HYDROLOGIC OPERATIONAL MANUAL

MAIN REPORT

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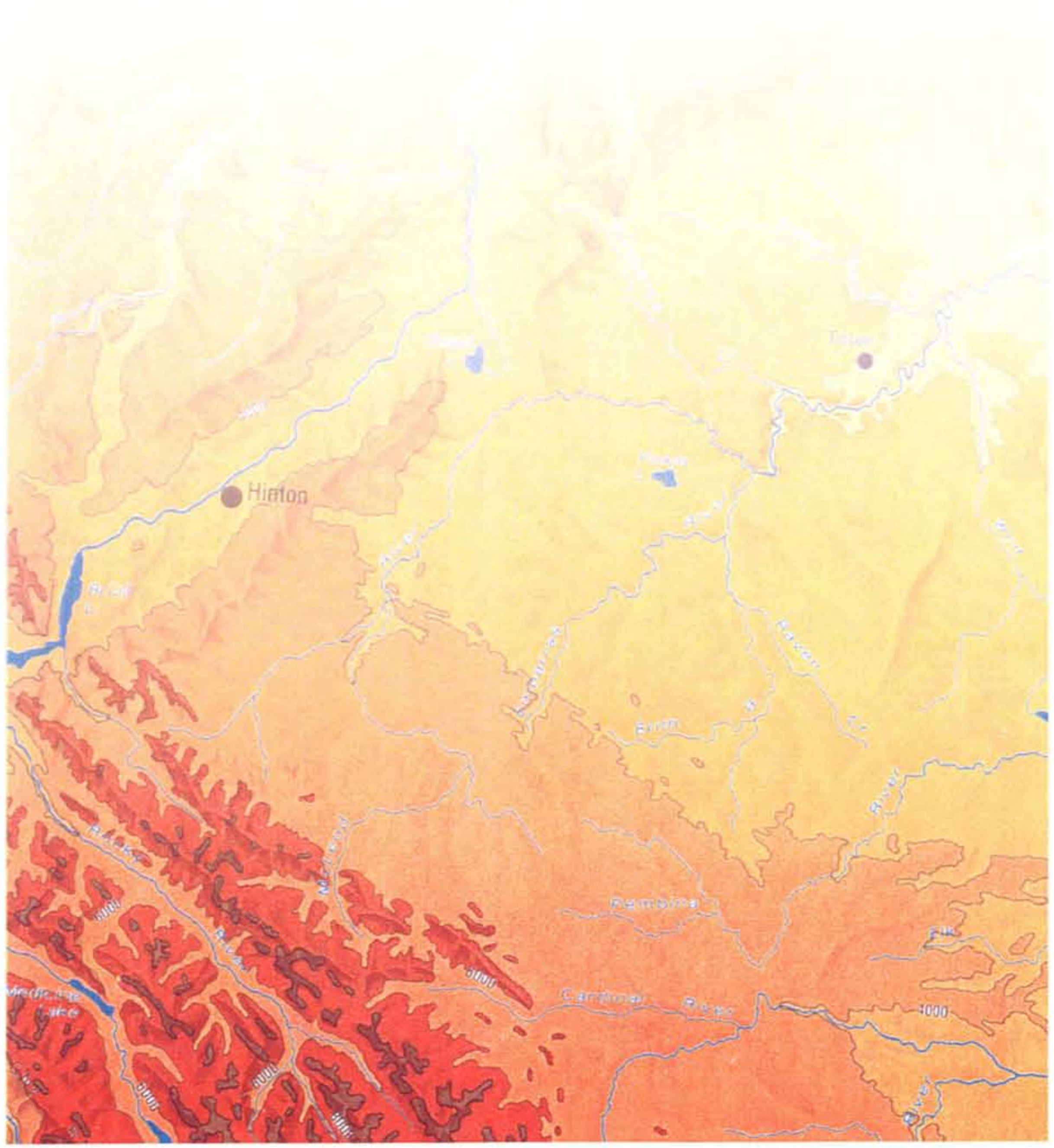
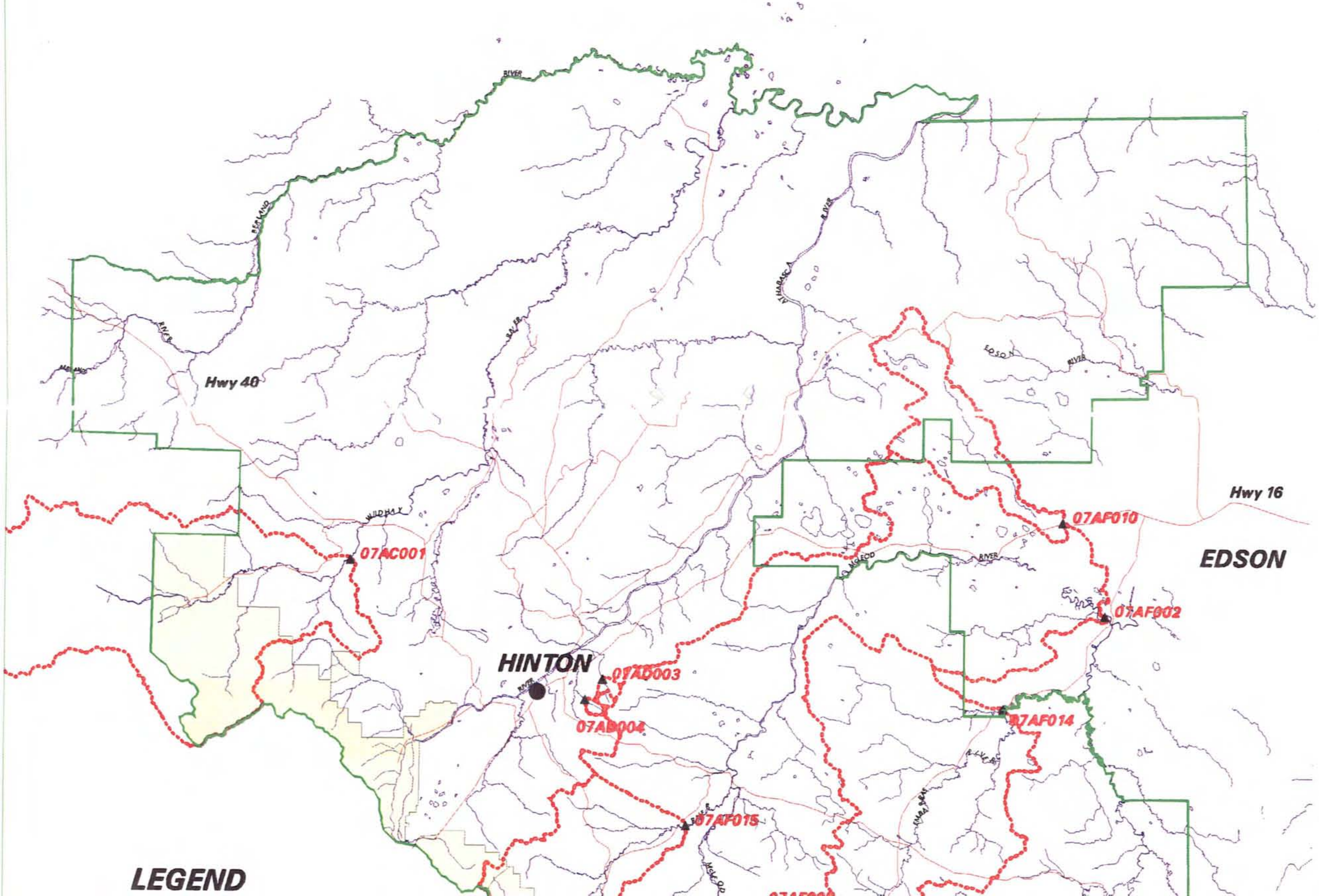


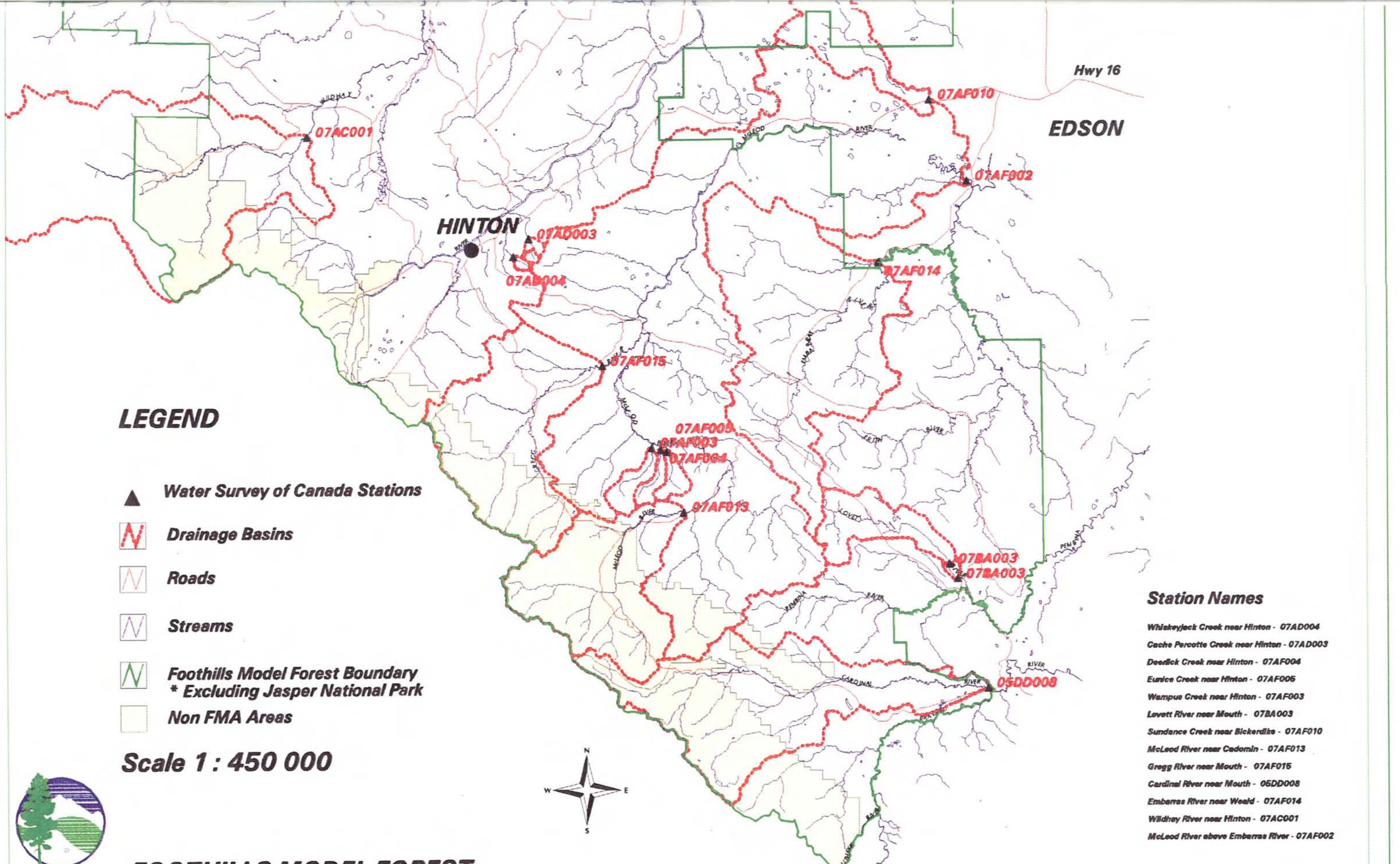
FOOTHILLS MODEL FOREST

MODEL FOREST
NETWORK
RÉSEAU DE
FORÊTS MODÈLES

February 1997

Figure 2: Locations of Regional Flow Monitoring Stations





FOOTHILLS MODEL FOREST

DISCLAIMER

The project/study on which this report is based was funded by the Foothills Model Forest under the Partners in Sustainable Development of Forests initiative delivered by the Canadian Forest Service of Natural Resources Canada.

The views, statements and conclusions expressed and the recommendations made in this report are entirely those of the authors and should not be construed as the statements or conclusions of, or as expressing the opinions of, Foothills Model Forest.

FOOTHILLS MODEL FOREST MISSION

"to develop and recommend as approach to sustainability and integrated resource management through research and technology developed by means of collaborative partnerships".

RELATIONSHIP BETWEEN FOOTHILLS MODEL FOREST AND RESOURCE MANAGEMENT AGENCIES

The Foothills Model Forest represents a broad range of stakeholder groups with interest in Alberta's forests and how they are managed. However, Foothills Model Forest has no resource management authority or responsibility. The authority over, and responsibilty for, the management of Alberta's public lands is vested in the Government of Alberta. The Government delegates certain rights and responsibilities to various resource industries and organizations which conduct their activities on public lands in Alberta. The Government of Alberta and other agencies and organizations will consider and respond to the recommendations of Foothills Model Forest from the perspective of their particular rights, reponsibilities, obligations and stewardship commitments.

ACKNOWLEDGMENTS

Janice Traynor of Foothills Model Forest was the driving force in formulating the need for and basic contents and approach of this manual. She provided invaluable input, from a user's perspective, as the manual progressed through its various draft stages. Staff from the The Forestry Corp. prepared the project area map, Figure 2.

Strong technical input and review throughout was provided by John Taggart of the Water Sciences Branch, Alberta Environmental Protection, Edmonton. His extensive experience with regional hydrologic studies in the province was key in focusing and refining the results.

The manual was based on a detailed regional hydrologic analysis by B.K. Hydrology Service for Foothills Model Forest, (unpublished). Much of the preparation of the raw data for this work (as summarized in Volume 2 available separately) was undertaken by Hydroconsult staff in a subcontract to B.K. Hydrology Service.

Hydroconsult staff involved in the preparation of this manual were:

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1.0 INTRODUCTION

1.1 BACKGROUND

Foothills Model Forest is developing a Watershed Assessment Model (WAM) to enable the planning and evaluation of timber harvesting plans and associated works and specifically their effect on the quantity and quality of surface water and the resulting impact on aquatic resources.

An integral component of this planning and evaluation for the WAM is to determine how the proposed timber harvesting may effect flows. To analyze this requires sound and sufficient existing or baseline streamflow data.

1.2 FOCUS

This summary of streamflow data and operational tools is intended for forest planners and managers, fishery biologists and governmental regulators. It is intended to provide general background information for planning developments and for assessing environmental impacts and to provide preliminary hydrologic design data for culverts, bridges or water supply sources.

The manual is not intended to replace detailed hydrologic evaluations for specific projects but rather to provide, in a simplified manner, the means of estimating hydrologic parameters. Thus it can be an effective tool and starting point for the detailed evaluations.

The Athabasca River within the Foothills Model Forest area is not included in this operational manual as its size, watershed characteristics, and thus flow magnitude are outside the range of the rest of the stations in the region. A hydrologic analysis of the Athabasca River should be based solely on its data and not those of the region.

1.3 CONTENTS

The contents and layout of the manual are as follows:

- Section 2.0 presents maps and graphical presentations indicating the streamflow data for the Foothills Model Forest area. Flow data (monthly patterns, duration, maximum recorded and probability of extreme events) for 5 watersheds of various sizes are presented. Maximum recorded flows for the same five locations are compared as well as an illustration of how low flows vary from year to year for a specific flow monitoring station.
- Section 3.1. Peak flows, required to design bridges, culverts and dams are presented in this section. Simplified techniques are provided to calculate peak flows on rivers/creeks
- Section 3.2. The rate of rise and fall of streamflow during a flood event is of importance in sizing spillways for dams and sediment ponds and to determine the length of time critical velocities could occur at culverts or bridges. This section presents the tools to determine these flood peak characteristics for any location.
- Section 3.3. The variability in flow from month-to-month and from year-to-year, that is the long term flow patterns rather than the extreme flood events discussed in the previous two sections, is important in assessing environmental impacts and in determining water availability for water users. Knowing the drainage area of the project, the section outlines and illustrates the tools to compute monthly flow ranges for high, mean and low runoff events.
- Section 3.4. The minimum streamflow, which usually occurs during the winter, is valuable in water quality and aquatic impact assessments and in determining the need for and size of storage facilities to meet a project's water demands. Of the 13 flow monitoring stations in the Foothills Model Forest with 9 or more years of flow data, only the McLeod River above Embarras River station has continuous winter flow data. The low flows for the remainder of the stations were analyzed into regional relationships. A comparison of winter flow to pre and post winter conditions is also shown in Section 2. This section enables the user, knowing the drainage area for any specific location, to compute a 7-day 1:10 year low flow, a duration and probability commonly used in aquatic and water quality assessments.

In summary then, high flows namely rate and volume are discussed and analyzed in Sections 3.1 and 3.2 respectively. Monthly flows for normal, high and low flow years are illustrated and presented in Section 3.3 while extreme short term low flows are discussed in Section 3.4. Figure 1 summarizes the purpose, contents and layout of the manual.

Volume 2, is an accumulation of the raw flow data and analysis of these data. It will be a useful reference document for those users who wish to delve into the supporting information for the manual.

2.0 PHYSICAL CHARACTERISTICS OF THE MODEL FOREST AREA AND AVAILABLE STREAMFLOW DATA

2.1 PHYSICAL CHARACTERISTICS

The Foothills Model Forest Study area, outside of Jasper National Park, is delineated on Figure 2. The borders of the area can be roughly defined as:

- north side - the Berland River,
- east side - defined by the Weldwood of Canada (Hinton Division) Forest Management Agreement (FMA), area boundary. Generally the eastern border is roughly in line with Edson except for a corridor running part way between Edson and Hinton along Highway 16 which is not included in the Model Forest area.
- south side - the Southesk and Brazeau rivers.
- west side- the Divide which corresponds to the eastern boundary of Jasper National Park.

The elevations of the Study area range from 2500 metres (m) to 2000 m at the Jasper National Park border to as low as 850 m where the Athabasca River exits the area in its north-east corner. The area is primarily covered by conifer forests with some deciduous cover in the lower elevations along the eastern border. Above elevation 2000 along the western side of the area, the trees give way to bare rock, grasses and low height alpine vegetation in the steep areas.

2.2 LAND USE

The major urban center is Hinton in which the regional forestry and coal mining operations are centered. Forestry operations are spread out throughout the study area. Coal mines are operating north-east of Hinton (Obed) and south-east (Gregg River, Cardinal and Coal Valley) and a major new coal mine is proposed for the area south of Cadomin (Cheviot). The coal mine areas are designated on Figure 2 within the non FMA areas. Oil and gas developments occur primarily in the area west and north of Edson, which is the north-east corner of the Foothills Model Forest area.

The various types of land uses can be characterized considering their potential impact on watersheds and runoff characteristics, as follows:

- urban and associated industrial developments - intensive and permanent land use changes over limited areas,
- logging - intensive removal of vegetation from specific areas followed by a reforestation program. Access roads with culverts or bridges are required to support the operation . Stream diversion are rarely required.
- coal mining - intensive and permanent disturbance to the land over limited areas. Disturbed areas, upon completion of mining, are generally revegetated. Stream diversions, rock dumps, plant water needs and end-pit lakes can alter the runoff and flow patterns. Local haul roads in the pits and access roads, railways and powerlines are also required along with a water supply source and storage ponds.
- oil and gas development - well sites, access roads, pipelines and powerlines may be widespread. Stream diversions are generally not required. Oil fields may require a water supply source for injection.

2.3 PRECIPITATION

Average annual precipitation ranges from 500 mm to 700 mm. Intense summer storms may comprise a significant percentage of the total annual precipitation. Typically with an increase in elevation, rainfall increases, evaporation decreases and thus runoff increases. Some valleys in the lower ranges of the Rockies approaching Jasper National Park may, according to local anecdotal information, be in a "rain shadow."

A significant percentage of the annual streamflow volume is due to snowmelt particularly in an average to low rainfall year. In a year with high rainfall, streamflow generated by rainfall is more significant than that produced from snowmelt. Spring breakup may start as early as March and generally extends into May.

2.4 STREAMFLOW

2.4.1 Available Data

Figure 3 graphically illustrates the streamflow datasets available from regional Water Survey of Canada (Environment Canada) flow monitoring stations. Only stations with 9 years or more of data were included in the analysis. The largest station, the McLeod River above Embarras River is the only location where flow is measured on a year-round basis. At the rest of the stations, flow monitoring commences and finishes in March/April and October respectively. The high cost of operating year-round stations is the reason for the scarcity in winter flow data. The same Figure also illustrates the elevation range of the watersheds in the Model Forest area and the location of the flow monitoring stations within that range. All the flow monitoring sites are located in an elevation band from about 1000 m to 1500 m.

The drainage areas to the flow measurement locations are shown on Figure 2. Highlighted on Figure 4 are locations for which streamflow characteristics are shown on Figures 5 to 11 as discussed in the next section. Also indicated on this Figure is a simple methodology for determining drainage area.

2.4.2 Characteristics

Streamflow characteristics are illustrated for Whiskeyjack Creek, Eunice Creek, Wampus Creek, Wildhay River and McLeod River on Figures 5, 6, 7, 8 and 9 respectively. These stations are distributed over the Foothills Model Forest area as shown on Figure 4 and represent drainage areas ranging from 3.13 km^2 (Whiskeyjack Creek) to 2560 km^2 (McLeod River above Embarras).

Included are Eunice and Wampus Creeks in The Tri-Creek Experimental Watersheds south-east of Hinton. The Eunice Creek watershed was maintained in its natural conditions while the adjacent Wampus Creek was logged to evaluate the impact of logging on runoff and sediment.

The flow characteristics shown on Figures 5 to 9 are as follows:

- the variability of monthly flows. These data are useful in construction planning (what flows could be encountered during various in-stream construction periods).
- the percentage of time a certain daily flow magnitude is exceeded. This is useful, in determining the percentage of time flow could be less than a prescribed critical limit that might be established by regulatory agencies for with - drawing water from a stream for example.
- the maximum recorded flood hydrograph illustrates how rapidly flows increase and decrease in response to rainfall and is useful for in-stream construction planning (if a major flood event occurs while in-stream work is in progress, what is the warning time before the peak occurs and how long does the peak flow last. It can also be useful in computing the length of time a critical flow/velocity is exceeded re: fish passage at culverts. It is interesting to note that the maximum recorded flow for all five stations shown occurred as a result of the same June 1980 rainfall storm.
- the probability (defined as the recurrence interval in years), that the peak flow will exceed a certain value. This information is essential in sizing culverts, bridges and spillways for small dams which are typically sized for the 1:20 year, 1:100 year, and 1:200 year return periods respectively.

Some general observations with respect to the data presented for the 5 representative flow measurement locations are:

- monthly summer flows at all the stations are highly variable. The maximum June and July monthly flow is about 4 times the average June and July flow.
- the maximum daily recorded flow is 3.5 to 5.5 times greater than the maximum monthly flow and about 20 times greater than the average June and July monthly flow. (Note that the maximum instantaneous flow is even greater as shown on Figure 3.)
- the range of flows is clearly represented on the daily flow duration curve. Only about 5% of the time is flow high with the remainder of the time flow is relatively low.

A quick comparison of the 5 stations shown also illustrates some interesting differences between the Wildhay River and the remainder of the stations namely:

- the Wildhay has the least difference between the maximum and mean summer monthly flows (compare the "monthly flow patterns")
- whereas the flows rapidly decline after the maximum flood event at the other four stations, flows in the Wildhay are sustained at a higher level for a longer period of time (compare the "maximum recorded flood hydrographs"). This flow characteristic of the Wildhay River is also illustrated by the "daily flow duration". The other streams indicate that only about 5% of the time is the flow greater than a narrow low flow range (see where the "break" in the flow duration curve occurs), whereas about 10-20% of the time, the Wildhay River flow is greater than the narrow, and dominant low flow range.

A detailed analysis of the topographic and runoff characteristics of the Wildhay River watershed, not within the scope of this operational manual , would in all likelihood reveal that the Wildhay has more bogs and swampy areas that retain runoff and thus reduce maximum flows and at the same time sustain higher flows for a longer period of time after the flood peak has passed.

A quick comparison of the maximum flows recorded at the 5 stations (the maximum flood occured in June 1980 at each of the stations) is illustrated on Figure 10. The peak unit runoff from the Wildhay River is again shown to be significantly less than that of the other streams Whiskeyjack Creek is also shown to be an anomaly with respect to peak flows. Its location and/or topographic conditions in the low Athabasca River valley near Hinton appears to produce significantly lower peak flows, on a unit basis, than the other watersheds.

