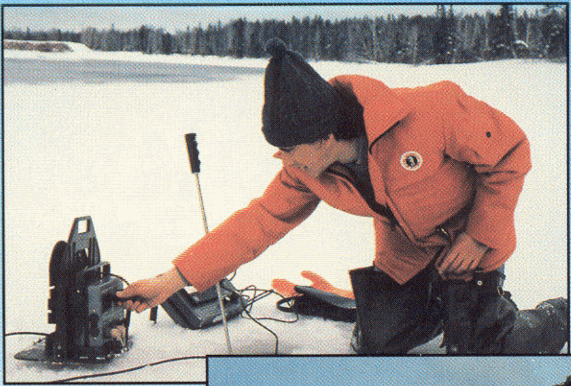
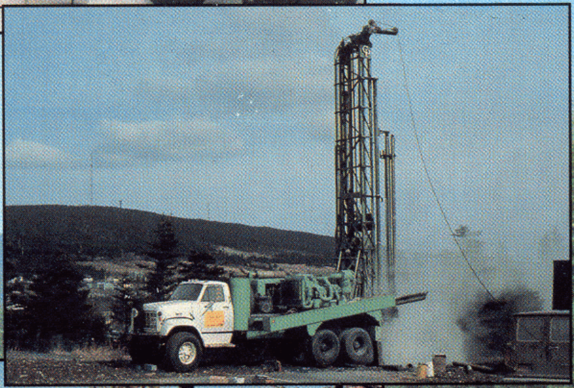
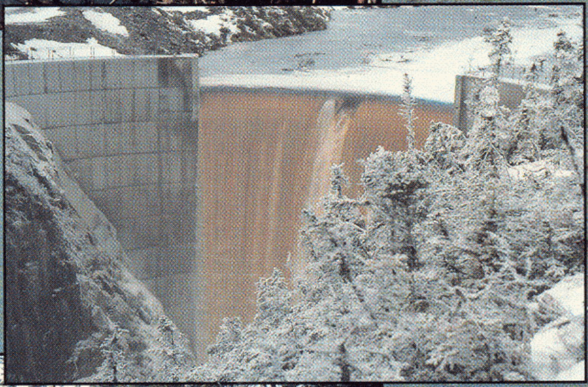
Regional Flood Frequency Analysis for the Island of Newfoundland

Users' Guide and Electronic Spreadsheet







GOVERNMENT OF NEWFOUNDLAND AND LABRADOR

Department of Environment
Water Resources Division

Regional Flood Frequency Analysis for the Island of Newfoundland

Users' Guide and Electronic Spreadsheet

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While every effort has been made to test the electronic spreadsheet, the Government of Newfoundland and Labrador makes no warranties expressed or implied, as to the performance of this spreadsheet. Users are expected to use professional engineering judgement in the application of the spreadsheet.

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1. INTRODUCTION

This Users' Guide and Electronic Spreadsheet (disk in back cover) is a companion report to: *Regional Flood Frequency Analysis for the Island of Newfoundland* (1999). The objective of that study was to develop a set of equations to estimate return period flood flows on ungauged watersheds. Flood flow estimates are required for the hydraulic design of instream structures and for floodplain management. This users' guide was designed to assist engineers in the application of these equations. The electronic spreadsheet automates the calculations. The 1999 regional flood frequency analysis provides one method to estimate flood flows. It is advisable to use several methods to estimate design floods. Previous regional flood frequency analysis in 1984 and 1990 can be used as checks.

Similar regional flood frequency analyses have been conducted in the past: Beersing (1990), Panu et al (1984) and Poulin (1971). Regular updates of the regional flood frequency analysis are justified on the basis of additional data, the capital costs of instream structures, and the annual cost of flooding. The 1999 study used flood and physiographic data from 50 gauged watersheds in 4 regions to develop a set of equations to estimate return period flood flows, the 1990 study used 39 watersheds in 4 regions, the 1984 study used 21 watersheds in 2 regions, and the 1971 study used 17 watersheds in one region. The 1999 study showed that successive study improved the accuracy of flood estimates.

Users' Guides were prepared for the 1990 study (Beersing 1990) and the 1984 study (Panu et al 1986). Beersing also prepared: *Regional Flood Estimation for the Island of Newfoundland using Lotus 1-2-3™* in 1990. The advantages of calculation on an electronic spreadsheet include: checking the sensitivity of the estimated flood flow to changes in physiographic parameters, avoiding arithmetic and coefficient selection errors, quick calculation of peak flows and their confidence limits, and printing of results.

The results of the single station frequency analysis are presented in the next section. These data are the return period flood estimates which were calculated from the flood data.

Sometimes flood estimates are required on a river near an existing gauging station. If the streamflow records are long, the results of the single station frequency analysis can be applied. In most cases, flood estimates are required on ungauged watersheds and therefore rely on regional flood frequency analysis equations for flood estimation. These equations have limitations. A guideline for flood estimation using single station frequency analysis and regional flood frequency analysis is provided as well as worked examples. The final section of this report provides documentation on the electronic spreadsheet RFFA99. RFFA99 automates the calculation of return period flood flows based on regional flood frequency analysis. RFFA99 is provided on disk in the back cover of this report. RFFA99 was developed in Lotus Version 5, and is provided in Lotus Version 5 and Excel Version 97.

2. SINGLE STATION FLOOD FREQUENCY ANALYSIS

The data base for single station flood frequency analysis consisted of all flood data to 1996 for 65 gauged watersheds on the island of Newfoundland as listed in Table 2.1. These watersheds were not affected by regulation, had at least 10 years of flood data, were not urbanizing, and passed all prerequisite statistical tests for frequency analysis. The locations of the hydrometric stations are shown in Figure 2.1.

The computer program CFA88 was used for single station frequency analysis. The Generalized Extreme Value (GEV) and the Three Parameter Log-normal (LN3) probability distributions were considered for frequency analysis. The choice between the GEV or the LN3 distribution was based on the mean absolute deviation between the theoretical and empirical probabilities of the upper half of the data set. Only the upper half of the data set was used because it is this portion of the curve with which we have the most interest: the 2-year return period and above. The LN3 distribution was the better fitting distribution on 42 (68%) of the 65 watersheds.

The estimated flood flow rates for the 2-, 5-, 10-, 20-, 50-, 100-, and 200-year return periods are listed in Table 2.2. Generally, the confidence in the estimate for long return periods is low when the sample size is small. Return period flows were qualified by calculating the 95% confidence interval around the estimates of the 2-, 20- and 100-year return period flows. The confidence intervals were calculated assuming a LN3 distribution in all cases. The confidence intervals in Table 2.3 are given as a percentage of the LN3 return period flows. Typical upper and lower 95% confidence intervals are indicated in Table 2.3 as the medians of the upper and lower 95% confidence intervals of each return period. Given the magnitude of some of the confidence intervals at high return periods, it is clear that high return period flows should not be used for some stations with small sample sizes.

Table 2.1 Data Base for Single Station Frequency Analysis

Station Number	Station Name	Area (km^2)	Start Year	Finish Year	Sample Size
02YA001	Ste. Genevieve River near Foresters Point	306	1970	1996	27
02YA002	Bartletts River near St. Anthony	33.6	1986	1996	11
02YC001	Torrent River at Bristols Pool	624	1959	1996	38
02YD001	Beaver Brook near Roddickton	237	1960	1978	19
02YD002	Northeast Brook near Roddickton	200	1980	1996	17
02YE001	Greavett Brook above Portland Creek Pond	95.7	1980	1996	17
02YF001	Cat Arm River above Great Cat Arm	611	1969	1982	14
02YG001	Main River at Paradise Pool	627	1986	1996	11
02YG002	Middle Arm Brook below Flat Water Pond	224	1987	1996	10
02YH001	Bottom Creek near Rocky Harbour	33.4	1985	1996	12
02YJ001	Harrys River below Highway Bridge	640	1969	1996	28
02YJ003	Pinchgut Brook at outlet of Pinchgut Lake	119	1986	1996	11
02YK002	Lewaseechjeech Brook at Little Grand Lake	470	1953	1996	35
02YK003	Sheffield River at Sheffield Lake	362	1956	1966	11
02YK004	Hinds Brook near Grand Lake	529	1957	1979	23
02YK005	Sheffield Brook near Trans-Canada Highway	391	1973	1996	24
02YK007	Glide Brook below Glide Lake	112	1984	1996	13
02YK008	Boot Brook at Trans-Canada Highway	20.4	1985	1996	12
02YL001	Upper Humber River near Reidville	2110	1929	1996	68
02YL004	South Brook at Pasadena	58.5	1983	1996	14
02YL005	Rattler Brook near McIvers	17.0	1985	1996	12
02YM003	Southwest Brook near Baie Verte	93.2	1980	1996	17
02YN002	Lloyds River below King George IV Lake	469	1981	1996	16
02YO006	Peters River near Botwood	177	1981	1996	16
02YO007	Leech Brook near Grand Falls	88.3	1984	1995	12
02YO008	Great Rattling Brook above Tote River Confluence	823	1984	1996	13
02YO010	Junction Brook near Badger	61.6	1985	1996	12
02YP001	Shoal Arm Brook near Badger Bay	63.8	1982	1996	15
02YQ001	Gander River at Big Chute	4400	1959	1996	47
02YQ004	Northwest Gander River near Gander Lake	2150	1983	1996	14
02YQ005	Salmon River near Glenwood	80.8	1987	1996	10
02YR001	Middle Brook near Gambo	275	1959	1996	38
02YR002	Ragged Harbour River near Musgrave Harbour	399	1977	1996	20
02YR003	Indian Bay Brook near Northwest Arm	554	1981	1996	16
02YS001	Terra Nova River at Eight Mile Bridges	1290	1953	1984	31
02YS003	Southwest Brook at Terra Nova National Park	36.7	1968	1996	29
02YS005	Terra Nova River at Glovertown	2000	1985	1996	12
02ZA001	Little Barachois Brook near St. Georges	343	1979	1996	18
02ZA002	Highlands River at Trans-Canada Highway	72	1982	1996	15
02ZA003	Little Codroy River near Doyles	139	1982	1996	15
02ZB001	Isle aux Morts River below Highway Bridge	205	1962	1996	35
02ZC002	Grandy Brook below Top Pond Brook	230	1982	1996	15
02ZD002	Grey River near Grey River	1340	1970	1996	19
02ZE001	Salmon River at Long Pond	2640	1944	1965	21
02ZG001	Garnish River near Garnish	205	1959	1996	38
02ZG002	Tides Brook below Freshwater Pond	166	1977	1996	20
02ZG003	Salmonier River near Lamaline	115	1980	1996	17
02ZG004	Rattle Brook near Boat Harbour	42.7	1981	1996	16
02ZH001	Pipers Hole River at Mothers Brook	764	1953	1996	44
02ZH002	Come by Chance River near Goobies	43.3	1961	1996	28
02ZJ001	Southern Bay River near Southern Bay	67.4	1977	1996	20
02ZJ003	Shoal Harbour River near Clarenville	106	1986	1996	11
02ZK001	Rocky River near Colinet	301	1949	1996	48
02ZK002	Northeast River near Placentia	89.6	1979	1996	18
02ZK003	Little Barachois River near Placentia	37.2	1983	1996	14
02ZK004	Little Salmonier River near North Harbour	104	1983	1996	14
02ZK005	Trout Brook near Bellevue	50.3	1986	1996	11
02ZL003	Spout Cove Brook near Spout Cove	10.8	1979	1996	18
02ZL004	Shearstown Brook near Shearstown	28.9	1983	1996	14
02ZL005	Big Brook at Lead Cove	11.2	1985	1996	12
02ZM006	Northeast Pond River at Northeast Pond	3.63	1954	1996	43
02ZM009	Seal Cove Brook near Cappahayden	53.6	1979	1996	18
02ZM016	South River near Holyrood	17.3	1983	1996	14
02ZN001	Northwest Brook at Northwest Pond	53.3	1966	1995	30
02ZN002	St. Shotts River near Trepassey	15.5	1985	1996	12

Note: Sample size may not coincide with the start and finish years due to missing data.

