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EVALUATION OF INCREASED PAVEMENT LOADING

Volume II - Computer Program Documentation

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16. Abstract

The effects of increased truck loads and higher tire pressures on performance of flexible pavements were investigated in this project. This report documents four computer programs developed on the project.

Program FEDESAL performs equivalent load calculations using static truck weight loadometer data. Program WIMESAL performs equivalent load calculations from the previous two programs as well as traffic volume and classification data to calculate design traffic loads for existing pavement sections. Program McPAD performs mechanistic pavement designs using the mechanistic damage models developed on this project.

This volume is the second in a two volume series. Volume 1 summarizes the research results and findings from the entire study.

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CHAPTER 1
INTRODUCTION

ARE Inc has developed the microcomputer programs FEDESAL, WIMESAL, TRAF18K and McPAD for the Arizona Department of Transportation. The purpose of FEDESAL is to analyze truck weight data collected at loadometer weight stations. Program WIMESAL analyzes truck weight data collected on a project level basis using weigh-in-motion (WIM) measuring devices. TRAF18K produces design traffic loading estimates from the FEDESAL output and traffic data. McPAD develops mechanistic flexible pavement designs based on the damage models generated in this project (Ref. 8). This manual describes the use of the programs and provides technical documentation for program maintenance.

OVERVIEW OF THE PROGRAMS

The objectives of the FEDESAL and WIMESAL programs are to give quick computations of average 18-kip equivalent single axle loads (18KESAL). Both programs can use either AASHTO load equivalence factors normally used in the production of the W-4 tables for both rigid and flexible pavements or new mechanistically derived load equivalence factors developed by ARE Inc for flexible pavements. For FHWA weight data, these averages are reported per 1000 vehicles by highway functional classifications and truck types. WIM weight data is reported on a project level basis by truck type with an estimate of total 18KESAL in the base year and for a ten- and twenty-year design period. The addition of the new ARE factors allows the user to enter different values for parameters which directly influence the computation of 18KESAL values. This allows greater flexibility in determining how accumulated axle loads affect pavement damage. For interim use, the AASHTO load equivalence factors were extended to allow the consideration of higher tire pressures in a manner consistent with the original factors.

Program TRAF18K computes design traffic loadings in terms of accumulated 18KESAL on design pavement sections. The program uses average vehicle load equivalence factors estimated by program FEDESAL and traffic volume and classification data from Arizona highways as inputs. The program is user friendly and allows for direct edition of vehicle load equivalence factor prediction coefficients.

Program McPAD generates mechanistic structural designs for new pavements using the mechanistic-based damage models developed in this project. As a basis for comparison, it also has the capability of generating designs based on the AASHTO Guide for Design of Pavement Structures (Ref.1). Because of the time required for a typical run, the program is designed to run in "batch" mode, however, it does have an interactive menu-driven component to assist in input data file preparation.

COMPUTER HARDWARE REQUIREMENTS

The computer programs have been designed and developed for operation on an IBM PC or compatible microcomputer using MS-DOS (MicroSoft Disk Operating System) with the following minimum features:

1) one disk drive for double sided, double density floppy disks and for the two ESAL programs, a second disk drive (preferably a hard disk),
2) 256 kilobytes of random access memory (RAM) in a central processing unit compatible with any of the typical personal computer micro-processors,
3) video monitor, and
4) printer.

If no hard disk is available, the ESAL programs can be run on a microcomputer with two floppy disk drives where one disk contains the program and all supporting data files required to operate the program and the other drive is reserved for a disk containing raw loadometer or WIM weight data files. To speed processing time and increase the quantity of data to be analyzed, the use of a hard (fixed) disk is strongly recommended.

OVERVIEW OF THE USERS MANUAL

This users manual provides operation and maintenance information for the four programs. The programs are user-friendly and thus require very little preparation before operation. This manual discusses the contents and formats of the required external data files for the programs so that data can be modified and entered easily. It also explains the sequence of data entry prompts and discusses the different computation options available to the user. The programs are written in modular form so that future improvements can be easily made; in many cases, by modifying only one of the subroutines. Therefore, descriptions of the purpose of each subroutine are also included.

Chapter 2 describes program FEDESAL and Chapter 3 describes program WIMESAL. Chapter 4 covers program TRAF18K and Chapter 5 documents program McPAD. The form and structure of both ESAL programs are similar, but they contain significant differences that require explanation. Therefore, complete descriptions of both programs are given with some material purposely duplicated in both Chapters 2 and 3. This means that each chapter is self-contained, so users who will work only with the FEDESAL program will not need to read Chapter 3 while those who use only WIMESAL will not need Chapter 2. For those users who may use both programs, the necessary documentation has been duplicated wherever possible to avoid confusion.

CHAPTER 2

PROGRAM FEDESAL FOR ANALYZING LOADOMETER DATA

Program FEDESAL computes average equivalent single axle loads per thousand vehicles by highway functional classification, vehicle classification and pavement type. It is designed to be used with a minimum of effort on the part of the user. Features such as two types of load equivalence factors which can both be adjusted for tire pressure effects, an axle load distribution shifting option, two vehicle classification schemes, and four five-year averaging options (dependent upon the type of equivalence factors chosen and the vehicle classification system used) offer a variety of methods to analyze the same weight data under different scenarios. In addition, a data checking routine is included which can be used to verify the data input files.

In order to explain the use of this program, a complete description of the requirements for its operation is given including the data input file descriptions and the series of input prompts to be answered.

PROGRAM OPERATING INSTRUCTIONS

To run the FEDESAL program, turn on the power for the microcomputer, video monitor and printer. Be sure the default drive contains the support data input files and enter the command FEDESAL. A series of prompts will appear on screen which, when answered, will set the parameters for the ensuing run and define how the equivalence factors will be computed. This section describes the series of prompts which set the program's execution path. Different results will be obtained by responding to the prompts in alternative ways.

Program Prompts to Set Run Parameters

The first statement which appears on the screen is a prompt to enter the names of the FHWA weight data files:

```
ENTER A MAXIMUM OF 20 INPUT DATA FILES
ENTER * WHEN FINISHED
```

To enter the name of the first file type the drive location (A, B, C, etc.) followed by a colon (:) and then the file name.

```
The drive and name of input file 1

        #:########.###
-----> 
```

Do not exceed the bounds of the format guide which appears directly above the cursor location. The file name can be shorter than the space provided but cannot be longer. A maximum of 20 file names can be entered. Each file is assumed to be an extension of the file just previously entered. Calculations are made by aggregating the data from all files. After the last file name has been entered, type an asterisk (*) and an answer check of all file names will appear.

```
******** FILE NAME ANSWER CHECK ********

     1     A:WEIGHT86.DAT

ARE THESE FILE NAMES CORRECT?

     1 - YES
     2 - NO

Enter 1 or 2  -----> 
```

At this point, either a 1 for YES or a 2 for NO must be entered. If the response is YES, the program will continue to the next question; if the response is NO, all file names must be entered once more.

When the data file names are correct, the user has the option of checking the contents of the data files for errors.

DO YOU WANT TO CHECK THE DATA FILES?

1 - YES

2 - NO

Enter 1 or 2 ----->

If the response is 1 (YES), the program will read each record of each file name entered and conduct several data checking steps to help ensure the quality of the data. If the response is 2 (NO), the desired function of the current run will be requested as described below.

The purposes of program FEDESAL are to calculate 18KESALs per thousand vehicles and to compute five-year averages of equivalent loads. Three program functions are available for these purposes:

PROGRAM FUNCTION

1 - Evaluate this years data only.

2 - Evaluate this years data,
move previous totals,
create new five-year averages.

3 - Compute five-year averages
using corrected data files.

WARNING!!!! Run function 3 only after errors in the
data files have been corrected that were
found following examination of the output
from function 2

Enter 1, 2, or 3 ----->

The primary purpose of function 1 is to compute 18KESALs per thousand vehicles for the FHWA weight data files entered. This allows computations to be made using special features of the program or to check the data files for any abnormalities which can then be corrected. The special features of this function include options for the evaluation of weight data using changes in legal load limits and the calculation of ARE Inc load equivalence factors using different levels of surface and base/subbase thicknesses, roadbed soil moduli and tire pressures. Function 2 computes new five-year averages from all the data contained in the files entered. This function deletes the oldest year of accumulated equivalent loads and vehicle counts from the five-year average summary data file and the values from the remaining years move back one column. The equivalent loads and vehicle counts calculated from the new load data files entered will then be written into one of four available five-year average summary data files (determined within the program) and new averages computed. Function 3 is only used if some change in the load data files occurs and only after function 2 has been run. With this function none of the data from previous years is deleted from the five-year average file. Only the most recent year is overwritten. This situation may occur if errors in the load data files are discovered after function 2 has been run and should only be used for this purpose. If function 3 is selected the program presents the user a second chance to verify the purpose of the run:

```
The purpose of this run is to correct the
output from function 2 after the FHWA weight
data files have been corrected.

Is this statement correct?

     1 -  Yes
     2 -  No

Enter 1 or 2 ----->
```

If the response is 1 (YES), the program will compute new five-year averages by replacing the most recent estimates of accumulated equivalent weights and vehicle counts with those calculated in this run. If the response is 2 (NO), the program function will be requested once more.

Two options of single axle equivalence factors are available:

EQUIVALENCE FACTORS

1 - AASHTO
2 - ARE Inc

NOTE: If ARE Inc factors are chosen and the five-year averages are not calculated be prepared to enter:

a) asphalt concrete surface thickness,
b) total base/subbase thickness,
c) modulus of roadbed soil and
d) tire pressure.

Enter 1 or 2 ----->

If option 1 is selected, the program will use the equivalence factors in file AASHTO.EQF, which are the equivalence factors used by the FHWA in producing the W-4 tables. An option is also available to allow the use of AASHTO compatible equivalence factors which have been adjusted for increased tire pressures. Therefore, if option 1 is chosen, the following prompt appears:

TIRE PRESSURE

1. Standard AASHO Road Test Pressure (75 psi)
2. ARE Inc Field Measurements of Existing Pressure (110 psi)
3. High Pressure (145 psi)

This is for FLEXIBLE pavement only.
Rigid pavement equivalence factors available only at 75 psi.

Enter 1, 2 or 3 -------->

Option 2 of the "EQUIVALENCE FACTORS" prompt above uses the ARE Inc factors found in file ARE.EQF. At this point, if five-year averages will not be computed, the program will present a series of prompts, to be described later, concerning the values of surface thickness, base/subbase thickness, modulus of roadbed soil and tire pressure which determine which values from the ARE equivalence factor tables will be used.

Axle load distribution shifting appears as a choice only if five-year averages are not computed. This option allows the user to estimate the effects of different legal load limits.

LEGAL LOAD SHIFTING

1 - Use axle load distribution shifting
2 - Do NOT use axle load distribution shifting

Enter 1 or 2 ----->

If the response is 1 (YES), axle load distribution shifting will be used and the user will have the opportunity to view and edit the data currently contained in file SHFTWGT.DAT. This editing procedure will be explained in a later section. If the response is 2 (NO), the next item will appear.

Two vehicle classification options are available:

VEHICLE CLASSIFICATION

1 - Arizona DOT classifications LT, MT, TS, TT and TST
2 - FHWA classifications 5 to 13

Enter 1 or 2 ----->

The first option summarizes the data according to the five vehicle classifications currently used by the Arizona DOT (LT, MT, TS, TT, TST). The second option summarizes the data for classes 5 through 13 used by the FHWA. Classes 1 through 4 of the FHWA represent motorcycles, passenger cars, pickups, and buses and will not be considered within program FEDESAL. The two types of vehicle classifications and the two types of equivalence factors determine which five-year average file is used.

The next entry is available for documenting the printed report. The effective date of the report can be either the current date or any other date desired by the user to give the time when the numbers computed became effective. A special format guide is given for date entry.

```
EFFECTIVE DATE OF REPORT (Month/Day/Year)
      **/**/**
----->
```

All calculations will be written to a disk file specified by the user which can be printed when the program finishes. The file name is entered by responding to the following prompt:

```
OUTPUT FILE

The drive and name of the output file

      #:########.###
----->
```

Sixty (60) columns are provided for any special comments desired by the user to further document the printed output.

```
COMMENTS
      ____________________________________________________________
----->
```

After all data have been entered, an answer check is provided of all the items entered up to this point. For example, if this year's data is to be evaluated only using AASHTO factors, axle shifting, and Arizona's vehicle classification system effective 05/01/86 for a test run written to the file C:OUTPUT86.DAT, the sample input entries would appear as follows:

```
******** ANSWER CHECK ********

   PROGRAM FUNCTION:  Evaluate this years data only
EQUIVALENCE FACTORS:  AASHTO
  LOAD DISTRIBUTION
           SHIFTING:  Will be used
     CLASSIFICATION:  Arizona DOT classifications LT, MT, TS, TT and TST
     EFFECTIVE DATE:  05/01/86
        OUTPUT FILE:  C:OUTPUT86.DAT
           COMMENTS:  Test run

ARE THESE ENTRIES CORRECT?

     1 - YES
     2 - NO

Enter 1 or 2 ----->
```

If the response to this entry is 1 (YES) the program will respond with the statement:

```
          ***** DO NOT INTERRUPT - PROGRAM RUNNING *****
```

If the response to the answer check is 2 (NO), all run specifications must be entered again.

For each weight data file entered the following statement will appear with its given file drive and name specification.

```
          >>>>>>>>>> Reading File A:WEIGHT86.DAT
```

Prompts to Set ARE Inc's Single Axle Load Equivalence Factors

These prompts give the user a choice of different levels of factors which identify appropriate load equivalence factors. If five-year averages are to be computed, the levels of the input variables are automatically set within the program. This is done to standardize the computation of five-year averages in order to maintain consistency from year to year in the input parameters. The program indicates the default values as:

TO COMPUTE THE FIVE-YEAR AVERAGES, THE
FOLLOWING DEFAULT VALUES WILL BE ASSIGNED

Surface Thickness = 3 in.
Base/Subbase Thickness = 14 in.
Roadbed Soil Modulus = 12000 psi
Tire Pressure = 105 psi

If only data from the current year are to be analyzed, choices of the appropriate levels of surface thickness, base/subbase thickness, roadbed soil modulus and tire pressure are given. Three allowable values given for each parameter are:

ASPHALT CONCRETE SURFACE THICKNESS

1	Thin	-	< 1 in.	(assigns 0 inches)
2	Medium	-	1 - 5 in.	(assigns 3 inches)
3	Thick	-	> 5 in.	(assigns 6 inches)

Enter 1, 2 or 3 ----->

TOTAL BASE/SUBBASE THICKNESS

1 Thin - < 10 in. (assigns 4/4 inches)

2 Medium - 10 - 17 in. (assigns 6/8 inches)

3 Thick - > 17 in. (assigns 8/12 inches)

Enter 1, 2 or 3 ----->

ROADBED SOIL MODULUS

1 = Low < 8000 psi (assigns 4000 psi)

2 = Medium 8000 - 16000 psi (assigns 12000 psi)

3 = High > 16000 psi (assigns 20000 psi)

4 = Actual Value

Enter 1, 2, 3 or 4 ----->

Instead of the categorical values of roadbed soil modulus, the user has the option of entering the actual value. The following prompt appears when the user selects option 4.

ACTUAL ROADBED SOIL MODULUS

The allowable range is 3000.0 psi to 21000.0 psi

(The decimal point is required)

1234567890

----->

Following the prompt for roadbed soil modulus, the user is asked to enter the expected values of tire pressure for all vehicle classes.

TIRE PRESSURE

1 Standard AASHO Road Test Pressure (75 psi)

2 ARE Inc Field Measurements of Existing Pressures (110 psi)

3 High Pressure (145 psi)

4 Actual Value

Enter 1, 2, 3 or 4 ----->

The user again has the option to enter the actual value of tire pressure, if known, like the entry for roadbed soil modulus.

ACTUAL TIRE PRESSURE

The allowable range is 70.0 psi to 160.0 psi
(The decimal point is required)

```
       1234567890
----->
```

After all inputs required to use ARE Inc factors have been entered, an answer check is provided. For example, if a thin surface thickness, medium subbase thickness, medium roadbed soil modulus and tire pressure of 100.0 psi were selected, the input entries would appear as follows:

******** ANSWER CHECK ********

ASPHALT CONCRETE THICKNESS:	Thin -	< 1 in.
BASE AND SUBBASE THICKNESS:	Medium -	10 - 17 in.
ROADBED SOIL MODULUS:	Medium	8000 - 16000 psi
TIRE PRESSURE:	100.0 psi	

ARE THESE ANSWERS CORRECT?

1 - YES
2 - NO

Enter 1 or 2 ----->

At this point enter either 1 for YES or 2 for NO. If the response is YES the program will return to the main sequence of questions; if the response is NO, the user must re-enter the data related to ARE Inc factors.

Editing Axle Load Distribution Shifting Data

When the axle load distribution shifting option is selected, the contents of the file SHFTWGT.DAT will appear on the screen in the format shown in Figure 2.1. The current entries for tare weights, current legal limits and proposed legal limits are shown for each axle set type and gross vehicle weight. At the bottom of the display, the user has the option of editing one of the three types of data or, if they are correct, return to the main sequence of questions. If the user chooses to edit tare weights, the following sequence of prompts appears:

ENTER NEW TARE WEIGHTS FOR ALL AXLE SET TYPES
(Decimal points are required)

Front Axle Current Value = 5000.00

1234567890
Correct Number -----> 5000.

Single Axle Current Value = 5000.0

Figure 2-1. Contents of axle load distribution shifting data file SHFTWGT.DAT as it appears on the screen.

AXLE SHIFTING PARAMETERS

Tare Weights (pounds)

Front Axle:	5000.0
Single Axle:	5000.0
Tandem Axle:	15000.0
Triple axle:	20000.0

Maximum Weights (pounds)

	Current Law	Proposed Law
Front Axle:	20000.0	22000.0
Single Axle:	20000.0	22000.0
Tandem Axle:	32000.0	33000.0
Triple Axle:	42000.0	44000.0
Gross Weight:	80000.0	85000.0

TYPE OF DATA TO MODIFY

0 = None - the weights are correct
1 = Tare Weights
2 = Current Load Limits
3 = Proposed Load Limits

Enter 0, 1, 2 or 3 ----->

```
                    1234567890
Correct Number -----> 5000.

Tandem Axle Current Value = 15000.0


                    1234567890
Correct Number -----> 15000.

Triple Axle Current Value = 20000.0


                    1234567890
Correct Number -----> 20000.
```

For each axle set type, the program displays the current value and asks for the correct value. If the value is already correct, then reenter the same number at the cursor location. Remember to use the decimal point in its proper place; otherwise, erroneous numbers will appear. Once all entries are made for one of the three data types, the display shown in Figure 2.1 appears once more showing the corrected entries. At that point, either another type of data can be edited or the user can return to the main sequence of questions. The editing procedures for maximum weights under the current and proposed laws are the same except gross vehicle weights are also included:

```
Gross Vehicle Current Value = 80000.0


                    1234567890
Correct Number -----> 80000.
```

When option 0 is selected, all edited values of the three types of data are written to file SHFTWGT.DAT where they are available for future use.

Program Output

Once the weight data file names have been entered by the user and all prompts have been answered, program execution begins. At this point, the user must wait 15 to 30 minutes (depending on the size of the weight data file) for the program to read all the data, perform its calculations and print the output report. When finished, the following message appears on the screen:

Program Finished

The results of this analysis
are contained in the output file C:OUTPUT86.DAT

The four pages of the FEDESAL output are given in Figure 2.2. The output shows the responses to the questions input by the user for the run at the top of each page. If ARE Inc equivalence factors were chosen, the values of each of the three road characteristics and the tire pressure entered by the user appear.

The numerical summaries of the analysis for each functional class are presented in the lower portion of each printed page. If Arizona's vehicle classification system was selected, LT, MT, TT, TS and TST are printed underneath the vehicle class heading. The numbers 5 to 13 appear there if the FHWA system was selected. Total vehicle counts and current 18 KIP ESAL per 1000 vehicles are printed for each vehicle classification. If five-year 18KESAL averages were selected, these numbers appear for both rigid and flexible pavements in two additional columns (not shown).

DATA INPUT FILES

Before the program can be run, the first four sets of files presented below must exist in the default disk drive. The fifth set consisting of truck weight data in the FHWA format may exist in any available drive. The five sets of input data files are as follows:

AVERAGE 18 KIP EQUIVALENT SINGLE
AXLE LOADS PER 1000 VEHICLES
USING FHWA TRUCK WEIGHT DATA

COMMENTS: ARE Inc Equivalence Factors Used
Rigid Factors not Calculated
Example Run for Final Report

Station Location: Interstate

Road Characteristics Used to Compute ARE Inc Factors

Surface Thickness:	Medium = 1 - 5 in.
Base/Subbase Thickness:	Medium = 10 - 17 in. overall
Roadbed Soil Modulus:	12000.0 psi
Tire Pressure:	105.0 psi

VEHICLE CLASS	TOTAL VEHICLE COUNTS	CURRENT 18 KIP ESAL PER 1000 VEHICLES		FIVE-YEAR AVERAGE 18 KIP ESAL PER 1000 VEHICLES	
		RIGID	FLEXIBLE	RIGID	FLEXIBLE
LT	0	.0	.0	.0	72.7
MT	1	.0	92.4	.0	2980.1
TS	8	.0	24933.8	.0	27348.1
TT	0	.0	.0	.0	33513.7
TST	4	.0	9440.8	.0	11231.3

Figure 2.2. Example output from program FEDESAL using ARE Inc equivalence factors (page 1 of 4).

AVERAGE 18 KIP EQUIVALENT SINGLE
AXLE LOADS PER 1000 VEHICLES
USING FHWA TRUCK WEIGHT DATA

COMMENTS: ARE Inc Equivalence Factors Used
Rigid Factors not Calculated
Example Run for Final Report

Station Location: Primary/Secondary

Road Characteristics Used to Compute ARE Inc Factors

Surface Thickness: Medium = 1 - 5 in.
Base/Subbase Thickness: Medium = 10 - 17 in. overall
Roadbed Soil Modulus: 12000.0 psi
Tire Pressure: 105.0 psi

VEHICLE CLASS	TOTAL VEHICLE COUNTS	CURRENT 18 KIP ESAL PER 1000 VEHICLES		FIVE-YEAR AVERAGE 18 KIP ESAL PER 1000 VEHICLES	
		RIGID	FLEXIBLE	RIGID	FLEXIBLE
LT	1	.0	81.3	.0	70.1
MT	2	.0	1167.7	.0	963.2
TS	3	.0	19434.0	.0	13180.7
TT	0	.0	.0	.0	.0
TST	2	.0	3667.9	.0	5971.9

Figure 2.2. Example output from program FEDESAL using ARE Inc equivalence factors (page 2 of 4).