This quick comparison of the 5 stations illustrated indicates the strengths of analyzing streamflow on a regional basis. By analyzing a large region, a much wider array of data representing variable drainage areas and topographic conditions can be presented and utilized in the evaluation or design of projects. It also, as indicated by the Wildhay River, illustrates how flow differences may occur within a region.

In Figure 11, a comparison of the variability of winter flow is presented for the McLeod River above Embarras. This is the only station in the Foothills Model Forest Study area for which long term continuous winter flow data are available. The graphs illustrate that pre and post winter flows in October and April respectively are highly variable, but that late winter low flows do not vary significantly. Thus a wet, high flow fall period (such as 1989-1990, middle top graph) results in somewhat high flows into November-December, however the January flows are almost the same as those following a dry, low flow fall period (such as 1992-1993, middle bottom graph).

The development of ice, during a severe cold spell in late November to early December, can have a significant impact on flow at specific locations which may not always be represented in the recorded flow data from Water Survey of Canada. During a cold spell when ice forms rapidly (either as a thermal ice cover on a slow moving river or as overflows and icings on steep, shallow river systems such as the McLeod River above Cadomin), as much as 50% of the available flow may be "lost" to the production of ice. As soon as the cold spell ends or the full ice thickness has formed, the streamflow increases again illustrates this.

3.0 FLOW ANALYSIS

3.1 FLOOD PEAK

This section discusses design flows required for bridges, culverts, dams and sediments ponds and as required to calculate flood levels for proposed facilities next to a river or creek.

Figure 12 illustrates the 1:2 year to 1:100 year peak flow curves for the region. The 1:2 year flood is an event that, on the average, will be equalled or exceeded once ever 2 years. The 1:100 year flood, on the average, would be equalled or exceeded once ever 100 years. It should be noted that:

- several 1:100 year floods could occur over a shorter, say 10 to 20 year interval and then again, might not occur for more than several hundred years.
- a 1:100 year flood could occur as a result of an intense, local rainfall in one area one year and the next year a similar storm causes a flood in an adjacent watershed. Although it might appear at first that a 1:100 year flood has occurred two years in a row, this is not the case as the same watershed was not affected.

Plotted on the graph and tabulated also are the 1:2 to 1:100 year flood flows for the Water Survey of Canada Stations in the region with 9 years or more of flow data. The graph shows the similarity or in some instances, the lack of similarity, of specific streamflow monitoring locations to the region-wide analysis. The equations of the curves are indicated.

Figure 13 illustrates a flow chart for computing peak flows for a location on a stream that has a Water Survey of Canada flow monitoring station or a location on a stream that has no flow data. For the first case, the peak flows should be computed using the peak flow values computed for the Station. If there are no flow data, the average regional curves should be used.

It should be stressed that the techniques outlined in this manual are to be used for general, "first-cut" flow values only. Depending on the nature of the works or project being designed, the peak flow may either be very critical or not so critical. For example the peak flow magnitude is critical in sizing a spillway for a dam. On the other hand, it may not be very critical in determining the water level for a stream with a wide floodplain re: the establishment of a design water level or in calculating the burial depth of a water pipeline across a stream. At a culvert on a stream with severe icings, the potential ice development, rather than the peak flow, is generally critical in determining the number and sizes of culverts required or whether a bridge is warranted.

Aside from this "warning note" about limitations of the results presented, the data base for calculating peak flows in the region is good to excellent for drainage areas greater than 10 km^2. For drainage areas less than 10 km^2 particularly those located in the steep front range of the Rockies, the data base is poor. Computing peak flows for these areas requires extensive experience.

3.2 FLOOD VOLUMES

The previous section calculated the maximum peak flow. For a small mountain stream, the maximum flow might only last one hour while on a large river like the McLeod upstream of Edson, a high flow might be sustained for several days.

The total volume of flow (flow in cubic metres per second times the length of time) from the beginning to the end of the flood is important in sizing dams and spillways, holding ponds and to determine for how long a certain threshold flow, critical to fish passage for example, could occur .

Figure 14 illustrates the typical rise and fall of flow of during a flood (lower left hand corner). The length of time the flood peak occurs is shown as flood duration in days in the upper right hand corner graph. The flood volumes for each Water Survey of Canada flow monitoring station for the 1:2 year to 1:100 year flood events was computed as shown on the Table. Lastly by analyzing the elevation of the drainage areas contributing to the flow monitoring stations, the runoff volumes from different elevation ranges (below 1250 m, 1250m to 1500m and above 1500m) was computed to generate 3 relationships between unit runoff volume versus return period. The total volume of flow during a flood event is thus computed by multiplying this unit value times the drainage area of the project's location.

Figure 15 presents the flow chart and methodologies to compute flood volumes for location on streams with or without a Water Survey of Canada flow monitoring stations.

3.3 MONTHLY FLOWS

The monthly flows for a range of low and high flow conditions are analyzed in this section. This information is useful in environmental impact assessments. For example if a project increases (due to clearing) or decreases (due to water withdrawal) the flow at a specific location, the data presented graphically and in tabular format on Figure 16 will enable the user to compute the hydrologic impact as a percentage of the natural flow.

Figure 17 illustrates the flow chart and steps to compute monthly flows for locations on streams with or without a Water Survey of Canada flow monitoring station.

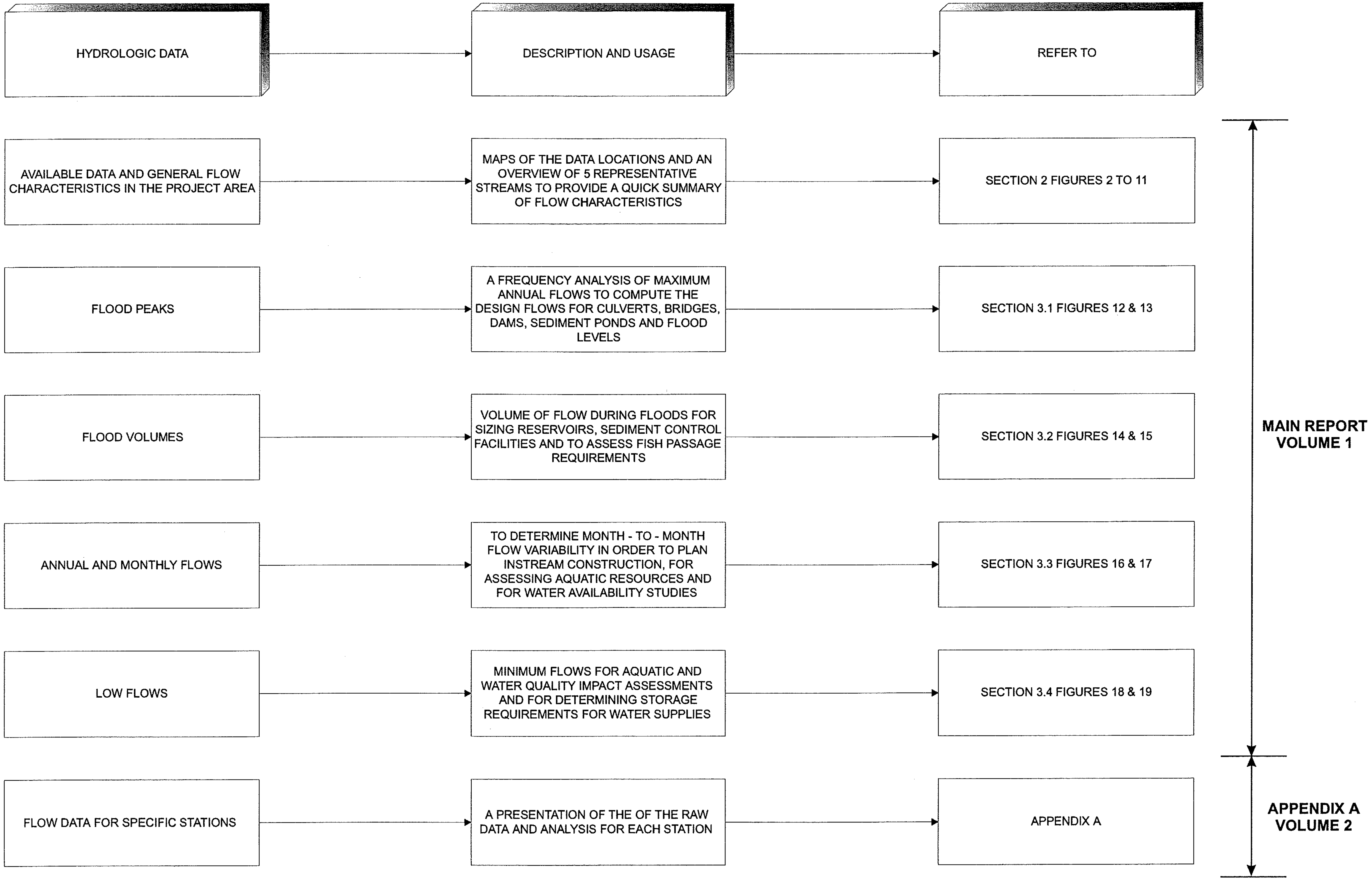
The regional analysis of monthly flows excluded the months of November to February inclusively since inadequate flow data exist for the winter months. As mentioned previously, only at the largest flow monitoring station in the region, the McLeod River above Embarras River, is flow measured during the winter months. To apply winter data from the McLeod River to another location, and particularly to small steep drainage areas, requires site specific observations, measurements and analysis by a hydrologic specialist.

3.4 LOW FLOWS

Extreme, short duration low flows are often analyzed for a 7 day period. For a 1:10 year drought criteria (1:10 year low flow), the event is commonly referred to as the $7Q_{10}$ Low Flow. From the available streamflow data, the lowest 7 day flow (the average flow for 7 days) was determined for each year and then a probability analysis undertaken to compute the 1:10 year low flow event. (On average, the flow would be equal to or less than this magnitude once every 10 years.)

Figure 18 presents a graphical relationship between the $7Q_{10}$ and drainage area. Except for the McLeod River above Embarras River, the data analyzed are for the open-water, non-winter period only. The effect of including the lower winter flow period can be seen by comparing the plotting location of the McLeod River above Embarras (the top right hand data point) to the general regional curve. For the non-winter flow period, the $7Q_{10}$ at this station would be about 4.0 m^3/second, (the plotting position of the regional curve straight above the data point) compared to a winter $7Q_{10}$ of 1.1 m^3/second. The qualitative relationships between the non-winter and winter flows for the McLeod River above Embarras River is also demonstrated for 6 years on Figure 11. As a first estimation, the winter $7Q_{10}$ for the region can be determined by drawing a line below and parallel to the regional line and through the McLeod River above Embarras River data point. As noted on this Figure, site specific winter flow values should be determined from observations, measurements and analysis by a hydrologic specialist.

Figure 19 illustrates the flow chart and steps to compute the $7Q_{10}$ Low Flow for the non-winter period at locations on streams with or without a Water Survey of Canada flow monitoring station. It also indicates a first order approximation that can be used to compute the winter $7Q_{10}$ Low flow for any location in the region.



HYDROLOGIC DATA	DESCRIPTION AND USAGE	REFER TO
AVAILABLE DATA AND GENERAL FLOW CHARACTERISTICS IN THE PROJECT AREA	MAPS OF THE DATA LOCATIONS AND AN OVERVIEW OF 5 REPRESENTATIVE STREAMS TO PROVIDE A QUICK SUMMARY OF FLOW CHARACTERISTICS	SECTION 2 FIGURES 2 TO 11
FLOOD PEAKS	A FREQUENCY ANALYSIS OF MAXIMUM ANNUAL FLOWS TO COMPUTE THE DESIGN FLOWS FOR CULVERTS, BRIDGES, DAMS, SEDIMENT PONDS AND FLOOD LEVELS	SECTION 3.1 FIGURES 12 & 13
FLOOD VOLUMES	VOLUME OF FLOW DURING FLOODS FOR SIZING RESERVOIRS, SEDIMENT CONTROL FACILITIES AND TO ASSESS FISH PASSAGE REQUIREMENTS	SECTION 3.2 FIGURES 14 & 15
ANNUAL AND MONTHLY FLOWS	TO DETERMINE MONTH - TO - MONTH FLOW VARIABILITY IN ORDER TO PLAN INSTREAM CONSTRUCTION, FOR ASSESSING AQUATIC RESOURCES AND FOR WATER AVAILABILITY STUDIES	SECTION 3.3 FIGURES 16 & 17
LOW FLOWS	MINIMUM FLOWS FOR AQUATIC AND WATER QUALITY IMPACT ASSESSMENTS AND FOR DETERMINING STORAGE REQUIREMENTS FOR WATER SUPPLIES	SECTION 3.4 FIGURES 18 & 19
FLOW DATA FOR SPECIFIC STATIONS	A PRESENTATION OF THE OF THE RAW DATA AND ANALYSIS FOR EACH STATION	APPENDIX A

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FOOTHILLS MODEL FOREST

MODEL FOREST NETWORK
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NO.	DATE	REVISION	BY

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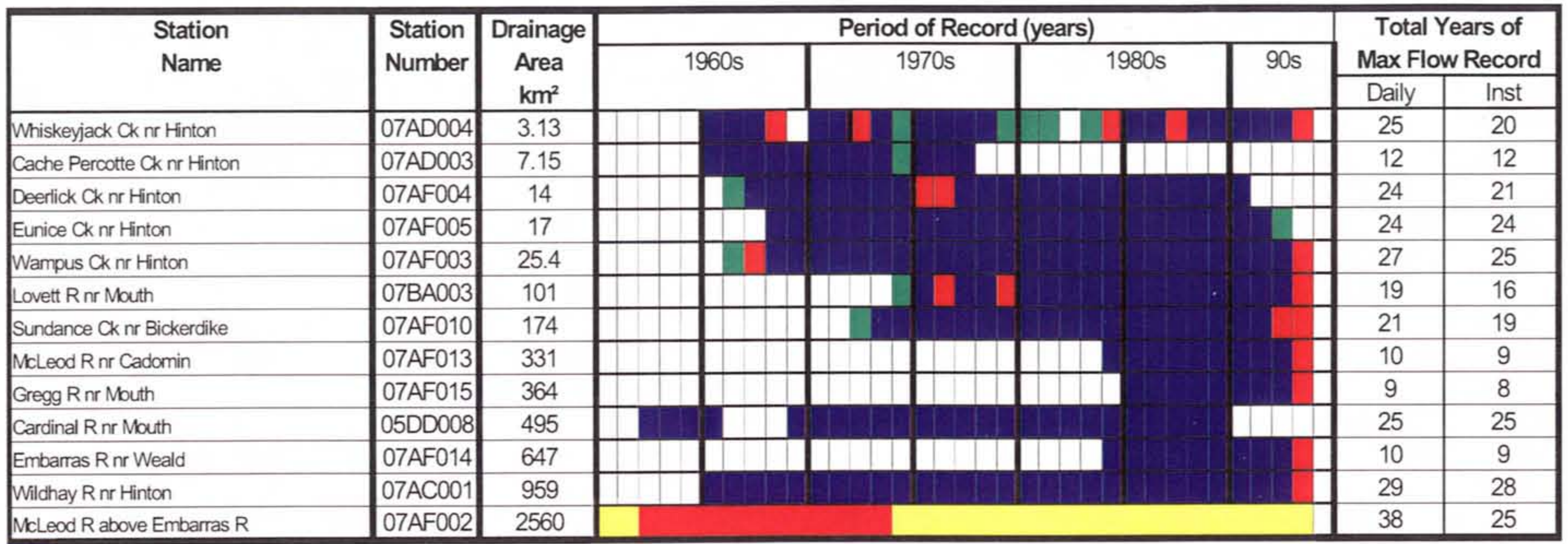
APP: Wim Veldman
REV: 0
DATE: Feb 1997

TITLE:
HYDROLOGIC OPERATIONAL MANUAL

FLOW CHART OF HYDROLOGIC DATA, USAGE AND MANUAL ORGANIZATION

JOB NO. 182
FIG. 1

REGIONAL STREAMFLOW GAUGING STATIONS



Station Name	Station Number	Drainage Area km²	Total Years of Max Flow Record Daily	Total Years of Max Flow Record Inst
Whiskeyjack Ck nr Hinton	07AD004	3.13	25	20
Cache Percotte Ck nr Hinton	07AD003	7.15	12	12
Deerlick Ck nr Hinton	07AF004	14	24	21
Eunice Ck nr Hinton	07AF005	17	24	24
Wampus Ck nr Hinton	07AF003	25.4	27	25
Lovett R nr Mouth	07BA003	101	19	16
Sundance Ck nr Bickerdike	07AF010	174	21	19
McLeod R nr Cadomin	07AF013	331	10	9
Gregg R nr Mouth	07AF015	364	9	8
Cardinal R nr Mouth	05DD008	495	25	25
Embarras R nr Weald	07AF014	647	10	9
Wildhay R nr Hinton	07AC001	959	29	28
McLeod R above Embarras R	07AF002	2560	38	25

🟦 = Seasonal records - maximum instantaneous and maximum daily values

🟨 = Continuous records - maximum instantaneous and maximum daily values

🟥 = Maximum daily values only

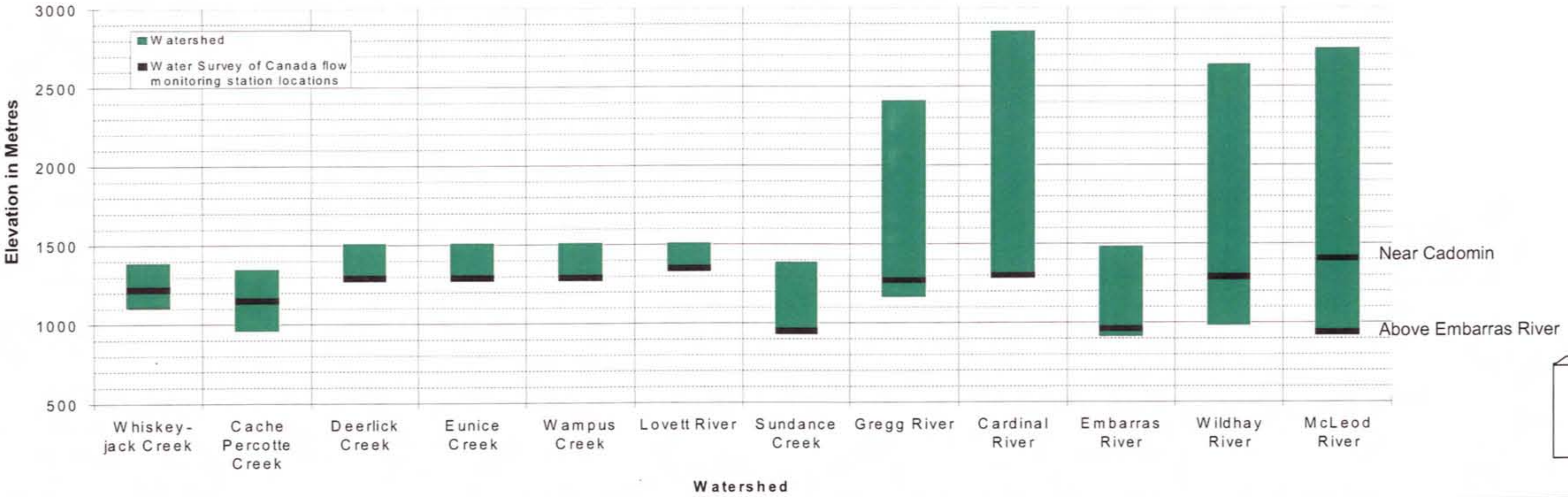
🟩 = Miscellaneous records - maximum values unavailable

INCREASING SIZE OF DRAINAGE AREA

REGIONAL HYDROLOGIC FLOW DATA

NOTES:

1. Only flow monitoring stations in the Model Forest area with 9 years or more data tabulated and used in the hydrologic analysis.



SHOWS THE ELEVATION RANGE FOR THE DIFFERENT WATERSHEDS AND THE LOCATION OF THE FLOW MONITORING STATIONS

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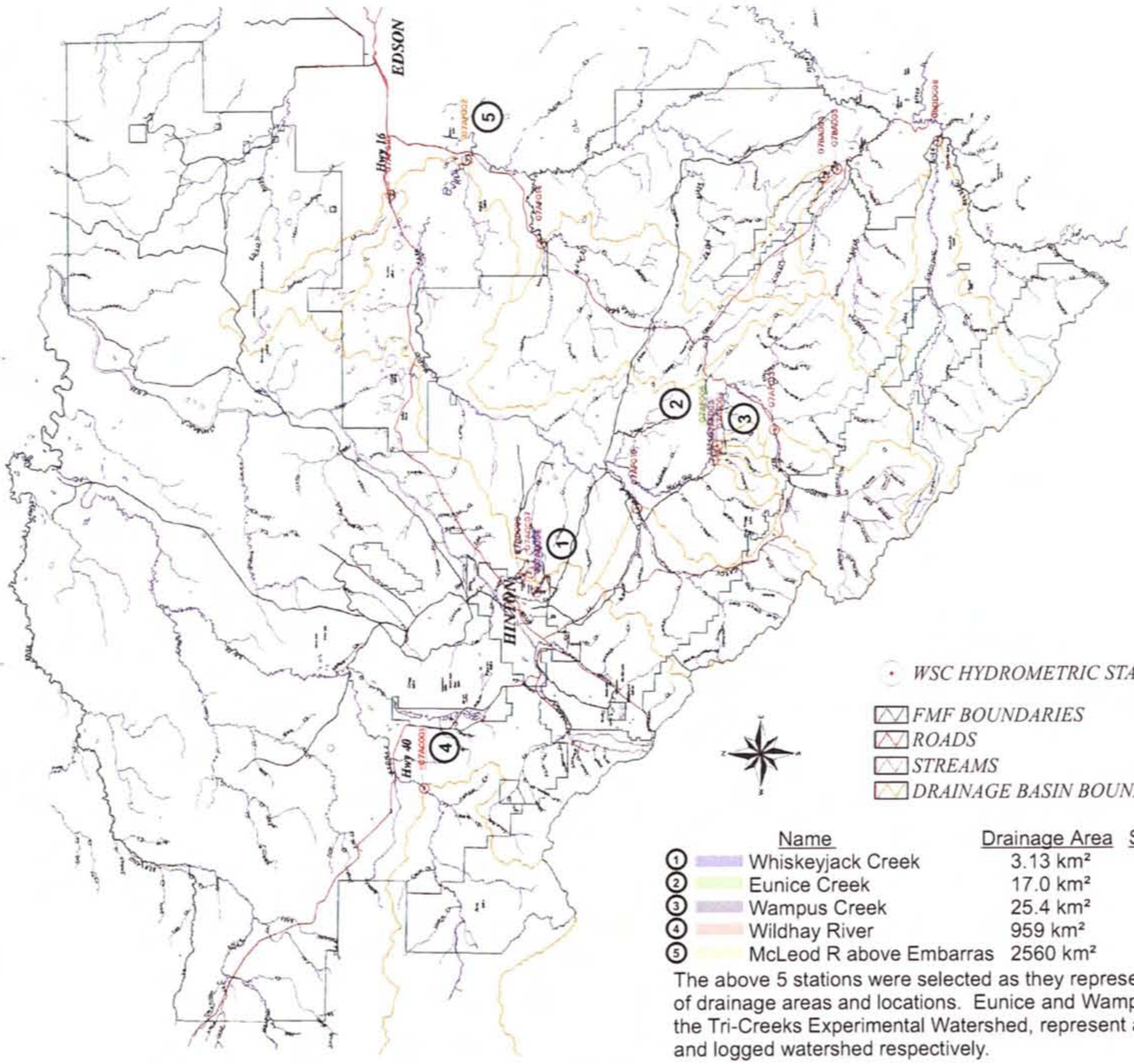
HYDROLOGIC OPERATIONAL MANUAL

EXTENT AND CHARACTERISTICS
OF FLOW MONITORING STATIONS
AND WATERSHEDS

JOB NO. 182
FIG. 3

FOR FULL SIZE MAP, SEE FIGURE 2. MAP REPEATED HERE TO ILLUSTRATE LOCATION OF REPRESENTATIVE FLOW MONITORINGSTATIONS FOR WHICH DATA IS SHOWN ON FIGURES 5 - 11.



