VOLUNTARY MEASURES
ENERGY EFFICIENCY STUDY

December 1995

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1.0 INDUSTRY UNTRODUCTION

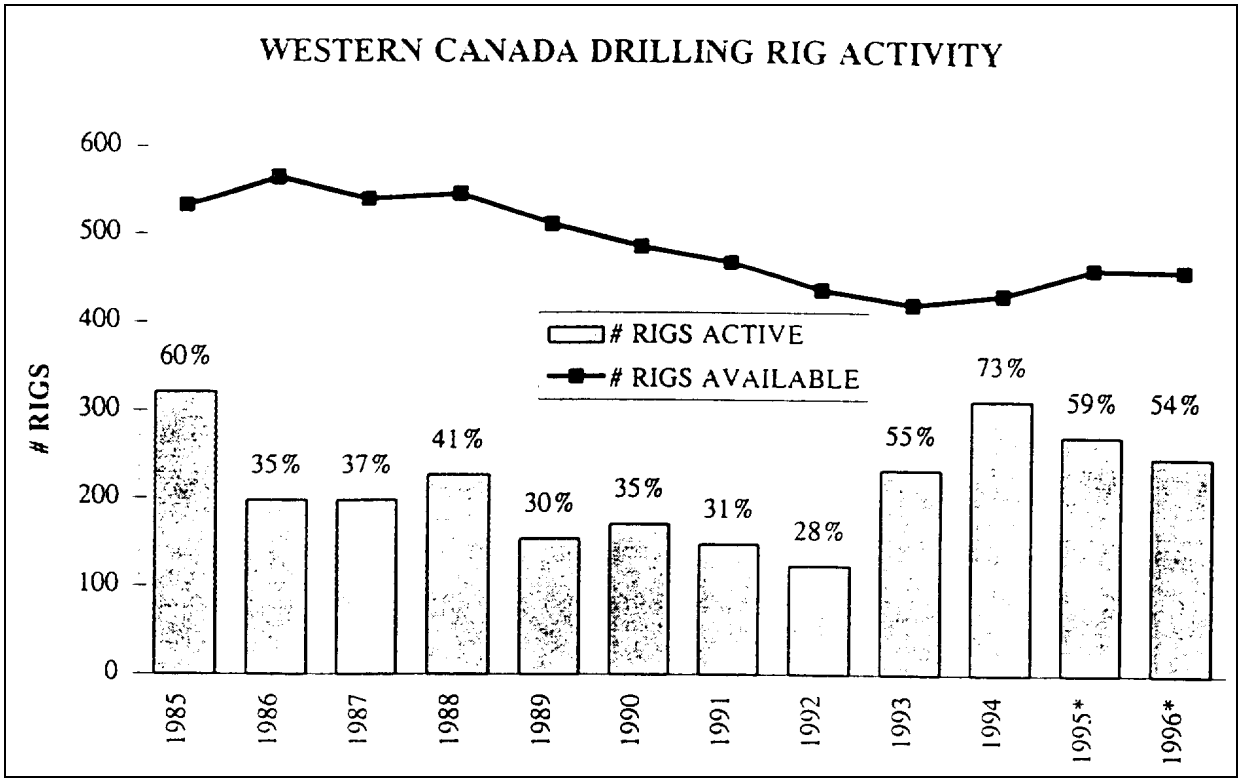
The Canadian Association of Oilwell Drilling Contractors (CAODC) represents the interests of the drilling and well servicing contractors in Canada. The drilling and well servicing industry is composed of 41 drilling and approximately 60 service rig contractors that operate over 1000 rigs, primarily in Western Canada.