AVERAGE 18 KIP EQUIVALENT SINGLE
AXLE LOADS PER 1000 VEHICLES
USING FHWA TRUCK WEIGHT DATA

COMMENTS: ARE Inc Equivalence Factors Used
Rigid Factors not Calculated
Example Run for Final Report

Station Location: Urban

Road Characteristics Used to Compute ARE Inc Factors

Surface Thickness: Medium = 1 - 5 in.
Base/Subbase Thickness: Medium = 10 - 17 in. overall
Roadbed Soil Modulus: 12000.0 psi
Tire Pressure: 105.0 psi

VEHICLE CLASS	TOTAL VEHICLE COUNTS	CURRENT 18 KIP ESAL PER 1000 VEHICLES		FIVE-YEAR AVERAGE 18 KIP ESAL PER 1000 VEHICLES	
		RIGID	FLEXIBLE	RIGID	FLEXIBLE
LT	5	.0	73.8	.0	72.6
MT	4	.0	1679.4	.0	986.0
TS	8	.0	17865.0	.0	12880.7
TT	0	.0	.0	.0	.0
TST	4	.0	4007.6	.0	6021.8

Figure 2.2. Example output from program FEDESAL using ARE Inc equivalence factors (page 3 of 4).

```
                    AVERAGE 18 KIP EQUIVALENT SINGLE
                      AXLE LOADS PER 1000 VEHICLES
                      USING FHWA TRUCK WEIGHT DATA

COMMENTS:  ARE Inc Equivalence Factors Used
           Rigid Factors not Calculated
           Axle Shifting Option NOT Used
           Example run for final report

  FHWA DATA FILES USED

        1     86WEIGHT.DAT
```

Figure 2.2. Example output from program FEDESAL using ARE Inc equivalence factors (page 4 of 4).

1) AASHTO.EQF
2) ARE.EQF
3) SHFTWGT.DAT
4) Four files with total accumulated equivalent axle loads and vehicle counts for five years
5) Truck weight data in FHWA format

The contents and formats of each of these files are briefly described below.

AASHTO.EQF

This file contains the 18-kip single axle equivalence factors from the AASHTO Guide to Design of Pavement Structures (Ref. 1) as they currently appear in the FHWA W-4 weight tables. This file also contains the AASHTO compatible factors for flexible pavements which have been extended to account for increased tire pressures. Appendix A provides a descriptive listing of the contents of file AASHTO.EQF. For each record, the first four variables are descriptive items of the final four variables which are the rigid and flexible 18-kip equivalence factors. The columns where each variable is located and its respective Fortran format are:

1) Axle set type (column 1, I1).
2) Weight interval index (columns 2-3, I2).
3) Lower limit of weight interval (columns 4-13, F10.1).
4) Upper limit of weight interval (columns 14-23, F10.1).
5) Rigid 18-Kip ESAL factor (columns 24-33, F10.4).
6) Flexible 18-Kip ESAL factor for 75 psi tire pressure (columns 34-43, F10.4).
7) Flexible 18-Kip ESAL factor for 110 psi tire pressure (columns 44-53, F10.4).
8) Flexible 18-Kip ESAL factor for 145 psi tire pressure (columns 54-63, F10.4).

All equivalence factors and their respective weight class intervals for both rigid and flexible pavements are stored by the numerical index of four axle set types found in column 1 which are defined as:

1 = single axle, single tires
2 = single axle, dual tires
3 = tandem axle
4 = triple axle

For each axle set type, columns 2 and 3 contain the weight interval indices for the equivalence factors defined by the lower bound in columns 4-13 and the upper bound defined in columns 14-23. These weight intervals are sorted from lowest to highest with no gaps larger than one pound between intervals. The highest weight interval contains as its upper bound a very large number such that no correct axle set weight will ever exceed it (unless there is an error). The weight interval indices are assigned in numerical order with 1 assigned to the lowest weight class interval and sequentially up to the highest weight class interval within each axle set type.

Equivalence factors for rigid and flexible pavements appear in columns 24-33 and 34-63, respectively. Equivalence factors for axle set types 1 and 2 are identical at 75 psi since the FHWA does not currently distinguish between single axle, single tires and single axle, dual tires. The FHWA also does not account for triple axles and, therefore, no factors appear for these in the file. The file has this format because the file containing ARE Inc factors does account for a difference between the first two types of axle sets and includes equivalence factors for triple axles. A similar format was maintained between the two files because the method used to compute axle set type does not vary with choice of factor type. If a method to calculate factors for single axle, single tires or triple axles using FHWA data is developed, the new values can easily be inserted into the file. Currently, if a triple axle is found in the weight data file when the FHWA factors are used, the program assigns the axle set an equivalence factor equal to a tandem value for the same weight interval.

This file can be easily expanded to include up to 25 weight intervals for each axle set type without any modifications to the program. For example, more precise results are produced when smaller weight intervals and their corresponding load equivalence factors are supplied. This may be accomplished by redefining the lower and upper bounds of each interval and inserting the corresponding load equivalence factors in their appropriate columns in the data file.

ARE.EQF

This file contains the mechanistic load equivalence factors derived by ARE Inc. A descriptive listing of the contents of this file is provided in Appendix B. A broad range of equivalence factors are included based on several variables which theoretically influence their magnitude. In addition to axle weight, these include surface thickness, base/subbase thickness, tire pressure, roadbed soil modulus and axle set type.

The file is divided into four sets of factors defined by axle set type:

1) Rows 1 to 27 - single axle, single tire
2) Rows 28 to 72 - single axle, dual tires
3) Rows 73 to 117 - tandem axle
4) Rows 118 to 162 - triple axle

These row assignments are inflexible since the program reads this file sequentially, based on an expected record count for each axle set type.

For each record in the file, the first four variables are descriptive items and the remaining nine variables are the flexible pavement load equivalence factors for nine combinations of surface and base/subbase thicknesses. The columns and respective Fortran formats for each variable are:

1) Classification interval index (columns 1-2, I2).
2) Roadbed soil modulus (columns 3-8, F6.0).
3) Tire pressure (columns 9-12, F4.0).
4) Weight of axle set in 1000's (columns 13-16, F4.0).
5) 18-Kip equivalence factor for surface thickness < 1 in. and base/subbase thickness < 10 in. (columns 17 to 26, F10.4).
6) 18-Kip equivalence factor for surface thickness < 1 in. and base/subbase thickness 10-17 in. (columns 27 to 36, F10.4).
7) 18-Kip equivalence factor for surface thickness < 1 in. and base/subbase thickness > 17 in. (columns 37 to 46, F10.4).
8) 18-Kip equivalence factor for surface thickness 1-5 in. and base/subbase thickness < 10 in. (columns 47 to 56, F10.4).
9) 18-Kip equivalence factor for surface thickness 1-5 in. and base/subbase thickness 10-17 in. (columns 57 to 66, F10.4).
10) 18-Kip equivalence factor for surface thickness 1-5 in. and base/subbase thickness > 17 in. (columns 67 to 76, F10.4).
11) 18-Kip equivalence factor for surface thickness > 5 in. and base/subbase thickness < 10 in. (columns 77 to 86, F10.4).
12) 18-Kip equivalence factor for surface thickness > 5 in. and base/subbase thickness 10-17 in. (columns 87 to 96, F10.4).
13) 18-Kip equivalence factor for surface thickness > 5 in. and base/subbase thickness > 17 in. (columns 97 to 106, F10.4).

When ARE Inc factors are selected, all of these values are read into data arrays in the program. The combination of surface and base/subbase thicknesses entered determines which set of equivalence factors will be used in a multivariate interpolation algorithm to find an approximation to the actual 18K equivalence factor based on the axle set type, weight, tire pressure and roadbed soil modulus. For single axles, single tires, three levels of each of these variables appear. Therefore, for each of the nine combinations of surface and base/subbase thicknesses there will be twenty-seven different combinations for which each will have an equivalence factor. The other three axle set types have five different weight levels and three levels of the other two factors for a total number of forty-five combinations of these three factors, each with a specific equivalence factor assigned to it.

The sorting of variables within the file is crucial to correct operation of the interpolation algorithm. Within each axle set type, the levels of roadbed soil modulus must appear in ascending order with each value of tire pressure. All values of tire pressure must appear in ascending order with each value of weight (in 1000s).

SHFTWGT.DAT

This file contains the weights used in the axle load distribution shifting option to determine what the actual axle set weights would be if legal load limits were changed and how accumulated 18 KIP ESALs would be affected. The first record contains the assumed tare (or unloaded) weights for each axle set. The columns where each variable is located and its respective format are:

1) front axle (columns 1-10, F10.1)
2) single axle (columns 11-20, F10.1)
3) tandem axle (columns 21-30, F10.1)
4) triple axle (columns 31-40, F10.1)

Records 2 and 3 contain the current and proposed legal load limits, respectively, for the different types of axle sets and gross vehicle weight. The columns where each variable is located and its respective format are:

Record 2 Current Load Limits and Record 3 Proposed Load Limits

1) front axle (columns 1-10, F10.1)
2) single axle (columns 11-20, F10.1)
3) tandem axle (columns 21-30, F10.1)
4) triple axle (columns 31-40, F10.1)
5) gross vehicle weight (columns 41-50, F10.1)

All values in all records must contain a decimal point or erroneous numbers will be read. When the shifting option is specified, the current values of file SHFTWGT.DAT will appear on the screen. The program allows new values to be entered in their place if they are not correct.

Files for Five-Year Averages

Four files are available to store total accumulated equivalent loads and vehicle counts in order to compute five-year averages of accumulated 18KESALs per thousand vehicles for three classifications:

1) pavement type
   a) rigid
   b) flexible
2) functional classification
   a) interstate
   b) primary/secondary
   c) urban
3) vehicle classification
   a) five classifications of Arizona
   b) classifications 5 to 13 of the FHWA

These data are stored in the files:

1) FHWA5AV5.DAT - FHWA factors, five vehicle classifications
2) FHWA5AV9.DAT - FHWA factors, nine vehicle classifications
3) ARE5AV5.DAT - ARE Inc factors, five vehicle classifications
4) ARE5AV9.DAT - ARE Inc factors, nine vehicle classifications

The program reads the appropriate file and then overwrites it depending on the responses to the input prompts concerning factor types and vehicle classifications. Therefore, in computing the five-year averages, it is necessary to know which years are represented in the file before the new averages are calculated. The averages are updated each time data for a new year are processed. It is recommended that the fifth oldest year be used first, then the fourth, and so on until data from the five most recent years are used. If AASHTO equivalence factors are used, the program allows factors computed at different tire pressures in the same file to make allowance for increasing tire pressure over time. The columns for each variable and its respective Fortran format are:

1) Pavement type index (column 2, I1).
2) Functional classification index (column 3, I1).
3) Vehicle classification index (column 4, I1).
4) Total accumulated loads, year 1 (columns 5 to 19, F15.4).
5) Total accumulated loads, year 2 (columns 20 to 34, F15.4).
6) Total accumulated loads, year 3 (columns 35 to 49, F15.4).
7) Total accumulated loads, year 4 (columns 50 to 64, F15.4).
8) Total accumulated loads, year 5 (columns 65 to 79, F15.4).
9) Total vehicle counts, year 1 (columns 80 to 84, I5).
10) Total vehicle counts, year 2 (columns 85 to 89, I5).
11) Total vehicle counts, year 3 (columns 90 to 94, I5).
12) Total vehicle counts, year 4 (columns 95 to 99, I5).
13) Total vehicle counts, year 5 (columns 100 to 104, I5).

FHWA Truck Weight Data Input Files

The weight data to be analyzed are contained in FHWA weight data files. These should reside either on the hard (fixed) disk or on a separate floppy disk. The program asks the user to enter the proper disk drive location and name and then, after responses are given to all input prompts, it reads each file from beginning to end. A data checking option (described in detail later) is available to check the contents of these files for accuracy. The user can do little to adjust the data in this file, however, since it consists of measurements collected at different locations over time. A complete format of this file is displayed in Table 2.1. Each vehicle will have one or two records depending on the number of axles. Much of the data contained in each record is not used for the purposes of this program. The columns and respective Fortran format for each variable read are:

1) Functional classification (columns 4-5, I2).
2) Station identification number (columns 6-8, A3).
3) Vehicle type code (columns 18-23, F6.0).
4) Load status code (column 41, I1).
5) Total weight of truck or combination (columns 42-45, F4.0).
6) A-axle weight (columns 46-48, F3.0).
7) B-axle weight (columns 49-51, F3.0).
8) C-axle weight (columns 52-54, F3.0).
9) D-axle weight (columns 55-57, F3.0).
10) E-axle weight (columns 58-60, F3.0).
11) (A-B) axle spacing (feet and tenths) (columns 61-63, F3.1).
12) (B-C) axle spacing (feet and tenths) (columns 64-66, F3.1).
13) (C-D) axle spacing (feet and tenths) (columns 67-69, F3.1).
14) (D-E) axle spacing (feet and tenths) (columns 70-72, F3.1).
15) Total wheelbase (columns 73-76, F4.1).
16) Continuation indicator (column 80, I1).

The columns and format for each variable read by FEDESAL from the continuation record are:

1) F-axle weight (columns 29-31, F3.0).
2) G-axle weight (columns 32-34, F3.0).
3) H-axle weight (columns 35-37, F3.0).
4) I-axle weight (columns 38-40, F3.0).
5) J-axle weight (columns 41-43, F3.0).
6) K-axle weight (columns 44-47, F3.0).
7) L-axle weight (columns 47-49, F3.0).

Table 2.1. Format of FHWA truck weight record (Page 1 of 2).

FACE RECORD

Columns	No. of Columns	Description
1	1	Truck weight record code (7)
2-3	2	State code
4-5	2	Functional classification
9	1	Direction of travel
10-11	2	Year of data
12-13	2	Month of data
14-15	2	Date of month
16-17	2	Hour of day
18-23	6	Vehicle type code
24-25	2	Body type
26	1	Engine type
27-28	2	(open)
29-31	3	Registered weight (thousands of pounds)
32	1	Basis of registration
33-35	3	(open)
36-40	5	Commodity code
41	1	Load status code
42-25	4	Total weight of truck or combination
46-48	3	A-axle weight (hundreds of pounds)
49-51	3	B-axle weight " " "
52-54	3	C-axle weight " " "
55-57	3	D-axle weight " " "
58-60	3	E-axle weight " " "
61-63	3	(A-B) axle spacing (feet and tenths)
64-66	3	(B-C) axle spacing " " "
67-69	3	(C-D) axle spacing " " "
70-72	3	(D-E) axle spacing " " "
73-76	4	Total wheelbase
77-79	3	Record serial number
80	1	Continuation indicator (0 = no continuation record 1 = has a continuation record)

*Note: No data in Columns 6-8.

Table 2.1. Format of FHWA truck weight record (Page 2 of 2).

CONTINUATION RECORD*

Columns	No. of Columns	Description
1-28	28	Same as columns 1-28 of the face record
29-31	3	F-Axle weight (hundreds of pounds)
32-34	3	G-Axle weight " " "
35-37	3	H-Axle weight " " "
38-40	3	I-Axle weight " " "
41-43	3	J-Axle weight " " "
44-46	3	K-Axle weight " " "
47-49	3	L-Axle weight " " "
50-52	3	M-Axle weight " " "
53-55	3	(E-F) axle spacing (feet and tenths)
56-58	3	(F-G) axle spacing " " "
59-61	3	(G-H) axle spacing " " "
62-64	3	(H-I) axle spacing " " "
65-67	3	(I-J) axle spacing " " "
68-70	3	(J-K) axle spacing " " "
71-73	3	(K-L) axle spacing " " "
74-76	3	(L-M) axle spacing " " "
77-79	3	Record serial number
80	3	Continuation indicator (2 = first continuation record for a vehicle with more than 13 axles 9 = last continuation record)

*Used only for truck combinations having six or more axles and immediately follows the face record.

8) M-axle weight (columns 50-52, F3.0).
9) (E-F) axle spacing (feet and tenths) (columns 53-55, F3.1).
10) (F-G) axle spacing (feet and tenths) (columns 56-58, F3.1).
11) (G-H) axle spacing (feet and tenths) (columns 59-61, F3.1).
12) (H-I) axle spacing (feet and tenths) (columns 62-64, F3.1).
13) (I-J) axle spacing (feet and tenths) (columns 65-67, F3.1).
14) (J-K) axle spacing (feet and tenths) (columns 68-70, F3.1).
15) (K-L) axle spacing (feet and tenths) (columns 71-73, F3.1).
16) (L-M) axle spacing (feet and tenths) (columns 74-76, F3.1).
17) Continuation indicator (column 80, I1).

DETAILED PROGRAM DOCUMENTATION

This section describes in greater detail the structure of the program and the functions of each subroutine. The computer code is extensively documented and many questions concerning its operation can be answered by referring directly to the source code. Descriptions of the algorithms used to compute functional class, vehicle type codes, axle shifted weights and interpolate ARE Inc equivalence factors values are explained. A list of all important internal variables and their definitions is given along with a listing of the subroutines and their functions.

Functional Classification

The program uses the variable IFNTCL from the FHWA weight data file to assign all calculations from each truck record to one of the following functional classifications:

1)	Interstate	IFNTCL = 01 or 11
2)	Primary/Secondary	02 <= IFNTCL <= 09
3)	Urban	12 <= IFNTCL <= 19

After all weight data are read, the program prints reports for each of these three highway classifications.

Vehicle Classifications

The six-digit vehicle type code, VEHTYP, read from the FHWA weight file is translated into a different form for reporting purposes. Arizona currently uses a five vehicle classification system and the FHWA has its own interpreted code of thirteen vehicle classes. The purpose of this section is to briefly describe how both translations work.

FHWA vehicle type code. Table 2.2 describes the format of the six-digit vehicle type code found in the FHWA weight data files. The first character is a basic vehicle type code number including the integers from 0 to 8. The codes 0 and 1 relate to personal passenger vehicles and buses and are not used. The remaining digits of the code refer to a count of the number of axles found on the power unit and any attached trailers. The second page of Table 2.2 gives the translation of these codes. Thus, by examining the number of nonzero digits in the code a good description of the configuration of the truck can easily be found and a translation made to one of the two types of vehicle classification systems.

Vehicle Classifications of Arizona. The vehicle classification system used by Arizona is shown in Table 2.3. The classes of interest for this program are those for commercial vehicles only. Subroutine CLSFY5 interprets the six-digit code as follows:

Arizona Code	FHWA Description	Basic Vehicle Type Character
LT	Single-unit trucks with two-axles, four-tires	2
MT	Single-unit trucks with two-axles, six-tires	2
TS	Tractor + semitrailer	3
TT	Truck + full trailer	4
TST	Truck or Tractor and two or more trailers	5,6,7 or 8

Table 2.2. Description of six-digit FHWA vehicle type code (Page 1 of 2).

Vehicle Type Coding Chart*

	1st Digit	2nd Digit	3rd Digit	4th Digit	5th Digit	6th Digit
Personal passenger vehicles	basic vehicle type = 0	9	0	Table A- light trailer modifier	0	0
Buses	basic vehicle type = 1	9	0	Table B- axle & tire modifier	0	0
Single-unit trucks or tractors	basic vehicle type = 2	Table C- total axles	Table D- Total axles on first trailer	Table A- light trailer modifier	0	0
Tractor + Semitrailer	basic vehicle type = 3	Total axles on power unit	Table D- Total axles on first trailer	0	0	0
Truck + full trailer	basic vehicle type = 4	Total axles on power unit	Table D- Total axles on first trailer	0	0	0
Tractor + semitrailer + full trailer	basic vehicle type = 5	Total axles on power unit	Table D- Total axles on first trailer	Table D- Total axles on second trailer	0	0
Truck + full trailer + full trailer	basic vehicle type = 6	Total axles on power unit	Table D- Total axles on first trailer	Table D- Total axles on second trailer	0	0
Tractor + semitrailer + 2 full trailers	basic vehicle type = 7	Total axles on power unit	Table D- Total axles on first trailer	Table D- Total axles on second trailer	Table D- Total axles on third trailer	0
Truck + 3 full trailers	basic vehicle type = 8	Total axles on power unit	Table D- Total axles on first trailer	Table D- Total axles on second trailer	Table D- Total axles on third trailer	0

Table 2.2. Description of six-digit FHWA vehicle type code (Page 2 of 2).

<u>Table A - Light Trailer Modifier</u>

0	No trailer
1	Camp trailer
2	Travel or mobile home
3	Cargo or livestock trailer
4	Boat trailer
5	Towed equipment
6	Towed auto
7	Towed truck
8	"Saddle mount" (Tractors or trailers with front axles on unit ahead)
9	Type trailer not determined

<u>Table B - Axle and Tire Modifier</u>

0	Axle arrangement not recorded
1	Two-axle, four-tire
2	Two-axle, six-tire
3	Three-axle
4	Four or more axles

<u>Table C - Total Axles</u>

0	Panel and pickup
1	Heavy two-axle, four-tire
2	Two-axle, six-tire
3	Three-axle
4	Four-axle
5	Five-axle
6	Six-axle
7	Seven-axle
8	Eight axles or more

<u>Table D - Total Axles on Trailer</u>

1	Single-axle trailer
2	Two-axle trailer
3	Three-axle trailer
4	Four-axle trailer
5	Five-axle trailer
6	Six-axle trailer
7	Two-axle trailer with axles in spread tandem configuration
8	Three-axle trailer including a spread tandem configuration
9	Four-axle trailer including a spread tandem configuration

VEHICLE TYPE CODING EXAMPLES

	Vehicle	Code
1.	Car	090000
2.	2-axle bus	190300
3.	3-axle tractor without trailer (bobtail)	230000
4.	3-axle tractor + 2-axle semitrailer	332000
5.	2-axle tractor + 1-axle semitrailer + 2-axle full trailer	521200

Table 2.3. Examples of Arizona's vehicle classification system.

CODE	VEHICLE DESCRIPTION
LT	Pickup truck Pickup with shell Panel truck Van with no rear window
MT	Single truck - 2 axles, dual tires Single truck - 3 axles
TS	Tractor-semi trailer - 3 axles Tractor-semi trailer - 4 axles Tractor-semi trailer - 5 axles
TT	Truck and trailer - 4 axles Truck and trailer - 5 axles Truck and trailer - 6 axles
TST	Truck, semitrailer, and full trailer - 5 or more axles Truck and two full trailers - 6 or more axles

Vehicle Classifications of the FHWA. The FHWA has defined a total of thirteen vehicle classes, but only the nine classes related to trucks are used in the program. Subroutine CLSFY13 first determines the total number of axles on the power unit and trailers (if any). Then, using the basic vehicle type code (which interprets the number of individual units for the vehicle), one can determine which of the thirteen FHWA classes the vehicle belongs. This process is best described in the chart shown in Table 2.4. The basic vehicle type codes appear in the rows and total axles appear in the columns. The correct FHWA classification number is found at the intersection of the appropriate row and column. Refer this number to Table 2.5 which describes the configuration of each vehicle class.

