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THE EFFECT OF PAVEMENT SKID RESISTANCE ON WET PAVEMENT ACCIDENTS IN INDIANA

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Final Report

THE EFFECT OF PAVEMENT SKID RESISTANCE ON WET PAVEMENT ACCIDENTS IN INDIANA

TO: J. F. McLaughlin, Director
Joint Highway Research Project

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FROM: H. L. Michael, Associate Director
Joint Highway Research Project

File: 8-5-22

The attached Final Report is on a JHRP investigation made in an attempt to evaluate the relationship of slippery characteristics of Indiana highways and accidents. The research was performed and the Report prepared by Mr. Jonathan L. Levy, Graduate Instructor in Research on our staff, under the direction of Professor H. L. Michael. Mr. Levy was materially assisted and frequently consulted personnel of the ISHC Research and Training Center.

The major finding of the Study is that there appears to be little relationship between slippery pavement surfaces when wet and accidents, assuming that skid index is a good measure of slipperiness and that accidents from accident records is a good measure of safety. Other factors, such as traffic volume and geometrics as well as highway classification, were found to be important in the skid index - accident measure relationship.

The Report is submitted as the Final one on this Study.

Respectfully submitted,

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Final Report

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by

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by the

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ABSTRACT

Levy, Jonathan Lenard. M.S.C.E., Purdue University, December 1976. The Effect of Pavement Skid Resistance on Wet Pavement Accidents in Indiana. Major Professor: Harold L. Michael.

Road accidents in the United States are a major cause of death, suffering and economic loss. This research investigated the relationship between accidents on wet surfaces and the skid resistance of those surfaces.

The State of Indiana currently is involved in skid testing all state highways. For these test results to be of more use, the research attempted to specify a minimum level of skid resistance acceptable for driving safety.

The research studied ninety-four road sections throughout Indiana. Data collected for each section included length, traffic volume, pavement type, number of intersections, and skid test results. Accident data for each section over a three year period (1973-1975) was collected and included 4416 accidents. For each wet surface accident an estimate was made if skidding was a cause of the accident.

For analysis a wet accident index was formulated, defined as the number of wet surface accidents divided by the number of dry surface accidents for a section. This index was used as an indicator of the relative safety in comparing sections of highway when wet. A skidding ratio was also used, defined as the proportion of wet surface accidents probably caused by skidding divided by the total number of wet surface accidents.

Initial data analyses showed little correlation between the wet accident index and average skid number. Plots of these parameters showed significant scatter. Use of averaging methods did little to improve the correlation.

During later analysis the same methods were used on the different classes of road sections (Interstates, four-lane, two-lane). These methods provided better results.

Interstate sections had little increase in accidents on wet surfaces compared to dry conditions. This is probably due to the high geometric and access control standards used in their construction. The effect of the skid number on wet surface accidents could not be detected. This was primarily due to the small range of skid numbers on the interstate sections sampled.

Four-lane non-interstate sections showed reducing values of the skidding ratio for increasing skid numbers. A five point moving average for the skidding ratio versus skid number allowed the fitting of two regression lines to the data. A critical minimum skid number value was determined by the intersection of the two lines at a value of 44.

Two-lane roads showed a relationship between the wet accident index and skid number when grouped by traffic volume and geometrics. This relationship indicated that slipperiness was of greater importance on moderate volume roads (3000-5000 vpd), and roads with moderate geometrics. The effect of skid number was less on roads with very good or bad geometrics or higher or lower volume counts.

The research concludes that there are several factors involved in specifying minimum skid number values and that there is no single value which applies to all road sections. The type of road, its volume, geometry and amount of access control should all be considered in determining minimum skid number standards.

CHAPTER I: INTRODUCTION

Problem Statement

The safety of our roadways today is a serious problem; in 1974 in Indiana 1231 people were killed and 66,285 were injured. At the same time the population incurred the financial loss from an additional 150,884 property damage only accidents (1).* Of these accidents 23.3 percent were listed on police reports as occurring on wet road surfaces while the roads were wet only about 11 percent of the time (2). It is generally accepted that wet pavements are more dangerous than dry ones, and that some types and conditions of pavements are more slippery when wet than others, thus causing those roads to be more dangerous. In addition to causing accidents because of skidding, the reduced deceleration ability of slippery pavements may result in higher collision speeds and thus increased accident severity.

Hypothetically, if there were no financial restraints imposed, the natural response to this situation would be to upgrade all roads to the minimum level of slipperiness technologically possible. With the existant financial restraints, however, it becomes necessary to be able to plan available expenditures within a program of safety improvements to best reduce accident costs. Thus in order to determine the utility of expending resources to decrease the slipperiness of surfaces, information on expected results of such changes on accident incidence and severity is required.

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*Numbers in parentheses refer to entries in the Notes.

Objectives

The purpose of this study was to determine what effect, if any, the measured wet pavement skid resistance of the roadway surface has had on accident occurrence in the past few years. Skid resistance on wet surfaces is usually presented as skid numbers, which are defined as the coefficient of dynamic friction multiplied by 100. The goal of this study was to define the relationship between skid number and accidents for different road types and conditions. In particular it was desired to define those skid number values which indicate decreasing marginal return of increased safety for further increases in skid resistance. These values could be then used as the recommended minimum skid number value for that type of road as defined by safety considerations. The effect of other variables (i.e. other roadway characteristics, traffic volume, location within state, etc.) were also evaluated.

This research should benefit road users in Indiana by defining a goal of reduced accidents through skidding. The possibility of wasteful use of funds caused by developing or using unnecessarily high skid resistant surfaces is also reduced. Upon successful completion of the research, emphasis can be placed on development of surfaces which will maintain high standards of safety for extended periods of time and on the elimination of substandard surfaces wherever they may be.

Indiana State Highway officials and engineers should find the research findings to be of value in establishing optimum resurfacing schedules, and in determining whether the use of expedient methods (use of thin overlays) or longer term methods are more desirable. Warrants for use of types of surfaces will then also be possible by using this and other research output along with information on actual accident costs and surface material availability and cost.

CHAPTER II: LITERATURE SEARCH

During 1973 the Federal Highway Administration circulated a memorandum which instructed all states to maintain a state-wide skid number inventory of all primary highways with speed limits of 40 mph or above (3). Concern in Indiana with the importance and use of roadway skid numbers was emphasized in three related papers at the 1975 Purdue Road School.

Improved and standardized methods of measuring skid resistance have increased the accuracy and validity of studies comparing skid resistance with accidents. Advances in the technology of providing skid resistance meanwhile have made results of these studies more useful due to the availability of improved paving mixtures, overlays and methods, such as grooving.

With this new technology, however, the problem still is not solved. Whitehurst states "The problems associated with the measurement of skid resistance have received far greater attention than have those associated with establishing the desired level of skid resistance" (4). This study was an attempt to provide part of this needed information.

Indiana

Indiana has been actively concerned with the problem of slippery pavements since 1951, with the development of a stopping distance test car at Purdue by the Joint Highway Research Project. The development and use of the test car is described in a Purdue University research report by

David Grunau (5). A few years later, stopping distance information was used at Purdue by Vergil Stover in evaluating a method to locate slippery pavements by the use of accident records (6).

The skid test car developed at Purdue was used by the State highway commission from 1954 to 1967 when a prototype two-wheel towed trailer type tester was evaluated. This led to the purchase of a skid trailer in 1968. A second trailer unit went into operation in the state during the summer of 1976 (7). A research report titled "Skid Resistance of Indiana Pavements" by the I.S.H.C. Research and Training Center was completed in February 1976 (8). The report is divided into 3 sections; High-accident location phase, Portland concrete phase and Bituminous concrete phase. The High-accident location phase is of particular interest to this research in that it attempted to answer many of the problems considered. The Research and Training Center selected 120 high accident locations to study but 51 of these 120 were disqualified for various reasons and only 69 sites were used. Data on skid numbers, AADT's and accidents were obtained for the 69 sites. Statistical analysis carried out on this data showed no strong correlation between skid numbers and accident factors. Due to data and analysis problems, however, it cannot be assumed that the lack of significance found indicates that no correlation existed between skid numbers and accidents.

Past Correlations

Correlations of skid number and accidents have been performed by the Road Research Laboratory in Crowthorne, England. In Skidding in Personal-Injury Accidents in Great Britain in 1965 and 1966 (9) comparisons were made for accidents listed by police records as including skidding on wet or dry roads. The data indicate that the rate of skidding on wet pavements was approximately twice that found on dry pavements and is higher at a 70 mph speed limit than at a 30 mph limit. In "Traffic Control and Roadway Elements", a publication by the Highway Users Federation for Safety and Mobility, reference is made to an article by one of the Road Research Laboratory researchers (10). Barbara E. Sabey compared skid numbers to accident experience and found a definite relationship which appeared to be linear in nature (Figure 1).

Another article from the Road Research Laboratory was the Effects of Resistance to Skidding Accidents: Surface Dressing on Elevated Section of M4 Motorway (11). In this before and after study, it was found that all accidents were reduced by 45 percent, wet road accidents by 63 percent and wet road accidents involving skidding by 75 percent after application of the surface dressing.

In another study, this one done in the United States (12), it was estimated that rates of wet pavement accidents are 2.2 times higher than the rates on dry pavements. It was also predicted that 50 percent of the accidents on wet slippery surfaces could be eliminated by the use of surface treatments. Moyer agrees with these findings, reporting that skidding accident rates are about twice as high as dry rates on below standard surfaces and as much as eight times as high on surfaces well below acceptable standards (13).

Prior attempts at determining minimum skid numbers fall into two categories, use of accident analysis or by determination of theoretical friction requirements. NCHRP Report No. 37 (14) combines results from both categories to create a minimum value. The report considers the factors used in earlier reports, including accidents, vehicle-pavement interactions, economics and feasibility. It then recommends a minimum skid number of 37 with certain

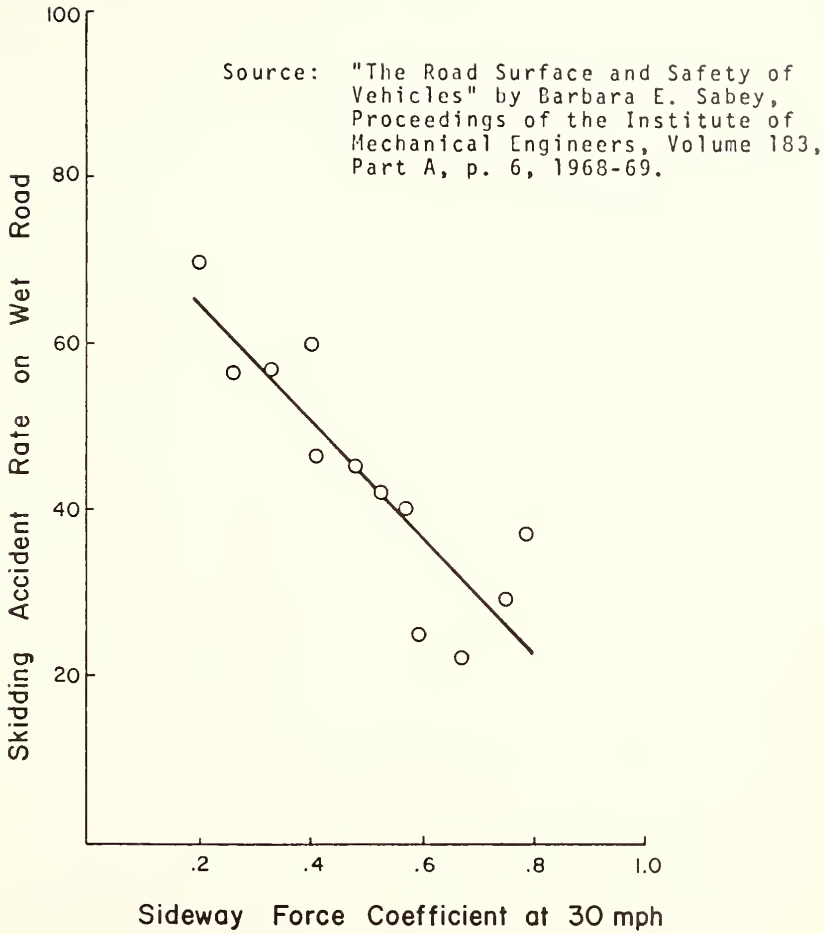

Figure 1. Skidding Accident Rate and Skidding Resistance (Great Britain)

reservations. This minimum skid number of 37 varies for different vehicle speeds such that a minimum value of 39 measured at 40 mph is recommended for roads with a 55 mph average travel speed (15).

The NCHRP report also includes possible analysis methods for use when working with slippery pavements. One method for "Detection of Skid Traps" uses the following formula:

$$R_T = (A_w/A_d)\ (D_d/D_w)$$

where

R_T = skid trap ratio

A_w = number of accidents when wet

A_d = number of accidents when dry

D_d = number of days when surface dry

D_w = number of days when surface wet

Higher relative values of this ratio indicate increasing likelihood of slippery pavement problems, with unity recommended as the cutoff point for corrective action.

Another method is recommended for the ranking of projects for skid proofing.

$$R_r = (SN_{min}/SN)\ (D_w/D_d)\ (ADT/\overline{ADT})\ (V/\overline{V})$$

where

SN_{min} = minimum skid number for type of road in question

SN = SN at site

ADT = average daily traffic for that site

$\overline{ADT}$ = average daily traffic for state highway network

V = mean traffic speed for site

$\bar{V}$ = mean traffic speed for state highway network

D_d = as previously defined

D_w = as previously defined

This formula is to be used to choose the highest priority roads for surface treatments or repairing.

Presently, there is a great deal of research taking place in the area of skidding accidents and surface improvements. The FCP Annual Progress Report lists 23 recent publications and 73 research projects in progress throughout the United States (16). Many of these studies will probably be reported at a second international skid prevention conference, scheduled for May 1977 at Columbus, Ohio.

One source of information used extensively for the analysis for the research reported here was Accidents on Rural, Two-Lane Roads and Their Relation to Pavement Friction by the Kentucky Department of Transportation (17). Unfortunately this report became available after the design of this experiment had been finished and data collection had begun. Some of the methods eventually used in the analysis for this study, especially restriction of the analysis to two lane roads to reduce confounding, could then have been included in the experiment design.

The Kentucky study used 230 test sections of 2-lane road. The accident data was collected from computer files for the three years 1969-71. A method used successfully in the study was the method of moving averages.

Figures 2-8 show the sections plotted with their skid number and their ratio of wet to dry accidents with volume stratification. The results of moving averages and skid number grouping are then shown. Table 1 shows the recommended critical skid numbers based on the two methods.

SOURCE: "Accidents on Rural Two-Lane Roads and their Relation to Pavement Friction" by Rizenbergs et al, Kentucky Bureau of Highways, Report 443, p.7, 1976.

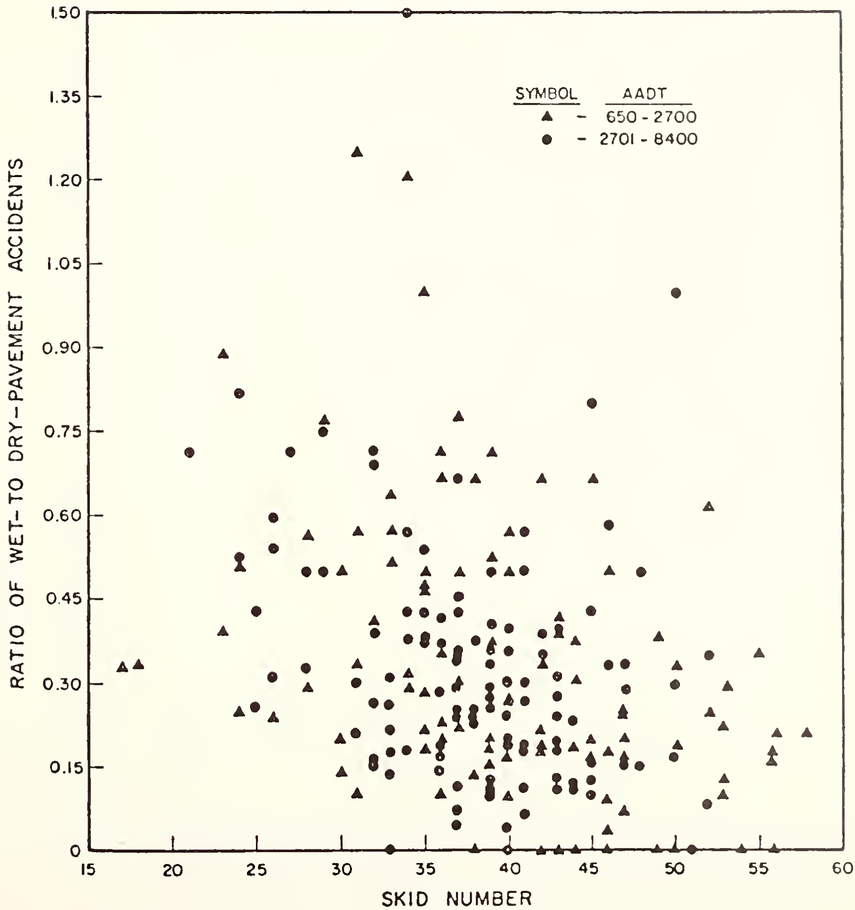

Figure 2. Test Section Averages: Ratio of Wet- to Dry-Pavement Accidents Versus Skid Numbers, with AADT Stratification

SOURCE: "Accidents on Rural Two-Lane Roads and their Relation to Pavement Friction" by Rizenbergs et al, Kentucky Bureau of Highways, Report 443, p.9, 1976.

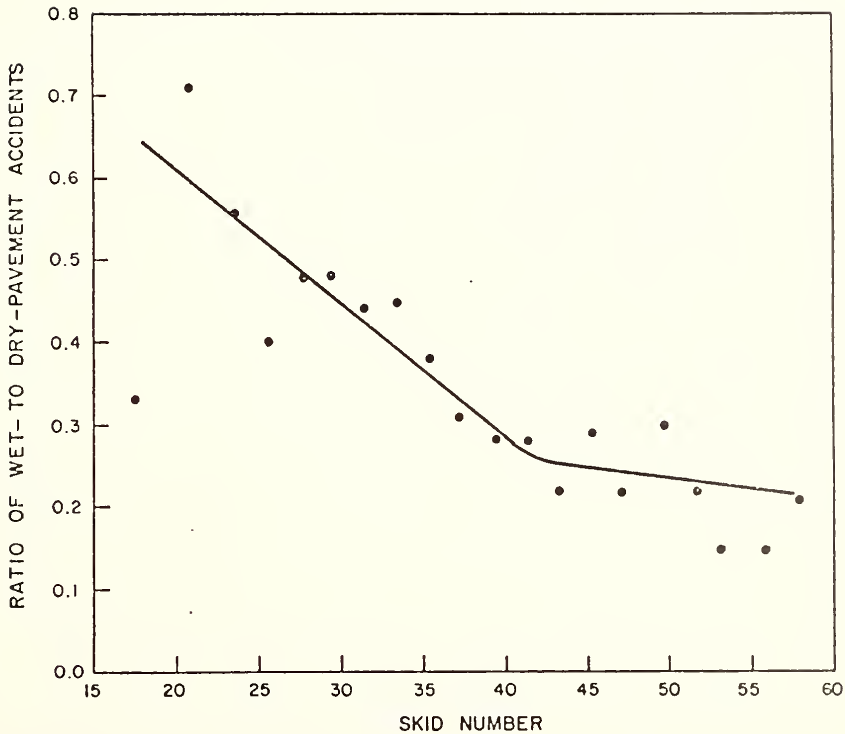

Figure 3. Average Ratio of Wet- to Dry-Pavement Accidents of 230 Test Sections - Grouped by Skid Number - Versus Skid Number without Volume Stratification

SOURCE: "Accidents on Rural Two-Lane Roads and their Relation to Pavement Friction" by Rizenbergs et al, Kentucky Bureau of Highways, Report 443, p.10, 1976.

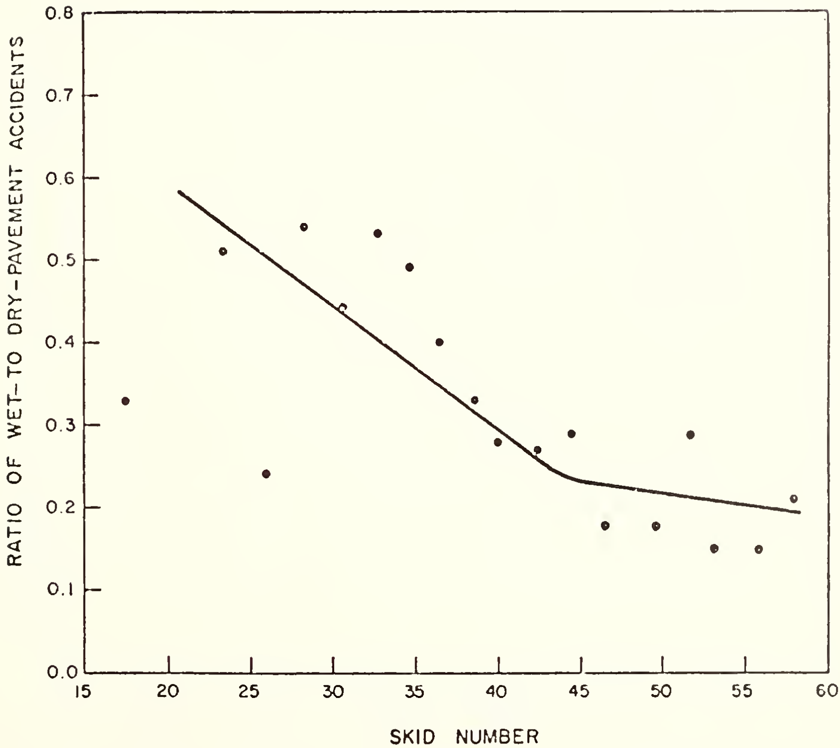

Figure 4. Average Ratio of Wet- to Dry-Pavement Accidents of 110 Test Sections - Grouped by Skid Number - Versus Skid Number with Volume Stratification at AADT below 2701

SOURCE: "Accidents on Rural Two-Lane Roads and their Relation to Pavement Friction" by Rizenbergs et al, Kentucky Bureau of Highways, Report 443, p.11, 1976.

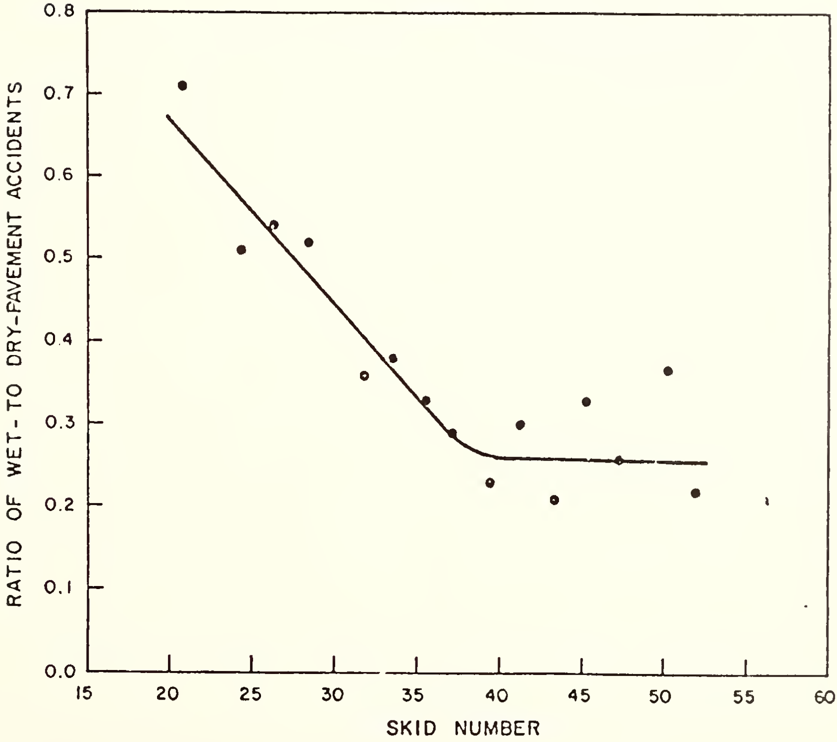

Figure 5. Average Ratio of Wet- to Dry-Pavement Accidents of 120 Test Sections - Grouped by Skid Number - Versus Skid Number, with Volume Stratification at AADT above 2700

SOURCE: "Accidents on Rural Two-Lane Roads and their Relation to Pavement Friction" by Rizenbergs et al, Kentucky Bureau of Highways, Report 443, p.12, 1976.

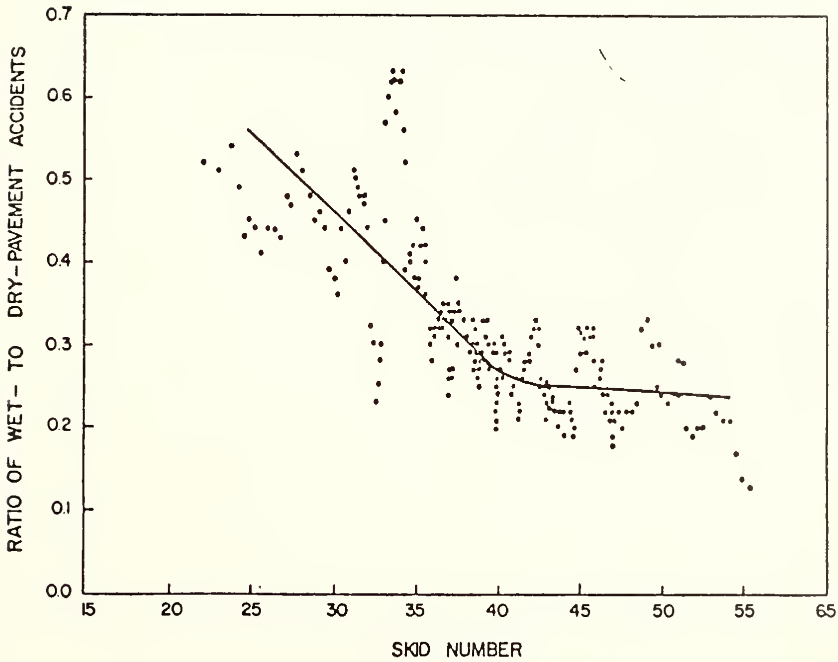

Figure 6. Ten-Point Moving Averages: Ratio of Wet- to Dry-Pavement Accidents for 230 Test Sections Versus Skid Number, without Volume Stratification

SOURCE: "Accidents on Rural Two-Lane Roads and their Relation to Pavement Friction" by Rizenbergs et al, Kentucky Bureau of Highways, Report 443, p.13, 1976.

