METHODOLOGY FOR UTILIZING SURVEY SKID DATA

by

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Research Analyst

(The opinions, findings, and conclusions expressed in this report are those of the author and not necessarily those of the sponsoring agencies.)

Virginia Highway & Transportation Research Council
(A Cooperative Organization Sponsored Jointly by the Virginia Department of Highways & Transportation and the University of Virginia)

Charlottesville, Virginia

October 1975
VHTRC 76-R18

SUMMARY

This report sets forth procedures for utilizing survey skid data with consideration given to testing variabilities and relationships between the three testing devices used in Virginia — namely, the Virginia Department of Highways & Transportation's trailer, the Virginia Highway & Transportation Research Council's trailer, and the Council's stopping distance car.

Within test series variability, or testing precision, as well as day-to-day variability due to systematic errors is discussed, and a method of determining confidence limits for site averages is indicated. Application of the site averages against an assumed minimum standard utilizing confidence intervals is demonstrated. Current testing frequencies are reviewed in light of the testing variabilities determined and reductions are suggested.

Relationships between the testing devices in use since the summer of 1974 are verified and modified as necessary based on 1975 correlation data.

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INTRODUCTION

A great amount of research effort has been expended over the past twenty years in the general area of skid resistance, and more and more states are embarking on survey skid programs utilizing locked-wheel skid testers. However, relatively little information has been published regarding the statistical characteristics of survey skid data and the limitations these characteristics impose on the use of the data, including the determination of whether or not minimum skid number standards are met. Gillespie, Meyer, and Hegmon in their paper entitled, "Skid Resistance Testing from a Statistical Viewpoint" concluded that "Even if skid tester and test tire variances could be eliminated, the necessity of statistical analysis of skid test data remains because of the variance in pavements themselves."(1) The same authors, in NCHRP Report 151, discuss various sources of testing error with trailers and include a section on confidence criteria for a skid test program.(2) However, the confidence criteria established in this study are based on testing precision only (equivalent to the variability of a series of measurements obtained on a homogeneous pavement). Thus, any systematic variation over time due to changes in tires or tire condition, temperatures, and operational procedures is not accounted for. (Sources of both random and systematic error are discussed in detail in NCHRP Report 151.)

In addition to the testing errors noted above, in evaluating data one should consider the relationship between testing devices. When more than one testing device is used in a state, the relationships between the devices should be known, and preferably any skid number standards should be established in terms of one of the devices.

PURPOSE AND SCOPE

The purpose of this report is to identify the magnitude of skid testing variabilities in Virginia for the three testing devices used — The Virginia Department of Highways & Transportation skid trailer (VDHT trailer), and the Virginia Highway & Transportation Research Council's trailer and stopping distance car (VHTRC trailer and car). An evaluation of the current testing frequencies is made considering testing variabilities with changes where they appear reasonable.

A second purpose is to update the relationships between the three Virginia testing devices. The current relationships were developed during a 1974 correlation program as reported in "Evaluation of the New Virginia Department of Highways and Transportation Skid Testing Trailer."(3)

The report does not deal with the development of minimum skid number standards for Virginia; work in that area is under way in a separate project by the author and D. C. Mahone. However, methods of applying survey results against minimum standards with consideration given to testing variabilities are discussed.

Testing variabilities, as discussed in the next section, will be determined through the use of correlation data obtained during the summers of 1974 and 1975, and also through the use of control site data collected by both trailers from July 1974 through July 1975. Some actual survey data are also shown to demonstrate the magnitude of site variability one might expect during routine survey testing, and to demonstrate how confidence intervals might be placed around the average site skid number when applying the average to a minimum standard.

The 1975 correlation data are also used later in the report to update the relationships between the three testing devices, which are currently based on the 1974 correlation data.

ANALYSIS OF TESTING VARIABILITIES

Testing Precision

As indicated previously, a testing error for a given test device exists within a routine series of tests all taken on the same site at essentially the same time. Any change in the magnitude of this error from site to site is due essentially to differences in homogeneity in the sites with regard to skid resistance. In the previous study by the author cited above,(3) it was determined from the 1974 correlation data that testing variability as determined by repeat testing at the same site was approximately the same for the three testing devices at all speeds, with the average site standard deviation being about 2 skid numbers. There was, however, significant differences in testing variabilities between sites, with some indication that texture may influence variability.

The results of the 1975 correlation program, as shown in Table 1, indicate a somewhat better precision for the VDHT trailer. The average site standard deviations were about 1.5 SN for the VDHT trailer and about 2.5 SN for the VHTRC trailer and car. As will be discussed later, this apparent difference in testing precision would mean more tests are required to predict a site mean value within certain limits if the VHTRC trailer or car were used as opposed to the VDHT trailer.

While the normal site standard deviation for homogeneous sites is about 2 SN as discussed above, this variability may increase greatly for less homogeneous sites as illustrated by the actual survey data shown in Figure 1. Sites as shown in Figure 1 represent the same mix type in a specified lane and may be several miles in length. For several of the sites shown, the standard deviation is greater than 2 SN, and even exceeds 4 SN for two of the sites. It seems obvious in looking at Figure 1 that those sites having the highest standard deviation (the first and fourth) should each probably be considered as two sites, divided at about milepoint 3.5 for one and about milepoint 19.0 for the other. As will be discussed in more detail later, sites having a high variability should be examined closely when the average site value is near the desired minimum skid value.

Table 1

1975 Correlation Results

Site*	Date Tested	Tire	VDHT TRAILER						VHTRC TRAILER						VHTRC CAR					
			30 mph		40 mph		60 mph		30 mph		40 mph		60 mph		30 mph		40 mph		60 mph	
			$\bar{x}$	S_s	$\bar{x}$	S_s	$\bar{x}$	S_s	$\bar{x}$	S_s	$\bar{x}$	S_s	$\bar{x}$	S_s	$\bar{x}$	S_s	$\bar{x}$	S_s	$\bar{x}$	S_s
1	7-7-75	New	47.3	1.07	40.8	1.22	30.9	0.35	52.0	0.00	44.5	2.50	35.5	2.24	52.5	2.26	46.0	2.91	39.3	1.83
	7-8-75	Bald	29.6	2.62	22.5	1.21	13.7	1.27	27.4	0.89	20.0	2.24	11.8	1.79	40.4	1.71	30.6	0.65		
2	7-7-75	New	61.2	1.09	54.5	1.87	42.4	0.97	66.6	2.27	60.2	2.05	48.0	1.37	63.0	1.07	60.0	1.00	51.1	0.92
	7-8-75	Bald	33.6	1.81	25.1	2.35	16.7	0.96	36.5	5.97	26.2	3.49	19.6	1.34	45.7	0.90	36.1	1.74	24.4	2.10
3	7-9-75	New	49.3	0.76	44.4	1.36	37.8	1.40	56.5	1.12	51.0	2.24	44.0	2.09	63.2	3.24	58.7	1.69	50.8	1.67
	7-8-75	Bald	37.4	2.59	30.9	2.[illegible]5	24.1	0.75	41.0	5.18	34.0	2.74	26.2	3.49	54.6	2.46	47.7	5.76		
4	7-9-75	New	45.5	0.91	42.6	1.76	38.0	1.15	54.5	2.50	49.0	2.74	43.5	1.37	59.3	4.07	57.1	1.94	50.7	2.76
	7-8-75	Bald	39.4	2.00	35.3	3.03	27.1	1.43	45.0	3.25	42.0	3.95	34.4	7.16	52.4	5.34	50.2	2.12		
5	7-9-75	New	44.9	1.16	36.2	1.02	26.9	1.07	49.0	1.12	42.5	2.09	32.5	1.12	49.6	2.20	44.3	3.85	38.8	0.82
	7-10-75	Bald	27.6	1.25	19.7	1.50	13.0	0.97	29.8	2.17	22.0	0.00	14.2	2.86	36.2	5.16	30.8	2.14		
6	7-9-75	New	51.8	1.32	46.2	2.18	37.6	1.87	59.2	2.17	55.0	1.12	45.0	2.09	62.7	2.08	56.7	2.79	48.0	2.01
	7-10-75	Bald	33.4	1.39	25.3	1.50	20.2	0.97	39.5	3.06	30.7	2.49	23.0	2.29	49.8	6.14	42.1	4.92	36.2	5.73
Average S_s				1.50		1.76		1.10		2.48		2.31		2.44		3.06		2.63		2.23

*Sites 1-6 are the same as sites 1-6 in the 1974 correlation program and as described in the report "Evaluation of the New Virginia Department of Highways and Transportation Skid Testing Trailer."

