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Summary Pilot Watershed Report: Forested Watershed Study, Canada: Summary Technical Report, PLUARG Task C, Activity 2

International Reference Group on Great Lakes Pollution from Land Use Activities

Canada. Department of the Environment. Great Lakes Forest Research Centre

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INTERNATIONAL REFERENCE GROUP ON GREAT LAKES POLLUTION FROM LAND USE ACTIVITIES

INTERNATIONAL JOINT COMMISSION

SUMMARY PILOT WATERSHED REPORT
FORESTED WATERSHED STUDY, CANADA

SUMMARY TECHNICAL REPORT

PLUARG TASK C ACTIVITY 2

FORESTED WATERSHED STUDIES

DECEMBER 1, 1977

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Environment Canada

Great Lakes Forest Research Centre

Sault Ste. Marie, Ontario

1. AGENCIES INVOLVED

The core study which was the basis for this report was initiated and conducted with the help and guidance of the administration of the Great Lakes Forest Research Centre, Canadian Forestry Service. Funding was provided primarily by the Centre and the Pollution from Land Use Activities Reference Group. The author wishes to express his sincere thanks to the personnel from both agencies who have contributed to this undertaking.

3. DISCLAIMER

This report has been prepared utilizing results from a study conducted in northwestern Ontario, outside the Great Lakes Basin, but still on the Canadian Shield, as well as other meagre information that was available on forestry operations and water quality within the basin. It is being used as part of the Task C activities of the Pollution From Land Use Activities Reference Group, International Joint Commission. Findings and conclusions are those of the author and do not necessarily reflect the views of the Reference Group or its recommendations to the International Joint Commission.

4. ACKNOWLEDGEMENTS

The author is indebted to associates at the Great Lakes Forest Research Centre and members of PLUARG, especially the Task C Committee, who contributed to this report. A note of special thanks must also be extended to all those, and particularly Ontario Ministry of Natural Resources personnel, who provided the background information to construct this rough framework of the effects of forestry operations upon water quality in the Great Lakes Basin.

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8. SUMMARY

This project was set up as a long-term investigation of the impact of current forestry practices upon the water, soil and vegetation of the boreal forest ecosystems of Ontario. Where the impact was shown to be detrimental economically and ecologically acceptable alternative practices were to be developed.

Because of time, money and manpower constraints only clearcutting and/or scarification in one major ecosystem have been investigated to date. The study area was established at the Experimental Lakes Area in the Kenora, Ontario area, outside the Great Lakes Basin, before the initiation of the PLUARG Task C studies.

Results indicate that, in the jack pine-black spruce ecosystem of northwestern Ontario, with its generally shallow, coarse soil and low rainfall, revegetation is rapid following clearcutting and although changes in elemental losses were detected in the surface runoff they were not of a dramatic nature. For instance, unit loss of total phosphorus increased approximately three to five times natural background levels immediately after harvesting, but, following four or five years of regrowth the increase was less than double. Suspended sediment loss was two to three times greater than natural erosion following harvesting, but within four or five years had returned to near natural levels. The components of natural geologic erosion are very low in the surface runoff of the area, so even three to five time increases did not result in any values exceeding present Ontario drinking water standards. Therefore, at least in the area studied, forest harvesting was a minor contributor to water pollution. Other forest management techniques and other forest ecosystems will not be studied intensively within the PLUARG time frame.

Forestry operations, including clearcutting, partial cutting, scarification, regeneration and tending such as hand, mechanical or chemical cleaning, thinning, improvement cuts, pruning, fertilization, and cultivation, in the Canadian portion of the Great Lakes Basin annually cover about 111,000 ha or 0.49 percent of the terrestrial area. The major forested areas occur in the Lakes Superior and Huron Basins. There are 21 pulp and paper mills on the Great Lakes which produce annually far more phosphorus (12 times) and suspended sediment (110 times) than that estimated to come from the terrestrial areas disturbed by all the field operations of forest management. The materials emanating from undisturbed forested areas in the basin are considered to be products of natural geologic erosion.

9. INTRODUCTION

9.1 Study Objectives

1. To determine the impact of current forestry practices upon the water, soil and vegetation of the boreal forest ecosystems of Ontario.

2. Where the impact is shown to be detrimental to any of these factors, to develop economically and ecologically acceptable alternative practices.

9.2 Study Approach

Although this study was not conducted within the Great Lakes Basin it is the only Canadian study available in Ontario dealing with any aspect of forest management practices and their effect upon water quality and quantity. The study site was the Experimental Lakes Area maintained by the Fisheries and Marine Service of the Federal Department of the Environment, about 55 kilometres southeast of Kenora, Ontario.

To date only clearcutting and/or scarification have been investigated because of manpower, time and financial constraints. However, forest management in Ontario includes many different treatments such as various cutting methods, fire control, the use of herbicides, pesticides and fertilizers, and has to contend with a great variety of climatic, soil and vegetation types.

9.3 Methods

The study at the Experimental Lakes Area included twelve small watersheds of 35 to 1250 hectares (88 to 3000 acres) located in the headwaters of the English and Winnipeg rivers systems.

Vegetative conditions on the watersheds consisted of uncut mature jack pine (*Pinus banksiana* Lamb.) and black spruce (*Picea mariana* [Mill.] B.S.P.) intermixed with white birch (*Betula papyrifera* Marsh.) and aspen (*Populus* spp.), through various ages of harvesting, with a number of watersheds in each group. Owing to the uniformity of the bedrock and mantle and the uniform age and structure of the vegetation it was felt that major disruptions of the system should be detectable by studying watersheds in uncut, and cutover conditions of various ages since cutting.

Water samples were collected weekly from April until October, analyzed immediately for forms of nitrogen and phosphorus at the camp laboratory, and then sent to the Federal Freshwater Institute in Winnipeg for determination of cations and anions. Only the active growing season was covered because detectable surface runoff from most of these small watersheds was greatly reduced, sometimes to nil, during the dormant season.

Data were collected from 1973 to 1976 for all watersheds. The elemental concentrations were combined with the total weekly runoff to establish a weekly unit loss per hectare for each watershed. The watersheds were then assigned to their specific disturbance category in order to develop a separate average weekly loss per hectare for each of uncut, one-year-old cut, two-year-old cut, etc. conditions. These averages were then extrapolated to forty weeks, which is approximately the ice-free period for most of these small watersheds, to give an annual unit loss of elements from small headwater watersheds in each disturbance category.

