Environmental Protection Series

Locomotive Emissions Monitoring Programme 1999-2000

Transportation Systems Branch
Air Pollution Prevention Directorate
Environment Canada

April 2002
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This report has been prepared by The Railway Association of Canada in partnership with Environment Canada, for the Transportation Systems Branch, Air Pollution Prevention Directorate, Environment Canada.

Executive Summary

Canada's railways handled more freight than forecast in 1999 and 2000 and recorded the industry's lowest levels of nitrogen oxide emissions, since 1975. Nitrogen oxide emissions in 1999 and 2000 were 6.8% and 5.0%, respectively, below the voluntary cap for the year. Carbon dioxide emissions per unit of freight transported have declined by more than 5% per year since 1997, and by an average of 2.4% since 1990.

The Railway Association of Canada's (RAC) report for 1999 and 2000 shows that freight traffic was 22% and 29% higher in 1999 and 2000, respectively, than in 1990. Intercity rail passenger travel increased from just over four million to almost four and one quarter million riders. Total fuel consumption was down by 3.5% over the decade.

Greenhouse gas emissions were 5.4% and 3.5% lower in 1999 and 2000, respectively, when compared to the base year of 1990 and nitrogen oxide emissions were lower by 5.6% and 3.8% during the same period. Despite continued increases in freight traffic, Canadian railways emitted a total of 107.22 kilotonnes of nitrogen oxides in 1999 and 109.29 kilotonnes in 2000; both totals are still well below the agreed-upon target of 115 kilotonnes, demonstrating that industry-developed solutions are effective and efficient.

The findings are contained in RAC's latest filing under the terms of the Memorandum of Understanding between Environment Canada and the RAC, signed in 1995 and covering the period 1990–2005.

The data collected by the railway industry under the monitoring program include annual traffic volumes in gross ton-miles and net ton-miles, the annual diesel fuel consumption for mainline and branchline service and for yard switching and passenger service, and the annual emissions of oxides of nitrogen (cap of 115 kilotonnes) and carbon dioxide, as well as of hydrocarbons, oxides of sulphur, particulate matter, and carbon monoxide, for information purposes.

As well, the railways calculated and reported voluntarily on their fuel consumption and emissions in three designated Tropospheric Ozone Management Areas for 2000: the Lower Fraser Valley in British Columbia, the Windsor–Quebec City Corridor, and the Saint John area in New Brunswick. They also segregated their data for winter and summer operations and tracked measures being undertaken to reduce fuel consumption and consequent emissions.

The reasons for the government–industry initiative are evident. Canada's transportation sector produces more greenhouse gas emissions than any other sector, approximately 25% of the total in 1997, and this is anticipated to increase to 32% by 2010 and to 53% by 2020[1]. Within the transportation sector, road transportation is the most significant source of emissions, accounting for over 70% (passenger cars and light trucks 44.1% and commercial trucks 27.2%)[2]. The rail industry accounts for only 4% of the transportation sector total, despite handling more than half of all the ton-miles moved in Canada.

In recent years, Canada's railways have invested in new fuel-efficient locomotives and new high-capacity freight cars and have introduced other operational efficiencies to reduce fuel consumption and associated emissions. Since 1990, Canada's railways have been improving their fuel efficiency at a rate of approximately 2.4% per year.

Canada's railways are very proud of their achievements in the area of fuel efficiency and reducing atmospheric emissions and will remain a safe, efficient, and effective way to transport goods in Canada, helping Canadian industries remain competitive in domestic and international markets.

1 Transportation Climate Change Table. Transportation & Climate Change: Options for Action, Options Paper of the Transportation Climate Change Table. November 1999.

2 Ibid.

Résumé

Le volume de trafic de marchandises des chemins de fer du Canada a été plus élevé que prévu en 1999 et en 2000, mais il accuse néanmoins le plus faible taux d'émissions d'oxydes d'azote de l'industrie depuis 1975. En effet, les émissions d'oxydes d'azote en 1999 et en 2000 totalisaient 6,8 % et 5,0 % respectivement, soit un taux inférieur au plafond volontaire établi pour l'année. Les émissions de dioxyde de carbone par unité de volume de trafic de marchandises ont diminué de plus de 5 % par année depuis 1997 et de 2,4 % en moyenne depuis 1990.

Selon l'Association des chemins de fer du Canada, le volume de trafic de marchandises pour 1999 et 2000 était supérieur de 22 % et 29 % respectivement à celui de 1990. Le service voyageurs par train interurbain est passé d'un peu plus de quatre millions à près de 4,25 millions de voyageurs. La consommation totale de carburant a baissé de 3,5 % pendant la décennie.

Les émissions de gaz à effet de serre étaient de 5,4 % et de 3,5 % de moins, en 1999 et en 2000 respectivement, que l'année de référence 1990 et les émissions d'oxydes d'azote étaient aussi moindres, de 5,6 % et de 3,8 %, pendant la même période. Malgré des augmentations continues du volume du trafic de marchandises, les chemins de fer canadiens ont émis au total 107,22 kilotonnes d'oxydes d'azote en 1999 et 109,29 kilotonnes en 2000; ces deux totaux sont bien inférieurs à l'objectif de 115 kilotonnes, ce qui montre que les solutions choisies par l'industrie sont efficaces et efficientes.

Ces résultats sont exposés dans le dernier rapport de l'Association des chemins de fer du Canada, présenté conformément au protocole d'entente entre Environnement Canada et l'Association, daté de 1995, et touchant la période de 1990 à 2005.

Les données recueillies par l'industrie des chemins de fer dans le cadre du programme de surveillance comprennent le volume de trafic annuel en tonnes-mille brutes et en tonnes-mille nettes, la consommation annuelle de carburant diesel pour le service de ligne principale et de ligne secondaire, le service de manœuvre et le service voyageurs, et les émissions annuelles d'oxydes d'azote (plafond de 115 kilotonnes), d'hydrocarbures, d'oxydes de soufre, de particules, de monoxyde de carbone et de dioxyde de carbone, à titre d'information.

De plus, les chemins de fer ont calculé et déclaré, volontairement, la consommation de carburant et les émissions dans les trois Zones de gestion de l'ozone troposphérique (ZGOT) désignées pour 2000 : la vallée inférieure du Fraser en Colombie-Britannique, le corridor Windsor-Québec et la région de Saint John au Nouveau-Brunswick.

Les raisons de l'initiative du gouvernement et de l'industrie sont évidentes. Le secteur des transports du Canada produit plus d'émissions de gaz à effet de serre que tout autre secteur, soit environ 25 % du total en 1997, et ce total devrait augmenter à 32 % d'ici 2010 et à 53 % d'ici 2020[1]. Dans le secteur des transports, le transport routier est la source d'émissions la plus importante, comptant pour plus de 70 % (automobiles et camions légers, 44,1 %, et camions utilitaires, 27,2 %)[2]. L'industrie ferroviaire ne représente que 4 % du total du secteur des transports, même si elle englobe plus de la moitié de toutes les tonnes-mille transportées au Canada.

Depuis quelques années, les chemins de fer du Canada ont investi dans de nouvelles locomotives efficaces sur le plan de la consommation de carburant et de nouveaux wagons à marchandises à grande capacité; de plus, ils ont apporté d'autres modifications opérationnelles économiques en vue de réduire la consommation de carburant et les émissions connexes. Depuis 1990, les chemins de fer du Canada ont amélioré leur efficacité de carburant à un rythme d'environ 2,4 % par année.

Les chemins de fer du Canada sont très fiers de leurs réalisations dans le domaine de la consommation de carburant et de la réduction des émissions atmosphériques, qui ne les empêchent pas de demeurer un moyen de transport sûr, efficace et efficient de marchandises au Canada, et d'aider ainsi les industries canadiennes à rester concurrentielles sur les marchés nationaux et internationaux.

1 Table des transports et du changement climatique. 1999. *Les transports et le changement climatique : Options à envisager.* Rapport sur les options de la Table des transports et du changement climatique. Novembre 1999.

2 Ibid.

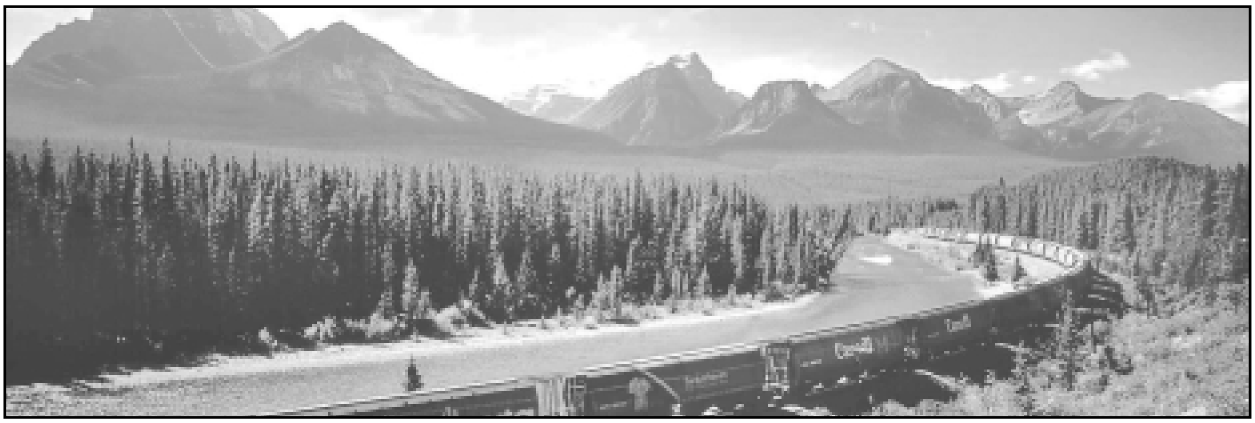
Table of Contents

List of Tables

List of Figures

1.0 Introduction

The Memorandum of Understanding between Environment Canada and The Railway Association of Canada (RAC), signed on December 27, 1995, requires RAC to submit an annual report to Environment Canada on the emissions of exhaust gases from locomotives used in rail service. The report is to include data on the traffic moved, the fuel consumed, estimates of the consequent emissions of certain exhaust gases, and information on any improvements in equipment or operating practices that will lead to reduced emissions.



2.0 Data for 1975 to 2000

2.1 Traffic Data

The volume of traffic, measured in gross ton-miles (gtm) and in net ton-miles (ntm), for the years 1975–2000 is shown in Tables 1a, 1b, 1c, and 1d. Estimates are also given in Table 1d for the year 2005. The data for the years up to and including 1996 are taken from "Rail in Canada,"[3] while those for 1997, 1998, 1999, and 2000 are from information supplied to RAC by its member railways. The traffic data are plotted in Figure 1.

The term "gross ton-miles" refers to the aggregate of the ton-miles handled, calculated using the total weight of the trailing tonnage of the trains moved. It excludes the contribution of the weight of the locomotives pulling the trains.

The term "net ton-miles" refers to the aggregate of the ton-miles handled, calculated using the total weight of the commodities in the cars of the trains moved. In this case, it includes the ton-miles involved in the movement of railway materials.

When the Locomotive Emissions Program was established, it was decided that the projection of future traffic and fuel consumption data would be based on 1990 levels. The following assumptions were made for the total traffic volume to be handled by the railways in Canada after that date:

a) Gross ton-miles would increase at an average annual rate of 1.2% of the 1990 volume.

b) Net ton-miles would increase at an average annual rate of 1.5% of the 1990 volume.

c) The ratio of net ton-miles to gross ton-miles would therefore increase at an average annual rate of 0.3%, reflecting the ongoing improvements in the effectiveness of freight cars.

[3] Statistics Canada Catalogue 52-216 Annual.

