EXECUTIVE SUMMARY

ES.1 LEGISLATIVE BACKGROUND

Emissions from heavy-duty diesel vehicles are major contributors to the total California inventory of particulate and nitrogen oxide (NO_x) emissions. These emissions pose potentially serious environmental and public health impacts. Losses in agricultural productivity from environmental impacts are estimated by the Air Resources Board (ARB) at $300 million to
$1 billion per year. Public health impacts include increased rate of respiratory diseases and cancer. Additionally, excessive black smoke from heavy-duty vehicles continue to be the primary target of public complaints regarding air pollution.

In response to the above concerns, Senate Bill 1997 was enacted in 1988, authorizing ARB to design and implement a Heavy-Duty Vehicle Inspection Program (HDVIP). Following a detailed field study of the design of an effective program, the ARB implemented the HDVIP in November, 1991. In addition, a companion Periodic Smoke Inspection (PSI) program requiring periodic self-inspection for California Fleet vehicles was instituted in 1993 in accordance with Senate Bill 2330. The HDVIP and PSI programs were very successful in reducing the number of smoky trucks, but the test procedure used (the "snap acceleration" test) was the focus of much controversy. The California Trucking Association (CTA) has argued that the test incorrectly failed clean trucks, and trucking firms have litigated this issue several times, but the test has been upheld by California courts in all cases.

In the latter part of 1993, Assembly Bill 584 was enacted by the California Legislature and signed into law by the Governor. This bill amended the provisions of the California Health and Safety Code governing the HDVIP and specifically required the ARB to adopt the SAE J1667 procedure as soon as it became available. The HDVIP was suspended by the ARB in October, 1993 to redirect staff to investigate reformulated diesel fuel performance issues. Around the same time, the State Legislature enacted Assembly Bill (AB) 584 which required that the test procedure used in the HDVIP produce "consistent and repeatable" results and states that this requirement is satisfied by the adoption of the SAE J1667 procedure. AB584 further required that the program must be implemented to cause no false failures, or else ensure that false failure be remedied without penalty to the owner.

ES.2 PROGRAM REDIRECTION

In order to satisfy the twin objectives of adopting the SAE J1667 procedure and ensuring that any redirected program be consistent with the requirements of AB 584, the ARB conducted two field studies. The first was called the Random Truck Opacity Survey. As the name implies, HDDVs were randomly sampled from the fleet and tested using the new SAE J1667 procedure. The purpose of this survey was to obtain a detailed understanding of the smoky opacity distribution of the California Fleet, so that both the extent for the smoke truck problem and the potential failure rate under a redirected HDVIP (using the J1667 procedure) could be quantified. The second study was the Truck Repair Study, where a sample of in-use trucks with relating high smoke opacity could be recruited and have their engine malperformances (if any) diagnosed and corrected through repair. The purpose of the Truck Repair Study was to develop standards for smoke opacity using the J1667 test that conformed to the legislative intent of AB584. An overview of the J1667 procedure, the Random Truck Opacity Survey, and Truck Repair Study is provided below.

A key element of the inspection procedure for smoke emissions from HDDVs is the method of smoke measurement used. Historically, the SAE J1243 recommended procedure was the basis for the smoke measurement method, and this method was applicable to any specific test cycle employed. During the "snap-acceleration" test, smoke emissions can be emitted as a relatively short duration puff of smoke, and the response time of the instrument used to measure the opacity of the puff has a major effect on the measured value of peak smoke opacity. The most significant difference between the J1667 procedure and the procedure employed previously by ARB is in the instrument response time specifications.

Between August and November of 1996, the ARB conducted a random roadside smoke testing program for heavy duty diesel vehicles. This test program, formally known as the Random Truck Opacity Survey (RTOS)[1], included the application of the SAE J1667 snap-acceleration smoke test procedure to randomly selected heavy duty diesel vehicles in an effort to develop a profile of heavy duty diesel vehicle smoke characteristics in for the California fleet. Through this study, SAE J1667 smoke test results were obtained for a usable sample of 1002 vehicles (testing results for 190 vehicles were unusable due to incomplete data). The RTOS provided a detailed characterization of the smoke opacity distribution of HDDVs for all model year groups of interest to this TSD.

