PESTICIDE POLLUTION
in the
SOUTH SYDENHAM RIVER WATERSHED

A Report Prepared for the
Land Resource Research Centre
Ottawa, Ontario.

DECEMBER, 1988

I.J. Shelton and G.J. Wall
Land Resource Research Centre,
Guelph, Ontario

ACKNOWLEDGEMENTS

A number of people provided information, editorial comments and suggestions and production assistance during the preparation of this document. They include P. Beck, A. Bos, H. Graham, G. Johnson and R. Lampman (Ontario Ministry of the Environment); G. Driver, R. Frank, P. Johnson, B. Ripley, W. Roberts and S. Singer (Ontario Ministry of Agriculture and Food); D. Craig and I. Westlaken (St. Clair Region Conservation Authority) D. Wilson and D. Irvine (cartography, University of Guelph); D. Coleman (Environment Canada) and C.J. Acton, S. Khan, J. Nowland, E.A. Pringle and R. Thompson (Agriculture Canada). The authors are greatly indebted to these people for their contributions.

TABLE OF CONTENTS

TABLE OF CONTENTS (CON'T)

LIST OF TABLES

LIST OF FIGURES

1.0 EXECUTIVE SUMMARY

There has been concern over the presence of pesticides in municipal and private well drinking water sources in the Dresden area. Agriculture Canada has initiated a preliminary study to evaluate the nature and extent of the pesticide problem in the South Sydenham River Watershed, identify any existing gaps in knowledge of pesticides in the area and recommend action that will aid in the development of effective remedial measures.

Agriculture is the predominant land use in the watershed, with most of the cropland used for field crop production. Cashcrops such as corn (in continuous and rotational systems) sweet corn, peas, tobacco and horticultural crops tend to be concentrated on the sand plain areas of the Bothwell and Strathroy regions, whereas soybean, wheat and forage production and poultry, dairy and livestock operations is predominant in areas with finer textured and heavier clay and loam soils.

In 1983, a total of 419,000 kg of pesticides were used in the Sydenham River basin (including both North and South branches). Of this amount, 97 % was used on field crops and the remainder on horticultural crops. The rate of application on horticultural crops (5.8 kg/ha) was double that of the field crop rate (2.3 kg/ha). Alachlor was the most used pesticide (107,000 kg; 26 % of the total, followed by atrazine (70,000 kg; 17 %). The OMAF pesticide survey of 1988 will show a marked difference as alachlor was banned in 1985. Presumably metolachlor, a pesticide with similar chemical properties and function to alachlor, will have increased in use from the 58,000 kg (14 %) in 1983. Pesticide use in the townships of the South Sydenham River region mirrors that of the entire Sydenham field crops account for greater than 90 % of the total cropland area.

Approximately 50 % of the South Sydenham River watershed was estimated to have a high potential for the soils to transfer pesticides to surface and ground water systems. The townships with the highest potential for water quality problems included Dawn and Warwick (Lambton County), Caradoc and Ekfrid (Middlesex) and Chatham (Kent). Relative to other townships in Southern Ontario, those in the South Sydenham River watershed were found to have a generally higher risk of pesticide contamination in water systems.

The Ontario Ministry of the Environment (MOE) has been testing for the presence of pesticides in the river and drinking water at the Alvinston and Dresden municipal waterworks since 1984. Both of these locations derive their drinking water from the Sydenham River. Atrazine has been detected every year over the 1984-88 period at both sites. Alachlor was detected in 1984 and 1985 and exceeded its Interim Maximum Acceptable Concentration (IMAC) levels once each year at Dresden (raw and treated water). Metolachlor was not detected until 1985 and has been detected annually since then at both locations (except in 1987 at Alvinston). Other pesticides which have been detected occasionally are cyanazine, dicamba, metribuzin, prometryne, simazine and 2,4-DB. Higher pesticide levels have been observed to coincide with farm activities (peak spray periods), rainfall events and increased water turbidity and nitrate and potassium levels.

The Ontario Ministry of Agriculture and Food (OMAF) pesticide surveys of the raw and treated water at the Dresden waterworks is indicative of the MOE results. Atrazine was detected throughout the year during the entire study period (1981-87), and exceeded the IMAC in 1984 and '87. The level of atrazine and/or D-ethyl atrazine appeared to increase slightly over the study period, and this trend concurs with results from pesticide studies conducted at the mouth of the Thames River, located to the south of the South Sydenham River watershed. Alachlor was detected in 1982, '84 (when the IMAC was exceeded) and '85 but not after this, whereas metolachlor appeared in both the raw and treated water samples from '85 to '87. Cyanazine was detected in both raw and treated water samples in 1982, '83 and '84 (when the IMAC was equalled), '86 and '87. Peak levels of all pesticides observed coincided with farm activities (spraying period from May-August).

Water samples from private wells in the South Sydenham River watershed were analyzed for pesticides in 1985-'86. In 1985, the most commonly detected pesticides were alachlor, atrazine and metolachlor, with the IMAC for these chemicals exceeded in 1% of the wells. Cyanazine, metribuzin, prometryne and simazine also were found. A few of the pesticide occurrences were related to pesticide accidents in the vicinity of the wells and to the general condition of the wells. In 1986, atrazine was detected in 53 % of the wells tested, D-ethyl atrazine in 40%, and alachlor and metolachlor in 1% each. Major ion chemistry analyses indicated that the Maximum Acceptable Concentration (MAC) for nitrate was exceeded and high levels of chloride and sodium found in some wells. A groundwater study utilizing piezometers was initiated in 1988, and preliminary results from the first season of data collection indicate that atrazine is the most predominantly found pesticide (detected at 6 out of 7 sites). Traces of cyanazine, simazine and D-ethyl simazine were found in two locations.

The Ontario Pesticide Education Programs (OPEP) have been conducted since 1986 through a cooperative program with MOE, OMAF and the pesticide industry. This program has been expanded under the Food Systems 2002 (FS 2002) program (OMAF), which also continues OMAF's Integrated Pest Management (IPM) program begun in 1969. In terms of education, FS 2002 focused on horticultural and field crop producers in 1987 and will continue to focus on these groups.

Enough regional monitoring has been done of surface and groundwater in the South Sydenham River watershed to indicate that a pesticide problem exists. However, prior to the implementation of satisfactory remedial actions and education programs, further information is required. For example, little is known about the on-farm translocation of pesticides through surface water systems, soils, tile drains, groundwater systems and the atmosphere. The proportion of pesticides that are moved through water systems through these pathways and through the air is unclear.

Questions regarding pesticide breakdown during translocation and the fate of metabolites have not been addressed to a great extent. Major ion concentrations can be used as a possible indicator of pesticide occurrence, depending on soil type, the depth to groundwater, pesticide type and other factors. Knowledge of this relationship could be expanded upon. While monitoring should continue to further document the problem, further research on other aspects of the pesticide problem could complement remedial strategies. Existing education programs should be coupled with mandatory regulations regarding pesticide use.

2.0 RECOMMENDATIONS

1. Surface water quality monitoring in the South Sydenham River watershed should continue to provide further documentation of the problem. The list of pesticides tested for should be updated to reflect chemicals currently on the market.

2. The groundwater monitoring program should continue and be expanded to include other soils in addition to sands in order to determine the extent of groundwater contamination. Both deep and shallow water aquifers should be tested. An in-depth review of existing groundwater studies (Canadian and American) should be undertaken and gaps in the current data identified.

3. Some research has been done to determine relationships between pesticides and soil and water chemistry. Investigation of these relationships should continue focusing on development of tools to predict pesticide contamination problems.

4. The breakdown of pesticides in soils has been documented. However, less is known about the persistence of pesticides and their metabolites in water systems. Pesticide metabolites need to be identified so that monitoring programs can incorporate the breakdown chemicals into the screening process. Analytical methods for the monitoring of metabolites may not be as well-developed as for pesticides. Further research on these topics could contribute to the knowledge of pesticide translocation.

5. The pathways by which agricultural pesticides reach water supplies requires further research. In order for farmers to reduce pollution, the percent of pesticides which are transported to water supplies by precipitation, overland flow, groundwater flow, spray, through tile drains (or a combination of these) must be known. Existing information on pesticide movement through various pathways (North American and global) should be compiled and gaps in the data identified. Research should be promoted with emphasis placed on field rather than laboratory studies.

6. Remedial measures to control pesticide movement into the atmospheric and water systems need to be examined. The interrelationships between these systems must be identified to ensure the development of remedial measures which will positively impact one system will not result in the deterioration of the quality of another system.

7. Studies of well water pesticide contamination often point to faulty pesticide management practices around the well site rather than aquifer contamination. Provincial programs on the education of the use and handling of pesticides exist (eg.

Integrated Pest Management, FS2002); but may not be fully utilized unless accompanied by legislation and mandatory regulation for grower certification. The feasibility of including such regulations into Provincial regulations should be examined.

8. There is a need for a continued evaluation by Health and Welfare of guidelines for pesticide residues in drinking water. The guidelines should be expanded to include information on pesticide metabolites. Metabolites should also be included in any guidelines that are issued for new pesticides on the market. "Action" or "awareness" levels that alert agencies and the public to unacceptable or high levels of pesticide concentrations would be beneficial. Generally, these values would be lower than the Interim Maximum Acceptable Concentrations (IMAC). These should be revised as information becomes available.

9. A task force comprised of researchers directly involved in the collection and analysis of pesticide information and environmental quality data should be established. The role of this task force would be to assimilate all available data. It could also be involved in integrating pest management programs with other existing programs such as phosphorus and fertilizer management to provide more comprehensive educational packages for farmers.

3.0 INTRODUCTION

Recent pesticide monitoring studies have determined that agricultural pesticides are entering the waterways of Southern Ontario. This fact has been of concern to residents of the Dresden area, since the town's municipal water supply comes from the southern branch of the Sydenham River - a waterway that flows through an intensively farmed region of Southwestern Ontario. Not only have pesticides been found in the river water at Dresden, but many of the private wells in the South Sydenham watershed also have tested positively for a number of agricultural chemicals.

In the latter part of 1988, Agriculture Canada, in response to the presence of pesticides from agricultural sources in the water supply in the Dresden area, proposed that a preliminary literature and data review should be done with the objective of determining a better understanding of the problem. The activities associated with the study would be to identify existing pesticide and water studies on the area, determine which studies were ongoing in nature, compile relevant water quality and pesticide use information, identify gaps in the knowledge or areas where additional information would complement and enhance existing data and produce recommendations for action that will aid in the development of effective remedial measures.

4.0 THE STUDY AREA

4.1 General Information

The South Sydenham Watershed is located in Southwestern Ontario (Fig. 1). The area includes portions of the townships within three counties: Kent (Camden, Chatham and Zone townships), Lambton (Dawn, Brooke, Euphemia and Warwick) and Middlesex (Adelaide, Caradoc, Ekfrid, Lobo, London, Metcalfe and Mosa). Major towns and villages within the watershed include Glencoe and Strathroy (Middlesex), Alvinston and Watford (Lambton), Bothwell and Dresden (Kent). The watershed spans an area that extends from north of Ilderton southwest to the town of Dresden. The Thames River Watershed is located directly south and east of the area while the North Sydenham and Saugeen River basins bound the region to the northwest and north. The watershed is greater than 100 km in length and 35 km in width at its widest point. It covers an area of approximately 130,000 ha.

4.2. Physiography & Soils

The South Sydenham River Watershed is comprised of a series of sand and clay plains bounded to the north and northeast by till moraines (Figure 2). The Seaforth moraine extends east from Watford to north of Strathroy, then northeast to Ilderton. The Lucan moraine forms the eastern boundary of the watershed and extends from Ilderton to Komoka. The headwaters of the watershed lie in an undrumlinized till plain, where the soils are mainly gray brown luvisols on ridged clay loam parent materials. Generally, the slopes range from between four and nine percent (Fig. 3; Acton and Harkes, 1988).

Major physiographic features of the watershed include the Bothwell and Caradoc Sand Plains and the Ekfrid Clay Plain. The Caradoc Sand Plain is located in the upper reaches of the watershed in the area surrounding and south east of Strathroy. The Bothwell sand plain, similar in nature to the Caradoc, is located in the lower section of the watershed. This plain encompasses most of Euphemia township and the watershed portions of Chatham, Camden and Zone townships. The gray brown luvisolic soils on both plains have developed on an undulating, lacustrine sandy parent material with slopes of one to three percent.

The Ekfrid Clay Plain forms a band between the two sand plains, extending southeast from Alvinston and south of Watford to Ekfrid township. The soils on this plain are predominantly gray brown luvisols and gleysols formed on clay parent materials. Slopes are level to undulating, generally not exceeding four percent. The bevelled till plain area that extends from Dresden to Alvinston has similar soils to the Ekfrid plain but the landscape is slightly more undulating.

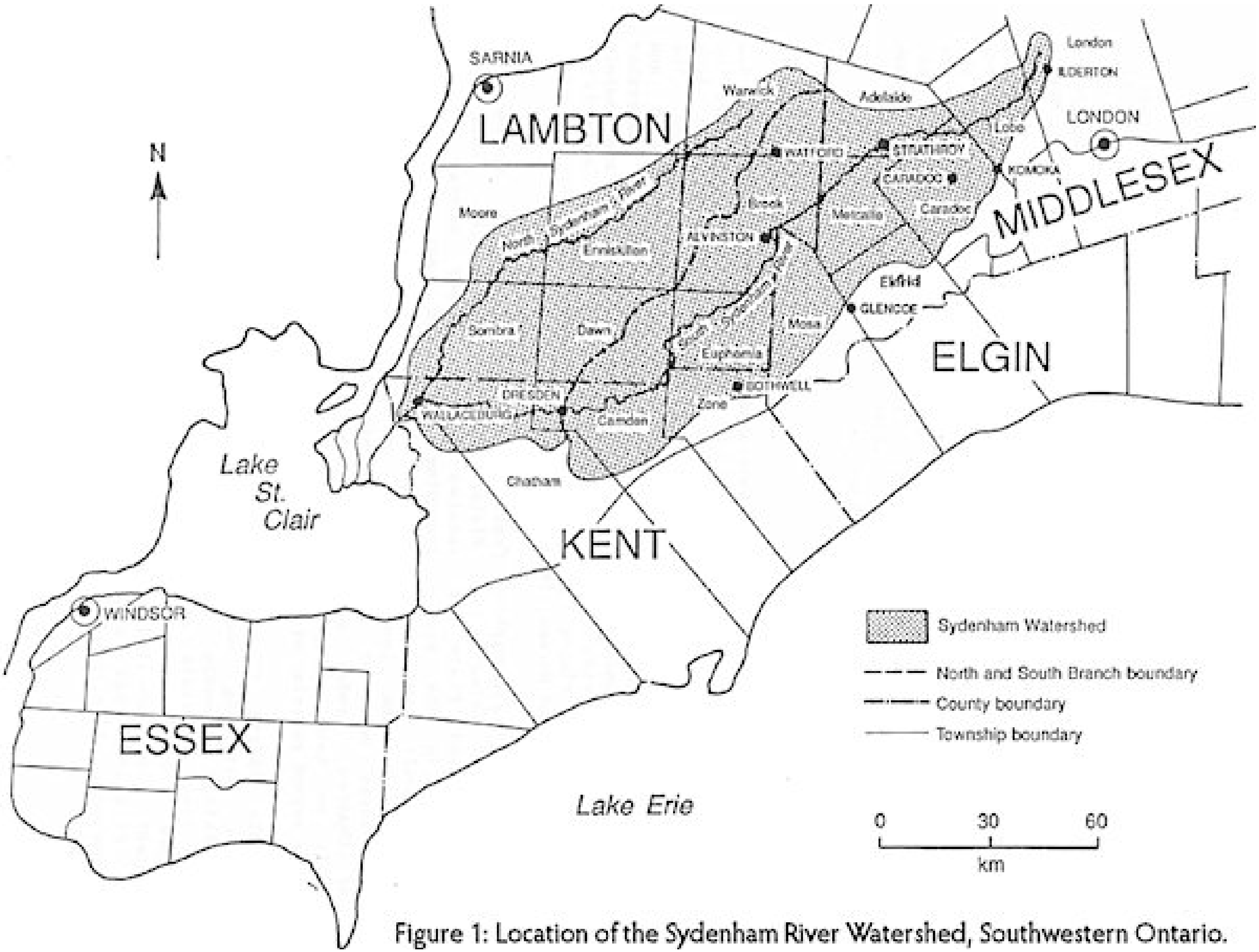
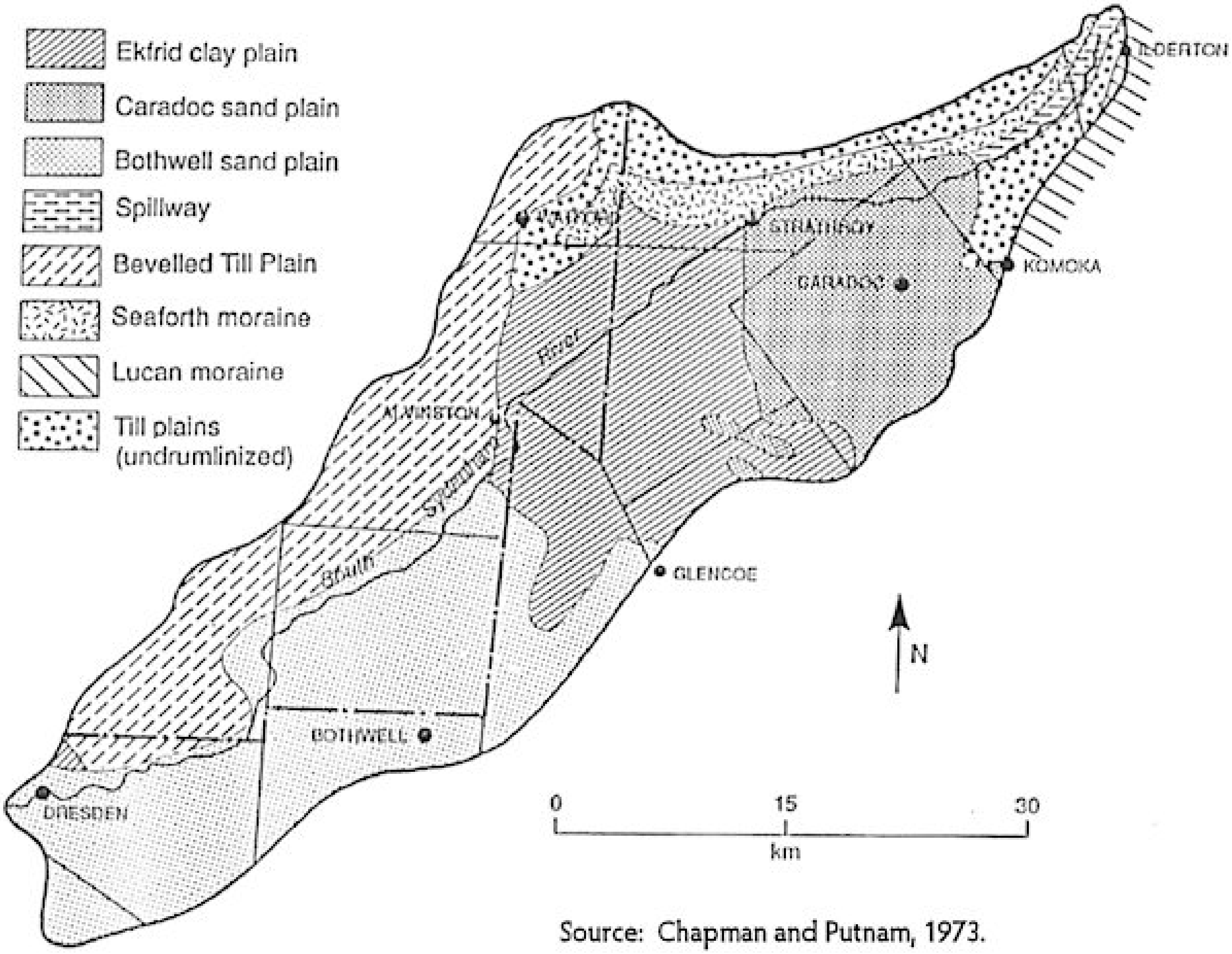


Figure 1: Location of the Sydenham River Watershed, Southwestern Ontario.



