AN EXAMINATION OF NATURAL AND REGULATED FLOWS IN DUTEAU CREEK, BRITISH COLUMBIA

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1. INTRODUCTION

Over the past several decades regular conflicts have occurred between Fisheries and Oceans Canada and the Vernon Irrigation District over flows in Duteau Creek. Duteau Creek, which drains to the Shuswap River via Bessette Creek, supports a significant population of coho in its lower reaches. The upper watershed is fully-licensed and provides irrigation and domestic water supplies to the Vernon Irrigation District.

Flows to lower Duteau Creek are released through "Headgates", the diversion structure in Duteau Creek operated by the Vernon Irrigation District. Releases may be either by spill from a full head pond, or by a bypass (a 30 inch culvert leading to Duteau Creek). Conflicts occur in years of low snowpack and low anticipated reservoir inflows. In these years releases to Duteau Creek are curtailed to maintain storage in Aberdeen, Haddo and Grizzly Swamp Reservoirs.

In an effort to ameliorate low flows, Fisheries and Oceans Canada participated in development of the Grizzly Swamp Reservoir, which went into operation in 1978, paying for 1,000 acre-feet of developed storage. Despite this, low flows remain a concern.

Coulson examined the hydrology of Duteau Creek in 1971 and in a supplemental study in 1974. Since his studies were completed, the streamflow and reservoir level measurement networks have been expanded and upgraded and approximately 14 years of continuous data are now available for analysis. The overall purpose of the study is to review, evaluate and summarize the existing hydrological data, with the following objectives:

1. Determine the natural flows that would occur in the Duteau Creek basin if no storage or diversion were present;

2. Determine present water demands from Duteau Creek and describe the existing reservoir management and water conservation practices; and

3. Examine alternative water management practices that meet the flow requirements of both Fisheries and Oceans and the Vernon Irrigation District.

2. STREAMFLOW AND RESERVOIR LEVEL MEASUREMENTS

Duteau (also called "Jones") Creek has been developed for irrigation and domestic water supplies since the 1890's. Over the last century, the water control and distribution structures in the basin have been expanded and rebuilt several times. The most recent modifications occurred from the mid-1960's to late 1970's. During this period, the dams and the outlet structures of Aberdeen and Haddo Reservoirs were reconstructed, a new diversion structure ("Headgates") was built in Duteau Creek (1971), and the water distribution network was rehabilitated. Grizzly Swamp Reservoir was added to the storage system in 1978 (Figure 1).

Duteau Creek drains into Bessette Creek and then to Shuswap Lake. The Vernon Irrigation District diverts water from Duteau Creek into the Okanagan Basin. The drainage area of Duteau Creek, above the diversion structure, is 182 km^2. Aberdeen, Haddo and Grizzly Swamp Reservoirs control 109.6 km^2 (60%) of the total drainage area (Table 1). The remaining natural draining portion of the basin lies mostly at lower elevations (Table 1).

2.1 Streamflow and Reservoir Level Stations in Duteau Creek

Table 2 lists the period of record for streamflow and reservoir level data published by the Water Survey of Canada or available from the Vernon Irrigation District. Records extend back to 1928; though, prior to the 1970's most of the records are seasonal and only a limited number of stations were operating. It is difficult to use these older records for description of the hydrologic regime because of the major rehabilitation of the water control structures in the late 1960's and 1970's.

Overlapping, year-round records for the three (or two) storage reservoirs, for the Vernon Irrigation District diversion at Headgates and for the flow at "Duteau Creek above Lavington (08LC006)" gauge are only available from 1975 to 1988. This period is used to describe the hydrology of the Duteau Creek watershed.

TABLE 1: CHARACTERISTICS OF SUB-BASINS AND DESCRIPTION OF RESERVOIRS IN DUTEAU CREEK WATERSHED -

Sub-basin	Drainage Basin Characteristics: Basin Area (km^2)	Median Elevation (m)	%area over 1500 m (%)	Reservoir Characteristics[1]: Elevations (m) Outlet Invert	Elevations (m) Crest of Spillway	Reservoir Storage (dam^3) Live[2]	Dead	Potential[3]	Water Surface Area (ha at Capacity[4]	at crest of spillwa
Haddo Lake	4.4	1290	0	1263.9	1269.4	2730	280	1390	94	82
Aberdeen Lake	55.7	1440	34	1273.0	1278.9	11560	3790	1650	279	264
Grizzly Swamp	49.5	1370	24	1279.9	1289.2	5400	0	2450	208	153
TOTAL	109.6					19690	4070	5490	581	499
Unregulated Sub-basin	72.4	1330	0							

1. Data are from WMB drawings: 4567-120-1 Grizzly Swamp Reservoir: Storage and Basin Data
4567-1-1 Aberdeen Lake Reservoir: Storage and Basin Data
4567-34-1 Haddo Lake Reservoir: Plan of Reservoir
These drawings are part of the Storage Inventory Programme. South Thompson Basin - Fraser System.
2. Storage between outlet invert and crest of spillway. Spillways are not gated.
3. Potential storage occurs between the crest of spillway and crest of dam minus a freeboard allowance.
4. At elevation of dam crest.

TABLE 2: PERIODS OF RECORD FOR STREAM AND RESERVOIR LEVEL GAUGES IN THE DUTEAU CREEK WATERSHED.

Station	Station #	Period and Type of Operation: Seasonal	Miscellaneous	Continuous	Comments
Water Survey of Canada Streamflow Stations					
Duteau Creek near Lavington	08LC006	1935-51 1959-66 1968-73	1967	1974-1988	automatic level gauge since 1976
Duteau Ck at outlet of Haddo Lk	08LC014	1973-79			weir below outlet of Haddo Lake daily stage observations. Rating by the Water Management Branch
V.I.D. Diversion near Lavington	08LC007	1935-51 1964-66			Parshall flume in open ditch Read daily. Additional data in Coulson (1971)
Water Survey of Canada Reservoir Level Stations					
Haddo Lake at the outlet	08LC044	1968-74	1975-86		After 1975, slope gauge read weekly in summer, start of month in winter. Gauges operated by the WMB. Storage-elevation tables prepared by the WMB (see Table 1).
Aberdeen Lake at the outlet	08LC043	1968-74	1975-86		
Grizzly Swamp near Haddo Lk	08LC047		1978-86		Reservoir built in 1977/78
Vernon Irrigation District Streamflow Stations					
Diversion at Headgates	-			1972-88	Propellors in 16 and 48 inch pipes accumulate acre-feet passing. Gauge read daily
Haddo Lake at the outlet	-	1980-88			daily observations of stage at weir below Haddo Lake
Vernon Irrigation District Reservoir Level Stations					
Aberdeen Lake	08LC043	1928-68	1987-88		Observations of stage as above
Haddo Lake	08LC044	1928-68	1987-88		
Grizz. Swamp	08LC047				

Daily records are available of the flow diverted by the Vernon Irrigation District at Headgates and of the flow in Duteau Creek downstream of Headgates (Duteau Creek near Lavington, 08LC006). Reservoir levels are only read monthly during the winter and weekly during the summer, as a result, hydrology is based on monthly flows.

2.2 Processing of Water Survey of Canada and Vernon Irrigation District Records

The records collected by the Vernon Irrigation District for their diversion at Headgates, and the Water Survey of Canada and V.I.D. reservoir level records require processing before use in this study. As described below monthly diversions at Headgates and monthly changes in reservoir storage volumes were calculated from these records.

The Vernon Irrigation District records, on a daily basis, the total acre-feet of water that passed through either their 16" or 48" diversion pipe. There are two recording gauges for each pipe. These daily observations of total diversion were converted to daily water use by subtracting a given day's reading from the next day's reading. Monthly water use was calculated by accumulating the daily flows. Total monthly water use was similar for both of the gauges on each diversion pipe.

The only difficulty with the record occurred when flow was switched from the 16" to 48" pipe in the spring or from the 48" to the 16" pipe in the fall. Generally, the last reading on the pipe that is switched out of use occurs on the day before the switch is completed. Consequently, the next time flow returns to that pipe, the totalizer gauge will start at some value greater than the final reading in the previous season. It was assumed that this additional water use actually occurred on the day the pipe was switched out of use and it is transferred back to the previous season. Disagreements between the two gauges on each pipe also ocassionally occurred in the same months.

As noted in Table 2, the three reservoir level gauges are read on the first of each month during the winter (October through April) and every seven days during the irrigation season. Consequently, during the irrigation season reservoir level readings may not fall on the first day of each month. Linear interpolation was used to estimate the reservoir levels on the first day of the summer months.

It also appears that, particularly during the mid-70's, winter reservoir levels were only recorded to the nearest foot or half-foot. This introduces some discrepancies when calculating winter inflows to the reservoirs.

Reservoir levels were converted to total live storage volumes with the aid of storage tables provided by the Water Management Branch (see Drawing References in Table 1). The photogrammetrically and survey-derived storage tables are assumed to refer to the same datum as the slope gauges in the reservoirs.

Storage for a given month (or year) in a particular reservoir was calculated by subtracting the total live storage on the first day of the period from the total live storage on the first day of the next period. Negative storage changes indicate releases or removals from storage; positive storage changes indicate increased water levels and storage in the reservoirs. The net change in storage for a given month, for all three (or two) reservoirs is the sum of the individual storage changes.

2.3 Measurement Units Used in this Report

Streamflows and reservoir storage volumes are reported in the metric system used by the Water Survey of Canada. In this system, volumes of water are expressed in cubic decametres (dam^3). A cubic decametre is 1000 cubic metres (m^3) of water.

A cubic decametre of water is approximately 85% the size of acre-foot. The exact conversion is:

One acre-foot = 1.2335 cubic decametres (1)

Some storage volumes are also reported in acre-feet throughout the report.

In some instances, monthly streamflows are reported as a total in cubic decametres; in other instances, streamflows are reported as a monthly mean flow in cubic metres per second (m^3/s). Monthly streamflow volumes in cubic decametres may be converted to a monthly mean flow in m^3/s by:

$$(\text{Volume } (dam^3))/86.4\ /(\text{No. days in Month}) \qquad (2)$$

A cubic metre per second is equivalent to 35.315 cubic feet per second (cusecs or ft^3/s). Conversion to imperial units (cusecs) is by:

$$\text{Cusecs } (ft^3/s) = \text{Cubic metres per second } (m^3/s) \times 35.315 \qquad (3)$$

2.4 Calculation of Additional Streamflow Data from the Available Streamflow and Reservoir Level Data

The streamflow and reservoir level stations in Duteau Creek do not provide all the measurements required for an analysis of hydrologic regime. Additional flows were estimated as follows:

Mean Inflow to Duteau Creek Basin:

Over any period (a year or a month), this is defined as:

$$\text{BASIN OUTFLOW + TOTAL STORAGE CHANGE + TOTAL EVAPORATION} \qquad (4)$$

where the basin outflow is the sum of the flows diverted by the Vernon Irrigation District at Headgates and the flow recorded at the "Duteau Creek near Lavington" gauge. The total storage change is the sum of the storage changes in each of the three (or two) reservoirs.

Monthly or annual evaporations from the reservoirs are the only unmeasured quantities in equation (4). These may be estimated from the small lake evaporation normals prepared by the Atmospheric Environment

Service (Canadian Climate Normals, Volume 9: 1951-1980). The normals quoted for the McCulloch climate station are 75 mm in May, 92 mm in June, 125 mm in July, 100 mm in August, 68 mm in September and 28 mm in October. McCulloch, at 1250 m, is at nearly the same elevation as the three reservoirs in Duteau Creek.

Table 3 quotes total normal evaporations for Aberdeen, Haddo and Grizzly Swamp based on the reservoir surface areas at the crest of the spillway (see Table 1):

Table 3: Monthly Normal Evaporations for Aberdeen, Haddo and Grizzly Swamp Reservoirs (dam^3).

Month	Aberdeen	Haddo	Grizzly Swamp	Total	Range of Total
May	198	62	115	375	+/- 56
June	242	75	141	458	+/- 69
July	330	103	191	624	+/- 94
August	264	82	153	499	+/- 75
September	179	56	104	339	+/- 50
October	74	23	43	140	+/- 20
TOTAL	1283	401	747	2430	

There are several problems with the quoted monthly evaporations. First, typical standard deviations are approximately 15% of the monthly normals or about 400 dam^3 on an annual basis. The effect of using average evaporations will be to bias monthly flow estimates. Fortunately, maximum evaporations occur during summer months when the inflows are relatively large and year-to-year variations in monthly evaporations are relatively insignificant in calculation of total flow.

Second, the monthly evaporation totals are based on a reservoir surface area corresponding to a full, or "spilling", reservoir which may over-estimate actual evaporation in some months. Finally, the small lake approximation may not be suitable for some of the reservoirs.

Flows from the Unregulated Portion of the Basin

Flows from the unregulated portion of the Duteau Creek watershed can be calculated for any period (a month or a year) as:

BASIN OUTFLOW - RELEASES FROM STORAGE (5)

where the basin outflow is the sum of the flow diverted by the Vernon Irrigation District at Headgates and the flow recorded at the "Duteau Creek near Lavington" gauge. The releases from storage are recorded at the "Duteau Creek at the outlet of Haddo Lake (08LC014)" gauge, which measures all flows leaving the reservoir system.

There are several limitations to the approach. First, Haddo Lake outflow data are only collected seasonally (June to September) and flows during the remainder of the year must be estimated in some other fashion. Also, as discussed in Section 2.5, the calculation in equation (5) produces "negative flows" in some months, either as a result of errors in flow estimates at Haddo wier or Headgates, or as a result of exceptional transmission losses.

Consequently, monthly flows from the unregulated portion of the basin were estimated as:

COLDSTREAM x 1.238 (6)

where "Coldstream" refers to flows recorded at the "Coldstream Creek above Municipal Diversion (08NM142)" gauge and 1.238 represents the ratio of drainage area in the unregulated portion of Duteau Creek to that above the "Coldstream Creek above Municipal Diversion" gauge. For equation (6) to produce accurate results, two assumptions must be met:

- Mean annual runoffs must be similar in each basin; and

- The mean annual flow must be distributed over the months of the year in a similar fashion.

The two basins have similar median elevations and percentages of area over 1500 m (Tables 1 and 8A) and are close together. As a result, it is reasonable to assume that equation (6) applies to the unregulated portion of Duteau Creek. Some standard error is associated with the estimates from Equation (6); unfortunately, it is not easily determined without measurement of flows in both basins.

Inflows to the Regulated Portion of the Basin

The total inflow to the regulated portion of Duteau Creek, over any period, can be calculated as:

$$\text{TOTAL INFLOW - OUTFLOW FROM NATURAL BASIN} \qquad (7)$$

Both quantities in Equation (7) were defined in previous sections. Inflow to individual sub-basins are prorated from this total as follows:

	% Total Basin Area	% Flow
Aberdeen	51%	56%
Haddo	4%	2%
Grizzly Swamp	45%	42%

The % flows into each reservoir were calculated through two steps. First, the annual runoff in each sub-basin was estimated from a regression equation between mean annual runoff (1975 - 1984) and % area over 1500 m for Coldstream Creek (08NM142), Duteau Creek (Table 5), Vance Creek (08LC040), West Kettle River (08NN012) and Trapping Creek (08NN015). The % flows were then calculated from the drainage areas weighted by the estimated mean annual runoff. The % flows differ only slightly from the flows calculated on the basis of % total basin area, but may better represent the actual relative inflow amounts.

2.5 Apparent Problems with the Flow and Reservoir Data

During calculations to estimate various unmeasured flows in the Duteau Creek watershed, described in the previous section, several inconsistencies became apparent. Where possible, data were altered, or re-analyzed, to eliminate inconsistencies; in other cases, it was unclear how to adjust or re-analyze the data.

These inconsistencies are described in detail below because of their potential importance to the data analysis.

2.5.1 Flows from the unregulated portion of Duteau Creek

Flow contributions from the unregulated portion of Duteau Creek can be directly estimated as:

$$\text{BASIN OUTFLOW} - \text{RELEASES FROM STORAGE} \qquad (5)$$

where the total basin outflow is the sum of the V.I.D. diversion at Headgates and the flow passing Headgates that is measured at the "Duteau Creek near Lavington" gauge. The releases from storage are recorded (seasonally) at the "Duteau River at the outlet of Haddo Lake" gauge. Performing this calculation produced negative flows in some years for July and August, and near-zero flows in some other years. The natural flows calculated from equation (5) were compared to those estimated from the Coldstream Creek record (see Section 2.4; Equation (6)). Over the 1973 to 1979 period, the flows calculated from equation (5) were consistently less than those calculated from equation (6). The difference averaged 679 dam^3 in July and 344 dam^3 in August. These differences amount to approximately 11% of the total July outflow and 7% of the total August outflow. Possible explanations for the discrepancy include:

- an incorrect rating curve for the "Duteau Creek at outlet of Haddo Lake" gauge which over-estimates releases from the reservoir;

- wear and damage to the measurement devices in the diversion pipes at Headgates so that the V.I.D. flows are underestimated;

- an incorrect rating curve at the Water Survey of Canada gauge "Duteau Creek near Lavington", causing underestimation of flows; or

- transmission losses between Haddo Lake and Headgates due to seepage into channel bed and banks and evaporation. Losses would average 0.25 m^3/s (9.8 cfs) in July and 0.13 m^3/s (4.5 cfs) in August.

It is not a simple matter to determine whether any or all of these possibilities produce the inconsistent estimates of flow from the unregulated portion of Duteau Creek. However, errors in the "Duteau Creek near Lavington" station are the least likely explanation.

A review of rating table #4 for the "Duteau Creek at the outlet of Haddo Lake" gauge and some recent flow measurements near the gauge indicated that the rating table appears unbiased. Problems with recorded flows at this site may also result from calculating daily discharges from once or twice daily stage observations during the irrigation season when flow fluctuates over a large range each day in response to demand. However, it is difficult to see how this would produce a consistent bias.

Flows from the unregulated portion of Duteau Creek were calculated from the Coldstream Creek records, as described in Section 2.4, to avoid this problem. The general assumption is that the error lies in the record of releases from Haddo Lake. If the error is due to transmission losses or to the other two factors, the results discussed in Chapters 3 and 4 will be influenced.

2.5.2 Inflows to the Regulated Portion of Duteau Creek

Over any period (a month or year), inflows to the regulated portion of Duteau Creek can be estimated as:

TOTAL BASIN INFLOW - OUTFLOW FROM NATURAL BASIN (7)

where the total basin inflow is the sum of the V.I.D. diversion at Headgates and the flow measured at the "Duteau Creek near Lavington" gauge, plus storage changes and losses to evaporation. Storage changes are calculated, for each reservoir, from observed or estimated reservoir levels on the first of each month as the difference between total storage on the first of the month and the first of the next month. Total storage was determined from the storage tables prepared by the Water Management Branch (see Table 1). Monthly evaporation normals are discussed in Section 2.4. Inflows to the regulated portion of Duteau Creek could also be estimated as:

RELEASES FROM STORAGE + STORAGE CHANGE + EVAPORATION (8)

Potential concerns about the measured releases from Haddo Lake are discussed in the previous section. When total basin inflows are calculated from equation (7), negative inflows occur during 26 months. These negative inflows occur in any months but April, May and June and range from a few to -1649 dam^3.

These negative inflows may result from the errors discussed in Section 2.5.1 or from errors in estimation of storage change resulting from:

- inaccurate or incorrect recording of reservoir levels; or
- inaccuracies in storage tables for the three reservoirs.

It is my feeling that the negative inflows result from errors in estimation of monthly storage change. The negative inflows are highly variable, indicating that they are not associated with a consistent bias in one of the other measurements. Second, the negative inflows exhibit a characteristic pattern. Months with negative flow are generally preceded or followed by months with exceptionally high flows, suggesting that storage change is incorrectly apportioned between the two months.

Because the monthly inflows to the regulated portion of the basin are important in examining storage requirements and general reservoir operations, it was felt that the records should be adjusted to produce a set of consistent and positive inflows.

When adjusting the storage records, it was assumed that annual maximum and minimum level observations for each reservoir were correct; adjustments generally consisted of altering the rate of decline of storage over the fall and winter period rather than altering the overall decline in storage volume (Appendix A). This approach was sufficient to produce consistent and positive inflows throughout most of the record. Problems remain in the winter of 1979-1980. Total observed decline in storage over this period is approximately 1200 dam^3 greater than the total basin outflow. Since it was unclear how to adjust the record, some months through this period were left with negative inflows.

There is obviously some (unquantifiable) uncertainty concerning the precision of the monthly inflow estimates in any particular year. As well, some bias may exist in the record. Transmission losses or underestimation of some streamflows may act to bias calculated reservoir inflows.

3. NATURAL REGIME OF THE DUTEAU CREEK

The natural flow regime in Duteau Creek can be estimated from two different approaches:

- Recorded streamflows and reservoir levels can be manipulated to estimate natural inflows to the Duteau Creek watershed; or

- Water Survey of Canada gauging records can be used to develop regional relationships betwen flow and physiography or climate. These relationships can then be applied to Duteau Creek.

Manipulation of records of regulated flows in Duteau Creek provides the best estimate of mean annual and mean monthly natural flows. Because of the uncertainties discussed in Section 2.5 these estimates are compared to natural flows at nearby Water Survey of Canada gauges.

Natural seven-day low flows cannot be calculated from the measurements of regulated flows in Duteau Creek. These must be estimated from a regionalization of Water Survey of Canada flow records.

3.1 Regional Climate

Duteau Creek lies on the Thompson Plateau (Holland 1976). The climate in this region is continental and Duteau Creek lies in the driest and hottest part of B.C. Average daily maximum July and August temperatures at the Vernon climate station for the 1951-1980 period are 27 and 25.8 degrees Centigrade. Extreme maximums reach 38.5 and 35.6 degrees Centigrade (AES 1984).

The Vernon climate station, at an elevation of 555 m, has a normal 1951 - 1980 precipitation of 347.7 mm; 102.8 mm falls as snow (AES 198-). Precipitation is relatively evenly distributed throughout the year with a minor springtime minimum.

Precipitation and temperature are affected by elevation. The McCulloch climate station, at an elevation of 1250 m, has lower average daily maximum temperatures (22.1 and 21.6 degrees Centigrade in July and August) and a total precipitation of 663.8 mm. 55% of the annual precipitation falls as snow.

On the Thompson Plateau, most of the total runoff occurs in April through July in response to melt of the accumulated winter snowpack. Elevation exerts a major control over maximum normal accumulations, though other factors cause large variation in the accumulation observed in a particular elevation band (see Figure 4).

Annual snow accumulations, measured by the Water Management Branch (Water Management Branch 1989) on a particular date, may be used to predict runoff. In the Okanagan, summer water yield and annual flood magnitude are correlated with the snowpack water equivalent (Church 1988).

3.2 Regional Hydrology Studies

The Water Management Branch has been active in predicting mean annual (and other) natural flows in ungauged watersheds in the Okanagan sub-region. Reksten (1973) developed relationships between 1971 and 1972 April to July unit runoff and various physiographic parameters for natural flows in the Okanagan sub-basin. Letvak (1980) summarized a series of reports on estimating annual runoff on the east side of the Okanagan Valley. His approach uses a third-order polynomial equation involving basin physiographic parameters (elevation, distance to a "barrier" and a latitude index) to estimate flows for a given year. Annual estimates are normalized to long-term mean annual flows by comparison with local gauges.

As well, specific watersheds in the Okanagan sub-region have been studied. Coulson (1971) examined storage requirements on Duteau Creek for 1968 to 1970 inflows and releases consisting of licenced withdrawals and fisheries requirements. A second report (Coulson 1974) examined data to 1973 and estimated the natural flow regime in Duteau Creek. MacTaggart (1973) examined the feasibility of constructing the Grizzly Swamp Reservoir for the Vernon Irrigation District.

3.3 Regionalization of Water Survey of Canada Stations

Duteau Creek lies on the Thompson Plateau in the Southwest Interior Region (Region 6; Engledow 1969). This region has 53 Water Survey of Canada gauges with complete records over the 1975 to 1984 period. Unfortunately, a large portion of these gauges are either affected by regulation or diversion and their records cannot be easily adjusted to reflect the natural flow regime. A total of 21 stations with natural flow were identified in Region 6 and the adjoining Regions 11 (South Thompson, including the eastern Fraser Plateau) and 8 (Kootenay Highlands) that may be included in a regional analysis (see Table 4). Streams with natural flow were identified from various Inland Waters Directorate publications (e.g. Water Survey of Canada 1989).

Regions or sub-regions can be identified from the Water Survey of Canada network by several different methods (cf. Tasker 1982). The approach used here to identify areas of homogeneous hydrology is described in Rood (1988) and consists of examining the correlations between the pattern of annual mean flows and of mean monthly flows for the various Water Survey of Canada records. Correlation tables are prepared for both the annual mean flows and mean monthly flows for the stations in Table 4. Generally, mean monthly flows were moderate to well-correlated over most of the stations. The same is not true for the annual mean flows. The correlation net drawn for the mean annual flows indicates four separate subregions within the area covered by the Water Survey of Canada stations with natural flow. Duteau Creek falls into a subregion including the Upper Salmon River, the area west and north of Vernon and the Upper West Kettle Valley. As well, good correlations are observed with the records from Vaseaux Creek. Drainage basin area may play a role in producing weak correlations of annual mean flows. Typically, the basins used in this study are small and subject to local influences.

The gauges lying in the subregion that includes Duteau Creek are marked with an asterisk in Table 4. It is this set of Water Survey gauges that are most appropriately compared to Duteau Creek.

TABLE 4: WATER SURVEY OF CANADA STATIONS IN REGIONS 6, 8 AND 11 WITH COMPLETE RECORDS FROM 1975-84 AND NATURAL FLOW

Station Name	Station #	Drainage Area (km^2)	Region #
Bellevue Ck near Okanagan Mission	NM035	73.3	6
*Bolean Ck near the mouth	LE094	224	6
Bull Creek near Crump	NM133	46.9	6
*Camp Ck at mouth near Thirsk	NM134	33.9	6
*Coldstream Ck above Municipal Diversions	NM142	58.5	6
Daves Creek near Rutland	NM137	31.1	6
*Ewer Creek near the mouth	NM176	52.8	6
Greata Creek near the mouth	NM173	78.0	6
Pearson Creek near the mount	NM172	73.6	6
*Salmon River above Salmon Lake	LE075	143	6
*Vaseaux Ck above Solco Creek	NM171	117	6
*Vaseaux Ck between Solco and Dutton Cks	-	138	6
*Whiteman Ck above Bouleau Ck	NM174	112	6
*Vance Ck below Deafies Creek	LC040	73.3	11
Guichon Ck above Tunkwa Lk Diversion	LG056	78.2	6
Witches Brook near Merritt	LG009	139	6
Hedley Creek near the mouth	NL050	389	6
Pasayten R above Calcite Creek	NL069	562	6
Tulameen R below Vuich Creek	NL071	256	6
Whipsaw Ck below Lamont Creek	NL036	185	6
*Trapping Creek near the mouth	NN019	144	8
West Kettle R near McCulloch	NN015	230	8

3.4 Natural Annual Mean Flows in Duteau Creek

Table 5 provides an annual water balance for Duteau Creek for the 1975-1988 period. Estimated inflows to the basin, which closely approximate natural annual mean flows, were calculated from the total basin outflow, annual storage change and estimated evaporative losses (see Section 2.4). Natural outflows may differ from natural inflows by an amount which reflects storage changes in the lakes which existed in the basin before development. This natural storage carryover is expected to be much less than 1000 dam^3.