Table 1a: Annual Traffic and Fuel Consumption Statistics, 1975-1981

		1975	1976	1977	1978	1979	1980	1981
TRAFFIC DATA								
GROSS TON-MILES ALL FREIGHT	million gtm	266 941.9	273 360.4	282 114.8	285 196.6	307 917.7	308 474.5	309 174.6
NET TON-MILES ALL FREIGHT	million ntm	138 576.6	142 178.5	148 900.3	151 036.8	163 660.8	164 347.3	163 925.8
RATIO of NTM/GTM		0.519	0.520	0.528	0.530	0.532	0.533	0.530
FUEL CONSUMPTION DATA								
FREIGHT SERVICE SUBTOTAL - Existing Locomotive Fleet	Imp. gal.	407 052 164	419 203 247	436 291 345	440 024 087	459 310 810	455 812 403	443 860 816
SUBTOTAL - CNR & CPR New Low Emissions Locomotives	Imp. gal.							
MAINLINE & BRANCHLINE								
TOTAL MAINLINE & BRANCHLINE SERVICE	Imp. gal.	407 052 164	419 203 247	436 291 345	440 024 087	459 310 810	455 812 403	443 860 816
YARD SWITCHING SERVICE	Imp. gal.	33 676 252	36 409 975	36 784 996	36 986 113	39 794 091	37 338 811	32 560 311
WORK TRAIN SERVICE	Imp. gal.	8 311 573	8 975 287	10 010 070	8 870 030	10 387 399	8 894 352	9 946 747
TOTAL YARD & WORK TRAIN SERVICE	Imp. gal.	41 987 825	45 385 262	46 795 066	45 856 143	50 181 490	46 233 163	42 507 058
TOTAL FREIGHT OPERATIONS	Imp. gal.	449 039 989	464 588 509	483 086 411	485 880 230	509 492 300	502 045 566	486 367 874
PASSENGER FUEL	Imp. gal.	n/a	n/a	n/a	n/a	n/a	n/a	n/a
TOTAL FUEL - ALL OPERATIONS	Imp. gal.	449 039 989	464 588 509	483 086 411	485 880 230	509 492 300	502 045 566	486 367 874
TOTAL FREIGHT FUEL / GTM	Imp. gal. per 1000 gtm	1.6822	1.6995	1.7124	1.7037	1.6546	1.6275	1.5731
TOTAL FREIGHT FUEL / NTM	Imp. gal. per 1000 ntm	3.2404	3.2676	3.2444	3.2170	3.1131	3.0548	2.9670

Table 1b: Annual Traffic and Fuel Consumption Statistics, 1982-1988

			1982	1983	1984	1985	1986	1987	1988
TRAFFIC DATA									
GROSS TON-MILES	ALL FREIGHT	million gtm	275 560.4	298 510.0	329 577.2	314 688.0	319 685.7	342 010.5	346 386.6
NET TON-MILES	ALL FREIGHT	million ntm	147 380.4	158 815.9	176 411.9	168 080.4	168 987.9	186 344.5	188 020.8
RATIO of NTM/GTM			0.535	0.532	0.535	0.534	0.529	0.545	0.543
FUEL CONSUMPTION DATA									
FREIGHT SERVICE	SUBTOTAL - Existing Locomotive Fleet	Imp. gal.	391 445 966	411 156 794	437 852 458	427 680 176	430 613 225	439 597 337	448 134 752
	SUBTOTAL - CNR & CPR New Low Emissions Locomotives	Imp. gal.							
MAINLINE & BRANCHLINE									
	TOTAL MAINLINE & BRANCHLINE SERVICE	Imp. gal.	391 445 966	411 156 794	437 852 458	427 680 176	430 613 225	439 597 337	448 134 752
YARD SWITCHING SERVICE		Imp. gal.	29 261 667	26 029 182	26 732 542	26 613 387	25 877 445	25 531 119	26 666 102
WORK TRAIN SERVICE		Imp. gal.	8 607 211	8 110 350	8 822 318	8 486 384	6 419 695	5 648 588	5 463 752
	TOTAL YARD & WORK TRAIN SERVICE	Imp. gal.	37 868 879	34 139 532	35 554 860	35 099 770	32 297 140	31 179 707	32 129 854
TOTAL FREIGHT OPERATIONS		Imp. gal.	429 314 845	445 296 325	473 407 319	462 779 947	462 910 365	470 777 044	480 264 606
PASSENGER FUEL		Imp. gal.	n/a	n/a	n/a	n/a	n/a	n/a	31 996 890
TOTAL FUEL - ALL OPERATIONS		Imp. gal.	429 314 845	445 296 325	473 407 319	462 779 947	462 910 365	470 777 044	512 261 496
TOTAL FREIGHT FUEL / GTM		Imp. gal. per 1000 gtm	1.5580	1.4917	1.4364	1.4706	1.4480	1.3765	1.3865
TOTAL FREIGHT FUEL / NTM		Imp. gal. per 1000 ntm	2.9130	2.8039	2.6835	2.7533	2.7393	2.5264	2.5543

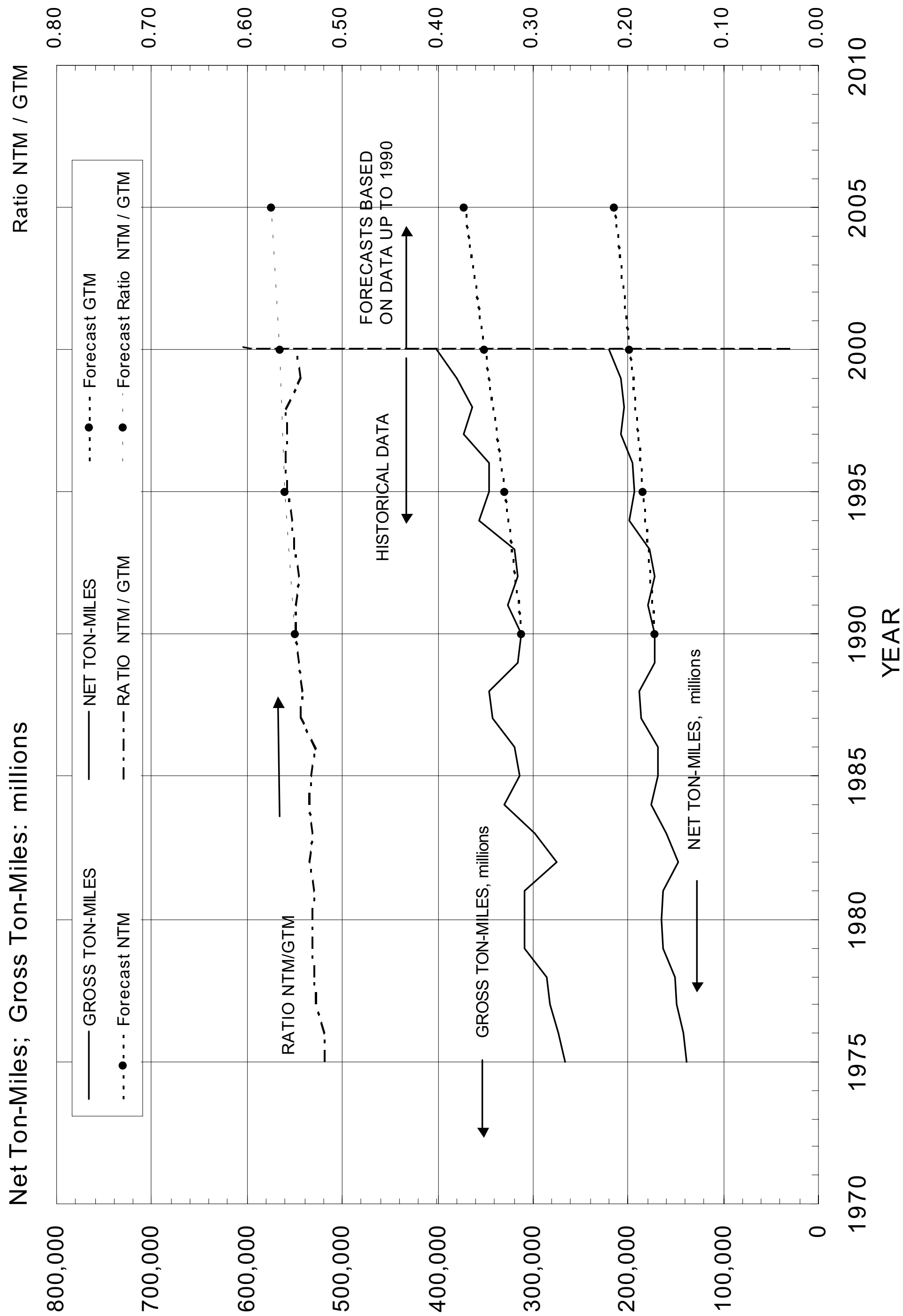
Table1c: Annual Traffic and Fuel Consumption Statistics, 1989-1994

			1989	1990	1991	1992	1993	1994
TRAFFIC DATA								
GROSS TON-MILES	ALL FREIGHT	million gtm	316 193.2	311 605.6	326 623.9	316 598.2	319 633.0	357 407.3
NET TON-MILES	ALL FREIGHT	million ntm	172 662.4	171 321.8	179 752.7	172 922.6	176 587.7	197 853.0
RATIO of NTM/GTM			0.546	0.550	0.550	0.546	0.552	0.554
FUEL CONSUMPTION DATA								
FREIGHT SERVICE	SUBTOTAL - Existing Locomotive Fleet	Imp. gal.	413 537 710	401 454 041	413 727 374	401 827 787	399 367 750	425 960 693
	SUBTOTAL - CNR & CPR New Low Emissions Locomotives	Imp. gal.						
MAINLINE & BRANCHLINE								
	TOTAL MAINLINE & BRANCHLINE SERVICE	Imp. gal.	413 537 710	401 454 041	413 727 374	401 827 787	399 367 750	425 960 693
YARD SWITCHING SERVICE		Imp. gal.	25 399 966	26 425 932	26 425 476	26 649 476	27 209 986	30 157 938
WORK TRAIN SERVICE		Imp. gal.	4 084 975	3 447 258	2 966 169	3 231 506	2 605 223	2 589 165
	TOTAL YARD & WORK TRAIN SERVICE	Imp. gal.	29 484 941	29 873 190	29 391 645	29 880 982	29 815 209	32 747 103
TOTAL FREIGHT OPERATIONS		Imp. gal.	443 022 651	431 327 231	443 119 019	431 708 769	429 182 960	458 707 796
PASSENGER FUEL		Imp. gal.	33 656 118	22 620 559	15 802 221	14 175 071	15 295 429	13 220 138
TOTAL FUEL - ALL OPERATIONS		Imp. gal.	476 678 769	453 947 790	458 921 240	445 883 840	444 478 389	471 927 934
TOTAL FREIGHT FUEL / GTM		Imp. gal. per 1000 gtm	1.4011	1.3842	1.3567	1.3636	1.3427	1.2834
TOTAL FREIGHT FUEL / NTM		Imp. gal. per 1000 ntm	2.5658	2.5176	2.4652	2.4965	2.4304	2.3184

Table1d: Annual Traffic and Fuel Consumption Statistics, 1995-2000, and Projections for 2005

			1995	1996	1997	1998	1999	2000	2005
TRAFFIC DATA									
GROSS TON-MILES	ALL FREIGHT	million gtm	346 357.1	346 513.5	372 696.1	362 831.3	380 023.5	401 760.0	372 660.1
NET TON-MILES	ALL FREIGHT	million ntm	193 456.3	194 444.2	208 347.7	203 403.6	206 827.2	220 812.1	214 192.0
RATIO of NTM/GTM			0.559	0.561	0.559	0.561	0.544	0.550	0.575
FUEL CONSUMPTION DATA									
FREIGHT SERVICE	SUBTOTAL - Existing Locomotive Fleet	Imp. gal.	426 629 212	412 290 696	447 260 000	414 419 000	396 413 000	404 487 000	260 152 041
	SUBTOTAL - CNR & CPR New Low Emissions Locomotives	Imp. gal.							154 000 000
MAINLINE & BRANCHLINE									
	TOTAL MAINLINE & BRANCHLINE SERVICE	Imp. gal.	426 629 212	412 290 696	447 260 000	414 419 000	396 413 000	404 487 000	414 152 041
YARD SWITCHING SERVICE		Imp. gal.	30 846 036	29 989 213	24 953 000	25 961 000	19 125 000	19 109 000	27 000 000
WORK TRAIN SERVICE		Imp. gal.	2 153 384	1 442 189	1 326 000	1 650 000	1 106 000	854 000	2 500 000
	TOTAL YARD & WORK TRAIN SERVICE	Imp. gal.	32 999 420	31 431 402	26 279 000	27 611 000	20 231 000	19 963 000	29 500 000
TOTAL FREIGHT OPERATIONS		Imp. gal.	459 628 632	443 722 098	473 539 000	442 030 000	416 644 000	424 450 000	443 652 041
PASSENGER FUEL		Imp. gal.	12 406 652	12 939 884	13 435 498	12 888 000	12 840 000	13 408 000	14 000 000
TOTAL FUEL - ALL OPERATIONS		Imp. gal.	472 035 284	456 661 982	486 974 498	454 918 000	429 484 000	437 858 000	457 652 041
TOTAL FREIGHT FUEL / GTM		Imp. gal. per 1000 gtm	1.3270	1.2805	1.2706	1.2183	1.0964	1.0565	1.1905
TOTAL FREIGHT FUEL / NTM		Imp. gal. per 1000 ntm	2.3759	2.2820	2.2728	2.1732	2.0145	1.9222	2.0713

Figure 1: Freight Traffic Data



2.2 Fuel Consumption Data

The fuel consumed by the railway locomotives in Canada for the years 1975–2000 is shown in Tables 1a, 1b, 1c, and 1d. Estimates are also given in Table 1d for the year 2005. The data for the years up to and including 1996 are taken from "Rail in Canada,"[4] while those for 1997, 1998, 1999, and 2000 are from information supplied to RAC by its member railways.

The fuel consumption is broken down into the quantities used for:

- mainline and branchline freight movement;
- yard switching and work train service; and
- passenger train service (information for this was available only for the period since 1988).

The data are plotted in Figure 2.

A measure of the efficiency with which freight traffic is handled is the fuel consumption per unit of traffic volume. These data, in units of gallons per 1000 gross ton-miles and gallons per 1000 net ton-miles, are shown in Tables 1a, 1b, 1c, and 1d and are plotted in Figure 3.