The Random Truck Opacity Survey included collection of all data required for the J1667 test as well as additional data to classify the subject test vehicle and engine population according to gross vehicle weight rating (GVWR) class and model year. These data were utilized after data cleaning and applying the optical path and ambient corrections, to develop estimates of future failure rates.

[1] Although formally known as the Random Truck Opacity Survey, the test program measured smoke emissions from all types of in-use heavy duty diesel vehicles operating on California roadways, including buses.

The requirement in AB584 to prevent false failures is based on the concept that an engine in good operating condition and set to manufacturers specifications should meet applicable standards. Since the components of in-use engines are subject to wear and deterioration, deriving a precise definition of an engine in"good" operating condition is difficult. Even is such a definition were available, it would be time consuming and expensive to check if all components in any given engine meet this definitions. From an emissions perspective, ARB has previously utilized the concept of identifying gross polluters in the fleet in an inspection/maintenance program, and subjecting these gross polluters to repair. Hence, ARB's focus is on engines where the emission control system is malperforming, which certainly implies that the engine is not in good operating condition.

The ARB conducted the Truck Repair Study to determine the appropriate standard by procuring and repairing a sample of heavy-duty diesel vehicles spanning a range of smoke opacities. The distribution of post-repair smoke opacity levels as measured on the J1667 procedure is utilized to select a standard that would result in no false failures per the legislative requirement of AB584. In order to determine whether any false failures would result through the imposition of a standard, it is ideal to have a sample with as wide a representation of different engine designs, (characterized by the make, model type and model year designation) as possible. However, the resource and time constraints obviously limited total repair sample size. Initially, ARB had expected to test 100 engines and have these repaired to manufacturer specifications; hence, the study was initially termed as the "Hundred Vehicle Study" (HVS). Due to time and other resource constraints, 71 engines were repaired under this study; hence the study was renamed as the Truck Repair Study.

ES.3 ANALYSIS OF RESULTS OF THE TRUCK REPAIR STUDY

The 71 vehicles recruited for the Truck Repair Study included 63 pre-1991 model year vehicles and eight (8) 1991 and later model year vehicles. Of the 63 vehicles in the first

group, 3 were not fully repaired. The sample of 63 pre-1991 engines (including those that were not fully repaired) were well distributed over the opacity range for the initial field test opacity. As shown by the data below, the sample is almost evenly represented over the opacity range, except in the 75 to 85 percent opacity range, so that cutpoints can be selected in the 40 to 65 percent opacity range with reasonable sample representation. The distribution of the pre-1991 engine sample by opacity range for pre-repair opacity is as follows:

Opacity Range	Sample %
35 to 45	15.87
45 to 55	17.46
55 to 65	15.87
65 to 75	26.99
75 to 85	4.76
85+	19.05

The selection of the pass/fail cutpoints for pre-1991 engines should ideally be based on the optimization of the errors of commission and omission, as per the previous TSD for the HDVIP. However, the new legislative language requires that ARB developed procedures so that no engine will fail smoke standards and procedures when the engine is in good operating condition and set to manufacturers specification. Given the restrictive language of the legislation, selection of standards is based on a zero error of commission rate.

The post-repair opacity distribution is as follows for pre-1991 vehicles.:

Opacity Range	Sample %
5 to 10	6.3
10 to 15	23.8
15 to 20	17.5
20 to 25	15.9
25 to 30	20.6
30 to 35	6.3
35 to 40	4.8
40 +	4.8 (Not fully repaired)

As can be seen from the above distribution, the majority of the engines were repaired to smoke levels below 30 opacity points. The highest post-repair smoke opacity recorded for a fully repaired engine was 38.7 percent.