Legal Load Limit Shifting

ARE Inc has developed as part of the FEDESAL program, subroutines SHFWGT and AXLADJ which calculate the effects of changes in vehicle load limit laws on average 18KESAL estimations. Legal limits for trucks apply to single, tandem and triple axle weights plus the gross vehicle weight. The process through which the program adjusts weights under the existing and proposed load limit laws will be discussed for all individual axle sets and gross vehicle weights.

The principle of constant legality is the guiding criterion for all calculations for the weight shift algorithm: the new load limit laws must not change the existing legal status of a vehicle, so that a vehicle which is legal under the current law will remain legal under a new law. Conversely, a vehicle which is not legal under the current law will remain illegal under a new law. Calculated 18KESAL values must conform to this general principle.

Tare weights are defined as the empty or unloaded weight applied to each axle set type. The four tare weights input by the user are:

1) Front axle
2) Single axle

Table 2.4. FHWA codes 5 through 13 based on the first digit of the six-digit FHWA code and the total number of axles on the vehicle.

		Total Number of Axles on Truck					
		2	3	4	5	6	7 or more
Basic Vehicle Type Code	2	5	6	7	7	7	7
	3	8	8	8	9	10	10
	4	8	8	8	9	10	10
	5	11	11	11	11	12	13
	6	11	11	11	11	12	13
	7	11	11	11	11	12	13
	8	11	11	11	11	12	13

Table 2.5. Description of FHWA vehicle codes 5 through 13.

5 - Two-Axle, Six-Tire, Single Unit Trucks - All vehicles on a single frame including trucks, camping, and recreation vehicles, motor homes, etc., having two axles and dual rear wheels.

6 - Three-Axle Single Unit Trucks - All vehicles on a single frame including trucks, camping, and recreational vehicles, motor homes, etc., having three axles.

7 - Four or More Axle Single Unit Trucks - All trucks on a single frame with four or more axles.

8 - Four or Less Axle Single Trailer Trucks - All vehicles with four or less axles consisting of two units, one of which is a tractor or straight truck power unit.

9 - Five-Axle Single Trailer Trucks - All five-axle vehicles consisting of two units, one of which is a tractor or straight truck power unit.

10 - Six or More Single Trailer Trucks - All vehicles with six or more axles consisting of two units, one of which is a tractor or straight truck power unit.

11 - Five or Less Axle Multi-Trailer Trucks - All vehicles with five or less axles consisting of three or more units, one of which is a tractor or straight truck power unit.

12 - Six-Axle Multi-Trailer Trucks - All six-axle vehicles consisting of three or more units, one of which is a tractor or straight truck power unit.

13 - Seven or More Axle Multi-Trailer Trucks - All vehicles with seven or more axles consisting of three or more units, one of which is a tractor or straight truck power unit.

3) Tandem axle
4) Triple axle

The effect of these tare weights is that empty vehicles will have little or no weight adjustment under the new weight limit laws. The procedure considers the possibility that manufacturers might redesign trucks to meet the new load limits. If truck design changes occur that would significantly alter average tare weights, new values can easily be inserted into the SHFTWGT.DAT data file.

It is recommended that no adjustments be made regarding steering axle weights. No significant tare weight shifts due to changing truck designs or significant amounts of weight shifts due to goods loaded over the steering axles are anticipated. All other axle set weights will be adjusted. For each truck, it is necessary to consider two components:

1) the load limit changes for each axle set and
2) a load limit change for the gross vehicle weight.

The methodology to shift axle set weights is a three step process:

1) Shift the axle set weights.
2) Test to see if gross vehicle weight conforms to the principle of constant legality.
3) If constant legality is not met, readjust the axle set weights.

The first calculation is only used for the axle set weights which are greater than their appropriate tare weights; otherwise the actual weights are not altered. Weights for each axle set on each truck (excluding the steering axle) are shifted after an adjustment is made for an average tare weight assigned to the axle set and equating the ratio of actual weights to maximum legal weights under the current and proposed load limit laws:

$$\frac{\text{SHIFTED WEIGHT - TARE WEIGHT}}{\text{NEW LOAD LIMIT - TARE WEIGHT}} = \frac{\text{ACTUAL WEIGHT - TARE WEIGHT}}{\text{OLD LOAD LIMIT - TARE WEIGHT}}$$

Solving for SHIFTED WEIGHT yields the formula used in the computer program:

$$\text{SHIFTED WEIGHT} = \frac{\text{(NEW LOAD LIMIT - TARE WEIGHT)*(ACTUAL WEIGHT - TARE WEIGHT)}}{\text{(OLD LOAD LIMIT - TARE WEIGHT)}} + \text{TARE WEIGHT}$$

In this equation, if actual weight equals the old load limit, then the shifted weight will be equal to the new load limit. If actual weight is greater than the old old limit (i.e. illegal), the shifted weight will be greater than the new load limit also (i.e., illegal). Thus, using this equation, an axle set weights that were legal under the old load limit will still be legal under the new load limit. Likewise, axle set weights illegal under the old limits will still be illegal under the new load limits. Therefore, for all trucks, the principle of constant legality is maintained for all axle sets. To simplify calculations, it is assumed that if at least one axle set of a truck is illegally loaded, then the axle set load limits have been violated and all axle sets, as a group, will also be considered illegally loaded.

After the new axle loads have been estimated, new gross vehicle weights can be calculated. Table 2.6 lists the eight possible scenarios to test the principle of constant legality on these weights. With one exception, this principle is violated if the legality of the axle set weights and the gross weight under the existing load limit does not match the legality of the axle set weights and the gross vehicle weight under the proposed load limit. This situation occurs four times. For example, if all axle set weights are legal and gross weight is legal, after using the formula to estimate new axle weights, which will still be legal, it is possible that the gross weight under the new law will be illegal. This situation where a truck which was legally loaded suddenly becomes

Table 2.6. Eight possible scenarios to test the principle of constant legality following axle load distribution shifting.

	LEGAL STATUS OF EXISTING WEIGHTS		LEGAL STATUS FOLLOWING AXLE WEIGHT SHIFTING		APPLY READJUST-MENT?	LEGAL STATUS FOLLOWING READJUSTMENT	
	AXLE SETS	GROSS WEIGHT	AXLE SETS	GROSS WEIGHT		AXLE SETS	GROSS WEIGHT
1	X	0	X	X	NO		
2	X	X	X	0	YES	X	X
3	0	X	0	X	NO		
4	0	X	0	0	NO		
5	X	0	X	X	YES	X or 0	0
6	X	0	X	0	NO		
7	0	0	0	X	YES		
8	0	0	0	0	NO	0	0

X - Legal 0 - Illegal

illegally loaded is not desirable. Therefore, some readjustment of the axle set weights is necessary for the following situations:

2) Axle set and total weights are legal,
   Shifted total weight is illegal.

5) Axle set weights are legal and total weight is illegal,
   Shifted total weight is legal.

7) Axle set weights are illegal and total weight is illegal,
   Shifted total weight is legal.

The case where under the existing load limit laws axle set weights are illegal and gross weight is legal and under the proposed load limit law axle weights are illegal and gross weight is illegal has been omitted from this list. The reason for this is the axle set weights are already illegal and will continue to be illegal under the proposed limits so making the gross weight legal under the new law will not make the axle set weights legal. It will still be an illegally loaded truck. Therefore, the principle of constant legality has not been violated.

The situations from Table 2.6 where no readjustment is necessary because the principle of constant legality have not been violated are:

1) Axle set and total weights are legal,
   Shifted axle set and total weights are legal.

3) Axle set weights are illegal and total weight is legal,
   Shifted axle set weights are illegal and total weight legal.

4) Axle set weights are illegal and total weight is legal,
   Shifted axle set weights are illegal and total weight illegal.

6) Axle set weights are legal and total weight illegal,
   Shifted axle set weights are legal and total weight is illegal.

8) Axle set and total weights are illegal,
Shifted axle set and total weights are illegal.

The readjustment, when required by one of the three violations of the principle of constant legality, equates the ratio of the actual gross vehicle weight to the existing load limit with the ratio of the new gross weight with the proposed load limit:

$$\frac{\text{ACTUAL GROSS VEHICLE WEIGHT}}{\text{EXISTING GROSS VEHICLE LOAD LIMIT}} = \frac{\text{NEW ACTUAL GROSS VEHICLE WEIGHT}}{\text{PROPOSED GROSS VEHICLE LOAD LIMIT}}$$

This results in a formula to find the new actual gross vehicle weight:

$$\text{NEW ACTUAL GROSS VEHICLE WEIGHT} = \frac{(\text{ACTUAL GROSS VEHICLE WEIGHT})*(\text{PROPOSED GROSS VEHICLE LOAD LIMIT})}{\text{EXISTING GROSS VEHICLE LOAD LIMIT}}$$

A factor is then calculated so that the sum of all the axle set weights is equal to this final gross vehicle weight. For this equality, each of the shifted axle set weights is multiplied by this factor. The weight of the steering axle is not multiplied by this factor and remains the same under both existing and proposed load limits. The multiplication factor to be applied to the shifted axle weights is:

$$XK = (GVW_F - WGTS_1) / \sum_{i=2}^{ISETS} WGTS_i$$

where:

GVW_F = final gross vehicle weight,
$WGTS_1$ = weight of steering axle,
$WGTS_i$ = shifted weight of the i^{th} axle set (i=2,...,ISETS), and
ISETS = the number of axle sets.

The new weights for each axle set are

$$WGTS_{iF} = XK*WGTS_i \qquad i = 2,\ldots\ldots,ISETS$$

All axle set weights, after passing through this algorithm, are used to determine the 18-kip equivalent single axle load for each axle set type. By making two runs of the program, one with the axle load shifting option and one with no axle shifting, the effects of changes in load limits on average 18KESAL per 1000 vehicles can be compared.

Interpolation

ARE Inc has developed a set of 18-kip single axle load equivalence factors for flexible pavements as a function of six variables: surface thickness, base/subbase thickness, tire pressure, roadbed soil modulus, axle set type and axle set weight. An option to use the ARE Inc factors instead of the FHWA factors is included in the program. Given this set of six independent variables, a mathematical model that will equate their specific values to the proper load equivalence factor is desired but is currently not available. This is due to the lack of empirical evidence required to establish an unambiguous relationship.

It is possible to develop an approximation equation using least squares and some suitable transformation of the data. However, this method would most likely introduce bias into the relationship by predicting values consistently low or consistently high compared to the true value for certain ranges of the independent variables. This would, in turn, disproportionately affect accumulated totals.

An alternative method is to find a polynomial equation that fits the observations in the data file exactly and assume all values between two adjacent points lie on a smooth curve. The process of extracting "in-between" values is known as interpolation. The program uses a multivariate form of LaGrangian interpolation based on the following formula, which is a summation of N terms, each consisting of a computed fraction derived from the N values of X_i and the known functional value, Y_i:

$$F(X) = \sum_{i=1}^{N} \frac{\prod_{\substack{j=1 \\ i \neq j}}^{N} (X - X_j)}{\prod_{\substack{j=1 \\ i \neq j}}^{N} (X_i - X_j)} *(Y_i)$$

where:

N = the number of levels of the independent variable,
X_i = the value of the variable at the ith level,
Y_i = the functional value at X_i,
Σ = notation for summation of terms and
π = notation for product of terms.

If the value to be interpolated, X, equals X_i, then all but one of the fractions equals 0 and the other fraction, corresponding to Y_i, equals 1, which means $F(X) = Y_i$ and the interpolated value fits exactly. If the value to be interpolated, X, lies between X_{i-1} and X_i, then the function given above computes an estimate of the true value by forming a polynomial equation of N-1 degrees based on the N pairs of data (X_i, Y_i). One nice feature of this formula is that the independent values do not need to be evenly spaced. However, all combinations of independent variables and their corresponding equivalence factor must be distinct. For example, if 3 = f(10), then the relation 2 = f(10) cannot also simultaneously exist.

If the ARE Inc load equivalence factors are used, the inputs to the interpolation equation are chosen at the beginning of the program during the interrogation routines where surface thickness, base/subbase thickness, roadbed soil modulus and tire pressure are chosen by the user.

The two remaining variables, axle set type and axle weight, are determined from each truck record. Surface thickness, base/subbase thickness and axle set type determine which arrays of the factors are used. Roadbed soil modulus, tire pressure and axle set weight serve as the independent variables in the interpolation equation.

Extrapolation is defined as calculating the factor's value for a set of independent variables where at least one lies outside the range of values used to develop the interpolation equation. Whenever a value is estimated in this manner, considerable caution should be used because the implied assumption is that the equations remain valid beyond the extreme values in the data. These interpolation equations are either of degree 3 or degree 5, which means it must compute a value of 0 either two or four times for some set of independent variables, depending on which equation is used. This, in turn, means that its behavior outside the maximum or minimum value for each variable may result in totally inappropriate answers.

For this reason, the interpolation process was modified for low values of axle set weights. For some cases, predicted load equivalence factors were negative when interpolation was required for weights between 4000 and 10000 pounds. For weights below 4000 pounds, the predicted values increased as weight decreased. For this reason, two separate linear interpolations are used for weight values between 0 and 4000 pounds and 4000 and 10000 pounds.

Computation of Five-Year Averages

The computation of average 18KESAL per thousand vehicles using five years of weight data is calculated as the ratio of the total five-year equivalent axle loads divided by the total number of vehicles for all five years of data. This is done for k sets of data where k is the number of distinct classifications determined by pavement type, functional classification and truck type. The following formula calculates $EWVHRT_k$, which is a five-year average such that each individual year's data used in its computation is weighted in proportion to its size compared with all five year's data.

$$EWVHRT_k = 1000* \left[\sum_{i=1}^{5} \sum_{j=1}^{IVHCNT_k} TESAL_{ijk} / \sum_{i=1}^{5} IVNCNT_{ik} \right]$$

where:

$TESAL_{ijk}$ = the total equivalent weights of the j^{th} truck in the i^{th} year for the k^{th} class, and

$IVHCNT_{ik}$ = the total number of trucks in the i^{th} year in the k^{th} class.

This formula will usually yield different results than just using the average value of five averages (one for each year). The formula given above is preferred since it is equivalent to finding the total accumulated weights for five years and dividing by the total number of vehicles for the same five-year period and does not give undue weight to data from any one year.

Data Checking Procedures

An option available in the program is a simple data checking routine. Many types of errors may occur in the weight data files. Although it is not possible to catch them all, it is possible to find several discrepancies which, when corrected, will give better estimates of accumulated equivalent axle loads.

The data checking option is offered as a selection on screen as described in the section, PROGRAM OPERATING INSTRUCTIONS. If data checking is chosen, the subroutine DATCHK is called after all weight data file names have been entered.

The types of errors found by the program include:

1) Functional classification (IFNTCL) must be a numeric value between 1 and 19 inclusive.

2) The total weight of the vehicle (TOTWGT) must equal the sum of the individual axle set weights.

3) The total length of the vehicle (TOTLGT) must equal the sum of the individual axle set lengths.

4) The number of axles implied by the six-digit FHWA code must match the number of nonzero axle weights present.

For example, if the name of the weight data file being checked is WEIGHT86.DAT and the total weight of a vehicle does not match the sum of the weights of all individual axles for that vehicle in record number 817, the following error message will be written to a file called ERROR.RPT:

```
The sum of the axle weights does not match
the total weight given in record 817, file WEIGHT86.DAT
```

Similar messages appear for the other types of data errors. This allows quick identification of many possible errors within the files. The errors can be corrected using a text editor program. When an error is found in any file, the variable ICHECK is set equal to 1 (it is equal to 0 otherwise). When all records in each file have been checked the following question appears on screen:

```
Errors have been found in at least one FHWA weight data file.
A list of them is located in file ERROR.RPT.
Do you want to continue processing?

    1 = YES
    2 = NO

Enter 1 or 2 ----->
```

If a 1 (YES) is entered, the weight data files are processed with the errors unchanged. If a 2 (NO) is entered, the program stops and corrections to the data file can be made.

If no errors were found in any data file (i.e., ICHECK = 0), the program asks the relevant input information and then begins processing using the files checked by the data checking routine. If the user does not want to continue processing, the program can be aborted by pressing the 'Ctrl-C' keys simultaneously.

Another type of error which may occur when the data within the file are inconsistent with the format specifications. If a character value occurs where a numeric value is expected, a READ error is given on the screen and execution is automatically aborted. The file must then be corrected before it can be used again.

Subroutine Descriptions

In this section, brief descriptions of each subroutine found in the program are given. They are written in modular form so that certain inputs to the subroutine may be analyzed and passed back to the main program or to another subroutine. Therefore, most subroutines can be easily modified without changes to other portions of the program, so long as the output of each subroutine is consistent with the format specified for the program as a whole.

SUBROUTINE	OBJECTIVE
INITL	Sets all parameters to initial values, summation array elements to zero, and reads in FHWA or ARE Inc load equivalence factors and axle load shifting data from exterior files to fill arrays.

SHFTVB	Edits axle load distribution shifting data. TARE(4) = Unloaded axle set weights. AXLIM1(5) = Current axle set and gross vehicle weight limits. AXLIM2(5) = Proposed axle set and gross vehicle weight limits.
AREQS	If ARE Inc factors are selected, surface thickness, base and subbase thickness, roadbed modulus value and tire pressure are used as inputs in order to select the appropriate set of factors.
AREDAT	Reads the ARE Inc equivalence factors and the appropriate levels of roadbed soil modulus, tire pressure and weight (in thousands of pounds) for a) single axles, single tires, b) single axles, dual tires, c) tandem axles and d) triple axles into the proper arrays.
DATCHK	Performs data checking operations.
CLSFY5	1. Determines type of vehicle and number of axles for the power unit and trailers (if any). 2. Translates vehicle type from FHWA six-digit code to one of five Arizona codes. 3. Calculates the number of axles per vehicle.
CLSFY13	1. Determines type of vehicle and number of axles for the power unit and trailers (if any).

	2.	Translates the six-digit FHWA code to one of nine commercial vehicle codes.
	3.	Calculates the number of axles per vehicle.
NLOADS	1.	Determines type of each axle set: a) single axle, single tire, b) single axle, dual tire, c) tandem axle or d) triple axle.
	2.	Accumulates weights of each axle set.
	3.	Determines number of axle sets.
	4.	Calls axle shifting subroutines, if requested.
	5.	Calculates equivalent 18-kip single axle load for each axle set.
SHFWGT		Calculates shifted axle weights under the proposed law and given tare (unloaded) weights.
AXLADJ		Adjusts axle weights if axle shifting criteria is met.
EQUIVL		Determines which weight classification the axle set belongs in order to establish the proper load equivalence factor.
AREFTR		Sets the arrays used by subroutine LGRNG to calculate the ARE Inc 18-kip load equivalence factors using LaGrange interpolation.
LGRNG		Interpolates an equivalence factor based on input values of roadbed soil modulus, tire pressure, axle weight and axle type.

MOVEYR — Moves vehicle counts and weight totals in five-year average files one column to the left. It overwrites the previous year's numbers in order to insert the most recent data into the permanent file.

PRNT — Prints total vehicle counts and 18KESAL data for each station location, vehicle classification and pavement type.

List and Description of All Important Internal Program Variables

This section lists the most important variables found in the FEDESAL program. For each variable, a brief description, its initialized value, and the appropriate dimension of the array, if applicable, are given. The variables are grouped into the following classifications indicating how the data enters the program:

1) Entered by the user before data is evaluated.
2) Initialized within the program.
3) Read from an external data file.
4) Calculated from the data for each individual vehicle.
5) Calculated as a cumulative total.
6) Used to compute five-year averages.

1. Variables entered by the user before data is evaluated.

IPROG - Determines program function:

1 = Evaluate this year's data only.
2 = Evaluate this year's data
move previous totals,
create new five-year averages.
3 = Evaluate this year's data,
create new five-year averages.

IFACTR - Selects either AASHTO or ARE Inc equivalence factors:

1 = AASHTO
2 = ARE Inc

ISHIFT - Specifies whether the axle load distribution shifting option is used:

1 = Use axle load distribution shifting.
2 = Do NOT use axle load distribution shifting.

DATE - Date program is run (Month/Day/Year).

COMMNT - Comments entered by the user.

FILEIN(20) - FHWA data input file names (maximum of 20).

If ARE Inc factors are chosen, the following variables are entered:

ISURTH - Asphalt concrete surface thickness.

=	1	-	THIN	< 1 in.	(0 in. assigned)
=	2	-	MEDIUM	= 1 - 5 in.	(3 in. assigned)
=	3	-	THICK	> 5 in.	(6 in. assigned)

IBASTH - Total base/subbase thickness.

=	1	-	THIN	< 10 in.	(8 in. assigned)
=	2	-	MEDIUM	= 10 to 17 in.	(14 in. assigned)
=	3	-	THICK	> 17 in.	(20 in. assigned)

JLEVEL - Surface and base thickness index for determining ARE Inc load equivalence factors.

= 1 for ISURTH = 1 and IBASTH = 1
= 2 for ISURTH = 1 and IBASTH = 2
= 3 for ISURTH = 1 and IBASTH = 3
= 4 for ISURTH = 2 and IBASTH = 1
= 5 for ISURTH = 2 and IBASTH = 2
= 6 for ISURTH = 2 and IBASTH = 3
= 7 for ISURTH = 3 and IBASTH = 1
= 8 for ISURTH = 3 and IBASTH = 2
= 9 for ISURTH = 3 and IBASTH = 3

XVAL(1) - Roadbed soil modulus.

- Low	< 8000 psi	(4000 psi)
- Medium	= 8000 to 16000 psi	(12000 psi)
- High	> 16000 psi	(20000 psi)
- Actual value		(User input)

XVAL(2) - Tire pressure.

- Standard AASHO Road Test Pressure	(75 psi)
- ARE Inc Field Measured Existing Pressures	(110 psi)
- High Pressure	(145 psi)
- Actual value	(User input)

2. Variables initialized within the program.

NSCRN = 0	- Identifies the screen for input or output.
MAXAXL = 13	- Maximum axles per vehicle.
MAXSET = 7	- Maximum axle sets per vehicle.
NAXTYP = 4	- Number of axle set types.
NFCTIN = 25	- Maximum number of equivalence factor intervals defined by upper and lower weight limits.
NPVTYP = 2	- Number of pavement types.
NSTLOC = 3	- Types of station locations.

NVEHCL - Number of vehicle classifications.

= 5 if Arizona classifications are used.

= 9 if FHWA vehicle classifications are used.

NYEARS = 5 - Years for averaging.

SPACE = 8.0 - The distance between axles, in feet, that distinguishes between single, tandem and triple axles.

3. Data read from external data files.

AASHTO load equivalence factor data input:

AXWTLM(NAXTYP,NFCTIN,2) - Lower and upper weight limits for each of the NFCTIN weight classes for each axle type.