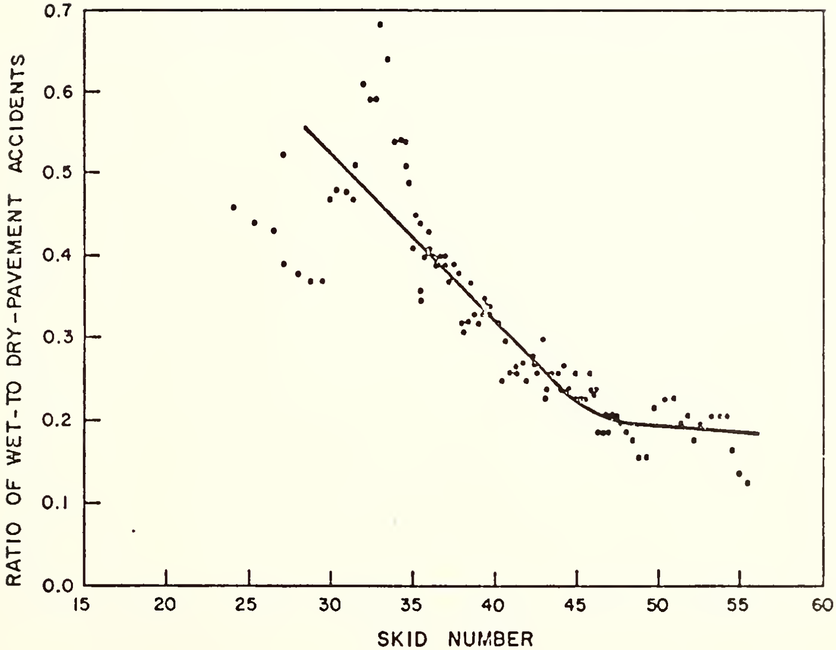

Figure 7. Ten-Point Moving Averages: Ratio of Wet- to Dry-Pavement Accidents for 110 Test Sections Versus Skid Number, with Volume Stratification at AADT below 2701

SOURCE: "Accidents on Rural Two-Lane Roads and their Relation to Pavement Friction" by Rizenbergs et al, Kentucky Bureau of Highways, Report 443, p.14, 1976.

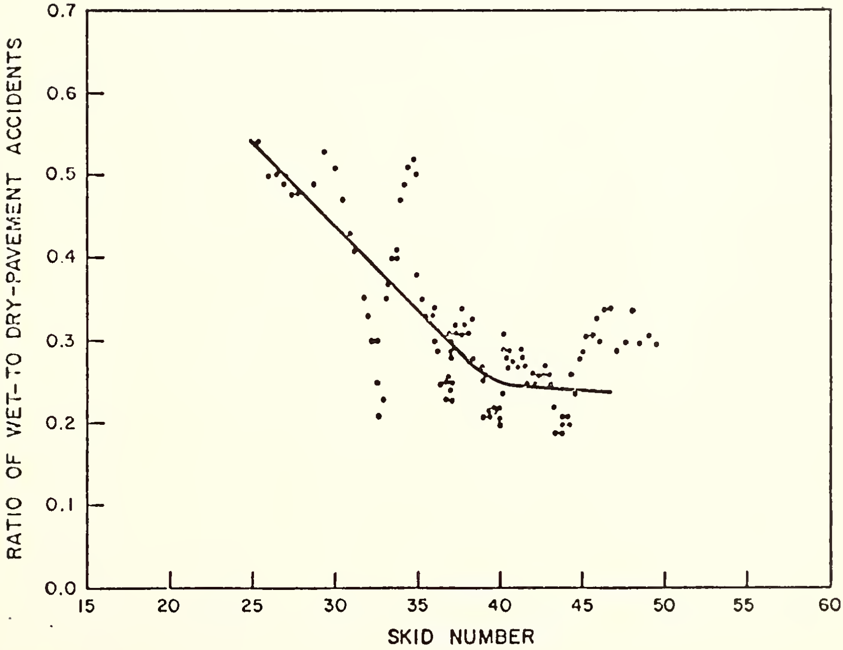

Figure 8. Ten-Point Moving Averages: Ratio of Wet- to Dry-Pavement Accidents for 120 Test Sections Versus Skid Number, with Volume Stratification at AADT above 2700

Table 1. Critical Skid Numbers

AADT Stratification	Averaging Methods	
	Grouped by SN	Moving Average
650 - 8400	41	40
2700 or Less	43	45
Above 2700	38	39

Source: Accidents on Rural Two-Lane Roads and Their Relation to Pavement Friction" by Rizenbergs et al, Kentucky Bureau of Highways, Report 443, p. 14, 1976.

It is probable that similar results, representative of Indiana's conditions should be obtained from this research.

Data Methods

Information pertaining to the factors involved in causing a vehicle to skid as well as information on continuing research into methods of accurately testing roadway surfaces to determine their skid numbers are readily available (18). Factors such as tire condition, driver reactions and visibility in wet weather are also important but it is generally agreed that wet surface conditions are the major controllable causal factor in vehicle skidding accidents.

Other background materials refer to safety and accident study methods in general. Cost-effectiveness in Traffic Safety by Arthur D. Little, Inc. explains the larger scope of highway system safety (19). The book explains how a particular factor such as skidding accidents relates to the entire system of highway safety. The manual on Uses of Traffic Accident Records by the National Conference on Uniform Traffic Accident Statistics provides some basic information on use of records in research and explains some of the basic statistical methods used (20). Information on more advanced statistics is commonly available in textbooks. It is also available in material dealing with statistical methods used in road safety (21).

Indications on the expected accuracy of typically available accident data are included in a report of the effect of darkness and road lighting in Britain (22) by Barbara Sabey. Table 2 shows how a noticeable number of accident records were miscoded either with the wrong time or light condition.

Table 2. Monthly Totals of Injury Accidents in 1969 by Hour of Day: According to Police Report of 'Daylight'

	Hr.	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
	1	6	5	6	25	8	7	5	9	7	6	2	5
	2	9	6	3	9	3	3	9	6	5	3	9	7
	3	7	9	1	6	-	2	3	5	1	2	2	4
DARK	4	9	6	6	3	5	3	5	5	5	5	5	4
	5	9	10	5	4	24	50	26	4	5	9	5	1
	6	8	7	13	23	75	88	84	64	11	6	2	1
	7	2	8	18	143	153	151	148	184	114	27	3	.
	8	25	165	673	703	673	726	701	646	719	768	251	12
DAWN	9	628	1086	1424	997	1232	1207	1148	852	1331	1719	1498	652
	10	827	806	749	708	757	775	816	786	757	910	943	792
	11	802	750	682	835	796	836	920	1050	863	865	898	793
	12	898	856	809	1051	1097	1023	1162	1342	1048	1013	1213	1020
DAYLIGHT	13	1146	1055	1163	1270	1497	1311	1373	1522	1364	1465	1563	1321
	14	1093	998	1074	1228	1355	1235	1355	1413	1200	1383	1472	1178
	15	1074	988	973	1272	1367	1263	1329	1556	1260	1252	1351	1176
	16	1176	1184	1367	1457	1577	1490	1414	1584	1409	1472	1443	1357
	17	1623	1559	1769	1739	2138	2013	1962	1833	2084	2170	1944	1549
DUSK	18	871	1277	1629	1856	1960	2026	2172	2013	2059	2066	1054	399
	19	50	416	901	1360	1517	1514	1451	1443	1339	758	25	5
	20	7	16	314	852	1276	1293	1374	1162	735	68	8	7
DARK	21	12	21	31	299	795	930	1027	769	90	17	16	8
	22	11	6	10	22	225	605	546	109	18	12	6	4
	23	6	8	8	22	22	71	62	18	9	15	11	9
	24	8	12	8	16	17	18	22	15	17	12	8	9

Source: Road Accidents in Darkness by Barbara Sabey, Transportation and Road Research Laboratory, Report LR 536, 1973.

Also used in this study with respect to the accident data was the "Accident Investigations Manual of the Indiana State Police"(23). The manual was needed to determine the exact meaning of the data recorded on the accident forms.

Recent Studies

During the final preparation of this report, additional reports on correlations between skid numbers and accidents became available. Two reports in particular are of interest, both are in the Transportation Research Board's Transportation Research Record 584. One is "Pavement Skid Resistance Requirements",by members of the Highway Safety Research Institute at the University of Michigan (24). Computer simulation of required skid resistance for various factors and maneuvers was performed. The effect of the depth of the water sheet was studied and included. A formula which gives the recommended required skid number as measured at 40 mph is presented. This formula is designed specifically for thruway type roads. A more specific explanation of the developed method with an example is given in the report.

The second report of interest is "Accidents on Rural Interstate and Parkway Roads and Their Relationship to Pavement Friction" by the Kentucky Department of Transportation and is part of the overall study which produced the earlier noted study on rural two-lane roads(25). This research used 110 sections (770 miles) of 4-lane controlled access roads, with accident data for the years 1970-72. Moving average and skid number groups are again used in the analysis. Wet and dry pavement accident rates are also used. Figure 9 shows the results of this study.

As can be seen, the relationship of wet to dry surface accidents to skid number is not as clearly defined as that found on the two lane routes. In comparing Figure 9 to other similar charts in this report one must note that the

Source: "Accidents on Rural Interstate and Parkway Roads and Their Relation to Pavement Friction" by Rizenbergs et al, Transportation Research Record, No. 584, p. 29, 1976.

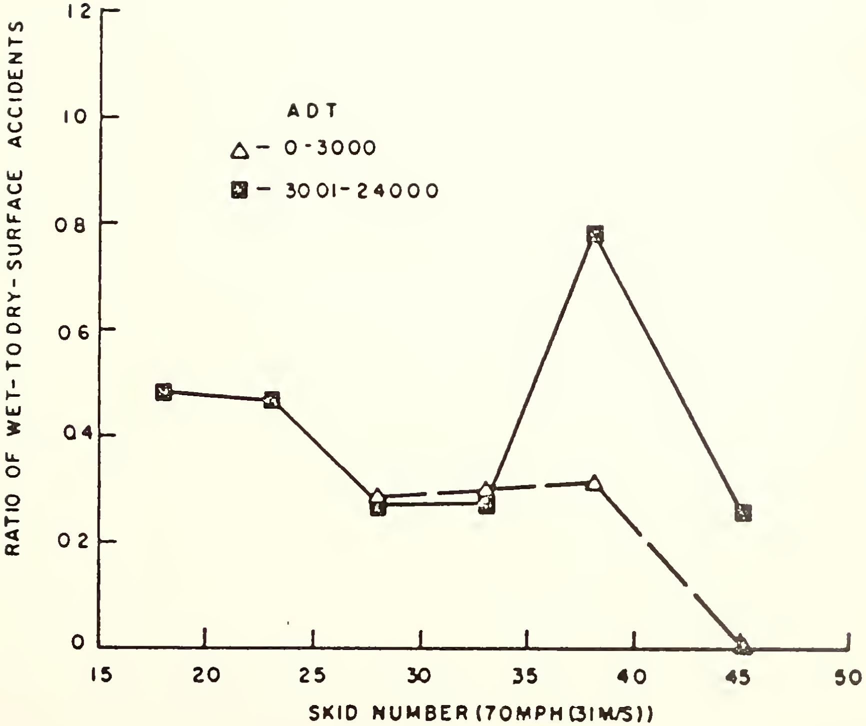

Figure 9. Ratio of Wet- to Dry-Surface Accidents Versus Skid Number

skid numbers are as measured at 70 mph. These can be converted to values taken at 40 mph by the following formulae developed in the Kentucky research:

For asphalt pavements,

$$SN_{40} = 0.92\ SN_{70} + 15$$

For PCC pavements,

$$SN_{40} = 1.17\ SN_{70} + 9$$

CHAPTER III: DATA COLLECTION

Road Section Selection

The first major decision in data collection was the unit of study to be used for the research. There were two major choices, use of average data for sections of roadway or for specific locations, such as intersections which were the most likely high accident locations.

One advantage of using intersections was the greater uniformity they have in characteristics. The use of high accident locations also leads to reasonable amounts of accident data for stable and easily identifiable conditions. The use of intersections has the additional advantage of limiting accidents to conflict type accidents. Advantages of using section data include the inclusion of all types of accidents and the relative ease of the collection of accident information as in Indiana rural areas accidents are filed by section.

The use of intersection data after study, however, was deemed impractical. Skid data was not available over a large enough span of time to provide adequate accidents for analysis, and the state police accident files are arranged such that it would be very time consuming to collect data on single intersections. This led to the decision that the study would be done with section data.

The next major question was how were these sections to be chosen. Available data provided certain criteria for this decision. The Indiana 1975 skid inventory was used as one data base and for accidents the study period of 1973-1975 was selected so as to provide for three years of accident data. Therefore all road sections which had been reconstructed, resurfaced, or built after 1972 were deleted.

Skid numbers are time dependent, thus to find average values for the study period, it was deemed necessary to have at least two time spaced measurements in order to adjust by linear interpolation. All sections with less than two readings, or with readings spaced less than two years apart were therefore deleted.

Sections which had a great increase in skid number values between two readings were also specifically noted. Such an increase in value is either due to a faulty reading or to unusual characteristics of the pavement. These characteristics are not correctly described by linear interpolation thus sections with great increases in skid numbers were eliminated.

This process left 529 sections of road for data collection. These sections were then numbered consecutively. A computer program was created which produced a list of non-repeating random numbers ranging from 1 to 529. The sections were then placed in order according to their assigned random number. For the duration of the experiment, sections were always selected with priority to their order on the random list.

During the design of the experiment, attempts were made to design the selection of sections such that analysis of variance would define the effects of pavement type and road class. To make such ANOVA possible it is necessary to choose sections such that any combination of the chosen factors has a sufficient number of data points for analysis. This attempt proved to be inadequate, and often times as many sections as possible to fill cells (combinations of factors) were taken by priority from the random order list.

A considerable number of the possible sections were also eliminated during the accident data gathering. Since accident data were identified by the township in which they occurred, it was necessary for correlation with the proper road section that all portions of a highway route in one township be also in one road section. This resulted in elimination of many road sections.

Other problems were also found in the accident gathering stage which led to disqualification of sections. Some sections were removed due to construction not earlier identified but noted on the accident form, while others could not have their accidents properly identified, due to common filing of accidents for routes which included two or more roads such as business and bypass routes for the same route number. These factors reduced the number of sections in the study to 94. During analysis, certain sections were also not used due to very low numbers of accidents, a fact which made certain analysis values impossible of calculation.

Skid Number Inventory

The skid number inventory is a list of skid numbers on all state and federal highway sections in Indiana. The sections are listed in State Highway Districts and Route Number. The inventory is maintained by the Research and Training Center of the State Highway Commission which also is responsible for the skid testing program.

The results listed are averages of skid number tests along with the date the skid number value was obtained. Most of the skid tests were performed during the summer months, thus the seasonal effect on the measurements should be minimized. The number of lanes and direction of traffic flow are given. Divided highways have separate sections for each direction of flow. Other information includes the maintenance section designation, type of surface, beginning and ending location of each section, and the contract number and completion date of the most recent construction, when available.

County Maps

County maps were needed to locate sections suitable for accident data collection. Difficulty was encountered at first in finding current maps. Some that were available were from 1937 and hence did not include the interstate system. More current maps were found at the Graphics Section of the Division of Planning of the Indiana State Highway Commission. The Section is in the process of updating all county maps and was able to provide maps for all the counties dating from 1960 to the present.

The maps were also used to collect data on the number of state and county road intersections on each road section and to develop an urbanization factor which would reflect the number and size of adjacent cities to each section. The length of each section was also taken from the maps.

Weather Data

Data on weather was obtained from the state climatologist's office. The number of hours of wet pavement condition was estimated for Fort Wayne and Indianapolis by use of hourly rainfall data for the year 1974. A method of analysis developed by the Texas Highway Department was used to estimate the hours of wet conditions from hourly rainfall data (Appendix A). Use of this data along with data on average hourly and monthly traffic volume variations in Indiana were used to determine that 11.609 percent of annual vehicle-miles of travel occur on wet pavements.

Traffic Volume Data

Traffic volume data for the sections was taken from a State of Indiana traffic volume map, which is prepared by The Division of Planning of the Indiana State Highway Commission. This map lists the twenty-four hour annual average total traffic for road sections throughout the entire state highway system. The 1972 volumes were used for most of the early data analysis. This was due to the delay in availability of the 1975 volumes map, which was not available until late in the analysis. For final analysis a linear interpolation of the two volumes to adjust to 1974 volumes was used.

Accident Data

Accident data was taken from the central files at the state police headquarters in the State Office Building in Indianapolis. Indiana state law provides that written reports be filed by all drivers and the investigating officer involved in a motor vehicle accident involving death, injury to any person or total property damage equal to 200 dollars or more (26).

Thus for each such accident there are usually two types of forms, the police report and the drivers report(s). In general the police report is more accurate and dependable, thus information regarding the accident was usually taken from this form. If the police report was incomplete or non-existant, the drivers report(s) were used for data.

The accident reports are stored in three forms, the original report forms as received, microfilm copies of the reports and selected data on computer tape. The advantages of use of the computer tapes in collecting accident data are considerable. They allow a much larger number of sections to be used due to the elimination of tedious manual searching for and copying of data. The state police presently, however, have no means that can be used to search the computer tape data by location. Searching is only possible by the names of the drivers and by the filing number. Presumably programs could have been written to allow searching by location but this was not feasible for this study.

All the problems noted were difficult, but surmountable. The problem, however, which eliminated the possibility of using the tapes was that details regarding the direction vehicles were traveling was not coded. Thus four-lane sections, where each direction was treated as a separate section, could not have been used. The description of the accident and other needed accident information (described later) were also not coded on the computer tape. Thus the decision to use manual collection of accident data was made, even though this decision restricted the study to one hundred road sections due to its time consuming character.

As noted earlier, a three year study period, covering the years 1973, 1974, and 1975 was used. This decision was based on the desire to use as long a period as possible without using years for which a skid number value could not be accurately estimated. Since most of the skid number values available were from testing in late 1972, 1973 and 1975, 1973-5 best defined a three year period, a time period length which is also generally accepted as a minimum number of years for accident data.

The accident forms are stored at state police headquarters in Indianapolis in their original form for two to two and one-half years prior to being placed on microfilm. Thus for this study 1974 and 1975 data were collected from the original forms while 1973 forms had to be read with one of the two available microfilm readers. Sample copies of the accident report forms, and the coding forms used in this study can be found in Appendix B.

The reports are filed as follows: first by year, then as Urban or Rural. The urban accidents are separated by county and city and then filed chronologically. Thus a tremendous amount of searching is necessary to find a particular location. Due to this problem all urban road sections were removed from the study.

The rural reports are separated by county, then by route number and then chronologically. The Township name is marked on each form, as is the direction of travel. Thus one is able to retrieve a group of reports and search them to find incidents on the proper section. This method was used to find accidents which occurred on the 94 sections for 1973-1975.

The data collected from each accident report included the month and year of the accident; the county, township, route and direction of travel. The accident diagram was used to decide if the accident actually took place on the roadway in question. If it did not the accident was not recorded.

The next piece of data taken was whether the accident was an intersection type or not. This was inferred by use of the space on the form marked "at its intersection with". Even if the accident did not occur physically within the intersection, the diagram was checked to see if the accident was of the intersection type (i.e. rear end accident into cars waiting for a traffic control device).

The number of vehicles involved and the number of persons killed or injured were also recorded. Whether the vehicles skidded before or after applying their brakes was also recorded for each vehicle. The character of the road, whether straight or curved, and whether it was level, on grade or at a hillcrest along with the surface condition (dry, wet, snow, ice), existing weather (clear, raining, snowing or fog), and light (day, night, dawn or dusk) were recorded.

The information as to the causal effect of skidding was only recorded if the roadway condition was wet. In those cases the diagram, description, speeds, and condition of the drivers was checked to see the probable effect wet pavement had on the accident, i.e. in the researchers opinion, did it cause the accident, have some effect on the accident or have no effect. An example of an accident not probably caused by skidding would be a vehicle driven at a reasonable speed being out-of-control on a curve, or a rear end accident into a waiting vehicle, when the evidence shows the following car skidded for a great distance. A wet pavement accident probably not caused by skidding would be a driver falling asleep and leaving the roadway.

A very few accidents on the selected road sections could not be included in the study due to lack of reliable information, non-accident incidents (car fires), or very incomplete reports. Basically accidents were discarded if from all the reports filed a reasonable guess on the required pavement condition data was not possible. Skidding, before or after braking was taken as noted on the accident reports, while the condition of the road information was checked with the description of the accident (i.e., an accident on an icy bridge described as a wet road was counted as snow/ice).

This brings up the question of the reliability and accuracy of accident data, as noted earlier in Chapter 2 by coding mistakes found in the Road Research Laboratory's Report (Table 2). Less than 5 percent of the accidents obtained for this study were disqualified by the researcher, but a greater percentage of the data had characteristics which either led the researcher to doubt the information, or in some cases there was very little information to doubt. There was reason to believe that some police reports either were never written or were incorrectly filed. This is illustrated by cases where just a drivers form (reporting more than $200 damage) which listed the name and department of the officer at the scene was filed, but no police report was in the files. Other cases noted were several chain reaction accidents where the earlier accident (which was of a type that required reporting) had no report in the files although the later accidents did. These cases indicate situations where it is obvious there are missing accident reports.

A problem especially troubling for this study was a tendency by the police not to note the existance of skidding if there were no visible skid marks, as often happens when a car skids on wet pavement. This fact resulted in a study by the researcher of the data reported on the accident reports as "skidded before" or "skidded after" braking. By evaluation of the accident diagram and description, the researcher found that 328 of the wet weather accidents probably had skidding as a causal factor. Of these 328 accidents, however, only 67.7 percent had skidding noted on the accident forms in the appropriate place as occurring.

Much information was also lost, because the investigating officers often did not draw a diagram and occasionally did not describe the accident, apparently because the vehicles had been moved from the roadway prior to the officers arrival. Many accidents had other characteristics which created doubt, such as contradiction between data on one form and another (i.e. different location, nature of injuries, time, road conditions, etc.), and between information on the same form (i.e. miscoded townships, dark checked for an 11 a.m. accident, etc.).

The study found 4416 accidents on the 94 sections used for this analysis. Of these, 2805 (63.5 percent) were on dry pavement, 918 (20.8 percent) were on wet pavement and 693 (15.7 percent) were on snow or ice. As reported by the State Police in their Annual Standard Summary of All Reported Accidents (27) for 1974, accidents during the year for the State of Indiana were 64.2 percent on dry pavements, 24.7 percent on wet pavements and 11.0% on snow/ice. The other 4.3 percent were listed as "Other" or "Not Stated". The difference in percentages between the state police annual report and the findings from the sample of this study reflects the use of the accident description in this study to obtain more accurate information on road conditions at the time of the accident.

The accidents of this study involved 2139 personal injuries and 106 deaths. Intersection accidents accounted for 39 percent of the study accidents. Straight and level accidents represented 72.8 percent of the total. The wet weather accidents were divided into 3 groups. Those not caused by skidding accounted for 30.8 percent of the wet weather accidents, possibly caused by skidding 33.4 percent, and probably caused by skidding 35.7 percent.

The question of how much effect the loss of visibility in wet conditions has on accidents is perhaps indicated by the fact that while 20.5 percent of the studied accidents during daytime conditions were wet weather accidents, only 19.8 percent of the nighttime accidents involved wet pavements. Although there are other factors, this indicates not as much effect from light conditions as might be expected.

Physical Observation

After much of the preliminary analysis was complete, it became clear that factors unknown to the researcher were influencing the research results. The decision was made to physically inspect a small sample of the sections, to see if any possible explanation of unusual results could be found. Factors such as lane width, curvature and grade were recorded, but the major factor examined was whether ponding or wheel ruts occurred on the sections. To facilitate the location of ponding areas, observations were made during rainfall. Wheel ruts were measured with a long straight edge and a ruler. The results of these observations will be discussed in the Analyses of Data Section.

Section Characteristics

The 94 selected sections are from throughout Indiana, with 16 in the Crawfordsville District, 15 from Fort Wayne, 9 from Greenfield, 23 from LaPorte, 11 from Seymour and 20 from Vincennes. Average skid number values (interpolated values for June, 1974) were distributed as to number of road sections as follows:

30-35	35-40	40-45	45-50	50-55	55 and Greater
16	25	20	17	14	2

Total Sections = 94

The distribution of sections by class of highway and pavement type is shown in Table 3. In the selection of section process, it was decided that for analysis a minimum of 5 sections would be desirable for each cell in Table 3. This was impossible to accomplish. It was then determined to select an equal number of two-lane and four-lane sections with the four-lane to be equally divided between Interstate and non-interstate. The elimination of six sections previously discussed reduced the number of four-lane sections to 44 with 22 Interstate.

Geometrics

During the data analysis, especially while considering the physical observations made on sample sections, it

Table 3. Distribution of Sections by Pavement Type and Road Class

	Pavement Type									
Class of Road	HAE I	HAE II	HAE III	HAE IV	HACA	HACB	Bit. Conc.	Sand Asph.	PCC	Total
Two-Lane	--	3	7	6	3	11	9	6	5	50
Four-Lane Non-Interstate	--	--	--	1	--	5	5	2	9	22
Interstate	--	--	--	--	--	--	--	--	22	22
Total	0	3	7	7	3	16	14	8	36	94

became obvious that other important factors needed consideration. It was then decided to collect data on the geometric design of the two-lane sections. Only two-lane sections were used due to the similarity of geometry on four-lane interstate or non-interstate sections. Thus the effect of geometrics would be much more pronounced on two-lane sections.

The data was provided for forty of the fifty sections by the Indiana State Highway Commission's Research and Training Center. The skid test crews take notes on the sections when testing, thus they were able to provide qualitative data on the extent of curves and hills on forty sections. Data for the other ten sections were taken either from topographical maps, county maps or physical observation. These qualitative data for the horizontal and vertical alignments were then combined into one factor as shown in Figure 10. The geometric factor for each section along with other data is given in Appendix C.

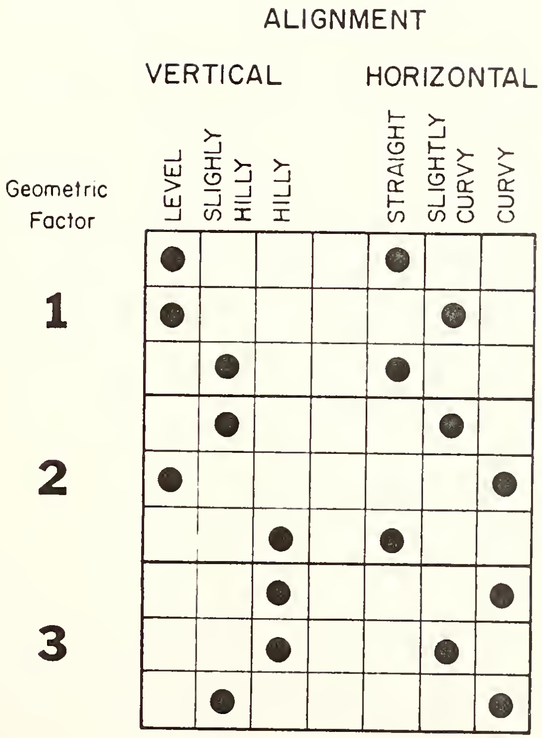

Figure 10. Geometric Factor For Vertical and Horizontal Alignment

CHAPTER IV: ANALYSES AND FINDINGS

Wet Accident Rate Ratio

In the initial stages of this research it was found that some objective indicator was needed. This indicator had to show the effect of wet pavement conditions on accidents for a section of road. This value must be as independent as possible of other section characteristics (i.e. volume, curvature, number of intersections, etc.).

The first indicator considered was the accident rate, a standard tool in traffic engineering. A rate often used is the number of accidents per million vehicle-miles of travel. The accident rate is a good descriptor of the total safety of the road, but by its nature, the rate describes the effects of all factors, thus it does not meet the standards set to describe the effect of such pavement conditions.