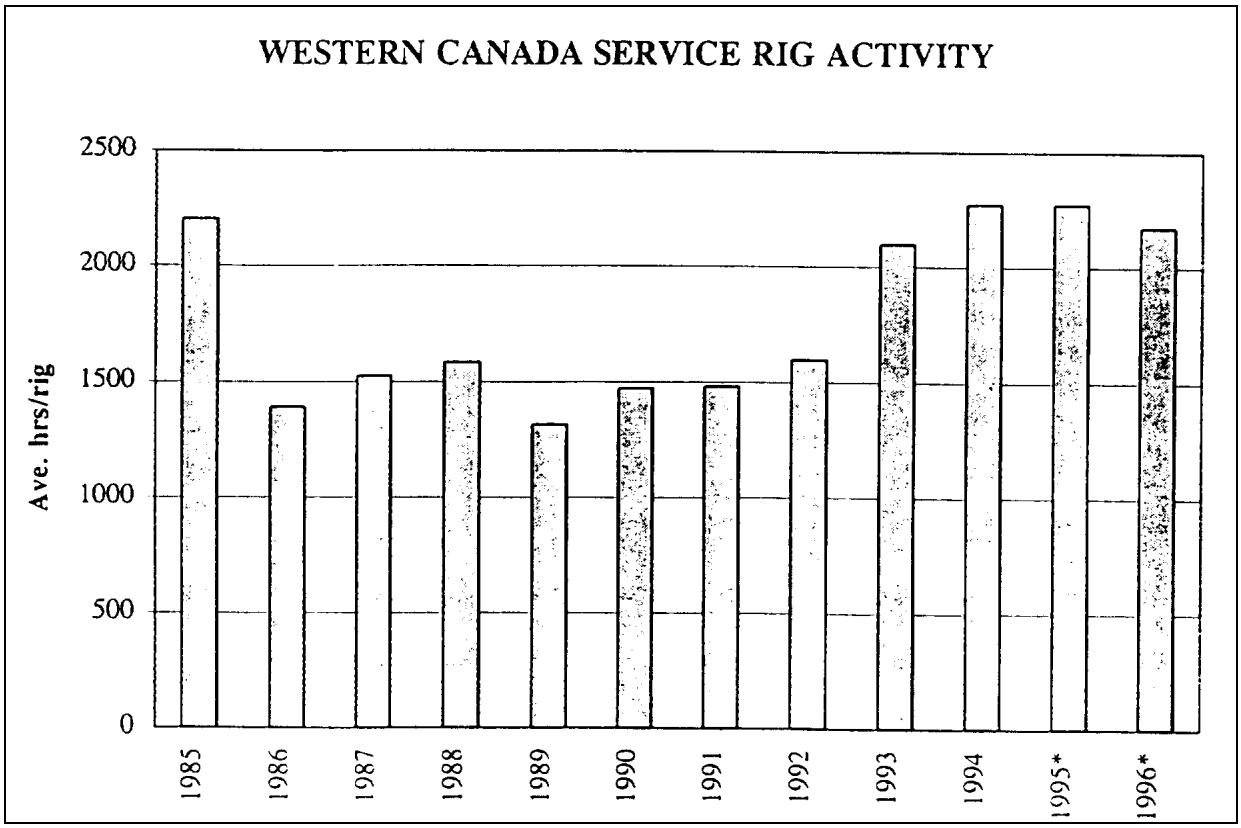
Drilling and well servicing contractors play a key role in the exploration and development of petroleum resources in Canada. Drilling contractors carry out the oil and gas well drilling operation under contract from various oil and gas companies. Well servicing contractors bring new wells into production and conduct workovers and maintenance on older wells to keep them producing efficiently.

Drilling and service rig activity generates a significant level of employment within the upstream oil and gas industry. Every drilling rig that is working in supports 75 direct field jobs, including contractor rig personnel, as well as a multitude of supply and service jobs required to support and enhance drilling operations. In 1994, there was an average of 213,400 people employed in drilling attributable field work, with payroll receipts in excess of one billion dollars.

The oil and gas industry has historically been cyclical. Over the last 15 years, drilling and well servicing contractors have experienced a full cycle of activity. Drilling contractors require an annualized utilization level of 50% to break even and a higher level to make good returns on investment. Profitability, or return on investment, in the industry has been poor over the last decade, with Just four years above the 50% utilization level. Three of the profitable years have occurred most recently, over the 1993 to 1995 period, allowing contractors to invest in new and improved equipment. Given the current economic fundamentals, the CAODC is forecasting another profitable year in 1996, a sustained level of activity never before experience by the industry and believed to be due primarily to the efficiency of the Canadian industry and the depoliticizing of energy markets.