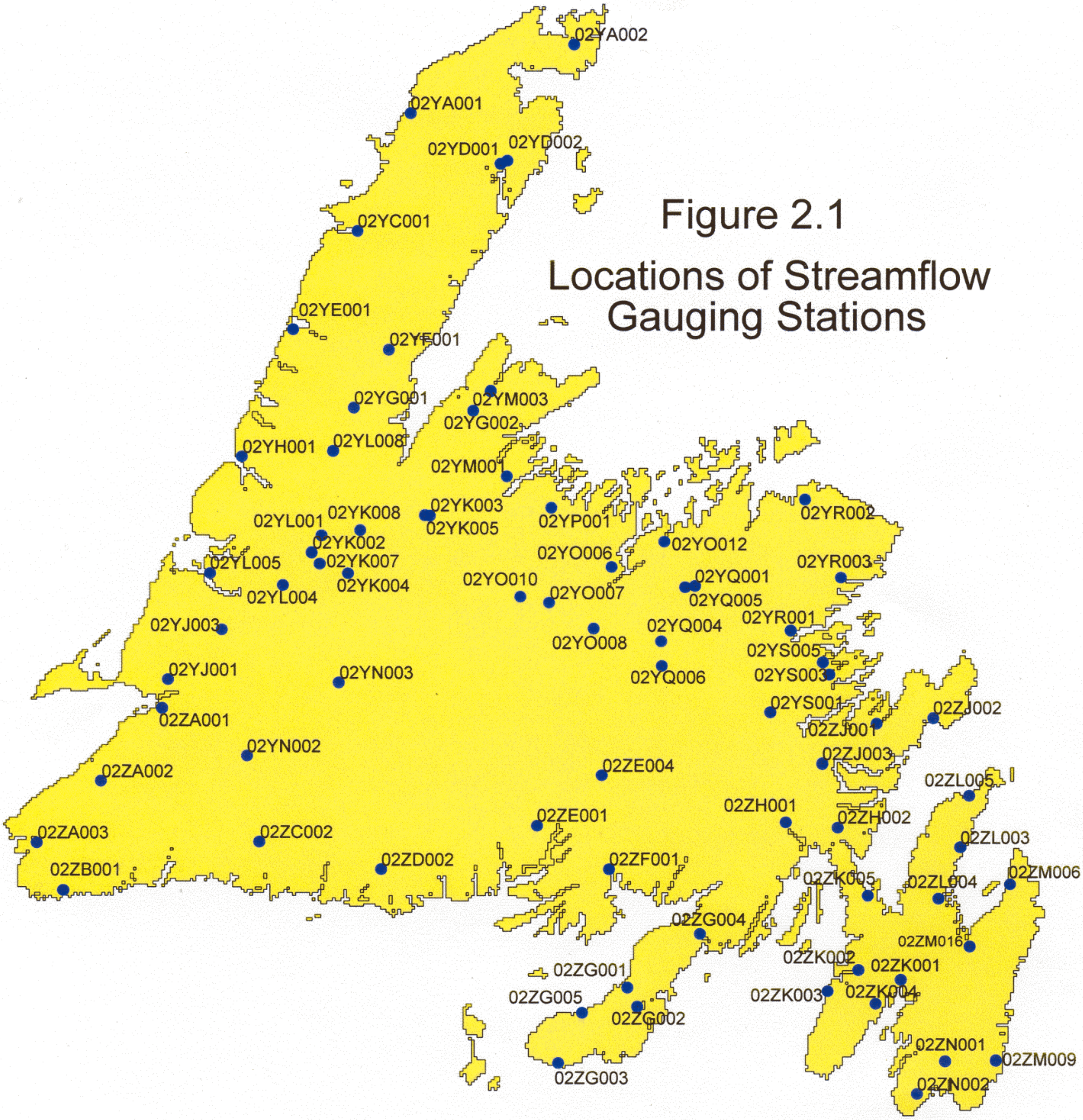

Figure 2.1

Locations of Streamflow Gauging Stations

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Table 2.2 Single Station Flood Frequency Analysis Results

Station Number	n	PDF	Area (km^2)	Q2 (m^3/s)	Q5 (m^3/s)	Q10 (m^3/s)	Q20 (m^3/s)	Q50 (m^3/s)	Q100 (m^3/s)	Q200 (m^3/s)
02YA001	27	LN3	306	30.1	40.4	48.3	56.8	69.1	79.2	90.1
02YA002	11	LN3	33.6	14.5	26.8	41.8	63.5	105	150	209
02YC001	38	LN3	624	187	251	294	338	395	439	485
02YD001	19	LN3	237	96.9	129	152	174	204	228	252
02YD002	17	LN3	200	38.0	49.4	57.4	65.5	76.6	85.4	94.4
02YE001	17	LN3	95.7	41.4	52.9	60.1	66.8	75.2	81.4	87.5
02YF001	14	LN3	611	260	337	397	460	552	627	708
02YG001	11	GEV	627	291	370	414	451	493	520	544
02YG002	10	LN3	224	45.6	65.2	79.0	92.7	111	126	141
02YH001a	11	GEV	33.4	4.52	5.73	6.46	7.11	7.89	8.43	8.93
02YJ001	28	GEV	640	312	415	483	549	634	698	762
02YJ003	11	LN3	119	31.3	36.6	38.7	40.2	41.7	42.5	43.2
02YK002a	23	LN3	470	119	151	175	201	238	267	299
02YK003	11	GEV	362	68.0	85.1	92.7	98.2	103	106	108
02YK004a	17	GEV	529	97.2	116	127	136	145	152	157
02YK005	24	LN3	391	73.8	93.2	106	118	133	145	157
02YK007	13	LN3	112	23.5	29.7	33.4	36.7	40.7	43.5	46.2
02YK008	12	LN3	20.4	9.77	18.5	27.2	38.3	57.0	74.8	96.3
02YL001	68	LN3	2110	582	709	787	859	948	1010	1080
02YL004a	13	LN3	58.5	43.4	64.6	82.0	101	130	154	181
02YL005	12	GEV	17.0	12.6	24.8	43.3	77.9	174	323	604
02YM003	17	GEV	93.2	39.3	56.3	67.3	77.7	90.8	100	110
02YN002	16	LN3	469	172	251	315	384	485	570	663
02YO006a	16	LN3	177	43.0	54.1	61.1	67.7	76.1	82.3	88.4
02YO007	12	LN3	88.3	27.3	37.3	48.3	62.8	88.7	114	147
02YO008	13	LN3	823	218	291	343	395	466	522	581
02YO010	12	LN3	61.6	9.22	15.5	22.6	32.6	51.0	69.8	94.0
02YP001a	14	LN3	63.8	22.5	26.2	27.8	29.0	30.1	30.8	31.4
02YQ001	47	LN3	4400	581	731	825	912	1020	1100	1180
02YQ004	14	LN3	2150	634	865	995	1110	1240	1330	1420
02YQ005	10	GEV	80.8	44.7	54.3	58.6	61.6	64.4	66.0	67.1
02YR001	38	LN3	275	27.4	34.4	38.7	42.7	47.5	50.8	54.0
02YR002	20	GEV	399	64.1	83.8	100	151	151	180	214
02YR003	16	GEV	554	59.3	71.3	76.7	80.6	84.1	86.0	87.4
02YS001a	20	GEV	1290	165	201	227	254	292	323	365
02YS003	29	GEV	36.7	13.0	17.0	19.9	22.8	26.8	29.9	33.3
02YS005	12	GEV	2000	239	297	323	342	359	368	375
02ZA001	18	GEV	343	115	156	182	205	234	254	273
02ZA002	15	LN3	72.0	49.9	85.2	121	165	241	313	399
02ZA003	15	LN3	139	149	211	252	292	344	384	424
02ZB001	35	LN3	205	340	509	635	765	947	1090	1250
02ZC002	15	LN3	230	357	486	577	668	790	886	984
02ZD002	19	GEV	1340	851	1190	1390	1580	1800	1950	2090
02ZE001	21	GEV	2640	282	348	383	402	443	464	484
02ZG001a	34	LN3	205	55.9	74.1	86.8	99.4	116	129	143
02ZG002	20	GEV	166	46.6	64.7	77.4	90.0	107	120	134
02ZG003	17	LN3	115	55.5	79.9	97.2	115	138	157	176
02ZG004	16	LN3	42.7	35.1	49.0	58.0	66.5	77.4	85.5	93.6
02ZH001a	32	GEV	764	249	325	369	407	452	483	511
02ZH002	28	GEV	43.3	31.3	43.4	50.6	56.9	64.3	69.4	74.1
02ZJ001	20	GEV	67.4	21.7	29.3	34.6	39.9	47.1	52.7	58.6
02ZJ003	11	LN3	106	30.1	49.4	66.6	86.5	118	145	177
02ZK001	48	LN3	301	144	199	238	277	329	370	412
02ZK002	18	GEV	89.6	71.1	106	132	158	195	225	256
02ZK003	14	LN3	37.2	66.8	79.1	82.7	84.8	86.5	87.4	88.0
02ZK004	14	LN3	104	91.3	130	162	197	249	294	342
02ZK005	11	LN3	50.3	24.5	38.7	50.0	62.3	80.3	95.4	112
02ZL003	18	LN3	10.8	8.52	12.2	14.5	16.8	19.6	21.7	23.8
02ZL004	14	LN3	28.9	16.0	22.7	26.8	30.6	35.3	38.8	42.1
02ZL005	12	LN3	11.2	4.82	7.26	9.51	12.2	16.4	20.3	24.7
02ZM006	43	GEV	3.63	3.29	4.46	5.28	6.11	7.25	8.14	9.08
02ZM009a	17	GEV	53.6	26.5	29.5	30.8	31.8	32.6	33.1	33.5
02ZM016	14	LN3	17.3	12.3	16.7	19.2	21.6	24.4	26.4	28.4
02ZN001	30	LN3	53.3	37.9	47.4	52.8	57.5	63	66.8	70.5
02ZN002	12	LN3	15.5	8.07	11.7	14.4	17.3	21.4	24.7	28.3

Notes: n - sample size,
PDF - probability distribution function,
QT - "T" year return period flood flow.
a - outlier(s) removed

Table 2.3 Ninety-five Percent (95%) Confidence Interval as a Percentage of the LN3 Return Period Flows

Station Number	n	Lower Limit	Q2	Upper Limit	Lower Limit	Q20	Upper Limit	Lower Limit	Q100	Upper Limit
02YA001	27	-10%	30.1	13%	-22%	56.8	32%	-30%	79.2	47%
02YA002	11	-29%	14.5	49%	-62%	63.5	218%	-75%	150	365%
02YC001	38	-10%	187	11%	-17%	338	21%	-21%	439	27%
02YD001	19	-13%	96.9	16%	-23%	174	31%	-29%	228	43%
02YD002	17	-12%	38.0	15%	-23%	65.5	33%	-30%	85.4	46%
02YE001	17	-15%	41.4	17%	-21%	66.8	27%	-26%	81.4	36%
02YF001	14	-12%	260	17%	-27%	460	44%	-36%	627	67%
02YG001	11	-17%	292	18%	-20%	449	22%	-23%	523	26%
02YG002	10	-22%	45.6	30%	-34%	92.7	53%	-41%	126	72%
02YH001a	11	-17%	4.53	19%	-22%	7.23	27%	-27%	8.68	34%
02YJ001	28	-12%	313	14%	-18%	554	22%	-22%	698	28%
02YJ003	11	-16%	31.3	12%	-10%	40.2	7%	-10%	42.5	6%
02YK002a	23	-9%	119	12%	-20%	201	30%	-28%	267	44%
02YK003	11	-20%	71.2	15%	-11%	93.8	6%	-9%	98.6	5%
02YK004a	17	-8%	90.0	13%	-29%	167	58%	-42%	255	99%
02YK005	24	-10%	73.8	11%	-16%	118	20%	-21%	145	27%
02YK007	13	-15%	23.5	17%	-20%	36.7	23%	-23%	43.5	28%
02YK008	12	-28%	9.77	51%	-54%	38.3	136%	-65%	74.8	206%
02YL001	68	-5%	582	6%	-8%	859	9%	-11%	1010	12%
02YL004a	13	-19%	43.4	28%	-37%	101	68%	-47%	154	100%
02YL005	12	-39%	16.5	50%	-39%	55.4	57%	-44%	83.9	70%
02YM003	17	-20%	39.2	24%	-26%	79.9	34%	-31%	105	42%
02YN002	16	-17%	172	23%	-33%	384	55%	-42%	570	80%
02YO006a	16	-13%	43.0	15%	-20%	67.7	25%	-24%	82.3	33%
02YO007	12	-11%	27.3	21%	-42%	62.8	119%	-59%	114	215%
02YO008	13	-15%	218	20%	-27%	395	41%	-34%	522	58%
02YO010	12	-18%	9.22	37%	-55%	32.6	168%	-69%	69.8	280%
02YP001a	14	-13%	22.5	11%	-9%	29.0	7%	-9%	30.8	7%
02YQ001	47	-7%	581	8%	-11%	912	13%	-14%	1100	16%
02YQ004	14	-21%	634	22%	-22%	1110	24%	-24%	1330	27%
02YQ005	10	-18%	44.7	16%	-15%	62.5	13%	-16%	66.0	13%
02YR001	38	-9%	28.5	10%	-13%	42.7	15%	-16%	50.8	19%
02YR002	20	-11%	64.4	15%	-25%	121	40%	-34%	170	60%
02YR003	16	-13%	58.9	12%	-12%	81.9	11%	-13%	80.3	12%
02YS001a	20	-7%	168	9%	-19%	254	27%	-26%	323	41%
02YS003	29	-10%	13.0	13%	-19%	23.4	26%	-25%	29.9	35%
02YS005	12	-19%	249	14%	-10%	327	6%	-9%	344	5%
02ZA001	18	-16%	115	21%	-28%	205	41%	-35%	254	57%
02ZA002	15	-20%	49.9	35%	-47%	165	107%	-59%	313	165%
02ZA003	15	-19%	149	23%	-27%	292	37%	-32%	384	47%
02ZB001	35	-14%	340	17%	-23%	765	30%	-28%	1090	41%
02ZC002	15	-16%	357	20%	-26%	668	38%	-33%	886	52%
02ZD002	19	-19%	846	21%	-23%	1620	27%	-26%	2060	43%
02ZG001a	34	-10%	55.9	12%	-17%	99.4	22%	-22%	129	30%
02ZG002	20	-16%	46.6	19%	-24%	91.6	32%	-30%	122	43%
02ZG003	17	-18%	55.5	23%	-28%	115	40%	-34%	157	53%
02ZG004	16	-18%	35.1	22%	-25%	66.5	32%	-30%	85.5	41%
02ZH001a	32	-11%	248	12%	-15%	417	17%	-18%	509	21%
02ZH002	28	-15%	31.0	17%	-19%	58.9	22%	-22%	74.8	27%
02ZJ001	20	-14%	21.7	17%	-23%	40.6	31%	-29%	53.5	42%
02ZJ003	11	-24%	30.1	40%	-47%	86.5	100%	-57%	145	149%
02ZK001	48	-10%	144	11%	-16%	277	20%	-21%	370	27%
02ZK002	18	-21%	70.9	27%	-30%	163	43%	-36%	230	56%
02ZK003	14	-21%	66.8	13%	-7%	84.8	3%	-5%	87.4	2%
02ZK004	14	-16%	91.3	23%	-34%	197	60%	-44%	294	90%
02ZK005	11	-25%	24.5	37%	-41%	62.3	77%	-50%	95.4	109%
02ZL003	18	-19%	8.52	22%	-24%	16.8	31%	-29%	21.7	39%
02ZL004	14	-22%	16.0	25%	-26%	30.6	32%	-30%	38.8	39%
02ZL005	12	-18%	4.82	30%	-42%	12.2	93%	-54%	20.3	146%
02ZM006	43	-10%	3.28	12%	-17%	6.20	21%	-21%	8.21	27%
02ZM009a	17	-7%	26.7	6%	-6%	31.3	4%	-6%	32.6	4%
02ZM016	14	-19%	12.3	21%	-23%	21.6	27%	-26%	26.4	33%
02ZN001	30	-10%	37.9	10%	-12%	57.5	13%	-14%	66.8	16%
02ZN002	12	-19%	8.07	27%	-35%	17.3	58%	-43%	24.7	83%
Median		-16%		21%	-24%		36%	-30%		46%

Notes: n - sample size, a - outlier(s) removed
QT - “T” year return period flow.