Average inflows range from a minimum of 18100 dam^3 (0.57 m^3/s in 1987 to a maximum of 57,400 dam^3 (1.82 m^3/s) in 1982, and average 38,000 dm^3 (1.20 m^3/s). Mean annual inflow to Duteau Creek is compared to other Water Survey of Canada gauges within the same sub-region on Table 8A. Mean annual flow in the basins varies with median elevation, elevation over 1500 m and the distance east from Okanagan Lake (Letvak 1979), as well as other factors.

Mean annual flows for the 1975-1988 period may not be representative of flows averaged over longer time periods. Table 6 shows the decade to decade variation in calculated (net) inflows to Okanagan Lake, the only long-term natural record of flows in the Okanagan sub-region. The 1975 to 1984 decade exhibited above-average inflows, suggesting that the Duteau Creek records in Table 5 may also represent above-average flows.

A better idea of the representativeness of the 1975-1988 flows may be obtained if the Duteau Creek flows can be correlated with the Okanagan Lake inflows to produce a long, artificial record for Duteau Creek. The calculated regression equation for 1975-1988 is:

$$\text{DUTEAU} = 18540 + .0388\ \text{OKANAGAN} \quad (r^2{=}0.80;\ S.E.{=}\ 5430) \qquad (9)$$

where both inflows are in dam^3. While a reasonably high r^2 is achieved, unfortunately the equation is biased, and produces poor estimates of low flows in Duteau Creek. Equation (9) predicts an inflow

TABLE 5: DUTEAU CREEK WATER BALANCE: OUTFLOWS, STORAGE CHANGES, EVAPORATIVE LOSSES AND CALCULATED NATURAL OUTFLOW.

YEAR	STORAGE CHANGE[1] (dam^3)						OUTFLOWS			ESTIMATED NATURAL OUTFLOW[4]	
	HADDO LAKE		ABERDEEN LAKE		GRIZZLY SWAMP[2]		V.I.D. Removal (dam^3)	Duteau Ck (08LC006) (dam^3)	Net Losses to Evaporation[3] (dam^3)	(dam^3)	(m^3/s)
	Jan 1st level (m)	Storage change	Jan 1st level (m)	Storage change	Jan 1st level (m)	Storage change					
1975	3.14	330	1.83	1250	-	0	16745	13400	990	32700	1.04
1976	3.66	870	2.44	6650	-	0	12076	28300	990	48900	1.55
1977	4.57	-230	5.40	-9700	-	0	18704	15400	990	25200	0.80
1978	4.57	-440	0.61	7180	2.44	3220	14258	14100	1740	40100	1.27
1979	3.96	-1220	4.37	-5780	7.67	-730	19406	12900	1740	26300	0.83
1980	1.52	680	1.52	4670	7.01	2700	14841	10500	1740	35100	1.11
1981	3.10	1090	3.86	3100	8.99	-2040	16236	29200	1740	49300	1.56
1982	4.72	-660	5.18	-2690	7.62	560	13482	45000	1740	57400	1.82
1983	3.80	1250	4.05	-1550	8.06	-2020	13966	40900	1740	54300	1.72
1984	5.49	-1150	3.35	-830	6.10	810	16016	20200	1740	36800	1.17
1985	3.96	440	3.20	-1040	7.01	0	19096	12300	1740	32500	1.03
1986	4.57	180	2.43	3010	7.01	0	19441	23400	1740	47800	1.51
1987	4.80	-1510	3.81	-6590	7.01	-2420	20312	6530	1740	18100	0.57
1988	2.44	700	0.00	5450	2.59	3040	12152	4580	1740	27700	0.88
								AVERAGE (1975-1984)		40600	1.29
								AVERAGE (1975-1988)		38000	1.21

1. Storage increases are positive; storage decreases are negative.
2. Grizzly Swamp Dam constructed for 1978 season.
3. Net evaporative losses are the increased evaporation resulting from the construction of reservoirs. Under natural conditions the total lake area was approximately 352 acres (Coulson 1974). The normals quoted in Table 3 were applied to this surface area and the estimated normal evaporation was subtracted from the total for the three (or two) reservoirs.
4. Defined as"Storage Change + V.I.D. Diversion +Duteau Ck Outflow + Net Loss to Evaporation".

TABLE 6: LONG TERM VARIATION IN TEN YEAR MEAN INFLOWS[1] TO OKANAGAN LAKE (WATER MANAGEMENT BRANCH)

Decade	Mean Annual Inflow (10^6 m^3)	% of Long Term Mean
1925-34	367.7	79.7
1935-44	382.9	83.0
1945-54	582.6	126.3
1955-64	485.4	105.2
1965-74	471.9	102.3
1975-84	572.7	124.2
1921-88 (68 years)	461.2	100

1. Annual inflows provided by D. Reksten, Water Management Branch, Victoria.

to Duteau Creek of 21,900 dam^3 for the minimum recorded inflow in Okanagan Lake (1931: 86,300 dam^3) and predicts an inflow to Duteau Creek of 26,100 dam^3 for the 1987 Okanagan Lake inflow, which is in excess of the recorded Duteau Creek inflow of 18,100 dam^3 (Table 5).

Flows were well below normal in both 1987 and 1988. However, it is not clear how often droughts of the severity of 1987 can be expected to recur. Coulson (1974) estimated natural outflows from Duteau Creek of 16,600 dam^3 in 1970 and 19,500 dam^3 in 1973. Both these years were considered "drought" years. The Duteau Creek outflow in 1987 falls halfway between these two values. While the 1970 inflow to Okanagan Lake is the lowest on record outside of 1929 to 1931, the 1987 and 1973 Okanagan Lake net inflows are only moderately low; ranking ninth and tenth in the 68 year record. Some caution should be used when attempting to estimate the return period of droughts in the Duteau Creek basin from the Okanagan Lake inflow record, particularly when apparent changes in climate over the period of record are considered (Barrett 1979).

3.5 Natural Mean Monthly Flows in Duteau Creek

Table 7 presents average monthly inflows to Duteau Creek calculated from average monthly outflows, average monthly storage changes and monthly evaporation normals for the 1975-1988 period. Inflows do not necessarily adequately represent the natural outflows that would be observed near Headgates because of the lakes in Duteau Creek prior to regulation.

The final column in Table 7 presents estimated mean monthly natural outflows for Duteau Creek based on routing 73% of the mean monthly inflows through the assumed natural lake system, adding the contribution from the unregulated portion of the basin and subtracting an estimated evaporation. In routing it was assumed that maximum natural storage amounted to approximately 3500 dam^3.

The natural mean monthly flows for Duteau Creek, expressed as a percentage of the mean annual flow, are compared to Water Survey of Canada records in Table 8B. Note that the natural mean monthly flows are well in

TABLE 7: DUTEAU CREEK WATER BALANCE: AVERAGE MONTHLY OUTFLOWS, STORAGE CHANGES, EVAPORATIVE LOSSES AND CALCULATED NATURAL OUTFLOW, 1975-1988.

MONTH	TOTAL[1,2] STORAGE CHANGE (dam^3)	V.I.D. Removal (dam^3)	OUTFLOWS Duteau Ck (08LC006) (dam^3)	Evaporative[3] Losses (dam^3)	ESTIMATED NET INFLOW (dam^3)	(m^3/s)	(mm)	ESTIMATED[4] NATURAL OUTFLOW (m^3/s)
January	-60	326	301	0	570	0.21	3	0.21
February	-80	381	409	0	690	0.29	4	0.27
March	-170	484	729	0	1040	0.39	6	0.37
April	2250	733	2191	0	5190	2.00	29	1.59
May	6310	2003	5518	374	14200	5.30	81	4.52
June	450	2986	4229	459	8120	3.13	46	3.85
July	-2760	3904	2205	624	3980	1.49	23	1.62
August	-3860	3595	1269	499	1520	0.57	9	0.69
September	-1370	1029	1219	339	1220	0.47	7	0.41
October	-190	362	698	140	1000	0.37	6	0.40
November	-10	184	542	0	720	0.28	4	0.30
December	-30	236	461	0	670	0.25	4	0.25

1. Storage increases are positive; storage decreases are negative.
2. Grizzly Swamp Dam constructed for 1978 season.
3. Evaporative losses are calculated from the lake evaporation normals for the McCulloch station (elevation 1250 m) reported in Canadian Climate Normals, Volume Nine.
4. Natural mean monthly outflows are calculated by routing a portion of the mean monthly inflows through an estimated storage volume of 3500 dam^3.

TABLE 8A: PHYSIOGRAPHIC AND RUNOFF CHARACTERISTICS OF THE STREAMS LYING IN THE VERNON SUBREGION

Stream	Station number	PHYSIOGRAPHIC CHARACTERISTICS[3] Basin Area (km^2)	Maximum Elevation (m)	Median Elevation (m)	Area over 1500 m Total (km^2)	Area over 1500 m %	MEAN ANNUAL FLOW 1975-1984 Mean Annual (m^3/s)	Standard deviation (m^3/s)	Runoff (mm)
Bolean	LE094	224.0	1700		41.2	18	1.079	0.282	152
Camp	NM134	33.9	1923	1454	14.1	42	0.152	0.041	141
Coldstream	NM142	58.5	1645	1120	0.6	1	0.276	0.111	149
Ewer	NM176	52.8	1551	1466	19.0	36	0.348	0.121	208
Lower Vaseaux[2]	-	138.0	1860	1530	65.8	48	0.542	0.202	124
Salmon	LE075	143.0	2039		54.4	41	0.733	0.177	162
Trapping	NN019	144.0	2286		41.9	29	1.669	0.372	366
Vance[1]	LC040	73.3	1890		6.4	9	0.504	0.186	217
Vaseaux	NM171	117.0	2304	1682	96.4	82	0.980	0.315	264
West Kettle	NN015	230.0	2317		160	70	3.845	0.793	527
Whiteman	NM174	112.0	2039	1448	39.0	35	0.504	0.186	217

1. Vance Creek above Deafies Creek record filled for 1983-1984 by correlation with the Coldstream above Municipal Diversion record.
2. Lower Vaseaux record was created by subtracting the Vaseaux Creek above Solco Creek (08NM171) record from the Vaseaux Creek above Dutton Creek (08NM015) record. The record for 08NM015 was filled for 1983 and 1984 by correlation with the 08NM171 record.
3. Some physiographic measurements from Reksten (1972).

TABLE 8B: % MEAN MONTHLY FLOWS FOR THE STREAMS LYING IN THE VERNON SUBREGION

		JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
Bolean	LE094	2.2	1.9	3.0	10.4	36.5	23.3	7.2	3.9	3.4	2.9	3.1	2.5
Camp	NM134	2.6	2.3	3.4	9.3	35.3	22.9	8.5	4.4	3.3	3.0	2.7	2.5
Coldstream	NM142	1.7	1.6	3.2	13.7	40.0	16.4	8.2	5.0	3.9	2.6	2.3	1.9
Ewer	NM176	1.3	1.2	2.2	10.5	42.4	25.0	6.2	3.2	2.5	2.1	2.0	1.6
Lower Vaseaux	-	1.4	1.4	2.7	7.0	47.4	2.1	8.3	2.8	2.4	2.0	1.9	1.5
Salmon	LE075	1.8	1.6	2.1	5.1	32.1	33.1	9.0	4.2	3.7	3.0	2.5	1.8
Trapping	NN019	1.2	1.1	2.6	13.6	38.7	22.9	7.9	3.3	2.9	2.3	2.0	1.6
Vance	LC040	1.4	1.2	3.7	14.2	35.9	20.7	8.7	4.6	3.3	2.5	2.2	1.6
Vaseaux	NM171	1.2	1.0	1.2	5.3	39.2	30.5	9.5	3.9	2.6	2.2	1.9	1.5
West Kettle	NN015	1.3	1.1	2.4	8.2	44.1	26.2	6.6	2.8	2.4	1.9	1.8	1.4
Whiteman	NM174	0.9	0.8	1.2	5.5	31.8	34.2	12.0	3.6	4.0	2.8	2.2	1.3
Average		1.5	1.3	2.5	9.6	38.7	23.6	8.6	3.6	3.1	2.4	2.2	1.7
Standard Deviation		0.5	0.4	0.9	3.8	4.3	8.6	1.5	0.8	0.8	0.5	0.4	0.4
Coeff. of Variation		34.0	34.1	35.2	39.5	11.2	36.6	17.2	21.0	25.9	21.3	19.6	27.0
Duteau Creek Natural Flows		1.5	1.7	2.6	10.8	31.7	26.1	11.4	4.8	2.8	2.8	2.0	1.8

excess of those calculated by Coulson (1974; his Table II) for the 1970 calendar year.

3.6 Natural Seven-Day Low Flows in Duteau Creek

Natural seven-day low flows can best be estimated from records at the Water Survey of Canada gauging stations lying in the same subregion. Table 9 lists unit ten year seven-day low flows for gauges within the subregion. The unit flows are reasonably consistent and have an average value of 0.33 L/s/km^2. There is no apparent relationship between the unit flows and mean annual runoff, basin area or other physiographic parameters.

The best estimate of the 10 year seven-day flow in Duteau Creek is 0.06 m^3/s (2.1 cusecs), as calculated from the average unit low flow in Table 9 and the Duteau Creek drainage area. The 95% confidence range on the predictions is 0.02 m^3/s (0.71 cusecs) to 0.151 m^3/s (5.33 cusecs). The lakes that existed in the Duteau Creek basin prior to development may have produced natural 10 year seven-day low flows near the upper end of the range.

3.7 Summary of the Natural Regime

The natural regime in Duteau Creek, as discussed in the previous sections, is summarized on Figure 2, following the text and Appendices.

TABLE 9: REGIONAL SEVEN-DAY LOW FLOWS AT WATER SURVEY OF CANADA STATION EXHIBITING NATURAL FLOW.

Stream	Station Number	Drainage Area (km^2)	Mean Runoff (mm)	Ten Year Seven Day Low Flow[1] Period of Record	Flow (m^3/s)	Unit Flow ($L/s/km^2$)
Bolean Creek	08LE094	224	152	1974-80	.036	.16
Salmon River	08LE075	143	162	1967-83	.024	.17
Camp Creek	08NM134	33.9	141	1965-83	.019	.56
Coldstream Creek	08NM142	58.5	149	1967-83	.011	.18
Ewer Creek	08NM176	52.8	208	1973-83	.022	.42
Vance Creek	08LC040	73.3	217	1979-83	.020	.27
Vaseaux Creek	08NM171	117	264	1972-83	.048	.41
Whiteman Creek	08NM174	112	192	1972-83	.023	.21
Trapping Creek	08NN019	144	366	1965-84	.061	.42
West Kettle River	08NN015	230	527	1965-84	.114	.50
	AVERAGE					.33
	95% CONFIDENCE LIMITS (based on logarithmic distribution)					(0.11, 0.83)

1. Analysis provided by the Water Survey of Canada. Based on an October 1 to September 30 year.

4. REGULATED HYDROLOGIC REGIME IN DUTEAU CREEK

The purpose of this chapter is to describe the existing diversion of waters from Duteau Creek, estimate the typical demand or water requirements from Duteau Creek, examine the performance of the reservoir system and identify storage and operating requirements to meet all demands for the 1975 to 1988 inflow sequence.

4.1 Licenced Diversion from Duteau Creek

Table 10 lists water licences for removals from Duteau Creek in priority order. Storage licences are listed separately. Note that a licence was issued on May 11, 1921 to divert waters from Paradise, McAuley (Gold), Gal (No. 1), Crib (No. 2) and Stoplog (No. 3) Creeks in the Upper Bessette Creek basin, into the Aberdeen Reservoir basin. This diversion has not been used for several decades.

Total licenced annual diversion on Duteau Creek amounts to 25,440 dam^3 (20,624 acre-feet). The diversion point for the majority of removals is Headgates. However, the two earliest and highest priority licenses have diversion points downstream of Headgates. To satisfy these licenses, the Vernon Irrigation District must release 480 dam^3 from Headgates between May 1 and September 30, amounting to a minimum release of 0.057 m^3/s (2 cfs) over this period. This release includes an increment for transmission losses (Coulson 1971).

The vast majority (95%) of the licences are for the April 1 to September 30 period (Table 10).

4.2 Present Water Demand from Duteau Creek

4.2.1 Annual diversions by the Vernon Irrigation District

Annual diversions by the Vernon Irrigation District can be calculated

TABLE 10: DIVERSION AND STORAGE LICENSES ON DUTEAU CREEK LISTED IN PRIORITY ORDER

Licence	Date	Holder	Diversion Point	Period	Licenced Amount (ac-ft)	Portion of Licence April 1-Sept 30 (ac-ft)	Portion of Licence Oct 1-Mar 31 (ac-ft)
Licenced Diversions from Duteau Creek							
F05279	03-11-90	-	downstream of Headgates	May 1-Sept 30	293	293	
F03599	21-05-02	-	downstream of Headgates	May 1-Sept 30	97	96.5	
C32119	01-09-06	V.I.D.	Headgates	Apr 1-Sept 30	14832 168	15000	
C25665	23-12-58	City of Vernon	Headgates	Apr 1-June 15	400	400	
C25909	18-03-60	Dist. Coldstream	Headgates	Apr 1-June 15	135	135	
C32123	18-10-66	V.I.D.	Headgates	Oct 1-Mar 31	168		168
C34985	27-05-68	City of Vernon	Headgates	All year	1532	766	766
C34700	16-08-68	V.I.D.	Headgates	Apr 1-Sept 30	3000	3000	
TOTAL					20624	19690	934

Licence	Date	Holder	Storage Site	Period	Licenced Storage (ac-ft)	Source of Waters
Licenced Storage on Duteau Creek						
C17842	01-09-06	V.I.D.	Haddo and Aberdeen	Oct 1-June 15	20000	Duteau Creek
F17529	21-10-30	District of Coldstream	Kalamalka Lake	Oct 1-June 1	135	Duteau Creek
C32125	29-11-66	V.I.D.	Goose Lake	Oct 1-June 15	2130	Duteau Creek
C34986	27-05-68	City of Vernon	Goose Lake	Oct 1-June 15	1530	Duteau Creek
C34701	16-08-68	V.I.D.	Grizzly Swamp	Oct 1-June 15	3000	Duteau Creek

from their records as described in Section 2.2 (see Table 5). Annual diversions by the Vernon Irrigation District are also described on "Annual Water Distribution Reports" prepared by the Vernon Irrigation District for the Water Management Branch. The Annual Water Distribution Reports include sources of water other than Duteau Creek: the V.I.D. also diverts waters from King Edward, Deer and Larch Creeks. Typically, the total water use exceeds the diversion from Duteau Creek by 400 to 1200 dam^3. There are some inconsistencies: in both 1981 and 1986 the reported water use is 2,000 to 3,000 dam^3 less than the diversion at Headgates. These water distribution reports are particularly useful because annual water use is divided into waterworks (domestic and commercial) and irrigation uses.

Waters are diverted by the Vernon Irrigation District to meet:

- Irrigation Requirements - diversions between April 1 and September 30;

- Domestic Requirements - diverted during the entire year; constitute a major portion of the diversion between October 1 and April 30; and

- Storage Transfers - Waters are diverted to Kalamalka (F17259) and Goose (C34986) Lakes between October 1 and April 15 for storage and later use during the irrigation season.

The annual diversions, recorded on the "Annual Water Distribution Reports" vary in response to three factors:

- a steady increase in the amount diverted for waterworks due to an increasing number of residential connections. Estimated waterworks diversions increase from 1990 dam^3 in 1981 to 2378 dam^3 in 1987 as the residential connections increased from 3225 to 3852;

- variable irrigation requirements in response to weather and variations in the total land irrigated. Reported irrigation demand ranges from a minimum of 11735 dam^3 (duty of 31 cm or 1.02 feet) in 1982 to a maximum of 18958 dam^3 (duty of 48 cm or 1.56 feet) in 1987. There seems to be a rough association between high irrigation demands and low inflows to Duteau Creek (see Table 5); and

- water rationing (irrigation supplies were rationed during 1988).

Total annual diversions are variable (see Table 5), but in no years is the licenced amount of 25,440 dam^3 (20,624 acre-feet) exceeded. Over the period of record, the Duteau Creek inflow exceeds the licensed and actual demand in every year but 1988. However, storage is required because maximum monthly demands occur during periods of low natural inflow.

4.2.2 Monthly diversions at Headgates

Monthly diversions at Headgates were calculated for the 1975 to 1988 period from daily observations of total water use at Headgates (see Section 2.3; also Appendix B). Average, maximum and minimum monthly diversions are reported for 1975 to 1987 on Table 11. Diversions for 1988 are not included because water rationing makes the flows non-representative.

Average diversions for April to September amount to 14504 dam^3, similar to the average value of 14930 dam^3, reported in Coulson (1971), for various years between 1919 and 1966 (recorded at Water Survey of Canada gauge "V.I.D. Diversion near Lavington 08LC007").

Average diversions between October 1 and March 31 are 2041 dam^3. This is assumed to represent a waterworks requirement of 1100 dam^3 (based on one-half of the average amount reported on the "Annual Water Distribution Reports") and transfers to Goose and Kalamalka Lakes averaging 941 dam^3.

Table 11: Average, Maximum and Minimum Diversions by the Vernon Irrigation District at Headgates, 1975 to 1987

Month	Total Monthly Diversion (dam^3) Mean	Maximum	Minimum
January	341	587	165
February	400	539	210
March	510	1126	227
April	717	1275	294
May	2086	2936	1150
June	3087	3904	1563
July	3990	6386	1950
August	3631	4328	1298
September	993	1765	539
October	360	1166	64
November	189	336	3
December	241	399	134

4.2.3 Minimum fisheries requirements

The minimum requirements for protection of fisheries in Duteau Creek are:

January 1 to March 31	2 cfs (.057 m^3/s)
April 1 to August 31	4 cfs (.113 m^3/s)
September 1 to December 31	5 cfs (.142 m^3/s)

Meeting minimum monthly flows may not entirely protect the fisheries resource. Fluctuating flows from day to day in response to reservoir releases and large spill volumes from Headgates can cause erosion and damage, particularly under ice-cover.

4.2.4 Total demand for waters from Duteau Creek

The demand for water in Duteau Creek is the sum of irrigation and waterworks diversions plus releases for downstream licences and fisheries protection (see Table 12). In calculating the monthly demands, it was assumed that the maximum waterworks requirements (1987) reported on the "Annual Water Distribution Reports" represented the present demand. It was further assumed that this demand was constant over the year and monthly demands could be calculated by dividing the annual total by 12. This may over-estimate winter domestic use and underestimate summer domestic requirements

Average irrigation and storage transfer demand was calculated as the mean monthly diversion from Table 11 minus the requirement for waterworks withdrawals. Maximum irrigation demands are not the maximum recorded in each month but rather represent the monthly demands reported in 1987, the year with the maximum total irrigation diversion. A waterworks demand was subtracted from the recorded monthly diversions.

4.3 Releases to Duteau Creek from Headgates, 1975 to 1987

Table 13 summarizes the average, maximum and minimum monthly discharges recorded at the Water Survey of Canada station "Duteau Creek near Lavington" (08LC006) for 1975 to 1988. The 1988 data are preliminary. This station records releases from Headgates. The release regime from Headgates appears to have altered somewhat over the years: the recorded minimum monthly flows in late winter tend to occur in 1975 or 1976, larger flows have been released since this then despite low inflows to Duteau Creek.

The average release regime, 1975 to 1988, is compared to the natural monthly hydrograph for the same period on Figure 3.

Monthly releases are compared to Fisheries requirements on Table 13. While a significant portion of the months between September and March exhibit flows less than fisheries requirements, the major problem is associated with February and March. Flows less than required are particularly damaging because the required release is already at a minimum. Note that the required release for January to March is

TABLE 12: ESTIMATED MONTHLY WATER DEMAND AT HEADGATES FROM THE DUTEAU CREEK WATERSHED

Month	Irrigation Demand[1] Average (dam^3) (A)	Irrigation Demand[1] Maximum[3] (dam^3) (B)	Waterworks[2] Demand (dam^3) (C)	Downstream Licencees (dam^3) (D)	Fisheries Demand (dam^3) (E)	Total Demand Average (dam^3) (A+C+D+E)	Total Demand Maximum (dam^3) (B+C+D+E)
January	142.8	142.8	198.2	0	152	493	493
February	201.8	201.8	198.2	0	137	537	537
March	312.7	312.7	198.2	0	152	662.9	662.9
April	717.3	1275	198.2	0	294	1209.5	1767.2
May	1904	2412	198.2	152	303	2557	3065
June	2908	3902	198.2	147	294	3547	4541
July	3811	4710	198.2	152	303	4464	5363
August	3451	3996	198.2	152	303	4104	4649
September	794.2	1765	198.2	147	367	1506	2477
October	71.2	71.2	198.2	0	379	648.4	648.4
November	0	0	198.2	0	367	565.2	565.2
December	42.7	42.7	198.2	0	379	619.9	619.9
TOTAL	14357	18831	2378	750	3430	20914	25389

1. Calculated as "Monthly Diversion" - "Waterworks Demand"
2. Calculated as reported waterworks diversion of 2378 dam^3 (1987) divided by 12.
3. Based on April to September period with the maximum diversion.

TABLE 13: AVERAGE, MINIMUM AND MAXIMUM MONTHLY DISCHARGES AT "DUTEAU CREEK NEAR LAVINGTON (08LC006)" FROM 1975 TO 1988.

