discrete observations, not equispaced in time. If the hydrographic data were complete and actual observations of streamflow had been made on a daily basis (every day with zero or few missing observations), the following "rigorous" approach would have been employed in the identification and estimation procedure, as described by Box and Jenkins(1970) and applied by Salway (1976, 1979) in an analysis of snow avalanche activity as a function of meteorological data. An explicit or strictly causal relationship does not exist between independent creeks but both may depend on similar generating processes, such as weather conditions, (Chow, 1964, 8-84) and posses similar secondary characteristics, such as soils, geology, terrain, topography, vegetation, etc., such that a transfer function may be found. In the case of daily streamflow data, the input and output series may be "usefully" regarded as generated from a series of independent 'shocks', a_t. These shocks are random drawings from a fixed distribution, usually assumed Normal and having a mean zero and a variance σ_a^2 (Box and Jenkins, 1970,p.8). The model identification and estimation procedure has been summarized by Salway (1976, 1979) and consists of the following steps.

1) Sample autocorrelation functions for the input series x_t and the output series y_t are computed up to 20 lags, together with the cross-correlation function between x_t and y_t, and examined for "stationarity". A "stationary" process is said to be strictly stationary, if its properties are unaffected by a change of time origin (Chow, 1964, 8-78). At least 50 pairs of equi-interval observations are required. If the correlation functions decay to insignificance at or before the third lag,

the series are regarded as stationary and differencing is unnecessary.

2) Partial autocorrelation functions (defined as the last autoregression coefficient obtained after successively fitting increasing orders of autoregressive process to the data) are computed for the input series, up to 20 lags. A suitable autoregressive moving average (ARMA) model is identified from the autocorrelation and partial autocorrelation functions (Chow, 1964, 8-84&85) and the parameters estimated using a least squares approach.

3) The ARMA model describing the input series is used to transform it into an approximate white-noise process (random and uncorrelated), and the same transformation is applied to the output series (Chow, 1964, 8-89). Pre-whitening of the input series produces more efficient estimates of the transfer function (Box and Jenkins, 1970, p.379).

4) The transfer function is then identified and least squares estimates obtained for the transformed input and output series.

5) If no secondary input series is contemplated, the transfer function is subtracted from the output series to obtain the stochastic noise component.

6) Autocorrelation and partial autocorrelation functions for the stochastic noise process are computed up to 20 lags and a suitable ARMA model, describing the process identified and estimated.

7) The transfer function and noise models are then combined and efficient least squares estimates of the parameters obtained. Any insignificant terms are eliminated and the final complete model re-estimated.

8) In this last step, tests of model adequacy are performed, as described

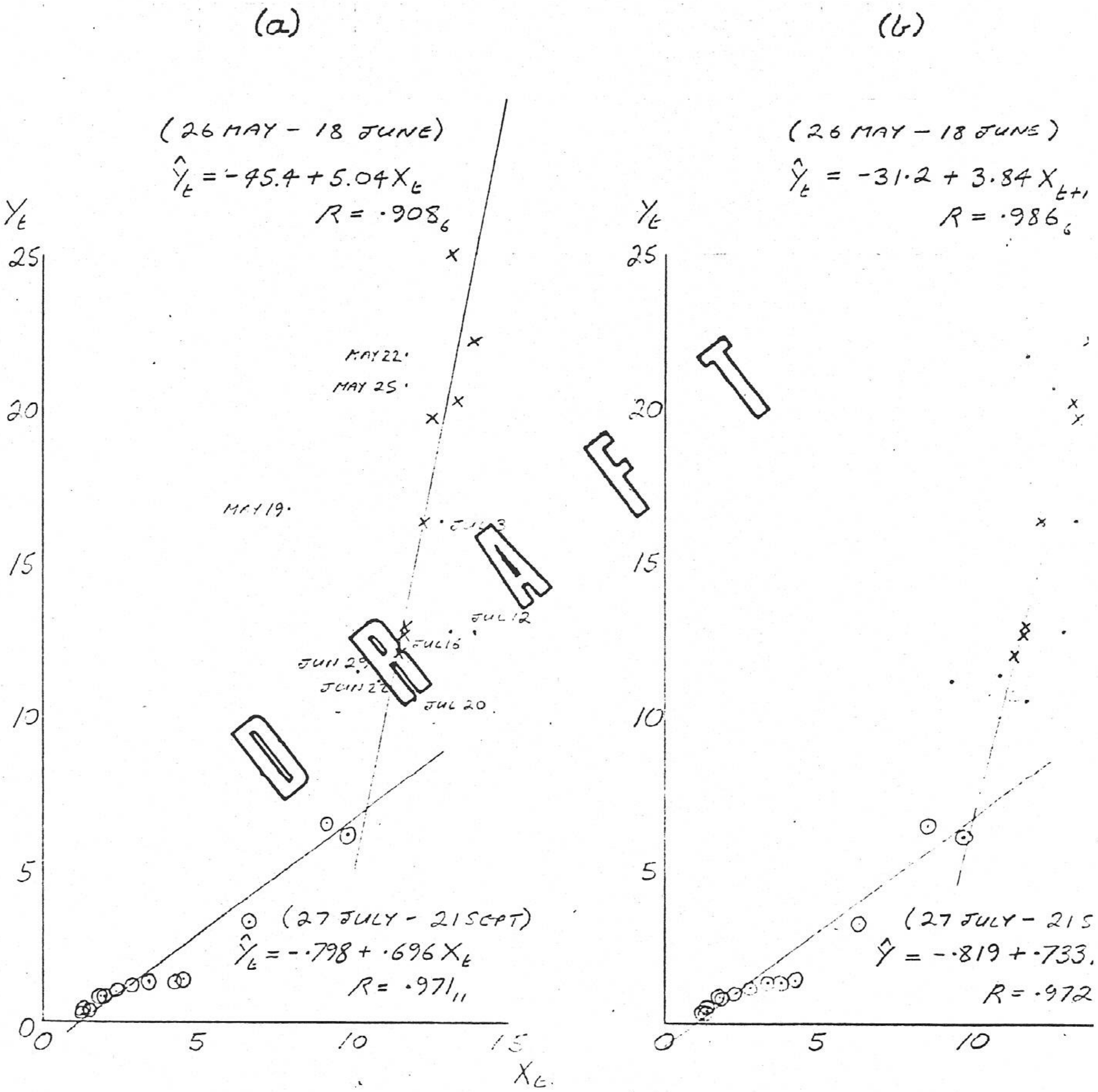
by Box and Jenkins (1970, pp.392-5). Among other things, insignificant autocorrelation in the residuals, is confirmed.

"Most of the statistical methods used in hydrologic studies are based on the assumption that the observations are independently distributed in time" (Chow, 1964,8-79). Serial correlation (autocorrelation) of the input and output series is often regarded as a nuisance and some kind of randomization of the experimental design is often introduced to validate analysis conducted, as if the observations were independent (such as the statistical analysis of annual or average monthly streamflows that are usually "less" serially correlated than daily streamflows). However, a great deal of hydrologic data occur in the form of time series, where observations are dependent and "where the nature of this dependence is of interest in itself" (Box and Jenkins, 1970,p.vii).

Without limiting the foregoing discussion, or diminishing its importance, it must now be stated that the irregularly spaced streamflow data, consisting of small samples (less than 30 cases per sample), used in the Perry Ridge study (Salway, 1982) and other samples, shortly to be discussed in this study, are hardly sufficient for the elaborate time series analysis, described above. A certain degree of randomness has already been accidentally introduced as a result of the irregular spacing of the observations in time. Furthermore, small samples cannot be used, to reliably estimate autocorrelation and cross-correlation functions. (Chow, 1964, 8-79,82,83 and 85). Hence, for the purposes of this study and the Perry Ridge study (Salway, 1982), the model identification procedure was reduced to the assumption that a simple linear transfer function exists between x_t and y_t and in some cases, a lag relationship exists (i.e. $y_t = b_0 + b_1 x_{t-k}$, where k is a positive or negative integer not equal to zero). The stochastic noise component was assumed to be zero, unless subsequent testing of the residuals, after model fitting, exhibited strong and obvious serial correlations. Efficient least squares estimates of the simple linear regression parameters were obtained immediately (step 7) and the models were then tested for adequacy (step 8). Anderson's method (described by Chow, 1964, 8-82 to 8-83) was used to test the first lag autocorrelation coefficients of the residuals for significance, and standard significance tests were applied to the higher order lag values. It should be particularly noted, that "if the residuals are uncorrelated, an ordinary regression analysis is valid" (Chow, 1964, 8-88). It is somewhat difficult to assign appropriate degrees of freedom for R-values, obtained by correlating small samples of time series, that exhibit artificially high first order autocorrelation values. Chow (1964) describes a method of determining the effective number of degrees of freedom (from Bartlett's work), but the procedure breaks down for small samples. It must, however, be assumed that the R-values, quoted in the following analyses will be associated with somewhat fewer degrees of freedom than n-2, where n is the number of observation pairs.

As stated previously, and referring back to Figure II-1, Kootenay Joe and Bulmer creeks have similar regimes. It is therefore worthwhile to examine firstly, the unlagged relationship between them. Figure II-3a is a graph of Kootenay Joe streamflow, y_t, versus Bulmer streamflow, x_t, for the period May 26 to September 21, 1981. Similar to the streamflow relationships for Perry Ridge creeks (Salway, 1982), a pair of straight

FIGURE II-3: 1981 FLOW RELATIONS BETWEEN KOOTENAY JOE AND BULMER CREEKS



Y = KOOTENAY JOE STREAMFLOW (CFS)

X = BULMER STREAMFLOW (CFS)

$\text{AREA(KJ)}/\text{AREA(BUL)} = .76$

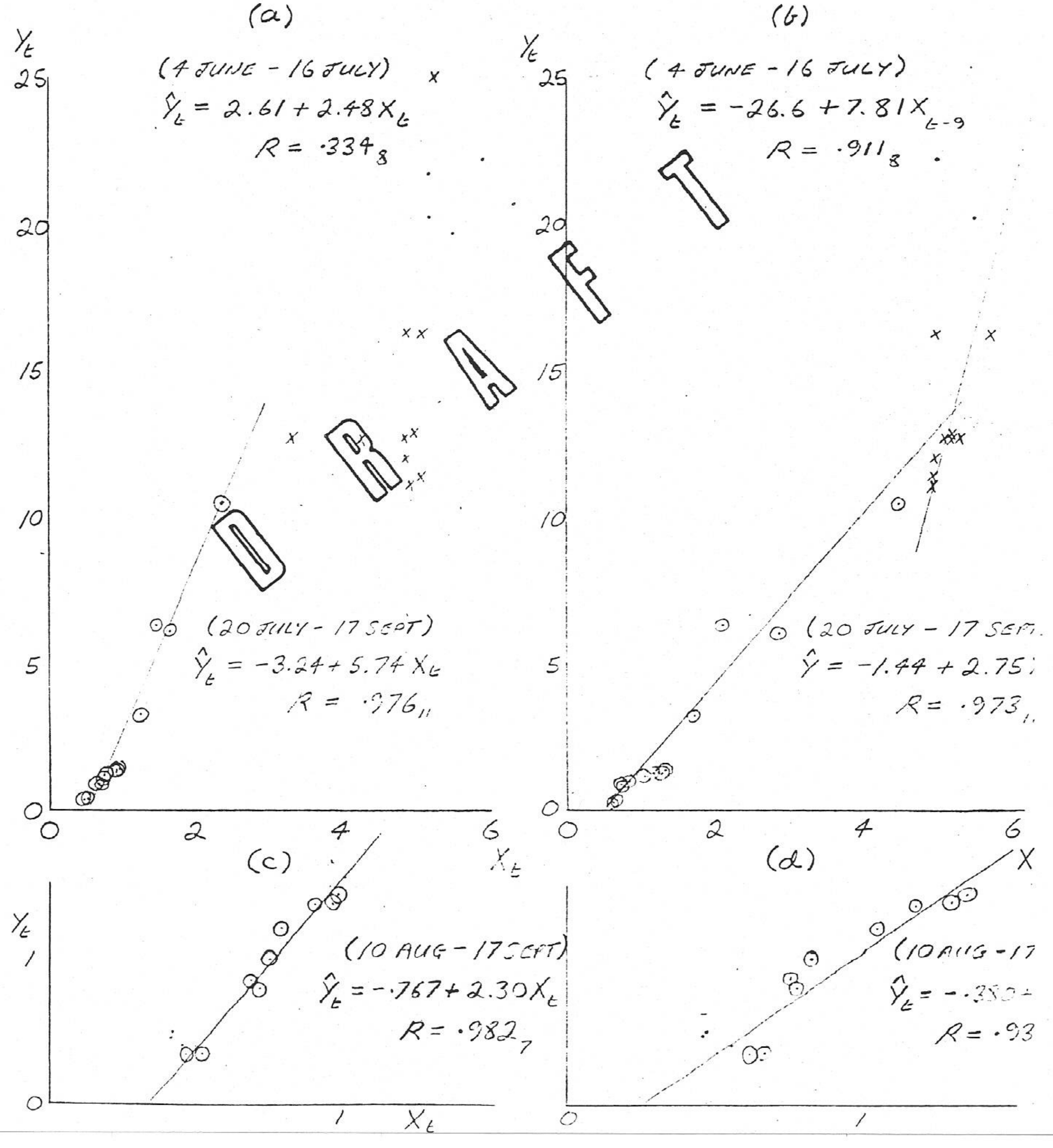
lines appear to best fit the data. Unfortunately, due to the late start in the study program, rising stage data (defined as period I in the Perry Ridge report) is missing from the Argenta Slope study. Nevertheless, a "good" fit was obtained for the high flow period II (May 26 to June 18) and the recession period III (July 27 to September 21). The secondary peaks between June 19 and July 26 are not well correlated. The two regression models are quoted in Figure II-3a, with their associated R-values and uncorrected degrees of freedom. A better relationship, for the high flow period II, is obtained by using the fact that Kootenay Joe peaks one day earlier than Bulmer. This is clear from Figure II-1 and II-3b. Note that the R-value has been increased from 0.908 to 0.986 with 1 and 6 degrees of freedom, using the first lag relationship. It is also worth noting that, for the recession period III, the b_1 value of the first lag equation is 0.733, which is very close to the ratio of the two drainage areas, 0.760. This corresponds to results obtained for Perry Ridge creeks (Salway, 1982, p.36). In order to estimate average low flows for Kootenay Joe creek over a period of several years, it is first necessary to establish a relationship between Kootenay Joe and another creek, with a similar regime and an historical streamflow record, spanning several years. Argenta creek has several years of record but exhibits quite a different response to that of Kootenay Joe creek. Kootenay Joe, like Bulmer creek, is much more similar to the Perry Ridge creeks (Salway, 1982, pp31-34). Gardner creek has a similar regime to that of Argenta creek and Gar creek seems to behave somewhere in between the two extremes, that could be represented by Argenta creek and Jerome creek. Therefore, it can be expected that the best relationships will be obtained by regressing Kootenay Joe and Bulmer on Jerome, Gardner on Argenta and Gar can be matched with either Jerome or Argenta and the best relationships selected. Carter creek has no well-defined regime. Figure II-4a is a graph of Kootenay Joe versus Jerome. A good relationship exists for the recession period III (July 20 to September 17) but a high flow relationship does not exist. However, by using the fact that Jerome creek peaked 9 days earlier than Kootenay Joe, in 1981, a significant relationship is generated, for the period (June 4 to July 16), with an R-value of 0.901, with 1 and 8 degrees of freedom. (N.B. Kootenay Joe streamflows were paired with ninth-lagged values of Jerome streamflows, interpolated where necessary, Figure II-4b). Such relationships would have to be confirmed with more closely spaced data and must be treated with caution. However, the principle that one creek can rise earlier or later than another, due to differences in snow-melt regime and climate and that lagged relationships can be developed, is worth noting and exploiting. Perry Ridge creeks peak earlier than Kootenay Joe and Bulmer creeks, probably for a variety of physical reasons. Two of these reasons may well be associated with the higher headwater areas and dominantly western aspects of these Argenta Slope creeks, compared with the somewhat lower elevations and south-easterly aspects of the Perry Ridge creeks. Both unlagged and lagged relationships, for the recession period III (July 20 to September 17), are very significant. The best relationship for prediction purposes appears to be the unlagged relationship, for the latter part of the recession period (August 10 to September 17), Figure II-4c with an R-value of

