SUMMARY OF TRUCK LOADING PATTERNS IN WASHINGTON STATE

WA-RD 314.1

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Washington State Transportation Commission
Transit, Research, and Intermodal Planning (TRIP) Division
in cooperation with the U.S. Department of Transportation
Federal Highway Administration

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16. ABSTRACT

This report summarizes a brief analysis of Washington State Department of Transportation (WSDOT) weigh-in-motion data. The report includes data from ten permanent WIM sites: four bending plate scales and six piezo-electric scales. The intent of this report is to provide an overview of the truck loading patterns observed at these sites, and to provide improved ESAL loading estimates for use by the WSDOT. The ten sites selected for this study reflect the variety of traffic loading conditions found within in the state. They are geographically dispersed across the state, represent a number of functional roadway classes, and serve a range of traffic volumes.

The WSDOT collected the data according to the 13 vehicle classifications set by the FHWA, the results in this report are presented with reference to both the FHWA system and to the WSDOT system. The WSDOT system, which is used in its pavement design guide and is incorporated into its traffic data computer system (TRIPS) divides vehicles into four classes: cars, single units, double units, and multi-trailer units.

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Truck Loading Patterns

SUMMARY OF TRUCK LOADING PATTERNS IN WASHINGTON STATE

by

Mark E. Hallenbeck
TRAC Director

Soon-Gwam Kim
Research Assistant
University of Washington

Washington State Transportation Center (TRAC)
University of Washington, JD-10
University District Building
1107 NE 45th Street, Suite 535
Seattle, Washington 98105-4631

Washington State Department of Transportation
Technical Monitor
Dave Thompson
Manager, Transportation Data Office

Prepared for

Washington State Transportation Commission
Department of Transportation
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DISCLAIMER

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This report summarizes a brief analysis of WSDOT weigh-in-motion data. The report includes data from ten sites; the four WSDOT bending plate sites and six piezo-electric sites. The intent of this analysis is to provide an overview of the truck loading patterns observed at these sites and to provide improved ESAL loading estimates for use within the WSDOT.

While data are collected by the WSDOT WIM equipment using the 13 FHWA vehicle classifications, the results in this report are presented using both FHWA's 13-vehicle classification system and the four vehicle classes used in the WSDOT pavement design guide and incorporated into WSDOT's traffic data computer system (TRIPS); these include single units, double units, and multi-trailer units. (Note that car volumes are assumed to contribute negligibly to the fatigue loadings of pavements and are ignored for this analysis.)

The ten sites selected for inclusion in this study illustrate the variety of traffic loading conditions found in the state of Washington. The ten sites are geographically dispersed across the state, come from a number of functional classes of roadway, and experience a variety of traffic volumes. The ten sites include urban, rural, and suburban sites and are located in all major geographic areas of the state. Table 1 lists the ten sites used in this study.

SUMMARY LOADING PATTERNS

Pavement loads are a function of the number of heavy vehicles using a highway and the axle loadings of each of those vehicles. To track (or estimate) pavement loadings, one of two methods can be used. The first directly measures axle loadings irrespective of vehicle type. With this methodology, vehicle-specific information is not needed, and all

Table 1. Site Descriptions

Site Name	Location	State Route	Geographic Location
B01	Kelso	I-5	Southeast
B02	Brady	SR-12	West (rural)
B03	Pasco	SR-395	Southcentral
B04	Cle Elum	I-90	Central
P04	Ferndale	I-5	West (Canadian Border - rural)
P05	Dayton	SR-12	Southeast
P06	Camas	SR-14	Southwest
P15	Spokane	SR-195	East
P19	Woodinville	SR-522	West (suburban)
P3N	Seattle (185th)	I-5	West (urban)

estimates (forecasts or estimates of previous traffic loadings) must be based on simple trend or time series techniques.

The second methodology measures the number of trucks (by type) using the highway and the average load per vehicle for each type of vehicle. Estimates of total load are then computed by multiplying the total number of vehicles using the road by the average load per vehicle. This two-step approach is more complex than the first monitoring technique, but it allows the consideration of different trends in the estimation of expected loads (for example, changes in the type of vehicles using the road, as well as the number of vehicles using the road).

To allow examination of loading patterns using either methodology in this report, three different measurements are examined at the ten WIM sites: the average equivalent standard axle load (ESAL) per vehicle for specific classes of vehicles, the total volume of those vehicles, and the total ESAL applied per day (both by vehicle class and for all classes combined).

The estimate of ESAL loading applied by each truck (by class) does not account for the changes in the volume of trucks that cross each WIM sensor; however, it does show how relative vehicle loading characteristics change over time, and it can be used to determine whether axle weights measured at one point in time are accurate representations of axle weights throughout the year.

The volume pattern for individual vehicle classes has been examined in other, more extensive, research investigations. This earlier research has shown that the volume patterns of commercial vehicles are very different from those of automobiles and that truck volumes vary over time and from location to location. The simple analyses done in this effort support those conclusions.

Total ESAL loading at a site incorporates both changes in vehicle volume and changes in vehicle loading. Most pavement design is based on this estimate, and therefore, the estimate is of significant interest to the WSDOT.

ANALYTICAL APPROACH

All estimates presented in the summary tables and graphs of this paper are averages for the month. These averages are computed as the mean value of the seven average days of the week for that month. That is, the mean Monday, Tuesday, Wednesday, etc. for each month are computed, and then these seven values are averaged. This procedure is consistent with the AASHTO Guidelines for Traffic Monitoring and accounts for uneven distributions in the number of weekdays and weekends in each month.

A concern related to the results presented in this report involves the presence of invalid data. The research team used a graphic approach to distinguish "bad" data from "good" data. Plotting the daily estimates of volume, ESAL per vehicle, and total ESALs allowed the research team to identify specific points in time when equipment malfunctions took place. Data collected during these time periods were then removed from the dataset used for the remainder of the project.

The project team recommends that more research be done to help simplify and speed up the determination of "valid" and "invalid" WIM data. This function needs to be performed more frequently and in a more automated fashion. This will allow WSDOT to spend resources maintaining equipment, rather than manually monitoring collected data. The scope and time frame for this project did not allow for an in-depth analysis of this important subject.

In several cases, the basic ESAL loading patterns examined in this project appeared to change systematically. It was not always clear whether these changes were caused by failure of the data collection equipment or by actual changes in traffic conditions. Where equipment failures could be identified, "invalid" data were removed from the dataset. Where this was not possible, the data remained in the dataset. These systematic changes had a significant impact on the variability of the ESAL estimates produced by this project.

The project team conducted a limited amount of WIM equipment and calibration checking using the estimated weights of front axles for 3S2 tractor-semi-trailer trucks. This vehicle is thought to have a reasonably stable front axle weight (usually between 8,500 and 12,000 pounds). Monitoring of front axle weights is often used as a calibration technique on WIM systems.

A review of the front axle weights at two sites (B03 and P04) showed that the front axle weight by itself is not a good indicator of scale operation or calibration. In several instances, the front axle calibration appeared to be quite good, while the weights of other axles (and consequently the ESAL per vehicle and total ESAL estimate) appeared to be invalid. Many of these invalid estimates were heavily correlated with significant reductions in traffic volume. It is possible that these sites had equipment failures in the outside lanes of traffic and that trucks traveling on the inside lanes were predominantly light (e.g., empty). This type of equipment failure would not be detected by the front axle calibration methodology. This limitation indicates the need for a more systematic and multi-faceted technique for detecting equipment malfunctions.

In most cases, equipment failures seem to result in low vehicle ESAL estimates or counts. The data examined in this project indicates that overestimation of weights and volumes are less of a concern. Thus, the results of this project may slightly underestimate total loadings. Given the lack of time and resources needed to perform careful quality control over the data collected by WSDOT, the project results should be treated as preliminary and should be subject to further review.

SEASONAL PATTERNS

There are ten pages of figures in Appendix A. These figures illustrate the seasonal patterns found at the ten test sites for each of the three estimates of loading: ESAL per vehicle by class and for all classes combined, volume by class and for all classes combined, and total ESAL loading by class and for all classes combined. Note that in some cases, months of data are missing from the figures and associated tables. These months have been removed by the project team as a result of concerns about the validity of the data collected at that site during those months.

ESALs Per Vehicle

The most surprising and striking result of the analysis of seasonal patterns of ESAL per vehicle was the variety of patterns shown in the data. The ten sites analyzed in this project produced essentially ten distinct seasonal patterns. With a few exceptions, the ESAL value per single unit truck remains fairly stable during the year, but in most cases, the ESAL per vehicle load estimate for the two larger truck classes changes substantially during the year. The more important aspects of these seasonal changes are discussed below.

Site B01 (on I-5 near Kelso) showed a rise in ESAL per vehicle in the larger truck classes (double and multi-units) from May to August, with lower loading rates during the remainder of the year.

Site B02 (on SR-12 near Brady) showed the opposite trend, with significant increases in ESAL per vehicle for multi-unit vehicles during the winter months. This rise

was not apparent in the double unit category, which actually experienced a decrease in ESAL per double unit during October and November.

Site B03 (On SR-395 near Pasco) showed this same increase in ESAL per vehicle during the winter, but the increase started much earlier than at B02 (October versus December) and included both double and multi-unit vehicles.

Site B04 (on I-90 near Cle Elum) showed a decrease during the winter in ESAL per vehicle for both double- and multi-unit vehicles. This was similar to the pattern at B01; however, the "winter low" was somewhat more severe than at B01 and lasted for a slightly shorter period. B01 and B04 showed patterns that were more closely related to each other than to the other eight sites, which may have been caused by their being interstate locations subject to relatively stable interstate traffic loadings.

Site P04 (on I-5 near Ferndale) had a much more peaked ESAL per vehicle pattern than other sites. In addition, the P04 peaking pattern was shared by all three aggregated vehicle patterns, not just the larger truck classes. All three truck classes showed increased loading rates per vehicle in the late spring and summer (May through August) with lows in February and November. It is important to note that P04 is also an interstate location, but it is located near the Canadian border and may not be subject to the same type of traffic movements experienced by other interstate roadways in the state (i.e., the international border may create traffic patterns that are different from those of interstate movements between states).

Site P05 (on SR-12 near Dayton) had a very unusual pattern in that it had twin peaks during November and February (the opposite of P04). In addition, the December and January loading rates were also high, although not as high as in November and February. Like P04, single unit vehicles were also affected by this cold weather pattern. This site is located in the grain belt of Eastern Washington and may be reflecting the movement of grain between elevators during the year. It is also possible that the piezo-electric WIM sensors were affected by cold temperatures; however, the Spokane site,

which also uses piezo-electric sensors and experiences cold temperatures, did not share this pattern.

Site P06 (SR-14 near Camas) had a traditional spring/summer peak, but this peak lasted only three months (May to July), much shorter than the peaks for sites B01, B04, and P04. It also differed from B01 and B04 in that the ESAL per vehicle value continued to change over time, whereas the ESAL per vehicle value at B01 and B04 tended to plateau during both the high and low periods.

Site P15 (SR-395 near Spokane) showed a relatively flat seasonal pattern, with a minor drop in ESAL per vehicle loadings at the end of the calendar year. The November drop was more pronounced for multi-unit vehicles than for double-unit vehicles, but both types of vehicles followed similar patterns.

Site P19 (SR-522 near Woodinville) had the flattest seasonal ESAL per vehicle pattern of all the WIM sites analyzed. This suburban Seattle site had almost no seasonal fluctuation for single-, double-, or multi-unit vehicle loads.

The other Seattle urban site (P3N, I-5 northbound only, at 185th in Seattle) had reasonably flat seasonal loading patterns, although several anomalies were present in the pattern at this site. These anomalies included a decreased ESAL per vehicle loading rate for multi-unit vehicles during the winter (November to February) and an increased ESAL per vehicle loading for double unit vehicles during March and April.

Volume Per Vehicle

The Kelso site (B01) showed a definite increase in truck traffic during the summer months. This increase in traffic was present for both the single and double unit vehicles, but not for the multi-unit vehicles, whose volume remained constant throughout the year.

B02 (Brady) showed a very different seasonal volume pattern, with volume increases in the fall and winter. As with B01, the single- and double-unit volumes rose during these seasonal peak periods, but multi-unit vehicle volumes remained fairly constant over time.

At Pasco (B03) the multi-unit vehicles showed a slight increase late in the calendar year. Volume increases at this site were not as significant as the ESAL per vehicle increases described above. A similar pattern was observed at B04 (Cle Elem), where a minor rise in truck volume was apparent in early fall (September and October), with decreases in the winter. Similar patterns were present for all three aggregated truck classes.

P04 (I-5 near the Canadian border at Ferndale) showed a high degree of traffic volume fluctuation. In addition, this site showed increasing volumes of single- and double-unit trucks during the summer, while the number of multi-unit trucks decreased. Similarly, the number of multi-unit vehicles rose during February and October, while the number of single- and double-unit trucks decreased.

At P05 (in Southeastern Washington), two traffic levels appeared to be present, with higher winter volumes (September through April) than summer volumes (May through August.) This pattern was true for all three vehicle types.

Traffic volumes at P06 (in Southwestern Washington) had a fairly flat pattern with a slight increase in double-unit volumes during the summer.

P15 (Spokane), P19 (Woodinville), and P3N (Seattle) also had fairly flat seasonal volume patterns; however, minor variations in volumes at these sites were apparent. For example, volumes for all truck categories at site P15 decreased somewhat during the winter (November through January), while volumes of single- and double-unit trucks at site P3N increased slightly during the summer. Truck volumes at site P19 did not appear to follow a specific seasonal trend but fluctuated randomly.

Total Load By Vehicle Class

As expected, total daily load (both by vehicle class and for all classes combined) showed a combination of the volume and load/vehicle characteristics. In some cases this resulted in highly variable loading patterns, and in other cases the loading patterns were quite consistent throughout the year.

Variable patterns were found at sites B01, B03, B04, P04, P05, P06. For each of the variable loading patterns, some months of the year contained total daily loadings that were less than half the total loadings that occurred at another part of the year. Again, some of this variability may have been due to problems with the reliability of the WIM calibration and equipment. However, the large number of stations that showed this variable condition indicates that high degrees of variability in the daily load applied by trucks is highly possible for many state highways.

