STRATFORD-AVON RIVER ENVIRONMENTAL MANAGEMENT PROJECT

PHYSICAL CHARACTERISTICS AND LAND USES OF THE AVON RIVER DRAINAGE BASIN

Technical Report R-9

Prepared by:

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PREFACE

This report is one of a series of technical reports resulting from work undertaken as part of the Stratford/Avon River Environmental Management Project (SAREMP).

This two-year project was initiated in April 1980, at the request of the City of Stratford. SAREMP is funded entirely by the Ontario Ministry of the Environment. The purpose of the project is to provide a comprehensive water quality management strategy for the Avon River Basin. In order to accomplish this considerable investigation, monitoring and analysis has taken place. The outcome of these investigations and field demonstrations will be a documented strategy outlining the program and implementation mechanisms most effective in resolving the water quality problems now facing residents of the basin. The project is assessing urban, rural and in-stream management mechanisms for improving water quality.

This report results directly from the aforementioned investigations. It is meant to be technical in nature and not a statement of policy or program direction. Observations and conclusions are those of the authors and do not necessarily reflect the attitudes or philosophies of the agencies and individuals affiliated with the project. In certain cases the results presented are interim in nature and should not be taken as definitive until such time as additional support data is collected.

Reference to equipment, brand names or supplies in this publication is not to be interpreted as an endorsement of that particular product or supplier.

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ABSTRACT

The Avon River Drainage Basin, part of the North Thames Basin, occupies 165 km^2 (64 mi^2). Eight percent of its area is occupied by the City of Stratford, while agricultural activities take up 82% of the land area. The total population of the basin was about 27,000 in 1980.

Most of the basin straddles the Stratford Till Plain but its eastern extremeties extend into a moraine area. Productive silt-loam soils have developed from the parent materials - sandy silt till and lacustrine clays and silts. Sands and gravels occur in the moraine area and along the river valley.

The majority of area farms are livestock operations particularly beef or dairy cattle. Therefore, crop rotations with forage are most common. Continuous row crops are, however, an important cropping pattern in the basin, one with significant erosion and water quality implications. While manure application rates seem to be acceptable, winter applications are practiced by up to one quarter of the livestock operators. This could pose a threat to water quality. The quality of manure storage facilities vary from farm to farm and is closely related to the size of the livestock operation.

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I. INTRODUCTION

The Avon River is a small tributary of the North Thames River, located entirely within Perth County. Arising in a moraine area to the east and north-east of Stratford, it flows in a south westerly direction through a level till plain. Eventually it joins the North Thames River above the town of St. Marys. The drainage basin of the Avon River occupies 165 km^2 (64 mi^2).

Basin lands have experienced a long period of human settlement. Principle land uses are agricultural (82%) and urban (8%). The developed urban area of Stratford exerts a dominant influence on the Avon River due to its large size relative to the basin area. Even above Stratford however, the intensity of agricultural use results in a water course that is no longer a "natural" stream.

This report documents information describing the physical and human geography of the area -- including geologic data, soils data, drainage characteristics, population, land uses and agricultural practices. The information is organized in terms of drainage areas in the basin. The basic breakdown for these drainage areas, presented in Figure 1, was governed by the location of water quality sampling stations established for the Stratford-Avon River Environmental Management Project. Throughout most of the report these sub-basins are aggregated into upper and lower basins. The precise demarcation for these two areas is water quality station 6 in Stratford. More generally, the split coincides with the division of lands above and below Stratford and with the division of rural lands between Downie Township to the West and North Easthope, South Easthope and Ellice Township to the East (Figure 2).