The wet accident rate was considered; this is defined as the number of accidents occurring on wet pavements per one million vehicle miles travelled on wet pavements. In order to find what volume travels during wet conditions, it was necessary to find the number of hours of wet pavement by month and hour of day. National weather service data was used along with a method developed by the Texas Department of Highways to find the number of hours of rain. The hours of wet pavement were then correlated with the percent of traffic volume normally occurring for the same month and the time of day (see Appendix A). A wet pavement accident rate was then computed.

This wet pavement accident rate gives a good indication of the safety of the road during wet condition but the rate also includes all other factors involved in the accidents occurring. The main difference between the two rates is that the slipperiness and other wet pavement factors should be much more pronounced in the wet rate.

To remove the effects of the non-wet weather factors, a ratio of the wet rate to the total accident rate was calculated. This result, called the wet accident rate ratio, is an indicator of the relative safety of a road section under wet pavement conditions.

Wet Accident Index

As the analysis continued, problems with the wet accident rate ratio were noted. Since the effect of wet accidents is in both the numerator and denominator of the ratio, some of the wet weather effect is obscured. The inclusion of snow accidents in the denominator also had a possible adverse effect, since badly cleared roads might have more accidents, and snowfall varies within the state, thus biasing the ratio.

Attempts to find the volume of traffic on road sections when they were dry proved unsuccessful. This was due to the difficulty of finding the percentage of time the road was covered with snow or ice. Information on the depth of snow on the ground was available on a daily basis, but there is no way to relate this to variations in snow removal and other factors.

The numbers of accidents occurring on a section of highway under wet and also under dry conditions, however, could be obtained. The procedure for obtaining the number of wet accidents on each section has been discussed. The accident data collection procedures also obtained the number of accidents occurring on dry pavements. The ratio formed by the number of wet accidents on a section divided by the number of dry accidents on the same section provided for each section a wet/dry accident index (called a wet accident index hereafter).

This index reflects by its increasing value the number of additional accidents happening due to wet conditions. This can be illustrated by considering a section of road that is just as safe when wet as when dry. On this section, one would expect the number of accidents wet or dry to be proportional to the volume of traffic traveling under these conditions. If this section's pavement was such that it became slippery when wet, the number of dry accidents (the dividend) would remain constant, but the wet accidents (numerator) would now include both the accidents which happen regardless of slipperiness and those caused by the slippery pavement. Thus the wet accident index would increase.

As noted earlier it is difficult to find the percent of time roads are dry. Thus an ideal value for the index cannot be specified. Nevertheless it can be assumed that under ideal wet pavement conditions the index value would be somewhere between 0.12 and 0.20.

For this study the mean value of the index was .32 with a standard deviation of .20. The range of values was from zero to one, but most extreme values were due to sections with low numbers of total accidents.

The wet accident index was used in many ways. A plot of this index versus skid number is shown in Figure 11. There is considerable scatter evident in this plot. There, however, is a slight downward trend of the maximum values of the index as the skid number increases.

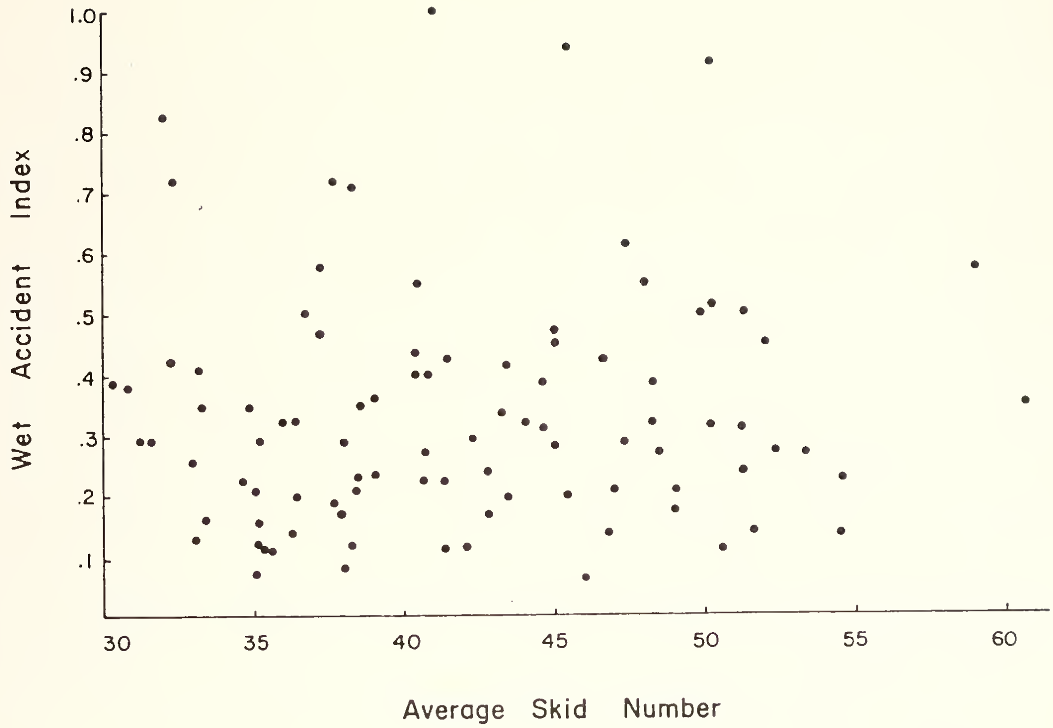

Figure 11. Wet Accident Index Versus Average Skid Number: Individual Measurements Plotted For All Test Sections

Moving Averages

Different methods were used to try to explain the relationship between the skid number and the wet accident index. One of the methods tried was a system of five-point moving averages. This method involves the sorting of the sections by their average skid number in order from lowest to highest. The sections are then grouped together in groups of five starting with the five sections having the lowest skid numbers. On each iteration, the group shifts one section to add the next higher section and to eliminate the lowest. For example using the 94 sorted sections, the groups used for each calculation would be; 1-5, 2-6, 3-7...88-93, 89-94. The total number of wet and dry accidents for each group are divided to find the index for each group. At the same time the five skid numbers are averaged. A graph of the results of this method is shown in Figure 12. It is obvious that this method had little effect at removing the scatter. Attempts to reduce scatter by increasing the group size were also unsuccessful.

Regression

Regression methods were used to fit a line to the data and then test the lines significance. A regression of the wet accident index on the average skid number was performed and the results are shown in Table 4.

The results of this regression show no correlation between the wet accident index and skid number. The fact that the F value is less than one leads to questions about the analysis. These questions are directed at the statistical model considered, the validity of the data, and the normality assumptions made in regression analysis. Whether the model itself should be rejected can be tested by taking 1/F and comparing it to a Table F value. In this case; H_0: Model is correct, $1/F=2.487<F_{.95,1,92}=3.96$, thus

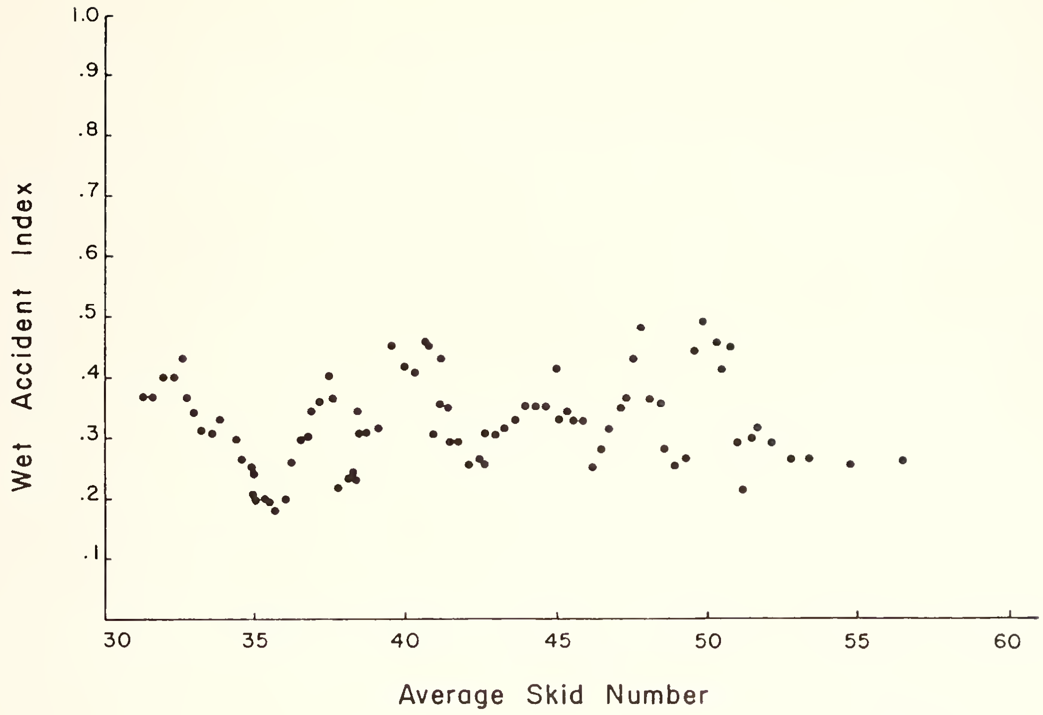

Figure 12. Wet Accident Index Versus Average Skid Number: Five Point Moving Average For All Test Sections

Table 4. Regression of the Wet Accident Index on Skid Number: Linear Model

	Degrees of Freedom	Sum of Squares	Mean Square	F Ratio
Regression	1	.01562	.01562	.4021
Residual	92	3.57414	.03885	
Total	93	3.58976		

R^2 = .004

we cannot definitely conclude that the model is not correct, but questions on the analysis still exist.

To clarify the difficulties with the analysis certain assumptions were checked. The normality of the index was checked by the Wilkes-Shapiro test. The assumption of normality could not be rejected (28).

Difficulty with the data was a possibility. The accident data showed many discrepancies, and the possibility of bias by any number of factors is not unreasonable. The skid number data exhibited high standard deviations in readings found within each section. This standard deviation averaged between 4 and 5 and values above 8 were not unusual. The range of the skid numbers was only 25.

The random design of the data collection was also considered. The sections were chosen using a random order list obtained from the skid number inventory. This skid number inventory, however, might have biases from the manner in which the sections were chosen for testing.

One other possible difficulty with the initial analysis was that the linear model was not applicable. Other models were therefore tried. An exponential transformation of the form; $y = ae^{-bx}$ was applied to the data using regression. These results, shown in Table 5 were better than the non transformed regression, but still explained only one percent of the variation and regression parameters still were not significant.

Another transformation which was tried was a parabola. Using the form $y = ax + bx^2$, the results are shown in Table 6. These results show less of a relationship than the linear model, thus the parabolic model was removed from consideration.

Stepwise regression was then run using nine variables for both the linear and exponential models. The nine section variables were; the average skid number, accident

Table 5. Regression of the Wet Accident Index on Average Skid Number: Exponential Model

	Degrees of Freedom	Sum of Squares	Mean Square	F Ratio
Regression	1	.34716	.34716	.9599
Residual	92	33.27373	.36167	
Total	93	33.62088		

R^2 = .0103

Table 6. Regression of the Wet Accident Index on Average Skid Number: Parabolic Model

	Degrees of Freedom	Sum of Squares	Mean Square	F Ratio
Regression	2	.01618	.00809	.20601
Residual	91	3.57358	.03927	
Total	93	3.58976		

R^2 = .0045

rate per million vehicle miles, type of pavement, number of lanes, proximity to urbanized areas, the state highway districts, the class of road, the 1974 volume of the road, and the number of intersections within the section. Summary tables for the two regressions are shown in Tables 7 and 8. In this case the linear model had better results than the exponential transformation, having both higher F and R-squared values.

Tests were then made to see if the average skid number was a significant factor, given the effects of the other 8 factors. Table 9 shows the results of these tests. In both cases there was no significant effect on the regression by the addition of the average skid number into the analysis.

Stratification Charting

In order to determine the cause for the data scatter, it was desirable to be able to identify which section each point represented, and to identify other characteristics of each section. Using this information trends due to these other factors might be observed. Since there were no available computer programs to create three-dimensional graphs, one was created. The wet accident index versus average skid number was used as a base, and various factors were printed to represent these points. In the case of overlapping points, a message was printed indicating the factor values and location of the point not plotted. The first section characteristic plotted was the section number. By referring to the section data, all available information about a point could be described.

The volume characteristic of each section was also charted by plotting volume group numbers, where a group defined traffic volume in 2000 vehicle increments. The volume stratification showed no obvious trends.

Table 7. Stepwise Regression of the Wet Accident Index on Average Skid Number: Summary Table for the Linear Model

Variable	F to Remove	F Signif.	Mult. R	R^2	R^2 Change	Simple R	Overall F	F Signif.
Total Accident Rate	8.682	.004	.294	.086	.086	.294	8.68	.004
Pavement Type	4.23	.043	.356	.127	.041	.029	6.61	.002
No. of Lanes	6.81	.011	.434	.188	.061	-.277	6.96	.000
Urbanization Factor	2.16	.145	.455	.207	.019	.217	5.83	.000
District	1.09	.300	.466	.217	.010	-.022	4.88	.001
Skid No.	0.76	.386	.473	.224	.007	.066	4.18	.001
Class of Road	0.12	.725	.474	.225	.001	-.155	3.57	.002
Volume	0.20	.655	.476	.227	.002	-.211	3.12	.004
No. of Intersections	0.11	.745	.477	.228	.001	.068	2.75	.007

Table 8. Stepwise Regression of the Wet Accident Index on Average Skid Number: Summary Table for the Exponential Model

Variable	F to Remove	F Signif.	Mult. R	R^2	R^2 Change	Simple R	Overall F	F Signif.
Total Accident Rate	3.52	.064	.192	.037	.037	.192	3.52	.064
Pavement Type	4.01	.048	.278	.077	.041	.080	3.82	.025
Volume	4.11	.045	.343	.118	.040	-.176	4.01	.010
Urbanization Factor	0.82	.368	.355	.126	.008	.127	3.20	.017
Class of Road	1.10	.297	.370	.137	.011	-.044	2.79	.022
No. of Lanes	1.14	.289	.384	.148	.011	-.168	2.51	.027
Avg. Skid No.	0.54	.463	.391	.153	.005	.102	2.22	.040
No. of Intersections	0.51	.479	.398	.158	.005	.006	2.00	.056
District	0.10	.747	.399	.159	.001	.070	1.77	.087

Table 9. Effect on Regression of the Average Skid Number, Given the Other Eight Factors

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Ratio
Linear Model				
Skid Number	1	.01562	.01562	.1557
Others|Skid Number	8	.80255	.10032	
	$H_0: B_{skid\ number} = 0 \mid B_{others}$			
	therefore accept H_0			
Exponential Model				
Skid Number	1	.34716	.34716	.5188
Others|Skid Number	8	5.35298	.66912	
	$H_0: B_{skid\ number} = 0 \mid B_{others}$			
	therefore accept H_0			

Trends were also not evident when the urbanization characteristic was plotted.

The effect from location of the road sections in different areas of the state was checked. By plotting the state highway district, it was found that there was no noticeable trend caused by location within the state.

The only characteristic where a possible trend was indicated was the type of pavement. Three of the eight sand asphalt sections had very high wet accident indices and high skid numbers. This possibly was due to hydroplaning on these very fine graded surfaces.

The computer created plots for the section characteristics noted are shown in Appendix D.

Monthly Grouped Data

To determine the effect of skid number alone, a method was tried which allocated accidents into groups by the interpolated skid number. This process was done using a computer program which, using each section and its two skid numbers and linear interpolation, found a skid number value for each of the 36 months between January 1973 through December 1975. The accidents were stored by the interpolated skid number on which they occurred. The wet accident index was then calculated for each skid number group (20-24, 25-29, 30-34, etc.). This was expected to produce reliable values due to the large number of accidents in each skid number group. The results of this method are shown in Figure 13.

The trends shown indicate a low wet accident index for the skid number group 35-39, and those above 50. The decrease in safety for the 40-44 and 45-49 skid number groups cannot be explained. This method was also tried using subsets of the sections (i.e. two-lane, interstates, etc.) with similar results.

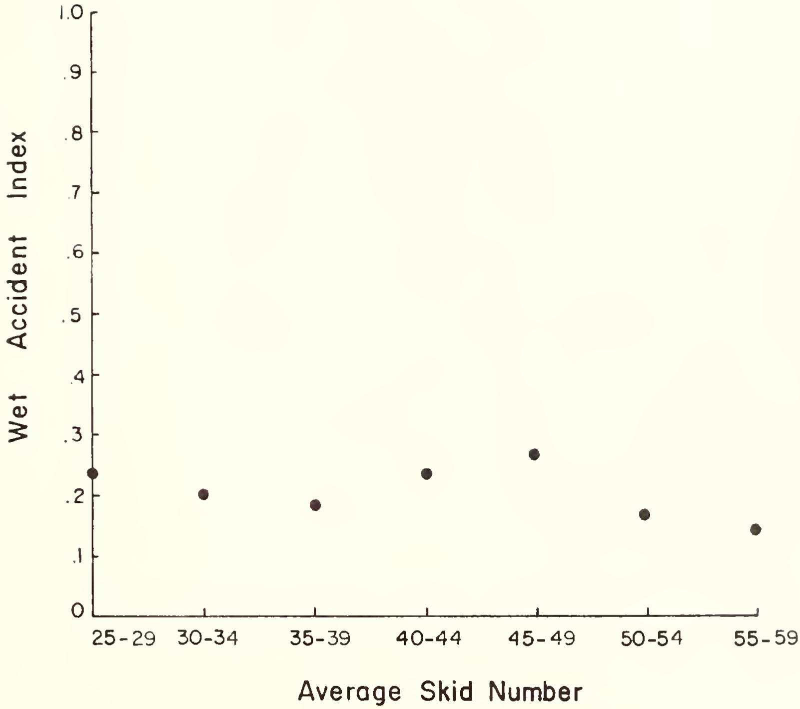

Figure 13. Wet Accident Index Versus Average Skid Number: Monthly Grouped Values For All Test Sections.

Quality Control Method

A method used by Blindaur in a research project at Purdue was used to see if the number of accidents for any section was beyond set control limits (29). This method is based on quality control statistical methods often used in manufacturing. The analysis uses the average accident rate for each type of section as a base. For this method three section types were defined and used; interstate, other four-lane routes and two-lane routes.

A program was developed which used the following formula to compute the expected bounds for each section.

$$R_c = R_a \pm K \frac{R_a}{m} + \frac{1}{2m}$$

where

R_c = critical rate for the section

R_a = average rate, by type of section

m = millions of vehicles miles travelled on section

K = constant; indicates number of standard deviations included, in this case K was taken as 2.

Figure 14 shows the sections that were above or below the control limits plotted by wet accident index versus average skid number. This was done to see if there was any relationship between sections with "out-of-control" accident rates and either its skid number as wet accident index. Looking at the plot it is noticed that all of the points above the control value fall either at a skid number of forty or below, or they are at high index values. At this point it is not clear whether the total accident rates are "out-of-control" due to wet weather conditions or due to other factors.

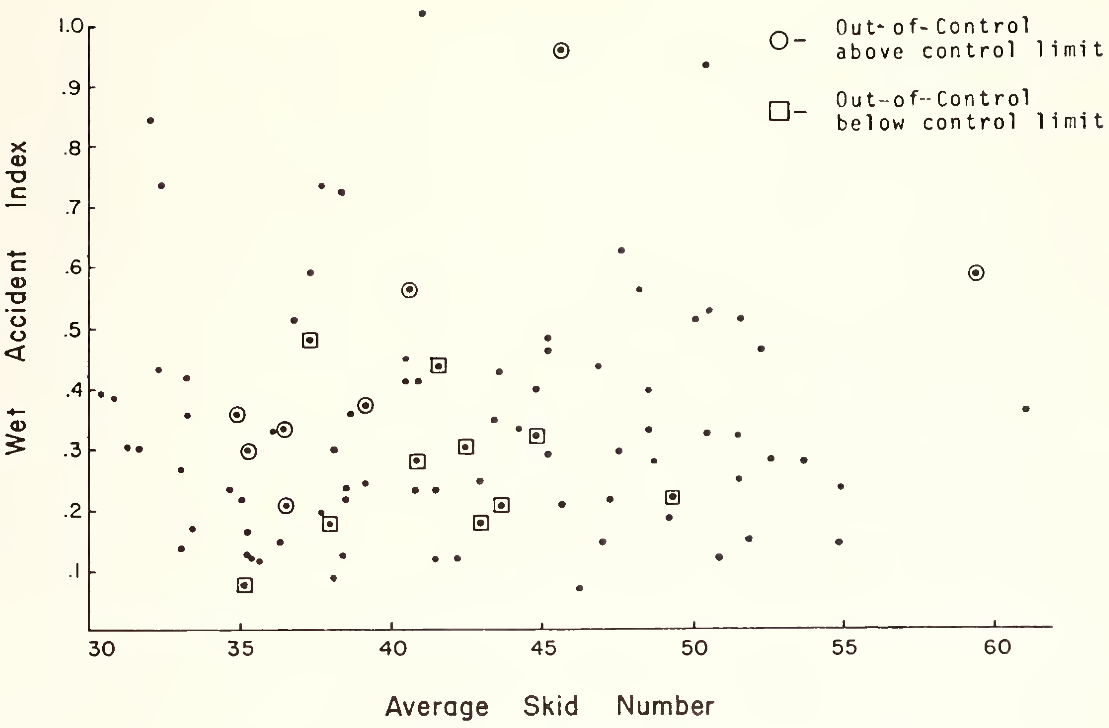

Figure 14. Wet Accident Index Versus Average Skid Number: Out-of-Control Points for Total Accident Rates using Quality Control Techniques

In order to try to answer this question, the same method was used again, but using the wet pavement accident rate rather than the total accident rate. The result of this analysis is plotted in a similar manner to the first case in Figure 15. As might be expected the sections over the control limits are those that tend to have high indexes, while those below the limits have low indexes. No real relationship with the skid number, however, is visible.

The large number of points outside of the two standard deviation range tends to indicate a non-normal distribution of wet surface accident rates. Since those sections which have conditions such that the total accident rate is out of control would also tend to have their wet-rate out of control, it was felt of interest to note those sections which had only the wet-rate above the control value. This is shown in Figure 16. Those sections tend to have higher than average wet accident indexes, but they again show no relationship with the average skid numbers.

Other Wet Accident Indicators

Indicators other than the wet accident index were also tried. During data collection from accident records, wet pavement accidents were classified as probably, possibly or not caused by skidding. A skidding ratio was formed for each section by dividing the number of accidents probably involving skidding by the total number of wet weather accidents. Also a skidding ratio was found using both probable and possible skidding accidents in the numerator. Other variations were the use of probable skidding and both probable and possible skidding accidents for the wet value in the wet accident index. These relationships are shown in Figures 6 thru 9, in Appendix D.

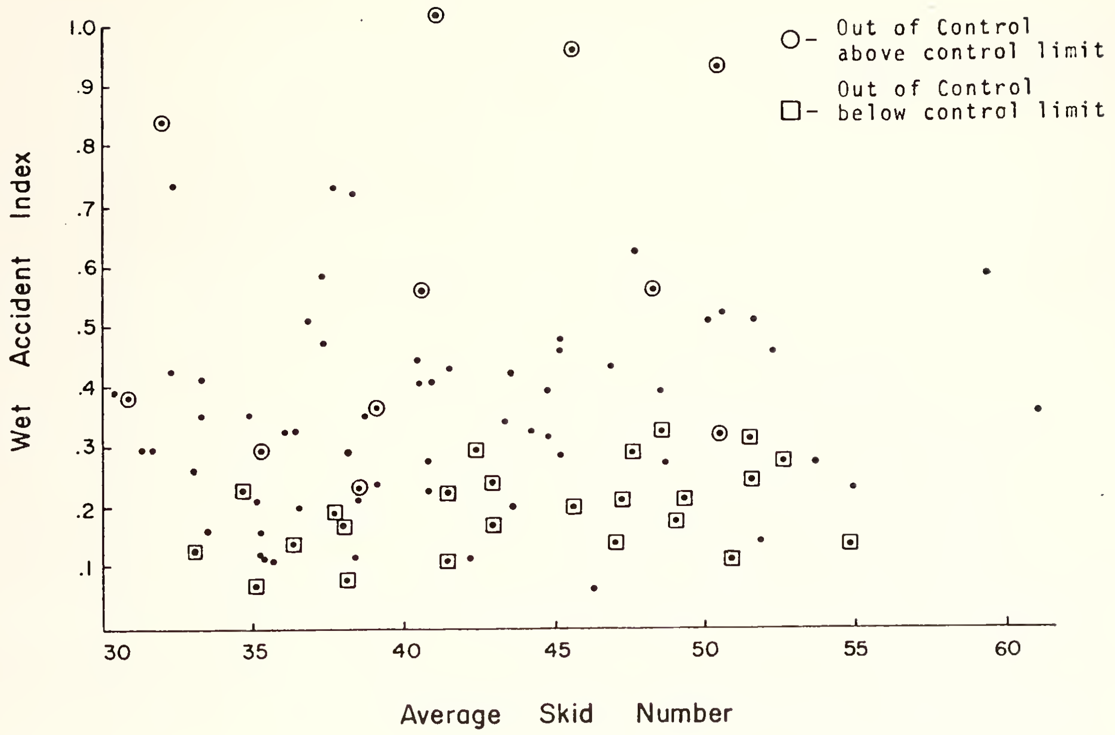

Figure 15. Wet Accident Index Versus Average Skid Number: Out of Control Points for Wet Accident Rates using Quality Control Techniques

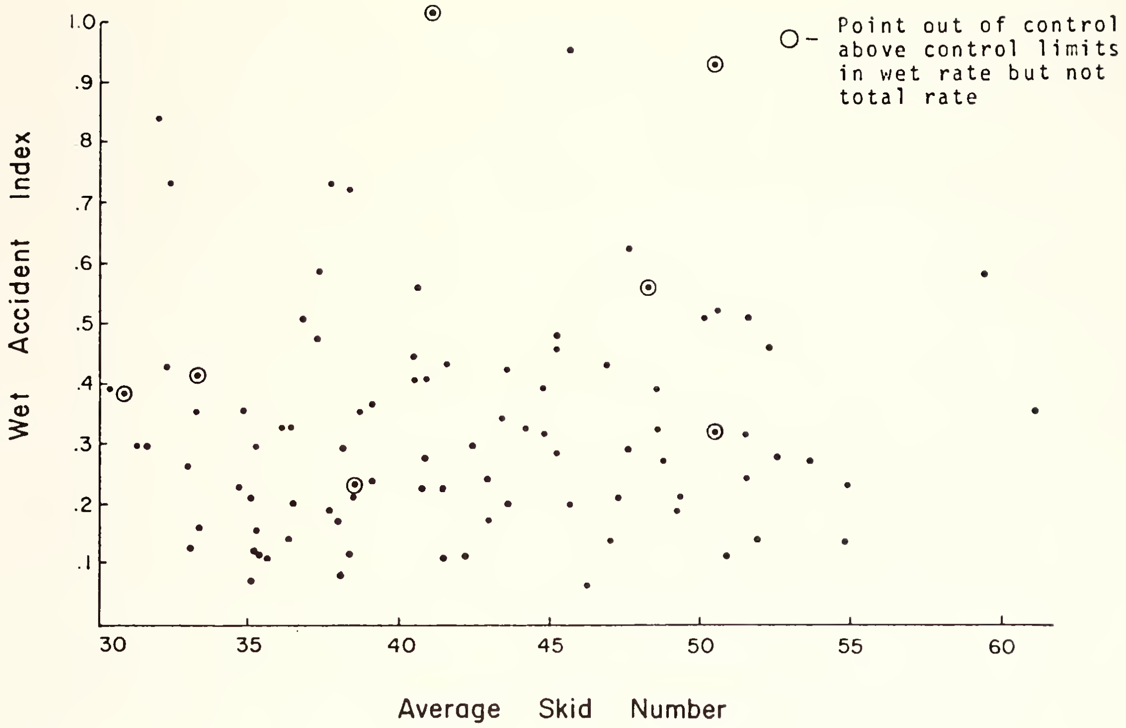

Figure 16. Wet Accident Index Versus Average Skid Number: Comparison of Out of Control Points for Wet and Total Accident Rates using Quality Control Techniques

The use of these different indicators showed no relationship between skid numbers and accidents in wet weather when all ninety-four sections were taken as one group. The plot of wet accident index versus average skid number as well as the other indicators were also analyzed by groups of sections. The major groups chosen were interstates, non interstate, four-lane and two-lane roads. Many analyses were tried on these groups as well as on the entire sample. The results of these analyses are discussed in the next chapter.