FIGURE II-4: 1981 FLOW RELATIONS BETWEEN KOOTENAY JOE AND JEROME CREEKS

$Y \equiv$ KOOTENAY JOE STREAMFLOW (CFS)

$X \equiv$ JEROME STREAMFLOW (CFS)

$\text{AREA (KJ)} / \text{AREA (JER)} = 2.28$



0.982, with 1 and 7 degrees of freedom. Note that in this case the b_1-value is 2.30 and the ratio of drainage areas is 2.28.

Figure II-5a is a graph of Bulmer versus Jerome streamflows. Once again, a good relationship is obtained for the low flow period (July 27 to October 1), but high flows do not display a logical correlation. By assuming that Jerome peaks 10 days earlier than Bulmer, a better high flow relationship results and the low flow relationship has a b_1-value, that is closer to the drainage area ratio. The best low flow relationship is the tenth-lag equation, for the period August 13 to October 1, with an R-value of 0.989 with 1 and 8 degrees of freedom and a b_1-value of 3.14, compared to the drainage area ratio of 3.00.

If Gar streamflow is plotted against Jerome streamflow for 1981, Figure II-6a, a strong correlation is obtained for the recession period (July 27 to October 1). Lagging Jerome streamflow by 9 days, produces some correlation of high streamflows, for the period, May 29 to June 28 and another good model for the recession period (July 30 to October 1). Gar streamflows correlate well with Argenta streamflows, from August 11 to October 1 and if it is assumed, that Argenta creek peaks 33 days later than Gar creek, (as it appears from Figure II-1), another strong relationship is obtained for the period, July 27 to October 1, Figure II-7a and II-7b.

Gardner streamflow is well correlated with Argenta streamflow, from July 7 to October 1, with an R-value of 0.961 with 1 and 16 degrees of freedom, Figure II-8a. No relationship exists between Carter and Argenta streamflows, Figure II-8b.

FIGURE II-5: 1981 FLOW RELATIONS BETWEEN BULMER AND JEROME CREEKS

Y = BULMER STREAMFLOW (CFS)
X = JEROME STREAMFLOW (CFS)
AREA (BUL) / AREA (JER) = 3.00

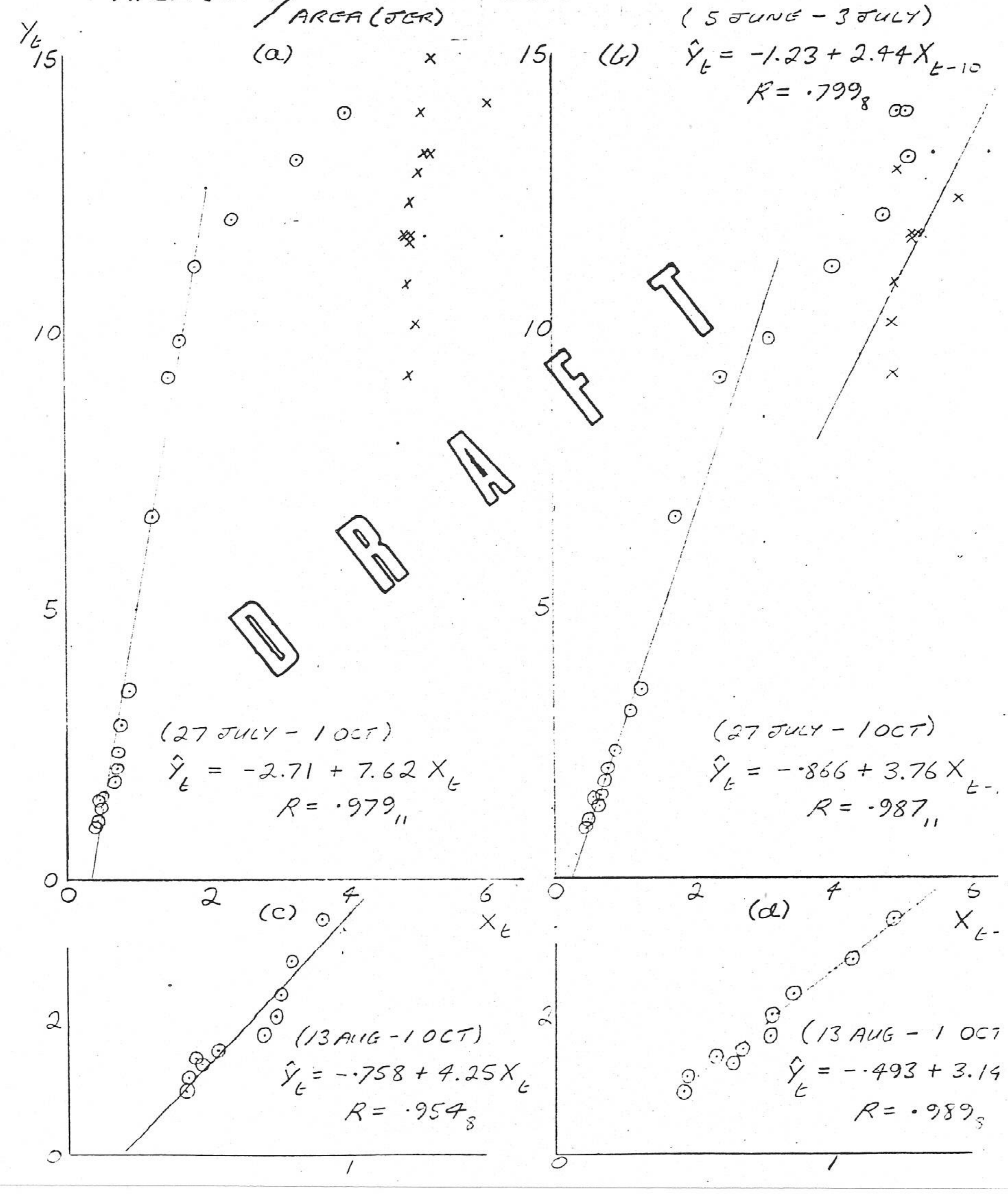


FIGURE II-6: 1981 FLOW RELATIONS BETWEEN GAR AND JEROME CREEKS

Y ≡ GAR STREAMFLOW (CFS)

X ≡ JEROME STREAMFLOW (CFS)

$\text{AREA(GAR)} / \text{AREA(JER)} = 1.11$

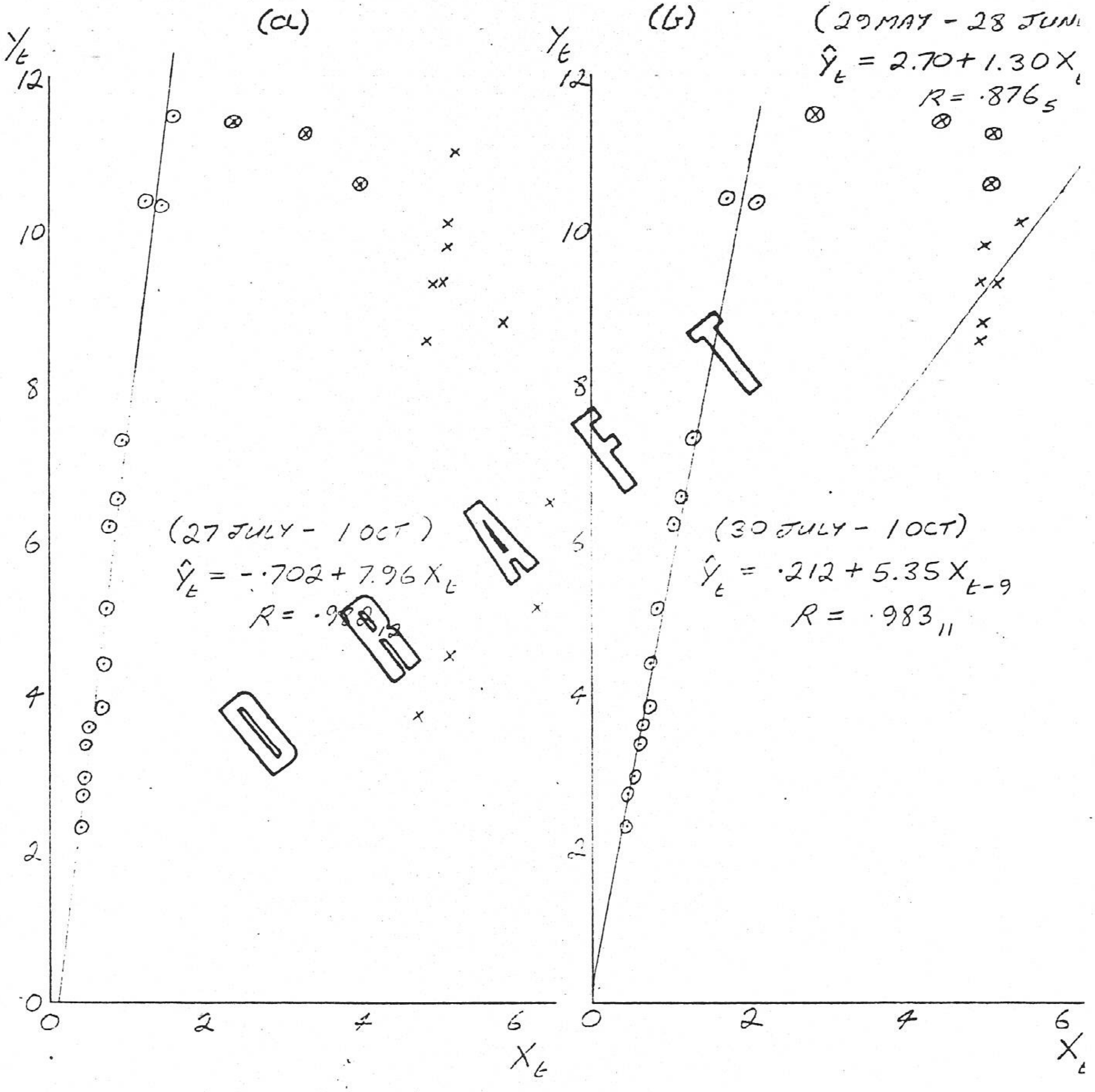


FIGURE II-7: 1981 FLOW RELATIONS BETWEEN GAR AND ARGENTA CREEKS

Y ≡ GAR STREAMFLOW (CFS)
X ≡ ARGENTA STREAMFLOW (CFS)