9.4 Key Parameters Studied

In terms of the list of five key parameters (sediment, total phosphorus, metals, toxics, and microorganisms) considered by Task C, suspended sediment and total phosphorus are the main ones affected by the harvesting aspects of forestry. Other land management aspects of silviculture could contribute toxic substances and pesticides but these were not studied. Wood processing mills can contribute metals, toxics and phenols; however, because they are point sources, these were not studied in detail. Many other elements were determined as shown in the following list.

Ammonia-nitrogen (NH_3-N)
Nitrate-nitrogen (NO_3-N)
Total dissolved nitrogen (TDN)
Suspended nitrogen (Susp N)
Total dissolved phosphorus (TDP)
Suspended phosphorus (Susp P)
Suspended carbon (Susp C)
Chloride (Cl)
Sulphate (SO_4)
Silicon (Si)
Sodium (Na)
Potassium (K)
Magnesium (Mg)
Calcium (Ca)
Total iron (Fe)
Suspended sediment (SS)

10/11. RESULTS, INTERPRETATION AND CONCLUSIONS

10/11.1 Land Uses and Practices

Table 1 shows that land management aspects of forestry have a greater potential for affecting Lakes Superior and Huron because of the predominance of forested land in their watersheds as compared with those of Lakes Erie and Ontario.

Table 1. Forest and recreation land on the Canadian Side of the Great Lakes Basin

Lake Basin	Forest km^2	Forest %	Recreation km^2	Recreation %	Total km^2
Superior	93282	98.8	225	0.24	94419
Huron	63276	75.0	1633	1.93	84375
Erie	3360	14.8	79	0.35	22753
Ontario	12321	42.6	307	1.06	28927

Over the entire province the number of provincial parks increased from 88 in 1964 to 117 in 1974. However, the area of parkland increased from 15,000 km^2 to over 42,000 km^2 in the same period. In 1974 there were 72 provincial parks in the Great Lakes Basin with a total area of 2767 km^2, only 6.5 percent of the parkland in the province. However, this area received 8.5 million visitors which was 78 percent of the total for the province. These figures, while not including national parks or privately owned/operated parks, demonstrate that recreational activity is increasing dramatically in the Great Lakes Basin.

Extensive recreation probably has very little impact on water quality unless areas receive undue pressure from canoeists, hunters or fishermen.

The Ontario Ministry of Natural Resources (OMNR), the major land management agency in the basin, is responsible for the management of about 212,000 km^2 of land, water and other natural resources. Tables 2 and 3 present annual breakdowns for 1974-5 and 1975-6 of forestry operations within the watershed.

In the Ontario portion of the Great Lakes watershed clearcutting accounts for about 0.16 percent of forestry operations annually, partial cutting, which is less disturbing, about 0.17 percent and scarification 0.01 percent of the total watershed. Regeneration and tending, generally less disturbing than harvesting, which includes hand, mechanical or chemical cleaning, thinning, improvement cuts, pruning, fertilization and cultivation accounts for 0.11 percent and pest control another 0.04 percent. Over all this amounts to an annual disturbance of over 111,000 ha or 0.49 percent of the Great Lakes Watershed.

Table 2. Disturbance on the Canadian side of the Great Lakes Watershed due to forestry operations during 1974-5[1] (areas in ha)

	Superior		Huron		Erie		Ontario		Total	
Operation	Ha	Percent	Ha	Percent	Ha	Percent	Ha	Percent	Ha	Percent
Clearcut	32381	.385	7181	.078	0	0	1003	.034	40565	.178
Partial cut	8737	.104	18264	.198	2648	.116	6184	.209	35833	.157
Scarification	1527	.018	319	.003	10	.001	0	0	1856	.008
Regeneration and tending	9690	.115	7141	.078	3143	.138	4970	.168	24944	.109
Pest control	8126	.097	2442	.027	158	.007	124	.004	10850	.047
Total	60461	.719	35347	.384	5959	.262	12281	.415	114048	.499

[1] Source: Ontario Ministry of Natural Resources annual summaries of silvicultural operations acquired from Regional Foresters concerned.

Table 3. Disturbance on the Canadian side of the Great Lakes Watershed due to forestry operations during 1975-6[1] (areas in ha)

	Superior		Huron		Erie		Ontario		Totals	
Operation	Ha	Percent	Ha	Percent	Ha	Percent	Ha	Percent	Ha	Percent
Clearcut	26605	.317	4609	.050	0	0	1379	.047	32593	.143
Partial cut	11187	.133	18556	.201	2727	.120	7648	.259	40118	.176
Scarification	1941	.023	806	.009	28	.001	179	.006	2954	.013
Regeneration and tending	8695	.104	9162	.099	5003	.219	3286	.111	26146	.114
Pest control	3720	.044	1100	.012	138	.006	1060	.036	6018	.026
Total	52148	.621	34233	.372	7896	.346	13552	.458	107829	.472

[1] Source: Ontario Ministry of Natural Resources annual summaries of silvicultural operations acquired from Regional Foresters concerned.

10/11.2 Loads

Unit area loadings were compiled by averaging the annual loads produced by the watersheds in each disturbance category over the course of four years (Table 4). Total dissolved phosphorus and suspended sediment appear to more than double following clearcutting. Suspended sediment production from these small watersheds has returned to preharvesting levels within four or five years, however, phosphorus does not seem to respond as rapidly.

Table 5 presents unit area loadings by months and demonstrates that the greatest losses occur during the spring, reflecting high runoff owing to snowmelt and spring rains. Losses are much lower during the summer because of reduced flow. These results are depicted graphically in figures 1 to 4 to reinforce further the observation that elemental losses are closely allied with flowrates in these small watersheds. Owing to the lack of complete flow data for the entire year no further attempt will be made to define seasonal losses.

In order to present estimates of total dissolved phosphorus and suspended sediment loads with the Beale ratio estimator (Tin 1965, Kendall and Stuart 1968), the missing months of flow data were estimated by comparison with complete annual records maintained for four watersheds near the camp. Most of these small watersheds have a period of 12 to 16 weeks during the winter when there is virtually no flow; the other months for which data are not available are in general, periods of very low flow; therefore, the estimates should be reliable.