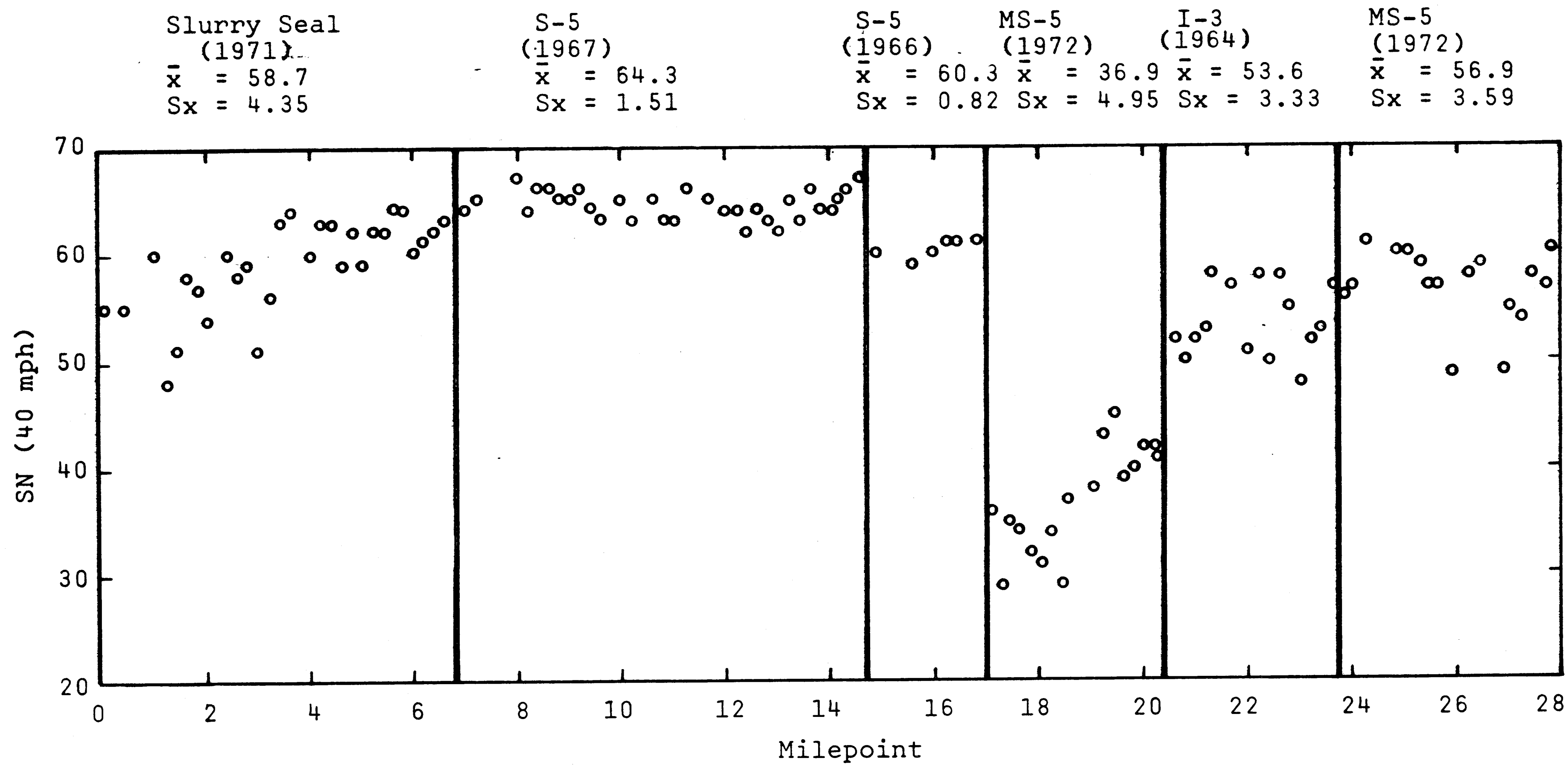

Figure 1. Survey test results on Route I-64 — EBTL Alleghany Co.

Systematic Error Over Time

It was also concluded from the 1974 correlation data that day-to-day variations in average skid numbers obtained at the same site were significantly different. This finding indicated that variability over time must be considered in interpreting survey skid results, and that it is desirable to perform control site testing as a routine part of the survey skid program. Day-to-day variations seemed to be less at test speeds of 40 and 50 mph, which indicated the choice of one of these speeds as the survey test speed. These results apply to the two trailers only since data were not available to evaluate the day-to-day variability with the VHTRC car.

Because a significant variation over time was expected it was specified that control sites be tested periodically as part of the normal survey test program at the normal test speed of 40 mph. Six sites were selected that appeared to be homogeneous throughout their length with regard to skid resistance and to be typical of surface types in use in Virginia. (Sites 1-6 in the 1974 and 1975 correlation studies.) Sites 1 and 2 are portland cement concrete sections with a burlap drag finish, site 4 is bituminous surface treatment, and sites 3, 5, and 6 are bituminous concrete type S-5. All sites have been in service for a number of years.

The results of the control site tests by the VDHT trailer are shown in Figure 2. With the exception of the test in July, 1975, all tests were run in series throughout the length of the site as is done in normal survey testing. Tests in July, 1975, were repeat tests at the same point since they were being obtained as part of the 1975 correlation program. Each point shown is the average of five tests.

Shown in Figure 2 for each site are the average of the daily means ($\bar{x}$), the standard deviation of the daily means (S_B), and the standard deviation within test series (SN) as computed by summing the squared deviations around each daily mean, dividing by n-1 (the total number of tests at the site minus 1), and taking the square root. The total variance over time at each site is the sum of S_B^2 and S_W^2, and clearly S_B^2 is the largest contributor to total variance. It should also be noted that S_W for all sites averages about 1.5 SN, which is equivalent to the value obtained in the 1975 correlation study as discussed above, and that S_B averages about 2.7 SN.

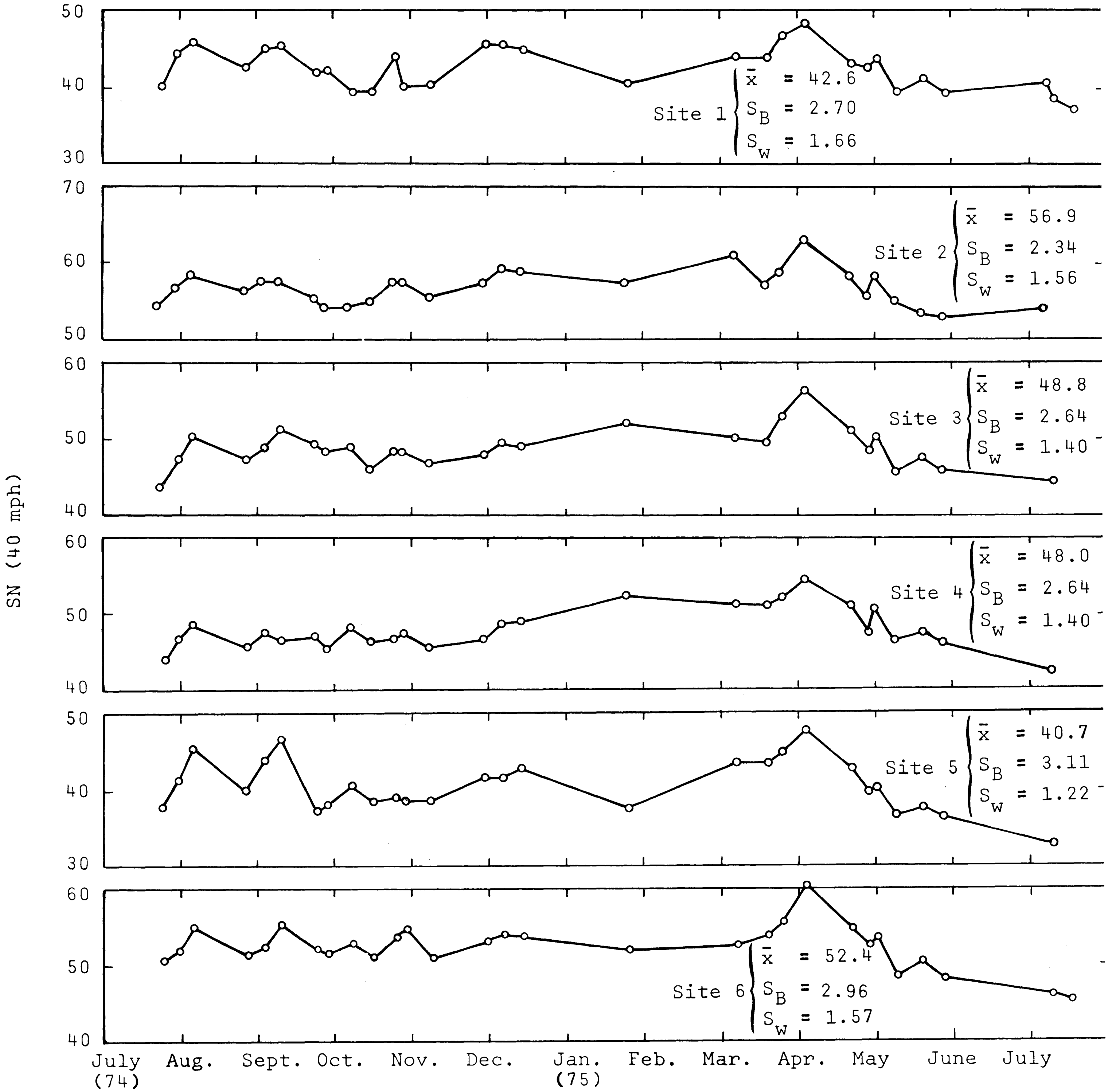

Figure 2. VDHT trailer — control site data.

The VHTRC trailer also tests six control sites periodically. Of these, sites 9 through 12 are bituminous concrete S-5 mixes, and sites 13 and 14 are portland cement concrete. Results of these control site tests are shown in Figure 3. Again S_B^2 is the largest contributor to total variance. For these sites S_B averages 2.8 SN, or almost the same as for the VDHT trailer, and S_W averages about 2.0 SN, or about 0.5 SN higher than for the VDHT trailer, which substantiates the better precision for the VDHT trailer than for the VHTRC trailer indicated by the 1975 correlation results.

As indicated earlier, data were not available from the 1974 correlation study to determine S_B for the VHTRC stopping distance car. Also, because of the time and manpower requirements to test with the car, control site testing has not been done as with the trailers. However, as part of the 1975 correlation control site 1 was run on three days by all three testing devices with the results shown in Figure 4. While the data are certainly limited, it seems evident that the S_B for the VHTRC car would be at least as great as those for the two trailers.

As indicated previously, a large portion of the source of variation over time is probably due to systematic errors as discussed in NCHRP Report 151. It appears however, in looking at the control site data shown in Figures 2 and 3, that even though the sources of error over time are probably systematic in nature, they combine in a fairly random way so that the variation in the means appears random. There does appear to be some seasonal trends, with the highest values occurring in March and April.

Of the possible sources of systematic variation air temperature, surface temperature, and tire tread depth were measured for the control site tests with the VDHT trailer. Of these, only air temperature was determined to have a statistically significant effect. It should be noted, however, that the method of measuring pavement temperature was ineffective, and that the range in tread depths measured was not large (essentially 9/32 to 11/32 in.). Over a larger range tread depths could be expected to be a significant factor.

The relationship determined between air temperature and the average control site deviation for a given day from the grand site mean was found to be

$$y = 5.40 - 0.08x,$$

where

y = the average control site deviation in skid numbers,

and

x = air temperature.

