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Technical Information

Symbols and Abbreviations

The following standard symbols are used in Statistics Canada publications:

- .. figures not available
- ... figures not appropriate or not applicable
- — nil or zero
- -- amount too small to be expressed
- p preliminary figures
- r revised figures
- x confidential to meet secrecy requirements of the Statistics Act

Prefixes of the International System of Units

prefix	Multiplication Factor	
peta	10^{15}	1 000 000 000 000 000
tera	10^{12}	1 000 000 000 000
giga	10^{9}	1 000 000 000
mega	10^{6}	1 000 000
kilo	10^{3}	1 000
hecto	10^{2}	100
deca	10^{1}	10
deci	10^{-1}	0.1
centi	10^{-2}	0.01
milli	10^{-3}	0.001
micro	10^{-6}	0.000001
nano	10^{-9}	0.000000001
pico	10^{-12}	0.000000000001

Energy Conversion Factors

1 barrel = .15891 cubic metres
1 ton = .9071847 metric tonnes

Fuel type	Natural unit	Multiplier
		terajoules
Coal: Anthracite	kilotonnes	29.53
Imported bituminous	kilotonnes	29.99
Canadian bituminous	kilotonnes	23.81
Sub-bituminous	kilotonnes	19.76
Lignite	kilotonnes	15.35
Coke	kilotonnes	28.83
Coke oven gas	gigalitres	18.61
Propane	megalitres	25.53
Butane	megalitres	28.62
Ethane	megalitres	18.36
Crude oil	megalitres	38.51
Still gas	megalitres	41.73
Motor gasoline	megalitres	34.66
Kerosene	megalitres	37.68
Diesel	megalitres	38.68
Light fuel oil	megalitres	38.68
Heavy fuel oil	megalitres	41.73
Petroleum coke	megalitres	42.38
Aviation gasoline	megalitres	33.52
Aviation turbo fuel	megalitres	35.93
Natural gas	gigalitres	37.97
Electricity	gigawatt hours	3.6
Steam	kilotonnes	2.75
Solid wood wastes	kilotonnes	18.00
Spent pulping liquor	kilotonnes	14.00

Abbreviations

1986$	1986 constant dollars
°C	degrees Celsius
cm	centimetre
ha	hectare
hr	hour
kg	kilogram
km	kilometre
km^2	square kilometres
kPa	kilopascals
kt	kilotonne
l	litre
m	metre
m3	cubic metre
MCm	million cubic metres
mg	milligram
mm	millimetre
Mt	megatonne
ng	nanogram
nec	not elsewhere classified
ppb	parts per billion
ppm	parts per million
SIC	Standard Industrial Classification
t	metric tonne
µg	microgram

Introduction

Understanding changes in environmental quality in Canada demands a wide variety of information to portray environmental change, its causes and its impacts. Physical and biological data, compiled by scientific, environmental and natural resource agencies, contribute to the evaluation of water, air, land and biotic resources. Social and economic data on population, agriculture, manufacturing, transportation and energy are essential in describing the role human activities play in the process of environmental change.

Environmental Perspectives: Studies and Statistics is a new publication for disseminating the results of surveys and data development projects related to the environment. It brings together data from a variety of sources including surveys undertaken by Statistics Canada, the agency's Environmental Information System, and other government and non-government databases. The publication will appear between issues of the quinquennial *Human Activity and the Environment* which was last published in 1991[1].

Whereas *Human Activity and the Environment* is a comprehensive compendium of environmental data, this publication should be seen more as a selection of data and analysis that reflect the progress of Statistics Canada in developing a more complete set of environmental accounts and underlying data bases. The topics covered in this volume have not been chosen to provide a balanced view of environmental conditions and related activities, but rather to fill perceived gaps in the environmental information system.

This edition of the publication covers five general themes. Chapters 1 through 4 relate to the impact of industrial activity on the environment. The first two chapters present newly developed data on energy use and greenhouse gas emissions. The third brings together economic and environmental data in a cross-sectional analysis of the pulp and paper industry. In Chapter 4, the movement of dangerous goods by truck and rail is examined. Information on interprovincial movements by class of material is presented along with statistics on accidents.

Chapters 5 and 6 analyze land use and soil conservation. Chapter 5 presents a case study on the changing use of land surrounding Riding Mountain National Park in Manitoba. More intensive land use around the park brings increased stress on park wildlife that use the surrounding area as part of their range. Chapter 6 contains results on soil conservation practices from the 1991 Census of Agriculture. Data on the prevention of soil erosion are presented on a provincial basis.

Chapter 7 combines data from the new Household Environment Survey with family expenditure information to provide an insight into environmental behaviour of households. Data pertaining to mode of travel to work, use of energy saving devices and many other practices having an environmental impact are examined in the context of various characteristics such as family income and dwelling type.

Chapters 8 through 12 deal with four new surveys related to recycling and pollution abatement. Chapter 8 presents pollution abatement and control expenditures by industry for 1989 as well as a six-year perspective on pollution abatement expenditures relative to total capital spending. Chapter 9 examines the 1990 survey of industrial packaging undertaken to provide benchmark data for the National Packaging Protocol which seeks to reduce packaging sent to disposal to 50% of the 1988 level by the year 2000. Waste management is examined from the perspective of private contractors and local governments in Chapters 10 and 11 respectively. The results of the initial survey of private waste management reported in Chapter 10 depict a $1 billion industry in 1989. Tables show financial data by province and firm size. Chapter 11 provides a preliminary look at the characteristics of waste management by local governments and the division of responsibilities for collection, disposal and recycling for those municipalities with a population greater than 50 000. Information is presented on recycling and hazardous waste programs as well as other aspects of waste management. Chapter 12 examines the prices of selected scrap and virgin materials in order to describe their respective behaviour in changing markets.

Finally, Chapter 13 reports on developmental work on resource accounting for oil and gas. Different valuation methods are compared and a series of estimates are provided for oil and gas reserves according to several assumptions about future prices and costs.

1. The next issue of *Human Activity and the Environment* will appear in 1994 in order to provide more timely data from the quinquennial Censuses of Population and Agriculture.

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1 Energy Consumption

by Kirk Hamilton

Energy in general, and fossil fuel in particular, plays an important role in the interaction between human activities and the environment. Each stage in the production, transport, refining, transformation and consumption of energy commodities has actual or potential consequences for the state and quality of the environment.

The production of energy commodities often requires gross physical changes in the environment, in the form of open-pit mines for coal or oil sands, or flooding of large areas to provide reservoirs for hydro-electricity. The transport systems for these commodities may entail physical changes such as above-ground pipelines, or may produce undesirable side-effects such as spills. Refining of energy commodities carries with it the risk of emissions of noxious or poisonous substances to the environment. And their transformation (for example, burning fossil fuels or the fission of nuclear materials to produce electricity) and consumption produces a full range of possible environmental consequences: release of noxious substances, emissions of oxides of carbon, sulphur and nitrogen, and accumulations of solid wastes requiring disposal.

As a result of energy conservation policies and rapid price increases until 1986, the efficiency with which energy is used has changed considerably in recent years. An aggregate indicator of this change is the primary energy/GDP ratio, which declined from 17.3 megajoules (MJ) per constant 1986 dollar in 1981 to 15.5 MJ per dollar in 1986, a fall of over 10% (Statistics Canada, 1991). This study aims to characterize energy use in Canada and to examine the macro-level changes that determine the overall efficiency of energy use.

To explore key aspects of the relationship between energy use and economic activity, detailed energy disposition accounts have been developed as part of the new National Accounts Environmental Component at Statistics Canada. These energy accounts measure the use of 9 major types of energy (coal, crude oil, natural gas, fuel oil, aviation gasoline, motor gasoline, liquefied petroleum gases, electricity and coke) for each of the 216 producing industries and 136 categories of final demand employed in the national input-output accounts (Statistics Canada, 1992a). A summary of the distribution of energy consumption by broad categories, based on these accounts, is shown in Table 1.

Table 1: Distribution of Energy Consumption

Sector	1971		1986	
	petajoules	percent	petajoules	percent
Business (excl. transport)	2 737	52.4	3 199	53.3
Transport	931	17.8	1 139	19.0
Household	1 551	29.7	1 654	27.6
Total	**5 219**	**100.0**	**5 992**	**100.0**

Source:
Statistics Canada, Industry Division.

The organization of energy data in Table 1 requires some explanation. Household energy includes that consumed in rented dwellings. Transport energy use includes for-hire transportation industries and energy for the operation of private vehicles, but excludes energy used for own-account transport (e.g. delivery vans) in the business sector. Business energy use spans all energy used in agriculture, mining, manufacturing and services, but excludes energy converted from one form to another (e.g. coal to electricity) and energy products used as feedstocks. In this accounting scheme, use of own product by energy producers is included in energy use. Table 1 sums to total private energy consumption.

Table 1 shows that household energy use as a proportion of the total declined by 2% between 1971 and 1986, because of stronger growth in the energy used in the business sector and transport. Energy use in the business sector is highly concentrated, as seen in Table 2. In 1986 the five largest energy using industries accounted for 31% of total business sector energy use.

Table 2: Large Industrial Energy Consumers, 1986

Industry	petajoules
Pulp and paper	344
Iron and steel	216
Non-ferrous metals	175
Industrial chemicals	148
Petroleum refineries	114
Total	**997**

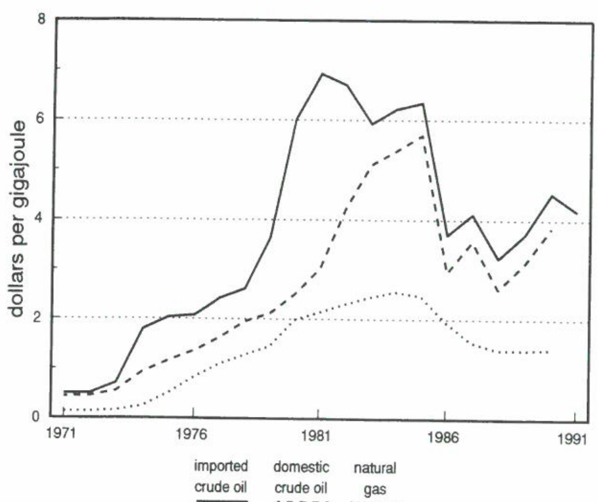
Source:
Statistics Canada, Industry Division.

PRICES

Price is an obvious determinant of the demand for energy. It is worth examining two levels of prices. One is the international and domestic price for crude oil, the former reflecting worldwide demand and scarcity (or cartel pricing in the case of crude oil) and the latter reflecting this as well as domestic energy policy. The second is the price paid by Canadian residential consumers for delivered energy commodities, which reflects local market conditions as well as taxes. In Figures 1 and 2 these prices are expressed in dollars per gigajoules so that they can be compared on a common basis of the energy content of the commodity.

As can be seen in Figure 1, crude oil prices have varied widely since the first OPEC oil shock in 1973. This figure compares imported crude oil, domestic crude oil and domestic natural gas prices. The striking feature of Canadian energy policy prior to 1984 was the establishment of a crude oil price substantially lower than the world price. These prices converged in 1984, but are not exactly equal because Figure 1 compares a domestic price that is weighted towards the well-head price in Alberta with the delivered price (including freight) of imported crude in Montreal. Natural gas prices at the field gate generally tracked the trends in crude oil prices but at a significantly lower level per unit of energy.

Figure 1: Crude Oil and Natural Gas Prices, 1971-1991

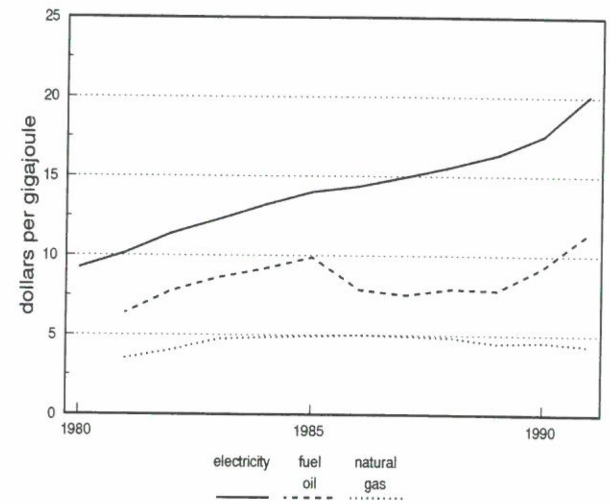


Source:
Canadian Petroleum Association, 1990.

Figure 2 compares the per-gigajoule prices (including taxes) of electricity, fuel oil and natural gas sold to households over the period 1980-1991. Electricity showed a steady increase in price over this period, whereas natural gas displayed both the lowest level and a virtually constant price. Fuel oil prices were much more erratic, falling sharply in 1986 (in step with crude oil prices), levelling off, then increasing in 1990 and 1991. It is noteworthy that electricity prices reached a level roughly 5 times those of natural gas by 1991.

While Figures 1 and 2 display current or nominal prices, the movement of energy prices relative to other prices is also of interest. Table 3 shows the nominal prices of imported crude oil and residential electricity and fuel oil, for 1981 as well as 1991. In addition, this table shows the movement in each of these prices relative to other prices since 1981. Over this decade, the price of imported crude oil declined substantially relative to other prices, while that of electricity showed a significant relative increase.

Figure 2: Residential Energy Prices, 1980-1991



Source:
Statistics Canada, 1992b.

Table 3: Energy Prices and Indices

Commodity	1981	1991	1991
	dollars per gigajoule		index
Imported crude oil	6.93	4.18	0.41
Residential electricity	10.14	20.11	1.23
Residential fuel oil	6.36	11.45	1.12

Note:
The index is relative to changes in the general price level since 1981. In the case of crude oil the GDP implicit price index is used to measure the price level, while for the residential energy prices the consumer price index, excluding energy and food, is used. For example, an index of 1.0 for imported crude oil would indicate that imported crude prices moved at the same rate as the general price level from 1981 to 1991.
Source:
Statistics Canada, Industry Division.

ENERGY INTENSITY OF BASIC MATERIALS

The energy intensiveness of a good or service is the total energy required in production directly (in the producing sector) and indirectly (by the producers of the inputs to the producing sector) per unit of output. For example, the energy intensity of an automobile consists of the energy consumed on the production line plus the energy required to make the steel, rubber, plastic and other component materials making up a car, divided by the dollar value of the car - this gives a measure in joules of energy per dollar of product. The data in the energy flow accounts and the input-output accounts to which they are linked permit straightforward energy intensity calculations (see, for instance, Hamilton, 1988).

By combining energy intensity in joules per dollar with producer prices it is possible to estimate direct and indirect energy requirements per physical unit of product. This is a particularly useful way to examine the changing energy intensiveness of basic materials over time. Because so much of buildings, other infrastructure and manufactured products are made up of lumber, steel, non-ferrous metals, paper products and cement, the energy intensiveness of these basic materials has a profound influence on the requirements for energy in the economy as a whole. Table 4 presents the estimated energy intensity of these products in 1971, 1981 and 1986.

Table 4: Energy Intensity of Basic Materials

Material	1971	1981	1986	Decrease 1971-86
	megajoules per tonne			percent
Lumber	1 554	1 669	1 454	6.4
Pulp and paper	24 215	20 921	17 329	28.4
Iron and steel	23 430	22 035	18 711	20.1
Non-ferrous metal	..	26 757	20 424	23.7
Cement	6 567	5 045	4 373	33.4

Source:
Statistics Canada, National Accounts and Environment Division.

The figures in Table 4 and subsequent tables measure total use of energy commodities, exclusive of the amounts used as feedstocks or converted into other forms of energy (e.g. when burning coal to produce thermal electricity). Imported products used as inputs into the production of these materials are assumed to have the same energy intensity as if they were produced in Canada. The figures therefore represent a pure measure of the energy required along the chain of production from extraction or harvest to final product.

When the materials are heterogeneous, changes in the product mix of the producing sector may influence the estimation of energy intensity[1]. Classification changes did not permit estimation of the energy intensity of non-ferrous metals in 1971, and so the percentage decrease shown in Table 4 for this material is from 1981 to 1986.

What emerges from this table is a striking drop in energy intensity for basic materials. Lumber shows an anomalous rise in 1981. However, lumber is generally low in energy intensity, and few opportunities exist for energy conservation in its production because it is a relatively unprocessed raw material. Pulp and paper and cement show substantial declines in energy intensity, while metals declined more moderately (although this is a fall over 5 years rather than 15 in the case of non-ferrous metals).

1. For example, carbon steel sheets increased from 21% to 31% of the constant dollar value of output of iron and steel from 1971 to 1986. Copper dropped from 25% to 14% of the constant dollar value of output of non-ferrous metals from 1981 to 1986.

ENERGY INTENSITY OF FINAL EXPENDITURE

Another useful way to summarize energy intensiveness and its change over time is to examine the energy intensiveness of the different categories of final expenditure. This is shown in Table 5.

Table 5: Energy Intensity of Final Expenditure, 1981-1986

Category	1981	1982	1983	1984	1985	1986
	megajoules per constant 1981 dollar					
Consumer expenditure	10.1	9.8	10.0	9.3	10.0	9.8
Investment in fixed capital	12.7	11.5	11.7	10.9	11.5	10.9
Government current expenditure	3.9	3.8	3.9	3.7	4.0	3.9
Exports	21.5	19.4	20.0	18.1	18.3	17.7
Imports	17.9	16.8	18.7	16.0	16.9	16.2

Source:
Statistics Canada, National Accounts and Environment Division.

It must be emphasized that this table presents not the energy consumed directly by (for instance) households, but rather the energy required to produce one dollar's worth of the whole spectrum of goods and services consumed by households. The energy consumed directly by households was shown in Table 1.

These figures reveal a consistent ranking of energy intensiveness by category of expenditure, with exports leading, followed closely by imports, then investment in fixed capital, consumer expenditure, and far behind, government current expenditure (which is largely wages and salaries and so does not entail significant energy use).

Notable declines in energy intensity from 1981 to 1986 include one of 14% for investment in fixed capital, 18% for exports and 10% for imports. The energy intensity of exports decreased by about 3.5% per year over this period, echoing the declines in energy intensiveness of basic materials measured earlier.

Some explanation is required for the row labelled "imports" in Table 5. The values reported in this row do not represent the actual energy intensities of our imports but rather, the energy intensities of these goods as if they were produced in Canada. The assumption implicit in these estimates is that foreign industries are exactly as energy intensive in the production of a particular commodity as are Canadian industries.

The results in Table 5 indicate that Canadian exports were approximately 20% more energy intensive than imports in 1981. By 1986 this gap had shrunk to 9%. Dollar

Table 6: Direct Energy Intensity by Industry, 1981-1986

Industry	1981	1982	1983	1984	1985	1986	1986	Annual change
	megajoules per constant 1981 dollar of output						rank	percent
1 Agriculture	8.1	7.4	10.5	7.3	7.5	7.2	14	-4.6
2 Fishing and trapping	19.6	19.6	17.7	20.3	16.6	15.9	6	-3.5
3 Logging and forestry	6.6	5.4	5.3	4.4	5.5	6.7	15	...
4 Mining	16.4	14.4	15.9	14.2	14.3	14.1	8	-3.5
5 Crude oil and natural gas	2.1	1.9	2.2	2.0	2.1	2.2	37	...
6 Quarries and sand pits	13.0	16.3	12.8	11.8	11.5	12.1	9	-2.1
7 Service related to mineral extraction	10.5	10.5	9.4	9.6	9.8	9.7	11	-1.2
8 Food processing	3.1	3.2	3.0	2.9	3.5	3.8	28	3.9
9 Beverages	5.7	5.6	5.0	4.8	5.7	5.9	21	...
10 Tobacco products	1.0	1.1	1.1	1.1	1.5	1.5	44	8.7
11 Rubber products	5.2	3.7	4.9	4.5	5.0	5.3	24	...
12 Plastic products	3.2	3.4	3.1	3.0	3.3	3.4	30	...
13 Leather products	1.7	1.7	1.8	1.9	2.6	2.4	36	8.8
14 Textiles	6.6	6.5	5.9	6.0	6.1	6.0	19	-1.7
15 Clothing	0.9	0.9	1.0	1.0	1.3	1.3	45	8.3
16 Wood products	5.2	5.5	5.0	4.9	4.6	4.2	26	-3.9
17 Furniture	2.0	2.5	2.2	2.2	3.1	2.8	32	8.1
18 Paper products	23.8	18.1	22.2	22.0	21.3	20.6	4	-2.7
19 Printing and publishing	1.1	1.2	1.2	1.1	1.5	1.6	42	8.0
20 Primary metals	25.4	26.1	24.9	21.7	23.3	22.7	3	-2.6
21 Fabricated metals	2.8	3.0	3.1	3.3	3.7	3.8	29	6.6
22 Machinery	1.9	2.5	2.4	2.3	2.8	2.6	33	6.4
23 Transport equipment	1.8	1.9	1.7	1.5	1.9	2.0	38	...
24 Electrical products	1.8	2.1	1.6	1.5	1.8	1.7	41	...
25 Non-metallic mineral products	25.6	26.0	23.8	23.7	24.2	24.8	2	...
26 Refined petroleum products	7.5	8.2	7.9	7.9	8.1	6.6	17	...
27 Chemical products	16.0	16.9	17.4	15.3	14.9	14.2	7	-3.0
28 Other manufacturing	1.9	1.9	1.8	1.8	2.3	2.6	34	6.3
29 Construction	2.1	2.0	1.8	1.9	1.9	1.8	40	-2.1
30 Transport	19.2	18.0	18.5	17.4	17.7	17.4	5	-2.1
31 Pipeline transport	42.4	37.7	27.4	34.4	41.8	36.0	1	...
32 Storage	6.0	6.3	5.4	7.8	8.3	7.6	12	8.1
33 Communication	2.1	2.2	1.9	1.9	2.1	1.8	39	...
34 Electric power and other utilities	11.4	12.8	12.4	11.7	12.3	12.0	10	...
35 Wholesale trade	5.4	5.3	4.7	4.9	4.7	4.1	27	-4.2
36 Retail trade	6.1	6.4	5.7	5.9	6.3	6.0	20	...
37 Finance and real estate	6.0	7.0	6.8	6.2	7.4	7.3	13	4.1
38 Insurance	1.3	1.1	0.9	0.7	0.7	0.7	46	-13.3
39 Government royalties on resources	-	-	-	-	-	-	47	-
40 Owner occupied dwellings	-	-	-	-	-	-	49	-
41 Business services	1.5	1.4	1.4	1.4	1.6	1.6	43	...
42 Educational services	5.9	6.1	5.5	5.9	7.4	6.6	16	4.2
43 Health services	2.7	2.8	2.4	2.7	2.6	2.6	35	...
44 Accommodation and food	6.0	6.3	6.0	6.5	7.1	6.6	18	3.0
45 Amusement and recreation	3.5	3.7	3.4	3.2	3.4	3.3	31	-1.0
46 Personal services	6.1	6.0	5.1	4.9	4.7	4.8	25	-4.9
47 Other services	4.5	4.6	4.5	5.0	5.3	5.3	23	4.0
48 Operating supplies	-	-	-	-	-	-	48	-
49 Travel, advertising and promotion	7.2	6.6	6.3	6.7	5.8	5.7	22	-4.4
50 Transport margins	-	-	-	-	-	-	50	-

Note:
Industries 48, 49 and 50 are fictive industries used for estimating the use of groups of commodities whose precise content is unknown.
Source:
Statistics Canada, National Accounts and Environment Division.

for dollar, therefore, Canada was a significant net exporter of energy embodied in the goods and services it traded.

DIRECT ENERGY INTENSITY BY INDUSTRY

Underlying the energy intensities presented in the preceding sections is the energy use per dollar of output of each of the 216 industries comprising the business sector of the input-output accounts. These direct energy intensities are presented for the years 1981 to 1986 at the level of 50 industries (see Table 6).

Although this table shows the rank of industries by energy intensiveness only for 1986, the ranking is remarkably stable over the years shown. Pipeline transport, with its high energy input and low value of output, ranks first, followed by the non-metallic mineral products industry (whose energy use is dominated by cement producers). These are followed in the top 5 by primary metals, paper products and the transport industry.

The annual changes in industry direct energy intensiveness were calculated over this period. Only those industries showing a significant trend appear in Table 6. While there are many instances of positive change (i.e. increasing energy intensiveness), these occur only for industries ranked very low in energy intensiveness. The majority

Table 7: Fuel and Electricity Shares by Industry, 1986

Industry	Coal	Natural Gas	Gasoline	Fuel oil	LPG	Electricity	Coke	Total
	percent							terajoules
1 Agriculture	1.7	10.3	29.2	37.5	3.1	18.2	--	179 243
2 Fishing and trapping	--	2.7	46.8	49.9	--	0.6	--	16 704
3 Logging and forestry	--	1.1	17.6	79.3	0.7	1.3	--	37 688
4 Mining	4.6	25.1	0.9	29.2	2.0	36.1	2.0	152 067
5 Crude oil and natural gas	--	19.4	20.2	7.5	5.9	47.0	--	47 015
6 Quarries and sand pits	--	10.9	7.0	67.2	--	14.7	--	10 621
7 Service related to mineral extraction	--	13.4	24.6	46.9	--	15.1	--	30 362
8 Food processing	--	70.6	4.1	9.9	1.2	14.0	--	114 441
9 Beverages	--	79.2	3.9	x	x	10.3	--	23 526
10 Tobacco products	--	x	x	x	x	25.4	--	1 770
11 Rubber products	x	67.7	x	x	0.6	21.0	--	12 816
12 Plastic products	x	54.1	2.2	3.8	x	38.7	--	12 562
13 Leather products	x	x	x	x	x	21.6	--	2 825
14 Textiles	x	x	0.6	x	0.6	17.6	--	32 082
15 Clothing	--	59.5	x	7.0	x	27.8	--	7 190
16 Wood products	--	42.1	4.0	16.9	2.3	34.6	--	44 321
17 Furniture	x	68.5	3.7	5.1	x	21.3	--	8 962
18 Paper products	x	26.4	0.1	20.8	0.2	50.6	x	358 294
19 Printing and publishing	--	60.4	5.0	2.6	2.0	30.0	--	12 680
20 Primary metals	2.5	26.5	x	x	0.2	38.1	28.6	420 190
21 Fabricated metal	--	76.6	2.7	3.2	1.7	15.8	--	48 451
22 Machinery	x	72.3	3.7	3.5	x	19.2	x	17 565
23 Transport equipment	x	x	x	x	x	20.4	x	68 253
24 Electrical products	x	x	x	x	x	26.7	x	25 379
25 Non-metallic minerals	18.6	x	0.6	7.6	0.7	11.1	1.7	129 473
26 Refined petroleum	x	41.1	x	x	0.4	12.3	x	113 529
27 Chemical products	x	68.7	x	3.8	0.5	25.9	x	242 535
28 Other manufacturing	--	69.7	x	x	x	20.9	--	12 309
29 Construction	x	x	60.0	29.8	2.4	3.9	--	105 298
30 Transport industry	0.1	5.2	10.7	79.1	2.1	2.8	--	497 737
31 Pipeline transport	x	92.9	--	1.1	x	6.0	--	84 349
32 Storage	--	17.9	6.9	56.7	2.8	15.8	--	6 713
33 Communication	--	18.7	28.8	26.9	4.3	21.3	--	24 879
34 Electric power and other utilities	--	7.3	6.9	0.7	0.2	84.9	--	164 023
35 Wholesale trade	x	13.9	54.9	14.8	4.2	11.9	x	118 028

Table 7: Fuel and Electricity Shares by Industry, 1986

Industry	Coal	Natural Gas	Gasoline	Fuel oil	LPG	Electricity	Coke	Total
	percent							terajoules
36 Retail trade	--	37.8	24.4	10.1	0.4	27.3	--	201 296
37 Finance and real estate	--	50.3	4.7	20.8	0.6	23.6	--	294 158
38 Insurance	--	24.4	19.8	20.9	2.2	32.6	--	4 370
39 Government royalties	--	--	--	--	--	--	--	--
40 Owner occupied dwellings	--	--	--	--	--	--	--	--
41 Business services	--	22.8	42.4	20.0	1.8	13.0	--	28 918
42 Educational services	x	55.1	x	14.8	--	29.1	--	7 395
43 Health services	x	19.2	30.1	35.5	x	12.9	--	22 068
44 Accommodation and food	--	47.6	1.3	23.9	0.7	26.5	--	95 703
45 Amusement and recreation	--	26.0	4.9	23.6	0.8	44.7	--	15 399
46 Personal services	--	10.8	12.2	52.2	2.7	22.1	--	19 837
47 Other services	--	16.1	52.7	19.2	1.5	10.6	--	30 173
48 Operating supplies	--	--	--	--	--	--	--	--
49 Travel, advertising and promotion	--	--	98.9	--	1.1	--	--	69 151
50 Transport margins	--	--	--	--	--	--	--	--

Note:
Industries 48, 49 and 50 are fictive industries used for estimating the use of groups of commodities where the precise commodity content is unknown.

of the most energy intensive industries showed declines between 2.1% and 3.5% per year.

FUEL AND ELECTRICITY SHARES BY INDUSTRY

The analysis to this point has concentrated on total use of energy and not on the fuels that constitute this total. Table 7 shows the percentage share of each type of energy in total use, by industry, in 1986. In total, the dominant energy type is natural gas with a share of nearly 33%, followed by electricity at roughly 25% and fuel oil at 24%.

Coal shows up as only 2.5% of energy use in the primary metals industry because most of it is converted to coke before use - coke in turn constitutes 28.6% of the energy used in this sector. Natural gas is the major energy input to pipeline transport, but is also important in beverages and fabricated metals. Gasoline is the dominant energy source in wholesale trade, to power fleets of delivery vehicles. Fuel oil, which includes diesel and aviation gasoline, is the chief energy source for the transport industry and logging and forestry. Finally, electricity is the major energy input to the paper products industry.

SUMMARY

The distribution of energy consumption across broad sectors has changed little since 1971, and the use of energy in the business sector remains highly concentrated in a few large industries. Crude oil and natural gas prices have been extremely volatile since 1973, while residential energy prices, particularly for electricity, have risen faster than the general price level since 1981. There is an overall trend towards increasing energy efficiency evident in the decreasing energy intensiveness of basic materials and in the direct use of energy per dollar of output in the major energy consuming industries. Among categories of final expenditure, exports, investment in fixed capital and imports, all showed marked declines in energy intensiveness from 1981 to 1986.

REFERENCES

Canadian Petroleum Association. *Statistical Handbook.* Calgary, 1990.

Hamilton, K.E. "Energy Intensiveness and Economic Performance Since 1971" in *Canadian Economic Observer*, 1: 12. Catalogue 11-010. Statistics Canada, Ottawa, 1988.

Statistics Canada. *Human Activity and the Environment 1991.* Catalogue 11-509, Ottawa, 1991.

----. *The Input-Output Structure of the Canadian Economy.* Catalogue 15-201, Ottawa, 1992a.

----. *Energy Statistics Handbook.* Catalogue 57-601, Ottawa, 1992b.

2 Canadian Greenhouse Gas Emissions: An Input-Output Study

by Robert Smith[1]

INTRODUCTION

Statistics Canada has recently initiated development of a set of accounts that will form an environmental component for the Canadian System of National Accounts. Four accounts will comprise this component: a natural resource stock account, a natural resource use account, a waste and pollutant output account and an environmental expenditure account.

The work presented below has been undertaken as a pilot study for the waste and pollutant output account. This account will integrate information on the types, quantities and destinations of waste material generated by economic activity into a framework based on the Canadian input-output tables published annually by Statistics Canada. In the present study information on the types and quantities of greenhouse gases released from Canadian production and consumption activity have been analyzed using an augmented version of the 1985 input-output tables (Statistics Canada, 1989). The general method for augmenting the input-output tables used here is based on the work of Victor (1972).[2]

Greenhouse gas emissions have been chosen for this pilot account for two reasons. First, greenhouse gas emissions are currently under scrutiny in Canada and elsewhere because of the likelihood that increased atmospheric concentrations of these gases will create an enhanced greenhouse effect (see below). The federal government, for its part, has committed Canada to the stabilization of greenhouse gas emissions at 1990 levels by 2 000 (Government of Canada, 1990). It is hoped that the work presented here will aid in the effort to meet this goal. Second, in contrast to many categories of waste emissions, a good deal of data are available for estimating greenhouse gas emissions. Thus, it is possible to present a very complete pilot account of these emissions.

THE GREENHOUSE EFFECT

The atmosphere surrounding the earth consists almost entirely of nitrogen and oxygen, with the remaining portion comprised of a variety of gases found in very low concentrations. A certain group of these trace gases are responsible for what has come to be known as the "greenhouse effect", which can be briefly explained as follows.

Short wave solar radiation passes relatively unhindered through the earth's atmosphere to the surface of the planet. Objects on the surface absorb this incoming radiation and are warmed. The warmed objects, in turn, re-emit longer wavelength (infrared) radiation back into the atmosphere. The atmosphere is less transparent to infrared radiation than it is to short wave radiation however. Trace quantities of water vapour, carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and a few other gases absorb some of the out-going infrared radiation, re-radiating it back to the earth's surface. In this way they act like the glass covering on a greenhouse. By preventing a portion of the infrared radiation from escaping to space, these "greenhouse gases" keep global temperatures much warmer than would be the case in their absence.

It is worth noting that the greenhouse effect is a naturally occurring phenomenon; it has not been created by human activity. However, there is concern that human-induced changes in the atmospheric concentrations of the greenhouse gases may significantly enhance the naturally occurring greenhouse effect. Although some evidence of the expected increase in global mean temperature has already been noted, an unequivocal demonstration of the enhanced greenhouse effect is not expected for at least another decade (Intergovernmental Panel on Climate Change, 1992). Studies have demonstrated conclusively, however, that the atmospheric concentrations of CO_2, CH_4 and N_2O have significantly increased from their pre-industrial values as a result of anthropogenic emissions (ibid.).[3] Humankind has also introduced a new and extremely powerful set of greenhouse gases into the atmosphere. Known collectively as the chlorofluorocarbons (CFCs), each of these has thousands of times the ability of CO_2 to absorb infrared radiation.

ESTIMATED 1985 GREENHOUSE GAS EMISSIONS BY ECONOMIC SECTOR

Table 1 lists the greenhouse gases that are included in this study. Emissions of these gases result from the activities of businesses, households[4] and governments. All three sectors purchase and consume commodities that either contain greenhouse gases that are released upon use

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1. The author would like to thank Patrick Adams for his work in developing the energy disposition tables that were used in this study.

2. Those readers interested in more details of input-output modelling and its use for environmental analysis are referred to the appendix at the end of this chapter. Details of the input-output model used in this study are available on request from the author.

3. Although water vapour is the most important greenhouse gas in terms of overall warming power, its atmospheric concentration is not affected significantly by human activities.

4. Households in this context include non-profit organisations.

(paints and solvents, for example) or that are converted to greenhouse gases as a result of use (fossil fuels are the most important example of the latter type of commodity). Using the emissions data discussed at the end of this chapter in combination with data from the 1985 input-output tables, it has been possible to estimate the 1985 greenhouse gas emissions from 49 industries and 4 categories of household and government expenditure. These estimates are shown in Table 2.

Table 1: Greenhouse Gases Included in this Study

Name	Formula / Acronym
Carbon dioxide	CO_2
Methane	CH_4
Nitrous oxide	N_2O
Volatile organic carbon compounds	VOCs
Nitric oxide and nitrogen dioxide	NO_x
Carbon monoxide	CO

The data presented in Table 2 show that the electric power and other utilities industry (34) was the largest industrial emitter of CO_2 in 1985. This industry also rates as the largest industrial emitter when ranked in terms of CO_2 equivalent emissions.[1] The transportation industry (30), primary metals industry (20), agriculture industry (1), and chemical products industry (27) make up the remainder of the top five industrial emitters in terms of CO_2 equivalents.

The concentration of industrial greenhouse gas emissions is highlighted by the fact that these five industries alone accounted for almost 58% of total CO_2 equivalent emissions from industries in 1985. The top ten emitters accounted for 76% of total industrial CO_2 equivalent emissions.

A direct cause and effect relationship exists between fossil fuel consumption and greenhouse gas emissions. It is not surprising, then, that four of the top five CO_2 equivalent emitting industries also rank among the five largest industrial consumers of fossil fuels. The agriculture industry stands out as something of an anomaly in this regard. It ranks fourth in terms of CO_2 equivalent emissions, but eighth in terms of fossil fuel consumption. The reason for the relatively high ranking of the agriculture industry in

1. CO_2 equivalent emissions are calculated using the concept of global warming potential (Intergovernmental Panel on Climate Change, 1992). Global warming potential (GWP) is the potential contribution to global warming over a specified time period (usually 20 or 100 years) of a given greenhouse gas relative to that of CO_2, which is assigned a GWP of 1. When 100 years is the considered time period, methane is calculated to have a GWP of 11, and nitrous oxide to have a GWP of 270. This means, for example, that the emission of one tonne of CH_4, considered over a period of 100 years from the date of emission, is equivalent to the emission of 11 tonnes of CO_2 in terms of its potential contribution to global warming.

No GWP values exist for VOCs, NO_x and CO. Thus, it is not possible to include these gases in CO_2 equivalent emission estimates. The reader is cautioned to keep this exclusion in mind when interpreting the CO_2 equivalent emission data presented here.

Table 2: Greenhouse Gas Emissions by Sector, 1985

Sector	CO_2	CO_2 equiv.[1]	CH_4	N_2O	VOC	NO_x	CO	CO_2	CO_2 equiv.[1]
	kilotonnes							rank	
Business sector									
1 Agriculture	9 525	24 663	973	16	64	127	610	8	4
2 Fishing and trapping	1 134	1 187	--	--	10	14	96	29	29
3 Logging and forestry	2 076	2 151	--	--	10	30	88	21	21
4 Mining	6 563	8 220	140	--	7	48	81	14	12
5 Crude oil and natural gas	7 845	16 459	779	--	33	184	143	11	6
6 Quarries and sand pits	474	488	--	--	1	7	10	35	35
7 Services related to mineral extraction	2 303	2 381	--	--	14	29	136	20	20
8 Food processing	4 773	4 816	--	--	10	9	33	15	16
9 Beverages	1 054	1 064	--	--	2	3	8	30	30
10 Tobacco products	63	63	--	--	--	--	--	46	46
11 Rubber products	511	514	--	--	5	2	1	34	34
12 Plastic products	350	353	--	--	1	--	2	40	40
13 Leather products	126	127	--	--	--	--	--	45	45
14 Textiles	1 263	1 269	--	--	2	2	6	27	28
15 Clothing	231	233	--	--	--	--	2	43	43
16 Wood products	1 796	1 815	--	--	48	10	860	23	23
17 Furniture	315	318	--	--	4	--	2	42	42
18 Paper products	9 985	10 046	--	--	19	38	96	7	9
19 Printing and publishing	423	427	--	--	1	1	4	38	38
20 Primary metals	24 492	25 060	--	2	15	35	449	3	3
21 Fabricated metals	2 002	2 017	--	--	12	2	8	22	22
22 Machinery	760	766	--	--	3	1	4	33	33
23 Transport equipment	2 772	2 791	--	--	28	4	11	19	19

Table 2: Greenhouse Gas Emissions by Sector, 1985

Sector	CO_2	CO_2 equiv.[1]	CH_4	N_2O	VOC	NO_x	CO	CO_2	CO_2 equiv.[1]
	kilotonnes							rank	
24 Electrical products	989	995	--	--	4	1	7	31	31
25 Non-metallic minerals	12 678	12 721	--	--	5	27	62	4	7
26 Refined petroleum	8 201	8 302	--	--	51	39	240	10	11
27 Chemical products	12 612	16 903	--	16	233	29	31	5	5
28 Other manufacturing	450	454	--	--	3	1	3	36	36
29 Construction	7 511	7 848	1	1	132	93	841	12	13
30 Transport industry	33 713	34 874	14	4	98	259	614	2	2
31 Pipeline transport	4 519	4 891	32	--	--	--	--	16	15
32 Storage	418	423	--	--	--	--	3	39	39
33 Communication	1 417	1 453	--	--	8	7	63	25	26
34 Electric power & other utilities	84 540	85 300	16	2	15	272	142	1	1
35 Wholesale trade	7 239	7 537	1	1	60	48	418	13	14
36 Retail trade	8 760	8 983	1	1	44	34	305	9	10
37 Finance and real estate	11 444	11 540	--	--	9	10	66	6	8
38 Insurance	161	165	--	--	1	1	5	44	44
39 Government royalties on resources	-	-	-	-	-	-	-	...	...
40 Owner occupied dwellings	-	-	-	-	-	-	-	...	...
41 Business services	1 412	1 456	--	--	9	7	66	26	25
42 Education services	330	332	--	--	--	--	1	41	41
43 Health services	1 258	1 290	--	--	6	4	41	28	27
44 Accommodation and food	4 331	4 361	--	--	1	2	10	17	18
45 Amusement and recreation	440	445	--	--	1	1	4	37	37
46 Personal services	946	961	--	--	21	2	14	32	32
47 Other services	1 673	1 736	--	--	13	9	90	24	24
48 Operating supplies	-	-	-	-	47	-	-	47	47
49 Travel, advertising & promotion	4 300	4 536	1	1	55	39	386	18	17
50 Transportation Margins	-	-	-	-	-	-	-	...	...
Sub-total, business sector	**290 181**	**323 596**	**1 962**	**48**	**1 106**	**1 432**	**6 060**		
Household sector									
Motor fuels & lubricants	40 694	44 709	11	14	374	251	2 514	...	...
Home heating fuels	48 719	48 986	2	1	111	41	641	...	...
All other goods	3 007	3061	0	0	101	7	55	...	...
Government - current expenditures	17 859	18 225	2	1	59	52	289	...	...
Sub-total, household and government sectors	**110 278**	**114 980**	**15**	**17**	**645**	**351**	**3 499**	...	...
Total, whole economy	**400 459**	**438 576**	**1 977**	**65**	**1 750**	**1 783**	**9 559**	...	...