Consistent loading patterns were found at sites B02, P15, P19, P3N. However, even at these "consistent" sites, average daily loads varied by as much as 65 percent from their highest to their lowest monthly average. With day-of-week variations incorporated (i.e., the differences between weekday and weekend traffic), variation in total daily load even at "consistent" sites appeared to be quite high.

DAY OF WEEK

Because of the limited scope of the project, the day of week analysis included only seven sites of data and evaluation of conventional five-axle, semi-trailer trucks (Axle Bin 9). These seven sites showed that weekend vehicle loads (expressed as ESALs/vehicle) were often different than weekday vehicle loads. However, in some cases the weekend loads per vehicle were higher than weekday loads, and in other cases they were lower. In almost all cases, total vehicle loadings were lower on Sundays than weekdays (because of the lower truck volumes). Total daily loadings on Saturdays were not consistently lower than weekday loadings.

At site B02 the average load per vehicle decreased for both Saturday and Sunday in relation to weekdays. This site was the only one of the seven sites to show this characteristic. Three of the sites, B03, B01, and P04, had higher average loadings per vehicle on both weekend days than on the weekdays.

At the other three sites, results were mixed. At both P06 and B04, the highest ESAL per vehicle loading occurred on Sunday, but average load per vehicle on Saturday

fell within the loading range of the other days of the week. At P19 vehicles traveling on Sunday had a lower average ESAL per vehicle than for the remaining days of the week, while vehicles traveling on Saturday had the highest average loading..

These results indicate that weighing trucks only on weekdays may yield a biased measure of average load per vehicle. Unfortunately, without more information, a correction factor cannot be developed to correct for this bias.

SUMMARY OF FINDINGS

ESALs Per Axle

Previous research done for WSDOT has shown that average loadings applied by many of the vehicle classes averaged approximately 0.25 ESALS per axle per vehicle. A comparison of this estimate to the data collected at the ten test sites reveals that this estimate is a reasonable, although somewhat conservative value.

The value for Bin 9 (five-axle, semi-trailer trucks), the largest truck category, was 0.24 ESALS. All of the remaining vehicle classes except Bin 4 (buses) had ESAL loadings that were less than this value. The larger combination vehicles fell between 0.15 and 0.2 ESALS per axle, with the larger values corresponding to the larger vehicle classes.

However, the ESAL per axle value varied considerably from site to site and from day to day at specific sites. The standard deviation of the ESAL per vehicle value for Bin 9 was 0.3. This yielded a coefficient of variation of 25 percent. The coefficient of variation for the other large vehicle classes was even higher than that for Bin 9 vehicles, reaching a high for Bin 13 at 31 percent. Day to day variation was even higher than site-to-site variation, with the standard deviation of the ESAL per vehicle value ranging from 0.40 to 0.55.

This high level of variation was partly due to the presence of empty trucks in the sample. The distribution of ESAL values per vehicle was not a normal distribution. It had two distinct peaks, one for loaded vehicles and one for unloaded vehicles. Modest changes in the ratio of loaded to unloaded vehicles can have a significant impact on the computed

ESAL per vehicle value and contributed significantly to the variation found in these estimates.

Axle Bin 4, which includes many of the recreation vehicles (RVs) and buses in Washington State, also showed a high ESAL loading per axle, although the total ESAL per vehicle was relatively modest. (Given the short time-frame allowed for this analysis, it was not possible to determine the true number of axles per vehicle in Bin 4, since both two-axle and three-axle vehicles are incorporated into this vehicle classification.) With two axles per vehicle, the ESAL/axle was 0.28. With three axles per vehicle, the ESAL/axle ratio dropped to 0.19. Using 2.5 axles per vehicle yielded an estimate of 0.23. As with the Bin 9 vehicles, the COV for Bin 4 was roughly 25 percent.

This high level of variation in the daily, seasonal, and geographic stratifications in the dataset indicate that relatively precise estimates of ESAL loadings will be difficult to develop for most WSDOT analyses.

Tables 2 and 3 show the average annual loadings found for this project and indicate recommended ESAL per vehicle loadings that are applicable for use within the Department.

Table 2. ESAL Per Vehicle By Aggregated Class and Site

SITE	S.UNIT	D.UNIT	M.UNIT	ALL
B01	0.37	1.53	1.39	1.31
B02	0.23	0.77	1.34	0.6
B03	0.37	1.48	1.52	1.36
B04	0.39	1.05	1.53	1.06
P04	0.43	0.78	0.43	0.61
P05	0.55	1.3	1.28	1.17
P06	0.4	1.09	0.84	0.8
P15	0.4	0.94	1.14	0.84
P19	0.4	0.76	1.79	0.76
P3n	0.2	0.48	0.9	0.43
Mean	0.374	1.018	1.216	0.894
Stdev	0.099	0.340	0.399	0.317

Table 3. ESAL Per Vehicle By Axle Class and Site

Site	Bin_4	Bin_5	Bin_67	Bin_8	Bin_9	Bin_10	Bin_11	Bin_12	Bin_13	All
B01	0.645	0.258	0.381	0.259	1.745	1.399	0.934	1.121	2.043	
B02	0.474	0.149	0.3	0.173	1.152	0.715	0.673	1.318	1.45	0.598
B03	0.622	0.28	0.39	0.27	1.551	1.2	1.202	1.32	1.633	1.318
B04	0.7	0.31	0.38	0.31	1.13	1.09	1.53	1.27	1.67	1.07
P04	0.739	0.22	0.418	0.208	0.907	0.61	0.391	0.231	0.607	0.62
P05	0.714	0.452	0.459	0.461	1.362	1.372	1.24	1.122	1.35	1.135
P06	0.283	0.326	0.539	0.326	1.441	0.792	0.386	0.783	0.9	0.797
P15	0.563	0.283	0.522	0.389	1.041	0.979	0.743	1.046	1.283	0.844
P19	0.572	0.242	0.491	0.501	0.845	0.617	0.505	1.664	1.825	0.747
P3N	0.38	0.126	0.29	0.138	0.825	0.545	0.558	0.73	1.143	0.432
Mean	0.569	0.265	0.417	0.304	1.200	0.932	0.816	1.061	1.390	0.840
Standard Dev.	0.150	0.092	0.086	0.119	0.314	0.321	0.395	0.398	0.433	0.286

ESAL Per Vehicle

Not surprisingly, because it includes the largest vehicles, Axle Class 13 showed the highest ESAL per vehicle rate in the dataset. It averaged almost 1.4 ESALs per vehicle, while one site had an ESAL/vehicle loading rate of 2.04. The standard, five-axle semi-trailer (Axle Class 9) had the second most damaging loading rate, averaging 1.2 ESALs per vehicle. The highest Axle Bin 9 loading rate was 1.75 ESALs per vehicle.

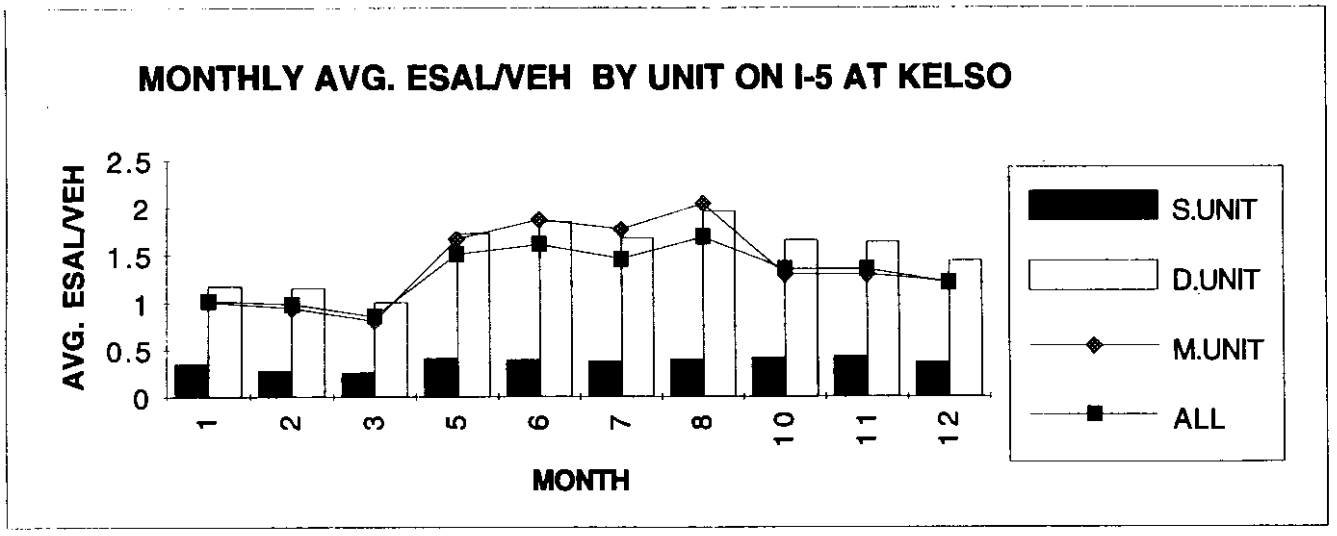
In most cases, the medium large truck configurations (Axle Classes 10, 11, and 12) cause less pavement damage than either the standard, five-axle semi-trailer or the large, seven and greater axle, double-trailer configurations. The ESAL per vehicle estimate for each of these classes averaged below 1.0, although individual sites showed daily ESAL per class averages of just under 1.7. Minimum ESAL values ranged as low as 0.23 for Axle Class 12.

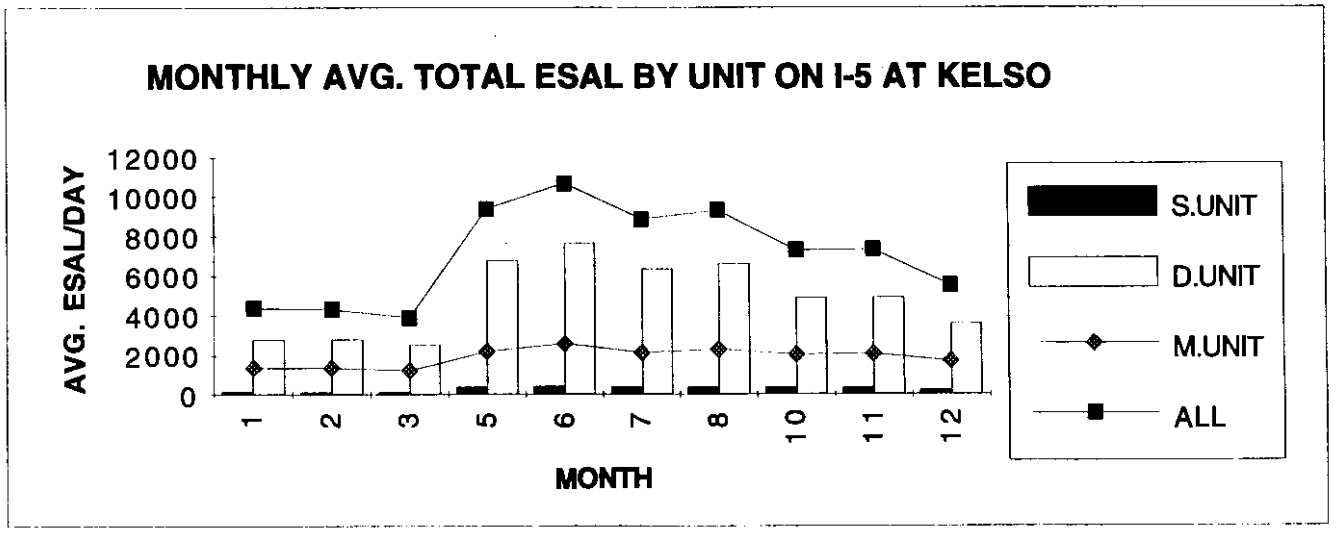
For the more aggregated WSDOT vehicle classes (singles, doubles, multi-units), the ESAL per vehicle rate increased as the size of the vehicle increased. This differed from the FHWA axle classification system, in which two of the multi-unit configurations (five- and six-axle, multi-unit vehicles) had lower ESAL per vehicle loadings than the conventional 3S2 semi-trailer (a double unit). However, this was not true at all sites. In four of the six sites, the double-units classification had a higher average ESAL per vehicle than the multi-unit classification.

It appears that Axle Bins 10, 11, and 12 balance the heavier Axle Bins 9 and 13. These vehicle classes tend to decrease the ESAL per unit value for both double- and multi-unit vehicle classes. (Axle Bin 10 falls into the double-unit vehicle class, while Axle Bins 11 and 12 fall under the multi-unit vehicle class.) Where the number of vehicles in Axle Bins 10, 11, and 12 is large relative to Bins 9 and/or 13, the ESAL per vehicle rate for the aggregated vehicle class can be substantially lower than that for Axle Bins 9 and 13 alone.