Month	Monthly Discharge (m^3/s) Maximum	Minimum	Average	Downstream[1] Licensees (m^3/s)	Fisheries Requirements (m^3/s)	% Months less than Required (%)
January	.548 (83)	0 (75)	.112	0	.057	43
February	.958 (83)	0 (75)	.169	0	.057	64
March	1.06 (83)	0 (75)	.272	0	.057	50
April	2.37 (83)	.069 (75)	.845	0	.113	7
May	3.87 (83)	.247 (88)	2.06	-.057	.113	0
June	4.13 (81)	.223 (88)	1.63	-.057	.113	0
July	4.42 (82)	.133 (75)	.823	-.057	.113	7
August	.878 (83)	.130 (77)	.474	-.057	.113	14
September	1.08 (82)	.074 (77)	.470	-.057	.142	21
October	.919 (78)	.034 (77)	.260	0	.142	57
November	.695 (83)	.002 (75)	.209	0	.142	64
December	.547 (82)	.002 (75)	.172	0	.142	71

1. Waters released for downstream licencees are diverted and not available to meet fisheries requirements.

TABLE 14: ESTIMATED NET SPILL IN THE DUTEAU CREEK RESERVOIR SYSTEM, APRIL 1 TO JUNE 30, 1975-1988 ASSUMING EMPTY RESERVOIRS ON APRIL 1 (SCENARIO 1)[1] AND RESERVOIRS AT THEIR AVERAGE LEVEL ON APRIL 1 (SCENARIO 2)[2]

Year	Aberdeen Reservoir Flows (dam) Inflow	Scenario 1 ($11560\ dam^3$) Spill	Scenario 2 ($7400\ dam^3$) Spill	Grizzly Swamp-Haddo Reservoir Flows (dam^3) Inflow	Scenario 1 ($7200\ dam^3$) Spill	Scenario 2 ($5700\ dam^3$) Spill	Flow from Unregulated System (dam^3)	Diversion at Headgates (dam^3)	Net Spill (dam^3) Scenario One	Scenario Two
1975	15700	3700	7900	12400	480	6300	7500	5150	10900	16600
1976	18200	6200	10400	14300	6700	8200	8300	2520	18700	24400
1977	12200	200	440	9600	2000	3500	5100	6620	700	6400
1978	16100	4100	8300	12700	5100	6600	8400	4850	12800	18500
1979	12900	900	5100	10100	2500	4000	3900	7390	0	5600
1980	13800	1800	6000	10900	3300	4800	2500	4500	3100	8800
1981	18200	6200	10400	14300	6700	8200	5700	5750	12900	18600
1982	19800	7800	12000	15600	8000	9500	11000	6930	19900	25600
1983	21900	9900	14100	17200	9600	11100	13800	5630	27700	33400
1984	15900	3900	8100	12500	4900	6400	9000	4790	13000	18700
1985	14000	2000	6200	11000	3400	4900	5300	6930	3800	9500
1986	18700	6700	10900	14700	7100	8600	9000	5800	17000	22700
1987	6900	0	0	5400	0	0	3200	7590	0	0
1988	11100	0	3260	8700	1100	2600	2600	3530	200	4900

1. Scenario 1 assumes Grizzly Swamp and Aberdeen are empty; Haddo with 3.05 m (10 ft) of storage.
2. Scenario 2 assumes Grizzly Swamp and Aberdeen are their average level; Haddo with 3.05 m (10 ft) of storage

approximately the same as the estimated 10 year seven-day natural low flow.

4.4 Inflows to Aberdeen, Haddo and Grizzly Swamp Reservoirs

4.4.1 Operating regime

The general character of the operating regime for the Duteau Creek Reservoirs is described in the following paragraphs. These are adapted from Coulson (1971) or from comments by Brian Harvey (Vernon Irrigation District) or Roy Hamilton (Department of Fisheries and Oceans):

- The discharge gates on Aberdeen and Grizzly Swamp Reservoirs are generally closed at the end of the irrigation season (approximately October 1). Reservoirs fill over the winter and spring period, though storage in both of these reservoirs is released at various periods during the fall and winter.

- Releases from Haddo Reservoir continue after the end of the irrigation season. Haddo is only drawn down to approximately 10 feet in order to maintain sufficient head for emergency requirements such as fire-fighting, etc.

- Water is diverted from Duteau Creek to Goose Lake (developed storage capacity of 2000 dam^3) between October 1 and June 15. These waters are used by the Vernon Irrigation District and the City of Vernon throughout the summer period.

- Grizzly Swamp has no dead storage and is seldom completely drawn down in order to maintain a fish population in the reservoir (note that it was emptied in April of 1982, 1983 and 1984).

The Headgates structure includes a small holding reservoir with a capacity of 37 dam^3 (30 acre-feet). During the irrigation season, the pond is kept as full as possible, as the 37 dam^3 only represents about 3 hours storage at maximum demand. The operator is required to check water levels in the head-pond, estimate demand and radio to Haddo Reservoir for releases. Since the travel time from Haddo Reservoir to Headgates is approximately 6 hours, considerable judgement is required by the operator to balance reservoir releases, headgate pond levels and demand.

Changes in demand, over-estimation of demand or rainfall in the unregulated portion of Duteau Creek may result in spill at the Headgates structure. These spills produce large variations in daily flows at the "Duteau Creek near Lavington" gauge.

4.4.2 Spill from the reservoir system

Inflows to Aberdeen, Haddo and Grizzly Swamp Reservoirs were calculated as described in Section 2.4. The reservoir system is primarily filled in April, May and June. Waters stored in these months are released for diversion for irrigation and waterworks throughout the rest of the year, with the major release from storage occurring in August (Table 7).

Haddo Reservoir has only a very small drainage area which is incapable of filling the reservoir. Consequently, Haddo Reservoir stores spill from Aberdeen and Grizzly Swamp Reservoirs until full; at this point, the reservoir system is at capacity. Spill from the reservoirs passes into Duteau Creek. This water is not entirely wasted; some of the spill may be extracted at Headgates, though inflow from the unregulated portion of Duteau Creek is typically high over this same period, irrigation demands are often low and a significant portion of the spill passes Headgates and travels downstream.

Table 14 presents calculated net spill volumes for the Aberdeen Reservoir and Grizzly Swamp and Haddo Reservoirs, assuming two different initial reservoir conditions on April 1. In the first scenario, Grizzly Swamp and Aberdeen Reservoirs are empty on April 1 and Haddo Lake is at a level of 3.05 m (10 feet). In the second scenario, Grizzly Swamp and Aberdeen Reservoirs are at their average April 1st level (1975-88) and Haddo Lake is at a level of 3.05 m (10 feet).

As Table 14 indicates, net spill, over and above diversion requirements at Headgates, occurs in nearly all years, even assuming that Aberdeen and Grizzly Swamp Reservoirs are empty in April. For empty reservoirs, Aberdeen does not fill in 1987 and 1988; Grizzly Swamp and Haddo do not fill in 1987. The shortfall in Aberdeen Reservoir amounts to 4660 dam^3 in 1987 and 500 dam^3 in 1988. The shortfall in the Grizzly Swamp-Haddo system amounts to 1800 dam^3 in 1987. If the reservoirs are at their average level on April 1, the shortfall in Aberdeen Reservoir amounts to 500 dam^3 in 1987.

Consequently, under most inflow circumstances over 1975 to 1988, it is possible to draw down the reservoirs over the winter period and fill the reservoirs and meet the diversion requirements for April, May and June with water that would have been "spilled" under other conditions.

4.2.2 Prediction of inflows to the reservoir system

In order to adequately operate the reservoir system, it is necessary to know, as early as possible, the likely inflows to the reservoir system.

Measurements of water equivalent in the snowpack, reported by the Water Management Branch (Water Management Branch 1989), provide an opportunity for early prediction of inflow volume. The first measurements of the snowpack are usually on or near February 1 and provide the earliest opportunity for prediction. There are twenty-two snow courses in the Okanagan sub-region, distributed over elevation ranging from 940 m to 1840 m. Figure 4 shows the general trend of maximum normal water equivalent with elevation. Typically, normal water equivalent increases rapidly above elevations of 1500 m though broad variation occurs around the average curve.

A snow course, Aberdeen Lakes (2F01A; 1250 m) lies in Duteau Creek, with records extending from 1938 to 1988. However, the February 1 and March 1 water equivalents are not well correlated with reservoir inflows over the 1975 to 1988 period. This is not too surprising; the majority of the runoff is generated from areas with elevations over 1500 m. Nearby higher elevation snow courses (i.e. Mission Creek, 2F05; 1780 m) approximately 15 km from Duteau Creek provides a better correlation between reservoir inflows and water equivalent. For February 1 water equivalents the best equation is:

$$\text{INFLOW} = 13200 + 19.2\ (\text{MISSION}) + 87.9\ (\text{VASEAUX}) \qquad (10)$$
$$(r^2 = 0.37;\ SE = 6070)$$

where the inflow is in dam^3 for the April 1 to June 30 period and the water equivalent is in mm. For March 1 observations, the best equation is:

$$\text{INFLOW} = 11600 - 16.9\ (\text{MISSION}) + 184.4\ (\text{VASEAUX}) \qquad (11)$$
$$(r^2 = 0.56;\ SE = 5090)$$

Correlations are low and standard errors are high for both these equations but they may be useful for reservoir management. Based on February 1, 1989 snowpack water equivalents, the 1989 reservoir inflow is predicted to be 26,500 dam^3, a below average inflow.

4.5 Storage Analysis for the Duteau Creek Reservoir System

A long-term water balance for Duteau Creek system is outlined on Table 15, based on measurement from 1975 to 1988. In the long-term, the water balance is only altered to a limited extent by year-to-year storage changes. All values are long-term average values and wide variation in any value may be expected in any given year.

Net spill is the release of water to Duteau Creek over and above minimum fisheries and downstream licensed requirements. In Table 15, the net demand at the reservoir outlet is underestimated because not all the contribution from the unregulated basin can be utilized at Headgates due to the difference between the distribution of monthly flows and monthly demands. Some of this water must be spilled.

Table 15: Long-term reservoir balance for Duteau Creek

Average Inflow to Reservoirs		28,200 dam^3
Average Demand at Headgates	20,900	
Average Evaporation Demand	2,430	
Average Contribution from Unregulated Basin	9,850	
Net Demand at Reservoir Outlet		13,500 dam^3
Estimated Net Spill		14,700 dam^3

The size of the reservoirs necessary to guarantee releases sufficient to meet the monthly demand may be calculated from the monthly reservoir inflows. The purpose of these types of analyses is to define the relationship between storage volume, inflows, drafts and dependability. The interest, in this study, is in defining the critical storage volume required to meet net demands during the 1975 to 1988 inflow sequence.

Storage analysis based on a limited historical record suffers from certain limitations. First, the results of the analysis are only strictly applicable to future inflows if they are of the same magnitude and occur in the same order as the historical record. This is a particular problem in Duteau Creek where the major limitation on reservoir dependability is imposed by the combined 1987 and 1988 inflow seasons. It is not clear how often a drought of this severity occurs.

Second, the analysis assumes perfect operation of the reservoir and diversion system (i.e. no unnecessary spill at Headgates) and advance knowledge of the inflow sequence so that reservoirs can be drawn to "zero" during the critical period.

Storage analysis is based on the following variable:

$$S = \quad (I_j - Q_j) \quad t \qquad (12)$$

where S is the cumulative sum of the difference between the inflow I_j and the demand Q_j. The reservoir system was analyzed for two separate demands:

1. The average demand for irrigation plus waterworks, downstream licensee and minimum fisheries requirements and the normal evaporation demand; and

2. The maximum demand for irrigation plus waterworks, downstream licenses and minimum fisheries requirements plus the normal evaporation demand increased by one standard deviation.

Separate analyses were completed for the Aberdeen reservoir and for the combined Grizzly Swamp-Haddo Reservoirs.

The demand that must be met by the reservoir system is:

(DEMAND AT HEADGATES - NATURAL OUTFLOW + EVAPORATION) (13)

where the demand at Headgates is as described above (see Tables 2 and 12) and the natural outflow is as calculated in Section 2.3. The natural outflow exceeds the demand at Headgates in some months; in these months the demand at the outlet of the reservoir only consists of losses to evaporation.

The analysis starts with a full reservoir (i.e. storage = 0) and unlimited storage and accumulates the difference between inflows and demand over 1975 to 1988. Storage cannot exceed "zero". When the cumulative sum is greater than zero the reservoir system is spilling and the sum is re-set to "zero". The critical storage is, then, the minimum value of the cumulative sum. The required critical storage, for the 1975 to 1988 period, for the Aberdeen and the Grizzly Swamp-Haddo Reservoirs are given on Table 16.

Table 16: Critical Storage to meet demand over the 1975-1988 inflow period.

Reservoir System	Required Storage (dam^3) Average Demand	Maximum Demand	Existing Capacity (dam^3)
Aberdeen	8100	10200	11600
Grizzly-Haddo	6500	8100	7400
TOTAL	14500	18300	19000

The existing capacity on the Haddo-Grizzly Swamp system (Table 16) assumes that Haddo Reservoir levels remain above 3.05 m (10 feet).

Aberdeen Reservoir is adequate to meet the maximum demands during the 1987-1988 drought. The Grizzly Swamp-Haddo Reservoirs are slightly undersized. This analysis assumes perfect operation. Problems in actual operation arise because of spill at Headgates, other losses, and operation without knowledge of the future inflow sequence. These require some additional, but uncalculable, amount of storage.

5. ALTERNATE WATER MANAGEMENT PRACTICES IN DUTEAU CREEK

Water availability and water demand exhibit varying relationships over a typical decade. While average inflows to the reservoir systems are nearly twice the average demand, storage capacity problems still occur because of the year-to-year variability of inflows and of irrigation demand. Droughts, of varying severity, occur in Duteau Creek. They may also be of varying duration -- from one year to a decade or more. Unfortunately, little information is available on the expected return period for droughts of various severities and lengths.

While demands from Duteau Creek are much less than average flows, maximum demands cannot be practically met with the existing storage system, for a drought such as occurred from Fall 1986 to December 1988 (Section 4.5). The reservoir system can meet requirements during this drought under typical irrigation demand. It is not entirely clear how often a drought of similar severity to 1987-1988 occurs, however, a guess of approximately once in ten to once in twenty years may not be unreasonable.

While the storage system may be inadequate to meet all demands in one year out of ten, in many other years waters are available to meet all requirements and provide significant spill volumes to Duteau Creek below Headgates. This occurs in six or seven years out of ten. In the remaining two or three years, average or maximum demands can be met and some small spill may occur (see Table 14).

Natural and Regulated Hydrological Regimes

Development and operation of storage reservoirs and the Headgates diversion structure have affected flows in Duteau Creek (Figure 3). Mean annual flow has decreased as a result of diversion and mean monthly flows are less in each month.

Minimum flows have also been affected. Natural ten year seven-day low flows were estimated to be 0.06 m^3/s (2.1 cfs), approximately the same as the flow required for the protection of fisheries through January, February and March. Flow releases from Headgates have often been less than this value (Table 13); approximately 50% of the months from 1975 to 1988 record flows less than 0.057 m^3/s; minimum monthly flows have been zero.

Pre-spill to provide minimum fisheries flows

As described in Section 4.2, the major problem with minimum flows occurs in winter months -- January, February and March. Flows less than fisheries requirement are observed in these months in years of low reservoir inflows and in years when reservoirs are above minimum levels and significant spill occurs over and above requirements at Headgates (see Table 14).

An opportunity exists to provide minimum, or improved, fisheries flows by "pre-spill" in those seven or so years out of ten when large reservoir inflows are expected. In pre-spill the reservoirs are drawn down over January, February and March to minimum levels, and the water released through Headgates as fisheries flows. Reservoir inflow volumes are sufficient to fill the reservoirs, meet diversion demands and provide spill. Pre-spill, by increasing the available storage capacity, may also reduce downstream water levels during the summer inflow period.

Pre-spill of waters to meet fisheries flows, requires:

1. Prediction of inflow to the reservoir from measurements of the snowpack on February 1 and March 1.

2. Management of reservoir water levels in the late-summer and fall period to ensure sufficient reservoir storage to meet requirements and provide waters for pre-spill.

A series of rule curves for reservoir operation will be prepared in conjunction with the Water Management Branch, Victoria.

Storage Improvements for Fisheries Flows

As discussed, modifications to reservoir operation have the potential to improve fisheries flows in most years. However, waters for pre-spill release are unlikely to be available in years of low snowpack and predicted low reservoir inflows.

Storage improvements are required to meet all demands, but particularly fisheries requirements, in drought years. Storage improvements may consist of:

1. Expansion of the existing reservoir system; or

2. Development of additional storage reservoirs elsewhere in the basin. This storage could be reserved exclusively for fisheries purposes.

Development of other storage will not necessarily solve minimum flow requirements for fisheries. Water must be released through Headgates and negotiation would be required with the Vernon Irrigation District to ensure that these waters are released to the benefit of downstream fisheries.

Expansion of Existing Storage

The Grizzly Swamp Reservoir seems to be the most suitable site for expansion of storage, for two reasons (MacTaggart 1973):

- The potential storage on Grizzly Swamp Reservoir is large; and

- Increased storage on Grizzly Swamp would allow similar control of inflows as presently occur in the Aberdeen system.

Alterations to existing storage may consist of raising the dam and spillway structures or altering the existing spillway to take advantage of the existing potential storage (Table 1).

Development of New Storage Sites

Few good sites for storage development remain in Duteau Creek, because of previous developments. Existing lakes in the unregulated portion of the basin (Doreen, Flyfish, Aileen, Loon, Ruth, Brunette and Wollaston Lakes) are mostly small, with less than 50 hectares surface area. Lake levels must be raised at least 2 metres to provide even 1,000 dam^3 of storage. As well, many of the lakes, such as Doreen Lake, have small contributing areas and may not generate sufficient runoff to fill the reservoir in dry years. One possibility, requiring more detailed investigation, is to develop the swamp lying west of Grizzly Hill in the upper part of the natural portion of Duteau Creek.

Alternatively, limited storage, consisting of less than 1,000 dam^3 or so, could be developed on one of the small lakes and used to supplement other releases by the Vernon Irrigation District.

5.1 Long-Term Demand for Water in Duteau Creek

As described in Section 4.2, water use from Duteau Creek is less than the total licenced amount. It is not known what the projected demands for water are for the next few decades.

One apparent trend is an increase in domestic (waterworks) consumption within the Vernon Irrigation District. Domestic water use conflicts with release of minimum fisheries requirements since this increased domestic demand will be imposed on the limited storage volume available during the winter, when fisheries requirements must also be met. As discussed in Section 4.2.1, annual domestic diversion has increased by approximately 400 dam^3 since 1975.

5.2 Summary of Recommendations

Data Collection

1. Continue observations of water levels in Haddo, Grizzly Swamp and Aberdeen Reservoirs on the first of each month. Additional water level observations when reservoirs are spilling would assist in calculating reservoir inflows;

2. Establish a higher elevation snow-course in the Duteau Creek basin to improve reservoir inflow prediction;

3. Additional observations of water levels at the "Duteau Creek at outlet of Haddo Lake" gauge. Review of rating curve and gauge operation;

4. Prepare annual summaries of monthly diversions at Headgates, storage changes on the three reservoirs and flows in Duteau Creek recorded at the "Duteau Creek near Lavington" gauge. Use these data to calculate reservoir inflows;

5. Make miscellaneous measurements of flows from the natural portion of Duteau Creek for comparison with flows from the "Coldstream above Municipal Diversions" gauge; and

6. Readings at the various gauges at Headgates should be overlapped for several days when switching from one pipe to the other.

Further Technical Studies

1. Measure transmission losses in Duteau Creek;

2. Review snow course data to improve predictive capability for inflows to reservoir;

3. Further study of Water Survey of Canada, Atmospheric Environment Service and Water Management Branch records to estimate frequency and severity of droughts in Duteau Creek; and

4. Examine long-term demand for water from the Duteau Creek watershed. It is understood that the Vernon Irrigation District has already examined this problem.

Reservoir Operation Improvements

1. Develop "rule curves" for reservoir operation to ensure release of minimum fisheries requirements in most years through "pre-spill"; and

2. Regular meetings between the V.I.D. reservoir manager and Fisheries and Oceans to manage fisheries releases.

Storage Development

1. Examine the potential to increase storage on Grizzly Swamp reservoir to enable to Vernon Irrigation District to better manage irrigation, waterworks, downstream and fisheries releases during droughts;

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APPENDIX A: ADJUSTMENTS TO REPORTED RESERVOIR LEVELS, HADDO, ABERDEEN AND GRIZZLY SWAMP RESERVOIRS, 1975-1988

		INITIAL AND ALTERED RESERVOIR LEVELS (ft)					
Year	Month	Grizzly Swamp		Aberdeen		Haddo	
		Initial	Altered	Initial	Altered	Initial	Altered
1976	Feb			8.7	8.2		
1977	Jan			17.7	17.9	15.0	16.0
	Feb			18.0	17.9		
	July			18.7	17.5		
	Sept			5.0	6.0		
	Oct			2.0	3.5		
	Nov			2.0	2.5		
1978	Mar					12.0	12.5
	Dec					15.5	13.5
1979	Mar	27.5	25.2				
	Sept			8.9	10.0		
	Oct			6.0	7.0		
	Dec			7.5	5.5		
1981	Apr	27.3	29.0				
1983	Sept			14.6	13.7		
1984	Sept			12.0	13.5		
	Oct			10.3	11.0		
1985	Jan			10.5	9.3		
	Aug			12.0	14.0		
	Sept			0.0	8.0		
	Oct			0.0	4.0		
1986	Dec			12.5	12.8		
1987	Jan			12.5	12.7		
	Feb					13.0	14.0
	Aug			6.9	7.5		
	Sept			0.0	3.5		

APPENDIX B: MONTHLY DIVERSIONS AT HEADGATES: 1975-1988
DATA SUPPLIED BY THE VERNON IRRIGATION DISTRICT

Year	Monthly Diversion (dam^3)											
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
1975	254	212	227	294	1960	2899	4050	3543	1436	1166	336	367
1976	323	358	372	417	2346	1866	3345	1298	799	735	3[1]	215
1977	232	210	1126	958	2476	3188	4236	4205	1047	348	277	399
1978	456	361	370	419	1150	3278	3916	2968	595	301	226	218
1979	253	372	526	989	2712	3689	4671	4465	862	355	153	357
1980	587	532	317	766	2168	1563	3786	3765	617	269	202	270
1981	442	539	644	628	1477	3648	2887	4157	1257	210	166	183
1982	165	77	315	744	2286	3904	1950	2818	917	64	45	198
1983	268	381	581	701	1901	3029	2426	3643	539	195	90	213
1984	393	481	498	785	1647	2357	4403	3852	962	260	184	195
1985	320	421	463	712	2936	3286	5106	4328	954	212	175	186
1986	385	404	492	634	1643	3525	6386	4160	1162	236	218	198
1987	356	530	697	1275	2412	3902	4710	3996	1765	325	200	134
1988	135	136	149	937	928	1664	2790	3138	1493	398	306	167
Average (to 1987)	341	400	510	717	2086	3087	3990	3631	993	360	189	241

1. Value not included in reported average.

Figure 1: Plan of the Duteau Creek Watershed showing Water Survey of Canada Stations Scale 1:125,000