The three trucks not fully repaired included: one that had been incorrectly rebuilt; a second with a very worn engine, as confirmed by excessive blowby; and a third where repairs completed did not bring the smoke opacity down as expected. In the last case, the mechanic suggested injector problems, but this could not be confirmed as the owner was unwilling to wait for further diagnostics and potential repair. This engine had a post-repair smoke opacity of 47 percent, while the very worn engine has a post-repair smoke opacity of 49.8 percent. Under a very conservative analysis, one could consider the engine with possible injector problems as the highest post-repair value for an engine in "good working order" since the problems remain unconfirmed. One could also potentially argue that the acceptance of the "worn" engine into the program indicates it may have been marginal and the its opacity could represent the best possible post-repair value for an engine that may be nearing the end of its useful life. However, mechanic confirmation of excessive blowby provides a strong case for excluding this vehicle from the sample.

A similar opacity distribution analysis is of more limited value for the sample of 1991 and later model year engines because of the small sample of vehicles.

No.	Vehicle No.	Pre-Repair Opacity	Post-Repair Opacity
1	67	22.8	18.9
2	56	28.2	11.0
3	65	29.2	20.5
4	70	30.3	19.2
5	63	31.3	30.6
6	71	38.8	28.5
7	43	43.4	25.6
8	4	57.5	15.1

The post-repair smoke opacity of the small sample appears relatively high. For example, no engines were repaired to below 10 percent opacity unlike the pre-1991 model year sample. In addition, two engines (on vehicle 63 and 67) showed negligible smoke opacity reduction after repair. (i.e., the pre- and post-repair smoke opacities differed by less than 5 percent). Indeed, the repair records on the 1991+ engines indicate some mechanics to be unfamiliar with electronic systems (see Chapter 5) In addition, two trucks in the sample (the Isuzu trucks) were repaired at a Ford dealership, so that the quality of the repair itself is in some doubt. The results of the small sample are at odds with the fact that most 1991+ vehicles have very low smoke emissions, and certification peak smoke levels are 50 to 70 percent below certification peak smoke levels for pre-1991 engines.

ES.4 SELECTION OF STANDARDS

In response to the legislative intent of AB584, the selected standards must be such that

- **none of the vehicles repaired to "good operating condition" can fail the standard.**
- **issues regarding variability in smoke measurement must be addressed to prevent false failures.**

The first point is directly addressed using the post-repair opacity distributions.

For pre-1991 engines, a reasonable choice of the highest opacity after repair is 38.7 percent, indicating a possible range of standards above 39 percent opacity. However, the existence of one engine (repaired to 47 percent opacity) that only had unconfirmed additional malperformances could suggest that a more conservative standard be applied. For 1991+ engines, the equivalent highest post-repair value is 30.6 percent, suggesting a possible range of standards above

31 percent. It should be noted however that this is based on a largely unsatisfactory sample in terms of size and repair quality.

Another issue to be considered is one of variability of measured smoke opacity. There are three types of variability, one associated with the engine itself, the second with test performance, and the third associated with variation among different meters certified to the J1667 standard. The issue of engine variability is complex since it is dependent on the time period over which it is measured. Engines may become more variable with use and over time for reasons associated with deterioration of parts, or contamination by ambient dust or fuel impurities. A key factor in this analysis is that variability associated with detectable causes are not accounted for in the standard setting process as its causes are associated with correctable malperformances.

The second type of variability is associated with the engines' cycle-to cycle variability and test implementation variability, all other factors remaining constant. This variability is associated with observed differences in the J1667 smoke measurement between one snap cycle and another snap cycle conducted on an engine in good working order. In order to be sure that no in-use deterioration has taken place between one J1667 measurement and the next, the tests have to be performed within a relatively short time, using the same meter, on engines known to be in good working order. To estimate this variability, we have utilized data from the post-repair smoke opacity checks conducted by the dealership staff and by the ARB field staff. These measurements were usually conducted within a two hour time span and independent data from two tests on the same engine can be found for 25 engines in the 71 engines sample. Analysis of the paired differences between snap idle measurements for the 25 engines indicates a mean difference of -0.25 and a standard deviation (σ) of 2.2 opacity

percent. In the absence of any large scale variability study, a test variability allowance of 4 to 5 opacity points representing 2σ for a 95 percent confidence level appears reasonable, to insure that no engine is failed incorrectly due to test variability.