Notes:
Readers familiar with input-output accounting will note that the format of this table does not correspond exactly to that of the national input-output tables. Specifically, the following categories of final demand have been excluded: fixed capital formation, inventory change, imports and exports. These have been excluded because they do not result in direct greenhouse gas emissions and because their exclusion simplifies the presentation.
Industries 48, 49 and 50 are fictive industries used for estimating the use of groups of commodities whose precise content is unknown.
[1] CO_2 equivalent emissions include CO_2 emissions plus N_2O and CH_4 emissions expressed as equivalent CO_2 emissions.

terms of CO_2 equivalents is found in its very large emissions of CH_4 and N_2O. Farm animals, cattle in particular, release a great deal of CH_4 during their digestion processes. This accounts for almost all of the CH_4 emissions from the agriculture industry. Nitrification processes in soils to which nitrogenous fertilizers have been applied account for the very large emissions of N_2O. The agriculture industry is estimated to have accounted for 50% of total industrial CH_4 emissions and 33% of total industrial N_2O emissions in 1985.[1]

Table 2 shows an estimated 114 980 kt of CO_2 equivalent emissions from households and governments in 1985, which represents more than 26% of the economy-wide emissions. The majority (93%) of household and govern-

1. Had it been possible to include landfill CH_4 emissions in this study, other industries would have shown higher CH_4 emissions in Table 2 to the extent that they contribute to bio-degradable material in landfill sites. Since landfill CH_4 emissions represent 38% of total CH_4 emissions as estimated by Environment Canada (Jaques, 1992, p. xviii), this exclusion puts the agriculture industry in an unfairly poor light in comparison to other industries.

ment CO_2 equivalent emissions come from the consumption of motor and heating fuels.

The conventional wisdom that industry, especially heavy manufacturing, is the major polluter in the economy is borne out by the results presented in Table 2, at least in terms of greenhouse gas emissions. It should not be left unsaid, however, that households account for more CO_2 equivalent emissions than any single industry.

GREENHOUSE GAS INTENSITY OF PRODUCTION

It is possible, using an input-output model, to estimate the greenhouse gas emissions associated with the delivery of $1 000 of a given commodity (that is, a good or a service) to final consumption.[1] The nature of input-output models is such that both the direct and indirect emissions associated with commodity production can be included in these estimates. Direct emissions are defined as the emissions from the commodity producing industry. Emissions from those industries that supply the producing industry with the inputs used in the commodity's production are defined as indirect emissions. Table 3 shows the direct and indirect greenhouse gas emissions associated with the delivery to final consumers of $1 000 worth of each of 92 unique commodities.

The first value in Table 3 indicates that in 1985 each $1 000 worth of grain purchased by final consumers resulted in the emission of an estimated 0.8963 t of CO_2 from Canadian industries. The other values shown in Table 3 can be similarly interpreted.

It is interesting to compare the greenhouse gas intensity of various commodities but, before doing so, a note of caution is in order. In many cases, more than one commodity is produced by a given industry. For example, both grains and live animals are produced by the agriculture industry. In these cases, the greenhouse gas intensity of the co-produced commodities will be identical, and will reflect the average intensity of one unit of "production" from the industry regardless of what commodities comprise this production. The reader is warned, then, not to take the rankings of co-produced commodities as absolute, but in-

1. Final consumption includes household consumption expenditure, investment in fixed capital, inventory change, government current expenditure and net exports.

Table 3: Greenhouse Gas Intensity of Commodities, 1985

Commodity	CO_2	CO_2 equiv.[1]	CH_4	N_2O	VOC	NO_x	CO	CO_2	CO_2 equiv.[1]
	tonnes per thousand dollars							rank	
1 Grains	0.8963	1.7768	0.0555	0.0010	0.0054	0.0087	0.0386	28	12
2 Live animals	0.8963	1.7768	0.0555	0.0010	0.0054	0.0087	0.0386	27	11
3 Other agricultural products	0.8968	1.7707	0.0549	0.0010	0.0053	0.0087	0.0384	26	13
4 Forestry products	0.7561	0.8194	0.0033	0.0001	0.0037	0.0080	0.0255	34	43
5 Fish landings	1.1486	1.2268	0.0022	0.0002	0.0091	0.0134	0.0859	19	25
6 Hunting & trapping products	1.1486	1.2268	0.0022	0.0002	0.0091	0.0134	0.0859	20	26
7 Iron ores & concentrates	1.0858	1.2866	0.0158	0.0001	0.0019	0.0068	0.0136	23	24
8 Other metal ores & concentrates	1.2093	1.3826	0.0133	0.0001	0.0020	0.0063	0.0165	17	20
9 Coal	1.0859	1.2867	0.0158	0.0001	0.0019	0.0068	0.0136	22	23
10 Crude mineral oils	0.4835	0.7761	0.0266	0.0000	0.0017	0.0071	0.0082	66	46
11 Natural gas	0.4871	0.7775	0.0264	0.0000	0.0018	0.0071	0.0083	65	45
12 Non-metallic minerals	0.8894	1.0660	0.0136	0.0001	0.0026	0.0079	0.0134	29	28
13 Services incidental to mining	0.8305	0.8795	0.0020	0.0001	0.0042	0.0075	0.0329	30	41
14 Meat products	0.7083	1.0286	0.0193	0.0004	0.0033	0.0046	0.0198	40	30
15 Dairy products	0.7091	1.0272	0.0191	0.0004	0.0032	0.0046	0.0197	39	34
16 Fish products	0.7115	1.0285	0.0190	0.0004	0.0032	0.0047	0.0201	36	31
17 Fruit & vegetable preparations	0.7051	1.0188	0.0187	0.0004	0.0032	0.0046	0.0196	42	36
18 Feeds	0.7050	1.0165	0.0185	0.0004	0.0032	0.0046	0.0196	43	37
19 Flour, wheat, meal & other cereals	0.7093	1.0274	0.0191	0.0004	0.0032	0.0046	0.0197	38	32
20 Breakfast cereal & bakery products	0.6905	0.9618	0.0173	0.0003	0.0032	0.0044	0.0189	45	40
21 Sugar	0.7093	1.0274	0.0191	0.0004	0.0032	0.0046	0.0197	37	33
22 Miscellaneous food products	0.7061	1.0209	0.0188	0.0004	0.0033	0.0046	0.0197	41	35
23 Soft drinks	0.6271	0.6816	0.0025	0.0001	0.0019	0.0025	0.0092	49	52
24 Alcoholic beverages	0.6270	0.6815	0.0025	0.0001	0.0019	0.0025	0.0092	50	53
25 Tobacco, processed unmanufactured	0.4016	0.5012	0.0066	0.0001	0.0017	0.0023	0.0100	78	69
26 Cigarettes & tobacco, manufactured	0.4016	0.5012	0.0066	0.0001	0.0017	0.0023	0.0100	79	70
27 Tires & tubes	0.5814	0.6486	0.0012	0.0002	0.0045	0.0022	0.0053	55	54

Table 3: Greenhouse Gas Intensity of Commodities, 1985

	Commodity	CO_2	CO_2 equiv.[1]	CH_4	N_2O	VOC	NO_x	CO	CO_2	CO_2 equiv.[1]
		tonnes per thousand dollars							rank	
28	Other rubber products	0.5595	0.6300	0.0015	0.0002	0.0041	0.0021	0.0054	57	58
29	Plastic fabricated products	0.6252	0.6957	0.0015	0.0002	0.0045	0.0022	0.0067	51	51
30	Leather & leather products	0.3737	0.4205	0.0018	0.0001	0.0017	0.0015	0.0050	81	77
31	Yarns & man made fibres	0.6046	0.6437	0.0011	0.0001	0.0025	0.0018	0.0052	52	55
32	Fabrics	0.5893	0.6273	0.0010	0.0001	0.0023	0.0017	0.0051	54	59
33	Other textile products	0.5931	0.6311	0.0010	0.0001	0.0024	0.0018	0.0052	53	56
34	Hosiery & knitted wear	0.2678	0.2788	0.0010	0.0000	0.0010	0.0010	0.0038	86	86
35	Clothing & accessories	0.2773	0.2883	0.0010	0.0000	0.0010	0.0010	0.0039	85	85
36	Lumber & timber	0.6619	0.7076	0.0017	0.0001	0.0067	0.0046	0.0937	46	48
37	Veneer & plywood	0.6588	0.7045	0.0017	0.0001	0.0067	0.0046	0.0951	47	49
38	Other wood fabricated materials	0.6567	0.7024	0.0017	0.0001	0.0065	0.0045	0.0888	48	50
39	Furniture & fixtures	0.4607	0.4976	0.0009	0.0001	0.0028	0.0017	0.0140	69	71
40	Pulp	1.2551	1.3041	0.0020	0.0001	0.0034	0.0056	0.0192	13	21
41	Newsprint & other paper stock	1.2516	1.3006	0.0020	0.0001	0.0034	0.0056	0.0193	15	22
42	Paper products	1.1080	1.1559	0.0019	0.0001	0.0034	0.0048	0.0167	21	27
43	Printing & publishing	0.4115	0.4203	0.0008	0.0000	0.0014	0.0018	0.0068	75	78
44	Advertising & print media	0.4024	0.4112	0.0008	0.0000	0.0014	0.0017	0.0067	77	80
45	Iron & steel products	1.7957	1.8849	0.0032	0.0002	0.0020	0.0042	0.0296	9	9
46	Aluminum products	1.8807	1.9710	0.0033	0.0002	0.0020	0.0044	0.0311	7	7
47	Copper & copper alloy products	1.8711	1.9614	0.0033	0.0002	0.0020	0.0044	0.0309	8	8
48	Nickel products	1.8991	1.9905	0.0034	0.0002	0.0020	0.0045	0.0314	5	6
49	Other non ferrous metal products	1.7604	1.8496	0.0032	0.0002	0.0023	0.0042	0.0287	10	10
50	Boilers, tanks & plates	0.6995	0.7452	0.0017	0.0001	0.0020	0.0020	0.0096	44	47
51	Fabricated structural metal products	0.9377	0.9856	0.0019	0.0001	0.0021	0.0026	0.0139	25	38
52	Other metal fabricated products	0.7413	0.7870	0.0017	0.0001	0.0021	0.0021	0.0105	35	44
53	Agricultural machinery	0.4295	0.4383	0.0008	0.0000	0.0012	0.0013	0.0064	72	74
54	Other industrial machinery	0.5271	0.5684	0.0013	0.0001	0.0016	0.0017	0.0080	63	64
55	Motor vehicles	0.3313	0.3379	0.0006	0.0000	0.0015	0.0010	0.0046	84	84
56	Motor vehicle parts	0.3430	0.3496	0.0006	0.0000	0.0015	0.0011	0.0047	82	82
57	Other transport equipment	0.4242	0.4330	0.0008	0.0000	0.0017	0.0018	0.0064	73	75
58	Household appliances & receivers	0.4106	0.4194	0.0008	0.0000	0.0014	0.0013	0.0063	76	79
59	Other electrical products	0.3807	0.3884	0.0007	0.0000	0.0013	0.0012	0.0059	80	81
60	Cement & concrete products	2.7703	2.8237	0.0024	0.0001	0.0023	0.0072	0.0168	3	3
61	Other non-metallic mineral products	2.5183	2.5706	0.0023	0.0001	0.0024	0.0066	0.0158	4	4
62	Gasoline & fuel oil	0.7634	0.9730	0.0166	0.0001	0.0037	0.0063	0.0163	33	39
63	Other petroleum & coal products	0.8114	1.0458	0.0164	0.0002	0.0052	0.0061	0.0136	32	29
64	Industrial chemicals	1.2530	1.5681	0.0041	0.0010	0.0151	0.0044	0.0097	14	14
65	Fertilizers	1.0299	1.5340	0.0311	0.0006	0.0057	0.0073	0.0237	24	16
66	Pharmaceuticals	1.2420	1.5582	0.0042	0.0010	0.0158	0.0043	0.0091	16	15
67	Other chemical products	1.2023	1.5218	0.0045	0.0010	0.0148	0.0043	0.0095	18	17
68	Scientific equipment	0.4344	0.4735	0.0011	0.0001	0.0021	0.0016	0.0069	70	73
69	Other manufactured products	0.5485	0.5953	0.0018	0.0001	0.0023	0.0019	0.0083	59	60
70	Residential construction	0.5311	0.5724	0.0013	0.0001	0.0035	0.0033	0.0231	61	62
71	Non-residential construction	0.5311	0.5724	0.0013	0.0001	0.0035	0.0033	0.0231	60	61
72	Repair construction	0.5311	0.5724	0.0013	0.0001	0.0035	0.0033	0.0231	62	63
73	Pipeline transportation	1.8972	2.0501	0.0139	0.0000	0.0004	0.0018	0.0024	6	5
74	Transportation & storage	1.3950	1.4776	0.0026	0.0002	0.0044	0.0101	0.0258	11	18
75	Radio & television broadcasting	0.2085	0.2129	0.0004	0.0000	0.0010	0.0010	0.0064	91	91
76	Telephone & telegraph	0.2085	0.2129	0.0004	0.0000	0.0010	0.0010	0.0064	90	90
77	Postal services	0.2085	0.2129	0.0004	0.0000	0.0010	0.0010	0.0064	89	89
78	Electric power	4.7870	4.8338	0.0018	0.0001	0.0012	0.0157	0.0098	1	1
79	Other utilities	4.7827	4.8295	0.0018	0.0001	0.0012	0.0156	0.0098	2	2
80	Wholesale margins	0.4793	0.5250	0.0017	0.0001	0.0030	0.0027	0.0167	68	66
81	Retail margins	0.4904	0.5025	0.0011	0.0000	0.0018	0.0021	0.0117	64	68
82	Imputed rent, owner occupied dwellings	0.0337	0.0348	0.0001	0.0000	0.0002	0.0002	0.0013	92	92

Table 3: Greenhouse Gas Intensity of Commodities, 1985

	Commodity	CO_2	CO_2 equiv.[1]	CH_4	N_2O	VOC	NO_x	CO	CO_2	CO_2 equiv.[1]
		tonnes per thousand dollars							rank	
83	Other finance, insurance & real estate	0.4206	0.4305	0.0009	0.0000	0.0009	0.0012	0.0049	74	76
84	Business services	0.2149	0.2204	0.0005	0.0000	0.0012	0.0011	0.0068	88	88
85	Education services	0.5570	0.5658	0.0008	0.0000	0.0010	0.0016	0.0050	58	65
86	Health services	0.2173	0.2217	0.0004	0.0000	0.0010	0.0009	0.0056	87	87
87	Amusement & recreation services	0.3333	0.3399	0.0006	0.0000	0.0010	0.0012	0.0055	83	83
88	Accommodation & food services	0.5609	0.6308	0.0039	0.0001	0.0011	0.0019	0.0068	56	57
89	Other personal & miscellaneous services	0.4794	0.5163	0.0009	0.0001	0.0028	0.0021	0.0119	67	67
90	Transportation margins	1.3543	1.4099	0.0026	0.0001	0.0042	0.0098	0.0250	12	19
91	Operating, office, lab. & food supplies	0.4329	0.4863	0.0024	0.0001	0.0046	0.0020	0.0084	71	72
92	Travel, advertising & promotion	0.8121	0.8622	0.0021	0.0001	0.0054	0.0056	0.0350	31	42

Note:
[1] CO_2 equivalent emissions include CO_2 emissions plus N_2O and CH_4 emissions expressed as equivalent CO_2 emissions.

stead as general indicators of their greenhouse gas intensity relative to other commodities.

When either CO_2 or CO_2 equivalent emission intensity is considered, electric power (78) was the most polluting commodity produced in the Canadian economy in 1985. "Other utilities" (79) (mainly natural gas and water supply) ranked second. Note that commodity 79 is co-produced with electricity by the electric power and other utilities industry (industry 34 in Table 2). Cement (60) and other non-metallic mineral products (61) were ranked next. Pipeline transportation (73) and the primary metals - iron and steel (45), aluminum (46), copper (47), nickel (48) and other non-ferrous metals (49) - round out the list of the ten most highly CO_2 intensive commodities produced in 1985.

The agricultural and food commodities (1-3 and 14-22) show significant increases in intensity when ranked in order of CO_2 equivalents. This change is expected given the large emissions of CH_4 and N_2O from the agriculture industry shown in Table 2 above.

INDUSTRIAL EMISSIONS BY FINAL DEMAND CATEGORY

Production activity takes place to meet the demand for commodities from final consumers. It is reasonable, then, to ask what portion of total industrial greenhouse gas emissions are attributable to the production required to meet the demand from different final consumption categories. Table 4 shows such a breakdown of industrial greenhouse gas emissions.[1] As one might expect, production to meet the demand for commodities from households is responsible for the greatest portion of industrial greenhouse gas emissions.

Some explanation is required for the row labelled "imports" in Table 4. The emissions reported in this row are not the actual emissions that occurred in other countries during the manufacturing of Canada's imported commodities. Rather, they represent the emissions that would have obtained had we produced domestically, instead of importing, this group of commodities. The assumption implicit in these estimates is that foreign industries emit the same quantities of greenhouse gases in producing one unit of a particular commodity as do Canadian industries.

The results reported in Table 4 indicate that Canada exported a more greenhouse gas intensive set of goods and services than it imported in 1985. Put another way, Canada was a net exporter of greenhouse gas emissions as a result of its international trade.

CO_2 EMISSIONS PER UNIT OF ENERGY CONSUMPTION, 1970-1990

It was noted above that greenhouse gas emissions are causally related to fossil fuel consumption. In particular, anthropogenic CO_2 emissions result mainly from the combustion of fossil fuels.

The magnitude of fuel combustion-related CO_2 emissions is a function of two variables. Most obviously, the quantity of fossil fuels burned has a direct impact on the magnitude of CO_2 emissions. Less obvious is the effect of the variability of CO_2 emissions per unit of energy across fossil fuel types. Since each fuel type results in different CO_2 emissions per unit of energy, the composition of overall energy consumption will affect aggregate CO_2 emissions. A shift in consumption from coal to natural gas, for example, would result in lower CO_2 emissions, other things equal, since natural gas combustion results in only 55% as

1. It must be emphasized that the figures shown in Table 4 are the emissions associated with the production activity required to meet the demand for commodities from final consumption categories. They do not represent the emissions associated with the consumption of these commodities once they have been purchased. The latter were shown in Table 2.

Table 4: Industrial Greenhouse Gas Emissions by Demand Category, 1985

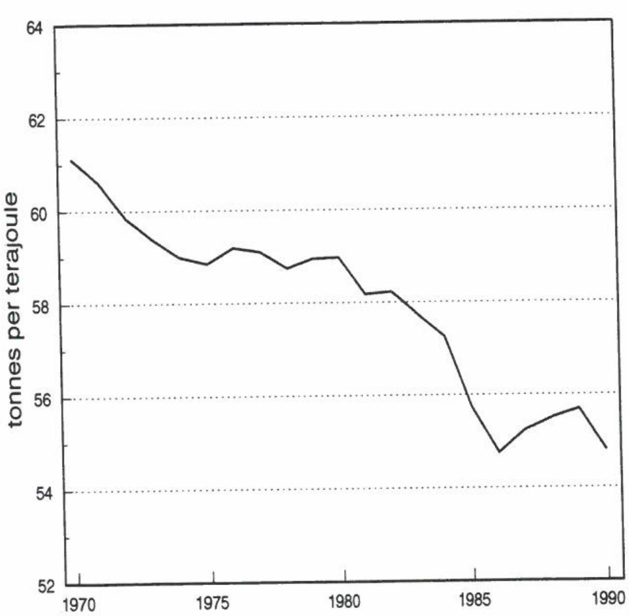
Final Demand Category	CO_2	CO_2 equiv.[1]	CH_4	N_2O	VOC	NO_x	CO
	kilotonnes						
Household expenditure	127 299	142 198	839	21	402	586	2 060
Investment in fixed capital	39 423	41 829	96	5	238	226	1 502
Exports	98 433	113 259	906	18	358	502	2044
Imports	69 088	78 550	492	15	298	288	1 105
Government current expenditure	21 685	23 320	75	3	94	103	383

Note:
1. CO_2 equivalent emissions include CO_2 emissions plus N_2O and CH_4 emissions expressed as equivalent CO_2 emissions.

much CO_2 per unit of energy as does the combustion of coal (Jaques, 1992, p. xx).

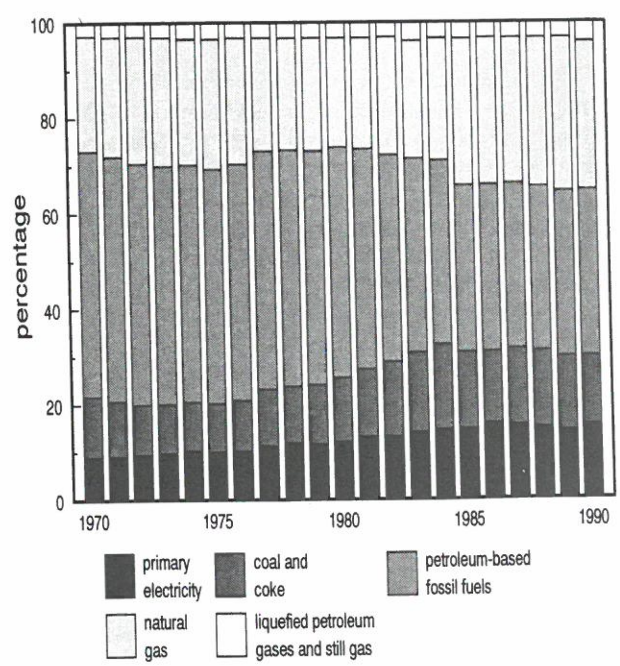
Figure 1 shows the effect on total fossil fuel combustion-related CO_2 emissions of the changing composition of Canadian energy consumption during the period 1970-1990. It is clear from this figure that the trend in Canada since 1970 has been toward a less CO_2 intensive energy mix. CO_2 emissions per unit of total energy consumption declined at an annual rate of 0.29 t/TJ over this period.

Figure 1: Direct CO_2 Emissions per Unit of Energy Consumption, 1970-1990



The reasons for the decline in the CO_2 intensity of energy consumption can be seen in Figure 2, which shows the composition of total energy consumption during the period 1970-1990. During the past two decades, the share in Canadian energy consumption of both natural gas and primary electricity (hydro and nuclear) has increased, entirely at the expense of petroleum-based fossil fuels.[1] Since natural gas is the least CO_2 intensive fossil fuel (ibid.), and primary electricity does not result in any direct CO_2 emissions, this change in energy mix results in the decreasing trend shown in Figure 1. The percentage of consumption met by coal also increased during this period, but not enough to offset the reduction in CO_2 intensity resulting from the increased share of natural gas and primary electricity.

Figure 2: Composition of Total Energy Consumption, 1970-1990



1. Petroleum-based fossil fuels include diesel fuel, light and heavy fuel oils, kerosene, motor and aviation fuels.

CONCLUSION

Several useful pieces of information have emerged from the results presented above. Perhaps most important is the highly concentrated nature of industrial greenhouse gas emissions. When considered in terms of CO_2 equivalent emissions, the five largest industrial sources accounted for almost 58% of 1985 industrial emissions. Particularly noteworthy is the fact that the electric power and other utilities industry alone was responsible for 26% of all industrial emissions. The very large emissions from this industry meant that electricity was the most greenhouse gas intensive commodity in the Canadian economy in 1985. Each $1 000 worth of electricity delivered to final consumers resulted in the emission of nearly 5 tonnes of CO_2 equivalents.

The importance of transportation activity in total greenhouse gas emissions is also clear from the above analysis. The transportation industry (which includes for-hire land, air and marine transportation services) is the second largest source of CO_2 equivalent gas emissions among all industries. This is so even though the emissions from transportation activity undertaken by firms, households or governments on own-account are not included in the estimated emissions from the transportation industry. All told, transportation is a significant source of greenhouse gas emissions.

Households also appear as very important sources of greenhouse gas emissions. The consumption of commodities by households contributed almost 22% of economy-wide 1985 CO_2 equivalent emissions. On top of this are the 142 Mt of CO_2 equivalent emissions, or 44% of total industrial emissions (see Table 4), that are associated with the production of commodities ultimately purchased by households. This is not meant to imply that households are solely responsible for the greenhouse gases emitted during the production of the commodities they purchase; the responsibility for these emissions must be shared between the consumers who demand the commodities and the industries that meet this demand. Nonetheless, it serves to highlight the importance of household consumption in overall greenhouse gas emissions.

To conclude, it can be said that the input-output accounting and modelling frameworks have proven to be useful tools for the analysis of greenhouse gas emissions. The majority of anthropogenic greenhouse gas emissions have been included in the input-output model used here and some interesting results have followed. However, where the nature of emissions is such that there exists no linear and constant relationship to annual economic activity, specifically in the cases of CFCs and landfill methane emissions, the input-output framework alone is inappropriate. Future work will require the development of extensions to the framework that will allow the incorporation of emissions that are sporadic, stock driven or otherwise related in an non-linear way to human activity.

DATA SOURCES AND EMISSION ESTIMATION METHOD

The gases considered in this study include carbon dioxide, methane, nitrous oxide, volatile organic compounds (VOC), nitric oxide and nitrogen dioxide (collectively, NO_x) and carbon monoxide (CO).

Chlorofluorocarbons are notable for their absence in this list. The reason for this absence is explained briefly a few paragraphs below. Also missing from the list is tropospheric ozone (O_3)[1], another powerful greenhouse gas. Tropospheric ozone has been excluded because it is not emitted to an appreciable extent as a by-product of economic activity. Instead, it is formed in the troposphere through chemical reactions involving the precursor gases VOC, NO_x and CO, all of which are emitted in large quantities as by-products of economic activities.

The method and coefficients used in the estimation of the 1985 emissions of carbon dioxide, methane and nitrous oxide have been adopted from an Environment Canada report titled *Canada's Greenhouse Gas Emissions Estimates for 1990* (Jaques, 1992). The CO_2, CH_4 and N_2O emission estimates reported here are, with some important differences, directly comparable with those published for 1990 by Environment Canada.

The first, and most obvious, difference between the estimates reported here and those reported by Environment Canada is that the former are for the year 1985, while the latter are for the year 1990. It was not possible to use 1990 as the base year for this study as no input-output tables for that year are yet available. 1985 was chosen instead, because of the availability of a good inventory of VOC, NOx and CO emissions.

More significant than the choice of a different base year is the exclusion of CFC emissions in the present study. This exclusion is due in part to a lack of data to establish the link between CFC emissions and economic activity at the detailed level represented in the input-output tables. It is also a function of the somewhat inflexible nature of the input-output structure which only allows the modelling of greenhouse gas emissions with constant and linear relationships to annual economic activity. Many types of CFC emissions do not meet this criterion. In any given year CFC emissions are, to a large extent, determined by the stock of the chemicals that has accumulated in prior years and, therefore, bear little relationship to economic activity in that year.[2]

A third departure is the exclusion here of several emission sources included in the Environment Canada report. These have been excluded mainly because of the afore-

1. The troposphere is the lowest level of the earth's atmosphere.

2. Environment Canada estimates that 1990 CFC emissions amounted to 11 kt (Jaques, 1992, p. xviii).

mentioned lack of data and/or inflexibility of the input-output framework. With respect to CO_2, emissions from non-energy uses of petroleum products other than ammonia production (1990 estimate: approximately 10 000 kt) have been excluded, as well as all biomass related CO_2 emissions.[1] The following sources of CH_4 emissions have also been excluded: waste incineration (< 2 kt), landfill sites (1 405 kt) and slash burning (38 kt). As already noted, landfill sites account for 38% of the total 1990 CH_4 emissions estimated by Environment Canada (Jaques, 1992; p. xviii). Thus, the estimated total 1985 CH_4 emissions reported here are significantly lower than Environment Canada's 1990 estimate. Finally, the emissions of N_2O from nitric acid production, anaesthetics, propellants and high-voltage transmission lines have all been excluded here. These sources account for less than one percent of total 1990 N_2O emissions estimated by Environment Canada.

The last departure from Environment Canada's 1990 greenhouse gas inventory is the inclusion of VOC, NO_x and CO. Only CO_2, CH_4, N_2O and CFC emissions are estimated in the former. The inclusion VOC, NO_x and CO yields more complete information and is not without precedent. A major international body engaged in research on global warming, the Intergovernmental Panel on Climate Change, includes these gases in its list of greenhouse gases (Intergovernmental Panel on Climate Change, 1992), as does the International Energy Agency of the Organisation for Economic Cooperation and Development (International Energy Agency, 1991). For the sake of completeness and because of the international precedents, it was decided that VOC, NO_x and CO should be included in this study.

. The estimated total VOC, NO_x and CO emissions reported in this study match those reported in the *Canadian Emissions Inventory of Common Air Contaminants (1985)* (Kosteltz and Deslauriers, 1990 and Deslauriers, Personal communication) with, again, some important differences. The most significant of these is the exclusion of the following emission sources in the present study: forest fires (201 kt VOC, 37 kt NO_x, 1 141 kt CO); slash burning (96 kt VOC, 20 kt NO_x, 1 134 kt CO); structural fires (6 kt VOC, 12 kt CO); and municipal and industrial incineration (6 kt VOC, 2 kt NO_x, 9 kt CO). These sources have been excluded because they are not related in a linear and constant way to identifiable economic activity.

Another difference with the Environment Canada study, of less importance, is the modified procedure for estimating VOC, NO_x and CO emissions from heavy duty road vehicles (trucks and buses) used in this study. In spite of this, the estimated emissions from these vehicles are in good agreement in the two studies. Furthermore, since heavy duty road vehicles contribute a relatively small proportion of the total emissions of these three gases, the differences in these estimates have little effect on the estimated total emissions. The estimated emissions of VOC, NO_x and CO from government activities are higher than those reported in the other study, also because of a different estimation method. Again, the effect of this difference on total emissions is very small.

It should be emphasized that, the exclusion of the major emission sources mentioned above notwithstanding, the estimated total 1985 VOC, NO_x and CO emissions reported here agree closely with those published in the *Canadian Emissions Inventory of Common Air Contaminants (1985)*.

1. Biomass emission sources include the combustion of wood and spent pulping liquor wastes at pulp and lumber mills; slash burning; forest fires; fuelwood combustion; municipal and industrial waste incineration; and landfill sites. Environment Canada excludes these emissions from the estimated total CO_2 emissions reported in *Canada's Greenhouse Gas Emissions Estimates for 1990* because of uncertainty in estimating the magnitude of the corresponding natural sink for CO_2 (such as growing forests). Because it did not have a reliable estimate of both the biomass sink and source terms, Environment Canada felt it misleading to include only biomass CO_2 sources in its estimated total emissions. The estimated magnitude of biomass CO_2 emissions in 1990 is 109 Mt (Jaques, 1992, p. xviii).

APPENDIX

The input-output accounts published by Statistics Canada contain detailed information on annual production and consumption activities in the Canadian economy. The accounts consist of three tables. A "make" table lists the dollar values of all commodities produced by each Canadian industry. A "use" table details the purchases of these same commodities by industries for use as inputs in the production of other commodities. These purchases are referred to as intermediate commodity use. A "final demand" table lists the dollar values of commodities purchased by households and governments, investment in fixed capital, inventory change and net exports (exports less imports). The structure of the input-output accounts is such that there exists an identity between total commodity production (from the make table) and intermediate plus final consumption (from the use and final demand tables).

Using the three tables of the input-output accounts, and given two assumptions regarding the structure of production activity, it is possible to derive linear models (called input-output models) of the relationship between final commodity use and the levels of production activity required to meet this use.

A useful quality of input-output models is their ability to capture both the direct and indirect impacts of final demand on production activity. The impact of the demand for automobiles on the output of the automobile industry is a good example. As the demand for automobiles changes, the output of the automobile industry will adjust to reflect this change. This is an example of a direct impact of demand on production activity. There are, however, further impacts that will result from a change in the demand for cars. The steel industry, for instance, will also see the demand for its product affected by such a change. The change in demand for steel is an example of an indirect impact of demand on production activity. Such indirect demands can propagate through many industries of as a result of a change in the demand for just one commodity. Input-output models capture all these changes automatically, estimating the effect of a change in the demand for one or more commodities across the entire spectrum of economic activity.

There are some limitations on input-output modelling that should be noted. Most significant are the "snapshot" representation of the economy in the input-output accounts, and the assumption of fixed proportionality between the inputs employed in production processes and the outputs of these processes. To the extent that technological change is present in the economy, the first assumption limits the capacity of input-output models for accurately predicting future economic activity. Thus, the technique is most useful for studying the impact of demand changes in a given year or, at most, a few years into the future. The second assumption limits the accuracy of input-output models for impact analysis in any time period, as the capacity for input substitution that exists in the actual economy is not captured in the constant-proportion input-output framework.

Beyond purely economic analysis, input-output modelling can also be used to study the relationship between economic activity and the use of raw materials and generation of wastes. To do so requires two modifications to the standard conception of the input-output accounts. First, it is necessary to introduce physical quantities into the input-output framework. Second, the framework must be expanded beyond its normal market-activity boundary to include the non-marketed inputs and outputs of economic activity. Once these changes to the accounting framework are made, the incorporation of environmental inputs and outputs into the framework is conceptually no different than the incorporation of any marketed input or output. Just as industries produce commodities for the marketplace, they also produce waste materials that can be released into the environment. Similarly, just as industries purchase commodities for use in their production processes, they also make use of non-marketed inputs from the environment, air and water for example. It is possible to incorporate tables showing the inputs and outputs of these environmental commodities, in physical quantities, into the standard input-output framework. Assuming that these environmental commodities are produced and consumed in fixed proportion to the production and consumption of marketed commodities, a set of input-output accounts so modified can be used to study the relationship between production, consumption and the use of the environment as a source of raw materials and a sink for wastes.

REFERENCES

Deslauriers, M. Personal communication. October, 1991.

Government of Canada. *Canada's Green Plan for a Healthy Environment.* Ottawa, 1990.

Intergovernmental Panel on Climate Change. *1992 IPCC Supplement (Draft).* In press. 1992.

International Energy Agency. *Greenhouse Gas Emissions: The Energy Dimension.* Paris: Organisation for Economic Cooperation and Development/International Energy Agency. 1991.

Jaques, A. P. *Canada's Greenhouse Gas Emissions: Estimates for 1990.* Environment Canada Report EPS 5/AP/4, Ottawa, 1992.

Kosteltz, A. and M. Deslauriers. *Canadian Emissions Inventory of Common Air Contaminants (1985).* Environment Canada Report EPS 5/AP/3, Ottawa, 1990.

Statistics Canada. *The Input-Output Structure of the Canadian Economy, 1985.* Catalogue No. 15-201, Ottawa, 1989.

Victor, Peter A. *Pollution: Economy and Environment.* United Kingdom: George Allen and Unwin Ltd. 1972.

3 Pulp and Paper Industry Compliance Costs

by Craig Gaston

INTRODUCTION

The pulp and paper industry is currently under considerable scrutiny by environmentalists, regulators and the general public. This resource based industry is the main livelihood for over 76,000 Canadians and has a long history as one of Canada's most important economic activities. The industry has made significant progress over the last 20 years in reducing pollution but as the volume of production has increased and our ability to study the composition and the effects of the pollutants has improved, regulations have become more stringent. The increased concern over pollution comes at a time when U.S. customers are demanding a higher recycled fibre content in newsprint and European buyers are beginning to give preference to paper that has not been bleached with chlorine. These pressures translate necessarily into expensive capital expenditures and coincide with a period of weak demand and increasingly strong competition.

BACKGROUND

Canadian mills are often criticized for being old and inefficient. Fifty-eight percent of Canadian newsprint machines commenced operation prior to 1950 compared to 28% in the U.S. and 7% in Scandinavia. Also, 15% of annual production capacity is greater than 400 tonnes a year in Canada compared to 30% in the U.S., 80% in Sweden, 40% in Finland and 20% in Norway (Sinclair, 1990). Industry analysts claim that Canadian companies must modernize, shift to higher value products such as fine papers, and invest in pulp and paper mills outside of Canada (Headlam and Stevenson, 1990, p. 43).

This study examines the estimated cost of compliance to the 1992 federal regulations on traditional pollutants. How do compliance costs vary according to the type of treatment facility in place? What effect does the age of a mill have on estimated expenditures? How do these costs vary according to region, type of product, capacity, profitability, recent investment or foreign control? The aim of this chapter is to shed light on the nature of the pulp and paper pollution problem in Canada and on how the industry will be affected by certain federal regulations which take effect this year.

Economic Importance of Pulp and Paper

The pulp and paper industry comprised 82 firms which operated 147 mills in 1989. Although concentrated in Quebec, Ontario and British Columbia, plants are located in every province with the exception of Prince Edward Island. In terms of value added, the industry ranks first among all manufacturing industries in Canada, followed by the automobile industry. The industry has declined in relative importance since the fifties, when it accounted for 5.3% of GDP, to 1.4% of GDP in 1989. Canada ranks second in the world in terms of wood pulp production, and first in terms of exports of this commodity. Pulp and paper products accounted for 15% of total exports and 0.6% of employment in 1990.

The industry is currently under considerable financial pressure due to a combination of economic and environmental factors. The recent recession has resulted in many temporary mill shutdowns and several permanent closings. Environmentally, U.S. customers' increasing insistence upon recycled paper content and stricter pollution regulations portend large capital expenditures for de-inking mills and pollution abatement equipment.

Environmental Concerns

The pulp and paper industry is the focus of considerable attention due to its environmental impact. In 1987, waste discharges from the pulp and paper industry were the major industry-related environmental concern in British Columbia and New Brunswick according to provincial environmental authorities (Sinclair, 1990, p. 177). In Ontario and Quebec, the industry ranked third amongst polluting industries and only the chemical industry (a major supplier to the pulp and paper industry) and the mining industry were rated as high as the pulp and paper industry Canada-wide (Sinclair, 1990, p. 177). The industry has, however, made substantial environmental improvements over the last 20 years.

Water pollution has received most of the attention accorded to pulp and paper mills. The industry is not "... a significant contributor to global air pollution problems, such as acid rain or warming. Its [air pollution] problems are very localized and most likely nuisance odour-type problems" (Paul Shepson in Jamieson, 1991, p. 12). Pollution discharged to water consists mainly of wood particles too small to be filtered, organic material (mainly lignin) from the wood and waste chemicals used in the pulping and bleaching process. The wood particles, measured as total suspended solids (TSS), upset the aquatic habitat and ruin fish spawning beds. The dissolved organic material decomposes and in the process uses oxygen thereby reducing the ability of the water to support life. This potential is generally measured as biochemical oxygen demand (BOD) expressed in kilograms per tonne of product. Other organic materials such as resins, fatty acids and sulphur compounds are acutely toxic to fish. Mills that use elemental chlorine for bleaching have also been identified as a significant source of dioxins and furans, which are discharged in the wastewater (Environment Canada, 1991, p. 14-19). Environment Canada considers these substances to be highly toxic.

Regulation

The pulp and paper industry is currently faced with new federal regulations governing the release of various pollutants. From 1971 until 1991 only new mills or mills that underwent significant expansion were subject to restrictions under the Fisheries Act. The new constraints, introduced in 1992 and effective in December 1992, apply to all mills (although the criteria are somewhat different for mills discharging their effluent to off-site treatment facilities). The 1992 federal regulations, under the authority of the Fisheries Act, apply to the discharge of BOD, TSS, and effluents acutely lethal to fish. New regulations were also established under the authority of the Canadian Environmental Protection Act (CEPA) requiring the elimination of dioxins and furans from the effluent of pulp and paper mills performing chlorine bleaching. Regulations controlling defoamers and wood chip insecticides were also implemented under CEPA. Some provinces have also passed regulations limiting or banning organochlorines, a whole class of compounds which result from chlorine bleaching and which include dioxins and furans. This study examines the costs related to the abatement of TSS, BOD, and toxicity. Only mills that discharge effluent directly to receiving waters are examined here.

Treatment Facilities for Traditional Pollutants

Primary treatment facilities remove from 80 to 90% of the settleable portion of the suspended solids, usually by means of gravity clarifiers or settling basins. Secondary treatment is designed to remove BOD associated with the dissolved organic materials in the effluent, and normally uses a biological process. In Canada, aerated lagoons are most often used for secondary treatment. The objectives of this process are to reduce the BOD by 70% to 95% and to render the effluent non-toxic to fish. Although these facilities do reduce toxicity they are not effective in eliminating dioxins and furans.

The estimated capital cost to pulp and paper mills to be in compliance with the 1992 regulations is $2.2 billion (1990 dollars) or about $23 million per mill. This cost can vary from over $100 thousand to $100 million depending upon the circumstances of an individual establishment (Department of Fisheries and Oceans, 1991). By way of comparison, the average annual investment from 1978 to 1989 by mills in this study was $16.8 million per mill in 1989 dollars.

Table 1 shows that most pulp and paper mills in this study had primary treatment facilities in 1989 (84%). In 1989, only 30% of the mills in the sample had secondary treatment facilities. On average, mills without secondary treatment produced over 34 kg of BOD per tonne whereas those with these facilities generated effluent containing 8.8 kg per tonne, just over the 1992 federal limit of 5 kg per tonne. On average, the mills considered here generate 11.4 kg of TSS per tonne while the new limit is 7.5 kg per tonne.

Table 1: Treatment Facilities, 1989

Treatment facilities	Mills	TSS	BOD	Capacity
	number	kg per tonne		tonnes per day
None	20	19.3	17.2	379
Primary only	67	8.9	34.2	600
Primary and secondary	37	9.9	8.8	784
All direct discharge mills	**124**	**11.4**	**23.9**	**619**

Source:
Environment Canada, Regulatory Affairs and Program Integration Branch.

The variation in BOD factors by region reflects, to a large degree, the use of secondary treatment. Table 2 shows that only 13% of Quebec mills had secondary treatment facilities in 1989 and the BOD factors were highest in this province. Similarly, Prairie province mills had the lowest average BOD factor and the highest incidence of secondary treatment.