The curves in Figure 3 show the overall improvement that has been made in the movement of freight by Canadian railways in the period from 1975 to 2000. Operational factors result in year-to-year variations from the long-term trend line. The reduction in specific fuel consumption is the result of many factors. These include:

- the use of locomotives with engines and transmissions having increased efficiency;
- improved train handling practices;
- the use of improved wheel tread profiles;
- the use of freight car trucks with lower rolling and curving resistance;
- the use of locomotive-mounted and wayside rail gauge face lubricators; and
- the increase in average load per car.

[4] Statistics Canada Catalogue 52-216 Annual.

The estimates of future fuel consumption were made as follows:

a) The fuel consumption rate in gallons per 1000 gross ton-miles during the period from 1975 to 1990 was found to have had an annual decrement of 1.9% of the 1990 level. It was assumed that the various improvements being implemented and planned would cause the fuel consumption rate to continue to decrease at about one-half of this historical pace, or at an annual rate of 1% of the 1990 level, through to 2005. The projected values are shown in Figure 3.

b) The fuel consumption rate values were then applied to the projected traffic levels to obtain the estimated total freight fuel consumption to 2005.

c) The estimated passenger service fuel consumption was based on values predicted in 1990.

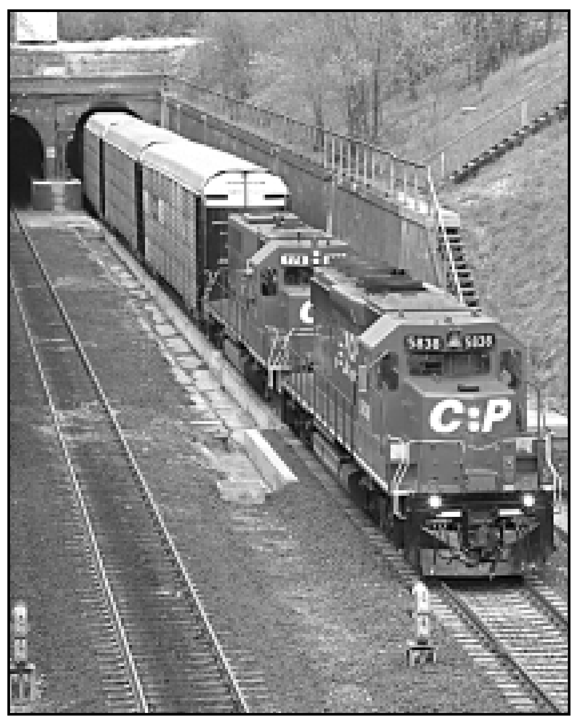


Figure 2: Fuel Data

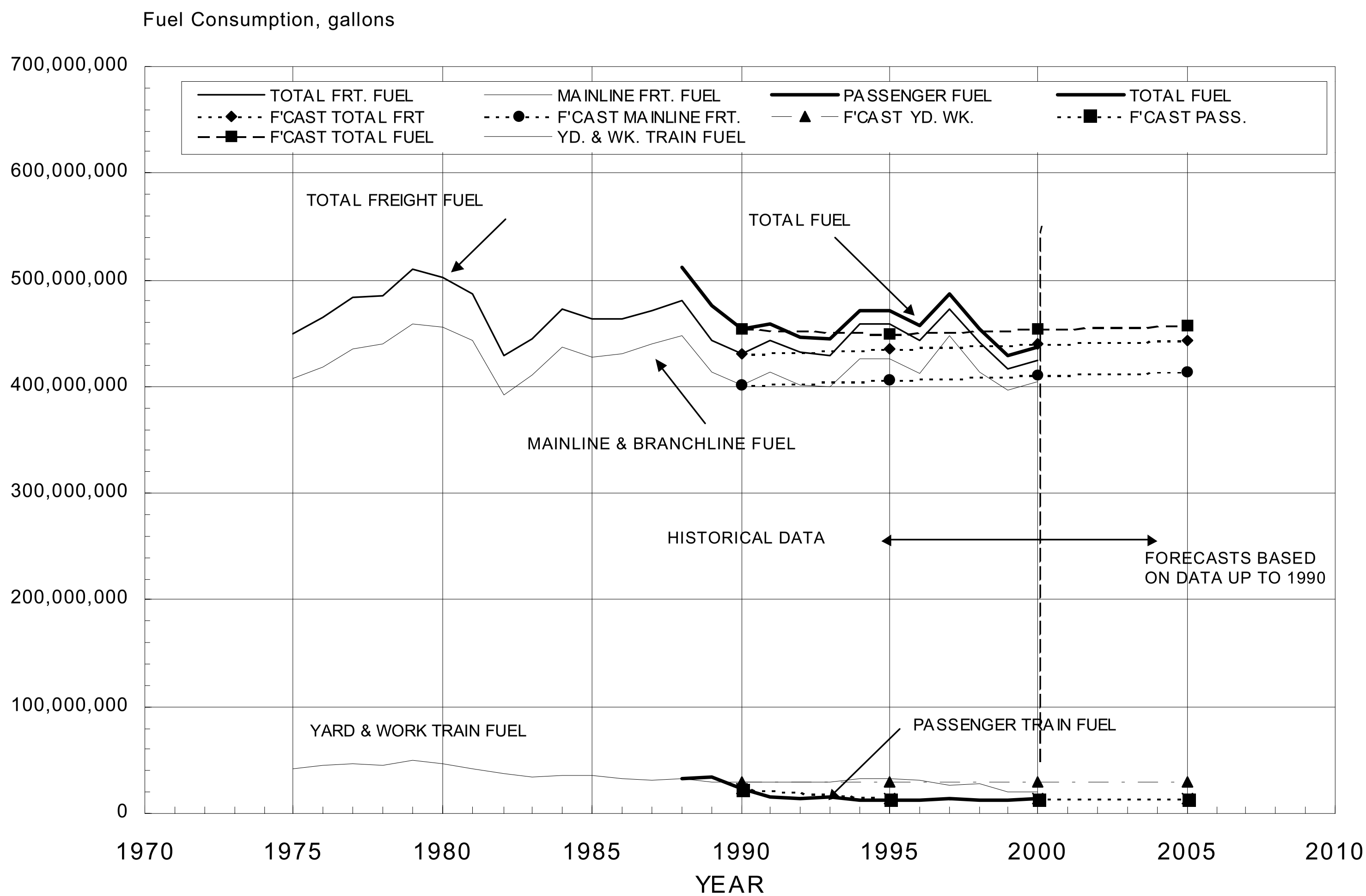
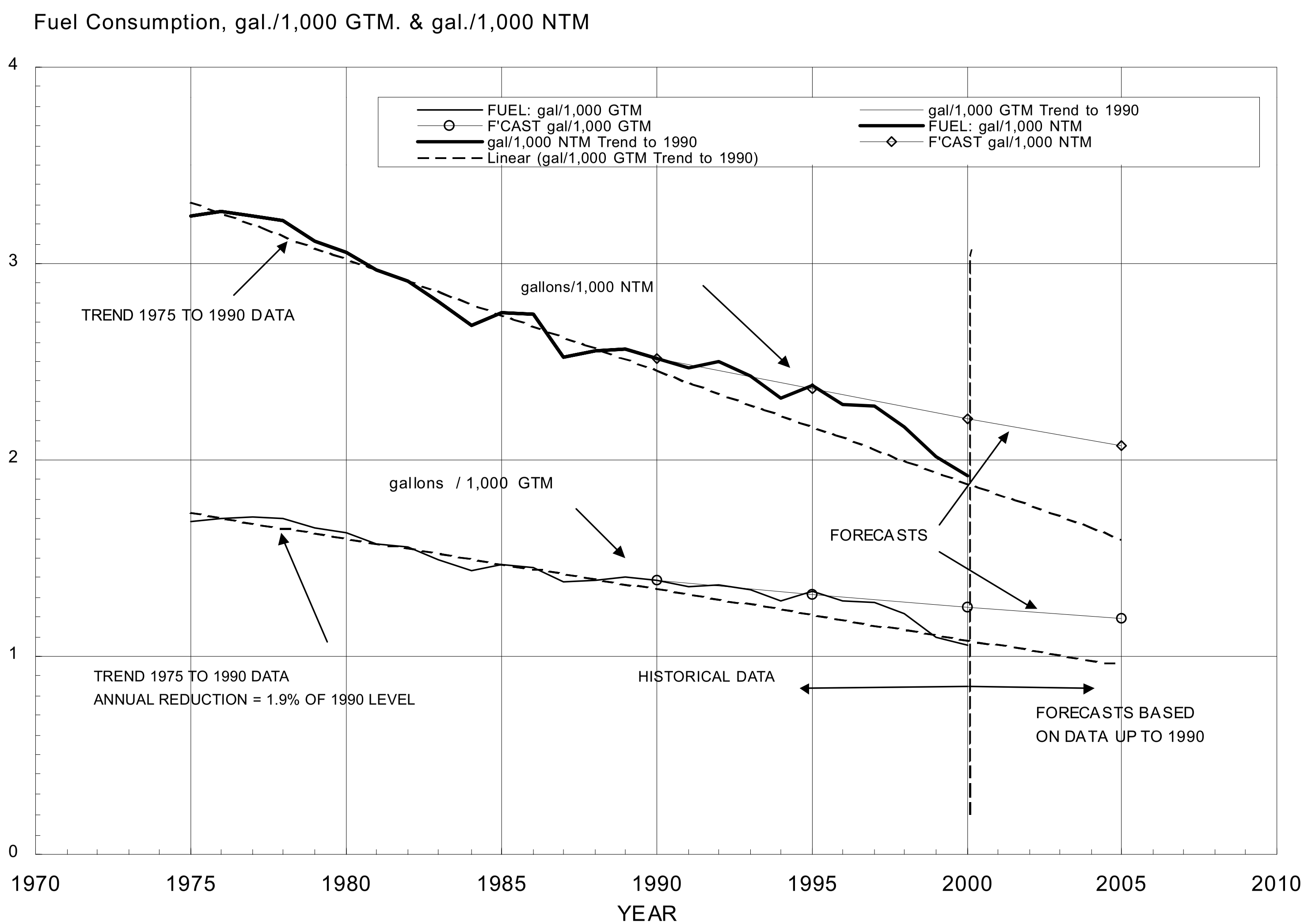


Figure 3: Fuel Consumption Data: gallons / 1000 GTM & gallons / 1000 NTM



2.3 Locomotive Emissions Data

The gaseous emissions from locomotive operation have been calculated using factors giving quantities of selected exhaust gases per gallon of fuel consumed. These factors were derived from extensive testing by the Association of American Railroads (AAR) and the locomotive manufacturers. They are shown in Tables 10 and 12 in the Environment Canada report, "Recommended Reporting Requirements for the Locomotive Emissions Monitoring (LEM) Program."[5] They are based on emissions data for the engines in the various throttle notch settings applied to the duty cycle for locomotive operation considered to be applicable to Canadian service conditions.

The emissions data are shown in Tables 2a, 2b, 2c, and 2d of this report. Values are shown for oxides of nitrogen (NO_x), carbon monoxide (CO), hydrocarbons (HC), oxides of sulphur (SO_x), particulate matter (PM), and carbon dioxide (CO_2) for the several types of service and for the total locomotive emissions for all railway operations.

The historical and forecast quantities of emissions of nitrogen oxides are also plotted in Figure 4. The projected values for locomotive emissions shown in Figure 4 are based on the forecast traffic levels and on the forecast efficiency of locomotive and train operation. The proposed cap of 115 kilotonnes per annum on emissions of nitrogen oxides is also shown in Figure 4.

The emission rates for oxides of nitrogen and carbon dioxide, the most significant emissions from railway diesel engines, are plotted in Figure 5 in terms of kilograms per 1000 net ton-miles.

2.4 Observations on Data

The efficiency with which the freight traffic was handled has continued to improve, and the improvement in the last three years has been at a rate considerably better than that forecast. This is shown in terms of fuel consumption per traffic unit (Figure 3) and in terms of emissions per traffic unit (Figure 5).

The emissions of oxides of nitrogen (Figure 4) were 6.8% and 5.0% below the cap of 115 kilotonnes in 1999 and 2000, respectively. The average emission level since 1990 was below the cap level by 0.5% in 1999 and by 0.9% in 2000. The emissions of oxides of nitrogen resulting from all freight operations were at the lowest level recorded since 1975 in 1999 but rose slightly in 2000. This notable performance was achieved in spite of the continued significant increase in traffic levels since 1994 over the forecast volumes, as shown in Figure 1. It is further discussed in Section 9.

The emissions of oxides of nitrogen and of the greenhouse gas carbon dioxide in terms of kilograms per 1000 net ton-miles have continued to decrease at an accelerated rate. The value of total emissions of oxides of nitrogen per work unit was better than the forecast rate by 9.1% in 1999 and by 11.6% in 2000. The graphs in Figure 5 show clearly the steady progress made since the late 1970s in rail freight transportation in this regard.

