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HYDROLOGIC AND LAND USE SURVEYS OF THE WESTFIELD RIVER WATERSHED

by

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ABSTRACT

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The Westfield River, Nova Scotia, a tributary of the Medway River, was selected as a study area to investigate stream fish production in an acid stream. Flow regimes in three sub-drainage basins of the Westfield were estimated, using hydrologic data from adjacent watersheds as models. Historical and present land usages in the Westfield drainage were also reviewed.

Key words: hydrology, forest practices, agriculture, recreation, mining, Westfield River

RÉSUMÉ

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La rivière Westfield, en Nouvelle-Écosse, un tributaire de la rivière Medway, a été choisie comme site d'étude de la production d'un cours d'eau en poissons. Les données hydrologiques de bassins avoisinants ont servi de modèles pour estimer le débit de trois bassins hydrographiques secondaires. Nous passons également en revue l'utilisation passée et présente du bassin de cette rivière.

INTRODUCTION

The discovery that acidification of lakes and streams was affecting fish populations in southwestern Nova Scotia (Farmer et al. 1980) prompted the Department of Fisheries and Oceans to initiate a research project to investigate the ecology of fish species in one of these acidified rivers. Biological productivity and nutrient flow were to be emphasized, and Atlantic salmon was of particular, though not of sole interest. A quick survey was made of all the major streams and many of the tributaries along the south shore of Nova Scotia. We selected the Westfield River, a left bank tributary of the Medway, for the following reasons: 1) the pH regime (annual mean ca. 4.9 in 1980) is low enough that we expected to find some indications of stress in local fish populations; 2) historically, the Westfield was one of the most important salmon spawning and nursery areas in the Medway system, with one of the highest fry densities in the system in the 1960's (Wyckes, unpubl. manuscript); 3) a sizeable salmon population still uses the Westfield River for spawning, but no data are now available as to whether the population has been reduced over the past 25 yr; 4) apparently healthy populations of other important anadromous and sport species, such as brook trout (*Salvelinus fontinalis*), alewife (*Alosa pseudoharengus*), and eel (*Anguilla rostrata*) are also indigenous to the Westfield; 5) the stream is small enough to enable us to install and utilize counting fences effectively.

In order to correlate biological changes to acid inputs, the hydrology of the Westfield River system must be understood. To accomplish this, estimates of flow regimes were made for the Westfield River, based upon known hydrology of the drainage basins and flow patterns of adjacent watersheds. A land use survey of the Westfield drainage basin was also conducted to determine activities in the watershed which might affect water quality and thus the research program. Several maps delineating clearcutting activities on Bowater-Mersey leaseholds were also compiled but have not been included in this report.

METHODS

HYDROLOGICAL

Hydrological data for the region were obtained from the Water Resources Branch of the Inland Waters Directorate in the form of a magnetic tape, which provided daily flow data for the Medway, Mersey, and LaHave Rivers.

Three computer programs were used to process these data. The first program, MINMAX, was developed by Montreal Engineering Company, Limited, to select annual minimum and maximum flow volumes for various flow durations. This program was used to determine flow volumes for 1-, 3-, 7-, 10-, 30-, 60-, and 90-d durations for annual maximum and minimum flows and these data were stored for further processing. In addition, mean monthly flows were calculated.

The second program (LOW FLOW), used to calculate low-flow frequency distributions based upon data produced by MINMAX, was obtained from the

Environmental Conservation Service of the Water Planning and Management Branch of Environment Canada. This program fits the Gumbel Type III distribution to observed data, estimating parameters by maximum likelihood, smallest observed drought or by moments. The most appropriate method was selected based upon tests of adequacy (Condie and Nix 1974).

A third program was used for analysis of high flows at the selected stations, using data produced by MINMAX. This program, called FRQPLT, was expanded from the Environment Canada program FDRPFFA (Condie et al. 1979) to produce printer plots. Frequency distributions were fitted to the data, using the Gumbel I, Log-Normal, Three Parameter Log-Normal, and the Log-Pearson Type III methods. Parameters were estimated by maximum likelihood with the moments used as a backup method. The frequency distribution fitting the data with the smallest error of estimate was selected as most representative.

Of the hydrologic data collected in this region, those for the Medway River were selected as being most acceptable because the Westfield is a tributary of the Medway and because both systems have some natural regulation. However, analyses were completed for data collected on the LaHave and Mersey Rivers to check the adequacy of the Medway data. These data allowed qualitative conclusions to be drawn regarding the effects of larger drainage areas with increased natural regulation, the result of natural storage in the drainage basin (lakes, swamps, ground water, and river channels).

LAND USE PATTERNS

Land use information was collected from provincial government sources in Halifax, Liverpool, and Bridgewater, Nova Scotia, and from private sources in Liverpool, Westfield, and North Brookfield, Nova Scotia. The drainage basin was surveyed to collect site-specific information, and telephone conversations with various private and governmental contacts in Nova Scotia provided supplementary information.

RESULTS AND DISCUSSION

HYDROLOGICAL

Regional data

Average low and high flow rates for the Medway, LaHave, and Mersey Rivers for each of the seven durations studied are presented in Table 1. Although variations in unit runoff from one sub-basin to another are relatively large, a trend is apparent. Small areas tend to have lower low flows and higher high flows than large areas which probably contain more surface and groundwater storage. This trend is evident when comparing results for the stations on the Medway River. Comparisons between rivers indicate the same trend due to the regulating effect of natural surface and groundwater storages. For example, results of the analyses for the LaHave and Medway Rivers (Table 2-5) indicate less natural regulation for the LaHave than for the largest drainage area of the Medway River. Topographic maps indicate that the LaHave River does indeed contain a smaller proportion of lakes than the Medway River.