Table 2: Attributes of Mills by Region

Region	Mills	Mills with treatment facilities		Effluent			
		Primary	Secondary	TSS	BOD	TSS	BOD
	number	percentage		kg per tonne per mill		thousand tonnes per day (all mills)	
Atlantic Provinces	19	81	25	13.6	24.5	118	215
Quebec	49	82	13	11.9	28.5	220	888
Ontario	27	96	27	4.6	19.1	75	304
Prairie Provinces	6	100	85	27.9	12.2	88	39
British Columbia	23	81	52	12.6	21.9	234	383
Canada	**124**	**84**	**30**	**11.4**	**23.9**	**735**	**1 829**

Source:
Environment Canada, Regulatory Affairs and Program Integration Branch.

The inverse relationship between BOD factors and the incidence of secondary treatment is not perfect, however, as shown by British Columbia where the BOD factor is almost the same as the Canadian average and more than half the mills have secondary treatment facilities. Process type is another important variable in explaining BOD factors.

COST OF COMPLIANCE TO RECENT FEDERAL REGULATIONS [1]

It is possible to assess the financial impact of the 1992 federal pollution regulations on pulp and paper mills by examining the estimated compliance costs[2] in the light of historical investment and earnings.

Traditionally, measures related to the pulp and paper industry are expressed in terms of a tonne of final product. This measure is widely understood by industry experts but it does not provide an intuitive appreciation for the actual impact of the required expenditures in relation to a mill's earnings. In this study we will examine the compliance costs relative to average annual investment in new plant and equipment and to average annual surplus[3]. In both cases we have calculated averages over time to avoid the cyclical variation which is inherent in data pertaining to this industry. The averages are based upon 12 years of data in the case of investment and 9 years for surplus. The data have been recalculated in 1989 dollars.

We will examine two ratios. The first is the capital cost of compliance per dollar of average investment by each mill. This ratio can be thought of as the number of years of average equivalent investment (AEI). The second ratio is the annualized capital cost plus operating cost per dollar of average surplus[4], hereafter referred to as the annualized cost ratio (ACR). The AEI is interesting in that it shows the impact of the estimated pollution abatement costs in terms of recent historical investment but it is incomplete since the investment in a mill does not reflect a mill's profitability. Table 3 shows that the ratio of average investment to average surplus increases with decreasing surplus suggesting that there is a minimum amount of investment required for a mill to remain competitive and that more profitable mills can distribute a larger proportion of profits as dividends. Of the two ratios, the ACR is perhaps the best measure of the impact of the regulations on a mill.

The AEI seems to be independent of the level of the ACR. However, it is clear that the overall compliance costs per dollar of surplus are inversely proportional to the ACR.

The average capital cost of compliance per mill is estimated at $25.7 million in 1989 dollars compared to $17.0 million of average investment. This is equal to 1.5 years of average equivalent investment (AEI). Average estimated annualized cost per mill is $4.4 million or 7.9% of the average annual surplus of $55.3 million.

Presence of Treatment Facilities

One of the most important factors determining compliance costs is whether a mill has already invested in treatment facilities. Twenty one mills already equipped with primary and secondary facilities must invest, on average, almost $13 million. This amount represents about half of a year's average equivalent investment. In comparison, 13 mills with no treatment facilities must invest almost $27 million or 2.2 years of AEI. This difference results from the combination of higher capital costs and lower average investment for mills without facilities. In terms of the ACR, mills with both types of facility must spend 3% of surplus annually compared to 14% for mills with no facilities. The majority of the mills considered here have primary treatment facilities only.

Capacity

Mill capacity does not seem to be a factor in terms of the years of AEI needed to comply with the regulations except for the smallest mills for which the AEI is 4.69 years. However, there is a clear correlation between mill size and the ACR which ranges from 6% for mills producing more than 1000 tonnes per day to 19.5% for the smallest mills producing less than 200 tonnes per day.

Although there are important economies of scale in this industry, they do not seem to be related to mill capacity. It is the size of the pulp and paper machines that matters: the total output can be produced by one large machine or two or more small ones. From Table 3 it can be seen that mills producing fewer than 300 tonnes per day were substantially less profitable than average yet so were the mills producing between 620 and 800 tonnes per day. The best performing mills had a daily capacity of between 300 and 620 tonnes per day. These mills had an average surplus of $247 per tonne compared to only $232 per tonne for mills producing over 1000 tonnes per day. Mills producing in the range of 620 to 800 tonnes per day are particularly notable, given their size, their relatively high compliance costs and low profitability representing an ACR of 13%.

1. Except where explicitly noted, all references to data in this section refer to Table 3.
2. Estimates of capital and operating costs for specific mills were prepared by N. McCubbin Consultants Inc. These data were used by Environment Canada to evaluate the anticipated impact of the Pulp and Paper Effluent Regulations published in the Canada Gazette on December 14, 1991.
3. Surplus is defined here as the value of shipments less the cost of energy, materials and labour. Since the study is conducted at the level of the individual mill, it is not possible in most cases to determine actual profits. Surplus, as defined here, includes head office overhead, certain purchased services, depreciation and profits.
4. The capital cost is expressed as annual payments over 20 years amortized at 8.19% (See McCubbin, 1990, p 63.)

Table 3: Cost of Compliance and Other Measures

	Mills	Capacity	BOD	Mills with secondary utilities	Average investment	Average surplus	Investment over surplus	Surplus over production	Compliance costs: Capital	Compliance costs: Operating	Compliance costs, Annualized: Over production	Compliance costs, Annualized: A.E.I.	Compliance costs, Annualized: A.C.R.
	number	tonnes per day	kg per tonne	percent	millions of dollars	millions of dollars	dollars per dollar	dollars per tonne	millions of dollars	millions of dollars	dollars per tonne	years	percent of surplus
All mills	**86**	**721**	**30.2**	**24.4**	**17.0**	**55.3**	**0.31**	**227**	**25.7**	**2.3**	**18.0**	**1.51**	**7.9**
Treatment													
None	13	504	21.5	...	12.3	35.5	0.35	223	27.2	2.8	31.4	2.22	14.1
Primary only	52	693	40.6	...	15.9	53.5	0.30	226	30.5	2.6	21.7	1.92	9.6
Primary & sec.	21	925	9.8	100.0	22.5	72.1	0.31	230	12.8	1.1	6.8	0.57	2.9
Capacity (tonnes per day)													
Over 1000	17	1 428	24.0	41.2	27.9	111.1	0.25	232	38.3	3.5	13.8	1.37	5.9
800 to 1000	14	885	33.9	28.6	23.4	66.2	0.35	210	28.7	2.3	14.7	1.23	7.0
620 to 800	9	706	43.4	44.4	24.2	46.9	0.52	198	39.0	3.1	26.8	1.61	13.5
300 to 620	34	478	32.3	14.7	11.4	40.0	0.29	247	21.0	1.9	22.1	1.84	9.0
200 to 300	8	273	21.1	12.5	5.7	16.7	0.34	207	7.9	1.4	25.6	1.39	12.3
Under 200	4	136	13.8	0.0	1.3	6.6	0.20	228	6.2	0.8	44.4	4.69	19.5
Year built													
Before 1900	8	365	14.0	0.0	8.6	30.3	0.28	256	13.8	1.1	19.3	1.61	7.5
1900 to 1971	64	769	35.6	18.8	18.8	59.6	0.32	226	29.4	2.7	19.2	1.56	8.5
After 1971	7	619	9.0	100.0	15.2	49.2	0.31	232	5.1	0.4	3.9	0.34	1.7
Product													
Integrated kraft	15	1127	16.2	46.7	21.2	89.5	0.24	241	29.9	2.7	13.7	1.41	5.7
Market kraft	19	746	18.1	47.4	17.6	58.9	0.30	222	20.3	1.6	12.1	1.15	5.5
Mechanical	5	457	11.9	20.0	17.1	27.9	0.61	176	12.5	2.0	18.8	0.73	10.7
Newsprint	29	757	36.2	6.9	17.8	62.2	0.29	237	30.4	2.6	19.6	1.70	8.2
Other paper and board	9	250	10.7	11.1	3.2	16.3	0.19	227	4.5	0.5	11.8	1.43	5.2
Sulphite, semi-chemical and dissolving	9	497	89.2	11.1	19.4	22.9	0.85	159	43.2	4.0	52.5	2.23	33.1
Region													
Atlantic Provinces	11	713	31.8	27.3	17.7	47.3	0.37	190	25.2	2.0	16.4	1.42	8.6
Quebec	36	615	35.1	8.3	15.7	49.3	0.32	242	27.3	2.1	21.4	1.74	8.9
Ontario	17	635	27.2	11.8	11.6	52.5	0.22	250	19.7	2.2	18.2	1.70	7.3
Prairie Provinces	4	633	14.5	75.0	26.5	53.5	0.49	211	10.2	1.2	8.1	0.39	3.8
B.C. coastal	9	1 214	40.8	33.3	29.2	99.8	0.29	229	55.0	5.1	22.1	1.89	9.7
B.C. interior	9	865	10.5	77.8	14.9	50.6	0.29	193	8.6	1.0	6.5	0.58	3.3
Investment													
Capital > average	31	1 052	32.8	32.3	32.0	84.3	0.38	230	38.5	3.5	18.2	1.20	7.9
Capital < average	55	535	28.7	20.0	8.5	39.0	0.22	224	18.5	1.6	17.7	2.17	7.9
Control													
Canadian	54	661	34.3	16.7	15.0	48.0	0.31	221	26.5	2.2	20.4	1.77	9.2
Foreign	32	823	23.2	37.5	20.2	67.7	0.30	234	24.2	2.3	14.9	1.20	6.4
Surplus (dollars per tonne)													
Over 250	22	709	28.1	36.4	17.1	75.7	0.23	299	26.1	2.3	17.4	1.52	5.8
200 to 250	21	953	23.0	19.0	19.0	78.1	0.24	237	28.6	2.7	15.3	1.50	6.5
160 to 200	22	696	35.8	18.2	17.9	46.8	0.38	196	26.9	2.3	18.8	1.51	9.6
Under 160	21	528	33.6	23.8	13.8	20.1	0.69	132	21.0	1.9	23.5	1.53	17.8

Sources:
Statistics Canada, National Accounts and Environment Division.
Environment Canada, Regulatory Affairs and Program Integration Branch.

Age and Modernization

The year that a mill was built does not necessarily dictate its efficiency or its pollution abatement except for mills which were built since 1971 when the first federal regulations came into effect. This fact is illustrated by the very low ACR (2%) for mills built since 1971 compared to 8.5% for mills built between 1900 and 1971. Those built prior to 1900 must spend, on average, 7% of annual surplus to be in compliance. It is interesting to note that the surplus per tonne of capacity was almost the same for recent mills and older mills, confirming that the actual age of the mill is not an important variable in profitability.

On the other hand, if modernization can be equated to a high level of investment averaged over the last 12 years then mills with above average investment might be expected to perform better and generate less pollution. This tendency exists to some extent as the surplus per tonne of capacity was $230 for high investors compared to $224 for low investors. The latter group of mills have a much smaller capacity (535 tonnes compared to 1052 tonnes per day). Although the mills with above average investment have a higher percentage of secondary treatment facilities (32% compared to 20%) their BOD factors are slightly higher. This reflects the fact that the smaller mills are less likely to produce their own pulp. Both groups of mills must spend 8% of their surplus annually to comply with the regulations, indicating that higher investment did not generally put mills in a better position with respect to compliance costs.

Product

The indicators by product category are very uneven, reflecting the underlying production processes and the presence of secondary treatment facilities. This latter variable, however, seems to be linked to the type of process. For instance, half of the producers of market kraft pulp in this sample have secondary treatment facilities yet their capital costs per tonne of product are higher than those of other paper and board mills, 11% of which have secondary facilities. Since the latter generally do not produce their own pulp, their BOD factors are low.

Although the AEI is much below average for mechanical pulp mills, these mills have one of the highest ACRs due to relatively high operating costs and a lower than average surplus per tonne of product. By far the highest compliance costs per dollar of surplus have been estimated for mills producing sulphite, semi-chemical or dissolving pulps. These mills generate a very high level of BOD and have a lower than average percentage of secondary facilities. Their required capital costs per tonne of product are three times the average and their surplus per tonne is 30% less than the average. These factors result in an ACR of 33% for the 9 mills in this category. These mills have an important impact on other characteristics in Table 3.

Region

Regionally, Quebec producers face the highest absolute compliance costs but they also produce more pulp and paper than those in other regions. Quebec mills account for 44% of the total capital costs of compliance but in terms of costs per dollar of surplus, mills on the Pacific coast[1] are the most affected. Average capital costs per mill in Quebec are estimated at $27 million, or about 1.7 years of AEI compared to 1.9 years for British Columbia coastal mills and only 0.4 years for mills in the Prairie provinces.

For the ACR, the pattern is similar although the differences between the regions are less marked. Mills in the Prairie provinces and the interior of British Columbia must spend 3% of surplus annually while mills on the Pacific coast must devote 10%. According to this measure there is little difference between mills in Eastern Canada despite the fact that Quebec has the lowest percentage of mills already equipped with secondary treatment facilities. The relatively low average surplus per tonne of product during the eighties in the Atlantic provinces and in the British Columbia interior mills increases this measure compared to other regions. In contrast, the above average surplus in Ontario reduces the relative impact of compliance costs in this province.

Control

The average capital and operating compliance costs are much the same for Canadian and foreign controlled mills yet the former were somewhat less profitable and thus had higher compliance costs relative to surplus. The 54 Canadian controlled mills had an AEI of 1.8 compared to 1.2 for the 32 foreign controlled mills.

The ratio of average investment to average surplus is very similar for both groups despite the higher surplus per tonne of product for the foreign controlled mills. (As shown in Table 3 for all mills considered here, there is generally an inverse relationship between level of surplus and this ratio). Average investment is indeed larger for foreign controlled mills but they are also larger and the investment per tonne of capacity is similar. There is no indication, therefore, that foreign controlled mills are less inclined to reinvest their earnings. On the other hand, the higher percentage of secondary treatment in foreign controlled establishments does not necessarily reflect a higher expenditure on pollution abatement. It would be necessary to examine the historical ownership records to determine this.

1. It is important to distinguish between B.C. coastal and interior mills because of the marked difference in their circumstances. Most interior mills had already acquired secondary treatment facilities whereas the coastal mills were relatively unequipped. Furthermore, due to the limited area surrounding coastal mills, it is necessary for many of them to use the activated sludge treatment process which is more costly.

Mills in Compliance

The mills that are deemed to have no costs resulting from the 1992 federal regulations on traditional pollutants are smaller, less profitable and had a higher investment per tonne of production than those for which such expenditures were assessed (Table 4). The low surplus per tonne of these mills seems to be mainly related to their product. These mills do not, by and large, produce newsprint or kraft pulp, products that generated a relatively high surplus per tonne during the eighties.

Table 4: Characteristics of Mills With and Without Compliance Costs

	With compliance costs	Without compliance costs
Number of mills	86	25
Average capacity (tonnes per day)	721	408
Average surplus (dollars per tonne)	210	169
Average investment (dollars per tonne)	64	104
Number with secondary facilities (percent)	24	48

Sources:
Statistics Canada, National Accounts and Environment Division.
Environment Canada, Regulatory Affairs and Program Integration Branch.

CONCLUSIONS

On average, mills not in compliance with the new federal regulations must spend an estimated 8% of operating surplus annually to purchase and operate the required treatment facilities. This percentage is inversely correlated with the production capacity of the mill and is strongly related to the type of product and the amount and type of pollution abatement equipment already in place. Although Eastern Canadian mills are often singled out as being old and less efficient, of the mills considered it is the British Columbia coastal mills that must devote the largest percentage of their surplus to this type of expenditure. For mills built before 1971, neither the age of the mill nor the level of investment over the last 12 years explains much of the variation in this percentage. Foreign controlled mills tended to perform better than Canadian controlled mills and had a higher percentage of secondary facilities already operational in 1989. These factors resulted in the former mills having a lower compliance cost per dollar of surplus.

Using average surplus as a denominator in the above measure gives an interesting perspective on the relative burden of compliance costs. Clearly, however, the performance of mills during the eighties is not necessarily a good predictor of their performance during the nineties, when the expenditures will have to be made. The high price of market pulp contributed substantially to surplus in the latter part of the decade. According to McCubbin (1990, p. 68), "the highest concentration of vulnerable mills is in the province of Quebec. All such mills are typified by high production costs, dated equipment vintage and high compliance costs." We have shown, however, that Quebec mills performed better than average during the eighties and invested a proportion of surplus equivalent to the average of all mills considered. The ACR in Quebec was only one percentage point higher than the general average. This potential contradiction illustrates one of the hazards of comparing estimated future costs to actual historical financial data. In the final analysis, however, there is no significant difference in the average surplus per tonne of product for mills that have both primary and secondary facilities, those that have only primary facilities or those that have none, a fact that suggests that pollution abatement costs have not detracted from the performance of pulp and paper mills in the past.

DATA SOURCES AND MEASUREMENT PROBLEMS

The following data files were used for this study:

Pollution Data

Information on BOD factors and treatment facilities came from the Pulp and Paper Mill Profile System described in Statistics Canada (1992, p. 96). The data pertain to 1989. This database contains information on 124 direct discharge mills.

Estimated Compliance Costs

As noted in the text, these data come from a report prepared for Environment Canada by N. McCubbin Consultants Inc. The report states that:

> "The approach of calculating estimates for each mill was selected as the best way of estimating the total costs for each industry sector and geographic region. Clearly, such estimates can never be as reliable as those based on detailed engineering analysis, flowsheets, site layout, soils studies and contractors bid prices. Several capital cost estimates were checked against independent estimates based on detailed studies, and were found to be within 20% of the latter costs. Some extreme mills are bound to exist where the individual costs estimated for this report are either excessive or inadequate. However, it is considered that the aggregate of any reasonably sized sub-set of mills (such as Quebec newsprint mills) is accurate within 20%" (McCubbin, 1990, p. 56).

Manufacturing Data

Records from the manufacturing survey for individual mills classified to SIC 271 were processed to obtain 1989 production figures by type of product. Surplus was calculated for the period 1981-1989 by subtracting the cost of materials, fuel and labour from the value of shipments. As noted in the text, this value is equivalent to operating profit before depreciation and depletion allowances except that it includes head office expenses. Since the study considers individual mills, it was not possible to derive a net profit estimate at this level. A weighted average of the annual surplus was calculated using the GDP implicit price deflator.

Investment Data

It was possible to obtain investment data dating back to 1979 from the Capital and Repair Expenditure Survey conducted by Statistics Canada. Although data exist prior to this year, it would have been difficult to match individual mills. Averages were computed using the price indexes for capital expenditure on plant and equipment for paper and allied industries.

Record Matching

The matching of company names by location was relatively straightforward, especially with the help of the *Pulp & Paper Canada Annual* for 1989. In some cases one source reported data on a combined basis whereas other sources reported on the individual establishments. Mills for which all data were not available were omitted from parts of the analysis. This problem explains the variance in the number of mills reported. For instance, in Table 4 only 111 of the 124 direct discharge mills could be matched to combine information on surplus and investment. In Table 3 only 86 of the 94 mills reported as having compliance costs could be matched to show all the variables.

Variance

The variance about the mean is quite high in many cells of the tables presented in this study. Although excluding the outliers would have an effect on the mean in some cases, the difference is not large enough to change the conclusions. It should be noted, however, that the measures for a mill in any given category may be quite different from the average.

REFERENCES

Department of Fisheries and Oceans. "Pulp and Paper Effluent Regulations." *Canada Gazette, Part I*, December 14, 1991.

Environment Canada. *The State of Canada's Environment.* Ottawa, 1991.

Headlam, B. and M.Stevenson. "Winning the Paper Chase." *Canadian Business*, June 1990, p. 43.

Jamieson, Scott. "Airing Some Concerns: The Next Wave in Pollution Control." *Pulp & Paper Canada*, 92, 10 (October 1991): 12-13.

McCubbin, Neil. "Economic Impact of Proposed Regulation of Pulp and Paper Industry." (Unpublished.) Prepared for Regulatory and Economic Affairs Division, Environment Canada, June, 1990.

Pulp & Paper Canada. *1989 Annual and Directory.* Southam Business Publications. St.-Laurent, Quebec, 1989.

Sinclair, William F. *Controlling Pollution from Canadian Pulp and Paper Manufacturers: A Federal Perspective.* Environment Canada, 1990.

Statistics Canada. *Databases for Environmental Analysis: Government of Canada.* Occasional, Catalogue 11-527, Ottawa, 1992.

4 Transportation of Dangerous Goods

by Marcia Santiago

INTRODUCTION

Cargo transportation is an essential element of economic activity. The transportation system itself — roads, railways, pipelines and seaways — is a tangible link between industrial production and the consumer population.

Many aspects of transportation are associated with some level of environmental impact, including fossil fuel consumption, land use change and pollution from both the vehicles and people that use the transportation network. These may be measured in terms of either energy and material consumed or substances released into the environment. Other aspects of transportation, such as environmental risk, are not so easily quantified. This is because risk to the environment is quite different in nature from impact. The potential for impact is substantially more difficult to describe than an actual or realized effect. It is, nonetheless, a dynamic element of the relationship between the human and physical environments.

This chapter examines the regulation concerning the transport of dangerous goods in Canada. This is followed by the presentation and discussion of a variety of data on the tonnage of dangerous goods moved by various modes of transport, and on accidents involving dangerous goods. These two sets of data are used to estimate some simple indicators of the risk of accidental release of material associated with transportation of dangerous goods.

TRANSPORT REGULATIONS

In a practical sense, risk in transportation is usually understood in terms of human safety. Transportation is regulated on two levels: in the economic or competitive context, as well as in terms of safety. Safety is one of the main objectives of the National Transportation Policy (National Transportation Act 1987).

Dangerous goods are encountered in many economic activities, notably in many basic resource industries. In various forms, they are involved in virtually all types of manufacturing. Many are not intrinsically dangerous to the physical environment. In fact, most are regulated on the basis of their potential danger to transportation safety and human health. The term "dangerous goods" may, as such, be misleading in an environmental context but it is used in this chapter because it is the regulatory term of reference.

In Canada, the movement of dangerous goods is largely controlled through the federal Transport of Dangerous Goods Act (1985) and its associated Regulations (1985, 1989). This legislation applies to all domestic and international movements of dangerous goods by Canadian carriers.

Within this context, dangerous goods are those commodities recognized by the Act as "any product, substance, or organism included by its nature or by the regulations in any of the classes listed in the Schedule" to the Act. This schedule contains over 3 000 commodities, which are classified by United Nations Product Identification Numbers (PIN). These dangerous goods are aggregated into nine classes which form the basis of specific regulatory measures. Dangerous goods are controlled at all stages of transport: labelling of shipments, identification of hazardous substances on bills of lading and cargo manifests, and marking of vehicles. These regulations also stipulate training of anyone handling, offering to transport, or transporting dangerous goods.

THE ECONOMIC CONTEXT

Table 1: Dangerous Goods Transported, by Mode of Transport, 1986

Class	Rail	Road	Marine
	thousand tonnes		
1. Explosives (potentially explosive material)	51	115	14
2. Compressed or liquefied gases	5 647	1 158	246
3. Flammable and combustible liquids	3 748	18 186	10 283
4. Flammable and combustible solids	117	359	283
5. Oxidizers and organic peroxides	645	1 562	155
6. Poisonous and infectious substances	99	246	111
7. Radioactive materials	--	34	17
8. Corrosive materials	3 435	1 372	921
9. Miscellaneous dangerous substances or articles	2 047	401	99
Total	**15 790**	**23 433**	**12 129**

Sources:
Transport Canada and Statistics Canada (OECD, 1988)

Table 1 shows that, overall, road transport accounts for 46% of the dangerous cargo tonnage shipped[1]. Shipments by rail and by marine carriers account for 31% and

1. The relative importance of various modes in dangerous goods movement varies with the method of estimating levels of activity. For example, the comparison between trucking and marine shipments may produce different results depending on whether or not the distance travelled is associated with the quantity of freight (i.e., tonne-kilometres vs. tonnes). Rail and road data are qualified in the following sections. For marine shipments, the figure shown is for international movements only; the tonnage of dangerous goods for domestic shipping is not available.

24%, respectively. Flammable and combustible liquids (Class 3 substances) are the dangerous goods most commonly transported, representing 63% of the total weight of dangerous goods shipments. In terms of the mode of transport, flammable and combustible liquids represent 85% of international marine, 78% of for-hire trucking and 24% of rail shipments of dangerous goods.

Rail Movements

Dangerous goods represented 9%, by weight, of all commodities transported by rail within Canada and across the Canada-U.S. border in 1989. Domestic shipments of dangerous goods amounted to 11 million tonnes (or 68% of the total weight of dangerous goods shipments) and 181 thousand carloads (or 72% of total carloads shipped). Trans-border shipments contributed the remainder, at 5 million tonnes and 69 thousand carloads. These movements are summarized, by origin and destination, in Table 2.

Differences in unit weight (that is, the average weight per carload) across rail corridors may be attributed to a number of factors. High unit weights (e.g., 74 tonnes per car for domestic movements originating in Alberta) may indicate that the dangerous goods carried mainly consist of heavy, bulk materials. These would include crude petroleum oil or semi-refined petroleum products. Lower unit weights might suggest that the commodities being transported are more refined and less dense products. Low unit weights may also indicate that dangerous goods are being carried in mixed carloads with other, non-regulated products.

One fifth of rail movements in dangerous goods (representing 4 million tonnes and 49 thousand carloads) took place within provincial boundaries. Interprovincial shipments totalled 7 million tonnes (42%) and 195 thousand carloads. Alberta, Ontario and Quebec accounted for most of the activity.

Six products account for 44% of the dangerous goods tonnage transported by rail from the U.S. Ranked highest, in terms of tonnage, is sodium hydroxide (81 thousand tonnes, Class 8). In this group, there are also two Class 3 commodities: cyclohexane (74 thousand tonnes) and benzene (27 thousand tonnes). Isobutylene (71 thousand tonnes) and propylene (65 thousand tonnes) are both Class 2 substances. One commodity, ethylenediamine tetra-acetic acid (EDTA), is classified by Transport Canada as an environmentally hazardous substance (Class 9.2, 44 thousand tonnes).

Similarly, among rail shipments of dangerous goods from Canada to the U.S., five products account for half of the tonnage. Three of these are compressed or liquefied gases (Class 2): ammonia (902 thousand tonnes), isobutane (396 thousand tonnes), and propane (313 thousand tonnes). Asbestos (473 thousand tonnes, Class 9) and sulphuric acid (468 thousand tonnes, Class 8) are also substantial components of the activity.

Table 2: Rail Movement of Dangerous Goods, by Origin and Destination, 1989

Origin	Destination							
	Nova Scotia and New Brunswick	Quebec	Ontario	Manitoba and Saskatchewan	Alberta	British Columbia and the Territories	United States	**Total**
				thousands of tonnes transported *carloads*				
Nova Scotia and New Brunswick	278	24	55	3	2	1	12	**375**
	4 136	*1 035*	*2 119*	*110*	*122*	*55*	*214*	***7 791***
Quebec	289	577	227	57	65	51	737	**2 003**
	5 985	*8 033*	*5 361*	*1 660*	*2 086*	*1 407*	*10 137*	***31 579***
Ontario	227	942	1 323	209	318	254	1 601	**4 875**
	7 266	*14 223*	*17 689*	*7 313*	*10 396*	*7 785*	*21 653*	***86 325***
Manitoba and Saskatchewan	16	5	181	257	8	36	172	**676**
	215	*151*	*2 856*	*3 907*	*233*	*588*	*2 457*	***10 407***
Alberta	53	255	530	292	721	2 329	2 490	**6 668**
	813	*3 172*	*6 404*	*4 117*	*9 775*	*28 926*	*32 094*	***86 111***
British Columbia and the Territories	--	5	12	7	32	577	47	**679**
	2	*200*	*4 833*	*147*	*522*	*7 794*	*672*	***9 896***
United States	2	183	342	29	121	82	62	**821**
	94	*4 967*	*36 821*	*507*	*1 793*	*1 026*	*785*	***14 005***
Total	**865**	**1 990**	**2 670**	**853**	**1 268**	**3 331**	**5 119**	**16 097**
	18 421	***31 781***	***39 821***	***17 761***	***24 927***	***47 581***	***68 822***	***249 114***

Source:
Statistics Canada. *Rail in Canada 1989*. Catalogue 52-216.

Road Movements

As in other industrial economies, road transport accounts for most of the dangerous cargo shipments within Canada (OECD, 1988). This reflects, to a great extent, the prominence of for-hire trucking in local freight distribution.

Table 3 is a summary of interprovincial dangerous goods movement by for-hire trucking in 1989. Shipments between and within urban areas account for 40% (1.9 million) of the shipments and 23% (7.7 million tonnes) of the weight transported. About 244 thousand shipments are made within Toronto's Census Metropolitan Area (CMA), the greatest number of dangerous goods movements within an urban centre. The greatest concentration of tonnage is transported within the Vancouver CMA, which accounts for 1.7 million tonnes of dangerous goods. Transborder activity accounted for 2% of shipments and 5% of dangerous goods tonnage. Compared to transborder rail movements, this is a considerably lower proportion of activity.

ACCIDENTS

Over time, the overall frequency of transportation accidents has tended simply to reflect the level of shipping activity. In 1991, the Transportation Safety Board reported a decrease in air and marine accidents compared to the previous year (TSB, 1992). In the same time period, there was an increase in the number of rail accidents but the accident rate actually declined somewhat (TSB, June 1992).

The pattern of transportation accidents that involve dangerous goods is also tied to the level of activity. Overland shipments account for most of the dangerous tonnage transported and it follows that the road and rail modes also account for most of the accidents involving dangerous goods (Table 4).

The likelihood of an accident may also be expressed, for either overland mode of transport, in terms of the total shipments. Among rail movements, it is estimated that one accident occurs for every 545 carloads, or 36 thousand tonnes, of dangerous goods transported. In for-hire trucking, the probability of accident is estimated at one in 21 thousand truckloads, or 70 thousand tonnes, of dangerous goods transported.

Between classes of dangerous goods, the occurrence of accidents is only weakly correlated with the quantities transported. In rail shipments, Class 3 substances account for 24% of the tonnage and 29% of the accidents (one accident for every 29 thousand tonnes transported). In road movements, these commodities account for 78% of the tonnage and 43% of the accidents (one accident for every 90 thousand tonnes transported).

An important dimension of any accident involving dangerous goods is whether or not material release occurs as

Table 3: Dangerous Goods Handled in For-hire Trucking, by Origin and Destination, 1989

Origin	Destination: Newfoundland and Prince Edward Island	Nova Scotia and New Brunswick	Quebec	Ontario	Manitoba and Saskatchewan	Alberta	British Columbia and the Territories	United States	Total
	thousands of tonnes / *thousands of truckloads*								
Newfoundland and Prince Edward Island	163	25	1	--	--	33	--	--	**223**
	18	*3*	--	--	--	*1*	--	--	***22***
Nova Scotia and New Brunswick	50	2 400	39	14	--	--	--	220	**2 725**
	7	*195*	*5*	*5*	--	*1*	*1*	*8*	***233***
Quebec	9	107	3 308	684	12	23	7	148	**4 299**
	4	*32*	*495*	*335*	*11*	*14*	*11*	*11*	***913***
Ontario	9	90	688	6 632	71	56	20	546	**8 113**
	11	*55*	*316*	*1 735*	*39*	*34*	*27*	*41*	***2 259***
Manitoba and Saskatchewan	--	4	5	176	2 983	214	47	293	**3 721**
	--	*1*	*2*	*29*	*245*	*29*	*7*	*11*	***325***
Alberta	--	--	11	40	949	6 810	924	264	**8 998**
	--	*1*	*3*	*9*	*62*	*402*	*68*	*13*	***557***
British Columbia and the Territories	--	7	4	16	26	793	3 392	124	**4 362**
	--	*1*	*3*	*8*	*6*	*45*	*297*	*9*	***367***
United States	2	19	139	492	53	73	60	8	**845**
	1	*4*	*21*	*75*	*9*	*11*	*9*	*2*	***131***
Total	**234**	**2 652**	**4 195**	**8 054**	**4 094**	**8 003**	**4 450**	**1 604**	**33 287**
	52	***291***	***845***	***2 196***	***372***	***372***	***419***	***96***	***4 808***

Source:
Statistics Canada. For-hire Trucking (Commodity Origin-Destination) Survey.

Table 4: Transportation Accidents Involving Dangerous Goods, 1990

Class	Total accidents: Road	Rail	Marine	Air	Total	Accidents with material release: Road	Rail	Marine	Air	Total
1. Explosives (potentially explosive material)	9	4	-	-	**13**	2	1	-	-	**3**
2. Compressed or liquefied gases	63	193	-	-	**256**	44	105	-	-	**149**
3. Flammable and combustible liquids	203	131	3	8	**345**	194	67	3	7	**271**
4. Flammable and combustible solids	15	10	-	1	**26**	14	1	-	1	**16**
5. Oxidizers and organic peroxides	11	15	-	-	**26**	8	4	-	-	**12**
6. Poisonous and infectious substances	44	14	1	3	**62**	42	9	1	2	**54**
7. Radioactive materials	4	-	1	1	**6**	1	-	-	-	**1**
8. Corrosive materials	99	74	2	1	**176**	94	39	2	1	**136**
9. Miscellaneous dangerous substances or articles	13	4	-	1	**18**	12	3	-	1	**16**
n.e.s	16	7	1	-	**24**	15	5	1	-	**21**
Total	**477**	**452**	**8**	**15**	**952**	**426**	**234**	**7**	**12**	**679**

Source:
Transport Canada. Dangerous Goods Directorate.

a result of the accident. With the data provided in Table 4, it is difficult to ascertain whether material release in accidents is related to mode of transport. Overall, 71% of all accidents that involve dangerous goods do result in material release. By relating the frequency of material release to the number of accidents, there would appear to be many more accidents with material release by road transport (89%) than by rail (52%). However, in terms of the tonnage of cargo transported, rail and road shipments have about the same probability of material release; there is about one accident in which material is released for every 70 thousand tonnes of material transported.

Simple frequencies cannot truly depict the magnitude of the impact that results from the accidental release of dangerous cargo. For example, in the summer of 1991 an accident provoked the derailment of twenty-five cars in St. Lazare, Manitoba (TSB 1992). Ten were carrying dangerous cargo and four of those ruptured. A toxic cloud was released, which contained methanol and acetic anhydride, and village residents were temporarily removed from the area.

HAZARDOUS WASTE

Class 9 substances, which are described as miscellaneous dangerous substances or articles, constitute a very small proportion of the total shipments and accidents involving dangerous goods. This category also includes hazardous waste such as PCBs (Table 5). Despite their minimal contribution to the total shipments of regulated substances, these commodities receive a great deal of public attention. Such a high profile is likely related to perceptions of the probability of accidents and spills, as well as the risks to health, safety and the environment that are believed to be associated with hazardous waste.

Table 5: Rail and Road Movements of Class 9 Substances, 1992

Class	Movements: Rail		Road		Average distance
	thousand tonnes	cars	thousand tonnes	trips	km
9.1 Miscellaneous dangerous goods	1 053	17 824	485	67 076	818
9.2 Environmentally hazardous substances	496	7 819	44	6 573	620
9.3 Dangerous wastes	2	42	..	..	..
9.9 Other	977	38 149	...	...	...
Total	**2 528**	**63 834**	**530**	**73 649**	**800**

Source:
Transport Canada. Dangerous Goods Directorate

Rail shipments of hazardous waste in 1992 were estimated at about two thousand tonnes or 42 cars, representing less than one tenth of one percent of Class 9 freight in this mode. Furthermore, Class 9 materials were involved in a very small proportion of the accidents involving dangerous goods. Among accidents involving dangerous goods where material was released, only 2% involved Class 9 cargo.

There is a great deal of discussion regarding the risks associated with storing, handling, and transporting hazardous waste. Some perceive that the transport of hazardous waste poses a greater health and safety risk than that of other classes of dangerous goods. Others believe that accidents involving hazardous waste are more likely to occur in transportation than in storage and handling or after equipment failure. There is one study, for the province of Manitoba, where it has been shown that the risk of accident in transportation is no greater than in any other activity involving hazardous waste (Manitoba Environment, 1991). It is difficult, however, to compile complete, reliable data and, therefore, to arrive at firm conclusions.

The risks associated with hazardous waste transport are difficult to ascertain. Among rail movements, the likelihood of an accident involving a Class 9 substance is estimated at one in 16 thousand carloads, or one in 632 thousand tonnes. Compared to the accident rate among dangerous goods, in general, this probability is considerably lower. Among road movements, it is estimated that one accident occurs for every 6 thousand shipments, or 41 thousand tonnes, of Class 9 substances. Based on these data, there is one accident for every 33 thousand tonne-kilometres of dangerous goods transported by road. It should be noted, however, that the estimates of shipment frequency and tonnage for road movement are based only on for-hire trucking whereas statistics on accidents cover all trucking. Thus, the probability of accidents may be overstated.

DATA SOURCES

By law, dangerous goods movements are monitored through a system of permits but, despite this requirement, there is no central source of data.

Data for rail shipments are collected by the Dangerous Goods Directorate of Transport Canada from the Canadian National and Canadian Pacific Railways. Data for the period 1987-1989 were supplied by Transport Canada to Statistics Canada for special studies on dangerous goods movement, which appeared in *Rail in Canada 1988* and *1989* (Catalogue 52-216).

The Transportation Division of Statistics Canada maintains databases on for-hire trucking. With the assistance of Transport Canada, commodities designated as being "dangerous" under the Act are identified on this database. A similar exercise is being undertaken with international shipping data. In all cases, estimates of dangerous goods shipments are based on bills of lading, cargo manifests or their equivalent; none are based on dangerous goods permits. At present, no data are available for the following types of shipments: own-account trucking, rail movements other than CN and CP, domestic shipping and permits for exception in all modes.

The data derived from bills of lading are coded by either the Standard Trade Commodity Classification or the Harmonized Commodity Description and Coding System. Neither corresponds precisely to the PIN classification and the estimates of movements of dangerous goods require adjustments. For example, in rail movements, Class 9.9 was created for mixed cargoes of regulated and non-regulated commodities.

REFERENCES

Manitoba Environment. *State of the Environment: Report for Manitoba, 1991*. Winnipeg, 1991.

Organization for Economic Cooperation and Development (OECD). *Transporting Hazardous Goods by Road.* Report prepared by an OECD Scientific Experts Group. Paris, 1988.

Transportation Safety Board of Canada (TSB). *Annual Report 1991.* Ottawa, 1992.

-----. *Summary of Railway Accidents/Incidents,* Ottawa, June 1992.

5 Land Use Change Around Riding Mountain National Park

by Douglas Trant

INTRODUCTION

Riding Mountain National Park has been described as:

> "An island of natural environment surrounded by a sea of man-altered environment. The transition zone from farmlands is illustrated dramatically by the wheat fields and pastures abutting the natural environment."
> (Parks Canada, 1987).

The park is a unique area of Canadian wilderness where habitats characteristic of eastern, western and northern Canada converge in a series of forests, grasslands, hills and valleys. Riding Mountain National Park's 3 000 square kilometre area is home to 5 000 elk, 4 000 moose, and over 1 000 black bears. Many other species such as wolf, beaver, cougar and osprey also inhabit this nature reserve. In summer months more than 30 000 people visit the park each weekend.

Riding Mountain National Park is located on the Manitoba Escarpment, and can be described as an elevated boreal island surrounded by prairie. Because of its unusual combination of attributes it was designated as an International Biosphere Reserve, as part of the United Nations Educational, Scientific and Cultural Organization's (UNESCO) Man-Biosphere Program. UNESCO established the Man-Biosphere Program in 1971 to ensure the preservation of unique natural environments in each of the world's biogeographic regions. A Man-Biosphere reserve typically consists of a protected core of natural environment together with adjacent areas which collectively form a zone of co-operation. The Man-Biosphere Program recognizes that socio-economic activities and natural ecosystems must co-exist in an effort to guarantee the survival of both. Some 266 Man Biosphere Zones have been selected globally to date.

In recent years the transition zone from park to agriculture has become narrower, making the likelihood of conflict between activities more probable. Close co-existence of agriculture and wilderness can induce conflict, as one interferes with the other. The survival of the nature reserve depends on careful organization, planning and management. The role of information to support decision-making in this process is important. The findings of this analysis and the information that supports it will be added to a larger inventory of data supporting the Biosphere Reserve Program at Parks Canada.

This study will examine the changing mosaic of socio-economic activity that surrounds Riding Mountain National Park. The inter-relation between park, biosphere reserve and beyond is explored from both spatial and temporal perspectives. Many Statistics Canada micro-databases have been tapped to generate a detailed profile of the area as it has evolved over the last twenty years. Most of these information bases are accessed through the National Accounts and Environment Division's Environmental Information System (EIS) which uses geo-referenced data within a geographic information system (GIS) framework.

This analysis is divided into three Sections. The first section provides background on the history of the park and focuses on issues that have emerged as human settlements and activities move closer to the park, placing more and more pressure on the nature reserve. This section will also describe the physical setting of Riding Mountain, by briefly looking at physiography, hydrology and important biotic communities.

The second section will look at changing population and land use trends around the park over the last twenty years. A detailed statistical profile consisting of a series of concentric zones around the park, will be used to indicate composite activity changes in relation to proximity to the park.

The third section examines changes in agricultural practices around the park. Trends in farm input levels and cropping practice changes will be examined over time to suggest potential effects on the park.

PHYSIOGRAPHY AND HISTORICAL BACKGROUND OF RIDING MOUNTAIN NATIONAL PARK

History

In the early 1800's the land that comprises Riding Mountain National Park was exploited largely as a timber resource for the construction of railways and farm buildings. In 1895, in response to continued pressure from growing settlements, the Dominion Government chose to set aside today's park area as a forest reserve. The purpose of this reserve was to continue to provide lumber to developing communities at controlled rates in an effort to maintain a continual long term supply of wood (Tabulenas, 1983, p. 175). As a new forest reserve, Riding Mountain came under the jurisdiction of the Forestry Branch of the former Department of the Interior. Husbandry of the reserve became the responsibility of foresters who controlled forest harvest rates. By the early 1900's increased demands for lumber and uncontrolled hunting access had diminished wildlife populations to dangerously low levels. In response to public concern, the Manitoba Government enacted legislation to make Riding Mountain into a game reserve (Tabulenas, 1983, p. 191).