- *WSC HYDROMETRIC STATIONS*

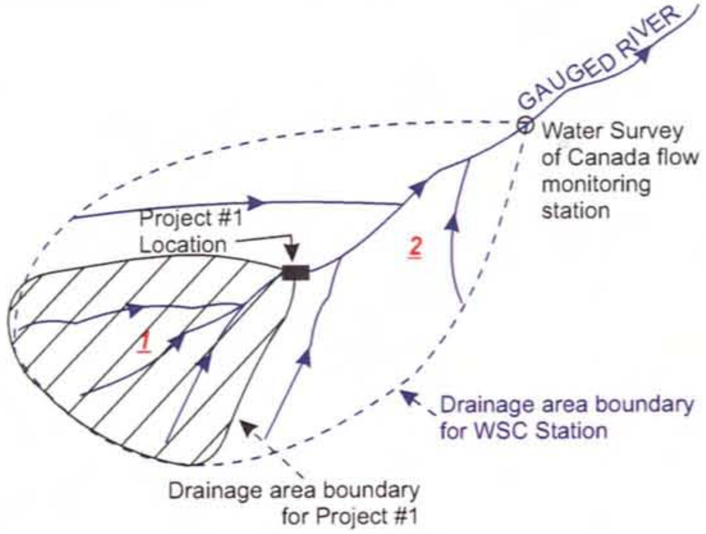
▨ *FMF BOUNDARIES*
▨ *ROADS*
▨ *STREAMS*
▨ *DRAINAGE BASIN BOUNDARIES*

	Name	Drainage Area	See Figures
①	Whiskeyjack Creek	3.13 km²	5, 10
②	Eunice Creek	17.0 km²	6, 10
③	Wampus Creek	25.4 km²	7, 10
④	Wildhay River	959 km²	8, 10
⑤	McLeod R above Embarras	2560 km²	9, 10, 11

The above 5 stations were selected as they represent the range of drainage areas and locations. Eunice and Wampus, part of the Tri-Creeks Experimental Watershed, represent a natural and logged watershed respectively.

HOW TO DETERMINE DRAINAGE AREA

To calculate the drainage area for Project #1:
- obtain a map with elevation contours,
- draw in the watershed boundary which defines the area draining into the stream above the location of Project #1,
- overlay transparent grid paper and trace the watershed boundary on the grid paper,
- using the same scale as the map, draw a 1 kilometre by 1 kilometre box on the grid paper and count the number of full and partial boxes inside the watershed boundary *1*. For a large area use a 10 kilometre by 10 kilometre box or planimeter,
- if Project #1 is close to the Water Survey of Canada flow station where the drainage area is known (Figure 3) just measure the area between Project #1 and the WSC Station *2* and subtract this area from that of the WSC Station drainage area.



HOW FLOW IS DETERMINED IN A RIVER

①

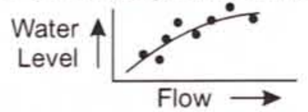
FLOW MEASUREMENT

- The depth, speed (velocity) and width of the river are measured and from this the flow (m³/s) is computed by Water Survey of Canada or Provincial technicians or others working for private companies

②

DEVELOPMENT OF A RATING CURVE FOR A RIVER

- Field measurements are taken for a wide range of flow and a



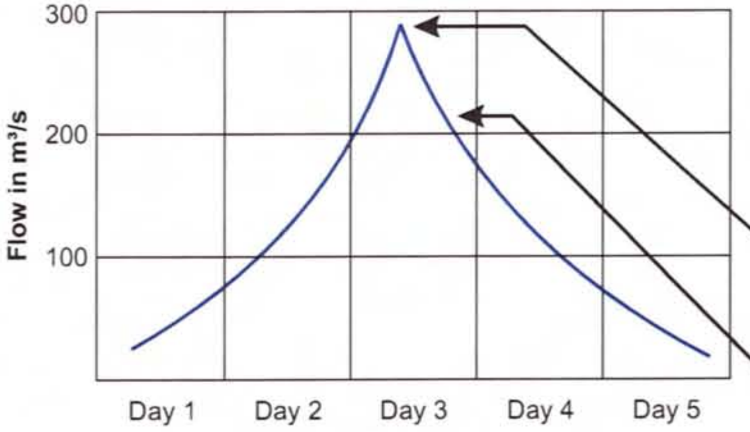
curve prepared from the individual measurements.

③

A FLOW MONITORING STATION

- A continuous **station** records the water level on a graph or in an electronic format

From the graph in ②, the flow can thus be computed at any time knowing the water level. A **staff gauge**, often installed on a short term basis for a specific project, gives water level and thus flow data only at the time of the reading. What happens to the flow between site visits is not known. A **crest gauge** records the highest water level that occured between site visits.



Maximum instantaneous flow (the maximum flow which may occur only for one or two hours during the day in which the highest flow is recorded)

Maximum daily flow (the average 24 hour flow for the highest flow day)

DEFINITION SKETCH FOR FLOW

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FOOTHILLS MODEL FOREST

MODEL FOREST NETWORK
RÉSEAU DE FORÊTS MODÈLES

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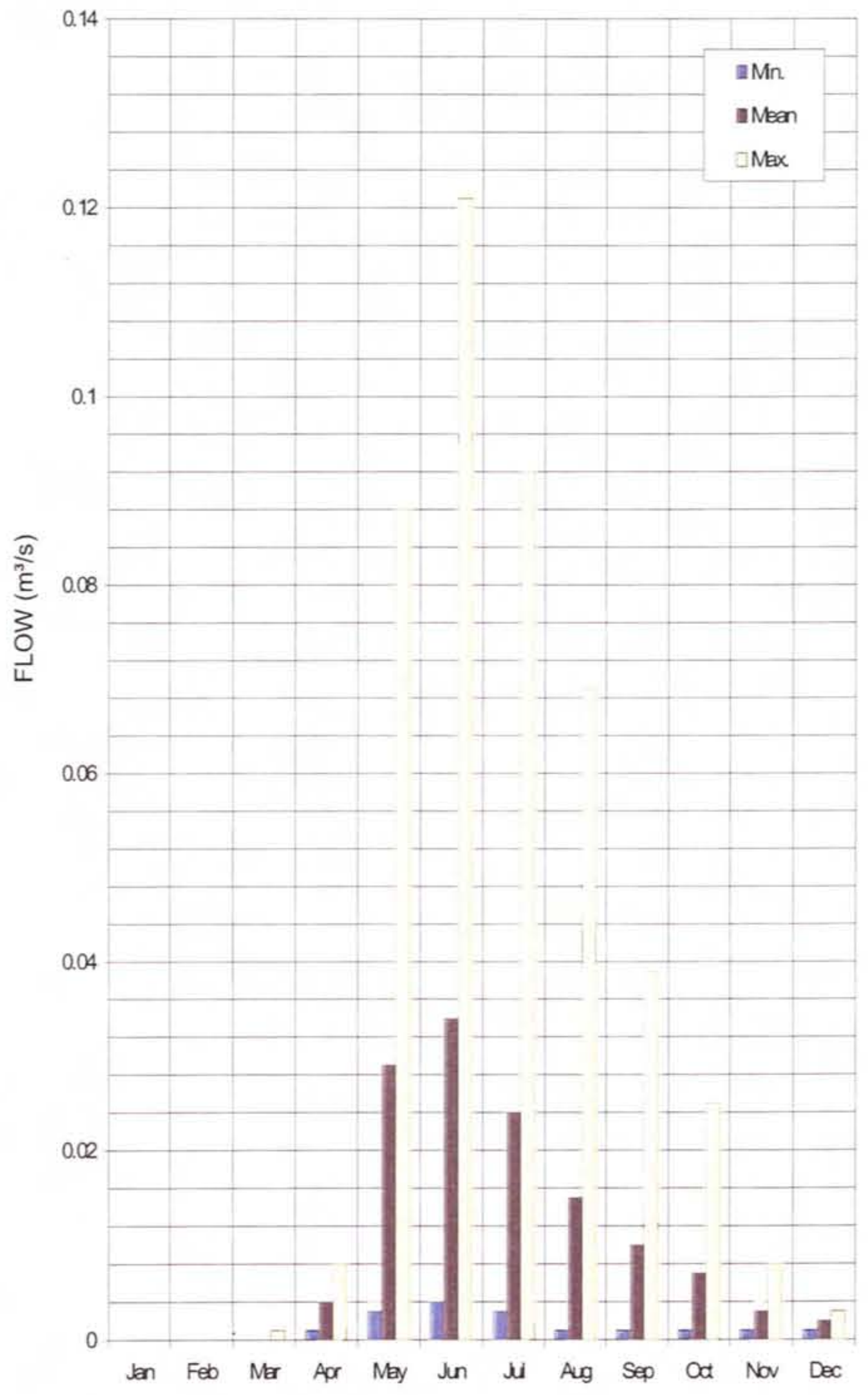
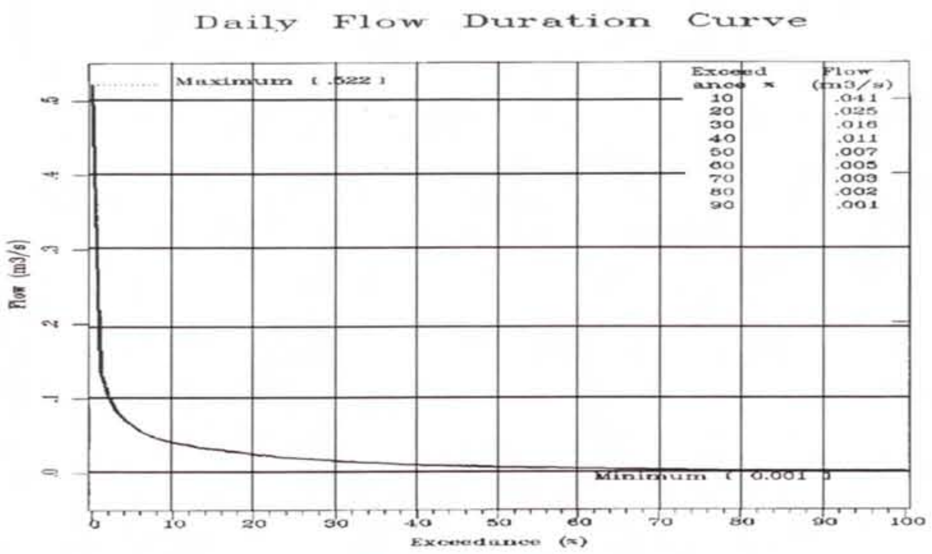
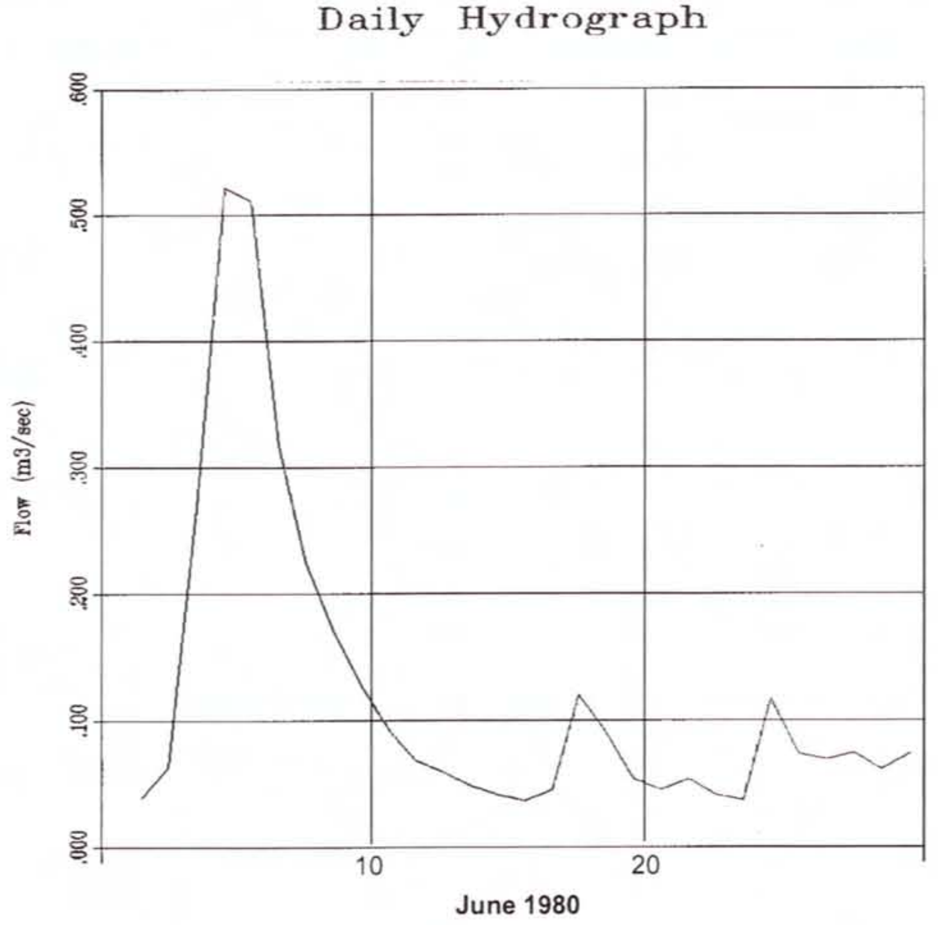
REPRESENTATIVE FLOW MONITORING STATIONS AND DEFINITIONS
JOB NO. **182**
FIG. **4**



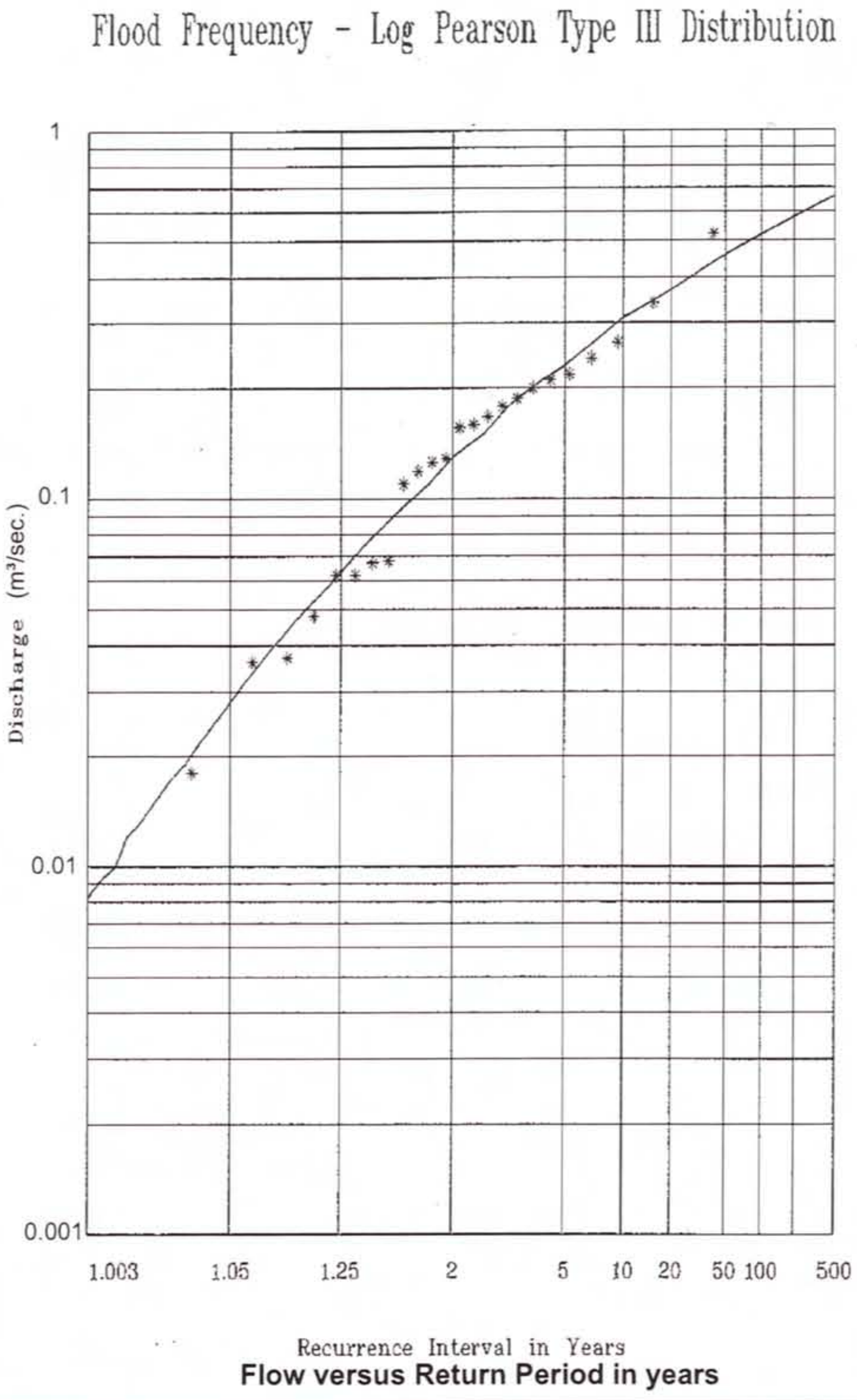
Monthly Flow Patterns
1965-1993



Daily Flow Duration



Maximum Recorded Flood Hydrograph



Flow versus Return Period in years

Water Survey of Canada Station No. 07AD004
Drainage Area 3.13 km²

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MODEL FOREST NETWORK
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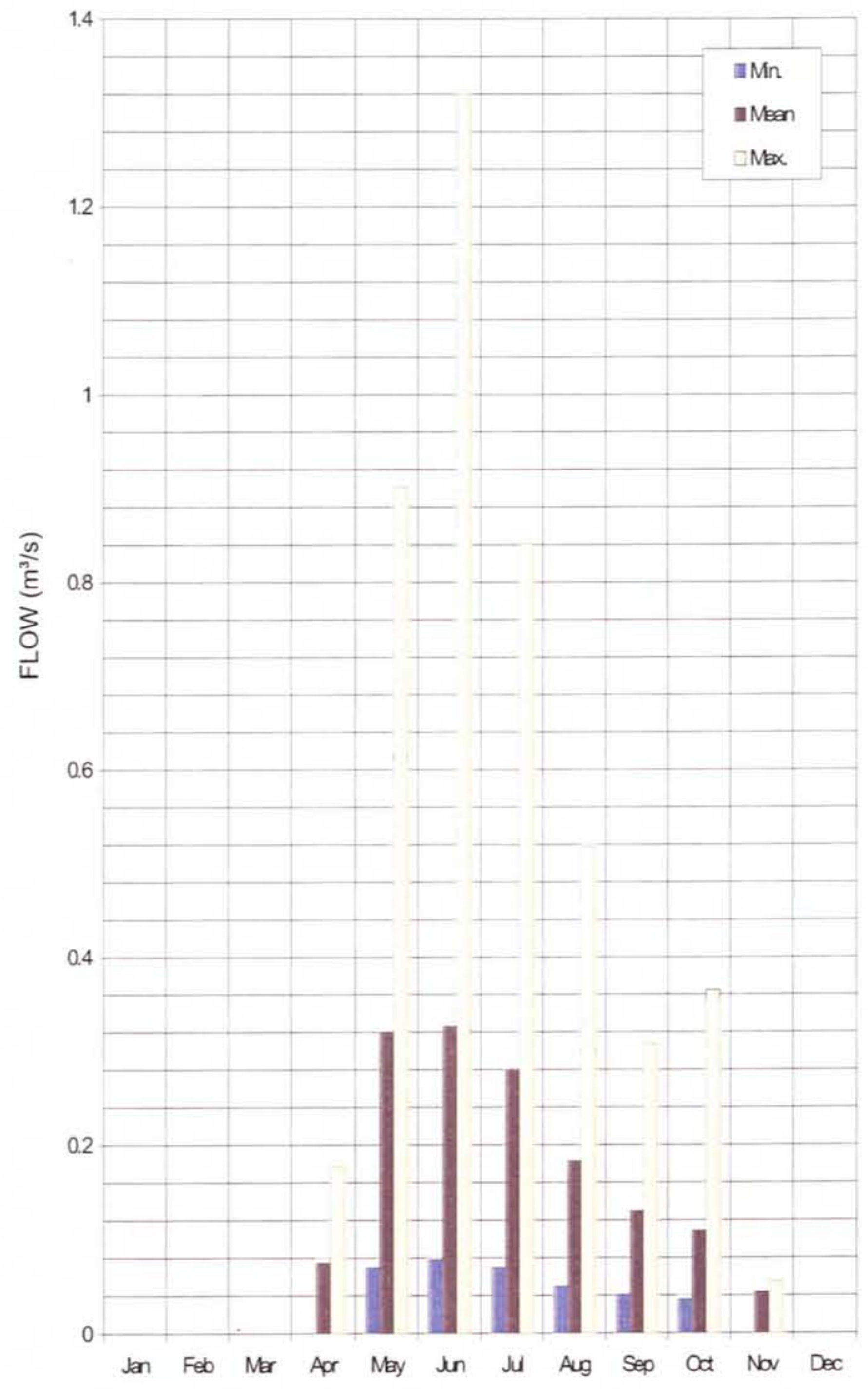
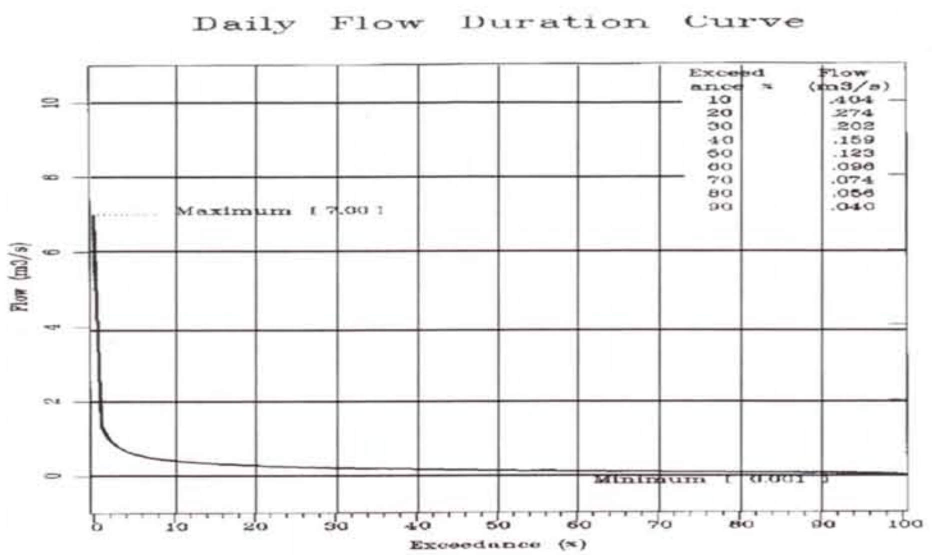
WHISKEYJACK CREEK