APPENDIX A

WIM SUMMARY GRAPHICS


MONTHLY AVG. ESAL/VEH BY UNIT ON I-5 AT KELSO
AVG. ESAL/VEH
2.5
2
1.5
1
0.5
0
1
2
3
5
6
7
8
10
11
12
MONTH
S.UNIT
D.UNIT
M.UNIT
ALL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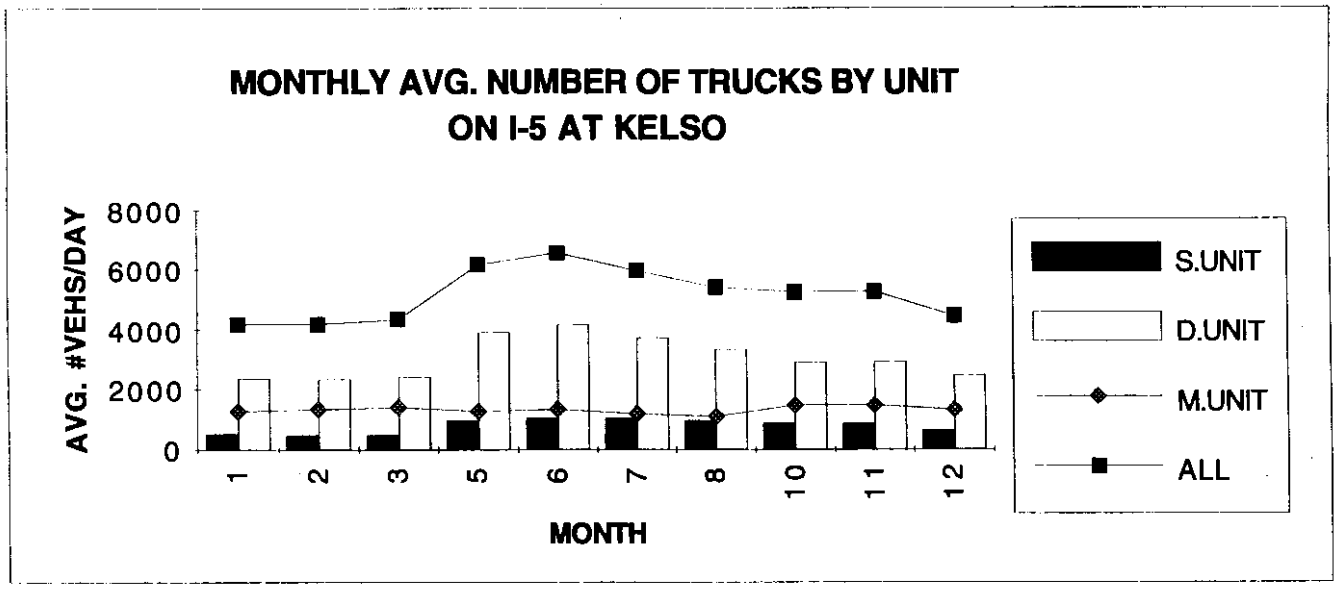
AVG. ESAL/DAY
12000
10000
8000
6000
4000
2000
0
1
2
3
5
6
7
8
10
11
12
MONTH
S.UNIT
D.UNIT
M.UNIT
ALL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ON I-5 AT KELSO
AVG. #VEHS/DAY
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6000
4000
2000
0
1
2
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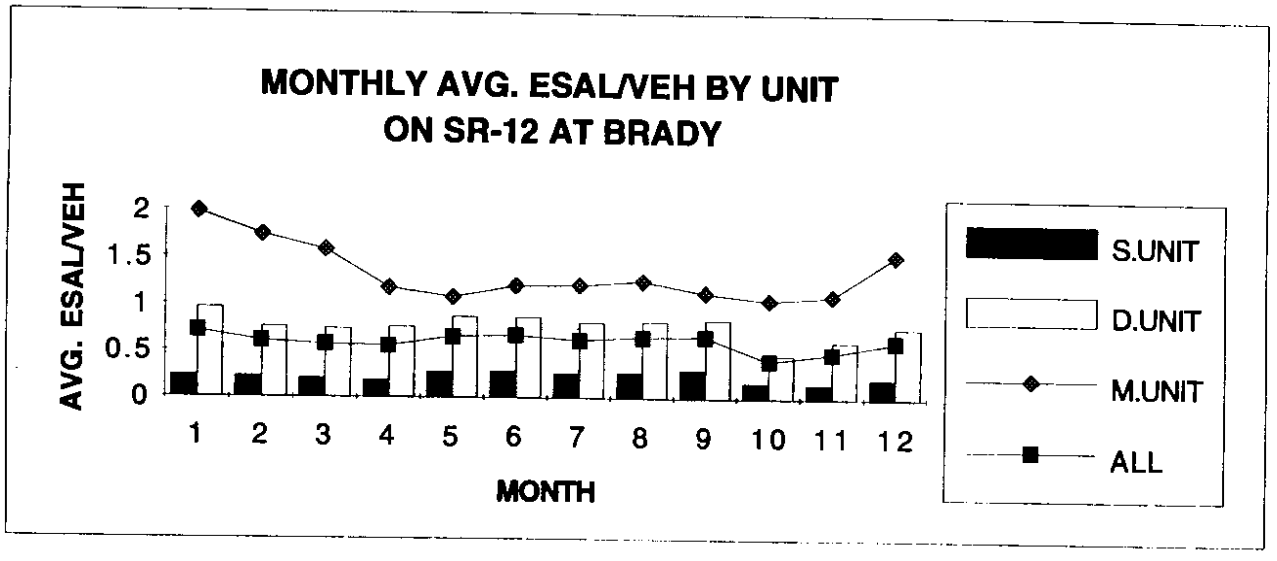
MONTH
S.UNIT
D.UNIT
M.UNIT
ALL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ON SR-12 AT BRADY
AVG. ESAL/VEH
2
1.5
1
0.5
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MONTH
S.UNIT
D.UNIT
M.UNIT
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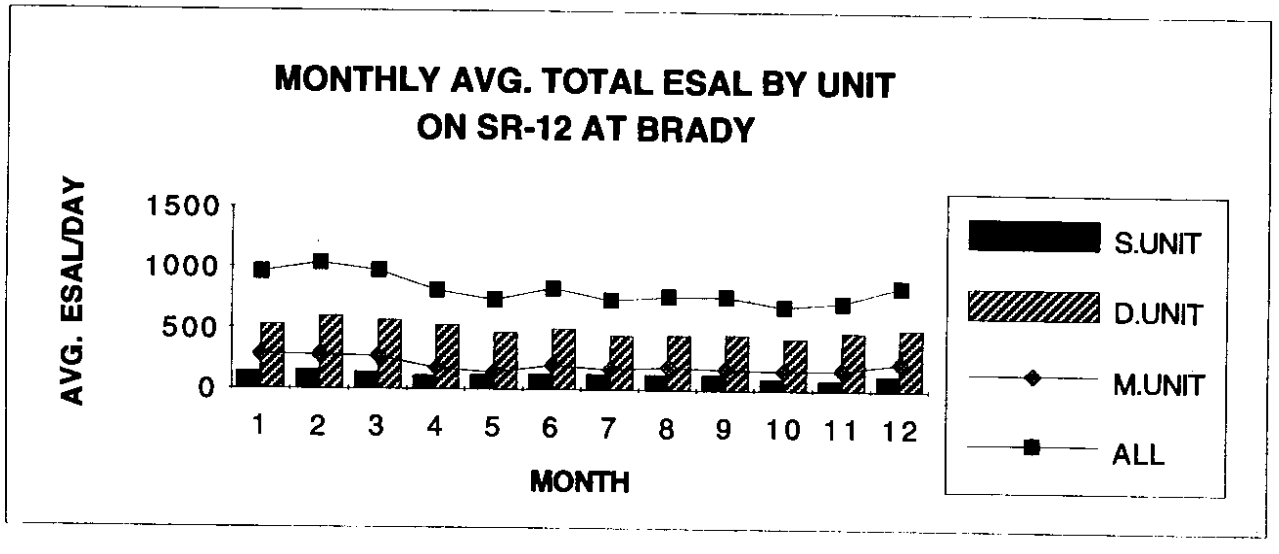
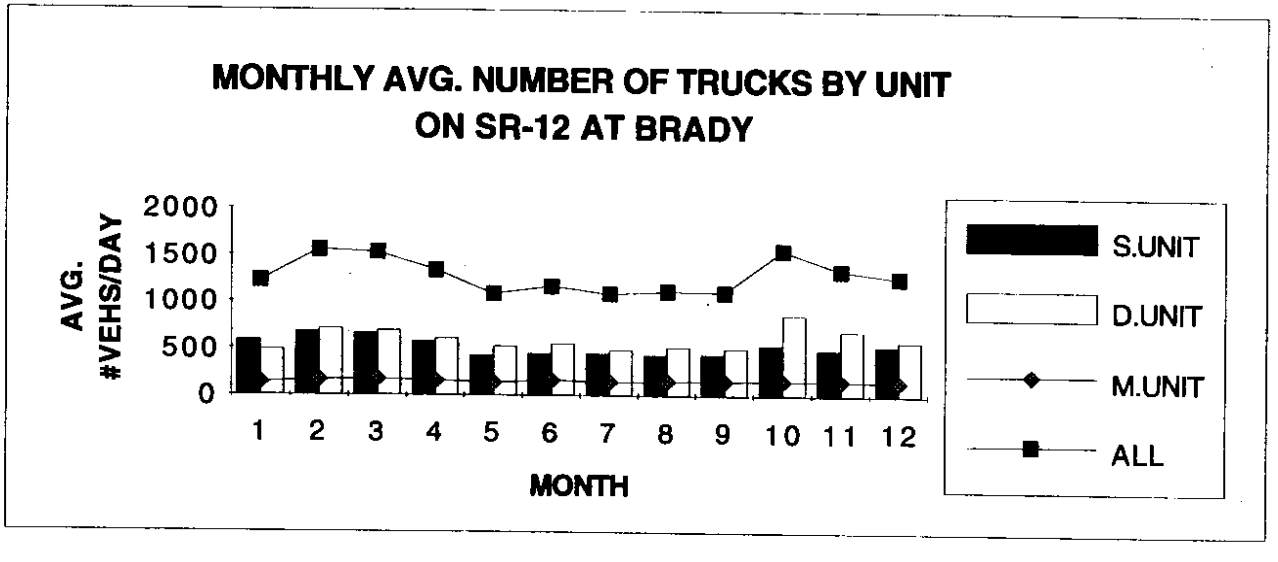
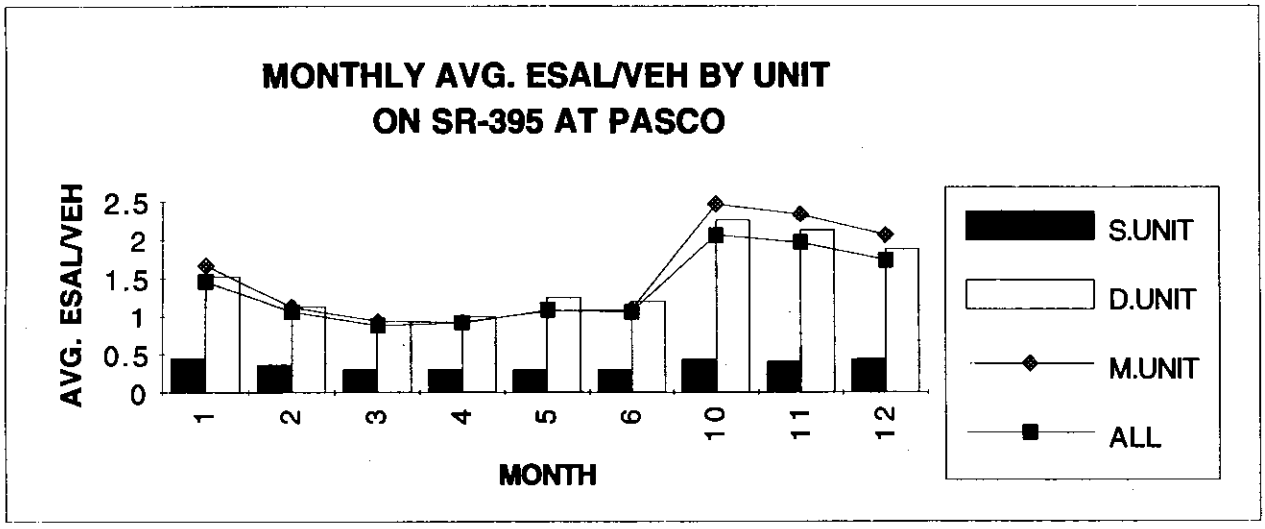
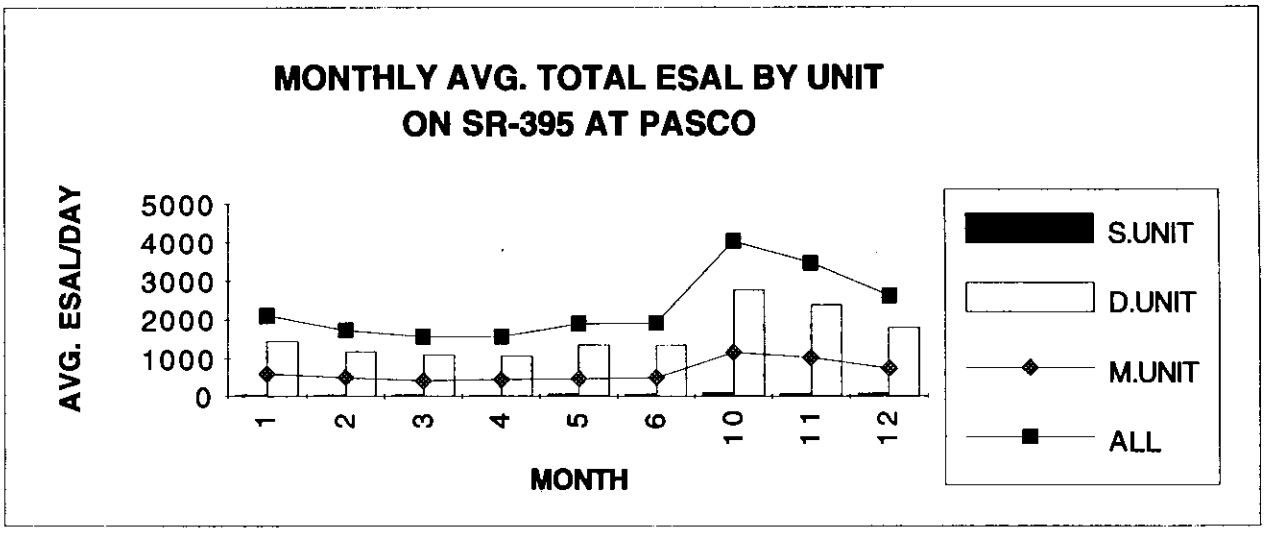
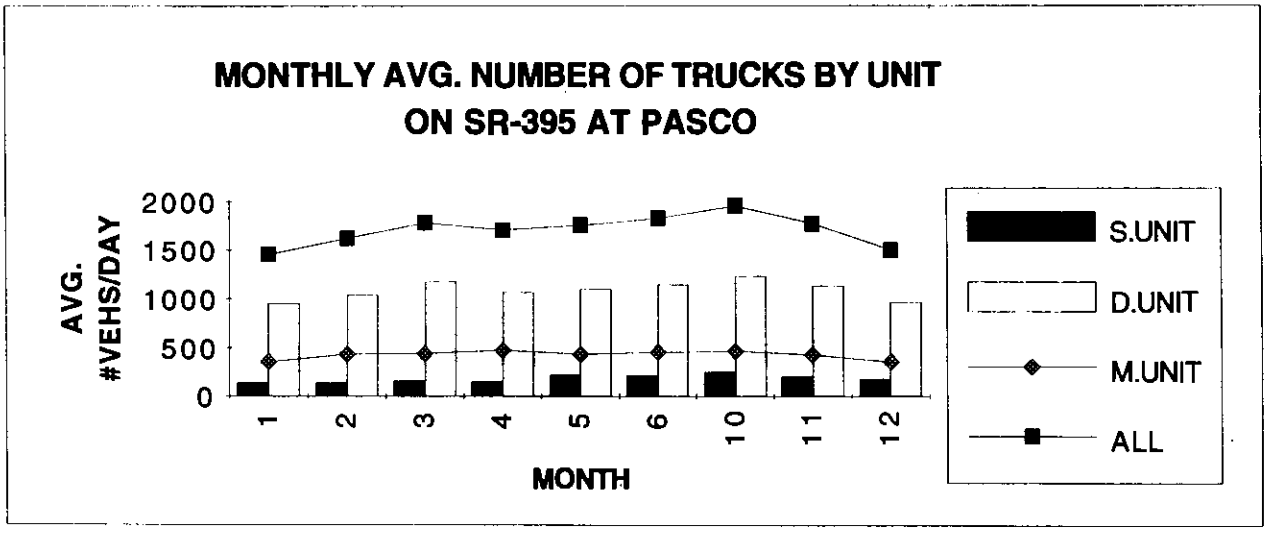
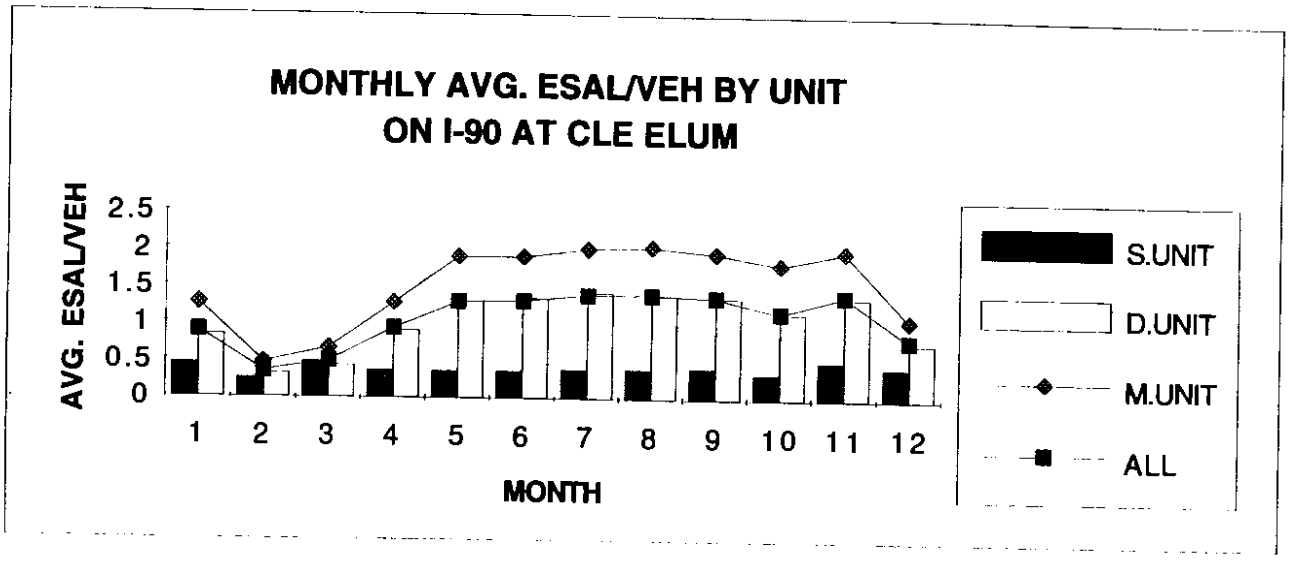