As previously indicated, data for the Medway River are most acceptable for predicting flows in the Westfield River. Considering the potential impacts of natural storages, the use of data for the Medway at Harmony Hills (01EE002) is appropriate for subareas such as Moose Pit Brook which have little natural regulation. For areas where large natural lakes exist such as Tupper and Round Lakes, data for the Medway at Charleston (01EE001) are more representative.

The Westfield River Basin was subdivided into three sub-drainage areas (Table 6) which represent the flow contributions from two branches of the river and measure flow near the biological sampling area (Fig. 1). The flow measurement stations were subsequently located at the sub-basin outlets, and were selected, in part, because of their accessibility and the need for frequent data collection. Measurement stations were equipped with automatic water level recorders, and the sites adequately prepared to allow good quality discharge measurements and water quality sampling.

The first station measures flows near the mouth of the Westfield River within the biological sampling area. The second measurement station was located on a stream within the basin with relatively little natural regulation, while the third station represents outflow from an upland area with one large lake which may buffer all inputs.

Further, more detailed study of the micro-hydrology of this drainage basin may indicate the need for additional data. In particular, part of the drainage area contributing to Durland Lake Brook may not contribute to flows at Round Lake under low flow or small storm conditions. Topographic maps indicate the existence of potentially large storages (swamps) which are connected to Round Lake by intermittent streams. Such storages may have a substantial effect on the magnitude and quality of inflows to Round Lake because surface storage areas (lakes and swamps) act to buffer flows and water quality.

Little detailed meteorological data are available in the immediate area of the study basin. The nearest manual rain gauge is located south of McGowan Lake between Harmony Mills and Westfield. Several rain gauges are located within approximately 50 km of the drainage basins and may be useful in determining the extent and magnitude of large storms. Automatic recording rain gauges should be installed at the existing site south of McGowan Lake and at new sites in North Brookfield and near Round Lake. Exact locations of these rain gauges are to be determined by field reconnaissance (Table 7).

Estimated flows

Estimated average monthly flows at each of the three stations within the Westfield River drainage basin are presented in Table 8. Results of the frequency analyses as applied to each sub-basin are presented in Tables 9 through 11.

Accuracy of results

There are limitations which must be recognized when evaluating the data presented in Tables 9-11. Inspection of the data presented in Table 1 indicates that average flows over short durations are much more affected by natural storage than

average flows over longer durations. As a result, estimates for stations two and three, although based upon all available existing hydrologic data, must be regarded as tentative and subject to verification by actual field measurements.

Significance of storages

The Westfield River drainage basin contains a large proportion of surface storage (lakes, swamps and river channels) relative to the total land area. The lakes alone occupy 8% of the area within the boundaries of the drainage basin. Consequently, surface water storage is extremely important in the Westfield River basin.

There are no groundwater data for the drainage basin. However, the underlying geology and the large surface water storage capacity suggest that surface water storage may have greater effects on the quality and quantity of flows in the Westfield River than does groundwater storage. This hypothesis needs to be confirmed by field investigations in the drainage basin.

LAND USE PATTERNS

General information

The Westfield River drainage basin encompasses 151 km² (58 mi²) of mostly forested land north of Liverpool, Nova Scotia (Fig. 1). There are seven lakes which account for 8% (12 km²) of the area within the drainage basin boundary. Although most of the land is forested, there are two small communities (North Brookfield and Westfield) which lie within the drainage basin, and there are private dwellings on the roads between the two communities. There are also a number of summer residences on Tupper Lake, Tupper Long Lake, and Little Tupper Lake.

In the extreme southern portion of the drainage basin about 3 km east of the Town of Westfield, there is a municipal incinerator for domestic refuse, serving the northern part of Queens County. Domestic refuse is burned, and the remaining non-combustible components are landfilled on-site. The landfill site covers about 1.5-2.0 ha of land about 1 km from the Westfield River.

The forest within the drainage basin is primarily coniferous with red spruce, balsam fir, hemlock, and white pine being the dominant species (Bulley, pers. comm.). On the average, there are about 1-2 cords of hardwood per ha, with red maple, white birch, and oak being the predominant deciduous species.

There have been no major fires in the drainage basin in recent history. However, in the summer of 1980, five forest fires were started in the drainage basin by an unidentified arsonist. In each case, the fire was suppressed before more than an acre of forest was burned, but local residents are concerned that a dry summer coupled with an active arsonist could cause widespread forest damage (Lawson, pers. comm.).

There are a number of small, abandoned gravel pits scattered throughout the study area which were used, evidently, in the past for road construction. There is one gravel pit still in use on Crown land north of the Town of Westfield.