The third issue regarding variability on the differences that can occur between different makes or models of smokemeters calibrated to the same standard. The J1667 procedure allows the use of different types of smokemeters using different techniques to measure smoke opacity. The issues were specifically addressed by the J1667 Committee. Tests were conducted on a sample of smokemeters, and paired measurements of smoke were obtained using two smokemeters to measure smoke on each J1667 cycle. A tolerance interval for the signed values of the paired differences of their opacities was computed. This tolerance interval covers an estimated 95% of the population of absolute values of paired difference and has a 95% confidence level. The standard deviation of these paired differences is 2.4% -- i.e. with high confidence, 95% of the signed difference of paired opacities of these five meters are less than 5%. This interval implies that 95% of the pairs of opacities of a heavy-duty diesel engine measured on the same occasion by any of these five meters will differ by less than 5%, with a high level of confidence. A maximum allowance of 5% in the standard for difference between opacities measured by different meters should insure that whether a tested engine exceeds a standard or not will rarely depend upon which meter is used.

Hence, a total variability margin of 8 percent, consisting of a 5 percent allowance for meters and 5 percent allowance for engine variability, is required to ensure that the standard will not cause any error of commission, with a high

level of confidence. This assumes that meter differences and engine variability are not correlated and the two margins are added as the sum of squares.

Using the reference post-repair high value of 47 percent for pre-1991 engines, and 30.8 percent for 1991+ engines, the equivalent standards should be 55 percent and 40 percent respectively which are identical to the standards used previously. However, in both cases, the post-repair high opacity values may not reflect complete or correct repairs and the standards may be too conservative. It appears possible and likely that a larger sample of data on repairs especially on 1991 and later engines could lead to a significantly lower standard than the 40 percent value derived in this analysis.

ES.5 TYPES OF REPAIR

The data base from the Truck Repair Study included written comments by mechanics on the types of repair. These comments were the basis for dividing the repairs performed into a few specific categories. Unfortunately, mechanics' written comments on repairs were unclear in some cases so that the exact sequence of repair, and costs and benefits for less-than-complete repair could not be fully determined. As a result, this analysis focuses on the endpoint of all repairs. The repair sample is based on data from all 71 trucks recruited, even though three were not fully repaired for reasons previously discussed. The sample has good representation of the heavy-heavy duty diesels makes.

High smoke emissions are normally due to:

- **Improper transient air fuel ratio control,**
- **Problems with the fuel injection system or fuel injection timing, or**
- **Inadequate intake air.**

Of these, transient air-fuel ratio control maladjustment is largely responsible for high smoke during the snap acceleration test.

All of the transient air fuel ratio controls are applicable only to turbocharged diesel engines, but all engines in the sample are turbocharged. 70 percent of engines (50) in the repaired sample had defects in this part of the system. In addition, this rate was very similar across different manufacturers' engines, and very similar to the rate observed in the repair sample developed by ARB when analyzing the HDVIP in 1989-90.

A large percentage of the other repairs were also to the rest of the fuel control system. These included adjusting the governor, fuel rack position or injection timing, which are necessary adjustments on all diesel engines. The impact of governor tampering on smoke opacity is engine model dependent, but governor tampering is relatively common on Cummins engines. The metering pump was rebuilt or replaced for a large fraction of the sample. Finally, injectors (or injection nozzles) were repaired or replaced in over one third of the engines (20) in the sample.

Most of the 1991 and later engines featured electronic control of injection timing as did a few 1988-1990 engines. In particular, the DDC Series 60 engines in the sample were all electronically controlled, and <u>every Series 60 Engine</u> in the sample was given an electronic control module program update. All electronically controlled engines had their internal diagnostics queried, but no system faults were found. This may be because current diagnostic systems in heavy-duty diesel engines are not designed to recognize faults causing high smoke on the snap-acceleration test. There are also some concerns on the ability of this test to recognize malperformances in electronic systems.

The replacement of the air filter was another common repair performed in one-third of the sample. Turbochargers needed replacement on 4 of 71 turbocharged engines but one was due to leaky oil seals, and was not repaired in this study. In addition, valves were adjusted on several engines, which is part of general tune-up but has limited impact on smoke opacity.