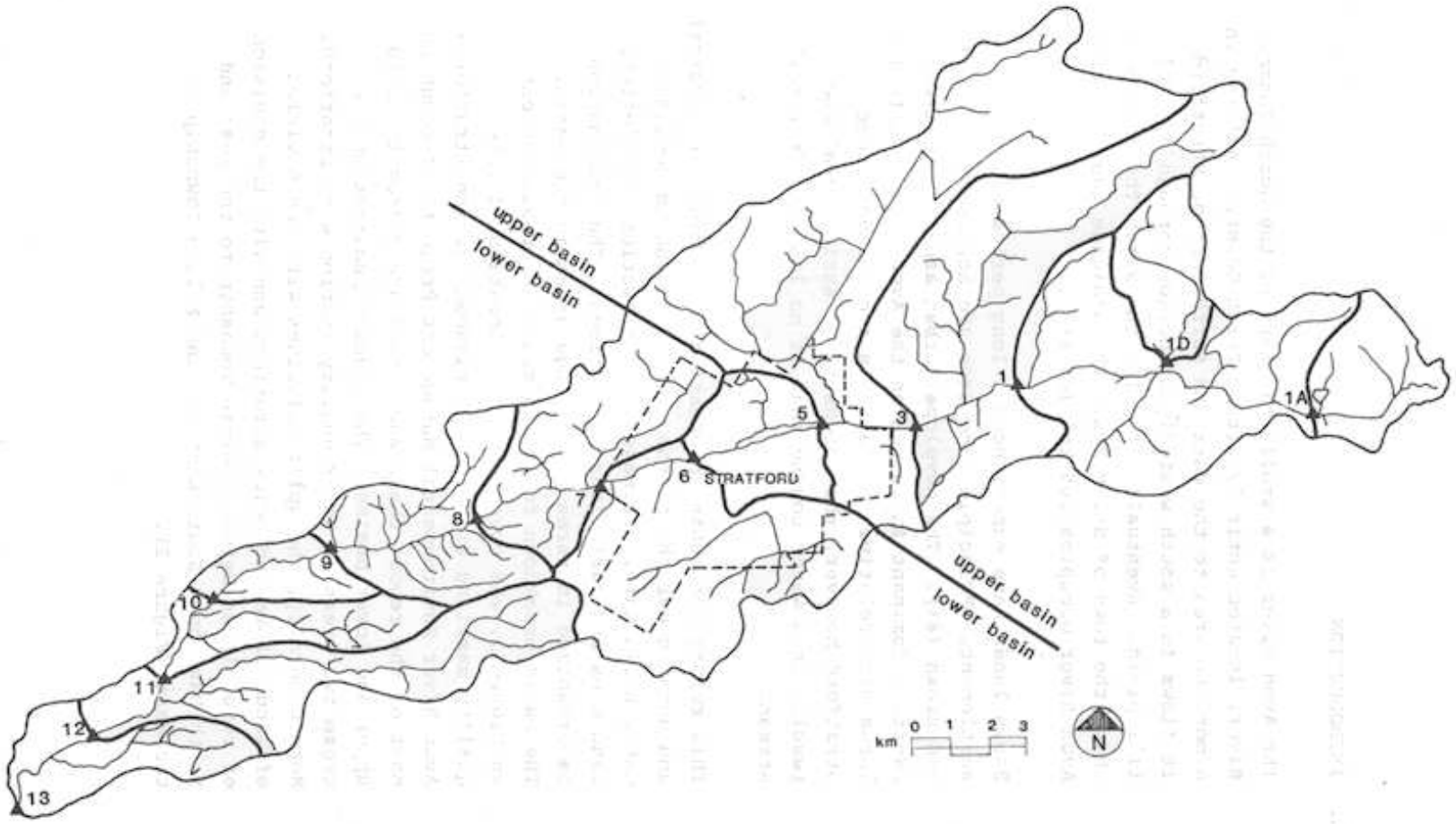

Figure 1: Delineation of Drainage Areas

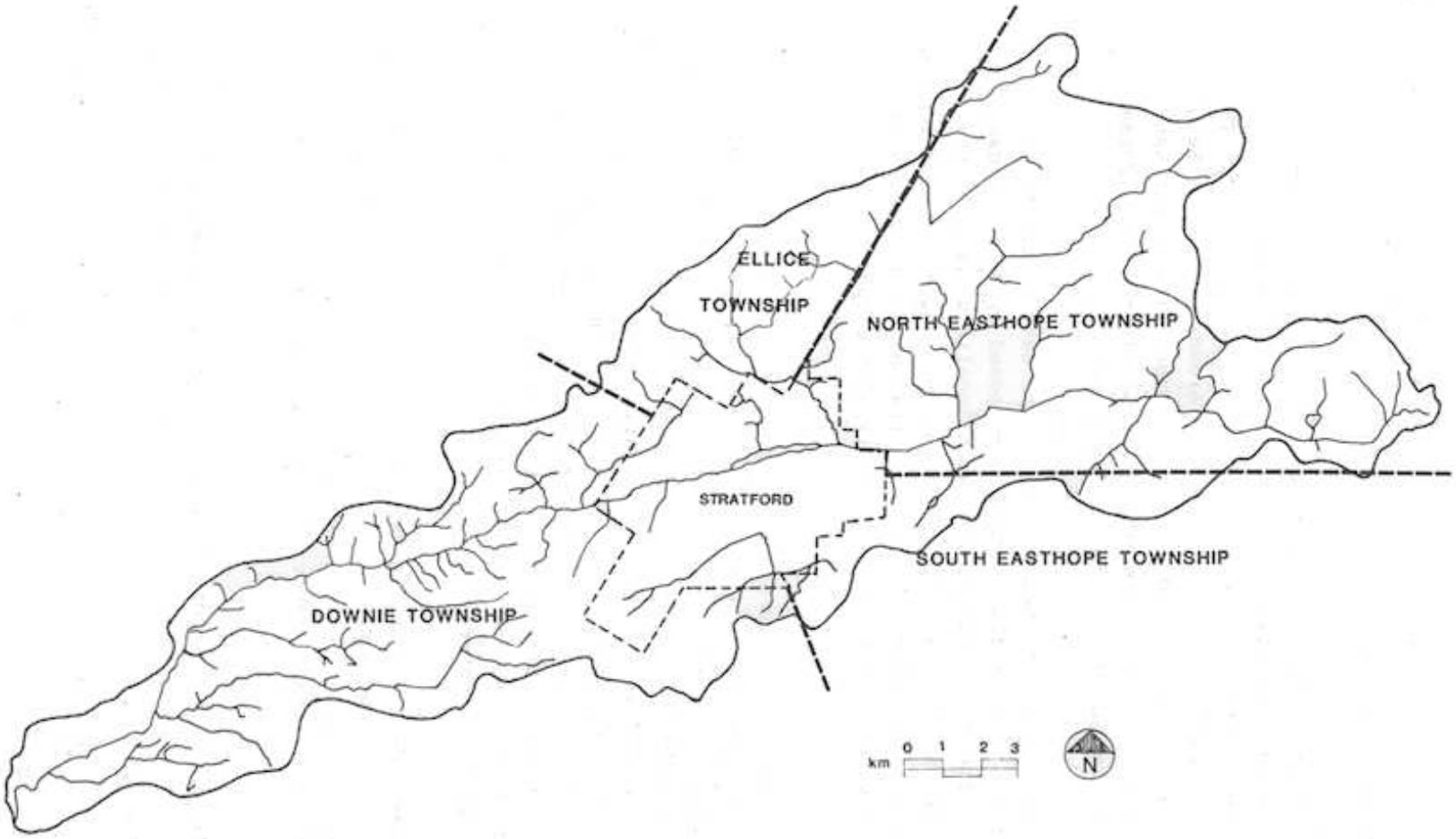

Figure 2: Political Jurisdictions

2. PHYSICAL CHARACTERISTICS

The lower basin comprises three separate bedrock formations. The Dundee formation lies in the extreme western portion of the basin. This formation consists of two layers. The upper member is composed of medium brown limestone. Below this is a layer of light brown limestone with quartz sand and chert. Most of the lower basin is in the Lucas Formation comprising Anderson member brown limestone.

The Amherstburg formation lies to the east of the Lucas Formation. Here the bedrock is composed of grey and dark brown limestone and dolomite with localized chert. This formation also covers most of the upper basin. Grey dolomite, limestone and chert characterize the Bois Blanc formation which covers the eastern extremity of the Upper basin (Figure 3) .

Principal land forms of the area are the Stratford Till Plain, which occupies most of the watershed, and, to the east, above Shakespeare, the Easthope moraine in the Waterloo Hills physiographic region. The Stratford Till Plain is a level to gently undulating till plain which slopes gently to the south-west. Local relief on the till plain is generally less than 3 meters (10 ft.). The Easthope moraine occupies the drainage area to the east of water quality station 1. Here the land is distinctly rolling, and relief can exceed 15 meters (50 ft.)

The Avon River arises in two swampy valleys or depressions in the Easthope moraine, the main one being the Gads Hill Swamp. It flows to the west following a narrow valley

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* Material in this section is taken from S.A.R.E.M.P. Technical Report No. S-13, and from Carroll 1981, Karrow 1971, Karrow 1977.

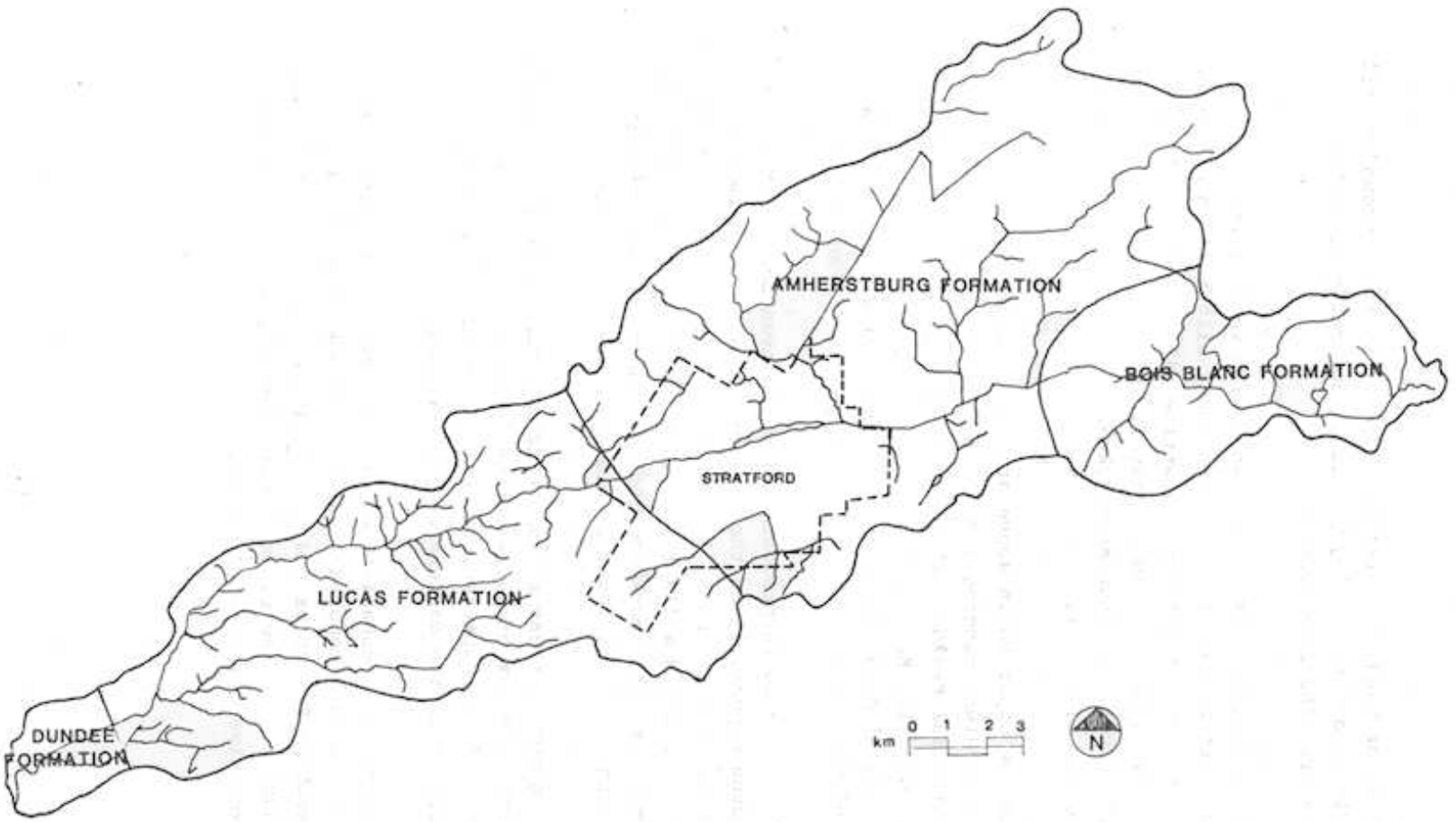

Figure 3: Bedrock Formations

associated with a former glacial spillway. Valley walls rise as much as 15 meters (50 ft.) to the surrounding till plain, and the valley itself is generally less than 300 meters (980 ft.) across.