Another variation in the group analyses was the removal of all sections with one or less wet weather accidents, as such low values resulted in highly variable indexes. Sand asphalt pavements were also removed from some analyses due to previous indication that three of these pavements had very high wet accident indexes with very high skid numbers. None of the analyses with removal of sections, however, resulted in meaningful relationships between the indicators and skid number.

Significant Skidding Ratio

The significant skidding ratio or SSR is a value based on tables of Cumulative Binomial Probability. This method was used by Stover for a J.H.R.P. Research Project in 1960 (30). This method as used defines the SSR with 95 percent confidence as the minimum percentage of wet weather accidents in which skidding was involved.

Tables in the Stover research report were used to determine the SSR for all sections which had wet weather accidents. These tables were derived from cumulative probability tables and are simple to use. One enters the table with the numbers of skidding and total wet accidents. The SSR is read directly.

This analysis was performed twice, once using accidents where skidding probably occurred as the number of skidding accidents (Figure 17). The second time both those classed as possible and probable skidding were used (Figure 18). The second method indicated very little relationship when the SSR was plotted against the average skid number. The first method gave better results.

As seen in Figure 17, there is no clearly defined line for all points, but there is a trend of a general reduction in SSR values for increasing average skid numbers.

Physical Observations

Information included in Table 10 is from observations taken while driving the five listed sections during wet pavement conditions. Due to the very small size of the sample, statistical analysis was not considered reasonable. Since all ninety-four sections are widely scattered around the state, the time involved in observing all sections made this impractical.

The purpose of taking the data was to determine if other variables might be important to the relationship between skid number and wet weather accidents. Factors such as ponding, wheel ruts, shoulders and degree of vertical and horizontal curvature were indicated as possibly having some effect.

A recent study by the Research and Training Center on road rutting was abandoned due to problems in data collection and the expense of the study.

Data on wheel ruts and ponding was not available and could not be obtained for the time period of the accidents. Other factors which showed a relationship in the physical observations were, therefore, sought. Information on vertical and horizontal alignment was available and was obtained for two-lane sections. Similar information on

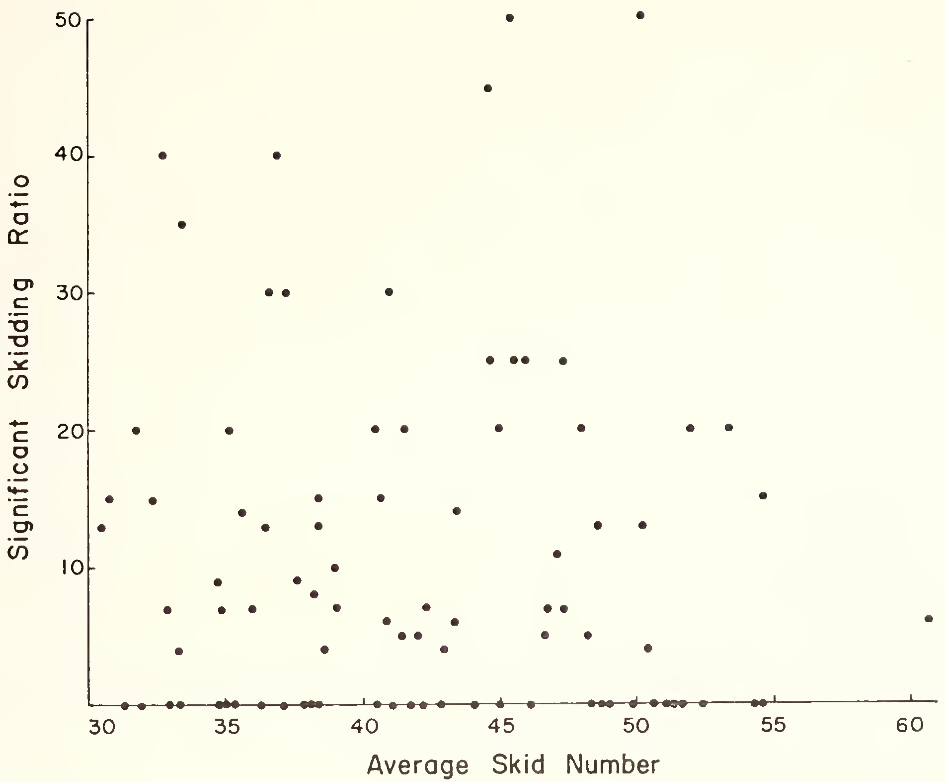

Figure 17. Significant Skidding Ratio (Probable Skidding) Versus Average Skid Number: Individual Values Plotted for all Test Sections

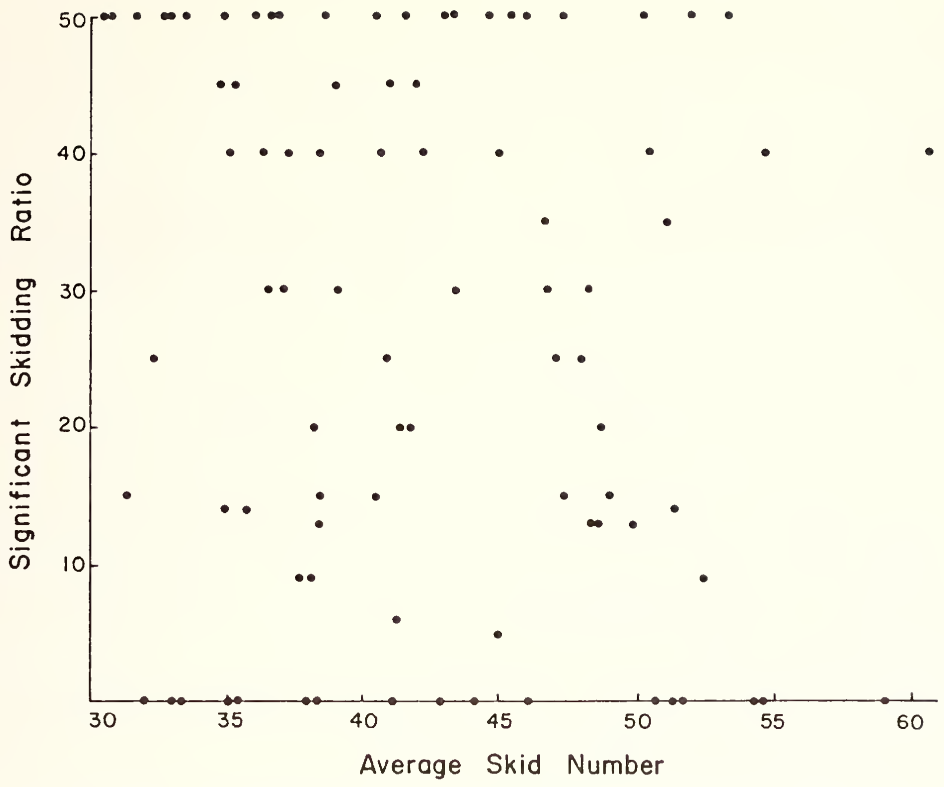

Figure 18. Significant Skidding Ratio (Possible Plus Probable Skidding) Versus Average Skid Number: Individual Values Plotted for all Test Sections

Table 10. Physical and Skid Characteristics of Five Sections

Section Number	Lane Width	Paved Shoulder	Curvature	Grade	Ponding	Wheel Ruts	Average Skid No.	Wet Accident Index	Skidding Ratio
7	10'	None	Mild	Mild	None	1/16"-1/8" at places	47.3	.61	.44
23	10'	None	Moderate Super-elevated	Mod.	None	1/2" most places	48.0	.55	.44
35	11'	None	Moderate Sharp at Points	Mod.	At bottom of hills	Minor	45.4	.94	.73
47	11'	None	None	None	Moderate at Shoulder	None	48.4	.33	.33
49	11'	3'	Mild	Minor	None	None	52.4	.27	0

four-lane and interstate roads was not collected as it is similar for all such highways in the state.

Analysis of Interstate Sections

The analysis included 22 sections of Interstate Highway in the state of Indiana. There were two sections on both I-74 and I-64, four on I-70, six on I-65 and eight on I-69. Each of the sections was chosen by random selection and each section was for travel in one direction only. These sections included 156.6 miles of interstate in one direction. Since 987 miles of interstate highway were open as of 1973, the sample represents 16 percent of the possible route miles and 8 percent of the roadway miles.

A total of 725 accidents were recorded for the sampled interstate sections. Three of the sections considered had zero wet pavement accidents and thus could not be used for some calculated values. The 22 sections had 91 (12.5 percent) accidents on wet pavement. This percentage is only slightly higher than the percent of volume (11.6 percent) traveling on wet pavements. Thus a major wet pavement skidding problem is not indicated on interstate routes.

This absence of difficulty with skidding accidents probably is at least partly a function of the excellent geometrics on these interstate highways. Geometric causes of skidding accidents, such as intersections, sharp grades and curves are all eliminated. Even if the vehicle should be out of control, the safer side slopes allow room for recovery prior to major damage. Indiana, being predominantly level, has very little significant curvatures and grades on interstate roads.

A major problem in analyzing possible factors affecting accidents by skidding on interstate roads was that the skid numbers for the interstate sections were very similar (see Figure 19). This made it difficult to conclusively determine

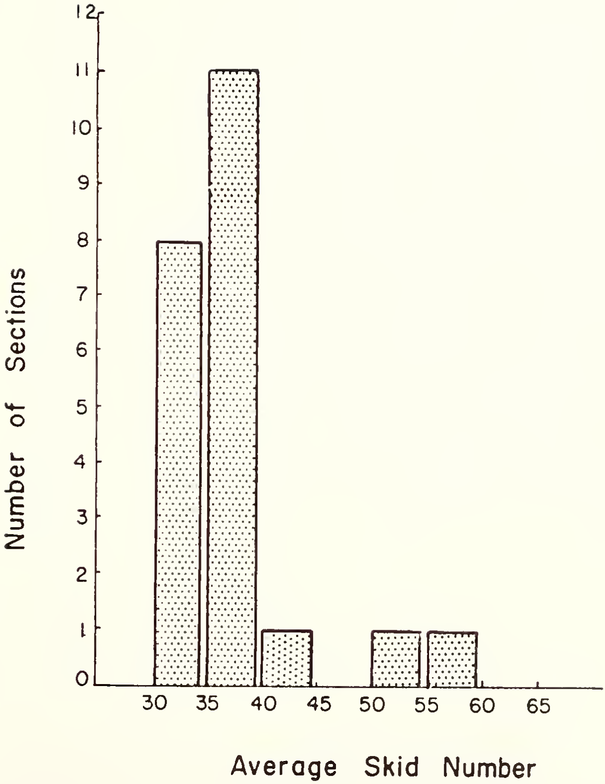

Figure 19. Number of Sections by Skid Number Group: For Interstate Sections

any trend in safety from the plot of skid number versus wet accident index (Figure 20).

There appears to be a trend for the maximum values to decrease with increasing skid number, but there is one unusual point. It has both a high skid number and a high wet accident index. The section is on I-64 which was still under construction near this section. As a consequence the traffic volume was very low and the few accidents resulted in a high index. The low traffic volume also resulted in maintenance of the higher initial skid number. Use of averaging methods on the wet accident index versus skid number resulted in no relationship.

The skidding ratio was also plotted for interstate sections (see Figure 21). The same small skid number range problem existed as with the wet accident index. Averaging methods clarified the downward trend seen in the skidding ratio with increasing skid numbers, but again the narrow range of skid number values makes it unreliable to use as a measure of that relationship.

The interstate sections were paved with Portland Cement Concrete, had a very small range of skid numbers, and had very few more wet pavement accidents than would have been expected on dry pavements. Relationships between the wet pavement accidents and skid number were not apparent.

Analysis of Other Four-Lane Sections

Twenty-two four-lane non interstate roads were considered in this study. On these a total of 991 accidents occurred, 22.3 percent of them on wet pavements. 130.2 miles of four-lane roads were used with each section representing one direction of travel.

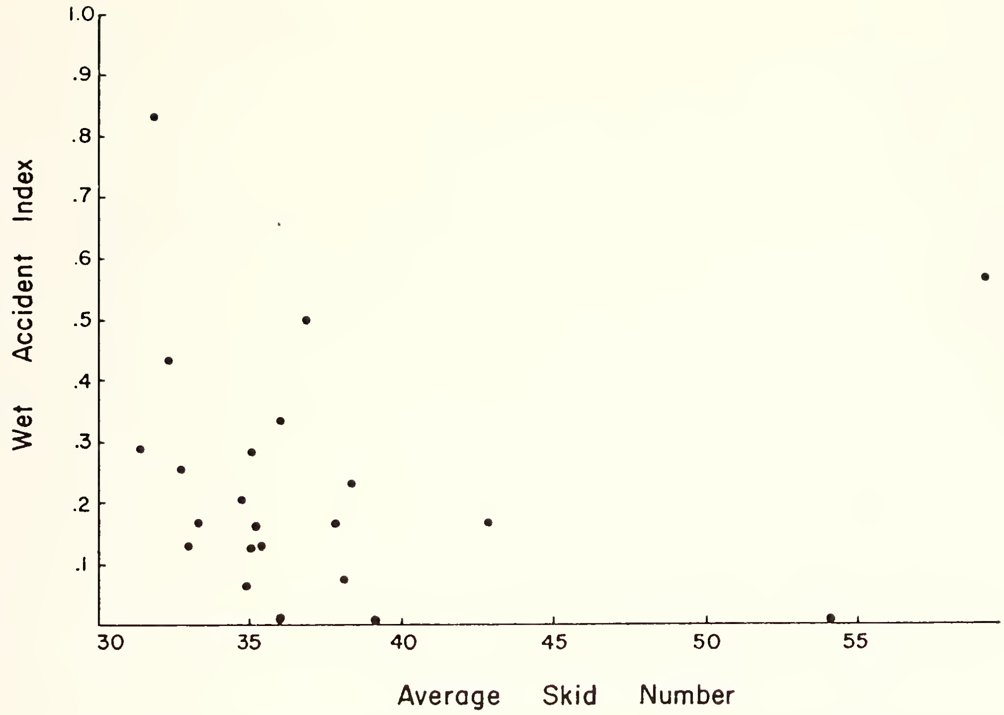

Figure 20. Wet Accident Index Versus Average Skid Number: Individual Measurements Plotted for Interstate Sections

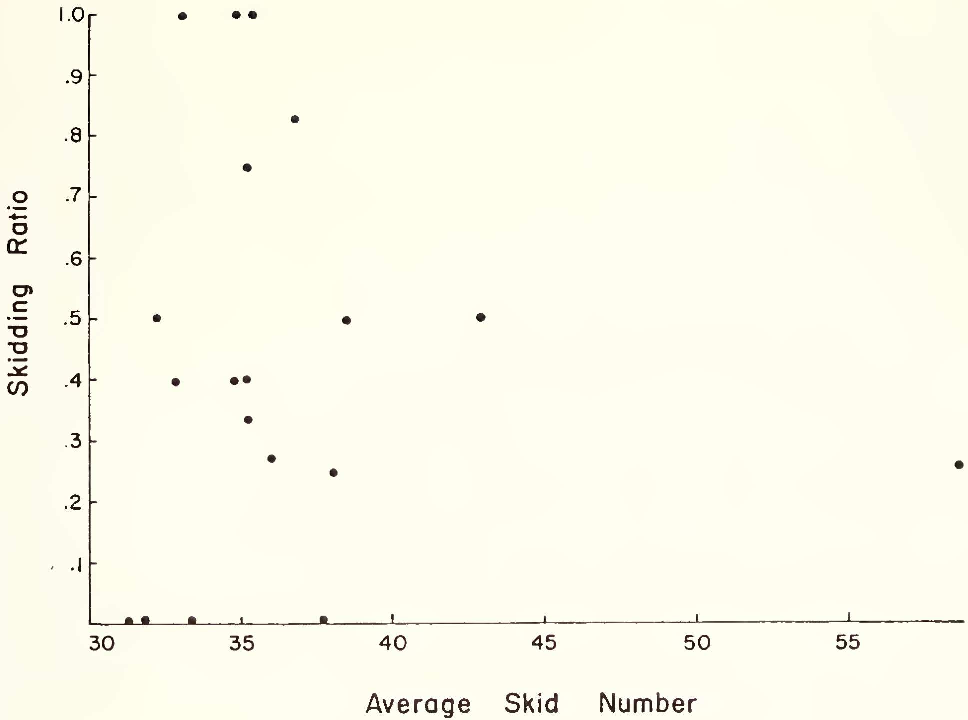

Figure 21. Skidding Ratio Versus Average Skid Number: Individual Measurements Plotted for Interstate Sections

Since the roads were wet for only 11.6 percent of the vehicle-miles travelled on them, the accidents occurring on wet pavements indicate that about twice as many accidents occurred on wet pavements as would have been expected on dry pavements. This increase in the percentage of wet accidents over those found on interstate sections is probably due to the existance of at grade intersections, other access points on these facilities, and less roadside area for recovery. The need for greater wet skid resistance is obvious.

The graph of the wet accident index versus the average skid number was plotted for non-interstate four-lane roads. Neither this graph (see Figure 22) nor the use of averaging methods provided noticeable trends. However the use of skidding ratios showed a relationship to the skid number when a five point moving average was used (Figure 23). Similar results were found when the interstates were added to the analysis as shown in Figure 24.

Although Figure 24 shows a downward trend of skidding ratio values for increasing skid number, the trend is not as clear as that on Figure 23, Other Four-Lane roads only.

Regression analysis was used to determine if a critical skid number value existed in the data of Figure 23. The regression fitted two straight lines. The first with negative slope for the points in the lower skid number range and the second a horizontal line for the higher value range. Trials were made to find the best skid number value at which to separate the higher and lower skid number ranges. The criteria used to find the best value was where the lower skid number range line had its best R-squared and F significance and where the higher range line was nearly horizontal (i.e. the b_1 parameter or slope was not significantly different than zero). The horizontal portion would indicate no correlation between the

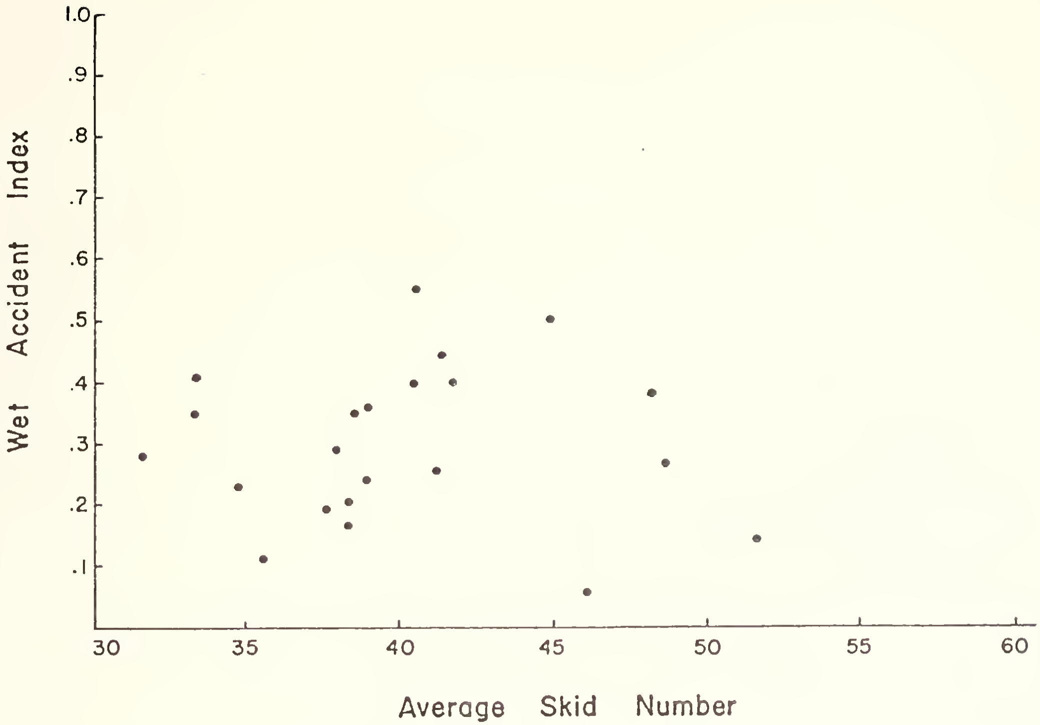

Figure 22. Wet Accident Index Versus Average Skid Number: Individual Measurements Plotted for Four Lane Non-Interstate Sections

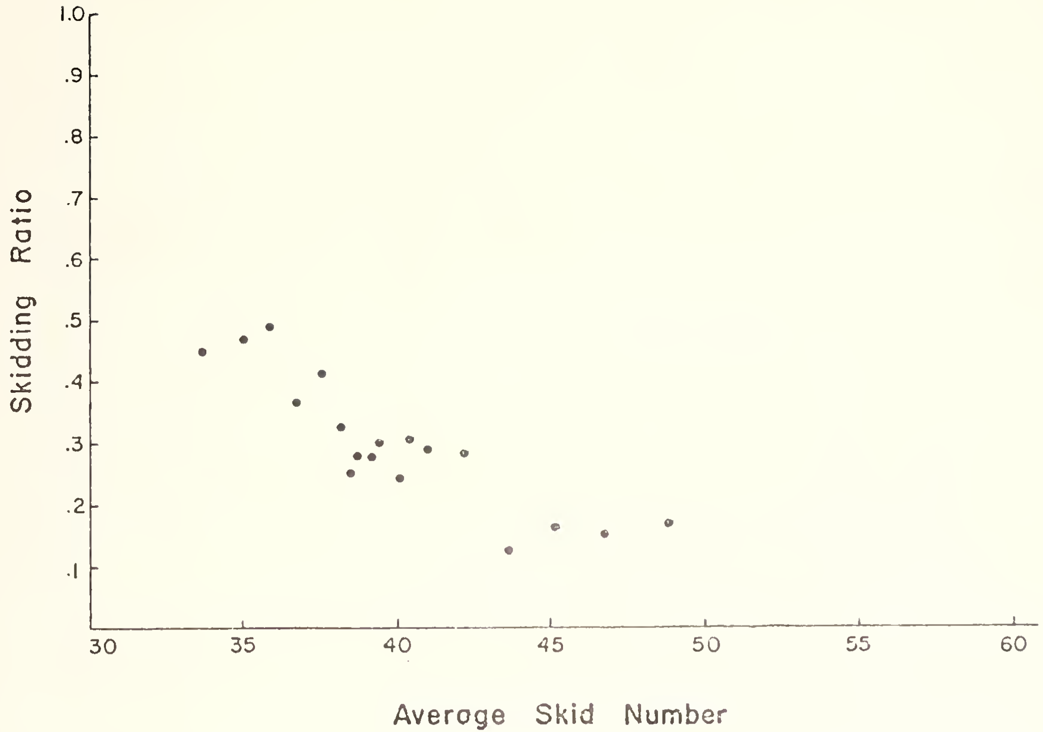

Figure 23. Skidding Ratio Versus Average Skid Number: Five Point Moving Average for Four Lane Non-Interstate Sections

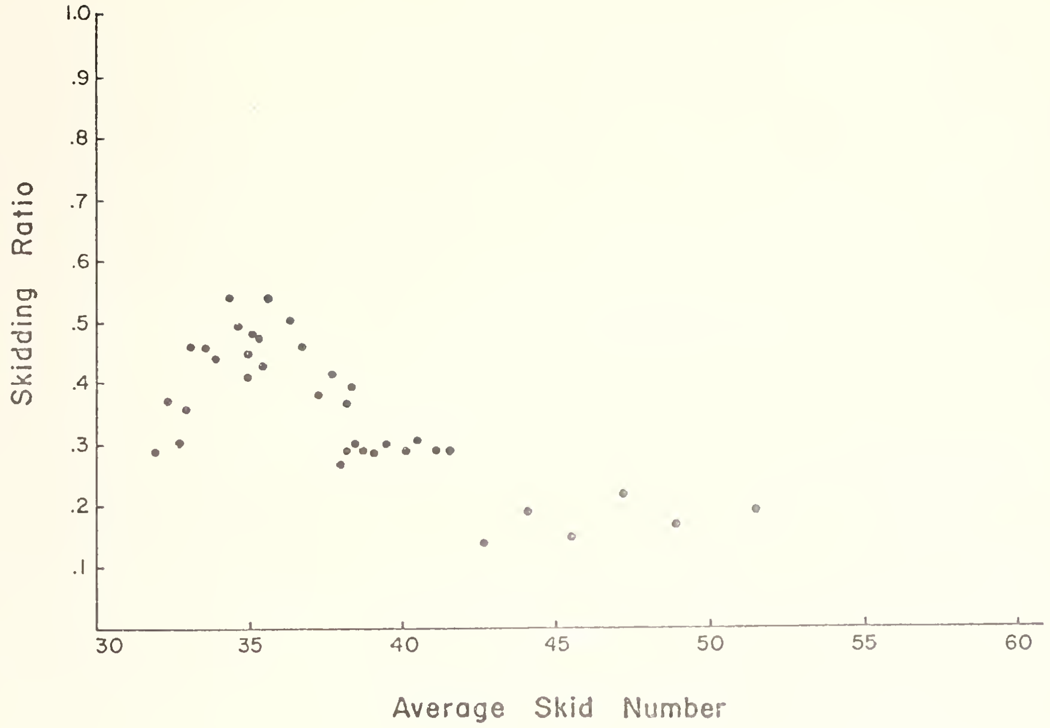

Figure 24. Skidding Ratio Versus Average Skid Number: Five Point Moving Average for all Four-Lane Sections

variables. In other words, on the horizontal line increases in skid number have no effect on the wet accident index.

Table 11 shows a summary of the chosen regression results. Figure 25 shows these fitted regression lines. The two lines intersect at a skid number value just higher than 44. Thus based on a five point moving average of the skidding ratio on average skid number, the critical minimum value for four-lane non-interstate roads is 44 (measured during the summer months at 40 mph).

The hypothesis was tested that an increase of wet accidents on four-lane non-interstate sections is caused by increased access points (as compared with interstate highways). The number of intersections was first used but showed no relationship, this was probably because the count of intersections did not include the many access points to private development.

A measure of the number of access points was the urbanization factor. The results of this analysis are shown in Figure 26. As can be seen the wet accident index values are higher for the more urbanized sections, those having more access points. Hence, Interstate highways, with few access points, would be expected to have the low wet accident index values found.