OVERVIEW OF FLOW CHARACTERISTICS

JOB NO. 182
FIG. 5

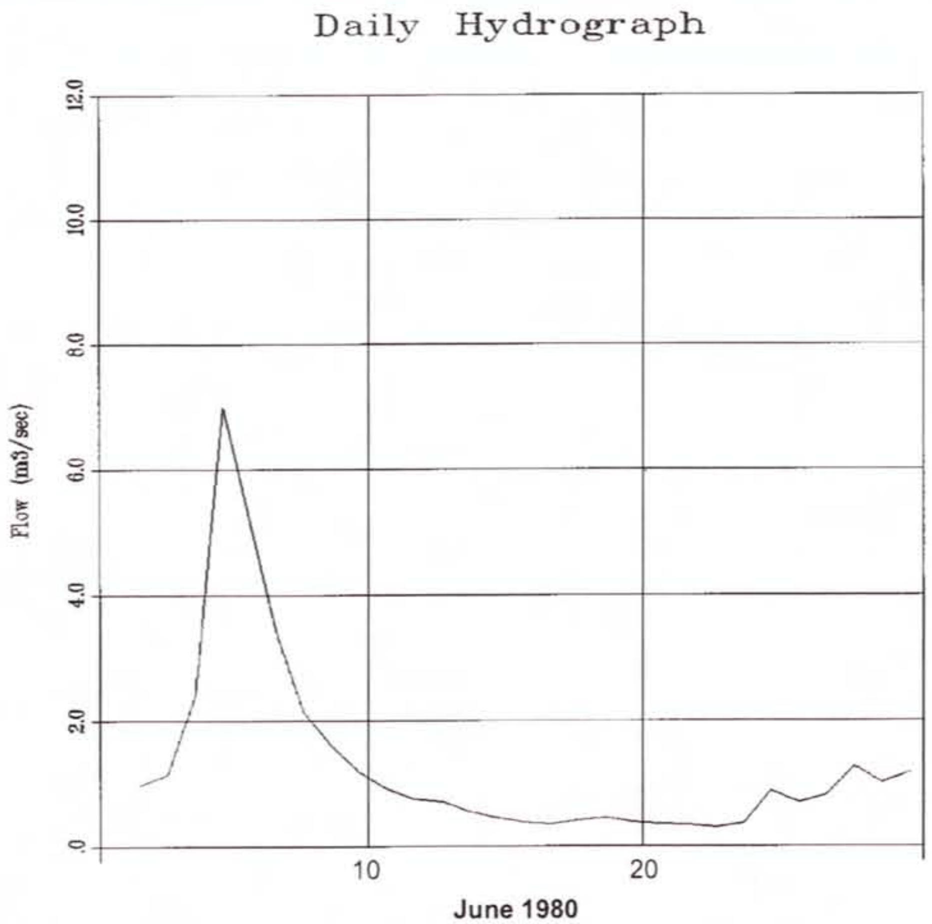


Monthly Flow Patterns
1967-1993

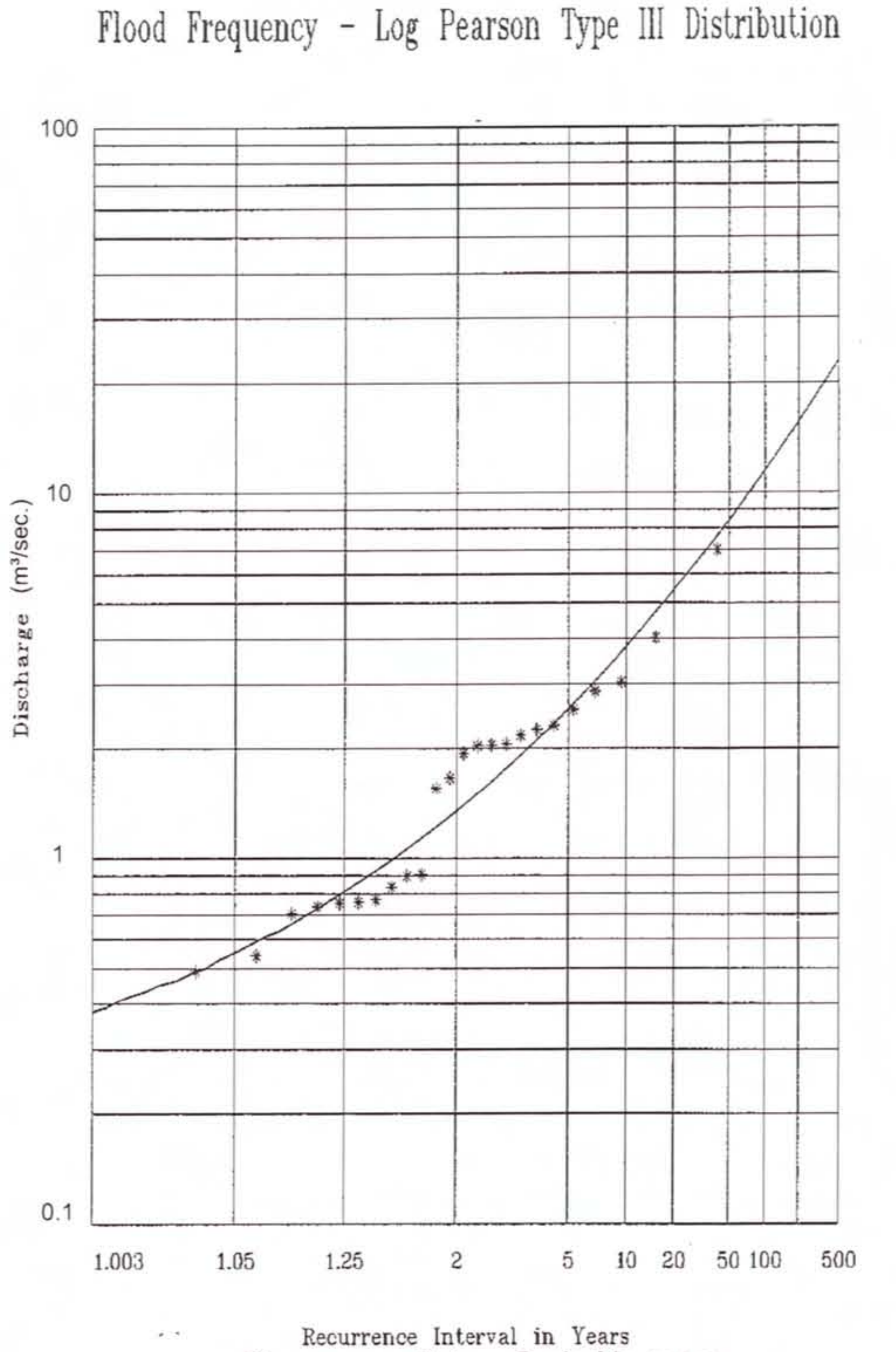


Exceedance %	Flow (m3/s)
10	.404
20	.274
30	.202
40	.159
50	.123
60	.096
70	.074
80	.056
90	.040

Daily Flow Duration



Maximum Recorded Flood Hydrograph



Flow versus Return Period in years

Water Survey of Canada Station No. 07AF005
Drainage Area 17 km²

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MODEL FOREST NETWORK
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EUNICE CREEK
OVERVIEW OF FLOW CHARACTERISTICS

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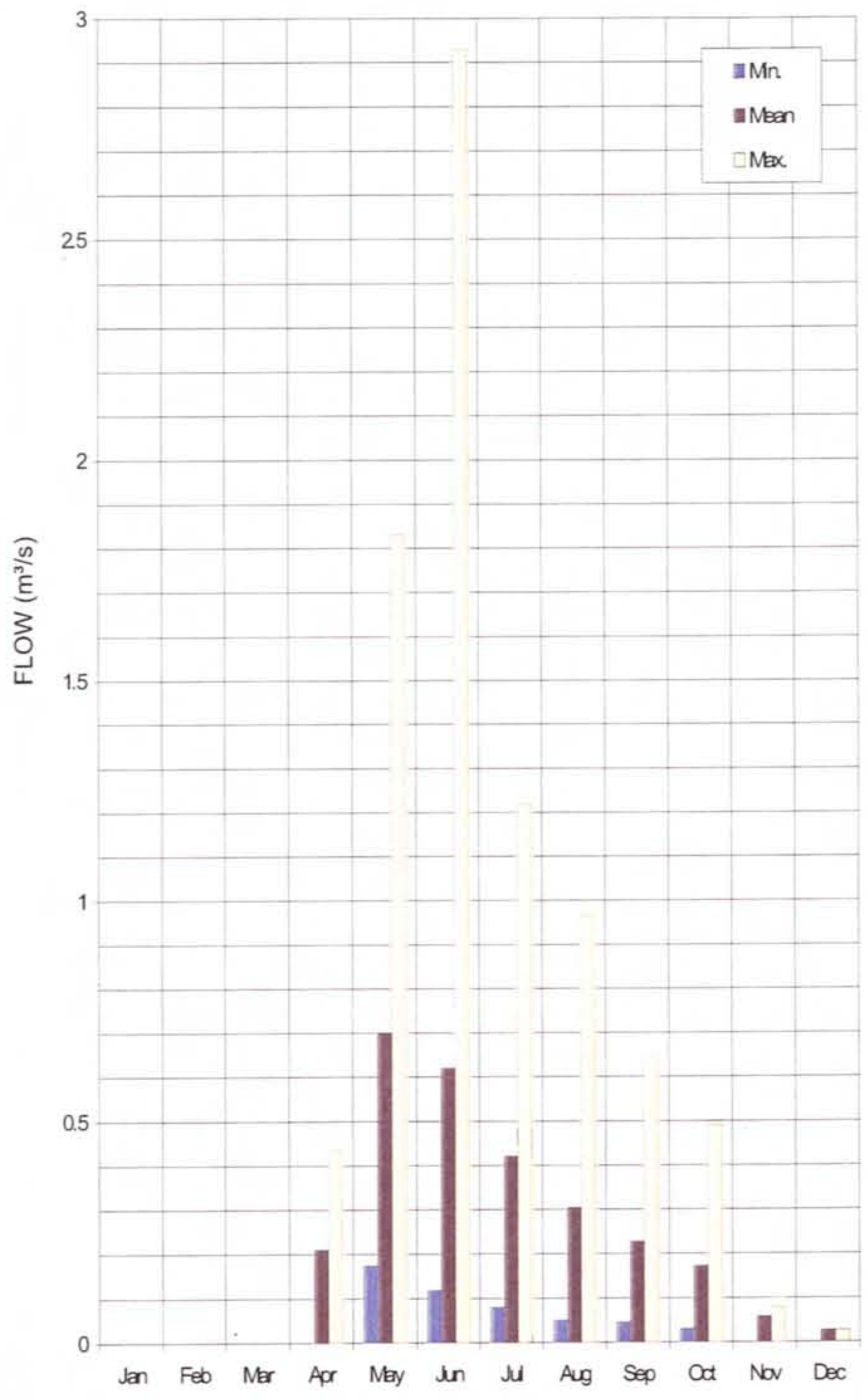
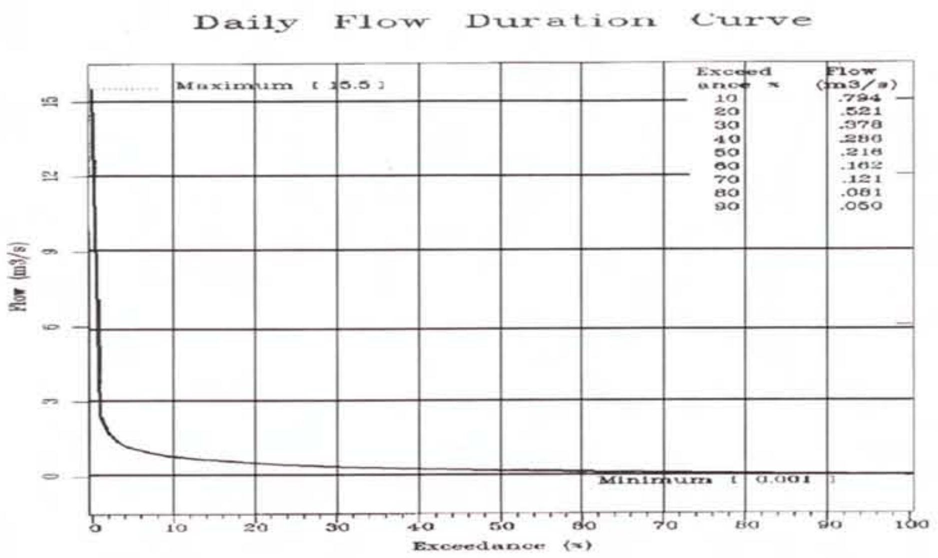
FIG. 6

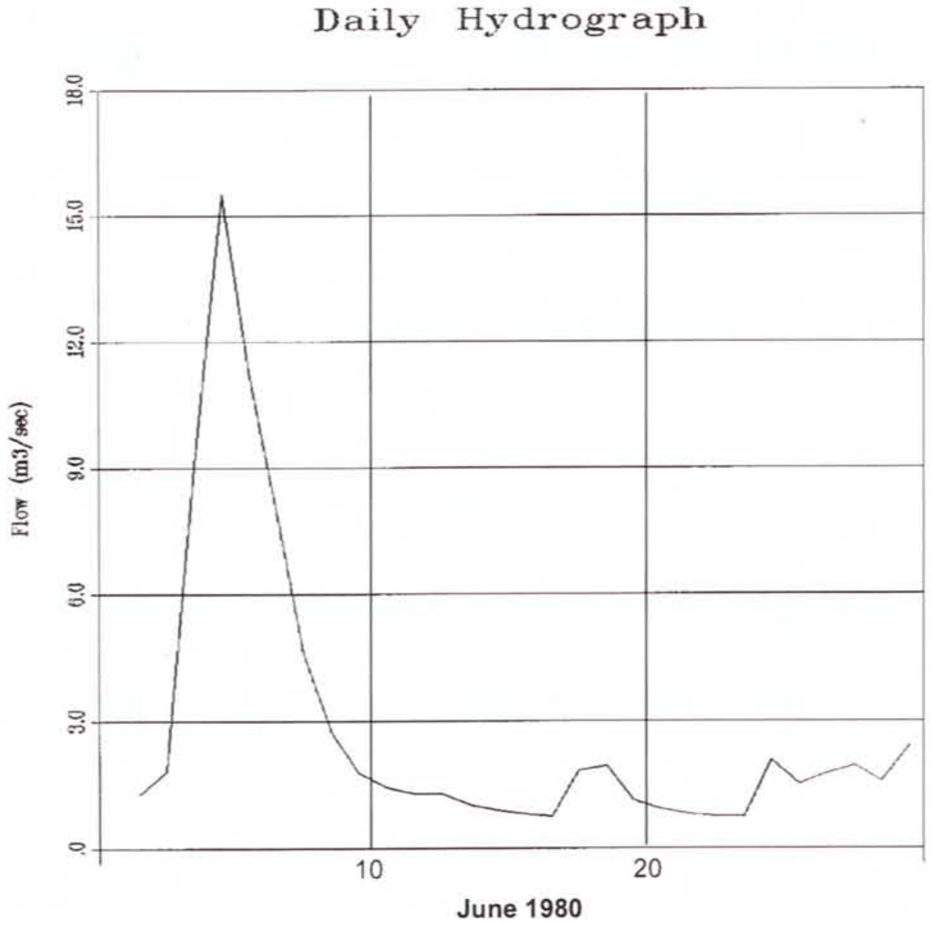


Monthly Flow Patterns
1966-1993

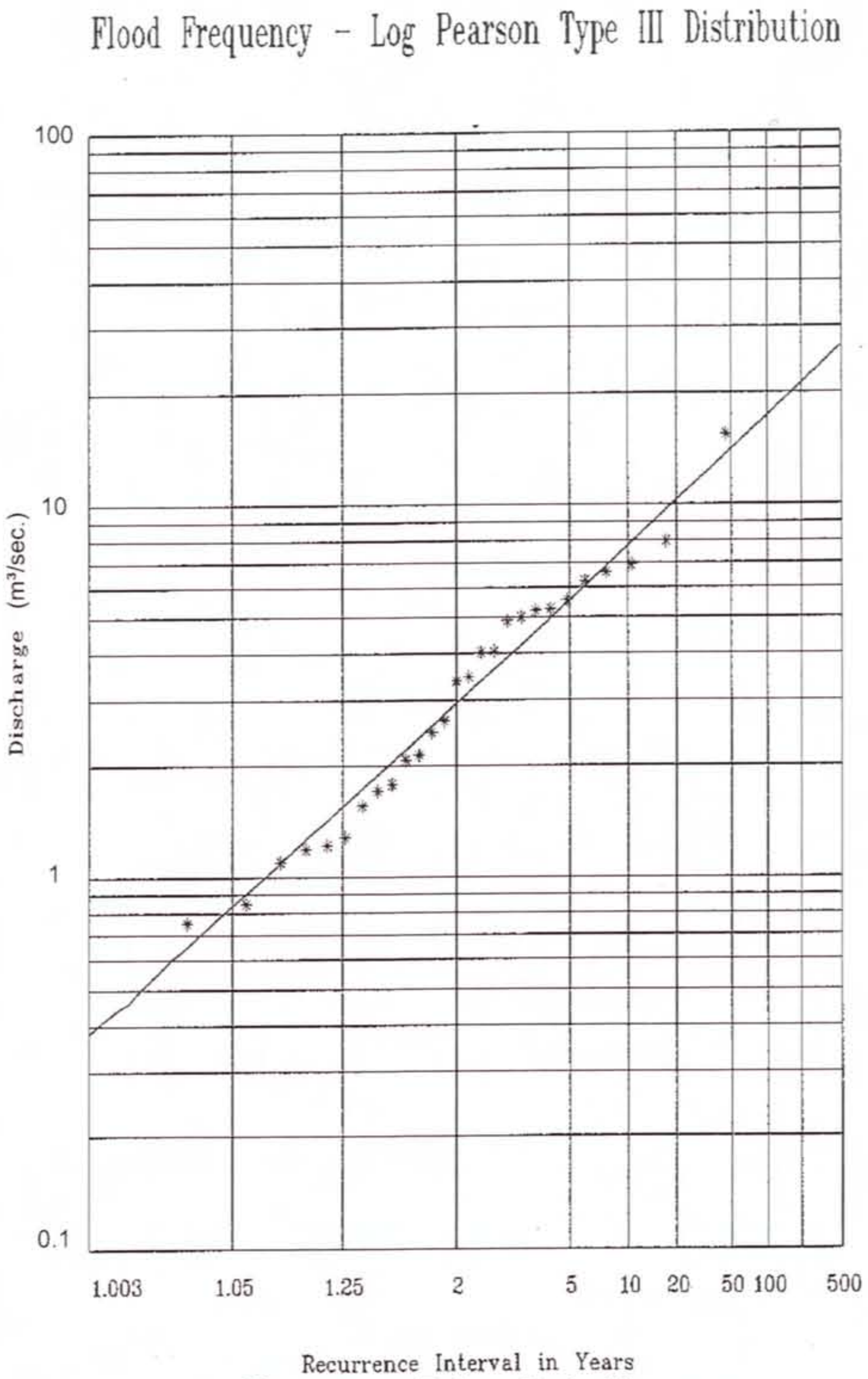


Exceedance %	Flow (m3/s)
10	.794
20	.521
30	.378
40	.286
50	.216
60	.162
70	.121
80	.081
90	.050

Daily Flow Duration



Maximum Recorded Flood Hydrograph



Flow versus Return Period in years

Water Survey of Canada Station No. 07AF003
Drainage Area 25.4 km²

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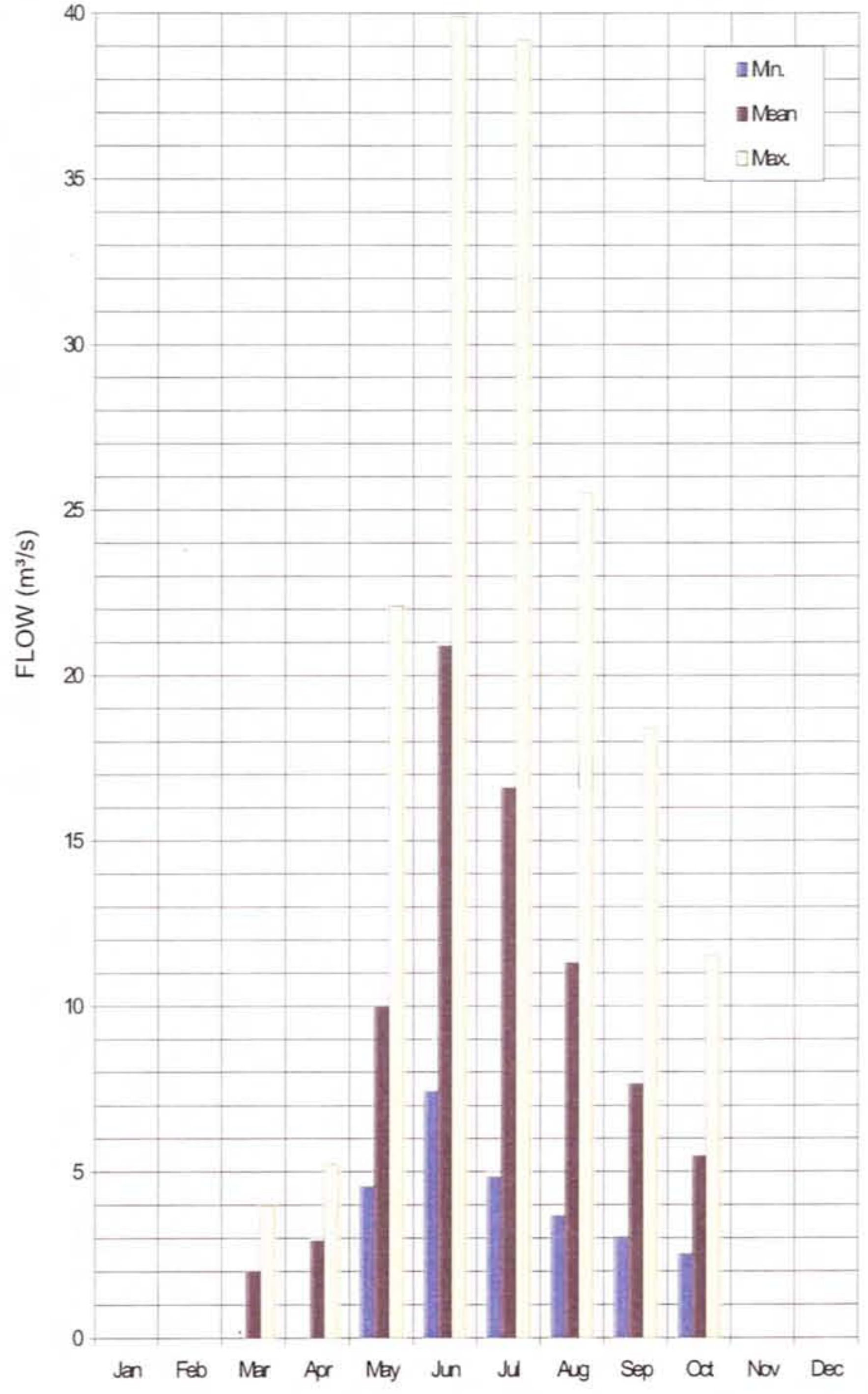
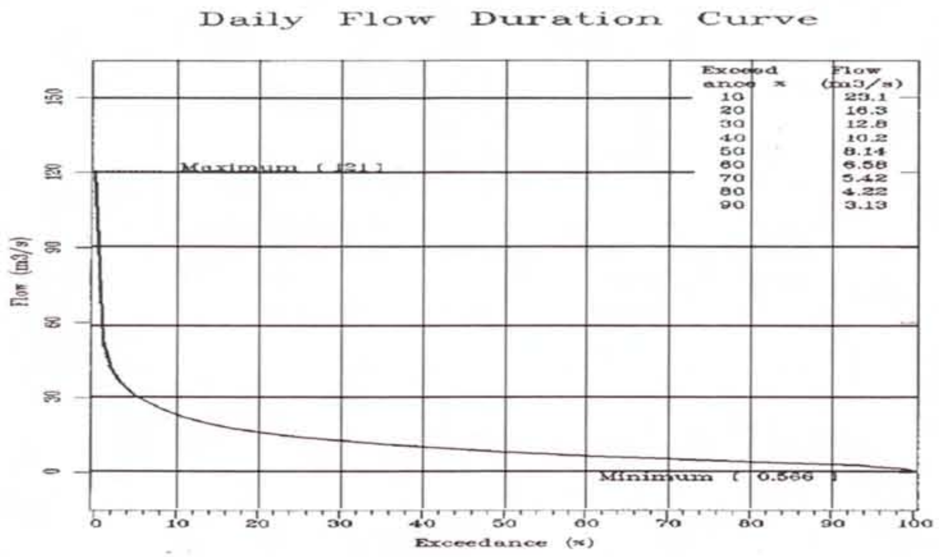
WAMPUS CREEK
OVERVIEW OF FLOW CHARACTERISTICS
JOB NO. 182
FIG. 7