Surficial deposits of the sub-basin west of station 1 consist largely of Stratford sandy silt till interspersed with large pockets of lacustrine silt and clay. Deposits of alluvial and outwash gravel, sand and silt occur along the river. Overburden thickness ranges from 15 (50 ft.) to 52m (170 ft.) .

In the upper basin above station 1, overburden thickness is greater, ranging from 37 (120 ft.) to 64m (210 ft.). Surficial geology is more complex with areas of silty to sandy till, Kame sand and Lacustrine silt and clay. Alluvial deposits occur along the main drains in the area, and there are local pockets of peat, muck and marl.

Silt loam soils predominate in the Avon basin. These are found especially on the flatter areas of the lower and upper basins. Sandy loams are found to the east in the moraine areas while to the west there are some clay loams. Small areas of muck and bottom land run along the main channel. Table 1 gives details of these soil types.

In general, these soils are imperfectly to poorly drained, with only 20% of the watershed considered well drained. As would be expected, these well drained areas are found largely in the eastern end of the basin.

Agricultural capabilities of these soils are quite high. Class 1 land comprises 60% of both Downie and North Easthope Townships and 50% of Ellice Township. About one quarter of these soils are in Class 2W, which indicates excessive moisture (Table 2).

TABLE 1. Soils Of The Avon Basin

Soil/Series		Hectares	Acres	% Watershed	
WELL DRAINED					
Huron Clay Loam	Huc	1437	3551	8.7	
Huron Silt Loam	Hus	217	536	1.3	
Harrison Silt Loam	Hsi	1111	2745	6.8	19.6
Waterloo Sandy Loam	Wsl	344	850	2.1	
Donnybrook Sandy Loam	Dsl	114	282	0.7	
IMPERFECTLY DRAINED					
Perth Silt Loam	Ps	8050	19892	48.9	
POORLY DRAINED					
Brookston Silt Loam	Bsl	3741	9244	22.7	
Gilford Loam	Gil	29	72	0.2	24
Parkhill Loam	Pl	182	450	1.1	
VERY POORLY DRAINED					
Muck	M	617	1525	3.8	
Bottom land	BL	617	1525	3.8	7.6
TOTAL		16462	40678		100

Source: Caldwell and Carroll, 1980

TABLE 2: Acreages Of Soil Capability For Agriculture*

Township	Class 1	Class 2	Class 3	Class 4	Class 5	Class 6	Class 7	Organic (0)	Totals
Downie	29,990	12,030	3,090	235	2,625	340	-	450	48,760
Easthope N.	25,795	2,625	8,775	65	4,035		-	2,430	43,725
Easthope S.	15,820	3,325	3,640	25	1,150	40	-	130	24,130
Ellice	24,075	23,105	3,555	75	2,050	115	-	3,135	56,110
Total Acres	95,680	41,085	19,060	400	9,860	495		6,145	172,725
Hectares	38,721	16,627	7,713	162	3,990	200		2,487	69,900

Source: Caldwell and Carroll, 1980

* Acreage values are for total township areas.

3. DRAINAGE NETWORK

As with many of Ontario's small agricultural watersheds, the Avon basin has had an intensive history of drainage engineering particularly in the early part of this century. In fact the main channel below Stratford is virtually the only remaining natural water course. The tributaries and that portion of the Avon River above Stratford have all been channelized at some time in the past.

As can be seen from drainage intensity figures in Table 3, the greatest rural drainage intensity is found in the lower basin where poorly drained soils are found.

Owing to the presence of storm sewers, the developed urban area is by far the most intensely drained area in the basin. As a result, the urban area seems to contribute a disproportionately large amount of baseflow to the river. For example, the 1980 summer baseflow at station 10 (Federal flow gauge - GD018) was estimated to be 0.35 m^3 sec^{-1} (12.5 $ft.^3$/sec.). In contrast, the estimated dry weather storm sewer flow for Stratford was 0.10 m^3 sec^{-1} (3 .5 $ft.^3$/s) and the sanitary effluent flow was 0.20 m^3 sec^{-1} (7.0 $ft.^3$/s).* This implies that the rural area above station 10, comprising 12,233 ha.(30,228 acres), yielded only 0.05 m^3 sec^{-1}(1.8 $ft.^3$/s) during dry weather episodes.

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* Characterization of Urban Dry Weather Loadings, SAREMP Technical Report U-3 (See Section 5. Agricultural Practices for format)

TABLE 3: Drainage Statistics For The Avon Basin

Sub-Basins (water monitoring stations)	Total Area (Ha)	Urban Area (Ha)	Length of Channel (m)			*Drainage Intensity (10^{-4} m^{-1})
			Avon	Primary Tributary	Other Tributaries	
1 (1A)	598	---	2736	1152		6.5
2 (1D)	567	---		5422		10.4
3 (0-1)	1868	---	2928	7742	7176	9.6
4 (1-3)	2378	---	2328	11160	13080	11.2
5 (3-5)	3527	152	1824	6192	34208	**12.5
6 (5-6)	---	658	2460 (1500=Lake Victoria)	130,200 (storm sewers)		not applicable
7 (6-7)	1899	446	1680	4327	13344	**13.8
8 (7-8)	1186	101	3000	9884	8112	**19.4
9 (8-9)	899	---	3120	5661	3200	13.3
10 (9-10)	360	---	2904	2352		14.6
11 (10-11)	650	---	2328	5472	1944	15.0
12 (11-12)	1204	---	1704	1344	18192	17.6
13 (12-13)	668	---	3240	5616		13.3
Total Rural	15105		27792	66824	99256	12.8

* Drainage Intensity (DI) = length of drains/drainage area (See Appendix 1 for British Units)

** For basin 5, 7 and 8 the DI calculation uses rural area only.

4. POPULATION

Considering the size of the Avon River basin and the relatively low flows that occur in the river, the basin is called upon to support a sizeable population - approximately 27,000 in 1980. Of this number, 26,300 resided in Stratford (Municipal Directory, 1982). The balance, 700 persons, are rural residents of Downie, North Easthope, South Easthope and Ellice Townships. The population density in Stratford is 19.4 persons per hectare (2.5 acres) while in the rural area there are 4.7 persons per 100 hectares (250 acres).

The rural population was estimated on the basis of the number of farm operations within the basin, 224 (Caldwell and Carroll, 1980) and the number of persons per household, 3.24, observed in Downie, Ellice and North Easthope Townships (estimated from data in the Municipal Directory, 1982). Each farm operation was assumed to correspond to one household in the basin.

Population growth in the rural townships which contain the Avon basin has been below 0.02% per year from 1971 to 1980. Over the same period, Stratford's population has grown at an average rate of 0.7% per year. In the past two years there has been no growth at all.

5. AGRICULTURAL PRACTICES *

The changes in agriculture which have generally occurred throughout Southern Ontario in the second half of this century have also had an impact within the Avon River watershed. New technology and mechanization has contributed to the specialization of enterprise type and an increase in scale of operation. The traditional mixed farming operation comprised of a small dairy herd, some beef cattle, a few pigs, some hens and a regular crop rotation has, in many instances, been replaced by large-scale operations. These include cash cropping operations where, for example, continuous corn is grown, or large-scale livestock operations where expensive methods of waste management are required. Evidence of these changes can be found in the fact that farmers in the basin are expanding the land base of their operation; out of 224 operators, 52 rent or own lots other than their principal "home" farm (Figure 4). Generally these changes have increased the potential for erosion problems and water quality impairment.

The following section will examine the patterns of agriculture in the Avon watershed and some of the relationships between physical factors, land use and water quality problems.

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* The material in this section is drawn from Caldwell and Carroll, 1980 and Carroll, 1981.