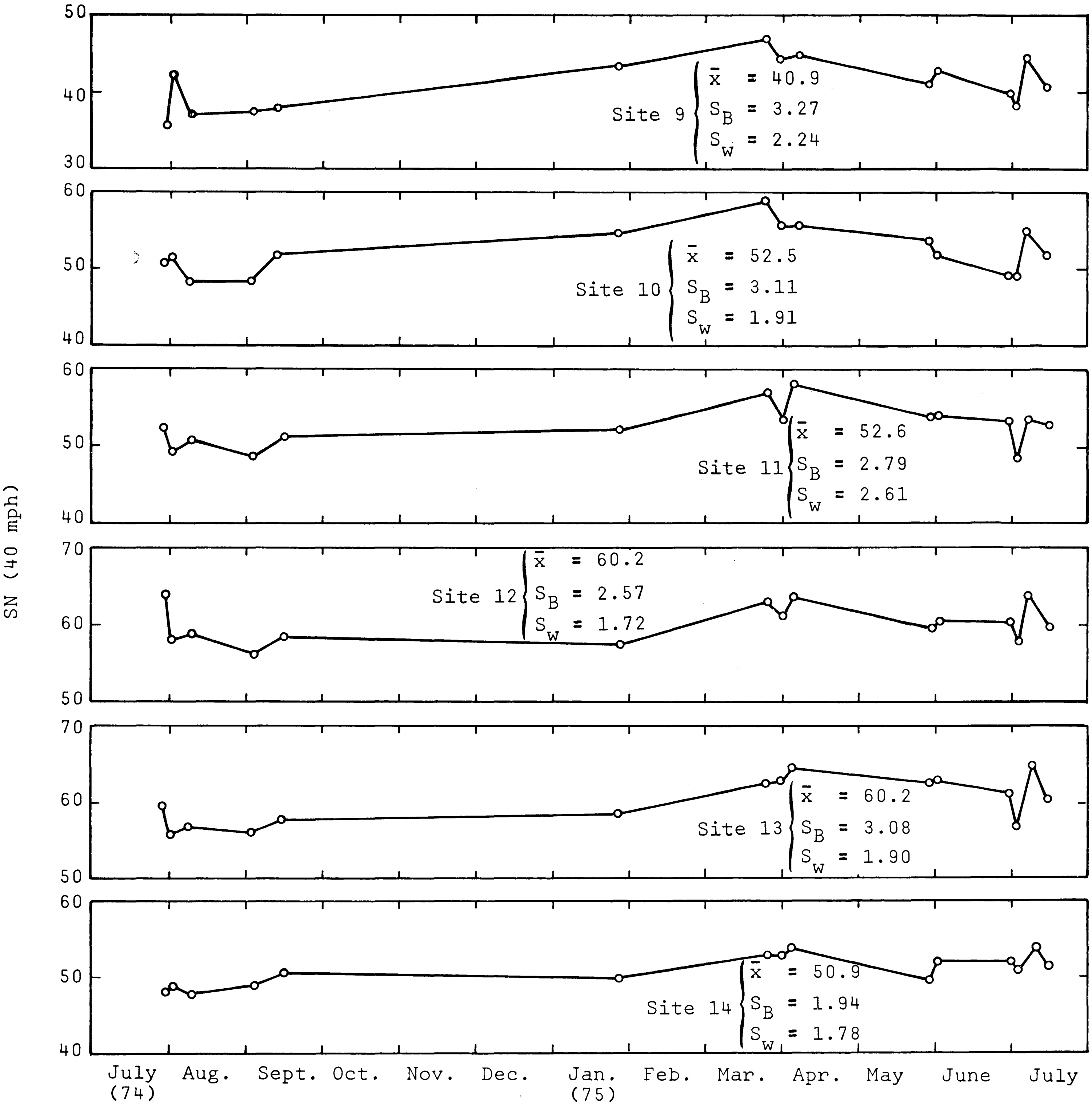

Figure 3. VHTRC trailer — control site data.

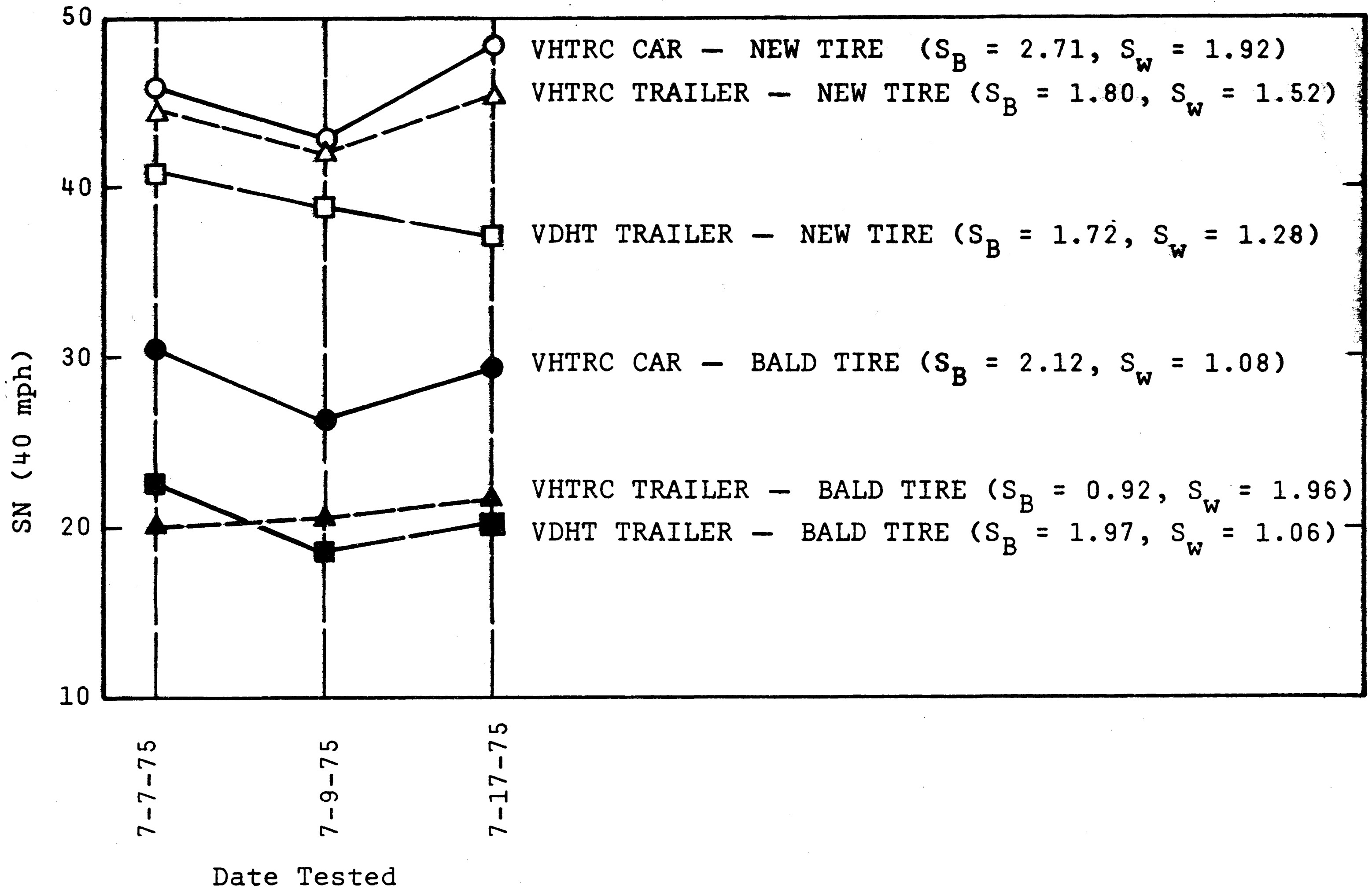

Figure 4. Repeat Tests — Site 1.

The analysis indicated a correlation coefficient of .47 and standard error of estimate of 2.36 skid numbers. While the above relationship is significant, it explains only 22% of the variance over time. Thus, even if corrections to survey data were made on the basis of air temperature one would still expect the S_B to be about 2.4 SN.

The effects of correcting for air temperature differences are illustrated in Figure 5 where the data for sites 1 and 3 have been corrected to an air temperature value of 70° F. As one would expect, the major effect is to decrease the seasonal trends as shown by comparing the site 1 and 3 data in Figures 2 and 5. Thus, the variation in the means after the correction for air temperature appears to be completely random.

It should be mentioned that in NCHRP Report 151 the systematic error between a group of 12 trailers was reduced to an average of 1.6 SN (i.e., $S_B \doteq 1.6$ SN) by controlling or correcting for the sources of systematic variation. While the persons conducting that study were not faced with the problem of reducing S_B for an individual trailer, their achievement is an indication that perhaps some variables can be measured and corrected so as to reduce the S_B.

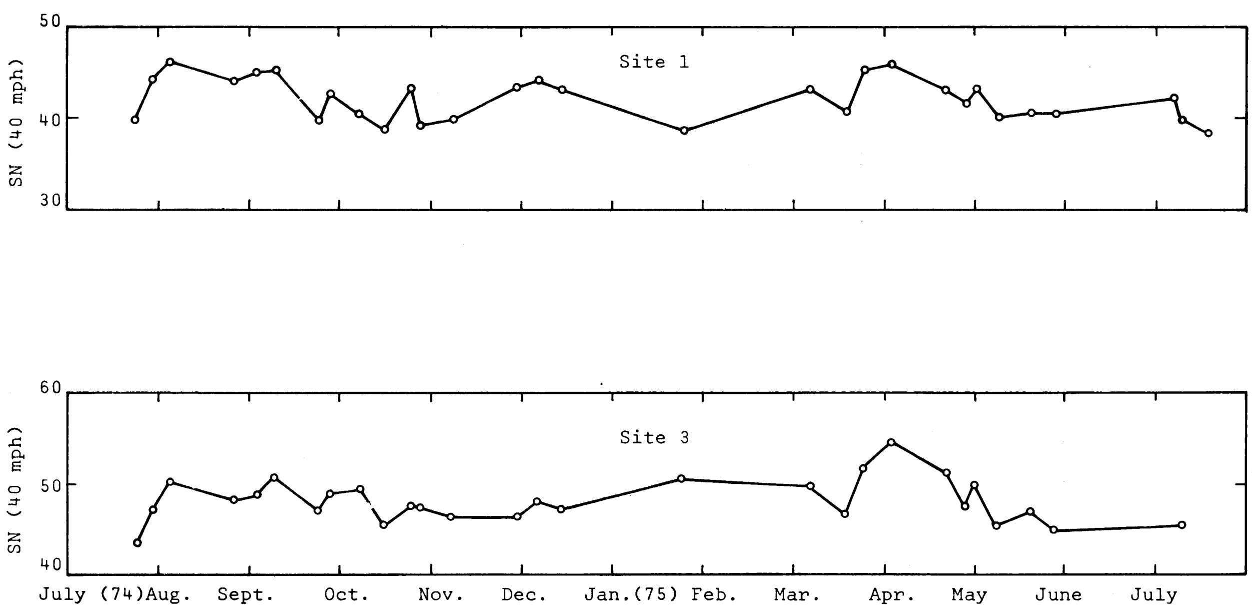

Figure 5. Control site data corrected to 70° F — VDHT trailer.