On average, all four engine model year groups showed significant reductions in smoke from repair. The pre-repair and post-repair average values are as follows, excluding the three vehicles where engines were not fully repaired.

	Average Pre-Repair Opacity	Average Post-Repair Opacity
Pre-1980	65.9	22.4
1980-1987	63.6	20.7
1988-1990	56.0	17.3
1991 +	35.0	21.2

Post-opacity levels were independent of pre-repair levels, so that larger reductions in opacity were obtained from high emitters.

The reduction in opacity obtained for 1991 + vehicles were similar to those for pre-1991 vehicles, except in two instances where no meaningful reductions were obtained. Because of the small total sample size, no detailed analysis could be performed. The opacity was generally reduced to the 11 to 20 percent opacity range after repair in six vehicles that exclude the two with minimal post-repair smoke reduction. Hence, the expectation is that a larger sample and better repairs could indicate an average post-repair smoke opacity level of about 15 percent, independent of pre-repair levels. This expectation is also consistent

with the fact the certification peak smoke levels for 1991+ engines have declined 50 to 70 percent from pre-1991 certification levels.

The Truck Repair Program had operational cost ceilings for repair in order to meet budgetary constraints, and the ceiling was set informally at about $750 (this is more than the standard authorized amount, and was intended as an internal budgetary guideline). This amount was supplemented by manufacturers for an additional $250 to $500, as required. In a few instances where the bill was over $1300, the customer agreed to pay the amount not covered by ARB or the engine manufacturer. Other than the three engines for which repairs were incomplete, all other engines were repaired to levels determined to be adequate by the dealers <u>without regard to cost.</u> Most repairs include a base cost associated with diagnostics and dynamometer testing so that these costs alone, independent of repairs, added a total of $120 to $180 representing 1 to 2 hours of mechanics time (typically @ $60/hr) and a dyno fee of $60 to $70.

The average costs for the sample of 68 fully repaired engines are as follows:

Pre-1980	**$732**
1980-1987	**$565**
1987-1990	**$827**
1991+	**$433**

The reason why the pre-1980 and 1987-1990 vehicle exhibited higher average costs is because there were some relatively rare repairs that were expensive and which inflated the average cost. For the pre-1980 engines, two engines had their turbochargers replaced. In the 1987-1990 vehicle sample, one engine had an intercooler replaced and another had a new injection pump installed. The

replacement parts increased costs by over $750 per engine, but the 1980-1987 sample did not have any similar repairs. A more realistic representation is to average costs across the three model year strata to obtain an average of $652.

Average repair costs for the eight (8) 1991 and newer engines was only $433, and this figure is lower than those for previous years largely because there were no major replacement part costs. This is due to the fact that the trucks are, on average, less than 5 years old, and the cost estimate may be quite reasonable for vehicles 2 to 6 years old (vehicles less than 2 years old are typically covered by manufacturers new engine warranty). However, as these trucks age, it is likely that average repair costs will increase due to the need to replace worn turbochargers, intercoolers, injection pumps and injectors.

ES.6 COSTS OF THE HDVIP AND PSIP

Implementation of the HDVIP and PSIP will impose certain costs on both the ARB and the regulated industry. These costs arise from a variety of program requirements and include: labor costs for program administration and enforcement, capital costs for vehicle inspections, costs for vehicle repair, and indirect costs due to vehicle and driver out-of-service time. ARB administrative costs are estimated using staffing levels and administrative procedures developed during the original HDVIP. Procedures developed during that program are expected to be implemented without change for the proposed HDVIP and PSIP. Moreover, the PSIP is not expected to increase staffing demands since HDVIP staff are expected to be able to handle PSIP administrative demands during normal periods of HDVIP inactivity. Fleet

staffing costs due to PSIP inspection requirements are estimated using heavy duty diesel vehicle populations from the ARB's MVEI7G emissions inventory model and fleet size statistics from the U.S. Department of the Census. Capital costs for the ARB are estimated based on equipment needs established during the original HDVIP and unit costs estimates derived from current market price data. A similar approach is taken to estimate fleet equipment demands and associated costs under the PSIP.