Source: Chapman and Putnam, 1973.

Figure 2: Physiography of the South Sydenham River Watershed

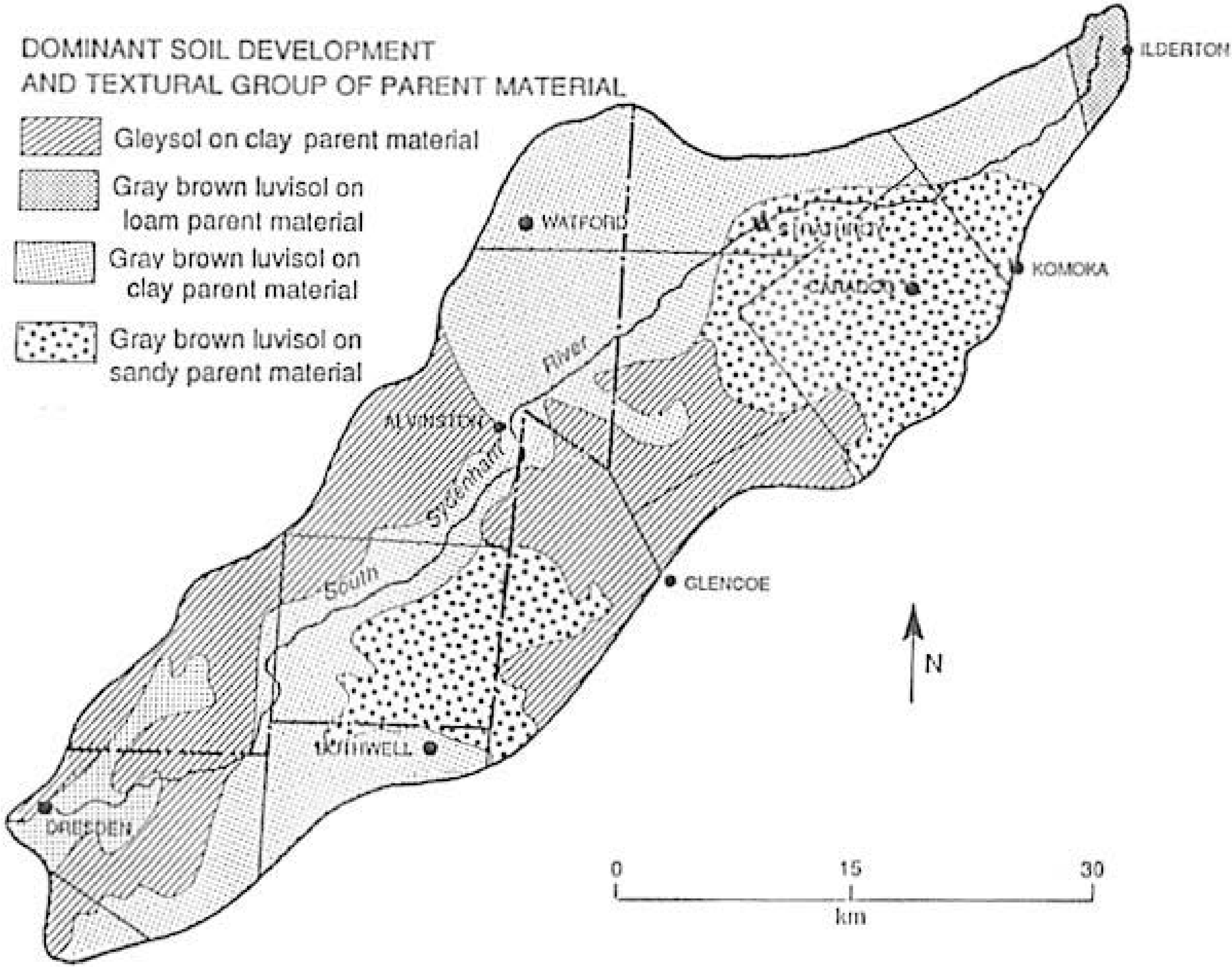


Figure 3: Soil Landscapes of the South Sydenham River Watershed

4.3. Land Use Activities

Farm-related activities account for a major portion of the South Sydenham River basin's land use. Agricultural land use information is presented in Table 1. In all counties, field crops occupy a predominant portion of the total land area: however; significant areas of horticultural land also exist. In Table 1, "Field cropland" includes crops such as field corn, field peas, small grains, soybeans, tobacco and hay crops. "Horticultural crops" refer to fruits and vegetables such as apples, green beans and tomatoes.

Table 1: TOWNSHIP LAND USE (FIELD and HORTICULTURAL CROPS)

County	Township (within the S. Sydenham Watershed)	Total Area (ha)	Area Field Crops (ha)	Area Horticultural Crops (ha)
KENT	Camden 60%*	17419	15719	320
	Chatham <5%	35697	31276	1953
	Zone 50%	11388	5649	100
LAMBTON	Dawn 50%	27964	17002	6
	Brooke 25%	30785	25414	39
	Euphemia	16511	10193	53
	Warwick 20%	29407	21407	63
MIDDLESEX	Adelaide 50%	17793	11546	19
	Caradoc 60%	25773	16019	792
	Ekfrid 25%	22545	13712	144
	Lobo 50%	19629	10929	128
	London <10%	35848	22409	717
	Metcalfe	15185	8806	380
	Mosa 60%	19923	11187	168

* The percentage beside the names of some townships indicates the approximate proportion of the total township's area that lies within the South Sydenham River watershed boundary.

Note that only portions of many townships actually are located within the boundaries of the entire Sydenham or South Sydenham River watersheds. As indicated by the data, cropland is a predominant land use within all of the townships. The data from Table 1 indicate that Kent has the greatest number of hectares of both field and horticultural crops, relative to the other counties. As might be expected, this county also uses the greatest amount of pesticides in each of these categories. In 1983 when the pesticide data was collected, Kent rated the highest with regards to its usage of both alachlor and metolachlor. The largest amount of atrazine, however, was used in Middlesex county.

Although many variations exist, farm types can be placed in at least one of six predominant farm activity groups, which are as follows (from personal communication, P. Johnson, OMAF, London):

1. Tobacco/rye crops
2. Continuous corn (cash crop)
3. Horticultural cash crops
4. Soybeans/Wheat
5. Dairy/hay/corn or other cash crops
6. Beef/hay/pasture/corn or other cash crops

There are some areas where one or more of these farming practices is more prevalent, generally, than the others. For example, cash crops,(field and horticultural) tend to be concentrated on the coarser-textured soils. Tobacco is grown in the western portion of the Caradoc Sand Plain while to the northwest, in the Strathroy area, sweet corn and peas are grown in addition to tobacco. Sweet corn production is also common in the Bothwell area. Much of the continuous corn cropping is confined to the more sandy areas, while soybeans and wheat are more favorable crops for areas with heavier soil (Lambton county). Beef operations with forage and pasture areas are found on the Ekfrid Clay plain. A variety of farming activities take place on lands with variable soil types, such as those around Alvinston and Glencoe. Farm activities on these soils tend towards livestock farming with some cash cropping. Note that, although certain farm activities may be predominant in certain areas, they are not confined to these regions and can be found throughout the watershed.

4.4 Pesticide Use

The Ontario Ministry of Agriculture and Food publication entitled "Survey of Pesticide Use in Ontario, 1983" (McGee, 1984) contains information on the quantities of active ingredients of the major pesticide groups, including herbicides (triazine, phenoxy and others), fungicides, insecticides and nematocides (Table 2). The information compiled in this report represents the pesticide use for entire counties, as specific information for the South Sydenham watershed was not available.

The major pesticide groups and amounts of each used on a county basis are presented in Table 3. Non-triazine or phenoxy pesticides (included in the "Other" group) are most prevalent, particularly in Kent County where they account for 50 percent (364,640 kg) of the total pesticide use.

Table 2: Chemical Families Of Selected Pesticides

Triazine Herbicides	Atrazine Cyanazine Metribuzin
Phenoxy Herbicide	2,4-D
Acetanilide Herbicide	Alachlor Metolachlor
Thiocarbamate Herbicide	Butylate
Nematocides	DCP (Dichloropropene /propane)

Note: These pesticides were reported as being the most commonly used chemicals in 1983.
Sources: Wall *et al.*, 1986; McGee, 1984.

Table 3: Use Of The Major Pesticide Groups In Kent, Lambton And Middlesex Counties

PESTICIDE GROUP	Amount (Kg) Of Pesticides Used In Each County		
	KENT	LAMBTON	MIDDLESEX
HERBICIDES - Triazine	205,780	193,220	243,650
- Phenoxy	14,380	23,030	20,270
- Other	364,640	267,570	256,610
INSECTICIDES	29,980	15,080	44,260
FUNGICIDES	27,830	6,120	2,360
NEMATOCIDES	14,490	1,880	97,030
TOTAL	657,100	506,900	664,180

Source: McGee, 1984.

The data in Table 4 is compiled from information in the report by Wall *et al.* (1984) on the Upper Great Lakes Connecting Channels. It represents general, county level information. Note that the data reported refer to the entire basin (north and south branches combined). The data indicate that Kent has the greatest number of hectares of both field and horticultural crops, relative to the other counties. As might be expected, this county also uses the greatest amount of pesticides in each of these categories. In 1983 when the pesticide data was collected, Kent rated the highest with regards to its usage of both alachlor and metolachlor. The largest amount of atrazine, however, was used in Middlesex county.

In the Sydenham watershed, a total of 419,000 kg of pesticides were used on agricultural land of which 97 percent (408,000 kg) and 3 percent (11,000 kg) were used on field and horticultural crops, respectively. Of the total amount, the eight most commonly used pesticides in 1983 (Table 2) accounted for 355,000 kg, or 85 percent.

Of the eight pesticides used, alachlor accounted for the largest proportion (107,000 kg), with atrazine applications amounting to 70,000 kg. These figures will have altered considerably since the banning of alachlor in 1985. However, many farmers will probably have substituted alachlor with metolachlor as a field crop herbicide.

Table 4: Selected Land Use And Pesticide Information For Kent, Lambton And Middlesex Counties And For The Sydenham River Basin.

DATA	Kent	Lambton	Middlesex	Sydenham
Total Area (ha)	204,800	132,950	140,500	182,300
Field Cropland (ha)	195,300	132,600	135,300	180,400
Horticultural Cropland (ha)	9,500	350	5200	1900
Pesticides Used on All crops (kg)	657,000	354,000	474,000	419,000
Application Rate All Crops (kg/ha)	3.2	2.7	3.4	2.3
Pesticides Field Crops (kg)	599,000	348,000	447,000	408,000
Application Rate Field (kg/ha)	3.1	2.6	3.3	2.3
Pesticides - Hort. Crops (kg)	58,000	6,000	27,000	11,000
Application Rate Hort.(kg/ha)	6.1	17.1	5.2	5.8
Pesticides - 8 Most Common (kg)	525,000	300,000	391,000	355,000
Application Rate Most Common (kg/ha)	2.6	2.3	2.8	1.9
Pest.-8 Most Common Field (kg)	521,000	300,000	385,000	354,000
Application Rate -8 Pest.-Field (kg/ha)	1.7	2.3	2.8	2.0
Pest.-8 Most Common Hort.(kg)	4,000	300	5,600	1,000
Application Rate -8 Pest.-Hort.(kg/ha)	0.4	0.9	1.1	0.5
Atrazine Used (kg)	115,000	60,000	138,000	70,000
Application Rate Atrazine (kg/ha)	0.6	0.5	1.0	0.4
Alachlor Use (kg)	164,000	92,000	57,000	107,000
Application Rate Alachlor (kg/ha)	0.8	0.7	0.4	0.6
Metolachlor Use (kg)	110,000	59,000	95,000	58,000
Application Rate Metolachlor (kg/ha)	0.6	0.4	0.7	0.3

Source: Wall *et al.*,1986.

Estimated pesticide use within townships of the South Sydenham watershed is presented in Table 5 and displayed graphically in Fig. 4.Note that not all of the township areas are contained within the watershed boundary. Therefore the actual pesticide use in the watershed would not be as high in some townships as indicated in Table 5.

These data are indicative of the trend shown in the county data as most of the pesticides used in any township are for field crops.

Table 5: Estimated Pesticide Use And Application Rates In Townships Of The South Sydenham River Watershed

County	Township	Estimated Pesticide Use in kg		
		Total Cropland	Field	Horticultural
KENT	Camden	47,471	45,585	1,886
	Chatham	102,226	90,700	11,525
	Zone	16,971	16,382	589
LAMBTON	Dawn	47,665	47,606	59
	Brooke	71,568	71,159	409
	Euphemia	29,095	28,540	554
	Warwick	60,849	60,192	657
MIDDLESEX	Adelaide	37,787	37,706	82
	Caradoc	56,188	52,863	3,325
	Ekfrid	45,852	45,250	603
	Lobo	36,604	36,066	538
	London	76,961	73,950	3,011
	Metcalfe	30,658	29,060	1,598
	Mosa	37,624	36,917	707

Source: Shelton *et al.*, 1988.

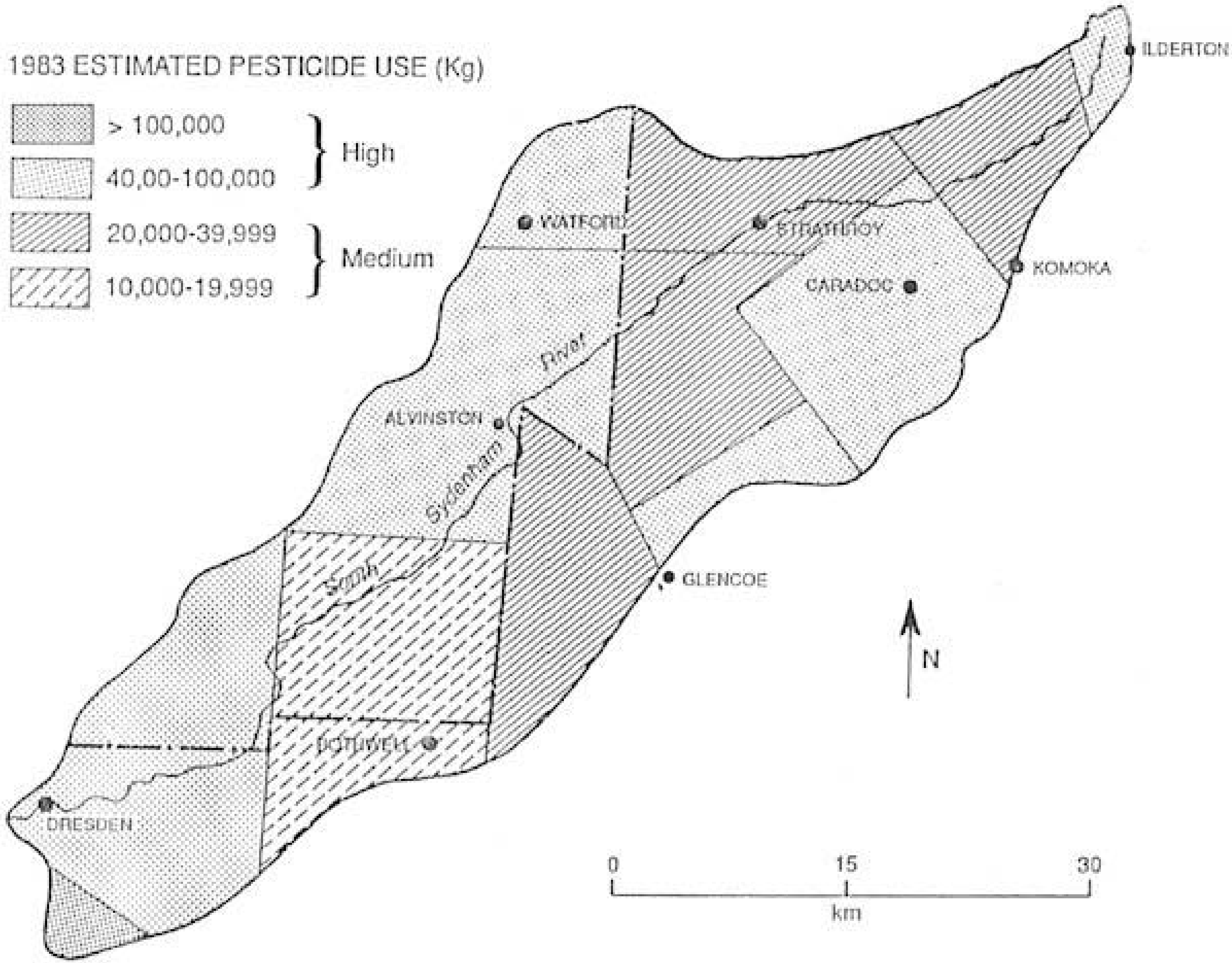


Figure 4: Estimated Pesticide Use in Townships of the South Sydenham River Watershed.