Despite the economic depression of the 1920's and early 30's, agriculture continued to expand and ultimately advanced to the very edge of the Riding Mountain Reserve. In response to this pressure, and a new public demand for leisure and recreational space, the Riding Mountain Preserve became a National Park in 1930. Since then two very different landscapes have evolved, and Riding mountain has become an island of wilderness within a sea of agricultural development (Tabulenas, 1983, p. 200).

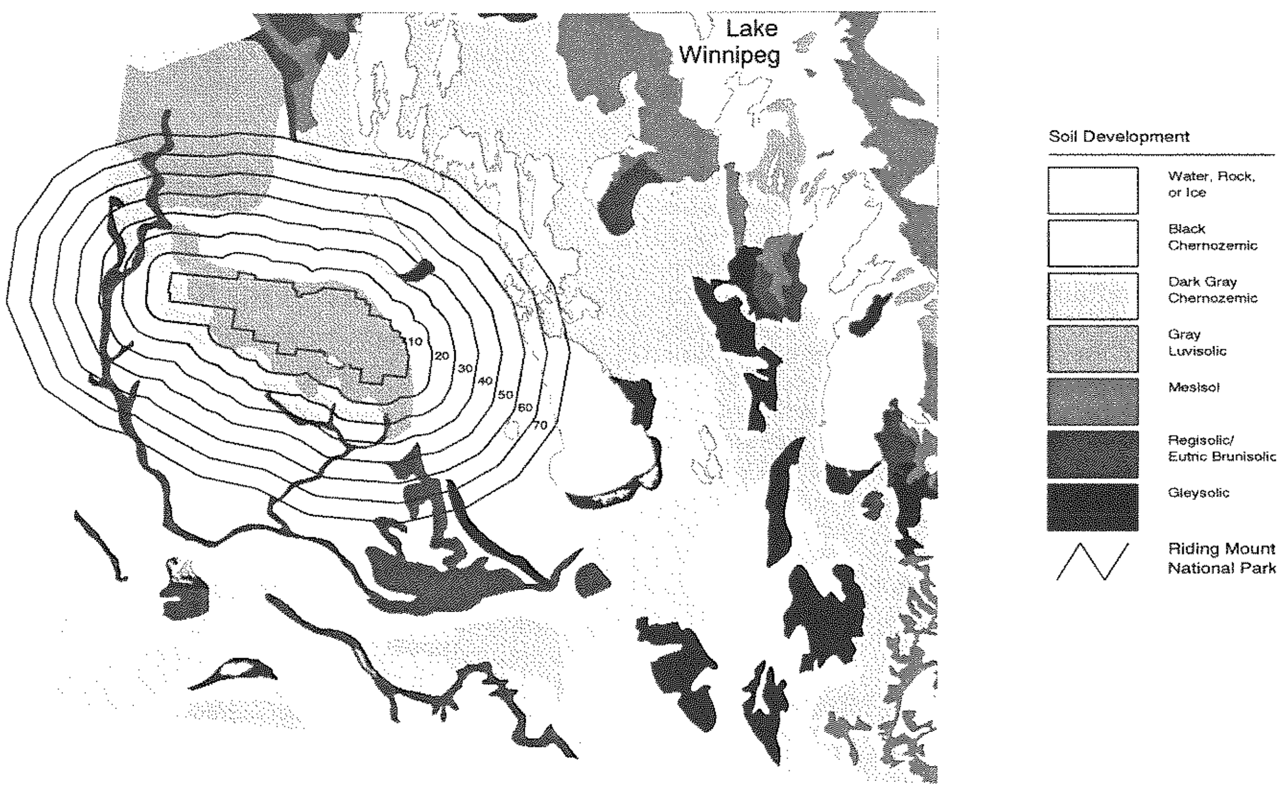
Physiography

Riding Mountain National Park straddles an upland plateau formed by the geologic faulting of the Manitoba escarpment and the subsequent deposition of glacial moraine landforms from the last glacial period some 12 000 years ago. The bedrock geology underneath the park and surrounding area is largely sedimentary, consisting of highly erodible shale types. The soils on Riding Mountain Plateau have developed from shale parent materials and are largely Grey Luvisols. These soils form in cool climates under woodland vegetation. (See map 1) The soils surrounding the Riding Mountain Plateau are largely Chernozems which form in cool climates under grassland vegetation. The Chernozems are quite fertile because of their high organic matter content and provide the soil base for a productive agricultural industry.

Hydrology

The Riding Mountain Plateau is the origin for many streams and rivers including the Wilson River, the Vermillion River, the Ochre River and the Turtle River. Flooding problems in these watersheds are not uncommon and are exacerbated by the build-up of shales in the stream network (Krawchuk, 1990, p. 113).The shale build-ups are primarily from erosion of alluvial fan material which has been disturbed by the recent clearing of land for agricultural use.

Map 1: Soil Types in Southern Manitoba



Notes:
Map 1 is from Agriculture Canada's 1:1 000 000 Soil Landscape Series. Riding Mountain National Park is outlined in black and is surrounded by a series of radial buffers which will form the basis for a socio-economic data analysis in the section Population and Land Use Characteristics.
Sources:
Agriculture Canada, Centre for Land and Biological Resources.
Statistics Canada, National Accounts and Environment Division.

Natural Vegetation and Ecological Communities

There are three distinct ecological communities within the Riding Mountain Biosphere Reserve. These are: Mixedwood Forest, Aspen-Oak Woodland and Grassland. The rough fescue prairie grassland within the park is of international significance as there are few undisturbed examples left in the world. (Most former fescue grasslands are now producing grain crops.) The hardwood forest community on the southern slopes of the park is also unique. This forest is growing 1 000 kilometres north of its traditional northern limit, and has survived because of the warm micro-climate created along the south facing escarpment (Krawchuk, 1990, p. 124).

POPULATION AND LAND USE CHARACTERISTICS

The land use and population study area is oval in shape and extends 250 kilometres in an east-west direction and 160 kilometres in a north-south direction. The study area represents more than 3.3 million hectares of park and surrounding farmland. A series of 10 km wide radial buffer zones have been developed to which micro-geographic data have been linked and aggregated[1]. Each radial zone around the central core represents an increasing area as the zones radiate away from the park. The 0-10 km zone is just under 320 thousand hectares while the 60-70 km zone is just under 656 thousand hectares. (See zone areas in Table 2 and Map 1.)

Rural populations have been declining in Manitoba and Saskatchewan for some years now. Manitoba's rural population declined by 1.9% between 1971 and 1986, while Saskatchewan's declined by 10.6%. The Riding Mountain area has experienced even sharper declines in population. (See Table 1 and Map 2.)

Table 1 indicates that rural population has declined by more than 21.6%, between 1971 and 1986. All zones showed a decline in rural population, zone 0-10 showed the smallest decline at 6.7%, and zone 20-30 showed the largest decline at 31.8%. These patterns indicate a declining farm population and an increasing trend towards living in urban centres.

Urban populations in the study area are quite small and exist primarily in zone 10-20 where the towns of Minnedosa and Dauphin are located. Zone 10-20 showed an urban increase of slightly more than 10.3%. Urban population for the study period grew by 16.4%. (See Table 1)

Changing demographic patterns around Riding Mountain reflect changing farm economics. Farm populations have been declining on the prairies for some time now. World grain prices have in part contributed to this decline. For example, in 1914, a tonne of wheat was worth $468 (1991 dollars) on the world market; in 1990, a tonne of wheat sold for an average of $113[2]. As the nature of farming changes in an intensely competitive international market, more and more rural dwellers move to urban areas. This trend is evident around Riding Mountain, as it is elsewhere in Canada.

Agriculture is the dominant land use activity around Riding Mountain National Park. Throughout the study period (1971-1986), agriculture has consistently occupied 80% of land around the park and directly provides almost a quarter of all employment in the study area. Table 2 describes farmland areas and changes in these areas as pro-

1. See Data Limitations section.

2. Statistics Canada, Canada Level Price Series, Agriculture Division, Farm Income and Prices Section, 1992.

Table 1: Change in Population, 1971 and 1986

Radial zone	Rural population			Urban population			Total population		
	1971	1986	Change in population 1971-1986	1971	1986	Change in population 1971-1986	1971	1986	Change in population 1971-1986
	number		percent	number		percent	number		percent
0-10 km zone	6 090	5 685	-6.7	0	0	0.0	6 090	5 685	-6.7
10-20 km zone	11 920	8 650	-27.4	10 415	11 485	10.3	22 335	20 135	-9.9
20-30 km zone	8 120	5 540	-31.8	0	1 030	..	8 120	6 570	-19.1
30-40 km zone	9 000	7 465	-17.1	4 375	4 435	1.4	13 370	11 900	-11.0
40-50 km zone	8 620	6 930	-19.6	4 450	4 280	-3.8	13 073	11 215	-14.2
50-60 km zone	10 030	8 755	-12.7	0	0	0.0	10 030	8 755	-12.7
60-70 km zone	12 530	8 955	-28.5	0	1 160	..	12 530	10 110	-19.3
Total	**66 310**	**51 980**	**-21.6**	**19 240**	**22 390**	**16.4**	**85 550**	**74 365**	**-13.1**

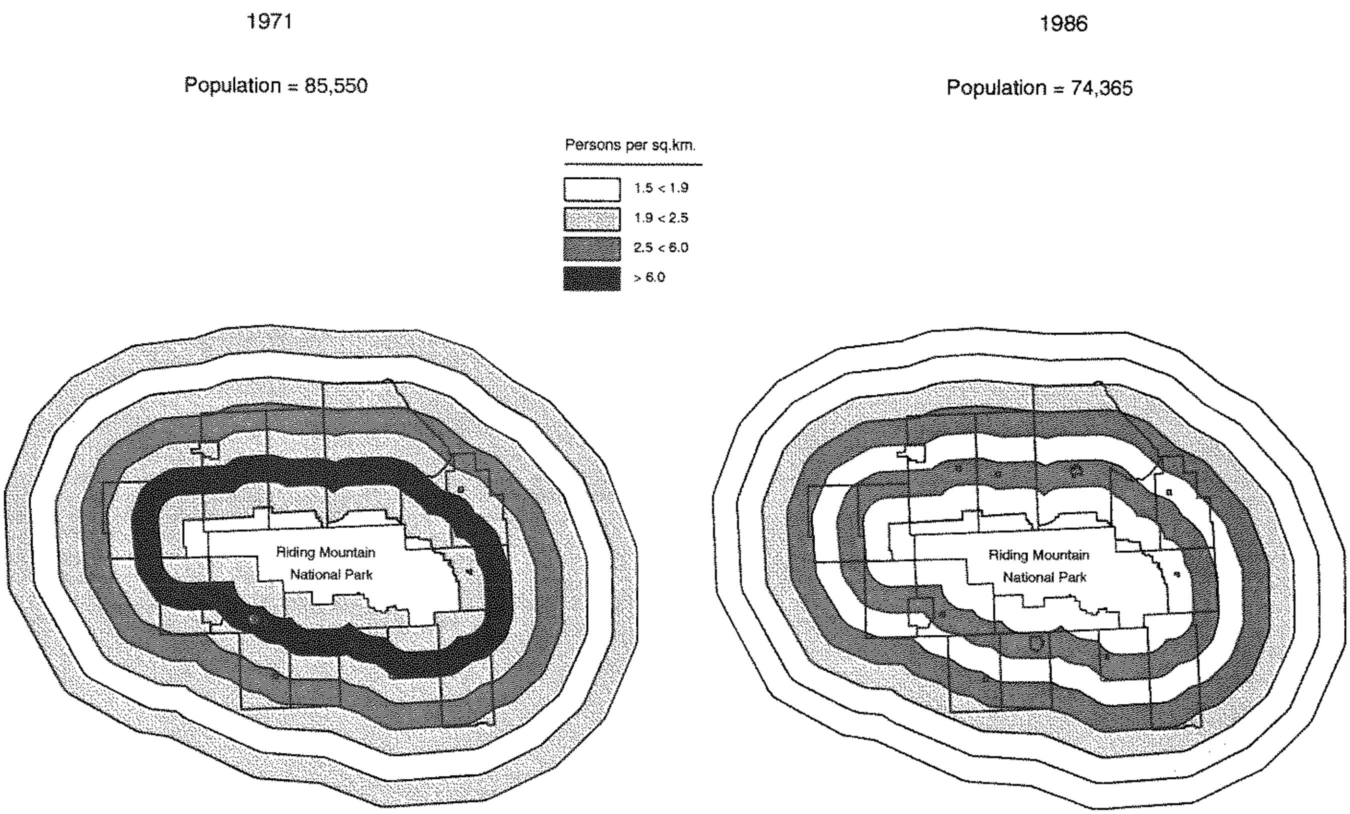
Notes:
10 kilometre radial buffers were used to classify data concentrically around Riding Mountain National Park.
Figures may not add to totals due to rounding.
Sources:
Statistics Canada, National Accounts and Environment Division and Census of Population.

Table 2: Change in Farmland Area, 1971 - 1986

Radial zone	Zone area	Farmland area 1971	Farmland area 1986	Proportion of zone area in farmland 1971	Proportion of zone area in farmland 1986	Change in farmland area 1971-1986	Average farm size 1971	Average farm size 1986	Average farm size Change 1971-1986
	thousand hectares			percent			hectares		percent
0-10 km zone	320	246	297	76.8	92.7	20.7	191	263	38.0
10-20 km zone	354	316	273	89.4	77.1	-13.8	216	273	26.7
20-30 km zone	411	388	383	94.4	93.2	-1.3	257	324	26.1
30-40 km zone	471	343	340	72.7	72.1	-0.9	238	314	32.2
40-50 km zone	535	443	420	82.8	78.7	-5.0	292	360	23.5
50-60 km zone	595	411	455	69.0	76.5	10.8	264	354	34.4
60-70 km zone	656	487	467	74.3	71.2	-4.2	288	374	29.8
Total	**3 341**	**2633**	**2 634**	**78.8**	**78.8**	**0.3**	**249**	**323**	**29.8**

Note:
10 kilometre radial buffers were used to classify data concentrically around Riding Mountain National Park.
Sources:
Statistics Canada, National Accounts and Environment Division and Agriculture Division.

Map 2: Population Density, 1971 and 1986



Note:
Municipalities making up the Riding Mountain Biosphere Reserve are outlined around the park.
Source:
Statistics Canada, National Accounts and Environment Division.

portions of total area for the 7 radial zones between the 1971 and 1986 census years. (See Map 3.)

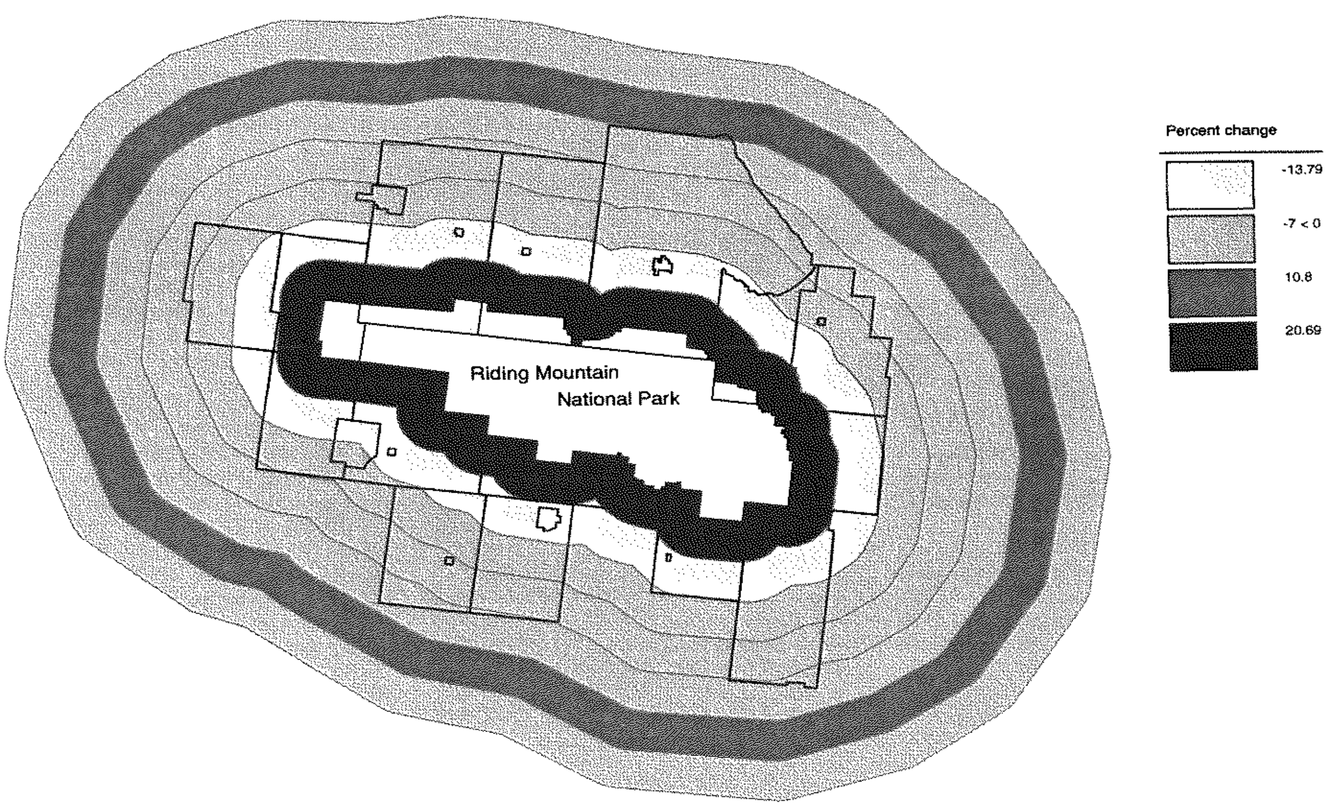
In brief, farmland area for the entire study area has essentially remained constant over the 15 year study period, showing an increase of less than 1%. However, significant changes have occurred when individual radial zones are examined. The 0-10 kilometre zone nearest the park shows the highest change where agricultural areas continue to expand. Farmland has increased by 20% in this zone, going from 77% of zone area to over 92%, making it second only to zone 20-30 at 93% agriculture. This trend indicates that the boundaries separating land use activities are becoming narrower and the likelihood of conflict between uses is therefore increased.

Idle land that used to form a cushion between activities is no longer there and the probability of having bears in farmers fields has increased as has the potential for animal poisoning by farm pesticides.[1]

Table 3 looks at the improved farmland[2] trends at varying distance from the park. Cropland trends are on the rise in all of the radial zones. The entire study area shows a 27.8% increase in cropland area. Since farmland areas in Table 2 have remained stable, and cropland areas in Table 3 are on the rise, it is apparent that a larger proportion of farmland is being placed in production and that land use intensity is increasing. Map 4 shows the radial distribution of cropland area changes around the park. The 0-10 zone shows the largest change with a 41.7% increase. Summerfallow areas are declining in all of the radial zones. The study area shows a decline of 43.8%. This is positive from a soil salinization perspective since the rate at which salinization occurs is dependent on soil moisture levels as they are affected by summerfallowing (Dumanski, 1986, p. 206). Summerfallowing contributes to salinization by raising soil moisture levels, and causing migration of stored salts.

1. Riding Mountain National Park warden Mac Estabrooks indicated, in a telephone conversation, that bear and elk were entering surrounding fields with increasing regularity.
2. Farmland that is considered improved can be cropland, improved pasture, summerfallow, or other improved land.

Map 3: Change in Farmland Area, 1971-1986



Notes:
Farmland change refers to change in proportion of zone farmland. Municipalities making up the Riding Mountain Biosphere Reserve are outlined around the park.
Sources:
Statistics Canada, National Accounts and Environment Division and the Census of Agriculture.

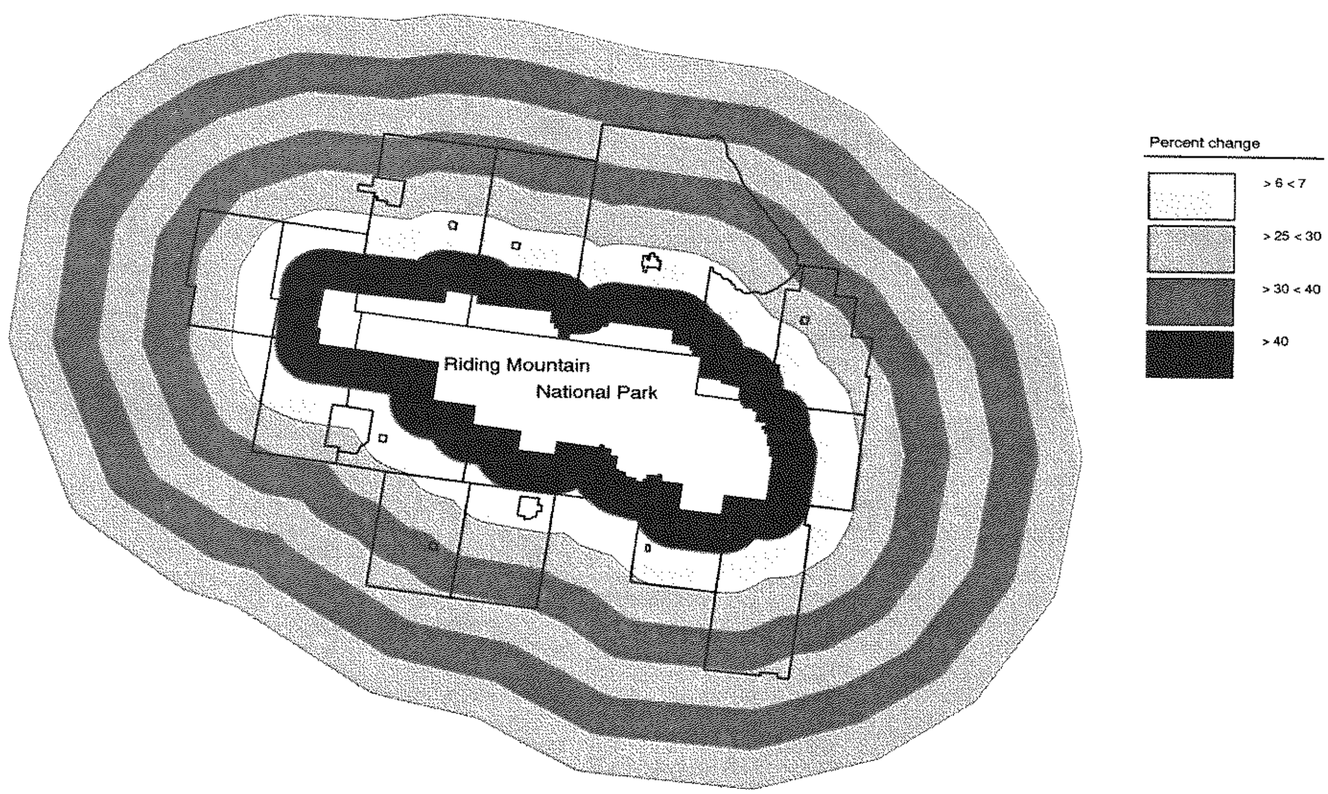
Table 3: Change in Improved Farmland Area, 1971-1986

Radial zone	Cropland 1971	Cropland 1986	Cropland Change 1971-1986	Improved pasture 1971	Improved pasture 1986	Improved pasture Change 1971-1986	Summerfallow 1971	Summerfallow 1986	Summerfallow Change 1971-1986	Other improved land 1971	Other improved land 1986	Other improved land Change 1971-1986
	thousand hectares			thousand hectares		percent	thousand hectares		percent	thousand hectares		percent
0-10 km zone	107	151	41.5	9	15	58.3	46	34	-25.9	4	4	1.2
10-20 km zone	145	154	6.3	11	9	-15.9	58	30	-49.3	5	3	-36.8
20-30 km zone	150	192	27.5	15	18	17.0	67	34	-48.3	6	4	-32.0
30-40 km zone	141	184	30.2	8	9	8.2	70	35	-49.4	5	4	-17.6
40-50 km zone	159	203	27.7	22	27	22.0	70	41	-41.6	6	5	-16.3
50-60 km zone	157	211	34.6	17	14	-15.7	73	40	-44.8	6	5	-16.4
60-70 km zone	177	224	26.7	16	17	6.5	80	42	-47.6	6	5	-9.4
Total	**1 035**	**1 318**	**27.3**	**97**	**107**	**10.4**	**463**	**256**	**-44.7**	**37**	**30**	**-18.9**

(Improved farmland)

Note:
10 kilometre radial buffers were used to classify data concentrically around Riding Mountain National Park.
Sources:
Statistics Canada, National Accounts and Environment Division and Agriculture Division.

Map 4: Change in Cropland Area, 1971-1986



Notes:
Cropland change refers to change in proportion of zone in cropland. Municipalities making up the Riding Mountain Biosphere Reserve are outlined around the park.
Sources:
Statistics Canada, National Accounts and Environment Division and the Census of Agriculture.

Table 4 depicts trends in unimproved farmland. These areas, with the exception of unimproved pasture, are showing significant declines. Woodland which is important to wildlife as cover, and as a food source, shows sharp declines in all of the radial zones. The zone closest to the park contains the highest proportion of farm woodland, of its 320 000 hectares 8 887 remained in farm woodland in 1986. (Some woodland still exists outside farmland areas but this amount must be less than 7.3% of the zone area, 92.7% of zone 0-10 is farmland.) Map 5 portrays the extent to which farm woodland areas have been declining around the park.

As human activities intensify and move closer to the park the likelihood of conflict increases. Agriculture-wildlife conflict can manifest itself in many different ways. For example, species such as the burrowing owl and prairie chicken can lose habitat to agriculture and be reduced in numbers or even disappear. Other birds such as the brown headed cowbird, thrive in a cleared cropland environment. These birds displace other species, such as the yellow warbler by reproducing in a parasitic manner, reducing the breeding success of other species (Environment Canada, 1991, p. 6-6).

Expanding agricultural land use further limits not only the diversity and numbers of wild animals, but that of plant life as well. Native plant communities are displaced and replaced by crop monocultures. (See below.) Even when land is later withdrawn from agriculture, the original grasses and wild flowers tend to be supplanted by hardier opportunistic weed species (Environment Canada, 1991, p. 6-6).

FARM INCOME, INPUTS AND AGRICULTURAL PRACTICES

The distribution of farm income per hectare of farmland around Riding Mountain appears to show a concentration of high income earners in the south on the black chernozemic soils, with lower incomes in the north on the luvisolic soils. (See Map 6 and Map 1.) Farmers in areas close to the park tend to have lower incomes, with the exception of some polygons[1] along the northern park boundary which are on dark grey chernozemic soils.

Agricultural practices have changed significantly on the Prairies over the last twenty years. As previous tables have indicated, fewer farmers are operating more farm area. In an effort to increase production and stay competitive, more farm inputs such as fertilizers, chemicals and fuels are being consumed than ever before. Bigger, more costly equipment is being purchased to operate larger and larger farms. Farmers have expanded their operations and have begun to rely on labour saving, capital intensive technology to operate these bigger farms. The environmental cost of these new technologies is substantial (Dumanski, 1986, p. 205).

Agricultural production in Canada has quadrupled in the last 60 years (Statistics Canada, 1991, p. 186). Farming methods and cropping practices have changed. Farms have become highly productive and are specializing in a narrower range of activities than ever before. Farms are

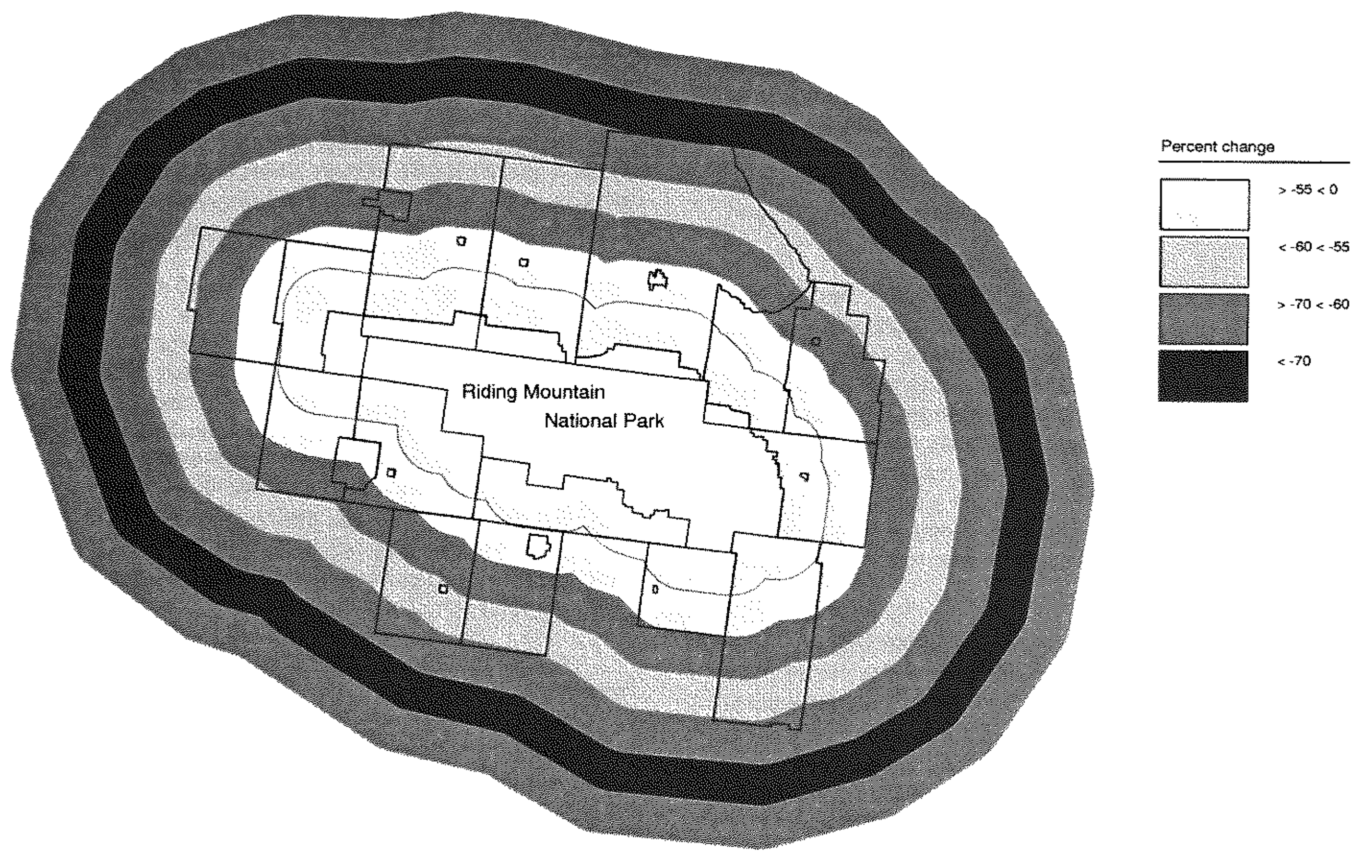
1. The spatial units (polygons) in Map 5 are generated from enumeration area centroid points. Thiessen polygons are created around each centroid using a "nearest neighbor function". Lines between points are bisected at the mid-point to form continuous boundaries around each point.

Table 4: Change in Unimproved Farmland Area, 1971-1986

	Unimproved farmland								
	Unimproved pasture			Woodland			Other improved land		
Radial zone	1971	1986	Change 1971-1986	1971	1986	Change 1971-1986	1971	1986	Change 1971-1986
	thousand hectares		percent	thousand hectares		percent	thousand hectares		percent
0-10 km zone	42	59	39.5	16	9	-45.2	63	25	-60.7
10-20 km zone	48	50	3.9	15	6	-60.6	83	21	-74.2
20-30 km zone	93	104	12.0	18	6	-64.8	132	25	-81.4
30-40 km zone	59	74	25.2	12	5	-59.0	108	29	-73.1
40-50 km zone	98	110	11.6	26	8	-70.2	160	28	-82.7
50-60 km zone	74	133	81.1	27	8	-72.3	132	44	-66.5
60-70 km zone	129	136	5.2	24	7	-69.7	185	36	-80.7
Total	**544**	**667**	**25.5**	**138**	**48**	**-63.1**	**863**	**207**	**-74.2**

Note:
10 kilometre radial buffers were used to classify data concentrically around Riding Mountain National Park.
Sources:
Statistics Canada, National Accounts and Environment Division and Agriculture Division.

Map 5: Change in Woodland Area, 1971-1986



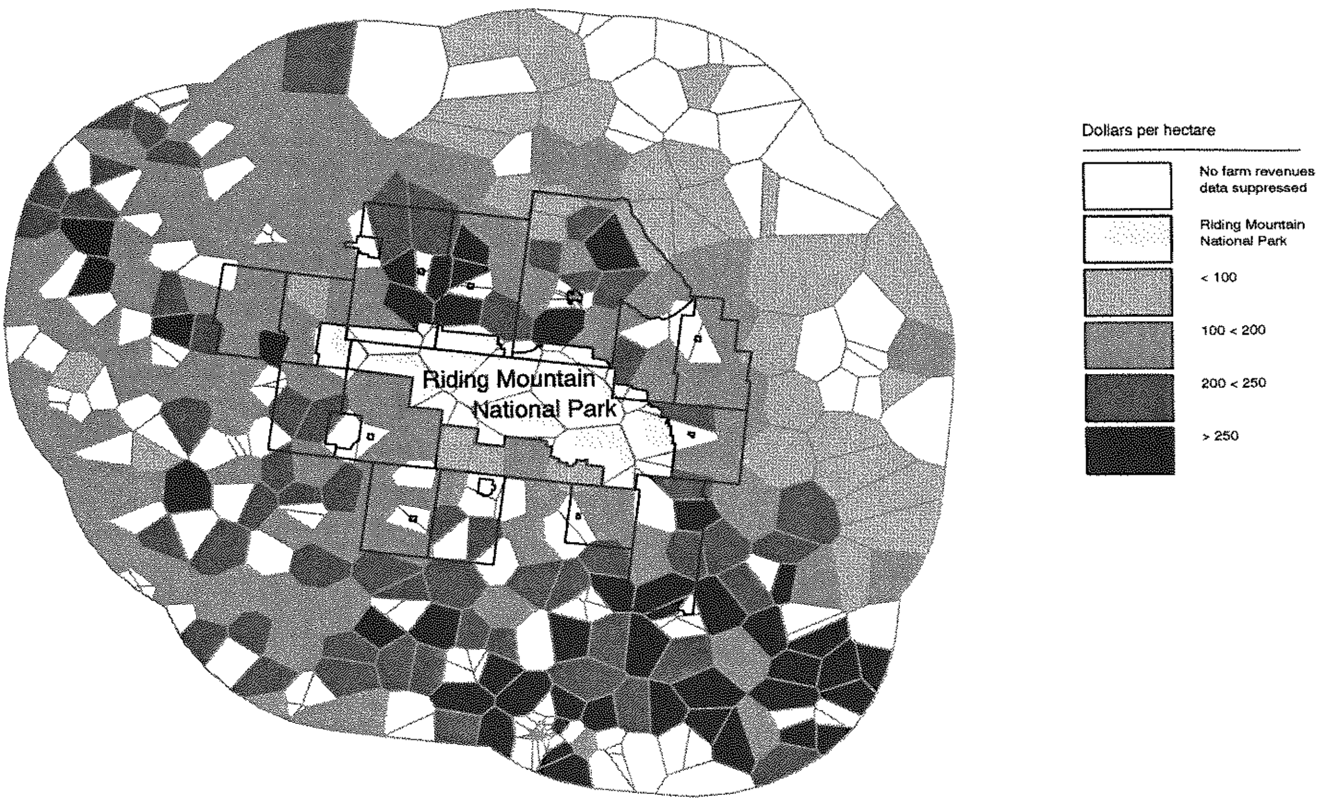
Notes:
Woodland change refers to change in proportion of zone farmland. Municipalities making up the Riding Mountain Biosphere Reserve are outlined around the park.
Sources:
Statistics Canada, National Accounts and Environment Division and the Census of Agriculture.

taking advantage of the economies of scale that result specialized functions. Increased production often implies modifying the natural environment, so that growth can take place unimpeded by environmental factors which might otherwise slow it. An extreme example of this is the use of a green house where natural conditions are so controlled that almost any crop can be grown at any latitude. A less extreme example is the growth of a typical field crop. Environmental factors such as moisture level, flora diversity, fauna variety, soil tilth, wind strength and nutrient availability are all controlled by man. Implementing these types of controls on a large scale (millions of hectares) has inevitable consequences for the natural environment. For example, agricultural production can change the water table level and may reduce the number of animal species present by limiting vegetational diversity which are food supplies to particular wildlife species.

The agricultural activity surrounding Riding Mountain is not the intense, high yielding type found in the mid-western United States. The range of crops that can be grown economically at such northerly latitudes is small, and consists mainly of grains and cereals, or close-row type crops. Table 5 summarizes how the majority of cultivated land is being utilized.

Close-row crops dominate the study area. In total they made up more than 85% of cultivated land in 1986, a decrease from more than 90% in 1971. The remainder of cropland in the study area is planted in forage type crops such as tame hay. Crop cover around the park is important because it influences food supply for wild animals, determines soil erosion rates, affects soil quality, affects water quality and influences ecological stability by limiting species diversity. The downward trend suggested by the data, away from completely close-row monoculture is positive because it indicates that crop rotation may be increasing and that the cropping base is becoming more diverse from an ecological perspective. Two crop types of

Map 6: Farm Revenue per Hectare of Farmland, 1986



Notes:
Farm revenues refer to farm sales in 1986. Municipalities making up the Riding Mountain Biosphere Reserve are outlined around the park.
Sources:
Statistics Canada, National Accounts and Environment Division and the Census of Agriculture.

Table 5: Change in Close-Row Monoculture Cropped Area, 1971 - 1986

Radial zone	Cultivated land area			Close-row monoculture area			Close-row monoculture proportion of total cultivated land		
	1971	1986	Change 1971-1986	1971	1986	Change 1971-1986	1971	1986	Change 1971-1986
	thousand hectares		percent	thousand hectares		percent			
0-10 km zone	153	185	21.3	131	143	9.1	85.9	77.3	-10.0
10-20 km zone	203	183	-9.7	180	152	-15.8	88.9	82.8	-6.8
20-30 km zone	217	226	4.2	192	185	-3.7	88.4	81.7	-7.6
30-40 km zone	211	219	3.8	195	198	1.7	92.6	90.7	-2.1
40-50 km zone	229	244	6.4	202	203	0.6	88.3	83.4	-5.5
50-60 km zone	229	251	9.5	210	217	3.5	91.4	86.4	-5.5
60-70 km zone	257	266	3.6	231	233	0.6	90.1	87.5	-2.9
Total	**1 499**	**1 574**	**5.1**	**1 342**	**1 331**	**-0.8**	**89.5**	**84.6**	**-5.6**

Note:
Cultivated land refers to land under crops and land in summerfallow.
Sources:
Statistics Canada, National Accounts and Environment Division and Agriculture Division.

note are oilseeds and specialty crops, which have both increased significantly over the study period.

The volume of agricultural fertilizers applied within 70 kilometres of Riding Mountain National Park has more than quintupled during the study period, from roughly 20 000 tonnes in 1970, to almost 150,000 tonnes in 1985. The application rate also increased from 65 kilograms per hectare to 145 kilograms per hectare. (See Table 6 and Map 7.)

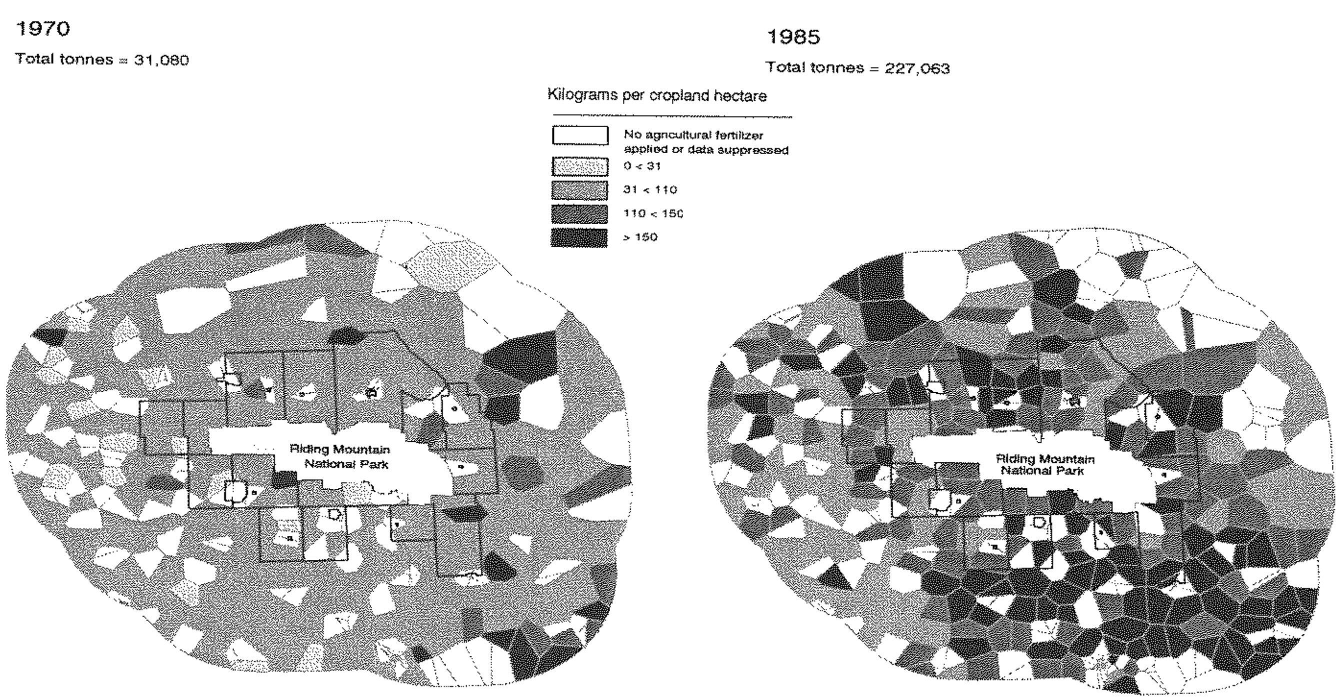
These rates have increased sharply, but are still well below those found in eastern Canada which can exceed 2 000 kilograms per hectare. Fertilized area around the park has gone up by 235% over the study period.