INDUSTRY ACTIVITY CHARTS
1985 TO 1996





* Denotes Forecast

FORECAST - 1996

October 19, 1995

WESTERN CANADA

QUARTER	ACTIVE RIGS	FLEET	UTILIZATION
1995 - 4th	270	461	59%
1996 - 1st	326	460	71%
1996 - 2nd	160	460	35%
1996 - 3rd	237	460	52%
1996 - 4th	267	460	58%
Average 1996	*248*	*460*	*54%*

1993		1994		1995*	
Drilling	Utilization	Drilling	Utilization	Drilling	Utilization
233	55%	312	72%	272	59%

* Denotes Q1 through Q3 actuals and Q4 forecast.

Assumptions: 9,962 Wells
$17 to $18/bbl (US)
$1.35/mcf (Cdn); (12 months to Nov. 1996)
8.1 days/well

2.0 THE CANADIAN ECONOMY AND GLOBAL WARMING

Canada has a small open economy that is supported by exports and international trade. Due to the size of our population, our domestic market is small and therefore our standard of living is dependent on selling our goods and services internationally and, to do so, we must be internationally competitive. Over the last decade, there has been an increasing debate on the effects of economic activity on the environment, in particular, the use of hydrocarbon fuels and their contribution to global warming. Since this debate is somewhat speculative and may never be fully resolved, there is danger in environmental regulations or taxes that address speculative concerns and unmeasurable outcomes. However, programs that encourage a voluntary approach that work within the realm of ordinary investment, increased efficiency and pollution reduction are far less distorting.

As a statement of principle in this highly competitive global economy, the CAODC does not support the imposition of any tax or fiscal measures chat unnecessarily increase cost and distort the competitiveness and investment decisions of an industry or the economy as a whole. We support the voluntary measures approach initiated by the Canadian Association of Petroleum Producers (CAPP) as the only competitive way to address the concerns that have been raised regarding CO_2 emissions. Voluntary and systematic investment in energy efficiency and emission controls will ensure that targets are met with resources efficiently allocated and global competitiveness maintained. By taking the voluntary route, we can ensure that industry becomes cleaner, investment is not distorted and the economy remains vital.

3.0 THE VOLUNTARY CHALLENGE

The CAODC, in keeping with the spirit of the CAPP Voluntary Challenge Registry Action Plan, has undertaken a survey and study to measure the increased energy efficiency of drilling contractor rig engines and crew trucks. This study is based on survey data from eight drilling contractors (see Appendix III), which at present collectively represent 194 rigs, or 42% of the Canadian fleet, and together amassed 42,920 operating days in 1994. The goal of the study is to demonstrate that the trend toward increased energy efficiency and reduction in energy intensity is apparent in the drilling industry and that this process is a in natural function of technology availability and capital replacement.

4.0 DRILLING RIG ENERGY CONSUMPTION

There are two types of rotatory drilling rigs, mechanical and electric, which come in three basic configurations related primarily to depth capacity. All rigs are powered by industrial engines that provide direct energy and electricity to power the various components of the rig. In many cases, these engines are the same type of engines that power transport trucks and heavy machinery, therefore, the drilling industry's energy use as a whole can be compared to a fleet of highway transport trucks.

When a rig is working, rig engines operate 24 hours a day with their use of fuel depending primarily on the type of well they are drilling (location, depth and diameter) and the geology of the formation. Fuel consumption depends on the horsepower generated with respect to an engine load factor, therefore, more fuel will be required at greater depths because deeper operations generally require more horsepower and higher load factors.

Table 1 - **Daily Operating Fuel Consumption by Depth**

Depth of Well (m)	**0-950**	**951-1400**	**1401-1850**	**1851-2450**	**2451-3050**	**3051-3700**	**3700+**
Fuel (P/day)	1,968	2,368	2,589	2,831	3,141	3,566	4,414

Note:
1. Based on data from the 1995 CAODC Land Drilling Rig Cost Study (LDRCS).

Over the last decade, engine manufacturers have moved toward new electronically controlled engines. By design, these engines are engineered to be more energy efficient and dramatically reduce engine emissions. Electronic engines are controlled by a small computer that, through a complex series of sensors, delivers only the fuel required at the particular moment, thereby eliminating the gusts of black smoke associated with partially combusted fuel apparent in older mechanical engines. As a rule, electronic engines deliver more torque and horsepower for a given amount of fuel and produce far fewer emissions. The stream of benefits this technology can produce for contractors is broad on both an environmental and operating cost basis and will eventually become the standard in the drilling industry, if current investment remains as it is today.