Analysis of Two-Lane Sections

Two-lane roadways in this study consisted of fifty sections comprising 323.8 miles of road and having 2700 accidents. Of these accidents, 606 (22.4 percent) were on wet pavements. This value is similar to the results as found in the four-lane non-interstate routes and again shows about twice the number of wet accidents as expected under dry pavement conditions.

Two-lane roads in Indiana showed no strong trends where the wet accident index or the skidding ratio was

Table 11. Regression of the Skidding Ratio on Average Skid Number for Four-Lane Non-Interstate Sections: Summary of Two Fitted Lines Shown in Figure 25

Line	No. of Cases	F Ratio	Significance of F	R^2	Equation of the Line
Lower Skid Number Range	15	44.45	.000	.77	Y=1.520-.0308X
Upper Skid Number Range (Horizontal)	3	.406	.639	.48	Y=.2279+.0029X

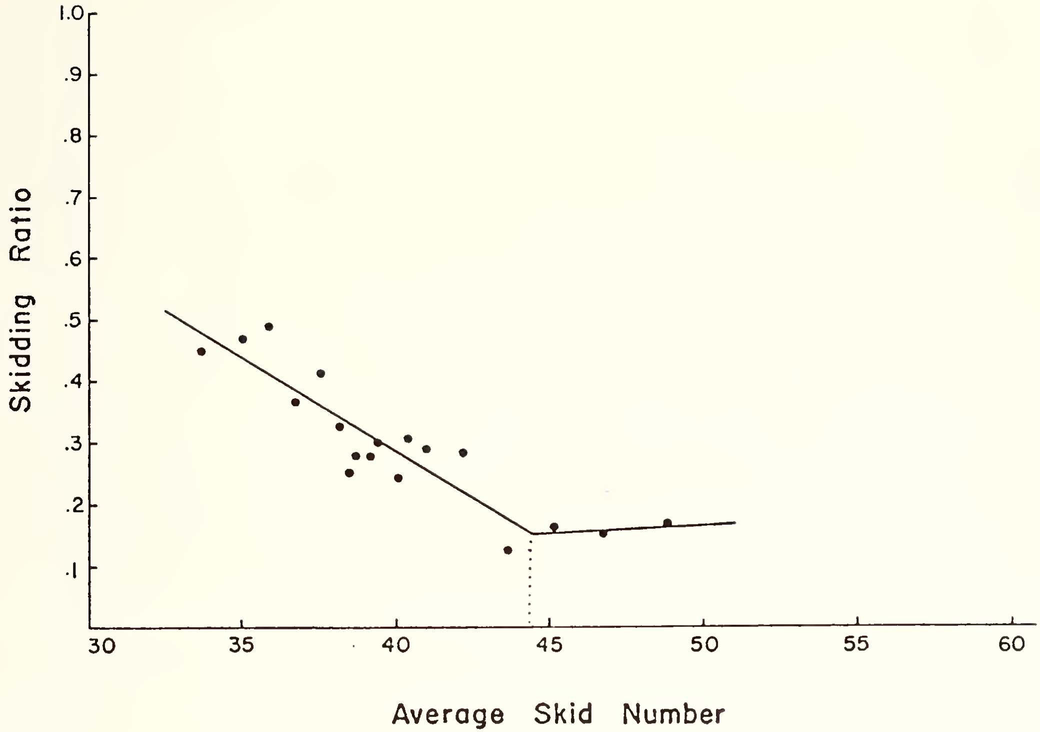

Figure 25. Skidding Ratio Versus Average Skid Number: Five Point Moving Average for Four Lane Non-Interstate Sections Showing Regression Lines

Code

1 - Not adjacent to a municipality of population greater than 3,500.

2 - One terminus adjacent to a municipality of population greater than 3,500.

3 - Section adjacent to a municipality of population greater than 3,500.

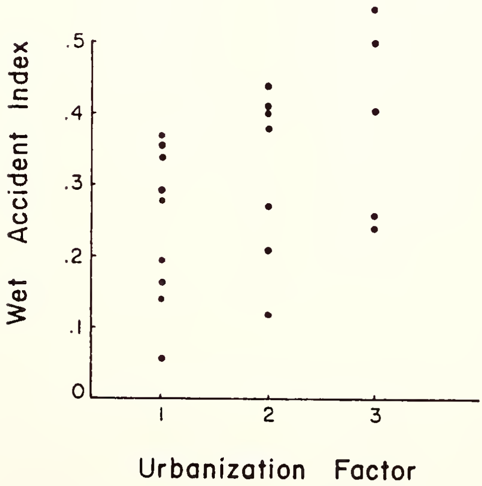

Figure 26. Wet Accident Index by Urbanization Factor: Four Lane Non-Interstate Sections

plotted versus the skid number (Figures 27 and 28). This was also true when averaging methods were used.

Because of this lack of trend for two-lane sections and very variable conditions of geometrics and volumes on such roads, it was decided to perform further analyses using groupings of two lane roads by geometric characteristics and/or volume ranges. The volume groupings selected were: less than 3000 vpd, 3000-5000 vpd and greater than 5000 vpd. The geometrics grouping is given in Figure 10 in an earlier chapter.

In order to test the effect of these two factors on the wet accident index, an analysis of variance was performed. The results are shown in Table 12. The only possible relationship indicated is geometrics with the wet accident index. This evidence, however, is not strong. The relationship of the two variables with the average skid number was also tested by the analysis of variance. The results are shown in Table 13. This ANOVA indicates a relationship between both factors and the skid number. Individually, volume shows strong significance, while geometrics has little.

Thus the relationship between the average skid number and the wet accident index could be affected by either the volume or the geometrics or both. In order to test the effect of the combination of the two factors, Table 14 was compiled. Within each cell it gives the number of points and the correlation coefficient between the skid number and the wet accident index for that cell.

The expected, or "successful" correlation coefficient is negative in value, because theoretically the wet accident index should decrease as the skid number increases. Table 14 shows that a high negative coefficient was found for five of the nine cells; three had low values (both positive and negative) less than or equal to 0.5 and one cell had an insufficient sample size.

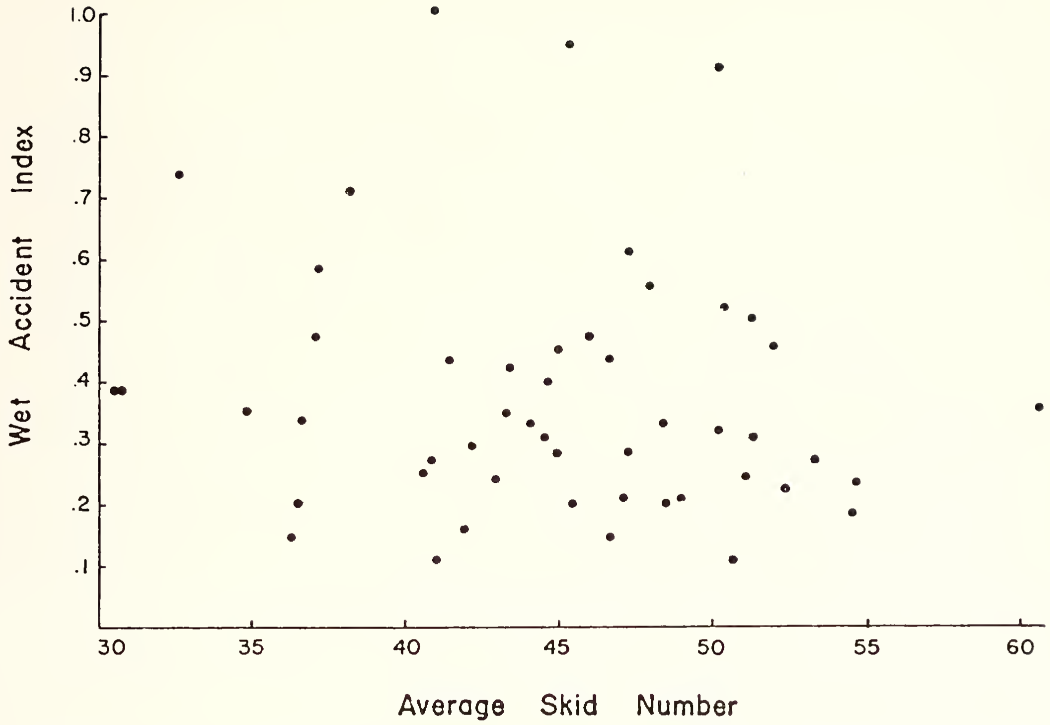

Figure 27. Wet Accident Index Versus Average Skid Number: Individual Measurements Plotted for Two-Lane Sections

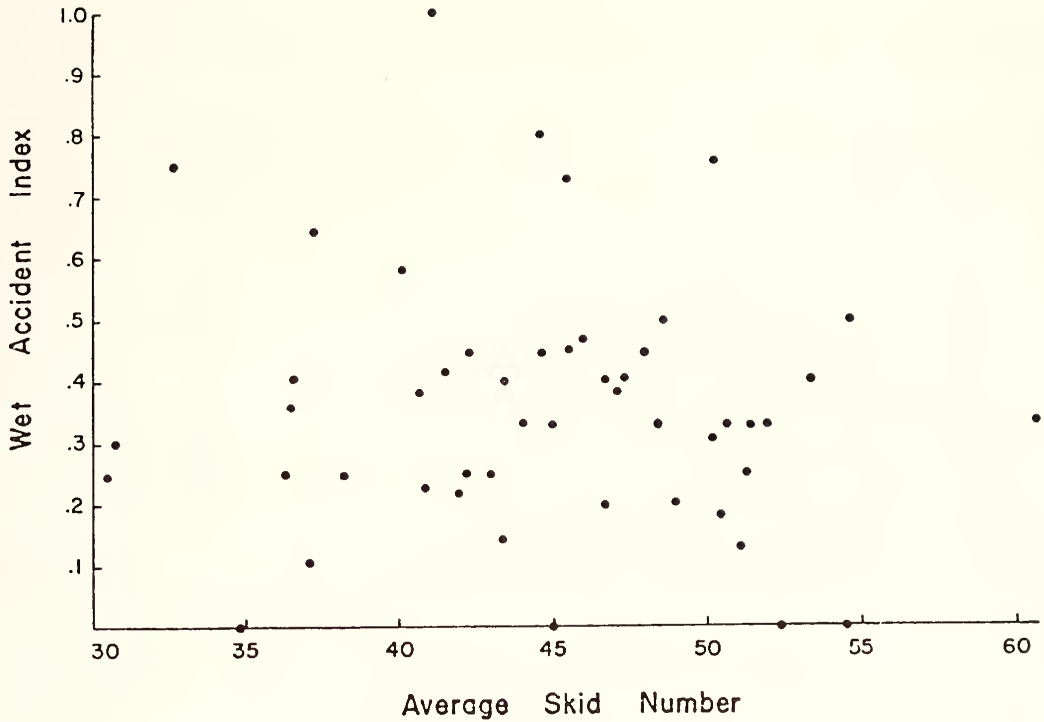

Figure 28. Skidding Ratio Versus Average Skid Number: Individual Measurements Plotted for Two-Lane Sections

Table 12. Analysis of Variance of the Wet Accident Index with Volume and Geometrics

ANOVA	Degrees of Freedom	Sum of Squares	Mean Square	F Ratio	Significance of F
Volume	2	.061	.030	.709	.999
Geometrics	2	.200	.100	2.339	.107
Two-Way	4	.065	.016	.383	.999
Residual	41	1.754	.043		
Total	49	2.060	.042		

R^2 = .117, Mult. R = .342

Table 13. Analysis of Variance of the Average Skid Number with Volume and Geometrics

ANOVA	Degrees of Freedom	Sum of Squares	Mean Square	F Ratio	Significance of F
Volume	2	431.047	215.525	6.044	.005
Geometrics	2	25.479	12.739	.357	.999
Two-Way	4	177.165	44.291	1.242	.308
Residual	41	1461.988	35.658		
Total	49	2073.242	42.311		

R^2 = .209, Mult. R = .458

Table 14. Correlation Between Wet Accident Index and Skid Number for Cells Grouped by Geometrics and Volume: For Two-Lane Sections

Volume	Geometrics: 1 - Straight Level	2 - Moderate	3 - Hilly Curvy	All
< 3000	(-.97,.95) 4 / -.12	2 / *	(-.98,.39) 5 / -.75	(-.64,.55) 11 / -.07
3000-5000	(-.85,-.01) 13 / -.56	(-.98,-.27) 7 / -.85	(-.98,.33) 5 / -.78	(-.80,-.23) 24 / -.58
> 5000	(-.97,.14) 6 / -.76	(-.62,.91) 6 / .39	3 / .50	(-.25,.71) 15 / .30
All	(-.54,.26) 23 / -.17	(-.54,.49) 15 / -.03	(-.81,.17) 12 / -.45	(-.40,.14) 50 / -.14

# of Observations / Correlation Coefficients

*The correlation coefficient for 2 or less points is not usable information.

Parentheses ( ) include the 95% confidence interval of the correlation coefficient where calculable.

Graphs of the points for each cell are shown in Figure 29. Comparing the graphs, the skid numbers tends to be lower in the sections with volumes above 5000. This is as expected from earlier analysis of variance which showed the significance of volume with skid number.

Further observation of Table 14 shows that of the three cells without reasonably large negative correlation coefficients, two have less than five points. If five points were considered a minimum to depict a trend, four of the cells are eliminated. This leaves five cells of which only one does not act as expected. This cell, representing moderate geometrics and high volumes, has one point far separated from the rest. Separate analysis of this point and its characteristics did not produce an explanation for its apparent non-conformity.

Much additional analysis was performed on the two-lane sections, both because they reflect the effect of many other factors and because the majority of road mileage in Indiana is on two-lane routes.

The results for two lane roads were expected to be similar to the results found by Kentucky D.O.T. as shown in Figures 2-8. According to the Kentucky report the percent of time with wet roads is similar (11 percent), and being adjacent to Indiana other characteristics do not differ tremendously.

A confidence elipse analysis was performed on the Kentucky and Indiana wet accident and skid number means to see if the Kentucky data fell into the confidence elipse of the Indiana data. As shown in Appendix E the Kentucky data does not fall within the 95 percent confidence interval of the Indiana data.

Much of the difference in results can be explained by the lack of skid numbers below 30 for Indiana. The upper ends of the curves Kentucky used to determine critical

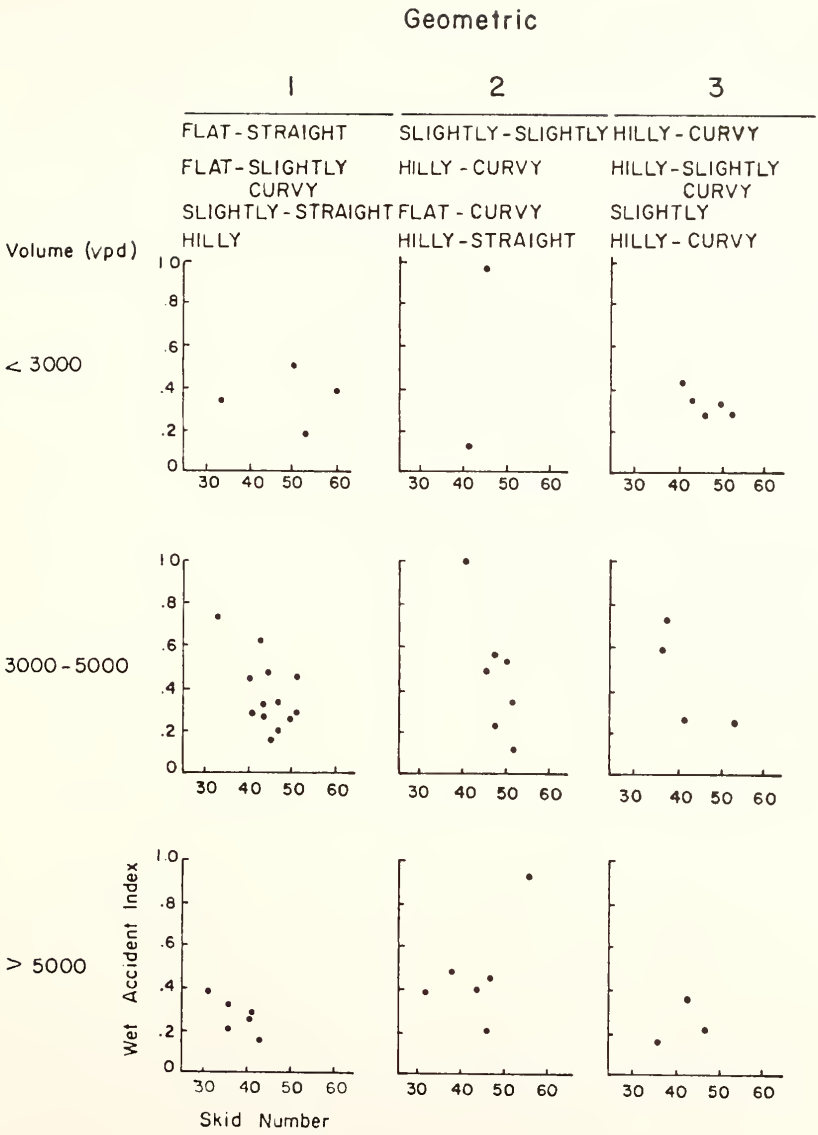

Figure 29. Wet Accident Index Versus Average Skid Number: Nine Cells Formed by Geometrics and Volume Stratification for Two-Lane Sections

point skid number values were below 30. Thus for two lane roads, assuming that all but the pavements are similar between the two states, the Indiana data available for this study did not have a sufficient range of data to properly define a critical point.

When this limitation in range was noted, the idea of forcing some low values was considered. The skid number inventory was searched but only one such section met the qualifications necessary to be used in this study. In most cases very low skid values found in Indiana during 1970 to 1973 skid testing resulted in repaving contracts prior to the end of 1975.

Whether a critical minimum skid number value can be set for all two-lane roads in Indiana is questionable. The indexes showed no trends when applied to all two lane roads, but when divided into groups by volume and geometric standards, trends do appear. Intuitively the friction requirements for roads with lower geometric standards should be higher. A car requires more traction on a curve than a straightaway. The effect of volume on skid resistance requirements is not as clear, but due to the increased number of conflicts which result from higher volumes, greater friction needs would be expected.

In this study it was found that there is a definite relationship between the volume group and average skid number. There is a tendency for higher volume roads to have lower skid numbers. This can be explained by the polishing effect of traffic.

Table 15 shows this decrease in skid number for increased volume. It also indicates a higher wet accident index for the middle group of both variables. Figure 29 shows that the wet accident index of the five cells belonging to one of the middle groups has higher values than the index values for the other four cells. There are

Table 15. Mean Determinate Values for Two-Lane Roads

Group	Mean Wet Accident Index	Mean Average Skid Number	Number of Cases
All	.344	44.85	50
<u>Volume</u>			
< 3000	.352	47.86	11
3000-5000	.378	46.12	24
> 5000	.321	40.60	15
<u>Geometrics</u>			
1 - Straight Level	.316	44.62	23
2 - Moderate	.407	45.20	15
3 - Hilly Curvy	.314	44.83	12

a number of possible explanations of this phenomena. The middle group on the geometrics may have more wet weather accidents than the other two groups because it has enough horizontal and vertical curvature to create skidding accidents. The "good" geometrics group has no major demands for high skid resistance due to geometry and the sections with sharp curvature and hilly conditions are such that the driver realizes the danger and proceeds at a safe speed for conditions. Thus where the vehicle needs a moderately high level of skid resistance, but this need is not obvious to the driver, the probability of a wet weather accident increases.

The effect of the volume involves both vehicle speed and possible conflicts. The low volume group (<3000 vpd) has a lower proportion of wet accidents due to the lesser conflicts. This is due to the fact that the probability of being in conflict with another vehicle reduces rapidly as the amount of traffic decreases. It also is due to the probability that the roads with lower volumes are in less developed areas, thus there would be fewer access points.

At the higher volumes (>5000), many hours have sufficient density to reduce traffic speeds, thus reducing the possibility of skidding accidents. The attention level of drivers also tends to be more on their driving task when traffic is heavier.

For the moderate volume group (3000 to 5000), there are numerous conflicts which cause accidents, but the decreased speeds and higher attention levels present in high volumes have not yet occurred. One should note that the wet accident index is higher for the low volume group than for the high volume group. This may be caused by the fact that lower speeds and greater attention on high volume sections reduce both conflict and single vehicle type accidents while on low volume roads only conflict type accidents are affected.

CHAPTER V: CONCLUSIONS AND RECOMMENDATIONS

Conclusions

There are many variables affecting accidents on a section of road during wet conditions. The pavement slipperiness when wet is measured as a skid number. This value, found by skid testing, represents the friction between a special standardized tire and the wet surface.

The thrust of this research was on the effect of the skid number on wet pavement accidents. The research did not accomplish its goal of finding desirable minimum skid number values for all classes of highways in Indiana. The research does, however, give some insight on how the skid number as measured at 40 mph can be related to wet pavement accidents.

The research found that skid number alone may not be a suitable indicator of wet pavement safety. The effect of the randomness of accident incidence is one factor which obscures a clear relationship between variables, but the general lack of improvement with averaging methods tends to indicate other factors are involved.

As shown with the two-lane sections, skid number along with geometrics and volume provide a better explanation of the variations in wet pavement accident occurrence. It also can be inferred from the results that a section of road may not be the proper roadway portion on which a minimum standard should be set. Individual intersections or different curves may warrant differing minimum skid number values. Thus either the entire section should be maintained at the highest minimum requirement, or specific locations within a section should be maintained at their required skid number values.

Interstates

The frictional needs of interstate highways is less than other highways as there is very little increase in accidents when the surface is wet. The geometrics and access control characteristics of the Interstate demand less in skid resistance than other roads, especially with recent average highway speeds around 62 mph.

For Indiana interstates as represented in this study, the skid number characteristics were very similar. All of the qualifying sections were Portland Cement Concrete and all but three had skid number values between 30-40. This prevented determination of a meaningful relationship between skid number and wet pavement accidents.

Four-Lane Roads

Four-lane non-interstate sections have geometrics approaching those of interstate routes. Thus other than the danger of less safe side slopes, the hazards away from intersections or access points are similar. The main difference is the existence of numerous at-grade access points. As the number of access or conflict points increases, the wet accident index tends to increase. Thus there should be a need for higher pavement friction near conflict points.

Similar to the two-lane sections but unlike the interstates, many different types of pavements are found, though the different types of pavement had similar wet pavement accident experience. The range of skid number values for four-lane roads is small but larger than interstates. The sections are reasonably well distributed between skid number values of thirty and fifty and thus allowed some observation of the effect of skid number. More results were found by use of the skidding ratio than the wet accident index.

A five point moving average of the skidding ratio versus average skid number resulted in a reasonable relationship. The points in the relationship were then fitted by regression into two straight lines, one of which was horizontal. A minimum critical skid number value was obtained from the intersection of these lines. The critical value of 44 (measured during summer months, at 40 mph) indicates the skid number value below which the proportion of wet pavement accidents which probably have skidding as a cause increases.

Two-Lane Roads

The two lane sections both received the most study and had the most to study. Many factors affect wet accident incidence on wet pavements and as many as possible were considered in the research. Two lane roads vary rather dramatically throughout the state and exhibit a wide variety of characteristics. The skid numbers vary more than on four-lane sections, but still had none below the value of thirty. The lower design standards of two-lane roads should lead to higher friction requirements because of many conflict points and sharp curves.

Traffic volume and geometry proved to be important variables required to define needed skid resistance.

The research found that moderate volume (3000-5000 vpd) sections had higher wet accident index values than lower or higher volume sections. This is perhaps caused by reduced conflicts on low volume roads and lower operating speeds on high volume roads.

The geometry of the sections also played an important role. Sections with good geometrics (very few curves or hills) had low wet accident indexes, due to their minimal need for skid resistance. Sections with bad geometrics (curves and hilly) also had low wet accident indexes. This is probably a result of drivers realizing the obvious danger of skidding, thus travelling at reduced speeds. The wet accident indexes were highest on sections with moderate geometrics. The high values perhaps result from the infrequency of the hills and curves which demand higher skid resistance. Thus the driver may develop a false sense of security and travel at higher than safe speeds.

After division of the sections into cells by traffic volume and geometry, relationships between the wet accident index and average skid number were apparent within cells. Unfortunately not enough data points occurred per cell to provide reliable minimum critical values.

Recommendations

No single minimum skid number value was found by this research which is applicable to all road types but some of the findings and methods should be useful. It is recommended that:

1. The wet accident index be used in measuring the effect of wet surfaces on accidents. This index is advantageous due to its ease of collection.
2. The skidding ratio be used in evaluation of the effect skidding has on wet surface accidents. The data to obtain this ratio as of current accident reporting must be obtained by careful analysis of all wet pavement accident reports. This is time consuming and expensive but could be minimized if investigating police were trained to record accurately the significance of skidding relative to the accident.

3. Separate studies be made of different classes of road and evaluation include the effect of geometrics and volume. Also desirable would be determination of the skid resistance requirements for intersections and curves.
4. Friction requirement be studied for different types of vehicles, especially trucks.
5. The development and implementation of the comprehensive accident location system in Indiana should be completed as soon as possible. Incorporation of the indicators used in this research could then be used to find problem road sections. The direction of travel for involved accident vehicles should be coded.
6. Increased attention be given to those sections found to be more hazardous because of low skid numbers. Two-lane roads with moderate geometrics and volumes and four-lane roads with many at-grade access points should be watched more carefully than others and pavement rehabilitation done before skid resistance falls to seriously low values.

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APPENDICES

APPENDIX A

DETERMINATION OF PERCENT OF TRAVEL ON WET PAVEMENTS

DETERMINATION OF PERCENT OF TRAVEL ON WET PAVEMENTS

Determination of Percentage of Time Pavement is Wet(1)

To obtain an estimate of the percentage of time that the pavement surface could be expected to be wet, US Weather Bureau records listing hourly amounts of precipitation were reviewed (2).

A procedure used by the Texas Highway Department for an unpublished study was used to determine the expected total hours of wet pavement (3). The following describes the criteria used for determining the hours of wet pavement: (The hourly listing of rainfall includes traces and all measurable amounts of 0.01 inches and greater).

1. On a given day, if a string of consecutive hours of trace rainfall occurs with no measurable rainfall (0.01 or greater) within the string, the first and last hours were not counted.
2. If within a string of consecutive hours of rainfall traces there occurs an hour of measurable rainfall (0.01 or greater), then the last hour of trace rainfall was counted. The first hour again was not counted.
3. If the first hour of a string of traces was a measurable rain (0.01 or greater), the first hour and every other hour of rain in that string, traces included, were counted.
4. If the last hour of a string of measurements was a rainfall of 0.01 inch or greater, that hour was counted plus one additional hour to allow for drying time.

Table 1A illustrates these criteria.

Table 1A. Example of the Determination of Hours a Pavement is Wet.

Day	1	2	3	4	5	6	Wet Pavement Hours
1	T	T	T	T	T		3
2	T	0.01	T	T	T	T	5
3	T	0.01	T	T	0.01	T	5
4	0.01	T	T	T			4
5	T	T	T	0.01			4
6	0.01	T		T	0.01	T	4
7	T	T		T	T	T	1
8	T	0.01		T	T	0.01	5
9	0.01	T	T	T	T	0.01	7

Calculation of Percent of Traffic Volume on Wet Surfaces

Table 2A shows the cumulative rainfall for Fort Wayne and Indianapolis as calculated using the Texas Highway Department method. Shown also is the percent of total wet hours found by month and hour of day. Hourly and monthly traffic volume variations for Indiana were taken from the Highway Engineering Handbook (4).