Confidence Interval Estimates

On the basis of the testing variabilities just discussed one can establish confidence interval estimates for both individual skid measurements at a site and the average site skid number. Assuming a normal distribution, the confidence interval for individual points is

$$\bar{x} \quad \pm \quad Z_{\alpha}\sqrt{\sigma_B^2 + \sigma_W^2}$$

and for the mean

$$\bar{x} \quad \pm \quad Z_{\alpha}\sqrt{\sigma_B^2 + \frac{\sigma_W^2}{n}},$$

where

$\bar{x}$ = the site mean value as determined from a series of measurements,

Z_{α} = the standard normal deviate associated with a confidence level of $1 - \alpha$,

σ_B^2 = day-to-day variability as estimated by S_B^2,

σ_W^2 = within test series variability as estimated by S_W^2, and

n = the number of tests run at the site.

Assuming, on the basis of the control site tests shown in Figures 2 and 3, that S_B is 3.0 SN, the 90% confidence limits for individual points and for the site mean are shown in Figures 6 and 7 for various values of S_W. Thus, if five tests were run at a site with the average being 45.0 and S_W being 2.0, the 90% confidence limits on the mean would be 45.0 ± 5.4, or 39.6 to 50.4 (Figure 7). The corresponding 90% confidence limits on the individual measurements would be 45.0 ± 5.9 (Figure 6).

Notice that in Figure 6 the confidence limits on the mean decrease as the sample sizes increase, but that the minimum limit is about 4.95, because S_B controls the minimum limit and is not influenced by increasing the sample size within a given series of tests. Thus, since most sites should have an S_W less than 4.0, the advantage of running more than five tests is minimal because the larger number of tests does not greatly reduce the confidence interval on the mean. The reduction is less than 1 SN for 90% confidence with S_W equal to or less than 6.0 as shown in Figure 7.

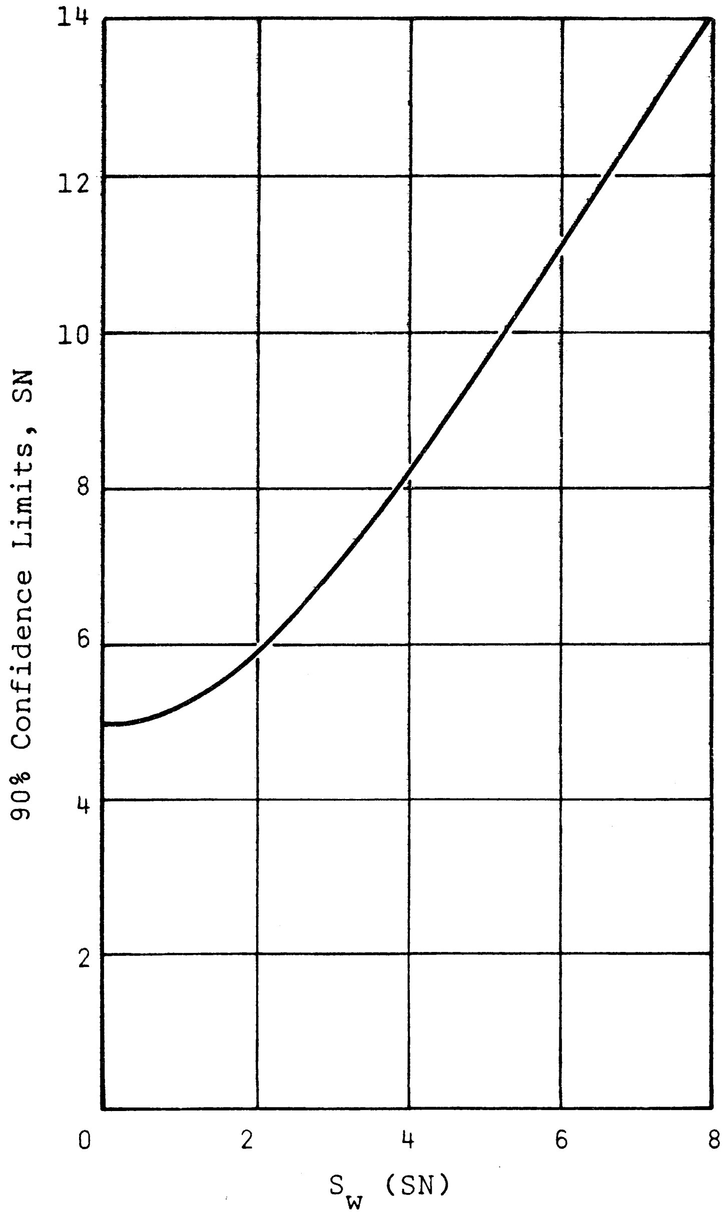

Figure 6. 90% confidence limits — individuals.

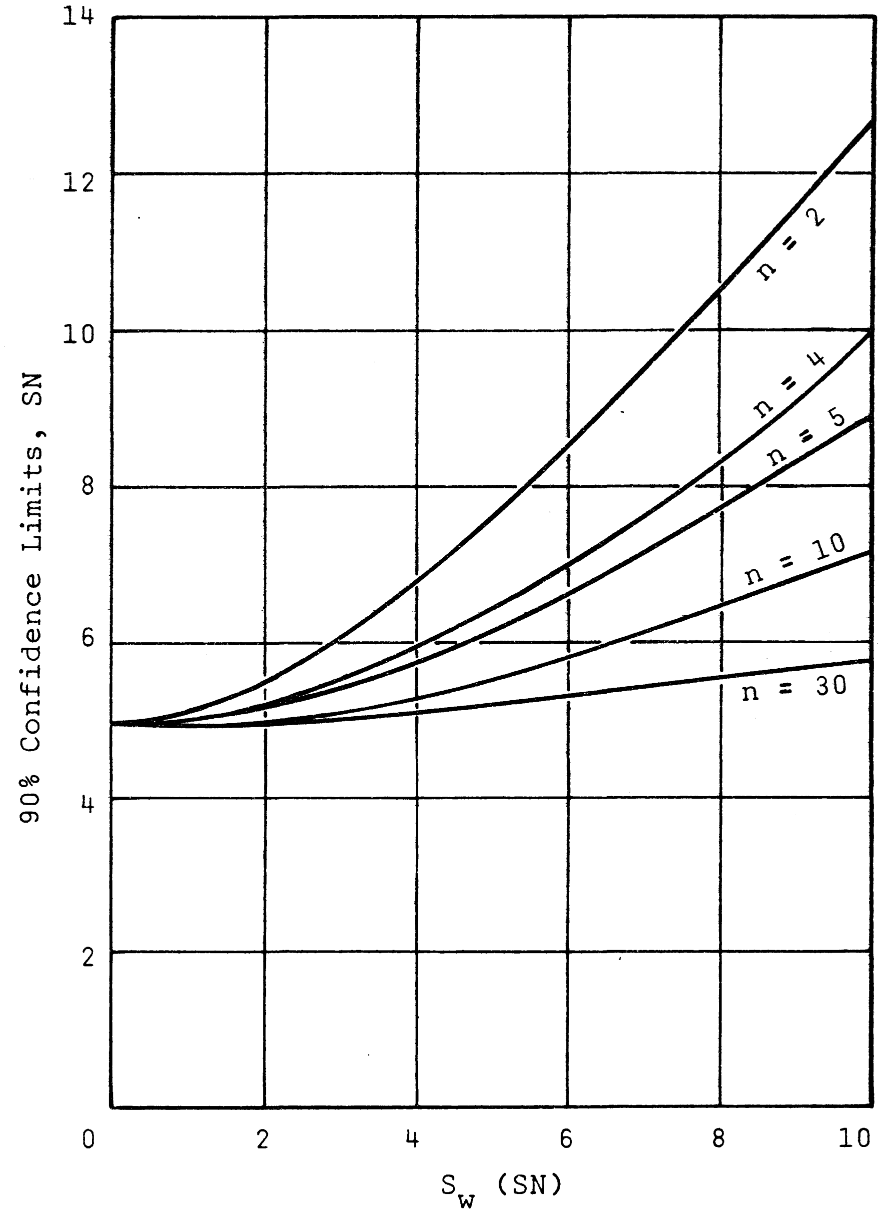

Figure 7. 90% confidence limits — averages.

Confidence Limits with Reference to Minimum Skid Standards

For the purpose of illustration, assume a minimum standard skid value of 35 for the VDHT trailer for tests run at 40 mph. (As indicated earlier, the most appropriate minimum values for use in Virginia are presently being determined.) Also, assume that the minimum standard value of 35 applies to the site average value, and that it is the minimum desired at anytime during the year.

On the basis of the above assumptions site skid values may be compared to the minimum standard as illustrated in Figure 8, where sites 1-4 represent the first four sections of the actual survey data previously shown in Figure 1. Clearly sites 1 through 3 exceed the minimum skid standard, but it cannot be stated with 95% certainty that site 4 exceeds the standard (since with 90% confidence each tail would contain 5%, one could say with 95% confidence the standard is exceeded if the lower limit falls above the standard). In fact, since the lower bound of the confidence limit falls well below the limit, there is a relatively high chance the average site value may at times fall below the standard.

Earlier it was indicated that S_W computed for site 4 is quite high, and that judging from Figure 1 the site probably should be broken into two sites at milepoint 19.0. If this is done the results are as shown for sites 4A and 4B in Figure 8, where site 4A clearly falls below the standard and site 4B would be judged as being above the standard. This occurrence clearly illustrates the need to consider the magnitude of S_W, especially when the site average is near the minimum standard value.

As indicated in the previous section, the confidence interval width is dependent (all other factors being constant) on the confidence level chosen. In this report a fairly high 90% confidence level is chosen since sites not clearly meeting the minimum standard should be evaluated on the basis of their wet pavement accident experience before any remedial action is taken. In addition, the use of the confidence interval method allows a user to judge when sites are clearly above or below standard, or when they are in a maybe category (as example, site 4 in Figure 8), in which case a more extensive analysis of the site may be desirable.