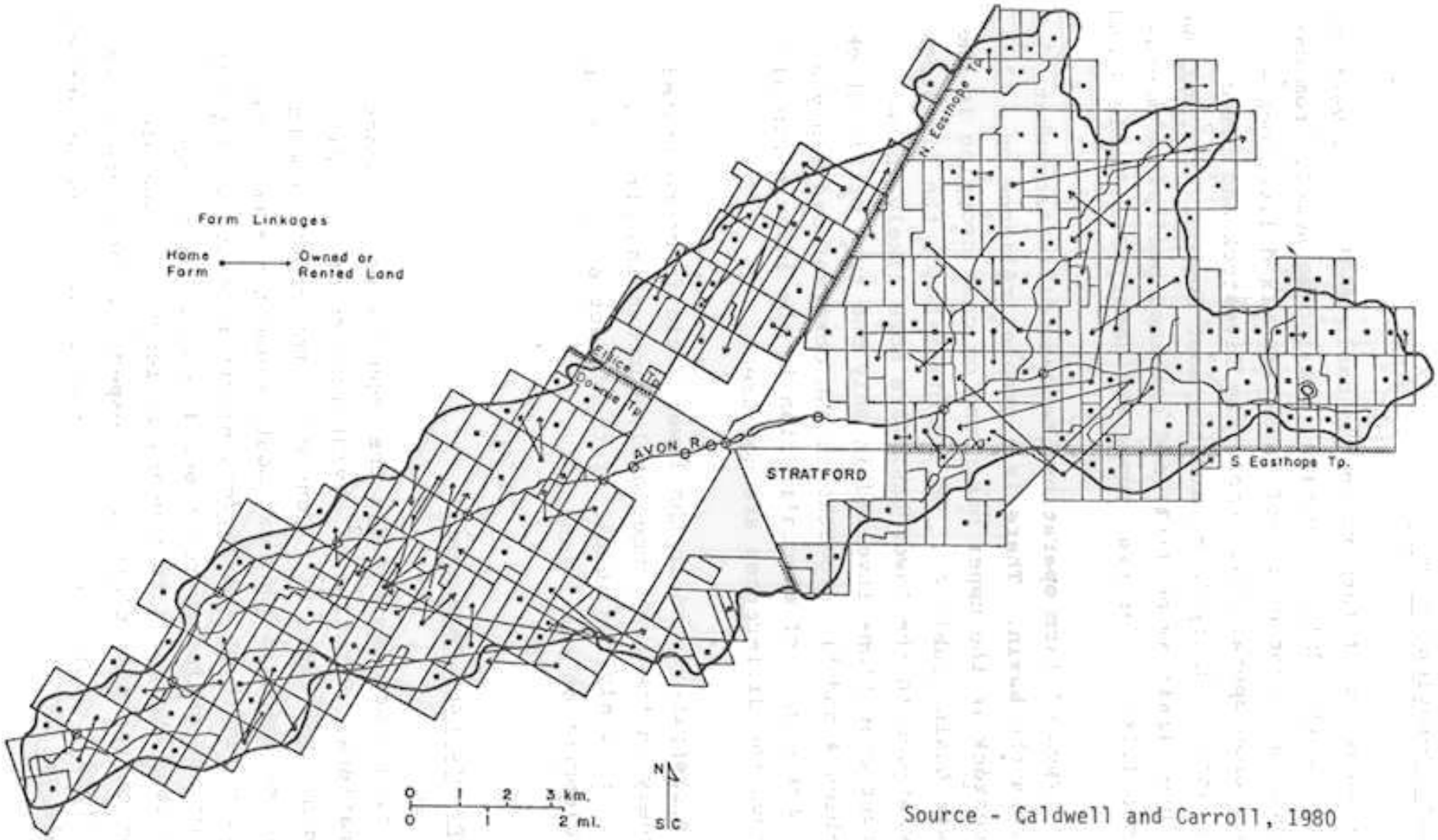

Figure 4: Farm Units

5.1 Farm Operations By Type

The majority of farmers in the basin (63%) run livestock operations. Only 16% derive farm income solely from cash crops, and another 18% of farms are mixed livestock - cash crop operations. Among the livestock and mixed operations, dairy farms are the most common (31%) followed by beef (16%) swine (16%) and combined beef-swine operations (11%). Operation types are detailed in Table 4 and 5.

The types of farm operations tend to differ somewhat across the basin. There is a greater reliance on livestock in the upper basin and on cash cropping in the lower basin (Table 4). On the other hand, the livestock operations in the lower basin are more likely to be larger operations involved in only one type of livestock (Tables 4 and 5). Together these observations imply a greater degree of specialization in the lower basin although the differences are not great.

Cash cropping found in the lower basin is concentrated largely in the area immediately surrounding Stratford This is likely the result of the impact of urban fringe development on rural land.

5.2 Crops and Crop Management

Cropping practices reflect the emphasis on livestock operations. Rotation of hay/grain/corn or hay/grain predominate (Table 6). Continuous row cropping with corn and beans is the next most frequent system. The average length of the hay/grain/corn rotation is 9 years and of the grain/hay rotation, 8 years. Cash crop rotations average 4 to 6 years in length. Beans are grown on the till plain areas, especially near and below Stratford. Grains and hay are more common above Stratford. (Table 7).

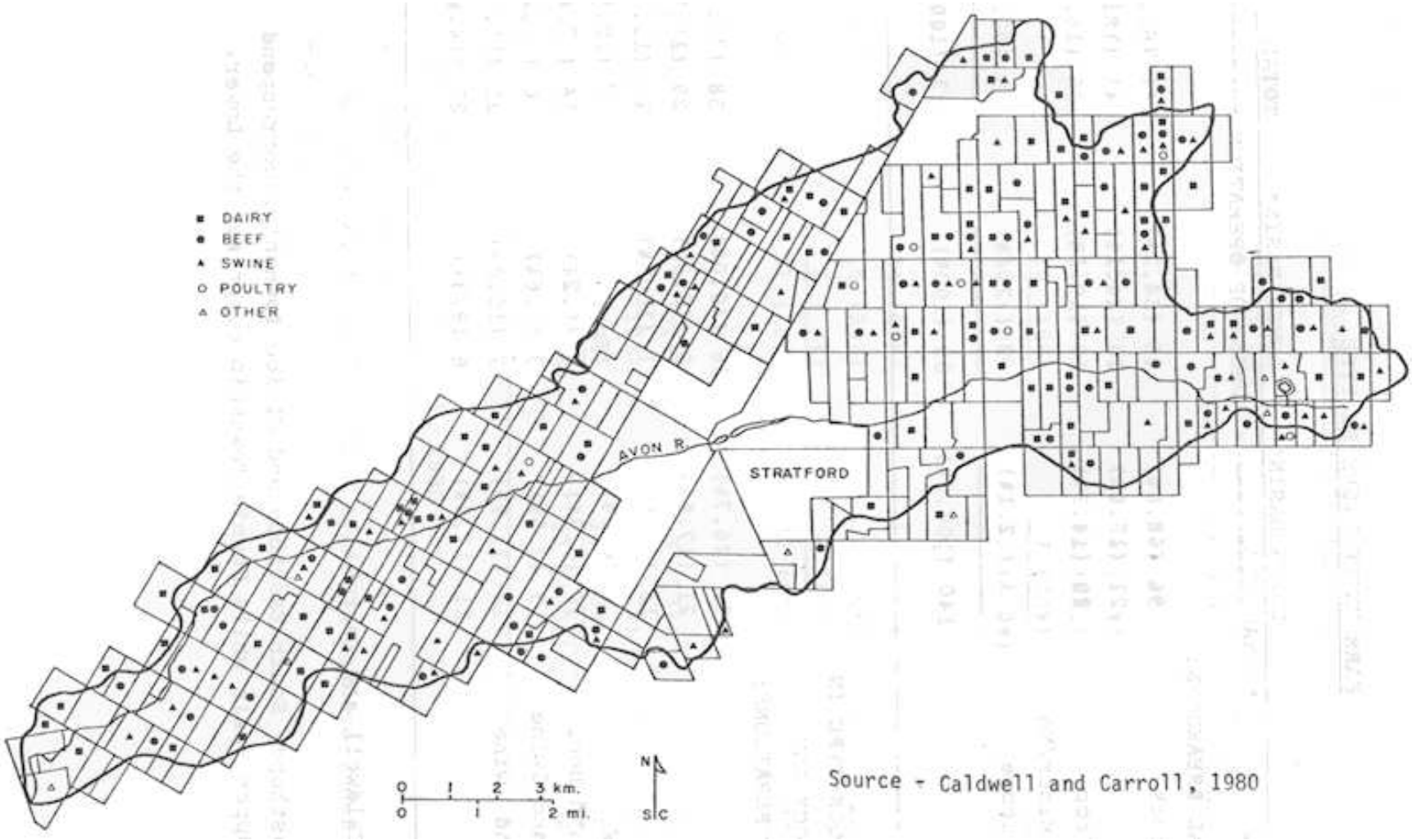

Figure 5: Livestock Operations

TABLE 4: FARM ENTERPRISES BY TYPE

		UPPER BASIN*		LOWER BASIN*		TOTAL	
		- - - - - - - - NUMBER OF OPERATIONS - - - - - - - -					
A)	GENERAL BREAKDOWN:						
	Livestock	96	(68.6%)	45	(54.2%)	141	(63.2%)
	Mixed	21	(15.0%)	20	(24.1%)	41	(18.4%)
	Cash Crop	20	(14.3%)	16	(19.3%)	36	(16.2%)
	Other/Minor/No Farm Income	3	(2.1%)	2	(2.4%)	5	(2.2%)
	Total	140	(100.0%)	83	(100%)	223	(100.0%)
B)	Livestock Type in Livestock and Mixed Operations:						
	Dairy	32	(26.7%)	26	(40.0%)	58	(31.4%)
	Beef	21	(17.5%)	8	(12.3%)	29	(15.7%)
	Swine	18	(15.0%)	11	(16.9%)	29	(15.7%)
	Poultry	1	(0.8%)	--		1	(0.5%)
	Dairy and Beef	10	(8.3%)	4	(6.2%)	14	(7.6%)
	Dairy and Swine	3	(2.5%)	3	(4.6%)	6	(3.2%)
	Beef and Swine	14	(11.7%)	7	(10.8%)	21	(11.4%)
	Other	21	(17.5%)	6	(9.3%)	27	(14.6%)