Table 6 shows total dissolved phosphorus loadings and Table 7 suspended sediment loadings calculated according to the Beale ratio estimator technique. It should be noted that the unit area estimates for both parameters are substantially lower than those presented in Table 4 where the Beale ratio estimator was not used because of the lack of flow data. Another major point in relation to suspended sediment is that it generally arises from channel and bank erosion, not sheet erosion, under natural conditions. However, channel and bank erosion were not investigated in this study. There was no major increase in suspended sediment production from these small watersheds. Therefore, even under disturbed conditions sheet erosion does not appear to be a problem when disturbance occurs from forestry operations on the Canadian Shield.

Table 4. Average unit loads (kg/ha/yr) over a four-year period (1973-6) from undisturbed and clearcut watersheds in northwestern Ontario[1]

Conditions	NH_3-N	NO_3-N	TDN[2]	Susp N	TDP[3]	Susp P	Susp C	Cl	SO_4	Si	Na	K	Mg	Ca	Fe	SS	pH
Undisturbed	.126	.108	2.028	.342	.032	.028	3.494	3.260	18.570	12.200	4.156	1.314	2.918	7.334	1.024	1.768	5.87
Cut one year	.248	.134	3.984	.634	.076	.056	6.364	6.590	18.114	19.660	6.228	5.442	4.414	12.900	4.018	4.742	5.84
Cut two years	.144	.144	2.126	.258	.036	.018	2.400	3.120	16.548	8.598	3.070	3.232	1.942	5.104	2.230	1.734	5.84
Cut three years	.268	.184	5.768	.544	.120	.044	5.972	9.624	27.736	16.728	9.072	8.488	5.492	13.152	7.896	3.048	5.46
Cut four years	.120	.128	3.576	.352	.072	.028	3.608	6.320	16.536	16.652	6.296	4.632	3.536	8.832	4.080	1.716	5.45
Cut five years	.052	.036	1.644	.124	.036	.008	1.388	2.108	13.184	6.428	2.460	1.616	1.412	3.856	1.752	1.108	5.48

[1] These values were not calculated using the Beale ratio estimator due to problems of applying the method

[2] Add TDN and Susp N to determine total nitrogen

[3] Add TDP and Susp P to determine total phosphorus

Table 5. Unit area loadings (kg/ha) for 1975 and 1976 by months in three selected disturbance categories

	Uncut			Cut one year			Cut four years		
	TDN	TDP	SS	TDN	TDP	SS	TDN	TDP	SS
1975									
April	.7602	.0136	--	---	---	--	---	---	--
May	.4342	.0098	.1076	.5373	.0103	.6270	1.1887	.0254	.2296
June	.4084	.0070	.4965	.5237	.0091	.8111	.8210	.0165	.4285
July	.3166	.0052	.1516	.3201	.0069	.3239	.5984	.0126	.3177
August	.0132	.0002	.0227	.0940	.0016	.1113	.1230	.0032	.1130
September	.1368	.0019	.1956	.5414	.0077	.7866	.6646	.0138	.2982

	Uncut			Cut two years			Cut five years		
	TDN	TDP	SS	TDN	TDP	SS	TDN	TDP	SS
1976									
April	.3904	.0068	--	.7912	.0116	.5000	.8032	.0250	.5350
May	.0465	.0008	.0584	.0594	.0008	.0486	.1116	.0022	.0498
June	.0225	.0004	.0372	.0764	.0013	.0926	.1035	.0022	.1180
July	.0950	.0010	.0788	.2085	.0034	.4105	.3309	.0044	.1694
August	.0051	.0001	.0059	.0204	.0003	.0353	.1400	.0035	.1304
September	.0011	.0000	.0003	.0066	.0000	.0084	.0193	.0006	.0149