Table 3A shows the calculation of the correction factor due to variations in rainfall and traffic volume by hour of day. In Table 3A the hourly percent of average daily traffic was converted to the percent of average.hourly traffic by multiplying by twenty-four. The percent wet of the average hour was multiplied by the corresponding percent of time wet in Table 2A. The products were summed and divided by 10,000 (both multipliers are in percent) to yield the hourly correction factor. Table 4A shows a similar process using months of the year rather than hour of day.

To find the percent of traffic volume travelling on wet surfaces for Indiana, the correction factors were multiplied by the proportion of time wet as follows:

$$\frac{\text{Number Hours Wet}}{\text{Total Number of Hours}} = \frac{2058}{(365 \text{ days})(24 \text{ hours/day})(2 \text{ locations})}$$

$$= .11746$$

$$.11746 \times .97308 \times 1.0157 = .11609$$

Thus the percent of traffic volume on wet pavements is 11.609.

Table 2A. Cumulative Number of Hours of Wet Pavement for Fort Wayne and Indianapolis by Month and Hour of Day During 1974.

Hour of Day	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total	Percentage of Total Wet Hours
0-1	8	5	10	9	8	8	1	7	6	3	5	6	76	3.69
1-2	7	6	8	10	8	7	1	7	7	2	6	6	75	3.64
2-3	7	6	7	10	8	8	1	8	8	0	10	6	79	3.84
3-4	6	6	9	8	10	5	2	6	8	2	12	6	80	3.89
4-5	7	7	9	8	7	5	1	6	9	3	14	6	82	3.98
5-6	10	8	6	8	8	3	1	5	9	3	12	7	80	3.89
6-7	10	8	8	7	7	3	1	6	10	3	12	8	83	4.03
7-8	6	8	9	7	8	3	1	5	6	5	10	8	76	3.69
8-9	7	8	8	10	10	7	1	5	5	7	11	10	89	4.32
9-10	8	0	0	12	8	6	1	5	3	6	11	10	88	4.27
10-11	8	9	5	13	6	4	1	6	1	5	14	10	82	3.98
11-12	10	9	9	12	6	4	5	6	2	4	11	9	87	4.23
12-1	11	8	9	11	9	4	3	7	2	4	10	9	87	4.23
1-2	11	7	12	9	11	6	1	6	2	3	12	9	89	4.32
2-3	10	7	9	9	8	4	0	5	2	2	11	7	74	3.59
3-4	10	6	7	8	9	8	1	3	4	3	11	8	78	3.79
4-5	9	6	7	9	10	7	1	3	6	5	13	7	83	4.03
5-6	9	6	9	10	14	7	1	7	7	5	13	8	96	4.66
6-7	8	5	10	9	15	9	2	7	8	5	11	8	97	4.71

Table 2A continued

Hour of Day	Month												Total	Percentage of Total Wet Hours
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec		
7-8	9	6	10	12	13	8	2	7	8	7	11	8	101	4.91
8-9	8	5	10	11	13	8	1	8	10	6	10	7	97	4.71
9-10	10	3	10	11	13	10	3	8	9	5	10	7	99	4.81
10-11	9	4	11	9	9	10	3	6	10	6	7	7	91	4.42
11-12	9	5	12	9	6	11	3	6	8	5	7	8	89	4.32
Total	207	157	213	231	224	155	38	145	150	99	254	185	2058	
Percentage of Total Wet Hours	10.1	7.63	10.3	11.2	10.9	7.53	1.85	7.04	7.29	4.81	12.3	8.99		

Table 3A. Calculation of the Correction Factor for Hour of Day.

Hour of Day	Percent of AADT	x	24	=	Percent of Average Hourly Traffic	x	Percent of Total Wet	=	Product
0-1	2.0				48.0		3.69		177.12
1-2	1.3				31.2		3.64		113.57
2-3	1.0				24.0		3.84		92.16
3-4	.8				19.2		3.89		74.69
4-5	.8				19.2		3.98		76.42
5-6	1.4				33.6		3.89		130.70
6-7	4.8				115.2		4.03		464.26
7-8	4.6				110.4		3.69		407.38
8-9	4.7				112.8		4.32		487.30
9-10	5.1				122.4		4.27		522.65
10-11	5.1				122.4		3.98		487.15
11-12	5.1				122.4		4.23		517.75
12-1	5.0				120.0		4.23		507.6
1-2	5.4				129.6		4.32		559.87
2-3	5.6				134.4		3.59		482.50
3-4	6.4				153.6		3.79		582.14
4-5	7.8				187.2		4.03		754.42
5-6	7.2				172.18		4.66		805.25
6-7	5.7				136.8		4.71		644.33

Table 3A continued

Hour of Day	Percent of AADT	x	24	=	Percent of Average Hourly Traffic	x	Percent of Total Wet	Product
7-8	5.5				137.0		4.91	648.12
8-9	4.4				105.6		4.71	497.38
9-10	4.1				98.4		4.81	473.30
10-11	3.5				84.0		4.42	371.28
11-12	2.7				64.8		4.32	279.94
							Total	10157.28

10157.28 ÷ 10,000 = 1.0157 (hourly correction factor)

Table 4A. Calculation of the Correction Factor for Month of Year.

Month	Percent of Average Monthly Volume	x	Percent of Total Time Wet	=	Product
January	74.1		10.1		745.45
February	81.7		7.63		623.37
March	84.3		10.3		872.50
April	94.2		11.2		1056.92
May	105.8		10.9		1151.10
June	111.8		7.53		841.85
July	119.9		1.85		221.81
August	124.8		7.04		878.59
September	118.6		7.29		864.59
October	108.1		4.81		519.96
November	96.4		12.3		1189.58
December	85.1		8.99		765.05
				Total	9730.77

9730.77 ÷ 10,000 = .97308 (monthly correction factor)

NOTES

1. The method described in this appendix is an excerpted quote from Elmore H. Dean, "Relationship of the Tire-Pavement Interface to Traffic Accidents Occurring under Wet Conditions", Report No. 133-1, Departmental Research, Texas Highway Dept., Austin, Texas, 1969, pp. 32-33.

2. Environmental Data Service, "Load Climatological Data--Indianapolis Indiana, Weir Cook Municipal Airport" and "Local Climatological Data--Fort Wayne, Indiana, Baer Field", January-December, 1974.

3. Texas Highway Department, "Computer Program for Analysis of Wet Pavement Curve Accidents", Unpublished Report, 1967.

4. Harold L. Michael, "Highway Planning" in Highway Engineering Handbook, ed. by Kenneth B. Woods (New York, McGraw-Hill, 1960), pp. 2-15,16.

APPENDIX B

ACCIDENT REPORT FORMS AND THE ACCIDENT CODING FORM

Mail Report To: INDIANA STATE POLICE, INDIANAPOLIS, INDIANA 46204

(8) TYPE ______ (9) SOURCE ______ (10-11) ANALYSIS ______ (12-13-14-15) LOSS ______ (16) LOCATION ______ (2-3-4-5-6-7) ACCIDENT NO ______

TIME

(17-18) (19-20) (21) (22) (23-24)

DATE OF ACCIDENT ______ Month Day Year DAY OF WEEK ______ TIME OF DAY ______ AM ______ PM

LOCATION

(25-26) (27) (28-29)

PLACE WHERE ACCIDENT OCCURRED — If accident occurred outside of city limits, indicate distance from nearest city or town limits, using two directions, if necessary

COUNTY ______ CITY OR TOWN ______

TOWNSHIP ______ (30-31)

______ Occurred within corporate limits

______ Occurred outside corporate limits

______ MILES NORTH ______ MILES SOUTH ______ MILES EAST ______ MILES WEST OF

LIMITS OF ______ City or Town

NORTH COORDINATE EAST COORDINATE SUBSECTION CLASS SUBSECTION (35-36)

ROAD ON WHICH ACCIDENT OCCURRED ______ (32-33-34) Name of Street or No. of Highway (US or STATE) If no No., use name

AT ITS INTERSECTION WITH ______ (37-38-39-40) Name or Number of Intersecting Street or Highway

IF NOT AT INTERSECTION ______ FEET (___N ___S ___E ___W) OF ______ Show nearest intersection, house number or other identifying landmark

DO NOT MARK IN BOXES

VEHICLES

Total Number of Vehicles Involved

VEHICLE NUMBER 1: (41) (42-43)	VEHICLE NUMBER 2: (41) (42-43)
YEAR ______ MAKE ______ TYPE ______ Sedan, Truck, Bus, etc. (44)	YEAR ______ MAKE ______ TYPE ______ Sedan, Truck, Bus, etc. (44)
LICENSE PLATE ______ Number State Year	LICENSE PLATE ______ Number State Year
DRIVER ______ (Print) Last Name First Middle	DRIVER ______ (Print) Last Name First Middle
ADDRESS ______ (Print) Street or R F D (45-46) (47)	ADDRESS ______ (Print) Street or R F D (45-46) (47)
______ City and State BIRTH DATE ______ AGE ______ SEX ______ (48)	______ City and State BIRTH DATE ______ AGE ______ SEX ______ (48)
DRIVER'S LICENSE ______ Number State Type (49)	DRIVER'S LICENSE ______ Number State Type (49)
OWNER ______ Last Name First Middle	OWNER ______ Last Name First Middle
ADDRESS ______ Street or R F D City State	ADDRESS ______ Street or R F D City State
PARTS OF VEHICLE DAMAGED ______	PARTS OF VEHICLE DAMAGED ______
ESTIMATE OF REPAIR $ ______	ESTIMATE OF REPAIR $ ______
VEHICLE REMOVED TO ______ BY ______	VEHICLE REMOVED TO ______ BY ______

INJURED

Total Number Killed (50) — Injured (51) — (52)

(53-54) (55)	(53-54) (55)
NAME ______ (Print) Last Name First Middle AGE ______ SEX ______	NAME ______ (Print) Last Name First Middle AGE ______ SEX ______
ADDRESS ______ (56) Street or R F D City (57) State	ADDRESS ______ (56) Street or R F D City (57) State
DRIVER ______ PASSENGER ______ IN VEHICLE NUMBER ______	DRIVER ______ PASSENGER ______ IN VEHICLE NUMBER ______
PEDESTRIAN ______ Other (EXPLAIN) ______	PEDESTRIAN ______ Other (EXPLAIN) ______
NATURE AND EXTENT OF INJURIES ______	NATURE AND EXTENT OF INJURIES ______

Mark First One That Applies (58)

1.	2.	3.	4.
Died as result of accident.	Visible signs of injury as bleeding wound, distorted limb or had to be carried away.	Other visible injuries, as bruises, swelling, abrasions, limping, etc.	No visible injuries, but complaint of pain or momentary unconsciousness.

DAMAGE TO OTHER PROPERTY ______ Name of Object (s) Owner's Name and Address Nature of Damages

______ ESTIMATE OF REPAIR $ ______

No. 301

This form is approved by the Superintendent, Indiana State Police, pursuant to Burns Indiana Statutes 47 1918, Acts 1939, Ch. 48

Figure 1B. Accident Report Form, Front Side For Both Police and Driver's Form

(58) CHEMICAL TEST
Driver Ped (Check one)
1 2

0___ ___ ___ No test offered
1___ ___ ___ Test offered but refused
2___ ___ ___ Breath test given
3___ ___ ___ Blood test given
4___ ___ ___ Urine test given

(60) ARREST—(Check one)
Driver
1 2

0___ ___ Not arrested
1___ ___ Arrested for D U I
2___ ___ Arrested for other violation

(61) SPEED LIMIT ________ MPH

(62) SPEED BEFORE ACCIDENT
Veh 1 _____ MPH Veh 2 _____ MPH

(63) CONTRIBUTING CIRCUMSTANCES INDICATED
Driver
1 2

1___ ___ Speed too fast
2___ ___ Failed to yield right of way
3___ ___ Drove left of center
4___ ___ Improper overtaking
5___ ___ Passed stop sign
6___ ___ Disregarded traffic signal.
7___ ___ Followed too closely
8___ ___ Made improper turn
9___ ___ Other improper driving
10___ ___ Inadequate brakes
11___ ___ Improper lights
12___ ___ Had been drinking

(64) VEHICLE DEFECTS
Driver
1 2

0___ ___ No defects
1___ ___ Brakes defective
2___ ___ Lights defective
3___ ___ Defective steering
4___ ___ Puncture or blowout
5___ ___ Other defects

(65) VISION OBSCURED
Driver
1 2

0___ ___ Not obscured
1___ ___ By buildings
2___ ___ By embankment
3___ ___ By signboard
4___ ___ Trees, crops, etc.
5___ ___ By hillcrest
6___ ___ ____________

(Specify other)

INDICATE ON THIS DIAGRAM WHAT HAPPENED

DRAW DIAGRAM TO SCALE

Indicate North by arrow

DESCRIBE WHAT HAPPENED
Refer to vehicle by number ________________________________

WHAT DRIVERS WERE DOING TO DO BEFORE ACCIDENT.
(66)
Driver No. 1 was headed ___N ___S ___E ___W on ______________
(Name or number of street or highway)

Driver No. 2 was headed ___N ___S ___E ___W on ______________
(Name or number of street or highway)

(Check applicable items for each driver.)

Driver 1	2		Driver 1	2		Driver 1	2	
						6___	___	Start from parked position
0___	___	Passing	2___	___	Backing	6___	___	Avoiding veh., obj., ped.
1___	___	Turn right	3___	___	Slow or stop	7___	___	Skidded before applying brakes
1___	___	Turn left	4___	___	Going straight ahead	8___	___	Skidded after applying brakes
1___	___	Make U turn	5___	___	Start in traffic lane	9___	___	Parked

WHAT PEDESTRIAN WAS DOING BEFORE ACCIDENT
(67)
Pedestrian was going ___N ___S ___E ___W ___along ___across or into ______________
Street or Highway

From ______________ to ______________
(N. E. corner to S. E. corner or from West side to East side, etc.)

(Check one)

0___ Not in roadway
1___ Walking in roadway with traffic
2___ Walking in roadway against traffic
3___ Pushing or working on vehicle
4___ Getting on or off vehicle
5___ Standing in roadway
6___ Other working in roadway
7___ Playing in roadway
8___ Other ______________ (Specify actions)
11___ Crossing or entering not at intersection
12___ Crossing or entering at intersection

CONDITION OF DRIVERS AND PEDESTRIANS
(Check one)

(68) Driver 1 2 — (70) Ped

0___ ___ ___ Had NOT been drinking
1___ ___ ___ Obviously drunk
2___ ___ ___ Ability impaired
3___ ___ ___ Ability not impaired
4___ ___ ___ Unknown if impaired

(69) (71)

11___ ___ ___ Apparently normal
4___ ___ ___ Eyesight defective
1___ ___ ___ Hearing defective
2___ ___ ___ Other defects
3___ ___ ___ Illness
4___ ___ ___ Fatigued
5___ ___ ___ Apparently asleep
6___ ___ ___ Attention diverted
7___ ___ ___ Advanced senility
8___ ___ ___ Other handicaps

(Specify other handicaps)

(72) TRAFFIC CONTROL
Driver 1 2 — Driver 1 2

0___ ___ Police officer — 4___ ___ Other lane markings
1___ ___ Automatic signal — 5___ ___ Stop sign
2___ ___ Yield right-of-way sign — 6___ ___ Warning sign or signal
3___ ___ Center line marked — 7___ ___ No passing zone
8___ ___ All others

(73) CHARACTER (74) (Check two)
1___ Straight
2___ Curve
1___ Level
2___ On grade
3___ Hillcrest

(75) SURFACE (Check one)
1___ Concrete
2___ Blacktop
3___ Sand or dirt
4___ Gravel
5___ Other

(76) CONDITION (Check one)
1___ Dry
2___ Wet
3___ Snow/Ice
4___ Other

(77) WEATHER (Check one)
1___ Clear
2___ Raining
3___ Snowing
4___ Fog
5___ Other

(78) LIGHT (Check one)
1___ Daylight
2___ Dark
3___ Dawn or dusk

(79) KIND OF LOCALITY
(Check one to show that area adjacent to roadway for 300' was primarily.)
1___ School or playground
2___ Industrial or business
3___ Residential
4___ Open country

(80) ROAD DEFECTS
1___ Foreign material on surface
2___ Loose sand, gravel, etc.
3___ Holes, ruts, dips, bumps, etc.
4___ Defective shoulders
5___ Obstruction not lighted or signaled
6___ Standing water, landslide, etc.
7___ Obstructed by previous acc.
8___ All other defects

WITNESSES
Name ______________ Address ______________ Location ______________
Name ______________ Address ______________ Location ______________

POLICE ACTION
ARRESTS Name ______________ Charge ______________
Name ______________ Charge ______________

INVESTIGATION Time notified of accident ______AM ______PM Time of arrival at the scene ______AM ______PM
Where else was investigation made? ______________ Is investigation complete? ___Yes ___No
Were photographs taken? ___Yes ___No Driver report form furnished to ___driver No. 1 ___driver No. 2

SIGNATURE ______________ Department ______________ Date of report ______________

ARB-2 Investigator's Report Rev. 72

Figure 2B. Accident Report Form, Back Side for Police Form

Operator's Report

READ CAREFULLY	MOTOR VEHICLE ACCIDENT REPORT STATE OF INDIANA INDIANA STATE POLICE, INDIANAPOLIS, INDIANA 46204	FILL IN COMPLETELY

INSTRUCTIONS

The driver of any motor vehicle involved in an accident which results in injury or death or total property damage of $100 or more must make a report on this form within five days. The failure or refusal of any person to report an accident as required is a cause for the suspension or revocation of the operator's or chauffeur's license and vehicle registration of such person. Such failure or refusal is also a misdemeanor punishable by a fine not in excess of $ [illegible].

If the driver is physically incapable of making the report, any occupant of the vehicle is required to do so. A witness may also be required to make a report. A supplementary report will be required whenever an original report is insufficient.

YOUR REPORT IS CONFIDENTIAL AND CANNOT BE USED AS EVIDENCE IN ANY TRIAL

The purposes of this report are to obtain information necessary to the administration of the Safety Responsibility Law and to obtain data useful in accident prevention. Complete and clear answers to all the questions are necessary. An accurate original report will avoid the necessity for supplementary reports. If you have difficulty in filling in the report consult your nearest police authority.

OBSERVE THE FOLLOWING RULES

1. PRINT ALL NAMES AND ADDRESSES and list your vehicle as Vehicle No. 1.
2. Answer all questions to the best of your knowledge. If unable to answer any question, mark "not known."
3. Under "LOCATION" of accident give sufficient information to locate the exact scene of the accident.
4. Under "Type of Vehicle" indicate the exact type or combination of vehicles, that is, coach, sedan with two wheel house trailer, tractor and semi-trailer, truck and four wheel trailer, motorcycle, etc.
5. The nature and extent of all damages and injuries must be clearly and completely stated. Whenever a doctor's statement of injuries or a garage estimate of the cost of repairs is immediately available, give this information. Otherwise give your own careful estimate.
6. A street car, bicycle, or animal drawn vehicle should be recorded as a vehicle for the purpose of this report. A person on skates, coaster wagon, sled, etc. should be classed as a pedestrian. Describe the conveyance and give its exact location in the street or on the roadway.
7. If the accident involved a fixed object, describe it fully and give its exact location. State also whether it was protected by flags, painting and/or lights.
8. Use a second report form or a sheet of paper the same size to report additional vehicles, injured persons, witnesses, or any other information for which there is not sufficient space.
9. Do not write in boxes. The boxes and printed numbers are for statistical use only.
10. SIGN THE REPORT in the space at the bottom of the form.

DESCRIBE WHAT HAPPENED:

Refer to Vehicle by No.__________

WHAT DRIVERS WERE DOING BEFORE ACCIDENT

Driver No. 1 was headed __N __S __E __W on __________ (Name or Number of Street or Highway) Driver No. 2 was headed __N __S __E __W on __________ (Name or Number of Street or Highway)

(Check applicable items for each driver)

Driver 1	Driver 2		Driver 1	Driver 2		Driver 1	Driver 2		Driver 1	Driver 2		Driver 1	Driver 2	
						___	___	Backing	___	___	Starting in traffic lane.	___	___	Skidded before braking
___	___	Passing	___	___	Turning left.	___	___	Slowing or stopping	___	___	Start from parked position.	___	___	Skidded after braking.
___	___	Turning right.	___	___	Making U turn.	___	___	Going straight ahead.	___	___	Avoiding veh., obj. pedestrian.	___	___	Parked.

WHAT PEDESTRIAN WAS DOING BEFORE ACCIDENT:

Pedestrian was going __N __S __E __W __along __across or into __________ (Street or Highway) From __________ to __________ (N.E. corner to S.E. corner or from West side to East side, etc.)

(Check one)

___ Crossing or entering at intersection.	___ Walking in roadway against traffic.	___ Standing in roadway.	___ Not in roadway.
___ Crossing or entering not at intersection.	___ Pushing or working on vehicle.	___ Other working in roadway.	___ Other (Specify actions)
___ Walking in roadway with traffic.	___ Getting on or off vehicle.	___ Playing in roadway.	___

ROAD

(72) TRAFFIC CONTROL Driver (Check One) 1 2	Driver 1 2	(73) (74) CHARACTER (Check two)	(75) SURFACE (Check one)	(76) CONDITION (Check one)	(77) WEATHER (Check one)	(78) LIGHT (Check one)	(79) KIND OF LOCALITY (Check one to show that area adjacent to roadway for 300' was primarily)
0__ __ Police officer.	4__ __ Other lane markings.	1__ Straight	1__ Concrete	1__ Dry	1__ Clear	1__ Daylight	1__ School or playground.
1__ __ Automatic signal.	5__ __ Stop sign.	2__ Curve	2__ Blacktop	2__ Wet	2__ Raining	2__ Dark	2__ Industrial or business.
2__ __ Yield right-of-way sign.	6__ __ Warning sign or signal.	1__ Level	3__ Sand or dirt	3__ Snow/Ice	3__ Snowing	3__ Dawn or Dusk	3__ Residential.
3__ __ Center line marked.	7__ __ No passing zone.	2__ On Grade	4__ Gravel	0____ Other	4__ Fog		4__ Open country.
		3__ Hillcrest	0____ Other		0____ Other		

(80) ROAD DEFECTS (Check one)
1__ Foreign material on surface.
2__ Loose sand, gravel, etc.
3__ Holes, ruts, dips, bumps, etc.
4__ Defective shoulders.
5__ Obstruction not lighted or signaled
6__ Standing water, landslide, etc.
7__ Obstructed by previous acc.
8__ All other defects.

WITNESSES:

Name	Address	Age	Sex	Location

WAS THERE A POLICE OFFICER AT THE SCENE: ______ Yes ______ No

If yes, give __________ (Name and badge number) Department __________ (City, county or state.)

Signature __________

Signature of Person Submitting Report Is Required | Address | City and State | Date

Mail Report To: INDIANA STATE POLICE, INDIANAPOLIS, INDIANA 46304 ARB-1 Operator's Report Rev 73

Figure 3B. Accident Report Form, Back Side for Driver's Form

SECT# ______ COUNTY TWNSHPS

RT.# ______ speed limit ______

DATE	Intersection	# VEH	KILLED	INJ.	SKID	CHAR.	COND.	Weather	Light	CAUSE
						/				
						/				
						/				
						/				
						/				
						/				
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Comments

Figure 4B. Accident Coding Form

CODE: ACCIDENT CODING SHEET (FIGURE 4B)

Date	- Number equivalent of month of occurence (i.e. January = 1, June = 6, November = 11).
Intersection	- 0 if not at intersection, 1 otherwise.
# Veh.	- Number of vehicles involved in accident.
Killed	- Number of persons killed in accident.
Inj.	- Number of persons injured in accident.
Skid	- Police reported skidding, each cell has either: 0 - no skidding, 7 - skidded before braking, 8 - skidded after braking, two cells allow for any two responses for any number of vehicles.
Char.	- Character of roadway, two cells, first: 1 if straight, 2 if curved; second: 1 if level, 2 if on grade, 3 if hillcrest.
Cond.	- Surface condition, 1 if dry, 2 if wet, 3 if snow or ice.
Weather	- 1 if clear, 2 if rain, 3 if snow, 4 if heavy fog.
Light	- 1 if day, 2 if night, 3 if dusk or dawn
Cause	- 0 if surface is not wet 1 if accident not caused by skidding 2 if accident possibly caused by skidding 3 if accident probably caused by skidding

APPENDIX C

SECTION DATA

Table 1C. Sections Used in the Study

Sect.#	Route	District[1]	County	Townships	Intersection[2] County Road/State Road	Urban[3] Factor	Geometric[4] Index
1	US52	C	Boone	Sugar Washington	12/1	2	---
2	US35	G	Delaware	Harrison	10/1	2	1
3	SR62	V	Vanderburgh	Perry	8/0	3	---
4	US136	C	Montgomery	Wayne	9/0	2	2
5	I65	S	Shelby	All	1	---	---
6	US50	V	Knox	Vincennes	1/2	3	---
7	US421	L	Carroll	Jefferson Tippecanoe	15/1	1	1
8	SR445	V	Greene	Center	0/1	1	3
9	I65	S	Jackson	Washington Vernon	2	---	---
10	I69	F	Huntington	Rock Creek Jefferson Salmonia	3	---	---
11	US30	F	Kosciusko	Washington	4/1	1	---
12	SR28	C	Fountain	Logan Davis	7/0	1	1
13	US24	F	Miami	Erie	2/0	2	3
14	SR66	V	Warwick	Ohio	8/1	1	2
15	I70	G	Hendricks	All	0	---	---
16	US30	L	Starke	Oregon	7/1	1	---

Table 1C continued

Sect.#	Route	District[1]	County	Townships	Intersection[2] County/State Road / Road	Urban[3] Factor	Geometric[4] Index
17	SR57	V	Greene	Washington Fairplay	15/1	1	1
18	SR46	S	Ripley	All	9/2	1	3
19	SR37	V	Lawrence	Marion	9/2	1	2
20	US41	C	Parke	Wabash	4/0	1	3
21	SR28	C	Clinton	Johnson Sugar Creek Kirlin	7/0	1	1
22	I69	F	Stueben	Stueben	1	---	---
23	SR28	C	Clinton	Washington	11/0	2	2
24	SR25	L	Cass	Bethlehem Clay	17/0	1	2
25	I65	L	White	Princeton West Point Round Grove	2	---	---
26	I69	F	Allen	Perry St. Joseph	1	---	---
27	US30	L	Starke	Oregon	7/1	1	---
28	US30	L	Lake	St. John	2/0	3	---
29	US41	V	Knox	Johnson	10/1	1	---
30	SR67	V	Knox	Vigo	14/3	2	2
31	I65	L	Lake	Eagle Creek	1	---	---
32	I69	F	Allen	Lafayette	1	---	---