5 Environment Canada, Environmental Protection series, Report EPS 2/TS/8, September 1994.

Table 2a: Annual Emission Statistics, 1975-1981

		EMISSIONS STANDARD FRGT & PASS.	FACTORS YARD & WORK	1975	1976	1977	1978	1979	1980	1981
		g/Imp. gal.	g/Imp. gal.	kilotonnes						
FREIGHT - MAINLINE & BRANCHLINE	NO_x	248.3		101.07	104.09	108.33	109.26	114.05	113.18	110.21
	CO	47.7		19.42	20.00	20.81	20.99	21.91	21.74	21.17
	HC	12.4		5.05	5.20	5.41	5.46	5.70	5.65	5.50
Adjusted to 0.15% Sulphur Fuel	SO_x	11.5		4.69	4.83	5.02	5.07	5.29	5.25	5.11
	PM	5.9		2.40	2.47	2.57	2.60	2.71	2.69	2.62
Based on 86.5% Carbon Fuel	CO_2	12 300		5 006.74	5 156.20	5 366.38	5 412.30	5 649.52	5 606.49	5 459.49
YARD SWITCHING AND WORK TRAIN SERVICE	NO_x		277,0	11.63	12.57	12.96	12.70	13.90	12.81	11.77
	CO		47.3	1.99	2.15	2.21	2.17	2.37	2.19	2.01
	HC		16.4	0.69	0.74	0.77	0.75	0.82	0.76	0.70
Adjusted to 0.15% Sulphur Fuel	SO_x		11.5	0.48	0.52	0.54	0.53	0.58	0.53	0.49
	PM		6.7	0.28	0.30	0.31	0.31	0.34	0.31	0.28
Based on 86.5% Carbon Fuel	CO_2		12 300	516.45	558.24	575.58	564.03	617.23	568.67	522.84
PASSENGER	NO_x	248.3		n/a	n/a	n/a	n/a	n/a	n/a	n/a
	CO	47.7		n/a	n/a	n/a	n/a	n/a	n/a	n/a
	HC	12.4		n/a	n/a	n/a	n/a	n/a	n/a	n/a
Adjusted to 0.15% Sulphur Fuel	SO_x	11.5		n/a	n/a	n/a	n/a	n/a	n/a	n/a
	PM	5.9		n/a	n/a	n/a	n/a	n/a	n/a	n/a
Based on 86.5% Carbon Fuel	CO_2	12 300		n/a	n/a	n/a	n/a	n/a	n/a	n/a
TOTAL - RAIL OPERATIONS	NO_x	248.3	277	112.70	116.66	121.29	121.96	127.95	125.98	121.99
	CO	47.7	47.3	21.40	22.14	23.02	23.16	24.28	23.93	23.18
	HC	12.4	16.4	5.74	5.94	6.18	6.21	6.52	6.41	6.20
Adjusted to 0.15% Sulphur Fuel	SO_x	11.5	11.5	5.17	5.35	5.56	5.59	5.87	5.78	5.60
	PM	5.9	6.7	2.68	2.78	2.89	2.90	3.05	3.00	2.90
Based on 86.5% Carbon Fuel	CO_2	12 300	12 300	5 523.19	5 714.44	5 941.96	5 976.33	6 266.76	6 175.16	5 982.32
EMISSIONS per FREIGHT TRAFFIC UNIT				kg / 1000 NTM						
NO_x				0.813	0.821	0.815	0.807	0.782	0.767	0.744
CO				0.154	0.156	0.155	0.153	0.148	0.146	0.141
HC				0.041	0.042	0.041	0.041	0.040	0.039	0.038
SO_x				0.037	0.038	0.037	0.037	0.036	0.035	0.034
PM				0.019	0.020	0.019	0.019	0.019	0.018	0.018
CO_2				39.857	40.192	39.906	39.569	38.291	37.574	36.494

Table 2b: Annual Emission Statistics, 1982-1988

		EMISSIONS STANDARD FRGT & PASS.	FACTORS YARD & WORK	1982	1983	1984	1985	1986	1987	1988
		g/Imp. gal.	g/Imp. gal.	kilotonnes						
FREIGHT - MAINLINE & BRANCHLINE	NO_x	248.3		97.20	102.09	108.72	106.19	106.92	109.15	111.27
	CO	47.7		18.67	19.61	20.89	20.40	20.54	20.97	21.38
	HC	12.4		4.85	5.10	5.43	5.30	5.34	5.45	5.56
Adjusted to 0.15% Sulphur Fuel	SO_x	11.5		4.51	4.73	5.04	4.93	4.96	5.06	5.16
	PM	5.9		2.31	2.43	2.58	2.52	2.54	2.59	2.64
Based on 86.5% Carbon Fuel	CO_2	12 300		4 814.79	5 057.23	5 385.59	5 260.47	5 296.54	5 407.05	5 512.06
YARD SWITCHING AND WORK TRAIN SERVICE	NO_x		277	10.49	9.46	9.85	9.72	8.95	8.64	8.90
	CO		47.3	1.79	1.61	1.68	1.66	1.53	1.47	1.52
	HC		16.4	0.62	0.56	0.58	0.58	0.53	0.51	0.53
Adjusted to 0.15% Sulphur Fuel	SO_x		11.5	0.44	0.39	0.41	0.40	0.37	0.36	0.37
	PM		6.7	0.23	0.24	0.24	0.22	0.21	0.22	
Based on 86.5% Carbon Fuel	CO_2		12 300	465.79	419.92	437.32	431.73	397.25	383.51	395.20
PASSENGER	NO_x	248.3		n/a	n/a	n/a	n/a	n/a	n/a	7.94
	CO	47.7		n/a	n/a	n/a	n/a	n/a	n/a	1.53
	HC	12.4		n/a	n/a	n/a	n/a	n/a	n/a	0.40
Adjusted to 0.15% Sulphur Fuel	SO_x	11.5		n/a	n/a	n/a	n/a	n/a	n/a	0.37
	PM	5.9		n/a	n/a	n/a	n/a	n/a	n/a	0.19
Based on 86.5% Carbon Fuel	CO_2	12 300		n/a	n/a	n/a	n/a	n/a	n/a	393.56
TOTAL - RAIL OPERATIONS	NO_x	248.3	277	107.69	111.55	118.57	115.92	115.87	117.79	128.12
	CO	47.7	47.3	20.46	21.23	22.57	22.06	22.07	22.44	24.42
	HC	12.4	16.4	5.47	5.66	6.01	5.88	5.87	5.96	6.48
Adjusted to 0.15% Sulphur Fuel	SO_x	11.5	11.5	4.94	5.13	5.45	5.33	5.33	5.42	5.90
	PM	5.9	6.7	2.56	2.65	2.82	2.76	2.76	2.80	3.05
Based on 86.5% Carbon Fuel	CO_2	12 300	12 300	5 280.57	5 477.14	5 822.91	5 692.19	5 693.80	5 790.56	6 300.82
EMISSIONS per FREIGHT TRAFFIC UNIT				kg / 1000 NTM						
NO_x				0.731	0.702	0.672	0.690	0.686	0.632	0.639
CO				0.139	0.134	0.128	0.131	0.131	0.120	0.122
HC				0.037	0.036	0.034	0.035	0.035	0.032	0.032
SO_x				0.034	0.032	0.031	0.032	0.032	0.029	0.029
PM				0.017	0.017	0.016	0.016	0.016	0.015	0.015
CO_2				35.830	34.487	33.007	33.866	33.694	31.074	31.418

Table 2c: Annual Emission Statistics, 1989-1994

		EMISSIONS STANDARD FRGT & PASS.	FACTORS YARD & WORK	1989	1990	1991	1992	1993	1994
		g/Imp. gal.	g/Imp. gal.	kilotonnes					
FREIGHT - MAINLINE & BRANCHLINE	NO_x	248.3		102.68	99.68	102.73	99.77	99.16	105.77
	CO	47.7		19.73	19.15	19.73	19.17	19.05	20.32
	HC	12.4		5.13	4.98	5.13	4.98	4.95	5.28
Adjusted to 0.15% Sulphur Fuel	SO_x	11.5		4.76	4.62	4.76	4.63	4.60	4.91
	PM	5.9		2.44	2.37	2.44	2.37	2.36	2.51
Based on 86.5% Carbon Fuel	CO_2	12 300		5086.51	4937.88	5088.85	4942.48	4912.22	5239.32
YARD SWITCHING AND WORK TRAIN SERVICE	NO_x		277	8.17	8.27	8.14	8.28	8.26	9.07
	CO		47.3	1.39	1.41	1.39	1.41	1.41	1.55
	HC		16.4	0.48	0.49	0.48	0.49	0.49	0.54
Adjusted to 0.15% Sulphur Fuel	SO_x		11.5	0.34	0.34	0.34	0.34	0.34	0.38
	PM		6.7	0.20	0.20	0.20	0.20	0.20	0.22
Based on 86.5% Carbon Fuel	CO_2		12 300	362.66	367.44	361.52	367.54	366.73	402.79
PASSENGER	NO_x	248.3		8.36	5.62	3.92	3.52	3.80	3.28
	CO	47.7		1.61	1.08	0.75	0.68	0.73	0.63
	HC	12.4		0.42	0.28	0.20	0.18	0.19	0.16
Adjusted to 0.15% Sulphur Fuel	SO_x	11.5		0.39	0.26	0.18	0.16	0.18	0.15
	PM	5.9		0.20	0.13	0.09	0.08	0.09	0.08
Based on 86.5% Carbon Fuel	CO_2	12 300		413.97	278.23	194.37	174.35	188.13	162.61
TOTAL - RAIL OPERATIONS	NO_x	248.3	277	119.21	113.57	114.79	111.57	111.22	118.12
	CO	47.7	47.3	22.73	21.64	21.88	21.26	21.19	22.50
	HC	12.4	16.4	6.03	5.75	5.81	5.65	5.63	5.98
Adjusted to 0.15% Sulphur Fuel	SO_x	11.5	11.5	5.49	5.23	5.28	5.13	5.12	5.43
	PM	5.9	6.7	2.84	2.70	2.73	2.65	2.65	2.81
Based on 86.5% Carbon Fuel	CO_2	12 300	12 300	5863.15	5583.56	5644.73	5484.37	5467.08	5804.71
EMISSIONS per FREIGHT TRAFFIC UNIT				kg / 1000 NTM					
NO_x				0.642	0.630	0.617	0.625	0.608	0.580
CO				0.122	0.120	0.118	0.119	0.116	0.111
HC				0.032	0.032	0.031	0.032	0.031	0.029
SO_x				0.030	0.029	0.028	0.029	0.028	0.027
PM				0.015	0.015	0.015	0.015	0.014	0.014
CO_2				31.560	30.967	30.321	30.707	29.894	28.517

Table 2d: Annual Emission Statistics, 1995-2000, and Projections for 2005

		EMISSIONS STANDARD FRGT & PASS.	FACTORS YARD & WORK	1995	1996	1997	1998	1999	2000	2005
		g/Imp. gal.	g/Imp. gal.	kilotonnes						
FREIGHT - MAINLINE & BRANCHLINE	NO_x	248.3		105.93	102.37	111.05	102.90	98.43	100.43	99.01
	CO	47.7		20.35	19.67	21.33	19.77	18.91	19.29	19.76
	HC	12.4		5.29	5.11	5.55	5.14	4.92	5.02	5.14
Adjusted to 0.15% Sulphur Fuel	SO_x	11.5		4.91	4.75	5.15	4.77	4.57	4.66	4.77
	PM	5.9		2.52	2.43	2.64	2.45	2.34	2.39	2.44
Based on 86.5% Carbon Fuel	CO_2	12 300		5247.54	5071.18	5501.30	5097.35	4875.88	4975.19	5094.07
YARD SWITCHING AND WORK TRAIN SERVICE	NO_x		277	9.14	8.71	7.28	7.65	5.60	5.53	8.17
	CO		47.3	1.56	1.49	1.24	1.31	0.96	0.94	1.40
	HC		16.4	0.54	0.52	0.43	0.45	0.33	0.33	0.48
Adjusted to 0.15% Sulphur Fuel	SO_x		11.5	0.38	0.36	0.30	0.32	0.23	0.23	0.34
	PM		6.7	0.22	0.21	0.18	0.18	0.14	0.13	0.20
Based on 86.5% Carbon Fuel	CO_2		12 300	405.89	386.61	323.23	339.62	248.84	245.54	362.85
PASSENGER	NO_x	248.3		3.08	3.21	3.34	3.20	3.19	3.33	3.48
	CO	47.7		0.59	0.62	0.64	0.61	0.61	0.64	0.67
	HC	12.4		0.15	0.16	0.17	0.16	0.16	0.17	0.17
Adjusted to 0.15% Sulphur Fuel	SO_x	11.5		0.14	0.15	0.15	0.15	0.15	0.15	0.16
	PM	5.9		0.07	0.08	0.08	0.08	0.08	0.08	0.08
Based on 86.5% Carbon Fuel	CO_2	12 300		152.60	159.16	165.26	158.52	157.93	164.92	172.20
TOTAL - RAIL OPERATIONS	NO_x	248.3	277	118.15	114.29	121.67	113.75	107.22	109.29	110.66
	CO	47.7	47.3	22.50	21.77	23.22	21.69	20.48	20.88	21.82
	HC	12.4	16.4	5.99	5.79	6.14	5.75	5.41	5.51	5.79
Adjusted to 0.15% Sulphur Fuel	SO_x	11.5	11.5	5.44	5.26	5.61	5.24	4.95	5.04	5.27
	PM	5.9	6.7	2.81	2.72	2.89	2.71	2.55	2.60	2.72
Based on 86.5% Carbon Fuel	CO_2	12 300	12 300	5806.03	5616.94	5989.79	5595.49	5282.65	5385.65	5629.12
EMISSIONS per FREIGHT TRAFFIC UNIT				kg / 1000 NTM						
NO_x				0.595	0.571	0.568	0.543	0.503	0.480	0.500
CO				0.113	0.109	0.108	0.104	0.096	0.092	0.099
HC				0.030	0.029	0.029	0.027	0.025	0.024	0.026
SO_x				0.027	0.026	0.026	0.025	0.023	0.022	0.024
PM				0.014	0.014	0.014	0.013	0.012	0.011	0.012
CO_2				29.223	28.069	27.956	26.730	24.778	23.643	25.477