3. REGIONAL FLOOD FREQUENCY ANALYSIS

3.1 Methodology

The database for the regional analysis was a subset of the database for the single station frequency analysis. There was a need to retain data for testing the regional equations. Only those stations which had an upper 95% confidence level of the 1:100 year flow (based on a three parameter log-normal distribution) which were less than 100% of the estimate were retained for regional analysis. Fifteen (15) stations were removed from the analysis and were retained for testing the regional equations. Fifty (50) stations remained for regional analysis.

The island was divided into 4 hydrologically homogeneous regions based on previous studies, the availability of data, regional flood characteristics, regional precipitation characteristics, regional physiographic characteristics, and the results of regression analyses on test regions. The hydrologically homogeneous regions identified in Figure 3.1 provided the best results. The delineation of the regions is approximate.

Equations were developed for each region which provided predictions of return period flood estimates based on physiographic data. The physiographic database is shown in Table 3.1. Details on the extraction procedures are given in Appendix A. The equations were of the form:

$$Q_T = c \times (var1)^{a1} \times (var2)^{a2} \times (var3)^{a3} \times \ldots$$

where, Q_T is the magnitude of the flood with return period T,

c, a1, a2, a3, ... are constants, and

var1, var2, var3, ... are variables which correspond to the significant physiographic parameters.

Taking the $\log_{10}$ of both sides of the equation linearizes the equation so that multiple linear regression can be performed.

$$\log_{10}(Q_T) = \log_{10}(c) + a_1 \times \log_{10}(var1) + a_2 \times \log_{10}(var2) + a_3 \times \log_{10}(var3) + \ldots$$

A forward stepwise regression was performed. The coefficients and variables in the final regional equations were selected based on the following criteria: 1) The coefficient of correlation between the dependent and independent variables had to be significantly high., 2) The standard error of the estimate had to be a minimum., 3) The final predictor variables had to be independent of each other., 4) Entry into the regression equation had to be significant at a 5% level using the F-ratio., and 5) The number of physiographic parameters in the regression equations had to be minimal.

3.2 Results

The final regional regression equations were as follows:

North-west Region:

$$\log_{10}(Q_T) = \log_{10}(c) + a_1 \times \log_{10}(DA) + a_2 \times \log_{10}(LAF)$$

North-east Region:

$$\log_{10}(Q_T) = \log_{10}(c) + a_1 \times \log_{10}(DA) + a_2 \times \log_{10}(LAF)$$

South-east Region:

$$\log_{10}(Q_T) = \log_{10}(c) + a_1 \times \log_{10}(DA) + a_2 \times \log_{10}(LAF)$$

South-west Region:

$$\log_{10}(Q_T) = \log_{10}(c) + a_1 \times \log_{10}(DA) + a_2 \times \log_{10}(LSF)$$

You will note that DA was var1 in all regions. LAF was var 2 in all but the South-west region where var2 was LSF. The coefficients, c, a1, and a2, are listed by return period in Tables 3.2a-d.

The standard error of the estimate in the South-west Region was much higher than the error in the other regions. Return period flood flows per unit area were quite variable in this region. An "Upper Envelope Curve" was developed which looked at only those watersheds which had high peak flows per unit area. This curve, while biased towards higher flood flows, had less error and an improved correlation. Within the applicable drainage area range, these floods represent the highest in magnitude on the island. The final regression equation was:

South-west Upper Envelope Curve:

$$\log_{10}(Q_T) = \log_{10}(c) + a_1 \times \log_{10}(DA)$$

The coefficients, c and a1, are listed by return period in Table 3.3.

3.3 Limitations

Regression equations should not be used if the values of the physiographic parameters are outside of the range of the physiographic parameters which were used in the development of the regression equations. Caution should be used when the values of the physiographic parameters are near the limits for their region. Table 3.4 provides a listing of physiographic extremes by region for guidance. The most important physiographic parameters are DA, LAF and LSF.

Due care needs to be exercised in the abstraction of physiographic parameters. The anticipated error in Q_T ranged from 1.7% to 3.4% for all regions and return periods when the error in the abstraction of the most important parameter (Drainage Area) was varied by 3%. A 3% error in the abstraction of LSF may result in an error as high as 18% in the flood estimate for the South-west Region. The LAF parameter was relatively insensitive to abstraction errors. These percentages are for the "average" case. The sensitivity of a regression equation for a specific watershed can be easily assessed by varying the independent variable(s) in an electronic spreadsheet.

While the SEE (standard error of the estimate) in $\log_{10}$ units is useful for the calculation of the upper 95% confidence limit (and other confidence limits) on the flood estimate for a specific watershed, it did not provide an indication of the expected percentage difference between the regional regression equation estimates and the single station frequency analysis estimates. Testing of the regression equations on the data set that produced them and on an independent data set indicated that the median absolute percentage difference between the regional regression equation estimates and the single station frequency analysis estimates was about 15% for the 2 year return period and about 40% for the 200 year return period.

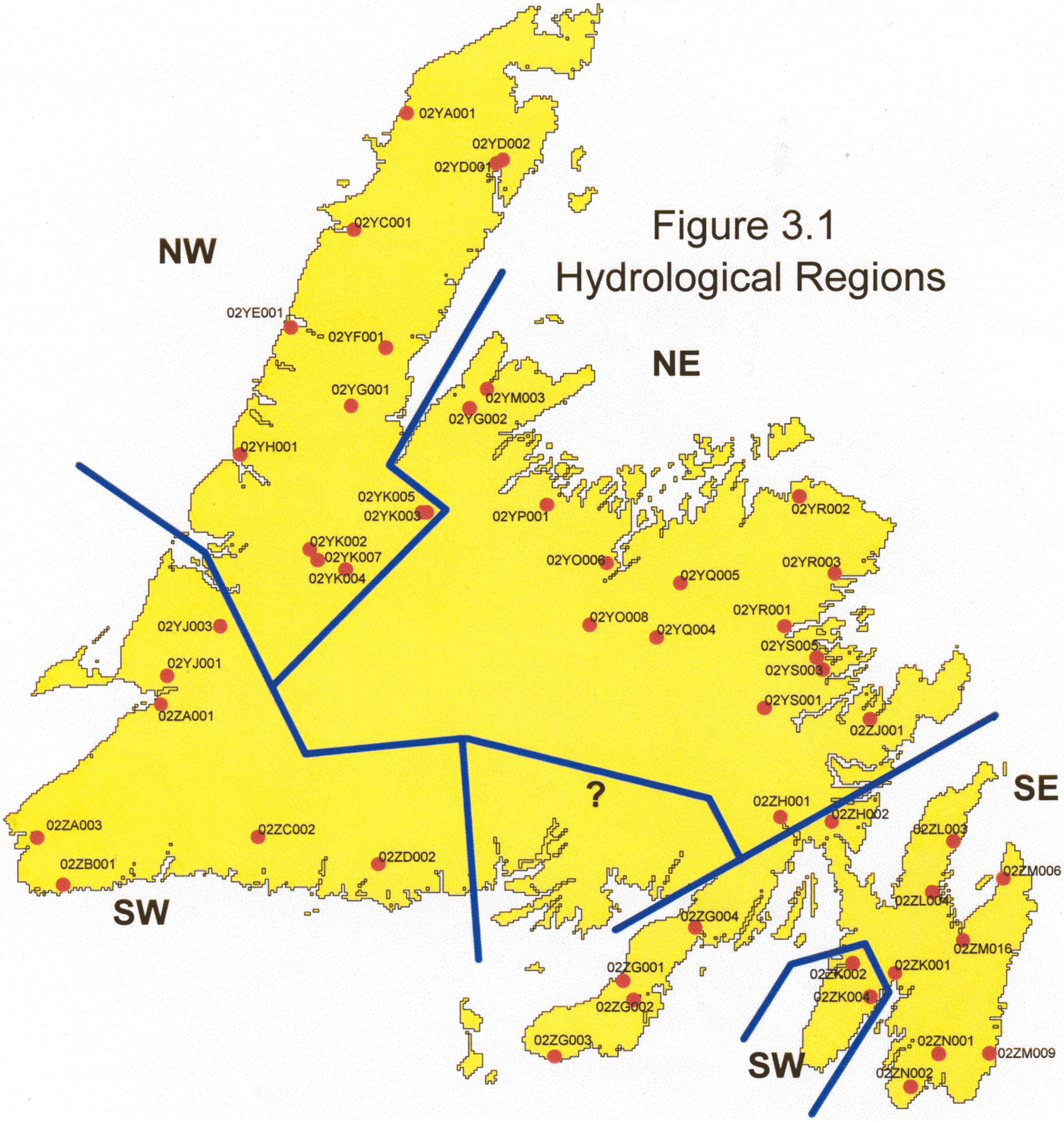

Figure 3.1
Hydrological Regions
NW
NE
SW
SE
?
SW
02YA001
02YD002
02YD001
02YC001
02YE001
02YF001
02YG001
02YM003
02YG002
02YH001
02YK005
02YK003
02YP001
02YR002
02YK002
02YK007
02YK004
02YO006
02YQ005
02YR003
02YJ003
02YO008
02YQ004
02YR001
02YS005
02YS003
02YJ001
02ZA001
02YS001
02ZJ001
02ZH001
02ZH002
02ZL003
02ZA003
02ZC002
02ZD002
02ZB001
02ZM006
02ZL004
02ZG004
02ZM016
02ZG001
02ZK002
02ZK001
02ZK004
02ZG002
02ZG003
02ZN001
02ZM009
02ZN002

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Table 3.1 Physiographic Database