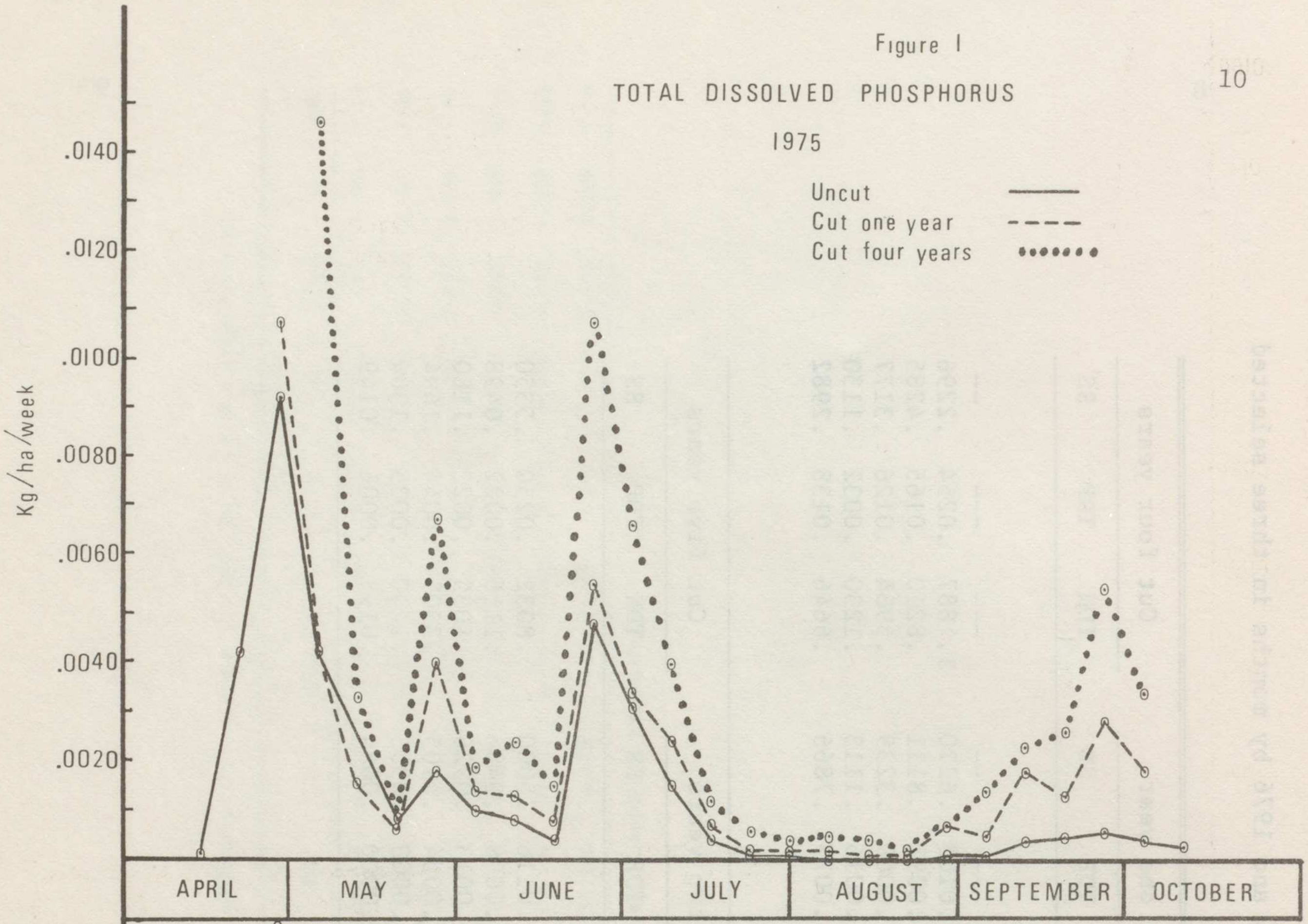

Figure 1

TOTAL DISSOLVED PHOSPHORUS

1975

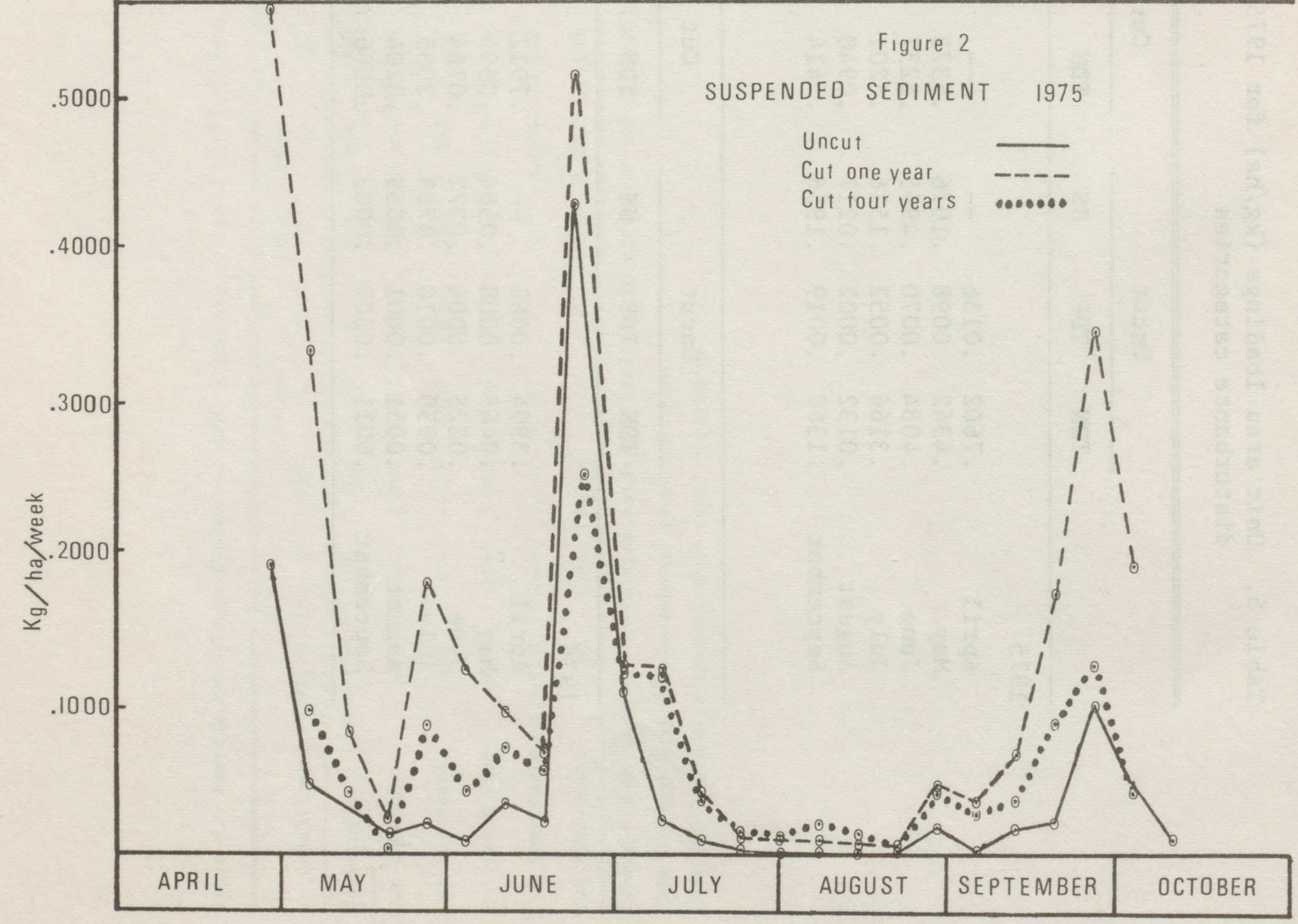

Figure 2

SUSPENDED SEDIMENT 1975

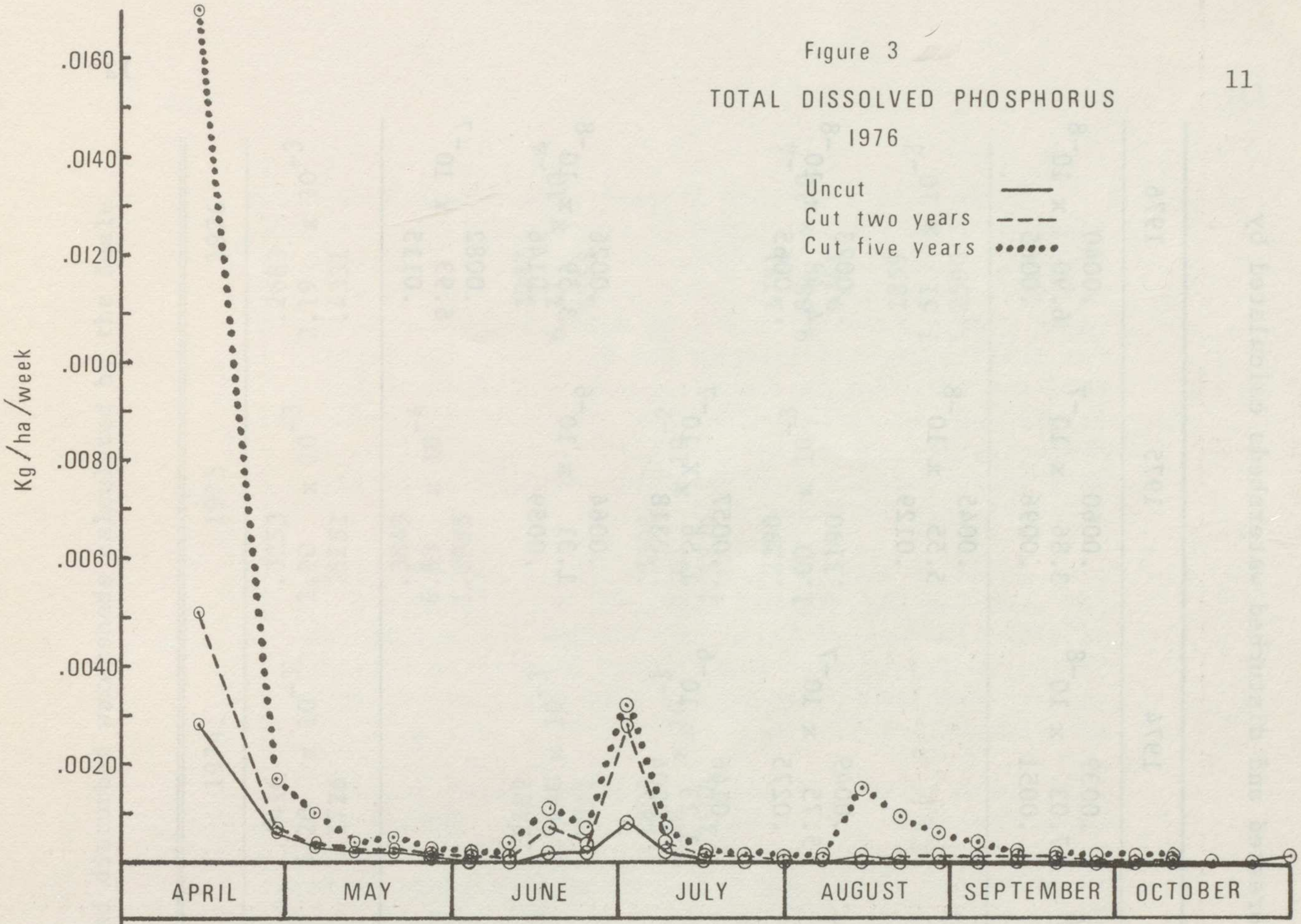

Figure 3

TOTAL DISSOLVED PHOSPHORUS 1976

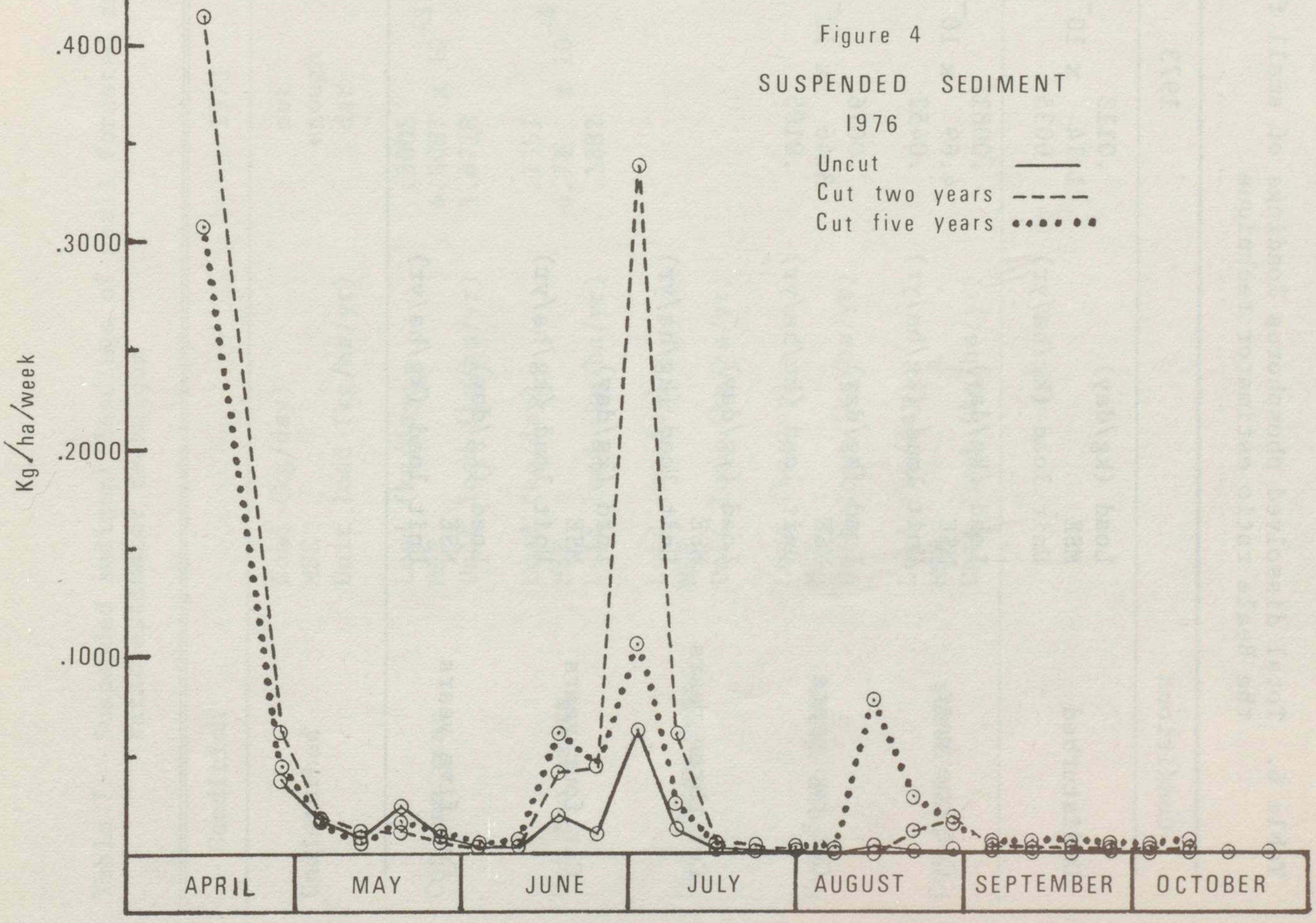

Figure 4

SUSPENDED SEDIMENT 1976

Table 6. Total dissolved phosphorus loadings of small forested and disturbed watersheds calculated by the Beale ratio estimator technique

Conditions		1973	1974	1975	1976
Undisturbed	Load (kg/day)	.0113	.0039	.0060	.0040
	MSE	1.14 x 10^{-6}	7.03 x 10^{-8}	3.86 x 10^{-7}	6.90 x 10^{-8}
	Unit load (kg/ha/yr)	.0035	.0051	.0096	.0065
Cut one year	Load (kg/day)	.0081		.0045	
	MSE	4.69 x 10^{-7}		5.55 x 10^{-8}	
	Unit load (kg/ha/yr)	.0452		.0129	
Cut two years	Load (kg/day)	.0076	.0049		.0023
	MSE	3.46 x 10^{-7}	5.75 x 10^{-7}		4.48 x 10^{-8}
	Unit load (kg/ha/yr)	.0105	.0275		.0065
Cut three years	Load (kg/day)		.0146	.0057	
	MSE		3.23 x 10^{-6}	1.56 X 10^{-7}	
	Unit load (kg/ha/yr)		.0204	.0318	
Cut four years	Load (kg/day)			.0064	.0026
	MSE			1.31 x 10^{-6}	3.59 x 10^{-8}
	Unit load (kg/ha/yr)			.0089	.0146
Cut five years	Load (kg/day)				.0082
	MSE				6.93 x 10^{-7}
	Unit load (kg/ha/yr)				.0115

Table 7. Suspended sediment loadings of small forested and disturbed watersheds calculated by the Beale ratio estimator technique

Condition		1973	1974	1975	1976
Undisturbed	Load (kg/day)	not enough data	.4416	.3253	.2683
	MSE		5.20×10^{-3}	2.90×10^{-3}	2.19×10^{-3}
	Unit load (kg/ha/yr)		.5726	.5251	.4331
Cut one year	Load (kg/day)	.3005		.3849	
	MSE	4.8087×10^{-3}		6.63×10^{-4}	