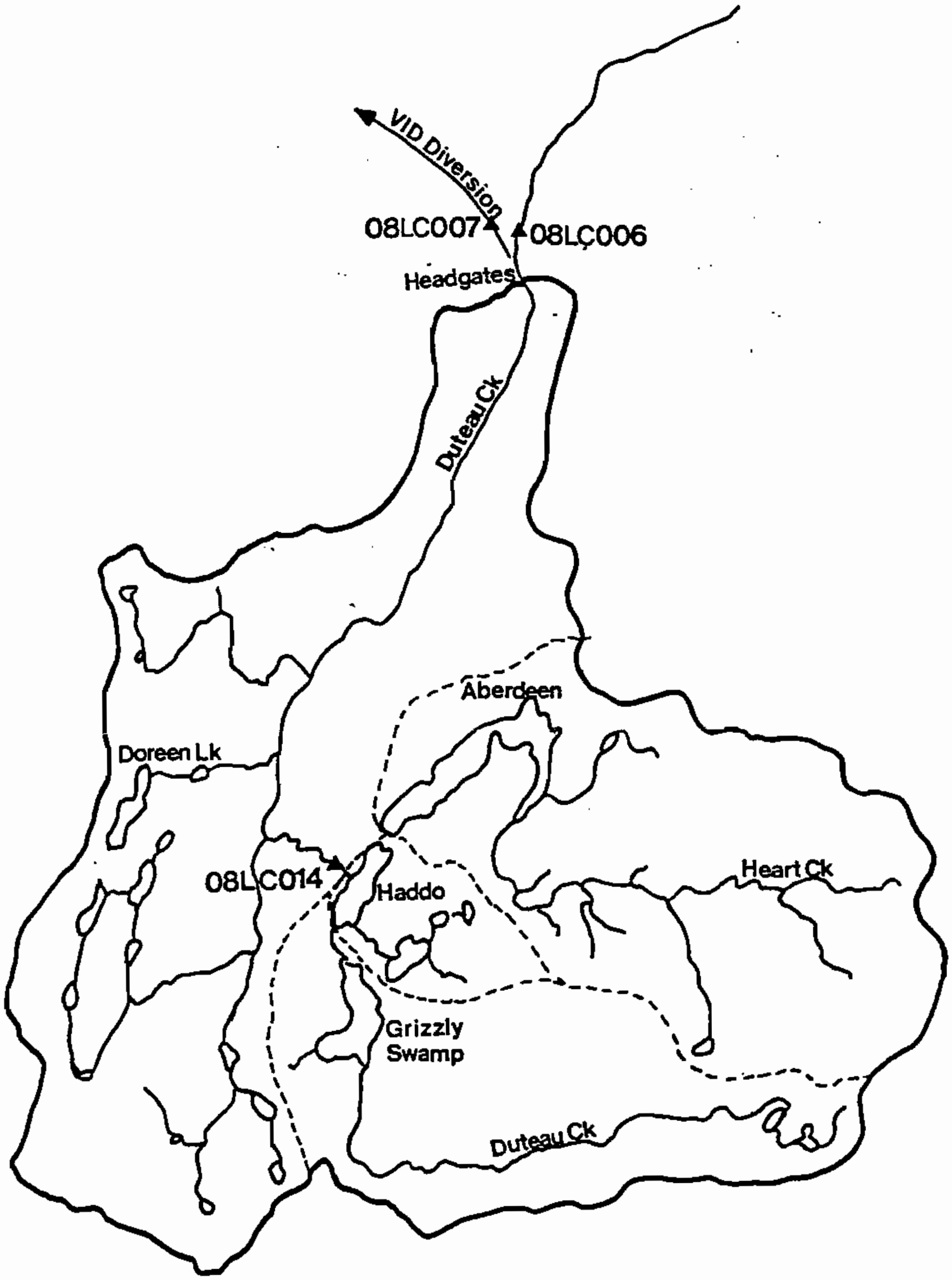


Figure 2: Natural Flow Regime in Duteau Creek
Mean Monthly Flows, 1975-1988

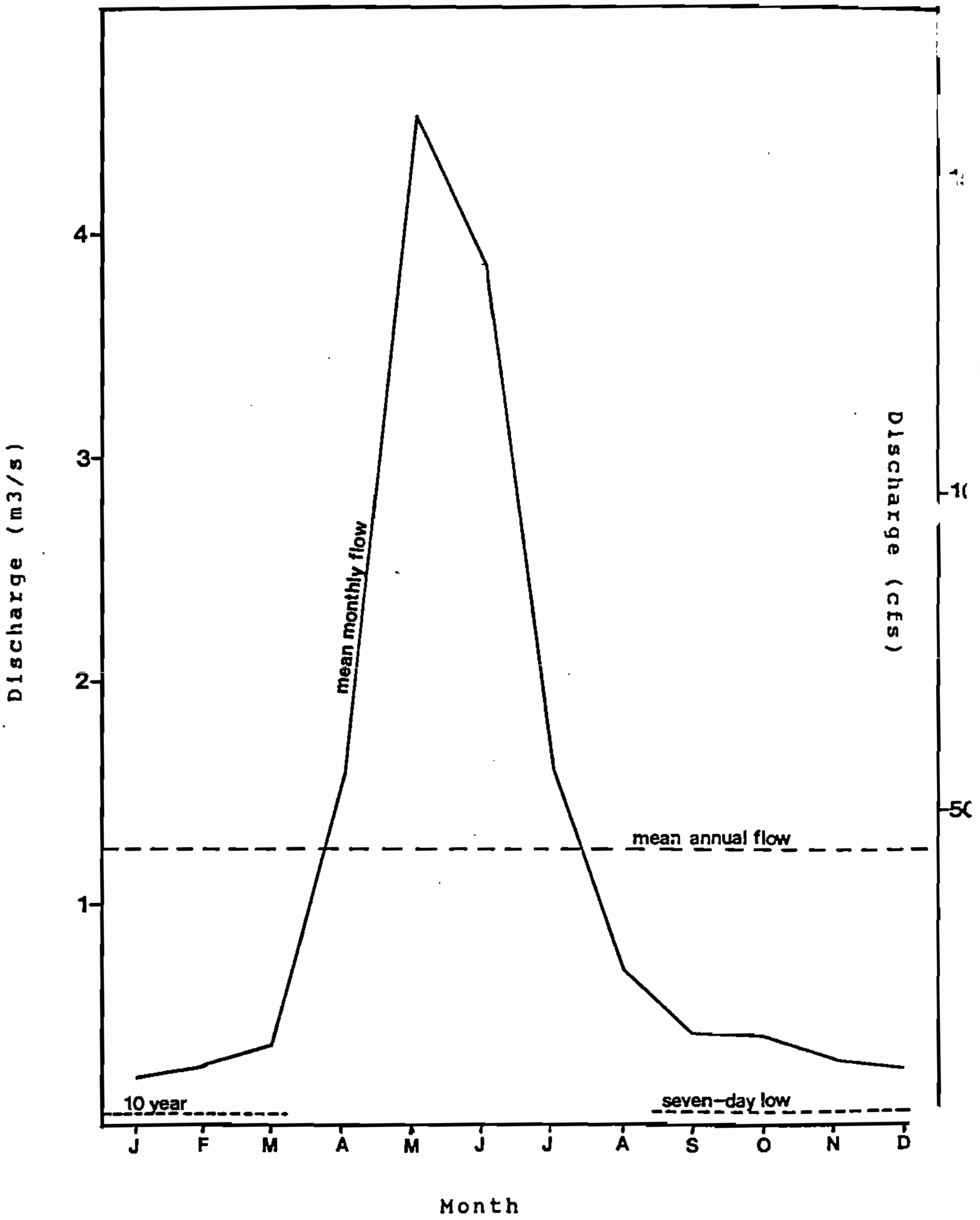


Figure 3: Regulated Flow Regime in Duteau Creek
Mean, Maximum and Minimum Monthly Flows
1975-1988

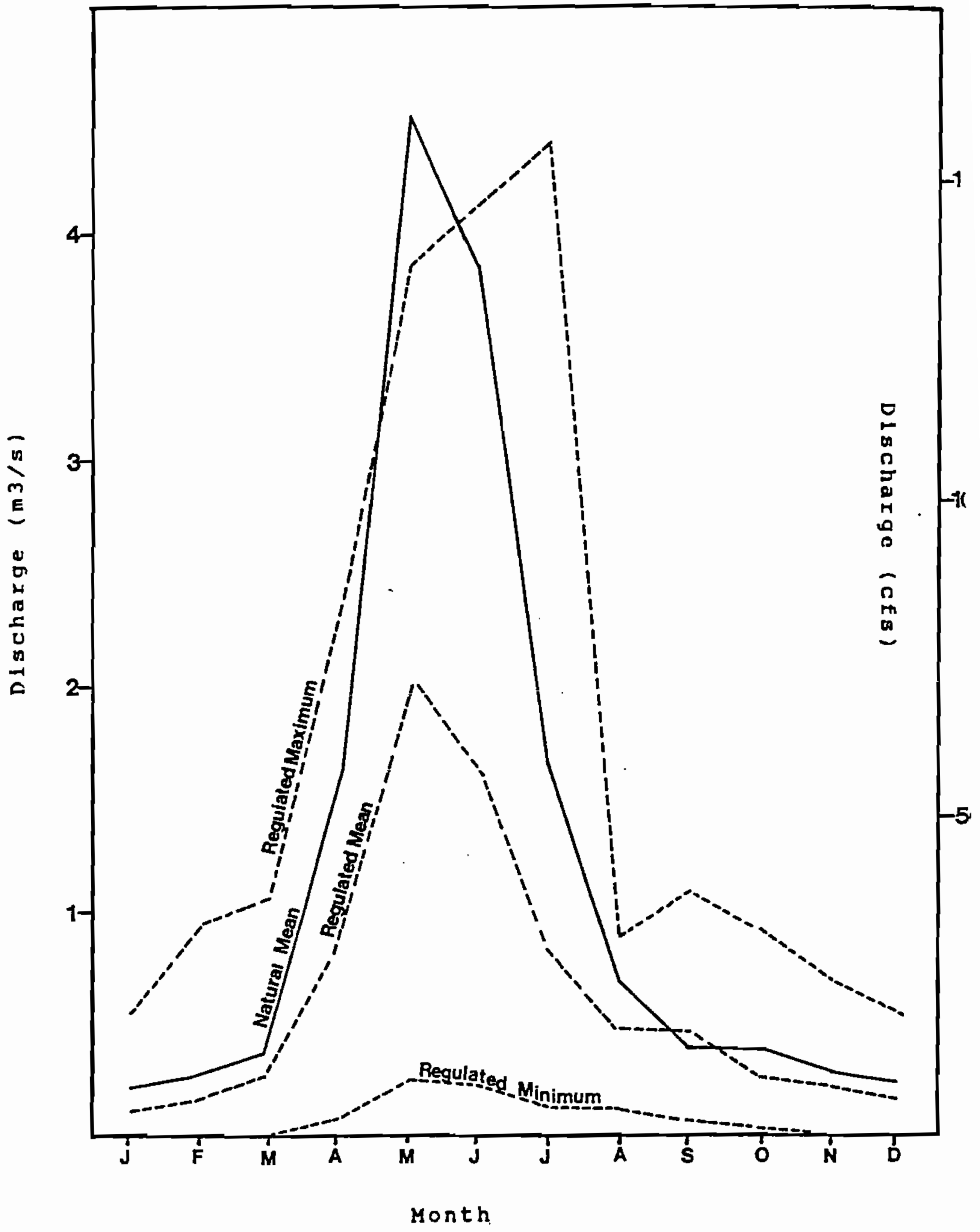
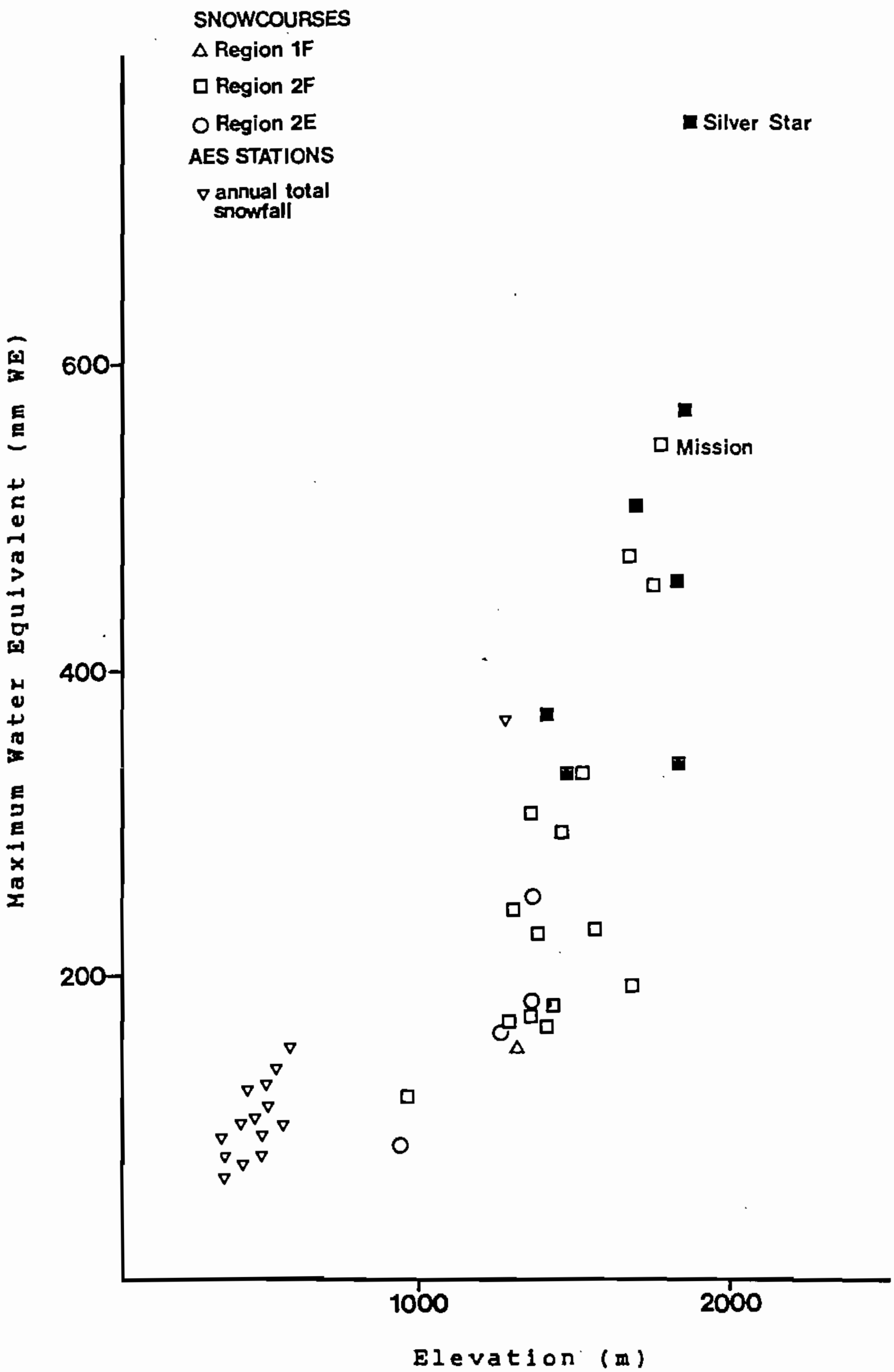


Figure 4: Maximum Normal Water Equivalent versus Elevation for the Okanagan and surrounding Regions (Water Management Branch 1988)



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Project: 98112

April 12, 1999

Riverside Forest Products Ltd.
RR#2
Lumby, BC
V0E 2G0

Attention: Harold Waters

Re: Duteau Creek Watershed

Enclosed is the final text for the Interior Watershed Assessment for the Duteau Creek Watershed report dated March 1999. Also, the final meeting minutes have been sent to Eric Goodman.

If you have any questions, please call me.

Yours truly,

Michael J. Milne, M.E.S.

Encl.

/jp

cc: Bob Harding - Department of Fisheries and Oceans
Susan Latimer - Ministry of Environment
Dave Gooding - Ministry of Environment
Rita Winkler - Kamloops Forest Region
Eric Goodman - Vernon Forest District
Renee Clark - North Okanagan Water Authority
Peter Love - Riverside Forest Products
John Jobst - Tolko Industries Ltd.

Interior Watershed Assessment

for the

DUTEAU CREEK WATERSHED

(Vernon Forest District)

Prepared for
RIVERSIDE FOREST PRODUCTS LIMITED
Lumby Division

and

TOLKO INDUSTRIES LTD.
Lavington Division

by
DOBSON ENGINEERING LTD.
#4 - 1960 Springfield Road
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March 1999

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Interior Watershed Assessment

for the

DUTEAU CREEK WATERSHED

(Vernon Forest District)

1.0 INTRODUCTION

At the request of Riverside Forest Products Limited, the ***Interior Watershed Assessment Procedure (IWAP)*** for the Duteau Creek watershed was updated to incorporate the terrain mapping information and new inventory data pertaining to logging history and green-up heights.

The purpose of the assessment was to determine current watershed conditions, the effect of past land-use practice on the watershed and the potential impacts from proposed forest development. The assessment follows the Interim Watershed Assessment Procedure as provided by the Ministry of Forests (MoF) and Ministry of Environment, Lands and Parks (MELP) *[refer to Section 4.0]*.

This report replaces the previous watershed assessment completed in 1996.

The Duteau Creek watershed is located southwest of the Village of Lumby within the Vernon Forest District *[Figure 1]*. Duteau Creek is a community watershed providing water for the North Okanagan Water Authority (NOWA). The entire watershed was assessed upstream of the Headgates water intake (referred to as the lower point of interest [POI 1]). The majority of Crown land in the watershed is held under forest license by Riverside Forest Products Limited - Lumby Division, with a minor portion part of a forest license held by Tolko Industries Ltd., Lavington Planer Division. The Small Business Forest Enterprise Program (SBFEP) also has several timber sales proposed within the watershed.

A Watershed Assessment Committee (WAC) including representatives from Riverside Forest Products Limited - Lumby Division, the MoF, MELP, Department of Fisheries and Oceans (DFO), NOWA and Tolko Industries Ltd. was organized to provide input on related issues and concerns, and to review the results *[Appendix A]*.

The Department of Fisheries and Oceans (DFO) did not participate in the initial WAC meeting but requested to be kept informed of assessment results through receipt of the meeting minutes and the final report.

Comments forwarded to the WAC will be discussed at the final WAC meeting.

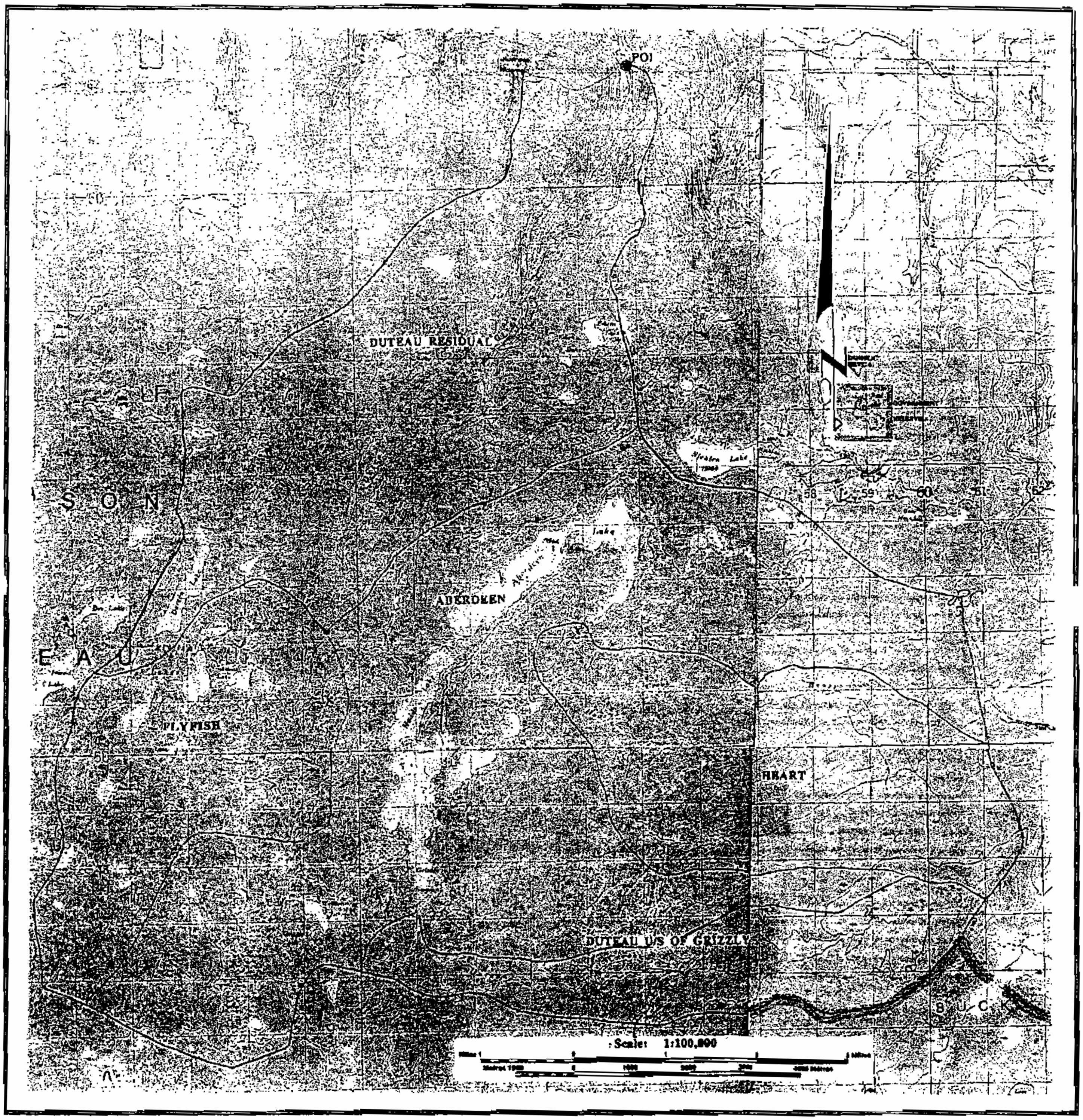

FIGURE 1
Location Map for the Duteau Creek Watershed (showing sub-basins).

2.0 RESULTS OF INITIAL ROUNDTABLE MEETING

2.1 Watershed Concerns

A summary of the comments and concerns presented during the initial roundtable meeting are listed below. Minutes from the meeting are provided in Appendix A.

<u>NOWA</u>

- Primarily concerned with forestry and range management, and their potential effects on water quality and quantity.
- Increases in turbidity and pathogenic organisms are specific concerns that may require special treatment at the intake.
- Cattle are a concern with respect to potential fecal contamination.
- Increased access for recreation and range use that may result from forest road construction is a concern in and around streams.
- The lower residual area adjacent to the canyon reaches are considered the most sensitive areas with respect to forest development.
- The hydrologic effects of the 1998 Aberdeen fire are not known at this time. Without understanding the cumulative effects of increased ECA in the Heart Creek basin, further development in the Aberdeen Residual and Duteau upstream of Grizzly sub-basin is a concern.
- Runoff rates into the upper reservoirs are a concern if accelerated by forest development. Slow, prolonged melt and runoff is desirable to minimize the volume spilled from the reservoirs and maximize the supply in the late summer and early fall low flow periods.
- The reservoirs should not be considered as "settling ponds" for fine sediment resulting from other uses in the watershed.
- Recreation use and cattle access in and around streams below Haddo Lake are concerns that require ongoing management.

<u>Department of Fisheries and Oceans</u>

- DFO was not represented at the meeting but has documented concerns with the mainstem channel downstream of Headgates intake. The channel below the intake has experienced a decline in available salmonid spawning habitat as a result of bedload capture. An agreement is in place with NOWA to maintain specified low flows over set periods of the year.

Ministry of Environment, Lands and Parks

- Similar concerns to those identified by DFO with the mainstem below the Headgates intake.
- Resident trout populations upstream of the intake and reservoirs in the upper watershed are also a concern with regard to channel stability, peak flows and potential increases in sedimentation from roads and cattle activity.

Ministry of Forests

- Specifically concerned with current and proposed ECA's in the watershed.
- Interested in the forest development plan review portion of the IWAP and its potential effects on current watershed conditions.

2.2 Specific Watershed Assessment Items

The points of interest (POI's) for watershed assessment will be at the Headgates intake and on the mainstem at the confluence with Flyfish Creek. Stream channel assessment information will be included for the reaches below Headgates, based on documented DFO fisheries concerns.

Sub-basins will be the same as in the 1996 IWAP and the H60 elevation will remain at 1,323 m. Hazard ratings for the watershed and sub-basins will be reported in tabular format. IWAP calculation data will be presented for all residual areas, sub-basins and the watershed. Specific areas of concern within the Duteau and Aberdeen residual areas will be discussed in the assessment text, but no hazard ratings will be reported for these areas. Residual area hazards are accounted for in the aggregated watershed hazard ratings for the associated POI.

The report should discuss: the hydrologic sensitivity of the watershed and sub-basins with respect to forest and other land-use development; the hydrologic implications of commercial thinning; and proposed aggregate cutblocks.

3.0 BACKGROUND INFORMATION

3.1 Physical Characteristics

Duteau Creek flows north from the Aberdeen Plateau into the White Valley and eventually into Bessette Creek at Lumby. The watershed area is approximately 17,000 ha with elevations ranging from 660 m at Headgates to over 1,800 m in the Grizzlys Hills. Biogeoclimatic zones include Interior Douglas Fir (IDF) at low elevations, and Interior Cedar Hemlock (ICH), Montane Spruce (MS) and Englemann Spruce and Sub-Alpine Fir (ESSF) at mid to upper elevations.

The western half of the watershed is dominated by metamorphic rocks of the Monashee or Shuswap Metamorphic Complexes[1]. These rocks are highly foliated and folded granitic gneisses, slate, schist and quartzite[2]. A pluton of granite and granodiorite of the Nelson Plutonic Rocks is present in the middle eastern section of the watershed. Both the Monashee and Nelson groups are mantled by a discontinuous sheet of basalt lava belonging to the Chilcotin Group. This volcanic sheet has been warped and forms abrupt and conspicuous rock escarpments throughout the area[3].

The watershed upstream of Headgates intake roughly consists of two parts: a canyon section and an upland section. In the upland section, surficial materials consist of moderate to well drained moraine with intervening depressional terrain that is poorly drained and dominated by organic deposits[4]. Moraine commonly consists of a veneer or blanket of sandy bouldery till. Rockfalls exist along the extensive lower escarpments composed of columnar basalt. Steep, short slopes susceptible to small slides (consisting of stratified sands and gravels) exist at the head of the canyon section. Isolated areas of glacio-fluvial outwash are present in the uplands area associated with broad glacial meltwater channels.

The canyon section is mapped as Class IV and V terrain with slopes consisting of rock outcrops, escarpments and steep gravelly colluvium in excess of 80% slope. Most of the landslide activity in the watershed is concentrated in this section, and includes large rockslides, debris torrents and debris avalanches[5]. A very narrow alluvial floodplain exists through the canyon dominated by boulder gravels.

Duteau Creek is a snow dominated hydrologic system with peak flows occurring from late April to mid-June. Hydrometric records are available for Duteau Creek near Lavington (WSC Station No. 08LC006) from 1919 to 1921, 1935 to 1951, and 1959 to 1996. Mean daily discharge is 0.67 m^3/s and maximum daily discharge was 16.2 m^3/s recorded in the spring of 1990. Unfortunately, maximum daily discharge is not available for the regionally high runoff years in 1996 and 1997. Flows with a return period of 30 and 40 years occurred in Bessette Creek downstream of Nicklen Creek immediately east of the Duteau watershed in 1996 and 1997, respectively.

The Duteau Creek system is regulated through three reservoirs in the upper watershed and the Headgates water intake, all operated by NOWA. The hydrologic effect of these reservoirs is to modify the runoff period and peak flows through storage. Depending upon the volume and timing of runoff, the reservoirs will have varying effects on downstream peak flows. For example, peaks will be reduced in low runoff years but may be unaffected in high runoff years.

[1] Jones, A. G., 1959. Geological Survey of Canada Memoir 296 Vernon Map-Area, British Columbia. Department of Mines and Technical Surveys

[2] Roed, M.A., 1998. Detailed Terrain Stability Mapping of the Duteau and Harris Creek Watersheds.

[3] ibid.

[4] ibid.

[5] ibid.

3.2 History of Past Forest Development

Timber harvesting has occurred in the watershed over the past 60 years. From 1930 to approximately 1950, partial cutting systems were employed in the lower elevation stands. Since the 1950s, clearcutting has been the dominant silviculture treatment in the even-aged Lodgepole pine and Englemann spruce-subalpine fir stands at higher elevation. Over the last 20 years, a significant portion of the annual harvest for Riverside Forest Products Limited and Tolko Industries Ltd. has come from salvage logging of Lodgepole pine stands infested with mountain pine beetle. More recently, an outbreak of spruce bark beetle has resulted in significant salvage harvesting in Englemann Spruce stands in the upper watershed.

In 1997 and 1998, the Small Business Forest Enterprise Program completed two commercial thinning blocks in the Heart Creek sub-basin. Approximately 30% of the basal area was removed from the blocks with the intent to promote more vigorous growth in the remaining Lodgepole pine stems. Two other commercial thinning areas are proposed in the Heart and Aberdeen sub-basins.

In the summer of 1998, the Aberdeen fire burned approximately 700 ha of the area east of Aberdeen and Haddo Lakes. The fire burned a combination of standing timber and existing reforested cutblocks. The majority of the burnt standing timber was salvaged in the fall and winter of 1998 by SBFEB and Riverside Forest Products Limited.