Figure 4: Locomotive Emissions Data - NO_x kilotonnes

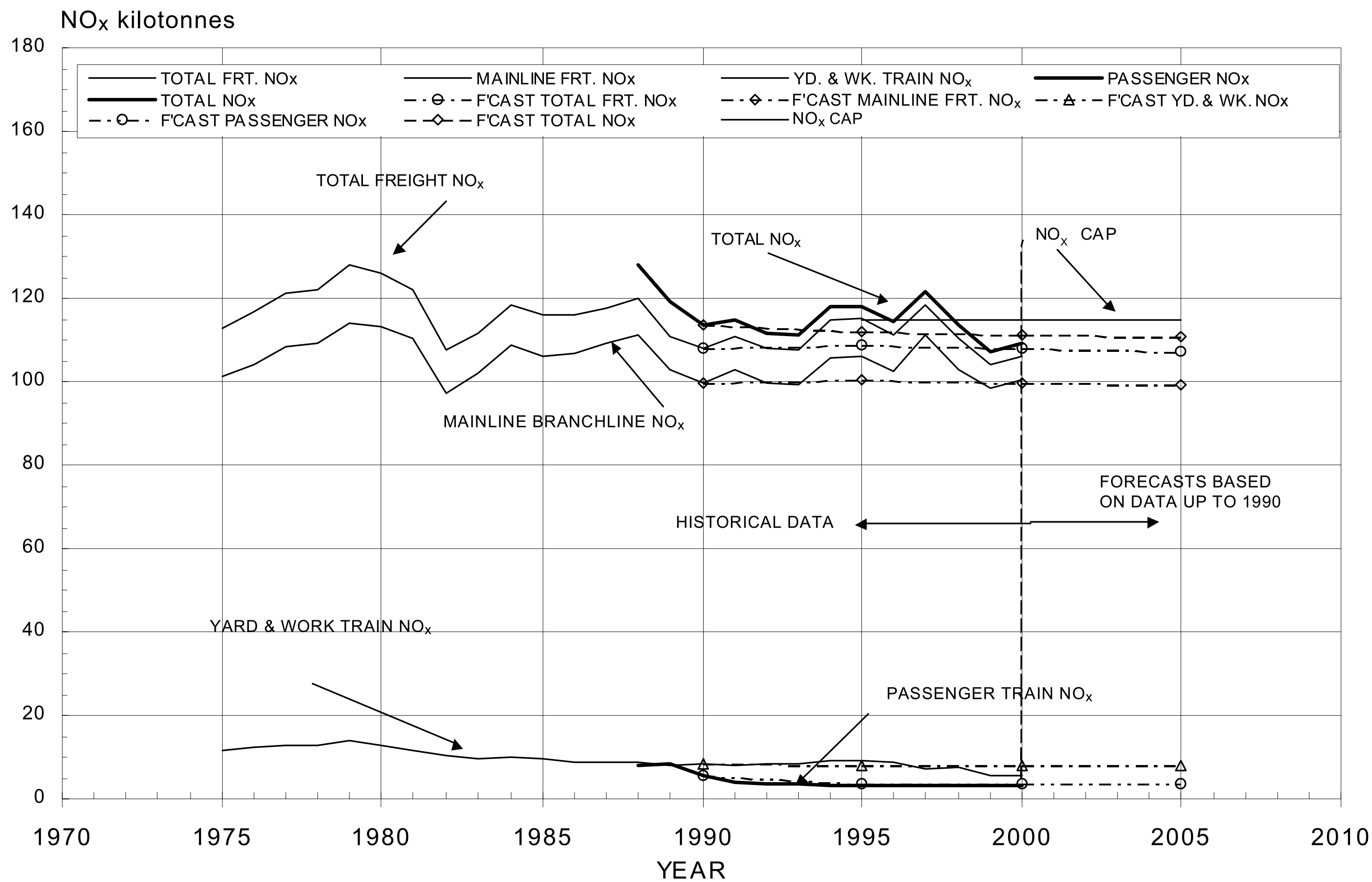
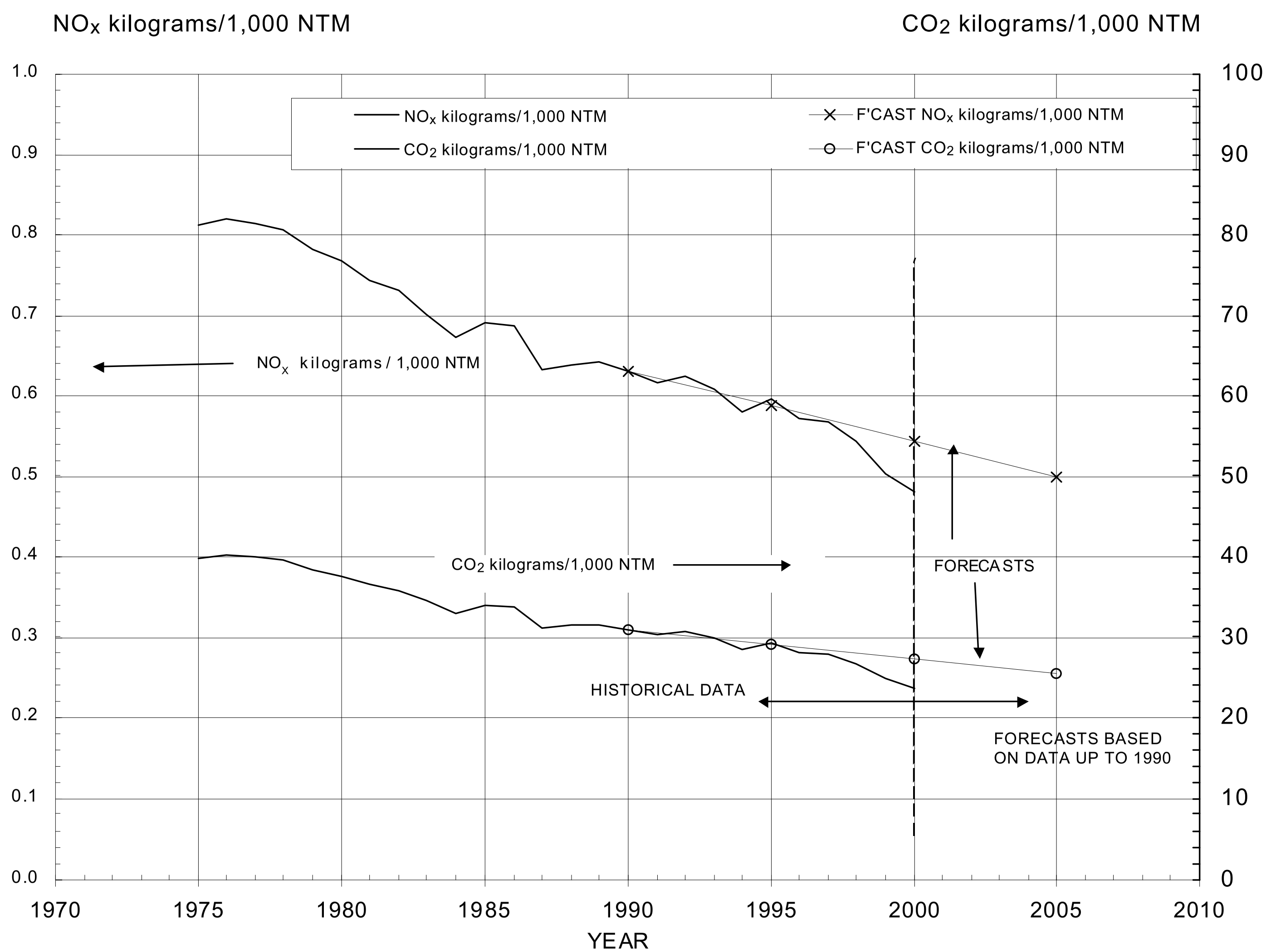
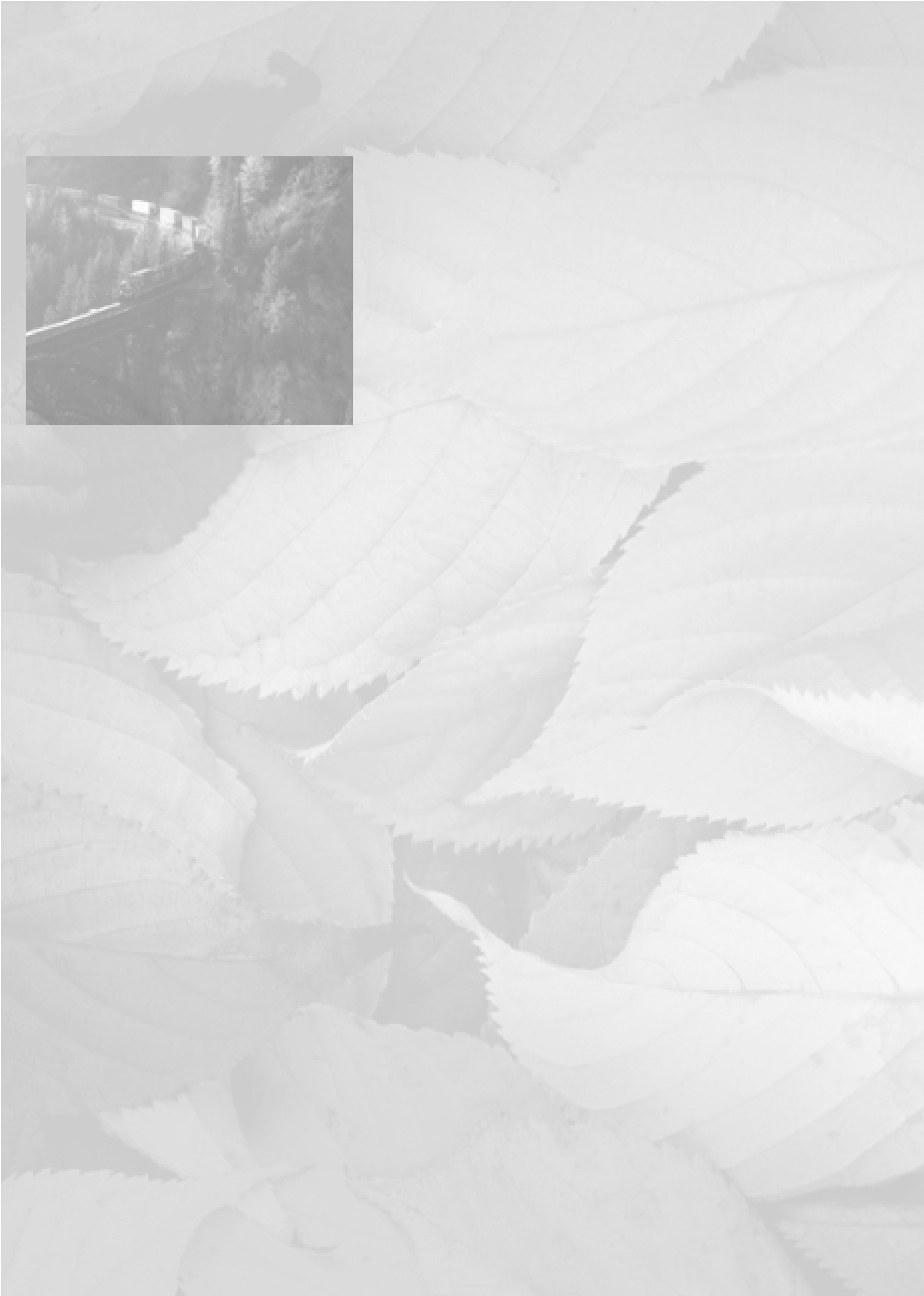


Figure 5: Freight Locomotive Emissions Data - NO_x & CO_2 kilograms / 1000 NTM





3.0 Fuel Consumption and Emissions in Tropospheric Ozone Management Areas (TOMAs) during 1999 and 2000

3.1 Annual Data

Three Tropospheric Ozone Management Areas (TOMAs) have been designated as being of particular interest for gaseous emissions. These areas, and the sections of the several railways that operate within them, are shown in Appendix I.