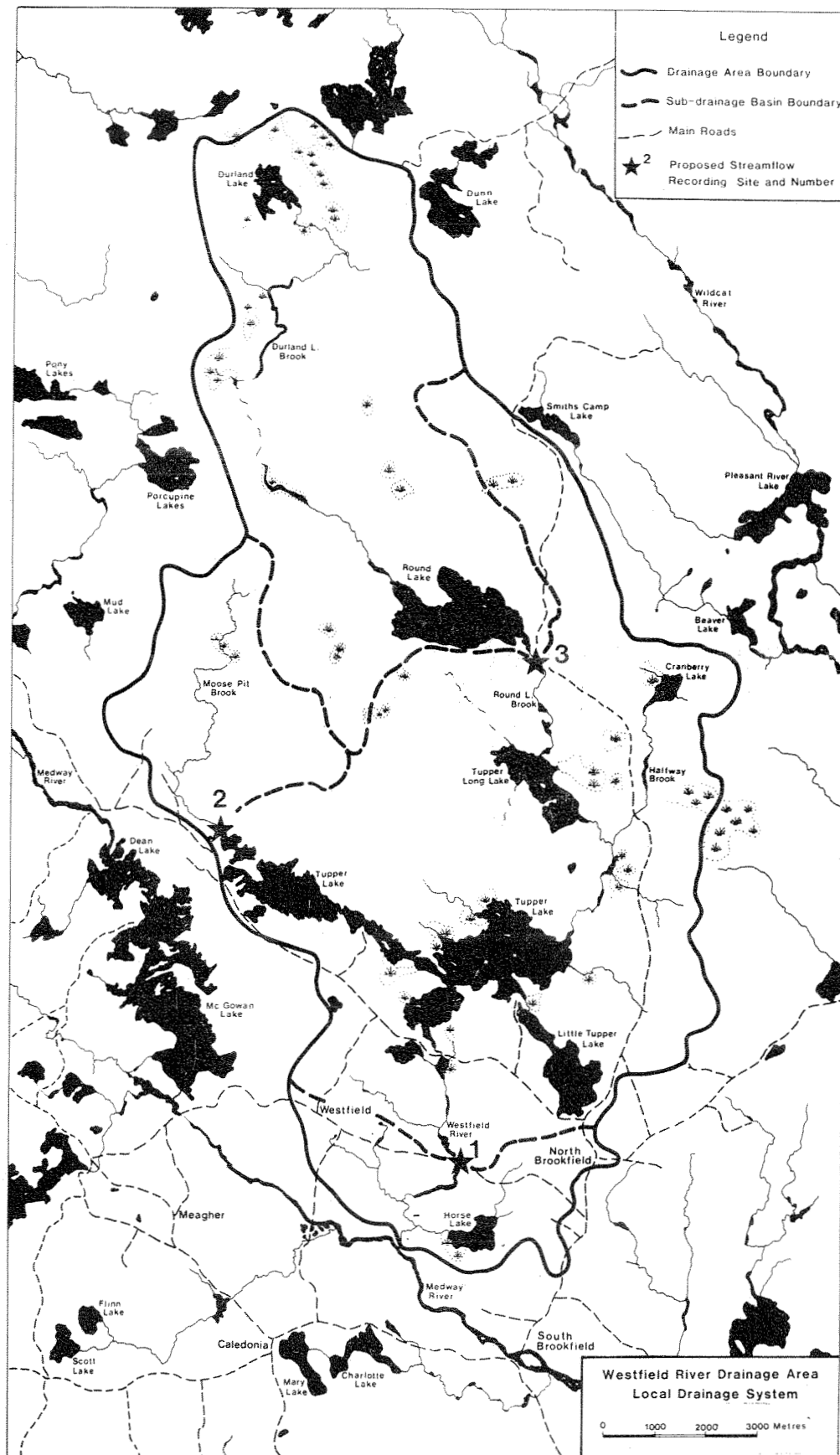


Fig. 1. The Westfield drainage basin is delineated by the heavy black line. The three sub-basins discussed in the text are delineated by dotted lines. The stars numbered 1-3 indicate locations of suggested stream gauging sites.

Historical land use information

The Town of Liverpool was settled in the 1780's, but the area in the vicinity of the Westfield River was not permanently settled until the early to mid 1800's (Farrell, pers. comm.). Most of the permanent residents in the drainage basin were concentrated south of Tupper Lakes, as they are today. One exception was a small community of 25-30 people located south of Dunn Lake, which gradually disappeared after the 1920's. The early settlers practiced mixed agriculture during the summer, and were involved in logging activities for the remainder of the year. During this period, all of the accessible areas in the drainage basin were selectively logged, using horses and oxen. The logs were floated down rivers and lakes to any of a number of small sawmills located on streams in the southern portion of the drainage basin (Silver, pers. comm.).

After about 1930, the mixed farming/lumber harvesting way of life began to disappear in this area, and is virtually nonexistent today. Much of the previously farmed land is not in use now, and abandoned orchards are common in the southern portion of the drainage basin. Intensive forest harvesting began in the 1970's. Logging in the central portion of the drainage basin was restricted until that time because the terrain is extremely rugged and inaccessible.

Property ownership

Most of the land in the study area is owned by companies or private individuals with forestry-related interests (Fig. 2). Bowater-Mersey Paper Company, headquartered in Liverpool, owns 48% of the land within the boundaries of the drainage basin. Crown land occupies 5% of the drainage basin, Scott Paper owns 2% of the land, and 8% of the area is occupied by inland lakes (Horse, Little Tupper, Tupper, Cranberry, Tupper Long, Round and Durland). Most of the remaining 37% of the land is privately owned, although Kirk Limited and George Eddy Company own relatively small portions of forested land.

Most of the northeastern and western shore of Tupper Lake was subdivided for summer or year-round homes by Canadian Estate Land Company of Toronto (see section: Recreational uses).