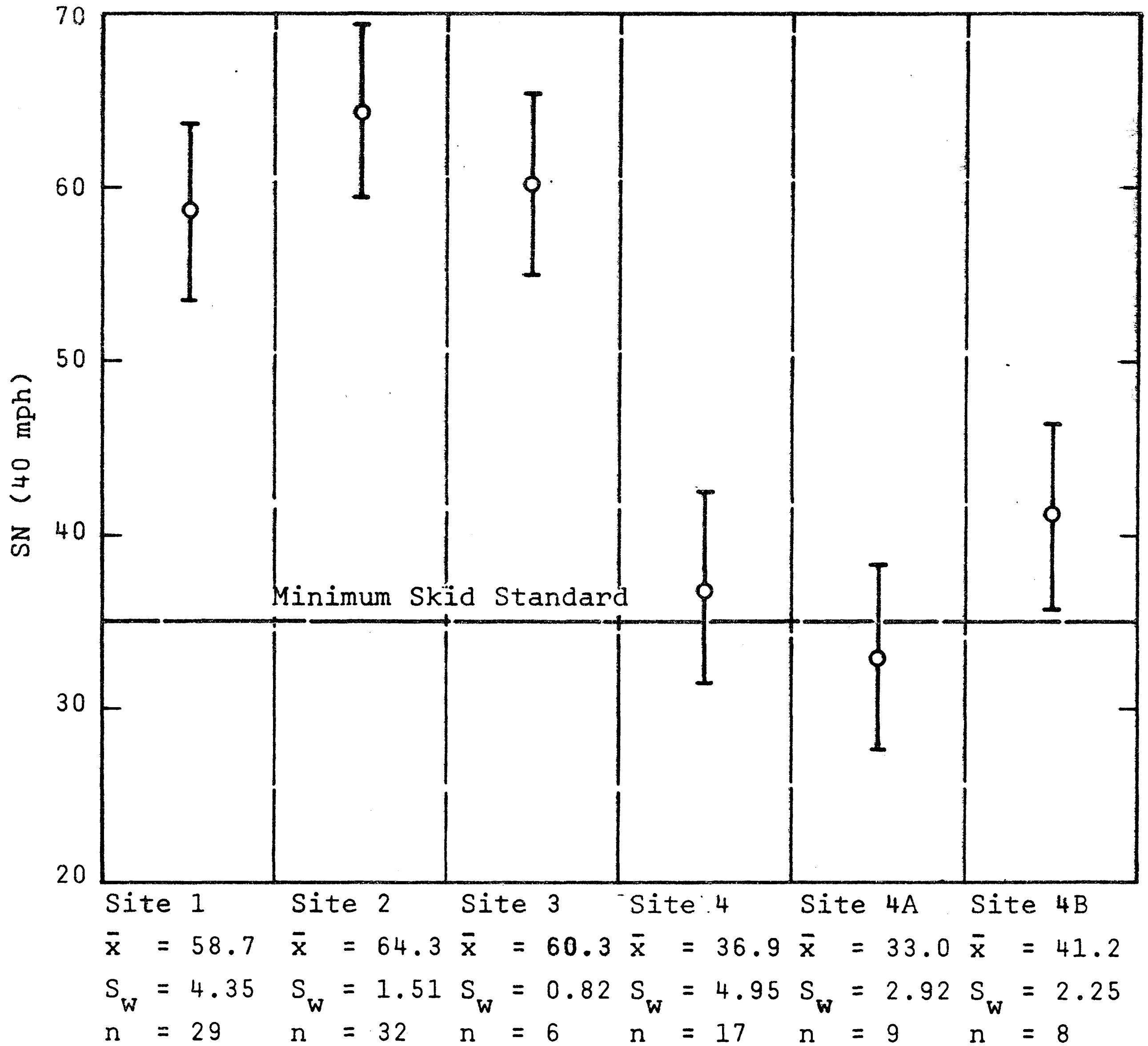

Figure 8. Comparison of site averages to minimum standard.

Evaluation of Testing Frequencies

The current testing frequencies were established in the report on "Test Procedures and Data Input Techniques for Skid Testing".(4) Basically it was stated that —

1. five tests per lane mile should be obtained, with a minimum of five tests per lane per mix type;

2. bridges with surface different than the adjacent road surface should be tested a minimum of three times per lane; and

3. preselected control sites should be tested periodically as part of the routine survey testing.

It seems obvious in looking at the actual survey data in Figure 1 and in Figure 8 that five tests per mile often is excessive, especially when the average value far exceeds a selected minimum standard, and when one considers, as indicated previously, that the S_B controls the minimum confidence interval width. It is the author's opinion that the testing frequency can be reduced by one-half to two or three tests per mile without significantly affecting the capability for drawing conclusions from the data. The desirable minimum number of tests per mix type is still felt to be five.

The results of reducing the testing frequency by one-half are shown in Figure 9, with the assumption that every other test shown in Figure 1 was not run. As can be seen, the conclusions one would reach based on the site averages and confidence intervals are identical to those indicated in Figure 8.

The major drawback to a reduced testing frequency is that sites having a high variability and an average near the standard, such as site 4, no doubt will be harder to divide into separate sites with the reduced number of tests. However, since it is anticipated that most sites will exceed any selected minimum standard the reduction in testing is desirable even if, at times, it is necessary to do additional testing at an increased testing frequency.

Since the multiple testing of bridges almost always requires circling with the testing vehicle and thus delays in the survey testing program, it would be desirable to establish a maximum value that if exceeded by a single test would mean no additional tests would be required. Utilizing the data shown in Figure 6, and assuming a conservatively high S_W of 5.0 SN, it was decided that if a single test on a bridge exceeded the minimum standard by 10 SN then additional tests would not be required. Otherwise, the minimum of three tests should be run.

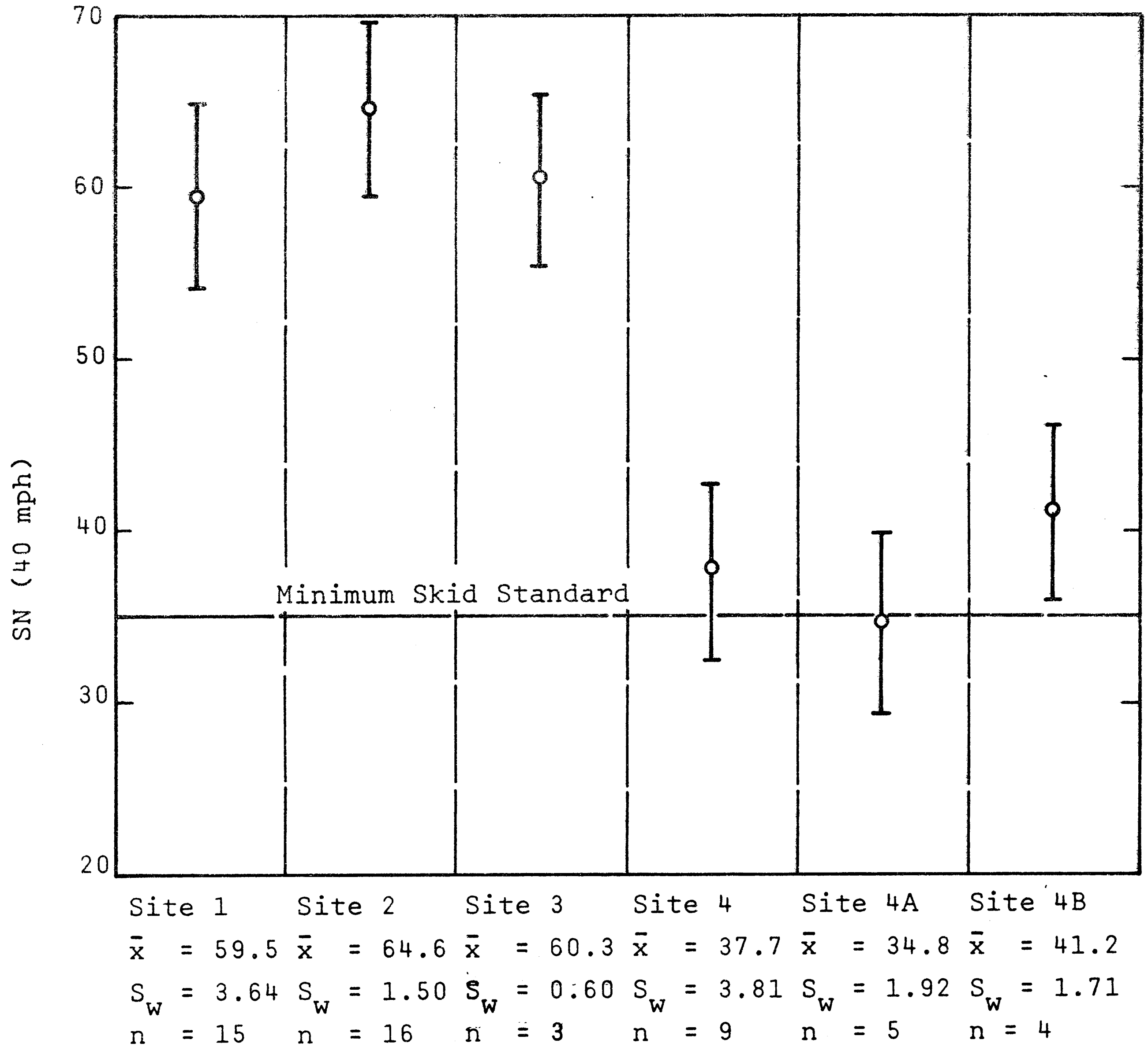

Figure 9. Results of reduced testing in comparing site averages to minimum standard.

RESULTS OF CORRELATION STUDY

As discussed in the Introduction, in addition to the testing errors associated with a given testing device one should consider the relationship between testing devices in evaluating data and in establishing minimum skid standards. For this reason the 1974 and 1975 correlation programs were undertaken. On the basis of the 1974 correlation results linear relationships of the form $y = a x + b$ were developed between each trailer and the car for all combinations of the test speeds of 30, 40, 50, and 60 mph where

y = predicted car skid number,

x = measured trailer skid number,

a = slope, and

b = intercept.

Subsequent to the 1974 correlation, it was decided it would be most appropriate to use a 40 mph test speed to develop a single relationship between each trailer and the car rather than having several relationships for various test speeds. In this approach, trailer results obtained at a speed other than 40 mph would be corrected to 40 mph based on an estimated speed-skid number gradient for the trailer, and then the 40 mph car skid number value would be predicted. If desired, a car skid number at a speed other than 40 mph could then be determined based on an estimated speed-skid number gradient for the car. It should be mentioned that D. C. Mahone has determined speed gradients for Virginia pavements for the VHTRC trailer.[5] These same gradients should also apply for the VDHT trailer, and, on the basis of the 1975 correlation data plotted in Figure 10, they do apply. Based on the data shown in Figure 10, the gradients for the car are close to those for the trailers, which finding was not necessarily expected since the trailers test at a constant test speed while the car tests from the initial test speed to zero speed. It would be desirable to determine speed gradients for the VHTRC car for the range of Virginia pavements, but until this is done the gradients determined by Mahone appear reasonable to use for the car.