Table 1C continued

Sect.#	Route	District[1]	County	Townships	Intersection[2] County Road/State Road	Urban[3] Factor	Geometric[4] Index
33	SR2	L	LaPorte	Kankakee	11/0	2	---
34	US41	V	Gibson	Patoka	10/1	1	---
35	US421	C	Clinton	Washington Union	10/0	1	2
36	US421	S	Ripley	Shelby Brown	13/0	1	1
37	US6	F	Elkhart	Union	7/0	2	1
38	I69	F	Dekalb	Union Grant	1	---	---
39	US40	G	Henry	Wayne	6/1	1	---
40	I65	S	Johnson	Blue River	0	---	---
41	SR37	V	Lawrence	Marshall	9/0	1	---
42	US52	C	Benton	Bolivar	6/0	2	---
43	US30	L	LaPorte	Hanna	6/1	1	---
44	US40	G	Henry	Wayne	6/1	1	---
45	SR46	S	Decatur	Clay	11/1	1	3
46	SR28	G	Tipton	Madison	8/0	1	1
47	SR43	L	White	Big Creek	3/0	1	1
48	I69	F	Huntington	Union	0	---	---
49	SR29	C	Clinton	Warren	9/0	2	1
50	US36	C	Putnam	Floyd	6/0	2	2

Table 1C continued

Sect.#	Route	District[1]	County	Townships	Intersection[2] County Road / State Road	Urban Factor[3]	Geometric Index[4]
51	I70	C	Clay	Posey	1	---	---
52	I70	C	Clay	Jackson	1	---	---
53	I64	V	Posey	All	3	---	---
54	US20	L	LaPorte	Hudson Wills	6/1	1	1
55	SR63	C	Vermillion	Highland	8/2	1	2
56	I69	F	Stueben	Jamestown	3	---	---
57	US27	G	Union	Brownsville Harrison	5/0	1	1
58	US20	L	St.Joseph	Penn.	5/3	3	1
59	I70	C	Vigo	Sugar Creek Harrison	2	---	---
60	US150	V	Martin	Halbert	6/1	2	3
61	SR3	G	Rush	Anderson	6/1	1	2
62	I64	V	Vanderburgh	All	2	---	---
63	SR67	S	Owen	Wayne	5/0	1	3
64	SR28	G	Madison	Pipe Creek	8/1	2	1
65	US31	L	St.Joseph	Clay	4/1	3	---
66	I74	C	Hendricks	Lincoln	0	---	---
67	I74	C	Fountain	Troy	1	---	---
68	I65	S	Johnson	Blue River	0	---	---

Table 1C continued

Sect.#	Route	District[1]	County	Townships	Intersection[2] County/State Road Road	Urban[3] Factor	Geometric[4] Index
69	I69	F	Huntington	Jefferson	1	---	---
70	US50	V	Knox	Steen	5/0	1	2
71	SR37	V	Orange	Orleans	6/0	1	3
72	US27	G	Union	Union	5/0	2	1
73	US30	L	Porter	Washington	6/0	2	---
74	US24	F	Huntington	Jackson	11/3	2	---
75	US6	L	Porter	Portage	6/0	3	1
76	US6	L	LaPorte	Scipio Noble	5/1	2	1
77	SR67	S	Morgan	Ray Jefferson	17/1	1	3
78	US231	V	Spencer	Carter	6/2	2	1
79	SR25	L	Fulton	Liberty	10/1	1	1
80	US30	L	Lake	St.John	3/0	3	---
81	US460	V	Posey	Center	8/0	1	2
82	US35	G	Howard	Liberty Jackson Taylor Union	15/0	1	1
83	US421	S	Decatur	Marion Salt Creek	8/0	1	2
84	US460	V	Perry	All	15/3	1	3

Table 1C continued

Sect.#	Route	District[1]	County	Townships	Intersection[2] County/State Road	Urban[3] Factor	Geometric[4] Index
85	US460	V	Spencer	Harrison	8/3	1	3
86	SR46	S	Monroe	Bean Blossom	4/0	1	3
87	US24	L	Jasper	All	9/2	1	1
88	US30	F	Kosciusko	Washington	8/1	1	---
89	US24	F	Huntington	Jackson Union	11/3	2	---
90	US24	L	Cass	Miami	12/0	2	2
91	US40	L	Porter	Washington	6/0	2	---
92	US231	L	Lake	Winfield	6/0	2	1
93	US35	L	Pulaski	Franklin	6/0	1	1
94	US24	F	Huntington	Dallas	5/1	1	2

[1] ISHC Districts; C - Crawfordsville, F - Fort Wayne, G - Greenfield, L - LaPorte, S - Seymour, V - Vincennes

[2] Where only one number is given, this indicates the number of interchanges on an interstate.

[3] Due to limited access and large ROW, urban factors were not taken for interstate sections.

[4] Geometric index value was taken and used only for two-lane sections.

Table 2C. Compiled Section Data

	ACCIDENTS/SECTION DRY	WET	SNOW	TOT	ACC.RATES ALL	WET	RATIO	SKID NUMBERS AVG.	INDIVIDUAL	READINGS	# MILES	VOLUMES 1972	1975	ROUTE		# LNS	PVMT TYPE
SECT# 1	14.	3.	1.	18.	1.09	1.32	1.21	38.35	10/73-40.5	9/75-34.8	7.6	3960.	3960.	US 52	WEST	4	BIT.CNC
SECT# 2	53.	13.	14.	80.	1.84	2.17	1.18	40.68	8/73-40.6	9/75-40.8	6.0	7375.	6215.	US 35	BOTH	2	BIT.CNC
SECT# 3	23.	6.	2.	31.	.60	.85	1.43	41.21	9/72-38.3	7/75-42.9	7.1	12875.	13350.	SR 62	WEST	4	P.C.C.
SECT# 4	9.	1.	2.	12.	.86	.52	.60	41.10	8/73-41.6	9/75-40.4	6.2	2520.	1840.	US136	BOTH	2	BIT.CNC
SECT# 5	12.	2.	4.	18.	.33	.27	.80	42.94	10/72-51.7	7/75-37.6	5.0	19000.	20200.	I 65	SOUTH	4	P.C.C.
SECT# 6	6.	3.	2.	11.	1.48	2.91	1.97	49.92	9/72-48.4	7/75-50.8	2.0	6750.	6825.	US 50	EAST	4	P.C.C.
SECT# 7	44.	27.	11.	82.	1.55	3.69	2.38	47.30	9/71-43.0	7/75-48.9	11.3	4585.	4125.	US421	BOTH	2	BIT.CNC
SECT# 8	9.	3.	1.	13.	3.16	5.27	1.67	44.05	9/70-39.5	8/75-45.4	1.3	2975.	2850.	SR445	BOTH	2	BIT.CNC
SECT# 9	69.	20.	9.	98.	1.08	1.60	1.48	35.13	10/72-33.7	7/75-36.0	9.8	15675.	17500.	I 65	SOUTH	4	P.C.C.
SECT# 10	31.	4.	17.	52.	.77	.43	.56	35.21	7/73-36.7	10/75-33.2	10.0	12675.	12250.	I 69	SOUTH	4	P.C.C.
SECT# 11	75.	27.	19.	121.	2.60	4.20	1.61	39.02	7/73-40.6	10/75-36.9	6.0	14220.	14145.	US 30	EAST	4	HAC-P
SECT# 12	20.	4.	6.	30.	1.06	1.02	.96	48.55	7/73-50.0	10/75-46.6	8.2	3290.	3085.	SR 28	BOTH	2	HAC II
SECT# 13	38.	8.	2.	48.	1.51	1.82	1.21	47.09	7/73-50.8	10/75-42.1	3.7	7800.	7860.	US 24	BOTH	2	HAC IV
SECT# 14	101.	20.	8.	129.	2.03	2.27	1.12	45.49	9/72-43.4	7/75-46.7	6.5	10000.	8425.	SR 66	BOTH	2	P.C.C.
SECT# 15	33.	11.	21.	65.	.59	.72	1.22	36.00	11/72-39.3	11/75-33.2	8.7	23100.	25275.	I 70	WEST	4	P.C.C.
SECT# 16	22.	5.	7.	34.	.74	.79	1.06	34.71	6/73-34.0	10/75-35.6	6.2	12150.	14180.	US 30	EAST	4	P.C.C.
SECT# 17	22.	4.	3.	29.	1.10	1.09	1.00	54.55	9/72-49.4	7/75-57.6	10.3	2500.	2270.	SR 57	BOTH	2	HAC IV
SECT# 18	33.	8.	1.	42.	1.34	1.84	1.38	42.95	8/72-55.7	8/75-35.3	9.0	2855.	3355.	SR 46	BOTH	2	BIT.CNC
SECT# 19	140.	53.	12.	205.	2.29	4.29	1.87	30.82	10/72-31.6	8/75-30.3	12.0	6650.	6875.	SR 37	BOTH	2	P.C.C.
SECT# 20	35.	8.	3.	46.	2.63	3.30	1.26	54.69	9/73-56.7	10/75-51.4	4.0	4345.	3825.	US 41	BOTH	2	HAC IV
SECT# 21	20.	7.	11.	38.	3.43	4.57	1.33	34.90	8/73-39.1	9/75-29.1	5.7	1725.	1800.	SR 28	BOTH	2	BIT.CNC
SECT# 22	17.	5.	14.	36.	.97	.98	1.00	31.28	5/73-33.7	10/75-28.5	5.0	15250.	12625.	I 69	NORTH	4	P.C.C.
SECT# 23	29.	16.	13.	58.	2.36	4.71	2.00	48.01	8/73-48.3	9/75-47.6	7.3	3235.	2995.	SR 28	BOTH	2	HAC II
SECT# 24	36.	17.	14.	67.	1.29	2.38	1.84	45.97	8/73-47.5	10/75-43.7	11.5	4470.	3930.	SR 25	BOTH	2	BIT.CNC
SECT# 25	19.	5.	28.	52.	.98	.68	.70	32.89	7/73-31.4	10/75-34.9	6.0	14675.	16950.	I 65	NORTH	4	P.C.C.
SECT# 26	24.	5.	9.	38.	.48	.46	.95	34.92	5/73-38.6	10/75-30.7	8.5	19680.	15630.	I 69	SOUTH	4	P.C.C.
SECT# 27	26.	9.	6.	41.	.87	1.38	1.59	33.30	6/73-32.5	10/75-34.3	6.2	12050.	14850.	US 30	WEST	4	P.C.C.
SECT# 28	29.	12.	3.	44.	1.93	3.81	1.97	33.40	6/73-33.0	10/75-33.9	2.2	17550.	19600.	US 30	WEST	4	OTHERS
SECT# 29	12.	2.	2.	16.	.43	.39	.90	38.31	9/72-35.4	7/75-40.0	5.9	11505.	11380.	US 41	SOUTH	4	BIT.CNC
SECT# 30	24.	5.	3.	32.	.74	.83	1.13	49.00	9/72-51.4	7/75-47.6	11.2	3860.	3370.	SR 67	BOTH	2	BIT.CNC

Table 2C. Continued

	ACCIDENTS/SECTION				ACC.RATES			SKID NUMBERS			#	VOLUMES		ROUTE		#	PVMT
	DRY	WET	SNOW	TOT	ALL	WET	RATIO	AVG.	INDIVIDUAL READINGS		MILES	1972	1975			LNS	TYPE
SECT# 31	49.	4.	40.	93.	.86	.27	.31	38.07	7/73-37.9	10/75-38.3	10.5	14975.	20675.	I 65	SOUTH	4	P.C.C.
SECT# 32	8.	1.	2.	11.	.21	.14	.68	35.30	7/73-37.0	10/75-33.0	7.4	13600.	12875.	I 69	SOUTH	4	P.C.C.
SECT# 33	16.	7.	9.	37.	1.35	2.13	1.58	41.40	6/73-39.7	10/75-43.5	6.1	6800.	7785.	SR 2	EAST	4	P.C.C.
SECT# 34	21.	4.	9.	34.	.77	.68	.85	37.68	9/72-38.0	7/75-37.5	7.9	11565.	9535.	US 41	NORTH	4	P.C.C.
SECT# 35	16.	15.	2.	33.	3.82	12.57	3.29	45.44	9/71-43.7	11/75-46.3	3.3	2575.	2295.	US421	BOTH	2	BIT.CNC
SECT# 36	17.	6.	1.	24.	1.05	1.90	1.81	60.84	10/72-60.9	8/75-60.8	7.7	2860.	2625.	US421	BOTH	2	OTHERS
SECT# 37	48.	13.	10.	71.	2.51	3.33	1.32	40.85	7/73-39.1	10/75-43.2	5.0	5420.	5030.	US 6	BOTH	2	HAE III
SECT# 38	19.	3.	4.	26.	.56	.47	.83	35.14	5/73-37.7	10/75-32.2	5.5	17425.	14500.	I 69	SOUTH	4	P.C.C.
SECT# 39	14.	2.	0	16.	1.23	1.11	.90	51.65	8/73-51.4	9/75-52.0	5.5	4270.	4330.	US 40	EAST	4	BIT.CNC
SECT# 40	6.	1.	5.	12.	.48	.29	.60	37.89	10/72-45.0	8/75-33.2	2.3	19100.	20300.	I 65	NORTH	4	P.C.C.
SECT# 41	14.	4.	1.	19.	.70	1.06	1.52	38.03	10/72-48.1	8/75-31.4	6.9	7225.	7200.	SR 37	NORTH	4	P.C.C.
SECT# 42	5.	2.	3.	10.	.62	.90	1.45	40.45	5/73-40.0	11/75-41.0	6.7	5880.	3650.	US 52	WEST	4	P.C.C.
SECT# 43	23.	8.	5.	36.	.76	1.22	1.61	38.57	6/73-39.6	11/75-37.2	6.2	13500.	14280.	US 30	EAST	4	P.C.C.
SECT# 44	17.	1.	5.	23.	1.77	.56	.31	46.10	8/73-43.2	9/75-50.1	5.5	4270.	4330.	US 40	WEST	4	BIT.CNC
SECT# 45	18.	5.	4.	27.	1.35	1.81	1.34	47.34	10/72-53.2	9/75-43.2	7.9	2190.	2365.	SR 46	BOTH	2	HAE III
SECT# 46	35.	5.	8.	48.	1.67	1.26	.75	46.80	8/73-47.6	9/75-45.7	5.4	5615.	4480.	SR 28	BOTH	2	HAE IV
SECT# 47	9.	3.	6.	18.	.89	1.07	1.21	48.40	6/73-50.0	7/75-46.8	4.9	3660.	3855.	SR 43	BOTH	2	HAE II
SECT# 48	8.	1.	6.	15.	.37	.18	.48	33.00	7/73-37.6	10/75-26.8	5.8	13400.	12500.	I 69	NORTH	4	P.C.C.
SECT# 49	15.	4.	3.	22.	1.25	1.65	1.32	52.38	8/73-57.9	11/75-43.7	5.0	2600.	3515.	SR 29	BOTH	2	OTHERS
SECT# 50	12.	12.	1.	25.	1.26	4.38	3.47	40.95	9/73-38.8	12/75-44.9	5.4	3640.	3030.	US 36	BOTH	2	OTHERS
SECT# 51	15.	1.	4.	20.	.28	.10	.36	34.95	11/72-38.2	11/75-32.2	6.8	17300.	19750.	I 70	EAST	4	P.C.C.
SECT# 52	14.	6.	3.	23.	.36	.68	1.89	32.26	11/72-35.4	11/75-29.6	6.6	16650.	18200.	I 70	EAST	4	P.C.C.
SECT# 53	7.	4.	7.	18.	1.04	1.67	1.61	59.08	7/70-60.9	7/75-58.6	17.0	1570.	2000.	I 64	EAST	4	P.C.C.
SECT# 54	32.	10.	3.	45.	2.62	4.21	1.61	44.57	6/73-48.4	10/75-42.3	4.6	3425.	3400.	US 20	BOTH	2	HAC-4
SECT# 55	19.	9.	4.	32.	.68	1.38	2.03	37.14	8/73-35.2	10/75-40.0	8.5	5110.	5060.	SR 63	BOTH	2	P.C.C.
SECT# 56	12.	6.	7.	25.	.95	1.65	1.74	36.91	8/71-41.4	10/75-34.9	4.2	12945.	10670.	I 69	SOUTH	4	P.C.C.
SECT# 57	11.	8.	3.	22.	1.17	3.08	2.63	32.65	7/72-29.5	9/75-34.6	5.0	3720.	3285.	US 27	BOTH	2	P.C.C.
SECT# 58	108.	41.	16.	165.	2.36	4.24	1.80	30.46	7/73-29.1	10/75-32.3	5.0	12475.	12940.	US 20	BOTH	2	HAC-8
SECT# 59	26.	6.	12.	44.	.99	.97	.99	38.38	11/72-44.9	10/75-33.2	5.2	14850.	16090.	I 70	WEST	4	P.C.C.
SECT# 60	24.	10.	4.	38.	1.89	3.60	1.90	43.39	10/72-44.6	8/75-42.6	8.2	2185.	2265.	US150	BOTH	2	HAC-8

Table 2C. Continued

	ACCIDENTS/SECTION				ACC.RATES			SKID NUMBERS			#	VOLUMES		ROUTE		#	PVMT
	DRY	WET	SNOW	TOT	ALL	WET	RATIO	AVG.	INDIVIDUAL	READINGS	MILES	1972	1975			LNS	TYPE
SECT# 61	27.	3.	5.	35.	1.29	.80	.67	50.69	7/72-47.6	9/75-52.6	5.9	3735.	4415.	SR 3	BOTH	7	MAT IV
SECT# 62	6.	0	0	6.	.48	0	0	54.27	9/72-53.6	7/75-53.5	12.0	1250.	2250.	I 64	WEST	4	P.C.C.
SECT# 63	19.	11.	2.	32.	1.32	3.29	2.49	37.17	10/72-43.8	8/75-32.8	4.9	4925.	4300.	SR 67	BOTH	7	MAC-B
SECT# 64	54.	11.	17.	87.	3.56	3.45	.97	36.54	8/73-44.1	9/75-26.1	3.6	4705.	6420.	SR 28	BOTH	7	MAT III
SECT# 65	148.	82.	27.	257.	2.42	5.58	2.31	40.54	6/73-41.7	10/75-39.1	7.7	24000.	25835.	US 31	SOUTH	4	BIT.CNC
SECT# 66	6.	5.	8.	19.	.64	1.22	1.90	31.97	8/73-27.5	11/75-39.0	3.8	15300.	13750.	I 74	WEST	4	P.C.C.
SECT# 67	17.	0	4.	21.	.43	0	0	35.86	8/73-31.7	12/75-42.8	9.2	9125.	9910.	I 74	EAST	4	P.C.C.
SECT# 68	8.	0	11.	19.	.62	0	0	38.78	10/72-42.3	7/75-36.6	2.8	19100.	20300.	I 65	SOUTH	4	P.C.C.
SECT# 69	6.	1.	7.	14.	.41	.21	.52	33.34	8/73-37.2	9/75-28.0	5.0	13025.	12375.	I 69	NORTH	4	P.C.C.
SECT# 70	32.	29.	3.	64.	1.87	6.14	3.28	50.23	9/72-54.4	7/75-47.8	4.8	6375.	6565.	US 50	BOTH	2	OTHERS
SECT# 71	17.	12.	0	29.	1.42	4.24	2.99	38.19	10/72-40.3	8/75-36.8	4.2	4200.	4575.	SR 37	BOTH	2	P.C.C.
SECT# 72	6.	3.	7.	16.	2.42	3.35	1.36	51.30	8/72-51.3	9/75-51.3	2.6	2435.	2200.	US 27	BOTH	2	MAT III
SECT# 73	33.	4.	4.	41.	.92	.65	.71	35.66	6/73-36.6	10/75-34.5	5.2	15785.	15575.	US 30	EAST	4	MAC-B
SECT# 74	26.	7.	10.	43.	1.43	1.68	1.18	48.68	7/73-50.0	10/75-46.9	6.4	8930.	8415.	US 24	EAST	4	MAT IV
SECT# 75	140.	46.	28.	214.	3.44	5.35	1.55	36.64	6/73-37.4	10/75-35.7	4.5	13080.	12385.	US 6	BOTH	2	MAC-B
SECT# 76	28.	12.	4.	44.	1.77	3.50	1.97	41.54	6/73-44.4	10/75-58.0	4.7	4850.	4810.	US 6	BOTH	2	MAC-B
SECT# 77	83.	28.	13.	124.	1.49	2.44	1.63	43.32	10/72-46.7	8/75-41.1	14.0	5785.	5225.	SR 67	BOTH	2	MAC-B
SECT# 78	20.	9.	3.	32.	1.85	3.76	2.03	45.04	9/72-41.5	7/75-47.1	4.1	3725.	3930.	US231	BOTH	2	MAC-B
SECT# 79	20.	9.	2.	31.	1.30	2.74	2.10	52.00	8/73-52.4	10/75-51.4	6.4	3650.	3270.	SR 25	BOTH	2	MAC-B
SECT# 80	29.	7.	5.	41.	1.90	2.34	1.24	39.06	6/73-44.1	10/75-32.8	2.1	17200.	19600.	US 30	EAST	4	OTHERS
SECT# 81	21.	11.	4.	36.	1.74	3.85	2.21	50.41	9/72-53.0	7/75-48.9	4.7	3455.	4300.	US460	BOTH	2	MAT IV
SECT# 82	57.	9.	16.	82.	.93	.74	.79	42.03	8/73-42.7	9/75-41.1	11.0	7270.	7360.	US 35	BOTH	2	MAC-B
SECT# 83	13.	4.	1.	18.	.96	1.54	1.61	51.31	8/72-57.7	9/75-47.2	5.3	3195.	3245.	US421	BOTH	2	MAC-B
SECT# 84	37.	10.	7.	49.	3.02	4.46	1.48	53.32	10/72-52.2	7/75-54.0	13.6	565.	1350.	US460	BOTH	2	MAT III
SECT# 85	41.	13.	1.	55.	2.78	4.75	1.71	50.16	9/72-48.7	7/75-51.3	6.7	2950.	2570.	US460	BOTH	2	MAT III
SECT# 86	28.	4.	4.	36.	2.01	1.62	.80	36.31	10/72-37.7	8/75-35.4	2.6	5955.	6445.	SR 46	BOTH	2	MAC-B
SECT# 87	33.	8.	9.	50.	1.73	2.00	1.16	51.12	8/73-52.7	10/75-48.8	7.7	2725.	3775.	US 24	BOTH	2	MAT III
SECT# 88	36.	10.	9.	55.	1.12	1.48	1.32	31.71	7/73-33.2	10/75-29.7	6.2	14810.	14230.	US 30	EAST	4	MAC-B
SECT# 89	26.	10.	4.	40.	.88	1.59	1.81	48.16	7/73-46.5	10/75-50.4	9.5	8895.	8675.	US 24	WEST	4	MAC-B
SECT# 90	41.	16.	30.	87.	1.97	2.62	1.33	44.74	6/73-45.5	10/75-43.8	6.9	5060.	6245.	US 24	BOTH	2	OTHERS

Table 2C. Continued

	ACCIDENTS/SECTION				ACC.RATES			SKID NUMBERS			#	VOLUMES		ROUTE		#	PVMT
	DRY	WET	SNOW	TOT	ALL	WET	RATIO	AVG.	INDIVIDUAL READINGS		MILES	1972	1975			LNS	TYPE
SECT# 91	15.	6.	7.	28.	.53	.82	1.55	41.76	6/73-42.7	10/75-40.6	5.1	15785.	20650.	US 40	WEST	4	HAC-B
SECT# 92	14.	4.	2.	20.	.89	1.29	1.45	42.17	6/73-40.7	10/75-44.0	4.9	3535.	4520.	US231	BOTH	2	HAC-A
SECT# 93	32.	9.	5.	46.	2.27	3.21	1.47	44.95	6/73-46.6	10/75-42.9	6.0	2715.	3270.	US 35	BOTH	2	HAC-A
SECT# 94	23.	10.	4.	37.	1.47	2.87	1.96	46.70	7/73-49.6	10/75-42.8	4.4	5125.	5290.	US 24	BOTH	2	OTHERS

APPENDIX D

PLOTS OF AVERAGE SKID NUMBER VS VARIOUS VARIABLES

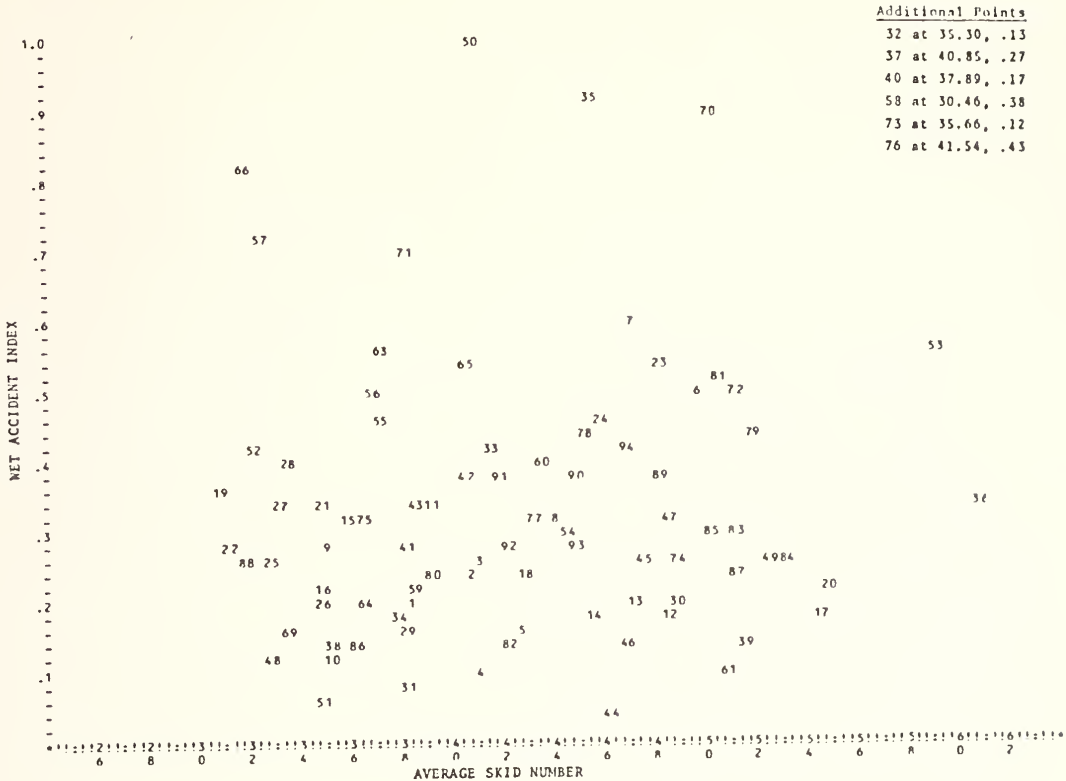

Figure 1D. Wet Accident Index Versus Average Skid Number by Section Number

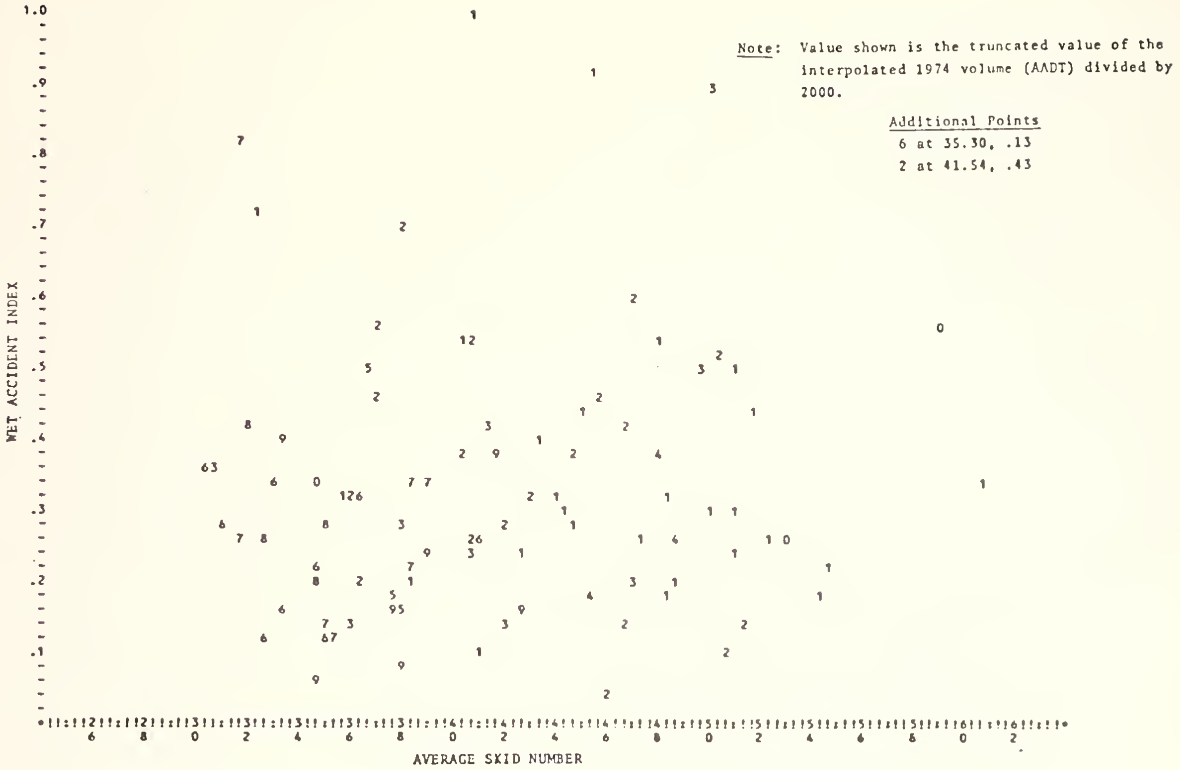

Figure 2D. Wet Accident Index Versus Average Skid Number by Volume Stratification