AREA (GAR) / AREA (ARE) = .556

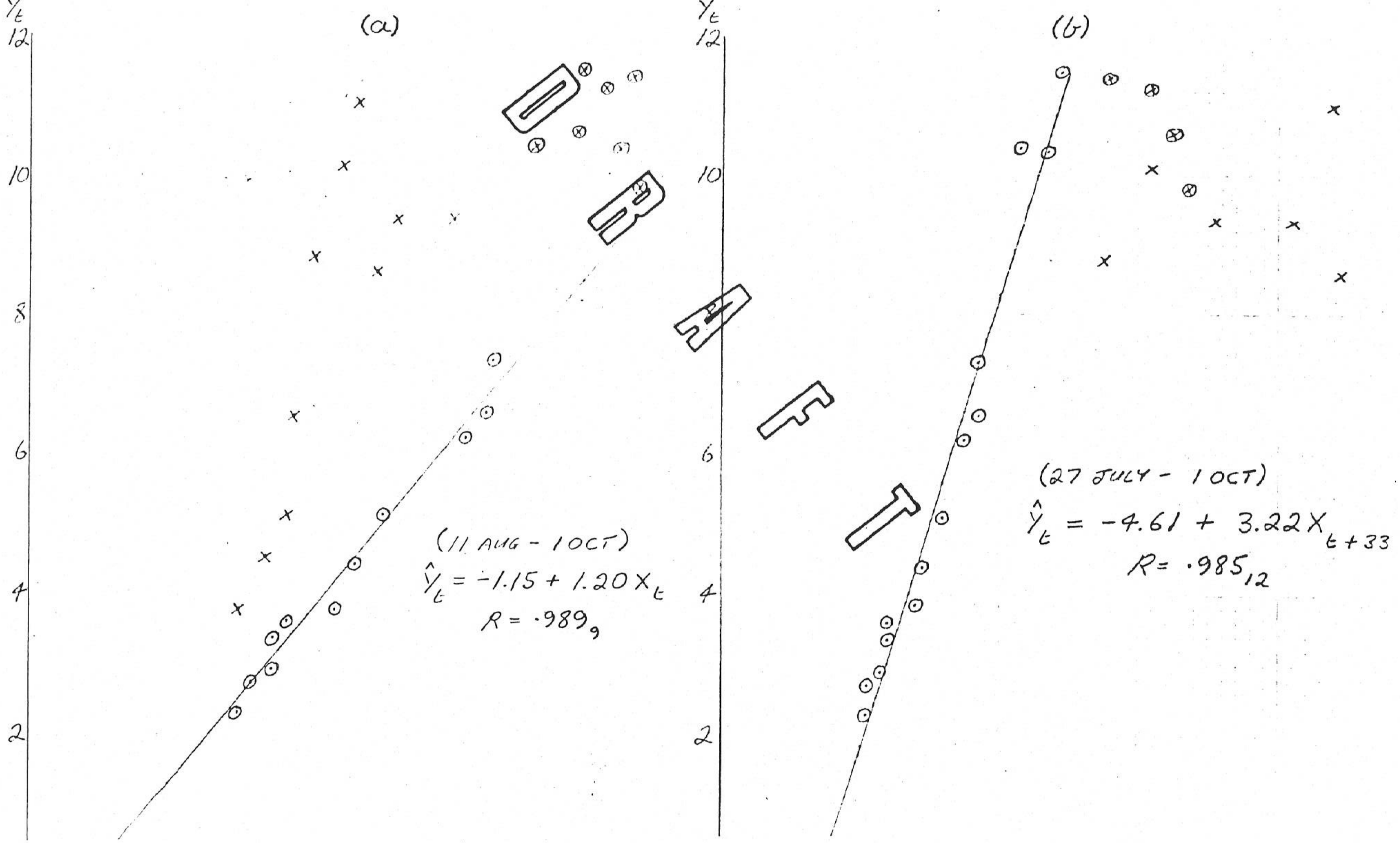
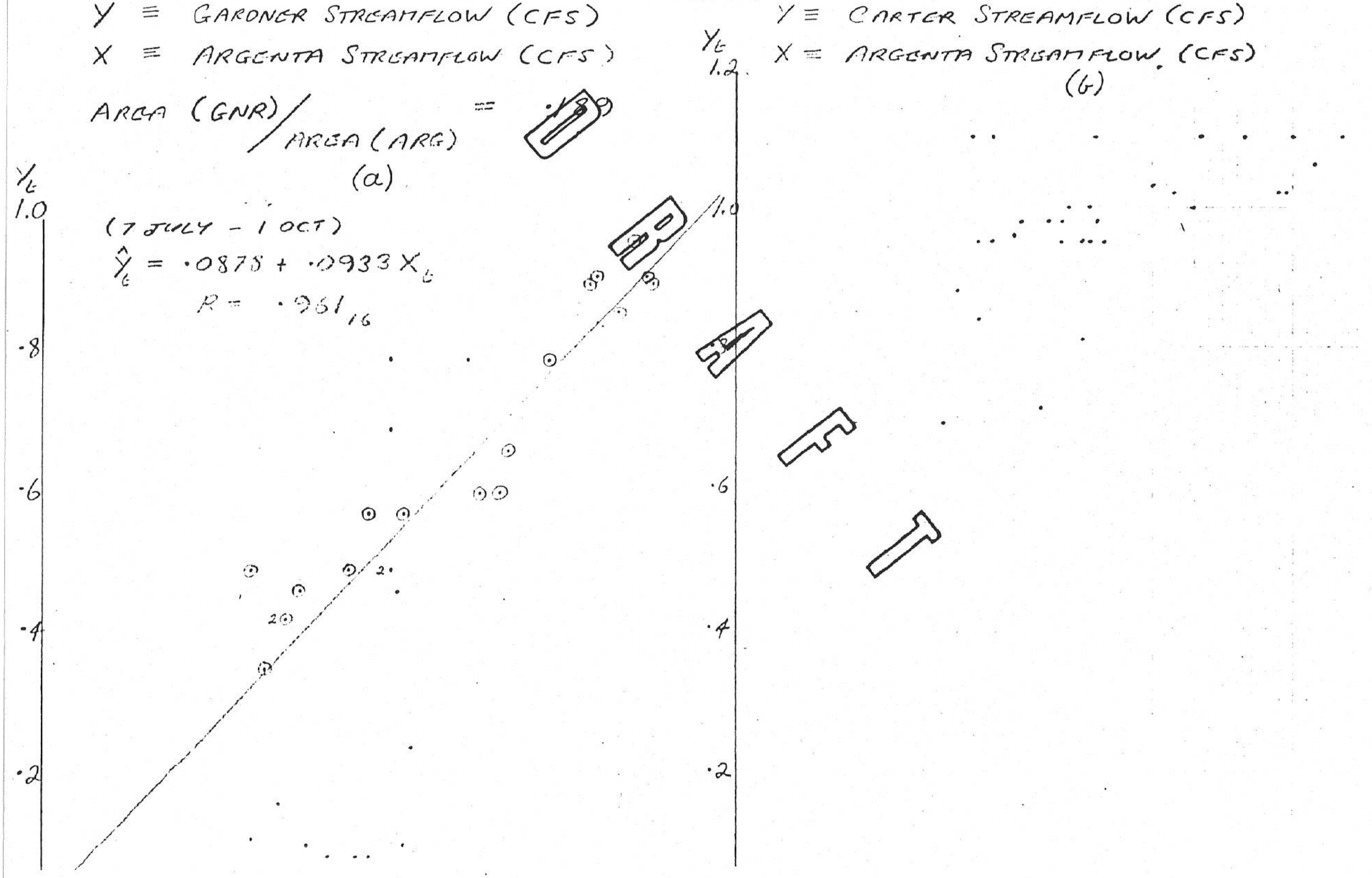


FIGURE II-8: 1981 FLOW RELATIONS BETWEEN GARDNER, CARTER AND ARGENTA CREEKS



In the Perry Ridge study (Salway, 1982), following the development of streamflow relationships for 1981, average monthly flows for the recession period (July, August and September) on Jerome creek were regressed on Winlaw creek, for the 1972-76 period. A strong relationship was obtained (R-value of 0.953 with 1 and 16 degrees of freedom). The b_1 value of .078, was similar to the drainage area ratio of 0.070, "thus providing strong evidence in support of the previous results, obtained for Jerome versus Hird, Benninger, Watson and McFayden creeks for 1981" (Salway, 1982, p.44), i.e., all the b_1-values were similar to the drainage area ratios during the recession period. The Winlaw creek results, strongly suggest that the relationships obtained for 1981, were not anomalous but probably can be relied upon to exist, relatively unchanged, fro year to year (unless of course, one watershed is subjected to some drastic treatment). The results obtained by regressing 5-day average flows for Winlaw versus Lemon creek during July, August and September, 1973-80, also suggest that such low flow relationships should "hold up" from year to year.

Figure IV-9a is a plot of Argenta versus Jerome streamflow for 1981. These creeks have very different regimes but low flows, for the period August 5 to September 30, seem to be related. The equation is

$$\hat{Y}_t = 0.857 + 5.82\, X_t, \quad R = 0.957_3.$$

If monthly flows on Argenta, for August and September and the years, 1972-76, are regressed on Jerome, a similar relationship is obtained,

$$\hat{Y}_t = -0.558 + 6.904\, X_t, \quad R = 0.860_8,$$

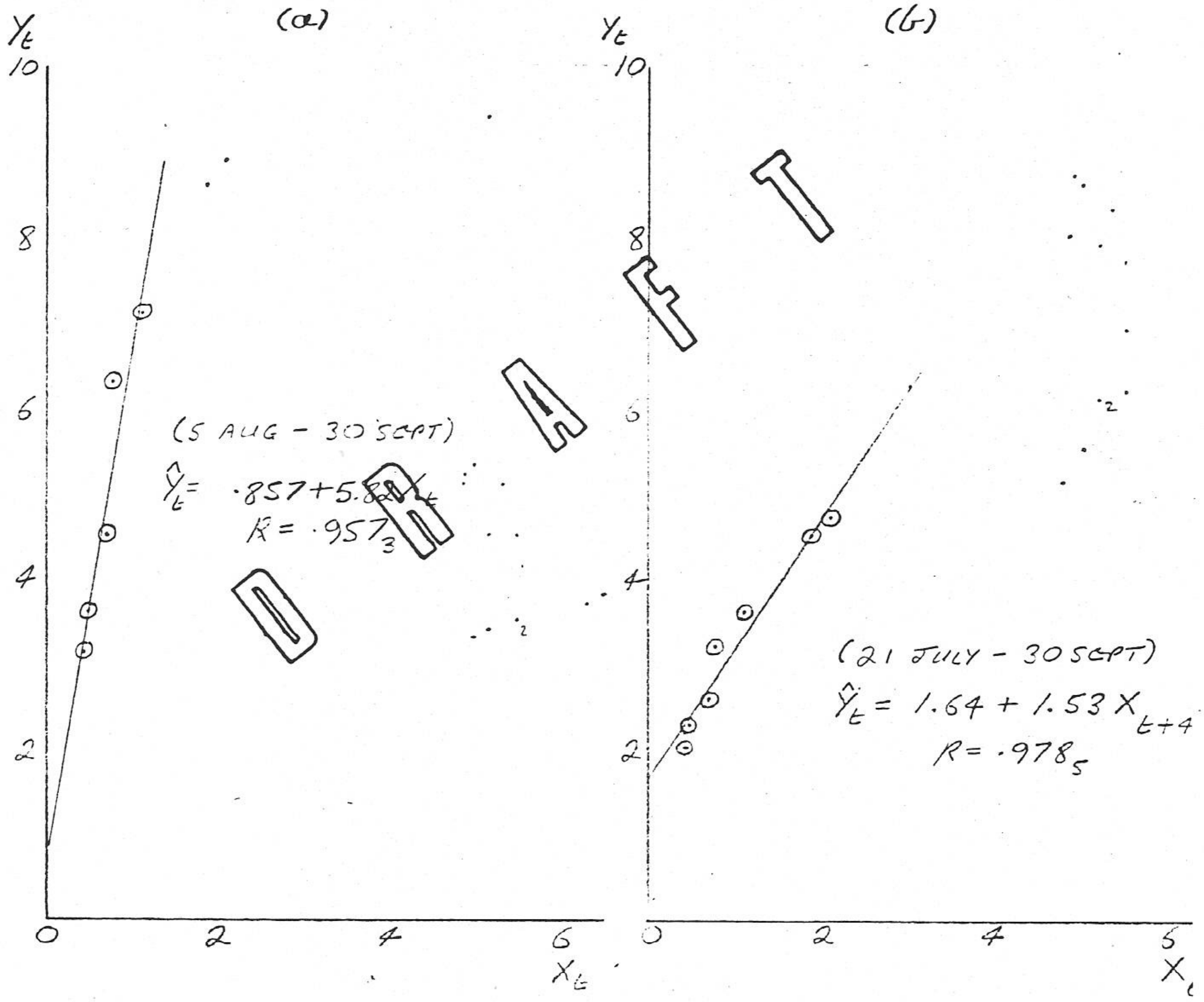
once again supporting the premise, that such low flow relationships have

FIGURE II - 9 : 1981 FLOW RELATIONS BETWEEN ARGENTA AND JEROME CREEKS

$Y \equiv$ ARGENTA STREAMFLOW (CFS)

$X \equiv$ JEROME STREAMFLOW (CFS)

$$\text{AREA (ARG)} / \text{AREA (JER)} = 2.00$$



(5 AUG - 30 SEPT)

$\hat{Y}_t = .857 + 5.82 X_t$

$R = .957_3$

(21 JULY - 30 SEPT)

$\hat{Y}_t = 1.64 + 1.53 X_{t+4}$

$R = .978_5$

longevity. Argenta creek may be regarded as peaking 42 days later than Jerome creek. Such an assumption does not give rise to a substantially better set of relationships however, Figure II-9b.