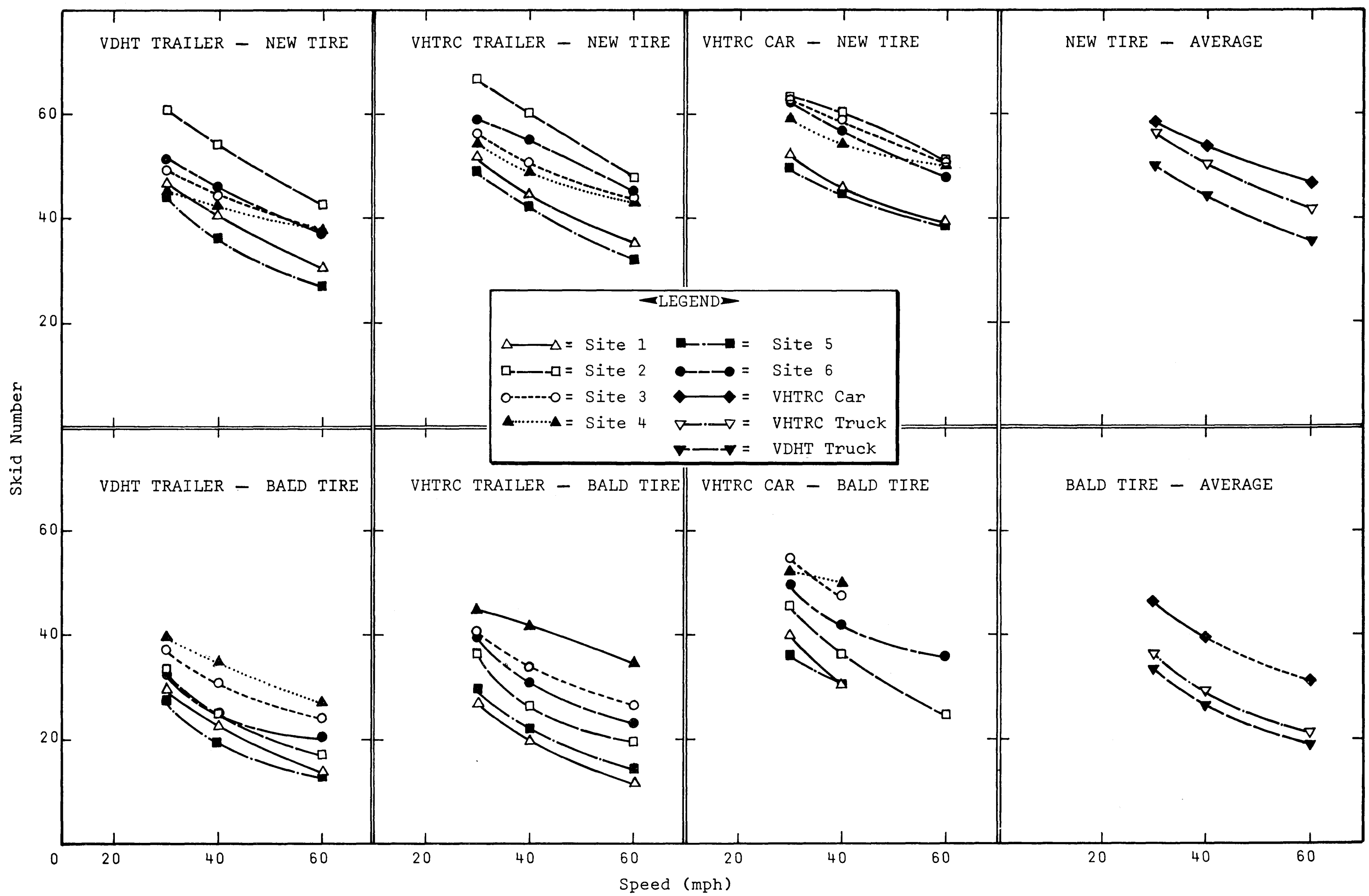

Figure 10. Speed-Skid No. Gradients — 1975 correlation data.

The 40 mph regression equations developed from the 1974 correlation study, as well as those from the 1975 correlation results, are shown in Figures 11, 12, and 13. As can be seen, very minor changes occurred from one year to the other, with the possible exception of the relationship between the two trailers. In examining the 1974 and 1975 correlation data more closely this change can be shown to be due principally to a larger relative difference between the trailers on sites 1 through 6 (which account for most of the higher SN values in the relationship) during 1975 than during 1974 (when using new tires in both years). This fact is well illustrated in Figure 14. While this difference may have occurred because of real changes in one or both trailers it was felt a more likely reason was that it evolved from some combination of systematic errors as discussed previously, especially if one considers the recent trends for both trailers as shown in Figures 2 and 3.

Because the 1974 and 1975 results were essentially the same, data for both years were combined to yield the relationships shown in Figures 15-17. As shown in Figure 15, the slope of the regression equation between the two trailers is almost equal to one as would be expected, with the VHTRC trailer obtaining results 3 to 4 skid numbers higher over the normal range in skid numbers obtained. Also shown in Figure 15 (as well as in Figures 16 and 17) are the correlation coefficient (r) and standard error of estimate (SE).

The relationships between each trailer and the VHTRC car are shown in Figures 16 and 17. The slopes in these relationships, .80 and .76, indicate that the VHTRC car obtains relatively higher results than the trailers on the low skid number sites than on the high skid number sites. This occurrence was not unexpected because of the differences in the method of testing with the car as opposed to the trailers. Since the car utilizes all four wheels, it measures skid resistance in more than just the left wheel path. Thus, when the car skids out of the wheel paths it usually encounters pavement with higher skid resistance, and thereby yields a higher skid number than do the trailers. Furthermore, it is felt this difference is greater at lower skid numbers since it is harder to maintain the car in the wheel paths, and because the differences in skid resistance within the pavement itself are probably greater because of polishing, bleeding, or some other effect in the wheel paths. The greater difference between the VHTRC car and the trailer on sites having a lower skid resistance may also be due in part to the greater speed-skid number gradient for the car on these sites than on high skid number sites, as is indicated by the composite curves shown on the right-hand side of Figure 10.

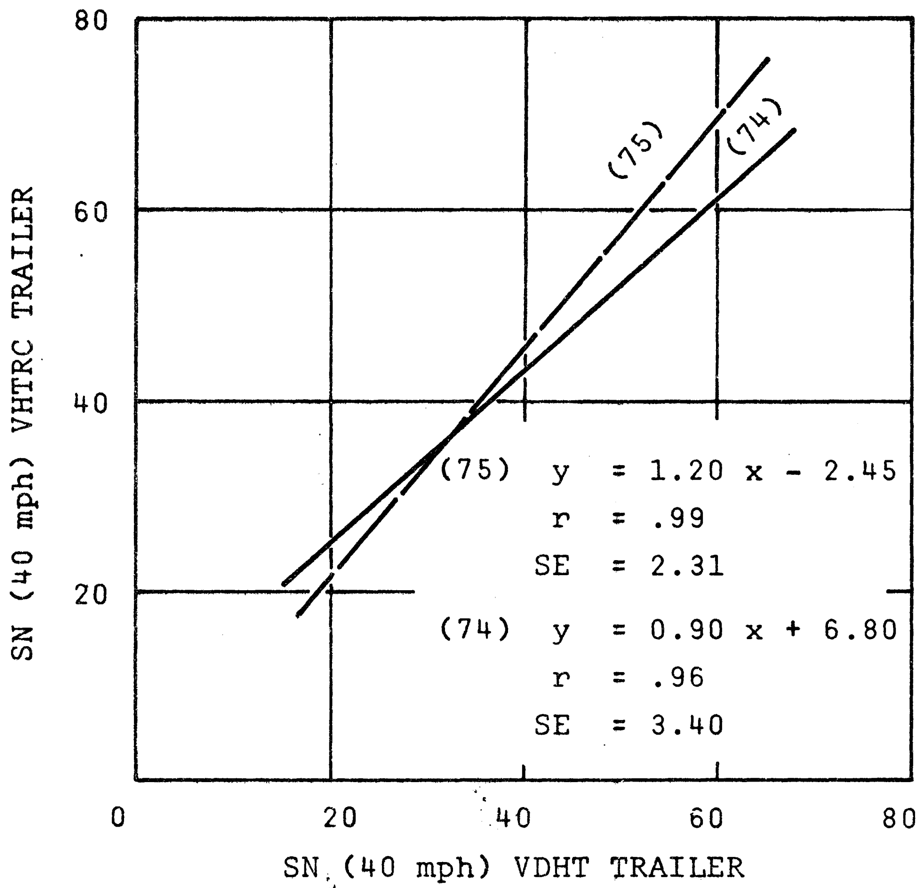

Figure 11. Skid number relationship — trailers (40 mph).

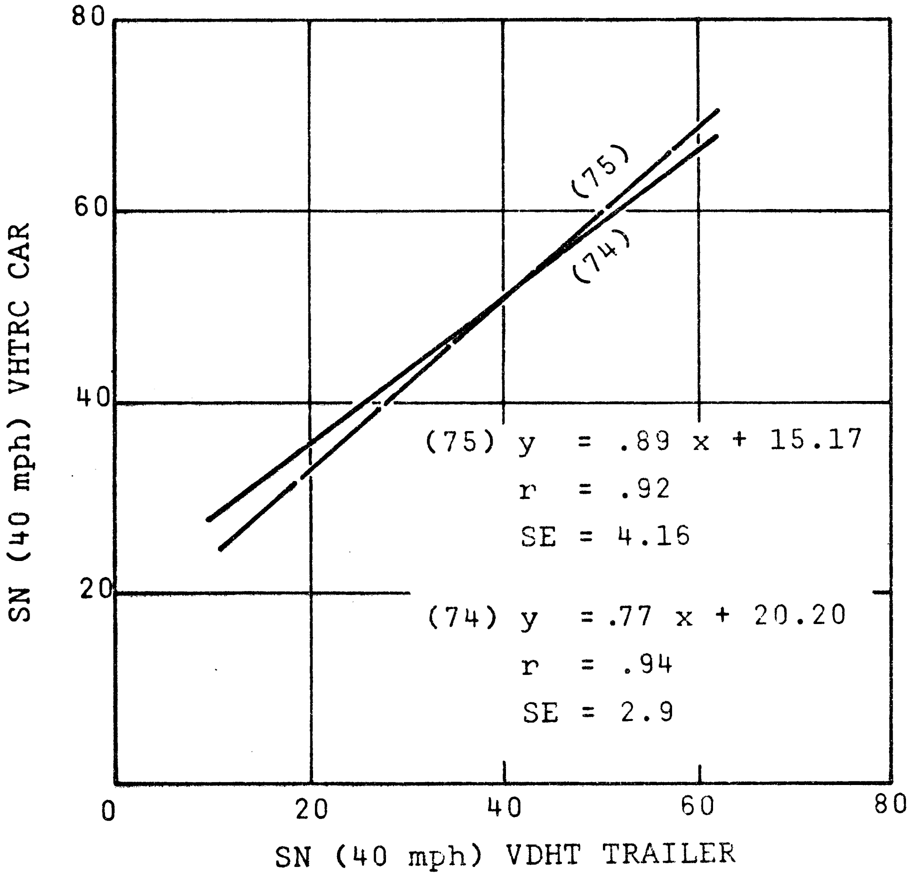

Figure 12. Skid number relationship — VDHT trailer and VHTRC car (40 mph).