	Unit load (kg/ha/yr)	1.6718		1.0985	
Cut two years	Load (kg/day)	.1351	.2482		.2297
	MSE	6.71×10^{-4}	1.9640×10^{-3}		6.77×10^{-4}
	Unit load (kg/ha/yr)	.1882	1.3811		.6555
Cut three years	Load (kg/day)		.1800	.3806	
	MSE		4.48×10^{-3}	1.01×10^{-2}	
	Unit load (kg/ha/yr)		.2508	2.1179	
Cut four years	Load (kg/day)			.2290	.1751
	MSE			1.00×10^{-3}	9.88×10^{-4}
	Unit load (kg/ha/yr)			.3190	.9741
Cut five years	Load (kg/day)				.1859
	MSE				1.51×10^{-3}
	Unit load (kg/ha/yr)				.2590

Table 8 is a further attempt to estimate phosphorus loadings from forested land to the Great Lakes. A bare minimum of samples, taken by the Ontario Ministry of the Environment in 1973, were available from four major rivers flowing into Lake Superior. Because of the small number of samples the data were not stratified and this led to the extremely high mean square errors and the rather high unit area loading estimates. These results should be used with extreme caution and only as an indication of possible maximum loadings. Sediment data were not available.

Study of four watersheds during a period extending over the undisturbed state in 1973, through a wildfire in June of 1974, and for the two succeeding years, indicated that the effects of fire on nutrient and erosion losses are of the same magnitude as those of clearcutting (Table 9).

There have been few fires of any magnitude in recent decades in the Great Lakes Basin. During 1973 there were 527 fires with a total area of 11 km^2, and in 1974, one of the worst potential fire years in recent time, there were 703 fires with a total area of 23 km^2 or less than .01 percent of the basin.