ID #	STATION NAME	GAUGE LOCATION LATITUDE DEG	LATITUDE MIN	LATITUDE SEC	LONGITUDE DEG	LONGITUDE MIN	LONGITUDE SEC	DRAIN AREA (KM^2)	FRAC TREE (-)	FRAC SWAMP (-)	FRAC LAKE (-)	FRAC L+S (-)	FRAC BAR'N (-)	FRAC ACLS (-)	LSF (-)	LAF (-)	LENGTH MAIN R (KM)	ELEV DIFF (M)	SLOPE M1 (%)	SLOPE M2 (%)	DRAIN DENSITY (KM^-1)	SHAPE FACTOR (-)
02YA001	STE. GENEVIEVE RIVER NEAR FORESTER'S POINT	51	8	18	56	47	32	306	0.64	0.14	0.22	0.35	0.00	0.96	1.78	1053	38.9	88	0.23	0.14	0.54	1.48
02YA002	BARTLETTS RIVER NEAR ST. ANTHONY	51	26	57	55	38	31	33.6	0.40	0.03	0.13	0.16	0.44	0.99	1.91	652	13.2	150	1.14	1.21	0.91	1.64
02YC001	TORRENT RIVER AT BRISTOL'S POOL	50	36	27	57	9	4	624	0.33	0.04	0.13	0.17	0.50	0.99	1.91	175	48.3	479	0.99	1.01	0.76	1.45
02YD001	BEAVER BROOK NEAR RODDICKTON	50	54	51	56	9	26	237	0.81	0.04	0.05	0.08	0.11	0.73	1.68	0	40.6	328	0.81	0.68	0.34	2.23
02YD002	NORTHEAST BROOK NEAR RODDICKTON	50	55	44	56	6	44	200	0.83	0.04	0.13	0.17	0.00	0.99	1.90	484	38.3	270	0.70	0.47	0.93	1.65
02YE001	GREAVETT BROOK ABOVE PORTLAND CREEK POND	50	9	37	57	34	45	95.7	0.49	0.06	0.06	0.12	0.39	0.88	1.82	134	24.5	700	2.86	3.09	0.75	1.64
02YF001	CAT ARM RIVER ABOVE GREAT CAT ARM	50	4	33	56	55	22	611	0.69	0.05	0.08	0.13	0.18	1.00	1.93	0	30.2	250	0.83	0.73	0.58	1.86
02YG001	MAIN RIVER AT PARADISE POOL	49	48	46	57	9	24	627	0.78	0.06	0.07	0.13	0.09	0.63	1.55	18.3	31.9	375	1.18	1.11	1.30	1.83
02YG002	MIDDLE ARM BROOK BELOW FLATWATER POND	49	48	22	56	20	33	224	0.83	0.06	0.09	0.15	0.02	0.96	1.88	299	26.4	255	0.96	0.75	0.45	1.84
02YH001	BOTTOM CREEK NEAR ROCKY HARBOUR	49	35	6	57	54	34	33.4	0.79	0.02	0.11	0.13	0.08	0.93	1.86	545	14.6	163	1.12	0.85	1.13	1.68
02YJ001	HARRYS RIVER BELOW HIGHWAY BRIDGE	48	34	31	58	21	48	640	0.79	0.09	0.06	0.14	0.07	0.75	1.67	141	60.0	509	0.85	0.35	1.12	1.81
02YJ003	PINCHGUT BROOK AT OUTLET OF PINCHGUT LAKE	48	48	21	58	0	56	119	0.86	0.05	0.05	0.10	0.04	1.00	1.95	290	16.6	164	0.99	0.78	1.73	1.54
02YK002	LEWASEECHJEECH BROOK AT LITTLE GRAND LAKE	49	9	43	57	25	28	470	0.55	0.06	0.10	0.16	0.29	1.00	1.92	274	54.9	561	1.02	0.59	0.63	2.32
02YK003	SHEFFIELD RIVER AT SHEFFIELD LAKE	49	20	10	56	37	57	362	0.67	0.07	0.11	0.18	0.15	1.00	1.91	688	37.0	351	0.95	1.13	0.43	1.85
02YK004	HINDS BROOK NEAR GRAND LAKE	49	4	21	57	10	46	529	0.35	0.24	0.12	0.36	0.29	0.95	1.77	666	49.3	320	0.65	0.32	0.64	1.78
02YK005	SHEFFIELD BROOK NEAR TRANS-CANADA HIGHWAY	49	20	11	56	39	56	391	0.68	0.08	0.10	0.17	0.15	0.94	1.85	590	38.1	378	0.99	1.07	0.19	1.98
02YK007	GLIDE BROOK BELOW GLIDE LAKE	49	6	50	57	22	9	112	0.87	0.09	0.04	0.13	0.00	0.98	1.91	132	26.8	234	0.88	0.90	1.28	1.61
02YK008	BOOT BROOK AT TRANS-CANADA HIGHWAY	49	15	59	57	6	14	20.4	0.75	0.22	0.02	0.24	0.01	0.65	1.50	0	10.1	137	1.35	1.16	1.28	1.47
02YL001	UPPER HUMBER RIVER NEAR REIDVILLE	49	14	26	57	21	45	2110	0.74	0.06	0.05	0.11	0.15	0.75	1.68	0	118.8	678	0.57	0.46	0.79	1.56
02YL004	SOUTH BROOK AT PASEDENA	49	0	43	57	36	47	58.5	0.94	0.01	0.01	0.02	0.05	0.08	1.06	0	13.2	130	0.99	1.04	1.34	1.54
02YL005	RATTLER BROOK NEAR MCIVERS	49	3	34	58	6	19	17	0.91	0.08	0.02	0.10	0.00	0.46	1.39	0	8.2	244	2.98	2.88	1.05	1.10
02YL008	UPPER HUMBER RIVER ABOVE BLACK BROOK	49	37	9	57	17	39	471	0.58	0.01	0.07	0.08	0.34	0.99	1.95	0	48.5	393	0.81	0.64	0.57	1.90
02YM001	INDIAN BROOK AT INDIAN FALLS	49	30	43	56	6	45	974	0.79	0.07	0.09	0.16	0.05	0.88	1.80	36.4	65.0	290	0.45	0.41	0.45	1.88
02YM003	SOUTH WEST BROOK NEAR BAIE VERTE	49	53	37	56	13	22	93.2	0.91	0.07	0.05	0.11	0.00	0.56	1.49	0	18.6	107	0.58	0.57	0.68	1.67
02YN002	LLOYD'S RIVER BELOW KING GEORGE IV LAKE	48	14	32	57	49	41	469	0.23	0.06	0.12	0.18	0.63	1.00	1.91	371	57.3	166	0.29	0.30	1.37	2.15
02YN003	STAR BROOK BELOW STAR LAKE	48	34	46	57	13	41	427	0.21	0.30	0.09	0.38	0.40	1.00	1.80	377	42.5	360	0.85	0.74	0.59	1.91
02YO006	PETER'S RIVER NEAR BOTWOOD	49	6	21	55	24	38	177	0.83	0.13	0.03	0.16	0.02	0.97	1.89	0	42.7	190	0.45	0.45	0.80	1.93
02YO007	LEECH BROOK NEAR GRAND FALLS	48	56	42	55	49	42	88.3	0.70	0.24	0.04	0.28	0.02	0.73	1.57	0	23.1	272	1.18	0.88	0.74	1.52
02YO008	GREAT RATTLING BR. ABOVE TOTE R. CONFLUENCE	48	49	38	55	31	50	823	0.73	0.19	0.05	0.24	0.03	0.55	1.40	0	69.0	221	0.32	0.30	0.69	1.80
02YO010	JUNCTION BROOK NEAR BADGER	48	58	23	56	1	21	61.6	0.81	0.09	0.10	0.19	0.00	0.89	1.79	601	18.2	187	1.03	0.62	0.77	1.55
02YO012	SOUTHWEST BROOK AT LEWISPORTE	49	12	58	55	3	11	58.7	0.80	0.08	0.12	0.20	0.00	0.67	1.55	128	22.7	134	0.59	0.42	0.54	1.87
02YP001	SHOAL ARM BROOK NEAR BADGER BAY	49	22	18	55	48	44	63.8	0.88	0.07	0.06	0.13	0.00	0.79	1.72	119	20.0	113	0.56	0.53	0.88	1.62
02YQ001	GANDER RIVER AT BIG SHUTE	49	0	55	54	51	13	4400	0.76	0.08	0.09	0.17	0.07	0.91	1.82	277	133.8	297	0.22	0.15	0.45	2.08
02YQ004	NORTHWEST GANDER RIVER NEAR GANDER LAKE	48	46	7	55	4	52	2150	0.66	0.25	0.06	0.31	0.03	0.44	1.22	0	104.2	265	0.25	0.17	0.45	1.63
02YQ005	SALMON RIVER NEAR GLENWOOD	49	0	41	54	55	3	80.8	0.85	0.11	0.04	0.15	0.00	0.87	1.79	0	22.5	372	1.65	1.03	1.09	1.78
02YQ006	SOUTHWEST GANDER RIVER BELOW LARSON FALLS	48	39	26	55	4	52	531	0.64	0.30	0.04	0.34	0.02	0.40	1.16	0	51.3	299	0.58	0.26	0.40	1.88
02YR001	MIDDLE BROOK NEAR GAMBO	48	48	28	54	13	28	267	0.75	0.07	0.18	0.24	0.01	0.98	1.86	881	49.3	177	0.36	0.32	0.26	1.93
02YR002	RAGGED HARBOUR RIVER NEAR MUSGRAVE HARBOUR	49	23	35	54	6	25	399	0.68	0.16	0.17	0.33	0.00	0.96	1.79	65.1	42.0	95	0.23	0.21	0.74	1.68
02YR003	INDIAN BAY BROOK NEAR NORTHWEST ARM	49	2	24	53	53	0	554	0.70	0.13	0.20	0.33	0.00	0.97	1.80	307	52.4	136	0.26	0.23	0.68	1.72
02YS001	TERRA NOVA RIVER AT EIGHT MILE BRIDGES	48	26	30	54	22	21	1290	0.55	0.21	0.09	0.30	0.15	0.92	1.76	138	105.0	207	0.20	0.12	0.73	2.35
02YS003	SOUTHWEST BROOK AT TERRA NOVA NATIONAL PARK	48	36	25	53	58	50	36.7	0.84	0.14	0.02	0.16	0.00	1.00	1.92	0	11.2	143	1.28	1.11	0.64	1.43
02YS005	TERRA NOVA RIVER AT GLOVERTOWN	48	39	43	54	1	5	2000	0.61	0.23	0.13	0.36	0.03	0.93	1.74	113	128.8	274	0.21	0.16	0.35	2.12
02ZA001	LITTLE BARACHOIS BROOK NEAR ST. GEORGE'S	48	26	44	58	23	55	343	0.60	0.02	0.07	0.09	0.30	0.83	1.78	0	65.5	463	0.72	0.68	1.04	2.45
02ZA002	HIGHLANDS RIVER AT TRANS-CANADA HIGHWAY	48	6	33	58	47	4	72	0.82	0.01	0.04	0.05	0.13	0.43	1.39	0	20.4	460	2.26	2.19	1.15	1.72
02ZA003	LITTLE CODROY RIVER NEAR DOYLES	47	49	19	59	11	40	139	0.66	0.07	0.04	0.11	0.16	0.73	1.66	131	25.2	450	1.78	1.46	1.46	1.68
02ZB001	ISLE AUX MORTS RIVER BELOW HIGHWAY BRIDGE	47	36	50	59	0	33	205	0.08	0.06	0.07	0.13	0.78	0.60	1.52	0	33.3	444	1.33	1.27	0.72	2.09
02ZC002	GRANDY BROOK BELOW TOP POND BROOK	47	51	27	57	44	0	230	0.20	0.01	0.05	0.06	0.82	0.34	1.30	38.4	28.9	360	1.24	1.08	0.96	1.84
02ZD002	GREY RIVER NEAR GREY RIVER	47	44	35	56	56	5	1340	0.04	0.16	0.04	0.20	0.75	0.63	1.51	0	60.0	310	0.52	0.34	0.15	5.31
02ZE001	SALMON RIVER AT LONG POND	47	56	40	55	54	50	2640	0.35	0.02	0.14	0.16	0.50	1.00	1.92	619	100.4	122	0.12	0.08	0.36	1.75
02ZE004	CONNE RIVER AT OUTLET OF CONNE RIVER POND	48	10	8	55	29	0	99.7	0.60	0.34	0.05	0.39	0.01	1.00	1.81	0	18.7	109	0.58	0.59	1.38	1.52
02ZF001	BAY DE NORD RIVER AT BIG FALLS	47	44	48	55	26	30	1170	0.32	0.05	0.18	0.24	0.44	0.96	1.84	401	68.1	282	0.41	0.34	0.61	2.15
02ZG001	GARNISH RIVER NEAR GARNISH	47	12	50	55	19	45	205	0.26	0.01	0.09	0.10	0.63	0.96	1.91	202	44.7	370	0.83	0.60	0.55	2.45
02ZG002	TIDES BROOK BELOW FRESHWATER POND	47	7	38	55	15	54	166	0.37	0.04	0.09	0.13	0.49	0.92	1.85	588	26.7	221	0.83	0.78	1.35	1.84
02ZG003	SALMONIER RIVER NEAR LAMALINE	46	52	29	55	46	39	115	0.16	0.06	0.07	0.13	0.73	0.92	1.85	42.8	24.5	136	0.55	0.34	1.55	1.62
02ZG004	RATTLE BROOK NEAR BOAT HARBOUR	47	27	2	54	51	18	42.7	0.34	0.03	0.14	0.16	0.46	0.92	1.83	123	10.0	107	1.07	1.10	1.62	1.53
02ZG005	LITTLE BARASWAY BROOK NEAR MOLLIERS	47	6	0	55	37	15	28.2	0.31	0.08	0.07	0.15	0.55	0.50	1.40	132	13.0	133	1.03	1.19	1.43	1.40
02ZH001	PIPERS HOLE RIVER AT MOTHERS BROOK	47	56	49	54	17	8	764	0.11	0.48	0.18	0.66	0.23	0.91	1.57	17.4	50.9	207	0.41	0.38	0.71	1.67
02ZH002	COME BY CHANCE RIVER NEAR GOOBIES	47	55	7	53	56	59	43.3	0.40	0.02	0.08	0.10	0.50	0.92	1.87	20.8	17.0	110	0.65	0.59	1.11	1.66
02ZJ001	SOUTHERN BAY RIVER NEAR SOUTHERN BAY	48	22	44	53	40	36	67.4	0.82	0.06	0.10	0.16	0.03	0.86	1.78	89.3	16.0	128	0.80	0.50	1.24	1.64
02ZJ002	SALMON COVE RIVER NEAR CHAMPNEYS	48	23	45	53	18	6	73.6	0.74	0.06	0.13	0.19	0.07	0.82	1.72	435	18.0	137	0.76	0.55	1.11	1.33
02ZJ003	SHOAL HARBOUR RIVER NEAR CLARENVILLE	48	12	24	54	2	23	106	0.65	0.10	0.07	0.17	0.18	0.68	1.58	166	25.1	250	0.99	0.91	0.66	1.66
02ZK001	ROCKY RIVER NEAR COLINET	47	13	29	53	34	6	301	0.51	0.02	0.10	0.12	0.37	0.57	1.49	8.79	45.2	165	0.37	0.23	0.96	1.95
02ZK002	NORTHEAST RIVER NEAR PLACENTIA	47	16	26	53	50	27	89.6	0.48	0.16	0.15	0.31	0.24	0.81	1.64	278	26.9	200	0.74	0.57	1.11	1.91
02ZK003	LITTLE BARACHOIS (BARASWAY) R NEAR PLACENTIA	47	10	53	54	2	27	37.2	0.86	0.11	0.02	0.13	0.01	0.34	1.24	0	14.6	228	1.56	1.77	1.16	1.48
02ZK004	LITTLE SALMONIER RIVER NEAR NORTH HARBOUR	47	7	15	53	44	0	104	0.23	0.38	0.08	0.46	0.31	0.91	1.67	116	28.5	236	0.83	0.66	1.50	1.85
02ZK005	TROUT BROOK NEAR BELLEVUE	47	36	21	53	45	53	50.3	0.36	0.00	0.07	0.07	0.57	0.50	1.45	91.6	14.8	137	0.92	0.88	1.18	1.90
02ZL003	SPOUT COVE BROOK NEAR SPOUT COVE	47	48	43	53	9	15	10.8	0.42	0.01	0.08	0.09	0.49	1.00	1.95	319	7.0	91	1.31	1.25	1.09	1.36
02ZL004	SHEARSTOWN BROOK AT SHEARSTOWN	47	35	2	53	18	29	28.9	0.70	0.00	0.04	0.04	0.27	0.39	1.36	0	13.4	122	0.91	1.03	1.14	1.73
02ZL005	BIG BROOK AT LEAD COVE	48	2	34	53	5	0	11.2	0.39	0.03	0.07	0.10	0.51	1.00	1.95	272	8.7	211	2.43	2.43	1.00	1.52
02ZM006	NORTHEAST POND RIVER AT NORTHEAST POND	47	38	6	52	50	14	3.9	0.75	0.17	0.04	0.21	0.04	1.00	1.89	265	2.6	64	2.44	2.42	1.04	1.24
02ZM009	SEAL COVE BROOK NEAR CAPPAHAYDEN	46	50	50	52	58	27	53.6	0.38	0.01	0.12	0.14	0.51	1.00	1.93	193	14.9	133	0.89	0.98	1.13	1.37
02ZM016	SOUTH (MAHERS) RIVER NEAR HOLYROOD	47	21	41	53	7	2	17.3	0.22	0.05	0.06	0.11	0.68	0.90	1.84	148	8.7	259	2.98	2.22	1.01	1.40
02ZN001	NORTHWEST BROOK AT NORTHWEST POND	46	51	8	53	18	11	53.3	0.09	0.00	0.13	0.13	0.79	1.00	1.94	132	14.6	93	0.63	0.61	1.09	2.06
02ZN002	ST. SHOTTS RIVER NEAR TREPASSEY	46	42	32	53	29	24	15.5	0.88	0.00	0.12	0.12	0.00	0.82	1.75	512	10.3	23	0.22	0.43	1.03	1.53
					Minimum			3.9	0.04	0.00	0.01	0.02	0.00	0.08	1.06	0	2.63	23	0.12	0.08	0.15	1.10
					Median			152.5	0.66	0.06	0.08	0.16	0.15	0.91	1.79	129.5	26.9	221	0.83	0.65	0.89	1.72
					Maximum			4400	0.94	0.48	0.22	0.66	0.82	1.00	1.95	1053	133.8	700	2.98	3.09	1.73	5.31