FACTOR(NAXTYP,NFCTIN,NPVTYP) - AASHTO equivalence factors for each axle type, weight class and pavement type.

ARE Inc equivalence factor data input:

YST(27) - Single axle, single tire load equivalence factors.

XST(27,3) - Roadbed soil modulus, tire pressure and axle weight (in 1000s) corresponding to single axle, single tire equivalence factors.

YDT(27) - Single axle, dual tire load equivalence factors.

XDT(27,3) - Roadbed soil modulus, tire pressure and axle weight (in 1000s) corresponding to single axle, dual tire equivalence factors.

YTN(27) - Tandem axle load equivalence factors.

XTN(27,3) - Roadbed soil modulus, tire pressure and axle weight (in 1000s) corresponding to tandem axle equivalence factors.

YTR(27) - Triple axle load equivalence factors.

XTR(27,3) - Roadbed soil modulus, tire pressure and axle weight (in 1000s) corresponding to triple axle equivalence factors.

Axle load distribution shifting data input:

TARE(4) - Weights of unloaded axles.

TARE(1) - Front axle
TARE(2) - Single axle
TARE(3) - Tandem axle
TARE(4) - Triple axle

AXLIM1(5) - Maximum weights under the current law.

AXLIM1(1) - Front axle
AXLIM1(2) - Single axle
AXLIM1(3) - Tandem axle
AXLIM1(4) - Triple axle
AXLIM1(5) - Gross vehicle weight

AXLIM2(5) - Maximum weights under the proposed law.

AXLIM2(1) - Front axle
AXLIM2(2) - Single axle
AXLIM2(3) - Tandem axle
AXLIM2(4) - Triple axle
AXLIM2(5) - Gross vehicle weight

FHWA weight data file input:

IFNTCL - Functional class.
VEHTYP - Six-digit FHWA vehicle type code.
LDEMP - Loaded or empty vehicle.
TOTWGT - Total weight of vehicle (in hundreds of pounds).

AXWGT(MAXAXL) - Axle weights (in hundreds of pounds).

AXSPC(MAXAXL) - Axle spacings (in feet).

TOTLGT - Total length of vehicle (in feet).

ICONT - End of record or continue to the next line.

4. Data calculated from each vehicle record.

IVTY - The first digit of the six-digit FHWA vehicle type code (VEHTYP).

IAXP - Number of axles of power unit.

IAX1 - Number of axles on first trailer.

IAX2 - Number of axles on second trailer.

IAX3 - Number of axles on third trailer.

NAXLE - The total number of axles for each vehicle.

ISTLOC - Location index for current record.

1 = Interstate (IFNTCL = 1 OR 11)

2 = Primary/Secondary (IFNTCL >= 2 and <= 9)

3 = Urban (IFNTCL >= 12 and <= 19)

IPVTYP - Pavement type index for current record (used for computing totals for both rigid and flexible 18KESALs when FHWA factors are selected and for flexible 18KESALs only when ARE Inc factors are selected).

1 = Rigid

2 = Flexible

IVEHCL - Vehicle type index for current record.

If FHWA vehicle classifications are used:

1 = Two-axle, six-tire, single unit trucks.

2 = Three-axle, single unit trucks.

3 = Four or more axle single unit trucks.

4 = Four or less axle single trailer trucks.

5 = Five-axle single trailer trucks.

6 = Six or more axle single trailer trucks.

7 = Five or less axle multi-trailer trucks.

8 = Six-axle multi-trailer trucks.

9 = Seven or more axle multi-trailer trucks.

If Arizona's vehicle classifications are used:

1 = LT

2 = MT

3 = TS

4 = TT

5 = TST

EQUIV(NPVTYP,MAXSET) - 18-kip single axle load equivalence factors for each pavement type and each axle set type.

ISETS - The number of axle sets for the current vehicle (values range from 1 to MAXSET).

WGTS(MAXSET) - Actual weight for each axle set in pounds.

IAXTYP(MAXSET) - Axle set type calculated for each axle set:
= 1 for single axle, single tire.
= 2 for single axle, dual tire.
= 3 for tandem axle.
= 4 for triple axle.

WEIGHT = Actual weight for each axle set.

XVAL(3) = WEIGHT/1000.

5. Data calculated as cumulative totals.

IVHCNT(NSTLOC,NVEHCL) - Current year vehicle counts for each station location and vehicle type.

TESAL(NPVTYP,NSTLOC,NVEHCL) - Total 18KESAL for each pavement type, station location and vehicle type.

TESALK(NPVTYP,NSTLOC,NVEHCL) - Total 18KESAL for each pavement type, station location and vehicle type per 1000 vehicles.

6. Data used to compute five-year averages.

IODVHC(NPVTYP,NSTLOC,NVEHCL,NYEARS)
- Previous years' total vehicle counts (4 years).

TRSMOD(NPVTYP,NSTLOC,NVEHCL,NYEARS)
- Previous years' total 18KESAL data (4 years).

EWVHRT(NPVTYP,NSTLOC,NVEHCL)
- (Ratio of total 18KESAL to total vehicle counts)*1000.

SUMMARY

This chapter presented user information and program documentation for program FEDESAL. The program uses loadometer data to produce estimates of 18KESAL per 1000 vehicles using the Federal Highway Administration computational method with the option of AASHTO load equivalence factors or new ARE Inc factors. All information which may be required by users of the program or by programmers to modify the program is included in the chapter. The next chapter covers a similar program called WIMESAL which analyzes weigh-in-motion data on a project level to produce base-year traffic loading estimates as well as ten- and twenty-year design projections. Some portions of this current chapter are repeated for clarity and completeness in documenting program WIMESAL.

CHAPTER 3

PROGRAM WIMESAL FOR ANALYZING WEIGH-IN-MOTION DATA

Program WIMESAL computes average equivalent single axle loads per 1000 vehicles on a project level basis by vehicle classification. It is designed to allow a minimum of effort on the part of the user. Two types of load equivalence factors, those used by the FHWA in generating the W-4 tables and those developed by ARE Inc which consider different levels of pavement characteristics, offer alternative methods for interpreting the same weight data. In addition, a data checking routine is included which can be used to verify the data input files.

In order to explain the use of this program, a complete description of the requirements for its operation will be given including the data input file descriptions and a series of input prompts to be answered.

PROGRAM OPERATING INSTRUCTIONS

To run the WIMESAL program, turn on the power for the microcomputer, video monitor and printer. Be sure the default drive contains the support data input files and enter the command WIMESAL. A series of prompts will appear on screen which, when answered, will set the parameters for the ensuing run and define how equivalence factors will be computed. This section describes the series of prompts which set the program's execution path. Different results will be obtained by responding to the prompts in alternative ways.

Program Prompts to Set Run Parameters

The first statement which appears on the screen is a prompt to enter the names of the files containing the WIM weight data:

```
ENTER A MAXIMUM OF 20 INPUT DATA FILES
ENTER * WHEN FINISHED
```

To enter the name of the first file type the drive location (A, B, C, etc.) followed by a colon (:) and then the file name.

```
          The drive and name of input file 1

                   #:########.###
           ----->
```

Do not exceed the bounds of the format guide which appears directly above the cursor location. The file name can be shorter than the space provided but cannot be longer. Up to 20 file names can be entered and will be read sequentially in the order of input. This allows data collected at the same location but contained in different files to be analyzed. When the prompt appears after the last file name has been entered, type an asterisk (*) and an answer check of all file names will be given.

```
          ******** FILE NAME ANSWER CHECK ********

               1     A:SELI1.WIM

          ARE THESE FILE NAMES CORRECT?

               1 - YES
               2 - NO

          Enter 1 or 2  ----->
```

At this point, either a 1 for YES or a 2 for NO must be entered. If the response is YES, the program will continue to the next prompt. If the response is NO, all file names must be entered once more.

When the data file names are correct, the user has the option of checking the contents of the data files for errors.

DO YOU WANT TO CHECK THE DATA FILES?

1 - YES

2 - NO

Enter 1 or 2 ---->

If the response is 1 (YES), the program will read each record of each file name entered and conduct several data checking steps (described in a later section) to help ensure the quality of the data. If the response is 2 (NO), the next item will appear.

Following the data checking option, fifty-five (55) spaces are available for the user to enter the location of the WIM measurements for the data contained in the files just entered.

LOCATION

----> ____

Two options of equivalence factors are available:

EQUIVALENCE FACTORS

1 - AASHTO

2 - ARE Inc

NOTE: If ARE Inc factors are chosen, be prepared to enter:

a) asphalt concrete surface thickness,
b) total base/subbase thickness,
c) modulus of roadbed soil and
d) tire pressure.

Enter 1 or 2 ---->

If option 1 is selected, the program will use the data as it appears in file AASHTO.EQF, which contains the load equivalence factors used by the FHWA in producing the W-4 tables. Option 2 specifies the use of the ARE Inc factors found in file ARE.EQF. At this point, the program will present a series of prompts (described later) concerning the values of surface thickness, base/subbase thickness, roadbed soil modulus and tire pressure. These determine which values from the equivalent weight table will be used.

The growth rate of traffic has typically been defined by ADOT as the average growth rate per year over a twenty-year period as determined by the formula:

$$GROWTH = 100*(ADT_{20}-ADT_0)/(20*ADT_0)$$

The growth rate input to WIMESAL may be determined using any length of design period since the program prompts the user for the desired growth rate:

```
YEARLY GROWTH RATE OF ADT
The decimal point is required.
(for example, enter 3.0 for a 3.0% increase per year)
      12345678
----->
```

The next entry is available for documenting the printed report. The effective date of the report can either be the current date or any other date desired by the user to give the time when the numbers computed became effective. A special format guide is given for date entry.

```
EFFECTIVE DATE OF REPORT (Month/Day/Year)
      **/**/**
----->
```

All calculations will be written to a disk file specified by the user which can be printed when the program finishes. The file name is entered by responding to the following prompt:

OUTPUT FILE

The disk drive and name of the output file

#:########.###

----->

Sixty (60) spaces are provided for any special comments desired by the user to further document the printed report.

COMMENTS

-----> ____

After all data have been entered, an answer check is provided of all the items entered up to this point. For example, if data from Interstate 20 with an expected growth rate of 2.3% per year is to be evaluated using AASHTO factors effective 05/01/86 for a test run written to the file C:OUTPUT86.DAT, the answer check would appear as follows:

******** ANSWER CHECK ********

LOCATION:	Interstate 20, three miles west of US 183 Jct.
EQUIVALENCE FACTORS:	AASHTO
TRAFFIC GROWTH:	2.3% per year
EFFECTIVE DATE:	05/01/86
OUTPUT FILE:	C:OUTPUT86.DAT
COMMENTS:	Test run

ARE THESE ENTRIES CORRECT?

1 - YES

2 - NO

Enter 1 or 2 ---->

If the response is 1 (YES) the program will respond with the statement:

***** DO NOT INTERRUPT - PROGRAM RUNNING *****

If the response to the answer check is 2 (NO), all run specifications must be entered once more.

For each weight data file entered, the following statement will appear with its given file drive and name specification.

>>>>>>>>>>> Reading File A:SELI1.WIM

Prompts to Set ARE Inc Single Axle Load Equivalence Factors

These prompts give the user a choice of different levels of factors which identify appropriate load equivalence factors. The user enters one of three levels available for surface thickness, base/subbase thickness, roadbed soil modulus and tire pressure. The final two entries allow the user to input the actual values, if known.

ASPHALT CONCRETE SURFACE THICKNESS

1 Thin - < 1 in. (assigns 0 inches)

2 Medium - 1 - 5 in. (assigns 3 inches)

3 Thick - > 5 in. (assigns 6 inches)

Enter 1, 2 or 3 ---->

TOTAL BASE/SUBBASE THICKNESS

1	Thin	-	< 10 in.	(assigns 4/4 inches)
2	Medium	-	10 - 17 in.	(assigns 6/8 inches)
3	Thick	-	> 17 in.	(assigns 8/12 inches)

Enter 1, 2 or 3 ----->

ROADBED SOIL MODULUS

1 =	Low	< 8000 psi	(assigns 4000 psi)
2 =	Medium	8000 - 16000 psi	(assigns 12000 psi)
3 =	High	> 16000 psi	(assigns 20000 psi)
4 =	Actual Value		

Enter 1, 2, 3 or 4 ----->

Instead of the categorical values of roadbed soil modulus, the user has the option of entering the actual value. The following prompt appears when the user selects option 4:

ACTUAL ROADBED SOIL MODULUS

The allowable range is 3000.0 psi to 21000.0 psi
(The decimal point is required)

1234567890
----->

Following the prompt for roadbed soil modulus, the user is asked to enter the expected value of tire pressure at this location.

TIRE PRESSURE

1 Standard AASHO Road Test Pressure (75 psi)
2 ARE Inc Field Measurements of Existing Pressures (110 psi)
3 High Pressure (145 psi)
4 Actual Value

Enter 1, 2, 3 or 4 ----->

With option 4, the user again has the option of entering the actual value of tire pressure, if known.

ACTUAL TIRE PRESSURE

The allowable range is 70.0 psi to 160.0 psi
(The decimal point is required)

1234567890
----->

After all user responses required to compute ARE Inc factors have been entered, an answer check is provided of the items entered. For example, if a thin surface thickness, medium subbase thickness, medium roadbed soil modulus and tire pressure of 100.0 psi were selected, the input entries would appear as follows:

******** ANSWER CHECK ********

ASPHALT CONCRETE THICKNESS:	Thin -	< 1 in.
BASE AND SUBBASE THICKNESS:	Medium -	10 - 17 in.
ROADBED SOIL MODULUS:	Medium	8000 - 16000 psi
TIRE PRESSURE:	100.0 psi	

ARE THESE ANSWERS CORRECT?

1 - YES

2 - NO

Enter 1 or 2 ----->

At this point, enter either 1 for YES or 2 for NO. If the response is YES the program will return to the main sequence of input prompts; if the response is NO, the user must re-enter the data related to ARE Inc factors.

<u>Program Output</u>

Once the weight data file names to be processed have been entered by the user and the prompts have been responded to correctly, program execution begins. At this point, the user must wait 15 to 30 minutes (depending on the size of the WIM weight data files) for the program to finish its calculations and generate the report. When the program has finished, the following message appears:

Program Finished

The results of this analysis
are contained in the output file C:OUTPUT86.DAT

The output file was specified by the user during the prompts to set the run parameters. The user can then examine the contents of the report file on the screen using a text editor, and if a hard copy is desired it can be sent to the printer. The three page sample output for this report is provided in Figure 3.1.

The top of each new page of the report summarizes the user responses to the various prompts posed by the program. These entries identify actual input values in order to provide a basis for comparison of runs at different levels. If AASHTO load equivalence factors are selected, the

PREDICTED ACCUMULATED LOADS AND
AVERAGE 18 KIP EQUIVALENT SINGLE
AXLE LOADS PER 1000 VEHICLES
USING WIM TRUCK WEIGHT DATA

LOCATION: Test Section
TRAFFIC
GROWTH: 1.50% per year
COMMENTS: ARE Inc Equivalence Factors Used
Rigid Factors not Calculated
Example Run for Final Report

Road Characteristics Used to Compute ARE Inc factors

Surface Thickness:	Medium = 1 - 5 in.
Base/Subbase Thickness:	Thick > 17 in. overall
Roadbed Soil Modulus:	15000.0 psi
Tire Pressure:	90.0 psi

PREDICTED TOTAL ACCUMULATED EQUIVALENT LOADS

VEHICLE CLASS	FLEXIBLE 1-YEAR	10-YEAR	20-YEAR
5	4824.	51622.	110725.
6	12730.	136222.	292188.
7	0.	0.	0.
8	11239.	119688.	255644.
9	652832.	6963483.	14894410.
10	0.	0.	0.
11	0.	0.	0.
12	70469.	751874.	1608661.
13	0.	0.	0.
TOTAL	752095.	8022889.	17161630.

Figure 3.1. Example output from program WIMESAL using ARE Inc equivalence factors (page 1 of 3).

PREDICTED ACCUMULATED LOADS AND
AVERAGE 18 KIP EQUIVALENT SINGLE
AXLE LOADS PER 1000 VEHICLES
USING WIM TRUCK WEIGHT DATA

LOCATION: Test Section
TRAFFIC
GROWTH: 1.50% per year
COMMENTS: ARE Inc Equivalence Factors Used
Rigid Factors not Calculated
Example Run for Final Report

Road Characteristics Used to Compute ARE Inc factors

Surface Thickness: Medium = 1 - 5 in.
Base/Subbase Thickness: Thick > 17 in. overall
Roadbed Soil Modulus: 15000.0 psi
Tire Pressure: 90.0 psi

VEHICLE CLASS	VEHICLE COUNTS	ESTIMATED AVERAGE ADT	AVERAGE NUMBER OF 18 KIP ESAL PER 1000 VEHICLES		ACCUMULATED WEIGHTS (1000s)			
			RIGID	FLEXIBLE	S.A. S.T.	S.A. D.T.	TDM AXL	TRP AXL
5	4	32	.0	819.9	23.	35.	0.	0.
6	2	16	.0	4327.1	21.	0.	33.	0.
7	0	0	.0	.0	0.	0.	0.	0.
8	3	24	.0	2546.9	26.	30.	34.	0.
9	18	144	.0	24656.6	185.	36.	901.	0.
10	0	0	.0	.0	0.	0.	0.	0.
11	0	0	.0	.0	0.	0.	0.	0.
12	5	40	.0	9581.1	49.	197.	102.	0.
13	0	0	.0	.0	0.	0.	0.	0.
TOTAL	32	256						

Figure 3.1. Example output from program WIMESAL using ARE Inc equivalence factors (page 2 of 3).

PREDICTED ACCUMULATED LOADS AND
AVERAGE 18 KIP EQUIVALENT SINGLE
AXLE LOADS PER 1000 VEHICLES
USING WIM TRUCK WEIGHT DATA

LOCATION: Test Section
TRAFFIC
GROWTH: 1.50% per year
COMMENTS: ARE Inc Equivalence Factors Used
Rigid Factors not Calculated
Example Run for Final Report

Road Characteristics Used to Compute ARE Inc factors

Surface Thickness: Medium = 1 - 5 in.
Base/Subbase Thickness: Thick > 17 in. overall
Roadbed Soil Modulus: 15000.0 psi
Tire Pressure: 90.0 psi

Total elapsed time: 3 hours and 0 minutes

Dates and times of WIM data collection

Begin		End	
Date	Time	Date	Time
9/15/82	7:30	9/15/82	8:15
9/23/82	9: 0	9/23/82	9:30
9/30/82	12:15	9/30/82	12:45
10/ 1/82	11:20	10/ 1/82	12:35

WIM data files used as input

1 WIM.DAT

Figure 3.1. Example output from program WIMESAL using ARE Inc equivalence factors (page 3 of 3).

program will print total predicted accumulated loads for both rigid and flexible pavements based on one-year, ten-year, and twenty-year traffic levels for each vehicle type. If ARE Inc equivalence factors are chosen, the program will print the same data for flexible pavements only. The vehicle counts, estimated average ADT, average number of 18KESAL per 1000 vehicles and accumulated weights (in 1000s) for each axle set type are printed below the values for each vehicle class. Since no mechanistically derived load equivalence factors were derived for rigid pavements, the program will not print rigid accumulated factors per 1000 vehicles if ARE Inc equivalence factors are selected. The total time of WIM data collection and beginning and ending dates and times presented on the final page of output are printed:

1) for each individual WIM input data file,
2) whenever the interarrival time between vehicles is greater than two hours from 12:00 midnight to 7:00 a.m. and
3) whenever the interarrival time between vehicles is greater than one hour from 7:00 a.m. to 12:00 midnight.

Finally, all data files entered by the user are printed in order to list the WIM files used in the analysis. The contents of the printed output contain all input data that would be required to duplicate the run, if necessary.

DATA INPUT FILES

Before the program can be executed, the first two files presented below must exist in the default disk drive. The truck weight data in the WIM format may exist in any available drive:

1) AASHTO.EQF
2) ARE.EQF
3) WIM Truck Weight Data Input Files

The contents and formats of each of these files are briefly described below:

AASHTO.EQF

This file contains the 18-kip equivalence factors from the AASHTO Guide for Design of Pavement Structures (Ref. 1) as they currently appear in the FHWA W-4 weight tables. This file also contains the AASHTO compatible factors for flexible pavements which have been extended to account for increased tire pressures. Appendix A provides a descriptive listing of the contents of file AASHTO.EQF. For each record, the first four variables are descriptive items of the final two variables which are the rigid and flexible 18-kip equivalence factors. The columns where each variable is located and its respective Fortran format are:

1) Axle set type (column 1, I1).
2) Weight interval index (columns 2-3, I2).
3) Lower limit of weight interval (columns 4-13, F10.1).
4) Upper limit of weight interval (columns 14-23, F10.1).
5) Rigid 18-Kip ESAL factor (columns 24-33, F10.4).
6) Flexible 18-Kip ESAL factor for 75 psi tire pressure (columns 34-43, F10.4).
7) Flexible 18-Kip ESAL factor for 110 psi tire pressure (columns 44-53, F10.4).
8) Flexible 18-Kip ESAL factor for 145 psi tire pressure (columns 54-63, F10.4).

All equivalence factors and their respective weight class intervals for both rigid and flexible pavements are stored by the numerical index of four axle set types found in column 1 which are defined as:

1 = single axle, single tires
2 = single axle, dual tires
3 = tandem axle
4 = triple axle

For each axle set type, columns 2 and 3 contain the weight interval indices for the equivalence factors defined by the lower bound in columns 4-13 and the upper bound defined in columns 14-23. These weight intervals are sorted from lowest to highest with no gaps larger than one pound between intervals. The highest weight interval contains as its upper bound a very large number such that no axle set weight should ever exceed it (unless there is an error). The weight interval indices are assigned in numerical order with 1 assigned to the lowest weight class interval and sequentially up to the highest weight class interval within each axle set type.

Equivalence factors for rigid and flexible pavements appear in columns 24-33 and 34-43, respectively. Equivalence factors for axle set types 1 and 2 are identical at 75 psi since the FHWA does not currently distinguish between single axle, single tires and single axle, dual tires. The FHWA also does not account for triple axles and, therefore, no factors for these appear in the file. The file has this format because the file containing ARE Inc factors does account for a difference between the first two types of axle sets and includes equivalence factors for triple axles. A similar format was maintained between the two files because the method used to compute axle set type does not vary with choice of factor type. If a method to calculate factors for single axle, single tires or triple axles using FHWA data is developed, the new values can easily be inserted into the file. Currently, if a triple axle is found in the weight data file when the FHWA factors are used, the program assigns the axle set an equivalence factor equal to a tandem value for the same weight interval.

This file can be easily expanded to include up to 25 weight intervals for each axle set type without any modifications to the program. For example, more precise results are produced when smaller weight intervals and their corresponding load equivalence factors are supplied. This may be accomplished by redefining the lower and upper bounds of each interval and inserting the corresponding load equivalence factors in their appropriate columns in the data file.