An example of this type of engine is the Detroit Diesel Series 50/Series 60. Initially introduced to the oil and gas industry in 1990, it has increased its presence on drilling rigs within the industry sample measured by this study from three engines in 1991 to 59 in 1995. Caterpillar and other engine

manufacturers are also incorporating electronic engines into their product lines, to replace older engines that were designed in the 1950s and 1960s.

Investment in new engines has been made possible by the increased, sustained activity within the drilling industry over the last three years. Investment is a function of profitability and drilling contractors see emissions reduction and energy efficiency in direct relation to the natural process of reinvestment in new energy efficient, durable technology, as old capital wears out. As industrial engines wear out, contractors are faced with the decision to rebuild the engine or replace it. On the margin, the new technology and better overall industry cash flow slants this decision toward replacement, which has substantial environmental as well as cost implications. Capital replacement will accelerate as more of this technology is adopted in the industry and establishes itself as an industry standard and, perhaps, as a competitive advantage. This study will illustrate that this evolution has substantial implications for energy use and emissions within the drilling industry.

5.0 STUDY METHODOLOGY

The study compares the increase in fuel efficiency of contractor diesel engines and trucks by comparing the average fuel consumption of an inventory of engines and trucks owned by eight contractors in 1991 and 1995. The results are on a "net" basis in that the net change in the quantity of a particular engine variety is aggregated into one of two categories, "Added" "Deleted". As some of the contractors participating in the survey have Crown through acquisition since 1991, the "Added" category contains more engines and trucks than the "Deleted" category. Therefore, the actual reported increase in fuel efficiency may be somewhat low, due to the dilution effect of the additional units but, nevertheless, the increase is significant.

5.1 Rig Engines

There are 40 varieties of engines in this study from two different manufacturers, Detroit Diesel and Caterpillar. As roughly 88% of the engines reported in the survey came from these two manufacturers, for the sake of simplicity, all other engine manufacturers were omitted. The total complement of engines in the study for 1991 and 1995 were 611 and 758, respectively. The net change from 1991 to 1995 was classified into two groups "Added" and "Deleted". Each category was aggregated and then averaged to obtain the overall average fuel consumption per hour. The category average was then calculated through simple averaging of fuel consumption per hour per engine. The engine fuel consumption per hour was obtained using, the following formula:

$$\frac{\text{bhp} \times \text{lbs/hp*hr}}{8.54} = \text{Imp. Gallons/hrs. (Imp. Gallons/hr x 4.54 = litres/hr.)}$$

The data for the formula was obtained using manufacturers' engine performance curves and the engine data was rated using the following specifications:

- where possible engines were rated at 1800 rpm (some older engines were rated at 1200, as they were not designed for 1800 rpm);
- a standard 60% load factor was applied to the rated power at 1800 rpm (or 1200 rpm), given in bhp (brake horsepower); and
- from the fuel curve at 1800 rpm (or 1200 rpm), the specific fuel consumption was recorded (measured in lbs./bhp*hrs.).

The resulting average for each category in imperial gallons per hour was then compared, to realize the overall results (Appendix 1).

5.1a Results

The results are summarized in the following table.

Table 2 - **Rig Engine Study Results**

	Added	**Deleted**
Number of Engines	221	74
Average Imp. Gallons per Hour	7.66	10.85

Improvement in fuel efficiency: 29.4%

5.1b Implications of Results

Industrial engines are durable and last for many years and, until recently, the kind of improvements demonstrated by electronic engines were not available to drilling contractors. The availability was constrained by both technology availability and industry financial limitations. A 29.4% decrease in fuel consumption, for the replaced engines measured by this study, has broad implications if applied across the industry. As this engine technology becomes more integrated into the drilling industry, there will be a substantial reduction in emissions and fuel requirements.

The following table illustrates the implications of a 29.4% industry-wide reduction in fuel requirements. Using 1994 activity data, this would result in a savings of approximately $20.03 million dollars, achieved through a reduction in fuel requirements.