Abbreviations:

ID # - identification number
DEG - degrees
MIN - minutes
SEC - seconds
DRAIN - drainage
FRAC - fraction of watershed occupied by ...
TREE - forest area
SWAMP - swamp area
LAKE - lake area
L+S - lakes plus swamps area
BAR'N - barren area
ACLS - area controlled by lakes and swamps
LSF - lakes and swamps factor
LAF - lake attenuation factor
LENGTH MAIN R - length of main channel
ELEV DIFF - elevation difference between outlet and watershed divide
SLOPE M1 - slope method 1
SLOPE M2 - slope method 2

Table 3.2a Regression Coefficients for the North-west Region

Q_T	c	a1	a2	SEE
Q_2	1.282	1.084	-0.392	0.093
Q_5	1.750	1.084	-0.402	0.089
Q_{10}	2.065	1.089	-0.413	0.087
Q_{20}	2.323	1.098	-0.422	0.086
Q_{50}	2.754	1.107	-0.435	0.092
Q_{100}	3.034	1.116	-0.445	0.097
Q_{200}	3.327	1.126	-0.455	0.104

SEE - standard error of the estimate in $\log_{10}$ units

Table 3.2b Regression Coefficients for the North-east Region

Q_T	c	a1	a2	SEE
Q_2	4.365	0.780	-0.372	0.117
Q_5	6.026	0.778	-0.386	0.127
Q_{10}	7.211	0.776	-0.394	0.131
Q_{20}	8.650	0.775	-0.410	0.130
Q_{50}	10.046	0.769	-0.409	0.144
Q_{100}	11.350	0.767	-0.415	0.152
Q_{200}	12.647	0.766	-0.420	0.161

SEE - standard error of the estimate in $\log_{10}$ units

Table 3.2c Regression Coefficients for the South-east Region

Q_T	c	a1	a2	SEE
Q_2	3.396	0.720	-0.157	0.088
Q_5	5.070	0.708	-0.168	0.088
Q_{10}	6.026	0.707	-0.170	0.092
Q_{20}	6.887	0.706	-0.169	0.098
Q_{50}	7.870	0.706	-0.167	0.110
Q_{100}	8.570	0.707	-0.165	0.119
Q_{200}	9.120	0.708	-0.162	0.129

SEE - standard error of the estimate in $\log_{10}$ units

Table 3.2d Regression Coefficients for the South-west Region

Q_T	c	a1	a2	SEE
Q_2	43.152	0.704	-5.112	0.140
Q_5	77.983	0.687	-5.475	0.162
Q_{10}	117.220	0.667	-5.743	0.177
Q_{20}	169.044	0.648	-5.998	0.192
Q_{50}	267.917	0.621	-6.306	0.210
Q_{100}	374.973	0.598	-6.533	0.224
Q_{200}	516.416	0.577	-6.750	0.237

SEE - standard error of the estimate in $\log_{10}$ units

Table 3.3 Regression Coefficients for the South-west Upper Envelope Curve

Q_T	c	a1	SMR	SEE	DA Range (km^2)	n
Q2	0.0256	1.765	0.995	0.027	72.0 - 230	6
Q5	0.0662	1.650	0.981	0.052		
Q10	0.1349	1.550	0.960	0.071		
Q20	0.2529	1.460	0.930	0.090		
Q20	0.822	1.225	0.927	0.103	37.2 - 230	7
Q50	0.841	1.262	0.928	0.105		
Q100	0.857	1.287	0.913	0.119		
Q200	0.855	1.314	0.888	0.140		

SMR - Squared Multiple R statistic

Table 3.4 Extremes of Watershed Physiography by Region

Region	Statistic	DRAIN AREA (KM^2)	LAF (-)	LSF (-)	FRAC ACLS (-)	FRAC LAKE (-)	FRAC SWAMP (-)	FRAC L+S (-)	FRAC TREE (-)	FRAC BAR'N (-)	SLOPE M2 (%)	DRAIN DENSITY (KM^-1)	SHAPE FACTOR (-)	n
NW	Minimum	33.4	0	1.55	0.63	0.04	0.02	0.08	0.33	0.00	0.14	0.19	1.45	13
	2nd lowest	95.7	0	1.68	0.73	0.05	0.04	0.12	0.35	0.00	0.32	0.34	1.48	
	2nd highest	624	688	1.92	1.00	0.13	0.14	0.35	0.83	0.39	1.13	1.28	2.23	
	Maximum	627	1053	1.93	1.00	0.22	0.24	0.36	0.87	0.50	3.09	1.30	2.32	
NE	Minimum	36.7	0	1.22	0.44	0.02	0.06	0.11	0.11	0.00	0.12	0.26	1.43	15
	2nd lowest	63.8	0	1.40	0.55	0.03	0.06	0.13	0.55	0.00	0.16	0.35	1.62	
	2nd highest	2000	307	1.89	0.98	0.18	0.25	0.36	0.88	0.15	1.03	1.09	2.12	
	Maximum	2150	881	1.92	1.00	0.20	0.48	0.66	0.91	0.23	1.11	1.24	2.35	
SE	Minimum	3.9	0	1.36	0.39	0.04	0.00	0.04	0.09	0.00	0.23	0.55	1.24	13
	2nd lowest	10.8	8.79	1.49	0.57	0.04	0.00	0.09	0.16	0.04	0.34	0.96	1.36	
	2nd highest	205	512	1.94	1.00	0.13	0.06	0.16	0.75	0.73	2.22	1.55	2.06	
	Maximum	301	588	1.95	1.00	0.14	0.17	0.21	0.88	0.79	2.42	1.62	2.45	
SW	Minimum	89.6	0	1.30	0.34	0.04	0.01	0.06	0.04	0.04	0.34	0.15	1.54	9
	2nd lowest	104	0	1.51	0.60	0.04	0.02	0.09	0.08	0.07	0.35	0.72	1.68	
	2nd highest	640	278	1.78	0.91	0.08	0.16	0.31	0.79	0.78	1.27	1.50	2.45	
	Maximum	1340	290	1.95	1.00	0.15	0.38	0.46	0.86	0.82	1.46	1.73	5.31	

Abbreviations:

Region - hydrological region
DRAIN - drainage
LAF - lake attenuation factor
LSF - lakes and swamps factor
FRAC - fraction of watershed occupied by ...
ACLS - area controlled by lakes and swamps
LAKE - lake area
SWAMP - swamp area
L+S - lakes plus swamps area
TREE - forest area
BAR'N - barren area
SLOPE M2 - slope method 2

4. ESTIMATING FLOOD FLOWS

4.1 Procedure

This procedure for the application of single station flood frequency analysis and regional flood frequency analysis for estimating flood flows should be treated as a guideline. Specific situations warrant that professional engineering judgment be used in the application of the regression equations. Some examples of these situations include: too few data for single station flood frequency analysis, physiographic parameters near or out of range, partial urbanization, inter-basin transfers of water, regulation, diversion, water withdrawals, channelization, and forestry operations. Single station flood frequency analysis and regional flood frequency analysis do not preclude other flood estimation techniques which can range simple lumped event models such as the Rational Method to complex distributed continuous models such as QUALHYMO.

The procedure for regional flood frequency analysis is as follows:

1.) Locate on a 1:50 000 scale National Topographic Series (NTS) map, the site where the flood flow estimate is required.

2.) Delineate the drainage divide on the applicable NTS map(s). The 1 : 50 000 scale map is used for drainage areas between 100 and 2000 km^2. The 1 : 250 000 scale map is used for drainage areas greater than 2000 km^2. For drainage areas less than 100 km^2, the 1:50 000 scale map is used along with the largest scale NTS map available.

3.) Abstract the following parameters: DA, LAF, LSF, FACLS, LAKE, SWAMP, L+S, TREE, BAR'N, SLOPE2, DRAIN and SHAPE. Only DA, LAF and LSF are used in the regional regression equations. All other parameters are abstracted to ensure that the watershed is physiographically similar to other watersheds in the selected region. Details are provided in Appendix A. Abstraction of some of the physiographic parameters is complex. Users not familiar with watershed abstractions can check their procedure on the watersheds with known physiographic data (Table 3.1). **LAF defaults to the value 50 when LAF = 0.** The need for this transformation has been discussed in the main report.

4.) Check that the physiographic parameters are in range. This is particularly important for DA, LAF and LSF since these parameters are used in the regional regression equations. Extremes of watershed physiography are listed in Table 3.4.

5.) Select the appropriate constants and coefficients from Table 3.2a-d based on the desired return period(s) and region(s), and substitute them into the regional regression equation(s). Hydrological regions are shown in Figure 3.1.

6.) Calculate the flood estimate using the equation derived in step 5. For cases where the watershed is near the boundary of the region, calculation of the flood estimate based on another region may be warranted.

7.) Calculate the upper and lower 95% confidence limits on the flood estimate. This is accomplished by multiplying the SEE in Table 3.2a-d by 1.96, adding it to and subtracting it from the $\log_{10}$ flood estimate, and then taking the anti-log of the results.

If there is a streamflow gauging station located on the same stream, then the results of a single station frequency analysis may provide more reliable results.

8.) A listing of gauged watersheds is provided in Table 2.1. If a streamflow gauging station coincides with the site where the flood flow estimate is required, then the results of the single station frequency analysis may be used without adjustment if the number of floods available for analysis is equal to or greater than that specified in Table 4.1. The single station flood frequency analysis used all available floods up to and including 1996. An update of the flood database and the single station flood frequency analysis may be warranted if the number of floods available for single station flood frequency analysis is small.

9.) If the drainage area of the streamflow gauging station is no more than 10 to 25% of the drainage area of the site where the flood flow estimate is required, then the results of the single station flood frequency analysis may be used with adjustment if the number of floods available for analysis is equal to or greater than that specified in Table 4.1. Table 4.1 was derived from an analysis of the absolute percentage deviation between the single station flood frequency estimates and the regional flood frequency estimates. Details are provided in Appendix B. An update of the flood database and the single station flood frequency analysis may be warranted if the number of floods available for analysis is small.

Table 4.1 Minimum Number of Peak Flows Required for Single Station Flood Frequency Analysis

Recurrence Interval (years)	Number of Peak Flows
2	10+
20	14+
100	18+

The flood flow adjustment for differing physiography is as follows:

$$Q_{Ts} = Q_{Tfg} (Q_{Trs}/Q_{Trg})$$

where, Q_{Ts} is the flood of return period “T” at the desired site “s”,

Q_{Tfg} is the flood of return period "T" from the single station frequency analysis (f) at the gauging station "g", (given in Table 2.2)

Q_{Trs} is the flood of return period "T" from the regional flood frequency analysis (r) at site "s" (steps 1-7),

and Q_{Trg} is the flood of return period "T" from the regional flood frequency analysis (r) at the gauging station "g" (steps 1-7).

4.2 Examples

4.2.1 Southwest Brook near Lewisporte

This example involves the calculation of the 1:20 year flood flow estimate (Q20) at an existing bridge on Southwest Brook near the Town of Lewisporte. The bridge is located about 5.7 km upstream from where Southwest Brook empties into Lewisporte Harbour as indicated in Figure 4.1. This watershed has been gauged for streamflow (id# 02YO012) from 1989 to 1995 near its outlet into Lewisporte Harbour.

1.) The location where the flood estimate is required is indicated in Figure 4.1. This map was reduced 50% to fit the page.

2.) The drainage divide was delineated on the 1 : 50 000 scale NTS map sheet 2 E/3. A very small proportion of the Southwest Brook watershed was on map sheet 2 E/2.

3.) The following parameters were abstracted: DA, LAF, LSF, FACLS, LAKE, SWAMP, L+S, TREE, BAR'N, SLOPE2, DRAIN and SHAPE.

Parameter	Value	Parameter	Value
DA	49.9 km^2	L+S	0.21
LAF	222	TREE	0.79
LSF	1.44	BAR'N	0.00
FACLS	0.82	SLOPE2	0.48
LAKE	0.14	DRAIN	0.66
SWAMP	0.07	SHAPE	1.89

4.) The physiographic parameters of the watershed was checked against the highs and lows of the physiographic parameters of the watersheds which were used in the development of the regression equations in the NE Region (Table 3.4). Drainage area (DA) was near the minimum for both watersheds. The value (49.9) was between the lowest (36.7) and second lowest (63.8) for this region. All other parameter values were between the second highest and the second lowest for those watersheds which were used in the development of the regression equations in the NE Region.

5.) Next, the appropriate constants and coefficients were selected from Table 3.2b based on the desired return period (Q20) and substituted into the regression equation for the NE Region:

$$Q_T = c \times (var1)^{a1} \times (var2)^{a2}$$

$$Q_{20} = 8.650 \times (DA)^{0.775} \times (LAF)^{-0.410}$$

6.) The flood estimate was calculated using the equation derived in step 5:

$$Q_{20} = 8.650 \times (DA)^{0.775} \times (LAF)^{-0.410}$$

$$Q_{20} = 8.650 \times (49.9)^{0.775} \times (222)^{-0.410}$$

$$Q_{20} = 19.5\ m^3/s$$

7.) The upper and lower 95% confidence limits on the flood estimate was calculated by multiplying the SEE for log(Q20) in Table 3.2b by 1.96, adding it to and subtracting it from the $\log_{10}$ flood estimate, and then taking the anti-log of the results.