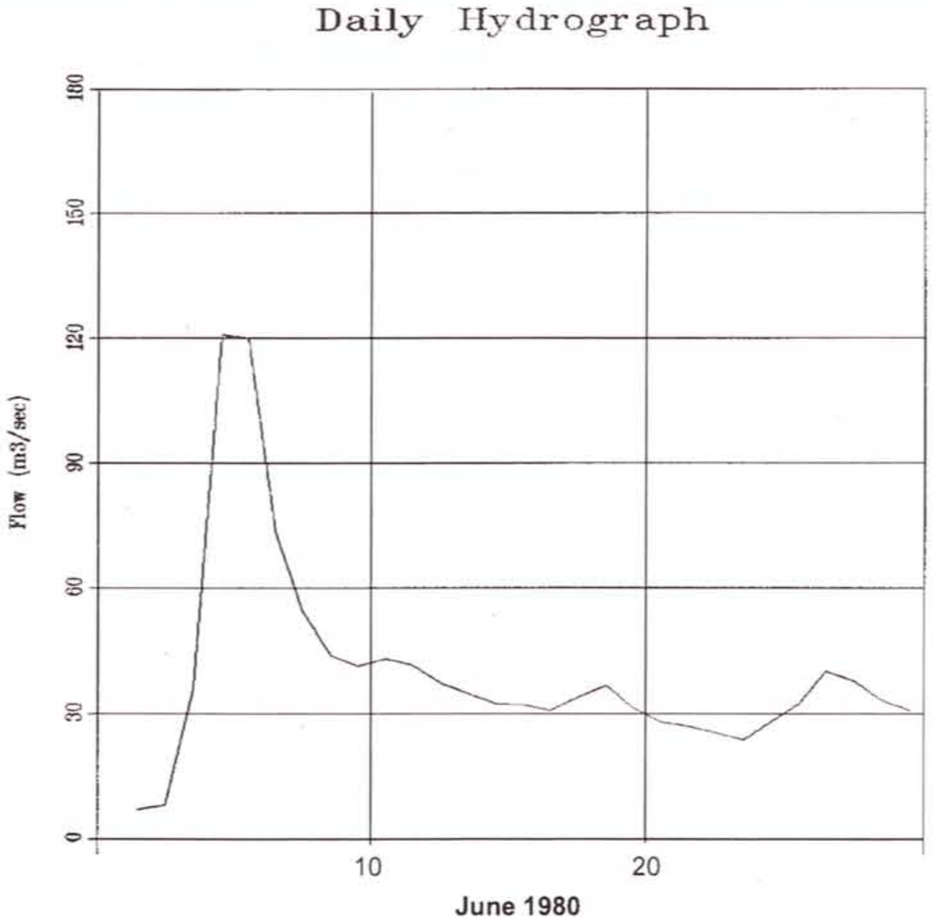


Monthly Flow Patterns
1965-1993

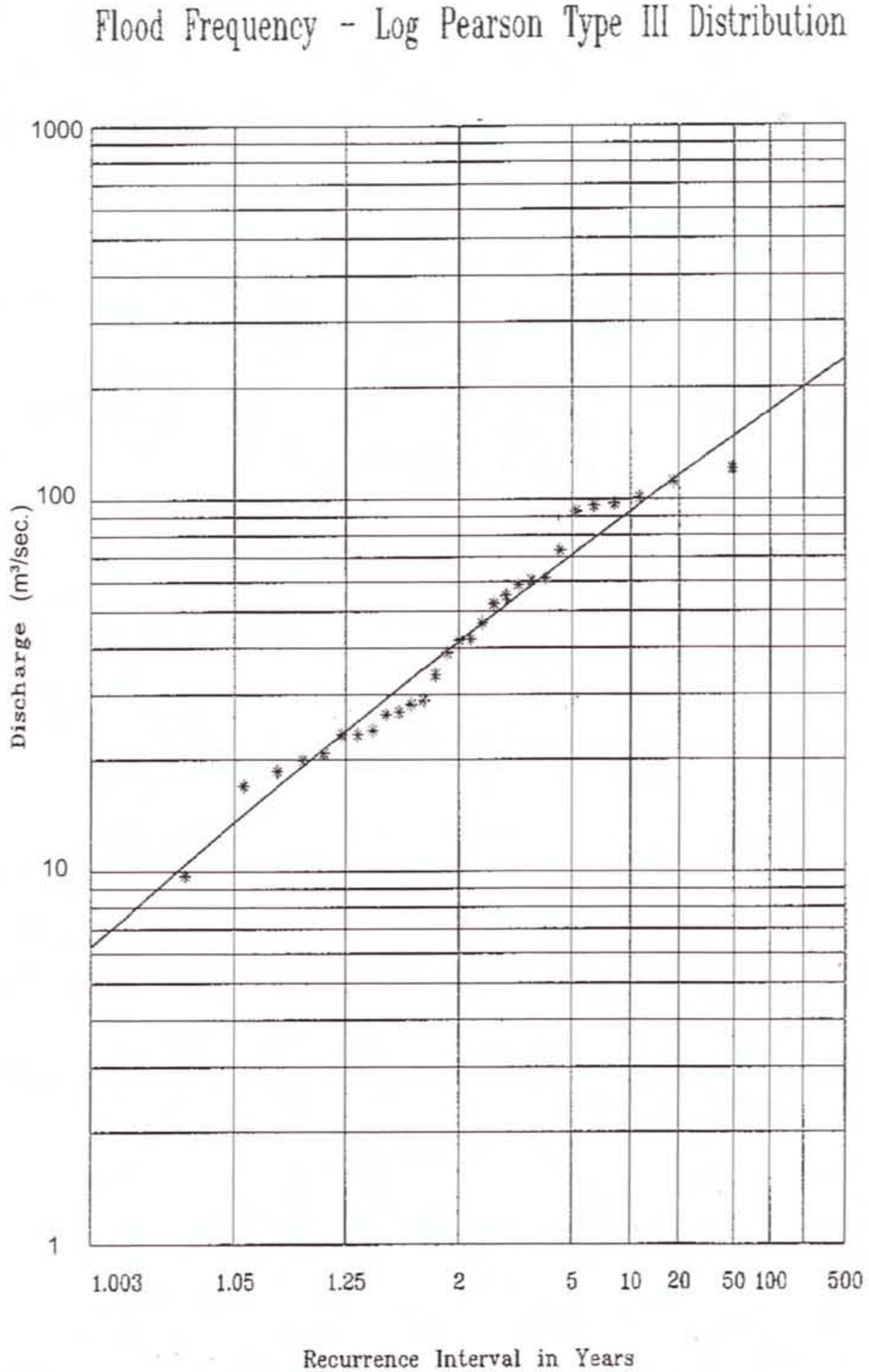


Exceedance %	Flow (m3/s)
10	23.1
20	16.3
30	12.8
40	10.2
50	8.14
60	6.58
70	5.42
80	4.22
90	3.13

Daily Flow Duration



Maximum Recorded Flood Hydrograph



Flow versus Return Period in years

Water Survey of Canada Station No. 07AC001
Drainage Area 959 km²

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MODEL FOREST NETWORK
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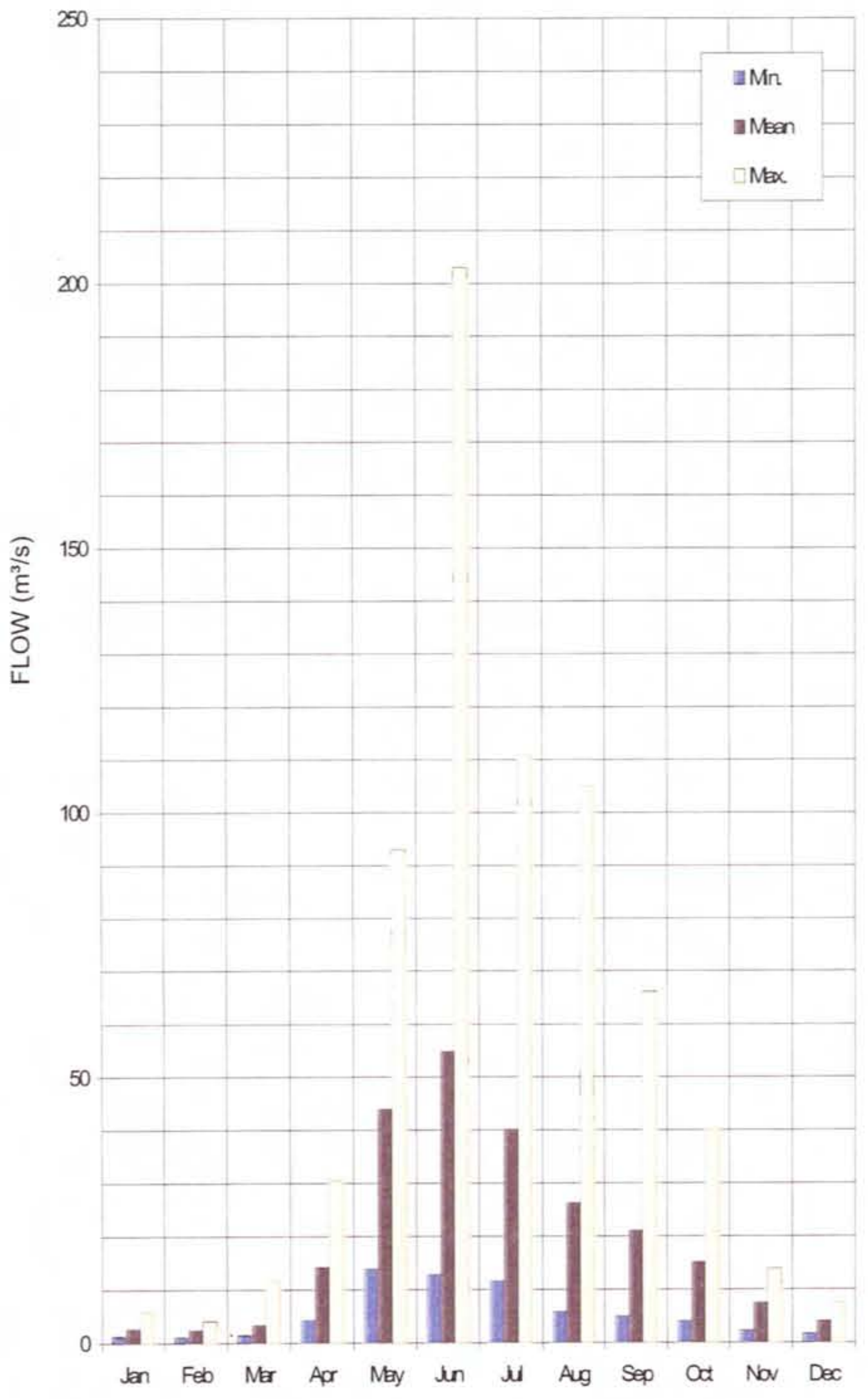
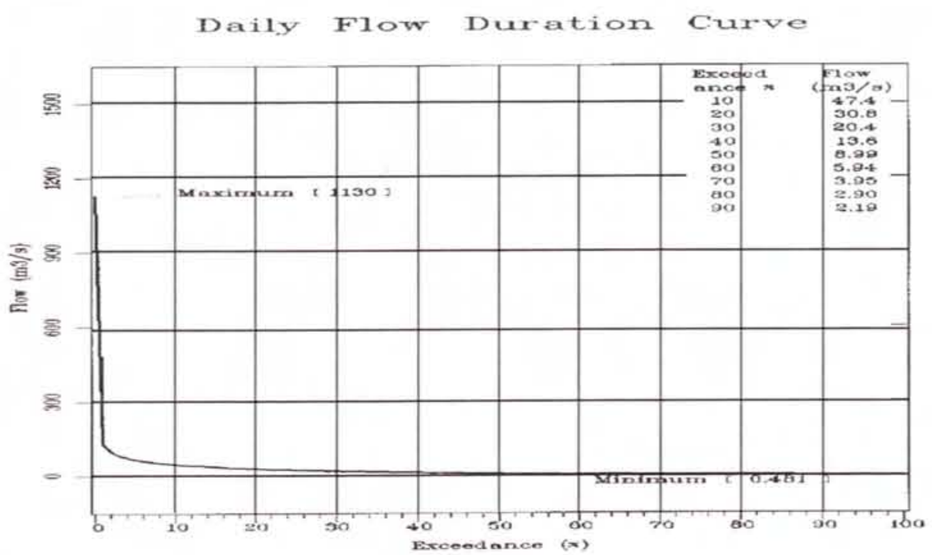
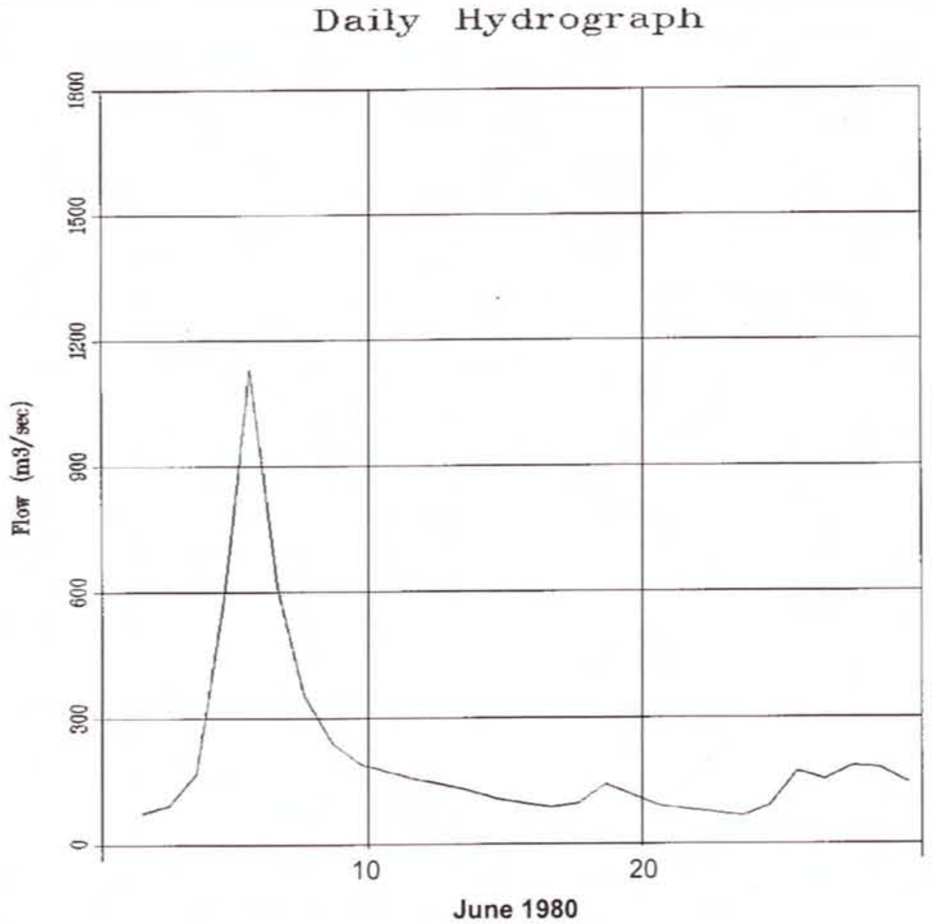
WILDHAY RIVER
OVERVIEW OF FLOW CHARACTERISTICS
JOB NO. 182
FIG. 8



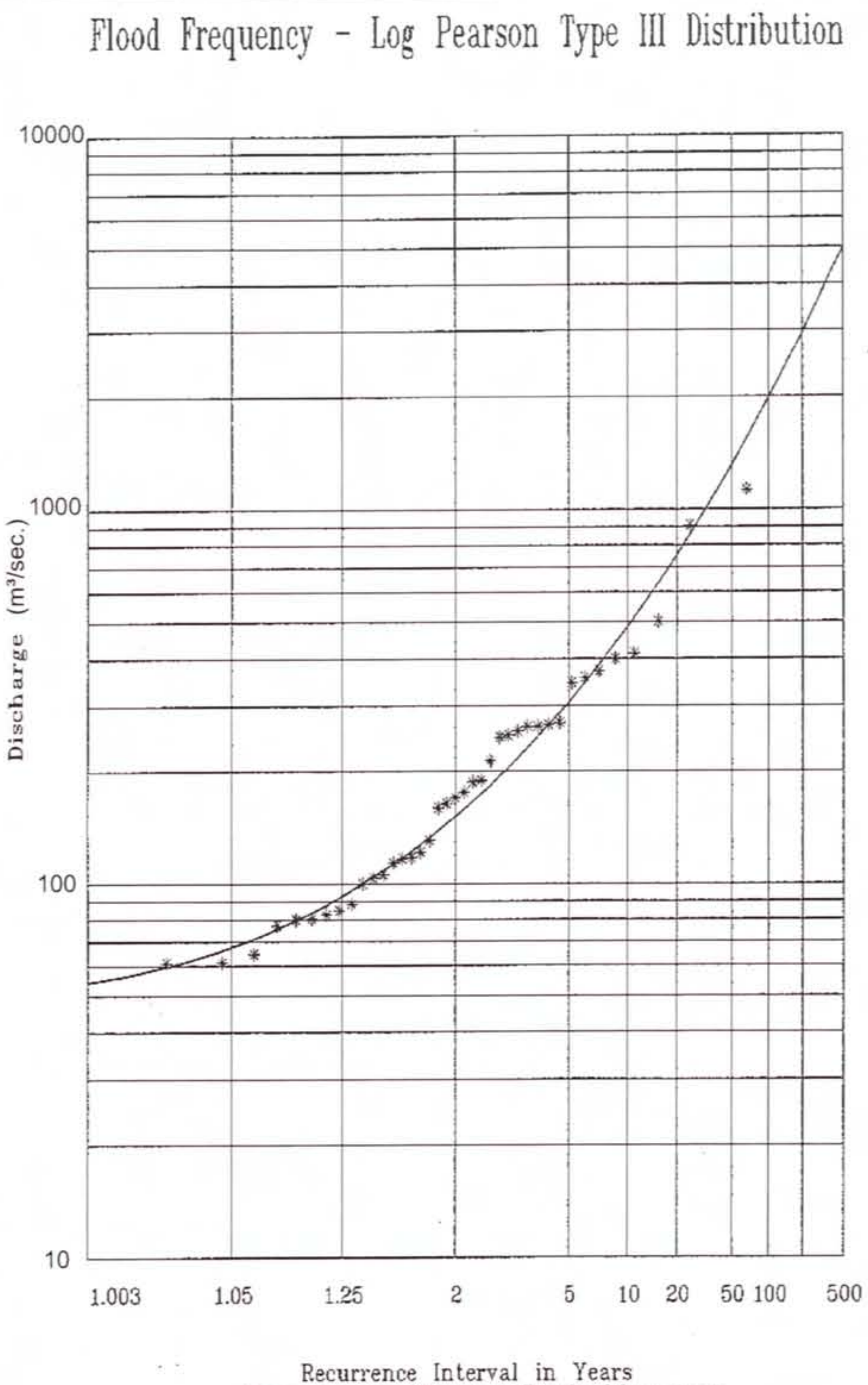
Monthly Flow Patterns
1954-1993



Daily Flow Duration



Maximum Recorded Flood Hydrograph



Flow versus Return Period in years

Water Survey of Canada Station No. 07AF002
Drainage Area 2560 km²

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FOOTHILLS MODEL FOREST

MODEL FOREST NETWORK
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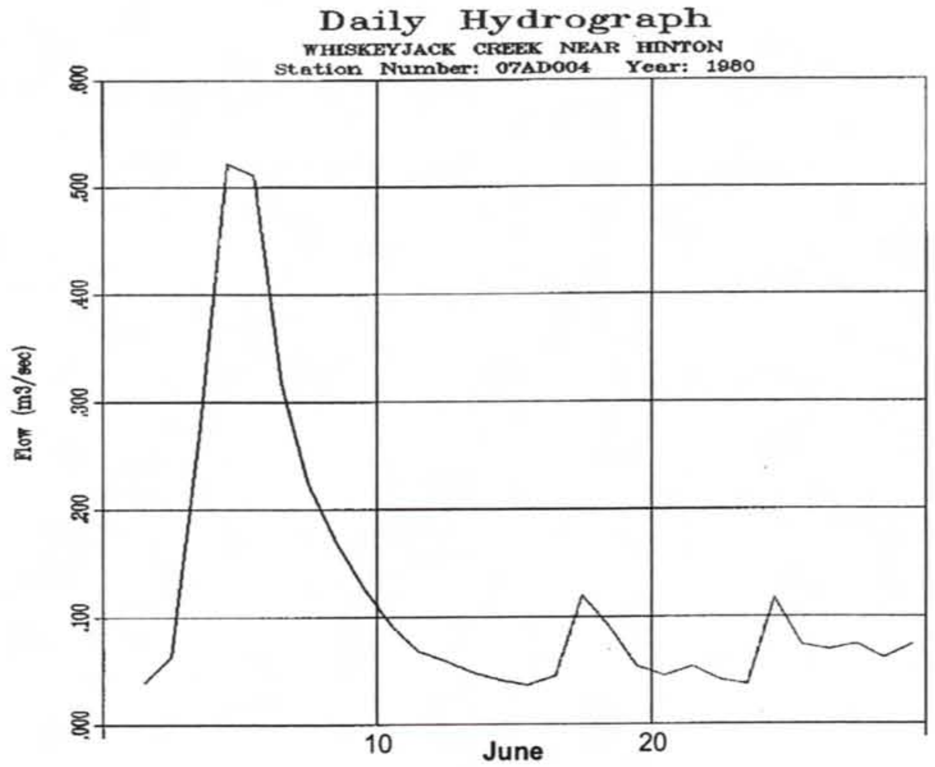
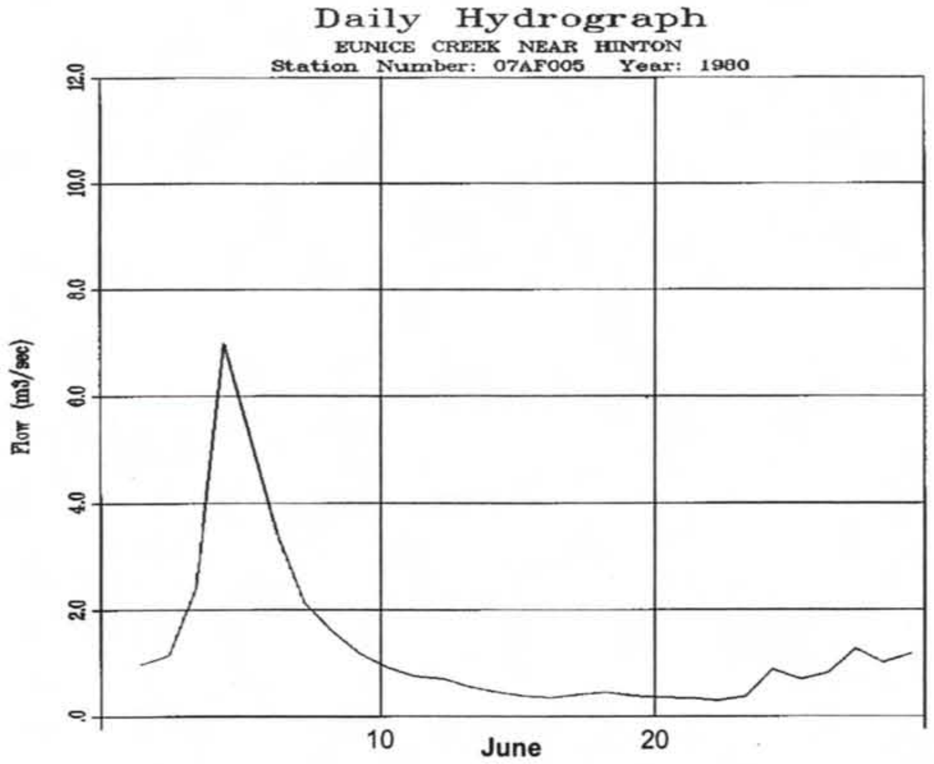
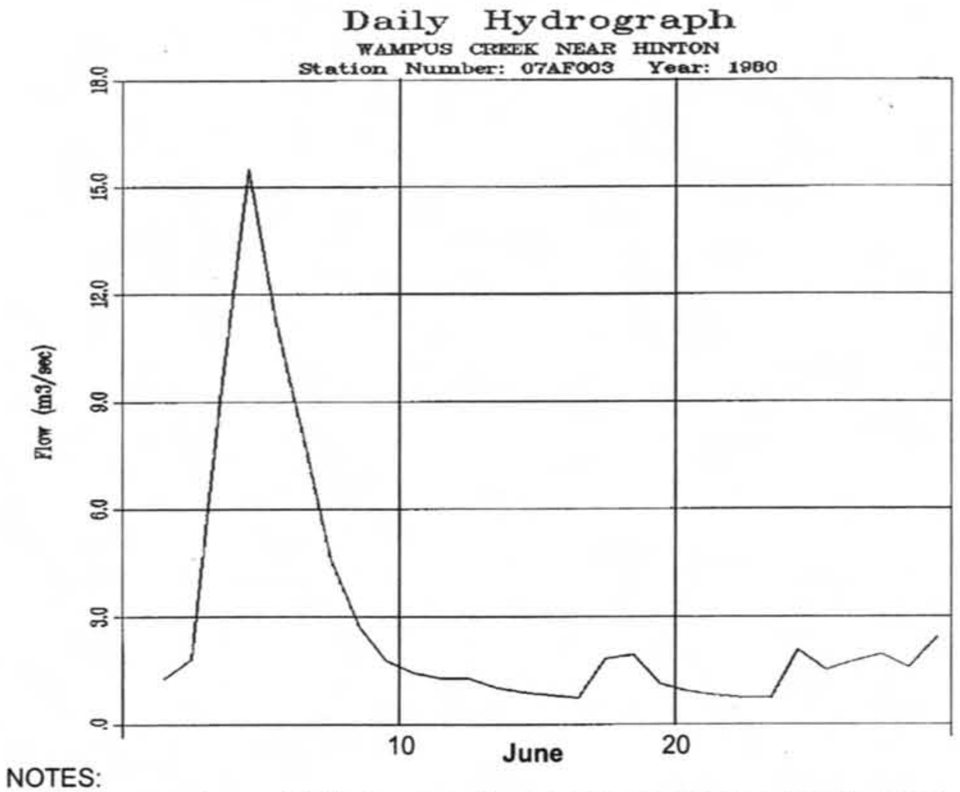
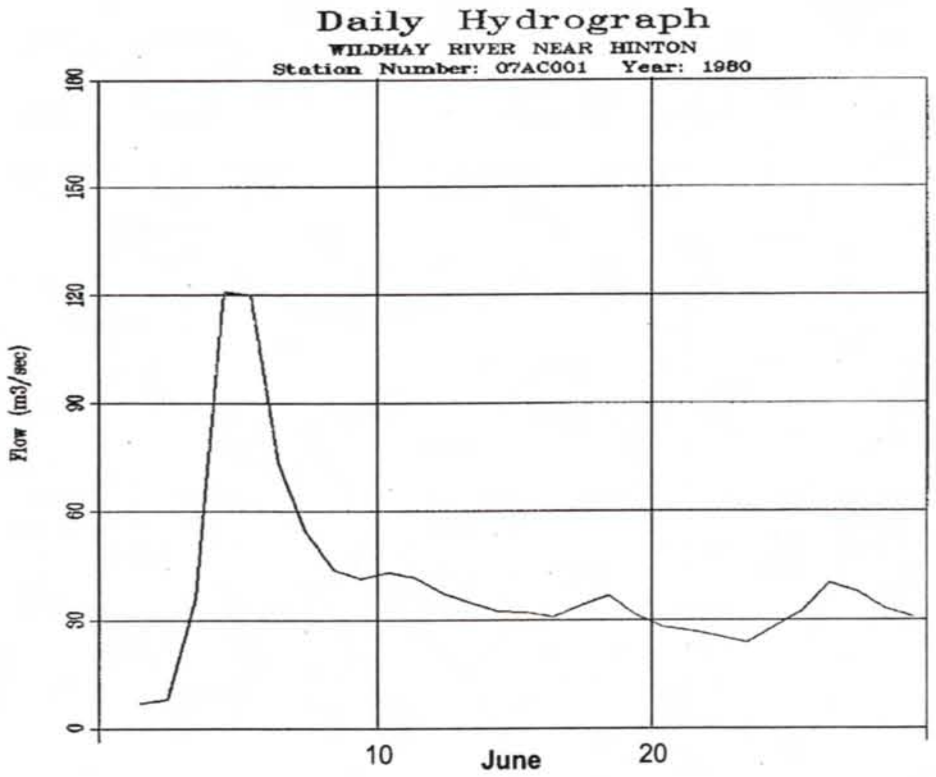
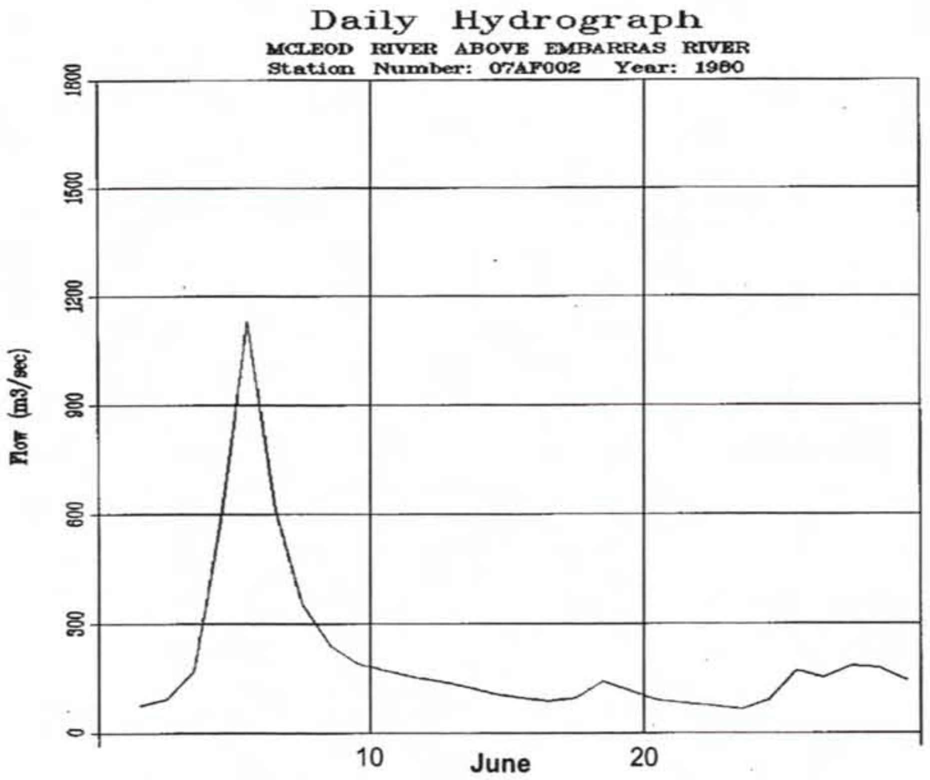
MCLEOD RIVER ABOVE EMBARRAS
OVERVIEW OF FLOW CHARACTERISTICS
JOB NO. 182
FIG. 9