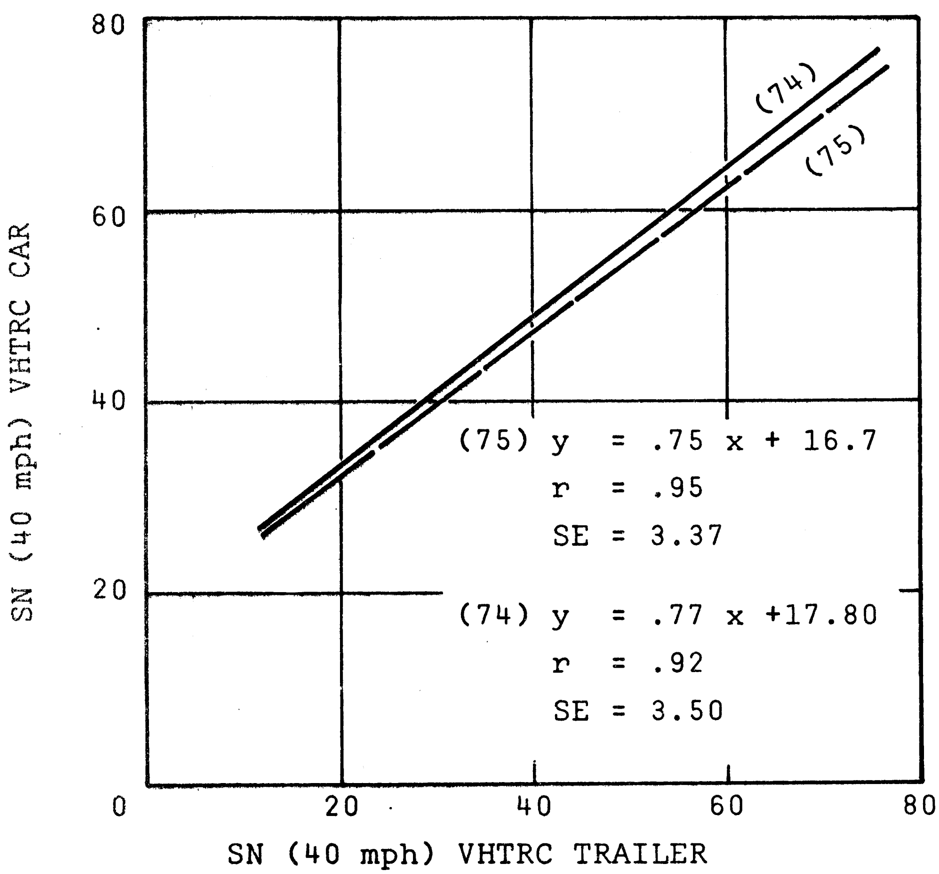

Figure 13. Skid number relationship — VHTRC trailer and car (40 mph).

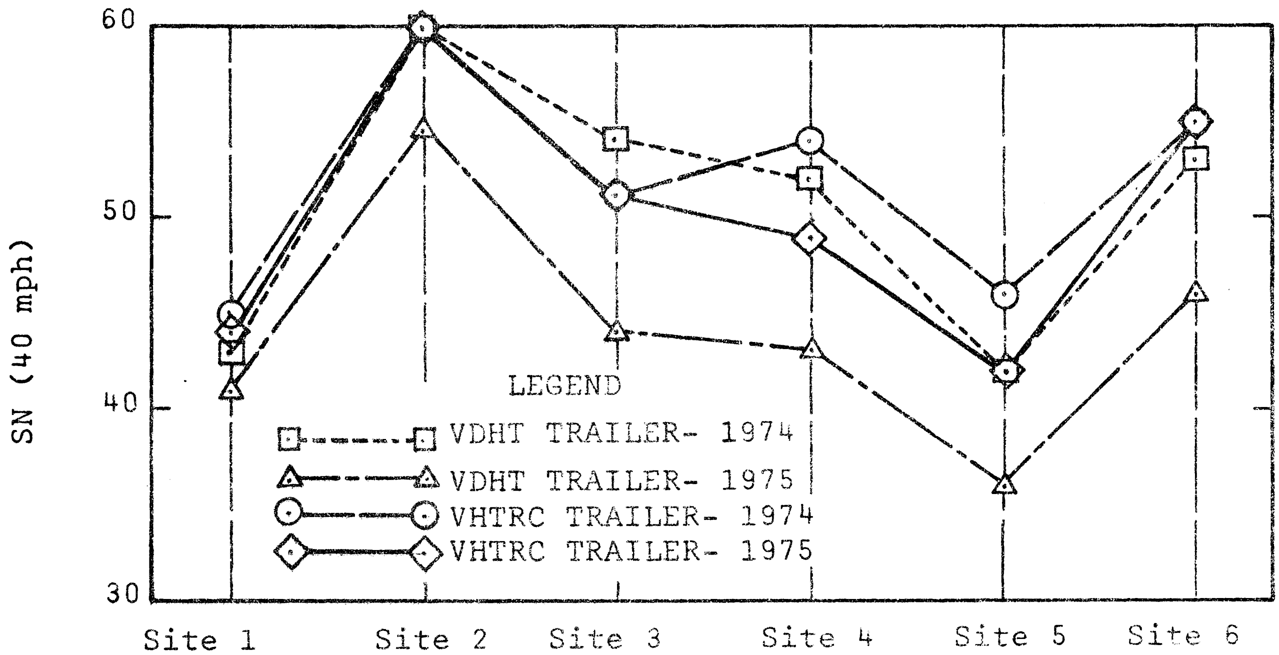

Figure 14. Trailer correlation results — sites 1 through 6.

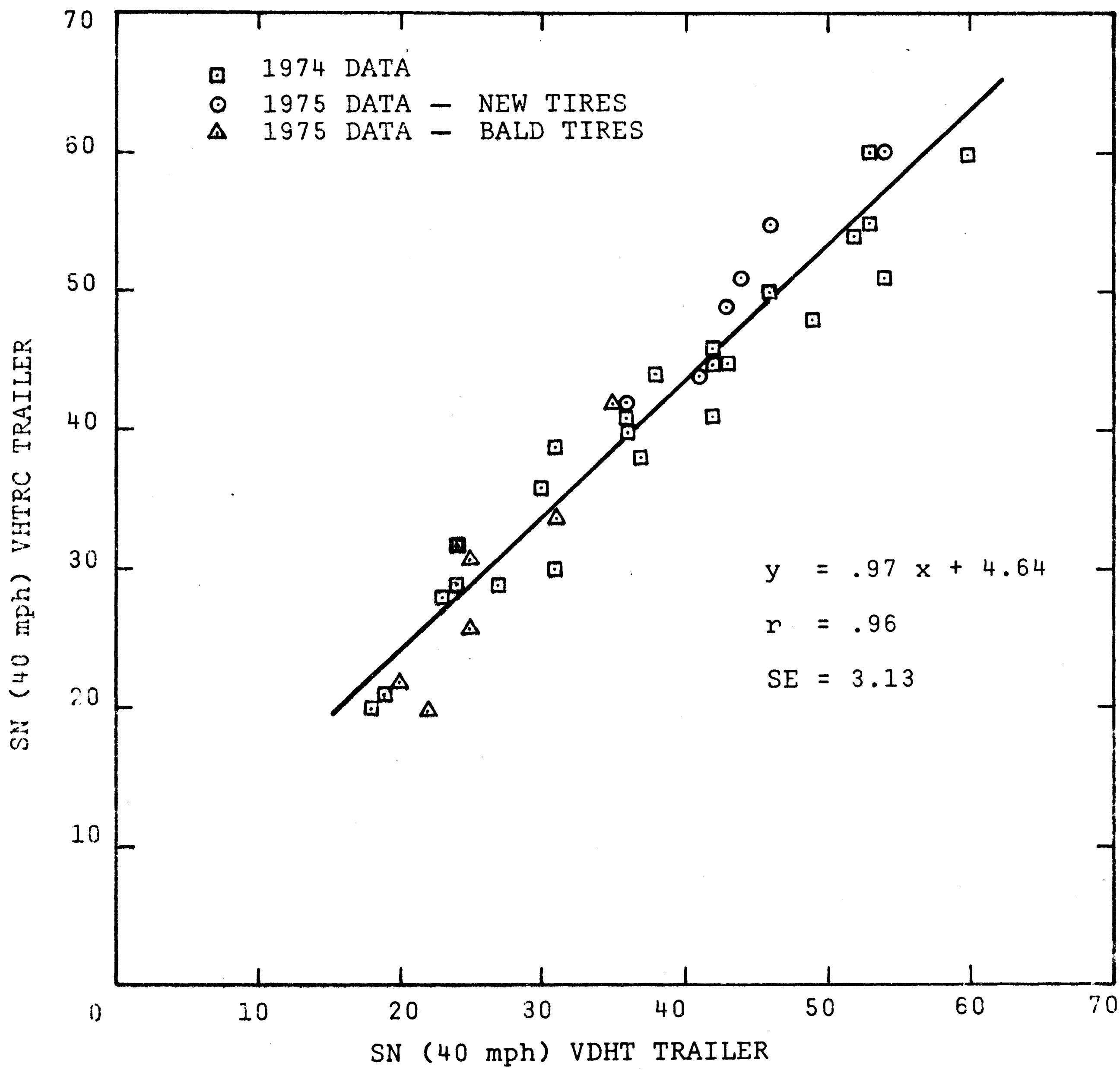

Figure 15. 1974 and 1975 combined regression results — trailers (40 mph).