$Q_{20} = 19.5$, $\log(Q_{20}) = 1.290$,
$1.96 \times \text{SEE for } \log(Q_{20}) = 1.96 \times 0.130 = 0.255$

$\log(Q_{20}) + 1.96 \times \text{SEE for } Q_{20} = 1.290 + 0.255 = 1.545$
$\log(Q_{20}) - 1.96 \times \text{SEE for } Q_{20} = 1.290 - 0.255 = 1.035$

Upper 95% Confidence Limit = $10^{1.545} = 35.1\ m^3/s$
Lower 95% Confidence Limit = $10^{1.035} = 10.8\ m^3/s$

8.) As indicated earlier, Southwest Brook near Lewisporte has been gauged for streamflow (id# 02YO012) from 1989 to 1995 near its outlet into Lewisporte Harbour (Table 2.1). The location where the flood estimate is required was about 5.7 km upstream from the gauging station. The drainage area at the gauging station was 59.8 km^2. The drainage area at the desired site was 49.9 km^2. The difference in the drainage area was about 17 %.

9.) Since the drainage area of the streamflow gauging station was less than 25% of the drainage area of the site where the flood flow estimate was required, then the results of the single station flood frequency analysis could be used with adjustment if the number of floods available for analysis is equal to or greater than that specified in Table 4.1. Originally, 7 floods were available for analysis (1989-1995). Flood data for 1996 and 1997 have since become available. The single station flood frequency analysis was updated for n = 9. The details are provided in Appendix C. The 1 : 20 year single station flood frequency estimates at the gauging station are shown in Table 4.2. Since the number of floods available for analysis was less than that specified in

Table 4.1, the regional flood estimate would be preferred over an adjusted single station estimate. The single station flood frequency estimates with adjustment can be used as a check. A value of 22.5 m^3/s was selected as the single station estimate.

Table 4.2. 1 : 20 Year Single Station Flood Frequency Estimates for Southwest Brook near Lewisporte

Distributions			
GEV	LN3	LP3	Wakeby
22.0	23.0	22.3	24.4

The flood flow adjustment for differing physiography is as follows:

$$Q_{Ts} = Q_{Tfg}\,(Q_{Trs}/Q_{Trg})$$

where, Q_{Ts} is the 1:20 year flood at the desired site “s”,
Q_{Tfg} is the 1:20 year flood from the single station frequency analysis (f) at the gauging station “g”, (22.5 m^3/s)
Q_{Trs} is the 1:20 year flood from the regional flood frequency analysis (r) at site “s” (steps 1-7, 19.5 m^3/s),
and Q_{Trg} is the 1:20 year from the regional flood frequency analysis (r) at the gauging station “g” (steps 1-7).

But:

$$Q_{Trg} = c \times (var1)^{a1} \times (var2)^{a2}$$
$$Q_{Trg} = 8.650 \times (DA)^{0.775} \times (LAF)^{-0.410}$$
$$Q_{Trg} = 8.650 \times (59.8)^{0.775} \times (128)^{-0.410}$$
$$Q_{Trg} = 28.2\ m^3/s$$

Now:

$$Q_{Ts} = Q_{Tfg}\,(Q_{Trs}/Q_{Trg})$$

$$Q_{Ts} = 22.5\,(19.5/28.2)$$

$$Q_{Ts} = 15.6\ m^3/s$$

The regional flood frequency estimate (19.5 m^3/s) was preferred over the single station flood frequency estimate with adjustment (15.6 m^3/s) due to a lack of flood data on Southwest Brook. The single station flood frequency estimate with adjustment served as a check. The 1 : 20 year flood estimate for the purposes of frequency analysis was selected as the regional estimate: 19.5 m^3/s.

Figure 4.1 Southwest Brook at Lewisporte

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4.2.2 Rose Blanche Brook near Rose Blanche

This example involves the calculation of the 1:100 year flood flow estimate (Q100) at an existing bridge on Rose Blanche Brook near Rose Blanche in the Southwestern Region as indicated in Figure 4.2. The bridge is located on the main highway (Route 470). This watershed has never been gauged for streamflow.

1.) The location where the flood estimate is required is indicated in Figure 4.2. This map was reduced 50% to fit the page.

2.) The drainage divide was delineated on the 1 : 50 000 scale NTS map sheet 11 O/10. A small proportion of the Rose Blanche Brook watershed was on map sheet 11 O/15.

3.) The following parameters were abstract :

Parameter	**Value**	**Parameter**	**Value**
DA	83.9 km^2	L+S	0.04
LAF	0	TREE	0.05
LSF	1.32	BAR'N	0.91
FACLS	0.37	SLOPE2	1.99
LAKE	0.04	DRAIN	1.48
SWAMP	0.00	SHAPE	2.04

4.) The physiographic parameters of the watershed were checked against the highs and lows of the physiographic parameters of the watersheds which were used in the development of the regression equations in the SW Region (Table 3.4). The drainage area (DA) for Rose Blanch Brook (83.9 km^2) was slightly below the minimum for this region (89.6 km^2). The LSF (1.32) was near the minimum (1.30). LAF was within the range of the second highest and the second lowest. The FACLS (0.37) was near the minimum (0.34). LAKE, SWAMP, L+S, and TREE were near or below the minimum. BAR'N was above the maximum. SLOPE2 exceeded the maximum, DRAIN and SHAPE were within range. Low FACLS, high BAR'N and high SLOPE2 all contribute to higher floods. In this instance, the upper 95% confidence limit value should be considered. Since many of the physiographic parameters are near or out of range, extreme caution should be used in interpreting the results. The "upper envelop curve" value will also be calculated.

5.) Next, the appropriate constants and coefficients were selected from Tables 3.2d and 3.3 based on the desired return period (Q100) and substituted into the regression equation for the "SW Region" and the "Upper Envelop Curve":

SW Region:	"Upper Envelop Curve":
$Q_T = c \times (var1)^{a1} \times (var2)^{a2}$	$Q_T = c \times (var1)^{a1}$
$Q_{100} = 374.973 \times (DA)^{0.598} \times (LSF)^{-6.533}$	$Q_{100} = 0.857 \times (DA)^{1.287}$

6.) The flood estimate was calculated using the equation derived in step 5:

$Q_{100} = 374.973 \times (DA)^{0.598} \times (LSF)^{-6.533}$	$Q_{100} = 0.857 \times (DA)^{1.287}$
$Q_{100} = 374.973 \times (83.9)^{0.598} \times (1.32)^{-6.533}$	$Q_{100} = 0.857 \times (83.9)^{1.287}$
$Q_{100} = 864\ m^3/s$	$Q_{100} = 256\ m^3/s$

The value for the SW Region appears unrealistic given that the "Upper Envelop Curve" estimate represents the largest floods. In addition, DA is below the minimum and LSF is near the minimum for application of the regression equations in the SW Region.

7.) The upper and lower 95% confidence limits on the flood estimate for the "Upper Envelop Curve" were calculated by multiplying the SEE for log(Q100) in Table 3.3

by 1.96, adding it to and subtracting it from the $\log_{10}$ flood estimate, and then taking the anti-log of the results.

$Q_{100} = 256$, $\log(Q_{100}) = 2.408$,

$1.96 \times$ SEE for $\log(Q_{100}) = 1.96 \times 0.119 = 0.233$

$\log(Q_{100}) + 1.96 \times$ SEE for $Q_{100} = 2.408 + 0.233 = 2.641$

$\log(Q_{100}) - 1.96 \times$ SEE for $Q_{100} = 2.408 - 0.233 = 2.175$

Upper 95% Confidence Limit = $10^{2.641} = 438\ m^3/s$

Lower 95% Confidence Limit = $10^{2.175} = 150\ m^3/s$

Since many of the physiographic parameters pointed toward a higher 1 : 100 year flood estimate, the upper 95% confidence limit value should be considered: 438 m^3/s.

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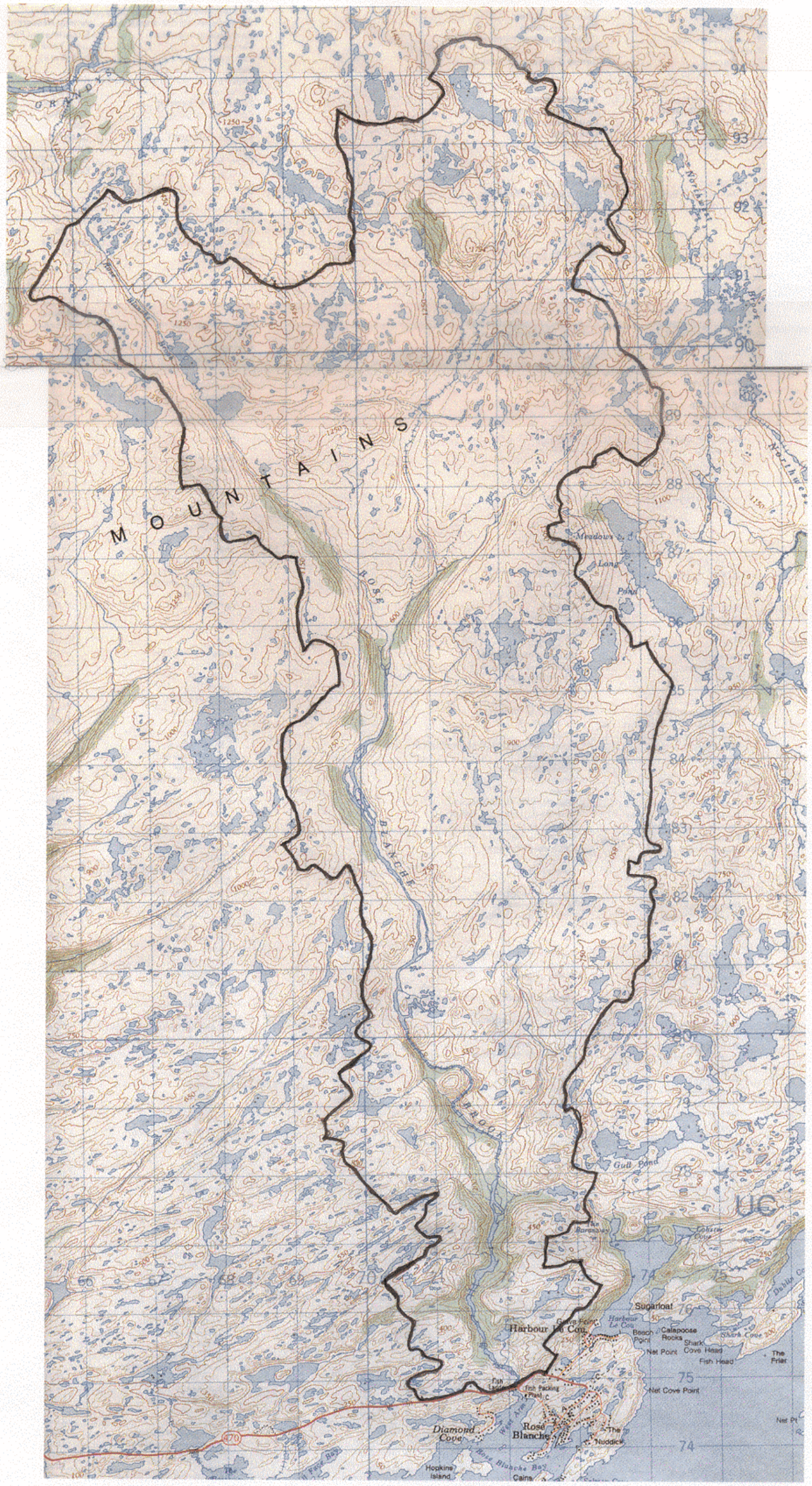
Figure 4.2 Rose Blanche Brook near Rose Blanche



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5. ELECTRONIC SPREADSHEET

The electronic spreadsheet can provide quick calculations of return period flows and their confidence limits. In addition, the sensitivity of the flood estimate to small errors in the physiographic parameters can be assessed along with the effect of region selection. The results can also be printed.

It is assumed that the user is familiar with spreadsheet operations such as loading files, entering data, and printing. The spreadsheet is provided in Lotus 5 and Excel 97.

A printout of the output using the Southwest Brook near Lewisporte example (section 4.2.1) is shown in Figure 5.1. The following data were input: Watershed Name, Region #, and all Parameter Values. The output is listed along side “Results:”. “Estimate” represents the flood estimate, L95%L represents the lower 95% confidence limit of the estimate (assuming a normal distribution of errors), and U95%L represents the upper limit.

Input is required for “Region #” and “DA” (drainage area). Optionally, the watershed name can be added for printout purposes. It is recommended that LAF be input for Regions 1-3 (NW, NE, and SE) and that LSF be input for region 4 (SW). Only DA is needed for Region 5 (**U**pper **E**nvelop Curve). All other parameters are not used in the calculation of the flood estimates. It is recommended however, that all physiographic parameters be calculated to ensure (or not) that the watershed under consideration has physiographic parameters which are consistent with the selected region. The spreadsheet will advise if the physiographic parameter are “near the range extremes” or if they are “out of range” under the “Remarks:” column. Only input cells will accept data.

Occasionally an “ERR” message will appear. This indicates that either the region was not specified as the number 1, 2, 3, 4, or 5, or if the drainage area was not specified.