Daily Hydrograph
WHISKEYJACK CREEK NEAR HINTON
Station Number: 07AD004 Year: 1980


Daily Hydrograph
EUNICE CREEK NEAR HINTON
Station Number: 07AF005 Year: 1980


Daily Hydrograph
WAMPUS CREEK NEAR HINTON
Station Number: 07AF003 Year: 1980


Daily Hydrograph
WILDHAY RIVER NEAR HINTON
Station Number: 07AC001 Year: 1980


Daily Hydrograph
MCLEOD RIVER ABOVE EMBARRAS RIVER
Station Number: 07AF002 Year: 1980

NOTES:

1. The year shown, 1980, represents the peak flow year for the recorded flow period for each of the stations shown.
2. Data for the various - sized flow monitoring stations intended to show:
   - the rate of increase in flow during the flood. Even in a large watershed such as the McLeod River, flows increases rapidly, reflecting runoff characteristics from a relatively steep terrain,
   - the rate of decline in flow after the flood peak. Although the lower peak unit flow from the Wildhay River may reflect lower rainfall / snowmelt values in this area in the 1980 event, the Wildhay River sustains a flow of 25 % of the peak flow for most of the month compared to less than about 10 % for the other watersheds indicative probably of more marshy conditions in the Wildhay River watershed which, as a result of storage capacity in the marshy areas, reduce and sustain peak and post - peak flows respectively,
   - hydrologic variations within a region,
   - Whiskeyjack Creek and Cache Percotte Creek in the Athabasca River Valley at Hinton, do not fit into the average flow conditions for the region,
   - the peak unit flow (see next point). Generally as the drainage area increases, the peak flow decreases.
3. Peak unit runoff as follows:

Name	Drainage Area	Peak Unit Flow
Whiskeyjack Creek	3.13 km²	0.17 m³ / sec. / km²
Eunice Creek (natural)	17.1 km²	0.41 m³ / sec. / km²
Wampus Creek (logged)	25.4 km²	0.61 m³ / sec. / km²
Wildhay River	959 km²	0.13 m³ / sec. / km²
McLeod River	2560 km²	0.44 m³ / sec. / km²

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MODEL FOREST NETWORK
RÉSEAU DE FORÊTS MODÈLES

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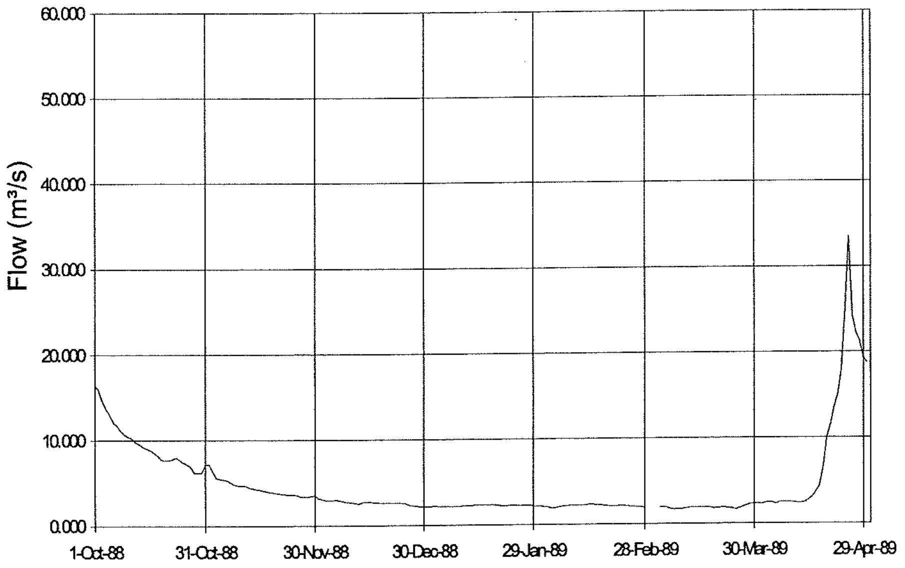
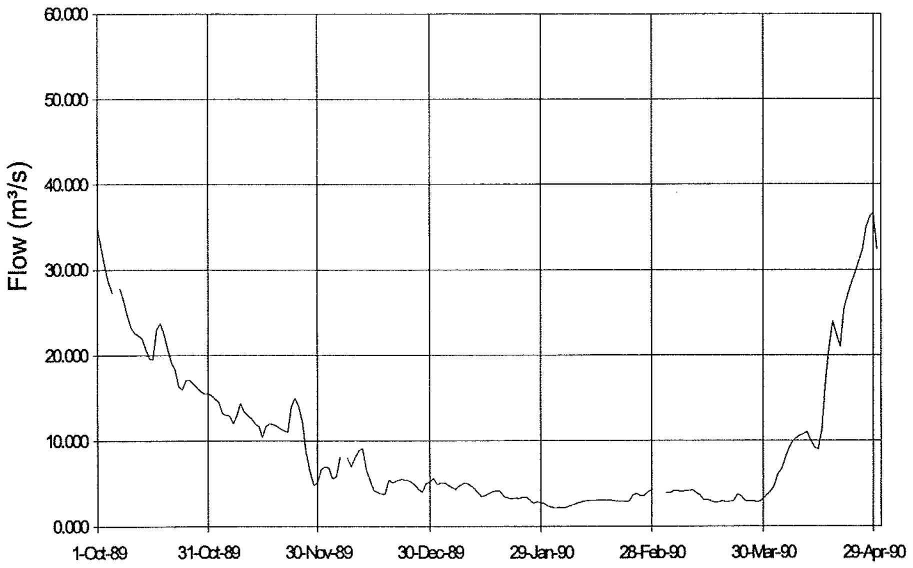
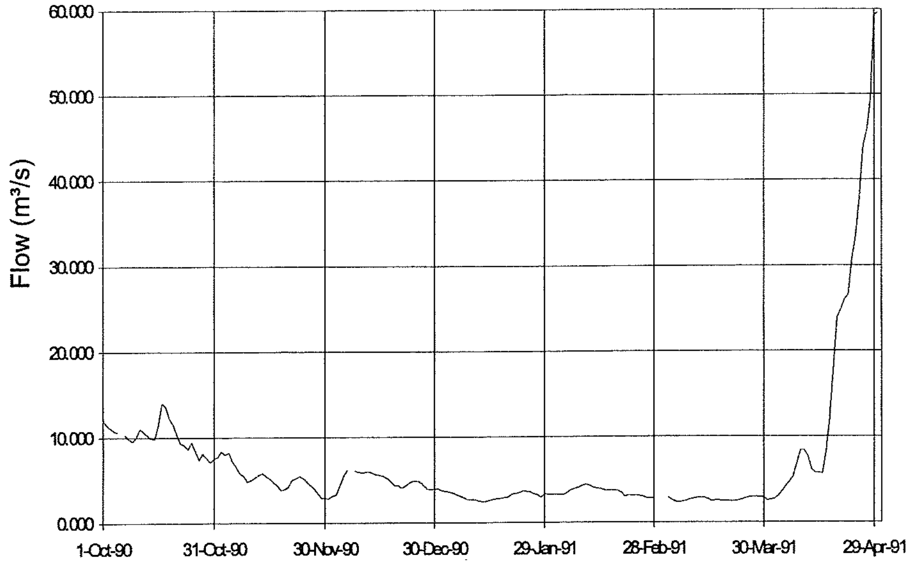
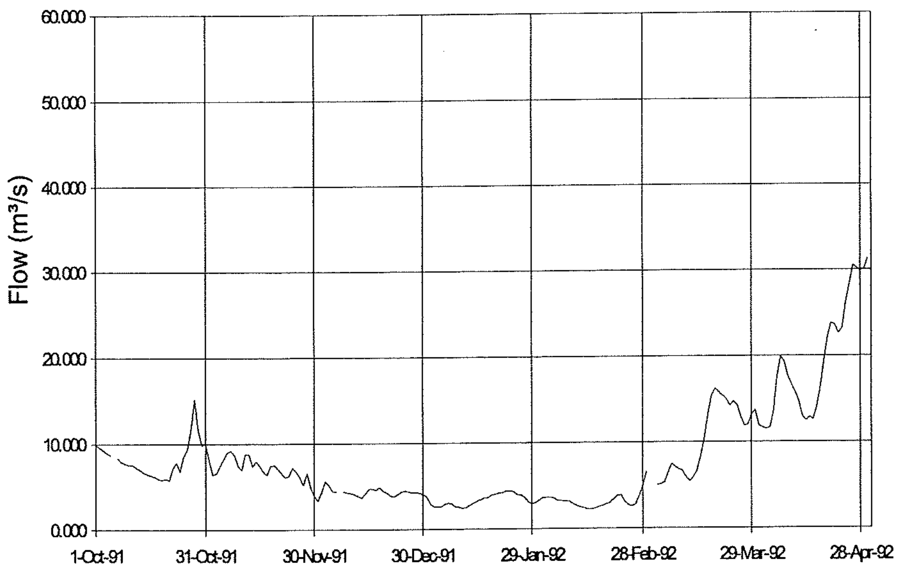
COMPARISON OF MAXIMUM
FLOWS FOR DIFFERENT
SIZED WATERSHEDS

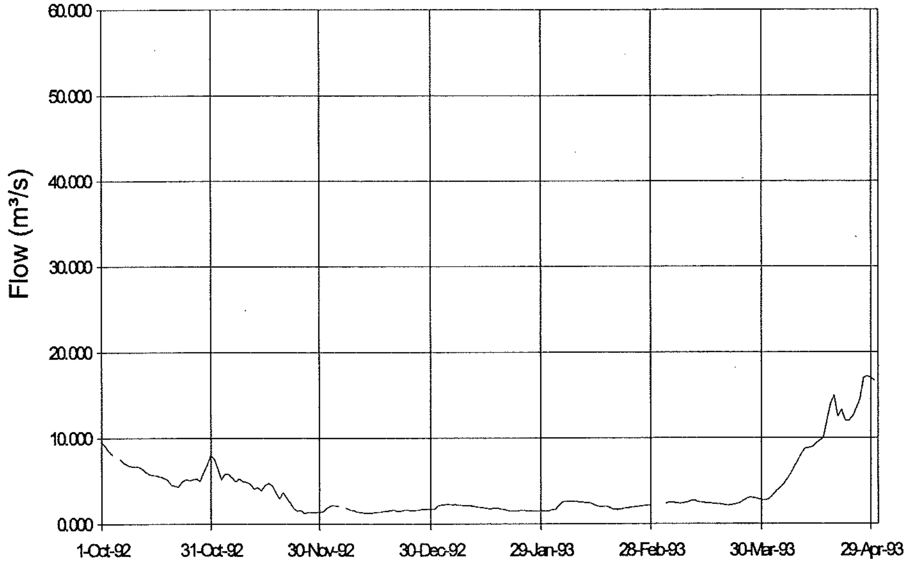
JOB NO. 182
FIG. 10

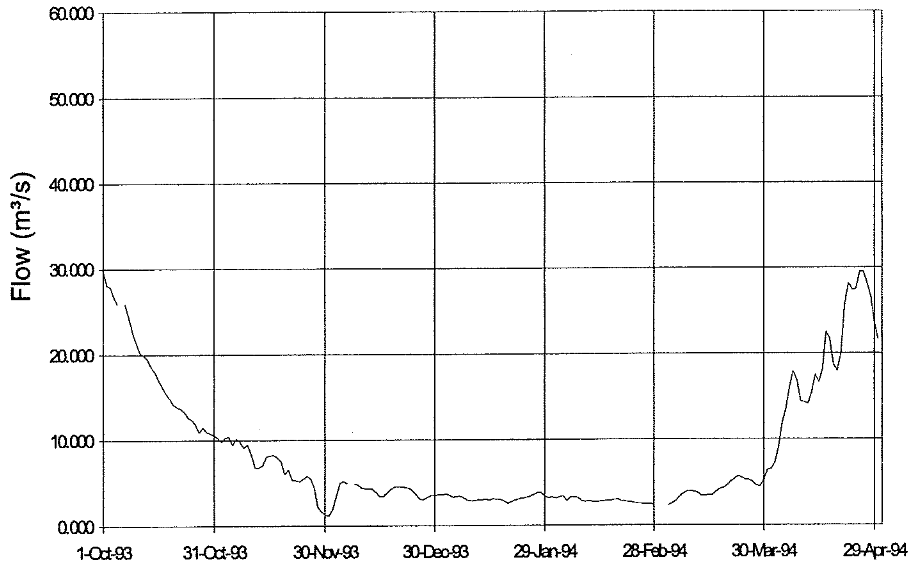












The graphs illustrate for the McLeod River flow measurement station:

- variability of flow in October (30+ m³/sec. to less than 10 m³/sec.),
- the rapid decline in flow in October - November at the onset of winter,
- the rapid short term decline in flow during an extreme cold spell at the beginning of winter when a high percentage of the flow is "lost" to forming ice. (see November 30 timeline in 1989, 1990, and 1993),
- quite uniform and consistent minimum flow which occurs in January - February,
- potential for flow increase as early as March,
- rapid increase in flow in April.

NOTE:

1. In the Model Forest area, this is the only flow station which records winter streamflow. (winter streamflow measurements are extremely labor intensive. Thus Water Survey of Canada measures streamflow in the winter at relatively few locations.)
2. See Figures 18 & 19 for a Low Flow Analysis of the Foothills Model Forest area

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FOOTHILLS MODEL FOREST

MODEL FOREST NETWORK
RÉSEAU DE FORÊTS MODÈLES

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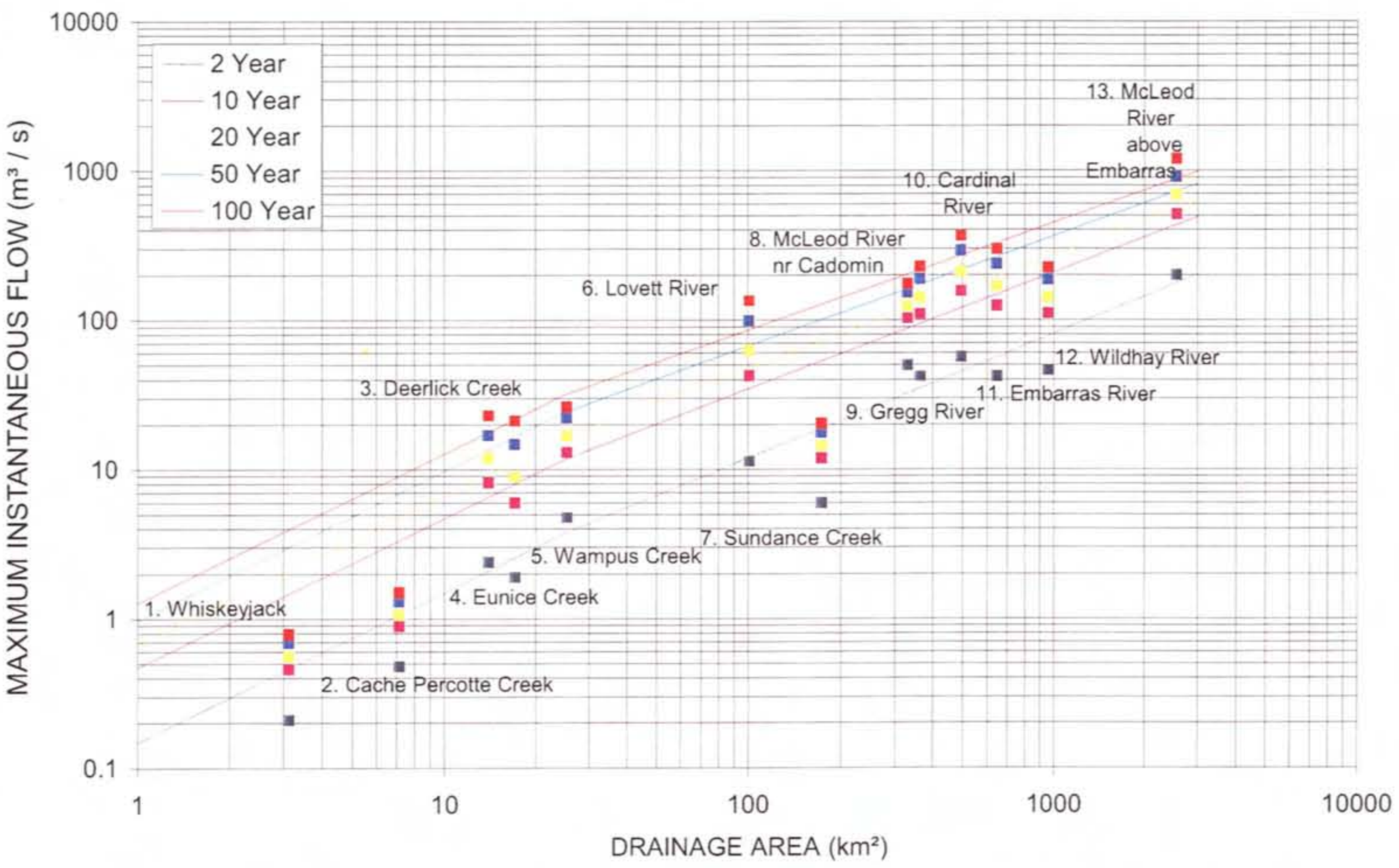
COMPARISON OF YEAR - T0 - YEAR LOW FLOW FOR THE MCLEOD RIVER ABOVE EMBARRAS RIVER

JOB NO. **182**
FIG. **11**

MAXIMUM INSTANTANEOUS FLOW VERSUS DRAINAGE AREA



Station Name	Number	Drainage Area (km²)	1:2 (m³/s)	1:10 (m³/s)	1:20 (m³/s)	1:50 (m³/s)	1:100 (m³/s)
1. Whiskeyjack Ck nr Hinton	07AD004	3.13	0.21	0.46	0.56	0.69	0.79
2. Cache Percotte Ck nr Hinton	07AD003	7.15	0.48	0.89	1.07	1.31	1.5
3. Deerlick Ck nr Hinton	07AF004	14	2.4	8.2	12	17	23
4. Eunice Ck nr Hinton	07AF005	17.1	1.9	5.99	8.97	14.8	21.2
5. Wampus Ck nr Hinton	07AF003	25.4	4.78	13	16.8	22.1	26.4
6. Lovett R nr Mouth	07BA003	101	11.4	42.6	63.1	99.1	135
7. Sundance Ck nr Bickerdike	07AF010	174	5.97	11.9	14.4	17.7	20.3
8. McLeod River nr Cadomin	07AF013	331	50.1	103	124	153	175
9. Gregg R nr Mouth	07AF015	364	42.1	110	142	189	228
10. Cardinal R nr Mouth	05DD008	495	56.7	157	211	293	366
11. Embarras R nr Weald	07AF014	647	41.9	125	169	238	298
12. Wildhay R nr Hinton	07AC001	959	46.2	111	142	187	225
13. McLeod R above Embarras R	07AF002	2560	200	510	690	910	1200

NOTES:

1. The lines represent average values developed from the analysis for the entire Model Forest Area. Thus they represent values to be used if there are no recorded streamflow data on the stream being evaluated. If the project is located on a stream with streamflow data, use the specific data for that stream rather than the average data. See the next Figure for the specifics on how to apply these two methods.