MONTHLY AVG. TOTAL ESAL BY UNIT
ON SR-12 AT BRADY
AVG. ESAL/DAY
1500
1000
500
0
1 2 3 4 5 6 7 8 9 10 11 12
MONTH
S.UNIT
D.UNIT
M.UNIT
ALL

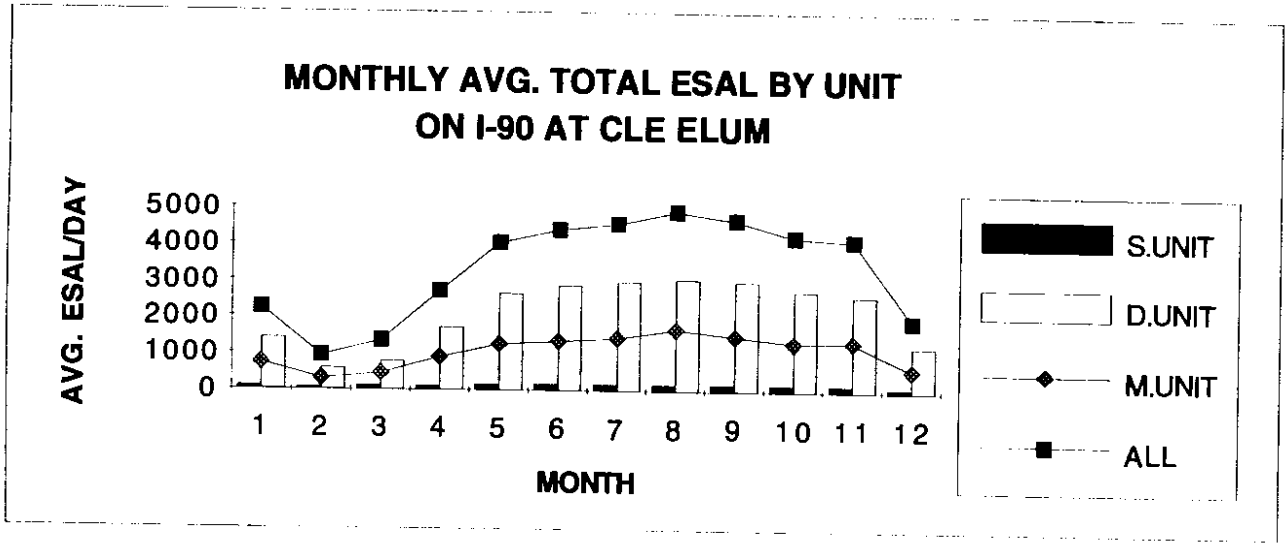

MONTHLY AVG. NUMBER OF TRUCKS BY UNIT
ON SR-12 AT BRADY
AVG. #VEHS/DAY
2000
1500
1000
500
0
1 2 3 4 5 6 7 8 9 10 11 12
MONTH
S.UNIT
D.UNIT
M.UNIT
ALL

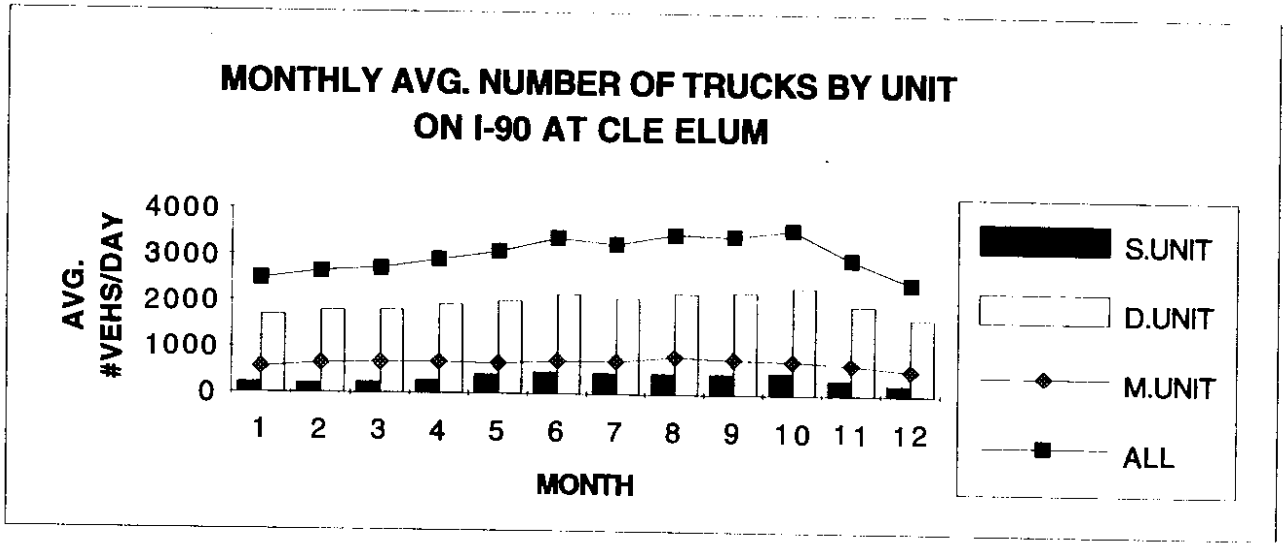

MONTHLY AVG. ESAL/VEH BY UNIT
ON SR-395 AT PASCO
AVG. ESAL/VEH
2.5
2
1.5
1
0.5
0
1
2
3
4
5
6
10
11
12
MONTH
S.UNIT
D.UNIT
M.UNIT
ALL

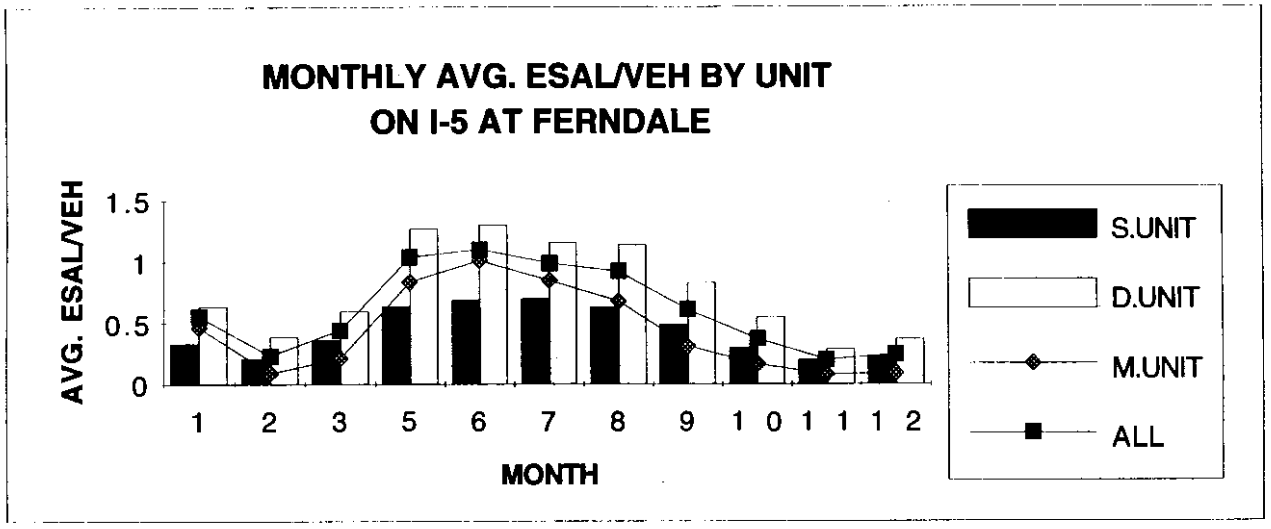

MONTHLY AVG. TOTAL ESAL BY UNIT
ON SR-395 AT PASCO
AVG. ESAL/DAY
5000
4000
3000
2000
1000
0
1
2
3
4
5
6
10
11
12
MONTH
S.UNIT
D.UNIT
M.UNIT
ALL

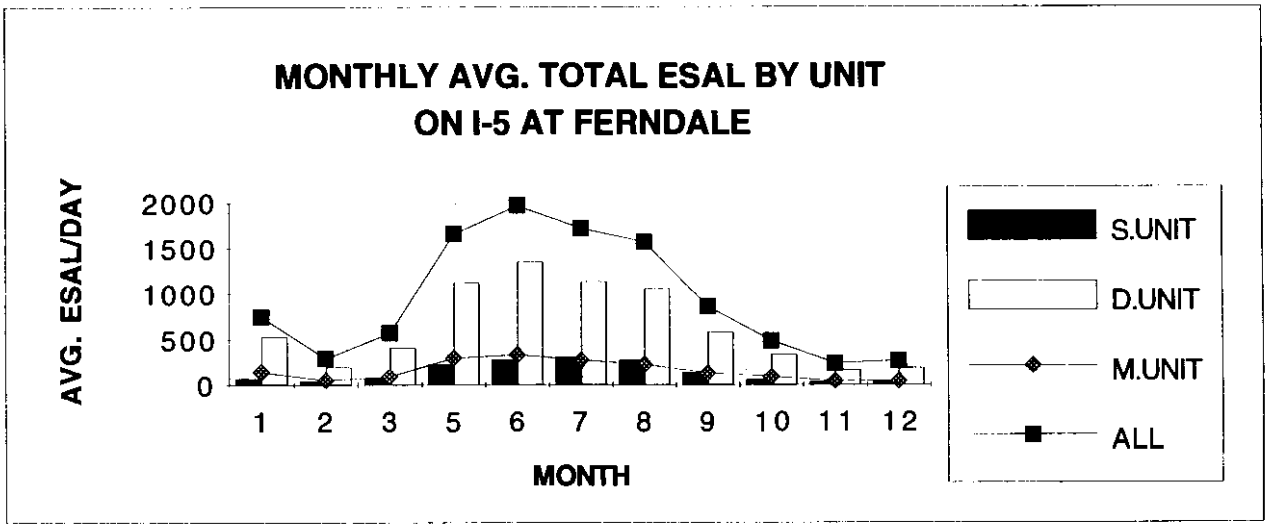

MONTHLY AVG. NUMBER OF TRUCKS BY UNIT
ON SR-395 AT PASCO
AVG.
#VEHS/DAY
2000
1500
1000
500
0
1
2
3
4
5
6
10
11
12
MONTH
S.UNIT
D.UNIT
M.UNIT
ALL