Table II-3 summarizes the best results of the previous analyses, as discussed above. Periods II and III are variable from creek to creek but generally refer to the high flow period and the recession period respectively. b_0 and b_1 are the regression coefficients, R_n is the correlation coefficient with 1 and n (uncorrected) degrees of freedom. Drainage area ratios (e.g. Kootenay Joe drainage area divided by Jerome drainage area equals 2.28) have been included, so that they may be compared to b_1-values for period III.

Table II-3

Streamflow Regressions

Creek	Period II			Period III			Drainage Area Ratio
	b_0	b_1	R_n	b_0	b_1	R_n	
			Versus Jerome				
KJ	-26.6	7.81_{t-9}	$.911_8$	-1.44	2.75_{t-9}	$.973_{11}$	2.28
Bul	-1.23	2.44_{t-10}	$.799_8$	-.866	3.76_{t-10}	$.987_{11}$	3.00
Gar	2.70	1.30_{t-9}	$.876_5$	.212	5.35_{t-9}	$.983_{11}$	1.11
			Versus Argenta				
Gar		N/A		-1.15	1.20_t	$.989_9$	.556
GNR		N/A		.0878	$.0933_t$	$.961_{16}$	.189
CAR		N/A			N/A		.551

Table II-4 shows how streamflow on Gardner creek increases as the creek "gains" below the gauge.

Table II-4

Gardner Creek Streamflow

Date	Gauge (2500') cfs	Above P.O.D. (2450') cfs	Below P.O.D. (2400') cfs	(2350') cfs	Road (2050') cfs
May 19	0.1				0.62
June 4	0.075	0.16	0.25	0.44	0.77
June 12	0.23				1.05
June 17					1.22
June 18	0.48	1.25			1.40
July 16	0.85	1.32			
Sept 17	0.41	1.24	1.70		1.57
Oct. 1	0.48	1.02	1.22		1.04

Careful measurements using the Marsh McBirney meter were made on the dates and at the locations indicated. It appears that, if the September 17 and October 1 low flows are averaged at the gauge and just above the P.O.D., the flows may be approximately related by,

$$Q_p / Q_g = 2.5,$$

where, Q_g is the discharge at the gauge and Q_p is the discharge just above the P.O.D. Referring back to Table II-3, it appears that the low flow equation,

$$\hat{Y}_t = 0.0878 + 0.0933 X_t,$$

can be rewritten, after multiplying the righthandside by 2.5,

$$\hat{Y}_t \doteq 0.22 + 0.23 X_t,$$

to more accurately describe the flow at the P.O.D. The surface drainage area of Gardner creek above the P.O.D. is 147 ha, hence the drainage area ratio for Gardner versus Argenta is 147/570 or 0.258. It is worth noting, that the new b_1-value for the low flow regression at the P.O.D., is now very similar to the drainage area ratio.

Table II-5

Average Low Flows

Creek	b_0	b_1	$\bar{X}$	$\bar{Y}$	Low Flow Estimates New cfs	Old cfs	Licensed Demand cfs
MJ	-0.767	2.30	0.398@	0.148	0.17	N/A	0.003
	-0.380	1.44	0.398	0.193			
Bul	-0.493	3.14	0.398	0.757	0.85	N/A	--
	-0.758	4.25	0.398	0.934			
Gar	0.212	5.35	0.398	2.34	2.27	1.92*	0.612
	-0.702	7.96	0.398	2.47			
	-4.61	3.22	2.62@	3.83			
	-1.15	1.20	2.62	1.99			
Gnr	0.0878	0.0933	2.62	0.33	0.33+	0.84*	0.28
Car				0.85	0.85	0.85*	0.173
Arg					2.62@	2.62@	0.506
Sal					N/A	N/A	0.018

@ From Water Survey of Canada historical records.

* From Water Management Branch.

\+ Well above P.O.D. (Flow at P.O.D. = 0.33 x 2.51 = 0.83 cfs).

Table II-5 describes how the best estimates of mean September flows, for each creek, can be obtained. For Kootenay Joe, two regressions are used, (the zeroth lag and the ninth lag relationships for the late recession, Figure II-4c and II-4d). The mean September flow for Jerome creek, for its entire period of historical record (1921-77; 13 years), is 0.398 ± 0.086 cfs (0.0113 ± 0.0024 m^3/s) at a confidence level of 95%. This value is substituted into the regression equations to obtain $\bar{Y}$ values of 0.148 cfs (0.00419 m^3/s) and 0.193 cfs (0.00547 m^3/s), for Kootenay Joe creek. These two values are averaged to obtain 0.17 cfs (0.0048 m^3/s), as the best estimate, which is then compared with the best estimates, obtained from Water Survey of Canada records or estimates made by Water Management Branch, if available. Finally the total licensed demand (domestic plus irrigation) is quoted. In the case of Kootenay Joe creek, the licensed demand is equivalent to 0.003 cfs (0.0001m^3/s), less than 2% of supply for an average September.

Similarly, for Bulmer creek, the zeroth lag and tenth lag relationships for the late recession (Figures II-5c and II-5d) were used to obtain the best estimate of 0.85 cfs (0.024 m^3/s).

For Gar creek, four regressions are used, the zeroth lag and the ninth lag on Jerome, (Figures II-6a and II-6b) and the zeroth lag and the thirty-third lag regressions on Argenta (Figures II-7a and II-7b). The mean September flow on Argenta creek for the period (1928-81; 14 years) is 2.62 ± 0.45 cfs (0.0742 ± 0.0127 m^3/s), at a confidence level of 95%. Three out of the four regressions give similar values but the thirty-third lag regression result is 70% higher than the average of the others. This is because small relative shifts in slowly tapering time series have little effect on the low flow calculations (b_0-values compensate for b_1-values). Hence, the zeroth lag and the ninth lag regressions give similar results. However, a thirty-three day shift is too much, since it included high flow values on Gar, and is rejected. The three close values are averaged to give 2.27 cfs (0.0643m^3/s), as the best estimate. It is pleasing to note, that the zeroth lag relationship between Gar and Argenta produced a similar result to the values using the two Gar versus Jerome relationships. The Water Management Branch estimate of 1.92 cfs (0.0544 m^3/s) is close, at about 85% of the study figure. Total licensed demand on Gar creek is equivalent to 0.612 cfs (0.0173 m^3/s), or about 25% of the estimated mean September flow.

The single zeroth lag relationship between Gardner and Argenta creek (Figure II-8a), suggests that 0.33 cfs (0.0093 m^3/s) is a good estimate of mean September flow, at the gauge. This translates to 0.83 cfs (0.0235 m^3/s), just above the P.O.D., using the conversion factor of 2.5, previously obtained. This figure of 0.83 cfs (0.0235 m^3/s) ties in very well with Water Management Branch's estimate of 0.84 cfs (0.0238 m^3/s). Total licensed demand on Gardner creek is equivalent to 0.28 cfs (0.0079 m^3/s) or about 30% of the estimated mean September flow.

The average flow on Carter creek for the 1981 field monitoring season was 0.85 cfs (0.0241 m^3/s) with very little variation, such that no flow relationships could be developed. This figure is identical to Water Management Branch's estimate of 0.85 cfs (0.0241 m^3/s). Total licensed demand on Carter creek is equivalent to 0.173

cfs (0.0049 m^3/s), or about 20% of the estimated mean September flow.

Total licensed demand on Argenta creek is equivalent to 0.506 cfs (0.0143 m^3/s) or about 20% of mean September flow.

No systematic flow records were taken on Salisbury creek during 1981. There are no historical records and no estimates of low flow. However, two measurements were made using the meter on September 17 and October 1, 1981 and flows of 13.13 cfs (0.3718 m^3/s) and 11.70 cfs (0.3313 m_3/s) respectively, were recorded. Since total licensed demand is equivalent to only 0.018 cfs (0.00051 m^3/s), there is obviously an enormous oversupply available.

The reliability of these low flow estimates may be inferred from the confidence limits on the mean September flows for Jerome and Argenta creeks, during their periods of record, the representative nature of climatic factors during these periods of record and the accuracy of the flow relationships, that were developed in this report.

The mean September flows were 0.398 ± 0.086 cfs (0.0113 ± 0.0024 m^3/s) for Jerome, at the 95% confidence level, using 13 years of data and 2.62 ± 0.45 cfs (0.0742 ± 0.0127 m^3/s) for Argenta, at the 95% confidence level, using 14 years of data. It can be shown, that the mean annual precipitation at South Slocan of 798 ± 68 mm, for the period, 1972-77, is not significantly different from the mean annual precipitation at South Slocan of 790 mm for the 30 year period, 1941-70. Since 4 of the 13 years of record on Jerome fall within the period, 1941-70 and 6 of the 13 years occur from 1972-77, it seems likely that the value of 0.398 cfs (0.0113 m^3/s) is a good estimate of the population mean September flow on Jerome creek. Similarly, from precipitation records, measured at Lardeau, 2.62 cfs (0.0742 m^3/s) should also be a good estimate of the population mean September flow for Argenta creek. The flow relationships used for the prediction of mean Septmeber flows, on the other creeks, are probably not less accurate than the estimates of mean September flows on Jerome and Argenta creeks, discussed above.

STREAM REACH INVENTORY AND CHANNEL STABILITY EVALUATION

The stream reach inventory and channel stability evaluation procedure, described by Pfankuch (1975), was applied to the main stems of Kootenay Joe, Gar, Bulmer and Argenta creeks, during the 1981 field season. Pfankuch forms were also completed for Gardner creek, just below its main P.O.D., Carter creek, at the weir, Mautner spring, at its source and Salisbury creek, in its headwater area and at the road. Pfankuch's method was chosen, because it was the most appropriate for evaluating timber harvesting impacts. "These procedures were developed to systemize measurements and evaluations of the resistive capacity of mountain stream channels to the detachment of bed and bank materials and to provide information about the capacity of streams to adjust and recover from potential changes in flow and/or increases in sediment production", (Pfankuch, 1975, p.1). Figure III-1 shows the field form used in the application of the procedure. Ratings were obtained for slope class, mass wasting, debris jam potential and vegetative bank protection for the upper banks, channel capacity, bank rock content, obstructions, cutting and deposition for the lower banks and rock angularity, brightness, consolidation, bottom size distribution, scouring, deposition and clinging aquatic vegetation, for the channel

Item Rated	
UPPER BANKS	
Landform Slope	Bank slo
Mass Wasting (Existing or Potential)	No evide potentia wasting
Debris Jam Potential (Floatable Objects)	Essentia immediat
Bank Protection from Vegetation	90% + pl and vari deep, de
LOWER BANKS	
Channel Capacity	Ample fo increase tained.
Bank Rock Content	65% + wi boulders
Obstructions Flow Deflectors Sediment Traps	Rocks, o embedded of pool without depositi
Cutting	Little o Infreque than 6"
Deposition	Little o of chann
BOTTOM	
Rock Angularity	Sharp ed plane su
Brightness	Surfaces stained.
Consolidation or Particle Packing	Assorted packed a
Bottom Size Distribution % Percent Stable Materials	No chang Stable m
Scouring and Deposition	Less tha affected depositi
Clinging Aquatic Vegetation (Moss & Algae)	Abundant moss lik ennial.