Forestry practices

Forest sprays: Although substantial acreage in Nova Scotia has been sprayed with herbicides and pesticides, none has been used on the forest in the study area (Waugh, pers. comm.). However, within 8 km of the drainage basin, several herbicides (Brushkiller 96[®], Round up[®], Krenite[®], Velpar[®]) were field tested in 1980. Because of the proximity of the field trials to the drainage basin and the aerial method of application, some spray could have drifted onto the study site in 1980.

Since spruce budworm is not a problem locally, no pesticide spraying is anticipated in the foreseeable future (Waugh, pers. comm.). However, both Bowater-Mersey and the Nova Scotia Department of Environment indicated that herbicides might be used in the drainage basin in the next few years (Waugh, pers. comm.; Bulley, pers. comm.). Since all spray activities must be approved by the Province, the Nova Scotia Department of Environment

can provide the most up-to-date forest spray information.

Forest harvesting: As the largest single owner of land in the watershed, Bowater-Mersey's activities could have a considerable effect on local water quality. Bowater-Mersey has a pulp and paper mill in Liverpool producing approximately 180 000 tons of paper per year, and it also operates a sawmill in Bridgewater. Since 1978, the Westfield River drainage basin has been extremely important in supplying the pulpwood and logs for Bowater-Mersey's operations. Both in 1979 and in 1980, approximately 180 ha of forest were harvested in the drainage basin, and in 1981 it is anticipated that about 120 ha will be logged, mostly north of Round Lake. Harvesting plans are not formulated beyond 1981, but the area will undoubtedly remain an important source of wood for at least 10 yr (Wamboldt, pers. comm.).

Each area that is clearcut is serviced by a road of sufficient size to handle heavy equipment and logging trucks. Wherever these roads cross a stream, a wooden bridge is constructed to accommodate logging-related traffic. However, when roads cross marshy, low-lying areas, metal culverts are utilized whenever possible because they are relatively inexpensive.

Clearcutting is the only harvesting method that has been practiced by Bowater-Mersey in the watershed since 1970. Although the Nova Scotia Department of Lands and Forests recommends that a 30-m buffer strip be retained in logged areas adjacent to streams and lakes, Bowater-Mersey frequently does not follow this recommendation. However, the Company stated that a great deal of care is taken when cutting near a stream or lake to avoid damaging the terrain.

Bowater-Mersey has found that natural regeneration is adequate to reforest its cutover land, so it does not conduct any reforestation activities in the area, nor is any of its property fertilized to enhance growth. As previously discussed, the Company is considering herbicide spraying to suppress growth of deciduous species, but indicated that it will contact the N.S. Dept. of Environment before embarking on a spray program (Bulley, pers. comm.).

Scott Maritimes Ltd. owns two blocks of land within the study area, one south of Durland Lake and a smaller section south of Smith Camp Lake (Fig. 2). The forest on the land south of Durland Lake has not been harvested in 30-40 yr, but Scott is now in the process of constructing a road to the area. It intends to begin selectively harvesting blocks of land (removing about 30% of the forest) in summer 1981 (unknown at present whether this operation was initiated), which will continue for 3-4 yr. The Scott land south of Smith Camp Lake was harvested in a similar manner in 1978. Scott does not plan to return to that section of land in the next 5 yr (Murray, pers. comm.).

There are three significant blocks of Crown land in the drainage basin (Fig. 2). The land north of Hen Lake has not been recently logged, and is covered primarily by scrub vegetation. Near the center of this section of Crown land, on the road between North Brookfield and Westfield, there is a gravel pit providing gravel for road construction in that general area. The Crown land adjacent to Halfway Brook is primarily softwood, which has been