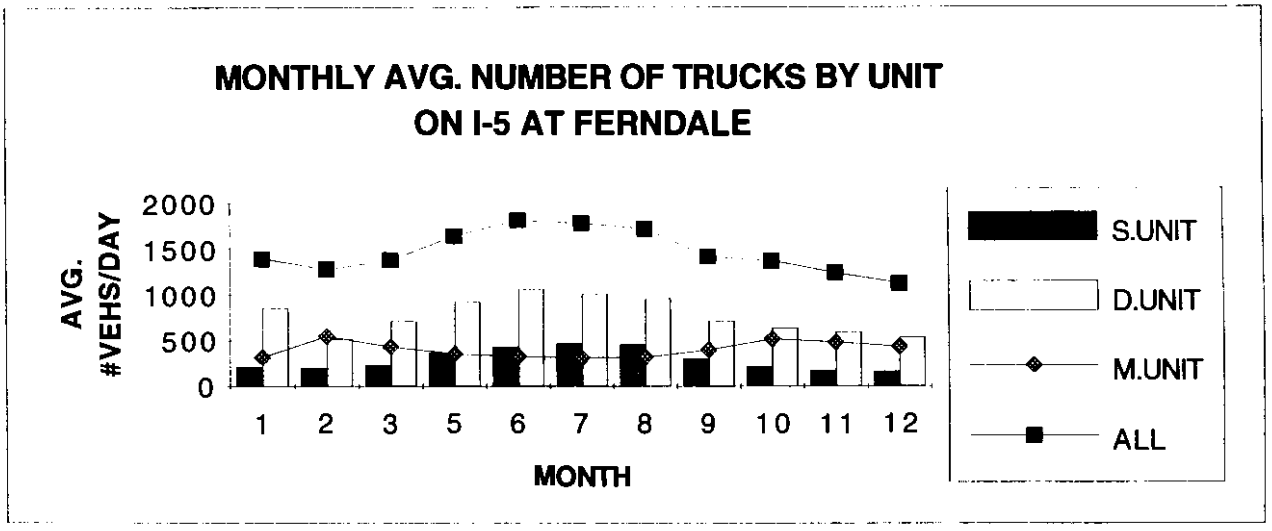

MONTHLY AVG. ESAL/VEH BY UNIT
ON I-90 AT CLE ELUM
AVG. ESAL/VEH
2.5
2
1.5
1
0.5
0
1 2 3 4 5 6 7 8 9 10 11 12
MONTH
S.UNIT
D.UNIT
M.UNIT
ALL

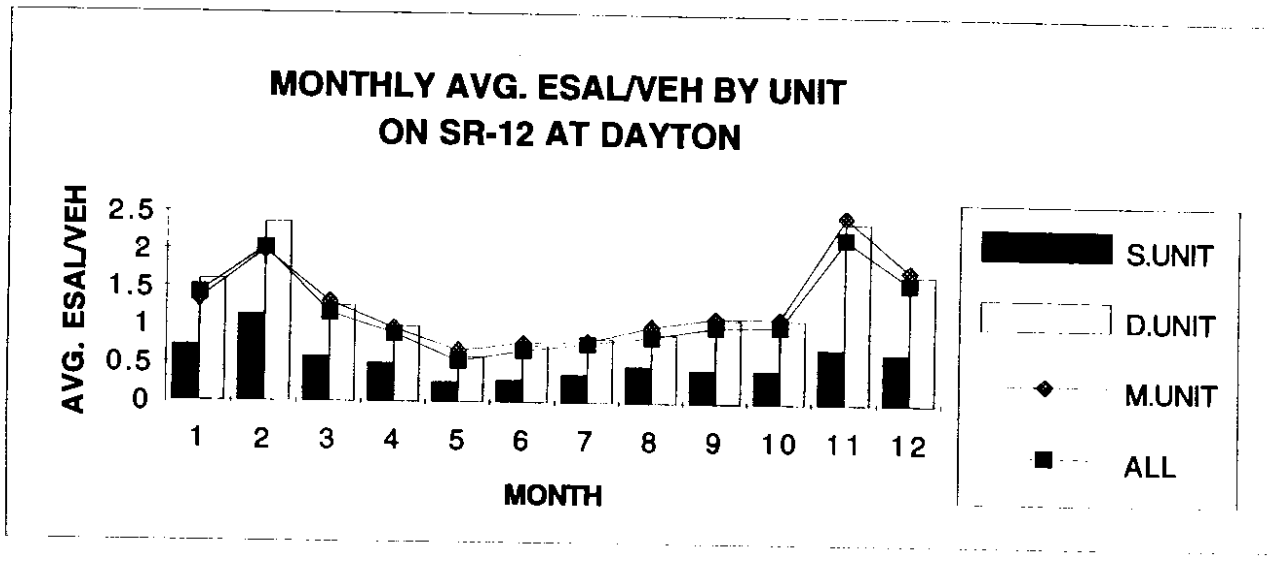

MONTHLY AVG. TOTAL ESAL BY UNIT
ON I-90 AT CLE ELUM
AVG. ESAL/DAY
5000
4000
3000
2000
1000
0
1 2 3 4 5 6 7 8 9 10 11 12
MONTH
S.UNIT
D.UNIT
M.UNIT
ALL

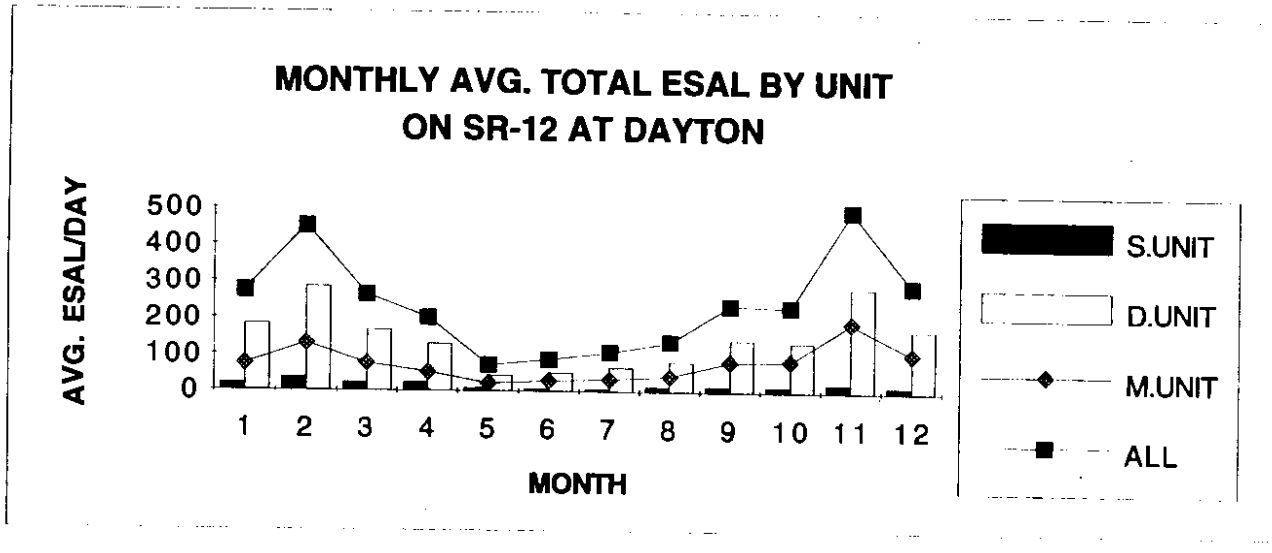

MONTHLY AVG. NUMBER OF TRUCKS BY UNIT
ON I-90 AT CLE ELUM
AVG. #VEHS/DAY
4000
3000
2000
1000
0
1 2 3 4 5 6 7 8 9 10 11 12
MONTH
S.UNIT
D.UNIT
M.UNIT
ALL

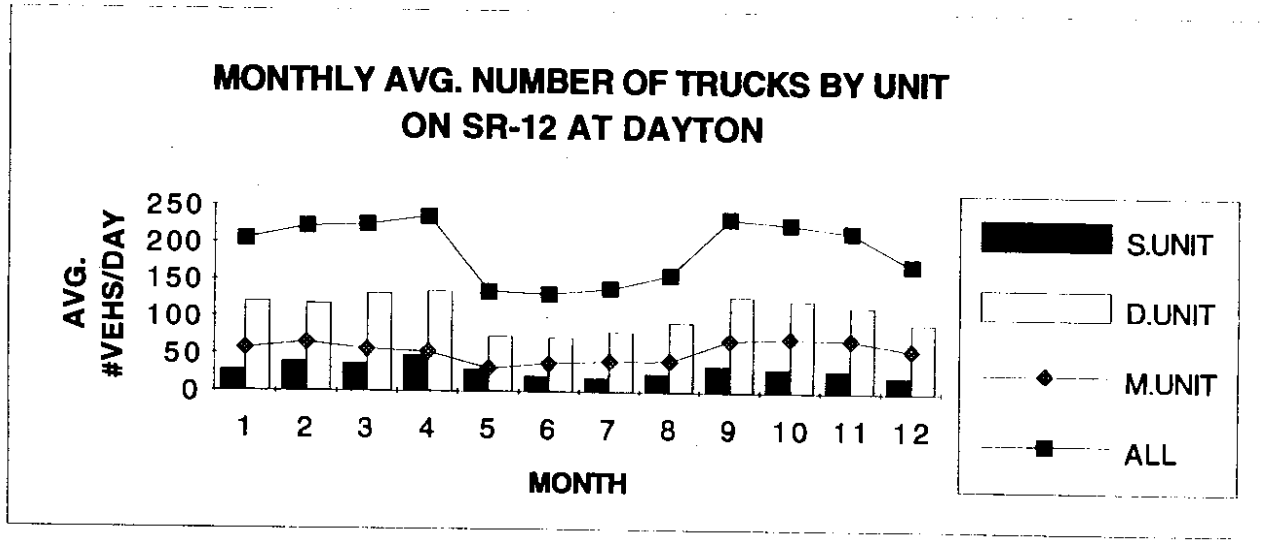

MONTHLY AVG. ESAL/VEH BY UNIT
ON I-5 AT FERNDALE
AVG. ESAL/VEH
1.5
1
0.5
0
1 2 3 5 6 7 8 9 1 0 1 1 1 2
MONTH
S.UNIT
D.UNIT
M.UNIT
ALL

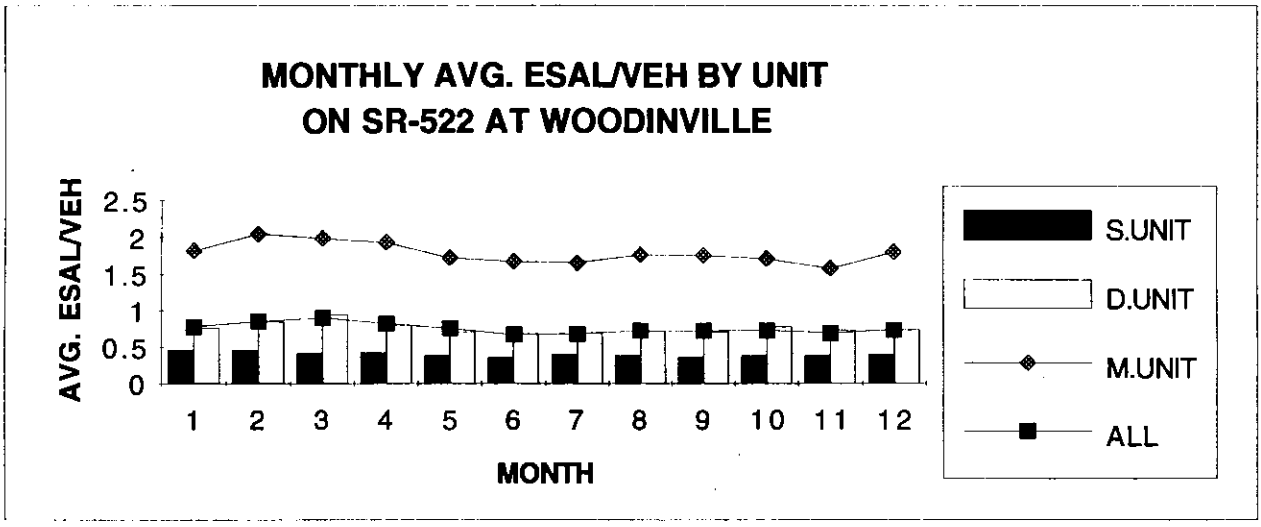

MONTHLY AVG. TOTAL ESAL BY UNIT
ON I-5 AT FERNDALE
AVG. ESAL/DAY
2000
1500
1000
500
0
1 2 3 5 6 7 8 9 10 11 12
MONTH
S.UNIT
D.UNIT
M.UNIT
ALL

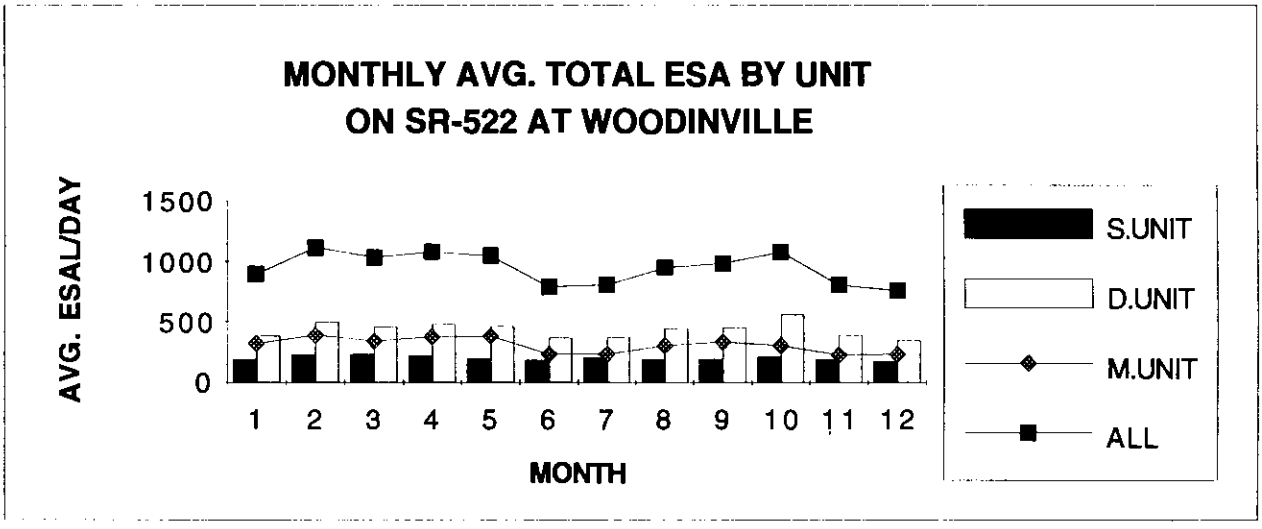

MONTHLY AVG. NUMBER OF TRUCKS BY UNIT
ON I-5 AT FERNDALE
AVG. #VEHS/DAY
2000
1500
1000
500
0
1 2 3 5 6 7 8 9 10 11 12
MONTH
S.UNIT
D.UNIT
M.UNIT
ALL