Source: Caldwell and Carroll

* North Easthope, South Easthope and Ellice Townships correspond to the Upper Basin while Downie Township comprises the Lower Basin.

TABLE 5: Livestock Operations By Size

	UPPER BASIN*		LOWER BASIN*		TOTAL BASIN	
	- - - - - - - - - -		NUMBER OF OPERATIONS**		- - - - - - - - - -	
Dairy						
1-25	15	(27%)	6	(17%)	21	(23%)
26-75	31	(55%)	22	(63%)	53	(58%)
76 +	10	(18%)	7	(20%)	17	(19%)
Total	56	(100%)	35	(100%)	91	(100%)
Beef						
1-50	34	(67%)	11	(55%)	45	(63%)
50-150	15	(29%)	7	(35%)	22	(31%)
151 +	2	(4%)	2	(10%)	4	(6%)
Total	51	(100%)	20	(100%)	71	(100%)
Swine						
1-100	14	(31%)	3	(13%)	17	(25%)
101-300	7	(16%)	4	(17%)	11	(16%)
301 +	24	(53%)	16	(70%)	40	(59%)
Total	45	(100%)	23	(100%)	68	(100%)

Source: Caldwell and Carroll, 1980

* See note to Table 4.

** An operator with two livestock types is counted under each type.

TABLE 6: Cropping Systems

SYSTEM	UPPER BASIN*		LOWER BASIN*		TOTAL BASIN	
	- - - - - - - NUMBER OF OPERATIONS - - - - - - -					
Continuous Row Crops	17	(12%)	15	(18%)	27	(12%)
Continuous Grain	4	(3%)	2	(2%)	6	(3%)
Continuous Hay/ Pasture	5	(4%)	1	(1%)	6	(3%)
Corn/Hay	3	(2%)	4	(5%)	7	(4%)
Grain/Hay	22	(15%)	3	(4%)	25	(11%)
Grain/Corn	14	(10%)	7	(8%)	21	(9%)
Corn/Hay/Beans	1	(1%)	1	(1%)	2	(1%)
Grain/Corn/Beans	4	(3%)	7	(8%)	11	(5%)
Grain/Hay/Beans	1	(1%)	1	(1%)	2	(1%)
Grain/Hay/Corn	68	(48%)	39	(46%)	107	(47%)
Grain/Hay/Corn/Beans	2	(1%)	5	(6%)	7	(3%)
Sod	1	(1%)	--	(0%)	1	(0.4%)
Total	142		85		227	

* See note to Table 4.

TABLE 7: Rural Land Use and Cropping in 1980

SUB-BASINS (Water Monitoring Stations)	1,2,3 (1A,1D,1)	4,5,6 (1 to 6)	7 to 13 (6to 13)	Total
GENERAL LAND USES (Ha)				
Total	3033	6563	6866	16462
Urban	----	810	547	1357
Rural	3033	5753	6319	15105
GENERAL LAND USES (Acres)				
Total	7495	16217	16966	40678
Urban	----	2001	1352	3353
Rural	7495	14216	15614	37325
SPECIFIC LAND USES				
Wood lots	311 (10%)	824 (14%)	475 (8%)	1610 (11%)
Pasture	390 (13%)	405 (7%)	471 (7%)	1266 (8%)
Crops				
Hay	484 (16%)	1213 (21%)	1140 (18%)	2837 (19%)
Corn	1190 (39%)	1906 (33%)	2703 (43%)	5799 (38%)
Small grains	571 (19%)	1314 (23%)	767 (12%)	2652 (18%)
White beans	----	70 (1%)	593 (9%)	663 (4%)
Other	86 (3%)	20 (0.3%)	171 (3%)	277 (2%)
TILE DRAINAGE (Ha) *	1640 (54%)	3152 (55%)	4761 (75%)	9553 (63%)
NUMBER OF BARNS	8	93	130	231

* Percentage values are of rural areas.

Tile drainage of fields is a common practice in the basin, covering over 60% of the crop land. Tiling is most prevalent on the till plain below Stratford to accommodate intensive cropping on poorly drained soils. Tile drainage above station 1 is focussed on low-lying areas and pockets of heavier organic soil found there. However, most of the soils in this area are well drained.

Cropping patterns in the lower basin and in the moraine area above station 1 are very similar. Corn is the predominant crop followed by small grains and hay in roughly equal proportions (Table 7). The till plain area of the upper basin shows the same general pattern, but proportionately less corn is planted in favour of more hay and small grains.

The similarity of cropping patterns in the lower basin till plain and the more erosive moraine area above station 1 suggests that erosion has not been an influential factor in crop selection.

An almost universal tillage practice in the Avon watershed is fall plowing with a moldboard plow. While approximately 7% of the farm operators make use of a chisel plow, the majority of these follow with a moldboard plow. Another fairly common practice in the fall is to either disc or cultivate prior to or following plowing. Secondary tillage in the spring usually involves 2-3 passes with a cultivator. On the final pass over the field a spike tooth harrow is attached. Discs are also used, especially when the field was in sod the previous year. Harrowing often follows seeding of the field in small grains. There are, however, various alternatives used by individual farm operators in the work of their fields.

The use of fertilizers is another almost universal practice throughout the Avon watershed. Two of the most popular fertilizers are 8-32-16 and 15-15-15. On grain, the application rates tended to vary between 100-200 lbs/acre and on corn, 150-250 lbs/acre. In some instances, especially on continuous corn, the application rates appear excessive, with the total amount of inorganic fertilizer ranging up to 600 lbs/acre. It should be noted, however, that these are only broad generalizations as both the analysis and rate of application vary significantly.

5.3 Manure Generation And Management

The generation and management of manure is an important issue since so many basin farms are livestock operations. Estimates of manure generation and application rates were developed using farm inventory data and typical levels of waste output (Carroll 1981, pg. 26-29). Results of this analysis, expressed in terms of animal units of waste, are depicted in Figures 6 and 7 and summarized in Table 8.

In the upper basin there are 68.2 animal units per livestock operation compared to 70.2 units in the lower basin. Of the 185 livestock and mixed operations in the basin, 93 produce fewer than 50 animal units per year while 12 produce more than 150.

Manure application rates are depicted in Figure 5 using three categories for rates of application: less than the optimum rate, between optimum and maximum acceptable rates, greater than maximum acceptable rates. These rates, defined by the **Agricultural Code of Practice**, relate to nutrient requirements for corn and consider soil type.