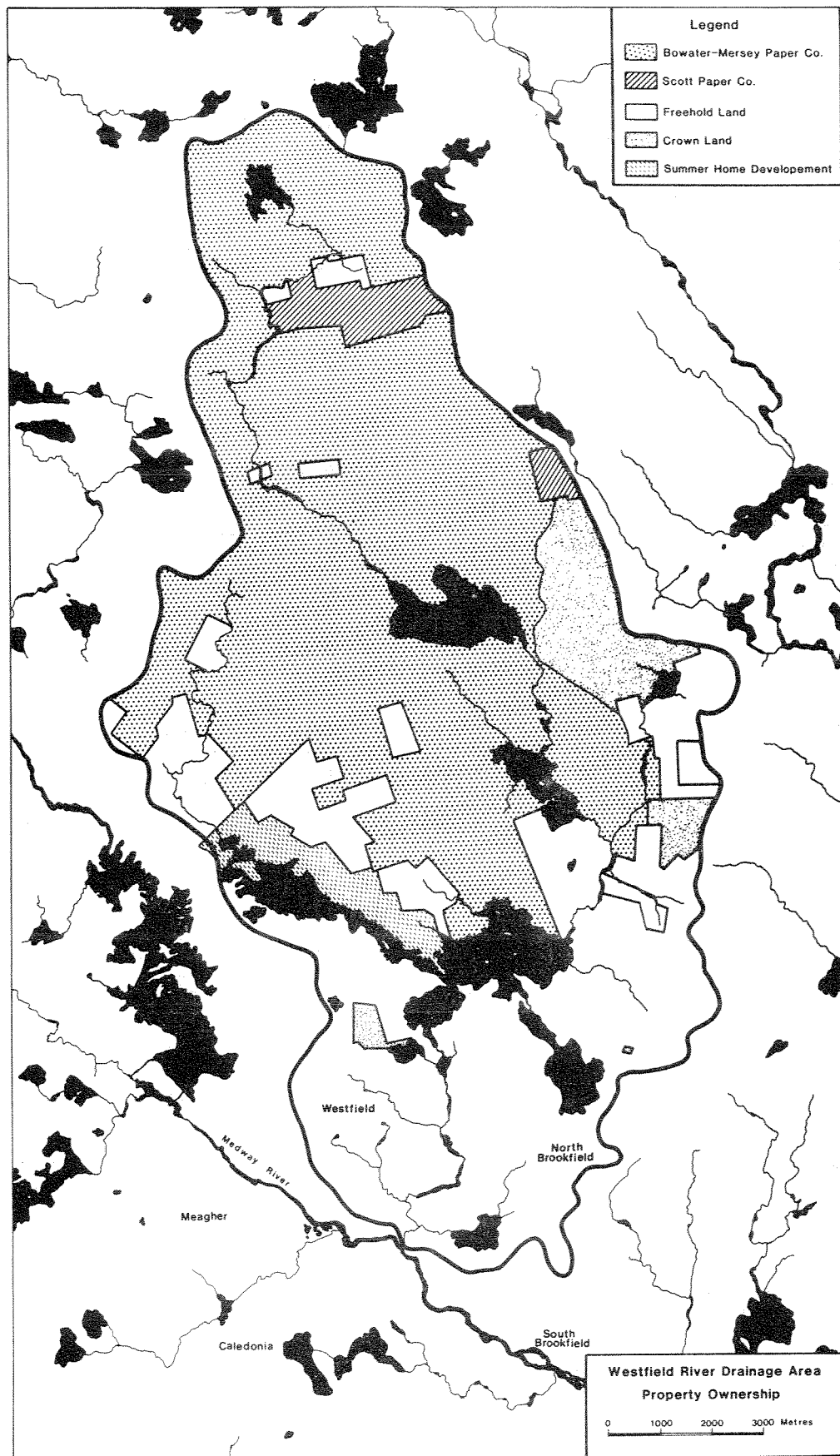


Fig. 2. Property ownership in the Westfield drainage system is indicated by the various shadings.

clearcut in blocks over the last 15 yr. After harvesting, the clearcut areas have been reforested either by site preparation followed by seedling plantings, or by selectively removing some tree seedlings to enhance growth of the remaining trees.

The largest block of Crown land, northwest of Cranberry Lake, lies within the boundaries of the Pleasant River Management Unit. In contrast to the rest of the drainage basin, this area is about 75% hardwood, which is harvested either by clearcutting small areas, or by selectively removing about 50% of the trees in small blocks (Rice, pers. comm.).

Forest harvesting on privately owned land is restricted to selective logging of timber and pulpwood. This will probably continue to be the harvesting method employed on these lands, because clearcutting requires specialized and expensive equipment (Silver, pers. comm.).

Mr. R. Silver of North Brookfield owns and intermittently operates a small sawmill on the eastern shore of Little Tupper Lake, which he uses mostly to saw timber cut on his own land (Silver, pers. comm.). This is the only sawmill in the drainage basin today.

Mining

There are no active mines within the drainage basin, nor was mining an important activity historically. However, gold was once mined commercially, and the shaft of the old mine is located near the Westfield River, as are several small pits from which gold was presumably extracted (O'Reilly, pers. comm.). Mining activities could increase in the future, because the entire southern portion of the drainage basin is licensed to Shell Canada Ltd. for base metal exploration, and exploratory activities are increasing in that area. A private operator considered establishing a silver mining operation at Round Lake during the first year of the study.

The geology of the drainage basin is an important factor affecting the stream acidification process because the underlying bedrock does not provide a source of buffering ions for ground or surface waters in the area. The northern portion of the drainage basin is underlain by granitic bedrock, containing deposits of copper, tungsten, tin, and gold. The granite is highly weathered, and as a result of this weathering some metallic species could be present in unusually high concentrations (Lytle, pers. comm.). The southern portion of the drainage basin is underlain by the slate-like meguma formation. Where the granite has intruded the meguma, there is a high degree of mineralization with tungsten, tin, and molybdenum commonly found, with silver and gold present as minor elements. These minerals are typically found in sulfur-bearing ores, which could contribute to the acidic surface water conditions by slow oxidation of sulfur in the bedrock. There is also a large quartz vein in the meguma formation containing considerable quantities of arsenopyrite, which could also contribute to acidification of surface waters. Both the granitic and the meguma formations are highly aluminized, and can cause unusually high aluminum levels in surface waters (Lytle, pers. comm.).

Agriculture

Although mixed farming was once the predominant form of livelihood in the drainage basin, agricultural activities are relatively unimportant today. There is only one obviously active farm in the drainage basin, a small dairy operation in North Brookfield. Their fields are probably limed to reduce acidity, and other agricultural chemicals (pesticides, herbicides, and fertilizers) may be used. However, there are probably less than 100 ha under cultivation in the entire drainage basin, because the remainder of the old farms are either abandoned or occupied by elderly ex-farmers who no longer farm the land. Other than the farm in North Brookfield, agricultural activities in the study area are restricted to gardening and to the use of old hayfields as pasture land for small numbers of cows and horses.