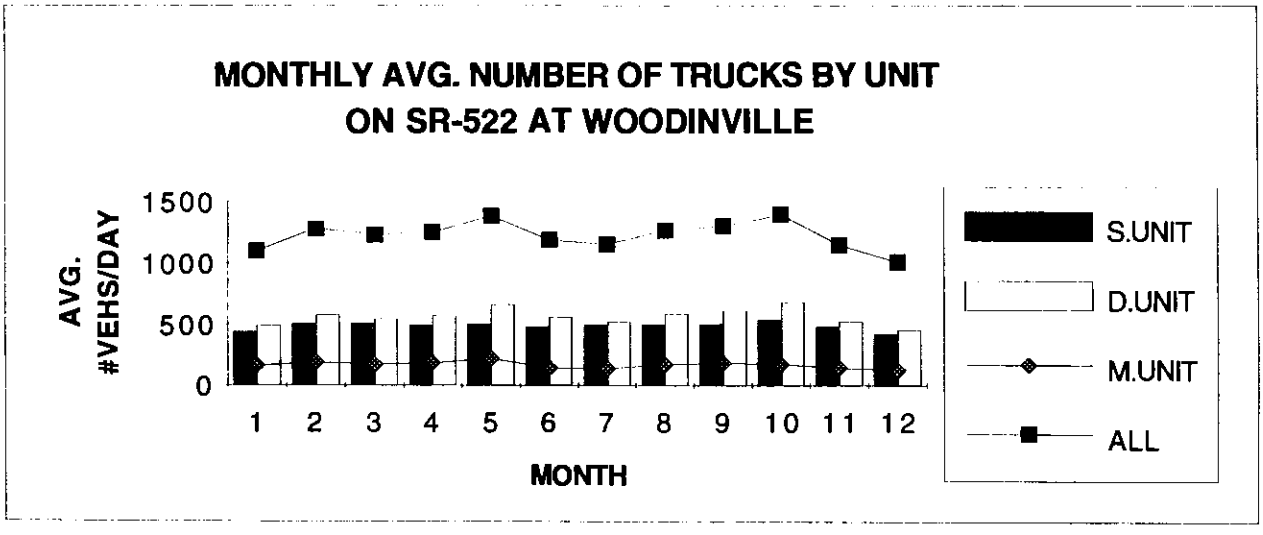

MONTHLY AVG. ESAL/VEH BY UNIT
ON SR-12 AT DAYTON
AVG. ESAL/VEH
2.5
2
1.5
1
0.5
0
1 2 3 4 5 6 7 8 9 10 11 12
MONTH
S.UNIT
D.UNIT
M.UNIT
ALL

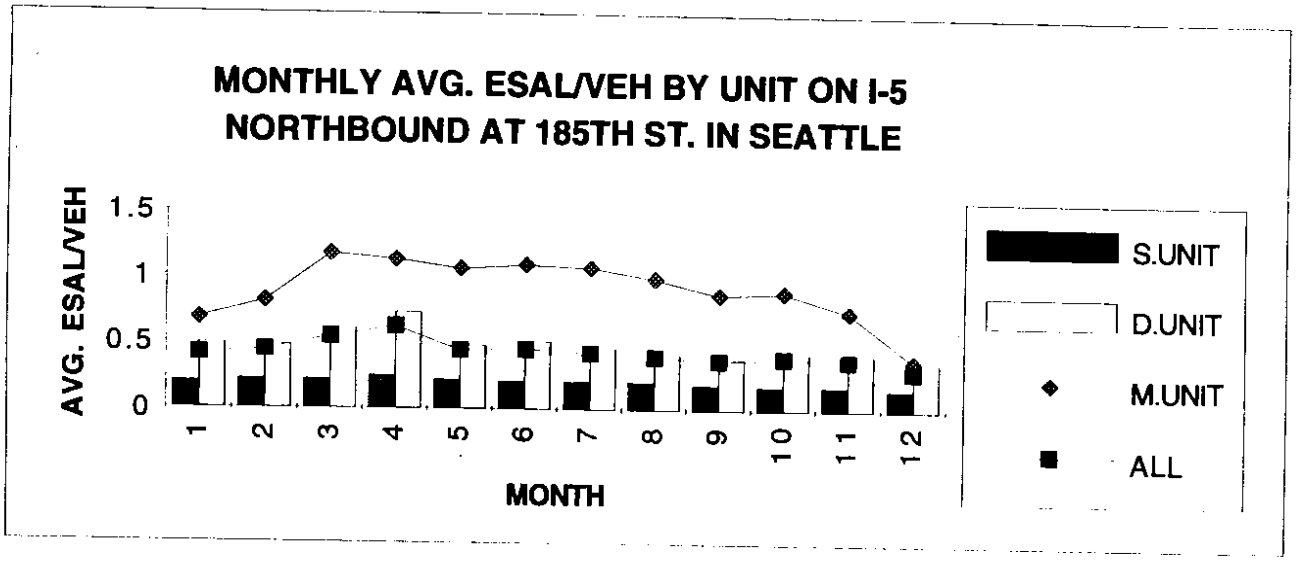

MONTHLY AVG. TOTAL ESAL BY UNIT
ON SR-12 AT DAYTON
AVG. ESAL/DAY
500
400
300
200
100
0
1 2 3 4 5 6 7 8 9 10 11 12
MONTH
S.UNIT
D.UNIT
M.UNIT
ALL

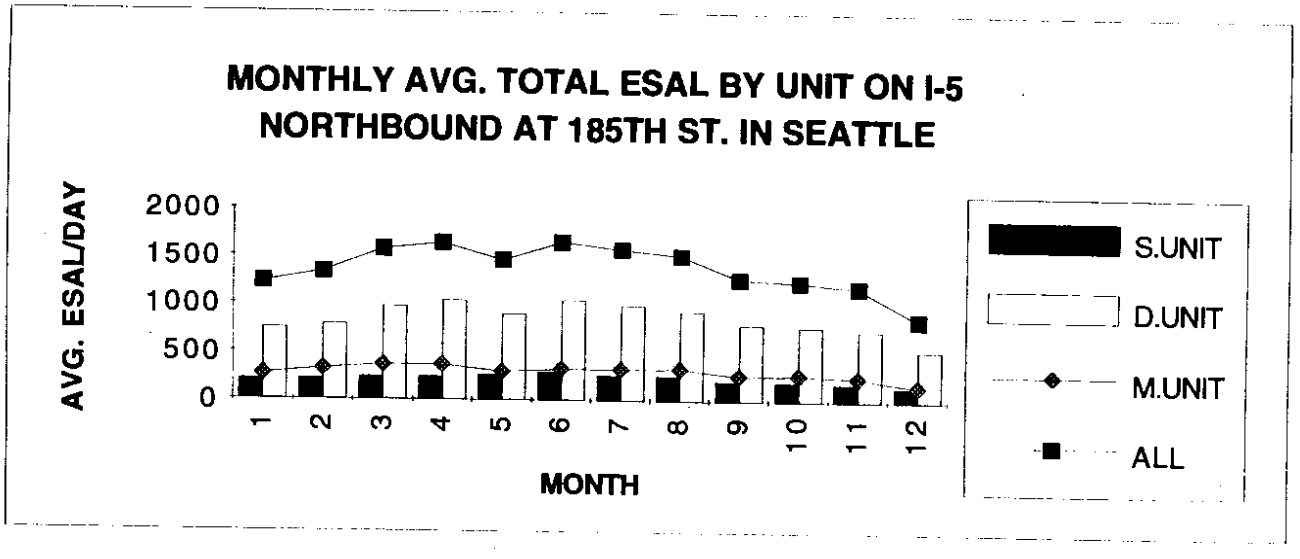

MONTHLY AVG. NUMBER OF TRUCKS BY UNIT
ON SR-12 AT DAYTON
AVG. #VEHS/DAY
250
200
150
100
50
0
1 2 3 4 5 6 7 8 9 10 11 12
MONTH
S.UNIT
D.UNIT
M.UNIT
ALL

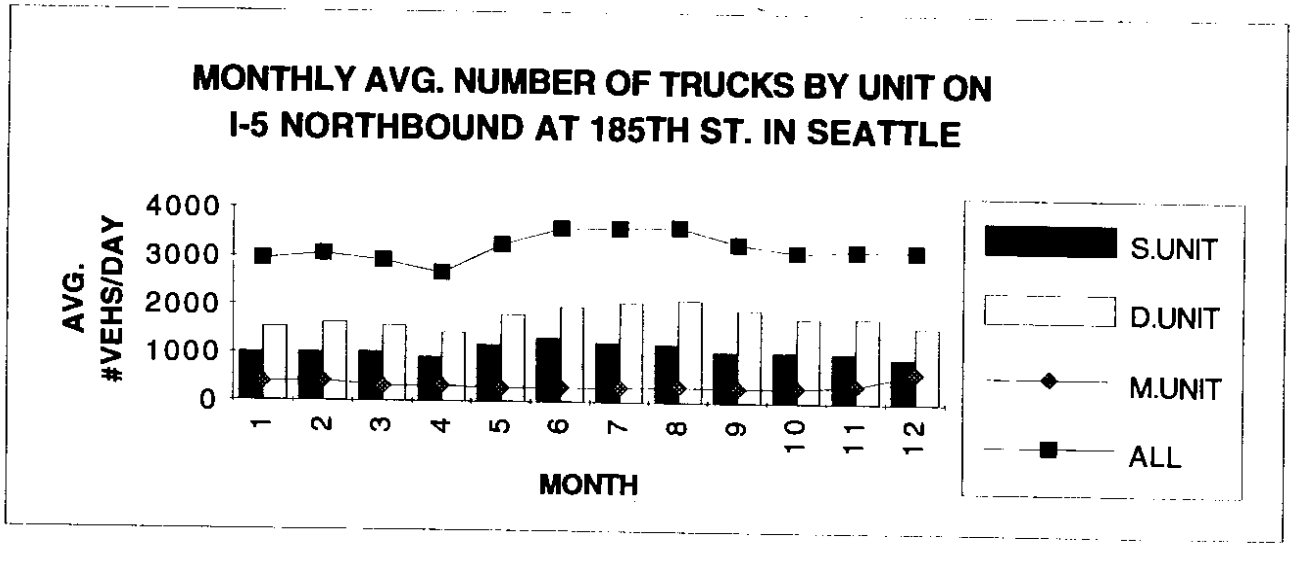

MONTHLY AVG. ESAL/VEH BY UNIT
ON SR-522 AT WOODINVILLE
AVG. ESAL/VEH
2.5
2
1.5
1
0.5
0
1 2 3 4 5 6 7 8 9 10 11 12
MONTH
S.UNIT
D.UNIT
M.UNIT
ALL

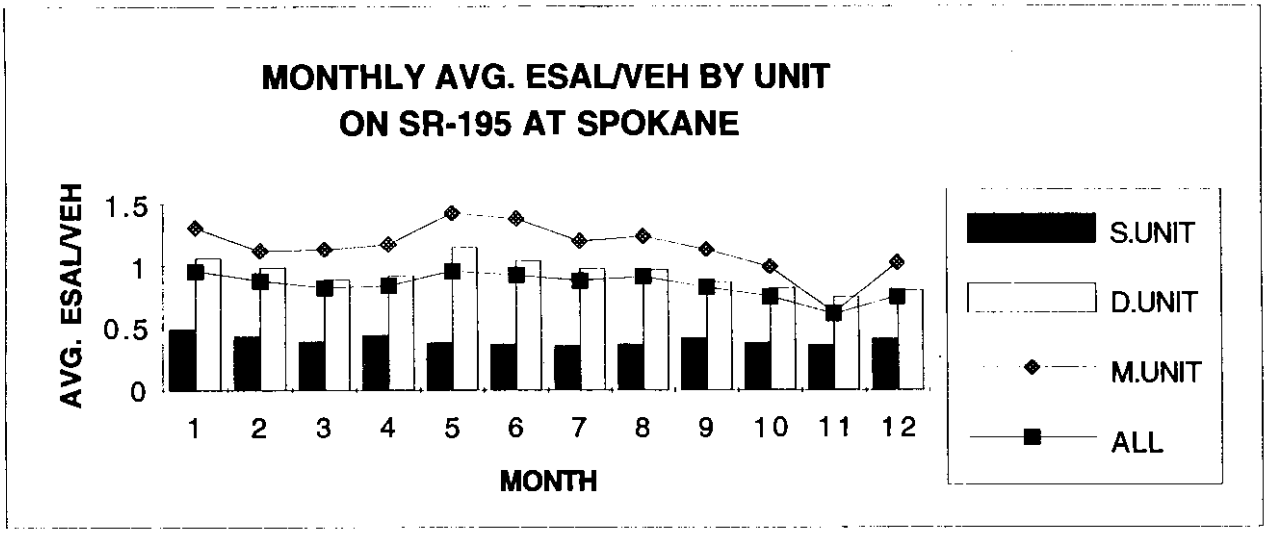

MONTHLY AVG. TOTAL ESA BY UNIT
ON SR-522 AT WOODINVILLE
AVG. ESAL/DAY
1500
1000
500
0
1 2 3 4 5 6 7 8 9 10 11 12
MONTH
S.UNIT
D.UNIT
M.UNIT
ALL