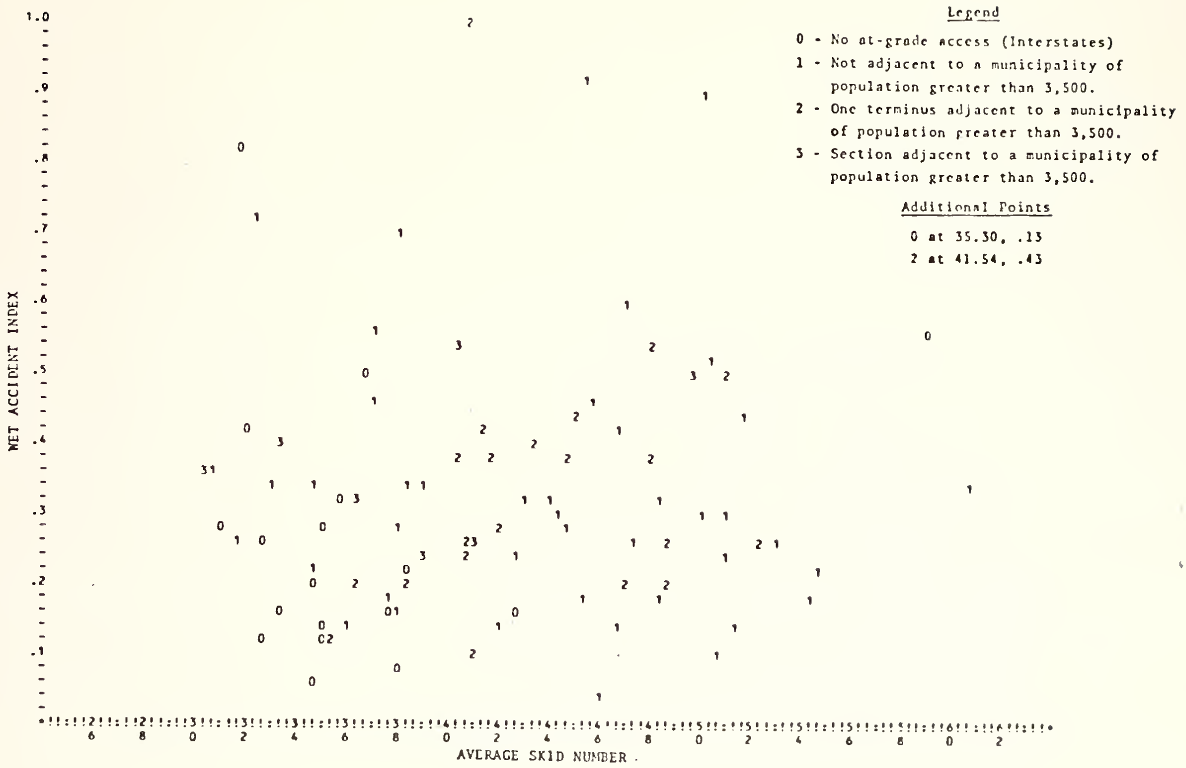

Figure 3D. Wet Accident Index Versus Average Skid Number by Urbanization Factor

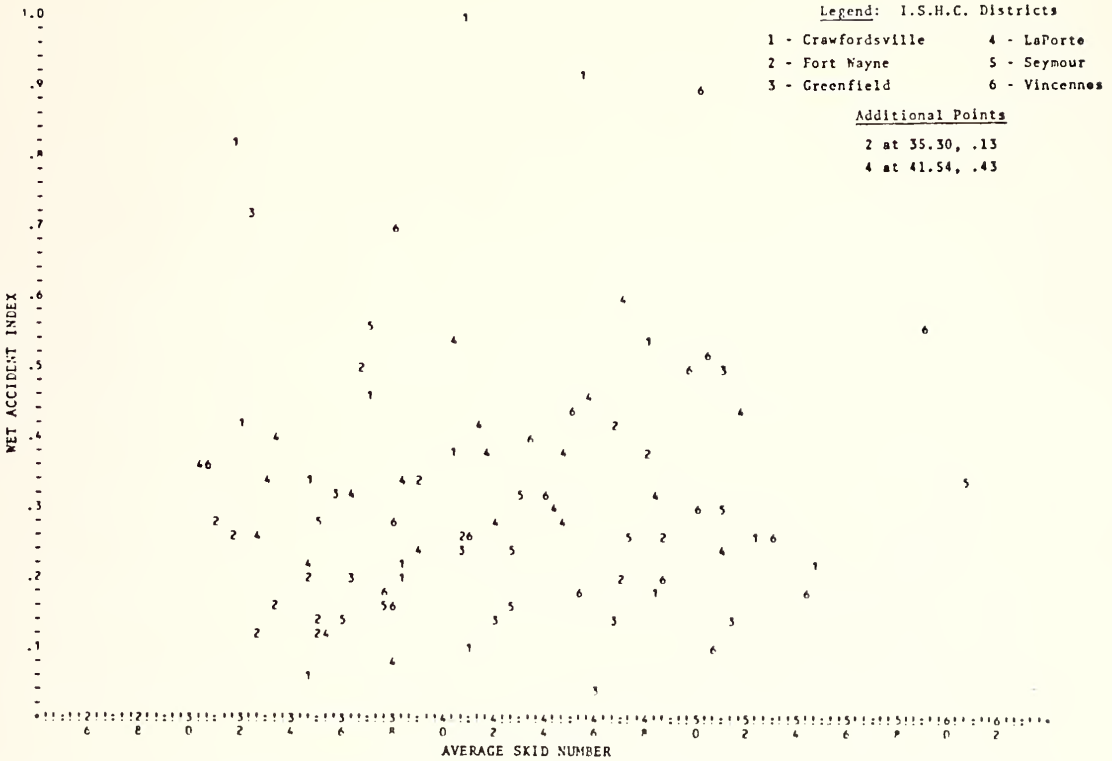

Figure 4D. Wet Accident Index Versus Average Skid Number by I.S.H.C. District

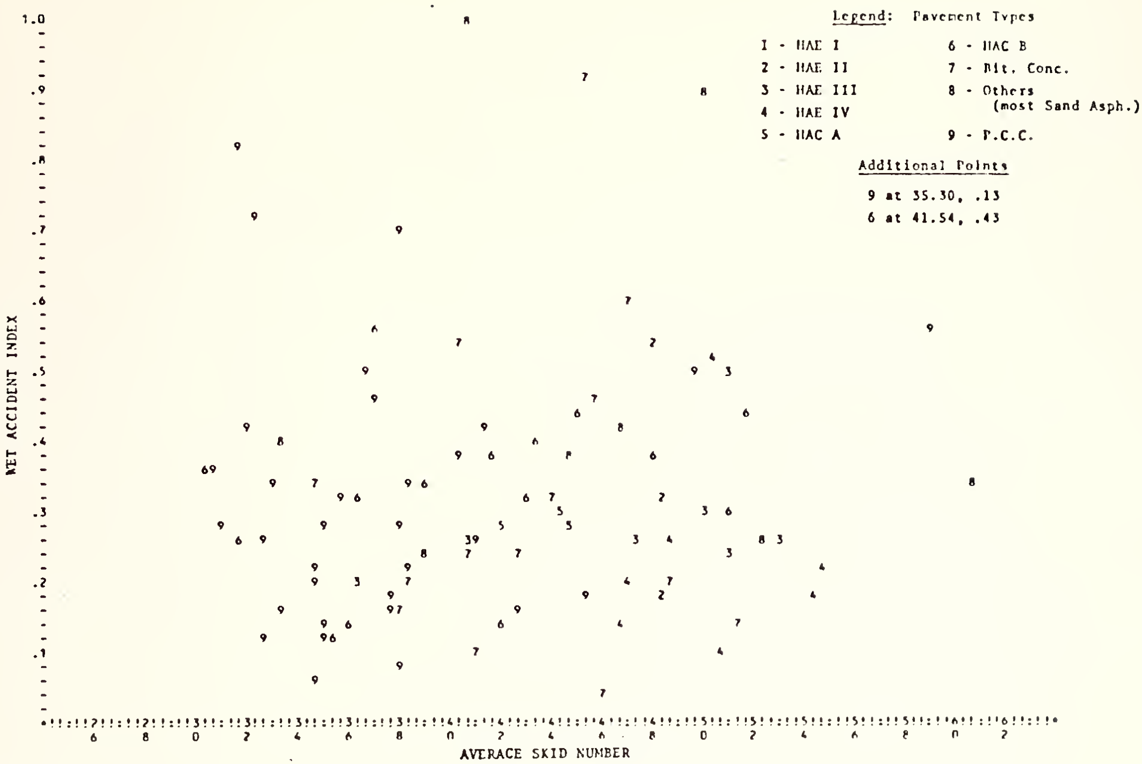

Figure 5D. Wet Accident Index Versus Average Skid Number by Pavement Type

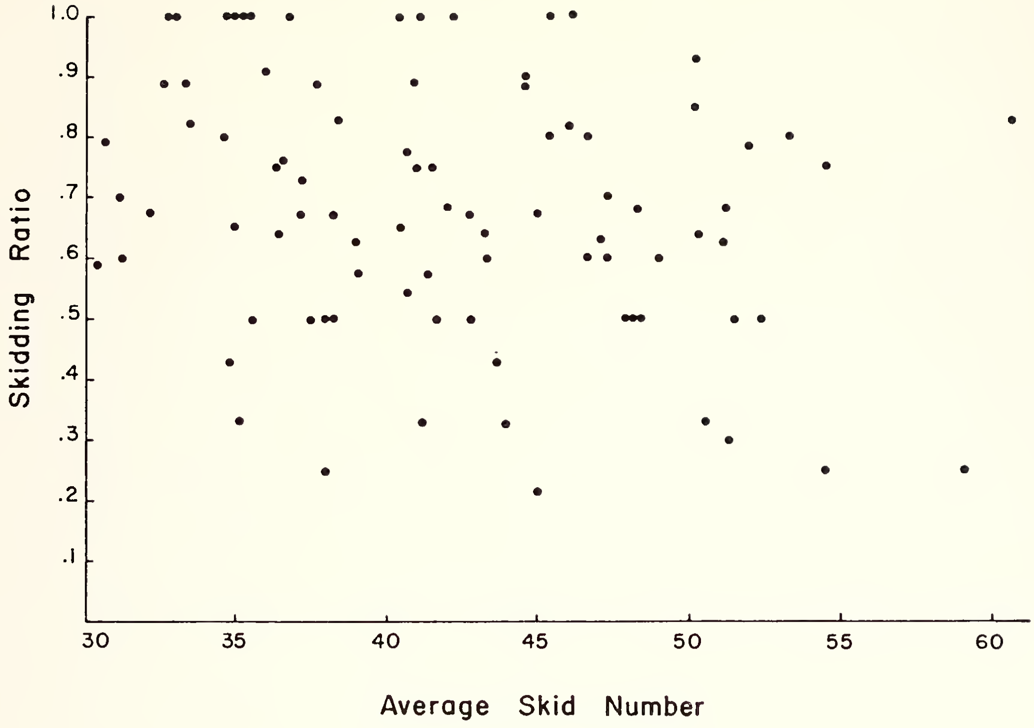

Figure 6D. Possible Plus Probable Skidding Ratio Versus Average Skid Number: Individual Measurements Plotted For All Test Sections

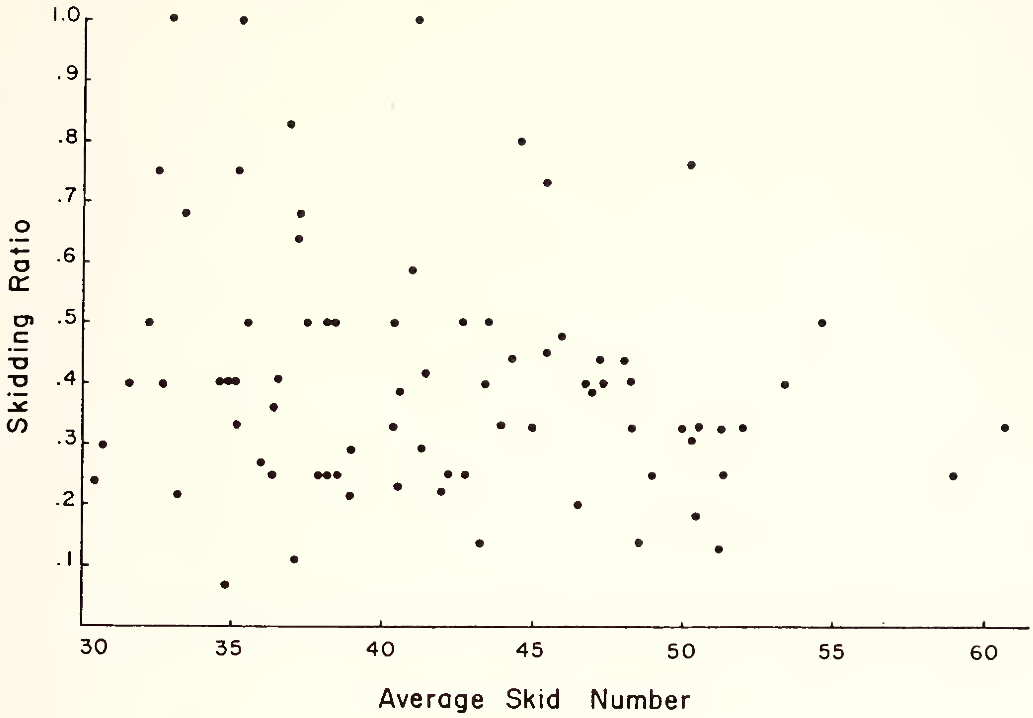

Figure 7D. Skidding Ratio Versus Average Skid Number: Individual Measurements Plotted For All Test Sections

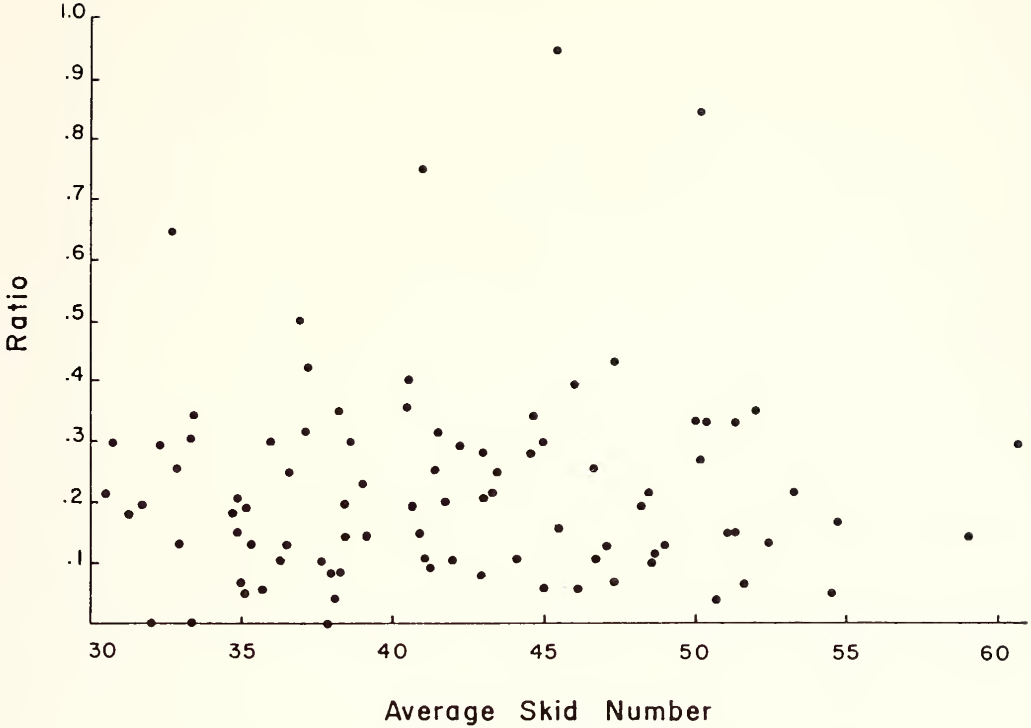

Figure 8D. Ratio of Possible Plus Probable Skidding Wet Pavement Accidents to Dry Pavement Accidents Versus Average Skid Number: Individual Measurements Plotted For All Test Sections

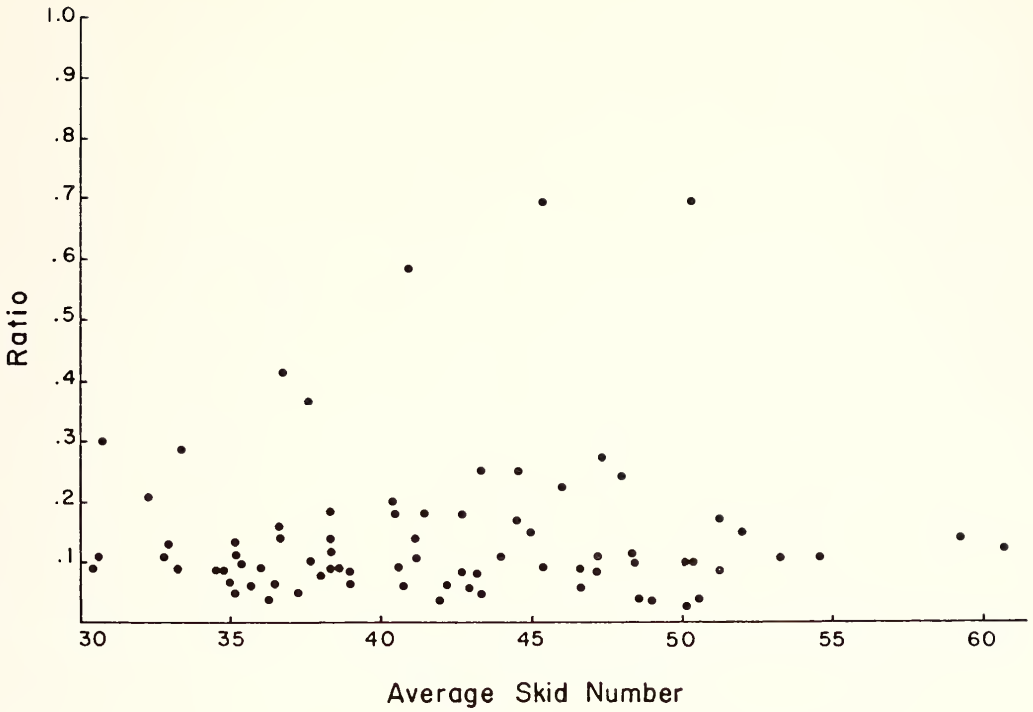

Figure 9D. Ratio of Probable Wet Pavement Skidding Accidents to Dry Pavement Accidents Versus Average Skid Number: Individual Measurements Plotted For All Test Sections

APPENDIX E

CONFIDENCE REGIONS FOR THE TWO LANE SECTIONS

CONFIDENCE REGIONS FOR THE TWO LANE SECTIONS

95% Confidence Region of the Means

Using a method from Morrison's Multivariate Statistical Methods the simultaneous 95% confidence region of the means of the wet accident index and the average skid number of the two-lane routes was formed. The following initial data was used;

	Mean	Stan/Dev	Cases	Correlation Coefficient
Wet accident index	.3754($\bar{x}$)	.2050(σ_x)	50	-.13552(σ_{xy})
Average skid number	44.8456($\bar{y}$)	6.5047(σ_y)	50	

$$\rho_{xy} = \frac{\sigma xy}{\sigma_x \sigma_y}, \therefore \text{ covariance of } x,y = \sigma_{xy} = \rho_{xy}\sigma_x\sigma_y$$

$$\sigma_{xy} = -.13552(.2050)(6.5047)$$
$$= -.18071$$

p = # of parameters = 2

$$X = \text{the covariance matrix equals} \begin{bmatrix} \sigma_{xx} & \sigma_{xy} \\ \sigma_{xy} & \sigma_{yy} \end{bmatrix} = \begin{bmatrix} .04202 & -.18071 \\ -.18071 & 42.3111 \end{bmatrix}$$

$$X^{-1} = \begin{bmatrix} 24.2435 & .10355 \\ .10355 & .02408 \end{bmatrix}$$

Thus the equation of the 95% confidence regions equals

$$24.243\, N(\mu_x-\bar{x})^2 + 2(.10355)N(\mu_x-\bar{x})(\mu_y-\bar{y}) + .02408N(\mu_y-\bar{y})^2$$
$$\leq \frac{(n-1)p}{(n-p)} F_{.95,p,n-p}$$

Therefore,

$$1212.2(\mu_x-.3754)^2 + 10.355(\mu_x-.3754)(\mu_y-44.846) + 1.204(\mu_y-44.846)^2 \leq 2.04(.20)$$

This equation represents an elipse in which 95 out of a hundred samples taken from the same population would include their means.

This elipse was used to see whether the Kentucky data came from a similar population. For Kentucky the mean wet accident index (μ_x) was 0.32 and the average skid number was 39.3.

Thus when these values are used in the formula above, one can test whether the Indiana data (used as a sample data) and the Kentucky data (used as the actual population mean values) differ. If the results show a point within the elipse (the inequality is true) then we cannot say there is a difference in the two data sets. Otherwise we can assume a significant difference between the two sets of data.

$$1212.17(.32-.375)^2 + 10.355(.32-.375)(39.3-44.846) + 1.204(39.3-44.846)^2 \leq 6.528$$

$$43.858 \not\leq 6.528$$

Thus the data for the two states are dissimilar.

Confidence Region for Data Points

A 95% confidence region for the data for two-lane sections points was also calculated. It later proved to have little worth to this study but the method used to develop it is presented here.

The basic formulas used are;

$$\left(\frac{\mu x-\bar{x}}{\sigma_x}\right)^2 - 2\rho\left(\frac{\mu x-\bar{x}}{\sigma_x}\right)\left(\frac{\mu y-\bar{y}}{\sigma_y}\right) + \left(\frac{\mu y-\bar{y}}{\sigma_y}\right)^2 \leq (1-\rho)^2 k^2$$

Where; all variables are the same as the elipse for the means

except $k^2 = -2Ln(2\pi\sigma_x\sigma_y\sqrt{1-\rho^2}\ c)$

where c is defined such that

$$\iint f(x,y)d_x d_y = 1-2\pi\sigma_x\sigma_y\sqrt{1-\rho^2}\ c$$

or $$\alpha = 1-2\pi\sigma_x\sigma_y\sqrt{1-\rho^2}\ c$$

$\alpha = .95$ $\quad c = .00602$
$k = 2.448$

thus;

$$\left(\frac{\mu_x-.375}{.2050}\right)^2 - 2(-.13552)\left(\frac{\mu_x-.375}{.2050}\right)\left(\frac{\mu_y-44.846}{6.505}\right) + \left(\frac{\mu_y-44.846}{6.505}\right)^2 \leq (1+.13552)^2(2.448)^2$$

is the 95% confidence region, while if the inequality ($\leq$) is changed to an equality (=) the formula represents the equation of an elipse within which 95% of the points are expected to fall. (Fig. 1E)

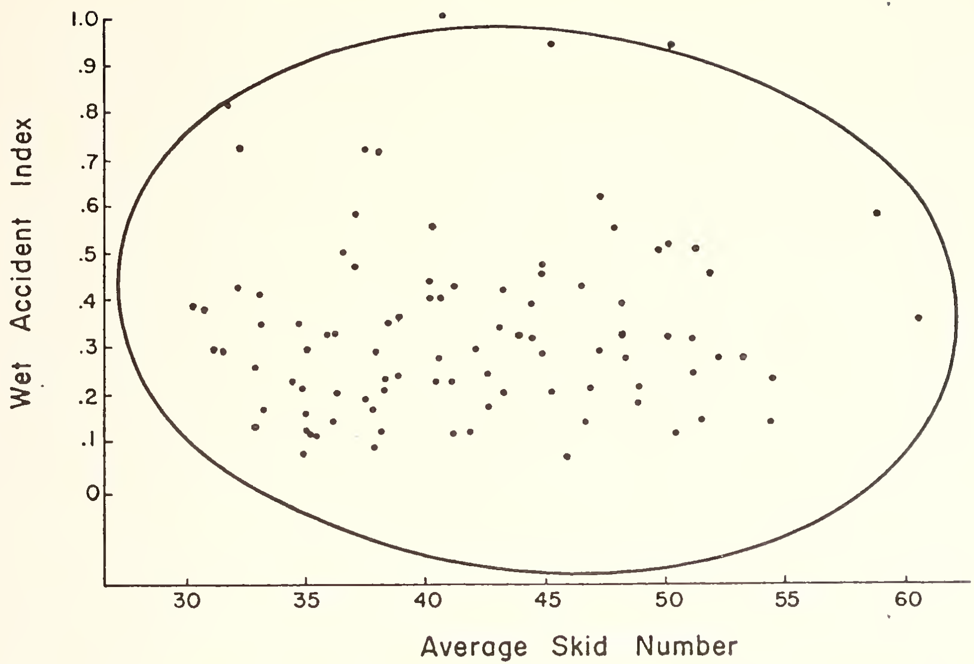

Figure 1E. Wet Accident Index Versus Average Skid Number: Individual Measurements and 95% Confidence Ellipse plotted For All Sections.

NOTES

1. Donald F. Morrison, Multivariate Statistical Methods, McGraw-Hill, New York, 1967.

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