<u>ARE.EQF</u>

This file contains the mechanistic load equivalence factors derived by ARE Inc. A descriptive listing of the contents of this file is presented in Appendix B. A broad range of equivalence factors are included based on several variables which theoretically influence their magnitude. In addition to axle weight, these include surface thickness, base/subbase thickness, tire pressure, roadbed soil modulus and axle set type.

The file is divided into four sets of factors defined by axle set type:

1) Rows 1 to 27 - single axle, single tire
2) Rows 28 to 72 - single axle, dual tires
3) Rows 73 to 117 - tandem axle
4) Rows 118 to 162 - triple axle

These row assignments are inflexible since the program reads this file sequentially, based on an expected record count for each axle set type.

For each record in the file, the first four variables are descriptive items and the remaining nine variables are the flexible pavement load equivalence factors for nine combinations of surface and base/subbase thicknesses. The columns and respective Fortran formats for each variable are:

1) Classification interval index (columns 1-2, I2).
2) Roadbed soil modulus (columns 3-8, F6.0).
3) Tire pressure (columns 9-12, F4.0).
4) Weight of axle set in 1000's (columns 13-16, F4.0).
5) 18-Kip equivalence factor for surface thickness < 1 in. and base/subbase thickness < 10 in. (columns 17 to 26, F10.4).
6) 18-Kip equivalence factor for surface thickness < 1 in. and base/subbase thickness 10-17 in. (columns 27 to 36, F10.4).
7) 18-Kip equivalence factor for surface thickness < 1 in. and base/subbase thickness > 17 in. (columns 37 to 46, F10.4).

8) 18-Kip equivalence factor for surface thickness 1-5 in. and base/subbase thickness < 10 in. (columns 47 to 56, F10.4).
9) 18-Kip equivalence factor for surface thickness 1-5 in. and base/subbase thickness 10-17 in. (columns 57 to 66, F10.4).
10) 18-Kip equivalence factor for surface thickness 1-5 in. and base/subbase thickness > 17 in. (columns 67 to 76, F10.4).
11) 18-Kip equivalence factor for surface thickness > 5 in. and base/subbase thickness < 10 in. (columns 77 to 86, F10.4).
12) 18-Kip equivalence factor for surface thickness > 5 in. and base/subbase thickness 10-17 in. (columns 87 to 96, F10.4).
13) 18-Kip equivalence factor for surface thickness > 5 in. and base/subbase thickness > 17 in. (columns 97 to 106, F10.4).

When ARE Inc factors are selected, all of these values are read into data arrays in the program. The combination of surface and base/subbase thicknesses entered determines which set of equivalence factors will be used in a multivariate interpolation algorithm to find an approximation to the actual 18K equivalence factor based on the axle set type, weight, tire pressure and roadbed soil modulus. For single axles, single tires, three levels of each of these variables appear. Therefore, for each of the nine combinations of surface and base/subbase thicknesses there will be twenty-seven different combinations for which each will have an equivalent weight. The other three axle set types have five different weight levels and three levels of the other two factors for a total number of forty-five combinations of these three factors, each with a specific equivalent factor assigned to it.

The sorting of variables within the file is crucial to correct operation of the interpolation algorithm. Within each axle set type, the levels of roadbed soil modulus must appear in ascending order with each value of tire pressure. All values of tire pressure must appear in ascending order with each value of weight (in 1000s).

WIM Truck Weight Data Input Files

The contents of these files are the data collected at various locations around the state with the WIM measuring device. They should reside either on the hard (fixed) disk or on a separate floppy disk. The program asks for the user to enter the proper disk drive location and name; then, after all input prompts are answered, it reads the file from beginning to end. A data checking option (described in detail later) is available to check the contents of this file for accuracy. The user can do little to adjust the data in this file, however, since it consists of measurements collected at different locations over time. The format of this file is different than the usual format of data files. The data for each truck record is not placed neatly into columns, but consists of intervening lines that contain special format statements describing the data. Therefore, a special statement reads the "/" that occurs between the year and month variables to define when a truck record occurs. The columns for each variable as they appear on a printed page and the columns the program actually read do not match exactly. Below are the columns as read by the program:

1) Month (columns 8-9, I2).
2) Day (columns 11-12, I2).
3) Year (columns 14-15, I2).
4) Hour (columns 17-18, I2).
5) Minutes (columns 20-21, I2).
6) Vehicle classification (column 33, I2).
7) Total weight of truck or combination (columns 50-55, F6.0).
8) A-axle weight (columns 57-61, F5.0).
9) B-axle weight (columns 63-67, F5.0).
10) C-axle weight (columns 69-73, F5.0).
11) D-axle weight (columns 75-79, F5.0).
12) E-axle weight (columns 81-85, F5.0).
13) F-axle weight (columns 87-91, F5.0).

14) G-axle weight (columns 93-97, F5.0).
15) H-axle weight (columns 99-103, F5.0).
16) I-axle weight (columns 105-109, F5.0).
17) J-axle weight (columns 111-115, F5.0).
18) K-axle weight (columns 117-121, F5.0).
19) L-axle weight (columns 123-127, F5.0).
20) M-axle weight (columns 127-131, F5.0).

The columns for all axle spacing data and their respective formats for each truck are read from the record directly following.

1) Total wheelbase (columns 51-55, F5.0).
2) (A-B) axle spacing (feet) (columns 63-67, F5.1).
3) (B-C) axle spacing (feet) (columns 69-73, F5.1).
4) (C-D) axle spacing (feet) (columns 75-79, F5.1).
5) (D-E) axle spacing (feet) (columns 81-85, F5.1).
6) (E-F) axle spacing (feet) (columns 87-91, F5.1).
7) (F-G) axle spacing (feet) (columns 93-97, F5.1).
8) (G-H) axle spacing (feet) (columns 99-103, F5.1).
9) (H-I) axle spacing (feet) (columns 105-109, F5.1).
10) (I-J) axle spacing (feet) (columns 111-115, F5.1).
11) (J-K) axle spacing (feet) (columns 117-121, F5.1).
12) (K-L) axle spacing (feet) (columns 123-127, F5.1).
13) (L-M) axle spacing (feet) (columns 129-133, F5.1).

DETAILED PROGRAM DOCUMENTATION

This section describes in greater detail the structure of the program and the functions of each subroutine. The computer code is extensively documented and many questions concerning its operation can be answered by referring directly to the source code. Descriptions of the algorithms used to compute functional class, vehicle type codes, axle shifted weights, and interpolate ARE Inc equivalence factors are explained. A list of all important internal variables and their definitions is given along with a listing of the subroutines and their functions.

Vehicle Classifications of the FHWA

The FHWA has defined thirteen vehicle classes altogether, but only classes 5 through 13 for heavy trucks are used by the program. Classes 1 through 4 are reserved for motorcycles, passenger cars, pickups and buses. Descriptions of the heavy truck classifications are given in Table 3.1 which explain the configuration of each vehicle class.

Interpolation

ARE Inc has developed a set of 18-kip single axle load equivalence factors for flexible pavements as a function of six variables: surface thickness, base/subbase thickness, tire pressure, roadbed modulus, axle set type and axle set weight. An option to use the ARE Inc factors instead of the FHWA factors is included in the program. Given this set of six independent variables, a mathematical model that will equate their specific values to the proper load equivalence factor is desired but is currently not available. This is due to the lack of empirical evidence required to establish an unambiguous relationship.

It is possible to develop an approximation equation using least squares and some suitable transformation of the data. However, this method would most likely introduce bias into the relationship by predicting values consistently low or consistently high compared to the true value for certain ranges of the independent variables. This would, in turn, disproportionately affect accumulated totals.

An alternative method is to find a polynomial equation that fits the observations in the data file exactly and assume all values between two adjacent points lie on a smooth curve. The process of extracting "in-between" values is known as interpolation. The program uses a multivariate form of LaGrangian interpolation based on the formula:

Table 3.1. Description of FHWA vehicle codes 5 through 13.

5 - Two-Axle, Six-Tire, Single Unit Trucks - All vehicles on a single frame including trucks, camping, and recreation vehicles, motor homes, etc., having two axles and dual rear wheels.

6 - Three-Axle Single Unit Trucks - All vehicles on a single frame including trucks, camping, and recreational vehicles, motor homes, etc., having three axles.

7 - Four or More Axle Single Unit Trucks - All trucks on a single frame with four or more axles.

8 - Four or Less Axle Single Trailer Trucks - All vehicles with four or less axles consisting of two units, one of which is a tractor or straight truck power unit.

9 - Five-Axle Single Trailer Trucks - All five-axle vehicles consisting of two units, one of which is a tractor or straight truck power unit.

10 - Six or More Single Trailer Trucks - All vehicles with six or more axles consisting of two units, one of which is a tractor or straight truck power unit.

11 - Five or Less Axle Multi-Trailer Trucks - All vehicles with five or less axles consisting of three or more units, one of which is a tractor or straight truck power unit.

12 - Six-Axle Multi-Trailer Trucks - All six-axle vehicles consisting of three or more units, one of which is a tractor or straight truck power unit.

13 - Seven or More Axle Multi-Trailer Trucks - All vehicles with seven or more axles consisting of three or more units, one of which is a tractor or straight truck power unit.

$$F(X) = \sum_{i=1}^{N} \frac{\displaystyle\prod_{\substack{j=1 \\ i \neq j}}^{N} (X - X_j)}{\displaystyle\prod_{\substack{j=1 \\ i \neq j}}^{N} (X_i - X_j)} *(Y_i)$$

where:

N = the number of levels the independent variable,
X_i = the value of the variable at the ith level,
Y_i = the functional value at X_i,
= notation for summation of terms and
= notation for product of terms.

The formula is a summation of N terms, each consisting of a computed fraction derived from the N values of X_i and the known functional value, Y_i. If the value to be interpolated, X, equals X_i, then all but one of the fractions equals 0 and the other fraction, corresponding to Y_i, equals 1, which means F(X) = Y_i and the interpolated value fits exactly. If the value to be interpolated, X, lies between X_{i-1} and X_i, then the function given above computes an estimate of the true value by forming a polynomial equation of N-1 degrees based on the N pairs of data (X_i, Y_i). One nice feature of this formula is that the independent values do not need to be evenly spaced. However, all combinations of independent variables and their corresponding equivalence factor must be distinct. For example, if 3 = F(10), then the relation 2 = F(10) cannot also simultaneously exist.

If the ARE Inc load equivalence factors are used, the inputs to the interpolation equation are chosen at the beginning of the program during the interrogation routines where surface thickness, base/subbase thickness, roadbed soil modulus and tire pressure are chosen by the user.

The two remaining variables, axle set type and axle weight, are determined from each truck record. Surface thickness, base/subbase thickness and axle set type determine which arrays of the factors are used. Roadbed soil modulus, tire pressure and axle set weight serve as the independent variables in the interpolation equation.

Extrapolation is defined as calculating the factor's value for a set of independent variables where at least one lies outside the range of values used to develop the interpolation equation. Whenever a value is estimated in this manner, considerable caution should be used because the implied assumption is that the equations remain valid beyond the extreme values in the original data. These interpolation equations are either of degree 3 or degree 5, which means it must compute a value of 0 either two or four times for some set of independent variables, depending on which equation is used. This, in turn, means that its behavior outside the maximum or minimum value for each variable may result in totally inappropriate answers.

For this reason, the interpolation process was modified for low values of axle set weights. For some cases, predicted load equivalence factors were negative when interpolation was required for weights between 4000 and 10000 pounds. For weights below 4000 pounds, the predicted values increased as weight decreased. For this reason, two separate linear interpolations are used for weight values between 0 and 4000 pounds and 4000 and 10000 pounds.

Data Checking Procedures

An option available in the program is a simple data checking routine. Many types of errors may occur in the weight data files. Although it is not possible to catch them all, it is possible to find several discrepancies which, when corrected, will give better estimates of accumulated equivalent axle loads.

The data checking option is offered as a selection on screen as described in the section, PROGRAM OPERATING INSTRUCTIONS. If data checking is chosen, the subroutine DATCHK is called after all weight data file names have been entered.

The types of errors found by the program include:

1) The total weight of the vehicle (TOTWGT) must equal the sum of the individual axle set weights.

2) The total length of the vehicle (TOTLGT) must equal the sum of the individual axle set lengths.

3) The number of axles on the vehicle must correspond to the definition of the vehicle class.

For example, if the name of the weight data file being checked is SELI1.WIM and the total weight of the vehicle does not match the sum of the weights of all individual axles in record number 817, the following error message will be written to a file called ERROR.RPT:

> The sum of the axle weights does not match
> the total weight given in record 817, file SELI1.WIM

Similar messages appear for the other types of data errors. This allows quick identification of many possible errors within the files. The errors can be corrected using a text editor program. When an error is found in any file, the variable ICHECK is set equal to 1 (it is equal to 0 otherwise). When all records in each file have been checked the following question appears on screen:

> Errors have been found in at least one FHWA weight data file.
> A list of them is located in file ERROR.RPT.
> Do you want to continue processing?
>
> 1 = YES
> 2 = NO

Enter 1 or 2 ----->

If the response is 1 (YES), the weight data files are processed with the errors unchanged. If the response is 2 (NO), the program stops and corrections to the data file can be made.

If no errors were found in any data file (i.e., ICHECK = 0), the program continues with the input prompts and then begins processing the data files examined by the data checking routine. If the user does not want to continue processing, the program can be aborted by pressing the two 'Ctrl C' keys simultaneously.

Another type of error which may occur when the data within the file are inconsistent with the format specifications. If a character value occurs where a numeric value is expected, a READ error is given on the screen and execution is automatically aborted. The file must then be corrected before it can be used again.

Time of WIM Operation

Subroutine TIMER calculates time of WIM operation. It reads the year, month, day, hour and minute for each vehicle from the WIM data file. The number of hours and minutes at this precise time from January 1, 1984 is then computed. Data files that contain dates earlier than this base number will not calculate correct dates and time of WIM operation. If necessary, an earlier base date can be used by changing the value for the variable IBASYR defined in subroutine INITL to a number evenly divisible by 4 (e.g., 72, 76 or 80) and recompiling the program. The program creates new beginning and ending times of WIM operation as described under the section PROGRAM OUTPUT and keeps track of total time.

TME.DAT. This file is used to store all beginning and ending times and dates to be printed in the output file at the end of the program run. It is created within the program; so if there happens to be a file of the same name on the default drive, the old file will be replaced by the contents of this new file. Therefore, avoid having any file of this name in the work area when using the WIMESAL program.

Subroutine Descriptions

In this section, brief descriptions of each subroutine found in the program are given. They are written in modular form so that certain inputs to the subroutine may be analyzed and passed back to the main program or to another subroutine. Therefore, most subroutines can be easily modified without changes to other portions of the program, so long as the output of each subroutine is consistent with the format specified for the program as a whole.

SUBROUTINE	OBJECTIVE
INITL	Sets all parameters to initial values, summation array elements to zero, and reads in FHWA or ARE Inc load equivalence factors and axle load shifting data from exterior files to fill arrays.
AREQS	If ARE Inc factors are selected, surface thickness, base and subbase thickness, roadbed soil modulus values and tire pressure are used as inputs in order to select the appropriate set of factors.
AREDAT	Reads the ARE Inc equivalence factors and the appropriate levels of roadbed soil modulus, tire pressure and weight (in thousands of pounds) for a) single axles, single tires, b) single axles, dual tires, c) tandem axles, and d) triple axles into the proper arrays.

DATCHK	Performs data checking operations.
NLOADS	1. Determine type of each axle set: a) single axle, single tire, b) single axle, dual tire, c) tandem axle or d) triple axle. 2. Accumulate weights of each axle set. 3. Determine number of axle sets. 4. Calculate equivalent 18-Kip single axle load for each axle set.
TIMER	Computes total time of WIM operation.
EQUIVL	Determines which weight classification the axle set belongs in order to establish the proper load equivalence factor.
AREFTR	Sets the arrays used by subroutine LGRNG to calculate the ARE Inc 18-Kip load equivalence factors using LaGrange interpolation.
LGRNG	Interpolates an equivalence factor based on input values of roadbed soil modulus, tire pressure, axle weight, and axle type.
PRNT	Prints total counts and 18KESAL data for each station location, vehicle classification and pavement type.
HEADER	Prints heading at beginning of each new page of output.

List and Description of All Important Internal Program Variables

This section lists the most important variables found in the WIMESAL program. For each variable, a brief description, its initialized value, and the appropriate dimension of the array, if applicable, are given. The variables are grouped into the following classifications indicating how the data enters the program:

1) Entered by the user before data is evaluated.
2) Initialized within the program.
3) Read from an external data file.
4) Calculated from the data for each individual vehicle.
5) Calculated as a cumulative total.

1. Variables entered by the user before data is evaluated.

FILEIN(20) - WIM data input file names (maximum of 20).

LOCATN - Location of WIM data measurements.

IFACTR - Selects either AASHTO or ARE Inc equivalence factors:

1 = AASHTO
2 = ARE Inc

GROWTH - Expected traffic growth rate for the next twenty (20) years.

DATE - Date program is run (Month/Day/Year).

FILOUT - Output file name.

COMMNT - Comments describing special features of analysis.

If ARE Inc factors are chosen, the following variables are entered:

ISURTH - Asphalt concrete surface thickness.

= 1	-	THIN	< 1 in.	(0 in. is assigned)
= 2	-	MEDIUM	= 1 to 5 in.	(3 in. is assigned)
= 3	-	THICK	> 5 in.	(6 in. is assigned)

IBASTH - Total base/subbase thickness.

= 1	-	THIN	< 10 in.	(8 in. is assigned)
= 2	-	MEDIUM	= 10 to 17 in.	(14 in. is assigned)
= 3	-	THICK	> 17 in.	(20 in. is assigned)

JLEVEL - Surface and base thickness index for determining ARE Inc load equivalence factors.

= 1 for ISURTH = 1 and IBASTH = 1
= 2 for ISURTH = 1 and IBASTH = 2
= 3 for ISURTH = 1 and IBASTH = 3
= 4 for ISURTH = 2 and IBASTH = 1
= 5 for ISURTH = 2 and IBASTH = 2
= 6 for ISURTH = 2 and IBASTH = 3
= 7 for ISURTH = 3 and IBASTH = 1
= 8 for ISURTH = 3 and IBASTH = 2
= 9 for ISURTH = 3 and IBASTH = 3

XVAL(1) - Roadbed soil modulus.

-	Low	< 8000 psi	(4000 psi)
-	Medium	= 8000 to 16000 psi	(12000 psi)
-	High	> 16000 psi	(20000 psi)
-	Actual value		(User input)

XVAL(2) - Tire pressure.

- Standard AASHO Road Test Pressure	(75 psi)
- ARE Inc Field Measured Existing Pressure	(110 psi)
- High Pressure	(145 psi)
- Actual value	(User input)

2. Variables initialized within the program.

NSCRN = 0	- Identifies the screen for input or output.
MAXAXL = 13	- Maximum axles per vehicle.
MAXSET = 7	- Maximum axle sets per vehicle.
MTHDYS(12)	- Number of days per month in non-leap years.
NAXTYP = 4	- Number of axle set types.
NFCTIN = 25	- Maximum number of equivalence factor intervals defined by upper and lower weight limits.
NPVTYP = 2	- Number of pavement types.
NVEHCL = 9	- FHWA vehicle classifications (5 to 13 are used).
SPACE = 8.0	- The distance between axles, in feet, that distinguishes between single, tandem and triple axles.

3. Data read from external data files.

AASHTO load equivalence factor data input:

AXWTLM(NAXTYP,NFCTIN,2)	- Lower and upper weight limits for each of the NFCTIN weight classes for each axle type.
FACTOR(NAXTYP,NFCTIN,NPVTYP)	- AASHTO equivalence factors for each axle type, weight class and pavement type.

ARE Inc equivalence factors data input:

YST(27) - Single axle, single tire load equivalence factors.

XST(27,3) - Roadbed soil modulus, tire pressure and axle weight (in 1000s) corresponding to single axle, single tire equivalence factors.

YDT(27) - Single axle, dual tire load equivalence factors.

XDT(27,3) - Roadbed soil modulus, tire pressure and axle weight (in 1000s) corresponding to single axle, dual tire equivalence factors.

YTN(27) - Tandem axle load equivalence factors.

XTN(27,3) - Roadbed soil modulus, tire pressure and axle weight (in 1000s) corresponding to tandem axle equivalence factors.

YTR(27) - Triple axle load equivalence factors.

XTR(27,3) - Roadbed soil modulus, tire pressure and axle weight (in 1000s) corresponding to triple axle equivalence factors.

WIM weight data file input:

MONTH	- Month of weight record.
IDAY	- Day of the month of weight record.
IYEAR	- Year of weight record.
IHOUR	- Hour of the day.
MINUTE	- Minute of the hour.
TOTWGT	- Total weight of vehicle (in pounds).
AXWGT(MAXAXL)	- Axle weights (in pounds).
AXSPC(MAXAXL)	- Axle spacings (in feet).
TOTLGT	- Total length of vehicle (in feet).

IVEHCL - Vehicle type index for current record

5 = Two-axle, six-tire, single unit trucks.
6 = Three-axle, single unit trucks.
7 = Four or more axle single unit trucks.
8 = Four or less axle single trailer trucks.
9 = Five-axle single trailer trucks.
10 = Six or more axle single trailer trucks.
11 = Five or less axle multi-trailer trucks.
12 = Six-axle multi-trailer trucks.
13 = Seven or more axle multi-trailer trucks.

4. Data calculated from each vehicle record.

EQUIV(NPVTYP,MAXSET) - 18-Kip single axle load equivalence factors for each pavement type and each axle set type.

ISETS - The number of axle sets for the current vehicle (values range from 1 to MAXSET).

WGTS(MAXSET) - Actual weight for each axle set in pounds.

IAXTYP(MAXSET) - Axle set type calculated for each axle set:
= 1 for single axle, single tire.
= 2 for single axle, dual tire.
= 3 for tandem axle.
= 4 for triple axle.

WEIGHT = Actual weight for each axle set.

XVAL(3) = WEIGHT/1000.

5. Data calculated as cumulative totals.

EW1YR(NPVTYP,NVEHCL) - Total 18KESAL factors, one-year.
EW10YR(NPVTYP,NVEHCL) - Total 18KESAL factors, ten-year.

EW20YR(NPVTYP,NVEHCL)	- Total 18KESAL factors, twenty-year.
IRO(NVEHCL)	- ADT for each vehicle class.
IRC(NVEHCL)	- Twenty-year ADT for each vehicle class.
NOVEH(1,NVEHCL)	- One-year vehicle counts for each class.
NOVEH(2,NVEHCL)	- Ten-year vehicle counts for each class.
NOVEH(3,NVEHCL)	- Twenty-year vehicle counts for each class.
IVHCNT(NVEHCL)	- Current year vehicle counts for each vehicle type.
TESAL(NPVTYP,NVEHCL)	- Total 18KESAL for each pavement and vehicle type.
TESALK(NPVTYP,NVEHCL)	- Total 18KESAL for each pavement and vehicle type per 1000 vehicles.
TOTTME	- Total elapsed time of data collection.