Table 3 - **Potential Industry Savings in 1994**

Depth of Well (m)		**0-950**	**951-1850***	**1851-2450**	**2451-3050**	**3051-3700**	**3700+**
Operating Days (1994)		14,273	38,573	22,592	12,433	5,557	3,994
Fuel per Day (P/day)		1,968	2,479	2,831	3,141	3,566	4,414
Total Fuel Used (P)		28,089,264	95,622,467	63,957,952	39,052,053	19,816,262	17,629,516
Applied Savings	45	3,716,210	12,650,852	81461,637	5,166,587	2,621,691	2,332,385
Reduction (P)	55	4,542,034	15,462,153	10,342,001	6,314,717	3,204,290	2,850,693
Diesel Price	N-Tax	23.5	23.5	23.5	23.5	23.5	23.5
(ç per P)	Tax	27.5	27.5	27.5	27.5	27.5	27.5
Contractor Savings	N-Tax	873	2,973	1,988	1,214	616	548
in Fuel ($,000)	Tax	1,249	4,252	2,844	1,737	881	784

Total Savings: $20.03 Million

Note:

1. 45:55 non-taxable:taxabLe fuel breakdown is due to federal excise tax rebate paid on fuel used for electricity generation
2. Fuel per Day is taken from the 1995 LDRCS.
   * 951-1850 is an average of the two applicable categories in the LDRCS.

On a rig to rig comparison, a rig with new electronic engines could provide a considerable competitive advantage to a contractor by using significantly less fuel to drill a well which, on a well depth basis, garners the following savings (29.4% reduction).

Table 4 - **Potential Cost Reduction Per Well**

Depth of Well (m)	**0-950**	**951-1400**	**1401-1850**	**1851-2450**	**2451-3050**	**3051-3700**	**3700+**
Average Days Per Well	2.75	6.36	10.25	13.64	29.47	51.75	70.43
Fuel (P/day)	1,968	2,368	2,589	2,831	3,141	3,566	4,414
Reduction in Fuel per Well (P)	1,591	4,428	7,802	11,353	27,214	54,255	91,398
Cost Reduction ($)	409	1,138	2,005	2,918	6,994	13,944	23,489

Note:

1. Reduction in Fuel per Well is obtained using: (Average Days per Well x Fuel per Day) x 0.294
2. Cost Reduction is applied using the 45:55 rule and the respective fuel cost per P; 23.5:27.5

Using the cost reduction per well, if you applied the fuel savings across the industry using 1994 operating days data, you would amass the following cost reduction in each depth category, given the number of wells per category.

Table 5 - **Potential Industry Cost Reduction**

Depth of Well (m)	**0-950**	**951-1850***	**1851-2450**	**2451-3050**	**3051-3700**	**3700+**
Operating Days (1994)	14,273	38,573	22,592	12,433	5,557	3,994
Average Days per Well	2.75	8.31	13.64	29.47	51.75	70.43
Reduction in Cost per Well ($)	409	1,572	2,918	6,994	13,944	23,489
Total Cost Reduction ($,000)	2,123	7,295	4,833	2,951	1,497	1,332

Potential industry cost reduction, from a 29.4% reduction in fuel required, is $20.03 million dollars.

Note:

1. Total Cost Reduction is obtained through the following formula:

$$\frac{\text{Operating Days}}{\text{Average Days per Well}} \times \text{Reduction in Cost per Well}$$

The drilling industry is a very competitive business where work is generally obtained by the lowest bidder and all costs effectively contribute to a company's competitiveness. The 29.4% cost reduction obtained by this part of the study will be accrued in the drilling industry over time without any fiscal or tax measures and the speed of the realization will be determined by the health of the industry.

5.2 Pick-up Truck Fleets

The life and usefulness of any particular vehicle is most often measured in age and in the number of kilometres it has travelled. Fleet trucks in the drilling industry travel considerable kilometres over a multitude of terrains and, therefore, are replaced on a regular basis. In 1991, there were 178 vehicles in our sample and in 1995 this number had increased to 243. The increase in the number of vehicles is again due primarily to the increasing size of a number of the contractors in our sample.