The fuel consumption in these areas is derived from a knowledge of the total traffic in the areas, expressed in gross ton-miles, as a proportion of the total rail traffic in Canada. The emissions are then calculated using the established factors for the various gases.

The results for the three TOMAs are shown in Tables 3a and 3b. The fuel used in the TOMAs is also shown as a percentage of the total fuel consumption in all rail operations. The fuel consumption in the three TOMAs expressed as a percentage of the total fuel consumption of the railways in Canada is shown in the table below.

The balance of the total fuel consumption in each of the years, i.e., 80.84%, 80.12%, 80.91%, 79.35%, 78.52%, and 78.51%, was used outside of the three TOMAs, across the rest of the country. The resulting emissions were therefore spread widely over areas with a relatively low population density.

3.2 Seasonal Data

The emissions in the TOMAs during 1999 and 2000, as specified in the initiating Memorandum of Understanding, have been divided into those in two seasonal periods:

- winter (7 months), January to April and October to December inclusively; and
- summer (5 months), May to September inclusively.

The division of traffic by winter/summer periods was received from the major railways for their entire systems. The division of traffic in the TOMAs in the seasonal periods was then taken as equal to that on the whole system for each railway. As the split was very close to the proportion of days in the periods, the latter ratio was used for the smaller railways for which no seasonal traffic data were received.

The fuel consumption in each TOMA was therefore divided in the proportion derived for the traffic on each railway, except in the case of GO Transit in TOMA No. 2, where the actual seasonal fuel consumption data were available. The emissions in the seasonal periods were then calculated as before, the results being shown in Tables 3a and 3b.

Percentage of Total Fuel Consumption of Railways in Canada

Year		1995	1996	1997	1998	1999	2000
TOMA No. 1	Lower Fraser Valley, B.C.	4.27	4.42	4.17	4.26	4.24	4.02
TOMA No. 2	Windsor–Quebec City Corridor	14.78	15.33	14.83	16.29	17.13	17.35
TOMA No. 3	Saint John area, N.B.	0.11	0.13	0.09	0.10	0.11	0.12

Table 3a: Tropospheric Ozone Management Areas – Traffic, Fuel and Emissions Data, 1999

TOMA					No.1 LOWER FRASER VALLEY, B.C.			No.2 WINDSOR–QUEBEC CITY			No.3 SAINT JOHN, N.B., AREA		
GROSS TON-MILES						SEASONAL SPLIT Winter	SEASONAL SPLIT Summer		SEASONAL SPLIT Winter	SEASONAL SPLIT Summer		SEASONAL SPLIT Winter	SEASONAL SPLIT Summer
CN				million gtm	6 453.102	58.53%	41.47%	37 800.851	58.53%	41.47%	357.348	58.53%	41.47%
CP				million gtm	9 275.067	58.41%	41.59%	18 150.540	58.41%	41.59%			
B.C. RAIL *				million gtm	279.063	58.08%	41.92%						
BURLINGTON NORTHERN SANTA FE RAILROAD				million gtm	300.000	58.08%	41.92%						
SOUTHERN RAILWAY OF B. C.				million gtm	127.600	58.08%	41.92%						
GO TRANSIT****				million gtm					60.24%	39.76%			
ESSEX TERMINAL RAILWAY				million gtm				20.100	58.08%	41.92%			
GODERICH - EXETER RAILWAY				million gtm				59.000	58.08%	41.92%			
CSX				million gtm				184.628	58.08%	41.92%			
CONRAIL				million gtm				0.000	58.08%	41.92%			
SO. ONT.-RAILINK				million gtm				135.194	58.08%	41.92%			
NORFOLK SOUTHERN				million gtm				590.741	58.08%	41.92%			
OTTAWA VALLEY - RAILINK**				million gtm				398.808	58.08%	41.92%			
QUEBEC GATINEAU				million gtm				663.462	58.08%	41.92%			
QUEBEC SOUTHERN				million gtm				47.600	58.08%	41.92%			
ST. LAWRENCE & ATLANTIC				million gtm				66.455	58.08%	41.92%			
N.B. SOUTHERN RAILWAY				million gtm							80.000	58.08%	41.92%
TOTAL FREIGHT				million gtm	16 434.832			58 117.379			437.348		
VIA				million gtm	50.778	58.08%	41.92%	1 533.403	58.08%	41.92%			
FUEL CONSUMPTION													
FUEL RATE - FREIGHT SERVICE				Imp. gal. per 1000 gtm	1.0964			1.0964			1.0964		
FUEL RATE - PASSENGER SERVICE				Imp. gal. per 1000 gtm	3.55			3.55			3.55		
FREIGHT FUEL CONSUMPTION IN TOMA				million Imp. gal.	18.019	10.531	7.488	63.720	37.261	26.459	0.480	0.280	0.199
VIA FUEL CONSUMPTION IN TOMA				million Imp. gal.	0.180	0.105	0.076	5.444	3.162	2.282	0.000	0.000	0.000
GO TRANSIT				million Imp. gal.				4.398	2.649	1.749			
TOTAL FUEL CONSUMPTION IN TOMA				million Imp. gal.	18.199	10.636	7.564	73.561	43.072	30.490	0.480	0.280	0.199
CANADIAN TOTAL FUEL CONSUMPTION				million Imp. gal.	429.484			429.484			429.484		
TOMA FUEL CONSUMPTION AS % CANADIAN TOTAL					4.24%			17.13%			0.11%		
EMISSIONS	EMISSIONS FACTORS STANDARD g/Imp. gal.	EMISSIONS FACTORS YARD g/Imp. gal.	EMISSIONS FACTORS COMBINED*** g/Imp. gal.										
OXIDES OF NITROGEN (NO_x)	248.3	277	250.0	kilotonnes	4.55	2.66	1.89	18.39	10.77	7.62	0.12	0.07	0.05
CARBON MONOXIDE (CO)	47.7	47.3	47.7	kilotonnes	0.87	0.51	0.36	3.51	2.05	1.45	0.02	0.01	0.01
HYDROCARBONS (HC)	12.4	16.4	12.6	kilotonnes	0.23	0.13	0.10	0.93	0.54	0.39	0.01	0.00	0.00
SULPHUR OXIDES (SO_x)	11.5	11.5	11.5	kilotonnes	0.21	0.12	0.09	0.85	0.50	0.35	0.01	0.00	0.00
PARTICULATE MATTER (PM)	5.9	6.7	5.9	kilotonnes	0.11	0.06	0.04	0.44	0.26	0.18	0.00	0.00	0.00
CARBON DIOXIDE (CO_2)	12 300	12 300	12 300	kilotonnes	223.85	130.82	93.03	904.81	529.78	375.02	5.90	3.45	2.45

Notes:

* B.C. RAIL gtm for TOMA No. 1 derived as % length of line in TOMA No. 1 of total line length.

** Gtm included in CP value.

*** Combined emission factors derived from standard & yard factors with fuel consumption data from Table 1d.

**** Seasonal split data are of fuel used.

Table 3b: Tropospheric Ozone Management Areas – Traffic, Fuel and Emissions Data, 2000

TOMA					No.1 LOWER FRASER VALLEY, B.C.			No.2 WINDSOR–QUEBEC CITY			No.3 SAINT JOHN, N.B., AREA		
GROSS TON-MILES						SEASONAL SPLIT Winter	SEASONAL SPLIT Summer		SEASONAL SPLIT Winter	SEASONAL SPLIT Summer		SEASONAL SPLIT Winter	SEASONAL SPLIT Summer
CN				million gtm	5 361.248	59.35%	40.65%	40 093.709	59.35%	40.65%	410.381	59.35%	40.65%
CP				million gtm	10 015.964	58.88%	41.12%	17 725.020	58.88%	41.12%			
B.C. RAIL *				million gtm	267.420	58.20%	41.80%						
BURLINGTON NORTHERN SANTA FE RAILROAD				million gtm	254.165	58.20%	41.80%						
SOUTHERN RAILWAY OF B. C.				million gtm	55.506	58.20%	41.80%						
GO TRANSIT****				million gtm					58.08%	41.92%			
ESSEX TERMINAL RAILWAY				million gtm				27.897	58.20%	41.80%			
GODERICH - EXETER RAILWAY				million gtm				59.000	58.20%	41.80%			
CSX				million gtm				162.758	58.20%	41.80%			
CONRAIL				million gtm									
SO. ONT.-RAILINK				million gtm				326.120	58.20%	41.80%			
NORFOLK SOUTHERN				million gtm				354.445	58.20%	41.80%			
OTTAWA VALLEY - RAILINK**				million gtm					58.20%	41.80%			
QUEBEC GATINEAU				million gtm				810.127	58.20%	41.80%			
QUEBEC SOUTHERN				million gtm				47.600	58.20%	41.80%			
ST. LAWRENCE & ATLANTIC				million gtm				70.224	58.20%	41.80%			
N.B. SOUTHERN RAILWAY				million gtm							80.000	58.20%	41.80%
TOTAL FREIGHT				million gtm	15 954.303			59 676.900			490.381		
VIA				million gtm	56.117	58.20%	41.80%	1 666.012	58.20%	41.80%			
FUEL CONSUMPTION													
FUEL RATE - FREIGHT SERVICE				Imp. gal. per 1000 gtm	1.0565			1.0565			1.0565		
FUEL RATE - PASSENGER SERVICE				Imp. gal. per 1000 gtm	3.55			3.55			3.55		
FREIGHT FUEL CONSUMPTION IN TOMA				million Imp. gal.	16.856	9.947	6.909	63.049	37.309	25.740	0.518	0.307	0.212
VIA FUEL CONSUMPTION IN TOMA				million Imp. gal.	0.199	0.116	0.083	5.914	3.442	2.472	0.000	0.000	0.000
GO TRANSIT				million Imp. gal.				4.672	2.714	1.959			
TOTAL FUEL CONSUMPTION IN TOMA				million Imp. gal.	17.055	10.063	6.992	73.635	43.465	30.171	0.518	0.307	0.212
CANADIAN TOTAL FUEL CONSUMPTION				million Imp. gal.	424.450			424.450			424.450		
TOMA FUEL CONSUMPTION AS % CANADIAN TOTAL					4.02%			17.35%			0.12%		
EMISSIONS	EMISSIONS FACTORS												
	STANDARD	YARD	COMBINED***										
	g/Imp. gal.	g/Imp. gal.	g/Imp. gal.										
OXIDES OF NITROGEN (NO_x)	248.3	277	250.0	kilotonnes	4.26	2.52	1.75	18.41	10.87	7.54	0.13	0.08	0.05
CARBON MONOXIDE (CO)	47.7	47.3	47.7	kilotonnes	0.81	0.48	0.33	3.51	2.07	1.44	0.02	0.01	0.01
HYDROCARBONS (HC)	12.4	16.4	12.6	kilotonnes	0.22	0.13	0.09	0.93	0.55	0.38	0.01	0.00	0.00
SULPHUR OXIDES (SO_x)	11.5	11.5	11.5	kilotonnes	0.20	0.12	0.08	0.85	0.50	0.35	0.01	0.00	0.00
PARTICULATE MATTER (PM)	5.9	6.7	5.9	kilotonnes	0.10	0.06	0.04	0.44	0.26	0.18	0.00	0.00	0.00
CARBON DIOXIDE (CO_2)	12 300	12 300	12 300	kilotonnes	209.78	123.78	86.00	905.72	534.62	371.10	6.37	3.77	2.60