Table 6: Change in Commercial Agricultural Fertilizer Application, 1970 - 1985

Radial zone	Commercial fertilizer tonnage 1970	Commercial fertilizer tonnage 1985	Commercial fertilizer tonnage Change 1970-1985	Area fertilized 1970	Area fertilized 1985	Area fertilized Change 1970-1985	Application rate 1970	Application rate 1985	Application rate Change 1970-1985
	tonnes		percent	thousand hectares		percent	kg per hectare		percent
0-10 km zone	1 843	14 382	680.3	28	106	279.1	66.13	136.12	105.9
10-20 km zone	2 950	16 533	460.4	43	119	175.3	68.52	139.47	103.5
20-30 km zone	2 944	23 258	689.9	47	147	215.0	62.98	157.95	150.8
30-40 km zone	2 576	22 059	756.3	43	154	257.3	59.68	143.00	139.6
40-50 km zone	2 989	22 022	636.9	46	157	237.6	64.28	140.33	118.3
50-60 km zone	3 009	25 902	760.8	48	171	255.9	62.59	151.40	141.9
60-70 km zone	3 635	25 076	589.8	53	179	236.6	68.47	140.33	104.9
Total	**19 947**	**149 233**	**648.2**	**309**	**1032**	**234.7**	**64.66**	**144.55**	**123.6**

Note:
10 kilometre radial zones were used to classify data concentrically around Riding Mountain National Park.
Sources:
Statistics Canada, National Accounts and Environment Division and Agriculture Division.

Map 7: Commercial Agricultural Fertilizer Application Rates, 1970 and 1985



Notes:
Fertilizer data for 1970 were estimated from expense data. These maps represent areas within 90 km radius of the park. Municipalities making up the Riding Mountain Biosphere Reserve are outlined around the park.
Source:
Statistics Canada, National Accounts and Environment Division.

Fertilizer tonnages for 1971 were estimated from fertilizer expense data. Changing commercial fertilizer tonnages do not fully account for increases in commercial nutrients applied. Fertilizer nutrient contents have been increasing steadily over time. The average nutrient content of fertilizers in 1971 was 48%. By 1986 this value had increased to 58% (Agriculture Canada, 1987).

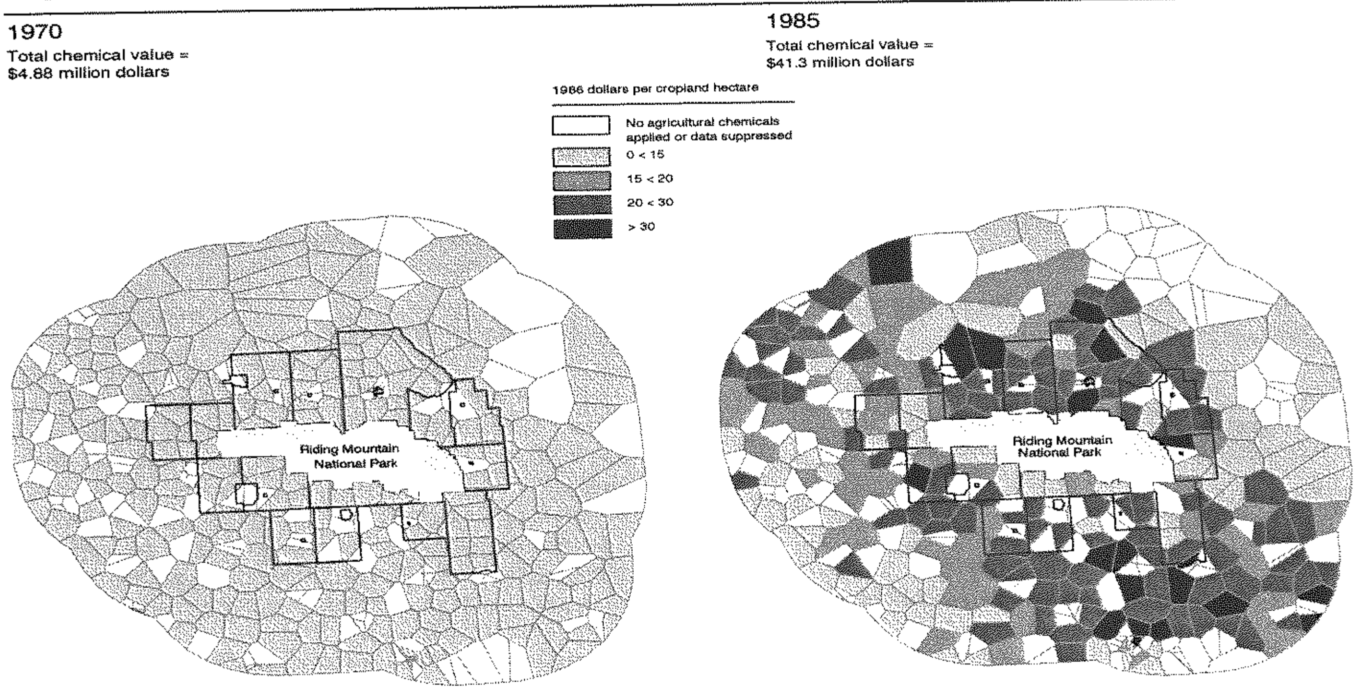
Agricultural pesticide applications have also increased substantially in the study period. Pesticide expenditures indicate that there has been a 744% increase in pesticides applied. These increases are large but actual application rates are one third of those in eastern regions of Canada. The use of pesticide expense data does not directly indicate changing pesticide volumes or toxicity levels. (See Tables 7 and 8, Map 8.)

Table 7: Change in Agricultural Pesticide Expenditures and Application Rates, 1970 - 1985

Radial zone	Agricultural pesticide expenditures			Cultivated land area			Value of pesticide per hectare of cultivated land		
	1970	1985	Change 1970-1985	1970	1985	Change 1970-1985	1970	1985	Change 1970-1985
	constant 1985 dollars		percent	thousand hectares		percent	dollars per hectare		percent
0-10 km zone	315 053	2 966 482	841.6	153	185	21.3	2.1	16.0	676.4
10-20 km zone	480 591	3 350 309	597.1	203	183	-9.7	2.4	18.3	671.7
20-30 km zone	422 734	4 009 348	848.4	217	226	4.2	1.9	17.7	810.0
30-40 km zone	489 741	4 209 813	759.6	211	219	3.6	2.3	19.2	727.8
40-50 km zone	522 824	3 668 696	601.7	229	244	6.4	2.3	15.1	559.5
50-60 km zone	457 376	4 407 643	863.7	229	251	9.5	2.0	17.5	780.4
60-70 km zone	516 911	4 444 918	759.9	257	266	3.6	2.0	16.7	730.2
Total	**3 205 230**	**27 057 210**	**744.2**	**1499**	**1 574**	**5.1**	**2.1**	**17.2**	**703.6**

Note:
10 kilometre radial zones were used to classify data concentrically around Riding Mountain National Park.
Sources:
Statistics Canada, National Accounts and Environment Division and Agriculture Division.

Map 8: Agricultural Pesticide Application Rates, 1970 and 1985



Note:
These map represents areas within a 90 km radius of the park. Municipalities making up the Riding Mountain Biosphere Reserve are outlined around the park.
Source:
Statistics Canada, National Accounts and Environment Division.

Table 8: Change in Areas Sprayed With Insecticides and Herbicides, 1970 - 1985

Radial zone	Area sprayed for insects 1970	Area sprayed for insects 1985	Change 1970-1985	Area sprayed for weeds 1970	Area sprayed for weeds 1985	Change 1970-1985
	hectares		percent	hectares		percent
0-10 km zone	3 316	6 124	84.7	41 538	111 147	167.6
10-20 km zone	5 234	5 043	-3.6	63 379	118 755	87.4
20-30 km zone	6 831	9 309	36.3	64 367	145 373	125.9
30-40 km zone	3 541	10 591	199.1	62 060	152 467	145.7
40-50 km zone	4 595	15 761	243.0	68 747	150 081	118.3
50-60 km zone	3 250	15 370	373.0	69 604	164 822	136.8
60-70 km zone	4 425	16 330	269.0	72 581	175 276	141.5
Total	**31 191**	**78 528**	**151.8**	**442 276**	**1 017 921**	**130.2**

Note:
10 kilometre radial zones were used to classify data concentrically around Riding Mountain National Park.
Sources:
Statistics Canada, National Accounts and Environment Division and Agriculture Division.

The increase in agricultural inputs around the park does not imply that the park itself is receiving increased inputs. The transportation mechanisms bringing residual agricultural inputs into the park protect the park to some degree. Streamflow is downslope away from the park, keeping water soluble pesticides and fertilizer nutrients from entering the park in surface water. Ground water is a possible route of entry, but the extent too which this source contributes to loadings on the park is very difficult to quantify without detailed subsurface hydrology data. More probable entry routes are via the wind, and in birds and animals as they forage in fields around the park.

CONCLUSIONS

Riding Mountain National Park has long been threatened by agricultural encroachment. The natural geographic barrier posed by the escarpment has always protected the park, and despite the changes that have occurred around the park, wildlife continues to thrive.

However, agricultural activities around Riding Mountain National Park are still intensifying.

- Tilled land areas close to the park have increased by more than 20%.
- Woodland areas close to the park have declined by more than 45%.
- Pesticide use has increased markedly.
- Fertilizer application rates have more than doubled.
- Fertilized areas have more than tripled.

The land base used by agriculture is expanding to take up more and more land. At the same time, cultivation activities are also increasing with higher proportions of farmland going into production. Farm pesticide and fertilizer application rates are also increasing, placing additional stress on natural systems. Reductions in biodiversity around the park brought on by large scale agricultural development and mono-cropping are potentially dangerous to established ecological balances within the park. Wildlife food supplies and subsequent population stabilities are as a result at higher risk.

These facts lead to important questions that will have to be answered if the relationship between the park and its surroundings is to remain stable in the long term. For example, what are the effects of current agricultural practices and what will further agricultural development do? Indeed, is the current relationship sustainable? What formula can be used to weigh environmental costs against the benefits of agricultural development? What measures can be taken to ensure a long term, viable co-existence? These and other related questions will have to be carefully considered by society in the years ahead.

DATA LIMITATIONS

This type of analysis has limitations that should be described. Micro-data for the Census Enumeration Areas used in this study, are stored on a single geographic co-ordinate, otherwise known as a point. This information has to be "rolled up" or aggregated to larger areas representing large land surfaces. The accuracy of this point-polygon match is determined by the density of points per polygon and the spatial distribution of the data represented by the points. In brief, where point densities are too low results have to be suppressed or ground truthed using paper maps. (Hamilton, and Trant, 1989, p. 340) The Riding Mountain study has used large surface areas with high point densities to ensure statistical reliability. The area is also more than 80% farmland, making the data distribution associated with the points quite homogeneous.

Other problems can arise when micro-data are aggregated to larger zones. Averaging of values can lead to under or over emphasis of certain characteristics for component smaller areas. The advantage of using composite concentric zones is that aggregate trends become discernible in contrast to the "noise" that is generated by individual data points.

REFERENCES

Agriculture Canada. *Statistics on Canadian Fertilizer Consumption 1985/1986*. Ottawa, 1987.

Dumanski. et al. "Soil Conservation in Canada." Journal of Soil and Water Conservation, Soil Conservation Society of America, July/August, 1986.

Environment Canada, *The State of Canada's Environment*. Ottawa, 1991.

Hamilton, K.E, and Trant, D.F. "Statistical Aspects of the Application of Geographic Information Systems in Canadian Environment Statistics." *Journal of Official Statistics*, Statistics Sweden, 5,1989.

Krawchuk, W.A. "The Riding Mountain Biosphere Reserve: A Synthesis of the Natural Resource Database". Masters Thesis. University of Manitoba, 1990.

Parks Canada. *Riding Mountain National Park Management Plan*. Environment Canada, Ottawa, 1987.

Tabulenas, D.T. *A Narrative Human History of Riding Mountain National Park and Area; Pre-history to 1980*. Parks Canada, micro-fiche report series 102, 1983.

6 The 1991 Census of Agriculture: Land Management for Soil Erosion Control

by Douglas Trant[1]

INTRODUCTION

Soil erosion and land degradation in general are problems of increasing economic and environmental concern. The main economic concern relating to land degradation is the loss of soil productivity, while the air and water pollution resulting from wind and water erosion are the primary environmental quality issues. Until recently, soil productivity declines have been masked by technological advances in the agricultural chemical industry, by the development of higher yielding cultivars, and by a seemingly endless supply of land and water resources. Investigation indicates that the economic costs of these degradation problems exceed one billion dollars annually, in terms of lost production (Fox and Coote, 1986). The environmental costs of water and air pollution resulting from continued wind and water erosion may be even higher. Although no estimates are available for Canada, estimates based on an American cropland area four times that of Canada's indicate that the combined annual environmental and economic costs of the U.S. soil erosion problem range from 4 to 44 billion dollars (Steiner, 1990). The magnitude of this range demonstrates just how difficult it is to estimate the cost of soil erosion.

A new land management module was added to the 1991 Census of Agriculture to provide a first comprehensive look at soil conservation practices on farms in Canada. Farm operators were asked to respond to a series of questions, mostly with simple yes or no answers. Because the survey is new, some of the results must be interpreted cautiously. Nonetheless, these data provide an indication of how well soil erosion and land degradation are being addressed across Canada. This chapter summarizes soil erosion control practices on a provincial basis.

1. The author would like to thank Marcia Santiago for her contribution to the research which supports this chapter. Thanks should also go to scientists at Agriculture Canada's Centre for Land and Biological Resources Research who provided valuable comments.

SOIL EROSION CONTROL PRACTICES

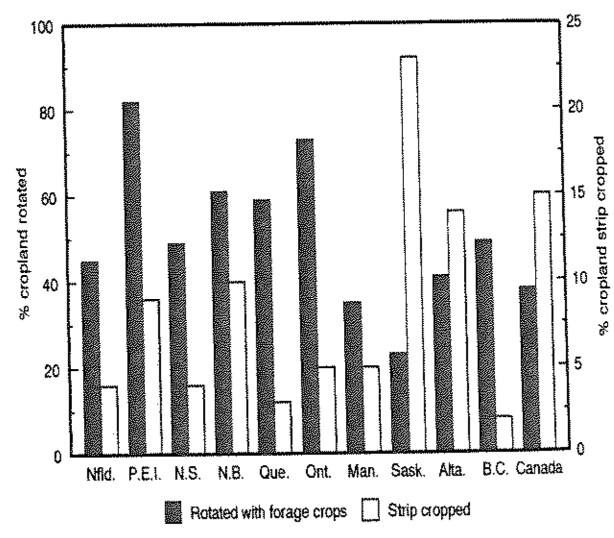
Soil erosion control practices on farms in Canada are shown in Table 1. More than a third of farms in Canada (36.9%) used a forage based crop rotation system on some of their cropland. This type of crop rotation helps promote soil aggregate stability and improves soil structure while recharging soil nitrogen when legumes such as alfalfa or clover are used. The historical decline in forage based crop rotations has contributed to soil quality deterioration in Canada (Dumanski et al.,1986).Crop rotations with forage are more prevalent in Eastern Canada. Differences in farm types account for much of the regional variation.

Table 1: Farms Reporting Erosion Control, 1991

Erosion control	Number of farms	Percent of farms
Crop rotation using forage	103 355	36.9
Winter cover crop	24 289	8.7
Grassed waterway	31 474	11.2
Strip cropping	22 006	7.9
Contour Cultivation	25 630	9.2
Other practices	61 818	22.1

Note:
A farm may use more than one erosion control practice, or none at all.
Sources:
Statistics Canada, National Accounts and Environment Division and Agriculture Division.

Figure 1: Potential Cropland Area in Forage Rotations and Strip Cropping, 1991

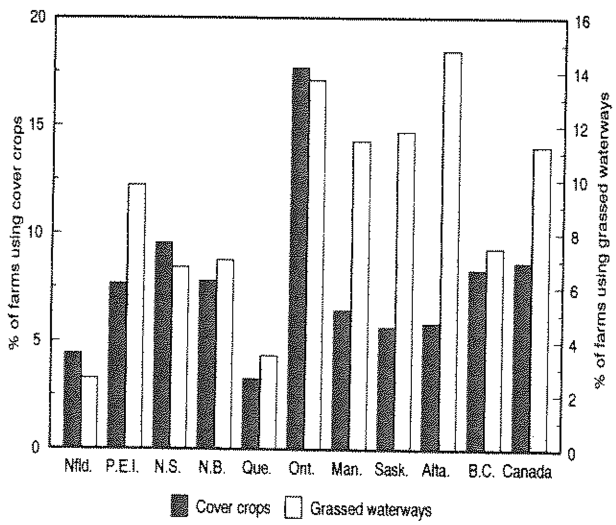


Note:
Not all cropland area on reporting farms is protected by a particular erosion control practice.
Sources:
Statistics Canada, National Accounts and Environment Division and Agriculture Division.

Strip cropping is an erosion control method where crops are planted in strips, and are often laid out parallel to the slope contour. For example, a grain crop can be planted along the contour, with alternating strips of hay and grain. The hay crop checks water run-off from the grain crop. Wind erosion can also be prevented using strip cropping. One crop can protect the other from high wind during a particularly vulnerable growth or harvest stage. Table 1 and Figure 1 show that strip cropping is used on 7.9% of farms managing 14.8% of cropland in Canada. It is most prevalent in Western Canada.

Winter cover crops are used on 8.7% of farms managing 10.5% of cropland. This practice serves mainly as protection against wind erosion in winter months. However, winter cover crops can also provide protection in spring when intense rainfall might erode unprotected soil surfaces (Figure 2).

Figure 2: Number of Farms Using Winter Cover Crops and Grassed Waterways, 1991



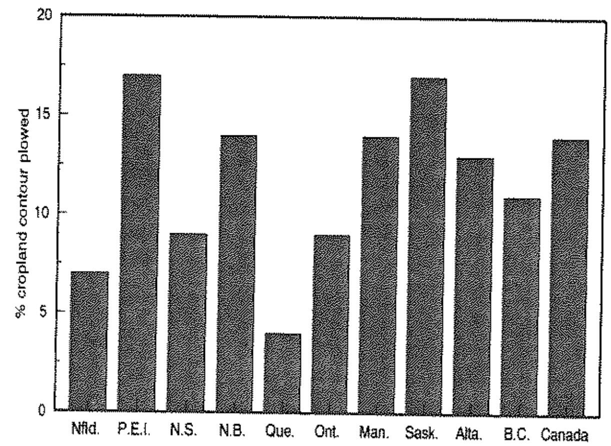
Note:
There are indications that the area of winter cover crops has been over reported by farmers responding to the Census.
Sources:
Statistics Canada, National Accounts and Environment Division and Agriculture Division.

Grassed waterways are an erosion control measure used to check overland flow and prevent gully erosion. Exposed soil surfaces on slopes can form gullies that may eventually grow in size to form ditches or ravines. Grassed waterways direct overland flow and protect soil surfaces.

Nationally, 11% of farms reported using grassed waterways. Alberta farms reported using this practice more than in any other province.

Another method of erosion control is to cultivate the soil parallel to the contour of the slope. This method traps soil particles between plough furrows rather than allowing water and soil particles to gain velocity and move down slope. Across the country 9% of farms use this method and as much as 14% of cropland is protected by these measures. Figure 3 shows the proportions of cropland potentially protected by contour cultivation. Saskatchewan and Prince Edward Island top the list with over 16% of their cropland potentially protected by contour cultivation.

Figure 3: Cropland Potentially Protected by Contour Cultivation, 1991



Note:
The percentages above represent a maximum and tend to overestimate area under contour cultivation.
Sources:
Statistics Canada, National Accounts and Environment Division and Agriculture Division.

Table 2 looks at farms by erosion control category, by province. Ontario farmers are more likely to use multiple soil erosion control practices. Seven percent of Ontario farmers used 4 or more erosion control practices.

Newfoundland has the smallest proportion of farmers using erosion control (Figure 4). This is due primarily to the types of agriculture found in Newfoundland. In 1991, Newfoundland had only slightly more than 2 000 hectares that were prepared for seeding. In contrast, Saskatchewan has single farms with seeded areas larger than 2 000 hectares. British Columbia and Nova Scotia have the second and third lowest percentages of participants in erosion control respectively. Both provinces have large tree fruit areas which contribute to their total cropland areas, and as such do not normally require tillage or substantial erosion control. The province with the highest percentage is Saskatchewan where almost 72% of all farmers use some form of erosion control. Sixty three percent of farms in Canada report employing one or more erosion control practices (Figure 4).

Table 2: Number of Farms Employing Erosion Control, 1991

Number of erosion control practices	Nfld.	P.E.I.	N.S.	N.B.	Que.	Ont.	Man.	Sask.	Alta.	B.C.	Canada
No erosion control	485	710	2 401	1 801	18 769	21 913	8 742	17 300	18 025	12 410	**102 556**
1 erosion control	160	1 063	1 059	978	15 959	25 237	8 947	24 160	22 226	4 846	**104 635**
2 erosion controls	44	260	317	267	1 961	10 474	4 064	9 745	8 992	1 237	**37 361**
3 erosion controls	29	209	126	110	892	6 255	2 610	6 134	5 343	492	**22 200**
4 erosion controls	6	68	44	63	268	3 065	922	2 396	1 868	147	**8 847**
5 erosion controls	1	34	24	25	126	1 256	305	823	616	57	**3 267**
6 erosion controls	0	14	4	7	96	345	92	225	136	33	**952**
7 erosion controls	0	3	5	1	5	88	24	57	39	3	**225**
All farms	**725**	**2 361**	**3 980**	**3 252**	**38 076**	**68 633**	**25 706**	**60 840**	**57 245**	**19 225**	**280 043**

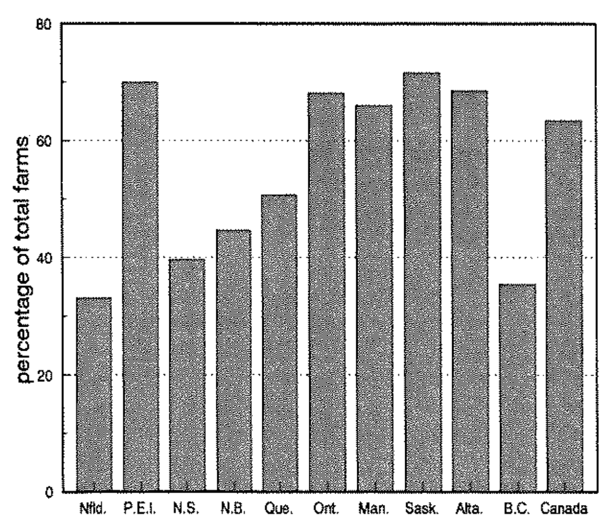
Sources:
Statistics Canada, National Accounts and Environment Division and Agriculture Division.

Table 3: Erosion Control Practice by Farm Type, 1991

Farm type	Crop rotation	Cover crops	Grassed waterways	Strip cropping	Contour cultivation	Other practices
			percentage of farms			
Livestock operations	43.4	10.0	12.7	7.2	9.9	21.3
Wide-row cropping [1]	65.5	20.1	12.9	7.6	8.7	27.3
Close-row cropping [2]	41.6	11.8	11.4	3.9	12.5	28.6
Forage cropping	57.6	8.0	11.9	3.4	6.4	19.7
Specialty farming and other	27.3	8.7	8.0	5.8	8.3	20.6

Notes:
Generalized farm types are derived by aggregating farm types from the Census of Agriculture. Ideally a land-based farm typing should be used here where farms are grouped according to land use rather than on sales. Agriculture Canada is proposing to analyse erosion control using land based farm types in the near future.
[1] Corn, soybeans, vegetables and other crops typically grown in wide rows more than 10 cm.
[2] Wheat, oats, barley and other crops typically grown in narrow rows less than 5 cm apart.
Sources: Statistics Canada, National Accounts and Environment Division and Agriculture Division.

Figure 4: Farms Using One or More Erosion Control, 1991



Sources:
Statistics Canada, National Accounts and Environment Division and Agriculture Division.

Table 3 shows the association between farm type and erosion control practice. Wide-row crops are potentially the most erosive crop type (Wischmeier, 1978). The data indicate that wide-row croppers do in fact respond to higher erosion risk and are the most frequent users of erosion control in 4 out of 6 erosion control techniques. Close-row cropping, potentially the second most erosive farm type, employs more contour cultivation and "other" erosion control practices most frequently.

SEED BED PREPARATION AND SOIL EROSION CONTROL

The 1991 Census of Agriculture asked farmers questions about their seed bed preparation techniques. Three broad practices were identified: conventional tillage, conservation tillage and no tillage. Conventional tillage actually turns soil over and buries crop residues, making the risk of soil erosion greater than with conservation tillage or no tillage. Conventional tillage methods are quite different from region to region. For example, equipment types vary, reasons for tillage vary, and the timing between tillages is often different. In conservation tillage, as the name implies, fields are cultivated fewer times with implements that do not turn the soil over. This conserves beneficial crop residues on the surface. Finally, seed bed preparation may be done without any tillage. This is considered the most environmentally benign tillage method from a physical degradation standpoint[1] (Wischmeier, 1978).

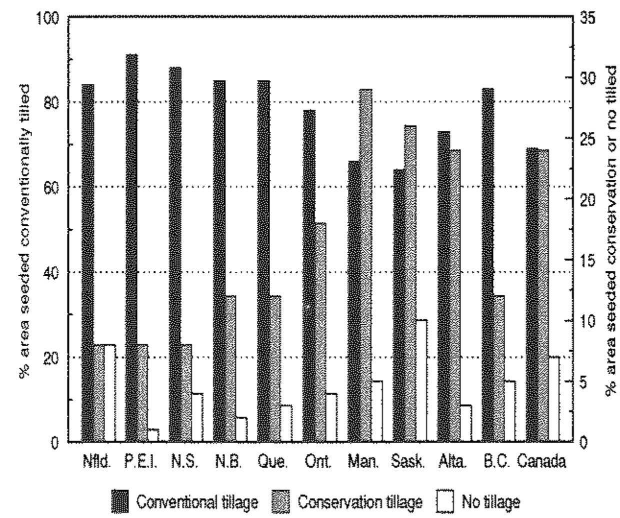
Most soil types suffer some degradation when tilled continually. Soil organic matter levels have a tendency to decline due to the increased oxidation caused by the turning and mixing action of cultivation. When organic matter levels decline most soils begin to deteriorate structurally. If a soil undergoes structural degradation and loses porosity and permeability, rain water does not infiltrate as quickly and water begins to run off. If this situation occurs on vulnerable soils, erosion becomes a definite risk. Another problem more commonly associated with conventional tillage is soil compaction. Compaction can lead to crop rooting problems by limiting the rooting zone and can also lead to water puddling in fields, which prevents cultivation until much later in the spring. One way of combating structural decline is to use a forage or legume in the crop rotation.

Seed bed preparation methods by province are shown in Figure 5. Conventional tillage is most prevalent in Prince Edward Island with more than 90% of seeded area cultivated with this method. Conservation tillage is most common in Manitoba at close to 30% of area prepared for seeding. No-tillage is also highest in the Prairies with a value approaching 10% in Saskatchewan.

Table 4 describes the association between soil erosion control and seed bed preparation. This table provides an indication of the degree to which agricultural soils are being protected across Canada. Nationally, more than 29 million hectares were prepared for seeding in 1991 with conventional, conservation tillage or no tillage. Four and one half million hectares out of 29 million (15.3%) had no erosion control applied and were not tilled using a conservation technique. Although not all require erosion control, these soils are potentially under the greatest stress, and could benefit the most from improved tillage practice or through the use of some erosion controls. Conversely, this implies that 24.5 million hectares (84.7%) of the area prepared for seeding had at least one erosion control applied, or was cultivated using methods that do not promote soil erosion. This is a positive sign and indicates that Canadian farmers are indeed combating the erosion problem.

1. The 1991 Census responses to the "no-tillage" question are somewhat overestimated because in some instances hay crops were reported as "no till" when only crops requiring seed bed preparation should have been reported.

Figure 5: Seed Bed Preparation Methods, 1991



Note:
No till areas indicated are higher than actual due to respondent error.
Sources:
Statistics Canada, National Accounts and Environment Division and Agriculture Division.

Table 4: Seed Bed Preparation Methods and Erosion Control Practices, 1991

Number of erosion control practices	Conventional tillage	Conservation tillage	No tillage	**Total seeded area**
	thousand of hectares			
No erosion control	4 447	1 110	356	**5 913**
1 erosion control	8 014	2 592	773	**11 379**
2 erosion controls	3 705	1 582	407	**5 694**
3 erosion controls	2 302	1 026	234	**3 562**
4 erosion controls	1 038	519	116	**1 673**
5 erosion controls	364	196	48	**608**
6 erosion controls	95	49	12	**156**
7 erosion controls	21	17	6	**44**
Total seeded area	**19 986**	**7 091**	**1 952**	**29 029**

Sources:
Statistics Canada, National Accounts and Environment Division and Agriculture Division.

CONCLUSIONS

The 1991 Census of Agriculture provides important baseline information on agricultural soil conservation practices in Canada. Data for a single year provide only a snapshot of soil conservation practices and obviously give no indication of whether the situation is getting better or worse. Nationally, the indications are generally encouraging, insofar as farm operators with 84.7% of seeded area use some form of soil erosion control or conservation practice, and that farms with the most potentially erosive crops are the most frequent users of 4 out of 6 erosion control measures.

The real question is: are farmers winning the fight? To answer this question more information is needed. For example, where is the 4.4 million hectares of conventionally tilled land to which no erosion control is applied? Is it located on vulnerable soils? Is the area steeply sloped? Do the farms generate significant net revenues or are they among the less productive? Future research should provide insight into these questions as Agriculture Canada's soil landscape maps are more directly linked to the Census data base. This will allow detailed analysis of erosion risk as it relates to farm land use, farm economics and agricultural conservation practices.

REFERENCES

Dumanski, J., D.R. Coote, G.Luciuk, C.Lok,"Soil Conservation in Canada", *Journal of Soil and Water Conservation.* 41:4, July-August 1986.

Fox, M.G. and Coote D.R., *A Preliminary Economic Assessment of Agricultural Land Degradation in Atlantic and Central Canada and Southern British Columbia.* Development Consulting House (DCH) For Agriculture Canada, Contribution 85-70, Ottawa, 1986.

Steiner F.K., Soil Conservation in the United States. Johns Hopkins University Press, Baltimore, 1990.

Trant, D., *Estimating Agricultural Soil Erosion Losses from Census of Agriculture Crop Coverage Data*, Research Paper Series #27, Analytical Studies Branch, Statistics Canada, 1989.

Wischmeier, W.H. and D.D. Smith, *Predicting Rainfall Erosion Losses - A Guide to Conservation Planning.* Agricultural Handook #537, Washington, D.C., United States Department of Agriculture, 1978.

7 Household Activity, Household Expenditures and the Environment

by Marcia Santiago

INTRODUCTION

Many areas of daily household activity affect the natural environment. Some, such as the consumption of fossil fuels for residential heating or automobile operation, have direct impact in terms of using natural resources and in releasing pollutants. There are also other activities that are relevant to environmental quality but whose impact is indirect. One example is the use of recycling facilities, as an alternative to the immediate disposal of solid waste.

Using data from two Statistics Canada surveys, one on household behaviour (Household Environment Survey, 1991) and another on household expenditures (Family Expenditure Survey, 1990, abbreviated as FAMEX), this chapter describes patterns of household activity and household expenditure that are relevant to environmental concerns. The reader should bear in mind that the data presented in this chapter describe the reported activity of households, which may be different from their actual activity. In the case of environmentally relevant behaviour, this effect has been labelled a "green bias". It has been shown that a heightened media or social profile may influence respondents to give what they expect to be 'appropriate' answers (Rathje 1990). The reader must also recognize that expenditure and activity decisions are conditioned as much by social and economic considerations as they are by conscious response to an environmental imperative. Nevertheless, expenditures and activity do provide some important insight into the relationship of households and the environment.

Three general areas are discussed: access to and use of recycling facilities, energy and water consumption, and commuting patterns. Patterns of activity and expenditure are summarized, along with their relationship to a number of geographic and economic factors.

ACCESS TO AND USE OF RECYCLING SERVICES

Although the public has long been concerned about the disposal of solid waste, this issue has become much more prominent in recent years. Perhaps in response to this issue, there has been widespread implementation of recycling facilities and programs. In 1991, access to various recycling facilities was reported by almost half of the households questioned in the Household Environment Survey. Access to paper recycling facilities was reported by 53% of households, with 49%, 50% and 42% of households reporting access to metal can, glass and plastic recycling facilities respectively. Among households that reported access to these facilities, about 86% reported that they used them.

Table 1 shows the rates of access to and use of paper recycling facilities in fifteen Census Metropolitan Areas. There is quite a range in the reported access to this service. The highest rates of access are reported in Kitchener-Waterloo (94%) and Victoria (92%), while Québec (24%) and Montréal (37%) report the lowest proportions of households with access. Reported use of the facilities also varies considerably, with the lowest rate reported in Winnipeg (55%) and the highest rate in Toronto (98%)

Table 1: Access to and Use of Facilities for Paper Recycling by Census Metropolitan Area, 1991

	With access	Reporting use
	percent of households	
Halifax	47 E	84 E
Québec	24 F	79 F
Montréal	37 E	77 E
Ottawa	70 D	91 D
Toronto	74 C	98 C
Hamilton	81 D	94 D
St. Catharines-Niagara	85 C	94 D
Kitchener-Waterloo	94 E	94 D
London	66 E	94 E
Windsor	77 D	95 D
Winnipeg	78 E	55 E
Edmonton	68 D	89 D
Calgary	47 D	75 E
Vancouver	72 D	93 D
Victoria	92 D	92 D
Canada	**53 B**	**86 B**

Note:
See the standard error symbols at the end of this chapter.
Source:
Statistics Canada, Household Environment Survey.

The type of service to which a household has access is related to the size of the municipality and to the type of dwelling (Table 2). This is in part because larger municipalities were the first to implement curbside collection programs and these generally served only single detached dwellings. Thus, it follows that the highest access rate (76%) is reported by households in single detached dwellings in major metropolitan areas. The same group also reports the highest rate of use (91%). In contrast, access rates for apartment dwellers are quite low (23% to 36%). Access might well be more difficult for apartment dwellers, which would partially explain their lower usage rate.

Table 2: Access to and Use of Facilities for Paper Recycling by Area and Dwelling Type, 1991

	With access	Reporting use
	percent of households	
Major metropolitan areas (population of 100 000 and over)		
Single, detached	76	91
Single, attached	66	90
Apartment or flat	35	83
Other	56	92
Mid-size metropolitan areas (population between 30 000 and 99 999)		
Single, detached	64	87
Single, attached	55	82
Apartment or flat	36	69
Other	52	81
Other urban areas (population less than 30 000)		
Single, detached	52	50
Single, attached	46	79
Apartment or flat	36	71
Other	43	63
Rural areas		
Single, detached	34	76
Single, attached	30	80
Apartment or flat	23	72
Other	26	65
Canada	**53**	**86**

Source:
Statistics Canada, Household Environment Survey.

ENERGY AND WATER CONSUMPTION

It is reasonable to say that many households have considerable scope to reduce their consumption of water and energy. While concern for the environment may be a factor in the decision to do so, the potential to reduce utility bills is likely to be an important motivator as well.

In 1990, urban households spent, on average, $1 170 on the consumption of water, fuel and electricity, which represents 14% of their spending on shelter, or 2.4% of their total spending. The average cost of water supply to primary residences was $118, or 10% of household spending on fuel and energy.

At least partly in response to these costs, many households have adopted energy-saving habits. Seventy-one percent of households with a thermostat report either that it is programmable or that it is regularly lowered during the heating season (Table 3).

Table 3: Energy and Water Consumption Practices and Expenditures

Percentage of households in 1991	
With a thermostat	88
With a programmable thermostat	13
With a regularly lowered thermostat	58
With compact fluorescent bulbs	11
With low-flow shower heads	28
With low-flow toilet tanks	9
Average household expenditure in 1990 (dollars per year)	
Electricity	644
Heating fuel	408
Water supply	118

Sources:
Statistics Canada, Household Environment Survey and Family Expenditure Survey.

Water-conserving practices are not as widely adopted as those for energy. Comparatively few households have either low-flow shower heads (28%) or low-flow toilet tanks (9%). This may be because, in many cases, the cost of water supply is not directly related to the quantity used.

The tenure of a dwelling influences the degree to which the household feels responsible for the dwelling's condition and, therefore, its energy and water consumption. Households owning their place of residence have control over changing fixtures (like the thermostats), whereas tenants usually depend on their landlords to make these types of changes. This factor may contribute to the differences in energy- and water-use habits between households owning their dwellings and those renting. (Table 4). A higher proportion of homeowners report implementing conservation measures.

Table 4: Energy and Water Consumption Practices by Tenure of Dwelling, 1991

	Owned dwellings	Rented dwellings
	percent of households	
With compact fluorescent bulbs	14	6
With thermostats	87	76
With programmable thermostats	16	7
With regularly lowered thermostat settings	56	42
With low-flow shower heads	34	19
With low-flow toilet tanks	12	5
All households	**64**	**36**

Source:
Statistics Canada, Household Environment Survey.

TRANSPORTATION

Commuting to the place of work is a common feature of most households' transportation activity, although the needs of households vary considerably. The potential environmental impact from this activity also varies depending on the modes of transport that are chosen: walking or cycling instead of using a motor vehicle, taking public transportation rather than driving a private vehicle.

The cost of transportation accounted for 17%, or $5 603, of total household expenditure (FAMEX, 1990). Most of this amount (88%) is for private vehicles, the rest being for public transport. Fuel alone accounts for 23% of expenditures on private vehicles.

Households show a clear preference for private automobile travel when commuting to and from work. Overall, 76% of households reported at least one member who drives to work (Table 5). This rate does vary among metropolitan areas, although it is generally quite high (Table 6). The rate of private vehicle use ranged from 83% in Windsor and Kitchener-Waterloo, to 65% in Halifax.

Table 5: Commuting Patterns by Area and Dwelling Type, 1991

	Households where at least one member		
	Has employment outside the home	Drives private vehicle	Uses public transportation
	thousand	percent	
Major metropolitan areas (population of 100 000 and over)			
Single, detached	2 255	77	17
Single, attached	639	74	24
Apartment or flat	1 391	57	34
Other	42	...	...
Other areas			
Single, detached	1 859	82	2
Single, attached	203	77	5
Apartment or flat	254	67	9
Other	115	...	...
Canada	**6 758**	**76**	**15**

Source:
Statistics Canada, Household Environment Survey.

In contrast, only 15% of Canadian households report that at least one member uses public transportation for travelling to and from their workplace. This rate also varies through metropolitan areas. It is generally higher in the larger and more densely populated metropolitan areas such as Toronto (33%) and Montréal (30%).

INCOME AND HOUSEHOLD ACTIVITY

Environmentally relevant expenditures and activities may also be associated with household income. This variable is correlated with some of the geographic factors, such as urban structure, already discussed in this chapter. Income is related to the level of education attained, which might in turn influence the overall environmental awareness and activities chosen in a household.

Table 6: Commuting Patterns by Census Metropolitan Area, 1991

	Households where at least one member				
	Has employment outside the home	Commutes by private vehicle as the driver		Commutes by public transportation	
	thousands	percent			
Halifax	85	65	D	16	F
Québec	174	78	D	17	F
Montréal	846	68	D	30	E
Ottawa	193	67	D	27	E
Toronto	952	69	D	33	E
Hamilton	161	80	D	11	G
St. Catharines-Niagara	81	84	D	6	G
Kitchener-Waterloo	87	83	D	...	H
London	91	80	E	16	F
Windsor	64	83	D	6	G
Winnipeg	163	74	D	21	E
Calgary	207	77	D	17	F
Edmonton	208	80	D	16	F
Vancouver	456	80	D	18	E
Victoria	68	69	E	13	G
Canada	**6 759**	**76**	**B**	**15**	**D**

Note:
See the standard error symbols at the end of this chapter.
Source:
Statistics Canada, Household Environment Survey.

In fact, higher household incomes are associated with higher rates of adoption of certain environmentally useful practices (Table 7). With respect to energy conservation practices, households in the highest income group report the highest use of compact fluorescent bulbs (16%); the proportion of households with programmable or regularly lowered thermostats is also highest in this group (79%). For access to facilities for paper recycling, the rates range from 40% in the lowest income group to 73% in the highest income group. The reported rate of use varies in much the same way, ranging from 77% to 93%. In both cases, the differences are also related to factors discussed in previous sections: tenure and type of dwelling. Higher income households are more likely to be owners and reside in single detached dwellings than households in lower income groups.

In contrast to the positive correlation between income and the adoption of environmentally useful practices, Tables 8 and 9 show that the use of public transport declines in favour of automobile use as income increases.

Vehicle operation expenditures illustrate the differences in consumption between higher and lower income households (Table 8). Among households in the highest income decile, 94% are automobile or truck owners, compared to 90% in the fifth and 68% in the third deciles of income. The pattern of expenditure on automotive fuel is similar. The average expenditure increases with household income, ranging from $659 in the first income decile to $ 2 048 in the tenth. In addition, among the higher income groups, more households report expenditures on this commodity. In contrast, the proportion of households that report expenditure on public transit is higher in the lowest two deciles of income than in the highest two. However, the opposite is true for their average expenditure on this service (Table 8). The highest proportion of households with at least one member commuting to work by public transportation is in the first income group (37%) but the lowest rate is in a middle income group, the seventh, at 21% (Table 9)[1].