The three large North American truck manufacturers, Ford, GMC/Chevrolet and Dodge/Jeep, represented all of the pick-up trucks in our study. There were 32 different models/makes covering a number of production years, some of which have an identical powertrain (a list of makes/models is contained in Appendix II.) The energy efficiency of the trucks was compared by equating the average miles per gallon (MPG) highway rating of the list of "Added" trucks to the list of "Deleted" trucks. This was done on a "net" basis, so that trucks present in both periods were counterbalanced and, therefore. cancelled each other out.

5.2a Results

Over the period measured by this study, the eight contractors added 176 vehicles and deleted 112, for a net increase of 64 trucks. The average production year for the 1991 and 1995 list of vehicles was 1988 and 1992, respectively, which in itself is evidence of a continuous capital reinvestment program on the vehicles side.

The following chart outlines the increase in fuel efficiency of the "Added" vehicles versus the "Deleted" vehicles.

Table 6 - **Pick-up Truck Study Results**

	Added	**Deleted**
Trucks	176	112
Average MPG	24.284	22.285

Improvement in fuel efficiency: 8.97%

Note:
1. Measures are 'MPG - Highway' obtained from manufacturer dealerships and Transport Canada's Fuel Consumption Guides.

5.2b Implications of the Results

In four years, the average production year for the list of trucks went from 1988 to 1992 and the vehicles that replaced the older vehicles were 8.97% more fuel efficient. The average length of time a truck is kept by a contractor is about three years (or between 150,000 and 200,000 km) which if you were to assume uniform annual use, each vehicle would travel approximately 58,000 km (or 35,400 miles) a year. Using the 243 trucks in this sample, these contractors will use 31,784.4 cartons less fuel every year, which equates to a $64,936 reduction in annual fuel expenditure (assuming 4.54 P/gallon and $0.45/P for gasoline). The per vehicle annual savings (130.8 gallons/truck per year) is not a particularly substantial amount but, when applied over a three year period on a fleet of 24 vehicles, it could reduce costs by approximately the value of a new truck - $20,000.

Vehicle manufacturers, in response to consumer demand for improved energy efficiency, have steadily increased the efficiency of their vehicles through aerodynamics, tire design and engine improvements. The resulting improvements in vehicle efficiency has enabled contractors to reduce their fuel consumption and tailpipe emissions, as well as reduce their operating costs.

6.0 TERTIARY ISSUES

Finally, the last important development in energy use on drilling rigs is the improvement of bit technology. The improvement in penetration rate and in durability have decreased the number of days that it takes contractors to drill a well, as indicated below.

Table 7 - **Annual Industry Results**

Year	Operating Days	Wells	Days/ Well
1990	55,347	5,678	9.7
1991	47,353	5,393	8.8
1992	38,551	4,762	8.1
1993	71,628	9,398	7.6
1994	97,442	11,882	8.2

There has been a 15.5% reduction in the industry average days/well figure during the 1990 to 1994 periods, which simply means that contractors can now drill more wells with a given outlay of energy.

Table 8 - **Technology Comparison**

Operating Days 1994	of Wells @ 8.2 Days/Well	of Wells @ 9.7 Days/Well
97,442	11,882	10,046

Difference: 1,836 wells

Using equivalent daily energy outlay with a given level of technology, contractors were able to drill 1,836 more wells in 1994 than they would have if the technology had remained the same as in 1990.

7.0 CONCLUSION

When the overall efficiency improvements in rig engines and trucks are coupled with improved bit technology, it is explicitly evident that there has been and continues to be movement toward substantial reductions in energy intensity in drilling operations. The natural process of capital reinvestment and technological improvement will continue to have a substantial impact on energy use and emissions in the drilling industry. As this study illustrates, in the absence of distortionary tax and fiscal measures, drilling contractors are becoming less energy intensive and more energy efficient, which is a typical, on-going mechanism in a competitive industry. It should be noted that competition and market activity are the primary drivers of these improvements and a competitive environment will continue to facilitate employment and investment within the entire economy. Drilling contractors will continue to conduct their business in a way that reduces their costs and increases their revenues which, as this study illustrates, is consistent with sound, sustainable economic and environmental goals.