4.5 Potential For Soils To Transfer Pesticides To Water Systems

Various properties and attributes of soils can affect their ability to inhibit or enhance the transfer of pollutants to surface and ground water systems (Shelton *et al.*, 1988). Coote and MacDonald (1974) assessed the soil potential for pollutant transfer to water systems for an extensive portion of Southern Ontario including Kent, Lambton and Middlesex Counties. Generalized versions of the Coote and MacDonald map are included in Appendix A.

Groupings of soil series were assessed as having a "high", "medium" or "low" potential to transfer pollutants to water systems. Ranking was based on soil texture, drainage, perviousness and slope (Coote *et al.*,1982). Separate ranks were given for surface and ground water systems. Depending on the particular combination of the two water system ranks, a soil group was placed in one of five pollutant transfer potential classes (Table A, Appendix).

In a recent study, Shelton *et al.* (1988) attempted to amalgamate some of the existing pollutant transfer information with pesticide use data. Areas of intensive agricultural use and high pesticide application rates were identified where transport of pesticides to water systems could result. The intensity of pesticide use in each township in Southern Ontario was ranked (high, medium, low), based on the total estimated pesticide use on cropland, relative to use in other townships (Fig. 4). The soil potential to transfer pollutants to both surface and ground water systems was determined for each township (Figures A and S, Appendix A).

Shelton *et al.* (1984) defined six Potential Problem Classes to relate pesticide use to pollutant transfer potential. This classification scheme was utilized to approximate which of the townships in Southern Ontario might be most likely to develop pesticide pollution problems in surface and/or ground water systems. These findings are summarized in Table 6. Figures 5 and 6 illustrate how the townships of the South Sydenham rate, relative to other townships in Southern Ontario.

Table 6: Soil Potential To Transfer Pesticides To Surface And Ground Water Systems

County	Township	Water System	
		Surface	Ground
KENT	Camden	Medium	Medium
	Chatham	High	High
	Zone	Low	Low
LAMBTON	Dawn	High	High
	Brooke	High	Medium
	Euphemia	Medium	High
	Warwick	High	High
MIDDLESEX	Adelaide	High	Low
	Caradoc	High	High
	Ekfrid	High	High
	Lobo	High	Low
	London	High	High
	Metcalfe	Low	Low
	Mosa	Low	Medium

Source: Shelton *et al.*, 1988.

Approximately 50 % of the area in the watershed was estimated to have a high potential for pesticide pollution problems in both surface and groundwater systems. With respect to surface water, approximately 10 % of the area had a medium rating and 40 % has a low rating. 20% of the watershed was given a medium rating in terms of groundwater pesticide pollution and 30 % a low rating.

Townships with "High" potential for pesticide pollution problems in both surface and groundwater systems are Dawn and Warwick (Lambton), Caradoc and Ekfrid (Middlesex) and Chatham (Kent). All of these townships were reported to have relatively high pesticide use compared to other areas of Southern Ontario (McGee, 1984). Soils in Dawn and Warwick Zone tended to be fine and medium textures (clay to silt loam), while those in Caradoc were coarser (gravelly loams to sands) and those in Ekfrid were generally finer (clays to sands over clays). The townships of Zone (Kent) and Metcalfe (Middlesex) have a relatively low pollutant potential ratings for both surface and groundwater pollutant potential (Class 5). Although the potential ranges from low to high in townships of the South Sydenham area, there is generally a higher concentration of higher pesticide pollutant potential areas in the watershed relative to other areas of Southern Ontario.

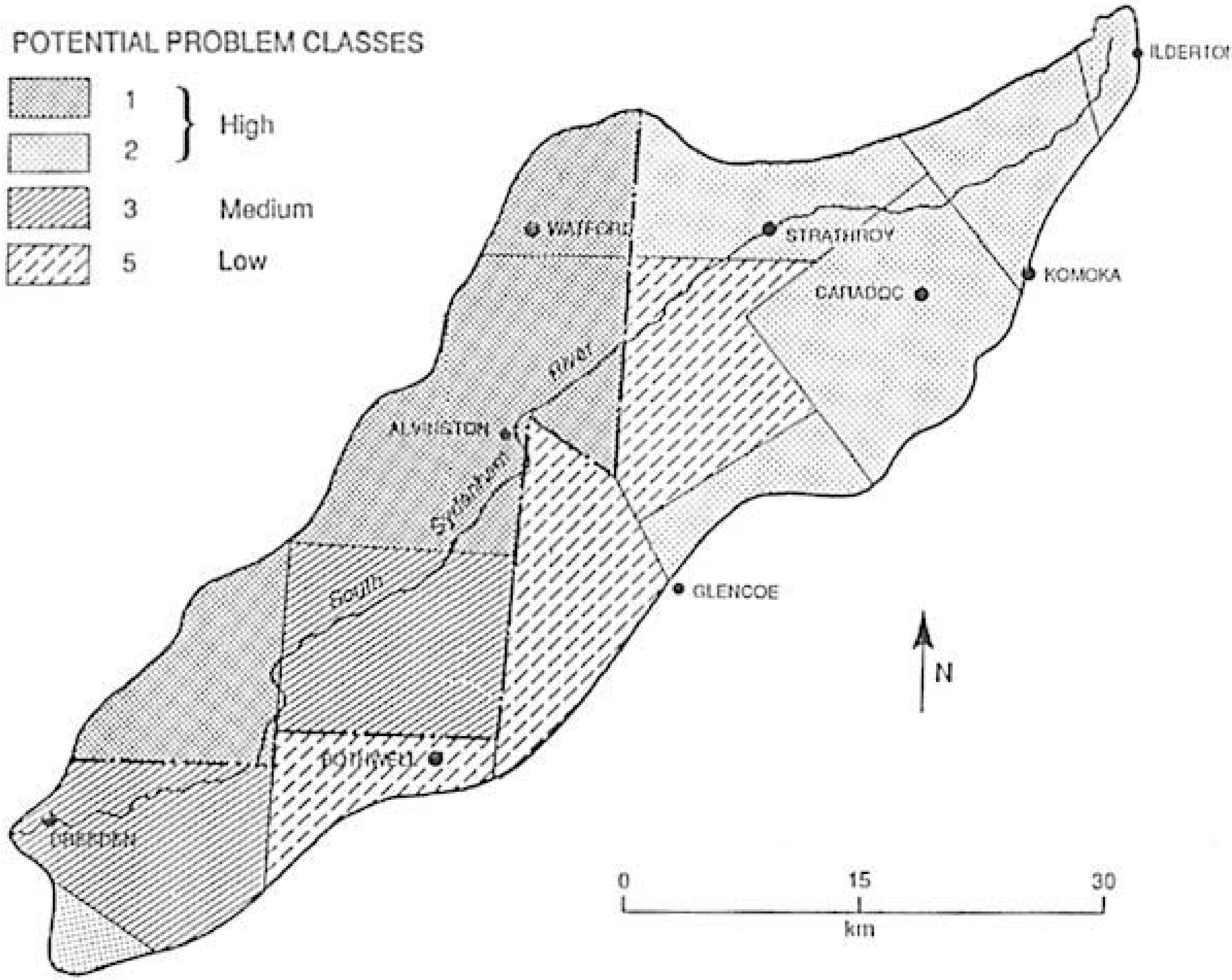


Figure 5: Potential Problem Areas for Pesticide Transfer to Surface water System.

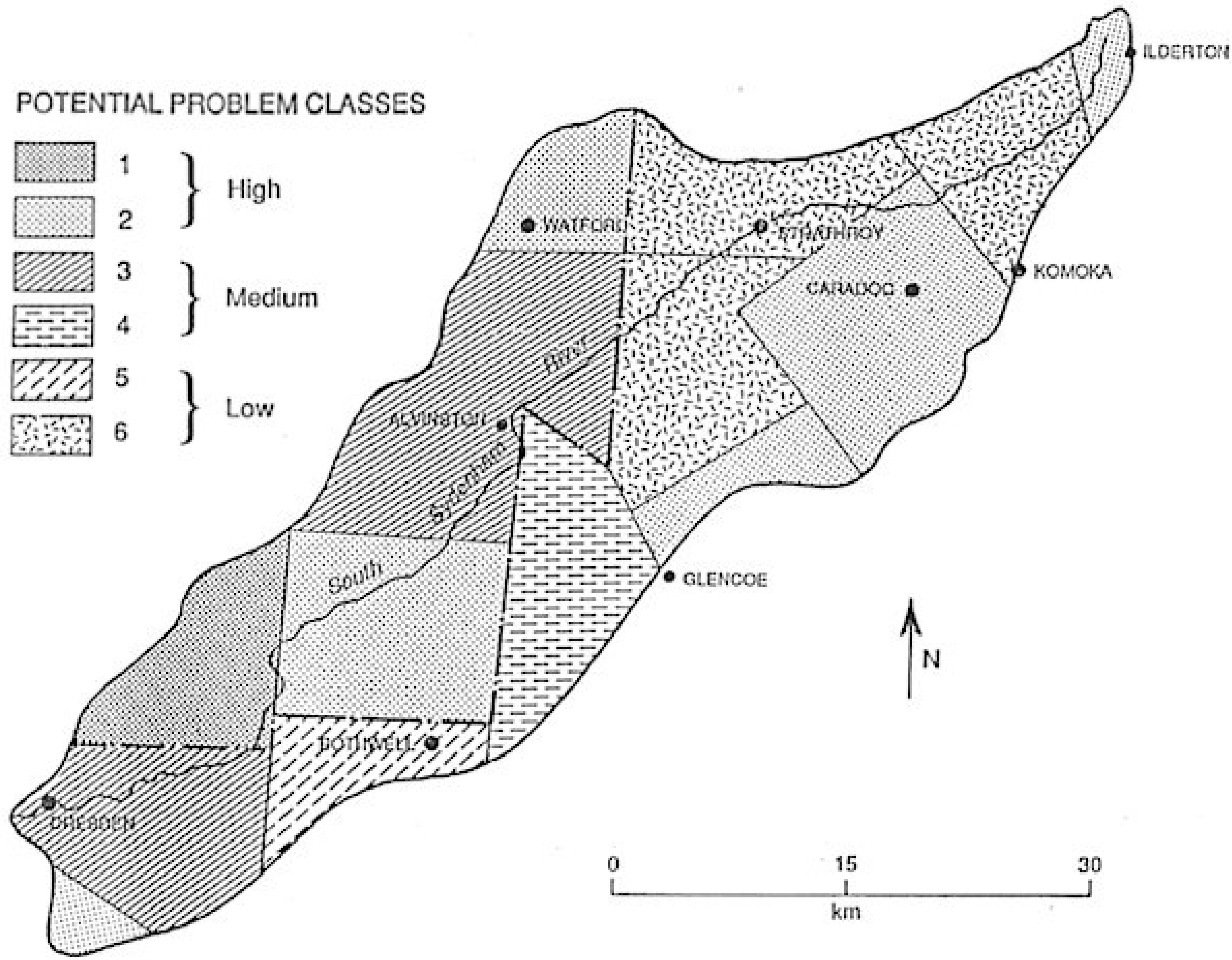


Figure 6: Potential Problem Areas for Pesticide Transfer to Groundwater Systems

5.0 PESTICIDE MONITORING PROGRAMS

Most of the monitoring programs and studies which focus on the South Sydenham River have been conducted by one of two agencies - MOE and OMAF. A summary of the major programs regarding surface and groundwater of the watershed follows.

5.1 Evaluations For Pesticide Residues In Surface Water

5.1.1 Ontario Ministry of the Environment

5.1.1.1 Published Data

i) Alachlor Monitoring of Ontario Drinking Water, 1985.

Concern over the fate of alachlor (trade name Lasso) in the environment and its known potential carcinogenic effects on animals in laboratory studies prompted the initiation of several programs in 1984. In a cooperative effort, Agriculture Canada and MOE took samples from several municipal waterworks and private wells, some of which were included in the Lower Sydenham watershed. Alachlor was detected in the water at both the Alvinston and Dresden waterworks. Alachlor was given temporary registration for the 1985 growing season.

In 1985 a program was initiated by the Ontario Ministry of the Environment in which municipal waterworks and private wells mainly in Southern Ontario were tested for the presence of alachlor and other pesticides. Of the total 15 waterworks included in the study, two - at Alvinston and Dresden - are located on the South Sydenham River. These municipalities use the river as their source of drinking water. Water samples at the treatment plants (both raw water and treated drinking water) were collected at these sites. Tests also were conducted in private wells in the area, to determine the presence and magnitude of pesticide residues in private drinking water sources. Some of the private wells tested are located in or in the vicinity of the South Sydenham watershed.

Results of this study were compiled in the December 1985 report "Alachlor Monitoring of Ontario Drinking Water, May-November 1985" (MOE,1985). Data from this report has been included and will be discussed in later sections.

ii) Pesticides in Ontario Drinking Water, 1985 and 1986

Water samples taken at the time of the alachlor study also were analyses for the presence of a range of pesticides. The tests were able to detect nine pesticides - alachlor, atrazine (plus D-ethyl atrazine), cyanazine, dicamba, metolachlor, metribuzin, prometryne, simazine (plus D-ethyl simazine) and 2,4-D. Results of the 1985 surface water analyses are reported in the 1987 Ministry of the Environment publication "Pesticides in Ontario Drinking Water - 1985" (MOE,1987a).

The surface water sampling program was continued in 1986. A range of pesticides were scanned for in the water samples from Alvinston and Dresden. Results of this study are reported in "Pesticides in Ontario Drinking Water - 1986" (MOE,1987b).

5.1.1.2 Unpublished Data

i) Pesticide Monitoring of Surface Water

Pesticide monitoring of raw river water and treated drinking water continued in 1987 and 1988 at both municipal waterworks. The data have not been released yet for widespread distribution; however, preliminary information on the tests is available and has been included in this report in the following section.

5.1.1.3 Results

i) Municipal Waterworks - Raw and Treated Water

Health and Welfare Canada established Interim Maximum Acceptable Concentration (IMAC) and Maximum Acceptable Concentration (MAC) limits for pesticide residues in water in 1985. Values for herbicides reported on in this summary are indicated in Table B of Appendix A.

In the 1985 study, two paired water samples (one raw and one treated water sample) were taken at intervals from each waterworks. Besides being filtered and chlorinated during the treatment process, powdered activated charcoal (PAC) was added to the raw river water at rates between 30 and 50 mg/L during the months of heaviest herbicide use (May to June) and after heavy rains (July - September). At other times, a rate of 5 mg/L was used. From 1986 onwards a rate of 5 mg/L was applied during normal flow conditions and 20 mg/L after rainfalls (Frank *et al.*, 1988). Summaries of selected data available for various pesticide concentrations observed at Alvinston and Dresden are included in Table 7.

The last three years of monitoring efforts have included a pesticide scan for a range of pesticides with the focus being placed on triazines, alachlor and metolachlor. The triazine pesticide group tends to be widespread in use (ie. corn and soybean crops), is moderately mobile and relatively persistent in the environment (MOE, 1987b).

Table 7: Pesticides In The Raw And Treated Dater At Municipal Waterworks

ALVINSTON

Year	Alachlor		Atrazine		Metolachlor		Metribuzin		Simazine		Prometryne		Cyanazine		2,4-DB		DICAMBA	
	Raw	Treated	Raw	Treated	Raw	Treated	Raw	Treated	Raw	Treated	Raw	Treated	Raw	Treated	Raw	Treated	Raw	Treated
1985																		
No. Samples	57	44	2	2	-	-	2	2	2	2	2	2	2	2	2	2	2	
No. Positive	3	0	0	0	-	-	0	0	0	0	0	0	0	0	0	0	0	
Range (µg/L)	Tr	0	0	0	-	-	0	0	0	0	0	0	0	0	0	0	0	
1986																		
No. Samples	13	7	13	7	13	7	13	7	13	7	13	7	13	7	-	-	-	
No. Positive	0	0	11	6	4	3	1	0	0	0	0	0	5	2	-	-	-	
Range (µg/L)	0	0	0.6	0.35<T	0.51<T	0.56<T	0.1	0	0	0	0	0	0.29<T	0.26<T	-	-	-	
			23	37	10.4	15.5							4.25	5.5				
1987	0	0	D	D	0	0	0	0	0	0	0	0	0	0	0	0	0	
1988	0	0	D	D	D	<T	0	0	0	0	0	0	<T	<T	0	0	0	

DRESDEN

YEAR	Alachlor		Atrazine		Metolachlor		Metribuzin		Simazine		Prometryne		Cyanazine		2,4-D		Dicamba	
	Raw	Treated	Raw	Treated	Raw	Treated	Raw	Treated	Raw	Treated	Raw	Treated	Raw	Treated	Raw	Treated	Raw	Treated
1985																		
No. Samples	84	65	23	20	-	-	23	20	23	20	23	20	23	20	20	17	20	
No. Positive	11	0	10	3	-	-	1	0	1	0	0	0	0	0	1	0	0	
Range (µg/L)	Tr-9	0	0.1-2.	0.3<T	-	-	2.1	0	0.3<T	0	0	0	0	0	0.9<T	0	0	
				0.5<T														
1986																		
No. Samples	26	6	26	6	26	6	26	6	26	6	26	6	26	6	-	-	-	
No. Positive	0	0	26	6	8	2	0	0	0	0	0	0	3	2	-	-	-	
Range (µg/L)	0	0	0.09<T	0.19<T	0.55	1.3<T	0	0	0	0	0	0	0.11<T	0.235<T	-	-	-	
			29.4	30.2	4.86<T	1.64<T							2.87	3.28				
1987	0	0	D	D	D	D	0	0	0	0	0	0	0	0	0	0	0	
1988	0	0	D	D	<T	<T	0	0	0	0	0	0	<T	<T	0	0	0	

Sources: 1985-86 Data - MOE 1987a,b
1987-88 Data - MOE unpublished data

Note: "D" indicates that pesticide was detected
"<T" indicates that pesticide detected in -mounts greater than the detection limit but not confident
“0" indicates that residues were below the detection limit

1984 - Of the 16 paired water samples taken at Dresden (June to December), alachlor was present in the untreated water six times (0.2 to 16 µg/L) and three times in the treated (0.3 to 7.0 µg/L). The IMAC was exceeded once in both raw and treated water samples.