3.3 History of Water Use

Earthfill dams were constructed in the upper watershed on Haddo and Aberdeen Lakes in the early 1900s. A diversion from the Harris Creek watershed into Heart Creek was built in the 1930s and recently refurbished in 1992. Through this diversion, Paradise and Gold Creeks are directed into Heart Creek with a total licensed capacity of 6.5 million m^3 per year of freshet runoff.

In the 1970s, an earthfill dam was constructed at Grizzly reservoir to create a third storage reservoir in the upper watershed. The reservoir was designed with additional storage that would be used to maintain summer and fall low flows for salmon spawning and egg incubation downstream of Headgates. This portion of the Grizzly reservoir project was funded by DFO. Minimum releases below Headgates were to be 0.06 m^3/s between January 1 and March 31, 0.11 m^3/s between April 1 and August 31, and 0.14 m^3/s between September 1 and December 31. DFO also has a special agreement with NOWA to provide a further release of water from Headgates upon special request, provided that the total volume released does not exceed 0.14 million m^3 per year.

The Headgates intake was originally constructed in the 1920s and rebuilt in the 1960s along with the construction of a new distribution system. The total licensed diversion through the Headgates facility exceeds 25 million m^3 per year.

4.0 PREVIOUS ASSESSMENTS/COMPLETED WORK

Funded by Forest Renewal BC, watershed assessments were completed for the watershed in March 1996 by Riverside Forest Products Limited. Components of the project included an Interior Watershed Assessment, Road Assessment, Channel Assessment, Gully Assessment and Riparian Assessment. A landslide rehabilitation assessment was also completed for the S33.1 road in the Duteau watershed of the Grizzly sub-basin in 1998.

NOWA has initiated a water quality monitoring program at three sites in the watershed. NOWA was the proponent on a recent (1998) landslide rehabilitation project on the Duteau mainstem, and has participated with MoF Range and Recreation Branches, and Riverside Forest Products Limited on several projects to control cattle and recreational access to the mainstem channel and reservoir area in 1998.

Terrain mapping, at TSIL level C, was completed for the watershed in 1998.

4.1 IWAP

The condition of the Duteau Creek watershed was rated as good in 1996 based on the results of the IWAP assessment. Moderate peak flow hazard ratings were calculated for all sub-basins and the watershed primarily as a result of the road densities above the H60 elevation. A moderate surface erosion hazard rating was calculated for the Flyfish sub-basin based on the length of road within 100 m of a stream and the number of active stream crossings. A moderate riparian hazard rating was calculated for the Aberdeen sub-basin based on the length of stream harvested to the bank. All other hazard ratings were low.

It was recommended that cumulative impacts from forest development should be maintained at a low level since Duteau Creek is a community watershed. A review and implementation of recommendations from other watershed restoration project components was suggested along with an update of the IWAP in 1997 following completion of Level C terrain mapping.

4.2 Road Condition Assessment

Approximately 300 km of road was surveyed in 1995 and 11 high risk sites were identified. Five of the 11 high priority sites were located on private land downstream of the Headgates intake.

The 11 high priority sites were recommended for prescriptions in 1996. Work on low and moderate priority sites was recommended if equipment was available during work on the higher priority areas.

Drainage improvement on the Haddo FSR east of the Duteau Creek mainstem crossing (high priority site) were undertaken by Riverside Forest Products Limited in 1998. A high priority bridge crossing was also removed from a tributary to Heart Creek in 1998.

In conjunction with NOWA, Riverside Forest Products Limited also completed road drainage improvement works on the Specs Lake Recreation Site and Grizzly reservoir access roads.

Work at Specs Lake included road relocation away from the stream channel and revegetation of a disturbed riparian area along the channel. The access road on the west side of Grizzly reservoir was deactivated to limit unauthorized vehicle access and prevent cattle from moving north along the reservoir.

4.3 Gully Assessment

Six defined gullies that were direct tributaries to the lower mainstem channel were identified and assessed using the *Gully Assessment Procedure Guidebook.* All assessed gullies were classified as low risk and no remedial works were required.

4.4 Channel Assessment

High and moderate sensitivity channel reaches were identified on aerial photography and assessed in the field. Bank erosion and sediment contribution was observed at one site downstream of the Aberdeen FSR road crossing above Grizzly reservoir. No remedial works were recommended for this or any other channel site in the watershed. An assessment of the channel on private land downstream of Headgates was recommended to identify sediment sources that may affect fish and fish habitat.

4.5 Riparian Assessment

Riparian zones along all channels in the watershed were assessed for proper riparian function. High priority sites for restoration were identified in the Heart Creek sub-basin and in a tributary channel flowing through polygon #482. Direct cattle access to tributary and mainstem channels was identified as a concern throughout the watershed upstream of the canyon. No remedial works have been undertaken on the high priority sites to date.

4.6 Water Quality Monitoring

In 1995, grab samples were gathered at seven sites in the watershed as part of the ongoing FRBC watershed project. NOWA continued the sampling program at one site in 1996 and three sites in 1997 on the Duteau Creek mainstem channel. The data is currently being catalogued and analyzed by MELP and NOWA.

4.7 Landslide Reports

In the spring of 1997, a slump occurred from road 533.1 at 2.4 km in the upper Duteau U/S of Grizzly sub-basin. Dobson Engineering Ltd. inspected the site in the fall of 1997 to determine the cause of the failure, and to recommend short and long-term remedial works.

The road was constructed in glacio-fluvial and glacio-lacustrine deposits, and the failure was caused by road drainage saturation of fine sediment overlying an impermeable clay layer. Deactivation of the road was recommended with bank protection along Duteau Creek.

In the fall of 1998, Riverside Forest Products Limited pulled back the headscarp of the failure to minimize further raveling and sediment input to the channel. A joint review of the site with Dobson Engineering Ltd., NOWA and Riverside Forest Products Limited is planned in 1999 to discuss further rehabilitation options.

Also in July of 1997, a landslide occurred on the west bank of Duteau Creek approximatley 0.5 km downstream of the Haddo FSR crossing near Edwin Lakes. The slide occurred on an undisturbed slope as a result of saturated soil conditions and possibly localized blowdown. An older slide scar was observed immediately upstream of the recent slide site. Bioengineering prescriptions were completed by Dobson Engineering Ltd. and the work was completed by Bar-Ten Springs Enterprises and NOWA in the fall of 1998.

4.8 Range and Recreation Management

In conjunction with range tenure holders and the Ministry of Forests, Recreation Section, the following fencing and site restrictions were completed by NOWA in 1998:

- Fencing and random camping site access restrictions along Duteau Creek downstream of Haddo Lake.
- Recreational vehicle access restriction to the foreshore of Grizzly Reservoir.
- Fencing and cattle guard placement in the Flyfish and Duteau Creek confluence area to prevent access to sensitive sites, and corral construction in the area to allow quick removal of stray cattle for relocation in permitted range areas (south of Haddo Lake and west of Grizzly Reservoir).

The general intent of NOWA's collaborative efforts with the MoF Range Section and grazing licensees are to restrict uncontrolled range and recreation use from the areas immediately surrounding the upper reservoirs, and riparian zones along the mainstem channel between Haddo Lake and the canyon section.

Fencing projects were completed along the Aberdeen FSR in the 1970s; between Doreen and Streak lakes in the 1980s; and along the east side of the Haddo Lake in 1991.

5.0 METHODS

The watershed assessment presented in this report is based on the 1998 interim watershed assessment procedure provided by the Kamloops Forest Region and BC Environment.

In summary, the assessment process consists of two primary components: an office assessment and a field assessment. The office assessment consists of the compilation and analysis of data to describe the basic geophysical characteristics of the watershed, along with the extent and location of past forest harvesting activities (the watershed report card).

The field assessment consists of a reconnaissance overview of the watershed to determine actual hydrologic hazards. The field assessment includes a reconnaissance level sediment source survey and channel assessment to identify sensitive and/or disturbed road segments and channel reaches. The reconnaissance level channel assessment procedure (ReCAP) is based on the *Channel Assessment Procedure Field Guidebook - December 1996.*

Accessible roads in the watershed were driven or walked where overgrown. Evidence of sediment movement on the running surface or in the ditchline was recorded and the potential delivery to streams was assessed. Stream channels were reviewed by reach at accessible sites. Evidence of flow or sediment loading related disturbance was assessed with reference to expected natural conditions. Harvested riparian areas were reviewed on aerial photographs and during the channel assessment. Riparian functions of shade, bank stability and large woody debris input were considered. Aerial photographs were used to map landslides and determine their size, age and connectivity to the channel system.

6.0 ASSESSMENT

Calculation results are presented in Table 1. A discussion of current watershed conditions based on the field assessment is provided in the following sections. Current watershed hazard ratings for each sub-basin and the watershed are listed in Table 2. Hazards for residual areas are considered in the greater sub-basin or watershed ratings and not presented in the table. A brief discussion of residual hazards has been included in the text based on a specific WAC request.

TABLE 1
Watershed Report Card 1999

Watershed Inventory Category	Duteau Residual	Flyfish Sub-basin	Aberdeen Sub-basin (POI 2)	Aberdeen Residual Area	Heart Sub-basin	Duteau U/S of Grizzly Sub-basin	Watershed (POI 1)
Area (ha)	4,355	2,129	10,480	7,129	2,087	1,264	16,962
H60 Elevation (m)	1,325	1,325	1,325	1,325	1,325	1,325	1,325
Total Area Harvested/Burnt (ha)	2,230	557	4,655	3,579	691	385	7,441
Percent Area Harvested/Burnt (%)	51	26	44	50	33	30	44
Equivalent Clearcut Area (ECA) (ha)	1,003	200	2,670	1,875	603	192	3,873
Equivalent Clearcut Area (ECA) (%)	23.0	9.4	25.5	26.3	28.9	15.2	22.8
ECA Above H60 (ha)	434	147	2,189	1,441	569	179	2,770
ECA Above H60 (%)	10.0	6.9	20.9	20.2	27.3	14.2	16.3
Road Density (km/km2)	1.9	1.3	1.6	1.7	1.1	1.4	1.6
High Sediment Source Roads (km)	0.2	0	0.1	0	0	0.1	0.3
Landslides (#)*	6	0	3	1	0	2	9
Road on Potentially Unstable Terrain (km)	6.6	0	1.2	0.2	0.0	1.0	7.7
Stream Crossings (#)	45	15	91	69	19	3	151
Stream Logged to the Bank (km)	22.8	6.5	46.7	36.2	9.3	1.2	76.0
Unstable Mainstem Channel (km) **	0.0	0.0	8.9	0.0	0.0	8.9	8.9

* Slides clearly visible on most recent aerial photography. Does not include channel bank failures. Additional slides which may be marked on terrain mapping are either historic and overgrown or classified as bank failures for the purpose of the watershed assessment.

** Only moderately disturbed mainstem channels upstream of POI have been included in the unstable mainstem channel calculations. There are no severely disturbed channels in the watershed.

6.1 Peak Flow

6.1.1 ECA

The upper watershed above Haddo Lake has gentle rolling terrain, porous sandy soils and a low drainage density[6]. Based on these topographic characteristics and the presence of the reservoirs in the system, the upper watershed (Aberdeen, Heart and Duteau U/S of Grizzly sub-basins) is considered to have a low sensitivity to changes in peak flow, volume and timing associated with forest development. Much of the runoff generated by snowmelt in this area contributes to local and regional groundwater flows rather than surface flow. This contribution to groundwater either emerges in the reservoirs downstream (local groundwater), or in the case of regional groundwater, possibly in the fan downstream of Whitevale Road. The mainstem channels in all sub-basins showed no evidence of recent peak flow related disturbance (Section 6.1.3), particularly following high 1996 and 1997 runoff years, indicating the effectiveness of the system in managing above average snowpack conditions. The current ECA in each of these basins is not a concern with respect to potential channel disturbance *[Table 1]* (Section 6.1.3).

Terrain in the Flyfish sub-basin and major tributary drainages upstream of the canyon in the residual area is also low and rolling. Beaver dams and marshland complexes that exist in the headwater regions of Flyfish and Crescent Creeks also assist in buffering peak flows. However, based on the direct connection of the lower drainage areas to the mainstem channel, the hydrologic sensitivity with respect to forest development is considered moderate for the Flyfish sub-basin and other direct tributary drainages in the residual area above the upstream of the canyon. The current ECA in the Flyfish sub-basin is low and not a concern with respect to potential channel disturbance *[Table 1]*.

The area along the canyon reaches (in the Duteau Residual area) and back from the break in slope above the canyon is considered highly sensitive to potential surface and groundwater alterations associated with forest development. As described in the terrain stability mapping reports, forest harvesting back from the break in slope can affect groundwater recharge and emergence along the steep canyon walls, which can further affect terrain stability. Very limited forest development has occurred along or above the canyon reaches, and no road or cutblock related landslides were recorded.

Partial cut harvesting by the Small Business Forest Enterprise program was completed in 1997 for several blocks in the Heart Creek basin. Approximately 30% of the basal area was removed in these areas to allow the suppressed Lodgepole pine to release. The harvesting occurred in the summer using low ground pressure equipment that required only narrow surface trails. No drainage infrastructure was required for the trails, and soil compaction and sub-surface drainage interruption has been negligible.

[6] Drainage density refers to the length of stream channel per kilometre squared.

Based on snow pack measurements made elsewhere in the Kamloops Forest Region under similar stands, the effect on snow accumulation and melt with up to 30% basal area removal is negligible. Based on the snow research, the past and proposed partial cut harvest blocks with approximately 30% basal area removal have not been included in ECA calculations. A field review of the SBFEP commercial thinning blocks supported the research findings. Thinning had removed only the lower and intermediate layers with minimum affect on canopy closure.

6.1.2 Roads

Roads upstream of the canyon section in the Duteau Residual area are located on generally benign terrain where drainage diversion and concentration concerns are minimal. No evidence of ditchline scour resulting from drainage concentration was noted.

The Aberdeen mainline has been built well back of the break in slope above the canyon reaches in the Duteau Residual area. Temporary access structures (roads) have been used where possible in steeper terrain along the canyon to minimize potential effects on natural hillslope drainage *[Photo 1]*.

6.1.3 Channels

Tributary channels upstream of the canyon show no evidence of peak flow related disturbance *[refer to Section 6.5]*. The mainstem channel through the canyon was active[7] during the 1996 and 1997 spring freshets, but disturbance has been limited to minor bank erosion. Stable old growth riparian vegetation has also limited potential disturbance. The upper watershed reservoirs, beaver dams and marshland complexes in the Flyfish sub-basin and Crescent Creek drainage appear to have effectively buffered the lower mainstem channel from the effects of these recent high flows. The rolling topography, porous soils and low drainge densitiy in the upper watershed has also reduced any potential peak flow effects on channels.

6.1.4 Peak Flow Hazard

Based on observed channel stability throughout the upper tributaries and lower mainstem channel, overall topographic conditions of the watershed upstream of the canyon, and presence of three large reservoirs in the system, the current peak flow hazard associated with past forest development is considered low for all sub-basins and the watershed *[Table 2]*. Peak flow hazards for the residual areas are considered within the greater basin or watershed hazards. It is, therefore, inferred that peak flow hazards are also low for residual areas.

[7] Active refers to the recent movement of boulder and cobble bed materials in the channel.

6.2 Surface Erosion

6.2.1 Roads

Roads on the plateau section of the watershed (Duteau Residual area above the canyon and all basins above) are located on benign terrain and surface erosion concerns are low *[Photo 2]*.

Sediment sumps are in place where feasible at road crossing locations and maintenance appears to be good. Inactive roads on the plateau are revegetated with grass and surface erosion is not a concern. Potential sediment delivery to channels in this area is very low to low, according to terrain hazard maps.

Cattle access to the channels at road crossings is causing some sedimentation *[Photos 3 and 4]*. Particular areas of concern include the Flyfish sub-basin, Aberdeen Residual area, Crescent Creek and Curtis Creek drainages.

One high and one moderate sediment source road section was identified in the watershed. The moderate sediment source location is on the Haddo FSR in the residual area immediately beyond the Duteau mainstem crossing. This road section termed "throttle hill" is a chronic source of fine sediment to the channel and has undergone recent ditchline cleaning and sediment sump construction. In spite of these works, sand and silt are still being washed into the mainstem channel, particularly during active hauling in wet weather *[Photos 5 and 6]*. Further sediment control works are required to reduce sediment input.

The high sediment source section is the failure on road 533.1 and the road running surface beyond the slide in the Duteau U/S of Grizzly sub-basin *[Photo 7]*. Secondary erosion of sand, silt and clay is occurring. A field review of this site with Riverside Forest Products Limited, NOWA and Dobson Engineering Ltd. is planned for 1999 to determine remediation alternatives.

Roads in the Duteau Residual area have been constructed well back of the canyon reaches and surface erosion concerns are low. Recent development in the Duteau Residual area upslope of the mainstem channel has utilized temporary access structures (roads) where possible that have been permanently deactivated *[Photo 1]*. These types of structures reduce both short and long-term sedimentation that can occur from forest roads and should continue where possible for blocks in this sensitive hydrologic area.

The recent (1997, 1998) partial cut harvesting in Heart Creek basin was done using low ground pressure equipment in the dry summer season. An assessment of these areas revealed that ground disturbance was negligible and there were no surface erosion concerns.

6.2.2 Hillslopes

The landslide scar below the 533.1 road is an active source of fine sediment to the channel (as outlined above). The recent (1997) landslide in the upper canyon below the Haddo FSR bridge was bioengineered in the fall of 1998 to reduce erosion and stabilize the hillslope. There were no other hillslope related sediment sources noted.

6.2.3 Surface Erosion Hazard

Based on the low sediment delivery potential from roads (as determined in the field assessment and terrain maps) and limited number of past forest development related landslides in the watershed, the surface erosion hazard is considered low for the Heart, Flyfish and Aberdeen sub-basins, and the entire watershed *[Table 2]*. The surface erosion hazard in the Duteau U/S of Grizzly sub-basin is moderate based on the recent input of sand and silt to the channel from the failure on the 533.1 road, and ongoing secondary erosion of the exposed soils. This moderate hazard can be reduced after slope and channel bank restoration has been completed. The surface erosion hazards are low in both the Aberdeen and Duteau residual areas.

6.3 Landslides

Nine landslides were mapped in the watershed *[Appendix F]*. Six slides have occurred in the canyon reach of the Duteau Residual area, five of which directly impacted the channel. One rockfall mapped in the Aberdeen sub-basin did not deposit in the channel, and two slides were mapped from the 533.1 road into upper Duteau Creek

All slides through the canyon reaches are natural and additional slides in this area can be expected given Class IV and V terrain conditions. Consideration of potential groundwater flow effects should be given to new development in and around the canyon reaches.

The most recent slide in the canyon, approximately 0.5 km downstream of the Haddo FSR bridge *[Photo 8]*, had a bioengineering prescription implemented in the fall of 1998 and will be monitored by NOWA for sediment stabilization.

The landslides from the 533.1 road occurred in an isolated glacio-fluvial sand and silt deposit along the Duteau U/S of Grizzly mainstem channel in the upper watershed *[Photos 9 and 10]*. Other similar surficial deposits have been mapped as Class IV or V terrain along the Duteau Creek downstream of Haddo Lake and Crescent Creek mainstem channels. The completion of terrain stability field assessments and surface soil erosion hazard assessments where required for proposed roads and cutblocks in these areas should identify any terrain or surface erosion concerns prior to development.

6.3.1 Landslide Hazard

Based on the low frequency of past forest development related slides, the landslide hazard is considered low for the Flyfish, Heart and Aberdeen sub-basins, residual areas and the entire watershed *[Table 2]*. The landslide hazard remains moderate in the Duteau U/S of Grizzly sub-basin based on the recent road failure and potential for similar occurrences at that location. The landslide hazard in the Duteau U/S of Grizzly sub-basin can be reduced through site rehabilitation. Landslide hazards in both residual areas are also low.

6.4 Riparian

According to forest cover mapping, 76 of 226 km of stream channel has been harvested to the banks. The majority of this riparian harvesting occurred in the Flyfish basin, Crescent Creek and Curtis Creek drainages, and Aberdeen Residual area.

Small tributary channels in the sub-basins and around the reservoirs that were harvested to the banks in the past are low gradient with stable banks. The loss of riparian cover in these areas may have affected stream temperature over the short-term, but vigorous regeneration of alder, willow and conifers is now occurring. Large woody debris is still present and functional in the assessed tributaries.

Both natural and cutblock boundary blowdown has occurred in the riparian zone between Haddo Lake and the upper canyon *[Photo 11]*. Partial salvage of accessible timber was completed in 1997 (CP 599). These reaches appear to be susceptible to blowdown and are sensitive to disturbance from increased woody debris input and possible avulsions. A Riparian Management Area (RMA) strategy should be developed for these reaches – one that reduces the risk of blowdown in the RMA and recommends possible salvage methods where blowdown occurs to be implemented on a site specific basis.

Cattle access to channels through old cutblocks in the Flyfish basin, Crescent Creek and Curtis Creek drainages, and Aberdeen Residual area is causing localized bank shearing and stream sedimentation. These areas should be brought to the attention of the MoF Range Section for assessment through the range use plan process.

6.4.1 Riparian Hazard

Based on the extent of riparian regeneration along previous harvested streambanks, the riparian hazard with respect to past forest development is considered low for all sub-basins and the watershed *[Table 2]*. Direct cattle access to tributary channels in the Flyfish and Crescent Creek basins, and Aberdeen Residual area remains a channel sedimentation concern. Blowdown along the mainstem channel below Haddo Lake is also a concern that requires management attention. Riparian hazards in both residual areas are also low.

TABLE 2
Watershed Hazards 1999

Drainage Area	HAZARD CATEGORY			
	Peak Flows	Surface Erosion	Landslides	Riparian
Flyfish Basin	Low	Low	Low	Low
Aberdeen Basin	Low	Low	Low	Low
Heart Basin	Low	Low	Low	Low
Duteau U/S of Grizzly Basin	Low	Moderate	Moderate	Low
Watershed	**Low**	**Low**	**Low**	**Low**

6.5 Channel Assessment

The mainstem channel was divided into 12 reaches based on distinct changes in channel morphology, channel gradient, or major tributary or sediment input *[Appendix D]*. At least two channel assessment sites were surveyed on each of the sub-basin tributary channels including Curtis Creek in the Heart basin and Crescent Creek in the residual area. Overview channel assessment information was also gathered for the reaches below the water intake (POI 1).

No channels in the watershed are highly disturbed. The upper Duteau Creek mainstem is moderately aggraded as a result of the 1997 and previous slides, and the lower Duteau mainstem below the intake is degraded as a result of bedload capture in the Headgates intake *[Appendix E]*. Channel descriptions are presented in descending order from the upper basins to the mouth and photographs can be found in Appendix C.

6.5.1 Duteau U/S of Grizzly Basin

Three mainstem channel reaches (J, K and L) were delineated in the Upper Duteau basin.

Reach L is a stable cascade-pool channel with large woody debris control *[Photo 12]*. The break between reaches K and L is at the landslide input location from the 533.1 road. Below this point, reach K, is moderately aggraded with sand and gravel from the most recent (1997) and previous slides (1980s) *[Photo 13]*.

The lower reach (J) is a moderately aggraded riffle-pool channel with large woody debris control *[Photo 14]*. This reach is acting as a deposition zone for gravel from upstream slide input. Sand-size sediment is actively being transported through this reach and may eventually reach the Grizzly reservoir.

Channel restoration activity on the two lower reaches is not feasible to reduce sediment transport. Stabilization of upstream sediment sources (slides at the 533.1 road) is the most effective long-term remediation alternative.

6.5.2 Heart Creek Basin

No reaches were delineated on Heart Creek. The mainstem channel has a low gradient stable riffle-pool morphology with large woody debris control *[Photo 15]*. Localized natural blowdown in the riparian zone is providing some sand and gravel input. No channel concerns were noted.

The Aberdeen fire in 1998 may have affected stream channel stability in the Heart Creek basin which could lead to increased sedimentation in the channel and downstream reservoirs. A joint MELP and NOWA review of stream channel conditions at the request of the SBFEP in Heart Creek is planned for 1999 to determine if any channel or riparian restoration activities are required.

6.5.3 Aberdeen Residual Area

Channels eligible for assessment (according to the CAP procedure) in the Aberdeen Residual area include the Curtis Creek tributary and the outlet from Haddo Lake to the Flyfish Creek confluence. Diversion ditches that connect the Grizzly reservoir (reach I), Aberdeen Lake and Haddo Lake are not applicable to channel assessment procedures.

Curtis Creek was assessed at the Curtis Mainline Road crossing. The channel has a stable riffle-pool morphology. Harvesting to the banks occurred in the 1980s but regeneration of alder, willow and some conifers has since colonized the riparian zone *[Photo 16]*. Cattle grazing on old adjacent blocks is allowing some direct access to the channel. Minor bank shearing and fine sediment input from range use is occurring.

The outlet of Haddo Lake (reach H) is identical to reach G which is discussed in Section 6.5.5.

6.5.4 Flyfish Basin

Flyfish Creek has numerous marshland complexes, beaver ponds and small lakes in the upper basin. The lower channel has a stable cascade-pool morphology with woody debris control *[Photo 17]*. At the confluence with the Duteau Creek mainstem, Flyfish Creek is a low gradient riffle-pool channel with no evidence of sedimentation or peak flow related concerns *[Photo 18]*.

6.5.5 Duteau Residual Area

Downstream of Haddo Lake the mainstem channel was divided into five reaches to Headgates (POI 1). Reaches H and G, immediately downstream of Haddo Lake, are low gradient riffle-pool channels. Large woody debris is abundant in these channels as a result of localized natural and cutblock boundary related blowdown in the riparian zone *[Photos 19 and 20]*. The channel bed and banks are stable through reaches H and G, and no cattle access to the channel was noted during the assessment. Lower reach G flows through Class V terrain where one old (pre-1972) bank failure was mapped. The channel banks and adjacent hillslopes in lower reach G are a natural source of sand and gravel to the channel. NOWA and Riverside Forest Products have noted cattle in the riparian areas along Reaches H and G. This area is sensitive to cattle disturbance and efforts to prevent access should continue.

Reach F is also a low gradient riffle-pool channel extending to the head of the canyon. Large woody debris is abundant from localized blowdown, particularly along old block boundaries *[Photos 11 and 21]*. The majority of blowdown was observed to be spanning the channel at the assessment location and partial salvage had already been undertaken in the adjacent block (CP 599).