Costs incurred due to vehicle repair require a more complex estimation methodology since the number of heavy duty diesel vehicles requiring repair is directly dependent on the number of vehicles failed under the HDVIP and PSIP and the number of vehicles which undertake preventive maintenance to avoid HDVIP or PSIP failure. To estimate the number of heavy duty diesel vehicles expected to fail the HDVIP and PSIP in the program evaluation years of 1999 and 2010, smoke opacity data developed during the Random Truck Opacity Survey was analyzed in conjunction with recommended program cutpoints. Based on this analysis, it is estimated that 13.1 percent heavy duty diesel vehicles will fail either an HDVIP or PSIP inspection in 1999 and 8.6 percent of such vehicles will fail an inspection in 2010. These estimates, combined with total vehicle populations from the MVEI7G emissions inventory model and per-vehicle repair costs, yield estimates of the total cost of failure-driven vehicle repair.

Some vehicle owners will elect to undertake voluntary repairs to avoid the risk of HDVIP and PSIP inspection failure. The costs of these deterrence-based vehicle repairs were estimated using data collected under the original HDVIP and MVEI7G data on the heavy duty diesel vehicle population. During the original HDVIP, the observed failure rate declined from 44.7 percent

immediately following program implementation to 18.5 percent just prior to program suspension. Basic analysis of this data indicates that approximately 26 percent of all heavy duty diesel vehicles were subjected to some level of improved maintenance in response to HDVIP implementation. This statistic compares favorably with the 33 percent estimate developed prior to implementation of the original HDVIP. Applying this fraction to total heavy duty diesel vehicle populations and the average costs of repair yields an estimate for the total cost of deterrence-induced repairs resulting from implementation of the HDVIP and PSIP.

Indirect costs due to HDVIP and PSIP implementation result from lost vehicle and driver time due to vehicle inspection and repair. These lost opportunity costs have been estimated using statistics for the heavy duty diesel vehicle population, the HDVIP and PSIP program inspection, failure, and repair rates, and estimates of the average time required to undertake inspections and repair vehicles.

Finally, vehicle owners will recoup a cost savings due to repair-induced reductions in vehicle fuel consumption. Estimates of fuel savings in 1999 and 2010 were derived using a detailed malperformance and vehicle repair model (also used to estimate repair-induced vehicle emissions impacts). Based on this model, a net reduction in heavy duty diesel vehicle fuel consumption of 0.69 percent is expected in 1999 and 0.66 percent in 2010. An estimate of total cost savings resulting from these reductions was developed by applying the percentage change estimates in fuel consumption to total heavy duty diesel fuel consumption statistics from the MVEI7G model and per-gallon fuel costs.

Table ES-1 presents a summary of estimated HDVIP and PSIP program costs.

	1999	2010
Total Annual Administrative Cost to Fleets and ARB	$19,936,549	$25,438,074
Annual Repair Cost	$21,162,379	$16,229,616
Annual Citation Penalty Cost	$1,337,857	$876,006
Annual Increased Maintenance Cost	$2,267,097	$2,947,141
Annual Lost Opportunity Cost of Time	$771,936	$567,603
Annual Cost of Fuel	($21,764,145)	($24,983,116)
Unadjusted Total Program Cost	$23,711,673	$21,075,324
Net Program Cost (Excluding Transfer Payments)[1]	$22,373,816	$20,199,318

[1] Net costs exclude citation penalty costs since these costs represent transfer payments rather than a consumption of resources. The citation penalty cost is accrued by vehicle owners, but net costs to the ARB are reduced by the same amount due to the collection of these penalties.

TABLE ES-1. HDVIP AND PSIP COSTS

ES.7 BENEFITS OF THE HDVIP AND PSIP

Implementation of the HDVIP and PSIP will produce a series of benefits which can be generally classified as follows:

- A reduction in the number of heavy duty diesel vehicles emitting excess smoke,
- A reduction in criteria and toxic air pollutant emissions from heavy duty diesel vehicles,
- A reduction in heavy duty diesel vehicle fuel consumption, and
- A potential improvement in heavy duty diesel vehicle reliability and performance.