Add the values in each column for a

Reach score of:<38=Exellent,

Item Rated	Stability Indicators by Classes							
UPPER BANKS	EXCELLENT		GOOD		FAIR		POOR	
Landform Slope	Bank slope gradient <30%	(2)	Bank slope gradient 30-40%	(4)	Bank slope gradient 40-60%	(6)	Bank slope gradient 60% +	(8)
Mass Wasting (Existing or Potential)	No evidence of past or potential for future mass wasting into channels.	(3)	Infrequent and/or very small. Mostly healed over. Low future potential.	(6)	Moderate frequency & size, with some raw spots eroded by water during high flows.	(9)	Frequent or large, causing sediment nearly yearlong OR imminent danger of same.	(12)
Debris Jam Potential (Floatable Objects)	Essentially absent from immediate channel area.	(2)	Present but mostly small twigs and limbs.	(4)	Present, volume and size are both increasing.	(6)	Moderate to heavy amounts, predominantly larger sizes.	(8)
Bank Protection from Vegetation	90% + plant density. Vigor and variety suggests a deep, dense root mass.	(3)	70-90% density. Fewer plant species or lower vigor suggests a less dense or deep root mass.	(6)	50-70% density. Lower vigor and still fewer species form a somewhat shallow and discontinuous root mass.	(9)	<50% density plus fewer species & less vigor indicate poor, discontinuous, and shallow root mass.	(12)
LOWER BANKS								
Channel Capacity	Ample for present plus some increases. Peak flows contained. W/D ratio <7.	(1)	Adequate. Overbank flows rare. Width to Depth (W/D) ratio 8-15.	(2)	Barely contains present peaks. Occasional overbank floods. W/D ratio 15-25.	(3)	Inadequate. Overbank flows common. W/D ratio >25.	(4)
Bank Rock Content	65% + with large, angular boulders 12" + numerous.	(2)	40 to 65%, mostly small boulders to cobble 6-12".	(4)	20 to 40%, with most in the 3-6" diameter class.	(6)	<20% rock fragments of gravel sizes, 1-3" or less.	(8)
Obstructions Flow Deflectors Sediment Traps	Rocks, old logs firmly embedded. Flow pattern of pool & riffles stable without cutting or deposition.	(2)	Some present, causing erosive cross currents and minor pool filling. Obstructions and deflectors newer and less firm.	(4)	Moderately frequent, moderately unstable obstructions & deflectors move with high water causing bank cutting and filling of pools.	(6)	Frequent obstructions and deflectors cause bank erosion yearlong. Sed. traps full, channel migration occuring.	(8)
Cutting	Little or none evident. Infrequent raw banks less than 6" high generally.	(4)	Some, intermittently at outcurves & constrictions. Raw banks may be up to 12".	(8)	Significant. Cuts 12"-24" high. Root mat overhangs and sloughing evident.	(12)	Almost continuous cuts, some over 24" high. Failure of overhangs frequent.	(16)
Deposition	Little or no enlargement of channel or point bars.	(4)	Some new increas in bar formation, most from coarse gravels.	(8)	Moderate deposition of new gravel & coarse sand on old and some new bars.	(12)	Extensive deposits of predominately fine particles. Accelerated bar development.	(16)
BOTTOM								
Rock Angularity	Sharp edges and corners, plane surfaces roughened.	(1)	Rounded corners & edges, surfaces smooth & flat.	(2)	Corners & edges well rounded in two dimensions.	(3)	Well rounded in all dimensions, surfaces smooth.	(4)
Brightness	Surfaces dull, darkened, or stained. Gen. not "bright".	(1)	Mostly dull but may have up to 35% bright surfaces.	(2)	Mixture, 50-50% dull and bright, ± 15%, ie 35-65%.	(3)	Predominately bright, 65% +, exposed or scoured surfaces.	(4)
Consolidation or Particle Packing	Assorted sizes tightly packed and/or overlapping.	(2)	Moderately packed with some overlapping.	(4)	Mostly a loose assortment with no apparent overlap.	(6)	No packing evident. Loose assortment, easily moved.	(8)
Bottom Size Distribution & Percent Stable Materials	No change in sizes evident. Stable materials 80-100%.	(4)	Distribution shift slight. Stable materials 50-80%.	(8)	Moderate change in sizes. Stable materials 20-50%.	(12)	Marked distribution change. Stable materials 0-20%.	(16)
Scouring and Deposition	Less than 5% of the bottom affected by scouring and deposition.	(6)	5-30% affected. Scour at constrictions and where grades steepen. Some deposition in pools.	(12)	30-50% affected. Deposits & scour at obstructions, constrictions, and bends. Some filling of pools.	(18)	More than 50% of the bottom in a state of flux or change nearly yearlong.	(24)
Clinging Aquatic Vegetation (Moss & Algae)	Abundant. Growth largely moss like, dark green, perennial. In swift water too.	(1)	Common. Algal forms in low velocity & pool areas. Moss here too and swifter waters.	(2)	Present but spotty, mostly in backwater areas. Seasonal blooms make rocks slick.	(3)	Perennial types scarce or absent. Yellow-green, short term bloom may be present.	(4)
	COLUMN TOTALS →		→		→		→	

Add the values in each column for a total reach score here. (E.____ + G.____ + F.____ + P.____ = _____).

Reach score of:<38=Exellent, 39-76=Good, 77-114=Fair, 115+=Poor.

Form R-1 2500-5 (6-73)

OVER

R-1 STREAM REACH INVENTORY and CHANNEL STABILITY EVALUATION

LOCATION

Forest Name ____________ & No. ____ Ranger Dist. ____________ Survey Date ________

Observer(s) ____________ Stream Name ____________

Reach Description & Other Identification ____________

Aerial Photo No. ________ Coordinates & Identification ________ P.W.I. W/S No. __ __ __ __ __ __ __

INVENTORY MEASUREMENTS & ESTIMATES*

Stream Size & Discharge { Survey Date Width ____ Ft. Ave.Depth ____ Ft. Velocity ____ f/s Discharge ____ cfs

{ At Maximum ____ Ft.* ____ Ft.* ____ f/s* ____ cfs*

Gradient ____ % Sinuosity ratio ____ Stream Order ____ Turbidity Level ____ Stream Stage ____

Channel Flow Pattern ____________

Soils Description ____________

Landform and/or Geologic Type ____________

Vegetative Type ____________

Number of debris jams &/or fish blocks/mile ____. Upstream watershed impacts (Types) ____________

Size Composition of Bottom Materials (Total to 100%)

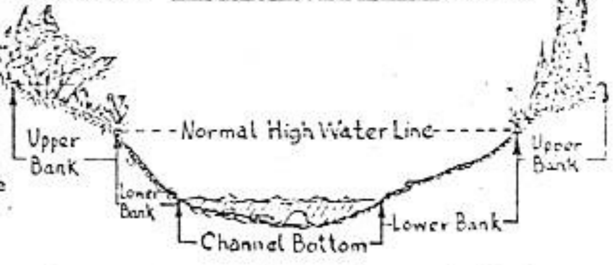
1. Exposed bedrock.......... ____ %
2. Large boulders, 3' + Dia.. ____ %
3. Small boulders, 1-3'...... ____ %
4. Large rubble, 6"-12"...... ____ %
5. Small rubble, 3"-6"...... ____ %
6. Coarse gravel, 1"-3"..... ____ %
7. Fine gravel, 0.1"-1"..... ____ %
8. Sand, silt, clay, muck... ____ %

Weather and Other Remarks ____________

INSTRUCTIONS

Use a separate rating form for each length of stream that appears similar. Complete the inventory items above using maps, aerial photos, and field observations and measurements. On the opposite side of this page, the channel and adjacent flood plain banks are subjectively rated, item by item, following an on-the-ground inspection. Circle only one of the numbers in parentheses for each item rated. If actual conditions fall somewhere between the conditions as described, cross out the number given and below it write in an intermediate value which better expresses the situation. Don't key in on a single indicator or a small group of indicators but use them all for the most diagnostic value. The indicators are inter-related so don't dwell on any one item for long. Do the best you can and the pluses and minuses should balance out. Keep in mind that each item directly or indirectly seeks to answer three basic questions: (1) What are the magnitude of the hydraulic forces at work to detach and transport the various organic and inorganic bank and channel components? (2) How resistent are these components to the recent stream-flow forces exerted on them? (3) What is the capacity of the stream to adjust and recover from potential changes in flow volume and/or increases in sediment production? Use your instruction booklet!

DEFINITION OF TERMS AND ILLUSTRATIONS

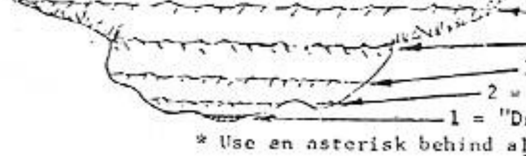


Upper Bank - That portion of the topographic cross section from the break in the general slope of the surrounding land to the normal high water line. Terrestrial plants & animals normally inhabit this area.

Lower Banks - The intermittently submerged portion of the channel cross section from the normal high water line to the water's edge during the summer low flow period.

Channel Bottom - The submerged portion of the channel cross section which is totally an aquatic environment.

Stream Stage - The height of water in the channel at the time of rating is recorded on the top half of this page using numbers 1 through 5. These numbers, as shown below, relate to the surface water elevation relative to the normal high water line. A decimal division should be used to more precisely define conditions, ie. 3.5 means 3/4ths of the channel banks are under water at the time of rating.



5 = Flooding. The flood plain is completely covered.
4 = High. Channel full to the normal high water line.
3 = Moderate. Bottom and ½ of lower banks wetted.
2 = Low. Bottom covered but very little of the lower banks wet.
1 = "Dry". Essentially no flow. Water may stand in bottom depressions.

* Use an asterisk behind all estimates that could be measured but weren't.

bottom. These and other observations were recorded, during descent, on foot, in the creek bed. Survey tape was used to identify inventoried locations, for future reference, and some appropriate photographic documentation was obtained, for Kootenay Joe and Gar creeks. Station numbers (locations down the channel, at which Pfankuch forms were completed), together with Pfankuch overall stability ratings, are indicated on the Hydrology Map (Appendix 1). Reaches below each station can be regarded as uniform, in terms of the overall stability rating, since stations were chosen only when significant changes became apparent in several of the Pfankuch parameters (i.e. a station rating applies to the reach below it, down to the next station, if that reach was in fact "walked"). Also included, as part of the stream reach inventory on the Hydrology Map, are tributaries and springs (adjacent to the channel), avalanche paths, zones of active mass wasting, bedrock canyons, in-channel natural and man-induced organic debris and debris jams. Stream gauging stations and P.O.D.'s (points of diversion for domestic and irrigation water supply) are also indicated.

The following sections discuss, in greater detail, the Pfankuch ratings for individual items, (including size composition of channel bottom materials, channel and upper bank gradients) as well as the information that was mapped for each creek. Table III-1 is a key to symbols used in Table III-2, that summarizes the Pfankuch inventory data obtained for all the creeks.

Kootenay Joe Creek

The mainstem of Kootenay Joe was inventoried on foot, from 1654 to 687 m. a.s.l. (refer to Tables III-1 and III-2).

Table III-1

Stream Reach Inventory and Channel Stability

Key to Symbols Used in Table III-2

Symbol	Definition
EL	Elevation (meters above sea level).
CH	Channel gradient (%).
Upper banks	
LB	Left bank (%) (V = vertical or nearly vertical).
RB	Right bank (%) (V = vertical or nearly vertical).
MW	Mass wasting, existing and potential (Pfankuch items*).
DJ	Debris jam potential (floatable objects).
VP	Vegetative bank protection.
Lower Banks	
CC	Channel capacity.
BR	Bank rock content.
OB	Obstructions (flow deflectors, sediment traps).
C	Cutting.
D	Deposition.
Channel Bottom	
RA	Rock angularity.
BRI	Brightness.
PP	Particle packing (consolidation).
DI	Distribution (Percent stable materials).
SD	Scouring and deposition.
V	Aquatic vegetation.
Channel Bottom Materials Size Composition (percent)	
B	Bedrock.
Lb	Large Boulders. (3 ft + in diameter)
Sb	Small boulders. (1 ft - 3 ft)
Ru	Rubble. (6" to 12")
Sr	Small rubble. (3" to 6")
Cg	Coarse gravel. (1" to 3")
Fg	Fine gravel. (0.1" to 1")
Ssc	Sand, silt, clay, muck.

Table III-1 cont.

Symbol	Definition
Pfankuch Classes	
P	Poor
F	Fair
G	Good
E	Excellent

N.B. Elevations were measured in feet and converted to meters. Gradients were measured in degrees and converted to percentages.

---

* Mass wasting (existing and potential) is rated for two types of trigger mechanism only.

1) Undercutting of upper banks, caused by high flows (natural or increased by off-site timber harvesting)

2) Overloading of upper bank material and/or lubrication of impermeable (or semi-permeable) layers, caused by water percolation or seepage (natural or increased by off-site timber harvesting). These ratings differ substantially from those assigned on the basis of direct impact, on-site timber harvesting activities, such as roads, skid trails, cutblocks and landings. On-site mass wasting hazards will generally be one or more classes higher than Pfankuch classes.

Table III-2

Stream Reach Inventories

EL	CH	LB	RB	MW	DJ	VP	CC	BR	OB	C	D	RA	BRI	PP	DI	SD	V	H	Lb	Sb	Ru	Sr	Cg	Fg	Ssc
Kootenay Joe																									
1654	27	25	25	E	F	G	E	E	G	E	E	F	G	F	G	G	G	0	5	60	20	5	5	5	0
1562	40	36	73	F	F	G	E	E	G	E	E	F	G	F	G	G	G	5	20	20	20	20	10	5	0
1242	32	65	70	G	F	G	G	E	G	G	G	F	F	F	G	G	G	5	15	15	10	10	30	10	5
1158	32	84	V	G	G	G	E	E	E	E	E	F	G	G	G	E	G	67	20	5	3	2	2	1	0
914	25	120	70	P	P	G	F	G	F	F	F	F	F	F	F	F	F	5	5	5	30	20	20	10	5
762	21	9	84	G	F	G	F	G	F	F	F	F	F	F	F	F	F	0	0	2	20	40	20	10	8
Gar																									
1097	47	58	36	E	E	E	E	G	E	E	E	G	G	G	E	E	G	0	0	5	10	10	35	35	5
991	36	84	84	F/G	F/G	G	E	G	G	G	E	G	G	G	E	E	E	0	0	0	5	40	40	10	5
914	23	70	49	G/E	F	G	G	G	G	G	G	G	[illegible]	G	G	G	E	0	0	0	0	10	15	15	60
808	18	47	70	G	G	G	G	F	E	E	E	[illegible]	G	G	G/E	G/E	E	0	0	0	0	5	40	35	20
792	18	70	70	G	G	G	G	F	E	E	E	G	G	G	G/E	G/E	E	0	0	0	0	5	40	35	20
Gardner																									
716	12	18	18	G	F	G	G	F	G	E	E	E	G	E	E	E	E	0	0	0	0	10	30	30	30
Salisbury																									
1814	47	70	70	E	F	E	E	E	E	E	E	E	G	G	G	E	G	60	20	5	5	5	5	0	0
1570	27	58	84	F	F	E	E	E	F	G	G	G	G	G	G	G	F	20	20	40	5	5	10	0	0
579		V		E	E	E	E	E	E	G	E	G	G	G	G	G	G	10	20	20	20	20	10	0	0
Bulmer																									
1265	25	84	84	G	G	E	E	E	E	E	E	G	G	G	G	E	G	10	10	10	10	20	20	10	10
1204	21	58	58	E	G	E	E	E	E	E	E	G	E	G	G	E	G	0	20	25	5	5	5	20	20
1097	25	58	58	E	G	E	E	E	E	E	E	G	G	G	G	E	G	5	1	1	5	10	30	30	18

Table III-2 cont.