Figure 5.1 Spreadsheet Output

Watershed Name: Southwest Brook near Lewisporte, 5.7 km upstream
Region #: 2
(NW=1, NE=2, SE=3, SW=4 or UE=5)

Parameters:	Value	Units	Range in Region: lowest	2nd lowest	2nd highest	highest	Remarks:
DA	49.9	km^2	36.70	63.80	2000.00	2150.00	Parameter near extreme
LAF	222	(-)	50.00	50.00	307.00	881.00	
LSF	1.44	(-)	1.22	1.40	1.89	1.92	
FACLS	0.82	(-)	0.44	0.55	0.98	1.00	
LAKE	0.14	(-)	0.02	0.03	0.18	0.20	
SWAMP	0.07	(-)	0.06	0.06	0.25	0.48	
L+S	0.21	(-)	0.11	0.13	0.36	0.66	
TREE	0.79	(-)	0.11	0.55	0.88	0.91	
BAR'N	0	(-)	0.00	0.00	0.15	0.23	
SLOPE2	0.48	(%)	0.12	0.16	1.03	1.11	
DRAIN	0.66	(1/km)	0.26	0.35	1.09	1.24	
SHAPE	1.89	(-)	1.43	1.62	2.12	2.35	

Results:		**Estimate**	*L95%L*	*U95%L*
DA+LAF or LSF	Q2 =	**12.35**	*7.28*	*20.94*
	Q5 =	**15.68**	*8.84*	*27.82*
	Q10 =	**17.83**	*9.87*	*32.21*
	Q20 =	**19.54**	*10.87*	*35.14*
	Q50 =	**22.29**	*11.64*	*42.70*
	Q100 =	**24.19**	*12.18*	*48.04*
	Q200 =	**26.14**	*12.64*	*54.06*

Results:		**Estimate**	*L95%L*	*U95%L*
DA only	Q2 =	**17.34**	*7.06*	*42.58*
	Q5 =	**22.38**	*8.72*	*57.49*
	Q10 =	**25.64**	*9.76*	*67.36*
	Q20 =	**28.46**	*10.59*	*76.48*
	Q50 =	**32.71**	*11.74*	*91.12*
	Q100 =	**35.53**	*12.42*	*101.70*
	Q200 =	**38.45**	*12.96*	*114.08*

Regional Flood Frequency Analysis for the Island of Newfoundland Version 1999

Consult "Regional Flood Frequency Analysis for the Island of Newfoundland - User's Guide and Electronic Spreadsheet" for instructions on use.

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Appendix A

Physiographic Parameters: Description and Abstraction

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Appendix A

Physiographic Parameters: Description and Abstraction

A number of physiographic parameters were selected for use in this study. This Appendix describes these parameters and indicates how they were determined.

The parameters selected and their units were:

l.	Drainage area (DA)	(km^2)
2.	Fraction of watershed occupied by forest (TREE)	(-)
3.	Fraction of watershed occupied by wetlands (SWAMP)	(-)
4.	Fraction of watershed occupied by lakes (LAKE)	(-)
5.	Fraction of watershed occupied by lakes and swamps (L+S)	(-)
6.	Fraction of watershed occupied by barrens (BAR'N)	(-)
7.	Fraction of drainage area controlled by lakes and swamps (FACLS),	(-)
8.	Lakes and swamps factor (LSF)	(-)
9.	Lake attenuation factor (LAF)	(-)
10.	Length of the main river (LENGTH)	(km)
11.	Elevation Difference (ELEVDIFF)	(m)
12.	Slope of the main channel method 1 (SLOPE1)	(%)
13.	Slope of the main channel method 2 (SLOPE2)	(%)
14.	Drainage Density (DD)	(km/km^2)
15.	Shape Factor (SHAPE)	(-)

Drainage area (DA), Fraction of watershed occupied by forest (TREE), Fraction of watershed occupied by swamps (SWAMP), and Fraction of watershed occupied by lakes

(LAKE), were determined from 1:50,000 scale National Topographic Series (NTS) maps using either a planimeter, a digitizer or a transparent grid with 0.01 km^2 blocks. Fraction of watershed occupied by barrens (BAR'N) was obtained by subtracting TREE, SWAMP and LAKE from DA. Fraction of watershed occupied by lakes and swamps (L+S) was calculated by summing LAKE and SWAMP. For basins with drainage areas greater than 2000 km^2, 1:250,000 scale NTS maps were used. Since less lakes and swamps are shown on 1:250,000 scale maps than on 1:50,000 scale maps, the values were adjusted upward based on comparisons of "representative" sample portions of each basin at each of the two scales. The area of forest and barren were then adjusted downward proportionally.

The fraction of the drainage area controlled by lakes and swamps (FACLS) was determined using 1:50,000 scale NTS mapping for all basins. A sub-basin was considered controlled if a lake or swamp at the outlet of the sub-basin had a surface area greater than 1% of the sub-basin. "Percentage of Basin Area Controlled by Lake and Swamp" is defined by Poulin (1971) in Figure A1.

Lakes and swamps factor (LSF) is a combination of the Fraction of drainage area occupied by lakes and swamps (L+S) parameter and the Fraction of watershed area controlled by lakes and swamps (FACLS) parameter. The algorithm is:

$$LSF = (1 + FACLS) - (L+S) / (1 + FACLS).$$

Lake attenuation factor (LAF) is a factor which sums the product of individual large (> 1% of DA) lake areas with their corresponding drainage areas. The algorithm is:

$$LAF = \sum_{i=1}^{n} \{(100 \times LAREA_i/DA) \times (100 \times CAREA_i/DA)\}$$

where, n is the number of lakes in the watershed with area greater than 1% of the watershed's drainage area, $LAREA_i$ is the area of a lake, DA is the drainage area of the watershed, and $CAREA_i$ is the drainage area which is controlled by a lake. " LAF" is defined in Figure A2.

Length of the main river (LENGTH) was determined using a map meter and 1:50,000 scale NTS mapping. The main river was the longest river in the watershed.

Elevation Difference (ELEVDIFF) was the difference in elevation between the outlet of the watershed and the highest point on the divide in the vicinity if the main channel.

Slope of the main channel method 1 (SLOPE1) was simply ELEVDIFF divided by LENGTH.

Slope of the main channel method 2 (SLOPE2) was the average slope of the curve that joins two points on the main river which are at 10% and 85% of LENGTH from the outlet. In effect, the slope of the main river was calculated over only 75$^{\%}$ of its length.

Drainage Density (DD) was determined by dividing the total length of streams by the drainage area.

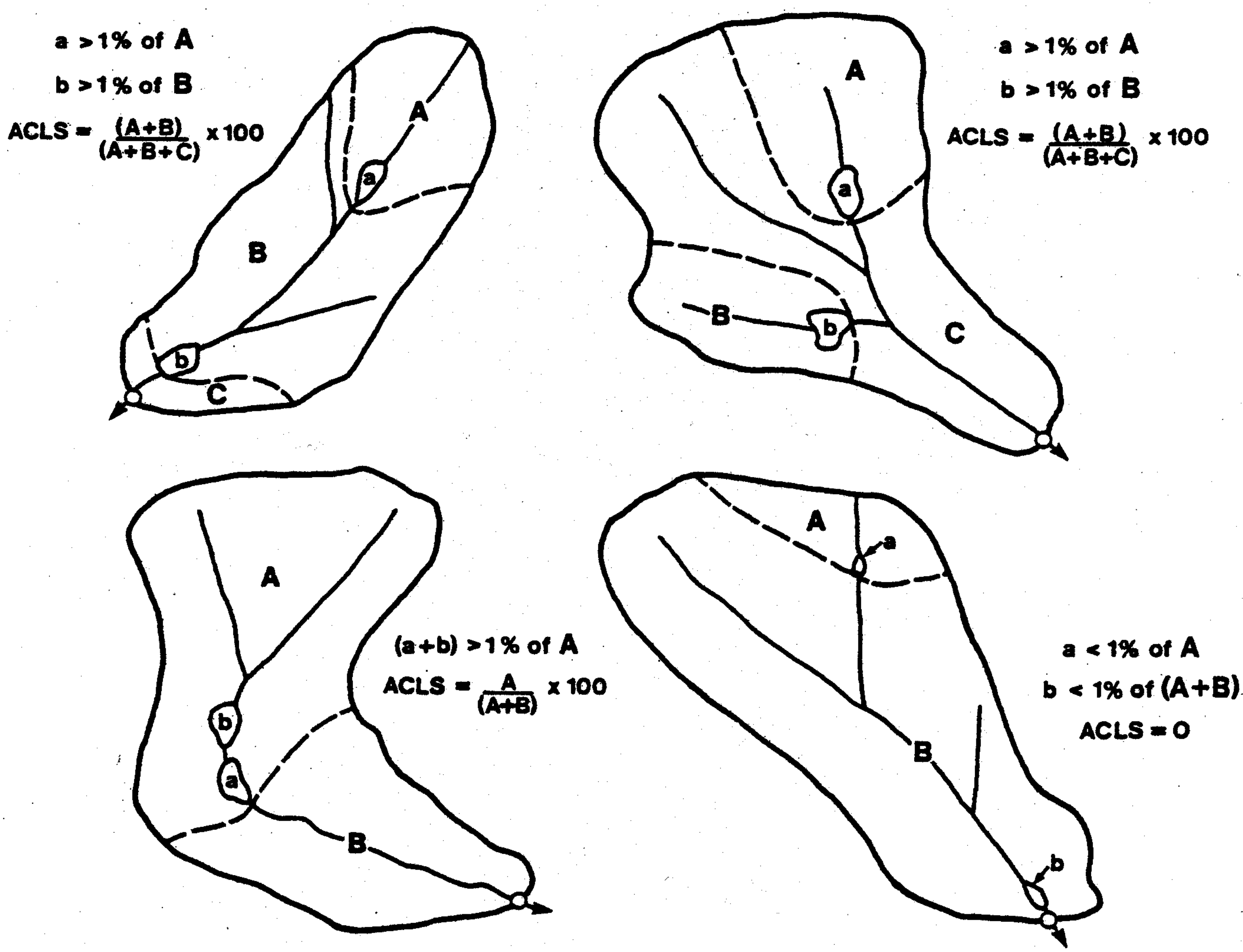
Shape factor (SHAPE) characterizes the physical shape of the watershed. The algorithm is:

$$\text{SHAPE} = 0.28 \times P / \sqrt{DA}$$

where P is the perimeter of the watershed, and DA is the drainage area. A circle would have a SHAPE of 1.00

Figure A1

PERCENTAGE OF BASIN AREA CONTROLLED BY LAKE AND SWAMP (ACLS) - DEFINITION



Legend

a, b AREA OF LAKE OR SWAMP

A, B AREA CONTROLLED BY LAKE AND SWAMP

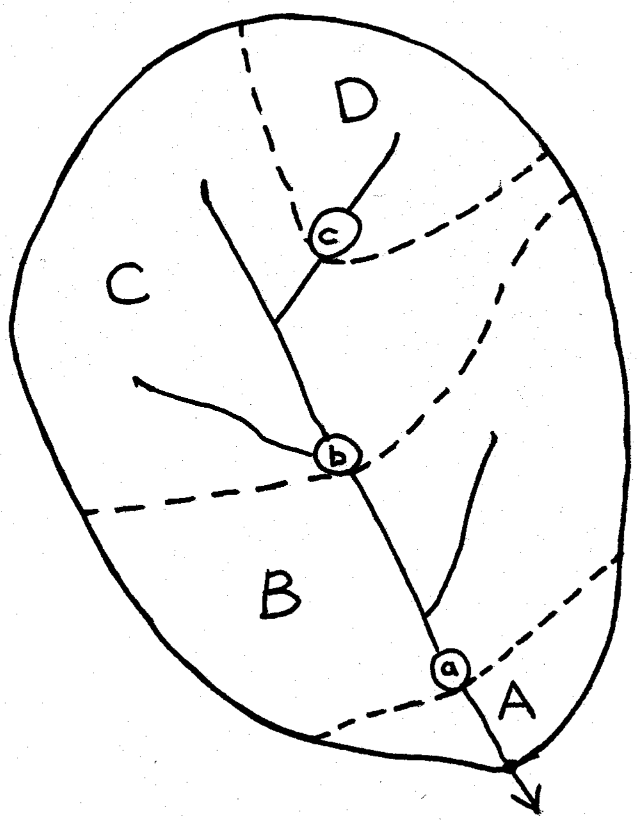
C UNCONTROLLED AREA

After Poulin (1971)

Figure A2 Lake Attenuation Factor (LAF) - Definition

$$LAF = \sum_{i=1}^{n} \{(100 \times LAREA_i/DA) \times (100 \times CAREA_i/DA)\}$$

where: n is the number of lakes in the watershed with area greater than 1% of the watershed's drainage area,
$LAREA_i$ is the area of a lake,
DA is the drainage area of the watershed, and
$CAREA_i$ is the drainage area which is controlled by a lake.



If area of lakes a, b, c > 1% of the drainage area (A+B+C+D), then

$$LAF = \{(100 \times a/(A+B+C+D)) \times (100 \times (B+C+D)/(A+B+C+D))\} + \{(100 \times b/(A+B+C+D)) \times (100 \times (C+D)/(A+B+C+D))\} + \{(100 \times c/(A+B+C+D)) \times (100 \times (D)/(A+B+C+D))\}$$

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Appendix B

Single Station Flood Frequency Analysis Estimate
versus
Regional Flood Frequency Analysis Estimate

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Appendix B

<u>Single Station Flood Frequency Analysis Estimate versus Regional Flood Frequency Analysis Estimate</u>

When flood data are available at or near a desired site, a single station flood frequency estimate may be preferred over a regional flood frequency estimate if the number of floods available for analysis is large and the required return period is small. In order to determine the minimum number of floods require to prefer the single station estimate over the regional estimate, the standard error of the estimate (SEE) for the single station estimate needed to be compared to the SEE for the regional estimate. The SEE's could not be compared directly since the SEE for the regional estimate was in log to base 10 units, and the SEE for the single station estimate was in natural log units. A Three Parameter Log-Normal distribution was assumed for single station frequency analysis in all cases. It was the better fitting distribution on most of the watersheds tested in this study. This distribution uses a natural log transform prior to parameter estimation. The SEE for the single station analysis was transformed to log to base 10 units by taking the natural exponent of the SEE and taking the log to base 10. The SEE's are compared for the 2, 20 and 100 year return periods and for sample sizes ranging from 10 to 50 in Figures B1, B2 and B3. The horizontal lines represent the maximum and minimum SEE's for the given return period in the NW, NE and SE regions. These lines are defined for the purpose of this appendix as the upper and lower limits on the regression equations. The SEE's were highest in the SW region and lowest using the "Upper Envelop Curve".

Figure B1 shows that the single station estimate for the 1:2 year return period flood are undoubtably superior to the regional estimate for sample sizes greater than 17. No single station estimate with sample size greater than 17 had a SEE which was less than the lower limit on the regression equation. For sample sizes from 10 to 17 the median SEE by sample size was less than the lower limit for all cases except n = 12 where the median was less than the midpoint between the two limits. Based on this analysis a minimum of 10 data are required to prefer the single station estimate for Q2 over the regional estimate. Less data may provide good estimates of Q2.