1985 - At Dresden, 84 raw water samples were collected. Of these, 6 had alachlor concentrations of greater that 1.0 µg/L, with the IMAC exceeded once, on June 1, 1985 (9µg/L). Trace concentrations (0.5 to less than 1.0 µg/L) were found on 7 occasions at Dresden and 3 at Alvinston. All 13 positive results (Dresden) were detected after rainfall (Table E, Appendix A) and these higher values were found to coincide with increased turbidity, total nitrates and potassium values. Table E (Appendix A), compiled by MOE, gives an indication of the fluctuations in pesticide, nitrate and potassium concentrations, turbidity and rainfall during a portion of the alachlor program's study period.

Atrazine was detected in 39 of 54 raw water samples, with concentrations exceeding 1 u/L (maximum 6.4 µg/L) in 22 samples. Cyanazine was detected on one occasion (0.3 µg/L). One incidence of 2,4-DB was reported out of 20 samples (0.9<T µg/L). Neither dicamba or metolachlor were detected. Out of 23 samples, one contained metribuzin (2.4 µg/L) and another contained a trace of simazine (0.3 µg/L).

Of 98 treated water samples taken at Dresden, 21 tested positively for atrazine (max. 4.3 µg/L). Concentrations were reduced (max. 1.4 µg/L) in all but one case with the addition of PAC.

1986 - No alachlor was detected in either raw or treated water samples at Dresden and Alvinston in 1986, '87 or '88. The absence of detectable levels of the herbicide in these samples can be attributed to the fact that alachlor was not available on the market from 1986 onwards (MOE, 1987b). Atrazine was detected (Dresden) in all 26 raw water and 6 treated water samples. The peak values (29.4 µg/L - raw; 30.2 µg/L - treated) occurred in June. 5 out of 13 raw samples (max.4.25 µg/L) and 2 out of 7 treated samples (max. 5.5 µg/L) contained cyanazine. 4.86 and 1.64 µg/L were the maximum amounts of metolachlor found in raw and treated water, respectively. At Alvinston, 11 of the 13 samples contained atrazine residues, with a peak value of 23 µg/L in June. Treated water tested positively in 6 out of 7 samples (max. 37 µg/L). Metolachlor was detected with maximum concentrations of 10.4 µg/L (raw water) and 15.5 µg/L (treated).

1987- Preliminary data indicates that atrazine and metolachlor were present in the raw and treated waters at both waterworks. A trace of dicamba was detected in the treated water at Dresden.

1988 - Preliminary data indicates that atrazine and metolachlor was present in the raw and treated waters at both waterworks.

5.1.2 Ontario Ministry of Agriculture and Food

5.1.2.1 Published Reports

i) Sydenham River Water and Municipal Drinking Water - Dresden

The Agricultural Laboratory Services Branch, OMAF, conducted a survey parallel to the MOE pesticide survey on the raw and treated water from Dresden for the period of 1981 to 1987 (inclusive). Water was sampled on a one to two weekly basis throughout the year. Analyses focused on five major pesticides-the s-triazine herbicides atrazine, cyanazine and metribuzin and the acetanilide herbicides alachlor and metolachlor. Results were submitted in 1988 to the Archives of Environmental Contamination and Toxicology in a paper entitled "Sydenham River Water and Municipal Drinking Water - Dresden, Ontario, 1981-87". Excerpts from this data set have been included in this report.

5.1.2.2 Results

The data in Table 8 refer to analyses done on raw and treated water samples collected from the Dresden waterworks. Results of the study are summarized below. The Interim Maximum Acceptable Concentration (IMAC) levels were not developed by Health and Welfare Canada until 1985 and 1986.

1981 - Atrazine was detected in 98% of both raw and treated water samples (max. 5.6/5.1 µg/L - raw/treated samples).

1982 - Alachlor, atrazine and cyanazine were detected 2, 91 and 20 %, respectively, of both raw and treated water samples. metribuzin was found in 7 % of raw water and 2 % of treated water samples.

1983 - Atrazine was identified in 100 % of both paired samples. 29 % of raw and 24 % of treated samples showed the presence of cyanazine, while only 2 % of raw water samples indicated metribuzin concentrations.

1984 - Alachlor, atrazine, cyanazine, metolachlor and metribuzin were found in both raw and treated water samples. The IMAC was exceeded for alachlor (16 µg/L - raw water/ 7 µg/L treated), atrazine (61 µg/L - raw water) and equalled for cyanazine (10 µg/L - both raw and treated water samples). Atrazine was detected during the entire year and alachlor, cyanazine and metolachlor were detected from may until December.

1985 - Atrazine, cyanazine and metolachlor were observed in both raw and treated water. Alachlor and metribuzin were found in raw water samples. The IMAC was not exceeded for any pesticide.

1986 - Atrazine was observed throughout the year (90 % raw/77 % treated samples).

Table 8: Frequency of s-triazine and chloroacetamide herbicides in raw river water and municipal drinking water between 1981-87.

Herbicide[1,2]	Year	Period	Paired samples	Water with residues (µg/L) Raw Number	Raw Mean + SD	Raw Highest	Drinking Number	Drinking Mean + SD	Drinking Highest
alachlor	1982	June	4	2	0.9 ± 1.0	1.6	2	0.9 ± 1.0	1.6
(5 µg/L)	1984	May -Sept.	21	7	3.4 ± 5.6	16.0	5	2.2 ± 2.7	7.0
	1985	June	4	3	1.4 ± 1.4	3.0	0	<0.05	-
atrazine +	1981	All year	50	49	1.3 ± 1.3	5.6	49	1.3 ± 1.2	5.2
de-ethyl	1982	All year	45	41	1.8 ± 1.6	6.9	41	1.8 ± 1.8	8.0
atrazine	1983	All year	50	50	2.4 ± 3.1	18.1	50	2.4 ± 2.9	16.3
(60 µg/L)	1984	All year	41	39	5.1 ± 10.4	61.0	39	3.9 ± 5.1	23.0
(IMAC)	1985	All year	32	29	1.7 ± 2.2	6.3	20	1.1 ± 1.1	4.3
	1986	All year	30	27	2.4 ± 2.2	22.0	23	1.7 ±1.6	5.7
	1987	All year	37	33	3.5 ± 11.0	62.3	33	8.3± 36.5	210.0
cyanazine	1982	June - Sept.	16	9	0.9 ± 0.9	3.0	9	1.0 ±1.1	3.6
(10 µg/L)	1983	May - Aug,	26	13	0.8 ± 1.0	3.5	12	0.8 ± 0.9	3.1
(IMAC)		Oct, Dec							
	1984	May - Sept	21	12	1.9 ± 2.8	10.0	11	1.9 ± 2.8	10.0
	1985	July	5	1	0.3	0.3	0	<0.05	-
	1986	June	4	2	3.6 ± 4.5	6.8	2	4.6 ± 6.0	8.8
	1987	June - July	7	4	1.7 ± 1.5	3.3	5	1.3 ± 1.5	3.1
metolachlor	1984	May -Sept	21	9	5.7 ± 8.8	28.0	8	3.5 ± 3.6	10.0
(50 µg/L)	1985	June-July, Dec	10	6	2.0 ± 1.8	5.1	0	<0.05	-
(IMAC)	1986	May - Aug	15	8	4.2 ± 4.5	15.0	6	2.3 ±1.5	4.5
	1987	May -Aug	12	7	4.4 ± 6.2	14.0	6	6.0 ± 7.8	16.0
metribuzin	1982	June	4	3	1.2 ± 1.4	2.8	1	0.1	0.1
(80 µg/L)	1983	August	5	1	1.5	1.5	0	<0.05	-
(MAC)	1984	May - July	13	3	7.7 ± 9.0	18.0	2	3.7 ±1.9	5.0
	1985	July	5	1	0.8	0.8	0	<0.05	-
	1986	July	4	1	1.7	1.7	0	<0.05	-

[1] No alachlor detected in 1986 and 1981, no metribuzin detected in 1987.

[2] IMAC - Interim Maximum Acceptable Concentrations, MAC - Maximum Acceptable Concentrations (National Health and Welfare, 1987)   Source: Frank *et al.*, 1986.

Metolachlor was the next most frequently observed herbicide (27/20 % of raw/treated samples), followed by cyanazine (7/7 %) and metribuzin (3/0 %).

1987 - Atrazine was observed in raw and treated samples (89 % of each) throughout the year, and exceeded its IMAC on June 30 (62 raw/210 treated µg/L). Cyanazine and metolachlor were detected in the paired samples.

Most of the pesticide residues were detected during the May to August period, which coincides with the major spray period in May and June. Frank *et al.* (1988) report that the addition of powdered activated carbon (PAC) in 1984 had no observable effect on drinking water quality. Increased dosages of PAC in 1985 effectively removed alachlor, cyanazine, metolachlor and metribuzin but only slightly reduced the mean residues of atrazine, although it did deduce the number of times that the herbicide was detected in treated water (43% of samples in 1984 compared to 15% in 1985).

Atrazine residues were observed to be highest in 1984 and 1987. External conditions in the watershed appear affect atrazine concentration levels in the water. These conditions include: normal events such as rainfall and turbidity; agricultural activities such as land use and the timing and type of tillage operations; and other variables such as runoff and erosion from degraded soils.

5.1.2.3 Other Studies

The following are studies which were conducted in Southern Ontario. Although these studies do not pertain specifically to the South Sydenham watershed, many of the conclusions drawn reflect physiographical areas, rainfall patterns and farming activities that are not unlike those in the Sydenham area. Hence, some of the results may provide added insight into the nature of pesticide problems in the South Sydenham watershed.

i) Contamination of Rural Ponds by Pesticides

Water samples from 211 ponds were analyses between 1971 and 1985 for pesticides suspected of entering the water (Frank *et. al.*,1987.) Of these,102 or 60% were found to be contaminated. Primary causes of contamination were transport via surface runoff from adjacent fields following rain events, airborne spray drift, accidental spillage and improper disposal of pesticide containers. Triazine herbicides were the most prevalent contaminants, and ponds associated with corn fields or rotational systems including corn crops were most often contaminated. Results were published in the paper "Contamination of Rural ponds with Pesticide,1971-85,Ontario,Canada" (Frank *et al.*,1987).

ii) Pesticide and Industrial Chemical Residues at the Mouth of the Grand, Saugeen and Thames Rivers

Water samples were collected at the mouth of the Thames River from January, 1981 to December, 1985. The Thames River watershed is located immediately to the south of the Sydenham watershed, and therefore the two watersheds share some of the same physiographic features - namely, the Bothwell and Caradoc Sand Plains and the Ekfrid Clay Plain. Farming activities tend to be similar in the two basins, with corn being the most prevalent crop. Pesticide use in the entire Sydenham basin (north and south branches) in 1983 was 407,670 kg - slightly more than one third of the amount used in the Thames Basin (1,509,670 kg; McGee,1984).

Twelve pesticides were identified in the Thames River water during the 5 year study period. Atrazine (including D-ethyl atrazine) was the most frequently identified herbicide, and the annual loading of this pesticide increased over the study period. Thames data, when combined with similar data from the mouths of the Grand and Saugeen Rivers, indicates that individual compound loadings were, in decreasing order, atrazine > metolachlor > cyanazine > alachlor > dicamba > 2,4-D > 2,4-DB > MCPA > dichlorprop. The preceding data was published in a paper entitled "Pesticide and Industrial Chemical Residues at the Mouth of the Grand, Saugeen and Thames Rivers,Ontario,Canada,1981-85" (Frank and Logan,1988).

5.2 Evaluations for Pesticide Residues in Groundwater

5.2.1 Ontario Ministry of the Environment

MOE has conducted pesticide monitoring programs of sensitive groundwater environments in Southern Ontario since 1983 (Beck, 1988a). Two types of studies are being conducted presently-monitoring of contaminants in private wells, and detailed monitoring of groundwater adjacent to fields where pesticides are used. The 1984-86 private well monitoring program is described below, while the detailed piezometer studies are explained in the "Unpublished Data" section.

5.2.1.1 Published Reports

i) Private Well Monitoring

A well monitoring program was initiated in the South Sydenham region in 1985 as part of the alachlor program. Water samples were taken on a weekly or bi-weekly basis and tested for a range of pesticides as well as coliform and major ion content. The private well monitoring program was continued in 1986, although different wells from the 1985 study were sampled. The 1986 test wells were concentrated in the shallow sand aquifers of the Bothwell and Caradoc Sand Plains and in the Ekfrid Clay Plain. Results of the studies are published in the 1985 and 1986 reports "Pesticides in Ontario Drinking Water" (MOE 1987a and b) and have been summarized in Section 7.2.1.3 of this report.

Sixty wells were selected with the use of a grid system (non-random) in 1985. As a result of requests for water tests from other private well owners, additional wells were added to the monitoring program to bring the total number of wells monitored to 292. Selected wells were not meant to be a representative sample of all private wells in Ontario. Some of the wells were located in or near to the South Sydenham watershed, and information on these sites has been included in this report (Table C, Appendix A).

In 1985,water samples from the sites were analysed for alachlor, atrazine (plus D-ethylatrazine), cyanazine, metolachlor, metribuzin, prometryne, simazine (plus D-ethyl simazine) and, occasionally, 2,4-DB and dicamba. In 1986, MOE's study objectives were to examine the extent to which shallow sandy aquifers might be contaminated through the normal use of agricultural pesticides, and to use strict well selection criteria to eliminate problems with well siting and poor well conditions (MOE,1987b).

5.2.1.2 Unpublished Data

i) Private Well Monitoring

Pesticide monitoring in private wells has continued in 1987 and 1988. In 1987, 21 wells were tested - 11 in the Bothwell and Caradoc sand plains and 10 in the Thedford Marsh area to the north of Watford and the South Sydenham watershed. In 1988, wells were tested in the Haldimand-Norfolk area, but not in the Sydenham region.

5.2.1.3 Results

i) Groundwater Sampling

MOE (1987b) reported that the 1986 well data was significantly different than the 1985 results. Nine pesticides were detected in 1985, whereas only 4 were detected in 1986. The overall pesticide concentrations in 1986 also were lower than those in 1985.

The results (1985) in Table C (Appendix A) show that the herbicides found in the most wells in the vicinity of the South Sydenham watershed include: alachlor, atrazine and metolachlor. These pesticides were detected in 22, 54 and 32 % of the wells, respectively.

Pesticides which also appeared, but in fewer wells, were metribuzin (1 % of all wells), simazine (1 %), prometryne (<1 %) and cyanazine (1 %). The IMAC was exceeded for alachlor in one well (max.101 µg/L), in 4 for atrazine (max.1270 µg/L) and 6 for metolachlor (max.1800 µg/L). These figures represent less than 1, 1 and 1 %, respectively, of the total number of wells listed in Table C. Generally, wells which are designated as being bored, dug, shallow or sandpoint, are less than 100 feet in depth and have poor location and construction are more prone to pesticide contamination than others.