SUMMARY

This chapter presented user information and program documentation for the program WIMESAL. The program uses weigh-in-motion data to produce accumulated 18KESAL for one, ten and twenty-year periods. It also produces estimates of 18KESAL per 1000 vehicles with the option of using AASHTO load equivalence factors or new ARE Inc load equivalence factors. All information which may be required by users of the program or by programmers to modify the program is included in this chapter.

CHAPTER 4

PROGRAM TRAF18K FOR ANALYZING TRAFFIC AND PROCESSED WEIGHT DATA

Program TRAF18K computes the total number of equivalent 18-kip ESAL applications sustained by each Arizona traffic section. It is designed to allow a minimum effort on the part of the user. The current form of the program is a modification of an existing Arizona mainframe program called TRAFPROG which is changed each year to analyze the new data. Program TRAF18K was developed to be generic and allow each year's data to be analyzed without changing the program.

In order to explain the use of the program, a complete description of the requirements for its operation will be given, including the data input file descriptions and the series of prompts that require user response.

PROGRAM OPERATING INSTRUCTIONS

To run program TRAF18K, turn on the power to the microcomputer, video monitor and printer. Since printout exceeds normal 80 column width, it is recommended that 80-column printers be operated in "compressed" mode. Be sure the program and its support data files are all on the default disk drive; then enter the command TRAF18K. Several prompts will appear on the screen which must be answered in order to run the program. This section describes these prompts and the appropriate responses that will allow the program to execute properly.

Figure 4.1 illustrates the first screen. The user enters the appropriate date in the format he wishes it to appear on the output (up to 30 characters is allowed).

Figure 4.2 presents the second screen that appears after the date is entered. This screen briefly describes the required data files that must be present on disk with the TRAF18K program. While generating this screen, the program searches for the first two data files identified, TRAFCOMM.DAT and TRAFBASE.DAT. If either or both of these files are

```
******** PROGRAM TRAF18K ********

Program modified by:

ARE Inc - Engineering Consultants

Austin, Texas

Version 2.0  -  October 10, 1987

for

Arizona Department of Transportation

ENTER THE DATE: OCTOBER 15, 1987
```

Figure 4.1. Initial screen for program TRAF18K.

```
REQUIRED INPUT DATA FILES ARE AS FOLLOWS:

TRAFCOMM.DAT  - Arizona classification data format
TRAFBASE.DAT  - File containing relationship between
                classification stations and volume stations
ADTyear.DAT   - This is the traffic volume data file for
                the current year.  For example, in 1987
                "year" = 1987 and the file is ADT1987.DAT
LOADCOEF.DAT  - File containing the coefficients to
                calculate vehicle load equivalency factors

NOTE: These files must be stored on the same disk as this program



     The traffic volume data file should contain the
most recent traffic volume data.  File names are specified
by a file name and extension as FILENAME.EXT.  For example,
1987 volume data is specified as:

      ADT1987.DAT


THE DRIVE AND NAME OF THE TRAFFIC VOLUME DATA FILE IS?----> ADT1987.DAT
Searching for LOADCOEF.DAT
```

Figure 4.2. Second screen for program TRAF18K.

missing, an error message is written immediately after the 'NOTE' and program execution is terminated. If both files are found, the program requests the name of the traffic volume data file. Once the file name is entered, the program then searches the disk for the file and writes an error message if it is not found. If the file is present, the program then searches for the last required data file, LOADCOEF.DAT. This activity is indicated at the bottom of the second screen. If the file is not found an error message is generated and execution terminates. If the file is present, the program opens it and proceeds to the third screen.

Figure 4.3 shows the third program screen. This screen presents the current values for vehicle load equivalence factors. The method used to define these factors was devised and implemented by Arizona DOT early in 1987 while analyzing the 1987 traffic data. The method uses a system of regression equations which define vehicle equivalence factors for each vehicle class as a function of future years. This method was developed because it was observed that vehicle equivalence factors were increasing yearly. The form of the regression equation is:

VEHICLE FACTOR = A + B*(YEAR - 1900)

ADOT had previously developed equations for only the three largest vehicle classes. The new program allows equations for all classes. If no equations are available for a class, the A coefficient then becomes the actual vehicle factor and the B coefficient is set to zero. Program TRAF18K allows the user to edit or modify the factors or equation coefficients directly during program operation. This is accomplished by responding with a 1 or 2 to the prompt shown at the bottom of Figure 4.3.

Figure 4.4 shows the editing prompts that appear if option 1 is selected. The "years to analyze" are the years at which future vehicle equivalency factors will be calculated. The base year is normally the current year. The middle year and final year can be anything the user desires depending on the values of equivalency factor selected for future years. The years at which accumulated 18-kip ESAL will be calculated and printed are always the base year, ten years into the future and twenty

```
VEHICLE LOAD FACTOR PARAMETERS

     Years to analyze
            BASE YEAR:  1987
          MIDDLE YEAR:  1992
           FINAL YEAR:  1997

     Coefficients to calculate vehicle factors
         EQUATION FORM:  FACTOR = A + B*(YEAR-1900)
CLASS    A FLEXIBLE   B FLEXIBLE    A RIGID      B RIGID
AUTO:     .000800      .000000      .000800      .000000
 BUS:     .250000      .000000      .250000      .000000
  LT:     .004600      .000000      .004600      .000000
  MT:     .400000      .000000      .400000      .000000
  TS:    -.870100      .021745    -1.721140      .039045
  TT:    -.456760      .017910     -.765480      .024650
 TST:   -3.476340      .060895    -3.578160      .062410

TYPE OF DATA TO MODIFY
     0 = None - the data is correct
     1 = Years to analyze
     2 = Equivalency coefficients

Enter 0, 1, or 2 -----> 0
```

Figure 4.3. Third screen of program TRAF18K.

ENTER NEW YEARS TO ANALYZE

Current Value for Base Year = 1987

1234567890
New Base Year ----->

Current Value for Middle Year = 1992

1234567890
New Middle Year -----> 1997

Current Value for Final Year = 1997

1234567890
New Final Year -----> 2007

Figure 4.4. Screen for selecting new "Years to Analyze" in program TRAF18K.

years into the future. These should be chosen as the "years to analyze" if consistency is to be maintained and vehicle equivalence factors for the correct analysis years are to be used. For each prompt shown in Figure 4.4, a new year may be entered. If the year shown by the program is correct, 'Enter' will keep the same value. After the prompts for all three years have been answered, the program returns to the screen shown in Figure 4.3. If the user selects option 2, the program will edit the vehicle equivalence factor coefficients. The user must first identify which coefficients to edit, either the flexible or the rigid pavement coefficients. Either one or both may be edited.

Figure 4.5 shows the screen that is scrolled while the coefficients are being edited. After each prompt, the user may enter either, both, or neither the A and B coefficients. If a new value is entered for any coefficient, it is taken and stored to the LOADCOEF.DAT file for use in the current run and for later use. If no value is entered for any coefficient, the old value is retained. Once all prompts have been answered, the program returns to the screen shown in Figure 4.3. The edit process may continue until all values are correct, at which time a 0 is entered at the prompt of Figure 4.3.

The program then prompts the user for information regarding the disposition of the program output. Figure 4.6 shows the output prompt screen. The user has the option to 1) write the output file directly to the printer to immediately obtain a hard copy or 2) direct the output to a disk file (named by the user) for later use or examination before printing. If an output file is desired, any valid DOS filename is acceptable. [CAUTION: Any existing file by the same name will be overwritten by the new program output; so be sure the specified output file does not already exist on disk or is no longer needed].

PROGRAM OUTPUT

After all prompts have been answered, the program begins execution and displays a message that it is running. The output file will then be written as instructed by the user. The output has the same format as the

ENTER NEW FLEXIBLE PAVEMENT EQUIVALENCY COEFFICIENTS
(Decimal points are required)

AUTOMOBILE COEFFICIENTS	A FLEX	B FLEX
Existing Values =	.000800	.000000
	1234567890	1234567890
Correct Values ----->		

BUS COEFFICIENTS	A FLEX	B FLEX
Existing Values =	.250000	.000000
	1234567890	1234567890
Correct Values ----->	0.25	

LT COEFFICIENTS	A FLEX	B FLEX
Existing Values =	.004600	.000000
	1234567890	1234567890
Correct Values ----->		

MT COEFFICIENTS	A FLEX	B FLEX
Existing Values =	.400000	.000000
	1234567890	1234567890
Correct Values ---->		

TS COEFFICIENTS	A FLEX	B FLEX
Existing Values =	-.870100	.021745
	1234567890	1234567890
Correct Values ----->		

TT COEFFICIENTS	A FLEX	B FLEX
Existing Values =	-.456760	.017910
	1234567890	1234567890
Correct Values ----->		

TST COEFFICIENTS	A FLEX	B FLEX
Existing Values =	-3.476340	.060895
	1234567890	1234567890
Correct Values ----->		

Figure 4.5. Screen for entry of flexible pavement load equivalence coefficients.

The output may be sent directly to the printer or stored in a file for later use.

```
WRITE OUTPUT FILE TO DISK OR PRINTER? (D/P)----> D

THE DRIVE AND NAME OF THE OUTPUT FILE IS?----> OUTPUT
```

OR

The output may be sent directly to the printer or stored in a file for later use.

```
WRITE OUTPUT FILE TO DISK OR PRINTER? (D/P)----> P
```

Figure 4.6. Screens for disposition of program output.

original Arizona TRAFPROG program. This was intended to maintain consistency with existing ADOT procedures.

An example of the output is shown in Figure 4.7. A separate output line is produced for each traffic section input. The original ADOT output routine has been modified to reflect the input values for vehicle equivalencies and the years at which cumulative loads are calculated. This serves to make the program generic in that it may be run each year on new data without changing the computer code and recompiling. This is unlike program TRAFPROG which was constrained to the year 1987.

DATA INPUT FILES

The following input data files are required to operate program TRAF18K:

TRAFCOMM.DAT - Arizona classification data format.
TRAFBASE.DAT - File containing relationship between classification stations and volume stations.
ADTyear.DAT - This is the traffic volume data file for the current year. For example, in 1987 "year" = 1987 and the file is ADT1987.DAT.
LOADCOEF.DAT - File containing the coefficients to calculate vehicle load equivalence factors.

The file formats for TRAFCOMM.DAT, TRAFBASE.DAT and ADTyear.DAT are the same as previously used by ADOT's original program TRAFPROG. These files currently reside on ADOT's mainframe and are also available on microcomputer disk. The formats for these data files are given in Tables 4.1, 4.2, and 4.3.

File LOADCOEF.DAT contains the vehicle load equivalence factor coefficients for use by the program. This file is supplied with the program and may be easily modified using the TRAF18K program's built-in edit routine which automatically places each variable in the proper location within the file.

RUN DATE: OCTOBER 15, 1987 ARB/ARE Inc - Vers. 2.0

```
**********************************************
*                                            *
*                 A D O T                    *
*                                            *
*       MATERIALS PAVEMENT SERVICES          *
*                                            *
*           T R A F F I C   D A T A          *
*                                            *
**********************************************
```

THESE TRAFFIC CALCULATIONS ARE BASED ON THE FOLLOWING ASSUMPTIONS:

1. THE ADT GROWTH RATE FACTOR IS LINEAR; THE ADT INCREASES BY THE SAME AMOUNT EACH YEAR.

2. THE AD T DIRECTIONAL SPLIT IS 50% IN EACH DIRECTION.

3. AASHTO AXLE LOAD EQUIVALENCY FACTORS ARE USED WITH:

PT = 2.5
SN = 5.0 FOR FLEXIBLE EQUIVALENCIES
D = 9.0 FOR RIGID EQUIVALENCIES

4. THE FLEXIBLE AND RIGID PAVEMENT AXLE LOAD EQUIVALENTS PER VEHICLE FOR A 20 YEAR DESIGN ARE:

FLEXIBLE PAVEMENT		RIGID PAVEMENT	
AUTOMOBILES	.0008	AUTOMOBILES	.0008
BUSES	.2500	BUSES	.2500
LT	.0046	LT	.0046
MT	.4000	MT	.4000
TS	1.2392	TS	2.0662
TT	1.2805	TT	1.6256
TST	2.4305	TST	2.4756

5. THE AXLE LOAD EQUIVALENTS PER VEHICLE FOR THE HEAVY TRUCKS ARE CALCULATED FROM THE FOLLOWING LINEAR EQUATIONS:

FLEXIBLE PAVEMENTS	RIGID PAVEMENTS
TS = -.87010 + .021745 * YR	TS = -1.72114 + .039045 * YR
TT = -.45676 + .017910 * YR	TT = -.76548 + .024650 * YR
TST = -3.47634 + .060095 * YR	TST = -3.57816 + .062410 * YR

WHERE, YR = YEAR - 1900, e.g. 1977 - 1900 = 77

IF YOU HAVE QUESTIONS CONCERNING THE BASIS FOR THESE ASSUMPTIONS AND CALCULATIONS CONTACT:

JOHN EISENBERG 255-8087

AL GASTELUM 255-7835

Figure 4.7. Example output from TRAF18K program (page 1 of 2).

LT - LIGHT TRUCK MT = MEDIUM TRUCK TS = TRACTOR & SEMI-TRAILER
TT = TRUCK & TRAILER TST = TRACTOR & SEMI-TRAILER

TWO - WAY PERCENT

100% OF THE ONE-WAY ACCUMULATED 18 KIP ESAL (THOUSANDS) THROUGH THE YEARS:

HIGHWAY	MILEPOSTS	TRAF SEC	CLASS STA	1987 ADT	2007 ADT	ANNUAL GROWTH	COM	LT	MT	TS	TT	TST	BUS	1987 FLEXIBLE	1997 FLEXIBLE	2007 FLEXIBLE	1987 RIGID	1997 RIGID	2007 RIGID
I 8	.00- .57	1	42	6281	6669	.3	39.4	57.8	14.3	20.7	3.8	3.4	.4	171	1904	4204	238	2667	5934
I 8	.57- 2.23	2	42	8497	13318	2.8	39.4	57.8	14.3	20.7	3.8	3.4	.4	235	2896	7081	326	4057	9996
I 8	2.23- 3.98	3	42	10834	20576	4.5	39.4	57.8	14.3	20.7	3.8	3.4	.4	302	3961	10196	419	5549	14393
I 8	3.98- 7.63	4	42	7768	12915	3.3	39.4	57.8	14.3	20.7	3.8	3.4	.4	215	2703	6714	299	3786	9478
I 8	7.63- 9.40	5	42**	7208	10901	2.6	39.4	57.8	14.3	20.7	3.8	3.4	.4	199	2427	5878	276	3400	8298
I 8	9.40- 12.21	6	41**	8571	12326	2.2	38.6	63.6	12.5	18.3	2.6	3.0	.3	199	2397	5728	277	3366	8108
I 8	12.21- 21.03	7	41	7832	10859	1.9	38.6	63.6	12.5	18.3	2.6	3.0	.3	182	2165	5123	253	3040	7252
I 8	21.03- 30.80	8	41	7110	10056	2.6	38.6	63.6	12.5	18.3	2.6	3.0	.3	166	2028	4925	230	2848	6971
I 8	30.80- 37.95	9	41	6821	10107	2.4	38.6	63.6	12.5	18.3	2.6	3.0	.3	159	1926	4640	221	2705	6568
I 8	37.95- 42.06	10	41	6170	8017	1.5	38.6	63.6	12.5	18.3	2.6	3.0	.3	143	1673	3891	199	2350	5508
I 8	42.06- 54.96	11	41	5507	5317	-.2	38.6	63.6	12.5	18.3	2.6	3.0	.3	127	1376	2967	176	1933	4200
I 8	54.96- 67.41	12	41	5806	6735	.7	38.6	63.6	12.5	18.3	2.6	3.0	.3	136	1537	3460	189	2159	4897
I 8	67.41- 73.48	13	41	5517	5670	.1	38.6	63.6	12.5	18.3	2.6	3.0	.3	127	1400	3066	177	1966	4341
I 8	73.48- 78.46	14	41	4767	5307	.6	38.6	63.6	12.5	18.3	2.6	3.0	.3	110	1235	2761	153	1735	3909
I 8	78.46- 87.04	15	41	4957	5349	.4	38.6	63.6	12.5	18.3	2.6	3.0	.3	114	1274	2825	159	1789	3999
I 8	87.04-102.23	16	41	5361	5141	-.2	38.6	63.6	12.5	18.3	2.6	3.0	.3	123	1337	2879	171	1878	4075
I 8	102.23-106.51	17	41	5933	8791	2.4	38.6	63.6	12.5	18.3	2.6	3.0	.3	138	1675	4036	192	2353	5713
I 8	106.51-111.42	18	41	5799	8306	2.2	38.6	63.6	12.5	18.3	2.6	3.0	.3	135	1624	3808	180	2282	5504
I 8	111.42-115.40	19	15	5141	5234	.1	35.1	43.3	7.5	39.1	3.6	6.5	.3	195	2179	4813	204	3182	7064
I 8	115.40-115.58	20	15**	2962	4975	3.4	35.1	43.3	7.5	39.1	3.6	6.5	.3	114	1462	3682	166	2135	5404
I 8	115.58-119.42	21	16**	3247	4756	2.3	46.6	30.7	6.2	54.4	2.9	5.8	.5	202	2474	6003	304	3750	9151
I 8	119.42-140.81	22	16	6770	12275	4.1	46.6	30.7	6.2	54.4	2.9	5.8	.5	425	5560	14206	640	8429	21778
I 8	140.81-144.57	23	16	6256	10740	3.6	46.6	30.7	6.2	54.4	2.9	5.8	.5	392	5035	12749	590	7633	19435
I 8	144.57-151.68	24	16	6371	11116	3.7	46.6	30.7	6.2	54.4	2.9	5.8	.5	399	5158	13117	601	7820	19996
I 8	151.68-161.53	25	62	5211	7737	2.4	43.8	29.3	7.9	54.5	2.8	5.5	.2	305	3743	9100	459	5678	13099
I 8	161.53-167.53	26	62	6057	11169	4.2	43.8	29.3	7.9	54.5	2.8	5.5	.2	357	4699	12117	538	7129	18491
I 8	167.53-169.54	27	62	5253	8384	3.0	43.8	29.3	7.9	54.5	2.8	5.5	.2	308	3867	9593	464	5866	14638
I 8	169.54-172.53	28	62	5763	9912	3.6	43.8	29.3	7.9	54.5	2.8	5.5	.2	339	4357	11026	511	6609	16826
I 8	172.53-174.54	29	62	5966	10829	4.1	43.8	29.3	7.9	54.5	2.8	5.5	.2	352	4601	11814	530	6900	18028
I 8	174.54-178.33	30	62**	6425	12409	4.7	43.8	29.3	7.9	54.5	2.8	5.5	.2	380	5075	13240	572	7690	20217
I 10	.00- .70	34	19	20007	45395	5.9	40.1	42.5	6.8	39.3	3.1	8.3	.3	971	13600	36051	1391	19601	53290
I 10	.70- 5.84	35	19	18207	30093	5.5	40.1	42.5	6.8	39.3	3.1	8.3	.3	847	11702	31339	1214	16855	45326
I 10	5.84- 11.91	36	19	16502	33190	5.0	40.1	42.5	6.8	39.3	3.1	8.3	.3	770	10469	27710	1104	15079	40077
I 10	11.91- 17.47	37	19**	16447	32856	5.0	40.1	42.5	6.8	39.3	3.1	8.3	.3	764	10374	27444	1095	14943	39693
I 10	17.47- 19.79	38	20**	13031	23922	4.2	42.8	27.8	6.3	51.4	3.8	10.7	.5	823	10081	28174	1187	15760	40963
I 10	19.79- 26.65	39	20	11129	17627	2.9	42.8	27.8	6.3	51.4	3.8	10.7	.5	699	8809	21925	1007	12750	31876
I 10	26.65- 31.17	40	20	10135	14626	2.2	42.8	27.8	6.3	51.4	3.8	10.7	.5	634	7776	10079	914	11262	27440
I 10	31.17- 45.36	41	20	9482	14408	2.6	42.8	27.8	6.3	51.4	3.8	10.7	.5	594	7400	18215	857	10718	26482
I 10	45.36- 53.96	42	20	9384	14178	2.6	42.8	27.8	6.3	51.4	3.8	10.7	.5	588	7309	17965	848	10587	26119
I 10	53.96- 69.66	43	20	9384	14178	2.6	42.8	27.8	6.3	51.4	3.8	10.7	.5	588	7309	17965	848	10587	26119
I 10	69.66- 81.22	44	20	9392	14206	2.6	42.8	27.8	6.3	51.4	3.8	10.7	.5	589	7318	17992	849	10600	26159
I 10	81.22- 94.15	45	20	9419	14215	2.5	42.8	27.8	6.3	51.4	3.8	10.7	.5	590	7334	10019	851	10622	26190

Figure 4.7. Example output from TRAF18K program (page 2 of 2).

Table 4.1. Input variables and formats in input file TRAFCOMM.DAT.

VARIABLE NAME	DESCRIPTION	TYPE AND NO. OF PLACES*	COLUMN NUMBERS
KLASS(200)	Classification station no.	I3	1-3
BUS(200)	Percent of all vehicles which are Buses for each station	F4.1	9-12
PCT(200)	Percent of all vehicles which are commercial for each station	F5.1	13-18
PERCOM(200,5)	Percent of all commercial vehicles which are of each of the five vehicle classes	5F5.1	19-23 24-28 29-33 34-38 39-43

*I - Integer Variable
F - Floating Point Real Variable
A - Alphanumeric Variable

Table 4.2. Input variables and formats for input file TRAFBASE.DAT.

VARIABLE NAME	DESCRIPTION	TYPE AND NO. OF PLACES	COLUMN NUMBERS
KODE	Route type I - Interstate S - State route U - Urban route	A1	1
NO	Route Number	A4	2-5
MP1	Beginning milepoint of section	F7.2	6-12
MP2	Ending milepoint of section	F7.2	13-19
BSEC	Traffic section Number	I4	20-23
BCLASS	Associated classification station number	I4	24-27
CODE	Highway type I-Interstate P-Primary U-Urban S-Secondary	A1	29
AST	Asterisks	A2	32-33

Table 4.3. Input variables and formats for input file ADTyear.DAT.

VARIABLE NAME	DESCRIPTION	TYPE AND NO. OF PLACES	COLUMN NUMBERS
ISEC(2000)	Traffic volume count section number	I4	1-4
GROW(2000)	Estimated growth rate	F6.1	10-15
IRO(2000)	2 way ADT in the base year	I7	16-22
IRC(2000)	Estimated 2 way ADT in 20 years	I8	23-30

DETAILED PROGRAM DOCUMENTATION

This section describes in greater detail how the program is structured and what functions the subroutines perform. The computer code is extensively documented and many questions concerning its operation can be answered by referring directly to the source code. A list of all important internal variables and their definitions is given along with a listing of the subroutines and their functions.