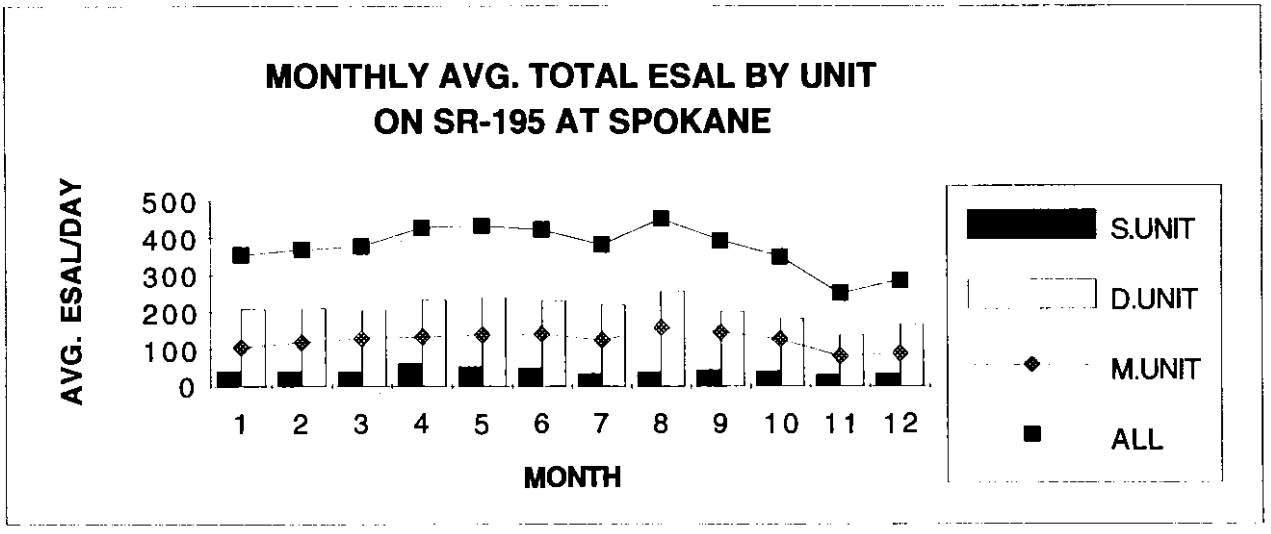

MONTHLY AVG. NUMBER OF TRUCKS BY UNIT
ON SR-522 AT WOODINVILLE
AVG. #VEHS/DAY
1500
1000
500
0
1 2 3 4 5 6 7 8 9 10 11 12
MONTH
S.UNIT
D.UNIT
M.UNIT
ALL

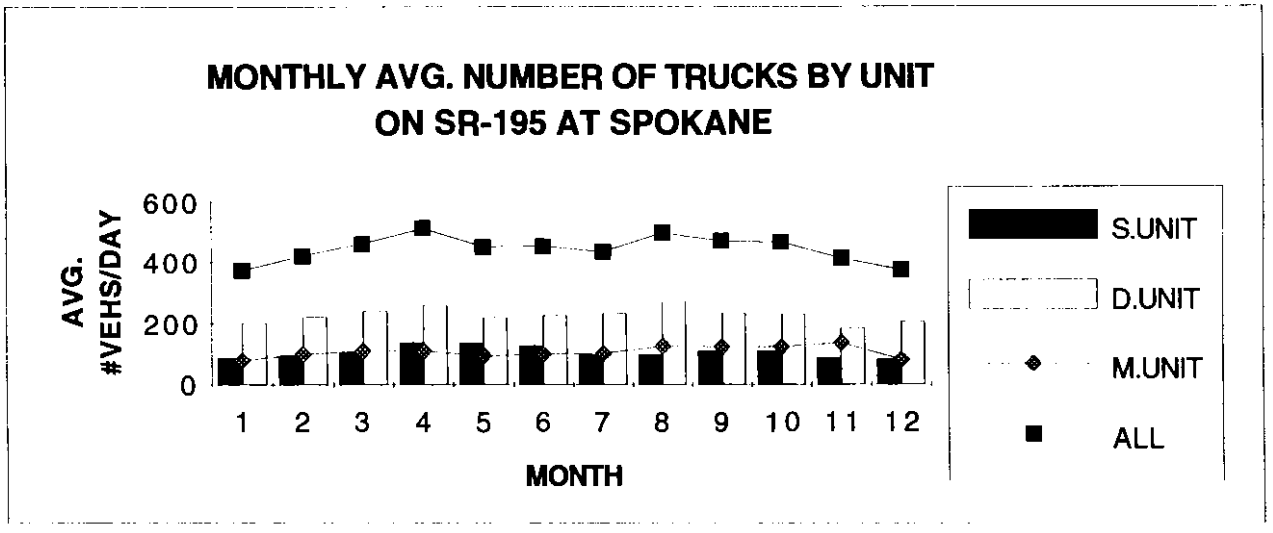

MONTHLY AVG. ESAL/VEH BY UNIT ON I-5 NORTHBOUND AT 185TH ST. IN SEATTLE
AVG. ESAL/VEH
1.5
1
0.5
0
1 2 3 4 5 6 7 8 9 10 11 12
MONTH
S.UNIT
D.UNIT
M.UNIT
ALL

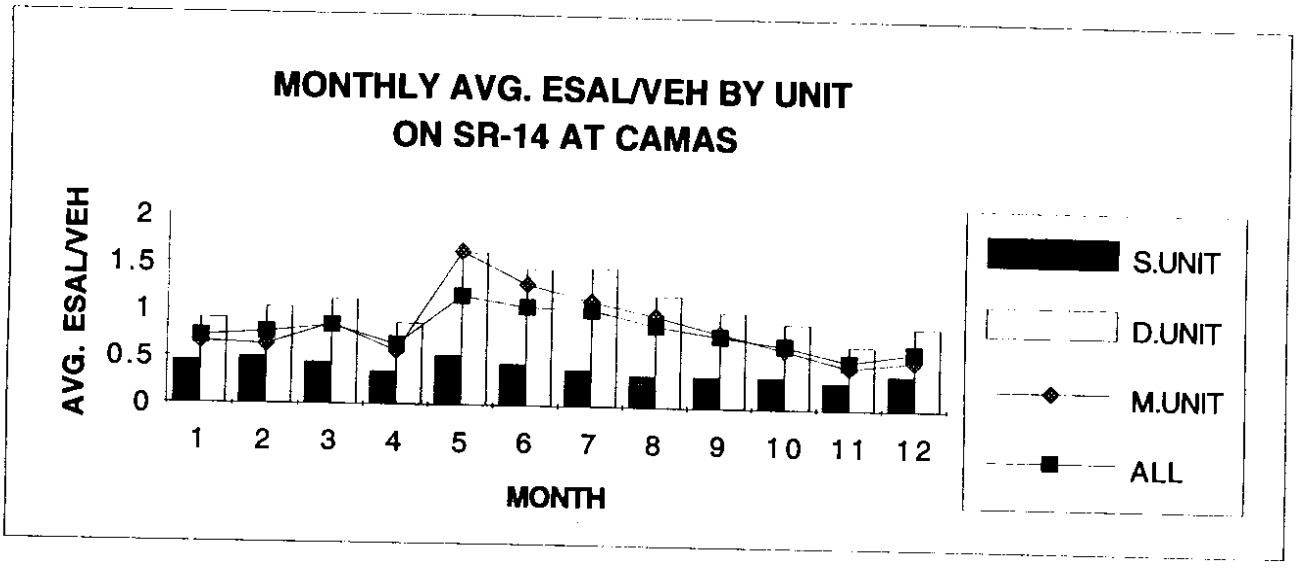

MONTHLY AVG. TOTAL ESAL BY UNIT ON I-5 NORTHBOUND AT 185TH ST. IN SEATTLE
AVG. ESAL/DAY
2000
1500
1000
500
0
1 2 3 4 5 6 7 8 9 10 11 12
MONTH
S.UNIT
D.UNIT
M.UNIT
ALL

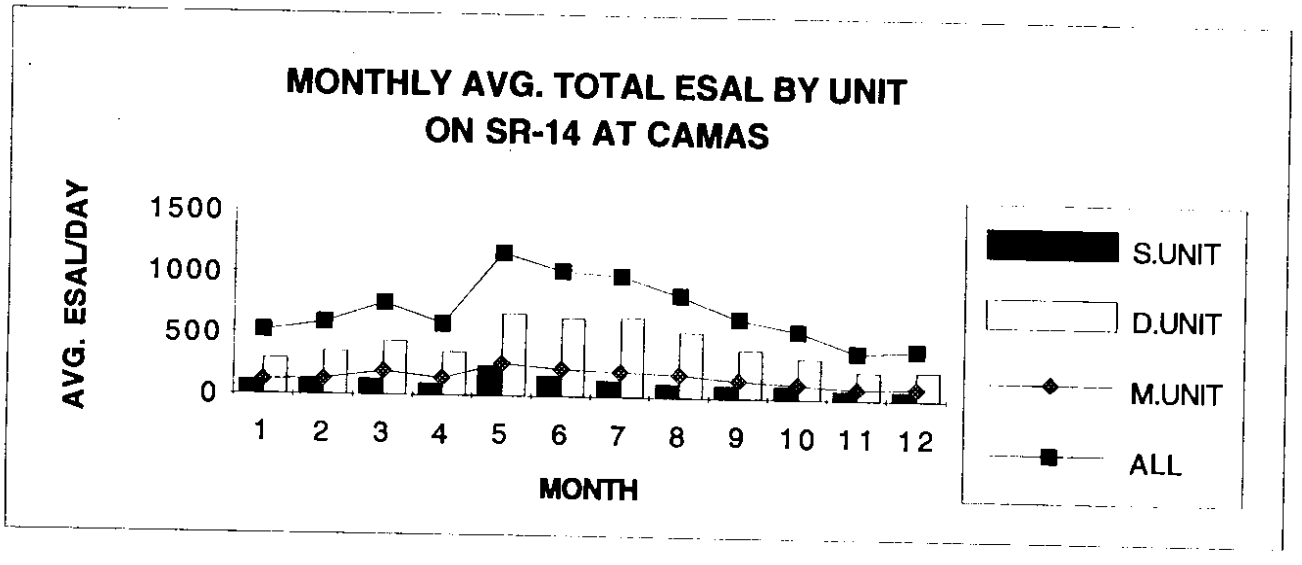

MONTHLY AVG. NUMBER OF TRUCKS BY UNIT ON I-5 NORTHBOUND AT 185TH ST. IN SEATTLE
AVG. #VEHS/DAY
4000
3000
2000
1000
0
1 2 3 4 5 6 7 8 9 10 11 12
MONTH
S.UNIT
D.UNIT
M.UNIT
ALL

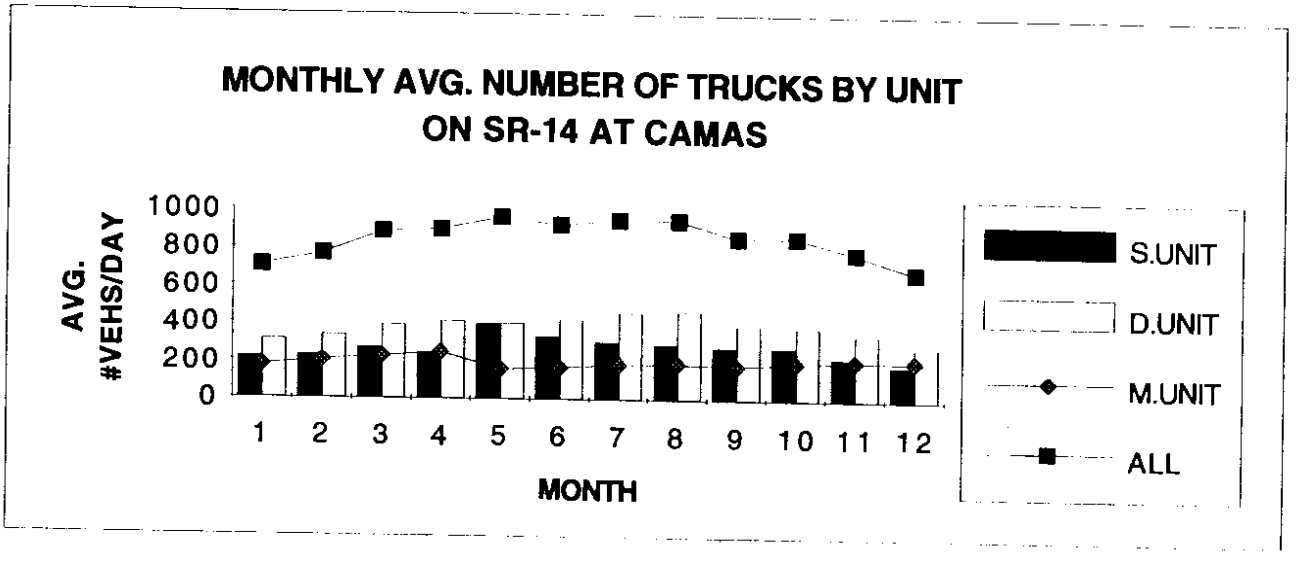

MONTHLY AVG. ESAL/VEH BY UNIT
ON SR-195 AT SPOKANE
AVG. ESAL/VEH
1.5
1
0.5
0
1 2 3 4 5 6 7 8 9 10 11 12
MONTH
S.UNIT
D.UNIT
M.UNIT
ALL


MONTHLY AVG. TOTAL ESAL BY UNIT
ON SR-195 AT SPOKANE
AVG. ESAL/DAY
500
400
300
200
100
0
1 2 3 4 5 6 7 8 9 10 11 12
MONTH
S.UNIT
D.UNIT
M.UNIT
ALL


MONTHLY AVG. NUMBER OF TRUCKS BY UNIT
ON SR-195 AT SPOKANE
AVG. #VEHS/DAY
600
400
200
0
1 2 3 4 5 6 7 8 9 10 11 12
MONTH
S.UNIT
D.UNIT
M.UNIT
ALL


MONTHLY AVG. ESAL/VEH BY UNIT
ON SR-14 AT CAMAS
AVG. ESAL/VEH
2
1.5
1
0.5
0
1 2 3 4 5 6 7 8 9 10 11 12
MONTH
S.UNIT
D.UNIT
M.UNIT
ALL


MONTHLY AVG. TOTAL ESAL BY UNIT
ON SR-14 AT CAMAS
AVG. ESAL/DAY
1500
1000
500
0
1 2 3 4 5 6 7 8 9 10 11 12
MONTH
S.UNIT
D.UNIT
M.UNIT
ALL


MONTHLY AVG. NUMBER OF TRUCKS BY UNIT
ON SR-14 AT CAMAS
AVG. #VEHS/DAY
1000
800
600
400
200
0
1 2 3 4 5 6 7 8 9 10 11 12
MONTH
S.UNIT
D.UNIT
M.UNIT
ALL

APPENDIX B

DIRECTIONS FOR CREATING WIM SUMMARY GRAPHICS

APPENDIX B

DIRECTIONS FOR CREATING WIM SUMMARY GRAPHICS

This appendix provides a brief description of the analysis steps used to create the graphs shown in the main body of this report, so that WSDOT staff can replicate this work and/or perform additional, similar analyses. This appendix describes the computer programs that need to be run, the inputs and outputs from those computer programs, and the various options that need to be selected. The Pascal computer programs discussed in this appendix were written by Soon-Gwan Kim, a PhD candidate at the University of Washington. Questions about these programs can be directed either to Mr. Kim, or to Mr. Mark Hallenbeck. Both can be reached at TRAC at (206) 543-8690.