EL	CH	LB	RB	MW	DJ	VP	CC	BR	OB	C	D	RA	BRI	PP	DI	SD	V	R	Lb	Sb	Ru	Sr	Cg	Fg	Ssc
Bulmer																									
732	27	25	81	G	G	E	E	E	E	E	E	E	E	G	E	E	G	5	30	30	30	5	0	0	0
671	9	18	18	E	E	E	G	G	E	E	E	G	G	G	E	E	E	0	1	5	5	24	30	30	5
610	14	18	18	E	G	E	E	G	E	E	E	G	E	E	E	E	G	0	2	5	5	10	30	30	18
Argenta																									
1074	40	100	100	F/G	G	G	E	G	E	E	E	E	E	G	G	E	G	5	5	30	30	20	5	3	2
998	27	58	47	F	G	F	E	F	E/G	E	E	E	G	G	G	E	G	0	0	0	5	15	30	30	20
892	18	100	100	F/G	G	F	E	F	E	G	E	G	E	G	G	E	G	0	0	10	10	20	20	20	20
Carter																									
792	?	18	18	G	G	G	E	P	G	G	G	N/A	N/A	P	F	G	F	0	0	0	0	0	5	20	75
Mautner Spring																									
937	27	25	25	E	E	E	E	N/A	E	E	E	N/A	N/A	F	E	E	E	0	0	0	0	0	0	5	95

Station 1 (1654 m.). Upper bank ratings are good to excellent, with the exception of a fair rating due to the presence of recent large organic debris.

Lower bank ratings are all excellent, except for a good rating due to the presence of newer, less firm obstructions and flow deflectors.

Channel bottom ratings are generally good, except that the rounded channel bottom materials do not imbricate well, hence the fair ratings. Bottom size composition percentages indicate a predominance of small boulders and large rubble. Channel gradient is not particularly steep at 27%, nor are the upper banks steep at < 30%.

The overall rating is 65, indicating that the reach from 1654 to 1562 m.is quite stable.

Station 2 (1562 m). The upper right bank (true right, looking down, i e. north side) is very steep, at about 70%, leading to a moderate (fair rating) existing and potential mass wasting hazard. Recent large organic debris is also present.

Lower bank and channel bottom ratings are as for station 1. There is some exposed bedrock on the left upper bank and about 5% in the channel bottom. The bottom materials consist mainly of a uniform distribution, ranging from large boulders to small rubble. Channel gradient is now steeper at 40%.

The overall rating is 77, indicating that this reach (1562-1242 m.), is less stable than the previous reach. The upper right bank gradients are 90%, 90% and 84% at 1509, 1494 and 1433 m. respectively.

Station 3 (1242 m). Gradients of the upper banks are 65% and 70% for the left and right banks respectively. This is a short canyon.

There seems to be less danger of mass wasting but large organic debris is still present.

There is, however, some indication of overbank flooding, an increase in flow deflectors and some erosion of the lower banks and deposition of coarse gravels.

Channel bottom rocks have more bright surfaces, an indication of instability. There has been a shift in bottom size composition to include depositional materials. Channel gradient is 32%.

The overall rating is 84, indicating that this reach (1242-1158 m), is less stable than the previous one and can be regarded as only fair.

Station 4 (1158 m.). This is the start of a bedrock canyon. Gradients of the upper banks are 84% and almost vertical rock for the left and right respectively. There is less organic debris present and low potential for mass wasting on the upper banks. Lower bank ratings are now all excellent and channel bottom material appears more stable, consisting mainly of large boulders, about 20%, resting on bedrock, about 70% exposed. Channel gradient at this point is 32%.

The bedrock canyon continues relatively unchanged from 1158 to 1052 m, after which, the walls open out. A second shorter canyon occurs between 953 and 930 m., at the mouth of which, there is a large debris jam. Large and small organic material appears to have been carried down the left upper bank, by snow slides and movement of the shallow colluvial material, in which it was poorly anchored.

The overall rating for the reach from station 4 (1158m), to the bottom of the second canyon (930 m), is 62, indicating that this reach is quite stable.

Station 5 (914 m.). Just below the large debris jam, the upper banks are very steep at 120% and 70% for the left and right respectively. Mass wasting potential is high and there are moderate to heavy amounts of organic material, impacting the creek channel.

There is occasional overbank flooding, due to unstable obstructions and flow deflectors, causing significant lower bank erosion.

The channel bottom items are all rated as fair, indicating moderate instability. Bottom materials consist predominantly of large and small rubble, coarse and fine gravel. Channel gradient is somewhat less than for the previous reach and measures out at 25%.

The overall rating is 115 for the reach from 930 m. to 762 m., indicating that this reach is only fair to poor and quite unstable.

Station 6 (762 m.). The gradient of the upper right bank is 84% but the left bank is only about 10%. Mass wasting potential appears low but there is a moderate debris jam potential.

There is occasional overbank flooding, due to unstable obstructions and flow deflectors, causing significant lower bank erosion, as for the previous reach. All channel bottom items are rated as fair and bottom materials consist mainly of rubbles and gravels.

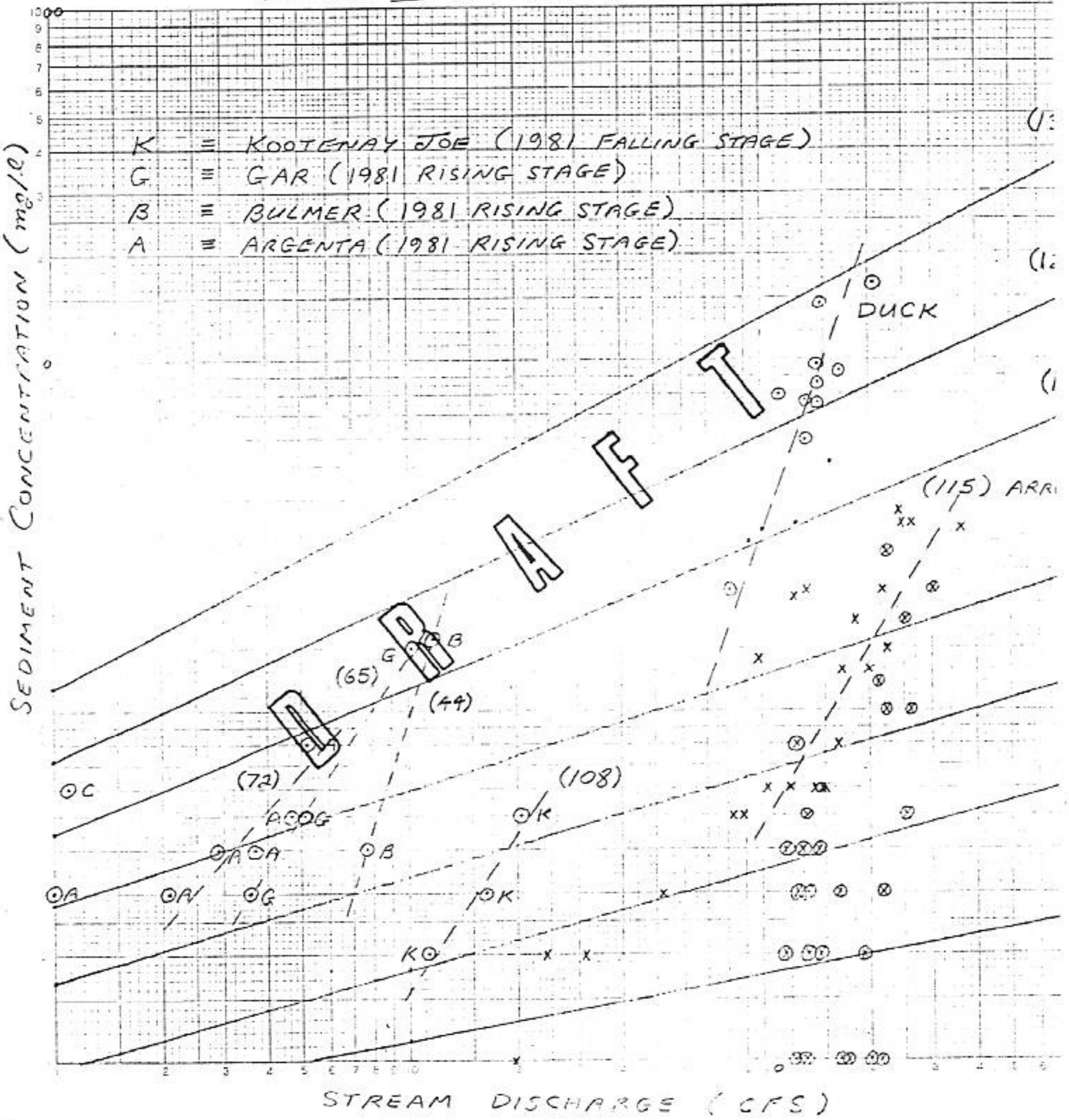
The overall rating for the reach from 762 m. to the gauge location at 678 m. is 108, i.e., fair to poor.

Infrequent and intermittent grab samples were taken during 1980, 1981 and 1982 by a local technician, at the gauging location, and subsequently analysed for suspended sediment concentrations (res. n-filt., 105°C). The highest values obtained were 4 mg/l on May 6, 1980, 5 mg/l on May 25, 1981 and 4 mg/l on May 31, 1982, with all other values at or less than 3 mg/l, indicating that Kootenay Joe is "gin" clear throughout most of the year. Streamflow was measured on May 25, 1981 at 20.7 cfs (0.586 m^3/s) but the highest recorded flow was 25.02 cfs (0.708 m^3/s) on June 4, 1981 and may of course have been even higher, on days close to this date, during which flow was not measured. Therefore, 5 mg/l is probably less than the maximum, that could have been observed in 1981 had the monitoring program been continuous and capable of detecting instantaneous peak flows and suspended sediment values.

Figure III-2 shows a set of sediment ratings (straight-line relationships) developed for over 80 streams in northern and central Idaho and northwestern Montana, by Rosgen (1975). Each regression corresponds to a particular Pfankuch overall stability rating and they were all found to be highly significant at the 99% level. Similar curves should be developed for the study area. In the absence of such curves, it is worth superimposing the sediment/discharge data that were obtained for the Argenta Slope in 1981, onto these standard curves. Observations recorded on Duck and Arrow creeks (near Creston) have also been included for comparison purposes. The observed Pfankuch ratings, at the gauge locations are also noted. The value of 115 for Arrow creek, at its base station, was obtained by the Ministry of Environment in 1980 (unpublished).

Using these curves, the stability ratings for the lower reaches on Kootenay Joe creek, suggest that suspended sediment concentrations during instantaneous peak flows may be high as 20-30 mg/l. The extreme variability of flows, during peak snowmelt periods, on Kootenay Joe

FIGURE III-2 : SEDIMENT RATING CURVES



creek would indicate, that above average years could produce large sediment loads, as high instantaneous peak flows flush out the creek channel, whereas lower than average flow years may produce little sediment.

Gar Creek

The mainstem of Gar creek was inventoried on foot, from 1097 to 792 m. a.s.l. (Tables III-1 and III-2).

Station 1 (1097m). Upper bank ratings are all excellent, with the exception of a fair rating, due to the moderately steep left bank. Lower bank ratings are all excellent, except for a good rating, assigned to the bank rock content category. Channel bottom items are good to excellent, since bottom materials are moderately well-packed and stable. Bottom size composition percentages indicate a predominance of gravels. The overall rating is 44, for the reach from 1097 to 991 m.

Station 2 (991m). An avalanche path impacts the creek in the north gully, just above station 2. Both upper banks are very steep (over 80%) and mass wasting (existing and potential) is small to moderate. There are some large logs aligned in the stream bed. These obstructions and flow deflectors have caused some erosion of the lower banks.

The channel bottom appears as stable as for the previous reach, with even greater amounts of aquatic vegetation, clinging to the rubble and gravel, that comprises the majority of the bottom materials.

There is a bedrock canyon from 975 to 953 m. with a channel gradient of 47% and both upper banks still over 80%. From 953 to 914 m., the channel gradient lessens, banks drop back and the creek becomes less confined.