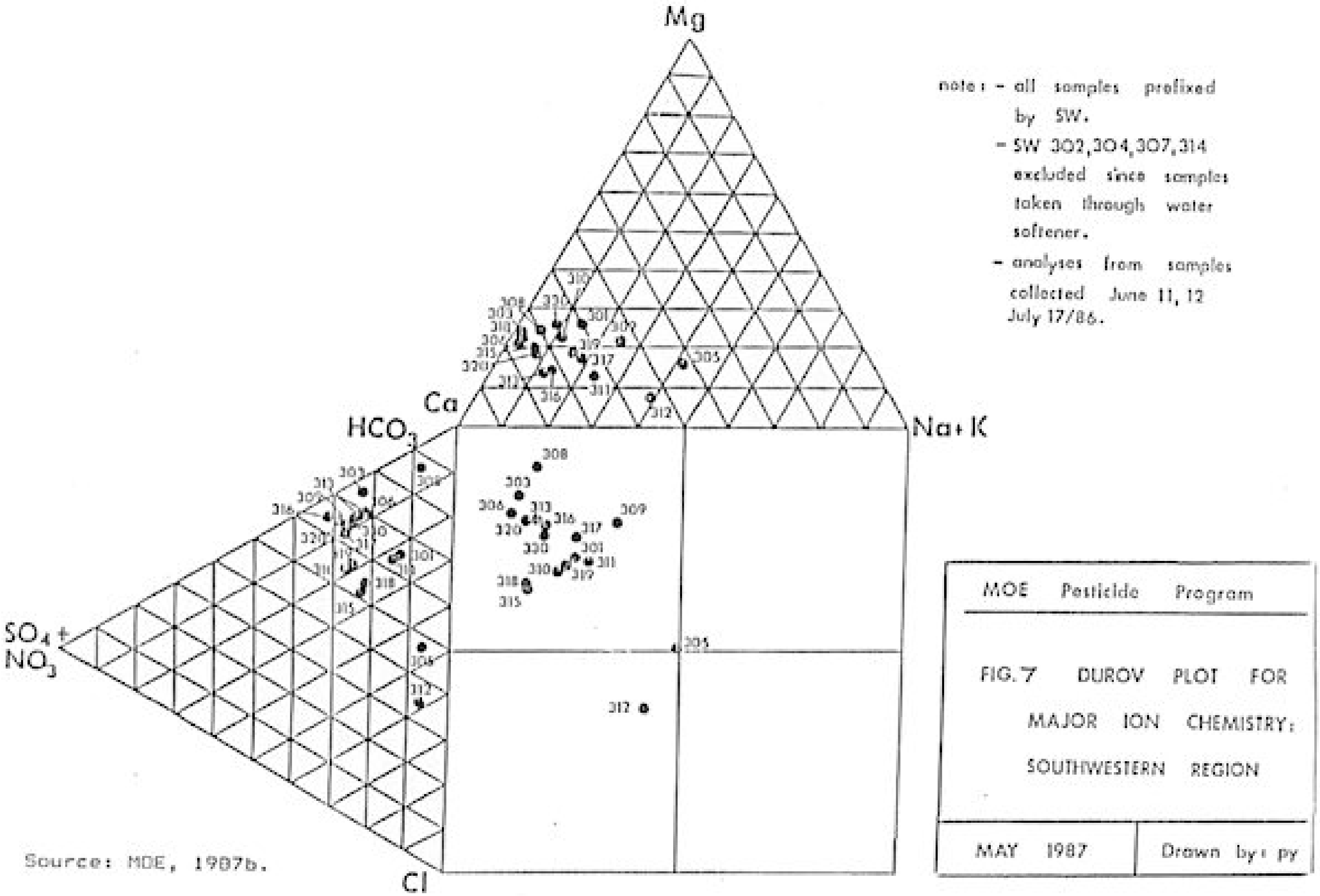
In 1986, four pesticides were tested for (atrazine, D-ethyl atrazine, metolachlor and cyanazine) in wells. Twenty one wells were tested (20 private and one municipal) in the vicinity of the South Sydenham watershed region (MOE,1987b).Fifteen of these wells were located in the watershed. Of these 15, 8 contained atrazine (53 %) and 6 (40 %) contained its metabolite, D-ethyl atrazine (Table D, Appendix A). One occurrence was reported for metolachlor (less than 1 %). None of the sites had detected concentrations that exceeded the IMAC. Suggested reasons for contamination included natural phenomena, such as sandy permeable soils in combination with a shallow water table, and man's activities (farming, road salting). The latter two reasons can affect much larger aquifer areas than the former reason.

ii) Major Ions

MOE identified the major ions that appeared in ground water during their 1986 study. The chemistry of major ions has been used as a means of characterizing groundwater quality and general groundwater classification (MOE,1987b). One hypothesis suggests that the ions indicate trends due to natural chemical reactions and mixing of different water types and contaminant input from sources such as agricultural practices, septic tanks and road salting.

MOE plotted their study results for sites in the Southwestern Ontario region (ie. near or in the South Sydenham watershed) on a Durov diagram, which is shown in Figure 7. This diagram is used to illustrate the normalized concentration and the dominant chemistry of the anions and cations.

The MOE data shows that the Maximum Acceptable Concentration (MAC) for nitrate levels was exceeded at 6 sites (MAC = 10 mg/L as a nitrate-nitrogen concentration). Three of these were located on the Caradoc Sand Plan, 2 on the Bothwell Sand Plain and 1 on the Ekfrid Clay Plain. The Maximum Desirable Concentration (MDC) for chloride (250 mg/L) was exceeded consistently in 1 well on the Bothwell Sand Plain. Sodium levels exceeded 20 mg/L at 9 sites (3 on the Caradoc Sand Plain, 5 on the Bothwell Sand Plain and 1 on the Ekfrid Clay Plain). Prior to 1987, the Medical Officer of Health for an area was notified if sodium



Source: MOE, 1987b.

concentrations exceeded 20 mg/L. However, in 1987 no reference was made to any specific concentration amount in the Canadian Drinking Water Guidelines.

iii) Monitoring of Pesticide Movement into Groundwater

MOE installed piezometers at seven sites in the shallow sand aquifer of the Caradoc/Bothwell sand plain between Bothwell and Strathroy in March, 1988 (Beck,1988). The piezometers are located adjacent to fields on which pesticides are used. The sites are tested on a weekly basis for the presence of triazines (atrazine, D-ethyl atrazine, cyanazine, metribuzin, simazine and D-ethyl simazine) and metolachlor. Soil samples for each site were taken at the time of installation and after summer application of pesticides. Groundwater chemistry (ie. major ion concentration) is determined at each site on a monthly basis.

1988 was the first year of a 3 year study, therefore, results have not been published yet. However, some preliminary observations regarding the 1988 data were made (Beck, 1988b). Atrazine and/or D-ethyl atrazine was found at 6 of the sites and were the most prevalent pesticide compounds of all chemicals tested for. Levels ranged up to 35 µg/L. Traces of cyanazine, simazine and D-ethylsimazine were detected at 2 of the sites. No metolachlor was found at any of the sites. One site has no pesticides present in detectable concentrations.

5.2.1.4 Other Studies

i) Contamination of Farm Wells by Pesticides

Alachlor, atrazine, dimethoate, metolachlor, metribuzin and trifluralin residues were found in wells where contamination was suspected and tested for in various areas of Ontario. Half of the wells were dug and the other half deep drilled wells. Not all of the wells had been contaminated by agricultural practices. Contamination from drawing water for spraying pesticides, pesticide spills and surface runoff from surrounding fields were all suggested means whereby the wells became polluted as a result of agricultural activities. Results were published in the papers, "Investigations of Pesticide Contaminations in Rural Wells, 1979-84, Ontario, Canada" (Frank *et al.*,1987) and "Survey of Farm Wells for Pesticides Residues, Southern Ontario, Canada,1981-1982, 1984" (Frank *et al.*, 1987). These studies were conducted separately from the MOE studies. The 1981-'82 data was collected from the Bradford Marsh area, while 1984 data was from Ridgetown.

6.0 PESTICIDE MANAGEMENT PROGRAMS

Recent studies indicate that many incidents of pesticide contamination are not related to agricultural accidents. However, since a few of the occurrences of pesticides in surface and groundwater can be directly related to accidental spills or misuse of agricultural pesticides, educational programs that promote the proper use of these chemicals are particularly significant. The following are several programs which focus on disseminating safety and management information to pesticide users.

6.1 Ontario Pesticide Education Program

In 1981, the Ontario Pesticide Education Program (OPEP) was initiated as a cooperative program involving the pesticide industry, MOE and OMAF. The program was designed to assist aerial applicators and pesticide vendors in obtaining certification to deal with pesticides.

This program is being continued and expanded under the educational component of the OMAF Food Systems 2002 program.

6.2 Food Systems 2002

Food Systems 2002 is a new program introduced by OMAF in January, 1988 . Billed as "an ecological systems approach to sustainable crop production, this program addresses issues such as environmental and health concerns, resistance to pesticides, and ever changing pest complex, the availability of new chemical pesticides, the lack of viable non-chemical alternatives and reduction in research emphasis on pest control (Roberts, 1988).

The objective of FS 2002 is a 50% reduction in pesticide use by the year 2002 while still maintaining efficient sustainable agriculture. The emphasis is on environmentally-sound pest control methods, including chemicals. FS 2002 is a continuation of OMAF's Integrated Pest Management (IPM) programs, which have been in place since 1969. The goal of FS 2002 is not to eliminate pesticides, but to select the best control strategies and techniques to produce a stable agro-ecosystem.

The project has 3 components-education, research and field delivery.

6.2.1 Education

The education component is being coordinated through the Ridgetown College of Agricultural Technology. The aim of the program is to educate and certify 35,000 - 40,000 horticultural and field crop growers in the safe use and handling of pesticides. OMAF is responsible for the training program, whereas MOE has a mandate to develop the legislation and regulations for mandatory certification.

6.2.2 Research

OMAF has identified areas in which more pesticide research is required including the fate of pesticides in the environment, new detection methods, systems analysis approach to pest management, non-chemical pest control alternatives, efficacy testing and application technology. Research will take place within the ministry and through solicited research.

6.2.3 Field Delivery

IPM programs are currently available for 6 fruit and vegetable crops (apples, grapes, peaches, pears, carrots, onions) but under FS 2002 an additional 19 commodities will be added to this list. In the 1988 year, these included cereals, field corn, rutabagas, asparagus, strawberries, muck vegetables and greenhouse floriculture. Field staff are responsible for disseminating this information, conducting feasibility and pest monitoring studies.

7.0 CONCLUSIONS

SOUTHERN ONTARIO

Monitoring of water quality in intensively farmed regions of Southwestern Ontario has revealed the occurrence of a wide range of agricultural chemicals.

Surface and Drinking Water

- Pesticides were detected, usually infrequently, in raw water samples at some municipal waterworks in Southern Ontario in 1986, but no concentration exceeded the IMAC.
- Atrazine, cyanazine, metolachlor, metribuzin and simazine were detected in raw water samples at 15 municipal water works throughout Southwestern Ontario in 1986. Pesticide levels were all below the Interim Maximum Acceptable Concentration (IMAC), (MOE 1987b).
- Atrazine, cyanazine, metolachlor and simazine were detected in treated water at 20 municipal water works (MOE,1987b). The levels of pesticide were reduced with adequate doses of powdered activated carbon (PAC).

Groundwater

- Atrazine, D-ethyl atrazine, alachlor and metolachlor were detected in 1986 in concentrations below the IMAC. Fewer pesticides were analysed for in 1986 as compared to 1985. Concentrations of pesticides detected had decreased from those of the previous year, due to the better condition of the wells tested in 1985.

SOUTH SYDENHAM WATERSHED

Monitoring of water quality in the South Sydenham watershed has provided information that supports other regional data. A wide range of agricultural chemicals has been consistently observed in water samples.

Surface and Drinking Water

- Atrazine and metolachlor have been the most frequently observed pesticides at Alvinston and Dresden since 1985. Data indicate that concentration levels do not appear to be decreasing and the occurrences in the total number of samples taken is increasing.
- Total pesticide concentrations appear to have remained constant or increased from 1981 to 1988.
- Generally, the highest pesticide residues are observed between May and August.

- High pesticide residues tend to coincide with spray periods and rainfall events.

- Higher pesticide levels tend to coincide with greater turbidity, and higher nitrate and potassium levels.

- The addition of Powdered Activated Carbon (PAC)(30-50 ppm)during treatment reduced pesticide concentrations to acceptable or undetectable amounts.

- Prior to 1985,alachlor was present in both raw and treated water samples taken from the Dresden waterworks. The IMAC was exceeded on June 19, 1984 (16 mg/L) and on June 1, 1985 (9 mg/L) at the Dresden location. Trace concentrations of alachlor were detected at the Alvinston waterworks in 1985, but no detectable amounts were found after treatment.

- The presence of alachlor in raw and treated water was not detected in studies conducted by MOE and OMAF from 1986 onwards, since it was no longer a registered herbicide after this time.

- Both MOE(1985-1988)and OMAF(1981-1987)studies show that atrazine is present in Dresden throughout most of the year in both raw and treated water samples. The IMAC was exceeded in 1984 (max. 61 µg/L in raw water) and in 1987 (max. 62.3 µg/L - raw water; 210 µg/L - treated). The OMAF study indicates that atrazine is present annually in 89 to 100 % of raw river samples and 63 - 100 % of the treated drinking water over a seven year period (Dresden, 1981-1987). No atrazine was detected at Alvinston in 1985, however, only two samples were analysed. Presence of the pesticide was observed in both raw and treated water samples in the period from 1986 to 1988, although levels did not exceed the IMAC at any time.

- Cyanazine was found in the raw water at Dresden each year during the 1982 to 1987 period, and every year except 1985 in the treated water samples (OMAF). MOE detected the pesticide in the raw water in 1985, and in both raw and treated water during the 1986 to 1988 period. The IMAC was not exceeded. No cyanazine was detected at Alvinston in 1985 or 1987. It was detected in both raw and treated water in 1986, and in trace amounts in the paired samples in 1988.

- Metolachlor was detected in the paired samples at Alvinston and Dresden from 1986 to 1988 (MOE). OMAF reported occurrences of the pesticide in raw water from 1984 to 1987, and in treated water in 1984,1986 and 1987. The IMAC was not exceeded during the 1984 to 1988 period.

- Metribuzin was detected in Dresden raw water samples from 1982 to 1986, and in treated samples in 1982 and 1984 (OMAF). The pesticide was not detected at Alvinston from 1985 to 1988 (MOE).

- Simazine was detected once in the raw water at Dresden (1985). No other detections were made at either Alvinston or Dresden from 1985 to 1988.

- A trace of 2,4-DB was detected once in the raw water at Dresden in 1985. No other occurrences are reported for either raw or treated water samples at either waterworks locations (19851988).

- A trace of dicamba was detected at Dresden in 1987. No other reports were made of this pesticide occurring in any of the paired samples at either location from 1985 to 1988.

- No prometryne was detected at Alvinston or Dresden from 1985 to 1988.

Groundwater

- Atrazine was the pesticide with the highest frequency of occurrence in private wells, both in the 1985 and 1986 MOE studies. A greater proportion of the total number of wells tested positively for atrazine in 1986 (57%) than in 1985 (54%). The IMAC for atrazine was exceeded in 4 out of 79 wells in 1985 (<1 %) but all well levels remained below the IMAC in 1986.

- The IMACs for metolachlor and alachlor were exceeded in less than 1 % of all wells (6 out of 79) in 1985, but was not exceeded in 1986.

- The IMAC for metribuzin was exceeded once in 1985, in the same well where alachlor and metolachlor levels were above the IMAC.

Estimated agricultural use of pesticides in townships of the South Sydenham watershed is 21.4 kg/ha. Pesticides which are commonly used on field crops (atrazine, cyanazine, metribuzin and simazine) are frequently observed in surface and ground waters. Triazines are the only pesticides being analysed for at present.

- Pesticide use in the counties of the South Sydenham watershed (Kent, Lambton, Middlesex) tend to be medium to high in relation to pesticide use in other Southern Ontario counties.

A study of the sensitivity of the soils to pollutant transport to water systems suggests that the soils in the South Sydenham Basin have a higher chance of developing problems, relative to other areas of Southern Ontario.

- 50 % of the watershed was estimated to have a high potential for the soils to transport pesticides to surface water systems. 10 % of the area was rated as having a medium potential and 40 % low.

- 50 % of the watershed was estimated to have a high potential for the soils to transport pesticides to ground water systems. 20 % of the area was rated as having a medium potential and 30 % low.

- The principal land use in the potentially sensitive areas generally is cash cropping, including corn, soybeans, sweet corn, field peas and some horticultural or tobacco crops.

Cropland source of pesticide contamination appears to be significant in the South Sydenham watershed but the nature and extent of transport pathways (overland / groundwater flow) remain unclear.

REFERENCES

Acton, C.J. and Harkes, R.,1988.Soil Landscapes of Canada (Map). Ontario Institute of Pedology. Guelph, Ontario.

Beck, P., 1988a. Pesticide Monitoring of Groundwater by Ontario Ministry of the Environment. Seminar presented at the Ontario Management Research and Services Committee Workshop, Agricultural Chemicals and Water Quality in Ontario. November 17-18, 1988. Kitchener, Ontario.

Beck, P., 1988b. Personal communication. November 22, 1988.

Chapman, L.J. and Putnam, D.F.,1973. The Physiography of Southern Ontario (second edition). Ontario Research Foundation, University of Toronto Press. Toronto, Ontario. 386 pp.

Coote, D.R. and E.M. MacDonald.1974. Preparation of Background Information for Agricultural Region Identification and Watershed Selection. *In* "Agricultural Land Uses, Livestock and Soils of the Canadian Great Lakes Basin. A Combined Report of the Activities of the Engineering Research Service and the Soil Research Service on Part of Agriculture Canada's Contribution to the Implementation of the Great Lakes Water Quality Agreement. 1973-1974. Section I, II, III". D.R. Coote, E.. MacDonald and G.J. Wall. Agriculture Canada, Ottawa, Ontario.

Coote, D.R., MacDonald, E.M., Dickinson, W.T., Ostry, R.C. and Frank, R.,1982. Agriculture and Water Quality in the Canadian Great Lakes Basin: I. Representative agricultural watersheds. J. Environ. Qual., 11(3):473-481.

Frank, R., Braun, H.E.,Ripley, B.D. and Clegg, B.S.,1987. Unpublished report. 9 pp.

Frank, R., Ripley, B.D., Braun, H.E., Clegg, B.S., Johnston, R. and O'Neill, T.,1987a. Survey of farm wells for pesticide residues, southern Ontario,Canada,1981-1982,1984.Arch. Environ. Contam. Toxicol. 16:1-8 (1987).

Frank, R., Clegg, B.S.,Ripley, B.D., and Braun, H.E.,1987b. Investigations of pesticide contaminations in rural wells, 1979-1984, Ontario, Canada. Arch. Environ. Contam. Toxicol. 16:9-22 (1987).

Frank, R. and Logan, L., 1988.Pesticide and industrial chemical residues at the mouth of the Grand, Saugeen and Thames Rivers,Ontario,Canada,1981-1985. Arch. Environ. Contam. Toxicol. 17:741-754 (1988).

Frank, R., Clegg, B.S., Sherman, C. and Chapman, N.D.,1988. Sydenham River Water and Municipal Drinking Water - Dresden, Ontario, 1981-87. Unpublished report. 11 pp.

Health and Welfare Canada,1987.Guidelines for Canadian Drinking Water Quality. Ministry of National Health and Welfare Canada. Ottawa, Ontario. 20 pp.

Johnson, P., 1988. Personal communication. October 13, 1988.

McGee, B.,1984.Survey of pesticide use in Ontario,1983. Economic Information. Economics and Policy Coordination Branch, Ontario Ministry of Agriculture and Food. Toronto, Ontario. 39 pp.

Ontario Ministry of Agriculture and Food, 1988. Guide to Weed Control. Ontario Ministry of Agriculture and Food, Publication 75. Toronto, Ontario. 200 pp.

Ontario Ministry of the Environment, 1985. Alachlor monitoring of Ontario drinking water, May - November 1985. Ontario Ministry of the Environment. Toronto, Ontario. 96 pp.