Cresent Creek is a small tributary that joins reach F approximately 1.5 km downstream of the Doreen Creek confluence. NOWA has expressed concern with the channels in Crescent Creek based on observed sand and gravel bars, and direct cattle access in the upper drainage. Aggraded channel conditions were observed in the lower channel *[Photo 22]* and range use in the riparian zone was noted above and below the Aberdeen FSR crossing. In the upper drainge, a large sediment wedge was observed in the main channel from a beaver dam release in the early 1990s *[Photo 23]*. NOWA documented increased turbidity at the Headgates intake following the event[8]. This event is the source of gravel bar deposits in the lower drainage.

The upper Duteau canyon reach (E) is a stable cascade-pool channel with increased sand and gravel bedload from the recent (1997) slide approximately 0.5 km downstream of the Haddo FSR crossing *[Photos 8 and 24]*. The slide had a bioengineering prescription implemented in the fall of 1998 and no further hillslope or channel restoration is required.

Upstream of Headgates (reach D) the channel has a stable cascade-pool morphology with some temporary sand and gravel deposition from upstream slides *[Photos 25 and 26]*. The riparian vegetation is in tact along the entire canyon reach and the channel banks are stable. Woody debris accumulations are present along the channel margins throughout the canyon upstream of Headgates.

[8] Clark, R., 1998. Personal Communication, NOWA.

The intake pond was drained and dredged in the summer of 1997 as a result of increased sedimentation from upstream sources. This elevated sedimentation trend will continue over the next two to five years barring additional landslides into the canyon reaches.

An old trail paralleling the mainstem channel with a cattle bridge approximately 2,000 m upstream of the Headgates intake was noted. Minor channel bank erosion and road fill failure was observed on the road *[Photo 27]*, and the bridge is rotting and will soon collapse into the channel *[Photo 28]*. According to the range permit holder for the area, the bridge and access trail is no longer required. The bridge should be removed as soon as possible and eroding fill locations along the trail should be pulled back and either bioengineered or armoured.

6.5.6 Mainstem Channel Downstream of Headgates

Downstream of Headgates (reaches B and C), the channel has a moderately degraded cascade-pool morphology as a result of bedload capture in the intake pond *[Photo 29]*. No bank disturbance or recent bedload movement was observed from the 1996 and 1997 spring freshet flows.

On the fan (reach A), the channel is also moderately degraded downstream of the Whitevale road crossing *[Photos 30 and 31]*. All of reach A is a riffle-pool channel flowing through alluvial deposits which are easily eroded if bedload supply or flow regimes are altered. The channel on the fan is valuable salmonid and resident trout spawning and rearing habitat and should be considered for enhancement. The re-introduction of spawning sized substrate below Headgates may be a possible mitigation alternative.

The lower fan channel closer to Highway 6 was not reviewed in the field. According to forest cover maps and aerial photographs, sections of the channel have been cleared to the banks for agricultural purposes.

6.6 Watershed Restoration Opportunities

- Surface erosion controls on "throttle hill" immediately beyond the Duteau mainstem crossing on the Haddo FSR.
- Removal of old cattle bridge from reach D upsteam of Headgates.
- Improvement or deactivation of the access road through the canyon above Headgates.
- Joint review of the 533.1 road failures with Dobson Engineering Ltd., Riverside Forest Products Limited and NOWA to determine remediation alternatives.

- Continued range and recreation management with the intent to control sedimentation in the reservoirs, tributaries and mainstem channels through controlled watering access or the provision of off-channel watering sites.

- Salmon and trout spawning and rearing habitat enhancement of lower Duteau Creek through aggregate input to the mainstem channel below Headgates.

7.0 PROPOSED FOREST DEVELOPMENT

Development is proposed by Riverside Forest Products Limited, Tolko Industries Ltd. and the Small Business Forest Enterprise Program for the period 1999 to 2005. All proposed blocks with harvest dates between 1999 and 2005 are either approved or proposed category "A" blocks *[Appendix B]*. Cutblocks with harvest dates of 2006 are being proposed by Riverside Forest Products Limited as category "I" or information blocks.

A total of 16 clearcut blocks are proposed by Riverside Forest Products Limited and Tolko Industries Ltd. as category "A" over the period 1999 to 2005. An additional 13 commercial thinning blocks are proposed by Riverside Forest Products Limited over the same period. One commercial thinning block is proposed by SBFEP in 1999. Approximately 30% basal area removal is planned for the commercial thinning blocks, which will have a negligible effect on canopy closure and snow accumulation (as demonstrated in the 1997 SBFEP commercial thinning blocks in the Heart Creek sub-basin). For this reason, commercial thinning block areas have not been included in ECA calculations. Two group selection blocks and one shelterwood block is proposed by Riverside Forest Products Limited in the lower residual area. Approximately 50% basal area removal is planned for these blocks which were assigned a 50% ECA for calculation purposes.

Beyond 2005, Riverside Forest Products Limited has four clearcuts and three commercial thinning blocks proposed as category "I."

Approximately 9.1 km of road is required to access all blocks from 1999 to 2006 with one new stream crossing. Hydrologic concerns specific to proposed forest development are discussed below.

7.1 Peak Flow

7.1.1 ECA

Over the development plan period (1999 to 2005), hydrologic recovery on old cutblocks and burns will exceed the rate of proposed development. The current watershed ECA of 22.8% (1999) will decrease to 20.8% (2005) with proposed development *[Table 3]*. With the inclusion of category "I" blocks scheduled for 2006, the watershed ECA will increase to 21.5%. Above the H60 elevation, the current watershed ECA will also be reduced from 16.3% (1999) to 14.9% (2005) despite proposed development. Category "I" blocks above the H60 elevation would increase the ECA to 15.5% (2006).

The current and proposed level of development is not expected to affect peak or low flows in the Duteau Creek mainstem channel.

The current and proposed level of development is not expected to affect peak or low flows in the Duteau Creek mainstem channel.

Proposed development will increase the ECA both above the H60 elevation and overall in the Duteau U/S of Grizzly sub-basin. In spite of the ECA increase, 2005 and 2006 levels are still considered low for the sub-basin and changes in peak or low flows are not anticipated.

Other minor ECA changes in the sub-basins and residual areas are not expected to affect discharge levels.

Proposed aggregate cutblocks in the Aberdeen sub-basin will not have an increased hydrologic effect over smaller cutblocks between 10 and 20 ha in size. Snow accumulation, melt rates and overall water yield should be generally consistent between small blocks and larger aggregate blocks.

TABLE 3
ECA Trends

	1999		2005		2006	
Drainage	**ECA >H60**	**ECA Total**	**ECA >H60**	**ECA Total**	**ECA >H60**	**ECA Total**
Flyfish	6.9	9.4	5.5	7.0	5.7	7.5
Aberdeen (POI 2)	20.9	25.5	19.1	23.4	19.9	24.0
Aberdeen Residual*	20.2	26.3	17.7	23.4	18.5	23.8
Duteau U/S of Grizzly	14.2	15.2	15.7	17.0	16.6	17.9
Heart	27.3	28.9	26.1	27.4	26.9	28.3
Duteau Residual*	10.0	23.0	9.2	21.4	9.8	22.2
Watershed (POI 1)	16.3	22.8	14.9	20.8	15.5	21.5

* **Note:** ECA values for residual areas are not normally included in this table, but due to expressed concerns by members of the watershed assessment committee, they are provided here for discussion purposes only.

7.1.2 Roads

Road construction to access proposed blocks in or above the canyon reaches in the residual area is a potential concern with respect to sub-surface and surface runoff flow alterations. The use of temporary access structures where possible or deactivation of conventional roads immediately following harvest will reduce this concern.

Proposed road construction in the Aberdeen and Flyfish sub-basins is located on benign terrain where the risk of drainage alteration and/or concentration is low.

There are no other road related drainage or peak flow concerns.

7.2 Surface Erosion

Increased cattle and recreation access in and around streams and reservoirs is a potential surface erosion and water quality concern with proposed development. Road layout and deactivation plans that address future access can reduce this concern.

Limited new road construction is required to access proposed development. One short section of road in the canyon section is proposed on soils with a high or very high erosion potential according to terrain maps. Completion of surface soil erosion assessments where required will address this concern. All other proposed road is located on soils with low or moderate erosion potential.

Aggregate blocks in the Aberdeen sub-basin have been proposed according to the Total Chance Plan (TCP). The intent of these larger blocks is to utilize temporary access structures where possible and minimize the length of active road that must be maintained to access operable timber in the watershed. This strategy maximizes the amount of available timber from a single access road, allowing the road to be deactivated sooner rather than maintained to access other small blocks along the road. The overall effect is to reduce the length of active, maintained road in the watershed which subsequently reduces the surface erosion potential over the long-term.

7.3 Landslides

Development proposed within the canyon section or back of the break in slope can affect sub-surface and surface drainage both within the block and downslope. Two partial cutblocks proposed in the upper canyon section are located on the canyon wall within Class IV or V terrain. Terrain stability field assessments (TSFA) that address both within block and downslope areas should be completed to determine suitability for development, and recommend road construction and harvest methods to reduce the risk of failures. In the lower canyon section, a partial cutblock is proposed above Class IV and V terrain. While a TSFA is not formerly required on this block, there are potential downslope stability concerns.

There are no other landslide concerns with proposed development.

7.4 Riparian

Increased access for range and recreation use in riparian areas is a potential concern with proposed development. As mentioned in Section 7.2, road layout and deactivation plans that address future range and recreation access should address this concern.

- There are potential hillslope stability concerns with three blocks proposed along the canyon section of the residual area. Two blocks fall within and the third blocks drains onto areas mapped as Class IV and V terrain. Terrain stability field assessments that review surface and sub-surface hydrology both within and downslope of the blocks should address this concern.

- Proposed aggregate cutblocks will not have an increased hydrologic effect over smaller cutblocks between 10 and 20 ha in size. Snow accumulation, melt rates and overall water yield should be generally consistent between small blocks and larger aggregate blocks.

- The goal of larger aggregate blocks is to minimize the amout of active road required to access available timber in the watershed. This strategy maximizes the amount of available timber from a single access road, allowing the road to be deactivated sooner rather than maintained to access other small blocks along the road. The overall effect is to reduce the length of active, maintained road in the watershed which subsequently reduces the surface erosion potential over the long-term.

- Increased access for range and recreation use in riparian areas in and around streams and reservoirs is a potential concern with proposed development. Road layout and deactivation plans that address future range and recreation access should address this concern.

- Blowdown has occurred both naturally and along cutblock boundaries along Duteau Creek between Haddo Lake and the canyon. A blowdown salvage plan that permits the removal of woody debris from stream channels, based on an assessment of natural woody debris supply levels, may expedite the process and reduce potential channel disturbance. No blocks are currently proposed along these reaches.

9.0 RECOMMENDATIONS

9.1 Forest Development Plan Recommendations

- Complete terrain stability field assessments on the three partial cutblocks in the canyon section that address the potential hydrologic effects of harvesting both within cutblocks and on downslope areas.

- Design road construction and deactivation plans for proposed blocks in and around streams and reservoirs that limit future range and recreation access to the channels or lakes.

- Utilize temporary access structures where possible to harvest cutblocks along the canyon reaches. If a permanent road is required, deactivate as soon as possible following harvest.

- Review the landslide site on road 533.1 in upper Duteau Creek prior to any upstream harvesting to determine further mitigation alternatives.

- Improve sediment controls on "throttle hill" immediately beyond the Duteau Creek mainstem crossing on the Haddo FSR.

- Develop a Riparian Management Area (RMA) strategy for mainstem channels between Haddo Lake and the canyon – one that reduces the risk of blowdown in the RMA and recommends possible salvage methods where blowdown occurs to be implemented on a site specific basis.

9.2 Other Recommendations

- Remove the cattle bridge from lower reach D and upgrade or deactivate the trail adjacent to the channel to reduce erosion and sedimentation.

- Continue proactive cattle management in conjunction with range permit holders and the MoF Range and Recreation Branches, particularly between Haddo Lake and the canyon and area around the upper reservoirs.

- Consider spawning substrate input to the Duteau Creek mainstem channel downstream of the Headgates intake.

- Complete the planned MELP/NOWA and SBFEP review of stream channels potentially affected by the Aberdeen fire, and rehabilitate disturbed stream channels and riparian areas where required.

- Assess observed bank shearing and channel sedimentation concerns in the Crescent, Flyfish and Curtis drainages and Aberdeen Residual area through the range use plan process.

MM/dd/jb

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To:	Harold Waters	From:	Michael Milne
Company:	Riverside - Lumby Division	File:	~~504~~ 509-064
		Project:	98112
Date:	April 15, 1999	Pages:	8

RE: Duteau Minutes

Attached are the Duteau minutes that were sent to Goodman. Jennifer is trying to send an emailed copy to you from her computer.

Sorry for all of the e-file screw-ups. I'm ready to go back to writing in charcoal on birch bark!

Michael

(if there are any problems with this transmission or if all pages are not received, please call (250) 861-5595)

DUTEAU CREEK

Interior Watershed Assessment Procedure
Final Roundtable Meeting
- Meeting Minutes -

Date: Monday, March 29, 1999

Time: 0900

Place: Vernon Forest District

Participants:

Susan Latimer	BC Environment, Vernon	- Co-Chair
Eric Goodman	Vernon Forest District	- Co-Chair
Vic Wright	Vernon Forest District	
Rita Winkler	Kamloops Forest Region	
Mike Stamhuis	North Okanagan Water Authority	
Renee Clark	North Okanagan Water Authority	
Peter love	Riverside Forest Products Limited	
Harold Waters	Riverside Forest Products Limited	
John Jobst	Tolko Industries Ltd.	
Michael Milne	Dobson Engineering Ltd.	
Don Dobson	Dobson Engineering Ltd.	

Agenda

1. Introductions - Eric Goodman
2. IWAP WAC Committee - Michael Milne
3. Watershed condition summary - Michael Milne
   - hydrologic sensitivity
   - channels and sedimentation
   - WRP priorities
4. Proposed development - Michael Milne
   - aggregated blocks
5. Review of Recommendations - Michael Milne

Meeting Minutes

1.0 INTRODUCTIONS

Eric Goodman opened the meeting and had the participants introduce themselves. He then turned the meeting over to Michael Milne.

2.0 WAC COMMITTEE

Michael summarized the role of the Watershed Assessment Committee (WAC) in the review of the draft report. The tasks to be completed at the meeting were:

- provide clarification on the draft report as requested
- develop a set of final recommendations for use by the planning forester in the development of future forest development plans for the Duteau Creek watershed
- develop additional WAC recommendations if required.
- finalize report by March 31, 1999 based on input from the WAC.

3.0 REVIEW OF WATERSHED CONDITION

- ***hydrologic sensitivity***

  It was the goal of the assessment to identify areas in the watershed that were considered more sensitive to development, and areas that might be less sensitive. Michael indicated that the Aberdeen sub-basin was considered to have low sensitivity to forest development. The Flyfish sub-basin and upper Duteau residual area was considered moderately sensitive, and the Canyon area above Headgates had a high sensitivity.

- ***sedimentation***

  There were limited areas in the watershed where sedimentation from roads was identified. Two high priority road sections were identified:

  - "Throttle Hill" located on the Haddo FSR, immediately east of the bridge across Duteau Creek, where sediment is transported into Duteau Creek
  - the landslide on Road 533.1 which impacted Duteau Creek u/s of the Grizzly Reservoir.

  Michael noted that during the field assessments it was noted that sedimentation to streams at road crossings resulting from cattle activity was a dispersed concern over the watershed. He noted that the landslides on the 533.1 Road and on Duteau Creek at the top of the canyon section, had both been sediment sources to the channels.

Renee inquired about the date of the terrain mapping and why it had not identified the most recent slides (1997). Don explained that the field work for the terrain mapping was carried out before 1997 and used earlier air photos. Harold noted that he and Michael had reviewed the 1997 air photos before they went into the field in 1998 and that the two slides were identified on those photos and inspected in the field. Renee commented that NOWA was concerned about the slides and the impacts they have on water quality.

- *channels*

  Michael summarized the channel assessments that were extended below Headgates to the confluence with Lawson Creek as a result of DFO concerns. For the section below Headgates he said the channel is considered to be degraded as a result of the loss of bedload which is cut off at the Headgates intake pond. Since lower Duteau has high value as Chinook habitat, DFO is concerned about the degraded habitat.

  The section of channel through the canyon was stable and did not exhibit any impacts from the high flows in 1997 that were present in Harris Creek immediately east of the Duteau watershed. It may be that the reservoirs have buffered the lower channels from high flow impacts. He also noted that there was an abandoned bridge above Headgates used as a cattle crossing that should be removed before it collapses into the channel causing an obstruction.

  Above the canyon to the Flyfish confluence the channel is a stable riffle pool type. However, there is a high risk of blowdown into the creek through this section which needs to be assessed.

  It was noted that Crescent Creek was a source of sediment into the main channel and that it originated from a failed beaver dam. Cattle activity was also noted in Crescent Creek and it is currently generating fine sediment that is being washed into the channels.

  Channels in the Flyfish basin showed no signs of past forest development related disturbance even though there had been extensive old logging. The channels in the upper basin are a sequence of swamps and beaver ponds. Overall, the sub-basin is considered to be moderately sensitive to development based on the direct connectivity (no lower reservoirs or ponds to buffer flows and sediment) of the lower mainstem channel to Duteau Creek.

  Above POI 2, the channels upstream of Grizzly Reservoir showed an increase in load from the 1970s and 1997 slides off the 533.1 road. Heart Creek was stable but has been impacted by the Aberdeen Fire in 1998. Michael asked Don to comment on the potential impacts of the fire. Don indicated that there may be increased phosphorous and nitrogen as well as significant increases in sediment load this spring. Susan noted that a joint NOWA/MELP review would be conducted on Heart Creek in 1999 based on a request by the SBFEP.

In summary, Michael noted that the field inspections identified limited cumulative effects from past forest development , but did note frequent impacts to channels from both range use and from recreation use.

4.0 NEW MAPS

Michael explained to the committee that a new set of maps had been produced since the draft report had been distributed. The maps in the draft had been prepared using the forest cover maps as the base . This was the original base used when the assessment was first carried out in 1995. The revised IWAP process recommended that the digital TRIM base be used. This oversight had been noted after the draft had been completed. Subsequently the TRIM data had been input into the GIS system and the watershed statistics recompiled. Michael noted that the difference between the two map bases was that TRIM typically has improved detail on stream networks which results in an increased number of road crossings and also an increased amount of stream logged to the banks. He provided revised pages for the text that contained the new numbers but stressed that these did not significantly change the report since it is based on the results of field work where the statistics may be used as a guide.

Mike S stated his concern about the lack of rigorous statistics in the report that support the conclusions made. He said that although he understood the conclusions, there was an apparent gap between the assessment results and the conclusions reached.

There was general discussion about the process and it was agreed that there could be some additional explanation in the report that would provide a better linkage between the assessment work and the conclusions. **Action Michael M**

5.0 REVIEW OF REPORT

Michael asked the committee how it would prefer to review the draft report. The committee recommended that he go through page by page and members would provide input/questions where as necessary. The following is an abbreviated summary of these discussions.

page 3. It was noted that there is a verbal not written agreement between DFO and NOWA regarding minimum flows in lower Duteau Creek.

page 4. Susan noted that the report did not include her concerns regarding channel stability that she had forwarded to Michael. She also inquired about the inclusion of the hazards for the residual areas. Michael replied that he would be including the issue about the channels . He stated that the hazard ratings are not included for the residual area separately because they are included in the ratings at the respective POI. Where it was appropriate, the draft does include expanded discussions regarding any specific concerns in the residual area.

page 5. Susan asked if the report could provide clarification on the buffering effect the reservoirs can have on peak flows. **Action Michael** page 6. Mike S questioned the stated area of the Aberdeen Fire. He understood from the Forest Service that the area was about 700 ha. Harold said that the area shown on the maps was the area provided by the ministry but that the size would be checked. **Action Michael**

page 7. Renee indicated that the text does not adequately identify that NOWA was the proponent for both the water quality monitoring program and the slide rehabilitation above the canyon. **Action Michael**

page 8. Renee suggested that the statement regarding efforts to control cattle access to the foreshore was actually to prevent cattle from drifting north. Cattle still had access to the foreshore. Vic asked if the asked if the channel assessment included a review of stream biota. Michael stated it did not. Renee also noted that in sec 4.6, that the seven sites mentioned in 1995 were grab samples only. The ongoing monitoring is at three sites initiated by NOWA in 1997. **Action Michael**

page 9. Renee suggested that the reference to the fencing and the cattle guard installed in 1998 should state that the intent was to keep the cattle west of grizzly and south of Haddo. **Action Michael**

page 12. Rita suggested that this was an area where there could be revisions made to provide a better linkage between the results of the field work and the conclusions reached. **Action Michael.** Mike S asked why there was no reference to changes in timing of runoff in addition to the comments about volume. **Action Michael**

page 13. Susan questioned the reported impacts of 30% basal area removal harvesting and the new numbers suggested by Dave Toews (Regional Hydrologist - Nelson Forest Region). Rita said that Toews numbers were still being discussed and had not been accepted at this time. John and Harold described the thinning as removal of smaller stems under the canopy, and that such removal had a negligible effect on canopy closure and ECA. Susan asked that the report-elaborate on specific commercial thinning sites proposed. **Action Michael** She also asked for some detail in sec. 6.1.3 as to why the impact of the 1997 runoff was low in the canyon reach. Michael agreed to include comment regarding old growth riparian vegetation in tact along the banks and overall bank stability. **Action Michael**

page 14. Mike S asked why RFP was proposing harvesting upstream of the slide off Road 533.1 when the slide had not been rehabilitated. He said NOWA expected the slide to be assessed to determine rehabilitation options prior to upstream development.. He said NOWA needs to see a linkage between identified problems affecting water, and actions taken to address the problem before it can agree to more harvesting. He asked that the report reflect NOWAs concern. **Action Michael**

Vic commented on photos 3 and 4 in the report regarding cattle impacts. There was discussion about what is being done, what can be done and what should be done to reduce cattle impacts on water quality.

page 15. Mike S requested that the report include additional information regarding the linkage on the this page. **Action Michael**

Renee suggested that the sec 6.3 should recommend that the slide be monitored.

page 16 Susan recommended that the section dealing with blowdown be revised to recommend that a "riparian" strategy be developed not a blowdown strategy. The intent should be to reduce the risk of blowdown through improved management of those area that might be subject to wind throw. **Action Michael**

page 17. Renee asked why the landslide hazard rating was not high for the canyon reach since there was the recent slide. Michael responded that the slide was not a result of forest development and there fore did not justify a high rating with regards to forest development impacts.

page 19. Renee noted that there was no mention of cattle in the vicinity of reaches H and G, when they are present in these areas (as reported by Riverside and NOWA). Re sec. 6.5.5, the report should mention cattle access to upper Duteau Creek. **Action Michael**

page 20. Mike S asked who was going to remove the old cattle bridge near Headgates?

page 21. Harold noted that the Category A blocks on the maps are either approved or proposed, and that the text should refer to them as such. **Action Michael**

page 22. Mike S reiterated that NOWA was very concerned with increasing the ECAs particularly above Grizzly. Michael noted that although the ECAs may increase in some units, the current ECAs in those areas are low. i.e. 14%-18%.

page 23. Susan noted that the comment s about roads in the canyon reach and the potential problems need to be rephrased to encourage temporary roads or deactivation of permanent roads as soon as possible following harvest and silviculture requirements. **Action Michael**.

Mike S questioned the wording of the section referring to partial cuts and terrain stability assessments for those areas above the canyon wall. The way it is written it appears that the stability assessment s are completed after harvesting. **Action Michael**

6.0 AGGREGATE BLOCK PROPOSAL

Eric had asked Rita to comment on the impact of the RFP proposal to develop large openings by aggregating several smaller blocks. He was concerned with block size recommendations provided in the Okanagan Timber Harvesting Guidelines. Harold commented that the blocks were proposed for two reasons; first, in response to recommendations by BC Environment to mimic natural disturbance patterns, and second to minimize the length of active road in the watershed. Rita indicated that research suggests that blocks greater than the one tree height in size used by Golding in earlier research have very limited effect on snow melt rates. Mike S said NOWA would be concerned about the timing of runoff from larger blocks. However he agreed that for the watershed above the reservoirs, if the quality of the runoff was unchanged and the quantity was not reduced, he had no comment . He advised the committee that the reservoirs were now classed as "B" lakes, but NOWA wanted them upgraded to an "A" class. Mike also said that it was his understanding that class B requirements would restrict the amount and timing of clearcutting around the reservoirs. Harold questioned the class "B" status as he had not seen anything written in this regard.

Michael indicated that it did not appear that there was any hydrologic reason to object to the larger blocks above the reservoirs since the locations had been carefully chosen to minimize environmental impacts. The most important benefit would be less active road.

The committee moved to review the recommendations.

7.0 REVIEW OF RECOMMENDATIONS

- *9.1 Forest Development Plan Recommendations*
  - bullet 1: Accepted
  - bullet 2: NOWA objects to any clearcutting in the lake management zone and would like to see any inactive roads in this zone deactivated.
  - bullet 3: Reword to indicate that if permanent roads are required then deactivation should occur as soon as possible following harvest, and drop the word "partial". **Action Michael**
  - bullet 4: add "should be completed before any harvesting occurs upstream".
  - bullet 5: accepted. John Donnelly to determine responsibility and advise road permit holders. **Action John Donnelly**
  - bullet 6: revise this recommendation to focus on the development of a riparian strategy that would minimize blowdown. **Action Michael**

- *9.2 Other Recommendations*
  - bullet 1: Accepted -Vic to arrange for removal. **Action Vic**
  - bullet 2: Accepted - **Action Vic**
  - bullet 3: Accepted - **Action Bob Harding**
  - bullet 4: Susan to provide revised wording to Michael. **Action Susan, Michael**
  - bullet 5: Accepted - **Action Vic**

8.0 TIMELINE FOR DISTRIBUTION OF FINAL REPORT

- Dobson to distribute draft minutes to committee members ASAP.
- Revisions/amendments to minutes to be sent to Dobson within five days of receipt of draft.
- Dobson to produce final minutes
- Final minutes to be included in final report
- Michael to revise draft report upon receipt of final minutes
- Final report to be submitted by April 15th
- Michael will provide Susan and Eric with copy of the watershed recommendation letter format used by Salmon Arm Forest District for their use in formalizing the WAP recommendations.