Recreational uses

The forest cover and rugged topography in the drainage basin make the area ideally suited for hunting and fishing. Moose are scarce in the area, so big game hunting is restricted to bear and deer. Ruffed grouse, ducks, woodcock, and snowshoe hare are the small game species hunted in the area. Overall, however, the area is not heavily hunted because of restricted accessibility (Wagstaff, pers. comm.).

Recreational fishing is concentrated on the streams in the drainage basin, although the lakes have been fished more heavily in recent years. Brook trout (*Salvelinus fontinalis*) is the principal game species in both lakes and streams, and yellow perch (*Perca flavescens*) are angled to a lesser extent in the lakes. Atlantic salmon (*Salmo salar*) are fished in the Westfield River, primarily by local residents (Wagstaff, pers. comm.).

The development of land for summer homes and cottages constitutes a relatively new recreational use of land in the watershed. There is a modest number of cottages on Tupper Lake, Little Tupper Lake, and Tupper Long Lake. However, all of the land along the western and northeastern shore of Tupper Lake has been recently subdivided for summer or year-round retirement homes by Canadian Estate Land Company of Toronto (Fig. 2). One hundred and forty lots have been surveyed, 85 of which are on the lakeshore. Virtually all of the lots have been sold, some homes have been built, and others are under construction. Each of these dwellings will have a separate septic system for treating its wastewater (Mednick, pers. comm.). There is speculation that the southwestern shore of Tupper Lake will also eventually be subdivided for development (Wagstaff, pers. comm.).

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R. L. Saunders and G. L. Lacroix reviewed the manuscript. J. Hurley and B. Fawkes typed it, F. Cunningham rephotographed the maps, and R. Garnett did the editing.

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Table 1. Average annual low and high flow rates for Medway, LaHave, and Mersey Rivers. (L/s/km² = liters per second per square kilometer of stream cross-section).

Station	Flow condition	Duration of discharge (d) (L/s/km ²)							Period of record
		1	3	7	10	30	60	90	
<u>Medway</u>									
01EE001 ^a (1390 km ²)	Low	2.84	2.99	3.18	3.33	4.23	5.74	7.32	1916-1979
	High	120	116	109	103	78.9	64.2	56.7	
01EE002 ^a (342 km ²)	Low	1.02	1.19	1.47	1.72	3.12	4.88	6.44	1945-1978
	High	193	171	138	122	80.3	61.4	54.3	
<u>LaHave</u>									
01EF001 ^a (1250 km ²)	Low	1.76	1.84	1.96	2.05	2.74	4.12	5.48	1916-1979
	High	187	164	131	118	80.6	62.6	53.9	
01EF003 ^a (728 km ²)	Low	1.15	1.20	1.28	1.36	2.12	3.43	5.19	1964-1978
	High	185	166	133	118	82.7	65.2	55.6	
<u>Mersey</u>									
01ED003 ^a (1960 km ²)	Low	7.56	11.6	14.9	15.5	19.0	20.8	21.8	1956-1978
	High	83	70	61.1	58.9	46.8	41.2	39.3	
01ED005 ^a (723 km ²)	Low	3.10	3.26	3.38	3.49	4.18	6.10	7.15	1970-1979
	High	106	105	100	95.5	76.2	63.0	57.4	
01ED007 ^a (295 km ²)	Low	2.75	2.95	3.31	3.51	4.59	6.14	7.57	1969-1979
	High	157	146	126	114	81	64	56.6	

^aEnvironment Canada Station Number.

Table 2. Flow statistics for the Medway River at Charleston; drainage area 1390 km², Station no. 01EE001.

Flow condition	Flow duration (d)	Mean flow (L/s/km ²)	Standard deviation (L/s/km ²)	Minimum flow (L/s/km ²)	Maximum flow (L/s/km ²)	Sample period (yr)	Type of analysis					
Low	1	2.84	2.84	0.130	-	63	Gumbel III ^a					
	3	2.99	2.93	0.183	-	63	Gumbel III ^a					
	7	3.18	2.98	0.199	-	63	Gumbel III ^a					
	10	3.33	3.07	0.207	-	63	Gumbel III ^b					
	30	4.23	3.67	0.299	-	63	Gumbel III ^b					
	60	5.74	4.65	0.420	-	63	Gumbel III ^b					
	90	7.32	5.12	0.771	-	63	Gumbel III ^b					
High	1	120	58.3	60	460	64	Gumbel I					
	3	116	54.3	58	430	64	Gumbel I					
	7	109	44.6	55.4	353	64	Gumbel I					
	10	103	39.0	53.3	312	64	Gumbel I					
	30	78.9	20.3	44.2	161	64	Gumbel I					
	60	64.2	13.7	42.8	108.8	64	Lognormal					
	90	56.7	11.5	35.7	85.7		Lognormal					
<u>Mean monthly runoff (L/s/km²)</u>												
<u>Jan.</u>	<u>Feb.</u>	<u>Mar.</u>	<u>Apr.</u>	<u>May</u>	<u>June</u>	<u>July</u>	<u>Aug.</u>	<u>Sept.</u>	<u>Oct.</u>	<u>Nov.</u>	<u>Dec.</u>	<u>Annual mean</u>
43.4	37.1	44.4	57.9	36.7	20.8	12.2	8.2	8.8	16.0	31.4	43.2	29.9

^aSmallest observed drought.

^bMaximum likelihood.

Table 3. Flow statistics for the Medway River at Harmony Hills; drainage area 342 km², Station no. 01EE002.