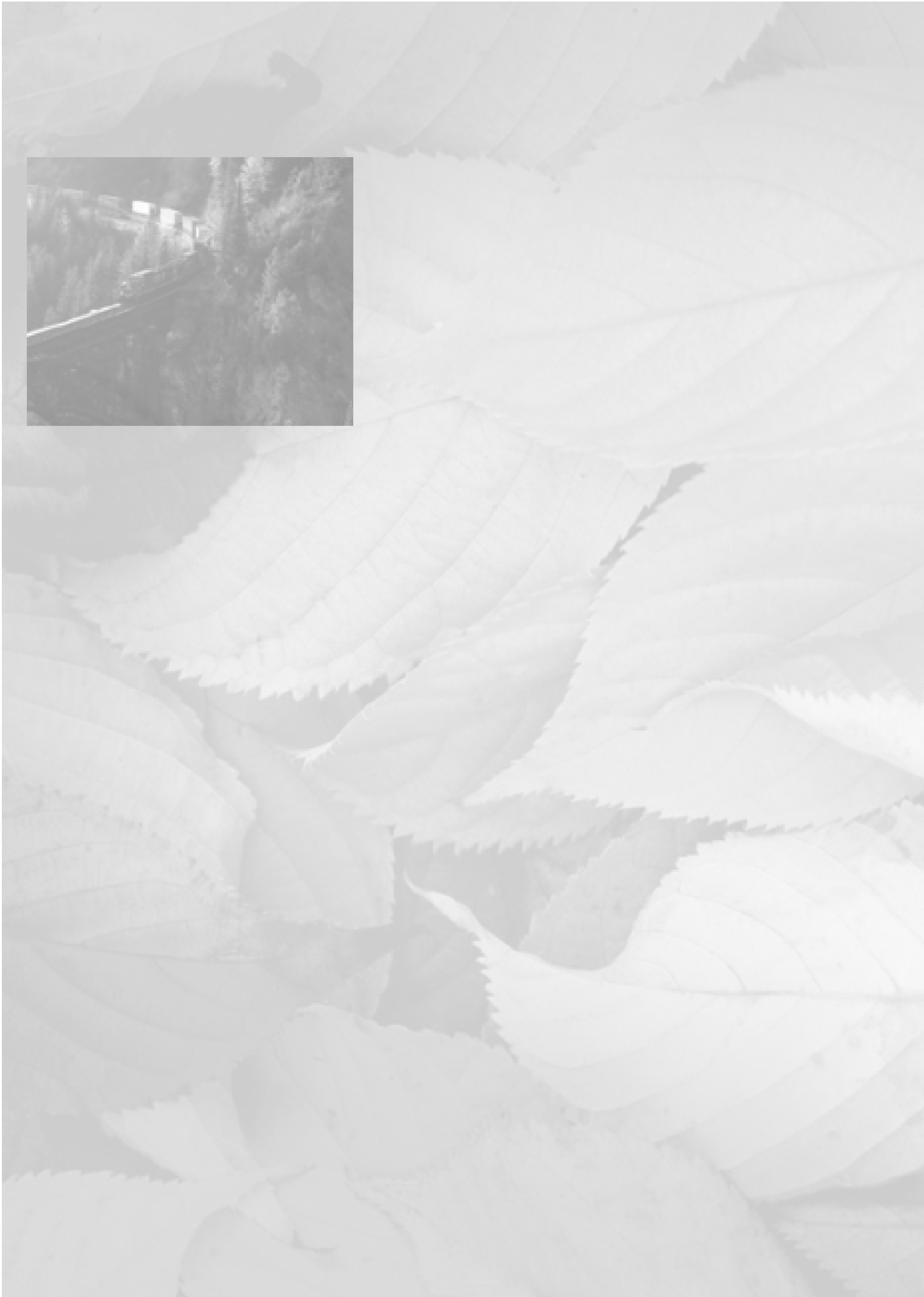
Notes:

* B.C. RAIL gtm for TOMA No. 1 derived as % length of line in TOMA No. 1 of total line length.

** Gtm included in CP value.

*** Combined emission factors derived from standard & yard factors with fuel consumption data from Table 1d.

**** Seasonal split data are of fuel used.



4.0 Locomotive Fleet

4.1 Composition

The composition of the Canadian locomotive fleet as of the end of 1999 and 2000 is shown in Tables 4a and 4b (mainline and branchline) and Tables 5a and 5b (yard and switching).

4.2 Locomotive Fleet Upgrade

New locomotives that are being introduced by the Canadian railways to replace older units have improved emission characteristics. The concentration of oxides of nitrogen in the exhaust gases of the diesel engines is similar to that of older locomotives, but a significant reduction in the overall fuel consumption of the locomotives is obtained. This means that the amount of fuel used to move the trains is reduced, and hence the amount of nitrogen oxides and carbon dioxide emitted is also significantly reduced.

The effects of this progressive change are seen in the accelerated downward trend, in 1998, 1999, and 2000, in the curves of fuel consumption per 1000 gross ton-miles and per 1000 net ton-miles, plotted in Figure 3. The emissions of the several exhaust constituents also show a continued downward trend, as seen in Figures 4 and 5 for nitrogen oxides and carbon dioxide.

Table 4a: Canadian Locomotive Fleet – Mainline and Branchline, 1999

BUILDER	ENGINE MODEL	HP	YEAR	TOTAL	CN	CP	VIA	BC RAIL	GO TRANSIT	TOTAL OTHER
GM/EMD	16V-265H	6000	'99	4		4				0
	20V-645E3	3600		6						6
	16V-710G3C	4300	'96-'99	241	174	61				6
	16V-710G3B	4000	'95	26	26					0
	16V-710G3	3800	'85-89	63	63					0
	12V-710G3 or 710G3A	3000	'88-'95	45					45	0
	16V-645F3B	3600	'85-'94	66	60					6
	16V-645E3B	3000	'85-'87	23				23		0
	16V-645E3C	3000		57			57			0
	16V-645E3M	3000	'88	25		25				0
	16V-645E3	3000	'66-'80	1 014	479	483		6		46
	16V-645D3A	2250	'64-'66	5						5
	16V-645D3	2250	'63	0						0
	CAT 3516	2075	'94	0						0
SUBTOTAL				1575	802	573	57	29	45	69
MLW	16V-251F	3700	'70-'84	7			7			0
	16V-251F	3600	'69-'82	24						24
	16V-251E	3000	67-'76	1						1
	16V-251B	2400	'63-'66	2						2
SUBTOTAL				34	0	0	7	0	0	27
GE	16V-7FDL-16	4400	'94-'95	302	103	184		4		11
	16V-7FDL-16	4000	'90-'94	84	55			26		3
	16V-FDL16	3900	'88	3				3		0
	16V-FDL16	3600	'80	6				6		0
	16V-FDL16	3200		15				15		0
	12V-FDL12	2250	'89-'90	3						3
SUBTOTAL				413	158	184	0	54	0	17
BUDD-RDC	DD 6-110	550	'55-'58	21			6	9		6
TOTAL MAINLINE & BRANCHLINE:				2 043	960	757	70	92	45	119

Table 4b: Canadian Locomotive Fleet – Mainline and Branchline, 2000

BUILDER	ENGINE MODEL	HP	YEAR	TOTAL	CN	CP	VIA	BC RAIL	GO TRANSIT	TOTAL OTHER
GM/EMD	16V-265H	6000	'99	4		4				0
	20V-645E3	3600		11						11
	16V-710G3C	4300	'96-'99	240	173	61				6
	16V-710G3B	4000	'95	0						0
	16V-710G3	3800	'85-89	63	63					0
	12V-710G3 or 710G3A	3000	'88-'95	52					45	7
	16V-645F3B	3600	'85-'94	64	60					4
	16V-645E3B	3000	'85-'87	23				23		0
	16V-645E3C	3000		54			54			0
	16V-645E3M	3000	'88	0						0
	16V-645E3	3000	'66-'80	940	393	491				56
	16V-645D3A	2250	'64-'66	16						16
	16V-645D3	2250	'63	0						0
	CAT 3516	2075	'94	3						3
SUBTOTAL				1 470	689	556	54	23	45	103
MLW	16V-251F	3700	'70-'84	7			7			0
	16V-251F	3600	'69-'82	23						23
	16V-251E	3000	67-'76	1						1
SUBTOTAL				31	0	0	7	0	0	24
GE	16V-7FDL-16	4400	'94-'98	352	143	184		14		11
	16V-7FDL-16	4000	'90-'94	84	55			26		3
	16V-FDL16	3900	'88	0						0
	16V-FDL16	3600	'80	12				12		0
	16V-FDL16	3200		15				15		0
	12V-FDL12	2250	'89-'90	3						3
SUBTOTAL				466	198	184	0	67	0	17
BUDD-RDC	DD 6-110	550	'55-'58	24		2	7	9		6
TOTAL MAINLINE & BRANCHLINE:				1 991	887	742	68	99	45	150

Table 5a: Canadian Locomotive Fleet – Yard & Switching & Grand Total, 1999

BUILDER	ENGINE MODEL	HP	YEAR	TOTAL	CN	CP	VIA	BC RAIL	GO TRANSIT	TOTAL OTHER
GM/EMD	16V-645E	2000	'71-'75,'86	292	110	129				53
	16V-645C	1800	'54-'67	208	204					4
	16V-645C	1750	'75-'81	202		195	7			0
	16V-645C	1500	'81-'94	16		16				0
	16V-645D	1500	'52	0						0
	16V-567C	1750	'51-'63	83		3				80
	16V-567B	1500	'51-'52,'78	12						12
	12V-645E	1500	'71-'80	10						10
	12V-645C	1350	'87-'89	8	8					0
	12V-645C	1200	'81-'85	64	56	8				0
	12V-567C	1200	'55-'60	69	18	39				12
	8V-645E	1000	'66-'67	2			2			0
	8V-645C	1000	'67-'69	0						0
	8V-567C	900	'51-'64	13		1				12
	8V-567B	800	'51-'54	1						1
	CAT3512	2000	90-'91	3						3
SUBTOTAL				983	396	391	9	0	0	187
MLW	12V-251C3	2000	'73-'81	4						4
	12V-251C	2000	'64-'76	25				4		21
	12V-251C	1800	'66	2				2		0
	12V-251B	1800	'56-'65	50						50
	12V-251B	1400	'59-'60	0						0
	6I-251B/C	1000	'59-'60	12						12
										0
	CAT 12V-3512	2000		27				27		0
SUBTOTAL				120	0	0	0	33	0	87
TOTAL - YARD & SWITCHING:				1 103	396	391	9	33	0	274
GRAND TOTAL - MAINLINE, BRANCHLINE, YARD and SWITCHING:				3 146	1356	1 148	79	125	45	393

Table 5b: Canadian Locomotive Fleet – Yard & Switching & Grand Total, 2000

BUILDER	ENGINE MODEL	HP	YEAR	TOTAL	CN	CP	VIA	BC RAIL	GO TRANSIT	TOTAL OTHER
GM/EMD	16V-645E	2000	'71-'75,'86	295	110	129				56
	16V-645C	1800	'54-'67	199	188		7			4
	16V-645C	1750	'75-'81	5						5
	16V-645C	1500	'81-'94	0						0
	16V-645D	1500	'52	0						0
	16V-567C	1750	'51-'63	259		197				62
	16V-567B	1500	'51-'52,'78	30		17				13
	12V-645E	1500	'71-'80	11						11
	12V-645C	1350	'87-'89	3						3
	12V-645C	1200	'81-'85	58	50	8				0
	12V-567C	1200	'55-'60	62	13	39				10
	8V-645E	1000	'66-'67	2			2			0
	8V-645C	1000	'67-'69	0						0
	8V-567C	900	'51-'64	14		2				12
	8V-567B	800	'51-'54	0						0
	CAT3512	2000	90-'91	27				27		0
SUBTOTAL				965	361	392	9	27	0	176
MLW	12V-251C3	2000	'73-'81	12						12
	12V-251C	2000	'64-'76	20				4		16
	12V-251C	1800	'66	2				2		0
	12V-251B	1800	'56-'65	28						28
	12V-251B	1400	'59-'60	24						24
	6I-251B/C	1000	'59-'60	34						34
	CAT 12V-3512	2000		0						0
SUBTOTAL				120	0	0	0	6	0	114
TOTAL - YARD & SWITCHING:				1 085	361	392	9	33	0	290
GRAND TOTAL - MAINLINE, BRANCHLINE, YARD and SWITCHING:				3 076	1 248	1 134	77	132	45	440

5.0 Operational Improvements

5.1 Train Handling Practices

The proportion of mainline locomotives fitted with dynamic brake equipment continues to increase. This allows the increased use of the dynamic brake for control of train speed rather than the use of the air brake system. As the latter does not allow the locomotive engineer to reduce the severity of a brake application already in force, it is frequently necessary to apply power at the same time as the brakes to maintain speed over variable track grades. This causes the fuel consumption to be increased significantly. When the dynamic brake is used to control speed, the severity of the application can be varied at will, and the fuel consumption is not significantly increased.

5.2 Rail Gauge Face Lubrication

The railways have continuing programs to ensure that the system of track-mounted rail lubricators is maintained in good operating condition. Railways that have applied on-board locomotive wheel flange lubricators also have programs to keep these in working order. Efficient rail gauge face lubrication has been shown in many tests to reduce fuel consumption.

5.3 Freight Car Productivity Improvement

The maximum allowable axle load has been increased on many lines in Canada. This enables the railways to use certain cars with a gross weight on rail of up to 286 000 lb. instead of 263 000 lb. The gross to tare ratio of such freight cars is increased so that the quantity of gross ton-miles accumulated to move a given amount of freight is reduced, contributing to the improvement in the ratio of net ton-miles to gross ton-miles forecast in Section 2.1 above and confirmed in Figure 1. The productivity improvement and the associated reduction in emissions are expected to continue.