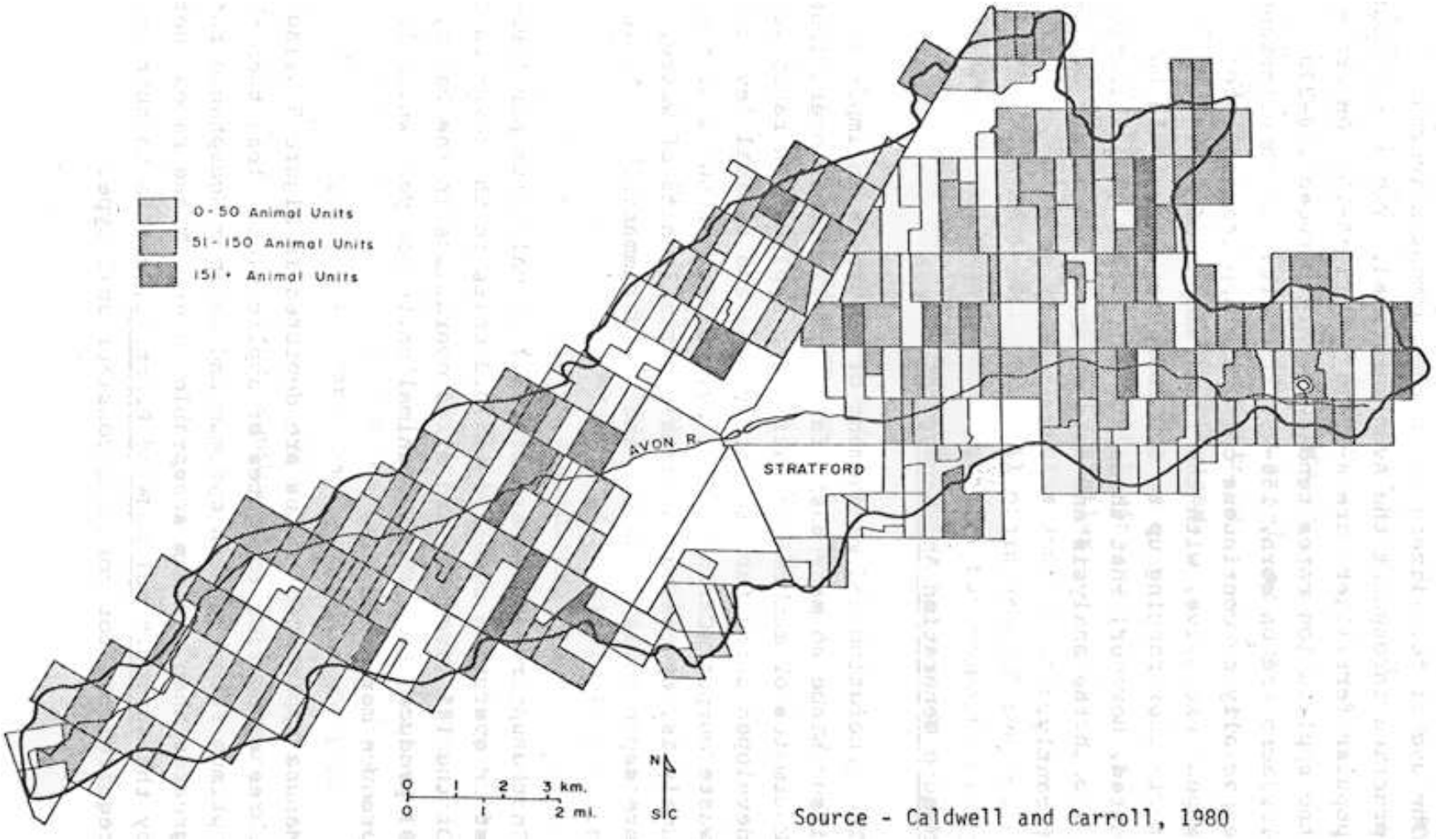

Figure 6: Manure Generation Rates

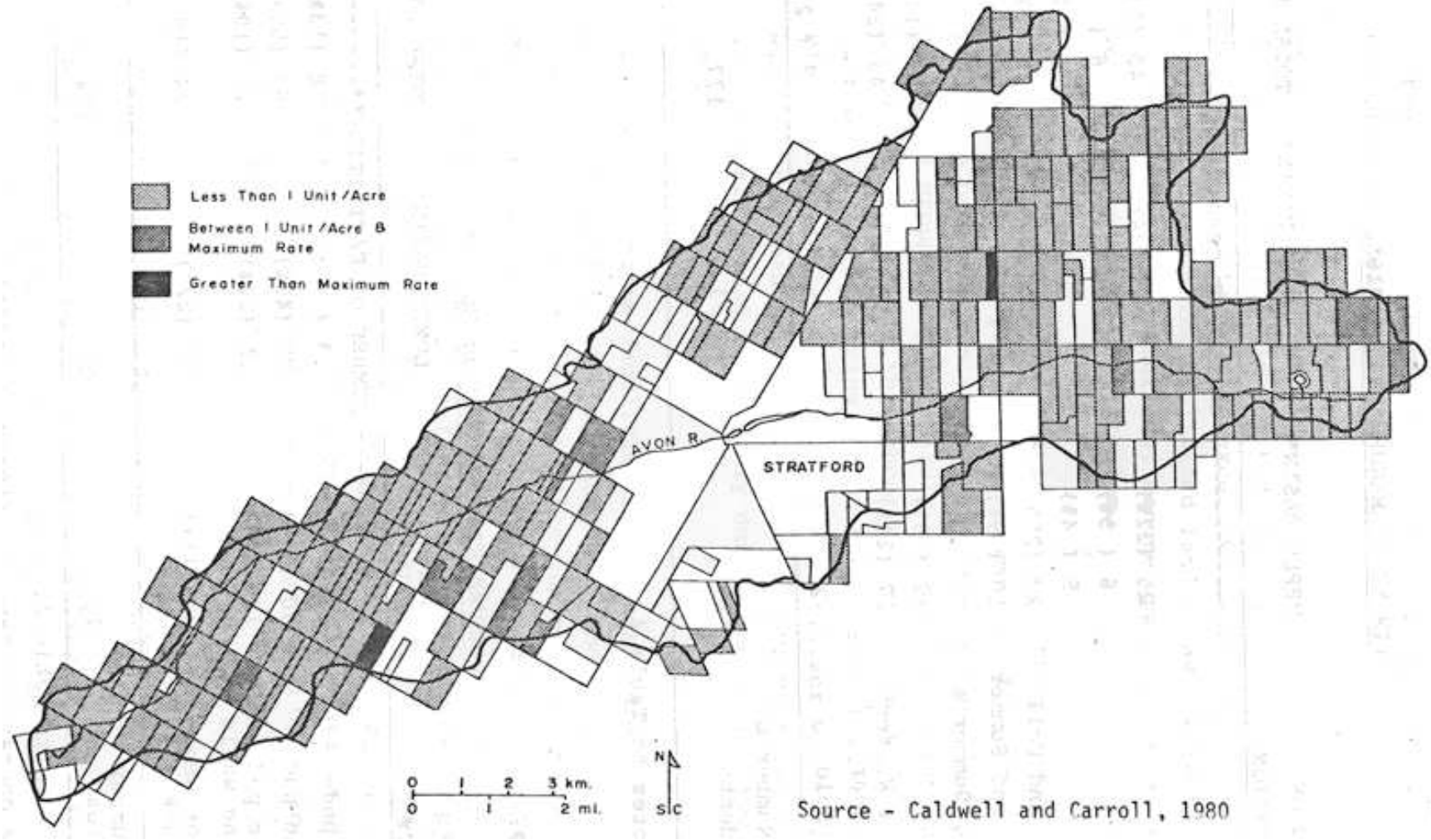

Figure 7: Manure Application Rates

TABLE 8: Timing Of Manure Applications

SEASON OF APPLICATION	UPPER BASIN*		LOWER BASIN*		TOTAL BASIN	
	- - - - - - - - NUMBER OF OPERATIONS - - - - - - - -					
Spring	25	(22%)	15	(24%)	40	(23%)
Summer	6	(5%)	--	(0%)	6	(3%)
Fall	5	(4%)	2	(3%)	7	(4%)
Spring and Fall	29	(25%)	19	(30%)	48	(27%)
Spring and Summer	10	(9%)	3	(5%)	13	(7%)
Spring, Summer & Fall	10	(9%)	7	(11%)	17	(10%)
Spring & Winter or All Year	27	(24%)	16	(25%)	43	(24%)
Manure Sold	2	(2%)	1	(2%)	3	(2%)
Total Number of Respondents	114		63		177	

* See notes to Table 4

TABLE 9: Manure Storage Facilities

STORAGE FACILITY	UPPER BASIN*		LOWER BASIN*		TOTAL BASIN	
	- - - - - - - NUMBER OF FACILITIES** - - - - - - - -					
ground pad	13	(16%)	5	(9%)	18	(13%)
concrete pad	40	(51%)	27	(49%)	67	(50%)
concrete pad with retaining walls	14	(18%)	11	(20%)	25	(19%)
liquid or semi- solid tank	12	(15%)	12	(22%)	24	(18%)
Total Number of Facilities	79		55		134	

* See note to Table 4.

** Some operations have two storage facilities.

In the case of the maximum rate, nutrient inputs exceed the adsorptive capacity of the soil.