Flow condition	Flow duration (d)	Mean flow (L/s/km ²)	Standard deviation (L/s/km ²)	Minimum flow (L/s/km ²)	Maximum flow (L/s/km ²)	Sample period (yr)	Type of analysis
Low	1	1.02	0.50	0.041	-	33	Gumbel III ^a
	3	1.19	0.73	0.058	-	33	Gumbel III ^a
	7	1.47	0.94	0.234	-	33	Gumbel III ^a
	10	1.72	1.42	0.315	-	33	Gumbel III ^a
	30	3.12	2.85	0.488	-	33	Gumbel III ^b
	60	4.88	3.86	0.839	-	33	Gumbel III ^b
	90	6.44	4.27	0.873	-	33	Gumbel III ^a
High	1	193	112	65	664	34	Gumbel I
	3	171	89.8	62.3	555	34	Gumbel I
	7	138	60.5	56.6	393	34	Gumbel I
	10	122.3	48.3	53.3	320	34	Gumbel I
	30	80.3	19.4	45.8	144	34	Gumbel I
	60	61.4	11.6	38.1	87.4	34	Log normal
	90	54.3	10.5	31.2	74.2	34	Log normal

Mean monthly runoff (L/s/km²)

Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual mean
37.8	31.4	37.0	55.9	34.7	18.0	10.1	7.20	8.60	15.8	30.4	41.6	27.4

^aMaximum likelihood.

^bSmallest observed drought.

Table 4. Flow statistics for the LaHave River at West Northfield; drainage area 1250 km², Station no. 01EE001.

Flow condition	Flow duration (d)	Mean flow (L/s/km ²)	Standard deviation (L/s/km ²)	Minimum flow (L/s/km ²)	Maximum flow (L/s/km ²)	Sample period (yr)	Type of analysis
Low	1	1.76	1.58	0.100	-	63	Gumbel III ^a
	3	1.84	1.63	0.108	-	63	Gumbel III ^a
	7	1.96	1.73	0.112	-	63	Gumbel III ^a
	10	2.05	1.79	0.120	-	63	Gumbel III ^a
	30	2.74	2.43	0.158	-	63	Gumbel III ^a
	60	4.12	3.71	0.207	-	63	Gumbel III ^a
	90	5.48	4.23	0.458	-	63	Gumbel III ^b
High	1	187	107	75	864	64	Gumbel I
	3	164	83.3	73.3	677	64	Gumbel I
	7	131	55.2	59.1	459	64	Gumbel I
	10	118.2	45.5	55.0	373	64	Gumbel I
	30	80.6	20.8	47.2	161.9	64	Gumbel I
	60	62.6	12.3	41.5	94.8	64	Log normal
	90	53.9	10.4	34.9	80.2	64	Log normal

Mean monthly runoff (L/s/km²)

Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual mean
37.6	30.6	40.8	58.0	31.9	16.4	9.31	7.02	7.70	16.4	33.5	40.8	27.4

^aSmallest observed drought.

^bMaximum likelihood.

Table 5. Flow statistics for the LaHave River above Morgan's Falls; drainage area 728 km², Station no. 01EF003.

Flow condition	Flow duration (d)	Mean flow (L/s/km ²)	Standard deviation (L/s/km ²)	Minimum flow (L/s/km ²)	Maximum flow (L/s/km ²)	Sample period (yr)	Type of analysis
Low	1	1.15	0.981	0.038	-	14	Gumbel II ^a
	3	1.20	1.014	0.044	-	14	Gumbel II ^a
	7	1.28	1.075	0.045	-	14	Gumbel II ^a
	10	1.36	1.149	0.046	-	14	Gumbel II ^a
	30	2.12	1.843	0.100	-	14	Gumbel II ^a
	60	3.43	2.900	0.183	-	14	Gumbel II ^a
	90	5.19	3.581	0.196	-	14	Gumbel II ^a
High	1	185	61.5	85	295	15	Gumbel I
	3	165.7	52.4	82.7	259	15	Log Pearson III ^b
	7	133	32.4	75.9	186	15	3 Para Lognormal
	10	118.4	24.9	70.6	166	15	Log Pearson III ^b
	30	82.7	11.9	55.4	101	15	Log normal
	60	65.2	9.28	43.6	81.5	15	Log normal
	90	55.6	10.22	35.2	73.3	15	Log normal

Mean monthly runoff (L/s/km²)

<u>Jan.</u>	<u>Feb.</u>	<u>Mar.</u>	<u>Apr.</u>	<u>May</u>	<u>June</u>	<u>July</u>	<u>Aug.</u>	<u>Sept.</u>	<u>Oct.</u>	<u>Nov.</u>	<u>Dec.</u>	<u>Annual mean</u>
35.6	31.3	42.4	60.3	32.8	15.0	7.31	6.61	6.26	22.6	35.1	49.4	28.5

^aSmallest observed drought.

^bMaximum likelihood.

Table 6. Sub-drainage areas for the Westfield River.

Station no.	Description	Drainage area (km ²)
1	Westfield River near Westfield	141.6
2	Moose Pit Brook above Tupper Lake	12.7
3	Round Lake Brook below Round Lake	48.8

Table 7. Existing meteorologic stations near the Westfield River drainage basin.