Study of an intensive recreation site near the Experimental Lakes Area (ELA) indicates that recreation can have a very deleterious effect in terms of environmental degradation. Continuous use appears to have more permanent impacts than the long-term rotations of forest harvesting. Soil compaction increased with increasing use. Compaction also occurs on skid trails and landings during the harvesting operation but studies have shown that freezing and thawing cycles help to relieve these conditions within a few years of the harvest. Bare soil and bare rock exposure was increased in heavily used recreation areas owing to destruction of vegetation. Erosion rates rose as was evidenced by frequent exposure of tree roots in highly impacted areas. However, Table 10 indicates that concentrations of total phosphorus and suspended sediment did not change because of the presence of the recreation area along both sides of the long narrow bay leading to the Rushing River.

Table 8. Total phosphorus loadings for 1973 of four major rivers flowing into Lake Superior

Watershed	Area (ha)	Mean annual flow (l/sec)	Forest cover (percent)	Number of[1] samples	Total Phosphorus		
					Daily load kg/day	Mean square error	Unit load kg/ha/yr
Black R.	231,156	27,696.96	100	7	58.51	1,251.38	.0924
Pic R.	515,536	46,161.60	100	9	282.59	67,451.37	.2001
Steel R.	108,868	15,066.24	100	9	25.51	1,710.36	.0855
Little Pic R.	126,521	15,632.64	100	9	66.50	1,805.98	.1919

---

[1] Samples taken from June to December of 1973 by the Ontario Ministry of the Environment, Water Resources Branch.