Only 1% of the farms considered had rates in excess of the maximum rates while 93% had application rates below the optimum. Those farms with excessive rates were swine enterprises operating on limited land areas. With the exceptions of these operations, manure application rates would not appear to be a problem.

The timing of manure application reveals that while few farmers may be applying excessive amounts of manure, pollution problems can arise as a result of application on frozen ground. Approximately one quarter of the farmers using manure apply it throughout the year (Table 8). Nutrient losses occurring during spring runoff will contaminate water courses and lower the fertilizer value of winter-spread manure. However, the majority of farmers in the basin spread manure only during the spring and fall.

Half of the storage facilities in the basin are simple concrete pads (Table 9 and Figure 8). Those will prevent some leaching of contaminants into the surrounding soil and water table but do not contain seepage and runoff from the manure pile. Retaining walls or liquid storage tanks, which comprise 37% of the facilities, do control seepage and runoff when well designed and managed. Ground pads make up the remainder of storage facilities. As would be expected, ground pads are found on small operations while liquid storage tanks are used on large scale operations, particularly with swine.

5.4 Farming Practices Along Major Water Courses

The Avon River flows along a narrow valley of outwash sands and gravels and alluvial

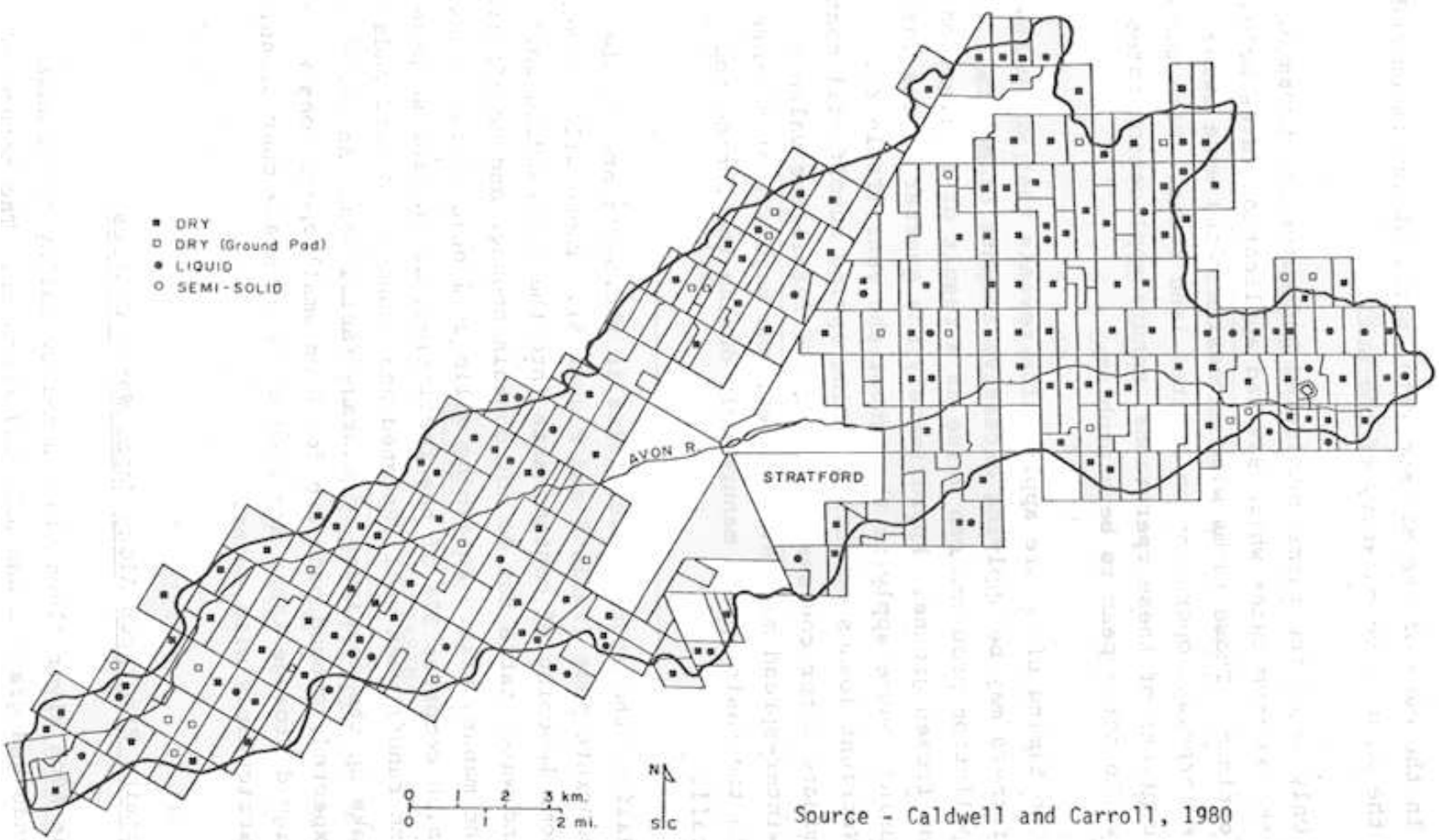

Figure 8: Manure Storage Facilities

deposits. The nature of the soils developed from these materials and the relatively steeply sloping topography have resulted in a low intensity use for these lands. Permanent pasture and wood-lots are the predominant land use. Frequently the pasture areas bordering the river are associated with livestock barns.

This pattern of land use repeats itself along certain of the tributary drains especially in the upper basin. In general, however, cropping is more frequent in fields bordering tributary drains in the basin since these drains run through more productive land than the bottom lands along the main branch.

The presence of pastures and associated livestock barns along the river pose a pollution threat. Direct contamination can result from cattle that are allowed to water in the stream while pasturing. In addition, runoff of snow melt and rainwater from barn yards, manure piles and heavily pastured land can carry nutrient and bacterial contaminants into the river. The farm inventory data and associated chronoflex maps were reviewed to identify potential problem sites. Results of this preliminary analysis are depicted in figures 9 and 10.

Identified livestock barns are those within 125 meters (410 ft.) of watercourses with manure stored in the ground or on a concrete pad without a retaining wall. While these results cannot be used to pinpoint specific sources since they have not been ground proofed, they do suggest that cattle access sites and runoff from manure storage areas could be important sources of contamination.