Name	Station No.	Lat.		Long.		Elevation (m)	Period of record	Type of observation
Bear River	8200500	44°	34'	65°	38'	8	1952-Date	Total precipitation
Bridgewater	8200600	44	24	64	33	23	1966-Date	Temperature Total precipitation
Greenwood	8202000	44	59	64	55	25	1942-Date 1964-Date	Synoptic report Hourly weather temperature Total precipitation Rate of rainfall Snow survey
Harmony	8202300	44	25	65	03	107	1950-Date	Total precipitation
Kejimkujik Park	8202590	44	26	65	12	127	1966-Date	Temperature Total precipitation
Springfield	8205200	44	40	04	51	167	1919-1920 1920-Date	Total precipitation Temperature Total precipitation

Table 8. Average monthly flow estimates (L/s) for Westfield River sub-drainage basins (Fig. 1).

Station	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual averages
Westfield River	6164	5252	6285	8196	5195	2944	1717	1159	1249	2265	4445	6115	4233
Moose Pit Brook	480	399	470	710	441	229	128	91.4	109	200	386	528	348
Round Lake Brook	2117	1810	2166	2825	1791	1015	595	400	430	781	1532	2108	1459

Table 9. Extreme flow estimates (L/s) for the Westfield River sub basin near Westfield (Fig. 1); drainage area 141.6 km².

Flow condition	Return period (yr)	Duration of discharge (d)						
		1	3	7	10	30	60	90
Low	1.01	1873	1940	1964	1976	2389	2974	3381
	1.11	924	963	1006	1003	1284	1683	2029
	1.25	640	670	711	739	932	1254	1561
	2.00	276	293	323	346	451	644	864
	5.00	944	105	120	136	186	281	418
	10.00	33.7	59.5	68.2	81.1	114	175	277
	20.00	30.8	39.0	44.2	55.1	78.7	121	200
	50.00	19.8	27.4	30.1	39.7	57.2	85.5	147
	100.00	16.3	23.7	25.5	34.4	49.7	72.3	126
High	1.005	6653	6606	6593	6583	6323	5261	4656
	1.050	9201	9013	8736	8536	7503	6370	5631
	1.25	12030	11700	11180	10790	8918	7503	6632
	2.00	15710	15290	14420	13760	10710	8895	7864
	5.00	20670	20150	18790	17700	13120	10570	9327
	10.00	24070	23360	21640	20390	14770	11560	10210
	20.0	27180	26420	24470	22930	16280	12460	10980
	50.0	31280	30390	28110	26190	18310	13540	11940
	100.0	34400	33360	30740	28740	19820	14320	12610

Table 10. Extreme flow estimates (L/s) for Moose Pit Brook above Tupper Lake (Fig. 1); drainage area 12.7 km².

Flow condition	Return period (yr)	Duration of discharge (d)						
		1	3	7	10	30	60	90
Low	1.01	29.1	40.9	53.3	75.6	173	233	257
	1.11	21.4	27.5	34.1	43.2	86.3	128	156
	1.25	18.2	22.3	27.1	32.6	60.6	94.0	121
	2.00	12.4	13.7	16.3	17.7	28.1	48.1	69.0
	5.00	7.23	7.14	8.89	9.03	12.2	22.5	35.0
	10.00	4.94	4.65	6.34	6.57	8.47	15.6	24.1
	20.0	3.32	3.09	4.87	5.32	6.80	12.1	18.1
	50.0	1.85	1.83	3.79	4.53	5.90	10.0	13.9
	100.0	1.06	1.25	3.31	4.24	5.60	9.28	12.2
High	1.005	483	563	626	626	597	470	401
	1.050	965	953	902	852	699	561	484
	1.25	1499	1401	1217	1113	821	654	570
	2.00	2223	1990	1634	1461	982	766	677
	5.00	3188	2786	2196	1918	1194	898	803
	10.00	3835	3315	2576	2223	1338	976	878
	20.00	4445	3820	2921	2515	1473	1046	945
	50.00	5245	4487	3393	2896	1651	1130	1027
	100.00	5842	4953	3737	3188	1782	1190	1085

Table 11. Extreme flow estimates (L/s) for Round Lake Brook below Round Lake (Fig. 1); drainage area 48.79 km².

Flow condition	Return period (yr)	Duration of discharge (d)						
		1	3	7	10	30	60	90
Low	1.01	646	669	677	681	823	1025	1165
	1.11	318	332	347	356	442	580	699
	1.25	220	231	245	255	321	432	538
	2.00	95.0	101	111	119	156	222	298
	5.00	32.5	36.3	41.3	46.9	64.1	97.0	144
	10.00	17.4	20.5	23.6	28.0	39.2	60.5	95.5
	20.0	10.6	13.4	15.3	19.0	27.1	41.7	69.0
	50.0	68.4	9.43	10.4	13.7	19.7	29.5	50.7
	100.0	5.63	8.17	8.79	11.9	17.1	24.9	43.4
High	1.005	2293	2277	2273	2269	2179	1813	1605
	1.050	3171	3106	3011	2942	2586	2196	1941
	1.25	4147	4033	3854	3718	3074	2586	2282
	2.00	5416	5270	4970	4742	3692	3066	2711
	5.00	7123	6943	6476	6099	4521	3643	3215
	10.00	8294	8050	7459	7026	5090	3995	3518
	20.00	9368	9107	8434	7904	5611	4294	3784
	50.00	10780	10470	9689	9026	6310	4668	4115
	100.00	11860	11500	10590	9904	6831	4936	4348