General Program Flow

The general flow of the program is illustrated in Figure 4.8. Operations performed by the program are shown within rectangular boxes and user interaction functions are shown within the circles.

Subroutine Descriptions

This section describes the main program and each of its subroutines. Each routine serves a specific function.

MAIN PROGRAM	Prompts the user for volume and output file names. Reads the three main data files. Performs accumulated equivalent load calculations. Writes output.
SUBROUTINE INIT	Initializes the program. Reads the run date from the user.
SUBROUTINE EDITCOEF	Displays vehicle load equivalence factor coefficients for all vehicle classes. Edits coefficients at the users discretion. Writes any new coefficients to LOADCOEF.DAT file. Transfers correct coefficients to main program for use in calculations.

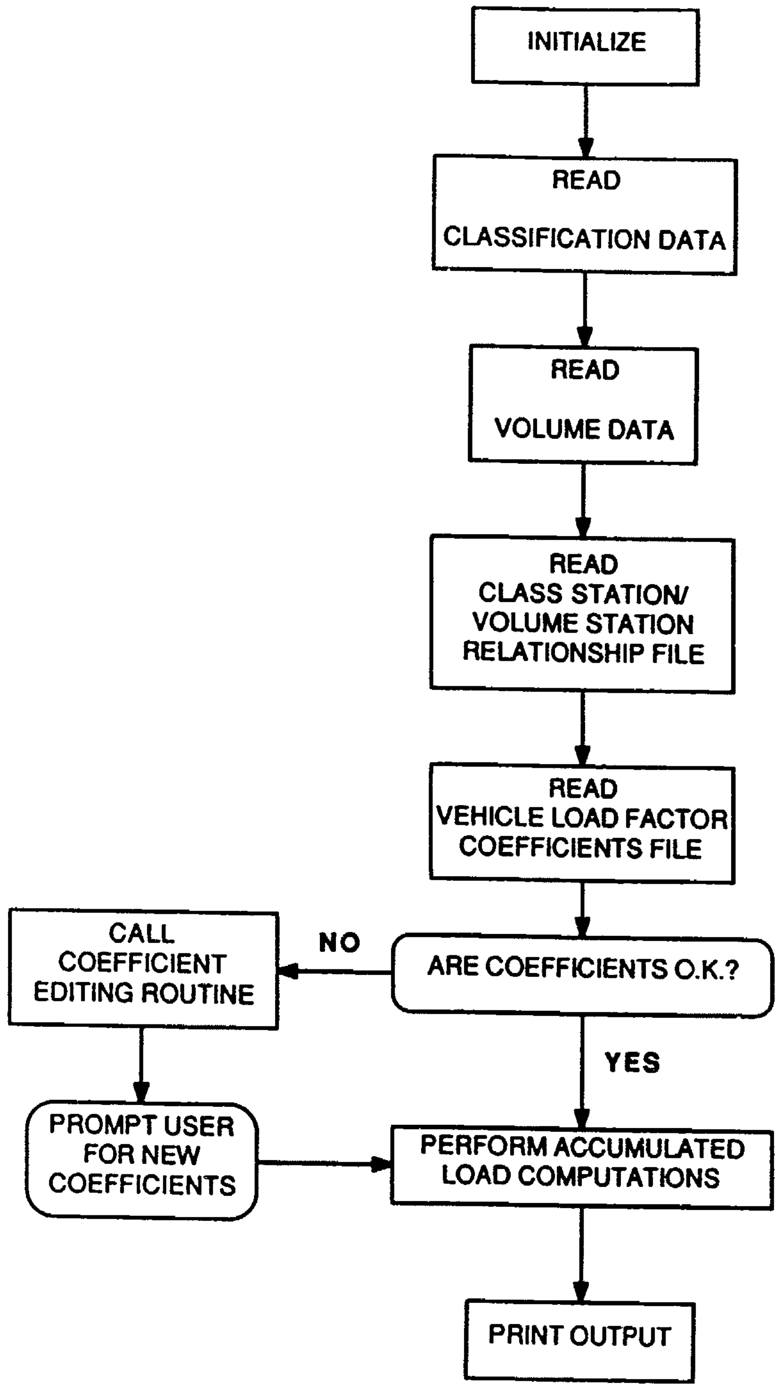

Figure 4.8. Flowchart for program TRAF18K.

SUBROUTINE EXIT — Called when a data file error is encountered. Closes all files. Writes an error message to the screen. Exits the program.

List and Description of Important Internal Variables

A number of internal variables are used in program TRAF18K to perform the required functions. The most important of these variables is described in Table 4.4.

SUMMARY

This chapter presents user information and program documentation for the program TRAF18K. The program uses traffic volume and classification data and equivalent axle load data to compute the total number of 18-kip equivalent single axle loads on each of the Arizona traffic sections. All information which may be required by users of the program or by programmers seeking to modify the program is included in this chapter.

Table 4.4. List and description of important internal variables.

VARIABLE NAME	DESCRIPTION
YEAR(3)	Values of years to analyze, converted to real numbers for calculation in regression equations
FLEX(3,5)	Flexible pavement vehicle load equivalency factors for the 3 years to analyze and the 5 commercial vehicle classes
RIGID(3,5)	Rigid pavement vehicle load equivalency factors for the 3 years to analyze and the 5 commercial vehicle classes
CARLDF(3)	Flexible pavement automobile load equivalency factors for the 3 years to analyze
BUSLDF(3)	Flexible pavement bus load equivalency factors for the 3 years to analyze
CARLDR(3)	Rigid pavement automobile load equivalency factors for the 3 years to analyze
BUSLDR(3)	Rigid pavement bus load equivalency factors for the 3 years to analyze
CAR18F(3)	Computed 18kip ESAL for automobiles on flexible pavements
BUS18F(3)	Computed 18kip ESAL for buses on flexible pavements
CAR18R(3)	Computed 18kip ESAL for automobiles on rigid pavements
BUS18R(3)	Computed 18kip ESAL for buses on rigid pavements
FLEOUT	Variable name of the output file
VOLIN	Variable name of the input file
DATE	Variable name of the user input date
OUT	Variable which tells program whether to write the output to a disk file or to the printer
NOVEH(3)	Total number of vehicles in each of the three analysis years
NOBUS(3)	Number of buses in each of the three analysis years
NOCOM(3)	Number of commercial vehicles in each of the three analysis years

Table 4.4. List and description of important internal variables (continued).

VARIABLE NAME	DESCRIPTION
NOCAR(3)	Number of commercial vehicles in each of the three analysis years
IFWT(3)	Total number of equivalent loads for flexible pavements in each of the three analysis years
IRWT(3)	Total number of equivalent loads for rigid pavements in each of the three analysis years
FWT(3)	Number of equivalent loads contributed by commercial vehicles for flexible pavements in each of the three analysis years
RWT(3)	Number of equivalent loads contributed by commercial vehicles for rigid pavements in each of the three analysis years
NSEC	Total number of traffic sections considered in the analysis

CHAPTER 5. PROGRAM McPAD FOR MECHANISTIC DESIGN OF FLEXIBLE PAVEMENT STRUCTURES

OVERVIEW

McPAD-1 is the first version of a mechanistic-based flexible pavement structural design program that was developed to use the new damage models (described in Volume 1, Chapter 3) and the corresponding 18-kip ESAL traffic projections derived from the new ARE Inc load equivalence factors. As a basis for comparison, the program also has the capability for generating pavement structural designs based on the new AASHTO Guide for Design of Pavement Structures - 1986 (Ref. 1). In fact, it incorporates some of the new reliability concepts described in the new Guide for both the mechanistic and AASHTO Guide based designs.

Because of questions surrounding the mechanistic models used in its development, McPAD-1 is intended to be an experimental program at this time. Through detailed review and continued application of the program in design situations, it is envisioned that some basis will be established for its adoption and implementation within Arizona DOT practice.

Unlike the WIMESAL, FEDESAL and TRAF18K programs, McPAD-1 was developed in two different programming languages, Fortran and dBASE III Plus. Basically, Fortran was used to develop the analytical component of the program (i.e., the part that actually develops the pavement designs), while dBASE III Plus was used to create an interactive, menu-driven input data file generator. Detailed documentation of the structure and function of the program is provided later in this chapter. The following two sections are provided to describe 1) some specific hardware considerations and 2) the operation of the program in a typical pavement design situation.

HARDWARE REQUIREMENTS/RECOMMENDATIONS

The McPAD-1 program was designed to run on almost any IBM-PC compatible system that 1) uses PC-DOS or MS-DOS as the disk operating system, 2) has at least 256 kilobytes of random access memory (RAM), 3) has a printer, 4) has a hard (fixed) disk drive and 5) has an 8087 (or 80287) math-coprocessor. Although not essential, the last two are strongly recommended because of their capacity to enhance the program's execution time. (Note: If an 8087 or 80287 math-coprocessor is not available, it would be necessary to recompile the Fortran-based analysis program, MCPAD1A.FOR, and produce an executable version, MCPAD1A.EXE, that would not require the chip).

PROGRAM OPERATING INSTRUCTIONS

To execute the McPAD-1 program (in an interactive environment), copy the two distribution diskettes, McPAD-1 and FoxBASE+ onto the hard disk. Then type "MCPAD1" (followed by the 'Enter' key). Since the screen-menu component of the program is written in the dBASE III Plus language and compiled with FoxBASE+, it will take a moment or so for the program to be loaded. [Note: The user also has the option of running the program in "direct-batch" mode without using the screen-menu program. Since, in this mode, the user must prepare his input data files by some other means, this operational mode is covered under a later section entitled, "Input Data Files."

The first major screen of the McPAD-1 screen program (see Figure 5.1) is basically an introductory or title screen. The second major screen (see Figure 5.2) provides a brief description of the function of the program and cautions the user about its application.

The third major screen (see Figure 5.3) is called the CONTROL MENU screen. As can be seen, it is the key to unlocking the various functions of the program that are used to prepare design problems and run them. Following is a description of the six (6) functions (options) that may be selected by the user.

```
00     00       000000     00    000000    000
00     00       00   00   0000   00   00    00
000   000  000  00   00  00  00  00   00    00
0000 0000 00 00 00   00 00    00 00   00 00 00
00 000 00 00    000000  00000000 00   00    00
00  0  00 00 00 00      00    00 00   00    00
00     00  000  00      00    00 000000    0000
```

Mechanistic Pavement Design Program
Version 1.0 - December 1987

Developed for:
Arizona Department of Transportation
Contract No: HPR-PL-1-31(219)

By:
ARE Inc - Engineering Consultants
Austin, Texas

Press Any Key to Continue ...

Figure 5.1. McPAD-1 program introductory screen.

NOTICE:

McPAD-1 is a computer program developed primarily for the mechanistic design of flexible pavement structures. As a basis for comparison, McPAD-1 also has the added capability to design flexible pavement structures based upon the procedures presented in the new AASHTO Guide for Design of Pavement Structures (1986). Documentation for the program is provided within the users manual (Volume 2 of the Final Report) prepared for the project entitled, "Evaluation of Increased Pavement Loading."

The program is based on sound engineering principles and every precaution was taken to insure accuracy during the development process. However, due to the nature of pavement design, it is possible that a situation could arise that might cause the program to abort or provide unreasonable solutions. Consequently, it is up to the user to not only familiarize himself with the capabilities and limitations of the program (as documented in the users manual), but also accept ultimate responsibility for the adequacy of the results.

Press Any Key to Continue ...

Figure 5.2. McPAD-1 program description and caution statement.

```
                CONTROL MENU

     No.        Option
     ------------------------------
      1. Create a new problem
      2. Delete a problem
      3. Update an existing problem
      4. Run problems
      5. Reset the system
      6. Exit the system

Enter Number of Desired Option (1-6): █
```

Figure 5.3. McPAD-1 Control Menu screen.

1. Create a New Problem

The screen-menu program is basically a data base manager that, for purposes of developing pavement structural design solutions, allows the user to create and store new problems or retrieve and update old (stored) problems. When Option 1 is chosen, the program assumes that the user intends to create a new pavement structural design problem and add it to the data base. It prompts the user to enter a problem name (consisting of 1 to 10 characters) that will be used to store information for a single design problem. If no name is typed and the 'Enter' key is pressed, the program will return to the CONTROL MENU. Since it is desirable to know what problems already exist in the data base, the program does provide a feature that allows the user to examine the list of existing problem names. This is accomplished by simply typing the word "DIR" in response to the prompt for the new problem name. Figure 5.4 provides an example of the DIRECTORY OF AVAILABLE PROBLEMS screen that would be displayed. Note that a description of the function of various cursor keys is provided so that the user may scroll through the directory if there are more problems than can be shown on the screen at one time. Note also that the program does not permit the user to enter the name of an existing problem in the data base. If he does, the program will automatically display the DIRECTORY screen (and subsequently return to the CONTROL MENU).

Once the user enters a legal (unused) name for the new data file, the program will then ask the user if he wishes to copy an existing problem into the new one. If the answer is Y (Yes), the program will ask for the name of the problem to be copied. (At this point, the user again has the option of examining the DIRECTORY OF AVAILABLE PROBLEMS screen before entering the name of the desired problem to copy). Once the name is entered, the program will display the first part of the McPAD-1 PAVEMENT STRUCTURAL DESIGN INPUTS screen, complete with the data from the problem that was copied (see Figure 5.5 for screen example). If the answer to the "Do you wish to copy a problem?" question is N (No), the program will immediately display the first part of this DESIGN INPUTS screen with some empty and some default values for the design input values. In either case, once the user enters data for the various inputs in the top portion

DIRECTORY OF AVAILABLE PROBLEMS

PROBLEM NAME	DESCRIPTION
MCPAD1-EX1	McPAD-1 Example Problem, AASHTO Materials, Light Traffic
MCPAD1-EX2	McPAD-1 Example Problem, AASHTO Materials, Moderate Traffic
MCPAD1-EX3	McPAD-1 Example Problem, AASHTO Materials, Heavy Traffic

ACTION

		Home	1st Problem	End	Last Problem
X	Exit	PgUp	Page Up	PgDn	Page Down

Figure 5.4. Directory of available problems (in data base) screen.

```
McPAD-1 PAVEMENT STRUCTURAL DESIGN INPUTS

Problem Name MCPAD1-EX5
Description  McPAD-1 Example Problem, Arizona Conditions, Moderate Traffic

No. of Layers in                              Mechanistic    AASHTO Guide
Pavement Structure  3                         Based Design   Based Design
                                              ============   ============
      Projected 18-kip ESAL Traffic               4292292               0



To Exit - Press the Cntrl & End Keys Simultaneously a Few Times
```

Figure 5.5. Top portion of McPAD-1 Pavement Structural Design Inputs screen.

of the screen, the program will display the rest of the screen (see example in Figure 5.6), so that the user may enter the remainder of his design input data. Once all the data for a particular problem is entered, the program will ask if the user wishes to add more data (i.e., create another problem). If so, the process starts over with the entry of a new problem name. If not, control is returned to the CONTROL MENU.

Note: If the user is interested in more descriptive information on the selection of appropriate input values, he should refer to a later section of this chapter entitled, "Input Data Files." It is important to point out here, however, that it is not necessary to provide data for both mechanistic and AASHTO Guide based design solutions. In fact, if the user enters a zero value for "Projected 18-kip ESAL Traffic" for either one of the two methods, the analysis program will assume that no design is required for that method and not permit the user to enter any additional design inputs for that method.

2. Delete a Problem

As the data base of design problems begins to grow, it may reach a point where the user may wish to do some "house-cleaning". In fact, some users may prefer not to maintain any problems at all in the data base. This option allows the user to eliminate old undesirable problems from storage within the data base. When chosen, the program prompts the user for the name of a problem that he would like to eliminate. If he wishes to examine the DIRECTORY OF AVAILABLE PROBLEMS (as in Option 1), he may do so by typing the word "DIR" in response to prompt for the name of the problem to be deleted. Once a legal (identifiable) problem name is entered, the program will display the data corresponding to that problem in order to verify the user's intention to delete it. Subsequently, the program will ask if any more problems are to be deleted. If so, the process is repeated. If not, control is returned to the CONTROL MENU.

McPAD-1 PAVEMENT STRUCTURAL DESIGN INPUTS

Problem Name MCPAD1-EX5
Description McPAD-1 Example Problem, Arizona Conditions, Moderate Traffic

No. of Layers in Pavement Structure 3

	Mechanistic Based Design	AASHTO Guide Based Design
Projected 18-kip ESAL Traffic	4292292	572847
Desired Reliability (%)	95.000	95.000
Overall Standard Deviation	0.490	0.490

		Mechanistic Based Design					AASHTO Guide	
Layer No.	Layer Description	Elastic Modulus (psi)	Poisson Ratio	Min. Thick. (in)	Max. Thick. (in)	Thick. Incr. (in)	AASHTO Layer Coef.	Spec. Thick. (in)
1	Hot-Mix Asphalt Conc	450000	0.300	3.00	6.00	1.00	0.44	0.0
2	Granular Base	50000	0.350	6.00	12.00	2.00	0.16	0.0
3	Granular Subbase	20000	0.400	6.00	20.00	2.00	0.12	0.0
Soil	Gravelly Sand	10000	0.450					

To Exit - Press the Cntrl & End Keys Simultaneously a Few Times

Figure 5.6. Complete McPAD-1 Pavement Structural Design Inputs screen.

3. Update on Existing Problem

This option is provided to allow the user to access an existing input data problem from the data base (by name) and update (or revise) it. When this option is chosen, the program will ask the user to identify the name of the problem he wants to update. As in Options 1 and 2, the user may examine the DIRECTORY OF AVAILABLE PROBLEMS by typing the word "DIR" in response to the prompt for the name of the problem to be updated. Once a legal (identifiable) problem name is entered, the program will display the McPAD-1 PAVEMENT STRUCTURAL DESIGN INPUTS screen along with the design input values corresponding to the selected problem. At this point, the user may edit any or all of the values in preparation for a new pavement design problem. Once all the desired values are updated or confirmed, the program will then display a line at the bottom of the screen (see below) that gives the user several options or alternative ACTIONs on what to do next:

ACTION: N=Next P=Previous S=Another R=Re-edit X=Exit

The N (or Next) action causes the program close the current input data problem and display the next one that appears sequentially in the data base for potential updating. The P (or Previous) action again causes the program to close the current input data problem and instead display the previous input data problem for potential updating. If S (or Another) is chosen, the program will prompt the user for the name of the input data problem to update. If R (or Re-edit) is selected, the user will be given the opportunity to change or re-edit the current input data problem. Finally, once all problem updates and revisions are completed, the user may select the X (or Exit) option, which will return control to the main CONTROL MENU.

4. Run Problems

Once all the desired design input data problems have been prepared, it is then necessary to analyze them using the McPAD-1 analysis program. This is accomplished using Option 4. When executed, the screen program will first display a screen (see Figure 5.7) that provides some instructions on how to select the desired design problems in the data base for execution. Essentially, all the user must do is put a 'Y' (for Yes) by the name of each problem in the data base he wants to have analyzed. The screen program will then write a disk file (FLAT.DAT) containing all the desired design problems and then execute the appropriate commands so that the analysis program will analyze the data and generate a "hard copy" of the results on a printer that has already been connected and prepared for operation with the system. While the analysis program is running, an appropriate message will be displayed on the screen. When finished, user control will be left at the disk operating system level (rather than the CONTROL MENU level). Figure 5.8 provides an example of the output that is generated by the McPAD-1 program for a single design problem.

5. Reset the System

The McPAD-1 design problem data base is ordered alphabetically by problem name. Once in a great while, this ordering may be disturbed. If this happens, resetting the system will refresh the problem name ordering of all McPAD-1 problems. Also, if operation is accidentally interrupted, all the problems that were identified for execution may still be set to be run. Resetting the system will clear these settings so that no problems will be set to run.

6. Exit the System

This option is provided so that the user may exit the McPAD-1 screen-menu program without having to run the analysis program. When executed, program operation is terminated and control is transferred to the disk operating system.

INPUT DATA FILES

Although the McPAD-1 program consists of multiple files, there is only one primary input data file that is of significance to the user. It is named "FLAT.DAT" and is generated by the screen-menu programs

RUN PROBLEMS

Please browse through the forthcoming list
of problems. To select a problem for execution,
place a "Y" in the column next to that problem name.

When finished, press the 'Cntrl' and 'End' keys
simultaneously to start the run.

To find available problems, use the 10-key pad.
Alternatively, press the 'Cntrl' and 'Home' keys
simultaneously; use the arrow keys to move
to the 'find' command, press the 'Enter' key, and
finally enter the name of the problem desired.

Press Any Key to Continue...

Figure 5.7. Instructions for selection of problems to run.

McPAD-1: MECHANISTIC FLEXIBLE PAVEMENT STRUCTURAL DESIGN PROGRAM
Version 1.0 - December 1987
Arizona Department of Transportation

Problem Name: MCPAD1-EX1
Description: McPAD-1 Example Problem, AASHTO Materials, Light Traffic

Design Input Summary:

	Mechanistic Based Design	AASHTO Guide Based Design
Projected 18-kip ESAL Traffic	749291	100000
Desired Reliability (Percent)	95.000	95.000
Overall Standard Deviation	.490	.490
Reliability Factor *	6.400	6.400
Design 18-kip ESAL Traffic *	4795170	639961

(* = Calculated Internally)

		Mechanistic Based Design					AASHTO Guide Based Design	
Layer No.	Layer Description	Elastic Modulus (psi)	Poisson Ratio	Min Thick (in)	Max Thick (in)	Thick Incr (in)	AASHTO Layer Coeff	Spec Thick (in)
1	Hot-Mix Asphalt Conc	450000	.300	4.00	6.00	1.00	.440	4.00
2	Granular Base	30000	.350	6.00	12.00	3.00	.140	6.00
3	Granular Subbase	15000	.400	6.00	18.00	3.00	.110	.00
4	Silty Clay	3000	.450					

Design Results:

	Mechanistic Solution	AASHTO Guide Solution
Layer 1 Design Thickness (in)	4.00	4.00
Layer 2 Design Thickness (in)	6.00	6.00
Layer 3 Design Thickness (in)	9.00	9.81
Allowable 18-kip ESAL Traffic	5101354	640659
Reliability Achieved (Percent)	95.541	95.010

Figure 5.8. McPAD-1 program - example output.

(MCPAD1S.FOX and MCUTILI.FOX) for evaluation by the analysis program (MCPAD1A.EXE). Figure 5.9 identifies the input variables for a single problem and illustrates their format and organization within the disk file. Multiple problems are analyzed within a single MCPAD1A execution when several eight-line input data problem sets are "stacked" one after the other within the FLAT.DAT file. Following is a description of all the input variables identified in Figure 5.9. The names indicated are the same as those used in the analysis program source code (MCPAD1A.FOR).