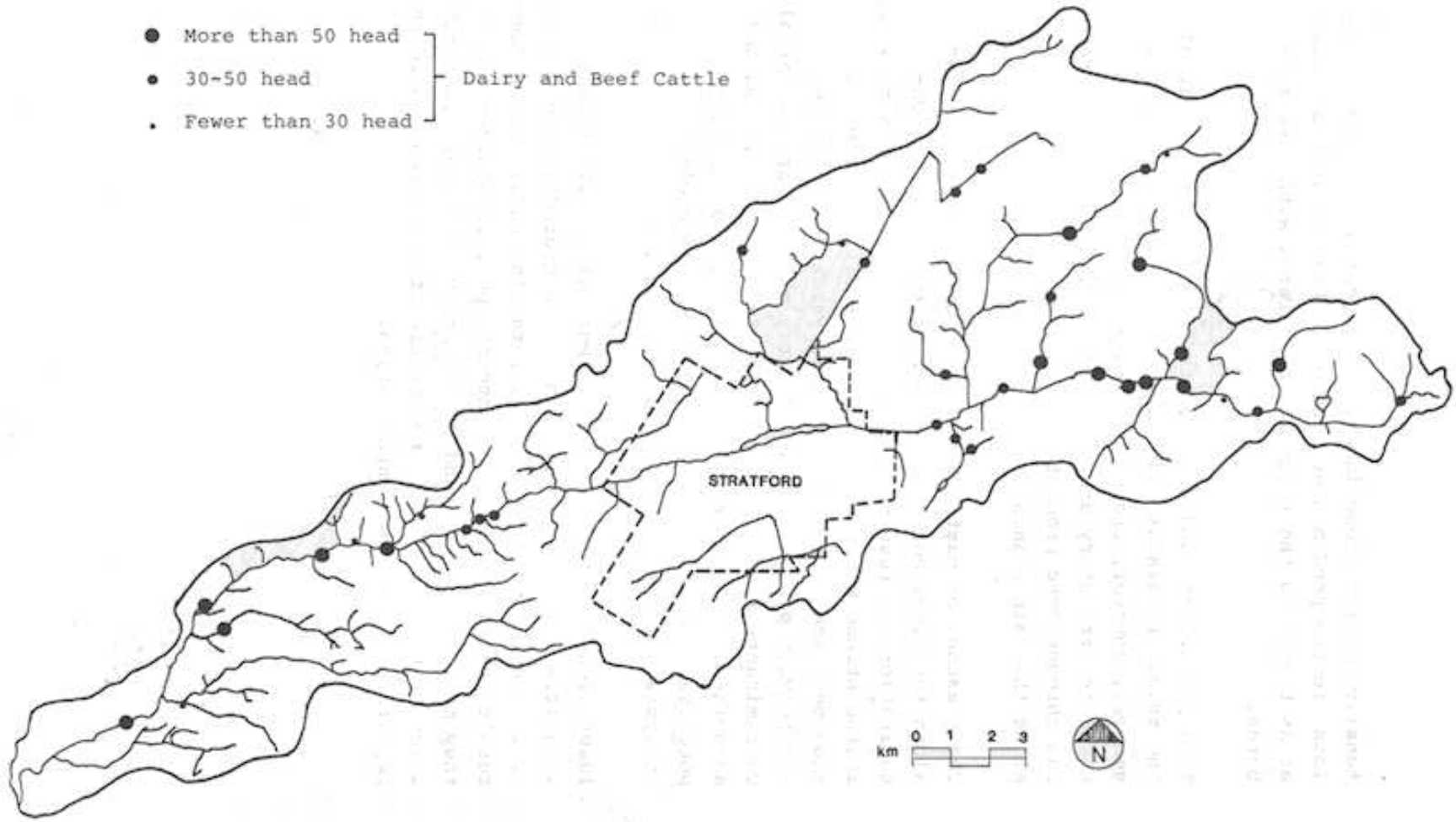

Figure 9: Cattle Access Sites

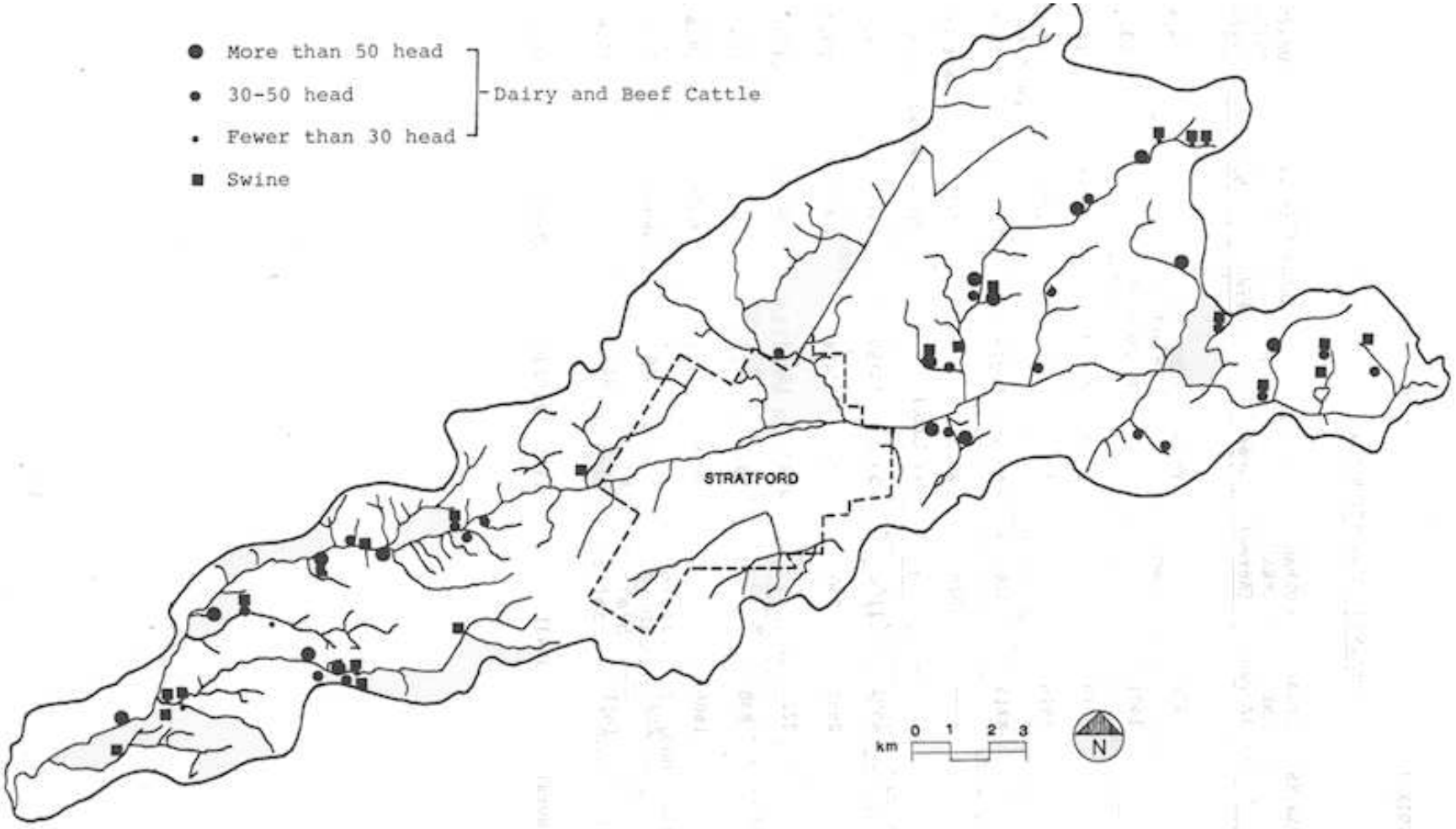

Figure 10: Livestock Barns Near Major Water Courses

APPENDIX 1: Drainage Statistics For The Avon Basin

Sub-Basins	Total Area (Acres)	Urban Area (Acres)	Length Of Channel (ft.)			Drainage Intensity (ft/acre)
			Avon	Primary Tributaries	Other Tributaries	
1	1478		8976	3780		8.6
2	1401			19429		13.9
3	4616		9606	25400	23543	12.7
4	5876		7638	36614	42913	14.8
5	8715	376	5984	20315	112231	16.5
6	----	1626	8070 (4921=Lake)		127165 (Storm Sewers)	Not Applicable
7	4692	1102	5512	14196	43780	17.6
8	2931	250	9843	32428	26614	25.7
9	2221		10236	18573	10499	17.6
10	890		9518	7717		19.3
11	1606		7638	17953	6378	19.8
12	2975		5591	4409	59685	23.3
13	1651		10630	18425		17.6
Total Rural		38431	91181	219239	325643	16.5

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STRATFORD-AVON RIVER ENVIRONMENTAL MANAGEMENT PROJECT
LIST OF TECHNICAL REPORTS

S-1 Impact of Stratford City Impoundments on Water Quality in the Avon River
S-2 Physical Characteristics of the Avon River
S-3 Water Quality Monitoring of the Avon River - 1980, 1981
S-4 Experimental Efforts to Inject Pure Oxygen into the Avon River
S-5 Experimental Efforts to Aerate the Avon River with Small In-stream Dams
S-6 Growth of Aquatic Plants in the Avon River
S-7 Alternative Methods of Reducing Aquatic Plant Growth in the Avon River
S-8 Dispersion of the Stratford Sewage Treatment Plant Effluent into the Avon River
S-9 Avon River In-stream Water Quality Modelling
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U-1 Urban Pollution Control Strategy for Stratford, Ontario - An Overview
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U-7 Characterization and Control of Urban Runoff
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R-1 Agricultural Impacts on the Avon River - An Overview
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R-4 Identification of Priority Management Areas in the Avon River
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R-6 Open Drain Improvement
R-7 Grassed Waterway Demonstration Projects
R-8 The Controlled Access of Livestock to Open Water Courses
R-9 Physical Characteristics and Land Uses of the Avon River Drainage Basin
R-10 Strip cropping Demonstration Project
R-11 Water Quality Monitoring of Agricultural Diffuse Sources
R-12 Comparative Tillage Trials
R-13 Sediment Basin Demonstration Project
R-14 Evaluation of Tillage Demonstration Using Sediment Traps
R-15 Statistical Modelling of In-stream Phosphorus
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R-17 Institutional Framework for the Control of Diffuse Agricultural Sources of Water Pollution
R-18 Cropping-Income Impacts of Management Measures to Control Soil Loss
R-19 An Intensive Water Quality Survey of Stream Cattle Access Sites