Table 7: Selected Practices and Characteristics by Household Income Group, 1991

Income groups	Owning their dwelling	Thermostats programmable or lowered	Compact fluorescent bulbs	Living in single detached dwelling	Access to paper recycling facilities and reporting use
	percent of households				
First (lowest)	21	61	7	16	77
Second	23	64	6	16	86
Third	27	63	7	22	81
Fourth	37	70	6	28	88
Fifth	42	70	8	30	87
Sixth	46	72	12	35	88
Seventh	53	73	11	39	86
Eighth	65	70	12	50	89
Ninth	73	76	13	62	90
Tenth (highest)	87	79	16	74	93
Canada	**55**	**72**	**11**	**44**	**85**

Sources:
Statistics Canada, Household Environment Survey and Survey of Consumer Finance.

CONCLUSIONS

Response to recycling programs appears to be very positive. In areas where the facilities are available, most households report that they are used. Some households, those residing in less densely populated areas or those living in apartments, for instance, have lower overall rates of access.

The data suggest that households are both conscious of their consumption of water and energy, and willing to take steps towards conservation. The extent to which energy and water-efficient fixtures are used is related to income level (at least, in the case of energy) and the tenure of the dwelling.

1. Note that in contrast to Table 8 which is in income deciles, Tables 7 and 9 show income groups. Consequently, there is not an even number of households in each group, a fact that, while unimportant for this analysis, does make it impossible to compare the three tables in detail.

Table 8: Selected Transportation Expenditures, by Household Income Decile, 1991

Income deciles	Households that own vehicles	Average household expenditure			
		Automotive fuel		Public transit	
	percent	dollars	percent reporting	dollars	percent reporting
First (lowest)	21	659	22	243	84
Second	52	764	53	347	81
Third	68	952	73	383	77
Fourth	81	1 058	83	350	70
Fifth	90	1 246	92	371	70
Sixth	90	1 415	91	339	74
Seventh	94	1 436	94	396	76
Eighth	96	1 852	97	383	72
Ninth	97	1 776	96	436	74
Tenth (highest)	94	2 048	98	459	77
FAMEX cities	**78**	**1 430**	**80**	**363**	**76**

Note:
"Average household expenditure" is the mean expenditure among all families reporting a non-zero expenditure in a given category.
Source:
Statistics Canada, Family Expenditure Survey.

Table 9: Commuting Patterns by Household Income Group, 1991

Income groups	Households where at least one member		
	Has employment outside the home	Commutes by private vehicle as the driver	Commutes by public transportation
	thousands	percent	
First (lowest)	150	48	37
Second	205	50	23
Third	277	50	33
Fourth	411	56	29
Fifth	435	58	28
Sixth	504	67	24
Seventh	1 016	71	21
Eighth	1 007	77	25
Ninth	1 131	80	24
Tenth (highest)	1 622	81	23
Canada	**6 759**	**72**	**25**

Source:
Statistics Canada, Household Environment Survey.

However, Canadian households generally remain committed to the use of private vehicles. For travelling to work, commuters far prefer to drive their cars instead of using public transportation. This preference is probably related to the level of service in the transit system and the particular circumstances of individuals. The above results show, nevertheless, that those considerations are more important to the households than the possible environmental effects.

DATA SOURCES

Refer to the publication *Households and the Environment* for details on the methodology of the 1991 Household Environment Survey. For comparisons between income categories, a subset of the Household Environment Survey was selected corresponding to the urban areas that were sampled in the 1990 Family Expenditure Survey. "FAMEX cities" include St. John's, Charlottetown, Summerside, Halifax, Saint John, Québec, Montréal, Ottawa, Toronto, Thunder Bay, Winnipeg, Regina, Saskatoon, Calgary, Edmonton, Vancouver and Victoria.

Expenditure data are taken from the Family Expenditure Survey. These are based on a survey of households in Census Metropolitan Areas.

REFERENCES

Rathje, W.L. "The History of Garbage". *Garbage: The Practical Journal for the Environment* 2(4): 33-39,1990.

Statistics Canada. *Family Expenditure Survey, 1990.* Catalogue 62-555, Irregular,Ottawa, 1991.

Statistics Canada. *Households and the Environment 1991.* Catalogue 11-526, Occasional,Ottawa,1992.

Alphabetic Designation of Percent Standard Error

A	0 to.5
B	.6 to 1.0
C	1.1 to 2.5
D	2.6 to 5.0
E	5.1 to 10.0
F	10.1 to 16.5
G	6.6 to 25.0
H	25.1 +

8 Pollution Abatement and Control Expenditures

by Craig Gaston

Pollution abatement and control expenditures (PAC) are of interest as a measure of the impact of environmental regulations on affected industries and, more broadly, as part of overall environmental expenditures in national income. Since both the desirable and undesirable outputs derive from the same process, the generation of pollution can be viewed as a joint product problem. In many cases, expenditures to reduce pollution are often not distinguishable from those outlays made to improve overall performance. There are, however, some expenditures which are solely for the purpose of pollution abatement and control. These are often described as "end-of-pipe" solutions. Using this restrictive but unambiguous definition, PAC capital expenditures amounted to over $1 billion in 1989, or about 1% of total capital expenditures in Canada. Table 1 shows that the distribution of PAC expenditure is very uneven across industrial sectors.

Table 1: Relative Importance of PAC Expenditures, Selected Industries, 1989

Industrial sector	PAC operating	PAC capital[1]	Total capital	PAC/ total capital
	million dollars			percent
Manufacturing	469	918	18 942	4.3
Paper & allied	76	368	5 501	6.7
Primary metals	258	288	2 341	12.3
Petroleum & coal	36	71	961	7.4
Chemicals	44	71	1 627	4.4
Mining	77	80	7 373	1.1
Utilities	x	106	19 486	1.1
Total economy[2]	**729**	**1 188**	**89 722**	**1.3**

Notes:
[1] See Statistics Canada (1992) for more detail on this survey, especially Appendix F for an explanation of the difference between the above data and those contained in Table 2 of Statistics Canada (1992).
[2] The total excludes capital items charged to operating expenditures and capital expenditures made by residential construction, agriculture, fishing and construction industries.
Source:
Statistics Canada, Investment and Capital Stock Division.

The Pollution Abatement and Control survey, conducted for the first time in 1989 by Statistics Canada, intentionally avoided the ambiguity inherent in the use of a broader definition such as "environmental expenditures". Internationally, there is no consistent approach. A similar survey conducted in the United States asks specifically for change-in-process expenditures as well as end-of-pipe expenditures as do France, Sweden and the Netherlands. Norway has abandoned PAC surveys altogether, rather than present partial results.

There is no doubt that the Statistics Canada PAC survey represents a lower bound on environmental expenditures. A survey of environmentally related expenditures prepared for Environment Canada by Dun and Bradstreet (1991), reported $20.9 billion in capital plus operating costs in 1989, over 12 times greater than the combined capital and operating expenditures figure resulting from the Statistics Canada survey. This wide difference is not surprising since it is possible to argue that major improvements costing many millions of dollars are at least partially environmentally motivated, even though the decision to invest is dependent on a number of factors aside from environmental protection.

HISTORICAL PAC EXPENDITURES

Statistics Canada has asked respondents to its regular annual Capital Repair and Expenditure Survey (CRES) to report capital expenditures by purpose, one of which is pollution abatement and control. The respondents are asked to assign their capital expenditures to the most relevant category in recognition of the fact that many expenditures could be assigned to more than one category. Even though the total for 1989 is similar to that reported in the PAC survey of the same year, an examination of the results by establishment shows important inconsistencies, a fact which demonstrates the need for strict definitions. Nevertheless, CRES provides us with a unique source of information covering the period 1985-1990.

Table 2: Capital Expenditure by Purpose, 1985-1990

Investment categories	1985	1986	1987	1988	1989	1990
	percent of total investment					
Expansion/ modernization/other	97.4	97.7	97.7	97.6	97.1	96.8
Pollution abatement and control	**.7**	**.7**	**.6**	**1.1**	**1.7**	**2.1**
Improvement to working environment	.9	1.0	1.1	.9	.8	.7
Reduction of energy costs	.9	.7	.5	.4	.4	.4

Source:
Statistics Canada, Investment and Capital Stock Division.

Table 2 shows a marked increase in the percentage of investment in pollution abatement equipment from 1988 to 1990 largely owing to the paper and allied industries and primary metal industries.

PAC EXPENDITURES BY PROVINCE

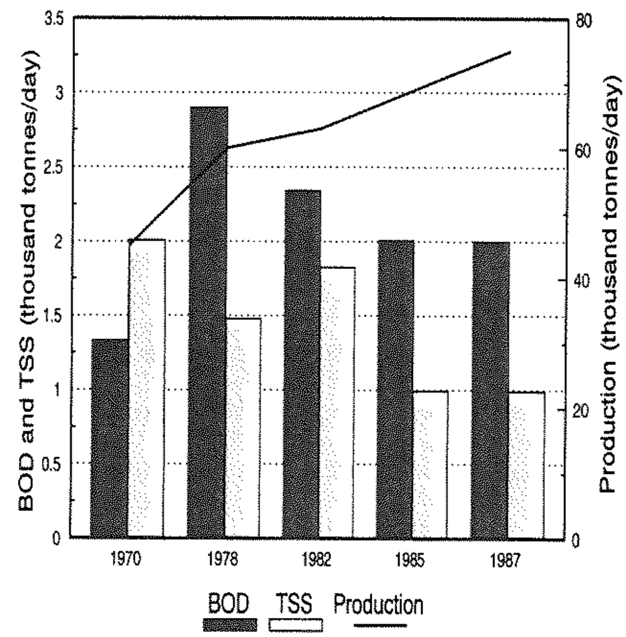
Table 3 shows that the large relative increase in PAC expenditures between 1988 and 1990 is accounted for mainly by Ontario and British Columbia. Investment in general, and investment in PAC in particular, tends to be volatile, and one would expect considerable variation of these ratios as the aggregates observed become smaller.

Although the 1989 PAC survey is felt to be more meaningful than CRES due to the stricter definitions, it is interesting to observe the movement of the latter over time (since the PAC survey itself has been conducted for only one year, 1991). Table 3 shows that no one province devotes a consistently higher proportion of investment to pollution abatement than the others.

PHYSICAL MEASURES OF POLLUTION ABATEMENT

An important measure of effectiveness of PAC expenditures is the reduction in pollutants. The 1989 PAC survey attempted to obtain information on the physical quantity of pollutants abated but experience has shown that this is difficult to achieve with a single questionnaire designed to cover all industrial sectors. Since a number of the most polluting industries are covered by environmental regulations, administrative data collected for this purpose are probably a better source of information on volumes of pollutants.

Figure 1: Discharges from Canadian Pulp and Paper Mills, 1970-1987



Source:
Environment Canada, 1991, p. 14-19.

As an example, the above chart shows the decline of pollutants from the pulp and paper industry compared with increasing production. Of course, the total volume of pollut-

Table 3: Provincial PAC Expenditures

Province	1989 PAC Survey			Capital and Repair Expenditure Survey PAC/total capital expenditure		
	PAC	Capital expenditures[1]	PAC / capital	1988	1989	1990
	million dollars		percent	percent		
Newfoundland	1.3	1 355	.1	.7	.6	1.8
Prince Edward Island	x	237	x	0	0	3.7
Nova Scotia	16.1	2 469	.7	.8	.7	.4
New Brunswick	67.3	2 010	3.3	2.6	1.0	.8
Quebec	255.4	19 512	1.3	1.5	2.5	1.4
Ontario	434.7	35 755	1.2	.8	1.5	2.0
Manitoba	12.9	2 548	.5	.3	2.4	.6
Saskatchewan	x	2 820	x	.5	.5	2.0
Alberta	182.2	11 702	1.6	.7	1.3	.7
British Columbia	200.2	10 310	1.9	2.0	1.7	5.4
Yukon	-	145	-	0	1.1	4.4
N.W.T.	x	860	x	x	x	x
Total	**1 188.0**	**89 722**	**1.3**	**1.1**	**1.7**	**2.1**

Note:
[1] The total excludes capital items charged to operating expenditures and capital expenditures made by residential construction, agriculture, fishing and construction industries.
Source:
Statistics Canada, Investment and Capital Stock Division.

ants abated is, in itself, an inadequate measure of environmental impact since the toxicity of the pollutant is also important. Recent regulations governing the production of dioxins and furans, for example, require that the levels of these chemicals be kept below the measurable concentration which, in this case, is 50 parts per quadrillion (10^{15}).

CANADIAN VERSUS UNITED STATES PAC EXPENDITURES

Unlike the Canadian survey, the U.S. industrial PAC survey asks respondents to report the portion of change-in-process investment which is related to pollution abatement. This is a subjective judgement by respondents that limits comparability both within and between sectors. The U.S. expenditures are higher than those for Canada at least partly for this reason.

Table 4: PAC Capital Expenditures as a Percentage of Total Capital Expenditures, Canada and U.S., 1989

	Total	Air	Water	Solid waste
		percent		
Canada	1.3	.6	.5	.2
United States	3.4	1.3	1.9	.2

Source:
OECD, 1992.

CONCLUSION

End-of-pipe pollution abatement and control expenditures have been increasing in absolute terms and as a percentage of total investment. These costs represent a lower bound on total PAC expenditures, many of which are impossible to isolate due to the complexity of the investment decision making process. There are no international standards in the definition or measurement of these costs and as a result, comparisons with other surveys should be made with caution.

There is an inherent ambiguity in interpreting PAC expenditures since end-of-pipe outlays are not necessarily the most efficient way to prevent pollution. In many instances, a change in production process leads to a more efficient use of energy and raw materials and reduces the need to install expensive and "non-productive" capital for the purpose of pollution abatement. Since the joint product nature of the problem precludes knowledge of the total costs associated with pollution control, it is useful to know the actual reductions in specific pollutants as well as expenditures on pollution abatement and control.

REFERENCES

Dun & Bradstreet Canada. *Market Survey of Environmental Expenditures by Canadian Business.* Report prepared for Environment Canada. Duns Marketing Services, May, 1991.

Environment Canada. *The State of Canada's Environment.* Ottawa, 1991.

Organization for Economic Cooperation and Development (OECD). *Pollution Abatement and Control Survey 1992.* ENV/EPOC/GEEI(92)11. Preliminary. Paris, 1992.

Statistics Canada, "Analysis of the 1989 Pollution Abatement and Control Survey". Uncatalogued. Investment and Capital Stock Division, Ottawa, 1992.

9 Packaging Use and Disposition

by Marcia Santiago

INTRODUCTION

Packaging material is used to protect, to contain, or to transport commodities. It is also used to market products and to communicate information about products. Most importantly, packaging may protect commodities from damage or spoilage. However, packaging is also associated with a number of environmental concerns, the most prominent of which is the disposal of solid waste.

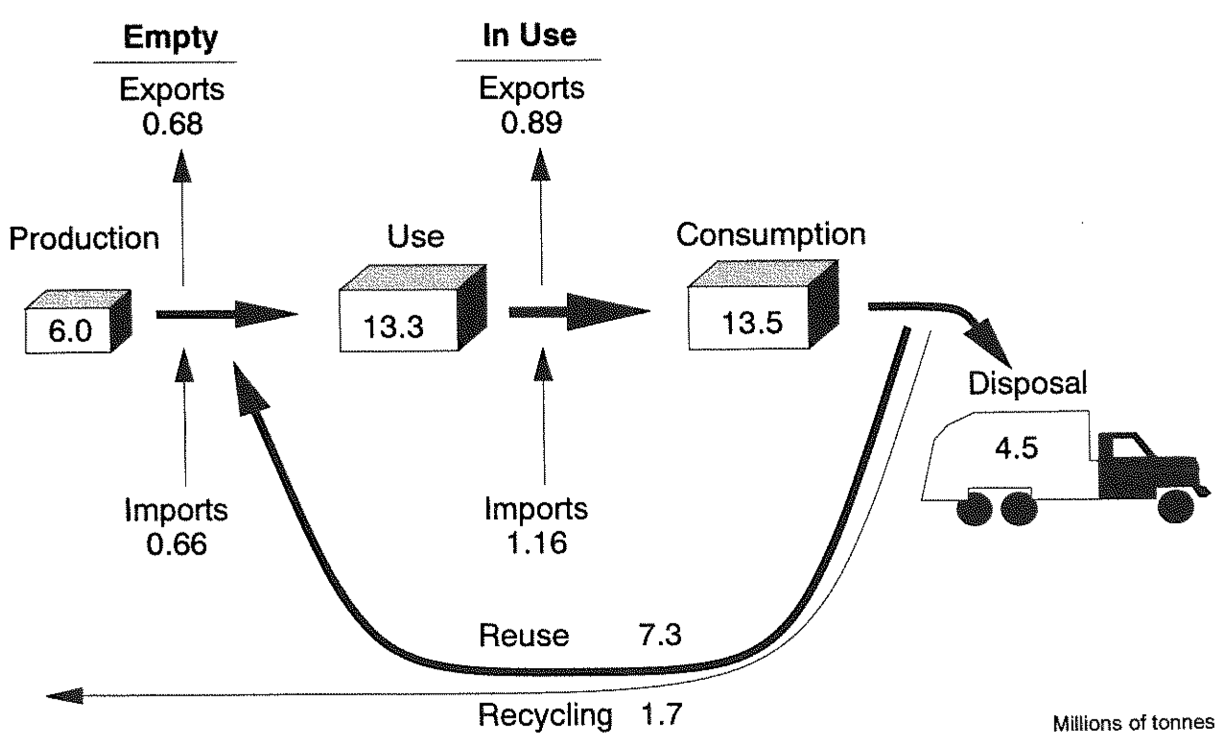
In 1989, Canadian environment ministers gave formal recognition to the need for packaging policy in managing solid waste. The National Packaging Protocol, which resulted from this recognition, recommended six management policies:

- packaging shall have minimal effects on the environment;
- priority will be given to the management of packaging through source reduction, reuse and recycling;
- a continuing campaign of information and education will be undertaken to make all Canadians aware of the function and environmental impacts of packaging;
- these policies will apply to all packaging used in Canada, including imports;
- regulations will be implemented as necessary to achieve compliance with these policies; and
- all government policies and practices affecting packaging will be consistent with these national policies.

Ultimately, the protocol seeks to reduce the quantity of packaging material that is sent to landfills. Over the next few years, diversion targets should be met and, by the year 2000, it is expected that packaging sent for disposal shall not exceed 50% of the 1988 level of 5.3 million tonnes (National Task Force on Packaging, 1992a).

Using results from the 1990 National Packaging Survey (ibid.), this chapter presents a profile of industrial packaging disposition and use. It describes the materials and the users of industrial packaging, with particular attention paid to the use, reuse, recycling and disposal of packaging.

Figure 1: Packaging Flows



PACKAGING FLOWS

Businesses typically handle packaging in conjunction with products they ship and with products they receive. Firms are described here as "using" packaging when it is filled with the product to be shipped whereas both businesses and households are said to have "consumed" packaging when it is removed from the product purchased. The use of packaging is equal to its consumption, except for the quantities attached to imported or exported goods. Since the survey included the waste management industry, estimates are available for the amount of household packaging waste that was recycled in 1990. It is therefore possible to calculate the total disposal for Canada as the difference between consumption and the sum of reused and recycled packaging (see Figure 1).

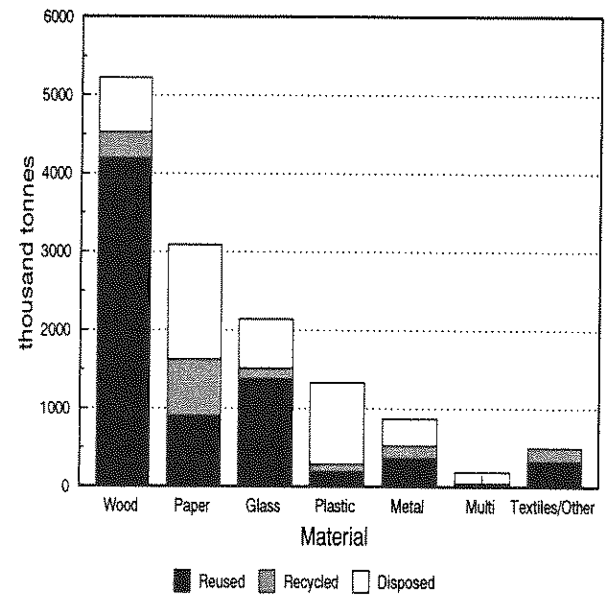
PACKAGING MATERIALS

The consumption of packaging materials amounted to 13.5 million tonnes during 1990 (see Table 1). Wood was the leading material employed, accounting for 39% of the total quantity consumed. Most wood packaging was in pallets, accounting for 4.9 million of the 5.3 million tonnes of wood packaging consumed. Consumption of paper packaging, including cardboard (paperboard) amounted to over 3 million tonnes (23% of the total), with the largest portion consisting of corrugated cartons, boxes and cases. Most goods sold, from food products to electronic equipment, have at least some amount of cardboard or paper packaging attached. Glass and plastic materials made up 16% and 10% of the total packaging consumed in 1990.

Eighty-five percent[1] of wood packaging was estimated to be reused or recycled. Pallets, the largest component of wood packaging, can be used over and over with only occasional minor repairs, so the low disposal of wood is not surprising. Glass also has a high rate of reuse and recycling (69%). For paper and plastic which represent the second and fourth largest volumes of packaging material, the rate of reuse and recycling is lower. Seventy-nine percent of plastic was disposed while 48% of paper was sent to landfills or incinerated. Paper was the largest material by weight to be disposed of. As a percentage of total packaging consumed in 1990, 33% (4.5 millions tonnes) was discarded.

1. The percentages in this paragraph reflect the proportions shown in Figure 2.

Figure 2: Disposition of Packaging, 1990



Sources:
Statistics Canada, National Packaging Survey and National Task Force on Packaging.

Table 1: Consumption and Disposition by Packaging Type, 1990

Material	Types	Total consumed		Total reused		Total recycled		Total disposed	
		thousand tonnes	percent	thousand tonnes	percent	thousand tonnes	percent	thousand tonnes	percent
Wood	pallets, boxes, crates	5 327	39.4	4 187	57.1	335	20.1	805	17.8
Paper	corrugated cartons, boxes, labels	3 149	23.3	899	12.3	723	43.4	1 527	33.7
Glass	carboys, bottles, containers	2 185	16.2	1 373	18.7	136	8.1	676	14.9
Plastic	containers, foam egg trays, wrap, liners	1 358	10.0	190	2.6	95	5.7	1 073	23.7
Metal	aluminum cans, caps, steel strapping	888	6.6	362	4.9	162	9.7	364	8.0
Multi-material	milk and juice cartons	193	1.4	7	--	36	2.2	150	3.3
Textiles and other materials	jute sacks, bags, wrapping	426	3.1	318	4.4	180	10.8	--	--
Total		**13 526**	**100.0**	**7 336**	**100.0**	**1 667**	**100.0**	**4 595**	**100.0**

Sources:
Statistics Canada, National Packaging Survey and National Task Force on Packaging.

PACKAGING USE BY INDUSTRY

The manufacturing sector was the largest user of packaging, accounting for well over 10 million tonnes of the total 13.3 million tonnes used (see Table 2). Manufacturing industries, excluding food, beverage, and tobacco, were least heavily involved in reuse of packaging. Use of packaging material was relatively evenly spaced across the other industry groups, except agriculture, for which use was estimated at 376 thousand tonnes. The estimated packaging use by the wholesale and retail trade industries is not surprising, given their activity of packaging goods and selling them to consumers. Of the important industries in terms of packaging use, the largest percentage of packaging reuse was in the beverage manufacturing industry. This is consistent with the large proportion of glass packaging, which is most commonly used in distributing beverages to consumers.

It is important to note that wooden pallets account for over one-third of all packaging used, by weight, and that there is an economic incentive to reuse these rather than to recycle or discard them. The high reuse of packaging as a percent of use is partly due to this fact. (See Table 2.)

Table 2: Industrial Use and Reuse of Packaging, 1990

Industry	Used (includes reused)		Reused	
	thousand tonnes	percent	thousand tonnes	percent of used
Agriculture	376	2.8	200	53
Manufacturing (excl. food and beverages)	4 287	32.3	1 630	38
Food manufacturing	3 556	26.8	1 444	41
Beverage manufacturing	2 423	18.3	2 076	86
Wholesale and retail trade	2 477	18.7	1 853	75
Other industries	138	1.0	129	93
Total	**13 257**	**100.0**	**7 332**	**55**

Sources:
Statistics Canada, National Packaging Survey and National Task Force on Packaging.

PROVINCIAL CONSUMPTION AND REUSE

The provincial pattern of recycling rates (as a percentage of consumption) is similar to that observed in the Local Government Waste Management Practices Survey (see Chapter 11, Table 3). In both cases, Ontario had the highest rate of recycling followed by British Columbia.

Table 3: Provincial Consumption and Recycling of Packaging, 1990

Province	Total consumed		Recycled	
	thousand tonnes	percent	thousand tonnes	percent of consumed
Newfoundland	166	1.2	--	--
Prince Edward Island	47	0.3	4	9
Nova Scotia	338	2.5	24	7
New Brunswick	295	2.2	13	4
Quebec	3 516	26.0	325	9
Ontario	5 820	43.0	1 065	18
Manitoba	514	3.8	31	6
Saskatchewan	328	2.4	17	5
Alberta	1 130	8.4	41	4
British Columbia	1 356	10.0	144	11
Yukon	5	0.0	0	--
North West Territories	11	0.1	0	--
Canada	**13 527**	**100.0**	**1 664**	**12**

Sources:
Statistics Canada, National Packaging Survey and National Task Force on Packaging.

DATA SOURCES AND METHODOLOGY

In 1991, Statistics Canada conducted the National Packaging Survey. A large representative sample of establishments in all major industry groups was selected. Thirty-two packaging categories were defined in the survey, spanning seven broad groups of materials: plastic, wood, textiles, glass, metal and multi-material packaging. Respondents were asked to report quantities (in tonnes) of packaging that was used during the 1990 calendar year. They were also asked to report the proportions of new and reused content in the materials. Finally, survey respondents were asked to report the quantities of packaging that were reused, recycled and sent for disposal.

Estimates of use, reuse, and recycling of packaging materials presented in this chapter were based upon the responses to the National Packaging Survey described in National Task Force on Packaging (1992b). Certain data collected by the survey were not deemed reliable. For instance, businesses were not generally capable of providing a good estimate of the amount of packaging discarded. Disposal was, therefore, calculated residually. Packaging attached to imports and exports of goods was based on data from the International Trade Division. The exports and imports of in-use packaging were pro-rated in proportion to the packaging used. Imports and exports of new packaging (not attached to goods) came from the International Trade Division of Statistics Canada. These data were available by commodity group and were allocated to industries and provinces on a proportional basis.

Provincial consumption of packaging was not measured directly since inter-provincial trade of in-use packaging was not known. Packaging was assigned to two categories, industrial and consumer. Total Industrial packaging was allocated to provinces according to provincial sales for each industry group, whereas consumer packaging was distributed according to provincial population. Provincial recycling rates for each packaging type and industrial sector were based upon survey data.

For further analysis of these data and for comparisons with the 1988 benchmark levels, see National Task Force on Packaging (1992b). For information on the establishment of the 1988 benchmark see National Task Force on Packaging (1992a).

REFERENCES

National Task Force on Packaging (NTFP). *National Packaging Protocol: 1988 Benchmark Estimates*. Report prepared for the Canadian Council of Ministers of the Environment. Office of Waste Management, Environment Canada. Hull, Quebec, December, 1992a.

National Task Force on Packaging (NTFP), *National Packaging Protocol: Results of the 1990 National Packaging Survey*. Report prepared for the Canadian Council of Ministers of the Environment. Office of Waste Management, Environment Canada. Hull, Quebec, December, 1992b.

10 Waste Management Industry Survey

by Craig Gaston

The waste management industry, which is not officially defined in the 1980 Standard Industrial Classification, includes all establishments that are primarily engaged in the collecting, hauling, recycling or disposing of waste material[1]. This industry is comprised of private companies as well as local government departments. Until recently, the waste management industry has not been surveyed by Statistics Canada. Therefore, two recent surveys covering the private and public components provide important, new information on the industry's structure in Canada. Chapter 11 provides preliminary information from the 1990 Local Government Waste Management Practices Survey and this chapter presents the 1989 Waste Management Industry Survey results.

The 1989 survey gathered information on 643 companies representing some 759 establishments. These establishments accounted for over $1.1 billion in revenues and employed almost 10 000 people. Table 1 shows that almost 72% of industry revenues were earned from collection and haulage of waste, while about 21% came from disposal. In principal, disposal revenues are earned by operators of waste disposal facilities such as landfills, incinerators, etc. There is evidence, however, that some respondents indicated disposal revenues even though they provided only collection and transportation services.

Relatively high disposal revenue shares can be expected in provinces which are characterized by densely populated urban areas where space suitable for new landfills is scarce. This pattern is detectable in Table 1 notwithstanding the exception of Newfoundland. Local government involvement in waste disposal also effects disposal revenues. A relatively high proportion of contractors are responsible for waste disposal in both Quebec and British Columbia according to the Local Government Waste Management Practices Survey[2]. Recycling services and sales of recycled goods accounted for less than 2% of industry income nationally. Even in Ontario, where recycling programs are best established[3], the share of total revenues from this activity was only 2.6%.

In Table 2 the category "Other expenses" contains such costs as depreciation, taxes and professional and contracted services.

Firm size appears to be a significant factor in the pattern of relative costs (see Table 3). Salary and wage costs as a percentage of total revenue increase with declining revenue size whereas tipping expenses show the opposite tendency. Fuel costs show a similar pattern to

1. These establishments are, for the most part, included in the Other Utilities Industry (SIC 4999).

2. See Chapter 11, Table 2.

3. See Chapter 11, Table 3.

Table 1: Revenues by Type of Service and Province, 1989

Province	Establishments	Total revenue	Collection and haulage	Disposal	Recycling	Sales of recycled goods	Sales of energy	Other sales
	number	millions of dollars	percent of provincial revenue					
Newfoundland	28	.9	45.8	46.8	1.4	.1	-	5.8
Prince Edward Island	5	x	x	x	x	x	x	x
Nova Scotia	45	13.2	81.5	13.3	1.7	.3	.4	2.8
New Brunswick	24	4.8	80.7	17.6	.5	.1	--	1.1
Quebec	207	339.6	70.0	22.6	.3	.1	--	7.0
Ontario	222	517.7	70.5	21.3	2.6	.8	.1	4.7
Manitoba	19	14.4	84.7	13.5	.8	.1	.6	.3
Saskatchewan	23	4.6	80.5	12.7	1.9	.1	-	4.8
Alberta	63	91.0	77.1	17.5	2.2	.1	.2	2.9
British Columbia	112	127.8	76.1	19.6	1.0	.1	.1	3.0
Yukon and N.W.T.	11	x	x	x	x	x	x	x
Canada	**759**	**1 119.1**	**71.9**	**20.9**	**1.6**	**.4**	**.1**	**5.0**

Sources:
Statistics Canada, Industry Division and National Accounts and Environment Division.

Table 2: Distribution of Expenses by Province, 1989

Province	Establishments	Total expenses	Tipping fees	Fuel and electricity	Other materials	Salaries and wages	Other expenses
	number	millions of dollars	percent of total expenses				
Newfoundland	28	0.8	2.2	12.9	10.9	46.6	27.5
Prince Edward Island	5	x	x	x	x	x	x
Nova Scotia	45	11.5	18.0	6.5	16.1	27.8	31.5
New Brunswick	24	4.3	6.2	7.2	37.8	30.6	18.2
Quebec	207	284.2	19.5	5.3	22.6	29.3	23.4
Ontario	222	448.8	30.1	4.2	14.6	24.5	26.6
Manitoba	19	12.1	25.3	6.5	6.9	22.1	39.2
Saskatchewan	23	4.1	13.5	9.8	10.8	36.3	29.6
Alberta	63	73.4	17.3	5.0	8.8	28.7	40.1
British Columbia	112	107.8	26.1	4.4	14.0	25.4	30.2
Yukon and N.W.T.	11	x	x	x	x	x	x
Canada	**759**	**952.0**	**24.9**	**4.7**	**16.5**	**26.6**	**27.3**

Sources:
Statistics Canada, Industry Division and National Accounts and Environment Division.

Table 3: Distribution of Expenses by Company Size, 1989

Revenue class	Companies	Total expenses	Tipping fees	Fuel and electricity	Other materials	Salaries and wages	Other expenses
	number	millions of dollars	percent of total expenses				
Greater than $5 million	27	665.2	26.5	3.5	17.2	24.0	28.9
$1 - $4.9 million	100	185.1	26.4	6.2	16.4	30.2	20.7
$.5 - $.9 million	100	59.2	15.0	9.4	11.5	34.5	29.5
Less than $.5 million	416	42.6	8.5	10.6	12.2	40.1	28.6
All companies	**643**	**952.0**	**24.9**	**4.7**	**16.5**	**26.6**	**27.3**

Sources:
Statistics Canada, Industry Division and National Accounts and Environment Division.

salaries and wages. The fact that larger firms are more likely to operate in densely populated urban areas could partly explain the correlation of tipping expense ratios to size.

Table 4: Employment and Salaries by Company Size, 1989

Revenue class of company	Employees	Salaries and wages	Salaries and wages per employee	Salaries and wages/ revenue
	number	millions of dollars	thousands of dollars	percent
Greater than $5 million	6 084	159.6	26.2	20.1
$1 - $4.9 million	1 868	55.9	29.9	26.7
$.5 - $.9 million	897	20.4	22.8	30.5
Less than $.5 million	947	17.1	18.0	34.6
All companies	**9 796**	**253.1**	**25.8**	**22.6**

Sources:
Statistics Canada, Industry Division and National Accounts and Environment Division.

Table 4 shows that about 60% of industry employment is in companies with revenues greater than $5 million.These companies account for over 70% of the total industry revenues. Although a larger proportion of revenues is paid to employees as the firm size diminishes, employees in the smaller firms earn a lower average salary.

This brief profile of the private sector waste management industry is limited by a lack of time series information. The growth of the industry over time and the changing composition of revenues and expenses is a subject of increasing interest as waste management continues to be a focus of public attention. For more information on the 1989 Waste Management Industry Survey see Statistics Canada (1992).

REFERENCES

Statistics Canada. "1989 Waste Management Survey". Uncatalogued. Industry Division, Ottawa, 1992.

11 Local Government Waste Management Practices Survey

by Craig Gaston and Alan Goodall[1]

INTRODUCTION

This chapter provides a preliminary report of some results from the national Local Government Waste Management Practices Survey. This survey sampled municipalities of all types and some special purpose boards known to be heavily involved in waste management. While questionnaires were mailed to a total of 1000 local government entities, data presented here reflect only 83 lower-tier municipalities[2] that had a population of greater than 50 000 in 1991. These 83 entities accounted for about half of the Canadian population.

The survey, the first of its kind for Statistics Canada, contained a number of questions designed to profile the practices of local governments with respect to the collection, transportation and disposal of garbage, as well as recycling and the handling of hazardous waste. As a pilot study, it was intended to obtain an overview of the structure and function of Canadian local government activities pertaining to waste management. Toward this end, the surveyed sample included every type of local government believed to have some responsibility for waste management. Questions were asked to determine whether the various functions were performed by the municipality surveyed, by contractors, or by another level of government. Information was also sought on a number of other items, including costs associated with waste management. A comprehensive examination of financial and other data is to be released in the final full survey report.

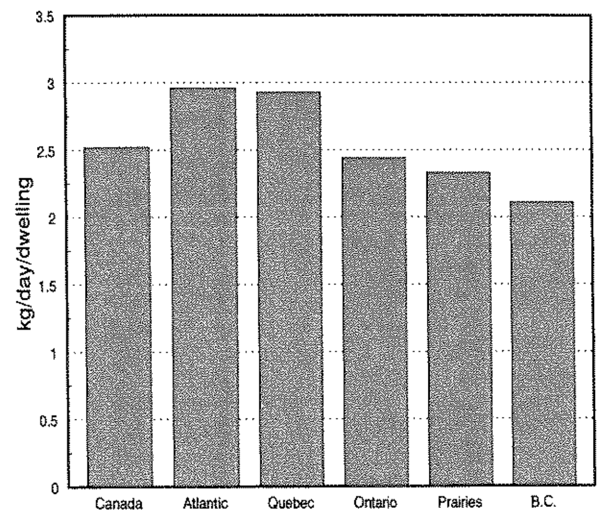
RESULTS

Based upon the total annual quantities reported, the 83 municipalities collected, on average, slightly over 0.9 tonnes of residential garbage[3] per dwelling served or about 2.5 kilograms per day (see Figure 1). Seventy-three of these municipalities reported having a recycling program, through which approximately 9% (by weight) of the total waste[4] stream was recycled. (This excludes private contracts by apartment building operators.)

Fifty-six of the municipalities had some form of residential hazardous waste program while only 10 had a program for non-residential hazardous wastes.

Thirty-six of the municipalities reported having arranged for waste composition studies, an important step towards effective waste management. In addition, 53 of the municipalities had some form of waste reduction program (public education, for example, but not recycling).

Figure 1: Garbage Collected per Dwelling, 1990



Sources:
Statistics Canada, Public Institutions Division and National Accounts and Environment Division.

Collection

Waste collection is primarily a function of lower-tier governments, frequently involving both contractors and municipal employees. Eighteen municipalities (22%) reported using only their own employees for this purpose and 40 (48%) reported hiring only contractors (see Table 1). On a regional basis, only 5% of Quebec respondents had their own employees performing this function while 84% of them used only contractors. Municipalities within census metropolitan areas (CMAs) or census agglomerations (CAs) with populations of less than 500 000 tended to use their own employees while those in CMAs or CAs greater than 500 000 relied more on contractors.

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1. The authors would like to thank Don Kerr for his painstaking work in assuring the quality of the data.
2. See the section titled: "Local Government: Upper and Lower Tiers".
3. On the questionnaire, garbage is defined as non-hazardous waste excluding materials diverted to a recycling program.
4. Waste is defined as any substance discarded for final disposal or recycling for which the owner or generator has no further use.

Table 1: Garbage Collection by Agent Responsible, Municipality Size and Region, 1990

	Population of CA/CMA to which municipality belongs				Region				
	50 000 - 499 999	500 000 - 999 999	1 000 000 and over	**Canada**	Atlantic Provinces	Quebec	Ontario	Prairie Provinces	B.C.
Number of municipalities reporting	37	14	32	**83**	5	19	37	7	15
Agent responsible for collection	percent of municipalities reporting								
Municipal employees only	32	14	13	**22**	40	5	27	14	27
Contractors only	30	64	63	**48**	40	84	41	14	40
Municipal employees and other	5	0	3	**4**	0	0	0	29	7
Municipal employees, other levels of government and other	3	0	0	**1**	0	0	3	0	0
Municipal employees and contractors	24	21	22	**23**	20	11	27	43	20
Municipal employees, contractors and other	5	0	0	**2**	0	0	3	0	7
Total	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**

Sources:
Statistics Canada, Public Institutions Division and National Accounts and Environment Division.

Table 2: Garbage Disposal by Agent Responsible, Municipality Size and Region, 1990

	Population of CA/CMA to which municipality belongs				Region				
	50 000 - 499 999	500 000 - 999 999	1 000 000 and over	**Canada**	Atlantic Provinces	Quebec	Ontario	Prairie Provinces	B.C.
Number of municipalities reporting	37	14	32	**83**	5	19	37	7	15
Agent responsible for disposal	percent of municipalities reporting								
Municipal employees only	35	21	6	**22**	60	11	16	71	13
Contractors only	24	0	44	**28**	0	58	14	29	33
Other levels of government only	30	64	44	**41**	40	32	57	0	33
Contractors and other levels of government	3	7	3	**4**	0	0	5	0	7
Municipal employees and other	3	0	0	**1**	0	0	3	0	0
Municipal employees and other levels of government	3	7	0	**2**	0	0	3	0	7
Municipal employees and contractors	3	0	3	**2**	0	0	3	0	7
Total	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**

Sources:
Statistics Canada, Public Institutions Division and National Accounts and Environment Division.

Disposal

Upper-tier governments play a much more important role in waste disposal than they do in collection. Thirty-three of the municipalities (41%) indicated that this function was handled solely by other levels of government (see Table 2). Contractors were exclusively involved in waste disposal for 23 (28%) of the municipalities while 18 (22%) used only their own employees. Again, population size is a factor as the municipalities within a CMA or CA having a population of under 500 000 tended to rely more on their own employees, whereas those within CMAs or CAs with a population greater than 500 000 contracted the function or relied more heavily on the upper tier. Regionally, Quebec municipalities tended to rely more on contractors for disposal while disposal programs were run most frequently by upper-tier local governments in Ontario.

Recycling Programs

Seventy-three municipalities (88%) reported having an organized recycling program (of which 54 provided details) (see Table 3). In all size groups and regions, the percentage of respondents with recycling programs was quite high, ranging from a low of 74% in Quebec to 100% in the Prairies. Both collection and preparation for sale of recyclable[1] materials are most often handled by contractors (see Tables 4 and 5). Municipal employees play a much smaller role in

Table 3: Recycling Programs and Percent of Waste Recycled by Municipality Size and Region, 1990

	Population of CA/CMA to which municipality belongs				Region				
	50 000 - 499 999	500 000 - 999 999	1 000 000 and over	**Canada**	Atlantic Provinces	Quebec	Ontario	Prairie Provinces	B.C.
Number of municipalities reporting	37	14	32	**83**	5	19	37	7	15
	percent								
Municipalities with recycling program	86	93	88	**88**	80	74	97	100	80
Waste recycled as a proportion of total waste collected	9	7	10	**9**	4	5	13	6	10

Sources:
Statistics Canada, Public Institutions Division and National Accounts and Environment Division.