2. Data from Whiskeyjack and Cache Percotte Creeks were not used in determining the lines. As shown, they produce significantly lower peak and unit flow than the remainder of the recorded streamflow locations although Sundance Creek and Wildhay River also produce relatively low peak flows.

3. Equations for the maximum instantaneous flow curves, for a drainage area greater than or equal to 25 km² are:

$$Q_2 = 0.255\ D.A.^{0.834}$$
$$Q_{10} = 0.945\ D.A.^{0.781}$$
$$Q_{20} = 1.42\ D.A.^{0.761}$$
$$Q_{50} = 2.25\ D.A.^{0.736}$$
$$Q_{100} = 3.12\ D.A.^{0.719}$$

Where Q_n = return period for which the design flow is being computed,
D A = drainage area in km².

4. For a drainage area less than 25 km², the curves are represented by the following equations:

$$Q_2 = 3.736\ (D.A./25)$$
$$Q_{10} = 11.674\ (D.A./25)$$
$$Q_{20} = 16.448\ (D.A./25)$$
$$Q_{50} = 24.047\ (D.A./25)$$
$$Q_{100} = 31.570\ (D.A./25)$$

DATA ADEQUACY

1. Good to excellent data exists for drainage areas greater than 10 km². Below 10 km², data are limited and restricted to 2 stations in the Athabasca River valley at Hinton which are not representative of peak flow conditions from the small steeper watersheds in the Foothills area.

2. Variability in peak flow from some watersheds. Sundance Creek produces significantly lower peak flows than the other streams which have flow measurement stations. For a project in a watershed with no recorded flow data, judge whether to use the average regional data as outlined in Figure 13 or to use data from a non - typical stream such as Sundance Creek. To determine this, compare watershed characteristics such as steepness, vegetation and presence of swamps etc. between an adjacent watershed with flow data and your Project Watershed.

PEAK FLOWS USED FOR BRIDGES, CULVERTS, DAMS.

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MODEL FOREST NETWORK
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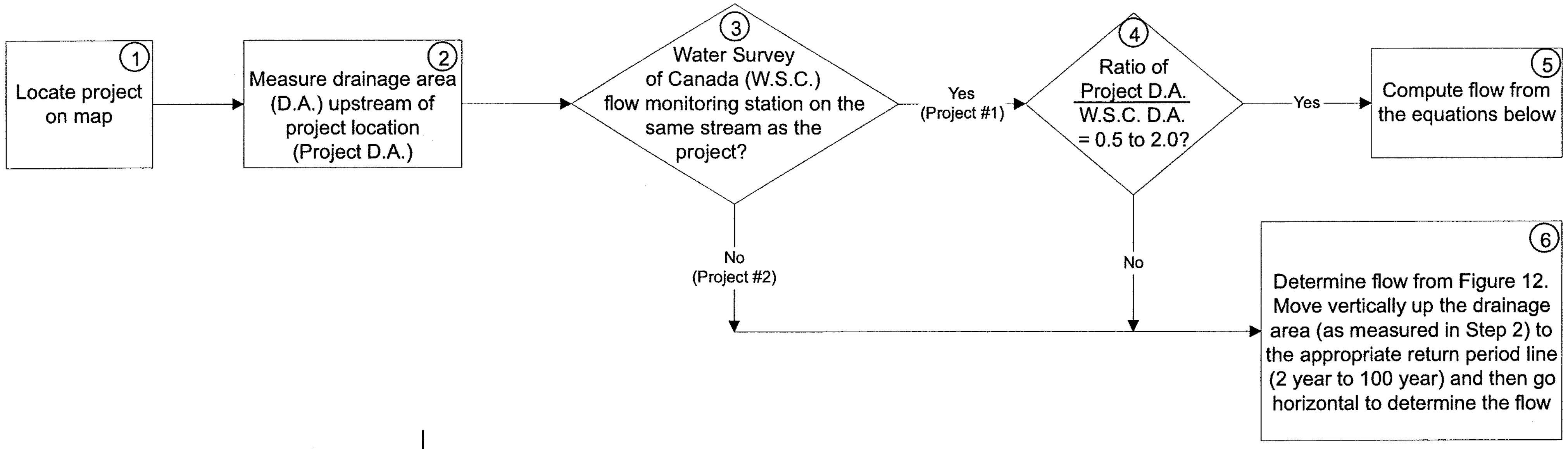
HYDROLOGIC OPERATIONAL MANUAL
MAXIMUM INSTANTANEOUS
FLOWS FOR VARIOUS RETURN
PERIODS AND DRAINAGE AREAS

JOB NO. 182
FIG. 12



FOR D.A. < 25 km² AND WSC D.A. < 25km²:

Required return period in years and thus flow magnitude depends on type / life of structure or project. (Q_2 is the 1:2 year flood, Q_{10} is the 1:10 year flood etc.)

See table on Fig. 12

As calculated in step 4

$$Q_2 = Q_{WSC2} \left(\frac{D.A.}{D.A._{WSC}}\right)^{0.834}$$

$$Q_{10} = Q_{WSC10} \left(\frac{D.A.}{D.A._{WSC}}\right)^{0.781}$$

$$Q_{20} = Q_{WSC20} \left(\frac{D.A.}{D.A._{WSC}}\right)^{0.761}$$

$$Q_{50} = Q_{WSC50} \left(\frac{D.A.}{D.A._{WSC}}\right)^{0.736}$$

$$Q_{100} = Q_{WSC100} \left(\frac{D.A.}{D.A._{WSC}}\right)^{0.719}$$

FOR D.A. < 25 km² AND WSC D.A. > 25km²:

$$Q_2 = Q_{WSC2} \left(\frac{25}{D.A._{WSC}}\right)^{0.834} \left(\frac{D.A.}{25}\right)$$

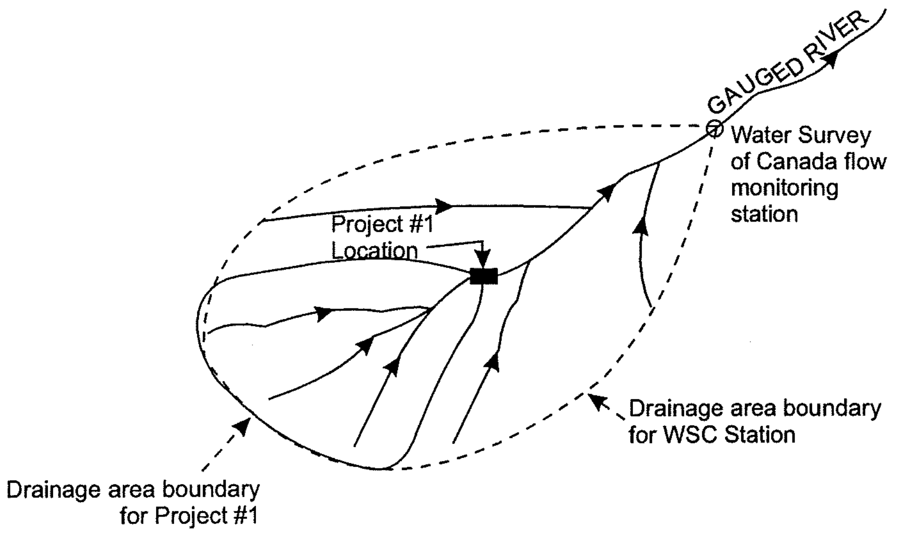
$$Q_{10} = Q_{WSC10} \left(\frac{25}{D.A._{WSC}}\right)^{0.781} \left(\frac{D.A.}{25}\right)$$

$$Q_{20} = Q_{WSC20} \left(\frac{25}{D.A._{WSC}}\right)^{0.761} \left(\frac{D.A.}{25}\right)$$

$$Q_{50} = Q_{WSC50} \left(\frac{25}{D.A._{WSC}}\right)^{0.736} \left(\frac{D.A.}{25}\right)$$

$$Q_{100} = Q_{WSC100} \left(\frac{25}{D.A._{WSC}}\right)^{0.719} \left(\frac{D.A.}{25}\right)$$

Use these equations if a Water Survey of Canada flow monitoring station is located on the stream being evaluated (the top line in the flow chart)



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FOOTHILLS MODEL FOREST

MODEL FOREST NETWORK
RÉSEAU DE FORÊTS MODÈLES

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APP: Wim Veldman
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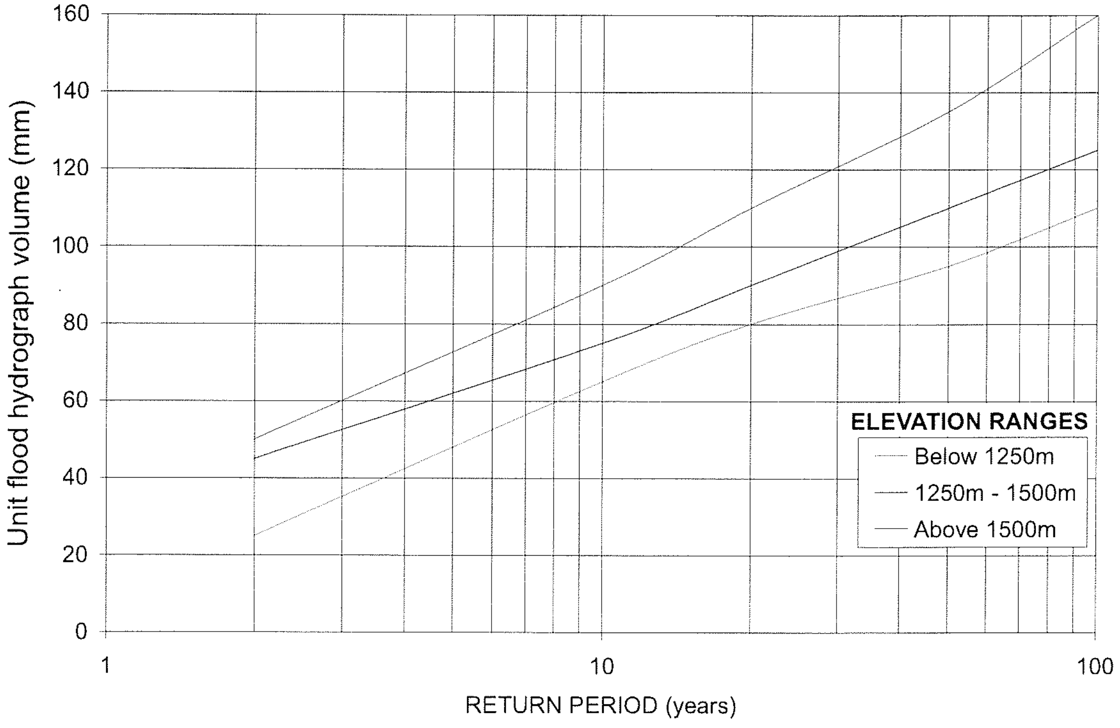
DATE: Feb 1997

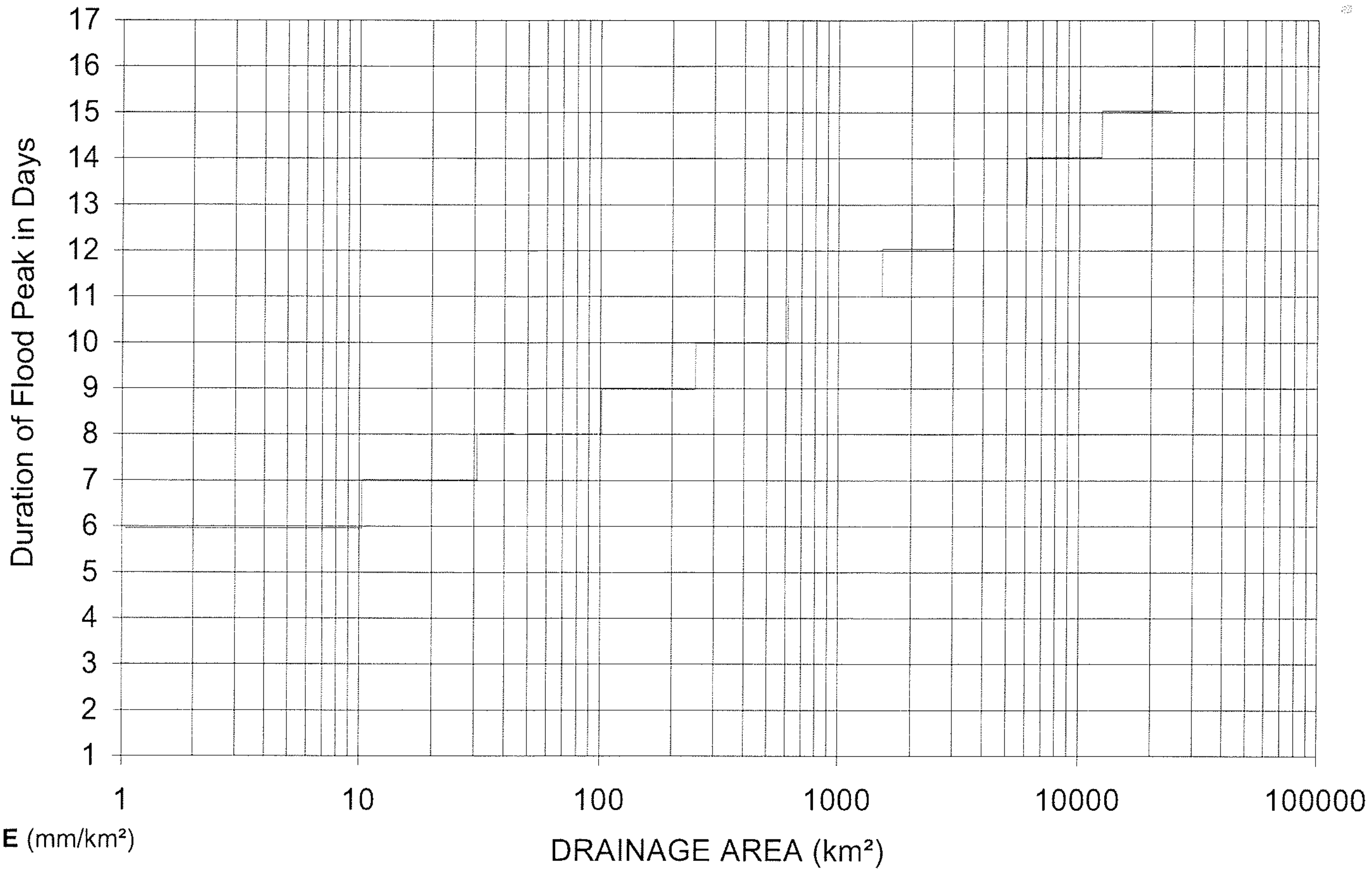
TITLE:
HYDROLOGIC OPERATIONAL MANUAL

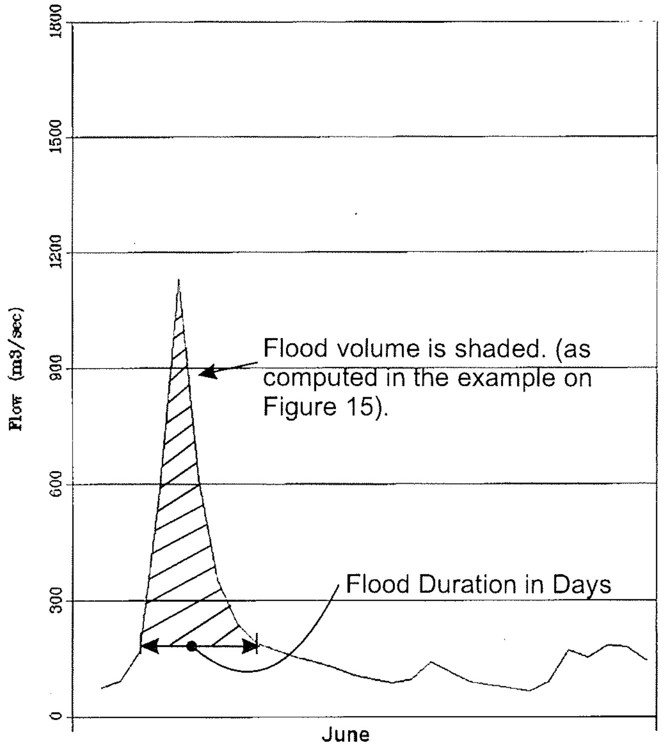
FLOW CHART FOR COMPUTING MAXIMUM INSTANTANEOUS FLOWS

JOB NO. 182
FIG. 13



FLOOD DURATION IN DAYS





Definition Sketch

UNIT FLOOD RUNOFF VOLUME (mm/km²)

Station Name	Number	Drainage Area (km²)	1:2 (mm)	1:10 (mm)	1:20 (mm)	1:50 (mm)	1:100 (mm)
1. Whiskeyjack Ck nr Hinton	07AD004	3.13	14	33	40	48	55
2. Cache Percotte Ck nr Hinton	07AD003	7.15	12	28	33	41	46
3. Deerlick Ck nr Hinton	07AF004	14	48	82	95	120	130
4. Eunice Ck nr Hinton	07AF005	17.1	35	71	92	110	130
5. Wampus Ck nr Hinton	07AF003	25.4	50	79	90	110	120
6. Lovett R nr Mouth	07BA003	101	33	100	140	220	300
7. Sundance Ck nr Bickerdike	07AF010	174	18	33	37	41	44
8. McLeod River nr Cadomin	07AF013	331	60	100	120	150	160
9. Gregg R nr Mouth	07AF015	364	45	93	11	140	160
10. Cardinal R nr Mouth	05DD008	495	35	73	94	130	150
11. Embarras R nr Weald	07AF014	647	24	66	82	95	110
12. Wildhay R nr Hinton	07AC001	959	32	57	68	80	90
13. McLeod R above Embarras R	07AF002	2560	41	81	97	120	130

NOTES:

1. See next figure for a calculation example.

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FLOOD RUNOFF VOLUMES FOR VARIOUS ELEVATION RANGES AND FLOOD DURATIONS

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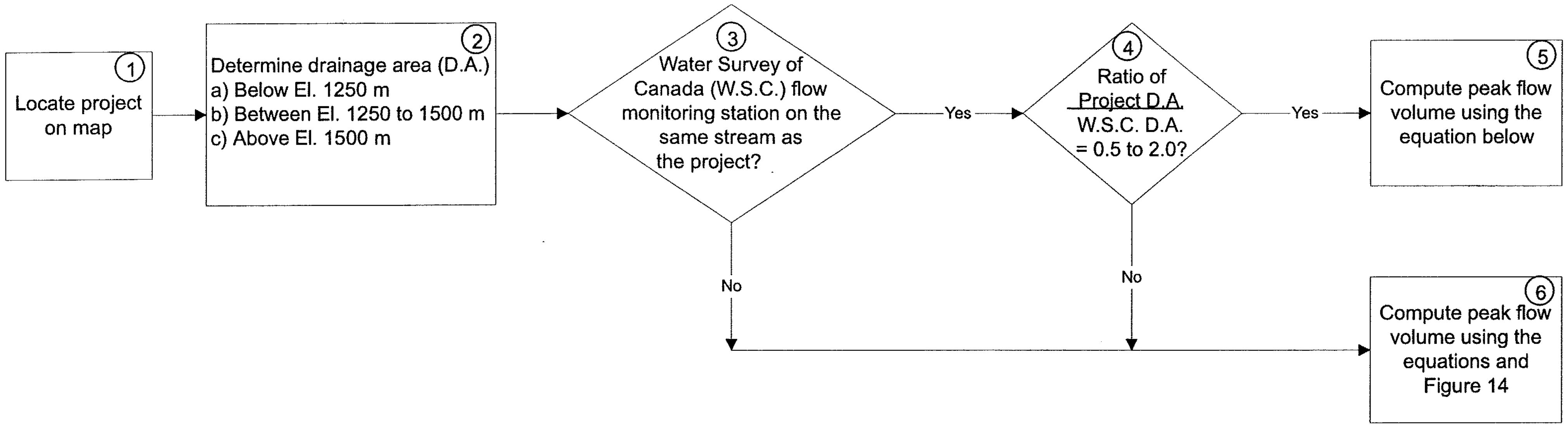
FIG. 14

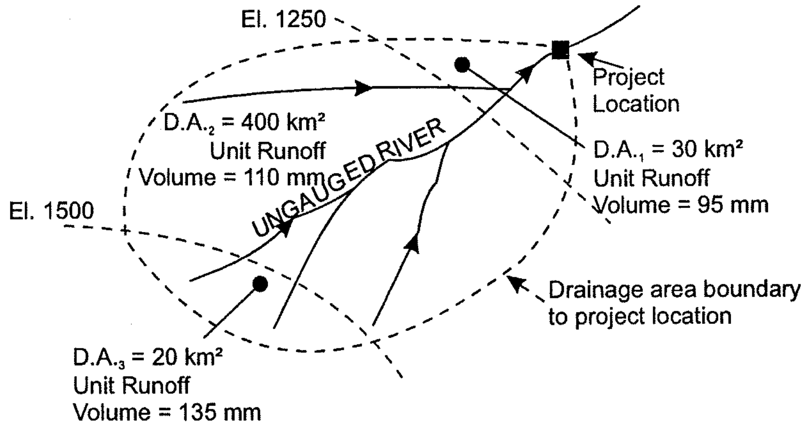


Select the return period flood you need → Peak Flow Volume at Project in dam³ (= 1000 m³) = Unit Runoff at the W.S.C. Station, dam³ / km² ← See table on Figure 14 x Project Drainage Area, km² ← As calculated in step 2

Use this method if a Water Survey of Canada flow monitoring station is located on the stream being evaluated (the top line in the flow chart)

TOTAL DRAINAGE AREA = 450 km²
From Figure 14, the duration of the flood is 10 days.
Thus a total runoff volume of 49,550,000 m³ occurs in 10 days which is an average flow of 57 m³ / second.

Duration of Peak Flow and Average Flow



EXAMPLE (Unit runoff volumes from Figure 14)

Peak flow volume at project = D.A.1 (Unit Runoff Volume$_1$) + D.A.2 (Unit Runoff Volume$_2$) + D.A.3 (Unit Runoff Volume$_3$)

For the 1:50 year flood = 30 (95) + 400 (110) + 20 (135)

= 49,550 dam³

Use this methodology if no Water Survey of Canada flow monitoring station is located on the stream being evaluated (the bottom line in the flow chart)

NOTES:
1. 1 dam³ = 1000 m³.
2. In calculating the volume in dam³, the drainage area unit can be km² and the unit runoff in mm as shown in the example.
3. The unit runoff volumes are as obtained from the upper left graph on Figure 14.