----Meeting adjourned at 1600 hrs ----

DD/

APPENDIX A

Watershed Assessment Committee Members and Meeting Minutes

Watershed Assessment Committee Members

Department of Fisheries and Oceans	Bob Harding P.O. Box 1160 1751 – 10th Avenue Salmon Arm, BC V1E 4P3 Phone: (250) 832-8037
Ministry of Environment, Lands and Parks	Susan Latimer BC Environment, Lands and Parks 2501 – 14th Avenue Vernon, BC V1T 8Z1 Phone: (250) 558-1719
	Dave Gooding Southern Interior Sub-Regional Office #201, 3547 Skaha Lake Road Penticton, BC V2A 7K2 Phone: (250) 490-8200
Ministry of Forests	Rita Winkler Kamloops Forest Region 515 Columbia Street Kamloops, BC V2C 2T7 Phone: (250) 828-4131
	Eric Goodman Vernon Forest District 2501 – 14th Avenue Vernon, BC V1T 8Z1 Phone: (250) 558-1700
North Okanagan Water Authority	Renee Clark 9848 Aberdeen Road Vernon, BC V1B 2K9 Phone: (250) 545-5368
Riverside Forest Products Limited	Harold Waters and Peter Love Lumby Division RR#2, Lumby, BC V0E 2G0 Phone: (250) 547-2111
Tolko Industries Ltd.	John Jobst Lavington Division P.O. Box 1540 Vernon, BC V1T 6C2 Phone: (250) 545-4992

Duteau Creek Watershed Assessment Committee Meeting
Initial Round Table

Date: March 12, 1999

Place: Vernon Forest District

Attendees: Eric Goodman - Ministry of Forests
Susan Latimer - Ministry of Environment, Lands and Parks
Renee Clark - North Okanagan Water Authority
Harold Waters - Riverside Forest Products Limited
Peter Love - Riverside Forest Products Limited
John Jobst - Tolko Industries Ltd.
Michael Milne - Dobson Engineering Ltd.

Absent: Rita Winkler - Ministry of Forests
Dave Gooding - Ministry of Environment, Lands and Parks
Bob Harding - Department of Fisheries and Oceans

Introduction of Attendees

Those present at the meeting agreed that the absent members would be kept apprised through the distribution of the initial meeting minutes and completed IWAP report. Known issues and concerns of those absent were to be discussed by the group where known.

Discussion of IWAP and WAC

The new IWAP procedure was discussed with reference to the older 1996 version. Changes in the new procedure include an amalgamation of IWAP levels 1, 2, and 3 into one field and office based process, and elimination of the old spreadsheet calculated hazard ratings. The current watershed condition and hazards are determined in the field by the hydrologist, and a forward-looking five-year development plan review is conducted.

The watershed assessment committee (WAC) is formed at the outset of the process and sets the terms of reference for the contract. Members of the WAC are required to attend both the initial and final round table meetings, unless alternate arrangements have been made (such as in Duteau Creek). If a WAC member cannot attend the final meeting then either; their concerns or comments should be forwarded to the co-chairs (Latimer/Goodman) prior to the meeting, an alternate representative should be sent, or the WAC member should opt out of the process.

Previous Work and Concerns

Results of the road condition report, channel, gully and riparian assessments, and landslide rehabilitation reports were discussed. Range management actions conducted in 1998 by NOWA, MoF and Riverside were also discussed.

Specific watershed concerns were presented:

NOWA - Primarily concerned with forestry and range management and their potential effects on water quality and quantity.
Turbidity and pathogenic pollutants are specific concerns that may require special treatment at the intake.
Cattle are a concern with respect to potential pathogenic contamination.
Increased access for recreation and range use that may result from forest road construction harvesting is a concern in and around streams.
The lower residual area adjacent to the canyon reaches are considered the most sensitve areas with respect to forest development.
The hydrologic effects of the recent Aberdeen fire are not known at this point. Without understanding the cumulative effects of increased ECA in the Heart Creek basin, further development in the Aberdeen residual and Duteau U/S of Grizzly basin is questionable.
Sub-basins changed, #'s changed based on TRIM *
Runoff rates into the upper reservoirs are a concern if accelerated by forest development. Slow, prolonged melt and runoff is desirable which minimizes the volume spilled from the reservoirs and maximizes the supply in the late summer and early fall low flow periods.
The upper reservoirs should not be considered at catchment basins for fine sediment generated by forestry and range.
Recreation and cattle access in and around streams below Haddo Lake are concerns that require ongoing management.

DFO - Were not represented at the meeting, but have documented concerns with the mainstem channel downstream of Headgates reservoir. The channel below the reservoir has experienced a decline in available salmonid spawning habitat as a result of bedload capture. An agreement is in place with NOWA to maintain specified low flows over set periods of the year.

MELP - Similar concerns as DFO with mainstem below Headgates reservoir.
Resident trout populations upstream of the intake and reservoirs in the upper watershed are also a concern with respect to potential sedimentation from roads and cattle access to channels.

MoF - Specifically concerned with current and proposed ECA's in the watershed. Interested in the development plan review portion of the IWAP and its potential effects on current watershed conditions. Proposed aggregate cutblocks are a potential concern that should be explained in the report.

Map Shown at Meeting (March 12) had errors in sub-basins – Not TRIM based – New info to be presented March 29

POI and Boundaries

The watershed boundaries from the 1996 IWAP will be used, but the POI will now be at the Headgates reservoir. This will exclude the private land downstream of the intake and the watershed boundaries will be amended to reflect this. Due to documented DFO and MELP concerns on the channel below the POI, channel assessment information for those reaches and a discussion of the current concern and potential restoration alternatives will be included in the report.

Current Watershed Condition

Overall, the watershed was described by the hydrologist as being in good condition with very limited detrimental effects from past forest development. Stream channels in the watershed are stable and the effects of high freshet flows in 1996 and 1997 were not seen. A buffering of peak flow effects was attributed to a combination of reservoirs and benign terrain in the upper watershed. The watershed upstream of the reservoirs was considered to have a low sensitivity to harvesting and increased water yield. Downstream of Haddo Lake, direct tributary drainages are considered more sensitive to potential changes in flows and sediment budgets.

Two road sections were identified as problem sediment source locations and possible remediation alternatives were discussed. Cattle grazing was identified as a cumulative sediment source concern, particularly downstream of the Haddo reservoir. Collaborative efforts on the parts of NOWA, MoF, Riverside Forest Products Limited and range tenure holders has helped to restrict cattle access to sensitive watershed areas. Efforts will be continued where possible.

Recently completed commercial thinning blocks in Heart and Aberdeen sub-basins were observed in the field and determined to have a negligible effect on canopy closure and ground disturbance.

Harold Waters detailed several forest development plan scenarios for the watershed, describing the area paralleling the canyon reaches as the most sensitive with respect to terrain stability and forest development. For the final report, a development plan scenario which accounts for watershed sensitivity will be presented. Currently, Riverside Forest Products Limited is seeking an increase in maximum cutblock size above the reservoirs which will parallel natural disturbance patterns, and help to reduce required access roads.

Tolko Industries Ltd. has development proposed along the south and west boundaries of the Flyfish sub-basin.

Post Fire Status

The field assessment was conducted in the summer of 1998 and the hydrologic effects of the Aberdeen fire are not known at this time. MELP has planned a field review of affected stream channels in 1999 to determine if rehabilitation measures are required and/or possible.

Terms of Reference

The final IWAP report will discuss:

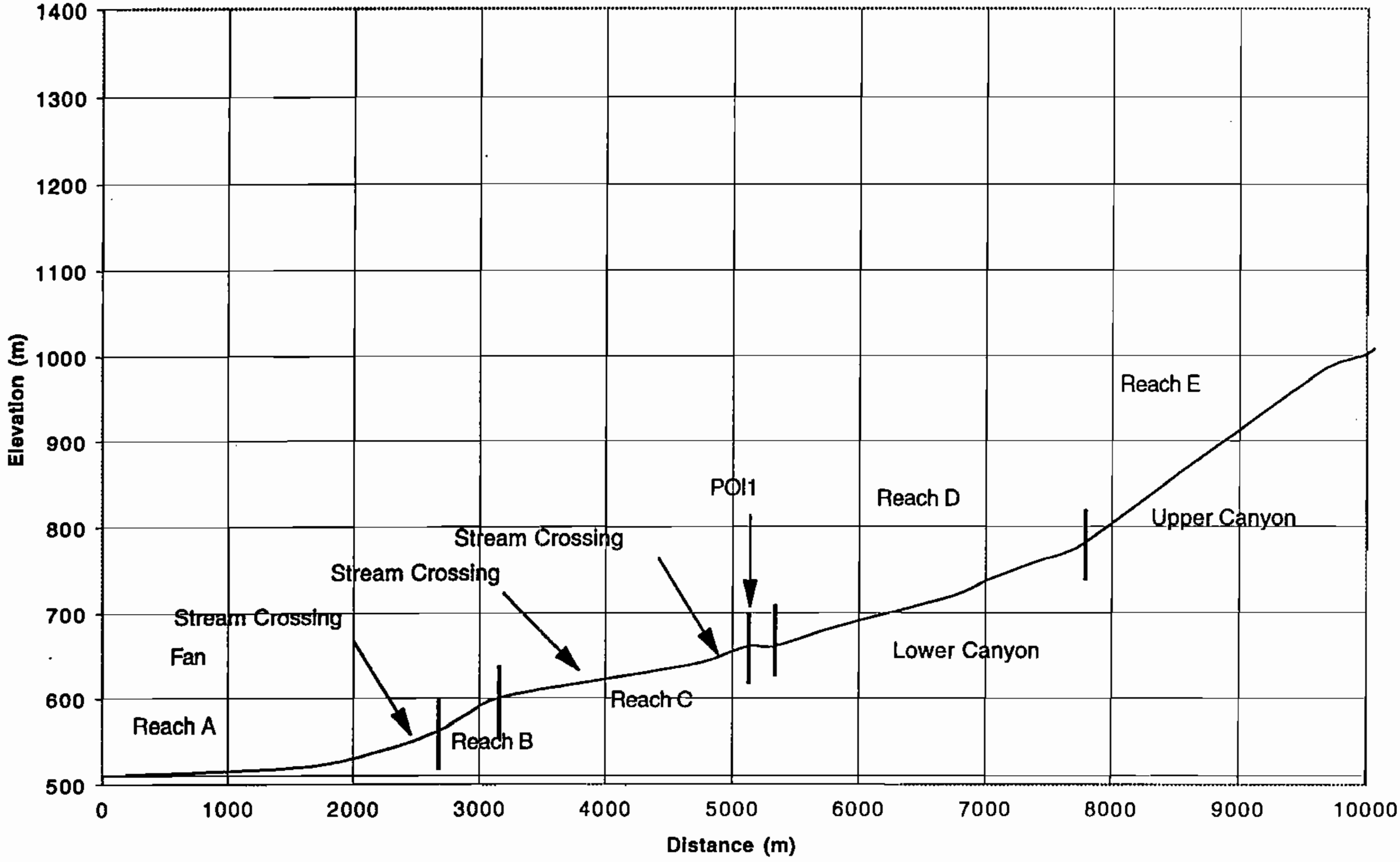
- Hydrologic sensitivity with respect to forest and other land-use development by sub-basin, residual and total watershed.
- Proposed aggregate cutblocks in the watershed and their overall effects on hydrology and road densities.
- Commercial thinning and its hydrologic implications.
- Cattle management in and around streams with a focus on reducing sedimentation.
- Natural blowdown conditions and salvage opportunities to minimize potential channel disturbance.
- COMPLAN development plan scenarios with respect to differing hydrologic implications.
- Current condition and rehabilitation alternatives for the mainstem channel downstream of the POI (Headgates reservoir).

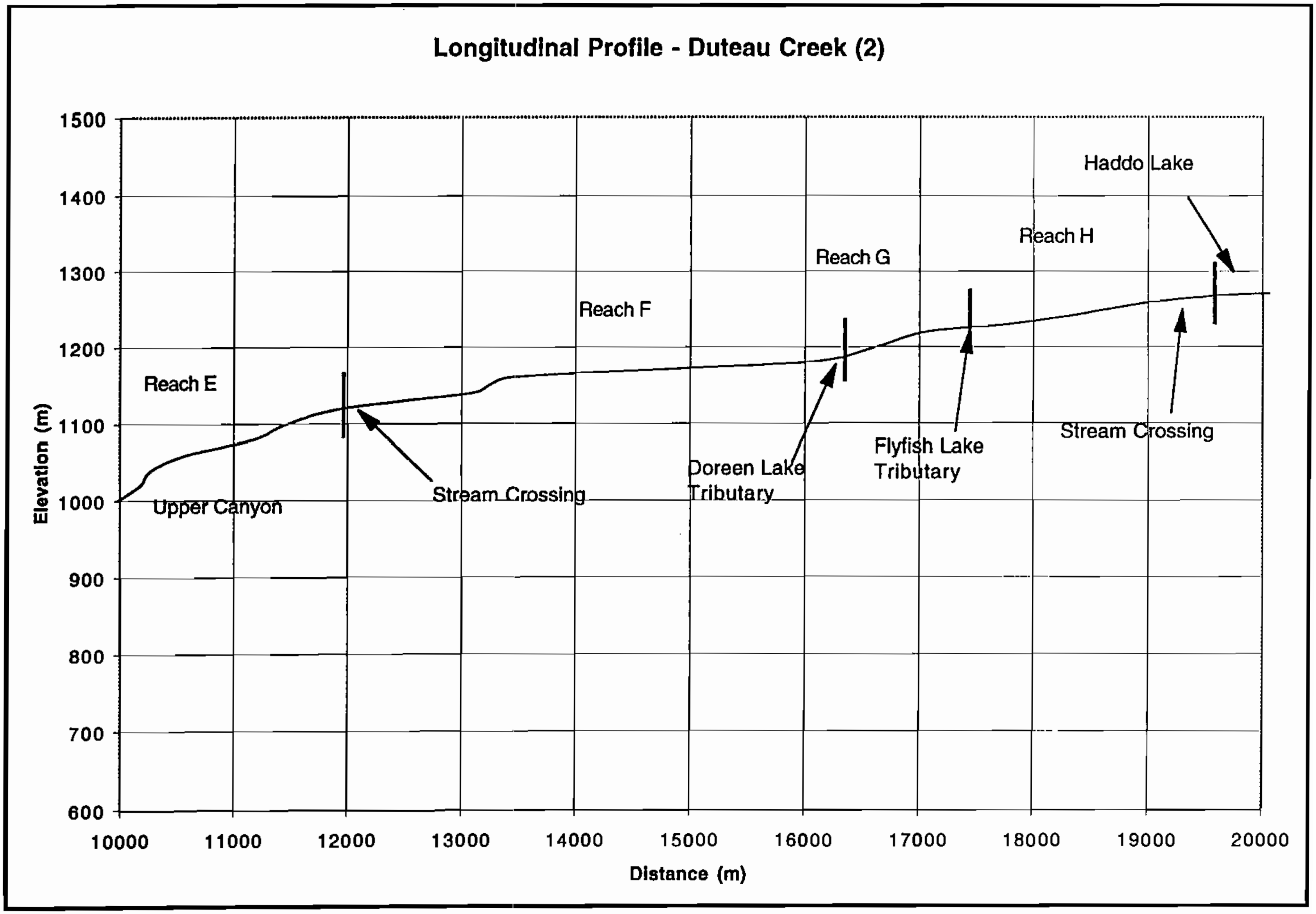
Final Meeting

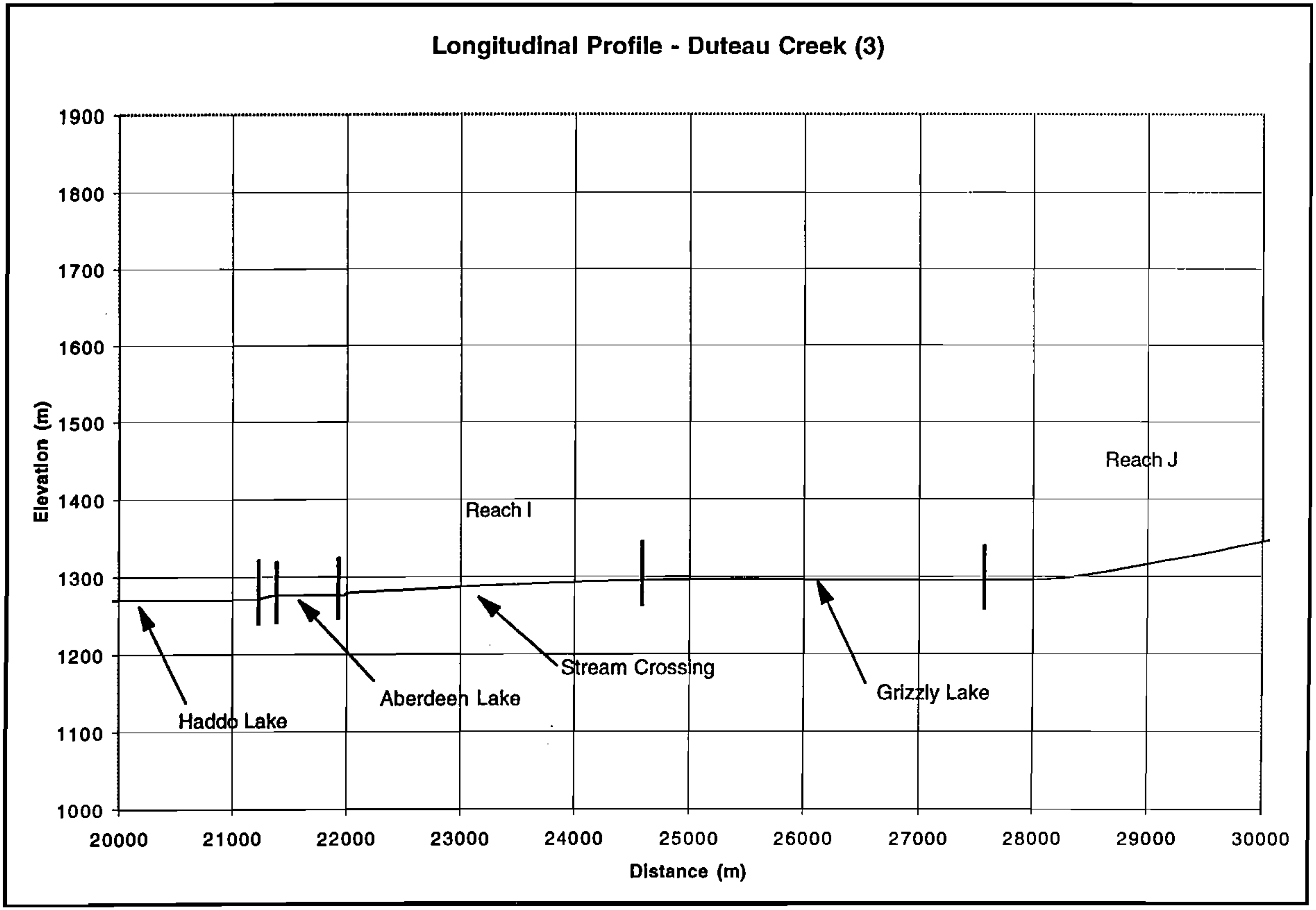
The final report will be circulated to all WAC members on the 22nd of March. A final meeting is scheduled for 9:00 A.M. on March 29, 1999 at the Vernon Forest District boardroom.

Not Complan – FCAP - Projection of harvest and Regen ....

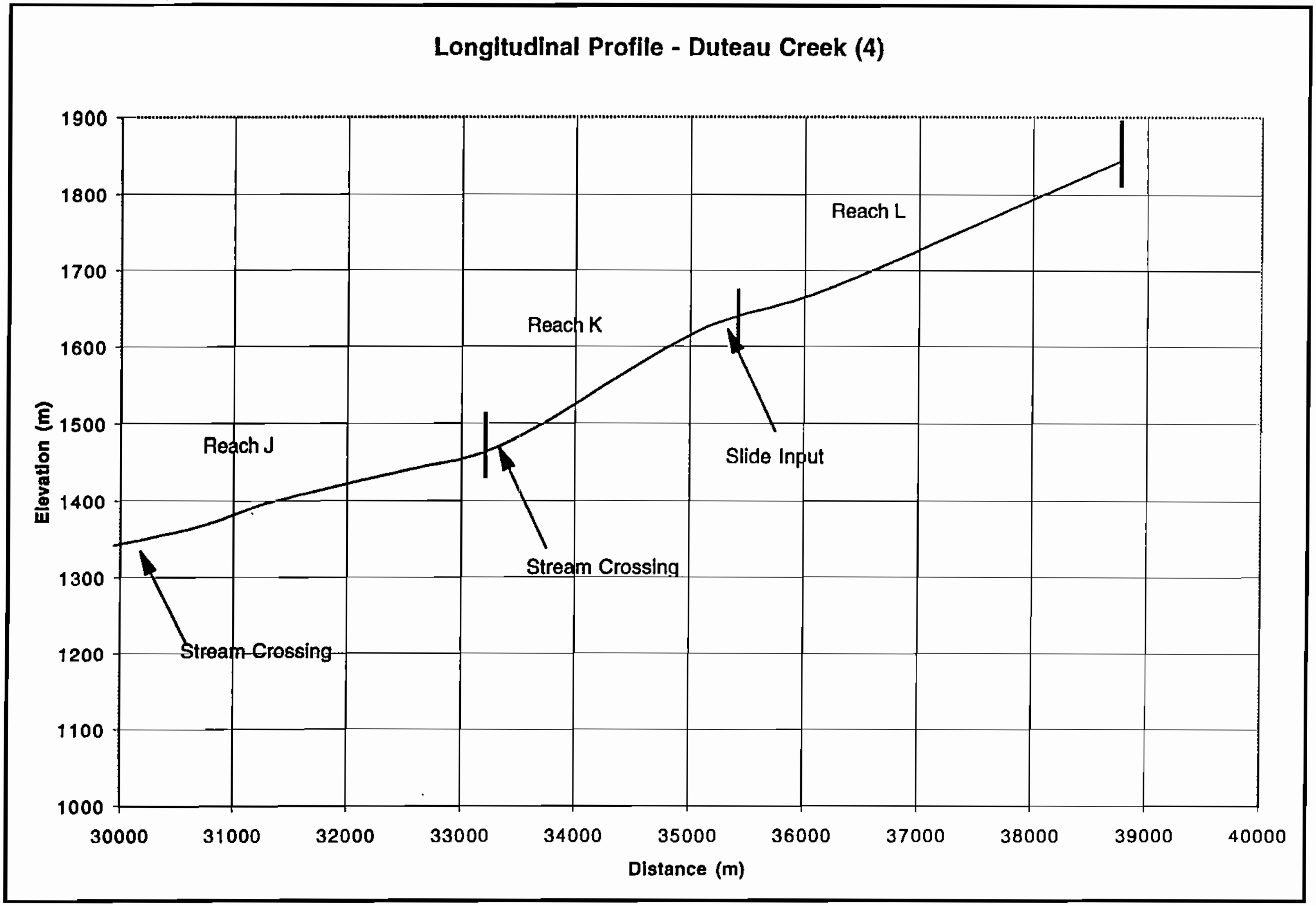
Longitudinal Profile - Duteau Creek (1)

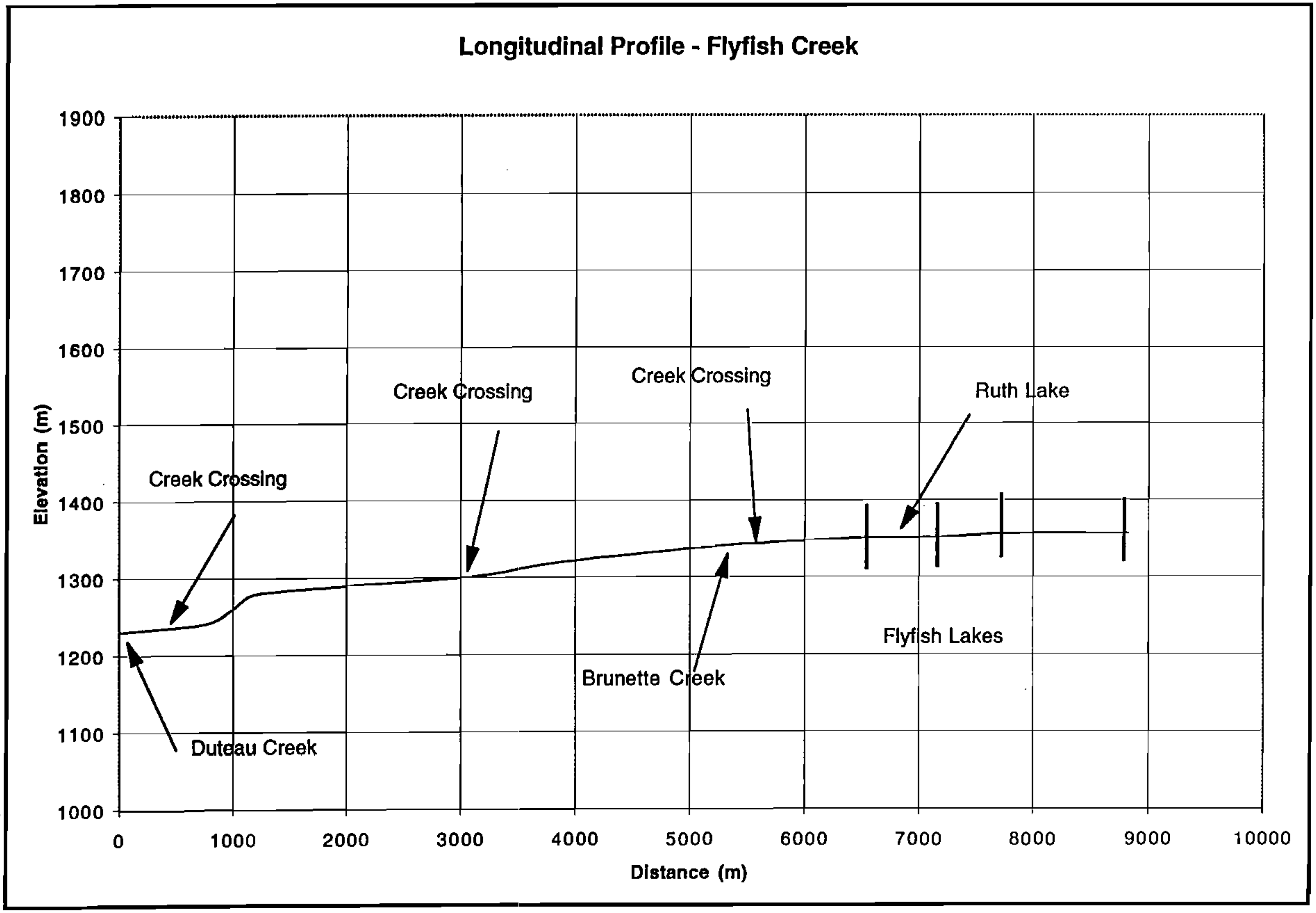



Longitudinal Profile - Duteau Creek (2)
Elevation (m)
1500
1400
1300
1200
1100
1000
900
800
700
600
10000
11000
12000
13000
14000
15000
16000
17000
18000
19000
20000
Distance (m)
Reach E
Upper Canyon
Stream Crossing
Reach F
Doreen Lake Tributary
Reach G
Flyfish Lake Tributary
Reach H
Stream Crossing
Haddo Lake