Table 4: Collection of Recyclable Materials by Agent Responsible, Municipality Size and Region, 1990

	Population of CA/CMA to which municipality belongs				Region				
	50 000 - 499 999	500 000 - 999 999	1 000 000 and over	**Canada**	Atlantic Provinces	Quebec	Ontario	Prairie Provinces	B.C.
Number of municipalities reporting	37	14	32	**83**	5	19	37	7	15
Agent responsible for collecting recyclable materials	percent of municipalities reporting								
Municipalities' employees only	11	14	22	**16**	20	5	22	14	13
Contractors only	46	36	56	**48**	40	58	57	14	33
Other levels of government only	8	21	6	**10**	0	5	14	0	13
Other only	14	7	0	**7**	20	5	0	29	13
Contractors and other	8	0	0	**4**	0	0	3	14	7
Municipal employees and contractors	0	7	3	**2**	0	0	3	14	0
Municipal employees, contractors and other	0	7	0	**1**	0	0	0	14	0
Municipal employees, contractors and other levels of government	3	0	0	**1**	0	0	3	0	0
No program	11	7	13	**11**	20	26	0	0	20
Total	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**

Sources:
Statistics Canada, Public Institutions Division and National Accounts and Environment Division.

these functions compared to general waste management. Other organizations (primarily volunteer organizations and private enterprises) also play an important part in recycling operations. Upper-tier local governments tend to be more involved in the handling and preparation for sale of recycled materials than in their collection.

Table 6 shows the percentage of municipalities offering a recycling program for each of the nine materials listed by type of collection service offered. Percentages are based upon information from the 54 respondents reporting the detail of their programs. All of the municipalities reported newsprint recycling for low density dwellings. As one might expect, the frequency of such programs decreases as the density of dwelling increases since the logistics of coordinating recycling programs for multiple unit dwellings may be more complex. The fourth column in Table 6 shows the percentage of local governments offering a depot recycling program. It should be noted that the existence of a program for compostable materials does not mean all possible materials in this category are collected. In some cases municipalities have reported collecting only Christmas trees.

Hazardous Waste Programs

Fifty-six (67%) of the municipalities reported they had a residential hazardous waste program. Ontario had the highest regional representation, with 95% of municipalities reporting some type of program (see Table 7). Note that for this survey, once-per-year household hazardous waste drop-off programs qualified as valid responses.

1. Material which, technically, can be reused as a raw material in the manufacture of a new product.

Table 5: Sorting and Preparing of Recyclable Materials for Sale by Agent Responsible, Municipality Size and Region, 1990

	Population of CA/CMA to which municipality belongs				Region				
	50 000 - 499 999	500 000 - 999 999	1 000 000 and over	**Canada**	Atlantic Provinces	Quebec	Ontario	Prairie Provinces	B.C.
Number of municipalities reported	37	14	32	**83**	5	19	37	7	15
Agent responsible for sorting/preparing recyclable materials	percent of municipalities reporting								
Municipal employees only	5	7	0	**4**	20	0	3	14	0
Contractors only	41	50	47	**45**	40	58	43	43	33
Other levels of government only	19	21	22	**20**	0	11	35	0	13
Other only	16	14	3	**11**	20	5	3	43	20
Contractors and other	5	0	0	**2**	0	0	3	0	7
Contractors and other levels of government	3	0	0	**1**	0	0	3	0	0
Other levels of government and other	0	0	3	**1**	0	0	3	0	0
Municipal employees and other levels of government	0	0	3	**1**	0	0	3	0	0
No program	11	7	22	**14**	20	26	5	0	27
Total	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**

Sources:
Statistics Canada, Public Institutions Division and National Accounts and Environment Division.

Backyard Composting

Thirty-two municipalities (39%) indicated that a backyard composting program existed within their boundaries. Of these, 28 provided data on the number of composters distributed. As reported, over 83 000 composters had been distributed. Thirty percent were supplied by the municipality, 17% by contractors, 42% by other levels of government, with the remainder supplied by other organizations.

Table 6: Recycling Collection Programs and Depots, 1990

Recyclable Material	Recycling collection program: Low density dwellings	Medium density dwellings	High density dwellings	Depots
	percent			
Newspaper	100	61	37	54
Cardboard	50	30	20	35
Fine paper	20	7	4	28
Glass	96	59	35	41
Ferrous metal	85	50	30	39
Non-ferrous metal	76	48	33	37
Plastic	67	37	30	37
Compostable materials	33	17	9	13
Used motor oil	15	7	2	13

Note:
Based on detailed information provided by 54 municipalities that provided details of their recycling programs.
Sources:
Statistics Canada, Public Institutions Division and National Accounts and Environment Division.

Disposal Facilities

Information was provided for 165 of the disposal facilities used by respondents (see Table 8). Sanitary landfills are the most commonly reported means of waste disposal for municipalities with a population of 50 000 and over. However, not all the sites (as described by respondents) appear to meet the criteria set for sanitary landfills. At a minimum, in addition to frequent and regular coverage of waste, a sanitary landfill must have either a natural or an artificial liner to prevent leachate from contaminating groundwater.

Of the 100 landfills reported, some detailed characteristics were provided for 60 sanitary landfills within local municipal boundaries (see Table 8). As reported, in addition to frequent coverage of waste, these sites had the attributes shown in Table 9.

DATA QUALITY

Completed questionnaires were received for all of the 83 lower-tier governments reported here. Most of these were contacted by telephone in order to clarify responses, correct inconsistencies and obtain missing information. As a result of this follow-up, data on the availability of programs and the agent responsible for their delivery is considered to be very accurate. The more detailed information on characteristics of disposal sites is of lower quality because not all municipalities were able to provide these data. Population counts were verified using information from the 1991 Census of Population.

Table 7: Hazardous Waste Program by Type of Program, Municipality Size and Region, 1990

	Population of CA/CMA to which Municipality Belongs				Region				
	50 000 - 499 999	500 000 - 999 999	1 000 000 and over	**Canada**	Atlantic Provinces	Quebec	Ontario	Prairies Provinces	B.C.
Number of municipalities reporting	37	14	32	**83**	5	19	37	7	15
	percent of municipalities reporting								
Residential	70	64	66	**67**	20	42	95	86	40
Non-residential	16	29	0	**12**	20	0	8	43	20

Sources:
Statistics Canada, Public Institutions Division and National Accounts and Environment Division.

Table 8: Garbage Handling and Disposal Facilities, 1990

Type of facility as reported by respondent	Number	Percent
Sanitary landfills	100	61
Other landfills	5	3
Volume reduction facilities (e.g. incinerators)	7	4
Material recovery facilities	7	4
Transfer stations	46	28
Quarry dumps	.	.
Total	**165**	**100**

Sources:
Statistics Canada, Public Institutions Division and National Accounts and Environment Division.

Table 9: Sanitary Landfills by Characteristics Reported, 1990

	Number reported			
Characteristic	Yes	No	No answer	**Total**
Presence of weigh scales	48	11	1	**60**
Natural attenuation	27	9	24	**60**
Artificial liner	17	35	8	**60**
Leachate collection system	29	27	4	**60**
Methane gas harnessing system	11	41	8	**60**

Sources:
Statistics Canada, Public Institutions Division and National Accounts and Environment Division.

Data were requested for the fiscal year ending nearest December 31, 1990 but many respondents reported programs implemented subsequent to that date. As it was not possible to correct for this tendency, some percentages are higher than would be expected for the reporting period requested. An analysis of responses to the recycling question indicates that the impact is greatest on local governments with the smallest population. There does not appear to be a regional bias to this tendency.

LOCAL GOVERNMENTS: UPPER AND LOWER TIERS

Local government in Canada includes all government entities below the provincial/territorial level which, by the terms of their establishment, do not form part of the provincial/territorial level. Within this broad category, structures and responsibilities of local governments are further divided between municipalities, special purpose boards and local school districts. Municipalities are subdivided into unitary, regional and quasi-municipalities. To prevent double-counting, these municipalities were further classified into upper and lower-tier. For the purposes of this survey, upper-tier municipalities are those encompassing one or more local government entities. Lower-tier municipalities are those within the jurisdiction of another municipality type.

Upper-tier municipalities typically include metropolitan corporations, regional districts, regional municipalities, and counties (in Ontario and Quebec). Lower-tier municipalities include cities, towns, villages, townships, rural municipalities, districts and counties (in Nova Scotia and Alberta), and some quasi-municipalities (e.g., local government districts, local improvement districts).

12 Materials Recovery and Recycling by the Industrial Sector

by Marcia Santiago

INTRODUCTION

Recycling is not new and neither is it limited to households. Industry has been active in recycling for some time. The materials collected for industrial reuse are broadly similar to those collected from households: metals, paper, glass and plastics.

From an environmental standpoint, there are some beneficial aspects to the manufacturing of metal products from recycled material rather than from ores or concentrates. First, producing components from scrap material, rather than from primary metal results in savings of 75-95% of energy costs (Chandler, 1990). In addition, considerably less pollution is released.

There are three essential components in a cost-effective recovery and recycling system: supply, technology and markets. The source of recovered material must be readily accessible and reliable. An efficient collection network is especially important in this regard. There must also be in place sufficient technological capability to reprocess recovered materials. Most importantly, the demand for the reprocessed materials must be well developed.

This chapter attempts to compare virgin and scrap material prices, in order to describe their relative behaviour in changing markets. In general, differences in movements of virgin and scrap prices are expected to reflect the overall pattern of manufacturing activity. In cases where there are no regulatory pressures, market forces dictate the extent to which scrap is used. For metals, the difference between scrap and ore price movements would reflect the relative energy demand of primary and secondary manufacturing depending on the quality of ore that is available.

PULPWOOD AND NEWSPRINT

Although environmental regulations and recently increased customer demand have focused attention on the recycled fibre content in paper, material recovery is actually a long-standing practice in the pulp and paper industries. Pulpwood chips, a by-product generated by sawmills in the processing of timber to lumber, are an alternative to logs and bolts in the production of pulp. Similarly, newsprint and fine paper may be used as recycled fibre content, in the production of either other printing and writing paper or paperboard and boxboard.

Chipping is a natural extension of the sawmill business, as it is an efficient way of handling the large volumes of pulp wood debris that accumulate. One consideration in handling such waste, which usually consists of short log ends and chunks, is the distance that the chips must be hauled from the sawmill to the pulp mill. A chipping operation may, by some estimates, reduce wood debris by almost half (Phillips, 1992). These chips are eventually used in the production of pulp, newsprint and other paper products (Table 1).

Table 1: Selected Material Inputs to Pulp and Paper Products, 1987

Commodity inputs	Commodities produced			
	Pulp	Newsprint	Paperboard and building board	Paper boxes, bags and containers
	millions of dollars			
Pulpwood	504	676	54	--
Pulpwood chips and other wood waste	784	313	82	--
Pulp	85	261	237	9
Miscellaneous paper	22	70	539	2 209
Total	**1 395**	**1 320**	**912**	**2 218**

Source:
Statistics Canada, Input-Output Division

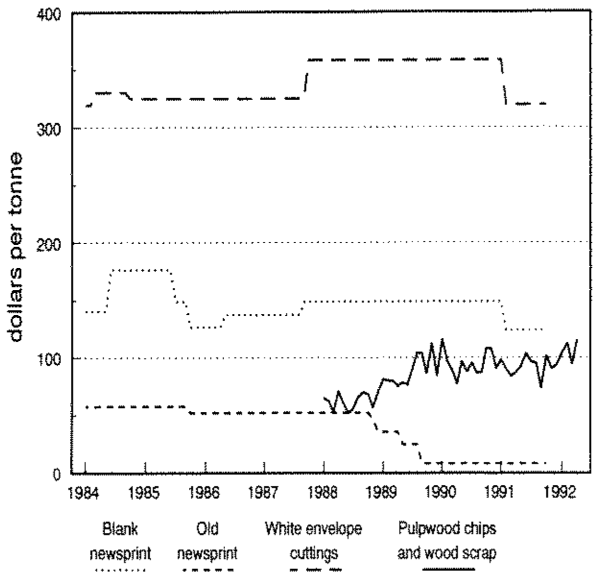
Markets for paper containing recycled fibre continue to grow. This is especially true in newsprint, despite recurring technical problems like "stickies" — a buildup of residual ink on the paper machine that requires a great deal of cost and effort to control. The development of markets for fine paper is also well under way. A Mississauga, Ontario firm was the first to supply customers with paper that contained fibre from its own wastepaper supply (Hedlund, 1992).

Unit prices[1] for some of these materials are shown in Figure 1. While the price of old newsprint has been well below that of unprinted scrap newsprint since mid-1988, the price for old newsprint began to fall about one and a half years ahead of the price for unprinted scrap newsprint. In contrast, prices for pulpwood chips and scrap wood actually increased until January 1990, when they reached their peak value of $116 per tonne. More recently, the United States has been tightening up its regulatory framework, re-

1. Unless otherwise specified, unit prices quoted in the text are based on October 1991.

quiring a higher recycled material content in newsprint and this may lead to higher prices in the longer term.

Figure 1: Scrap Wood and Paper Products, Monthly Unit Prices, 1984-1992



Sources:
Statistics Canada, International Trade Division.
Recoup Publishing Limited.

ALUMINUM

Between 1988 and 1990, production of secondary aluminum in market economies set record volumes of about 5.1 million tonnes. These high volumes are attributed to continuing improvements in the scrap collection system and increased recycling promotion by governments and environmental groups (EMR, 1991). This is especially true of used beverage cans.

Table 2: Aluminum Production and Trade, 1989

	Quantity	Value
	thousand tonnes	million dollars
Total Canadian production	1 555	...
Imports		
Aluminum ore and concentrate	2 541	111
Aluminum oxide	2 031	629
Aluminum waste and scrap	58	93
Exports		
Aluminum, not alloyed	614	1 450
Aluminum alloys	544	1 356
Aluminum waste and scrap	164	328

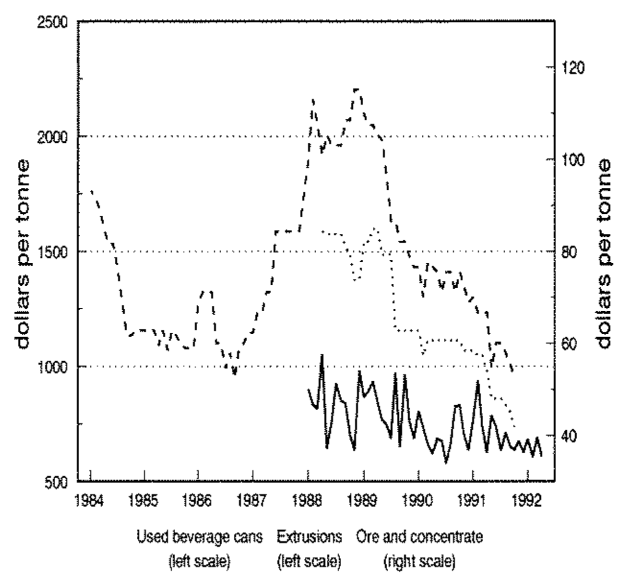
Source:
Energy Mines and Resources Canada, 1991.

In 1989, aluminum scrap represented a total of $328 million or 164 thousand tonnes in exports (Table 2). This mainly consisted of material recovered from industrial processes. Another source of aluminum scrap is consumer durable goods, which include pots, pans, flatware, appliances, as well as transportation equipment components. Packaging is also a large component of aluminum scrap; used beverage cans are the most common example.

Aluminum can scrap is used by both primary and secondary aluminum producers (Selke, 1990). The first step in recycling of aluminum cans is usually a preliminary screen with a magnet to remove any steel cans inadvertently mixed in. The cans are next shredded to one-inch pieces. Fines and dust are collected and removed by high efficiency cyclones to eliminate any explosion hazard. Magnets are again used to remove any steel scraps. Most other contaminants, such as paper, are removed in pneumatic processing. Finally, the aluminum scrap is charged in the furnace, where alloy composition is adjusted as required.

Compared to other nonferrous metal scrap, the unit prices for various grades of recovered aluminum are quite high (Figure 2). They range from $738 per tonne for used beverage cans to $947 per tonne for aluminum extrusions. This is also considerably higher than the unit value of aluminum ore and concentrate ($37 per tonne).

Figure 2: Aluminum Ore, Scrap and Extrusions, Monthly Unit Prices, 1984-1991



Note:
"Extrusions" refers to industrial scrap aluminum.
Sources:
Statistics Canada, International Trade Division.
Recoup Publishing Limited.

Part of the price difference between aluminum ore/concentrate and recovered aluminum is related to a basic cost issue: compared to one produced from ore or concentrate, a product manufactured from a recovered source of aluminum requires less energy. Because of the high energy requirements for refining aluminum ores, energy accounts for about one fifth of the cost of producing aluminum from ore (Chandler, 1990). Use of recycled aluminum represents an overall cost savings of about 40%.

However, the market for recycled packaging is subject to a number of stresses. First, aluminum is a somewhat more expensive packaging material than steel for producing beverage cans. In Ontario, some of the major soft drink manufacturers have begun to use cheaper bimetal cans. Although these alternatives may be used in steel recycling, they could pose problems for programs that depend on the more lucrative aluminum cans to fund other aspects of the recycling facility. Another factor is an environmental levy imposed on beer cans, to which some manufacturers of aluminum cans have attributed a recent drop in sales.

IRON AND STEEL

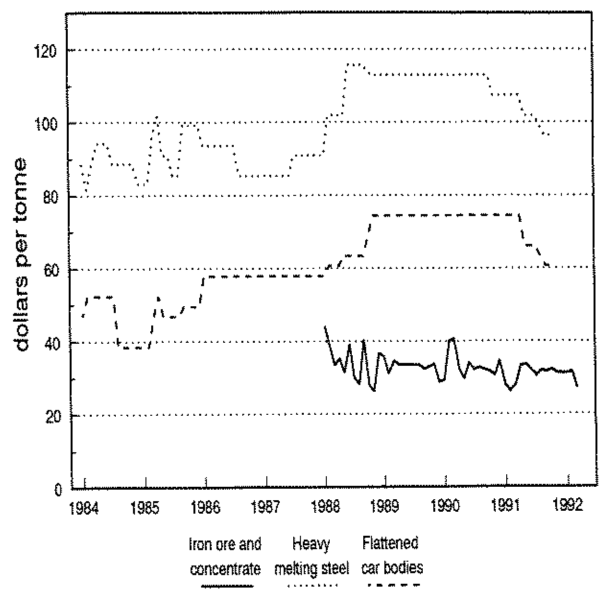
Ferrous scrap is used in steel produced in electric furnace mills and integrated mills. Foundries are also a large market for iron and steel scrap. In turn, automotive manufacturers are these industries' primary markets. As such, Canadian scrap prices often fluctuate with the pattern of growth in these industries. For example, activity in these industries has been slack recently and that pattern is reflected in the prices of steel scrap.

In Canada, new scrap averaged 17% of total finished steel and represented 60% of total purchased scrap (Stollery, 1983). High grade ferrous scrap competes directly with pig iron in steel furnaces because it can be used without intermediate smelting or refining. Thus, the price of ferrous scrap may be expected to vary positively with steel output. Stollery shows that changes in the price of ferrous scrap affect the demand for iron ore, which is also influenced by increases in the output of steel in the U.S.

Several grades of ferrous scrap are traded in secondary markets and two examples are shown in Figure 3. Heavy melting steel, valued at $96 per tonne, consists of wrought iron and steel segments that are at least four inches thick. Black and galvanized steel scrap, clippings, old auto bodies and fenders are all compressed to bundles of fixed sizes. Depending on the impurities, bundled scrap, as it is called, also has several grades. In late 1991, flattened car bodies were priced at $61 per tonne.

Prices for both iron ore and ferrous scrap (heavy melting steel and flattened car bodies) have been stable since the middle of 1988. Price changes for these commodities are shown in Figure 3. Scrap prices increased steadily from the beginning of 1984, when prices ranged from $47 per tonne to $89 per tonne, to the latter part of 1988, when they reached $74 per tonne to $113 per tonne. These prices, however, have felt the effect of recession. By the latter part of 1991, they had fallen well below the 1988 level.

Figure 3: Iron Ore and Scrap Steel, Monthly Unit Prices, 1984-1991



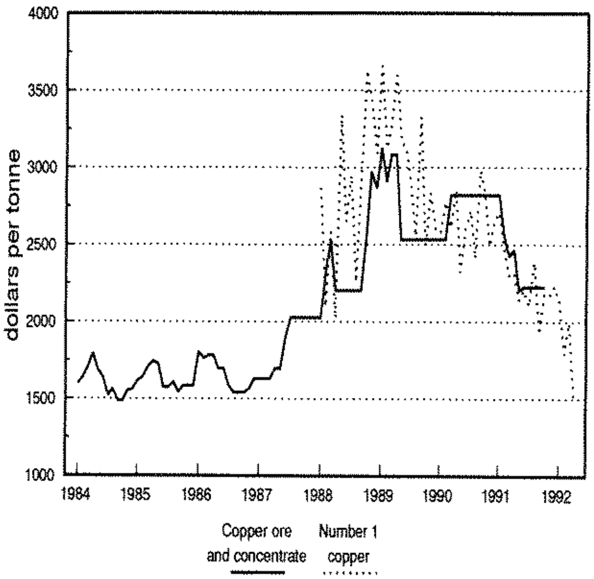
Sources:
Statistics Canada, International Trade Division.
Recoup Publishing Limited.

COPPER

A comparison of monthly copper ore and scrap unit prices is shown in Figure 4. Since 1984, the price movement has been similar to that of other primary and secondary metals. However, the unit price of copper ore and concentrate is about the same as that of Number 1 copper scrap, which is at least 96% pure copper and valued at $2.22 per kg. This is quite different from the pattern shown by iron and aluminum. It reflects differences in the quality of ores and concentrates that are traded. There is also a range of lower grade, refinery brass and smelter copper, whose prices range from $0.88 per kg to $1.83 per kg.

Historically, Stollery (1983) has shown that the prices of scrap copper have followed the pattern of activity in U.S. and European durable goods manufacturing. Although there are considerable differences in the energy requirements of primary and secondary copper production, the availability of fairly high-grade virgin material has maintained the relative market positions of ore and scrap.

Figure 4: Copper Ore and Scrap, Monthly Unit Prices, 1984-1991



Sources:
Statistics Canada, International Trade Division.
Recoup Publishing Limited.

DATA SOURCES

Price data for pulpwood chips, as well as metal ore concentrates, are based on quantity-weighted averages of import/export values. At the time of writing, time series based on the Harmonized Commodity Description and Coding System were available for the period September 1988 to April 1992. These are values declared at Customs, rather than announced or actual producer or purchaser prices. This is the most easily accessible source of non-confidential unit prices.

Price data for recovered materials were taken from a series of publications (Recoup). From this series, the most recent available issue was for October 1991 prices. In all cases, these are announced broker prices. Prices shown are specific to certain regions: Northeastern U.S. and Southern Ontario (used beverage cans), Ontario (ferrous scrap) or Toronto (other nonferrous scrap, paperstock). There may be quite a large difference between the announced prices and the discounted ones.

REFERENCES

Chandler, W.U. *Materials Recycling: The Virtue of Necessity* in S.E. Selke. *Packaging and the Environment: Alternatives, Trends and Solutions.* Lancaster, Pa: Technomic, 1990.

Energy Mines and Resources (EMR). *1990 Canadian Minerals Yearbook: Review and Outlook.* Catalogue M38-5/39E, Ottawa, 1991.

Hedlund, J. "Recycling Kicks Into High Gear". *Pulp & Paper Canada* 93(4):11, 1992.

Phillips, P.J. "At The Cutting Edge of Smallwood Pulping." *Pulp & Paper Canada* 93(5):37-38, 1992.

Recoup Publishing Limited. *Materials Recycling Markets.* Chesterville, Ontario. Monthly issues from 1988 to 1991.

Selke, S.E. *Packaging and the Environment: Alternatives, Trends and Solutions.* Lancaster, PA: Technomic, 1990.

Stollery, K.R. *Secondary Supply of Copper and Ferrous Metals and Canadian Metal Markets.* Technical Paper No. 3. Kingston, Ont.: Centre for Resource Studies, Queen's University, 1983.

13 Preliminary Estimates of the Value of Crude Oil and Natural Gas Reserves in Alberta

by Alice Born

INTRODUCTION

Economically recoverable sub-soil mineral deposits are wealth assets and not merely "free gifts of nature" as they are presently treated by conventional methods of national accounting. Thus, there is no national accounting for the total value of Canada's renewable or non-renewable natural resources and their physical depletion. Currently, the value of Canada's natural resources is excluded from Canada's National Balance Sheet Accounts, thus underestimating Canada's wealth.

This article presents preliminary results from a pilot study of the value of Alberta's crude oil and natural gas reserves. Statistics Canada proposes to include the value of Canada's natural resources in the National Balance Sheet. The development of *physical* accounts will provide a consistent national set of estimates of Canada's natural resource base, while the development of *monetary* accounts will provide a conceptual framework for monetary valuation of Canada's natural resources and their economic depletion.

Why should we measure the monetary value of Canada's natural resource endowment? Firstly, the use of natural resource assets generates substantial amounts of revenue and makes an important contribution to Canada's economic activity. The monetary accounts will provide an indication of the size of this income-generating potential. Secondly, monetary valuation of our natural resources provides a tool that allows us to compare Canada's net worth (assets - liabilities) to other industrialized countries without such natural resource endowments. The national balance sheet provides a total picture of a country's tangible and financial wealth thus aiding intertemporal and international economic structural comparisons. Thirdly, evaluation of a nation's future potential for sustained income generation can be enhanced by detailed analysis of national and provincial assets and liabilities. Revenues from non-renewable resources (e.g. royalties and land costs) may be converted into other assets capable of providing an ongoing return through savings and investment. An accounting representation should recognize that one kind of asset can be exchanged for another, the sale of a natural resource is exchanged for the acquisition of a new income-producing asset and the loss of the natural resource extracted. There is also public concern about the availability of mineral resources needed to sustain economic growth. Will resource availability seriously constrain the high standards of living in developed countries and the economic growth of the developing countries? It is hoped that natural resource accounting will address some of these issues.

Natural resource accounts can be used to measure the interrelationship between the economy and the environment. The focus of traditional systems of national accounts on market transactions in the economy has excluded accounting for changes in the quality of the environment and the stock and depletion of natural resources. Initiatives have been taken by the United Nations and several countries on satellite accounting for the environment in the System of National Accounts (SNA) in order to account for environmental and natural resources such as air, water, land, forests and sub-soil mineral deposits. The current revision to the SNA by the United Nations presents an opportunity to examine how natural resource accounting can be *linked to* or *incorporated in* the SNA (Bartelmus, 1991). In measuring sustainable development, there is a need to fully account for the use of both man-made and natural capital in order to recognize the possibility of non-sustainable growth and development (Bartelmus *et al*, 1991). The proposed SNA framework extends the concept of capital assets to cover both.

Only those reserves capable of producing economic benefits to their owners with current technology, scientific knowledge and relative prices and costs at the date to which the Balance Sheet relates will be included in the physical and monetary accounts. These natural resources have a high probability of being used in production of goods and services. Known reserves of oil and natural gas reserves that are not commercially exploitable in the foreseeable future are excluded from that Balance Sheet Accounts. These reserves may possibly become economical as the result of new technologies or major changes in relative prices similar to those of the oil shocks in the 1970s and 1980s. Accordingly, the physical and monetary accounts record, for any given year, the value of resources known to exist in that year, and to be economically viable given the technologies available in that year, all evaluated at the prices and costs prevailing in that year.

In December 1990 the Federal Government released *Canada's Green Plan*. Some of the initiatives from the *Green Plan* include: updating estimates of all natural resource stocks; increasing monitoring programs on the uses of renewable and non-renewable resources; and identifying the value of Canada's natural resources. Statistics Canada's role is to provide statistical information that integrates economic and environmental elements so that, for example, the value of natural resources is reflected in the Canadian System of National Accounts. Two pilot projects in natural resource accounting have been initiated by the

National Accounts and Environment Division at Statistics Canada. One considers a non-renewable resource, crude oil and natural gas reserves, and the other involves a renewable resource, timber.

This work on the development of natural resource accounts is part of the continuing work to complete the Canadian System of National Accounts (CSNA). The CSNA is one of the most complete national accounting systems in the world. The National Balance Sheet is only one component of this system and it provides estimates of Canada's wealth. When partial estimates of non-financial assets were first published as part of the National Balance Sheet in 1985, it was intended that further work be undertaken to complete the balance sheet by including other non-financial assets such as renewable and non-renewable resource assets.

This chapter presents both physical and monetary accounts for the crude oil and natural gas reserves of the Province of Alberta from 1961 to 1990. It is a shorter version of an earlier discussion paper (Born, 1992). For a more theoretical and expanded discussion, readers are referred to this previous paper.

THE OIL AND NATURAL GAS SECTOR IN ALBERTA

Alberta is the largest producer and owner of economically recoverable reserves of crude oil and natural gas in Canada. At the end of 1990, there were 530 million cubic metres of conventional crude oil reserves in Alberta, representing 60% of Canada's remaining established reserves of conventional crude oil, 1.7 billion cubic metres of marketable natural gas (62% of the Canadian total) and 524 million cubic metres of developed crude bitumen (100% of the Canadian total) (Canadian Petroleum Association, 1990; and Alberta Energy Resources Conservation Board, 1990).

The value of Alberta's production of conventional crude oil, natural gas and their associated by-products was $15.5 billion in 1990 or 83% of the value of Canada's total petroleum production (Statistics Canada, 1990). The value of Alberta's production from non-conventional sources (e.g. tar sands) was $2.8 billion, representing all of Canada's synthetic crude oil and bitumen production in 1990.

The upstream oil and natural gas sector is a capital intensive activity. Annual capital (namely exploration and development) expenditures in Alberta increased from $272 million in 1961 to $4.0 billion in 1990. Net fixed capital stock estimates for the sector have increased from $1.6 billion to $33.6 billion in that same period.

Royalties, and land acquisition costs and rental fees totalled $154 million in 1961 and $3.7 billion in 1990 for the province. Operating costs for extraction of oil and natural gas totalled $124.0 million in 1961 and increased to $4.8 billion in 1990.

Since most of Canada's petroleum production and remaining reserves are located in Alberta, this province has been examined first. Valuation models developed for Alberta's conventional reserves of crude oil and natural gas reserves are extended to other areas of Canada with oil and natural gas reserves and Alberta's non-conventional reserves of crude bitumen and will be published at a later date.

DEFINITION OF MINERAL RESERVES AND RESOURCES

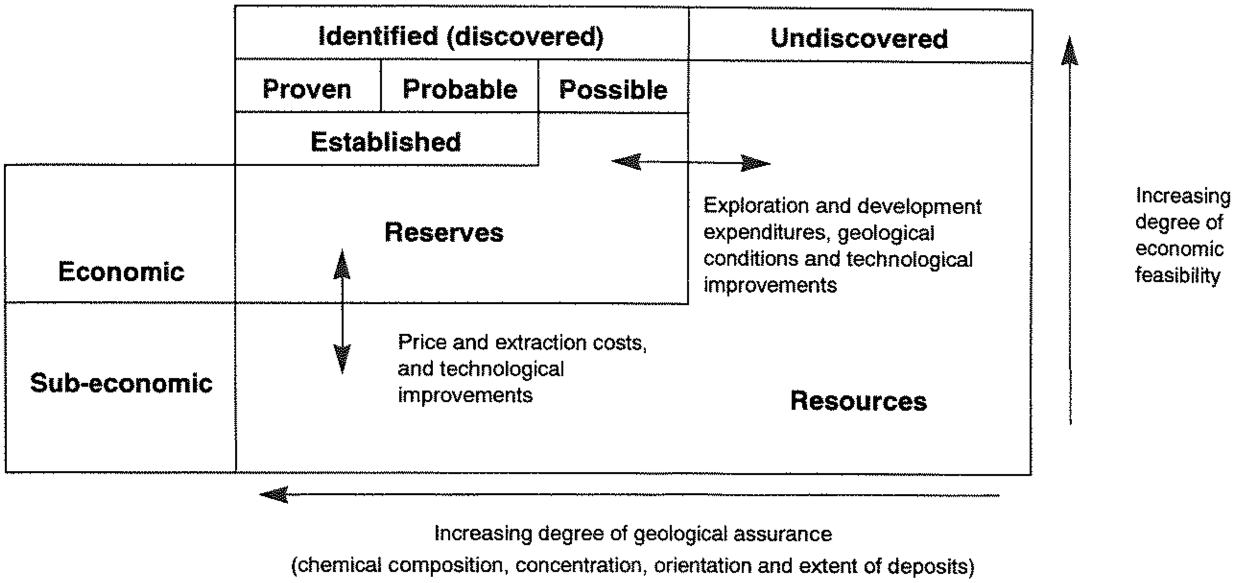
Estimates of the size of reserves of non-renewable (exhaustible) resources are continually being revised. In the development of physical accounts, the McKelvey Box is used to distinguish mineral resources from mineral reserves and to show what factors affect the size of the reserves (Figure 1). The vertical axis in Figure 1 represents the degree of economic recoverability and the horizontal axis measures the degree of geological certainty. Economically recoverable resources are located in the top left-hand corner of the diagram (e.g. identified proven, probable (established) and possible *reserves*). The feasibility of resource extraction decreases through to the lower right-hand section (e.g. sub-economic and undiscovered *resources*). The boundary between economic and sub-economic resources is affected by the relationship between prices and extraction costs, and technological improvements. The boundary between discovered and undiscovered resources fluctuates as the result of a petroleum company's investment in exploration and development, and differing geological conditions.

Oil and natural gas reserve estimates of Canada provided by the Canadian Petroleum Association (CPA), Alberta Energy Resources Conservation Board (AERCB), National Energy Board and other government agencies are reported as *established* reserves. Established reserves are "those reserves recoverable under current technological and present and anticipated economic conditions, specifically proved by drilling, testing or production, plus that judgement portion of contiguous recoverable reserves that are interpreted to exist from geological, geophysical or similar information, with reasonable certainty" (Tanner, 1986; p. 22).

The AERCB estimates two types of established reserves: *remaining* established reserves and *yet-to-be* established reserves, the sum of which is *remaining ultimate potential* established reserves[1]. Yet-to-be established reserves are based on estimates of future reserve growth from new discoveries and reserve additions to be recov-

1. The term "remaining" refers to initial established reserves less cumulative production.

Figure 1: The McKelvey Box Used to Distinguish Reserves from Resources



Source:
Modified after McKelvey, 1972.

ered from future enhanced recovery. The ultimate potential is defined as an estimate of established reserves that will have been developed in an area by the time all exploratory and development activity has ceased (AERCB, 1991). Estimates of the ultimate potential are used to forecast Alberta's oil supply. Table 1 shows the remaining and yet-to-be established reserves for crude oil and natural gas at the end of 1990.

Table 1: Established Reserves of Crude Oil and Natural Gas in Alberta, 1990

	Remaining established	Yet-to-be established	Remaining ultimate potential	Reserve life
	millions of cubic metres			years
Crude Oil	510	649	1 159	21
Natural Gas	1 649 000	1 420 000	3 114 000	35

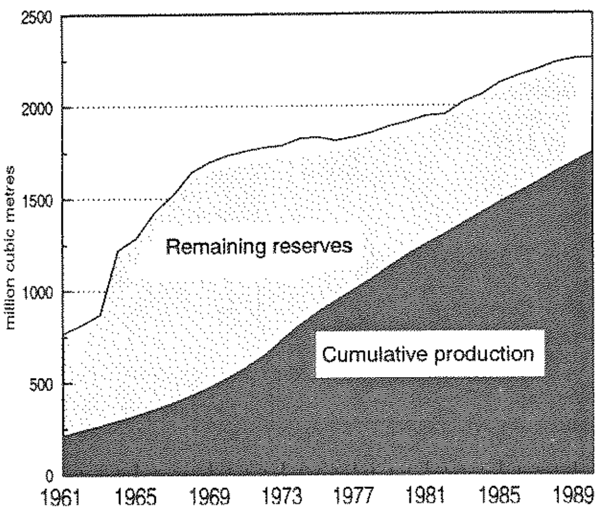
Source:
Alberta Energy Resources Conservation Board, 1991.

This study is concerned with identified economic resources which are defined as those deposits whose location, quality and quantity are known and that can be economically extracted at the time of determination. The physical accounts consist of opening and closing stocks of *remaining established reserves*, extraction (depletion) of reserves and their appreciation as the result of discoveries, development, revisions and enhanced oil recovery (secondary and tertiary recovery) since these reserves have a high probability of being extracted for economic purposes.

In natural resource accounting, both physical and monetary units are needed to provide a complete picture of the use and the stock of natural assets. Physical resource accounts show the total stock of reserves and changes in the stocks, thus providing the stock and flow data required for the monetary balance sheet accounts.

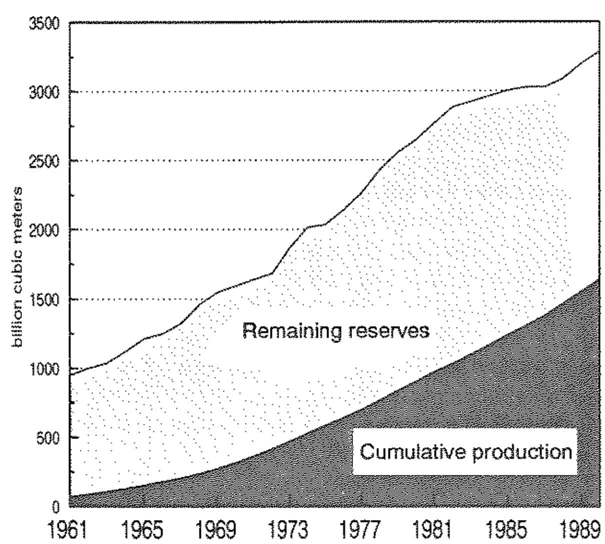
Estimates of remaining established reserves of crude oil and natural gas for the Province of Alberta are provided in Table 5 in the Physical Accounts for the period from 1961 to 1990. Figures 2 and 3 compare the remaining reserves and cumulative production for crude oil and natural gas. For crude oil reserves, the rate of depletion of reserves has remained stable since 1981, averaging 55.2 million cubic metres per year. However, the remaining reserve stock has declined by 27% during that same period. For natural gas reserves, the average depletion rate was 68.3 billion cubic metres from 1978 to 1987 but has increased to an average of 88.2 billion cubic metres for 1988 to 1990. The stock of remaining reserves of natural gas peaked at 1 853 billion cubic metres in 1982 but declined to 1 647 billion cubic metres in 1990. General current trends of reserve stocks indicate that reserve additions are not replacing reserve depletion. This is more prevalent for crude oil than for natural gas.

Figure 2: Summary of Remaining Established Reserves and Cumulative Production of Conventional Crude Oil in Alberta, 1961 - 1990



Sources:
Alberta Energy Resources Conservation Board.
Statistics Canada. National Accounts and Environment Division.

Figure 3: Summary of Remaining Established Reserves and Cumulative Production of Marketable Natural Gas in Alberta, 1961 - 1990



Sources:
Alberta Energy Resources Conservation Board.
Statistics Canada. National Accounts and Environment Division.

THE CONCEPT OF ECONOMIC RENT

The concept of economic rent is central to the monetary valuation of natural resources (Repetto *et al*, 1989). Economic rent constitutes the difference between the international commodity price and all factor costs of extraction, including a normal return to capital but excluding taxes, royalties and other costs that are not part of the cost of physical extraction. The value of the resource in the ground is equal to the future stream of income or economic rent derived from the extraction of the natural resource.

Economic rents obtained from the extraction of petroleum are defined as the returns in excess of those required to sustain production, reserve development and exploration (Kemp, 1992). As owners of the natural resources, governments may collect rents through auctioning of exploration rights, taxation or royalties. With competitive bidding for mineral rights, the host government collects anticipated or *ex ante* economic rents in a lump sum payment. A royalty system is used to ensure that the government receives an acceptable share of the realized or *ex post* economic rents.

Economic rents from natural resources are complex, consisting of Hotelling (scarcity) rents and Ricardian (differential) rents as well as locational rents (arising from differences in transportation costs). Since oil and natural gas reserves are non-renewable and their supply is finite, at least part of the net flow of income can be attributed to the scarcity of the resource. While much of the literature has focused on aggregate economic rent or Hotelling rents, there is little discussion on how to treat these different rents in the context of the development of natural resource accounts. There are conceptual difficulties in separating these resource rents as discussed in Born (1992).

In 1931, Hotelling provided a theoretical model of the behaviour of markets for exhaustible resources. The Hotelling "hypothesis" states that under certainty, in the absence of extraction costs and under competitive market conditions, the price of a natural resource rises at the market rate of interest. The ability of the theory to describe and predict actual behaviour of natural resource markets remains an area of considerable debate with little empirical evidence to support it. However, several recent studies in natural resource accounting of oil and natural gas reserves (Landefeld and Hines, 1985; Repetto *et al*, 1989; and Smith, 1991) use the Hotelling model as the basis for a method of monetary valuation. This is the "net price" approach presented below.

Others (Devarajan and Fisher, 1982, and Lasserre, 1985) have suggested the use of discovery costs plus the rent on exploration prospects (e.g. land acquisition costs) as an approximation for resource rents. The argument is that exhaustible-resource rents can be measured by what firms are ready to spend in exploration and development in order to make the resource available. This is the basis of the "replacement cost" method of monetary valuation discussed below.

MONETARY VALUATION OF OIL AND NATURAL GAS RESERVES

Mineral deposits should be viewed as capital assets that represent forms of national wealth. Ideally, reserves of mineral resources should be valued at the market prices at which the natural resource asset would be sold. However, most mineral stocks are not traded frequently on the market and their market values must be imputed. Three methods of monetary valuation are proposed in this study:

(i) Present Value

(ii) Net Price

(iii) Replacement Cost

Results from the different methods of valuation are presented for conventional crude oil and natural gas remaining established reserves in Alberta. These results are preliminary and may be further refined before the values are included formally in the Canadian National Balance Sheet Accounts. The three methods produce a wide range of monetary values and the difficulty is to determine what assumptions should be used and which set of estimates is most reliable.

Present Value

As a capital asset, a mineral deposit is valued on the basis of its net flow of income or "rent" that is anticipated over the lifetime of the deposit. If the capital market is competitive and the merit of any investment is assessed in terms of alternative investments, the expected income flow from the deposit is then discounted to establish the "net present value".