The programs must run on an MS-DOS based microcomputer, under the WINDOWS operating environment. Four sets of programs/applications are needed to perform the analysis sequence;

- the OFFICE software provided by International Road Dynamics (IRD, the WIM equipment supplier)
- a series of Pascal programs written by Soon-Gwan Kim,
- a word processing program, and
- a spreadsheet program.

These programs can be obtained through the WSDOT Transportation Data Office.

Microsoft Word for Windows, and Microsoft Excel for Windows were used for the analyses described in this appendix. As a result, the analysis steps presented below refer to these programs, however, most modern spreadsheet and word processing packages may be used for these steps.

Figure B-1 illustrates the steps followed in these procedures. This table also lists the names and contents of the input and output data files for each step of the process. The analysis sequence requires nine major steps. Specific instructions for each of these steps are presented below.

Figure B-1. Summary of ESAL Work

	PROGRAM	FUNCTION	INPUT DATA	OUTPUT DATA
1	OFFICE	Get site summary tables of trucks(4 ~ 13 class) from daily XX type of WIM data	Daily WIM data (e.g. 920501XX.B01 ~ 920731XX.B01)	Site summary table (e.g. B01SUMQ1.OUT)
2	MERGE.EXE	Combine one text file with another for getting yearly file	Quarterly files of site summary tables (e.g. B01SUMQ1.OUT, B01SUMQ2.OUT)	Combined file (any name) (e.g. B01SUM1.OUT)
3	REFMAT.EXE	Take out daily ESAL and daily number of trucks by class from the site summary table, and reform these two rows into files	Combined yearly file of daily site summary tables (e.g. B01SUM.OUT)	- Daily ESAL by class (e.g. B01SUM.ESL) - Daily number of trucks by class (e.g. B01SUM.VOL)
4	EXCEL	Create a file including only daily total values across class from classified files, and calculate daily ESAL/VEH across class	- Daily ESAL by class (e.g. B01SUM.ESL) - Daily number of trucks by class(e.g. B01SUM.VOL)	Daily total ESAL, daily total number of trucks and daily total ESAL/VEH across class (e.g. VOLESAL.B01)
5	EXCEL	Check errors (e.g. equipment failure, calibration failure etc.) based on yearly patterns of ESAL, number of trucks and ESAL/VEH	Daily total ESAL, daily total number of trucks and daily total ESAL /VEH across class (e.g. VOLESAL.B01)	- Yearly pattern of daily total number of trucks (e.g. VOLGRPH1.XLS) - Yearly pattern of daily total number of trucks and ESAL (e.g. VOLESLG1.XLS) - Yearly pattern of daily total ESAL/VEH (e.g. EPG1.XLS)
6	Editing	Delete erroneous daily records from yearly files of daily ESAL and daily number of trucks by class	- Daily ESAL by class (e.g. B01SUM.ESL) - Daily number of trucks by class (e.g. B01SUM.VOL)	- Revised daily ESAL by class (e.g. NB01SUM.ESL) - Revised daily number of trucks by class (e.g. NB01SUM.VOL)
7	AVG.EXE	Create day of week average (classified by 4 ~ 13 class) and monthly average (classified by single, double and multi unit) tables for daily ESAL, daily number of trucks and daily ESAL/VEH	- Revised daily ESAL by class (e.g. NB01SUM.ESL) - Revised daily number of trucks by class (e.g. NB01SUM.VOL)	- Day of week average tables ESAL (e.g. B01ESL.AVG) Num. of trucks (e.g. B01VOL.AVG) ESAL/VEH (e.g. B01EPV.AVG) - Monthly average tables ESAL (e.g. B01ESL.TAB) Num. of trucks (e.g. B01VOL.TAB) ESAL/VEH (e.g. B01EPV.TAB)
8	EXCEL	Convert ASCII files of monthly average tables to EXCEL format for graphing When the monthly average data is not ordered from January, and if necessary, sort the data by month	- Monthly average tables ESAL (e.g. B01ESL.TAB) Num. of trucks (e.g. B01VOL.TAB) ESAL/VEH (e.g. B01EPV.TAB)	- Reformed and sorted monthly average tables in EXCEL format ESAL (e.g. B01ESL.XLS) Num. of trucks (e.g. B01VOL.XLS) ESAL/VEH (e.g. B01EPV.XLS)
9	EXCEL	Graph monthly average ESAL, average number of trucks and average ESAL/VEH	- Revised monthly average tables in EXCEL format ESAL (e.g. B01ESL.XLS) Num. of trucks (e.g. B01VOL.XLS) ESAL/VEH (e.g. B01EPV.XLS)	Graphs of monthly average ESAL, average number of trucks and average ESAL/VEH (e.g. B01TAB.GRF)

Running OFFICE

This step runs the basic analysis software provided by the weigh-in-motion equipment manufacturer (IRD corporation). This software, called the OFFICE program, takes binary truck weight records stored by the IRD WIM scales, and summarizes them. The results are output in a ASCII text file, and are used for later analysis steps. Directions for running the OFFICE program can be obtained from the TDO.

Options within the OFFICE software program that should be selected are as follows:

Vehicle Classification Definition

4	Bus
5	2-Axle, 6-Tire Single Unit
6	3-Axle Single Unit
7	4+-Axle Single Unit
8	3- or 4-Axle Single Trailer
9	5-Axle Single Trailer
10	6+-Axle Single Trailer
11	5-Axle Multi-Trailer
12	6-Axle Multi-Trailer
13	7+-Axle Multi-Trailer

Select view lanes: All
Data included: Vehicle Only
Interval: Daily
Class: 4 ~ 13
Transfer report: width 132, length 24
Adjust report parameter: Report Type: Site Summary
Adjust Column Bin: Number of Bins 10 / First Bin 4
Adjust Row Bin: Number of Bins 12 / First Bin 0
Select count report: Include only " Site Summary"
Select file type: Daily
Select data: Combined Data Files
Change unit: US-KIPS & FT

The procedures that should be run are as follows:

- Place the daily WIM data files (files with "XX" in their filename) in the directory "\VEH_RCRD"
- The maximum number of days that OFFICE can handle at one time running only the "Site Summary Table" option is three months (one quarter). If you try to produce more tables in addition to "Site Summary Table," the number of files handled at a time should be reduced, otherwise, an "Out of Memory" error may occur.
- Run the OFFICE program with the options as stated above.
- Generate a report and transfer it to an appropriate directory.

Example:

- Data: one year of daily XX type WIM data from May,1992 to April,1993 (920501XX.B01 ~ 930430XX.B01)

- Run three months of data at a time. Four quarterly files of daily "Site Summary Tables" are produced. The TRAC project team named them
  B01SUMQ1.OUT
  B01SUMQ2.OUT
  B01SUMQ3.OUT
  B01SUMQ4.OUT

where B01 refers to site B01 (bending plate site 1).

Merging OFFICE Output

This step merges the output files for one WIM site that were produced in the previous step. It uses the Windows MERGE.EXE program. The steps are as follows:

- First, run MS WINDOWS and go to the directory containing the MERGE.EXE file.

- Click twice quickly on the MERGE.EXE file, or click on FILE in the menu bar and then run the MERGE.EXE file as you would normally start a WINDOWS executable file.

- Enter all three requested file names before typing the Enter key. (Follow the directions printed on the computer screen.) The first and second file names are the input files, the last file name you type is the output file name.

- If the two source files being merged are not located in the same directory, give the full path name of each of the files.

An example of this step is given below:

First(target) file name	Second(object) file name	New(merged) file name
B01SUMQ1.OUT	B01SUMQ2.OUT	B01SUM1.OUT
B01SUMQ3.OUT	B01SUMQ4.OUT	B01SUM2.OUT
B01SUM1.OUT	B01SUM2.OUT	B01SUM.OUT

Reformatting OFFICE Output

This step reformats the data in the merged files so that a standard spreadsheet or statistical package can be used to summarize the data. This is a PASCAL program written specifically to accept input from the Site Summary Report. The directions for running this program are as follows:

- Starting from WINDOWS, go to the directory that contains the program file REFMAT.EXE.

- Click twice quickly on the REFMAT.EXE file, or click on FILE in the menu bar and then run the REFMAT.EXE file as you would normally start a WINDOWS executable file.

- Enter the source file name as directed by the prompt on the computer screen, and then hit the ENTER key.

- If the source file is not located in the same directory as the REFMAT.EXE file, give the full path name when prompted for the file name.

The data in the site summary report labeled as "Unfltred" (daily number of vehicles by class) and "Tot ESAL" (daily ESAL by class) will then be taken from the site summary table, and stored in two files. These files are

- daily ESAL by class (*.ESL) and
- daily number of trucks by class (*.VOL).

The following example file names illustrate this step.

- Source file: B01SUM.OUT (yearly file of daily site summary tables)
- Output files: B01SUM.ESL (yearly file of daily ESAL by class)
  B01SUM.VOL (yearly file of daily truck volumes by class)

Excel Calculations

Once these two files of yearly data have been created, it is possible to create a third file containing estimates of average ESAL/truck by class for each day of the year. For this project, the EXCEL spreadsheet program was used to perform these steps. The required steps are described below:

- Run EXCEL or any other spreadsheet program.

- Open the file of daily ESAL by class and the file of daily number of trucks by class produced above, in the spreadsheet program. (In EXCEL these will be opened as TEXT files, but the values in the spreadsheet can still be used in numeric calculations. In some cases the PARSE command will need to be used to separate the daily volumes by class into separate spreadsheet columns.)

- Open a new spreadsheet file (destination file).

- Copy the columns of date information (day, month, year, day of week) from one of the two source files to the destination file.

- Copy a column of daily ESAL by class and a column of the daily number of trucks by class to the destination file.

- Create a new column that calculates the daily ESAL/VEH by dividing the column of daily ESAL by the column of daily number of trucks. (Repeat the copy and calculation steps for each vehicle class.)

- Save the destination file under an appropriate file name.

The following example file names illustrate this step.

- Source file: B01SUM.ESL (yearly file of daily ESAL by class)
  B01SUM.VOL (yearly file of daily number of trucks by class)

- Output file: VOLESL.B01 (yearly file of daily total ESAL, daily total number of trucks and daily total ESAL/VEH across class)

Excel Error Checks

Once the yearly file of daily values has been developed, it becomes possible to perform editing on the available data. For this project, the edits were relatively simplistic. The yearly files in the spreadsheet program were plotted against time. These values were then reviewed visually, and data that were considered to be "bad" were investigated further, and those determined to be invalid were deleted.

Editing of Data

This step can be accomplished either by deleting specific rows from the spreadsheet file created in the previous step, or by reading that file into a word processing program, and deleting data using that program's functions. It is best if the edited file is saved under a new file name, rather than replacing the original file. This creates an "audit trail" for the project, and allows further examination of the "bad" data at a later date without having to recreate the original file of daily values.

At the end of this step, the spreadsheet file must be saved in a TEXT format, so that it an be read into the averaging program described below.

Calculation of Averages

In this analysis step, the edited, daily estimates are averaged to create average day-of-the-week, average monthly, and average annual estimates. A Pascal program, AVG.EXE was written specifically to perform these tasks. The steps required to run this program are shown below.

- Starting from WINDOWS, go to the directory that contains the program file AVG.EXE.

- Click twice quickly on the AVG.EXE file, or click on FILE in the menu bar and then run the AVG.EXE file as you would normally start a WINDOWS executable file.

- Enter the source file name with the ENTER key according to the directions on the computer screen. Average day of week tables (classified by 4-13 class and by month) for ESAL, number of trucks, and ESAL/VEH will be created, as will monthly average tables (classified by single, double and multi unit vehicles).

- If the data source file is not located in the same directory as the file AVG.EXE, give the full path name when prompted for the file name.

The following example file names illustrate this step.

- Source file: NB01SUM.ESL (edited yearly file of daily ESAL by class)
  NB01SUM.VOL (edited yearly file of daily number of trucks by class)

- Output file: day of week average tables by month (classified by 4-13 class)
  B01ESL.AVG (ESAL)
  B01VOL.AVG (number of trucks)
  B01EPV.AVG (ESAL/VEH)
  monthly average tables (classified by single, double and multi unit)
  B01ESL.TAB (ESAL)
  B01VOL.TAB (number of trucks)
  B01EPV.TAB (ESAL/VEH)

Excel Summaries

The files produced in the previous step can then be read back into a spreadsheet program for final analysis and graphic output. For the main report in this project, the data were sorted by site and date, and then averaged to meet the needs of the project.

Excel Graphics

Finally, the summaries produced in the previous step can be plotted or formatted in other graphic formats as desired by the analysts.