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FLOW CHART FOR COMPUTING FLOOD VOLUMES

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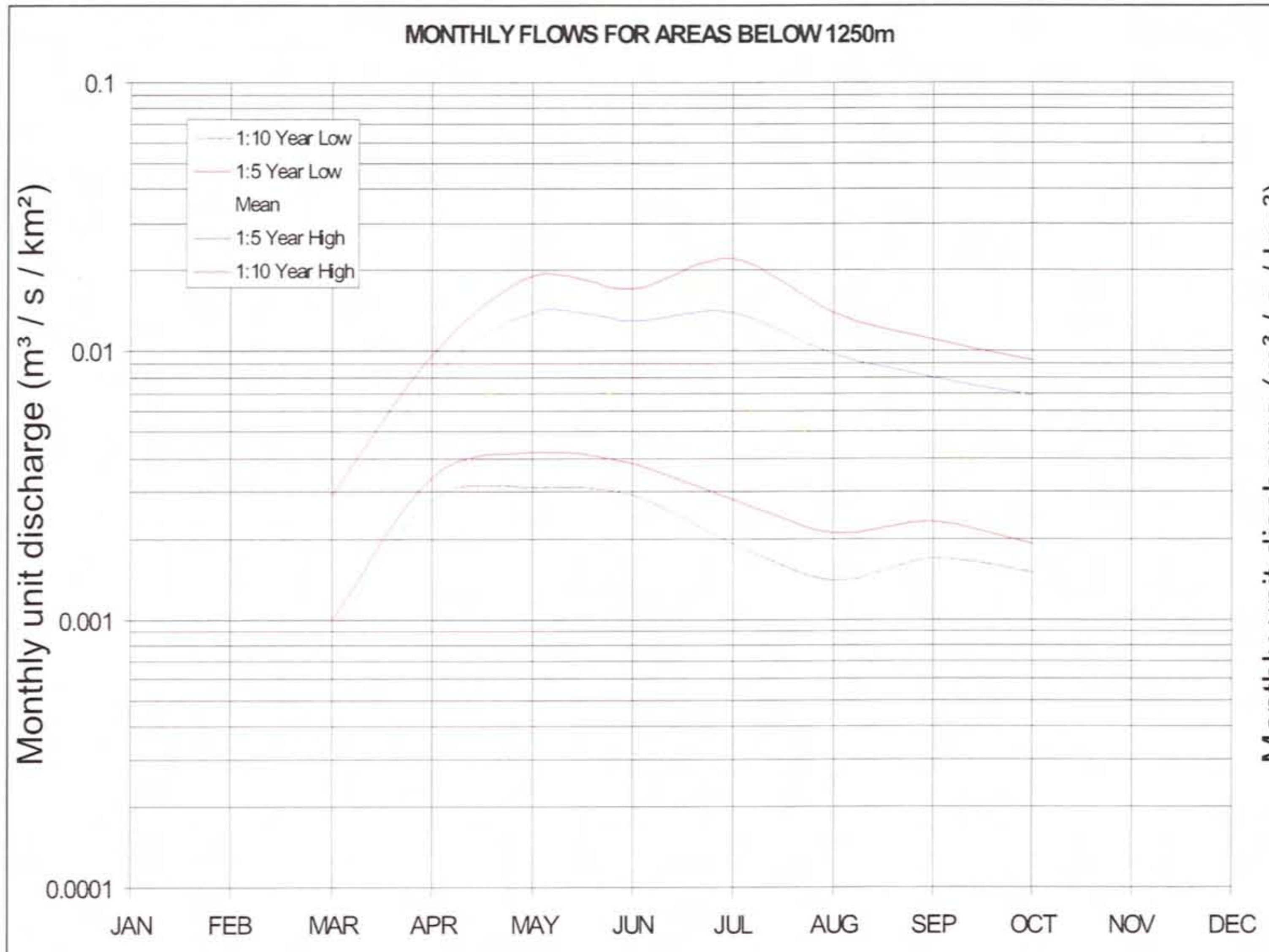
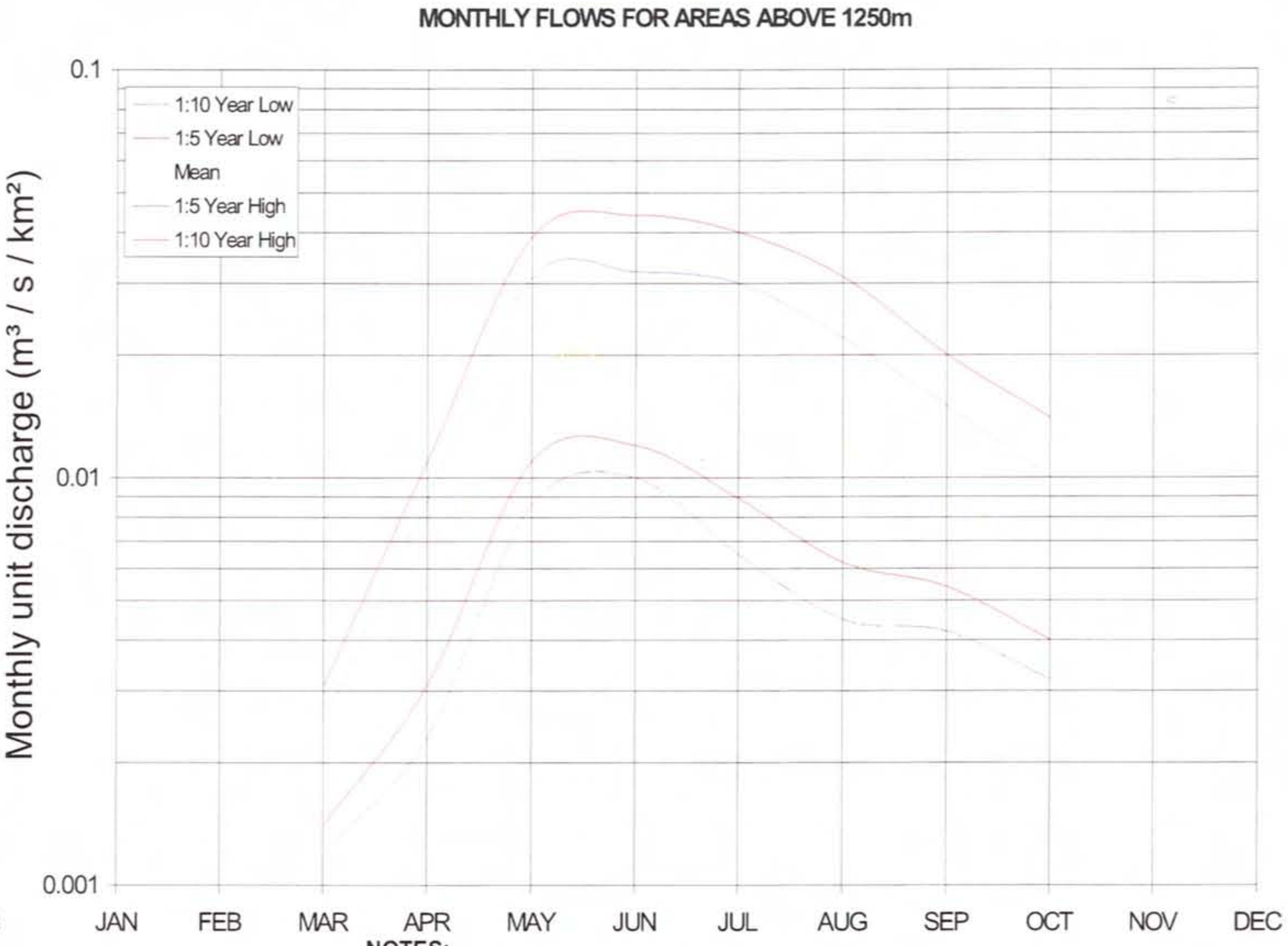
FIG. 15


MONTHLY FLOWS FOR AREAS BELOW 1250m


MONTHLY FLOWS FOR AREAS ABOVE 1250m

Monthly Unit Flows for Areas below Elevation 1250m

Period	Average Flow in the Region [(m³/s)/km²]				
	1:10 Low	1:5 Low	Mean	1:5 High	1:10 High
March	0.0009	0.0010	0.0015	0.0023	0.0029
April	0.0028	0.0034	0.0051	0.0079	0.0096
May	0.0031	0.0042	0.0076	0.0140	0.0190
June	0.0029	0.0038	0.0067	0.0130	0.0170
July	0.0019	0.0028	0.0062	0.0140	0.0220
August	0.0014	0.0021	0.0046	0.0098	0.0140
September	0.0017	0.0023	0.0043	0.0080	0.0110
October	0.0015	0.0019	0.0032	0.0069	0.0093

Monthly Unit Flows for Areas above Elevation1250m

Period	Average Flow in the Region [(m³/s)/km²]				
	1:10 Low	1:5 Low	Mean	1:5 High	1:10 High
March	0.0012	0.0014	0.0019	0.0025	0.0031
April	0.0023	0.0031	0.0054	0.0088	0.0110
May	0.0086	0.0110	0.0180	0.0310	0.0390
June	0.0100	0.0120	0.0190	0.0320	0.0440
July	0.0065	0.0089	0.0160	0.0300	0.0400
August	0.0045	0.0062	0.0120	0.0220	0.0310
September	0.0042	0.0054	0.0089	0.0150	0.0200
October	0.0032	0.0040	0.0064	0.0100	0.0140

NOTES:

1. The 1:10 year low flow, on the average, would be equaled or not be reached once every 10 years. The 1:5 year high flow, on the average, would be equaled or exceeded once every 5 years. The tables give values ranging from a 1:10 year low flow or drought case to a 1:10 year high flow or flood case.
2. To determine the monthly flow at any location, measure the drainage area in km² and multiply it by the values in the table.
3. Monthly values not shown are due to insufficient winter flow measurements in the Foothills Model Forest area.

DATA ADEQUACY

1. Open water flow data is excellent to compute monthly flows ranging from a 1:10 year low to a 1:10 year high event.
2. Data is poor to calculate winter flow. Only the McLeod River above Embarras River has continuous winter flow data. For calculating monthly flows for the winter months of January, February, November and December, qualitative assessments, supported by site specific observations, measurements and analysis by a hydrologic specialist are recommended.

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MODEL FOREST NETWORK
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MONTHLY UNIT FLOWS FOR VARIOUS
ELEVATIONS AND LOW
AND HIGH EVENTS

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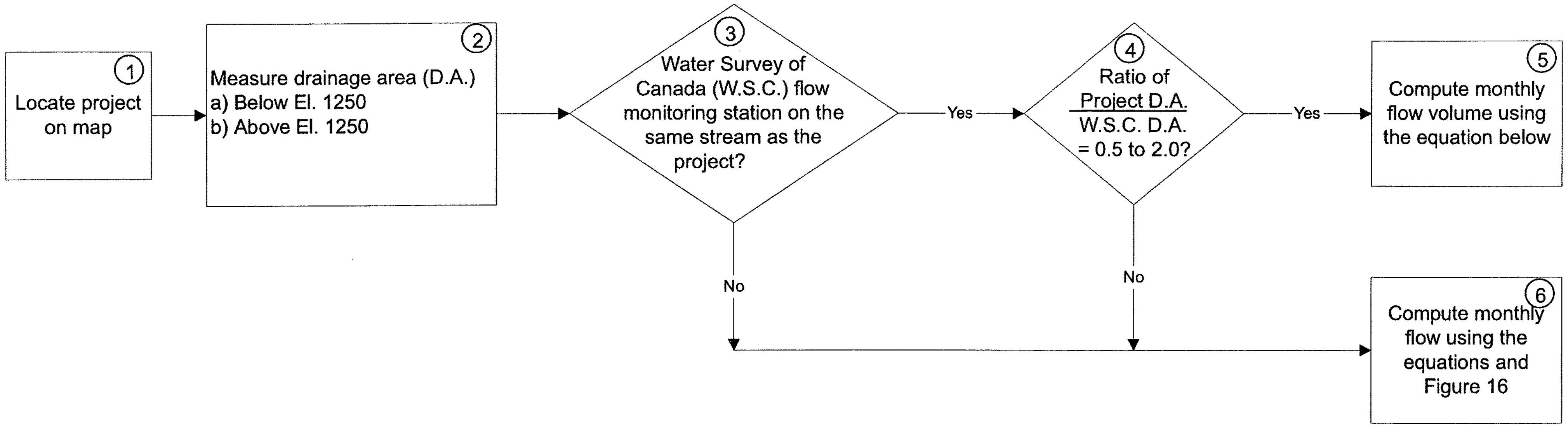
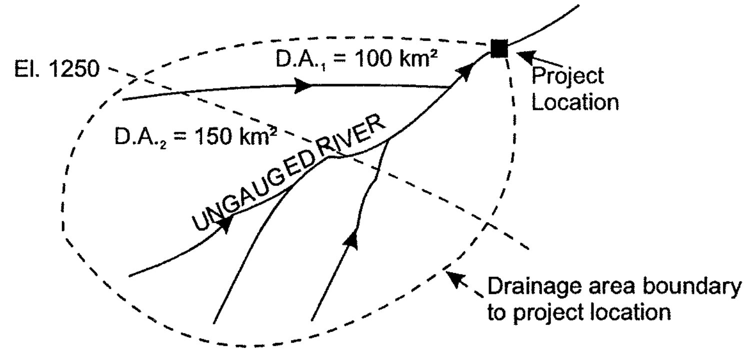
182

FIG.
16





Select the return period / severity (high or low) of the event you need and the month you need

Value for the flow conditions shown on Fig. 16 (1:10 year low to 1:10 year high)

As calculated in step 4

$$\text{Monthly Flow at Project in m}^3\text{/ sec} = \left(\frac{\text{Monthly Unit Flow}}{\text{Mean Monthly Flow}}\right)\left(\frac{\text{Project D.A.}}{\text{W.S.C. D.A.}}\right)$$

See table at right

Use this method if a Water Survey of Canada flow monitoring station is located on the stream being evaluated (the top line in the flow chart)

MEAN MONTHLY FLOW AT FLOW MEASUREMENT STATIONS

Station Name	Jan.	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Whiskeyjack CK nr Hinton				0.004	0.029	0.034	0.024	0.015	0.010	0.007	0.003	0.002
Cache Percotte Ck nr Hinton				0.008	0.056	0.059	0.056	0.028	0.024	0.017		
Deerlick Ck nr Hinton				0.104	0.374	0.372	0.266	0.157	0.133	0.101	0.037	
Eunice Ck nr Hinton				0.075	0.320	0.326	0.281	0.183	0.130	0.109	0.044	
Wampus Ck nr Hinton				0.210	0.699	0.621	0.421	0.304	0.228	0.172	0.057	0.026
Lovett R nr Mouth			0.096	0.380	1.770	2.240	2.210	1.350	1.110	0.704		
Sundance Ck nr Bickerdike			0.295	0.969	1.750	1.640	1.640	0.861	0.774	0.628		
McLeod R nr Cadomin			0.801	1.960	8.010	11.500	8.820	7.790	4.880	3.420		
Gregg R nr Mouth			0.614	1.710	6.530	7.680	7.470	6.220	4.010	2.740		
Cardinal R nr Mouth			0.000	0.000	7.450	12.600	10.400	7.650	5.820	3.970		
Embarras R ne Weald			1.100	3.960	5.710	5.260	6.240	5.160	4.010	2.920		
Wildhay R nr Hinton			2.010	2.920	10.000	20.900	16.600	11.300	7.650	5.480		0.000
McLeod R above Embarras R	2.730	2.470	3.400	14.300	44.100	54.800	40.200	26.300	21.100	15.200	7.600	4.080

NOTE: Except for the McLeod River above Embarras River, flow measurments are not taken at the rest of the stations during the winter months. Thus if no value is shown, it indicates measurements were not taken during those months.

EXAMPLE

Select the return period / severity (high or low) of the event you need

Select the month

As computed in step 2

From Fig. 16

As computed in step 2

From Fig. 16

1:10 year high June flow in m³ / sec = (D.A.₁ in km² below 1250 m) (Unit Runoff in m³/s/km²) + (D.A.₂ in km² above 1250 m) (Unit Runoff in m³/s/km²)

= (100)(0.017) + (150)(0.044)
= 8.3 m³ / second

Use this methodology if no Water Survey of Canada flow monitoring station is located on the stream being evaluated (the bottom line in the flow chart)

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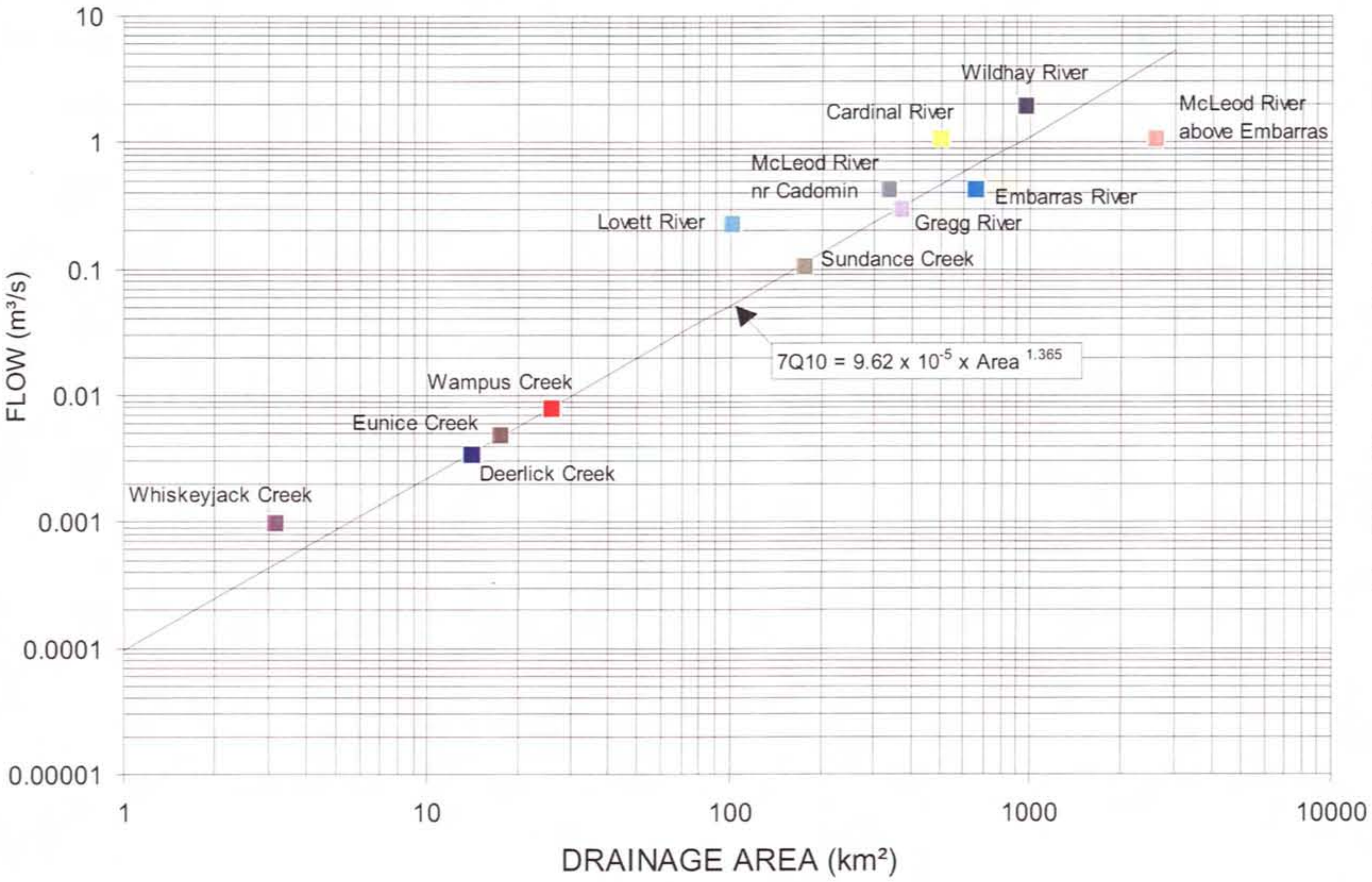
FLOW CHART FOR COMPUTING MONTHLY FLOWS
JOB NO. 182
FIG. 17

7Q10 LOW FLOWS VERSUS DRAINAGE AREA



7 Day Duration, 1:10 Year Low Flows

Station Name	Number	Drainage Area (km²)	Period Analyzed	7 Day Duration 1:10 Y ear Low Flow (m³/s)
Whiskeyjack Ck nr Hinton	07AD004	3.13	May - Oct	0.001
Deerlick Ck nr Hinton	07AF004	14	Apr - Oct	0.003
Eunice Ck nr Hinton	07AF005	17.1	Apr - Oct	0.005
Wampus Ck nr Hinton	07AF003	25.4	Apr - Oct	0.008
Lovett R nr Mouth	07BA003	101	May - Oct	0.235
Sundance Ck nr Bickerdike	07AF010	174	Mar - Oct	0.109
McLeod River nr Cadomin	07AF013	331	Mar - Oct	0.435
Gregg R nr Mouth	07AF015	364	Mar - Oct	0.303
Cardinal R nr Mouth	05DD008	495	May - Oct	1.11
Embarras R nr Weald	07AF014	647	Mar - Oct	0.436
Wildhay R nr Hinton	07AC001	959	May - Oct	2.03
McLeod R above Embarras R	07AF002	2560	Jan - Dec	1.09*

* Includes winter data. All the rest of the values are for non-winter conditions only.

NOTES:

1. Graph should only be used to calculate March to October 7 Day, 1:10 year low flow values. For low flow estimates for the rest of the months, that is the winter period, qualitative assessments, supported by site specific observations, measurements and analysis by a hydrologic specialist are recommended.
2. Only the McLeod River above Embarras River has continuous low flow data. Note the lower values for this location (the drop from the general curve value of 4 m³/s for non - winter flow to 1.1 m³/s for this location by including its winter flow data). Refer to Figure 11 for an illustration of the magnitude of winter flow versus pre and post winter flow.

DATA ADEQUACY

1. Open water low flow data are excellent to compute the 7 Day, 1:10 year low flow.
2. Data are poor to calculate winter flow with only one continuous flow monitoring station in the Foothills Model Forest area, namely the McLeod River above Embarras River.

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LOW FLOW ANALYSIS
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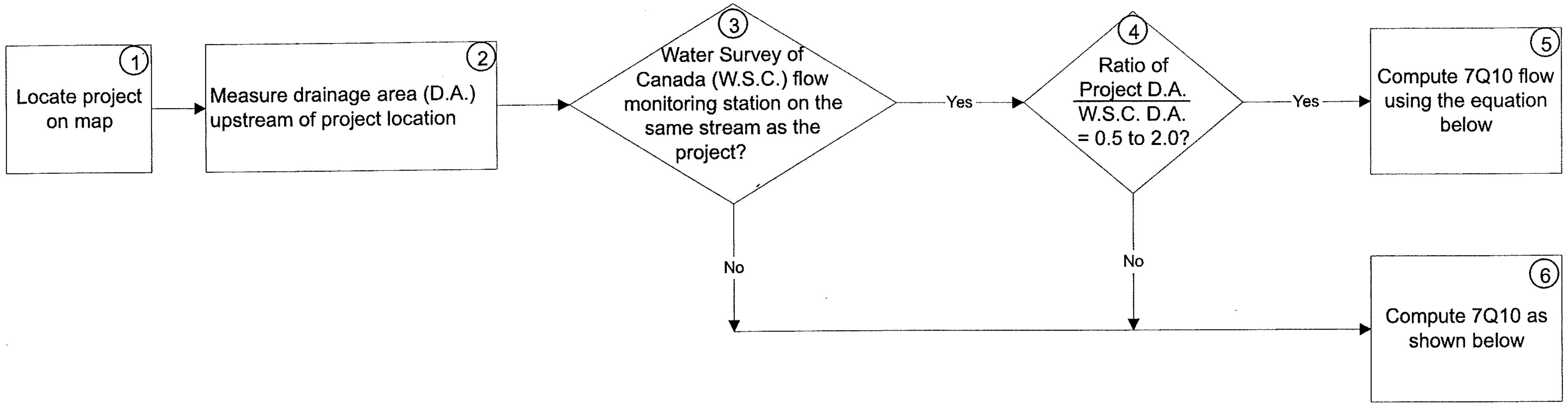
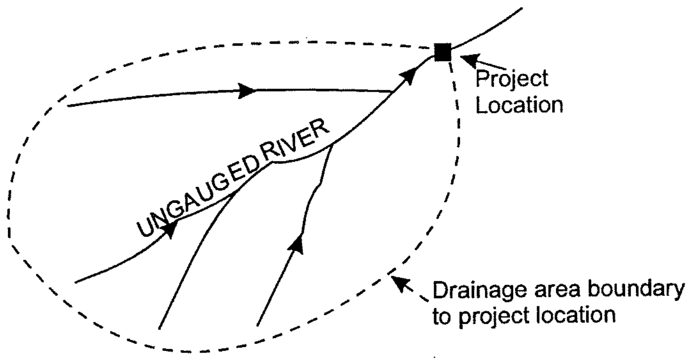
FIG. 18





NOTE:

Methodologies shown are for non - winter 7Q10 Low Flows only. As a first order estimate of winter low flow in the region, draw a line parallel to and below the regional line and through the McLeod River data point at the top right hand side of Figure 18.

STEP 5 DETAIL

See Table on Figure 18

As calculated in box 4

$$7Q10 = 7Q10_{wsc} \left(\frac{\text{Project D.A.}}{\text{W.S.C. D.A.}} \right)^{1.365}$$

Use this method if a Water Survey of Canada flow monitoring station is located on the stream being evaluated (the top line in the flow chart)

STEP 6 DETAIL

EXAMPLE

The low flow for a 7 day duration which could be equalled or lower than once every 10 years

Project D.A. as per step 4

$$\begin{aligned} 7Q10 &= 9.62\,(10^{-5})\,(\text{D.A.}^{1.365}) \\ &= 9.62\,(10^{-5})\,(100^{1.365}) \\ &= 0.0517\ \text{m}^3 / \text{second} \end{aligned}$$

Use this methodology if no Water Survey of Canada flow monitoring station is located on the stream being evaluated (the bottom line in the flow chart)

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JOB NO. 182
FIG. 19