Figure B2 shows that the single station estimate for the 1:20 year return period flood are undoubtably superior to the regional estimate for sample sizes greater than 20. No single station estimate with sample size greater than 20 had a SEE which was more than the lower limit on the regression equation. For sample sizes from 14 to 19 the median SEE was less than the lower limit. For n = 13 the median SEE was between the upper and lower limits. For n = 12 the median SEE was above the upper limit and the maximum SEE was nearly 4 times the upper limit. Based on this analysis a minimum of 14 data are required to prefer the single station estimate for Q20 over the regional estimate.

Figure B3 shows that the single station estimate for the 1:100 year return period flood are undoubtably superior to the regional estimate for sample sizes greater than 29. No single station estimate with sample size greater than 29 had a SEE which was more than the lower limit on the regression equation. For sample sizes from 19 to 28 the median SEE was less than the lower limit. For n < 19 the magnitudes of the SEE's increased above the lower and upper limits. Based on this analysis a minimum of 18 data are required to prefer the single station estimate for Q100 over the regional estimate.

Table B1 lists the recommended minimum number of floods to prefer the results of the single station flood frequency estimate over the regional flood frequency estimate. This table is reproduced in Section 4.1 Procedure.

Table B1 Minimum Number of Peak Flows Required for Single Station Flood Frequency Analysis

Recurrence Interval (years)	Number of Peak Flows
2	10+
20	14+
100	18+

Figure B1

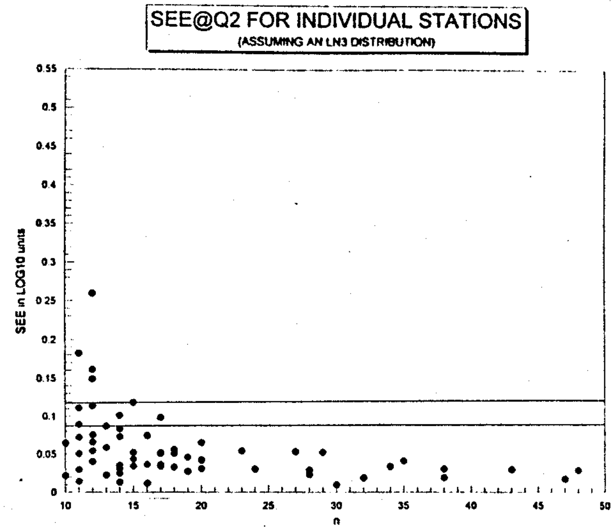


Figure B2

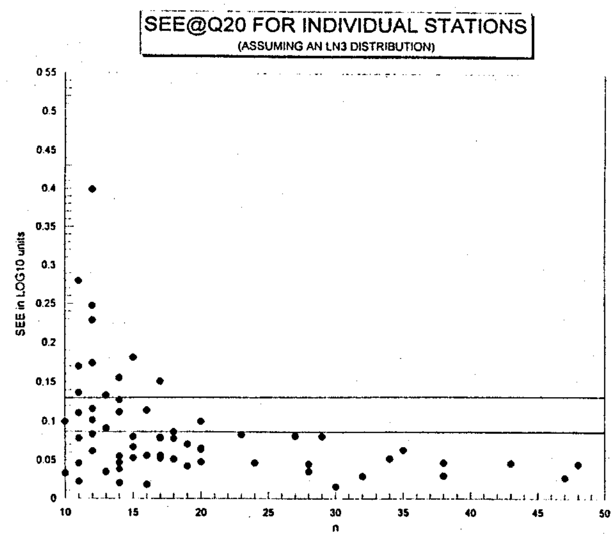
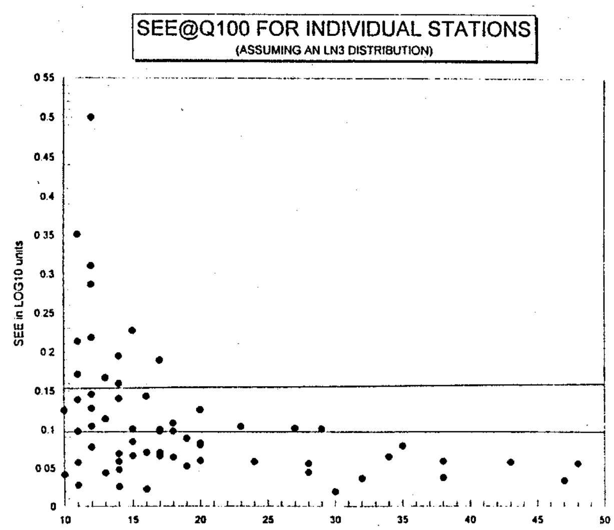


Figure B3



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Appendix C

Single Station Flood Frequency Analysis
Southwest Brook near Lewisporte

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Appendix C

Single Station Flood Frequency Analysis Southwest Brook near Lewisporte

The data base for single station flood frequency analysis of Southwest Brook near Lewisporte consisted of the flood data from 1989 to 1997 as indicated in Table C1.

Table C1 Flood Data for Southwest Brook near Lewisporte

Year	Maximum Instantaneous Discharge (m^3/s)	Date
1989	12.9	April 9
1990	22.4	May 21
1991	12.0	November 19
1992	15.3	June 17
1993	19.7	April 24
1994	10.6	April 8
1995	15.7	April 28
1996	15.1	September 25
1997	17.4	May 5

The computer program CFA88 was used for single station frequency analysis. All available probability distributions were considered for frequency analysis. The results are indicated in Table C2. This table is reproduced in Section 4.2.1 - the Southwest Brook example.

Table C2 1 : 20 Year Single Station Flood Frequency Estimates for Southwest Brook near Lewisporte

Distributions			
GEV	LN3	LP3	Wakeby
22.0	23.0	22.3	24.4

The 1:20 year estimate was selected as 22.5 m3/s. This is the average of the GEV and the LN3 distributions. These distributions were used for estimating return period floods on all other watersheds used in this study. Frequency plots are shown in Figures C1 and C2.

Figure C1 FREQUENCY ANALYSIS - 02Y0012

THREE PARAMETER LØGNØRMAL-MAX LIKELIHØØD

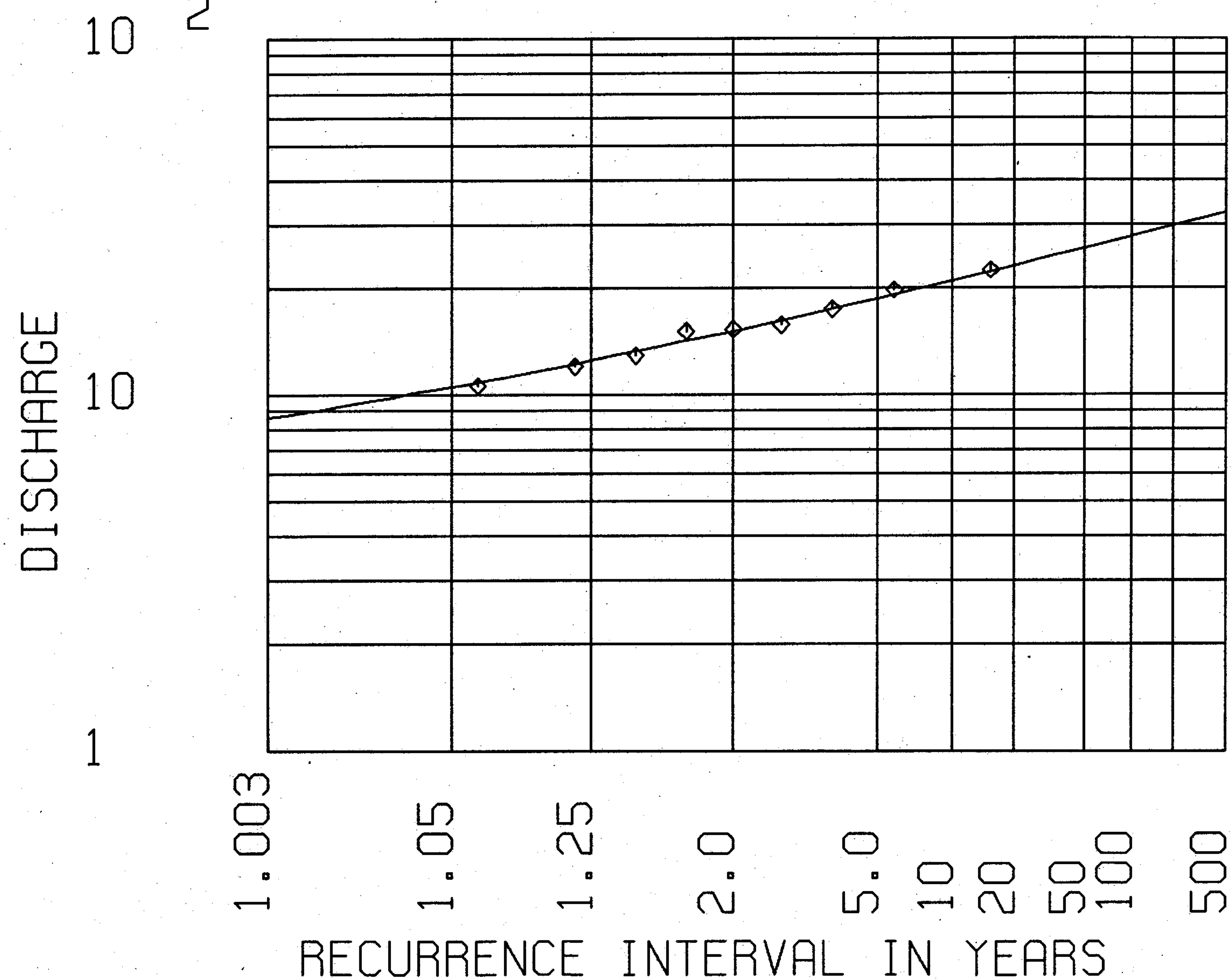
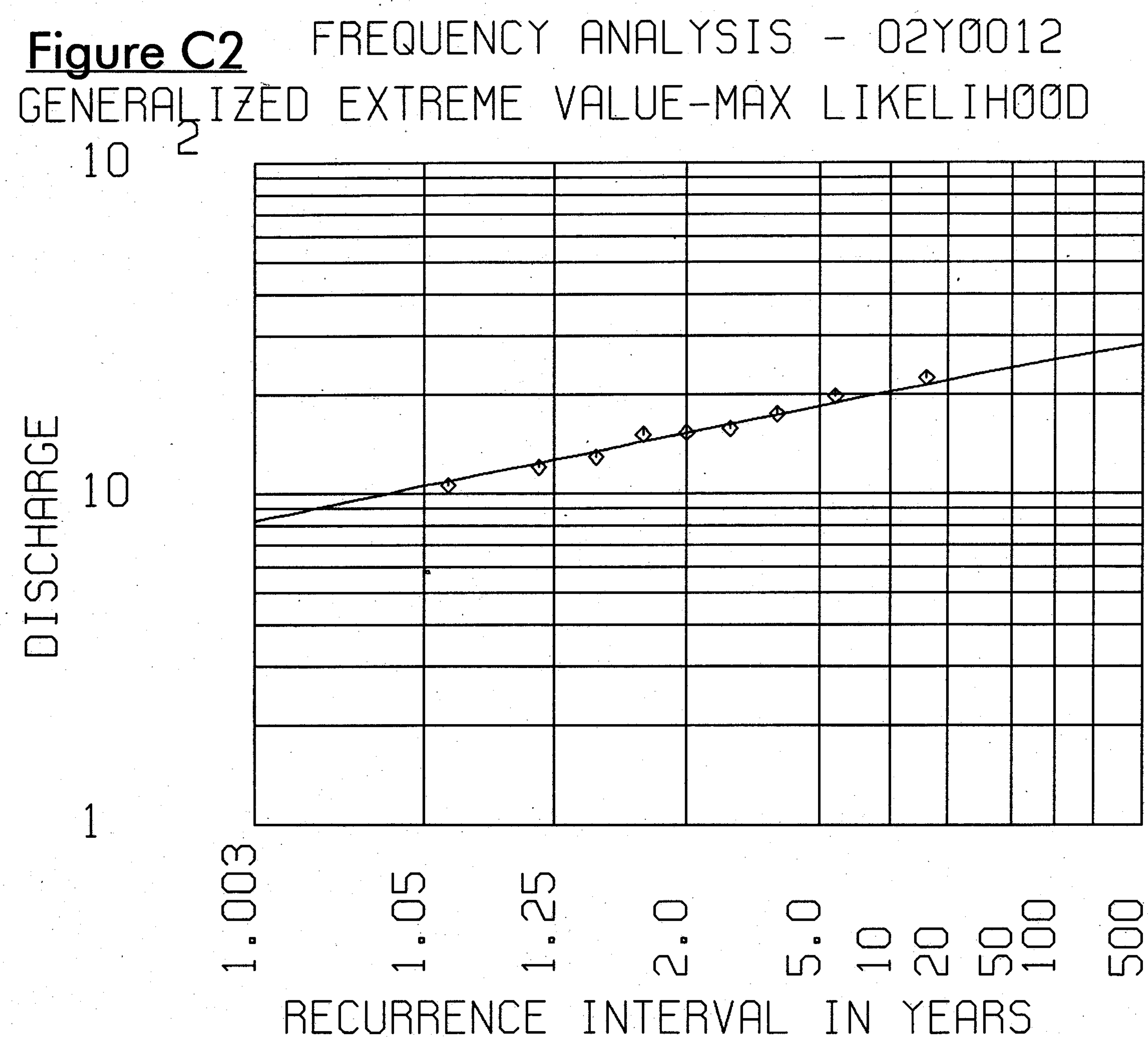


Figure C2



FREQUENCY ANALYSIS - 02Y0012
GENERALIZED EXTREME VALUE-MAX LIKELIHOOD
10^2
10
1
DISCHARGE
1.003
1.05
1.25
2.0
5.0
10
20
50
100
500
RECURRENCE INTERVAL IN YEARS