The present value approach or discounted value of future net returns has been proposed by the *UN SNA Handbook on Integrated Environment and Economic Accounting* (United Nations, 1990) as the most appropriate method of monetary valuation of opening and closing stocks and changes to stocks due to volumes and price changes. Discounted cash flow analysis is the standard approach used by companies to value properties and is used in annual corporate reports and U.S. Annual reports include the present value of future net cash flows from the estimated production of proven reserves based on the Reserves Recognition Accounting (RRA) method. The RRA method is based on a discounted cash flow or present value which assumes the continuation of current oil and natural gas margins discounted at an arbitrary 10% real rate. A comparison of the results from this study with those from various companies showed similar results (Born, 1992).

The choice of an appropriate discount rate for calculating the present value of reserves is problematic in terms of choosing a "private" or "social" discount rate. There are considerations of intergenerational equity, the opportunity cost of capital and social time preference. Discounting appears to be inconsistent with the concept of sustainable development since the higher the discount rate, the lower the importance attached to the future use of the natural stock (Pearce and Turner, 1990). Adelman (1986) suggests that a nation with a highly diversified portfolio of assets should use a discount rate near the commercial rate employed by industry to discount the flow of net revenues. Long-term corporate bond rates have been used extensively in other studies and are used in this study as the discount rate.

Some of the results from the present value calculations for oil and natural gas are presented in Table 2. Values presented in this report show that in 1990, the value of oil reserves in the ground ranges from $11.9 billion to $14.4 billion and the value of natural gas reserves ranges from $4.1 billion to $7.7 billion, discounted at long-term corporate bond rates. Present value estimates vary considerably depending on the assumptions made and this is their major weakness. Several assumptions relating to the appropriate discount rate, return to man-made capital and depreciation charges need to be chosen in order to produce results.

Net Price

The net price method, as developed by Landefeld and Hines (1985) applies the current average net price per unit (i.e. current revenues less current production costs per unit) to the physical quantities of established reserves. It can be interpreted as an application of the "Hotelling" model where the net price of the resource is expected to rise at exactly at the same rate of return on alternative investments (e.g. the rate of interest). The net price method is a special case of the present value method in which on average, long-run equilibrium is assumed to occur (i.e. the net price will rise at the rate of alternative investments) and the increase in the net price will exactly offset the discount rate.

The net price is calculated from revenues less operating costs less opportunity cost of man-made capital (i.e. the return to capital and depreciation charge) divided by the quantity extracted in a given period. This net price per unit extracted is multiplied by the remaining reserves to obtain the total value of the opening and closing stocks. A variant on this approach, outlined by Landefeld and Hines (1985), subtracts the current replacement cost of man-made capital rather than its opportunity cost.

Table 3 presents preliminary results for the value of reserve of oil and natural gas reserves in Alberta. Two values are shown: the first method subtracts the opportunity cost of man-made capital employed by the petroleum industry plus depreciation and the second method uses the same methodology as Landefeld and Hines (1985). Results from this study indicate that in 1990 the value of crude oil reserves in Alberta ranges from $20.0 billion to $41.2 billion and the value of natural gas reserves ranges from $10.4 billion to $65.1 billion using the net price approach.

The difference in the estimates from the two methodologies lies in the difference in the treatment of the man-made capital employed in exploring, developing and extracting the natural resource. In the method outlined by Landefeld and Hines (1985), there is no "normal return to (man-made) capital" excluded from the value added of the natural resource.

Most monetary values for oil and natural gas reserves reported in the current literature are based on the net price approach which assumes the Hotelling model. In Alberta, with the collapse of world oil and natural gas prices since 1986 along with increasing extraction costs, the value of resource rents has decreased significantly. Analysis of the data in this study finds that the assumptions of the Hotelling model are too restrictive. It appears that the current net price is not appropriate for valuing future production of reserves. The net price method seems to have undervalued future production during the 1960s and 1970s given the rapid increase in net price from 1972 to 1985 for both oil and natural gas. The net price method has overvalued future production in the early 1980s in light of the wellhead price collapse in 1986. However, the net price provides a basis for comparison with other studies (Repetto *et al*, 1989; and Smith, 1991) and the accounting procedures used in the net price method are similar to those used in the present value method. The net price has an advantage

Table 2: Estimate of the Monetary Value of Crude Oil and Natural Gas Reserves in Alberta Based on the Present Value Method, 1961-1990

Year	Crude oil reserves			Natural gas reserves			Total value of reserves		
	[1]	[2]	[3]	[1]	[2]	[3]	[1]	[2]	[3]
	millions of dollars								
1961	1 927.2	1 461.4	3 417.4	-309.7	-544.6	4 431.8	1 617.5	916.8	7 849.2
1962	1 747.9	1 564.6	2 846.2	110.6	-419.2	5 494.9	1 858.6	1 145.4	8 341.1
1963	2 049.5	1 700.2	3 216.2	930.6	-77.1	6 464.4	2 980.2	1 623.1	9 680.6
1964	2 081.7	1 963.7	3 826.8	1 182.1	378.7	7 333.0	3 263.8	2 342.3	11 159.8
1965	2 297.9	2 341.3	8 343.5	1 359.1	877.6	8 850.7	3 657.0	3 218.8	17 194.2
1966	2 071.2	2 257.4	9 460.0	1 256.5	1 148.5	10 334.9	3 327.8	3 405.9	19 794.9
1967	2 026.6	2 161.2	11 747.7	1 454.6	1 257.1	9 953.2	3 481.2	3 418.3	21 700.9
1968	2 343.1	2 063.3	12 643.4	1 343.5	1 268.5	10 013.8	3 686.6	3 331.8	22 657.2
1969	2 482.7	2 092.5	13430.9	1 056.6	1 230.0	10 429.2	3 539.3	3 322.6	23 860.1
1970	3 639.0	2 478.2	14 777.4	544.9	1 129.6	11 422.8	4 184.0	3 607.7	26 200.2
1971	5 018.6	3 398.9	16 873.1	380.0	996.4	12 568.4	5 398.6	4 395.3	29 441.5
1972	6 543.0	4 405.9	19 989.6	519.0	744.3	15 173.0	7 062.0	5 150.2	35 162.6
1973	10 801.3	6 291.0	25 131.2	1 331.9	747.9	19 724.0	12 133.2	7 038.9	44 855.2
1974	15 839.9	9 012.5	30 800.8	4 489.5	1 667.2	26 321.2	20 329.4	10 679.8	57 122.0
1975	15 394.4	12 313.9	30 412.2	9 892.1	4 145.9	25 839.9	25 286.5	16 459.8	56 252.1
1976	16 039.0	16 032.5	33 237.1	14 587.6	8 199.3	28 556.5	30 626.6	24 231.8	61 793.6
1977	21 037.0	19 639.8	35 206.3	21 206.3	14 146.9	29 984.0	42 243.3	33 786.7	65 190.3
1978	24 834.3	21 609.6	35 965.5	20 924.8	18 407.1	29 595.4	45 759.2	40 016.7	65 560.9
1979	28 646.9	24 196.2	40 686.2	25 882.8	22 296.3	34 833.9	54 529.7	46 492.4	75 520.1
1980	25 160.9	24 995.7	37 957.9	28 699.0	23 982.1	30 375.9	53 859.8	48 977.7	68 333.8
1981	22 013.9	24 178.7	33 676.1	21 155.2	22 398.5	22 826.3	43 169.1	46 577.2	56 502.4
1982	28 642.0	27 481.4	34 828.9	23 683.3	25 640.6	19 152.1	52 325.2	53 122.0	53 981.0
1983	47 051.1	35 846.1	36 610.1	30 644.7	32 469.5	18 467.3	77 695.9	68 315.6	55 077.4
1984	50 967.3	40 552.4	27 955.6	32 226.0	30 483.1	11 818.4	83 193.2	71 035.4	39 774.0
1985	50 620.5	49 074.0	22 891.9	37 082.5	36 008.1	9 966.4	87 702.9	85 082.0	32 858.3
1986	14 083.6	46 847.9	19 173.1	19 789.5	36 012.0	9 023.3	33 873.1	82 859.9	28 196.4
1987	20 838.2	37 988.1	20 368.2	6 788.5	27 817.3	12 752.7	27 626.7	65 805.4	33 120.9
1988	5 958.8	25 002.8	21 178.0	4 160.5	19 195.2	13 377.5	10 119.3	44 198.0	34 555.5
1989	9 218.4	13 358.7	21 958.4	2 491.9	9 420.2	15 225.2	11 710.3	22 778.9	37 183.6
1990	11 931.4	12 033.5	14 406.5	4 142.2	4 593.4	7 705.2	16 073.6	16 627.0	22 111.7

Notes:
[1] Discounted using a long-term bond corporate bond rate; based on year-end prices and costs.
[2] Same as [1] except based on a 4-year moving average.
[3] Based on "perfect knowledge" of production, prices and costs; discounted using a long-term corporate bond rate.
The results in this table should be treated as preliminary.

over present value calculations since there is no need to forecast or to make assumptions about future prices, extraction costs and rates, and interest rates.

Replacement Cost

Conceptually, resource rent is the most appropriate measure of the value of the resource in the ground. However, there are some problems involved when resource rents are used since rental values are not readily observed and must be imputed. Several studies have used the cost of discovering and developing reserves as a proxy for resource rent. The argument is that exploration and development dollars will be spent as long as the expected gain from finding the resource equals the marginal cost of exploration and development. The expected discovery value of the resource stock should be equal to the present value of its expected rents.

In this study the "full marginal discovery cost" approach developed by Eglington and Uffelmann (1983), Lasserre (1985) and McLachlan (1990) has been adopted to approximate resource rent. It is the sum of the marginal cost of exploration and development plus land acquisition costs divided by reserve additions in a given period (e.g. reserves from discoveries, development and revisions, and in the case of crude oil reserves, enhanced oil recovery) to yield a replacement cost per unit of crude oil or natural gas reserve added. A 5-year average is used to average the costs and the booked reserve additions. The average unit cost of booked reserves is multiplied by the remaining es-

Table 3: Estimates of the Monetary Value of Crude Oil and Natural Gas Reserves in Alberta Based on the Net Price Method, 1961-1990

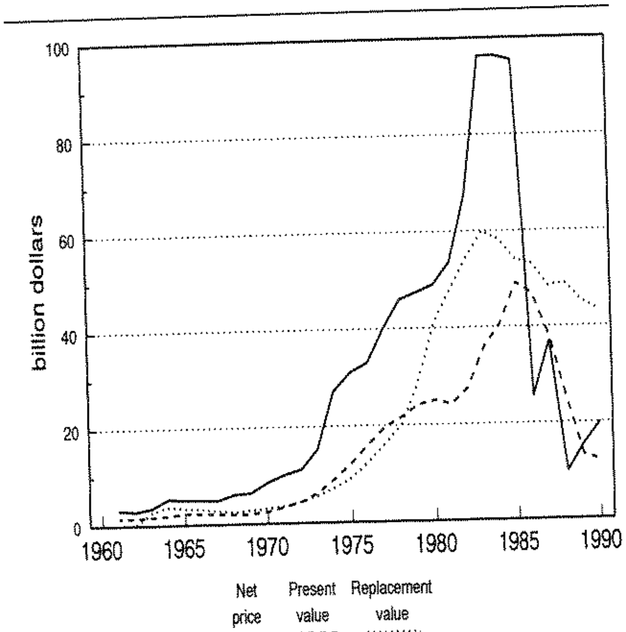
Year	Crude oil reserves		Natural gas reserves		Total value of reserves	
	[1]	[2]	[1]	[2]	[1]	[2]
			millions of dollars			
1961	3 189.1	5 279.7	-1 279.8	1 896.2	1 909.3	7 175.9
1962	2 896.6	5 121.3	335.7	2 783.2	3 232.3	7 904.5
1963	3 519.4	6 047.8	2 582.9	5 052.8	6 102.2	11 100.6
1964	5 384.0	10 188.4	3 258.2	5 877.8	8 642.2	16 066.2
1965	5 106.6	10 489.5	3 759.8	6 660.2	8 866.4	17 149.7
1966	5 145.1	11 633.1	3 703.0	7 132.0	8 848.2	18 765.0
1967	4 920.8	11 569.7	4 508.7	8 543.5	9 429.4	20 113.3
1968	6 154.9	13 280.6	4 608.4	9 560.2	10 763.3	22 840.8
1969	6 431.2	13 572.2	3 335.3	8 322.1	9 766.5	21 894.3
1970	8 510.3	14 730.0	1 700.6	7 567.3	10 210.8	22 297.3
1971	10 061.3	15 674.3	949.5	6 522.5	11 013.4	22 196.8
1972	11 094.0	15 411.8	1 218.0	6 967.6	12 312.0	22 379.4
1973	15 261.6	18 327.5	3 343.0	10 383.1	18 604.6	287 10.5
1974	27 161.3	31 408.5	13 130.9	23 953.7	40 292.2	55 362.2
1975	31 061.9	36 934.0	29 282.7	43 114.4	60 344.6	80 048.4
1976	32 959.5	39 137.6	45 249.7	63 037.7	78 209.2	102 175.2
1977	40 072.5	45 945.0	58 962.7	77 638.3	99 035.2	123 583.2
1978	45 944.0	52 143.1	59 089.6	81 672.9	105 033.6	133 816.0
1979	47 405.9	53 165.4	75 827.3	104 952.4	123 233.2	158 117.8
1980	48 936.2	57 747.7	108 121.9	158 274.1	157 058.1	216 021.9
1981	5 3520.6	68 341.5	92 319.5	162 327.4	145 840.1	230 668.9
1982	67 414.7	84 503.8	115 804.9	211 901.2	183 219.6	296 405.0
1983	96 300.4	111 590.3	111 886.2	187 556.8	208 186.6	299 147.0
1984	96 258.0	111 990.5	118 565.9	194 992.3	214 823.8	306 982.8
1985	95 353.3	113 337.7	113 027.7	179 398.8	208 380.9	292 736.6
1986	25 440.0	43 965.9	54 618.4	116 868.3	80 058.4	160 834.2
1987	37 004.5	56 728.0	19 029.6	82 871.6	56 034.1	139 599.6
1988	9 856.3	28 558.4	9 766.6	56 817.6	19 622.8	85 375.9
1989	15 438.4	35 650.5	6 041.1	57 122.9	21 479.5	92 773.4
1990	19 962.9	41 244.9	10 368.5	65 081.1	30 335.3	106 326.0

Notes:
[1] Net price equals revenue less operating costs, return on capital and depreciation charge.
[2] Net price is based on the methodology by Landefeld and Hines (1985).
The results in this table should be treated as preliminary.

tablished reserves of crude oil and natural gas to obtain the value of the stock.

Table 4 presents a summary of the estimates of the replacement cost value of crude oil and natural gas reserves. The replacement value for crude oil has declined from $60 billion to $43 billion over the 1983 to 1990 period. While replacement costs for reserve additions per unit have increased, the volume of remaining reserves has decreased by 22% over the period, thus accounting for the trend in the value of remaining oil reserve stock. The replacement cost value which represents the present value of obtaining reserve additions through exploration and development produces similar results to the present value method until 1987 (Figure 4).[1] This suggests that the expected discovery value of the resource stock is equal to the present value of its expected rents. The oil price collapse in 1986 and increasing capital costs have caused a significant decrease in the present value of oil reserves since 1986. It appears since 1986 that the assumption that the full marginal discovery cost can be used as a proxy for resource rent no longer applies in the short term.

Figure 4: Estimates of the Monetary Value of Crude Oil Reserves in Alberta, 1961-1990



Note:
The net price is from [1] in Table 3 and the present value is from [2] in Table 2.

1. Both the replacement cost value and the present value are "discounted" using a long-term corporate bond yield.

The replacement cost value for natural gas reserves shows an increase from $53 billion in 1982 to $81 billion in 1990. While physical reserve stocks have decreased by 12% from 1982 to 1990, replacement costs per unit of reserve added have more than doubled, thus producing increasing values for the total stock of natural gas. Present value and replacement cost value have similar trends until 1979 after which the replacement cost value increases and the present value decreases (Figure 5).

Table 4: Estimates of the Economic Value of Crude Oil and Natural Gas Reserves in Alberta Based on the Replacement Cost Method

Year	Crude oil reserves: Unit cost	Crude oil reserves: Value	Natural gas reserves: Unit cost	Natural gas reserves: Value	Total reserve value
	dollars per m³	millions of dollars	dollars per thousand m³	millions of dollars	millions of dollars
1963	4.35	2 632.5	1.86	1 728.6	4 361.1
1964	3.99	3 700.4	2.04	2 020.7	5 721.0
1965	3.50	3 384.6	2.28	2 412.6	5 797.2
1966	2.96	3 179.3	2.37	2 546.2	5 725.5
1967	2.41	2 734.6	2.77	3 101.6	5 836.2
1968	2.04	2 469.7	3.02	3 690.8	6 160.6
1969	2.30	2 810.5	3.37	4 296.3	7 106.8
1970	2.58	3 122.0	3.96	5 066.6	8 188.6
1971	3.02	3 547.3	4.69	5 984.8	9 532.1
1972	3.92	4 409.9	5.13	6 507.7	10 917.5
1973	5.38	5 655.9	5.63	7 860.1	13 516.0
1974	7.20	7 278.7	6.60	9 806.7	17 085.4
1975	9.66	9 183.1	7.30	10 593.9	19 777.0
1976	14.29	12 452.1	8.03	12 063.3	24 515.5
1977	19.40	16 098.3	8.65	13 570.4	29 668.7
1978	25.35	20 138.0	10.23	17 038.9	37 176.9
1979	37.99	28 877.1	13.08	22 472.3	51 349.4
1980	56.73	40 841.6	17.67	30 871.4	71 713.1
1981	68.74	47 842.8	22.88	41 082.8	88 925.7
1982	83.59	54 285.4	28.76	53 295.5	107 580.9
1983	91.04	59 886.8	31.92	58 292.1	118 178.9
1984	90.75	58 145.4	32.46	58 378.1	116 523.5
1985	83.21	53 960.1	31.35	55 428.3	109 388.4
1986	83.71	53 131.4	30.68	52 778.0	105 909.4
1987	78.89	48 424.2	35.11	57 988.6	106 412.8
1988	82.67	49 013.4	41.60	67 718.3	116 731.6
1989	80.71	45 235.6	46.10	76 050.7	121 286.4
1990	84.95	43 359.4	49.41	81 406.1	124 765.6

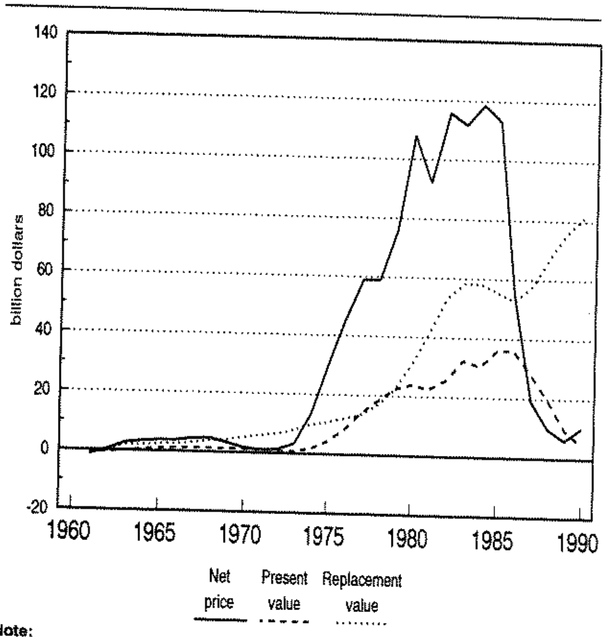
Notes:
The results in this table should be treated as preliminary.
Includes all exploration and development expenditures and land bonuses; data are time-lagged and unit costs are derived from a 5-year average of booked reserve additions; unit costs are averaged over 5 years.

It appears that the replacement cost method measures resource scarcity. It is not, however, a proxy for the measurement of the value of natural resource wealth which accounts for capital gains and losses due to price changes over time.

Comparison of Valuation Methods

Figures 4 and 5 provide a comparison of the estimates from the three different valuation methods described above. As previously discussed, present values and replacement cost values show similar trends until 1986. The net price estimates initially overvalue the reserve stock in the late 1980s given the price collapse of 1986 however they show a similar trend to present value after 1986.

Figure 5: Estimates of the Monetary Value of Natural Gas Reserves in Alberta, 1961-1990



Note:
The net price is from [1] in Table 3 and the present value is from [2] in Table 2.

In comparison with the net price approach, the present value approach provides a smoother times series since the method reduces price volatility by averaging or using actual wellhead price in cases [2] and [3] in Table 2, using interest rates related to the time period rather than assuming a constant discount rate such as 10% for the entire 30-year time span and averaging or using actual variable (extraction) costs in calculations [2] and [3] in Table 2.

The advantages and disadvantages of each method have been discussed. However, with the net price method, the assumption of long-run equilibrium in natural resource markets has little empirical support and produces volatile values. The selection of the most appropriate valuation method for the Canadian National Balance Sheet will reflect the most reliable method of market valuation. The present value method conforms most closely to corporate financial reporting of the market value of reserves and is the preferred method of valuation by national accountants. However assumptions about future prices, costs and discounts have to be made when using this method.

RECONCILIATION ACCOUNTS

Table 5 presents both physical and monetary Reconciliation Accounts for oil and natural gas reserves from 1961 to 1990. Net price values from Table 3 [1] for oil and natural gas are used to construct the monetary accounts in Table 5.

Reconciliation tables show the volume and price changes of the assets during the reporting period, in this case, one year. The basic formula for the reconciliation accounts is:

closing stock = opening stock + net reserve additions
- reserve depletion + revaluation

where revaluation reflects the change in net price during periods in the monetary accounts only.

The monetary reconciliation accounts reflect changes in the net value of the resource due to changes in physical reserves, wellhead prices and operating and capital costs. These changes will be reflected in the value of non-produced tangible assets in the Balance Sheet Accounts and ultimately in national wealth and net worth.

Table 5: Reconciliation Tables for Established Reserves of Crude Oil and Natural Gas in Alberta, 1961-1975

	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975
CRUDE OIL RESERVES															
Physical accounts (millions of cubic metres)															
Opening stocks	525.0	557.6	575.6	605.4	926.1	965.7	1 074.2	1 132.9	1 212.8	1 222.8	1 207.9	1 173.6	1 126.0	1 052.0	1 011.5
Gross additions	57.5	44.0	56.6	348.5	68.8	140.8	95.2	119.8	54.5	36.7	22.1	20.0	9.2	38.5	7.0
Discoveries	1.7	2.9	14.6	9.5	28.6	89.1	57.2	62.0	40.5	8.4	14.0	10.8	5.1	4.3	1.6
Development and reevaluation	31.5	21.8	12.6	88.2	42.6	13.5	15.7	14.8	-44.5	-7.6	8.7	-5.6	-6.0	3.3	2.1
Enhanced oil recovery	24.5	19.9	29.2	250.8	-2.4	38.3	22.2	42.9	58.5	36.1	-0.8	14.8	10.2	30.8	3.3
Depletion	25.1	26.2	26.8	27.9	29.2	32.2	36.6	39.8	44.4	51.7	56.4	67.4	83.3	79.0	67.5
Net change	32.4	17.8	29.8	320.6	39.6	108.6	58.6	80.0	10.1	-15.0	-34.3	-47.4	-74.1	-40.5	-60.5
Closing stock	557.6	575.6	605.4	926.1	965.7	1 074.2	1 132.9	1 212.8	1 222.8	1 207.9	1 173.6	1 126.0	1 052.0	1 011.5	950.9
Unit values (dollars per cubic metre)															
Average wellhead price	14.82	14.28	15.81	16.09	16.14	16.27	16.06	16.14	16.00	16.27	17.84	17.92	21.83	36.33	45.79
Production and capital costs	9.10	9.24	10.00	10.28	10.85	11.49	11.72	11.06	10.74	9.23	9.27	8.07	7.32	9.48	13.12
Net price	5.72	5.03	5.81	5.81	5.29	4.79	4.34	5.07	5.26	7.05	8.57	9.85	14.51	26.85	32.67
Monetary accounts (millions of dollars)															
Opening stocks	2 106	3 189	2 897	3 519	5381	5 107	5 145	4 921	6 155	6 431	8 510	10 061	11 094	15 262	27 078
Gross additions	329	221	329	2025	364	674	414	608	287	259	189	197	133	1034	229
Discoveries	10	15	85	55	151	427	248	314	213	59	120	106	74	115	52
Development and reevaluation	180	110	73	513	225	65	68	75	-234	-54	75	-55	-87	48	69
Enhanced oil recovery	140	100	170	1458	-13	183	96	218	308	255	-7	146	148	447	108
Depletion	144	132	156	162	154	153	159	202	234	364	483	664	1 209	1 146	2 205
Net change	185	90	173	1 863	209	521	255	406	53	-106	-294	-467	-1 075	-112	-1 977
Revaluation	896	-383	450	-2	-484	-481	-479	829	224	2 184	1 845	1 502	5 241	12 987	5 887
Closing stock	3 189	2 897	3 519	5381	5 107	5 145	4 921	6 155	6 431	8 510	10 061	11 094	15 262	27 161	31 062
NATURAL GAS RESERVES															
Physical accounts (billions of cubic metres)															
Opening stocks	878.6	879.9	912.1	928.2	992.0	1 057.6	1 072.6	1 119.1	1 223.6	1 273.4	1 279.4	1 276.3	1 269.1	1 396.6	1 486.5
Gross additions	13.3	49.7	35.8	85.9	89.7	40.6	73.9	134.6	87.5	46.2	45.4	45.2	183.3	147.0	20.8
Discoveries	9.6	8.9	3.1	7.2	11.3	2.1	24.3	15.3	18.6	7.6	4.8	12.5	7.8	8.6	0.8
Development and reevaluation	3.7	41.0	32.7	78.7	78.4	38.6	49.6	119.3	68.9	38.7	40.6	32.8	175.6	138.4	20.0
Depletion	11.9	17.6	19.6	22.1	24.2	25.5	27.5	30.0	37.8	40.1	48.5	52.4	56.0	57.0	56.6
Net change	1.4	32.1	16.2	63.8	65.5	15.2	46.4	104.6	49.7	6.2	-3.1	-7.1	127.4	90.0	-35.8
Closing stock	879.9	912.1	928.2	992.0	1 057.6	1 072.6	1 119.1	1 223.6	1 273.4	1 279.4	1 276.3	1 269.1	1 396.6	1 486.5	1 450.8
Unit values (dollars per thousand cubic metres)															
Average composite wellhead price	6.08	6.62	8.53	9.14	9.59	10.64	11.80	12.34	10.48	10.75	9.87	11.01	13.25	23.46	38.93
Production and capital costs	7.53	6.26	5.75	5.86	6.03	7.19	7.77	8.58	7.86	9.42	9.12	10.05	10.86	14.63	18.74
Net price	-1.45	0.37	2.78	3.28	3.56	3.45	4.03	3.77	2.62	1.33	0.74	0.96	2.39	8.83	20.18
Monetary accounts (millions of dollars)															
Opening stocks	-2 443	-1 280	336	2 583	3 258	3 760	3 703	4 509	4 608	3 335	1 701	949	1 218	3 343	13 126
Gross additions	-19	18	100	282	319	140	298	507	229	61	34	43	439	1299	420
Discoveries	-14	3	9	24	40	7	98	58	49	10	4	12	19	76	16
Development and reevaluation	-5	15	91	258	279	133	200	449	180	51	30	31	420	1 222	406
Depletion	-17	7	54	73	86	88	111	113	99	53	36	50	134	503	1 142
Net change	-2	12	45	210	233	52	187	394	130	8	-2	-7	305	795	-723
Revaluation	1 167	1 604	2 202	466	268	-109	618	-294	-1 404	-1 643	-749	275	1 820	8 994	16 872
Closing stock	-1 280	336	2 583	3 258	3 760	3 703	4 509	4 608	3 335	1 701	949	1 218	3 343	13 131	29 283

Note:
Discrepancies are due to rounding and data sources.
Sources:
Alberta Energy Resources Conservation Board.
Statistics Canada, National Accounts and Environment Division.

Table 5: Reconciliation Tables for Established Reserves of Crude Oil and Natural Gas in Alberta, 1976-1990

	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
CRUDE OIL RESERVES															
Physical accounts (millions of cubic metres)															
Opening stocks	950.9	871.3	830.0	794.5	760.2	719.9	696.0	649.4	657.8	640.7	648.5	634.7	613.8	592.9	560.5
Gross additions	-18.6	19.1	24.4	34.3	22.7	32.6	6.9	64.1	42.0	64.0	39.1	33.0	36.7	21.4	3.0
Discoveries	2.5	4.8	24.9	19.2	9.0	15.0	16.8	21.4	29.1	32.7	28.6	20.9	17.7	17.0	25.0
Development and reevaluation	5.9	5.1	-1.9	10.3	5.1	10.4	-16.5	24.8	-12.0	9.7	-14.1	1.6	2.5	-3.4	-25.6
Enhanced oil recovery	-27.0	9.2	1.4	4.8	8.6	7.2	6.6	17.9	24.1	21.6	24.6	10.5	16.5	7.8	3.7
Depletion	61.0	60.4	60.0	68.5	63.2	56.5	53.6	55.0	59.2	56.2	53.2	53.9	57.2	53.8	53.1
Net change	-79.6	-41.3	-35.6	-34.2	-40.5	-23.9	-46.7	8.5	-17.2	7.8	-14.1	-20.9	-20.5	-32.4	-50.1
Closing stock	871.3	830.0	794.5	760.2	719.9	696.0	649.4	657.8	640.7	648.5	634.7	613.8	592.9	560.5	510.5
Unit values (dollars per cubic metre)															
Average wellhead price	53.73	64.40	76.77	82.97	97.75	119.36	157.64	201.29	212.44	220.07	117.58	145.35	104.92	127.74	150.69
Production and capital costs	15.90	16.11	18.94	20.61	29.77	42.47	53.83	54.90	62.20	73.03	77.50	85.06	88.30	100.20	111.58
Net price	37.83	48.28	57.83	62.36	67.98	76.90	103.81	146.40	150.24	147.04	40.08	60.29	16.62	27.54	39.11
Monetary accounts (millions of dollars)															
Opening stocks	31 062	32 960	40 073	45 944	47 406	48 936	53 521	67 415	96 300	96 258	95 353	25 440	37 004	9 856	15 438
Gross additions	-704	922	1 411	2 139	1 543	2 507	716	9 384	6 310	9 410	1 567	1 989	610	589	117
Discoveries	95	232	1 440	1 197	612	1 154	1 744	3 133	4 372	4 808	1 146	1 260	294	468	978
Development and reevaluation	223	246	-110	642	353	554	-1 713	3 631	-1 803	1 426	-565	96	42	-94	-1 001
Enhanced oil recovery	-1 021	444	81	299	585	800	685	2 621	3 621	3 176	986	633	274	215	145
Depletion	2 308	2 916	3 470	4 272	4 296	4 345	5 564	8140	8 894	8 264	2 132	3 250	951	1 482	2 077
Net change	-3 011	-1 994	-2 059	-2 133	-2 753	-1 838	-4 848	1 244	-2 584	1 147	-565	-1 260	-341	-892	-1 959
Revaluation	4 909	9 107	7 924	3 601	4 270	6 422	18 732	27 656	2 527	-2 052	-69 360	12 824	-26 801	6 474	6 484
Closing stock	32 960	40 073	45 944	47 406	48 936	53 521	6 715	96 300	96 258	95 353	25 440	37 004	9 856	15 438	19 963
NATURAL GAS RESERVES															
Physical accounts (billions of cubic metres)															
Opening stocks	1 450.8	1 501.7	1 568.3	1 665.2	1 718.4	1 747.0	1 795.3	1 853.1	1 826.2	1 798.4	1 768.3	1 720.1	1 651.7	1 627.7	1 649.7
Gross additions	105.6	127.6	163.3	123.2	92.4	117.0	118.7	39.0	40.5	42.6	21.8	0.0	64.6	107.8	87.8
Discoveries	6.9	6.6	24.4	16.4	30.0	28.9	10.6	16.3	9.6	11.5	9.2	8.9	13.9	19.0	28.0
Development and reevaluation	98.7	120.9	138.9	106.8	62.5	88.1	108.1	22.7	30.9	31.1	12.6	-8.9	50.7	88.8	60.0
Depletion	54.6	61.0	66.4	70.0	63.8	68.6	60.9	66.0	68.3	72.8	69.9	68.4	88.6	85.8	90.1
Net change	51.0	66.5	96.9	53.2	28.7	48.4	57.8	-27.0	-27.8	-30.2	-48.1	-68.4	-24.0	22.0	-2.3
Closing stock	1 501.7	1 568.3	1 665.2	1 718.4	1 747.0	1 795.3	1 853.1	1 826.2	1 798.4	1 768.3	1 720.1	1 651.7	1 627.7	1 649.7	1 647.4
Unit values (dollars per thousand cubic metres)															
Average composite wellhead price	54.88	64.38	66.73	80.98	117.66	117.57	146.86	135.55	144.62	139.24	107.13	92.35	74.12	76.82	81.59
Production and capital costs	24.75	26.78	31.25	36.85	55.77	66.14	84.37	74.28	78.69	75.32	75.38	80.83	68.12	73.16	75.29
Net price	30.13	37.60	35.48	44.13	61.89	51.42	62.49	61.27	65.93	63.92	31.75	11.52	6.00	3.66	6.29
Monetary accounts (millions of dollars)															
Opening stocks	29 283	45 250	58 963	59 090	75 827	10 8122	92 319	115 805	111 886	118 566	113 028	54 618	19 030	9 767	6 041
Gross additions	3 182	4 797	5 795	5 436	5 719	6 016	7 418	2 389	2 670	2 723	692	0	388	395	553
Discoveries	208	248	866	724	1 857	1 486	662	999	633	735	292	103	83	70	176
Development and reevaluation	2 974	4 546	4 928	4 713	3 868	4 530	6 755	1 391	2 037	1 988	400	-103	304	325	376
Depletion	1 645	2 294	2 356	3 089	3955	3 527	3 806	4 044	4 503	4 653	2 220	788	532	314	567
Net change	1 537	2504	3439	2347	1764	2 489	3 612	-1 654	-1 833	-1 930	-1 527	-788	-144	81	-14
Revaluation	14 433	11 209	-3 312	14 390	30 525	-18 286	19 873	-2 271	8 513	-3 614	-56 879	-34 801	-9 119	-3 806	4 342
Closing stock	45 250	58 963	59 090	7 5827	108 122	92 319	115 805	111 886	118 566	113 028	54 618	19 030	9 767	6 041	10 368

Note:
Discrepancies are due to rounding and data sources.
Sources:
Alberta Energy Resources Conservation Board.
Statistics Canada, National Accounts and Environment Division.

Table 6: Value of Petroleum Royalties and Land Costs Paid to the Alberta Government, 1961-1990

Year	Royalties	Land costs	Total
	millions of dollars		
1961	55.0	85.4	140.4
1962	66.0	81.8	147.8
1963	73.0	89.8	162.8
1964	80.0	131.8	211.8
1965	79.2	193.7	272.8
1966	91.7	171.2	262.9
1967	107.4	161.2	269.0
1968	125.6	166.2	291.7
1969	136.3	181.1	317.3
1970	154.0	117.6	271.6
1971	190.4	126.2	316.6
1972	226.0	125.6	351.6
1973	422.6	145.4	568.0
1974	1 107.2	158.6	1 265.8
1975	1 477.7	209.9	1 687.6
1976	2 087.6	256.0	2 343.6
1977	2 398.9	682.1	3 080.9
1978	3 054.9	749.3	3 804.2
1979	3 623.3	1 153.0	4 776.3
1980	3 920.3	1 229.6	5 149.9
1981	4 496.7	736.1	5 232.8
1982	5 098.1	465.6	5 563.7
1983	5 467.2	565.1	6 032.3
1984	5 958.1	790.3	6 748.3
1985	5 843.3	1 021.1	6 864.4
1986	3 205.0	447.3	3 652.3
1987	2 634.7	841.1	3 475.8
1988	2 456.9	676.5	3 133.4
1989	2 559.0	551.7	3 110.7
1990	3 085.0	614.2	3 699.2

Source:
Statistics Canada, *The Crude Petroleum and Natural Gas Industry*, Catalogue 26-213 (various years).

Table 6 provides the value of royalties and land costs paid to the Alberta government from 1961 to 1990. The data demonstrate that the extraction of oil and natural gas generates significant amounts of revenue to the Alberta government. As suggested earlier, land costs represent an *ex ante* rent and royalties are *ex post*. With the decline in the value of rent from oil and gas reserves due to declining reserve stocks and prices, and increasing operating and capital costs, one can observe how potential income to government could also decrease.

SUMMARY

This study has examined the treatment of a non-renewable resource, oil and natural gas reserves in Alberta, in the national accounts. Natural resources have long been regarded as free gifts of nature by economists. The assumption that our natural resources are in infinite supply with a zero supply price is being reconsidered in national accounting. Since balance sheets measure national wealth, Canada's wealth is currently not being estimated correctly by including only man-made assets and excluding non-renewable and renewable resource stocks.

Physical accounts are necessary in order to describe the interrelationship between the environment and the economy. These accounts not only show the short-term exploitation of natural resources but also show the remaining stocks available for primary inputs to economic activity. The physical quantities are required in order to determine the monetary value of the remaining stock.

The focus of this study has been to determine an appropriate method of natural resource valuation. While the development of the physical accounts is based on the definition of established reserves, the monetary accounts require further evaluation in order to incorporate monetary values into the Canadian National Balance Sheet. The present value and the net price approaches seem to conform most closely to the development of wealth accounts. These approaches allow the value of man-made capital employed by the industry to be separated from the value of natural resource itself and identify capital gains and losses due to price changes. This is not the case for the replacement cost approach. While the present value approach is favoured by national accountants, in general and is used in corporate financial reporting, it is limited by the assumptions required.

Oil and natural gas reserves are assets and are components of the national wealth. By extending the definition of capital to cover both man-made and natural capital, a balance sheet presentation shows to what extent natural resource depletion is offset by the addition of man-made and natural capital. If future income and consumption are based on the level of capital stocks, it is important to include the value of the stock of natural resources as well as the value of the man-made capital in the Canadian National Balance Sheet Accounts in order to show whether or not we have sustainable growth and development.

By including the value of natural resources as a non-produced asset and the value of man-made capital in the Canadian Balance Sheet Accounts, one has a more complete picture of Canada's wealth. One can determine whether or not we are creating wealth while depleting our natural resource base or consuming the revenue generated from natural resource extraction. Incorporating the value of oil and natural gas reserve stocks into the Balance Sheet Accounts will be the next stage of this project.

REFERENCES

Adelman, M.A. "Oil Producing Countries' Discount Rates". *Resources and Energy,* vol. 8, 1986. p. 309-329.

Alberta Energy Resources Conservation Board. "Alberta's Reserves of Crude Oil, Oil Sands, Gas, Natural Gas Liquids and Sulphur". *ERCB ST91-18,* 1991.

Bartelmus, Peter. "Environment Statistics and Accounting". 48th ISI Session, Cairo Sept. 9-17, 1991.

Bartelmus, P. *et al.* Integrated Environmental and Economic Accounting: Framework for a SNA Satellite System; *Review of Income and Wealth,* ser. 37, no. 2, 1991 p. 111-148.

Born, Alice. "Development of Natural Resource Accounts: Physical and Monetary Accounts for Crude Oil and Natural Gas Reserves in Alberta, Canada". *Discussion Paper No. 12,* National Accounts and Environment Division, Statistics Canada, 1991.

Canadian Petroleum Association. *Statistical Yearbook* (various years).

Devarajan, S. and Fisher, A. "Exploration and Scarcity". *Journal of Political Economy,* vol. 90, no.6, 1982. p. 1279-1290.

Eglington, P. and Uffelmann, M. 'Observed Costs of Oil and Gas Reserves in Alberta, 1957-1979". *Discussion Paper No. 235,* Ottawa, Ontario: Economic Council of Canada. 1983.

Hotelling, H. "The Economics of Exhaustible Resources". *Journal of Political Economy,* vol. 39, 1931. p. 137-175.

Kemp, A., "Petroleum Policy Issues in Developing Countries". *Energy Policy,* Feb. 1992, p. 104-115.

Landefeld, J.S. and Hines, J.R. "National Accounting for Non-renewable Natural Resources in the Mining Industries". *Review of Income and Wealth,* vol. 31, 1985. p. 1-20.

Lasserre, P. "Discovery Costs as a Measurement of Rent". *Canadian Journal of Economics,* vol. 18, 1985. p. 474-483.

Levin, J. "Valuation and Treatment of Depletable Resources in the National Accounts". *IMF Working Paper 58,* International Monetary Fund, 1991.

McKelvey, V.E. Mineral Resource Estimates and Public Policy". *American Scientist,* vol. 60, 1972. p. 32-40.

McLachlan, M. "Replacement Costs for Oil and Gas in Western Canada: Methodologies and Application". *CERI Research Report 90-1,* Calgary, Alberta: Canadian Energy Research Institute, 1990.

Pearce, D.W. and Turner, R.K., *Economics of Natural Resources and the Environment.* Baltimore: The John Hopkins University Press, 1990.

Repetto, R. *et al.* "Wasting Assets: Natural Resources in the National Accounts". Washington: World Resources Institute, 1989.

Smith, R.S. "Income Growth, Government Spending and Wasting Assets - Alberta's Oil and Gas". Unpublished Manuscript, University of Alberta, Edmonton, Alberta, 1991.

Statistics Canada. *Exploration and Development and Capital Expenditures from Mining and Petroleum and Natural Gas Wells,* Catalogue 61-216 (various years).

----. *The Crude Petroleum and Natural Gas Industry.* Catalogue 26-213 (various years).

Tanner, J.N. "Reserves of Hydrocarbons in Alberta: A Review of Canadian Petroleum Association and Alberta Energy Resources Conservation Board Estimates and Methodology". *CERI Research Report 86-2,* Calgary, Alberta: Canadian Energy Research Institute, 1986.

United Nations. *SNA Handbook on Integrated Environmental and Economic Accounting: Preliminary Draft of the Part 1: General Concepts.* New York, 1989.

van Tongeren, J. *et al.* "Integrated and Economic Accounting: A Case Study for Mexico". *Environment Working Paper No. 50,* The World Bank, Environment Department, 1991.

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