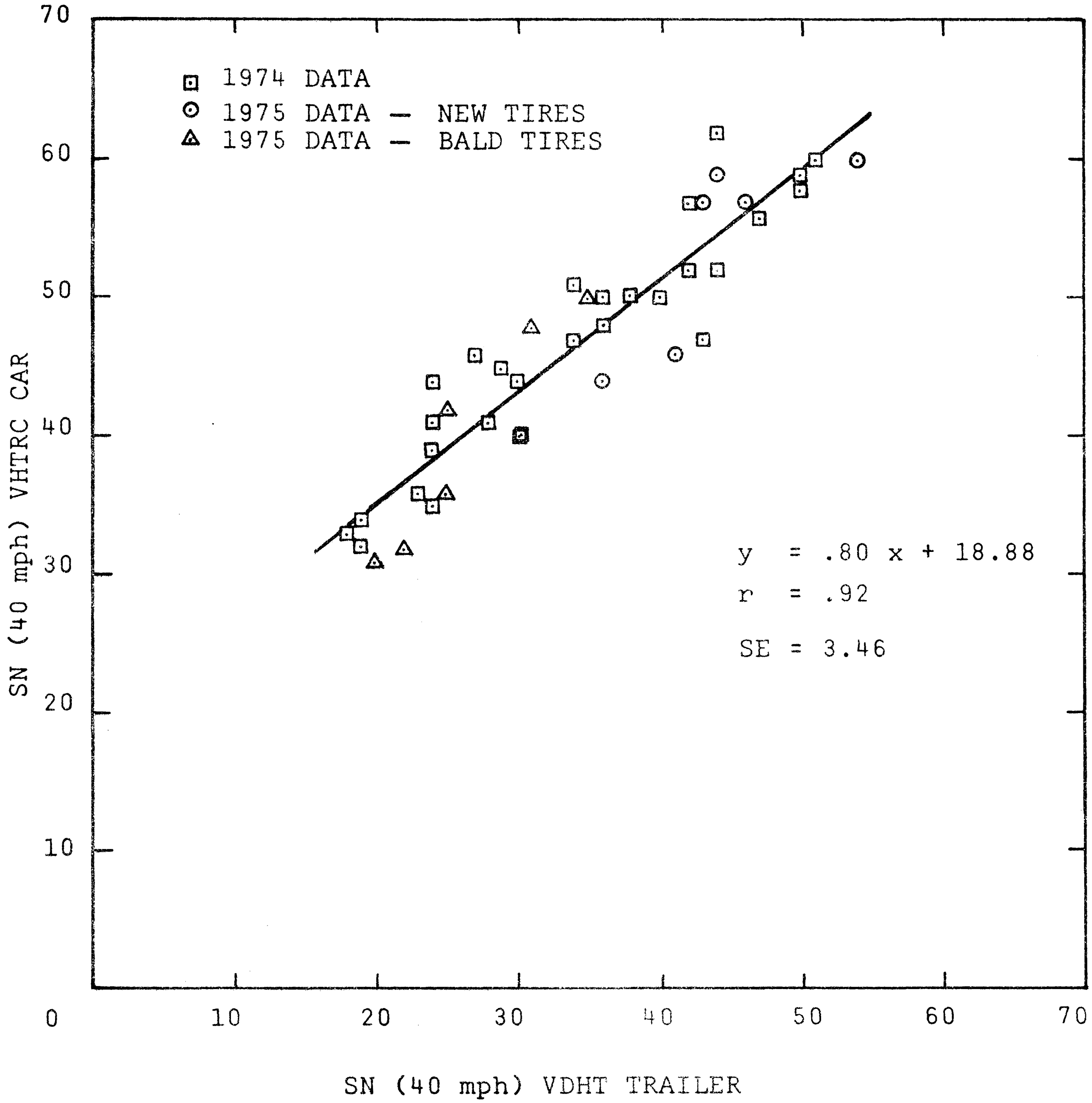

Figure 16. 1974 and 1975 combined regression results — VDHT trailer and VHTRC car (40 mph).

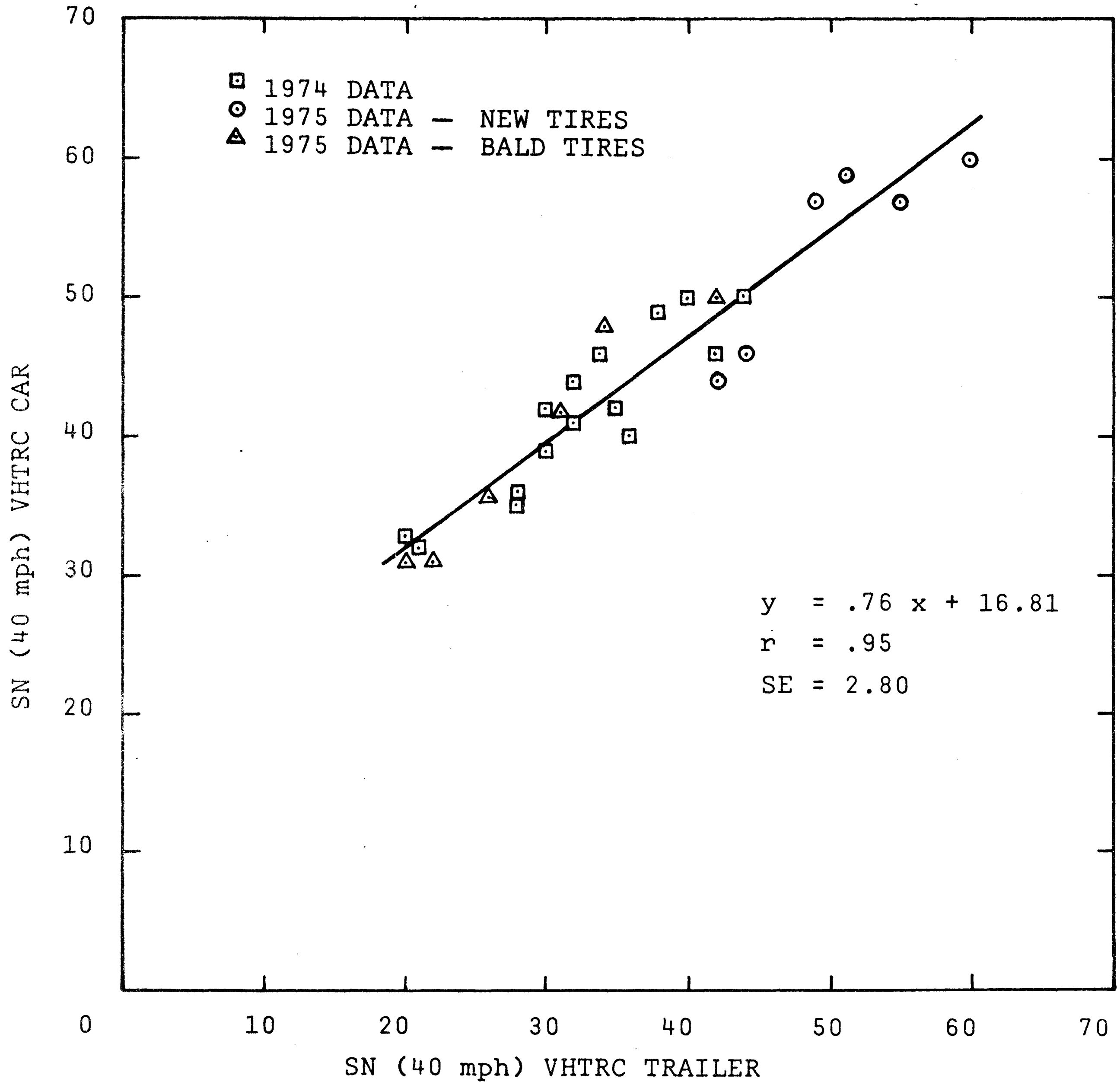

Figure 17. 1974 and 1975 combined regression results — VHTRC trailer and car (40 mph).

Confidence Interval Estimates Including Predicting Error

Previously it was shown how one may develop confidence limits for a site mean which included within test series variability and variability over time. Suppose, however, that confidence limits are desired for a predicted skid value as may be the case when tests are run with one vehicle but the results are expressed in terms of a standard vehicle.

One might argue that the standard errors (SE) shown in Figures 15-17 are that measure of the same systematic errors that account for the S_B for an individual testing device plus some error due to the interactive effects of different vehicles testing on different pavements, less any systematic error that may generally affect testing devices the same way day-to-day. One source of systematic error that may affect different testing devices the same day-to-day is temperature, and it was previously shown that the S_B after correcting for air temperature is about 2.4 skid numbers. Combining the S_B of 2.4 and the error in skid testing of 1.6 skid numbers (as determined in NCHRP Report 151 after correcting for all systematic errors) one obtains a standard deviation estimate of about 2.9 skid numbers, which is reasonably close to the standard error values shown in Figures 15-17.

Thus, on the basis of the discussion above it seems confidence limits on predicted values may be determined by considering variability within a test series (S_W), and the standard error value may be adjusted to include variability due to temperature effects. However, the confidence limits thus determined would be only slightly more (in the order of 0.5 skid number) than those shown in Figure 7, assuming an average standard error value of about 3.1 skid numbers. Thus, from a practical standpoint the limits shown in Figure 7 plus about 0.5 skid number may be applied to predicted skid number values utilizing the S_W value determined from the actual test data. Certainly, it would be desirable to verify through a testing program what proportion of the error in prediction is due to systematic errors which also accounts for the S_B.

RECOMMENDATIONS

On the basis of the prior discussion the following recommendations are offered with regard to the skid testing program in Virginia.

1. Confidence interval estimates should be determined for site averages on the basis of information shown in Figure 7. The average and its associated confidence limits can then be compared to selected minimum standards to determine if the average skid number appears adequate. Sites on which the lower confidence limit falls below the minimum standard should be evaluated in more detail (including analysis of accident data) to determine what, if any, corrective action should be taken at the site.

2. When standards are set in terms of the VHTRC car, but tests are run with either trailer, the relationships shown in Figures 16 and 17 should be used to determine the predicted car skid number. Confidence limits may then be applied to the predicted value through the use of Figure 7 by adding 0.5 to the limits shown.

3. Control tests should continue to be run as a normal part of the testing program. In addition, it would be desirable to obtain control tests for the car as often as possible for the next year to determine the variability of the car over time. Temperatures and tread depths should be recorded for the control tests as in the past.

4. The relationships between the testing devices should be verified during the summer of 1976.

5. Testing frequencies may be reduced to two or three tests per mile, but the desirable minimum per mix type is still five tests. A single test will be sufficient on a bridge, provided the result exceeds the minimum standard by 10 skid numbers. Otherwise, three tests should be run.

6. The speed-skid number gradients developed by Mahone with the VHTRC trailer may be used to predict skid number values at speeds other than 40 mph for the VDHT trailer and VHTRC car.

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