Ontario Ministry of the Environment, 1987a. Pesticides in Ontario drinking water - 1985. Ontario Ministry of the Environment. Toronto, Ontario. 31 pp.

Ontario Ministry of the Environment, 1987b. Pesticides in Ontario Drinking Water - 1986. Ontario Ministry of the Environment. Toronto, Ontario. 56 pp. plus appendices.

Ontario Ministry of the Environment, Pesticides in Ontario Drinking Water - 1987/1988. Unpublished data.

Roberts, W., 1988. Food systems 2002 - an update. Seminar presented at the Ontario Management Research and Services Committee Workshop, Agricultural Chemicals and Water Quality in Ontario. November 17-18, 1988. Kitchener, Ontario.

Shelton, I.J., Wall, G.J. and Dickinson, W.T., 1988. Potential for soils to transfer pesticides to water systems in southern Ontario. Ontario Institute of Pedology, Publication No. 88-3. Guelph, Ontario. 42 pp. plus appendices.

Wall, G.J.,Van de Kamer, J. and Johnson, B.G.,1986.Upper Great Lakes connecting channels study: activity number E.9 (Ontario) Pesticide Use Report. Research Branch, Agriculture Canada, Land Resource Research Centre, Guelph, Ontario. 67 pp.

APPENDIX A

Additional Information

Table A: Generalized criteria for a grouping of soils by potential to transport pollutants from the soil surface to water †

	Potential to transport to			Profile texture ‡									Drainage class §						Perviousness §			Slope (class)§		
Group	Surface water	Ground-water	Sub-group	Clay	Silty Clay	Silty Clay Loam	Clay Loam	Silt Loam	Loam	Sandy Loam	Loamy Sand	Sandy	Rapid	Well	Moderately Well	Imperfect	Poor	Very Poor	Rapid	Moderate	Slow	0 - 2.5% (1.2)	2-5% (3)	>6% (4+)
1	High	Low	a	X	X	X	X						X	X	X	X					X	X	X	X
			b					X	X				X	X							X			X
			b					X	X						X	X					X	X	X	X
			c	Sands over clay											X	X			X	X	X		X	X
			d	Organic soils									Tile-drained or pumped						N.A.¶			N.A.		
			e	Bottom land, alluvium, escarpment									N.A.						N.A.			N.A.		
2	Moderate	Moderate	b					X	X						X	X	X		X	X		X	X	
3	Low	High	b	Gravelly loam, loam over gravel												X	X	X	X	X		X	X	X
			c							X	X	X				X	X	X	X	X		X	X	X
			d	Shallow soils on bedrock									N.A.						N.A.			X	X	X
4	Low	Low	b					X	X				X	X					X	X	X	X	X	
			c	Sands over clay									X	X	X	X	X	X	X	X	X	X		
5	High	High	a	X	X	X	X										X	X	X	X		X	X	X
			b					X	X								X	X	X	X		X	X	X
			c	Rock outcrop									N.A.						N.A.			X	X	X

† Any soil occurring in tho basin that did not appear in this table of criteria was subjectively fitted to the closest appropriate group and subgroup.
‡ Includes consideration of textures of A, B, and C horizons.
§ As defined in Dumanski (1978).
¶ N.A. = not applicable.

Source: Coote *et al,* 1982.

Table B: Tolerance Limits for Selected Pesticides Observed in the Lower Sydenham Watershed

PESTICIDE		MAC µg/L	IMAC µg/L	AO	NOTES
Alachlor		-	5	-	1
Atrazine	(1986)	-	46	-	2
	(1987)		60		
Cyanazine		-	10	-	2
2,4-DB			18	-	1
Dicamba	(1986)	-	87	-	2
	(1987)	120			
Metolachlor	(1986)	-	105	-	2
	(1987)		50		
Metribuzin	(1986)	-	60	-	2
	(1987)	80			
Simazine		-	10	-	2
Pesticides (Total)		100	-	-	1

Notes:

1. Under review for possible revision, deletion from, or addition to the guidelines.
2. It is proposed that a guideline to be added for this parameter for the first time.

Limits apply to the sum of all forms of each substance present (metabolites included).

The IMAC's were developed in January, 1986 and some were revised in 1987.

Source: Ministry of National Health and Welfare, 1987.

Table C: Summary of Pesticide in Private Wells - 1985

County	Township	Type Of Well	Depth <Feet>	Soil Type	No. of Samples	Alachlor		Atrazine & D-ethyl Atrazine		Metolachlor		Metribuzin		Simazine & D-ethyl Simazine		Prometryne		Cyanazine	
						No.	RANGE	No.	RANGE	No.	RANGE	No.	RANGE	No.	RANGE	NO.	RANGE	No. #	RANGE
Kent	Camden		52		1	0		0		0		0		0		0		0	
“	“	spring	7		1	0		0		0		0		0		0		0	
"	"	dug	31	loam	12	0		6	0.14-3.53	3	1.5-5.6	1	1.4	0		0		0	
“	Chatham	sandpoint	16	clay	10	0		0		0		0		0		0		0	
“	“				7	0		3	0.17-2.03	0		0		0		0		0	
“	Zone				3	1	0.3	3	5.0-7.7	1	1.6	0		0		0		0	
“	“	sandpoint	12	sand-loam	11	2	1.2-3.3	1	0.61	1	33	0		0		0		0	
Lambton	Euphemia	dug	30		11	2	.12-.56	3	.17-.51	1	1.2	0		0		0		0	
"	"				8	0		2	.03- .72	0		0		0		0		0	
"	"				10	0		2	.63- 2.54	0		0		0		0		0	
"	"				8	0		2	.06-.40	0		0		0		0		0	
"	"				9	0		2	.21-.51	0		0		0		0		0	
"	"	sandpoint	12	sand	9	0		1	0.69	0		0		0		0		0	
"	"	dug	20	sand-loam	12	1	0.5	3	2.4- 9.3	2	1.7-5.5	1		0		0		0	
"	“	drilled	60		2	0		0		0		0		0		0		0	
"	“	dug	25	sand-loam	12	9	2.2 -12	12	72.0- 354.	2	.57-3.7	0		7	3.1-12	0		10	0.53
"	"		50	rock	2	0		0		0		0		0		0		0	
"	"				1	0		1	0.25	0		0		0		0		0	
“	Warwick	dug	100	clay-loam	0	0		0		1	1.5	0		0		0		0	
“	“	dug	90	clay-loam	12	0		2	.11-.30	1	0.52	0		0		0		0	
"	“	dug	83	clay-loam	6	0		1	0.05	0		0		0		0		0	
"	“	dug	93	clay-loam	8	0		0		2	.74 -2.2	0		0		0		0	
Middlesex	Caradoc	deep well			1	0		0		0		0		0		0		0	
"	"	shallow			I	0		1	6.7	0		0		0		0		0	
"	"				1	0		0		0		0		0		0		0	
"	"	dug	12	sand-loam	3	3	.47-1.3	3	76-160	3	20 -51	0		20	0.4-9.3	0		0	
"	"	sandpoint	44	sand	1	0		1	34	1	5.9	0		1	19	0		0	
“	“	dug	20	clay-sand	11	0		0		0		0		0		0		0	
“	“	dug			8	0		1	16.34	1	6.0	0		0		0		0	
"	"	dug	30	loam	19	1	0.3	3	09- 4.12	1	6.9	0		0		0		0	
"	"	sandpoint	25	sand-loam	23	7	.17-.35	23	20- 174.3	23	90-1300	0		5	1.7-4.9	1	0.84	0	
"	“	sandpoint	15	sand	26	3	.62-2.7	4	.00- 1.4	2	0.4-56	1	1	0		0		1	3.6
"	“				11	0		2	.16- .37	3	1.4-4	0		0		0		0	
"	"				5	0		0		1	1.1	0		0		0		0	
"	"	bored	80	sand	26	4	.19-7.7	10	.04- 5.4	5	.98-500	1	1.2	0		0		1	0.55
"	"				0	0		7	.22- 3.05	0		0		0		0		0	
“	"	dug	30	sand	1	0		0		0		0		0		0		0	
“	“	dug		sand	1	0		0		0		0		0		0		0	
"	“	sandpoint	25	sand	1	0		1	6	1	5.7	0		0		0		1	1.9
"	"	dug	13	sand-loam	2	0		0		0		0		0		0		0	
"	"				1	0		0		0		0		0		0		0	
"	"				1	0		I	0.22	0		0		0		0		0	
"	"				1	0		0		0		0		0		0		0	
"	“				1	0		0		0		0		0		0		0	
“	“				1	0		0		0		0		0		0		0	
“	"				1	0		0		0		0		0		0		0	
"	"				1	0		0		0		0		0		0		0	
"	EKFRID				2	0		0		0		0		1	.43- 23	0		0	
"	"	dug	50	sand	26	4	.23 -12	26	64.0 -1270	26	.2-.65	0		0		0		0	
"	"				8	0		3	.03-3.9	0		0		0		0		0	
"	“	dug	120	clay-1oam	16	2	.05-.19	1	0.14	0		0		0		0		0	
“	“				1	0		1	0.17	0		0		0		0		0	
“	LOBO				1	0		0		0		0		0		0		0	
"	"	dug			12	0		2	5.3-6.05	1	0.07	0		0		0		0	
"	“	dug	20	sand	22	2	.39-1.2	1	3.3	0		0		0		0		0	

	“	dug	30		1	0		0		0		0		0	0	0	
"	“	sandpoint	40		1	0		1	0.12	0		0		0	0	0	
“	“	dug	22	sand	1	0		0		0		0		0	0	0	
"	“	sandpoint	12	gravel	1	0		0		0		0		0	0	0	
“	“				1	0		0		0		0		0	0	0	
"	London				1	0		0		0		0		0	0	0	
"	"	dug		clay-loam	1	0		0		0		0		0	0	0	
"	“	dug	30	clay-loam	1	0		1	0.3	0		0		0	0	0	
“	“				1	0		1	0.13	0		0		0	0	0	
“	"	dug	12	clay	2	0		0		0		0		0	0	0	
“	“	sandpoint	12	clay	1	0		0		0		0		0	0	0	
“	"	dug	25	loam	1	0		1	0.06	0		0		0	0	0	
“	“	dug	30	sand-loam	1	0		0		0		0		0	0	0	
“	“				1	0		0		0		0		0	0	0	.
"	Metcalfe				1	0		0		0		0		0	0	0	
"	"	dug	27	sand	27	8	.1- 10	9	.09-5.2	2	.64 -2	0		0	0	0	
"	“	drilled	110	clay	6	5	.1- 2.3	5	6.70-43	4	1.1 -750	4	1.6 -24	0	0	1	1.4
"	“	drilled	120	clay	11	2	.47 -4.9	2	4.53-7.01	2	2.2 -11	1	2.7	0	0	1	1.7
“	"	dug	25	clay	6	5	11-101	4	3.6-14	4	437 -1000	4	2.2-300	0	0	2	.6 -.87
“	Mosa				1	0		1	0.2	0		0		0	0	0	
“	"				1	0		0		0		0		0	0	0	
“	“				1	0		0		0		0		0	0	0	
“	“				1	0		0		0		0		0	0	0	
	Mosa- Ekfrid				1	0		1	2.21	0		0		0	0	0	

Source: MOE, 1987a.

TABLE D: SUMMARY OF PESTICIDE OCCURRENCE IN GROUNDWATER - SOUTHWESTERN REGION

COUNTY	TWP	WELL TYPE	DEPTH (m)	DIAM (cm)	STATIC LEVEL (m)	SAMPLE NO.	ATRAZINE # +ve	Range of Concentration (µg/L)	D-ETHYL ATRAZINE # +ve	Range of Concentration (µg/L)	METOLACHLOR # +ve	Range of Concentration (µg/L)	ALACHLOR # +ve	Range of Concentration (µg/L)
Middlesex	Caradoc	Sandpoint	7.0	3.2	2.7	SW-301	0	-	0	-	0	-	0	-
Middlesex	Caradoc	Bored	11.0	91.4	2.4	302	1	3.2	0	-	0	-	0	-
Middlesex	Caradoc	Sandpoint	8.8	3.2	5.2	303	0	-	0	-	0	-	0	-
Middlesex	Caradoc	Sandpoint	9.1	10.2	2.4	304	0	-	0	-	0	-	0	-
Middlesex	Caradoc	Bored	9.9	91.4	4.3	305	0	-	0	-	0	-	0	-
Middlesex	Caradoc	Bored	9.1	91.4	3.6	306	0	-	1	0.44	0	-	0	-
Middlesex	Caradoc	Sandpoint	3.7	3.2	1.5	307	0	-	0	-	0	-	0	-
Middlesex	Ekfrid	Bored	7.3	91.4	0.9	300	1	0.36	1	0.46	0	-	0	-
Middlesex	Caradoc	Bored	9.9	91.4	5.2	309	1	0.14-3.00	1	0.54 -1.50	1	2.00	0	-
Middlesex	Ekfrid	Bored	6.1	91.4	2.7	310	14	0.36 - 4.2	9	0.33-1.10	0	-	0	-
Kent	Zone	Bored	7.0	91.4	2.4	311	2	0.30	0	-	0	-	0	-
Kent	Zone	Dug	4.0	91.4	1.2	312	I	0.20	0	-	0	-	0	-
Kent	Zone	Bored	9.1	76.2	2.1	313	5	0.20 - 0.40	3	0.24-0.63	2	1.40 -1.90	1	1.40
Kent	Zone	Bored	1.9	16.2	1.2	314	0	-	0	-	0	-	0	-
Lambton	Euphemia	Bored	12.2	16.2	3.1	315	0	-	0	-	0	-	0	-
Middlesex	Mosa	Bored	15.2	91.4	1.6	316	1	0.23	1	0.21	0	-	0	-
Lambton	Euphemia	Bored	7.6	76.2	3.0	317	1	0.34	0	-	0	-	0	-
Middlesex	Mosa	Bored	9.1	91.4	1.8	318	I	0.23	0	-	0	-	0	-
Middlesex	Rosa	Bored	8.5	91.4	1.5	319	1	0.28	0	-	0	-	0	-
Lambton	Euphemia	Bored	13.0	91.4	2.1	320	17	0.61-2.90	14	1.38-7.60	0	--	1	2.3
Middlesex	Caradoc	Drilled	30.0	25.4	10.7	330	0	-	0	-	0	-	0	-

Source: MOE, 1907b.

TABLE E: Dresden Alachlor & General Chem-pesticides

Date		Alachlor Conc µg/L	Turbidity FTU	Nitrate As N mg/L	Potassium As K mg/L	Remarks
		Untreated Water				
May	28	ND	35	2.1	2.6	
"	30	ND	49	2.1	1.6	May 30-31 rain event
"	31	TRACE				
June	1	9.0				June 1-3 rain event
"	2	3.2				
"	3	2.2 (3.0 OMAF)	51	7.6	3.2	
"	6	ND	43	3.0	2.6	Insuff. samples for pesticides
"	10	ND	55	1.97	2.9	
"	11	TRACE (OMAF)				
"	13	ND	43	1.9	2.8	All pesticides< MDL* insuff. for triazines
"	17	ND				
"	18	ND	54	2.6	2.85	
"	19	2.1	72	12.5	3.8	
"	20	1.4	53	10.6	3.6	
"	21	ND	62	6.5	3.25	June 17-22 rain event
"	22	TRACE	47	5.8	3.05	
"	24	ND	52	5.8	3.15	
"	25	TRACE(OMAF)				
"	26	-	52	3.50		All pesticides < MDL
"	27	ND	44	3.0	2.75	
July	2	ND				
"	4	ND	12.8	3.20		All pesticides < MDL
"	8	ND				
"	9	ND				
"	10	-	18.10	2.8		All pesticides< MDL except atrazine 2.6 µg/L
"	11	ND	37	2.1	3.0	
"	15	ND	30	1.3	3.0	July 15-19 rain event
"	16	1.0	105	8.9	3.05	
"	17	TRACE	119	5.2	4.3	All pesticides < MDL
"	18	ND	125	11.2	4.65	
"	19	TRACE	101	13.8	5.3	
"	22	TRACE	80	8.6	3.3	
"	23	ND				July 24 all pest.<MDL except atrazine - 2.0 µg/L metribuzin 2.35 µg/L
"	29	ND	58	3.2	3.8	July 31 all pest.< MDL except atrazine - 2.2 µg/L
Aug.	1	ND	48	1.2	3.1	
"	6	ND	53	0.26	2.85	
"	12	ND	36	<0.01	2.85	
"	13	ND				Aug.28 all pest.< MDL except atrazine 0.9 µg/L

* < MDL - less than minimum detection limits

ND = Not detected

\- = No alachlor sample taken

Source : MOE, 1985

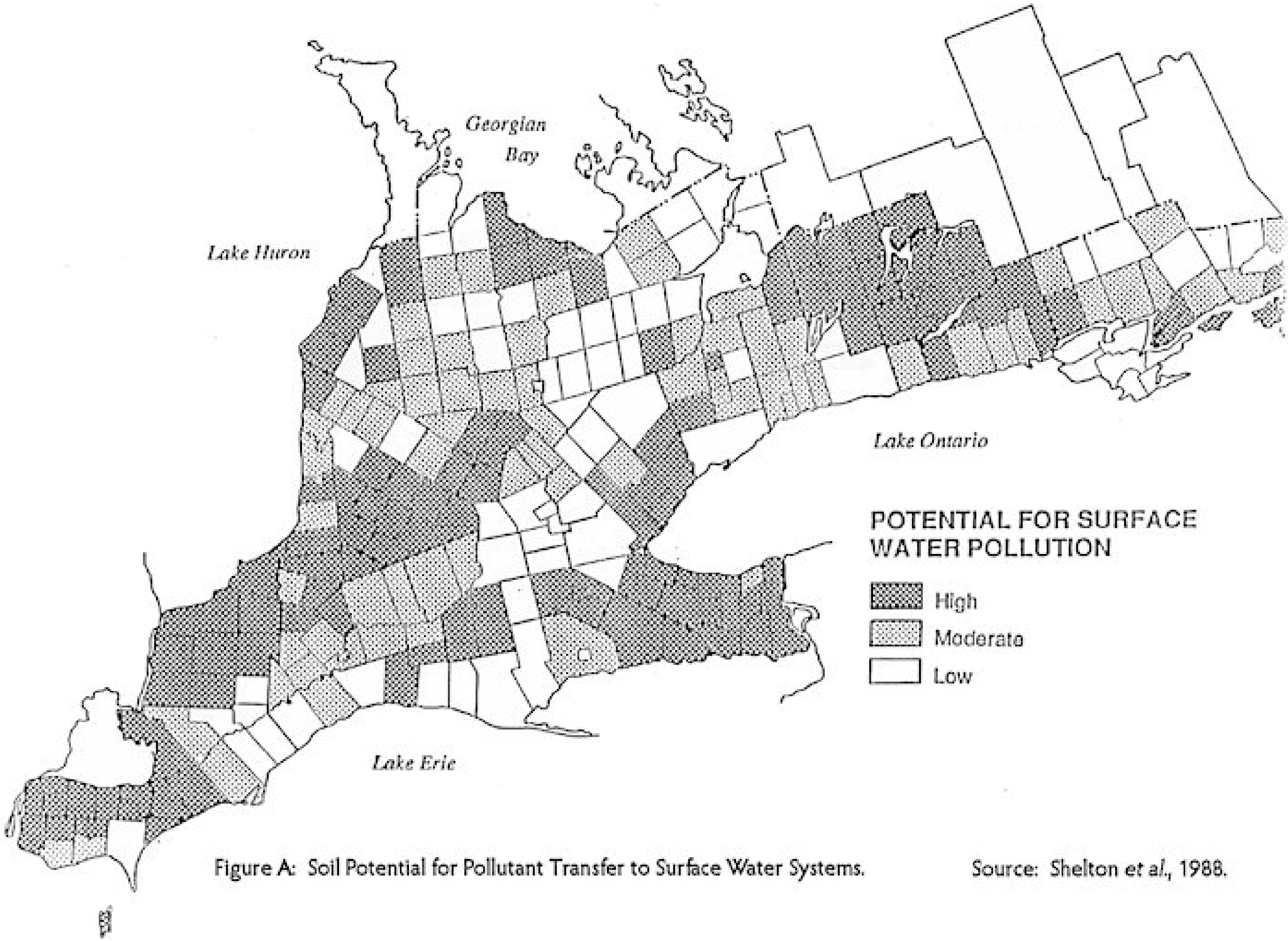


Figure A: Soil Potential for Pollutant Transfer to Surface Water Systems. Source: Shelton *et al.*, 1988.