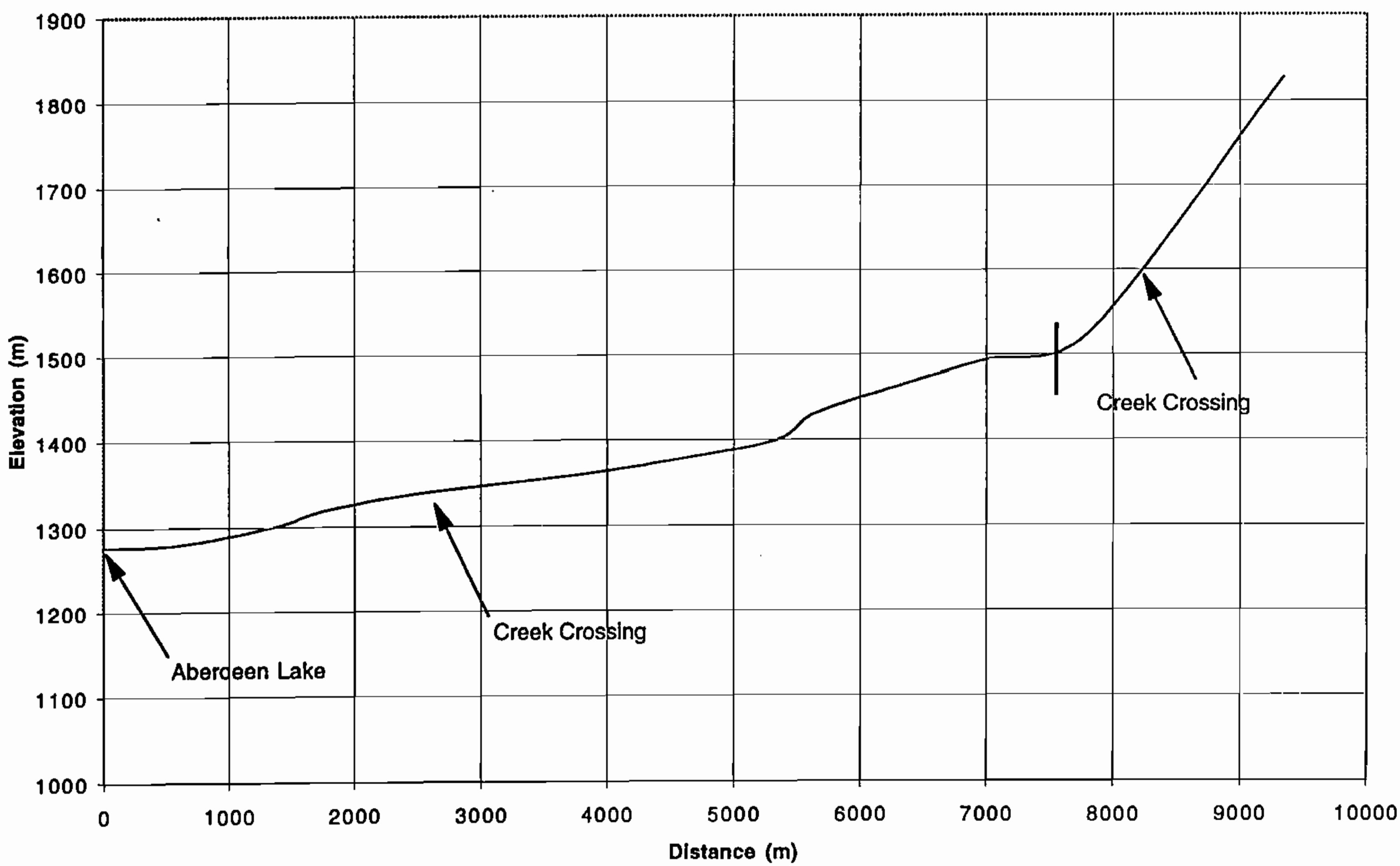


Longitudinal Profile - Duteau Creek (3)
Elevation (m)
1900
1800
1700
1600
1500
1400
1300
1200
1100
1000
20000
21000
22000
23000
24000
25000
26000
27000
28000
29000
30000
Distance (m)
Reach I
Reach J
Haddo Lake
Aberdeen Lake
Stream Crossing
Grizzly Lake


Longitudinal Profile - Duteau Creek (4)
Elevation (m)
1900
1800
1700
1600
1500
1400
1300
1200
1100
1000
Distance (m)
30000
31000
32000
33000
34000
35000
36000
37000
38000
39000
40000
Reach J
Reach K
Reach L
Stream Crossing
Stream Crossing
Slide Input


Longitudinal Profile - Flyfish Creek
Elevation (m)
1900
1800
1700
1600
1500
1400
1300
1200
1100
1000
Distance (m)
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
Creek Crossing
Creek Crossing
Creek Crossing
Ruth Lake
Duteau Creek
Brunette Creek
Flyfish Lakes

Longitudinal Profile - Heart Creek



APPENDIX E

Channel Assessment Forms

Form 1 - Classifying Channel Reaches

Sub-basin	Reach Letter	Reach Length (km)	Reach Slope (%)	Drainage Network Class	CAP Applies (Y/N)
D/S Residual	A	2.65	1.9	CA1aii	Y
D/S Residual	B	0.50	8.0	CA1bii	Y
D/S Residual	C	1.98	3.0	CA1aii	Y
Residual	D	2.45	4.9	CA1bii	Y
Residual	E	4.20	8.1	CA2bii	Y
Residual	F	4.10	1.5	CA1aii	Y
Residual	G	1.70	2.9	CA1bii	Y
Aberdeen	H	2.15	1.9	CA1bii	Y
Aberdeen	I	2.70	0.7	N/A	N (ditch)
Duteau U/S of Grizzly	J	6.15	3.3	CA1aii	Y
Duteau U/S of Grizzly	K	2.70	7.1	CA1bii	Y
Duteau U/S of Grizzly	L	2.35	6.6	CA1aii	Y

Forms 2, 3, 4, 5, and 6 (Assessment of Large Channels) - N/A

No aerial photograph assessments were conducted on the channels in Duteau Creek. The mainstem downstream of the Headgates reservoir is below the POI and beyond the terms of reference for the contract. Based on documented DFO interests, overview channel assessment field measurements and observations were made on these reaches to ascertain the nature of disturbance and to determine possible mitigation alternatives. Mainstem channels upstream of the POI are obscured by the forest canopy and not visible on aerial photographs. All mainstem and major tributary channels were field assessed as part of the IWAP procedure.

Field Form 2 - Disturbance Summary

Sub-basin: **Total Watershed**

Reach Letter	Reach Length (km)	Channel Type	Stream Length in Each Disturbance Class (km)			
			None (S or other)	**Low (A1, D1)**	**Moderate (A2, D2)**	**High (A3, D3)**
A	2.65	$RP_{c\text{-}w}$:D2			2.65	
B	0.50	CP_{b}:D2			0.50	
C	1.98	CP_{h}:D2			1.98	
D	2.45	$CP_{B\text{-}w}$:S	2.45			
E	4.20	$CP_{h\text{-}w}$:S	4.20			
F	4.10	$RP_{gs\text{-}w}$:S	4.10			
G	1.70	RP_{c}-w:S	1.70			
H	2.15	RP_{c}-w:S	2.15			
I	2.70	Ditch	2.70			
J	6.15	$CP_{g\text{-}w}$:A2			6.15	
K	2.70	$CP_{g\text{-}w}$:A2			2.70	
L	2.35	CP_{h}:S	2.35			
	Σ=33.63 km		Σ=19.65	Σ=0.0	Σ=13.98	Σ=0.0

Sum of moderate and high disturbance channels = 13.98 km
Sum % of moderate and high disturbance channels = 41.5%

Form 7 - Mainstem Channel Impact Values (Completed Based on Field Assessment Information - Field Forms 1 And 2)

Sub-basin Name	(a) Total Mainstem Channel Length (km)	(b) Total Length of Moderate and High Disturbed Channel (km)	(c) Impact Ratio = (b/a)	Mainstem Channel CIV	Channel Impact/Instability Rating
Mainstem below Headgates	5.13	5.13	1.0	1.0	High
Residual	12.45	0.0	0.0	0.0	Low
Aberdeen	4.85	0.0	0.0	0.0	
Duteau U/S of Grizzly	11.20	8.85	0.8	0.95	High
Total	**33.63**	**13.98**	**0.4**	**0.8**	**High**

Form 8 - Summary of Assessments Performed

Sub-basin Name	General Assessment	Detailed Assessment		CIV
		Air Photograph	Field	
Mainstem below Headgates	N/A*	N/A*	x	1.0
Residual	N/A	N/A	x	0.0
Aberdeem	N/A	N/A	x	0.0
Duteau U/S of Grizzly	N/A	N/A	x	0.95
Total	**N/A**	**N/A**	**x**	**0.4**

* **Note:** Channels downstream of the Headgates reservoir are below the POI and outside of the terms of reference for the IWAP contract. Overview field assessment measurements and observations were completed on reaches A, B and C but no aerial photograph analysis was done.

GENERAL ASSESSMENT
Analysis completed by: **N/A**
Date of analysis: **N/A**
DETAILED ASSESSMENT - AERIAL PHOTOGRAPH
Analysis completed by: **N/A**
DETAILED ASSESSMENT - FIELD (September/October, 1998)
Analysis completed by: **Michael Milne and Harold Waters**

Duteau Channel Assessment - Field Form 1

Sub-basin: **Duteau Creek**
Reach: **A**
Map-Sheet:

Date: **August 1998**
Crew: **Milne and Waters**
Weather: **Sunny**

Station	Wb (m)	d (cm)	s (%)	D (cm)	Channel Type
---	---	---	---	---	---
---	---	---	---	---	---
---	---	---	---	---	---
---	---	---	---	---	---
Average	4.0	100	1.9	30	RP_{c-w}:D2

Distance	Bank Type	Channel Type	Disturbance Indicators	Photo Roll and Frame
---	---	---	---	---
---	---	---	---	---
---	---	---	---	---
---	---	---	---	---
Average	A3/4	RP_{c-w}:D2	S1, S5, C2	30, 31

S1 Homogenous bed texture	C1 Extensive riffles or cascades	B1 Abandoned channels
S2 Sediment fingers	C2 Minimal pool area	B2 Eroding banks
S3 Sediment wedges	C3 Elevated mid-channel bars	B3 Avulsions
S4 Extensive bars	C4 Multiple channels or braids	D1 Small woody debris
S5 Extensive scoured zones	C5 Disturbed stone lines	D2 LWD function
		D3 Recently formed LWD jams

A (Erodible): 1=Silt, 2=Sand, 3=Gravel, 4=Cobble, 5=Boulder
N (Non-erodible): 1=Till, 2=Colluvium, 3=Bedrock

Comments: Channel is degraded as a result of bedload capture in Headgates reservoir. Riparian vegetation is intermittant along reach from agricultural land clearing.

Duteau Channel Assessment - Field Form 1

Sub-basin: **Duteau Creek**
Reach: **B**
Map-Sheet:

Date: **August 1998**
Crew: **Milne and Waters**
Weather: **Sunny**

Station	Wb (m)	d (cm)	s (%)	D (cm)	Channel Type
---	---	---	---	---	---
---	---	---	---	---	---
---	---	---	---	---	---
---	---	---	---	---	---
Average	7.0	75	8.0	50	CP_b:D2

Distance	Bank Type	Channel Type	Disturbance Indicators	Photo Roll and Frame
---	---	---	---	---
---	---	---	---	---
---	---	---	---	---
---	---	---	---	---
Average	A4/5	CP_b:D2	S1, S5	N/A

S1 Homogenous bed texture	C1 Extensive riffles or cascades	B1 Abandoned channels
S2 Sediment fingers	C2 Minimal pool area	B2 Eroding banks
S3 Sediment wedges	C3 Elevated mid-channel bars	B3 Avulsions
S4 Extensive bars	C4 Multiple channels or braids	D1 Small woody debris
S5 Extensive scoured zones	C5 Disturbed stone lines	D2 LWD function
		D3 Recently formed LWD jams

A (Erodible): 1=Silt, 2=Sand, 3=Gravel, 4=Cobble, 5=Boulder
N (Non-erodible): 1=Till, 2=Colluvium, 3=Bedrock

Comments: Degraded channel from bedload capture in Headgates reservoir. Riparian vegetation is mostly intact and the banks are stable.

Duteau Channel Assessment - Field Form 1

Sub-basin: **Duteau Creek**
Reach: **C**
Map-Sheet:

Date: **August 1998**
Crew: **Milne and Waters**
Weather: **Sunny**

Station	Wb (m)	d (cm)	s (%)	D (cm)	Channel Type
---	---	---	---	---	---
---	---	---	---	---	---
---	---	---	---	---	---
---	---	---	---	---	---
Average	7.0	75	3.0	30	CP_b:D2

Distance	Bank Type	Channel Type	Disturbance Indicators	Photo Roll and Frame
---	---	---	---	---
---	---	---	---	---
---	---	---	---	---
---	---	---	---	---
Average	A4/5	CP_b:D2	S1, S5	29

S1 Homogenous bed texture	C1 Extensive riffles or cascades	B1 Abandoned channels
S2 Sediment fingers	C2 Minimal pool area	B2 Eroding banks
S3 Sediment wedges	C3 Elevated mid-channel bars	B3 Avulsions
S4 Extensive bars	C4 Multiple channels or braids	D1 Small woody debris
S5 Extensive scoured zones	C5 Disturbed stone lines	D2 LWD function
		D3 Recently formed LWD jams

A (Erodible): 1=Silt, 2=Sand, 3=Gravel, 4=Cobble, 5=Boulder
N (Non-erodible): 1=Till, 2=Colluvium, 3=Bedrock

Comments: Degraded channel from bedload capture in Headgates reservoir. Riparian vegetation is mostly intact and the banks are stable.

Duteau Channel Assessment - Field Form 1

Sub-basin: **Duteau Creek**
Reach: **D**
Map-Sheet:

Date: **August 1998**
Crew: **Milne and Waters**
Weather: **Sunny**

Station	Wb (m)	d (cm)	s (%)	D (cm)	Channel Type
---	---	---	---	---	---
---	---	---	---	---	---
---	---	---	---	---	---
---	---	---	---	---	---
Average	6.5	100	4.9	30	CP_{B-w}:S

Distance	Bank Type	Channel Type	Disturbance Indicators	Photo Roll and Frame
---	---	---	---	---
---	---	---	---	---
---	---	---	---	---
---	---	---	---	---
Average	A4/5	CP_{B-w}:S	---	25, 26

S1 Homogenous bed texture
S2 Sediment fingers
S3 Sediment wedges
S4 Extensive bars
S5 Extensive scoured zones

C1 Extensive riffles or cascades
C2 Minimal pool area
C3 Elevated mid-channel bars
C4 Multiple channels or braids
C5 Disturbed stone lines

B1 Abandoned channels
B2 Eroding banks
B3 Avulsions
D1 Small woody debris
D2 LWD function
D3 Recently formed LWD jams

A (Erodible): 1=Silt, 2=Sand, 3=Gravel, 4=Cobble, 5=Boulder
N (Non-erodible): 1=Till, 2=Colluvium, 3=Bedrock

Comments: Riparian zone in intact old growth. The channel and banks are stable. 1996 and 1997 peak flows have been buffered through upstream reservoirs which has limited direct channel disturbance. Sand and gravel bars are present along the channel margins from landslide input to reach E.

Duteau Channel Assessment - Field Form 1

Sub-basin: **Duteau Creek**
Reach: **E**
Map-Sheet:

Date: **August 1998**
Crew: **Milne and Waters/Waters**
Weather: **Sunny**

Station	Wb (m)	d (cm)	s (%)	D (cm)	Channel Type
---	---	---	---	---	---
---	---	---	---	---	---
---	---	---	---	---	---
---	---	---	---	---	---
Average	7.0	100	8.1	50	CP_{h-w}:S

Distance	Bank Type	Channel Type	Disturbance Indicators	Photo Roll and Frame
---	---	---	---	---
---	---	---	---	---
---	---	---	---	---
---	---	---	---	---
Average	A4/5 and N3	CP_{h-w}:S	D3	24

S1 Homogenous bed texture
S2 Sediment fingers
S3 Sediment wedges
S4 Extensive bars
S5 Extensive scoured zones

C1 Extensive riffles or cascades
C2 Minimal pool area
C3 Elevated mid-channel bars
C4 Multiple channels or braids
C5 Disturbed stone lines

B1 Abandoned channels
B2 Eroding banks
B3 Avulsions
D1 Small woody debris
D2 LWD function
D3 Recently formed LWD jams

A (Erodible): 1=Silt, 2=Sand, 3=Gravel, 4=Cobble, 5=Boulder
N (Non-erodible): 1=Till, 2=Colluvium, 3=Bedrock

Comments: Slide input at 0.5 km downstream of Haddo FSR crossing has created two debris jams at the site. The channel has re-routed through the debris and removal is not required. The channel is stable through the canyon but is carrying increased sand, gravel and cobbles from 1997 landslide input.

Duteau Channel Assessment - Field Form 1

Sub-basin: **Duteau Creek**
Reach: **F**
Map-Sheet:

Date: **August 1998**
Crew: **Milne and Waters/Waters**
Weather: **Sunny**

Station	Wb (m)	d (cm)	s (%)	D (cm)	Channel Type
---	---	---	---	---	---
---	---	---	---	---	---
---	---	---	---	---	---
---	---	---	---	---	---
Average	10.0	100	1.5	15	RP_{gs-w}:S

Distance	Bank Type	Channel Type	Disturbance Indicators	Photo Roll and Frame
---	---	---	---	---
---	---	---	---	---
---	---	---	---	---
---	---	---	---	---
Average	A2/3	RP_{gs-w}:S	D2	21

S1 Homogenous bed texture	C1 Extensive riffles or cascades	B1 Abandoned channels
S2 Sediment fingers	C2 Minimal pool area	B2 Eroding banks
S3 Sediment wedges	C3 Elevated mid-channel bars	B3 Avulsions
S4 Extensive bars	C4 Multiple channels or braids	D1 Small woody debris
S5 Extensive scoured zones	C5 Disturbed stone lines	D2 LWD function
		D3 Recently formed LWD jams

A (Erodible): 1=Silt, 2=Sand, 3=Gravel, 4=Cobble, 5=Boulder
N (Non-erodible): 1=Till, 2=Colluvium, 3=Bedrock

Comments: The channel is stable with abundant LWD from blowdown in the riparian zone. Partial salvage of blowdown has occurred in the old blocks along the channel (CP 599). Abundant debris will eventually rot, form debris jams and cause avulsions. Sedimentation at the water intake will result from avulsions. A windthrow management strategy should be developed along the mainstem below Haddo Lake to determine how much blowdown should be removed from the channel during salvage to reduce the risk of avulsion.

Duteau Channel Assessment - Field Form 1

Sub-basin: **Duteau Creek**
Reach: **G**
Map-Sheet:

Date: **August 1998**
Crew: **Milne and Waters**
Weather: **Sunny**

Station	Wb (m)	d (cm)	s (%)	D (cm)	Channel Type
Average	10.0	100	2.9	15	$RP_{gs\text{-}w}$:S

Distance	Bank Type	Channel Type	Disturbance Indicators	Photo Roll and Frame
Average	A2/3	$RP_{gs\text{-}w}$:S	D3	20

S1 Homogenous bed texture	C1 Extensive riffles or cascades	B1 Abandoned channels
S2 Sediment fingers	C2 Minimal pool area	B2 Eroding banks
S3 Sediment wedges	C3 Elevated mid-channel bars	B3 Avulsions
S4 Extensive bars	C4 Multiple channels or braids	D1 Small woody debris
S5 Extensive scoured zones	C5 Disturbed stone lines	D2 LWD function
		D3 Recently formed LWD jams

A (Erodible): 1=Silt, 2=Sand, 3=Gravel, 4=Cobble, 5=Boulder
N (Non-erodible): 1=Till, 2=Colluvium, 3=Bedrock

Comments: Natural blowdown in the riparian zone is causing small debris jams in the channel with minor bank slumping and erosion.

Duteau Channel Assessment - Field Form 1

Sub-basin: **Duteau Creek**
Reach: **H**
Map-Sheet:

Date: **August 1998**
Crew: **Milne and Waters/Waters**
Weather: **Sunny**

Station	Wb (m)	d (cm)	s (%)	D (cm)	Channel Type
---	---	---	---	---	---
---	---	---	---	---	---
---	---	---	---	---	---
---	---	---	---	---	---
Average	10.0	100	2.9	15	RP_{gs-w}:S

Distance	Bank Type	Channel Type	Disturbance Indicators	Photo Roll and Frame
---	---	---	---	---
---	---	---	---	---
---	---	---	---	---
---	---	---	---	---
Average	A2/3	RP_{gs-w}:S	---	19

S1 Homogenous bed texture
S2 Sediment fingers
S3 Sediment wedges
S4 Extensive bars
S5 Extensive scoured zones

C1 Extensive riffles or cascades
C2 Minimal pool area
C3 Elevated mid-channel bars
C4 Multiple channels or braids
C5 Disturbed stone lines

B1 Abandoned channels
B2 Eroding banks
B3 Avulsions
D1 Small woody debris
D2 LWD function
D3 Recently formed LWD jams

A (Erodible): 1=Silt, 2=Sand, 3=Gravel, 4=Cobble, 5=Boulder
N (Non-erodible): 1=Till, 2=Colluvium, 3=Bedrock

Comments: The channel is stable but the riparian zone is prone to windthrow and should be managed as such.

Duteau Channel Assessment - Field Form 1

Sub-basin: **Duteau Creek**
Reach: **J**
Map-Sheet:

Date: **August 1998**
Crew: **Milne and Waters**
Weather: **Sunny**

Station	Wb (m)	d (cm)	s (%)	D (cm)	Channel Type
---	---	---	---	---	---
---	---	---	---	---	---
---	---	---	---	---	---
---	---	---	---	---	---
Average	3.5	50	3.3	20	CP_{g-w}:A2

Distance	Bank Type	Channel Type	Disturbance Indicators	Photo Roll and Frame
---	---	---	---	---
---	---	---	---	---
---	---	---	---	---
---	---	---	---	---
Average	A3/4	CP_{g-w}:A2	S4, C2	14

S1 Homogenous bed texture	C1 Extensive riffles or cascades	B1 Abandoned channels
S2 Sediment fingers	C2 Minimal pool area	B2 Eroding banks
S3 Sediment wedges	C3 Elevated mid-channel bars	B3 Avulsions
S4 Extensive bars	C4 Multiple channels or braids	D1 Small woody debris
S5 Extensive scoured zones	C5 Disturbed stone lines	D2 LWD function
		D3 Recently formed LWD jams

A (Erodible): 1=Silt, 2=Sand, 3=Gravel, 4=Cobble, 5=Boulder
N (Non-erodible): 1=Till, 2=Colluvium, 3=Bedrock

Comments: Channel is aggraded from upstream 1980's and 1997 slide events. Sand and small gravel is mobile in the system and can be expected to deposit on the fan at Grizzly swamp.

Duteau Channel Assessment - Field Form 1

Sub-basin: **Duteau Creek**
Reach: **K**
Map-Sheet:

Date: **09/30/98**
Crew: **Milne and Waters**
Weather: **Sunny**

Station	Wb (m)	d (cm)	s (%)	D (cm)	Channel Type
---	---	---	---	---	---
---	---	---	---	---	---
---	---	---	---	---	---
---	---	---	---	---	---
Average	3.0	50	7.1	35	CP_{g-w}:A2

Distance	Bank Type	Channel Type	Disturbance Indicators	Photo Roll and Frame
---	---	---	---	---
---	---	---	---	---
---	---	---	---	---
---	---	---	---	---
Average	A3/4/5 N3	CP_{g-w}:A2	S4	13

S1 Homogenous bed texture
S2 Sediment fingers
S3 Sediment wedges
S4 Extensive bars
S5 Extensive scoured zones

C1 Extensive riffles or cascades
C2 Minimal pool area
C3 Elevated mid-channel bars
C4 Multiple channels or braids
C5 Disturbed stone lines

B1 Abandoned channels
B2 Eroding banks
B3 Avulsions
D1 Small woody debris
D2 LWD function
D3 Recently formed LWD jams

A (Erodible): 1=Silt, 2=Sand, 3=Gravel, 4=Cobble, 5=Boulder
N (Non-erodible): 1=Till, 2=Colluvium, 3=Bedrock

Comments: Channel is aggraded from upstream 1980's and 1997 slide events.

Duteau Channel Assessment - Field Form 1

Sub-basin: **Duteau Creek**
Reach: **L**
Map-Sheet:

Date: **09/30/98**
Crew: **Milne and Waters**
Weather:

Station	Wb (m)	d (cm)	s (%)	D (cm)	Channel Type
---	---	---	---	---	---
---	---	---	---	---	---
---	---	---	---	---	---
---	---	---	---	---	---
Average	2.5	50	6.6	45	CP_{h-w}:S

Distance	Bank Type	Channel Type	Disturbance Indicators	Photo Roll and Frame
---	---	---	---	---
---	---	---	---	---
---	---	---	---	---
---	---	---	---	---
Average	A4/5	CP_{h-w}:S	---	12

S1 Homogenous bed texture
S2 Sediment fingers
S3 Sediment wedges
S4 Extensive bars
S5 Extensive scoured zones

C1 Extensive riffles or cascades
C2 Minimal pool area
C3 Elevated mid-channel bars
C4 Multiple channels or braids
C5 Disturbed stone lines

B1 Abandoned channels
B2 Eroding banks
B3 Avulsions
D1 Small woody debris
D2 LWD function
D3 Recently formed LWD jams

A (Erodible): 1=Silt, 2=Sand, 3=Gravel, 4=Cobble, 5=Boulder
N (Non-erodible): 1=Till, 2=Colluvium, 3=Bedrock

Comments: Stable channel with woody debris control.