APPENDIX I
Stationary Rig Engines

Manufacturer	Type	Quantity 1991	Quantity 1995	Net Change	Imperial Gallons per Hour @ 60%
Detroit Diesel	Series 40	0	40	40	4.54
Detroit Diesel	Series 50	1	52	51	7.06
Detroit Diesel	Series 60	2	7	5	8.11
Detroit Diesel	16V149-T1	1	1	0	37.90
Detroit Diesel	12V92-TA	0	3	3	15.99
Detroit Diesel	12V71-T	4	10	6	10.98
Detroit Diesel	12V71-N	11	0	-11	11.52
Detroit Diesel	8V71-N	34	7	-27	7.64
Detroit Diesel	8V71-T	6	0	-6	8.69
Detroit Diesel	6-71-Twin	135	137	2	11.99
Detroit Diesel	6-71-T	2	1	-1	5.31
Detroit Diesel	4-71-N	14	18	4	3.82
Detroit Diesel	4-71-T	10	9	-1	4.03
Detroit Diesel	3-71-N	19	27	8	2.89
Detroit Diesel	3-53-N	1	1	0	2.37
Detroit Diesel	6V92-T	2	2	0	7.05
Detroit Diesel	6V92-TA	0	1	1	7.03
Detroit Diesel	8V92-TA	0	1	1	10.59
Caterpillar	3512-DITA	0	2	2	43.04
Caterpillar	3412	5	12	7	10.40
Caterpillar	3412-TA	12	22	10	14.02
Caterpillar	3412-DITA	18	9	-9	20.42
Caterpillar	3408	19	17	-2	7.9
Caterpillar	3408-TA	21	21	0	9.74
Caterpillar	3408-DITA	7	7	0	12.31
Caterpillar	3406-TA	15	33	18	7.44
Caterpillar	3406-DITA	4	11	7	9.25
Caterpillar	3306-TA	34	56	22	5.48
Caterpillar	3306-DITA	0	11	11	7.17
Caterpillar	3304-TA	19	24	5	7.01
Caterpillar	3304-DITA	0	3	3	5.50
Caterpillar	D399	17	14	-3	30.82
Caterpillar	D398-TA	73	70	-3	24.48
Caterpillar	D379	57	65	8	14.05
Caterpillar	D353-TA	49	54	5	9.59
Caterpillar	D343-TA	5	2	-3	8.89
Caterpillar	D333	0	2	2	4.43
Caterpillar	D320	1	1	0	2.69
Caterpillar	D315	3	1	-2	2.81
Caterpillar	D311	10	4	-6	1.76
	TOTAL	**611**	**758**		

APPENDIX II
Pick-up Truck Fleet

	Make	Model	1991 Quantity	1995 Quantity
1	Ford	F150 4x4	33	24
2	Ford	F250	22	10
3	Ford	F350	5	1
4	Ford	1 Ton Crew Cab	5	7
5	Ford	1/2 Ton	4	1
6	Ford	Ranger 4x4	1	2
7	Ford	3/4 Ton	1	2
8	Ford	Explorer	0	3
9	GMC	Sierra 4x4	19	48
10	GMC	1/2 HD 4x4	28	39
11	GMC	1/2 Ton	8	2
12	GMC	2500 3/4 Ton	4	3
13	GMC	1 Ton	1	2
14	GMC	1500 3/4 Ton	0	2
15	GMC	Suburban	5	5
16	GMC	C3500	1	0
17	GMC	Sierra 4x4 Van	1	0
18	GMC	R15	1	0
19	GMC	Jimmy	0	2
20	Chevrolet	1/2 Ton 4x4	7	9
21	Chevrolet	1 Ton (Cheyenne)	1	3
22	Chevrolet	3/4 Ton Ext. Cab	0	5
23	Chevrolet	S-10 Ext. Cab	0	1
25	Dodge	D150	29	16
26	Dodge	Ram 1500	0	33
27	Dodge	2 WD	0	1
28	Dodge	W200	0	4
29	Dodge	Dakota	1	0
30	Dodge	W250 4x4	1	0
31	Dodge	2500	0	1
32	Jeep	Grande Cherokee	0	2
		Total	**178**	**243**

APPENDIX III
Participants

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