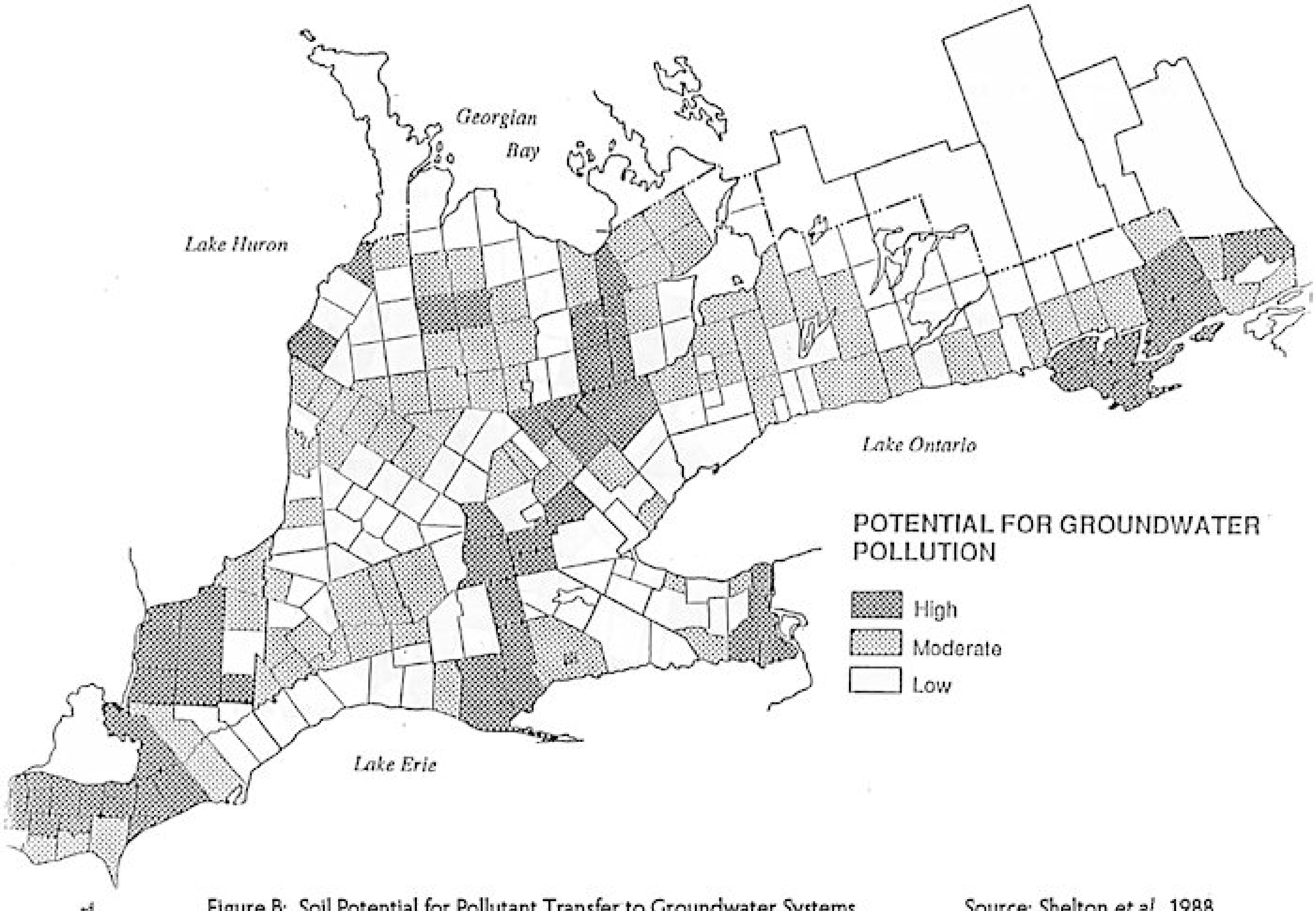


Figure B: Soil Potential for Pollutant Transfer to Groundwater Systems. Source: Shelton *et al.*, 1988

APPENDIX B

Notes on Chemicals

Source: OMAF,1988.

ATRAZINE. TRADE NAMES: AATREX, PRIMATOL, VECTAL. CHEMICAL FAMILY: S-triazine. CROP AND/OR NON-CROP REGISTRATIONS: Corn (ensilage, field, seed and sweet), low bush blueberries, triazine-tolerant canola (rapeseed) and non-cropland. SENSITIVE WEEDS: Will control a wide range of annual grasses and broadleaf weeds such as mustards, purslane, ragweed, smartweed, lady's-thumb, wild buckwheat, lamb's-quarters, pigweed, volunteer clover, barnyard grass, green foxtail, yellow foxtail and wild oats. Will also control quack grass, Canada thistle and nutsedge. Populations of lamb's-quarters, pigweed, ragweed and witch grass have been found which are resistant to atrazine and are therefore not controlled. UPTAKE AND TRANSLOCATION: Actively absorbed by roots and foliage although foliar absorption is usually small. It is translocated to the top of the plant and accumulates in the leaf margins and the growing points. BASIS OF SELECTIVITY: Metabolism by tolerant species. Spray timing avoids contact with low bush blueberries to prevent injury. APPLICATION METHODS: For corn, preplant incorporated, preemergence, or postemergence (with or without oil) usually before the annual weeds are more than 4 cm high; under dry weather conditions a shallow incorporation may enhance activity; oil or oil/surfactant blends will increase the postemergence activity. For low bush blueberries, preemergence application. For triazine-tolerant canola, postemergence. Dry bulk fertilizer may be impregnated with atrazine and applied preplant incorporated. Atrazine may be tank mixed with several other annual grass and broadleaf herbicides to increase the spectrum of weed control in corn. Split applications can be used to improve the control of some perennial weeds. RESIDUAL ACTIVITY: Can persist in the soil for varying lengths of time depending on rate, weather and soil conditions (longer kinder dry, cool weather conditions and in sandy soils). Postemergence treatments tend to persist longer than preemergence treatments. See section "Special Notes for Corn". UNIQUE CHARACTERISTICS: Atrazine may carry over for more than one planting season. One year after application there is usually no hazard to most rotational crops when 2 kg ai/ha or less is applied. Cool, dry weather and sandy soils are conditions under which problems may arise. Perennial weed control usually requires higher rates of atrazine. in which case, corn must be grown for more than one year. See "Notes on atrazine and simazine soil residues" in "Special Notes for Corn".

ATRAZINE/SIMAZINE. TRADE NAMES: EKKO. ERAMOX. CHEMICAL FAMILY: S-triazine/s-triazine. CROP AND/OR NON-CROP REGISTRATIONS: EKKO for corn (ensilage, field, seed and sweet). ERAMOX for non-crop land. SENSITIVE WEEDS: At the rates used on corn the following are controlled: mustards, ragweed, lady's-thumb, lamb's-quarters, purslane, smartweed, wild buckwheat, redroot pigweed, barnyard grass, yellow (oxtail, green foxtail, witch grass, wild oats, crab grass; perennial weeds such as quack grass, Canada thistle and nutsedge can be controlled with split applications — see product label for specifics and precautions. At rates used for non-crop land most annual and perennial herbaceous weeds are controlled. UPTAKE AND TRANSLOCATION: Absorbed by roots and foliage, although foliar absorption is usually small. It is translocated to the top of the plant and accumulates in the leaf margins. BASIS OF SELECTIVITY: Metabolism by tolerant species. APPLICATION METHODS: For corn: preplant incorporated, preemergence or postemergence with oil; preplant incorporation must be shallow with a harrow or cultivator as a disc usually incorporates too deep; rainfall is required to activate a preemergence application; postemergence applications must be made in an oil-water emulsion when grasses are in the 1 to 2 leaf stage and broadleaves are no higher than 10 cm. For non-crop land: preemergence and postemergence. RESIDUAL ACTIVITY: At rates recommended for corn, crops other than corn should not be planted for at least one year; two years after application. most rotational crops can be planted except for tobacco which should not be planted within three years. At the higher rates recommended for non-crop land, weeds will usually be controlled for two seasons or more. UNIQUE CHARACTERISTICS: Triazine-resistant weed species will not be controlled. Where crab grass exists in corn in heavy populations, a cultivation will be necessary. Atrazine/simazine is not recommended for muck soils. Since atrazine/simazine has a long residual period, corn must follow corn for at least one year.

CYANAZINE. TRADE NAME: BLADEX. CHEMICAL FAMILY: S-triazine. CROP AND/OR NON-CROP REGISTRATIONS: Corn (ensilage. field and sweet). triazine-tolerant canola (rapeseed). SENSITIVE WEEDS: Black nightshade, purslane, lady's-thumb, lamb's-quarters, prostrate knotweed, shepherd's-purse, wild buckwheat, wild mustard, wormseed mustard, velvetleaf, pigweed, crab grass, green foxtail, yellow foxtail, witch grass. fall panicum and barnyard grass. UPTAKE AND TRANSLOCATION: Readily absorbed by roots and foliage. When absorbed by roots it is translocated to the leaves. BASIS OF SELECTIVITY: Metabolism by tolerant crops. APPLICATION METHODS: Preplant incorporated in corn (wettable powder) but only in mixtures with other corn herbicides; incorporation equipment should be set to work no deeper than 10 cm. Preemergence in corn (wettable powder); moisture is required for activation. Early postemergence in corn up to the 3 leaf stage (wettable powder). Early postemergence in triazine-tolerant canola (liquidation formulation). RESIDUAL ACTIVITY: Cyanazine has a relatively short residual life in the soil; from normal spring applications there is no carryover of the herbicide to the next growing season. UNIQUE CHARACTERISTICS: Cyanazine is a short-lived triazine herbicide with flexible application time. Preemergence applications do not adequately control barnyard grass, fall panicum or pigweed under conditions which delay germination such as low temperature or dry soil surface. Emerged velvet-leaf will be controlled by the early postemergence application but subsequent germinating velvetleaf will not be controlled. Cyanazine is not recommended alone for use on heavy clay soil. Do not use on peat, muck soils, sandy soils or soils with less than 1% organic matter. Do not use the liquid formulation postemergence in corn. Do not add oil or surfactants other than as specified on the label. Cyanazine may be used in tank mixes and has been formulated with various other herbicides. See label for specifications.

CYANAZINE/ATRAZINE. TRADE NAME: BLAZINE. CHEMICAL FAMILY: S-triazine/s-triazine. CROP AND/OR NON-CROP REGISTRATIONS: Corn (ensilage, field and sweet). SENSITIVE WEEDS: Nightshade, purslane, lady's-thumb, lamb's-quarters, pigweed, prostrate knotweed, ragweed, shepherd's-purse, wild buckwheat, mustard and early germinating velvetleaf. Barnyard grass, crab grass, green foxtail, witch grass, yellow foxtail and early germinating fall panicum. UPTAKE AND TRANSLOCATION: Readily absorbed by the roots and foliage and translocated to the top of the plant. BASIS OF SELECTIVITY: Metabolism by tolerant species. APPLICATION METHODS: Preplant incorporated, preemergence, and early postemergence (wettable powder only) over a wide range of soil types and weather conditions. Incorporation equipment should be set to work at 5-10 cm depth. Immediate incorporation is not necessary. Preemergence activity is dependent on root uptake; thus a shallow incorporation into moist soil is necessary if at least 1.25 cm of rain does not fall within 7-10 days after application. Incorporation into dry soil is not recommended. Early postemergence application should be made when grasses are in the 1 to 2 leaf stage and broadleaf weeds are less than 5 cm high. DO NOT apply to corn beyond the 3 leaf stage. DO NOT add oil or surfactants. Use only wettable powder formulation for postemergence application. Can be tank mixed with dicamba for velvetleaf and triazine-resistant weed control. RESIDUAL ACTIVITY: Normally, season long activity. UNIQUE CHARACTERISTICS: Do not use on sandy soil (70% or more sand) or soils with less than 1% organic matter. Do not add oil or surfactants when used postemergence. Do not use liquid formulation postemergence. Cyanazine/atrazine provides improved control of barnyard grass and pigweed over cyanazine or atrazine alone. Damage from postemergence applications to corn under stress due to cold wet growing conditions is usually temporary unless the weather conditions are prolonged.

DICAMBA. TRADE NAMES: BANVEL, DYCLEER. CHEMICAL FAMILY: Benzoic acid. CROP AND/OR NON-CROP REGISTRATIONS: Field corn, spring and winter wheat, spring barley, spring rye, oats, summer fallow and stubble, pastures, red fescue, low bush blueberries and turf; non-crop areas such as roadsides, utility rights-of-way, railways and wasteland. SENSITIVE WEEDS: Annual, perennial and biennial broadleaf weeds, and numerous brush species including conifers. Particularly effective against velvetleaf, Canada thistle, field bindweed and various triazine resistant broadleaf weeds. Control is best when weeds are small and actively growing. UPTAKE AND TRANSLOCATION: Readily absorbed by roots. stems or leaves, and then translocated to other plant parts. BASIS OF SELECTIVITY: Metabolism by tolerant species. APPLICATION METHODS: Preemergence or postemergence in field corn. For all other crops and non-crop uses, postemergence applications are recommended. RESIDUAL ACTIVITY: Half-life in soil is approximately 30 days. Residue carry-over into the next season is not a problem when applied at rates recommended for crop situations. UNIQUE CHARACTERISTICS: Dicamba is often mixed with grass herbicides or with phenoxy herbicides to provide a broader spectrum of weed control. Spray drift is toxic to sensitive plants in the same manner as 2,4-D: thus similar precautions should be followed. There is also a possibility of dicamba vapor drift from treated plant foliage during high temperatures (in excess of 30°C). At higher rates dicamba can be toxic to trees and shrubs having roots under the treated area. See sections on Herbicide Drift and Reduction of Herbicide Drift.

DICAMBA / ATRAZINE. TRADE NAME: MARKSMAN. CHEMICAL FAMILY: Benzoic acid/s-triazine. CROP AND/OR NON-CROP REGISTRATIONS: Field corn. SENSITIVE WEEDS: Annual and biennial broadleaf weeds including the triazine-resistant biotypes. APPLICATION METHODS: Postemergence until the standing height of the corn is 13 cm (five leaf stage). UNIQUE CHARACTERISTICS: This mixture provides excellent control of triazine-resistant broadleaf weeds, maintains a low level of triazine for short term residue, and gives improved control of velvetleaf. See also notes on dicamba and atrazine.

DICAMBA / 2,4-D. TRADE NAME: DYCLEER 24. CHEMICAL FAMILY: Benzoic acid/phenoxy. CROP AND/OR NON-CROP REGISTRATIONS: Established turf and non-crop land. SENSITIVE WEEDS: Deciduous and coniferous brush; broadleaf herbaceous weeds. APPLICATION METHODS: Postemergence. UNIQUE CHARACTERISTICS: More effective than 2,4-D alone for control of Canada thistle, bindweed, smartweed and conifers. Has greater soil activity than 2,4-D alone. See also notes on dicamba and 2,4-D.

DICAMBA / MCPA. TRADE NAME: DYVEL. CHEMICAL FAMILY: Benzoic acid/phenoxy. CROP AND/OR NON-CROP REGISTRATIONS: Barley, spring wheat, winter wheat and oats. UNIQUE CHARACTERISTICS: Provides better control of mustards and hemp-nettle than dicamba alone. See also notes on dicamba and MCPA.