Table 9. Average unit loads (kg/ha/yr) for undisturbed and burned watersheds in northwestern Ontario[1]

Conditions	NH_3-N	NO_3-N	TDN	Susp N	TDP	Susp P	Susp C	CL	SO_4	Si	Na	K	Mg	Ca	Fe	SS
Undisturbed (1973)	.037	.171	1.220	.164	.024	.012	1.656	1.684	9.54	10.463	3.693	1.493	2.420	6.999	.756	.620
First year burn (1974)	.188	.364	3.920	.646	.090	.062	6.352	4.894	31.382	38.836	13.466	5.442	8.526	23.926	2.296	3.494
Second year burn (1975)	.190	.644	4.108	.588	.096	.058	5.992	6.288	41.602	36.212	12.228	6.492	8.326	23.444	2.594	4.312
Third year burn (1976)	.024	.124	.692	.116	.014	.008	.930	1.262	7.522	4.946	1.928	1.230	1.142	3.644	.322	.752

[1] These values were not calculated using the Beale ratio estimator due to problems of applying the method

Table 10. Monthly[1] average concentrations[2] (mg/l) during 1975 above, below and at the swimming beach of Rushing River Campground in northwestern Ontario

	NH_3-N	NO_3-N	TDN	TDP[3]	Susp P	Susp C	CL	SO_4	Si	Na	K	Mg	Ca	Fe	SS	pH
Above Campground																
June	.012	.004	.313	.005	.007	.618	1.95	3.75	.59	1.62	.62	1.06	2.96	.038	.64	6.95
July	.009	.002	.341	.004	.005	.808	1.64	4.00	.41	1.58	.57	0.98	2.43	.104	.75	6.97
August	.006	.001	.309	.004	.006	1.048	1.65	3.55	.34	1.63	.66	1.02	3.08	.078	1.09	7.03
September	.008	.001	.285	.005	.007	.658	1.65	3.80	.36	1.62	.48	1.08	1.84	.080	1.00	7.00
At Beach																
July	.006	.001	.270	.004	.005	.800	1.55	4.00	.38	1.52	.51	1.08	2.82	.088	.62	7.04
August	.005	.001	.266	.004	.005	.605	1.50	3.55	.35	1.55	.59	1.05	3.12	.120	.90	7.05
September	.004	.001	.245	.004	.006	.690	1.64	3.84	.36	1.54	.49	1.12	2.33	.080	.83	7.01
Below Campground																
June	.010	.004	.256	.004	.006	.510	1.80	3.65	.58	1.56	.56	1.05	2.94	.052	.70	7.06
July	.007	.002	.267	.004	.005	.556	1.52	4.00	.40	1.53	.51	1.04	2.88	.068	.62	7.04
August	.005	.001	.272	.004	.005	.560	1.55	3.55	.35	1.56	.61	1.06	3.12	.160	.96	7.09
September	.007	.001	.262	.005	.006	.674	1.72	3.80	.35	1.51	.48	1.11	2.25	.080	.69	7.09

[1] Samples taken weekly

[2] Flow data were not available, therefore loadings could not be calculated

[3] Add TDP and Susp P to determine total phosphorus

10/11.3 Point:Non-point Distribution

Although this study dealt only with non-point sources in the forestry field some data were acquired on point sources from pulp and paper mills in the Great Lakes watershed (Table 11). The eight mills on Lake Superior discharge either directly into the lake or into a river a short distance from the lake; the four mills on Lake Huron are some distance from the lake; Lake Ontario has four mills near the lake and five somewhat removed. Some of these point source problems, with discharges of mercury, zinc, and taste- and odour-creating compounds, have already been detected by the Upper Lakes Reference Group study and the Ontario Ministry of the Environment (OMOE) is currently attempting to reduce the pollutants produced by these mills. For instance, it was recently announced (November 16, 1977) that seven of the eight Abitibi mills in the province will institute a 44 million dollar program over the next five years for air and water pollution abatement. Three of these mills are on Lake Superior and one each in the Lake Huron and Lake Ontario watersheds.

10/11.4 Significance of Land Uses and Practices

Table 12 is a rough estimate, and therefore must be used with caution, of the contribution of total phosphorus and suspended sediment from forestry operations in the Lake Superior and Lake Huron watersheds. It can readily be seen that the pulp mills are the major producers. The field operation estimates were compiled using data from the northwestern Ontario studies and therefore may be low because rainfall is heavier and the soils are less sandy in the Great Lakes Basin than in the study area. Even with these low estimates, however, it would require an extremely large increase in losses from the field operations to achieve the levels produced by the pulp mills. Also, it should be noted that at least 50 percent of the total production from areas disturbed by forestry operations can be attributed to natural erosion.

Estimates using the data from Table 8 indicate the total phosphorus load from forested watersheds to be in the order of 1300 metric tonnes for the Canadian side of Lake Superior and about 880 metric tonnes for Lake Huron.

Table 11. Minimum industrial waste loadings (kg/day) for pulp and paper mills in the Great Lakes Basin[1]

		P	N	TDS	SS	CL	SO_4	Si	Na	K	Mg	Ca	Fe	Phenol	Cu	Hg	Ni	Zn	BOD
Superior																			
(8 mills)	1973	216		980,100	40,977											.05			230,490
	1974	217	1211	596,878	39,981	120,647	83,956	2,942	97,685	2,348	10,902	30,542	814	234	29	.31	31	205	256,410
	1975	[2]		297,500*	50,011														225,707
Huron																			
(4 mills)	1973			286,794	31,545									6.8					84,870
	1974			14,000*	17,400*														8,530*
	1975	173		15,400*	35,922														83,421
Ontario																			
(9 mills)	1973	153		251,667	33,115													122	45,867
	1974			8,843*	1,227*														3,150*
	1975			4,687*	18,701*														41,645
	1976			6,028*	1,839*									158					2,536*

[1] Personal communication from Social Sciences Division, Inland Waters Directorate, Burlington, Ontario

[2] Blanks indicate either no release of that element or data not available

*Reductions over years reflect fewer mills reporting rather than an actual decrease

Table 12. Total annual loading estimates from forestry operations in the Lake Superior and Lake Huron watersheds