Reducing the number of excessively smoking heavy duty diesel vehicles is the primary goal of the HDVIP and PSIP. Reductions in criteria and toxic air pollutants, reductions in fuel consumption, and any improvements in vehicle reliability and performance accrue as direct, but secondary, benefits of the smoke reduction repairs.

The reduction in the number of excessively smoking heavy duty diesel vehicles due to HDVIP and PSIP implementation was estimated using data collected during the original HDVIP. During that program, the observed failure rate declined from 44.7 percent immediately following program implementation to 18.5 percent just prior to program suspension. This change in vehicle failure rate can be directly converted to an estimate of the number of vehicles for which excess smoke emissions have been eliminated. However, based on the Random Truck Opacity Survey recently conducted by the ARB, some of the improvement observed during the original HDVIP has eroded and, therefore, implementation of the proposed HDVIP and PSIP can be expected to induce renewed vehicle maintenance practices in response to the threat of citation.

Based on the assumption that vehicle maintenance practices will equilibrate at the levels observed during the original HDVIP, an additional reduction of approximately 4,000 excessively smoking vehicles will be derived through implementation of the HDVIP and PSIP. This estimate is in addition to the reduction in smoking vehicles already derived through implementation of the original HDVIP. In total, an estimated 70,000 excessively smoking vehicles will be removed from California's roadways in 1999 and 2010 due to the combined effects of the original and proposed smoke inspection programs. While the vehicle maintenance impacts of the original HDVIP continue to be observed today (four years after program suspension), there is evidence that these benefits are eroding. The proposed HDVIP and PSIP will halt that any such erosion and induce the renewed maintenance practices required to ensure that the elimination of excessive smoke from 70,000 heavy duty diesel vehicles is achieved.

HDVIP- and PSIP-induced repairs will also bring about a reduction in emissions of ROG, NO_x, and particulate. Using a detailed engine malperformance model in conjunction with the MVEI7g emissions inventory model, Statewide emission reduction impacts (in tons per day) have been estimated as follows:

	ROG	**NO_x**	**PM-10**
1999	**6.37**	**12.24**	**5.24**
2010	**5.30**	**14.03**	**3.19**

As indicated in the cost discussion, this same malperformance model was used to estimate changes in the volume of heavy duty diesel fuel consumed due to HDVIP and PSIP implementation. The estimated reduction in heavy duty diesel fuel consumption of 0.69 percent in 1999 and 0.66 percent in 2010 translates to a savings of 16.7 million gallons of diesel fuel annually in 1999 and 19.2 million gallons of diesel fuel annually in 2010.

Implementation of the HDVIP and PSIP is also expected to cause reductions in the total mass of toxic emissions emitted by heavy duty diesel vehicles and potentially improve heavy duty diesel vehicle reliability and performance. However, due to the lack of definitive analysis tools for assessing the magnitude of these benefits, no quantitative estimate of program benefits in these areas has been developed.

ES.8 HDVIP AND PSIP COST EFFECTIVENESS

The primary cost effectiveness of the HDVIP and PSIP cannot be estimated conventionally in terms of dollars per mass of pollution reduced. The primary focus of the HDVIP and PSIP is to reduce smoke emissions, a reduction which cannot be meaningfully addressed in terms of emissions mass. Instead, as described above, primary program benefits were

estimated in terms of a 70,000 vehicle reduction in the number of excessively smoking heavy duty diesel vehicles operating in California.

As a secondary benefit, the HDVIP and PSIP also produce reductions in criteria pollutant emissions as a result of repairs performed to reduce excess smoke. These associated criteria pollutant impacts can be combined with program costs to derive a cost effectiveness estimate in units of dollars per pound of emission reduction. However, this cost effectiveness estimate only considers the secondary benefits of the HDVIP and PSIP.

Based on the estimated program costs and criteria pollutant emission reductions presented above, the cost effectiveness of the secondary benefits of the HDVIP and PSIP is estimated to be $1.29 per pound in 1999 and $1.23 per pound in 2010. These estimates compare favorably to alternative emission control programs which primarily target criteria pollutant reductions and typically cost between $2.50 and $5.00 per pound of emissions reduced.