The overall rating is 66 for this reach, from 991 to 914 m.

Station 3 (914 m). The upper left bank is quite steep at 70%. Mass wasting is not an evident problem, but in-channel organic debris has increased, such that large logs cover about 75% of the channel bottom. Hence, there has been some overbank flooding, causing erosion and deposition.

Channel gradient is 23%. The channel bottom shows signs of instability, with a predominance of fine materials, trapped in a log matrix. A debris jam exists in a short confined gully, at 869 m, filled with large boulders and logs. The overall rating is 77 for this reach, from 914 to 808 m.

Station 4 (808 m). The upper right bank is concave, mucky and steep near the top, at about 70%. This reach appears to have been impacted by livestock. Mass wasting does not seem to be a problem, however, and only small quantities of organic material, mainly small twigs and limbs, are present in the channel. Lower banks have little rock content but evidence of erosion is minimal.

Channel gradient is 18% and channel bottom items are rated good to excellent. Bottom materials consist mainly of gravels, sand, silt, clay and muck. The overall rating is 65 for this reach, from 808 to 792 m.

Station 5 (792 m). Both upper banks are steep at 70%. This is the gauge location and all items are rated as for station 4. Channel gradient is 18% and size composition for the channel bottom materials is also identical to the above reach.

Suspended sediment concentrations measured at this location, during 1981, appear in Figure III-2. The highest value obtained was 15 mg/l on June 1, 1981, compared with 6 mg/l on May 6, 1980 and 11 mg/l on July 5, 1982. Streamflow was measured on June 1, 1981 at 10.1 cfs (0.286 m^3/s) but the highest recorded streamflow was 11.5 cfs (0.326 m^3/s) on July 27, 1981. Sediment levels were probably not much higher than 15 mg/l on July 27, since discharge was not much greater than 10.1 cfs (0.286 m^3/s).

Gardner Creek

The two gullies and the main gully of Gardner creek were inventoried on foot from 1021 to 602 m.a.s.l. (Tables III-1 and III-2). From 1021 to 884 m., the two gullies are well defined with frequent outcroppings on either side. The beds are filled with shallow colluvium and possibly ephemeral. The gullies are steep, at around 60%, with upper banks of 80% or greater.

At 884 m., the two gullies join into one main gully and gradients decrease to 36% for the gully, 27% for the upper left bank and 18% for the upper right bank. From 884 to 869 m., this single wide gully has a gradient of about 27%.

From 869 to 853 m., it becomes steeper at 47%, more confined (about 3 m. wide), with steep upper left banks (over 80%, with outcroppings) but less steep upper right banks of 36% gradient. From 853 to 838 m., the single gully again becomes less steep, at about 27%. Below 838 m., the gully is quite clearly ephemeral. At 815 m., the gully gradient is around 30%, with an upper left bank gradient of 58% and an upper right bank gradient of 27%.

Four perennial springs rise at 770 m. There is a P.O.D. (point of diversion) on one of them. No surface water was observed above 770 m. on the date of the survey (September 24, 1981). The gauging station is situated at 762 m. and the main P.O.D. at 747 m. The creek gains considerably from the springs, down to the main P.O.D., picking up water from seeps in the upper right banks.

Station 1 (716 m). This station is situated just below the main P.O.D., where the creek is well defined. Upper banks have shallow gradients of about 18%. Mass wasting (existing and potential) is infrequent and small, but logging has resulted in increased in-channel organic debris. Lower banks show some signs of overbank flooding, due to obstruction and flow deflectors, but erosion and new deposition is minimal.

Channel gradient is around 12% and channel bottom items are almost all rated as excellent. Bottom composition is predominantly gravels, sand, silt, clay and muck. The overall stability rating for the reach from 716 down to the highway at 600 m, is 56, i.e. good.

Maximum values for suspended sediment concentrations of 6 mg/l on May 27, 1980 and 4 mg/l on June 1, 1982 were obtained. No real maximum was obtained in 1981, since suspended sediment measured out at 2 mg/l for the entire field season, i.e., the creek was essentially sediment-free all year.

Salisbury Creek

The north fork of Salisbury was inventoried from 1814 to 1570 m. a.s.l. and just above the highway at 579 m. (Table III-1 and III-2).

Station 1 (1814 m). This is a short bedrock canyon, just below the confluence of two tributaries. The upper banks are both steep at about 70% and the channel contains some large organic avalanche debris. Mass wasting of the upper banks, that are mainly exposed bedrock, is not a problem. Lower banks are rated excellent and the channel bottom is good to excellent.

Channel gradient is steep at 47% but bottom materials are moderately stable, consisting predominantly of large boulders (20%), resting on bedrock (about 60% exposed). The overall stability rating for this reach from 1814 to 1570 m. is 56, i.e. good.

Station 2 (1570m.). This is a major confluence, between the north and south forks. The upper right bank is very steep at 84% and mass wasting (existing and potential) of colluvial material is apparent. Large organic material is present in the channel. These unstable obstructions and flow deflectors have caused some erosion of the lower banks and minor deposition.

Channel bottom ratings are all good , with one fair rating, due to the relative absence of clinging aquatic vegetation. Channel gradient is about 27% and bottom materials consist mainly of large and small boulders, resting on bedrock (20% exposed). The overall rating for this reach is 82, i.e. fair.

Station 3 (579 m.). Just above the highway, Salisbury creek cascades in a series of waterfalls and pools, between the walls of a short bedrock canyon. The upper left bank is predominantly vertical rock, while the upper right bank is hummocky. Mass wasting (existing and potential) appears negligible and organic debris is essentially absent from the channel. Lower bank ratings are mainly excellent, with some erosion due to the vigorous flow.

Channel bottom ratings are all good. Bottom materials consist predominantly of boulders and rubble, with some exposed bedrock (about 10%). The overall rating for this reach is 63, i.e. good.

Suspended sediment concentrations were obtained in 1980,81 and 82. The maximum observed values were 8 mg/l on May 6, 1980, 20 mg/l on May 25, 1981 and no real maximum was observed in 1982. Discharge measurements were not made but flows were probably in excess of 100 cfs (2.83 m^3/s), during the spring freshet.

Bulmer Creek

The mainstem of Bulmer creek was inventoried on foot from 1265 to 1097 , and 732 to 610 m.a.s.l. (Tables III-1 and III-2).

Station 1 (1265 m.). Upper banks are both steep, at 84% but dense vegetation results in a good rating for mass wasting (existing and potential). There are some small twigs and limbs in the channel. The avalanche path above this reach does not appear to have affected it. Lower bank ratings are all excellent and channel bottom ratings are mostly good.

The channel gradient is 25%, with a wide distribution of bottom materials, including some exposed bedrock. The overall rating for this reach from 1265 to 1204 m. is 58, i.e. good.

Station 2 (1204 m.). Upper banks have now dropped back to about 58% and mass wasting does not appear to be a problem. Lower bank items are all rated excellent with channel bottom items, good to excellent. The channel is well-confined or entrenched and has a gradient of 21%. Some agradation of fine gravels and sands has occurred in this reach, in a matrix of large and small boulders. The overall rating for this reach from 1204 to 1097 m. is 52, i.e. good.

Station 3 (1097 m.). Upper banks are still about 58% and upper bank, lower bank and channel bottom ratings are almost identical to those for the previous reach. Channel gradient is also about the same, 25%, but bottom size composition has shifted somewhat, to reflect the deposition of increased amounts of finer mateials. The overall rating for this reach is almost the same as for the previous reach at 53.

Station 4 (732 m.). The upper right bank is steep at 81%, giving rise to some mass wasting (existing and potential). Only small amounts of in-channel organic debris are present. Lower bank items are all excellent and channel bottom items are good to excellent.

Channel gradient is 27%. Bottom materials consist mainly of large and small boulders and large rubble. There is 5% exposed bedrock. The overall rating for this reach from 732 to 671 m. is 52, i.e. good.

Station 5 (671 m.). Upper banks have dropped back to 18%. All upper bank items are rated excellent. There has been some overbank flooding but lower bank and channel bottom items are all rated good to excellent.

Channel gradient is only 9% and channel bottom materials consist mainly of small rubble, coarse and fine gravels. The overall rating for this reach, from 671 to 610 m. is 45, i.e. good to excellent.

Station 6 (610 m.). This is the gauge location. Upper banks are hummocky with shallow gradients of 18%. This reach is similar to the previous one with all items rated good to excellent. The overall rating is 44.

Two rising stage suspended sediment concentration measurements for 1981, are plotted on Figure III-2 for Bulmer creek, measured at the gauge location. The maximum value of 16 mg/l was obtained on May 25, 1981, associated with a flow of 11.7 cfs (0.331 m^3/s), compared with highs of 9 mg/l on May 6, 1980 and 7 mg/l on May 31, 1982. Maximum recorded streamflow on Bulmer creek in 1981 was 14.9 cfs (0.422 m^3/s) on June 5, 1981, but suspended sediment was not measured on that date.

Argenta Creek

The mainstem of Argenta creek was inventoried on foot from 1074 m. to the Federal hydrometric station at 684 m.a.s.l. (Tables III-1 and III-2).

Station 1 (1074 m). Both upper banks are extremely steep at about 100%. Mass wasting (existing and potential) is low to moderate but only small amounts of in-channel organic debris are present. Lower bank items are rated excellent, except for bank rock content, which is rated as good. The channel bottom is good to excellent.

Channel gradient is quite steep at 40%, with bottom materials, consisting mainly of small boulders and rubble. The overall stability rating for this reach, from 1074 to 998 m. is 62, i.e. good.

Station 2 (998 m). The upper left bank has a gradient of about 58%. Mass wasting has occurred at this seepage site, a number of years ago, depositing large organic material into the channel. The logs do appear to be stable, hence the good rating for debris jam potential. This upper bank is, however, poorly revegetated and further mass wasting is likely. Lower banks are rated excellent, except for a fair rating for bank rock content and the channel bottom is good to excellent.

Channel gradient is about 27%, with bottom materials ranging from small rubble to sand, silt, clay and muck. There are several seepage sites from 998 to 892 m, that can be regarded as zones of potential mass wasting into the creek. The overall stability rating for this reach is 71, since lower bank and channel bottom items are rated good to excellent.

Station 3 (892 m). Both upper banks are extremely steep at about 100%, not well anchored with vegetation, and present a significant mass wasting hazard. The lower banks and channel bottom items are still rated generally good to excellent, despite large quantities of old organic material. These logs appear stable.

Channel gradient is 18% with bottom materials, ranging from small boulders to sand, silt, clay and muck. The overall rating from 892 to 884 m. is 72, i.e. fair to good.

Suspended sediment concentrations for Argenta creek, measured during 1981, during rising stage, appear in Figure III-2. The highest value obtained was 8 mg/l on June 8, 1981, compared with 7 mg/l on May 6, May 27 and August 5, 1980 and 12 mg/l on July 6, 1982. Streamflow on June 8, 1981 was 5.20 cfs (0.147 m^3/s) but the highest recorded daily streamflow was 9.40 cfs (0.266 m^3/s) on July 8, 1981. Suspended sediment was not measured on that date.

Carter Creek

Carter creek was inventoried on foot from 892 to 678 m. a.s.l.

(Tables III-1 and III-2). One tributary crosses a logging road at 892 m, passing through a 12 in. (30 cm) culvert. It is joined by flow from a seepage source, emanating from a white calcareous site at 861 m. At 823 m, the creek sinks at an old skid trail. Running just east of the road through piles of slash, it enters a swampy area at 808 m. From 808 to 792 m, it gains, as it meanders through slash, runs just east of the road again and is intercepted by another skid trail, with a log culvert. After passing through a second, slightly lower swamp, filled with decaying wood fibre, it flows down a well-defined channel and over a small wooden weir, the gauging location.

<u>Station 1 (792 m)</u>. Upper banks have shallow gradients of about 18% and are rated good to excellent. Lower banks are rated good to excellent, except for a poor rating for bank rock content. Channel bottom items are rated either not applicable or generally fair to poor.

Channel gradient is only about 2% and bottom materials consist, essentially of about 25% gravels, set in a matrix of black organic muck, particles of mica schist and white calcareous silty-clay. The overall rating from 792 to the P.O.D. just below at 790 m. is only fair.*

With a year-round almost constant flow of about 1 cfs (0.0283 m^3/s), the creek flows down a gully at about 27% to a road, crossing through a log culvert at 762 m. At the highway, 747 m, the creek passes through a 21 in. culvert (53 cm), into another swamp, containing logging slash, where it is joined by Tarr creek.

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[*] The Pfankuch rating scheme is not really applicable to very small channels, without well-defined beds and lower banks. Hence, in the case of Carter creek and Mautner spring, numerical overall ratings have been replaced by the designation F for fair and E for excellent on the Hydrology Map.

Suspended sediment concentrations for Carter creek, measured at the gauge, during 1981, varied from 2 to 6 mg/1, during fairly constant flows of around 1 cfs (0.0283 m^3/s). A peak value of 9 mg/1 was obtained on May 19, 1980 but measured sediment levels did not rise above 4 mg/1 in 1982.

Mautner Spring

This spring, situated between Carter and Argenta creeks, rises in the bed of a gully ((A) on Hydrology Map) at 945 m. The gully bottom contains shallow colluvium.