	Lake Superior		Lake Huron	
		Metric tonnes per year		Metric tonnes per year
Total Phosphorus				
Pulp mills	216 kg/day	79	173 kg/day	63
Cutting and scarification	(40,000 ha)		(25,000 ha)	
Beale ratio estimate	.045 kg/ha/yr	1.8		1.1
ELA estimate	.130 kg/ha/yr	5.2		3.2
All field operations	(60,000 ha)		(35,000 ha)	
Beale ratio estimate	.045 kg/ha/yr	2.7		1.6
ELA estimate	.130 kg/ha/yr	7.8		4.6
Suspended Sediment				
Pulp mills	45,000 kg/day	16,400	34,000 kg/day	12,410
Cutting and scarification	(40,000 ha)		(25,000 ha)	
Beale ratio estimate	1.38 kg/ha/yr	55		34
ELA estimate	2.81 kg/ha/yr	112		70
All field operations	(60,000 ha)		(35,000 ha)	
Beale ratio estimate	1.38 kg/ha/yr	83		48
ELA estimate	2.81 kg/ha/yr	169		98

10/11.5 Delivery Ratio

It must be stressed that the forestry study was conducted on small watersheds and the estimates in the previous section are the only figures available at present. Total loadings in rivers were not part of the study; therefore, it is impossible to carry the estimates any further.

10/11.6 Physical Characteristics of Land

The shield landscape is a display of hills, ridges, valleys and lakes having irregular configurations controlled by the bedrock structural features and covered to varying degrees in a random fashion by shallow glacial detritus.

In the Experimental Lakes Area a generally shallow cover of glacial till overlies the bedrock. Extensive rock exposures occur on many of the hill crests. On hill slopes the cover of till is commonly less than 60 centimetres deep. Typical glacial features such as drumlin, recessional or lateral moraines were not found. Glacio-fluvial deposits such as outwash plain, fans, and kame-kettle features are not extensive although they occur in some of the valleys, and are found locally on hill flanks and crests. There is little evidence of infilling or erosion of valleys subsequent to glaciation, and the pattern of the deposits is consistent with their being derived from the ablation of a static ice sheet.

Extrapolation of results is complex if not impossible except in a very general way because of the extremely complex nature of conditions throughout the shield area.

10/11.7 Soils

At the Experimental Lakes Area the soil parent material appears to be derived entirely from granitic rock. Its texture is predominantly sandy loam, but it contains highly variable components of gravel and cobbles. The most completely sorted outwash and deltaic deposits are fine sand in texture.

Representative samples indicate a bulk density of 1.10 to 1.43 g/cm^3 and a moisture holding capacity of 4 to 10 percent at 0.3 bar and 2 to 5 percent at 15 bar. Particle size analysis resulted in 3.94 percent very coarse sand, 5.69 percent coarse sand, 23.06 percent medium sand, 45.26 percent fine sand, 17.18 percent very fine sand, and 4.66 percent silt and clay.

Soil profiles are typically humo-ferric podzols on well-drained uplands and humic gleysols in the basin plains. However, small-scale spatial variations in the internal drainage conditions of the soils are caused by changes in both the depth of soil parent material over bedrock and the microtopography. As a result, soil profiles representative of a wide range of drainage conditions may be found within an area that is explored by the roots of one large tree.

Most of Superior and the northern half of the Huron watersheds are comprised of shallow soils derived from glacial till over Precambrian bedrock ranging from loamy to sandy in texture with some localized deep deposits of sand and minor local deposits of clay. The southern half of Huron, all of Erie, and most of the Ontario watersheds are deep loams and clays with some fairly extensive pockets of deep sands and gravels.

10/11.8 Transferability

Transferability of the data to the entire Great Lakes watershed can only be sketchy at best; however, this must suffice for the present. Probable reliability will be questioned but the data are not available to define closely forestry contributions to Great Lakes water quality. Inaccuracies will undoubtedly arise but it appears that forestry field operations are a very minor contribution to problems in the Great Lakes.

12. RECOMMENDATIONS

Many substances considered as water pollutants are natural products of the forest through geologic erosion, nutrient leakage, and organic material deposition. Research demonstrates that water yield will increase following harvesting and then decline with revegetation, therefore, channel erosion and nutrient outputs will probably increase as well. The key questions are the amount of material available and the situations in which they could reach water bodies. Therefore, we must explore the area between potential and fact.

The land system, type of disturbance and distance of the activity from a water body are very critical factors in this consideration. For example, scarification for regeneration in jack pine and black spruce types is becoming a relatively common practice, however, most of the disturbance is carried out on flat or gently rolling terrain where runoff is negligible, infiltration is maintained, and revegetation is rapid. Therefore, pollution is not likely to occur. The harvesting system is also important in that clearcutting has a greater potential for disturbance than either strip or partial cutting.

Road construction on logging operations is sometimes a major source of sediment; however, a well planned road network can minimize problems, reduce delays and increase efficiency. Timing is critical, especially near streams and at crossings, where road construction should occur at low flow periods, approaches be kept as flat as possible, and any sediment flow be prevented or trapped on land before it reaches the water. Grade lengths should be kept to a minimum with a maximum grade of 10 percent. The road erosion study at ELA indicated about 6 percent of the roads have problem areas but the erosion and deposition is restricted to the right-of-way.

Impacts during silvicultural operations can be minimized by following a sound management plan. Suggested procedures are: (1) minimize skidding routes, (2) limit skid trails to low gradients, (3) leave buffer strips along water bodies, (4) harvest fine textured soils when frozen or on snow, (5) do not harvest steep slopes of fine textured soil, (6) keep vegetative residue out of lakes, streams, drainageways and ditches, and (7) scarify lightly to reduce massive disruption and keep time for revegetation to a minimum.

The importance of planning in the initial selection, construction, and maintenance of intensive recreation areas cannot be overemphasized. One major consideration is to match user volume to the carrying capacity of the site.

When pesticides are used, their effects on water quality can be minimized or prevented completely by following the manufacturer's instructions for use and storage, avoiding direct application to water surfaces, and applying appropriate quantities.

Potential pollution areas are those in close proximity to water bodies and it is here that care should be taken. The key to control lies in good land management of all forestry operations that may create a disturbance in natural ecosystems. Knowledge of all the aspects of pollution potential from forestry is far from complete.

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