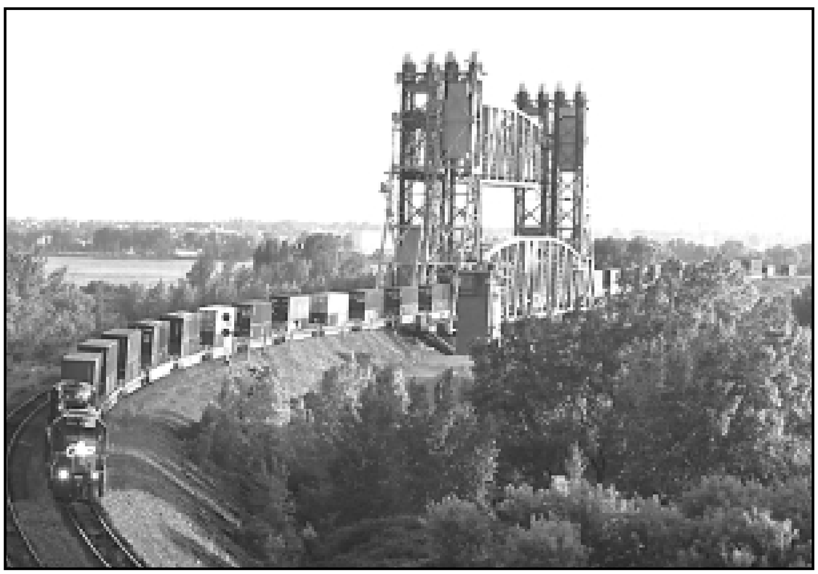
6.0 Improvements to Existing Locomotives

6.1 Low Idle Applications

The railways are extending the application of the "low idle" feature to more mainline locomotives. This feature allows the diesel engine to idle at a reduced speed with a consequently reduced load from fans and internal windage losses. The reduction in fuel consumption can be as much as 2 gallons per hour — as much as 3% of the annual fuel consumption on the accepted duty cycles. The use of the low idle feature is limited in some cases by the ability of the auxiliary power system to generate sufficient power for battery charging. However, a continued reduction in overall fuel consumption is expected from this feature.

6.2 Automatic Start/Stop Systems

Railways are installing devices on switching locomotives that will automatically shut down and restart the diesel engine when the locomotive is not in use. The device is regulated by several locomotive system parameters, such as water temperature and battery condition. It will restart the engine to idle for a time to prevent freezing and to charge the batteries. The railways now have a policy of shutting down unused engines when ambient temperatures permit; the so-called "Smart Start" systems will allow this practice to be extended all year.



7.0 Emissions Performance Data

No new emissions data have been made available to the industry by the AAR or by the manufacturers that will significantly change the calculations and projections in this report.

8.0 Diesel Fuel Properties

The rail industry uses diesel fuel that complies with the existing engine builder requirement of an average sulphur content of no greater than 5000 ppm. In general, the rail industry uses fuel with a much lower average sulphur content of approximately 1500 ppm. The industry is committed to making its best effort to use even lower sulphur content diesel fuel in the near future. Discussions with the fuel procurement officers in the major railways have been initiated with a view to purchasing low-sulphur diesel fuel from refiners that can guarantee to supply the low-sulphur fuel without a price premium. This is consistent with the rail industry's ongoing commitment to reduce both its greenhouse gas emissions through reduced fuel consumption and the sector's exhaust emissions through the introduction of Environmental Protection Agency Tier 0 and Tier 1 compliant locomotives, operational efficiencies, and the latest available technologies designed to increase tractive efficiency and to yield performance gains.

9.0 Observations and Conclusions

It has been observed, as shown in Figure 4, that the emissions of nitrogen oxides in 1999 and 2000 were below the voluntary cap of 115 kilotonnes per year by 6.8% and 5.0%, respectively, and that the average emission level since 1990 was below the cap level by 0.5% and 0.9%, respectively. It was previously shown that, because the rates of emissions of nitrogen oxides per gross and net ton-mile in the period from 1994 to 1997 were reduced at a rate slightly better than forecast (see Tables 2a, 2b, 2c, and 2d and Figure 5, the higher values of emissions in that period were the result of the increase in traffic level being significantly greater than forecast. The continued improvement in 1998, 1999, and 2000 shows the beneficial effect of the introduction of new, more efficient locomotives into the fleet.

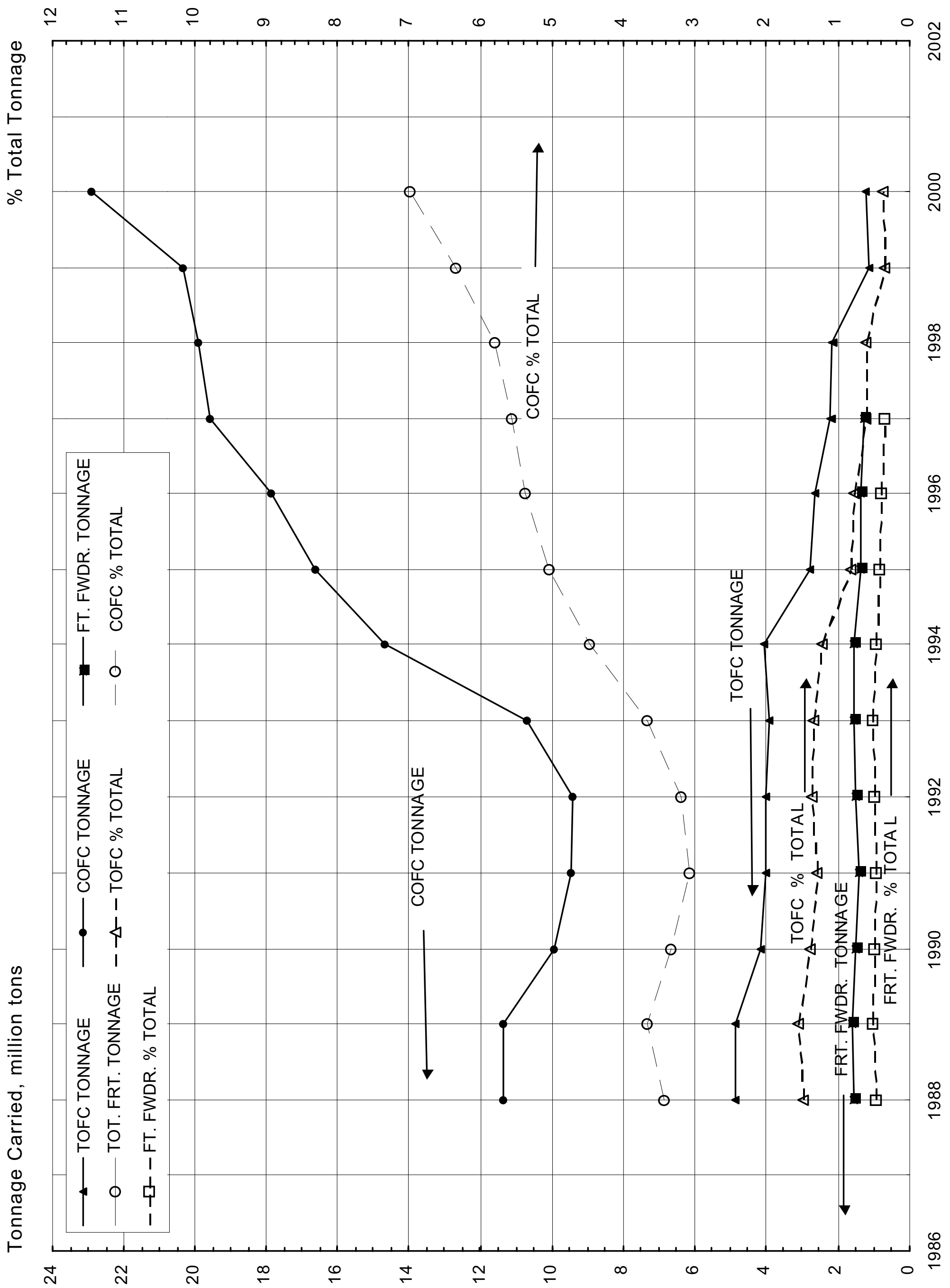
The rates of emission of nitrogen oxides and carbon dioxide in kilograms per 1000 net ton-mile, shown in Figure 5, have continued to decrease since the late 1970s. The rate of decrease, which since 1990 had closely followed the forecast, increased markedly in 1998, 1999, and 2000, showing the effects of the continual improvement in the efficiency of rail transportation.

One area of traffic growth continues to be in the movement of containers. Figure 6 shows the tonnage of intermodal traffic on Canadian railways from 1988 to 2000. The recent increase in container handling is clear, both in absolute terms and as a percentage of total tonnage moved. This portion of traffic increase is considered to be extremely sensitive to highway competition. If it were to be moved over the highway, then the associated emissions of the contaminants under examination would be increased by a factor of at least three times.

Traffic levels will continue to be followed to determine if the recent accelerated increase in rail traffic is short term or representative of a higher rate of growth. If the latter case prevails, then consideration should be given to the revision of the measure by which improvements are monitored. This concept was recognized in the Environment Canada report, "Recommended Reporting Requirements for the Locomotive Emissions Monitoring (LEM) Program."[6]
This revision would be based on the division of traffic between modes of transport. It would give credit for the net reduction in emissions resulting from a diversion of traffic from the highway to the railways or for the avoidance of adding traffic to the highway mode.

6 Environment Canada, Environmental Protection series, Report EPS 2/TS/8, September 1994, p. 21, section 4.6, Industry – Use, Growth, Performance.

Figure 6: Intermodal Freight Traffic Data



10.0 Summary

The railway industry in Canada continues its long-term trend of improving the efficiency of its operations, including fuel consumption and emissions. The railway mode should be viewed as an integral part of the solution to Canada's transportation needs. The attainment of these needs should put a premium on modes with net benefits in environment, safety, land usage, and cost effectiveness.

Appendix I: 1999

Railway Lines Included in Tropospheric Ozone Management Areas (TOMAs)

TOMA No. 1: Lower Fraser Valley, British Columbia

CP Rail System

Division	Subdivisions
Vancouver	Cascade
	Mission
	Page
	Westminster
	Marpole

Canadian National Railway

District	Subdivisions
Pacific	B.C. Harbour
	B.C. Hydro
	Rawlison
	Yale

B.C. Rail	3.07% of total
Burlington Northern Railroad	All
Southern Railway of British Columbia Ltd.	All

TOMA No. 2: Windsor–Quebec City Corridor, Ontario and Quebec

CP Rail System

Division	Subdivisions	Remarks
Quebec	All, Less:	
	Sherbrooke	
Toronto	All, Less:	
	Mactier	Medonte – Mactier
	Owen Sound	Shelburn – Owen Sound
Algoma	Chalk River	Smiths Falls – Arnprior

TOMA No. 3: Saint John area, New Brunswick

Canadian National Railway

District	Subdivisions
Champlain	Denison
	Sussex

New Brunswick Southern

Division	Subdivision	Remarks
	McAdam	Saint John – Welsford

Canadian National Railway

Note: The ownership of some subdivisions was in the process of being transferred to other railway operators. Traffic, in gross ton-miles, on such lines was included in the CN total for the TOMA.

District: Champlain

Subdivisions		
Becancour	Joliette	St. Claire
Bridge	Montfort	St. Hyacinthe
Champlain	Montreal	St. Laurent
Diamond	Mount Royal	St. Malo
Drummondville	Rouses Point	St. Remi
Freight Con	Sorel	Valleyfield

District: Great Lakes

Subdivisions		
Alexandria	Humberstone	Strathroy
Caso	Kingston	Talbot
Chatham	Leamington	Thorold
Dundas	Oakville	Uxbridge
Grimsby	Paynes	Weston
Halton	Stamford	York

Essex Terminal Railway	All
Goderich – Exeter Railway	All
CSX	All
Norfolk Southern	All
Ottawa Valley – RaiLink	Part
Quebec – Gatineau	All
Quebec – Southern	All
So. Ont. – RaiLink	All
St. Lawrence & Atlantic	All

Appendix I: 2000

Railway Lines Included in Tropospheric Ozone Management Areas (TOMAs)

TOMA No. 1: Lower Fraser Valley, British Columbia

CP Rail System

Division	Subdivisions
Vancouver	Cascade
	Mission
	Page

Canadian National Railway

District	Subdivisions
Pacific	Rawlison
	Yale

B.C. Rail	3.07% of total
Burlington Northern Railroad	All
Southern Railway of British Columbia Ltd.	All

TOMA No. 2: Windsor–Quebec City Corridor, Ontario and Quebec

CP Rail System

Division	Subdivisions	Remarks
SLH Quebec	All	
SLH Ontario	All	
Northern Ontario	Chalk River	Smiths Falls – Arnprior

TOMA No. 3: Saint John area, New Brunswick

Canadian National Railway

District	Subdivisions
Champlain	Denison
	Sussex

New Brunswick Southern

Division	Subdivision	Remarks
	McAdam	Saint John – Welsford

Canadian National Railway

District: Champlain

Subdivisions

Becancour	Joliette	St. Laurent
Bridge	Montreal	Valleyfield
Deux-Montagnes	Rouses Point	
Drummondville	Sorel	
Freight Con	St. Hyacinthe	

District: Great Lakes

Subdivisions

Alexandria	Halton	Uxbridge
Caso	Kingston	Weston
Chatham	Oakville	York
Dundas	Paynes	
Grimsby	Strathroy	
Guelph	Talbot	

Essex Terminal Railway	All
Goderich – Exeter Railway	All
CSX	All
Norfolk Southern	All
Ottawa Valley – RaiLink	Part
Quebec – Gatineau	All
Quebec – Southern	All
So. Ont. – RaiLink	All
St. Lawrence & Atlantic	All