DICAMBA / MCPA / MECOPROP. TRADE NAME: TARGET. CHEMICAL FAMILY: Benzoic acid/phenoxy: phenoxy. CROP AND/OR NON-CROP REGISTRATIONS: Spring wheat, barley, oats not under-seeded to legumes, stubble fields and summer fallow. SENSITIVE WEEDS: At field crop rates —wild buckwheat, cow cockle. lady's-thumb, green smartweed, mustards, hemp-nettle, Russian thistle, corn spurry, ffixweed, annual sow-thistle, shepherd's-purse, common ragweed, pigweeds, chickweed, lamb's-quarters, knotweed, volunteer rapeseed and sunflowers. APPLICATION METHODS: Postemergence when weed seedlings are in the 2 to 3 leaf stage, spring wheat and oats are in the 4 to 5 leaf stage, and barley is in the 2 to 3 leaf stage. Use water carrier and apply at 100 litres total spray mix per hectare. UNIQUE CHARACTERISTICS: This mixture controls a wider spectrum of weeds than any of the herbicide components used alone. Under certain conditions. this mixture may cause shortening of the straw of cereals but yield will not be affected.

2,4-D. TRADE NAMES: Numerous. CHEMICAL FAMILY: Phenoxy. CROP AND/OR NON-CROP REGISTRATIONS: Cereals, turf, pastures, non-crop land, asparagus, raspberries. strawberries, water weeds and brush. SENSITIVE WEEDS: Most broadleaf weeds, brush, Eurasian water milfoil. coontail. bladder-wort, water lily and water shield. UPTAKE AND TRANSLOCATION: Readily absorbed through leaves or roots. Translocated primarily in phloem with the sugars but can also move with water in the xylem. Accumulation is primarily in the young rapidly growing meristematic regions of roots or shoots. BASIS OF SELECTIVITY: Differences in interception, penetration, translocation, metabolism and sensitivity of active sites leads to greater activity in broadleaf weeds compared to grasses. APPLICATION METHODS: Postemergence (broadleaf weeds), stem-foliage or stem-basal (brush). RESIDUAL ACTIVITY: Half-life in soil is usually not longer than 1 or 2 weeks during the growing season due to rapid decomposition by soil microorganisms. UNIQUE CHARACTERISTICS: All weeds are more easily killed when growing rapidly in moist soil. Unfortunately some broadleaf crop, garden and ornamental plants are as sensitive to 2,4-D as many weeds and only a trace of the chemical as spray drift, vapor drift or contaminant in soil or water may cause serious damage. Even crops that can be sprayed safely can be sensitive at some stages of growth or at excessive application rates: thus label precautions should be followed carefully. Amines and esters are the most common formulations of 2,4-D. The esters are the most active and can be used at the lower rates and for brush control. Since vapor drift is a potential problem with the ester formulations, only the amines should be used on lawns, or near gardens or susceptible crop areas. Low-volatile esters can be used by agriculturalists or licensed applicators in areas where risk of damage to sensitive non-target vegetation is low. Recommendations are on the basis of acid equivalent. Commercial products differ in their content of acid equivalent and this must be considered in determining the amount of product to use.

2,4-D / DICAMBA / MECOPROP. TRADE NAMES: BANVEL 3. KILLEX, KIL-MOR. CHEMICAL FAMILY: Phenoxy/benzoic acid/phenoxy. CROP AND/OR NON-CROP REGISTRATIONS: BANVEL 3 and KIL-MOR for spring wheat, winter wheat, barley, corn, oats, non-crop land; KILLEX for turf. SENSITIVE WEEDS: At field crop rates — wild buckwheat, lady's-thumb, green smartweed. Russian thistle, sow-thistle, hedge bindweed, corn spurn, knotweed, volunteer cultivated buckwheat, common ragweed, cocklebur, stinkweed, mustards, prostrate pigweed. redroot pigweed and lamb's-quarters. At non-crop land rates — a wide range of broadleaf weeds including bull thistle. chicory, goat's-beard, ragwort, white cockle, poison-ivy. alder and sheep-laurel. APPLICATION METHODS: Postemergence when weeds are small and actively growing; see crop recommendations for specific timing. UNIQUE CHARACTERISTICS: This mixture controls a wider spectrum of weeds than any of the herbicides alone.

2,4-DB. TRADE NAMES: EMBUTOX E, COBUTOX. CHEMICAL FAMILY: Phcnoxv. CROP AND/OR NON-CROP REGISTRATIONS: Seedling alfalfa. bird's-foot trefoil, clovers (except sweet) direct seeded or under seeded in spring wheat, barley or oats; spring wheat, barley and oats: corn. SENSITIVE WEEDS: Many small broadleaf weeds such as stinkweed, ragweed. lamb's-quarters. wild buckwheat and mustards. Top growth control of Canada thistle, field bindweed and perennial sow-thistle. UPTAKE AND TRANSLOCATION: Absorbed through the foliage and readily translocated to the growing points. BASIS OF SELECTIVITY: Sensitive weeds rapidly convert 2,4-DB into 2,4-D; tolerant species do not make this conversion under normal conditions. APPLICATION METHODS: postemergence. RESIDUAL ACTIVITY: Essentially none. UNIQUE CHARACTERISTICS: Mustards are not usually controlled by 2,4-DB alone if sprayed beyond the four leaf stage; a tank mixture with MCPA will improve control of these larger mustards.

DICHLORPROP / 2,4-D. TRADE NAMES: Numerous. CHEMICAL FAMILY: Phenoxy/phenoxy. CROP AND/OR NON-CROP REGISTRATIONS: Spring and fall wheat and barley; turf; perennial weed and brush control on non-crop land. UNIQUE CHARACTERISTICS: Most properties of dichlorprop are very similar to those of 2,4-D. Chickweed, wild buckwheat. smartweed and some woody species are more sensitive to dichlorprop/2.4-D than to 2,4-D alone Do not use on oats.

METOBROMURON / METOLACHLOR. TRADE NAME: GALEX. CHEMICAL FAMILY: Substituted urea/ acetanilide. CROP AND/OR NON-CROP REGISTRATIONS: Soybeans. SENSITIVE WEEDS: Annual grasses including green, yellow and giant foxtail, smooth and hairy crab grass, barnyard grass. fail panicum, witch grass and annual blue grass. Broadleaf weeds including pigweed. lamb's-quarters, green smartweed, lady's-thumb, ragweed. shepherd's-purse, eastern black nightshade, cudweed, corn spurry, groundsel, purslane, chickweed, mustards and stinkweed. BASIS OF SELECTIVITY: Soybeans are planted deep enough that the chemical does not come in contact with the germinating seedlings. If beans are planted too shallow, injury will result. APPLICATION METHODS: Preemergence as an overall spray or banded over the crop row. RESIDUAL ACTIVITY: Winter cereals may be planted 4.5 months following application. UNIQUE CHARACTERISTICS: Mixture provides control of a wider spectrum of weeds than either component (metobromuron is more effective on broadleaf weeds and metolachlor is more effective on grasses). Optimum results are obtained when adequate rainfall occurs within 10 days after application. Do not use on muck or high organic soils, or coarse textured soils low in organic matter. See also notes on metobromuron and metolachlor.

METOLACHLOR. TRADE NAME: DUAL. CHEMICAL FAMILY: Acetanilide. CROP AND/OR NON-CROP REGISTRATIONS: Corn, soybeans, snap beans (yellow and green only), dry beans (white, kidney and pinto only), lima beans, potatoes. sugar beets and rutabagas. SENSITIVE WEEDS: Large and smooth crab grass; witch grass: barnyard grass; fall panicum; giant, green and yellow foxtail: yellow nutsedge; eastern black nightshade. UPTAKE AND TRANSLOCATION: Absorbed by germinating grasses mainly through shoot just above seed. Absorbed by germinating broadleaf weeds by roots and shoots. BASIS OF SELECTIVITY: Not established. APPLICATION METHODS: Preplan incorporated and preemergence. Early postemergence on corn (spike to two leaf stage of corn). Incorporation equipment should be set to work the soil 10 cm deep with a disc operating at 6-10 km/hr or a vibrating shank cultivator at 10-13 km/hr; one incorporation is sufficient and need not be immediate. Rainfall within 10 days is required for maximum activity of the preemergence application. RESIDUAL ACTIVITY: Activity will normally be maintained for 10-14 weeks. UNIQUE CHARACTERISTICS: The rate required depends on weed pressure (higher rate for heavier weed pressure). Yellow nutsedge control requires a preplant incorporated application. Winter cereals may be planted 4 to 5 months after metolachlor application. Many tank mix combinations are registered on various crops. Do not use on muck soils or coarse textured soils low in organic matter.

METOLACHLOR / ATRAZINE. TRADE NAME: PRIMEXTRA. CHEMICAL FAMILY: Acetanilide/ s-triazine. CROP AND/OR NON-CROP REGISTRATIONS: Corn (ensilage, field, seed and sweet). SENSITIVE WEEDS: Germinating annual broadleaf weeds and annual Brasses such as eastern black nightshade, lady's-thumb, lamb's-quarters, wild mustard, purslane, prostrate pigweed, redroot pigweed, wild buckwheat, smartweed, ragweed, crab Brass, barnyard grass. green (oxtail, yellow foxtail, giant fox-witch grass and fall panicum. Yellow nutsedge can be controlled with a preplant incorporated application. UPTAKE AND TRANSLOCATION: Mainly root uptake, with a small amount of shoot absorption. BASIS OF SELECTIVITY: Metabolism by tolerant species. APPLICATION METHODS: Preplant incorporated, preplant, preemergence and early postemergence (spike to 2 leaf). One incorporation is sufficient and need not be immediate. Incorporation equipment should be set to work the soil 10 cm deep with a disc operating at 6-10 km/hr or a vibrating shank cultivator at 10-13 km/hr. Rainfall within 10 days is required for maximum activity of the preemergence application. Metolachlor/atrazine may be applied in liquid fertilizers for preplant incorporated or preemergence weed control. Dry bulk granular fertilizers mar be impregnated with metolachlor/atrazine for preplant incorporation. RESIDUAL ACTIVITY: Activity will normally be maintained for 10-14 weeks; late germinating velvet- leaf and fall panicum will not be controlled. Soybeans, white beans, oats, or barley may be planted the following spring. UNIQUE CHARACTERISTICS: Will not control triazine-resistant weed species. Contains atrazine in low amounts which may carry over in a dry year. Is effective over a wide range of soil types and has a good margin of crop safety. Perennial weeds are not controlled.

METRIBUZIN. TRADE NAMES: LEXONE, SENCOR. CHEMICAL FAMILY: Triazine. CROP AND/OR NON-CROP REGISTRATIONS: Established asparagus, faba beans, potatoes, soybeans, transplant tomatoes and triazine-tolerant canota (rapeseed). SENSITIVE WEEDS: Lamb's-quarters, wild mustard, redroot pigweed, common ragweed, shepherd's-purse, lady's-thumb, velvetleaf, jimsonweed, prostrate pigweed. Russian thistle, yellow wood-sorrel. prickly mallow, chickweed, cocklebur, carpetweed. dandelion seedlings, barnyard grass, crab grass, foxtail, fall panicum, witch grass, Johnson grass seedlings and cheat crass. UPTAKE AND TRANSLOCATION: Some uptake through the foliage but the major route is via the roots. Translocation upwards in the xylem. BASIS OF SELECTIVITY: Degradation by tolerant species. APPLICATION METHODS: Preplant incorporated (potatoes, soybeans, tomatoes and triazine-tolerant canola); preemergence (asparagus. potatoes, soybeans and triazine-tolerant canota); postemergence (potatoes, tomatoes and triazine-tolerant Canola). RESIDUAL ACTIVITY: Varies with the climate. At normal use rates the half-life is one to two months. UNIQUE CHARACTERISTICS: Heavy rainfall following application may cause crop damage. Some varieties of potato, soybean and tomato are less tolerant than others. Triazine-resistant weeds are not controlled. Do not use on muck soils.

PARAQUAT/SIMAZINE. TRADE NAME: TERKAKLENE. CHEMICAL FAMILY: Bipyridylium/ triazine. CROP AND/OR NON-CROP REGISTRATIONS: Apples, pears, grapes, raspberries, highbush blueberries, asparagus, woody ornamentals and nursery stock, ,hchcr-belts and non-crop land. SENSITIVE WEEDS: Annual grasses and broadleaf weeds. UPTAKE AND TRANSLOCATION: Foliar absorption of paraquat but no translocalion: simazine is absorbed by roots, and translocated to leaves and shoots. BASIS OF SELECTIVITY: Used only on established plantings. APPLICATION METHODS: Foliar postemergence spray directed away from green bark and desirable foliage. For asparagus, apply after weed emergence but before crop emergence. The best foliage burn will result .hen applied on a dull or cloudy day, or in the evening. RESIDUAL ACTIVITY: Up to a year, depending on rate. UNIQUE CHARACTERISTICS: The mixture provides a rapid burn of existing green plant tissue and residual control of germinating weeds. Should be used only under established punts. Lower rates should be used on sandy soil.

PICLORAM/2.4-D. TRADE NAME: TORDON 101. CHEMICAL FAMILY: Pyridine/phenoxy. CROP AND/OR NON-CROP REGISTRATIONS: Weed and brush (including conifer) control in non-crop locations, industrial sites and rights-of-way. SENSITIVE WEEDS: Most broadleaf herbaceous weeds including Canada thistle, sweet and red clover. wild carrot, common ragweed, dandelion, goldenrod, dock, plantain, prickly lettuce, burdock, fleabane and vetch; deciduous and coniferous woody plants except white ash. UPTAKE AND TRANSLOCATION: Rapidly absorbed by the roots, stems and foliage. Translocation can be up or down. but like 2,4-D, accumulation is in young. rapidly growing meristematic tissue. BASIS OF SELECTIVITY: Effects on nucleic acid metabolism and growth are not observed in grasses and other tolerant species. APPLICATION METHODS: For deciduous and coniferous brush, apply either broadcast using a fixed nozzle (constant volume per hectare) or selectively using a spray gun (variable volume per hectare). As spray gun applications use a more dilute spray mix. this type of application must thoroughly wet the foliage, stem and root collar. Brush should be treated after foliage is well developed in spring or early summer. To ensure thorough coverage and minimize drift, brush to be treated should be less than 2.5 m tall. For cut surface treatment. mix with water or ethylene glycol (to reduce the freezing point. if necessary) and apply to cover the cambium layer of freshly cut stumps. For broadleaf herbaceous weeds, apply broadcast in spring or early summer after growth begins. RESIDUAL ACTIVITY: Soil residue carryover into the year following application is minimal when applied at recommended rates. Degradation is most rapid under warm, humid conditions. Because small residues of picloram in soil can be phytotoxic to crops such as soybeans, tobacco, tomatoes, potatoes, grapes, and many desirable ornamental plants, picloram may not to be applied to land used, or land that may be used, for the production of agricultural and horticultural crops. UNIQUE CHARACTERISTICS: A permit from the Ministry of the Environment is required for the purchase and use of picloram/2,4-D in Ontario. Picloram/2,4-D must not be applied over, or near, areas where roots of desirable trees or other plants may extend. Because spray drift is phytotoxic to sensitive plants, an approved drift control system or additive is recommended when making low volume applications adjacent to desirable.

PROMETRYNE. TRADE NAME: GESAGARD. CHEMICAL FAMILY: S-triazine. CROP AND/OR NON-CROP REGISTRATIONS: Potatoes, carrots, peas and transplanted celery. SENSITIVE WEEDS: Lamb's-quarters. lady's-thumb, corn spumy, pigweed, wild mustard, purslane, chickweed, hemp-nettle and green foxtail. UPTAKE AND TRANSLOCATION: Absorbed through foliage and roots. Translocated upwards through xylem accumulating in the apical meristems. BASIS OF SELECTIVITY: Metabolized by tolerant plants and to a lesser extent by sensitive plants, although this is not thought to be the major selective mechanism. APPLICATION METHODS: Preemergence or early postemergence (before weeds are 5 cm high). Apply before potatoes, carrots or peas emerge. Apply 7 to 14 days after celery is transplanted. RESIDUAL ACTIVITY: About 6 to 8 weeks. A fall cover crop of rye or oats may be sown on the treated land in the same season.

SIMAZINE. TRADE NAMES: PRINCEP NINE-T, SIMIADEX SIMAZINE FLOWABLE. CHEMICAL FAMILY: S-triazine. CROP AND/OR NON-CROP REGISTRATIONS: Corn; established asparagus, bird's-foot trefoil, raspberries, loganberries, blackberries, highbush blueberries; alfalfa, apples and pears established for one year or more; grapes established for three or more years; shelter belts established for at least one growing season (caragana, green ash, Siberian elm, American elm and Manitoba maple); new or established Christmas tree and woodland plantations (two year or older white pine and balsam fir); woody ornamentals and nursery stock established for at least one year (cedar. barberry, apple. flowering crabapple, box-wood, cotoneaster, dogwood, holly, rose, yews, chamaecyparis, hemlock, juniper, multiflora rose, peony, spruce, mugho pine, black walnut and white ash); aquatic weed control; non-crop land. SENSITIVE WEEDS: Annual broadleaf weeds such as pigweed, lady's-thumb, lamb's-quarters. purslane, ragweed. volunteer clover, wild buckwheat, smart-weed, plantain and groundsel; annual grasses such as barnyard grass, crab grass, wild oats and yellow foxtail (triazine-resistant biotypes of foxtail, lamb's-quarters, pigweed and groundsel will not be controlled); most perennial species starting freshly from seed; pond scums and filamentous algae such as *Chara* and *Nitella,* most emerged and submerged aquatic vegetation. UPTAKE AND TRANSLOCATION: Absorbed by roots; little or no foliar absorption; translocated upwards in xylem. accumulating in apical meristem and leaves. BASIS OF SELECTIVITY: Some species, such as corn, metabolize simazine. In most crops, selectivity is based on the roots of the crop plants being deeper than the depth to which simazine leaches. APPLICATION METHODS: Pre-plant incorporated (to a depth of 2.5 cm) or preemergence in corn; preemergence in other crops. Broadcast or band application. In fruit crops, apply a one metre wide band under the plants; cultivate or sod the area between the rows. For aquatic weed control, apply as a drawdown treatment or water volume application in drainage ditches and ponds with no water flow-through. RESIDUAL ACTIVITY: Soil residues may persist for more than one season. After spraying with simazine, do not plant any crop in the treated area in the same