Station 1 (937 m). Upper banks are quite shallow at 25%. All applicable items are rated excellent, except for a fair rating, assigned to the loose sandy material, comprising about 95% of the channel bottom.

The overall stability rating is excellent.*

Another spring rises in a similar gully ((E) on Hydrology Map), at about the same elevation, just north of Argenta creek and flows through old logging slash. Several more springs rise from the beds of gullies at around 750 m, between the two flanking gullies. Although these small flows are of the order of only 0.1 cfs (0.0028 m^3/s), they are important sources of domestic and irrigation supply for the Argenta community. It is worth noting, that the two upper springs, that rise at around 945 m, do so at a slope break. Above 945 m, both gullies are steeper and more confined. Vegetative indicators suggest, however, that the water table is within 1 m. of the surface, in the beds of both gullies up to at least 1050 m.

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* As per footnote on page 61.

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Kootenay Joe Creek

Using 1981 streamflow data, it has been shown that Kootenay Joe creek exhibits a rapid response to snow melt and high rainfall events. Peak discharge occurs earlier than peak flows, for the other Argenta Slope creeks, and recession is rapid. It possesses the highest peak flow (with the exception of Salisbury creek) and lowest low flow of all the creeks. Removal of forest cover in this drainage, resulting in snow redistribution effects, earlier and possibly more rapid snowmelt, and higher water yields, is likely to have a significant effect on the flow regime of this creek. Channel stability ranges from good, in some upper reaches, to poor, in the lower reaches, due to mass wasting and debris jam potential. Overbank flooding has occurred, with minor avulsions, along with erosion of bed and bank materials. The stability rating of 115, obtained at station 5, would indicate that annual water yield increase should not exceed about 6.5% (Isaacson, 1977). This would correspond to an equivalent clearcut area (ECA) of about 15% of the total drainage, at an average elevation of about 1300 m, according to Isaacson. In the Perry Ridge Report (Salway, 1982), WRENSS (1980) methodology was applied to the Hird creek basin and it was demonstrated that the approach is much more spohisticated than Isaacson's. Total allowable ECA will depend on sizes, shapes, orientations, aspects, slopes, elevations, etc. of cutblocks, roads and landings, and many other site specific factors, associated with surface erosion, mass wasting and channel stability. Nevertheless, Isaacson's figure is a useful guide. The stream reach inventory data for Kootenay Joe creek, indicates that there may be several suitable creek crossing sites. Site specific engineering information will be needed to select the best sites, such that mass wasting hazards are minimized and surface erosion of cutbanks, road bed and fill material is kept to a minimum. Logging slash and sediment should not be allowed to find its way into the channel, particularly above reaches that are already unstable, since this creek does appear prone to "flushing" events.

Kootenay Joe flows for 1981 were regressed on Jerome creek flows and two simple linear transfer functions obtained for the recession period, assuming a zeroth lag and a nine day lag. Low flows appeared to vary in proportion to drainage area ratios. Both relationships provided an accurate estimate of mean September flow for Kootenay Joe, as a function of Jerome average historical low flow. The estimate of 0.17 cfs (0.0048 m^3/s) for Kootenay Joe low flow is approximately 50 times current licensed demand. Hence, supply during the late summer/ early fall season does not appear to be a problem. Average peak flows may also be estimated from the high flow lagged relationship between Kootenay Joe and Jerome.

Gar Creek

Gar creek exhibits a smoothed, delayed response to snowmelt and calculations show that total discharge for the period, May to September, is about double,that which might be expected from its surface drainage area. An externally-supplied aquifer is postulated and deep storage to account for the regime. Removal of forest cover,in this drainage, will probably produce less efect on peak flows, than for Kootenay Joe, due to the buffering influence of deeper storage. Channel stability ranges from good to fair. The stability rating of 77 for station 3, suggests that annual water yield increase should not exceed about 13.5%, corresponding to an ECA of about 32% of the total drainage area, at an average elevation of 1300 m. The stream reach inventory data for Gar creek suggests several creek crossing sites but as for Kootenay Joe creek, the selection of the best site will require engineering input.

Gar flows for 1981 were regressed on Jerome and Argenta, for the recession period. The two zeroth lag transfer functions and the nine day lag function on Jerome, produced similar estimates of mean September flow. The average of the estimates was 2.27 cfs (0.0643 m^3/s), tying in closely with Water Management Branch's estimate of 1.92 cfs (0.0544 m^3/s). Hence, average September flows on Gar creek are almost 4 times current licensed demand and supply during the late part of the irrigation season appears more than adequate.

Gardner Creek

Gardner creek rises from springs at 770 m., gains from other springs as it descends to the main P.O.D. at 747 m. and exhibits a very smooth, delayed response. Aquifer storage is most likely in limestone beds, that outcrop at the same elevation as the springs. Removal of forest cover, within this drainage area will probably produce little change in regime. The single channel stability rating of 56, suggests that annual water yield increase should not exceed about 17.5%, corresponding to an ECA of about 40% of the total drainage area, at an average elevation of 1300 m.

Gardner flows for 1981 were regressed on Argenta, for the recession period. The zeroth lag transfer function gave an accurate estimate of average September low flow of 0.33 cfs (0.0093 m^3/s), at the gauge. It was shown that this probably corresponds to a flow of 0.83 cfs (0.0235 m^3/s) at the main P.O.D., agreeing very closely with Water Management Branch's estimate of 0.84 cfs (0.0238 m^3/s). Furthermore, low flows for Gardner and Argenta creeks appear to vary in proportion to the ratio of their drainage areas, suggesting that the Gardner surface drainage area adequately defines the storage area for that creek. Average September flows on Gardner creek are about 3 times current licensed demand. Supply does not seem to be a problem on Gardner creek.

Salisbury Creek

Salisbury creek streamflows were not monitored, since they are in excess of 100 cfs (2.83 m^3/s) during the spring runoff.

Stream channel ratings were obtained in the headwaters and at the base of the main channel. This is a deeply entrenched creek, the mainstem of which, may be difficult to cross. Further work is needed to determine potential impacts of timer harvesting or road building activities within this drainage.

Bulmer Creek

The regime of Bulmer creek is similar to that of Kootenay Joe and removal of forest cover within this drainage could produce changes in regime. Channel stability ratings are all good, in the upper and lower mainstem (the middle, steeper part of the mainstem was not inventoried). There appear to be suitable crossing sites at upper mainstem locations. Bulmer flows for 1981, were regressed on Jerome for the recession period. The zeroth and ten day lag relationships were used to estimate average September flow. A value of 0.85 cfs (0.024 m^3/s) was obtained but there is no licensed demand or Water Management Branch estimates of low flow.

Argenta Creek

Argenta creek exhibits a very smoothed, delayed response like Gardner creek. The historical hydrographs for this creek, along with its geological setting imply deep storage reservoirs. Removal of forest cover within this drainage would not produce as much change in regime, as a similar treatment would produce in Kootenay Joe drainage. Channel stability ratings are good. The stability rating of 72 for station 3 suggests that annual water yield increase should not exceed about 14%, corresponding to an EDA of about 33% of the total drainage area at an average elevation of 1300 m. The mainstem of Argenta creek would be difficult to cross without risk, and is not recommended.

Argenta flows are measured by Water Survey of Canada. The average September flow obtained from historical data is 2.62 cfs (0.0742 m^3/s), compared with current licensed demand of 0.506 cfs (0.0143 m^3/s), i.e. low flow is about 5 times licensed demand and therefore not a problem.

Carter Creek

Carter creek exhibits a fairly uniform flow of about 0.85 cfs

(0.0241 m^3/s), throughout the year. Removal of forest cover within this poorly defined drainage would probably not produce any regime changes. Channel stability at the gauge location is only fair. Timber harvesting activities have already taken place in this drainage. Supply exceeds current licensed demand by a factor of 5.

Argenta/Carter Slope

This slope contains several gullies, two with springs rising at around 945 m. It is difficult to predict the magnitude of seepage interception and diversion if a road is built across the slope. Should timber harvesting in this area be contemplated, further investigations are required.

As recommended in the Perry Ridge report (Salway, 1982), planning of roads, cutblocks and landings in domestic watersheds should be accompanied by the acquisition of site specific data to enable a WRENSS(1980) evaluation (or its equivalent) of hydrograph change, surface erosion, mass wasting and total potential sediment to be made. The generalized interpretive maps prepared by Utzig et al (1983) provide useful general guidelines to aid in the identification of very low, low, medium, high and very high hazard areas, prior to detailed development of harvesting plans, in sensitive watersheds.

Unfortunately, the ecological sampling program resulted in an average of only 20% coverage of drainage areas, for the Argenta Slope, interms of actual plots and field checks, even though the total, combined area of the watersheds constituted about 60% of the study area. Slopes between drainages were obviously of greater silvicultural interest but, for these areas, potential hydrological impacts are minimal. More precise information on soil textures (rather than an interpolated or extrapolated range of textures) for specific locations (rather than for terrain units, which are often too large) is required, along with structure, drainage and organic matter content, for a more precise evaluation of surface erosion hazard. Actual surface erosion and sediment delivery potential also depends on "active" parameters, such as vegetation-management factors, downslope lengths of disturbances, (cutblocks, landings and roads), slopes of disturbed areas (not the average slope of the entire terrain unit), actual distances and slopes to the nearest stream channel, along with slope roughness, shape, presence of gullies or natural barriers, ground cover, etc. Mass wasting potential also needs to be evaluated at the specific locations, where disturbances are planned, not just in general terms. Water quality objectives need to be determined and harvesting plans adjusted to satisfy these objectives. The WRENSS (1980) approach is a rational estimation procedure designed to evaluate the relative impacts of specific harvesting plans and is, therefore, an operational planning tool of considerable value.

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APPENDIX II

1981 Streamflow Data

(cfs)

Date		Day No.	KJ (678m)	GAR (792m)	GNR (762m)	BUL (610m)	CAR (792m)	ARG (884m)	JER (640m)
May	19	1	16.73	3.77	0.10	7.88		3.0	
	20	2						3.3	4.99
	22	4	21.7	4.5	0.15	11.7	1.1	3.4	5.15
	23	5						3.5	5.46
	24	6						3.5	5.46
	25	7	20.7	5.1		11.7	1.1	3.7	6.29
	26	8	19.7	6.5	0.09			3.8	6.46
	28	10				14.1	0.96	4.0	
	29	11	22.2	8.8	0.075		0.98	4.1	
	31	13						4.5	5.46
June	1	14	20.2	10.1	0.075		0.98	4.5	5.15
	2	15				13.2		4.7	
	4	17	25.02	11.0	0.075	13.2	0.98	4.7	
	5	18				14.9	1.00	4.8	
	7	20						5.1	5.30
	8	21	16.3		0.09	12.3	0.98	5.2	4.87
	10	23						5.3	4.99
	11	24	12.89	9.32	0.23	11.7	0.95	5.3	
	12	25				11.59		5.3	
	15	28	12.7		0.45	11.7	0.95	5.1	4.83
	17	30				11.72	1.00	5.1	
	18	31	12.02	8.59	0.58			5.0	
	19	32			0.45			5.0	
	22	35	11.1			10.8	0.95	5.0	
	23	36			0.68	9.19		5.0	
	29	42	11.4		0.78	10.1	0.81	5.0	
July	3	46	16.33	9.36	0.78	12.85	1.20	6.1	
	6	49				13.9	1.02	7.8	
	7	50		9.8	0.89			8.8	
	8	51						9.4	5.15
	12	55	12.70					7.7	
	13	56		10.6	0.89	13.9	1.02	7.9	
	16	59	12.73	11.22	0.85	13.1	1.06	8.3	
	20	63	10.5	11.4	0.90	12.0	1.10	8.7	
	21	64						8.9	2.10
	22	65						8.6	1.88
	23	66				11.14		8.3	
	27	70	6.1	11.5	0.90	9.8	1.10	8.0	
	30	73	6.47	10.37	0.95	9.13	1.38	8.5	
Aug	3	77	3.25	10.4	0.78	6.6	1.10	7.3	
	5	79						7.1	1.12
	10	84	1.42					6.7	
	11	85	1.38	7.3	0.65		1.10	6.7	
	13	87	1.36	6.55	0.59	3.40	1.00	6.6	
	17	91	1.2	6.2	0.59	2.80	1.02	6.3	0.79

Date	Day No.	KJ (678m)	GAR (792m)	GNR (762m)	BUL (610m)	CAR (792m)	ARG (884m)	JER (640m)
Aug. 20	94					1.03	6.0	
25	99	1.0	5.1	0.56	2.3	1.1	5.2	
31	105	0.8	4.4		2.0	0.95	4.7	
Sept. 1	106			0.56			4.7	
2	107						4.5	0.70
3	108	0.86	3.85	0.48	1.76	0.71	4.4	
14	119	0.35	3.6		1.5	0.95	3.7	
15	120			0.45			3.7	
16	121						3.6	0.47
17	122	0.33	3.35	0.41	1.30	0.84	3.5	
21	126	0.4	2.9		1.4	0.95	3.5	
22	127			0.41			3.4	
24	129			0.34			3.2	
28	133	0.5	2.7		1.1	0.88	3.2	
30	135						3.1	0.41
OCT. 1	136	0.47	2.27	0.48	0.89	0.69	3.0	