Line 1

NPROB = Name of the problem being analyzed.
[alphanumeric, columns 1-10]

TITLE1 = First part of problem description.
[alphanumeric, columns 11-35]

TITLE2 = Second part of problem description.
[alphanumeric, columns 36-75]

Line 2

T18M = Projected 18-kip ESAL traffic over the design period for mechanistic-based pavement design. If reliability feature is used, this should be an average projected value, not a conservative estimate. If this value is left zero or blank, no mechanistic design will be generated, regardless of the values of any other mechanistic input factors.
[real, columns 1-10]

RM = Desired reliability for mechanistic-based design, 50 to 99.999 percent.
[real, columns 11-15]

OSDM = Overall standard deviation for mechanistic-based design. If the reliability feature is used, this value should be selected based on the recommendations in the AASHTO Guide (Ref 1), at least until better mechanistic-based criteria can be developed. The recommended interim value is 0.49.
[real, columns 16-20]

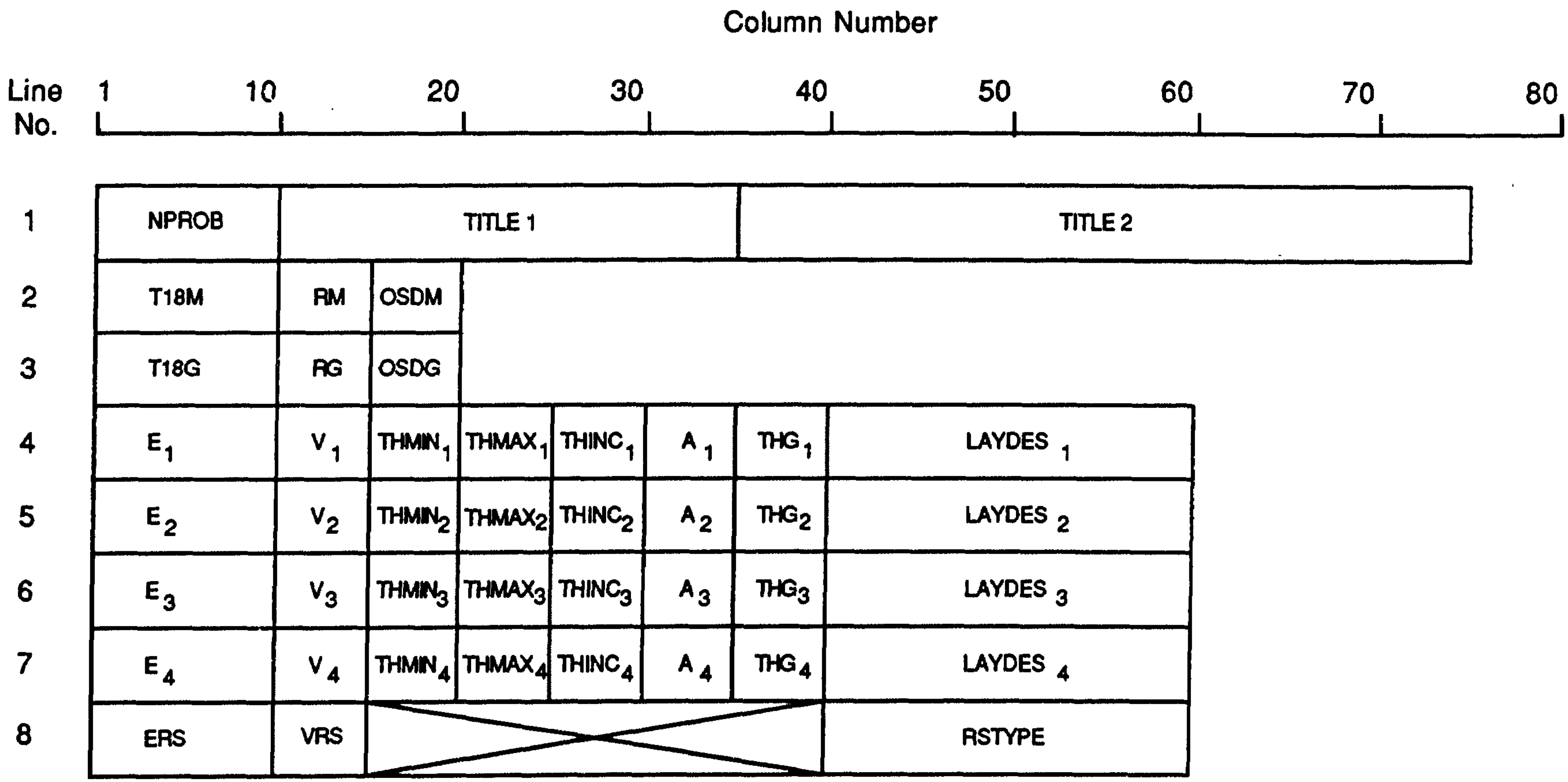

Figure 5.9. Structure of a single input data problem for the McPAD-1 analysis program (MCPAD1A.EXE).

Line 3

T18G = Projected 18-kip ESAL traffic over the design period for AASHTO Guide based pavement design. If reliability feature is used, this should be an average projected value, not a conservative estimate. If this value is left zero or blank, no AASHTO Guide based design will be generated, regardless of the values of any other AASHTO Guide based design inputs.
[real, columns 1-10]

RG = Desired reliability for AASHTO Guide based design, 50 to 99.999 percent.
[real, columns 1-10]

OSDG = Overall standard deviation for AASHTO Guide based design. If the reliability feature is used, this value should be selected based on criteria on the AASHTO Guide (Ref 1). The recommended value is 0.49.
[real, columns 16-20]

Lines 4, 5, 6 and 7

E_i = Elastic (Young's) modulus for pavement layer i, psi.
[real, columns 1-10]

V_i = Poisson's ratio for pavement layer i.
[real, columns 11-15]

$THMIN_i$ = Minimum thickness constraint for pavement layer i, inches. This value is for mechanistic design purposes and must be greater than zero unless layer i is not to be considered.
[real, columns 16-20]

$THMAX_i$ = Maximum thickness constraint for pavement layer i, inches. This value is for mechanistic design purposes and must be greater than the minimum thickness constraint for layer i. Furthermore, if this value is less than or equal to 3 inches for the surface layer (i = 1), the program will assume that T18M will have been derived using load equivalence factors for a thin surfaced pavement structure.

[real, columns 21-25]

$THINC_i$ = Thickness increment for layer i, inches. This value is used in the mechanistic-based pavement design process. It should be selected to provide practical or "constructable" pavement structural designs. It should also be noted that McPAD-1 will develop pavement structural designs from the bottom layer up. In other words, layer thicknesses will be incremented sequentially from the bottom-up until a feasible pavement structural design is found.
[real, columns 26-30]

A_i = AASHTO layer coefficient for layer i. Required only if AASHTO Guide based solution is desired.
[real, columns 31-35]

THG_i = Specified thickness of layer i for an AASHTO Guide based solution, inches. If left blank (or zero), the program will calculate the required layer thickness based on the "layered analysis" approach described on the Guide. When specified, the program assumes that a reasonable thickness has been chosen, therefore, no check is made on the minimum cover requirement for the layer below. If all layer thicknesses in the pavement structure are specified, the program will estimate the expected life in 18-kip ESAL and the corresponding reliability (if appropriate).
[real, columns 36-40]

$LAYDES_i$ = Description of layer i.
[alphanumeric, columns 41-60]

<u>Line 8</u>

ERS = Elastic (Young's) modulus for the roadbed soil, psi.
[real, columns 1-10]

VRS = Poisson's ratio for the roadbed soil.
[real, columns 11-15]

RSTYPE = Description of the type of material composing the roadbed soil.
[alphanumeric, columns 41-60]

Note:

The analysis program reads the name of the input data file from a separate one-line file called "INFNAME.TFR". For normal interactive operation, the name of the input data file is "FLAT.DAT", consequently, that is the name that is stored within the INFNAME.TFR file. However, it is possible for the user to avoid use of the screen-menu program and create his input data files using some other available text editor (in ASCII format and according to the organization in Figure 5.9). For these cases, the user should edit the INFNAME.TFR file and change the one line entry from "FLAT.DAT" to "BATCH-MODE", then execute the analysis program directly by typing "MCPAD1A". The analysis program will then read the modified INFNAME.TFR file, determine that it will need to run in batch mode and then prompt the user for the actual name of his input data file. Of course, if the user ever wishes to return to the normal interactive operational mode, he will need to change the contents of the INFAME.TFR file back to "FLAT.DAT".

DETAILED PROGRAM DOCUMENTATION

Program Structure

As mentioned previously, the McPAD-1 computer program actually consists of an assortment of executable programs, batch files, data base files and input data files. Figure 5.10 provides a diagram illustrating the organization of all these files into what is actually a program system. Following is a discussion of how these files interact in the process of solving a particular flexible pavement design problem.

Assuming that the user has properly installed McPAD-1 on his computer and also that he has prepared or assembled all the information that will be required to solve the problem, the first thing he must do is execute the Primary Control Routine (MCPAD1.BAT). This is accomplished by typing "MCPAD1" (followed by the 'Enter' key). This batch file, in turn, will

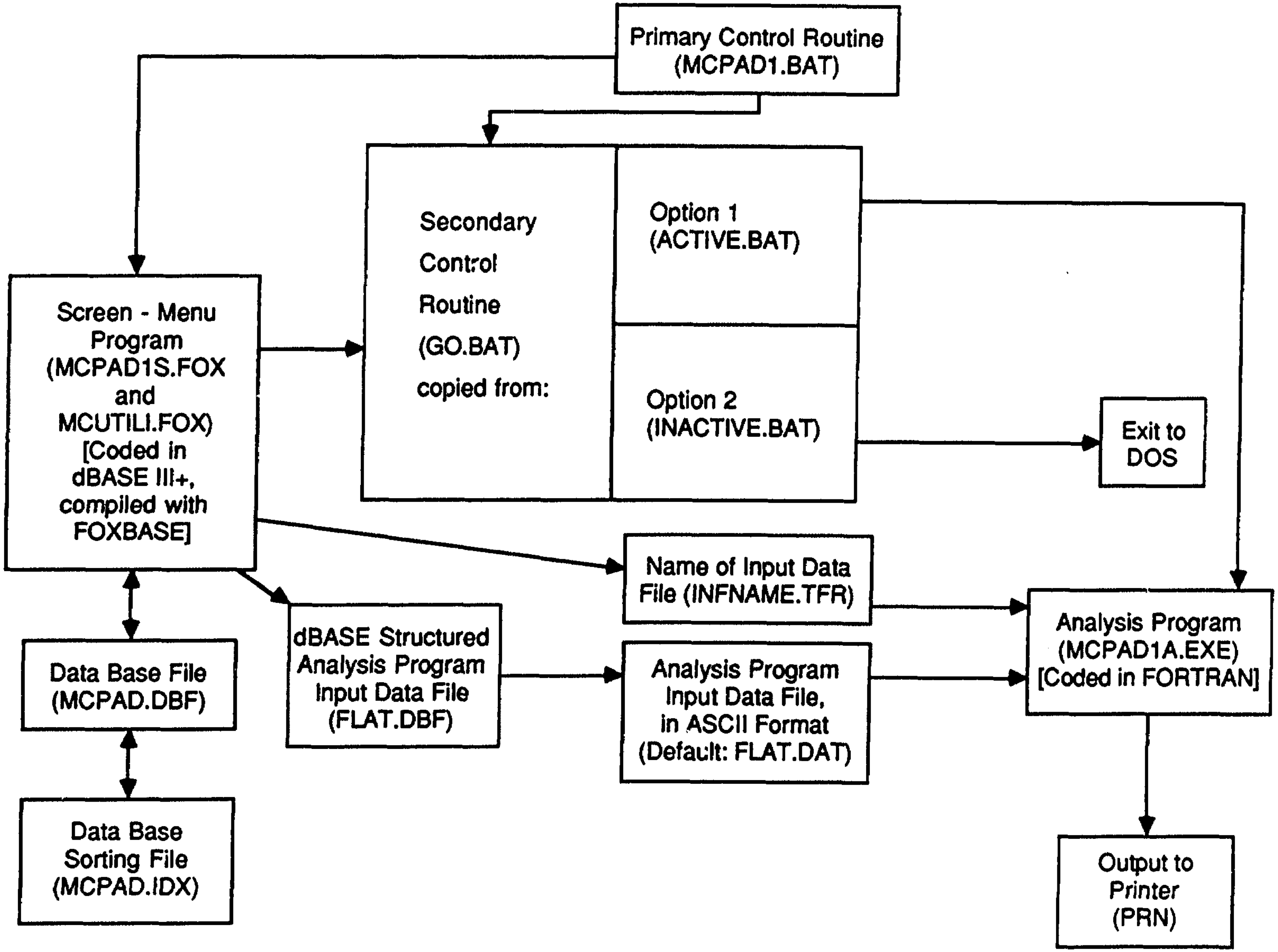

Figure 5.10. Organization of McPAD-1 program files.

first execute the screen-menu program (MCPAD1S.FOX and MCULTILI.FOX) and then the Secondary Control Routine (GO.BAT).

While the screen-menu program is running, the user will be creating and/or accessing input data problem sets stored within the data base file labelled, "MCPAD.DBF". This file is in dBASE III format and is sorted alphabetically according to an indexing file named, "MCPAD.IDX". When a series of problem sets are actually chosen for execution, they are initially stored within a dBASE III format file named "FLAT.DBF". This file is then translated into another one labelled "FLAT.DAT" which is in ASCII format. Depending on whether the RUN option or EXIT option is chosen by the user while in the screen-menu program, either the "ACTIVE.BAT" or "INACTIVE.BAT" file will be copied onto the Secondary Control Routine (GO.BAT). Then, when GO.BAT is executed by the Primary Control Routine (MCPAD1.BAT), the system will either execute the analysis program (MCPAD1A.EXE) or exit to the disk operating system (DOS).

If the analysis program is executed, it will open the file named "INFNAME.TFR" and determine the name of input data file to be read and analyzed. For normal interactive operation, the name of the input data file is "FLAT.DAT", however, as discussed under the previous section entitled, "Input Data Files," this name may be changed (within the INFNAME.TFR file) to "BATCH-MODE" for direct operation of the analysis program.

During execution of the analysis program (MCPAD1A.EXE), it should be recognized that the program will output its results directly to the printer. Therefore, it is important that the printer be connected and switched on during program execution. As illustrated in Figure 5.8, the entire output for one problem is contained within a single page.

Screen-Menu Program

The screen-menu component of the McPAD-1 program is written in the data base management language, dBASE III Plus. The source code to this component is contained within two files called "MCPAD1S.PRG" and

"MCUTILI.PRG". To avoid the need for purchasing dBASE (by Arizona DOT), we have used a separate compiler package known as FoxBASE+ to develop an executable version of the screen-menu program. This executable version is contained within two files named "MCPAD1S.FOX" and "MCUTILI.FOX" which require the use of the FoxBASE+ Runtime Module (which we can legally copy and provide to ADOT). [If ADOT ever decides to enhance or modify the screen-menu program, however, it will be necessary to purchase the dBASE III Plus software package from Ashton-Tate]. Since the program is designed primarily for interactive data entry, there are no special functions or operations that require any more detailed documentation other than provided by the previous section entitled, "Program Structure".

Analysis Program

The analysis program contains all the specialized code required to conduct the engineering aspects related to both mechanistic and AASHTO Guide based flexible pavement structural design. The source code to the program (MCPAD1A.FOR) is written in Fortran. It was compiled using MicroSoft Fortran (Version 4.0) to generate the executable code (MCPAD1A.EXE).

The program consists of a number of subroutines for accomplishing the variety of functions required for design. The most notable of these is actually a package of subroutines derived from the original elastic layer theory based computer program known as ELSYM5. This subroutine package is used to generate the critical pavement responses required for the mechanistic design process. Other key subroutines are also incorporated in order to treat the reliability aspects as well as generate interim calculations required for AASHTO Guide based design.

For mechanistic design, the process is basically very simple. With input information provided by the user (as described in the section entitled, "Input Data Files"), the program will try different feasible structural layer combinations, starting with thinnest, until it finds thinnest one in which the predicted load-carrying capacity (expressed in terms of 18-kip ESAL applications) exceeds the minimum allowable load applications as calculated based on the projected traffic (over the design period) and the desired reliability.

There are two equations used by the program to predict the load-carrying capacity of a given pavement structure. The first equation is based on the maximum tensile strain calculated at the bottom of the surface layer due to a simulated 18-kip single axle load. This equation, shown below, is used whenever, $THMAX_1$, the maximum potential surface layer thickness specified by the user exceeds 3 inches.

$$\log(N_f) = 3.25 - 7.50*\log(TNSTRN) - 4.10*\log(E_1)$$

In this equation,

N_f = predicted 18-kip ESAL applications that can be sustained before a terminal serviceability of 2.5 is reached,

TNSTRN = maximum tensile strain calculated at bottom of asphalt concrete surface layer under a simulated 18-kip single axle load and

E_1 = elastic (Young's) modulus, in psi, of asphalt concrete surface layer.

If $THMAX_1$ specified by the user is less than or equal to 3 inches, then the program assumes that the user has entered a projected 18-kip ESAL traffic estimate derived from the thin surface mechanistic load equivalence factors and uses the following equation to predict load-carrying capacity:

$$\log(N_f) = -7.75 - 4.28*\log(VSTRN)$$

where N_f is as previously defined and

VSTRN = maximum vertical compressive strain calculated at the top of the roadbed soil.

Relative to the reliability aspects, it should be pointed out that the program uses the following equation to calculate the minimum allowable (design) 18-kip ESAL traffic over the design period:

$$T18DM = T18M*10^{(ZM*OSDM)}$$

In this equation,

T18M = projected (average) 18-kip ESAL applications over the design period,

ZM = standard normal deviate corresponding to desired level of reliability (RM), and

OSDM = specified overall standard deviation for mechanistic design (recommended interim value from AASHTO Guide model is 0.49).

Finally, since the design pavement structure will most likely provide more capacity than the minimum allowable, the program does "back-calculate" and print the associated increased reliability.

For AASHTO Guide based designs, the program uses the same model that is documented in the recent publication (Ref. 1) and incorporated into AASHTO's DNPS86/PC_{TM} computer program. If AASHTO compatible 18-kip ESAL traffic projections are provided along with reliability inputs, layer coefficients and roadbed soil modulus, the program will develop a pavement structural design that can be compared directly with the design generated using the mechanistic approach. Like the mechanistic model, the mechanics of deriving a solution using the AASHTO Guide approach are relatively simple. In fact, it may be easier to interpret the method by examining the actual computer source code than reviewing the procedure described in the Guide.

For the benefit of interested users and future programmers who may be enhancing or modifying the analysis program, Table 5.1 provides a description of some of the key variables used in both the mechanistic and AASHTO Guide based design branches of the program.

SUMMARY

Considerable effort has been expended towards developing a mechanistic flexible pavement design program, McPAD-1, that will assist Arizona DOT in taking the first step towards implementing a pavement design procedure that is based on fundamental engineering mechanics and material properties. The program incorporates some of the user-friendly menu-driven features that make it appealing to many apprehensive users and, hopefully, will also make it easier to implement. Furthermore, the current AASHTO Guide based flexible pavement design procedure is incorporated into the program so that direct comparisons can easily be made under normal loading and tire pressure conditions, so that some basis for credibility can be established. If some confidence is developed in the program under these normal loading conditions, then it will be possible to accept the solutions it may generate under the higher loads and tire pressures that are being experienced now and probably in the future.

Table 5.1. Description of key variables used in McPAD-1 analysis program.

Variable Name	Description
ZM	Standard normal deviate corresponding to desired reliability (mechanistic analysis).
ZG	Standard normal deviate corresponding to desired reliability (AASHTO Guide analysis).
FRM	Reliability factor (multiplier on projected traffic for mechanistic analysis).
FRG	Reliability factor (multiplier on projected traffic for AASHTO Guide analysis).
T18DM	Minimum 18-kip ESAL traffic for mechanistic-based structural design.
T18DG	Minimum 18-kip ESAL traffic for AASHTO Guide based structural design.
NPL	Total number of pavement layers.
NEL	Total number of layers (including roadbed soil).
THFM( )	Array of design pavement layer thicknesses, inches (mechanistic solution).
THFG( )	Array of design pavement layer thicknesses, inches (AASHTO Guide solution).
ANF	Predicted 18-kip ESAL applications for a trial pavement structural design (mechanistic solution).
RMF	Calculated reliability for a trial pavement structural design (mechanistic solution).
AWT	Predicted 18-kip ESAL applications for a trial pavement structural design (AASHTO Guide solution).
RGF	Calculated reliability for a trial pavement structural design. (AASHTO Guide Solution)
TNSTRN	Maximum principal tensile strain calculated in bottom of surface (asphalt concrete) pavement layer under simulated 18-kip single axle load.
VSTRN	Maximum vertical compressive strain calculated at top of roadbed soil under simulated 18-kip single axle load.
NZT	Number of specified zero-thickness layers (AASHTO Guide analysis).
IZT	Index of last zero-thickness layer (closest to bottom) (AASHTO Guide analysis).
DPSI	Design serviceability loss (based on AASHO Road Test conditions and terminal serviceability of 2.5).
SNTOT	Cumulative AASHTO structural number for a trial pavement design.
SNTOP(i)	AASHTO structural number required above layer i+1.

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APPENDIX A

EXTENDED AASHTO LOAD EQUIVALENCE FACTORS
(As extracted from Volume 1, Appendix G)

CONTENTS OF FILE AASHTO.EQF

Axle Set Type	Weight Interval Index	Lower Weight Limit	Upper Weight Limit	Rigid Equivalence Factor	Flexible Equivalence Factors For Tire Pressures of 75 psi	110 psi	145 psi
Single Axle - Single Tire Factors							
1	1	0000.0	2999.0	0.0002	0.00166	0.00188	0.00206
1	2	3000.0	6999.0	0.0050	0.03349	0.03960	0.04390
1	3	7000.0	7999.0	0.0260	0.14560	0.18400	0.21000
1	4	8000.0	11999.0	0.0820	0.28510	0.37400	0.43600
1	5	12000.0	15999.0	0.3410	0.76113	1.06900	1.29700
1	6	16000.0	18000.0	0.7830	1.32469	1.93600	2.41300
1	7	18001.0	18500.0	1.0650	1.62017	2.40200	3.02400
1	8	18501.0	20000.0	1.3360	1.88481	2.82500	3.58200
1	9	20001.0	21999.0	1.9260	2.41311	3.67900	4.72200
1	10	22000.0	23999.0	2.8180	3.12827	4.85100	6.30500
1	11	24000.0	25999.0	3.9760	3.97662	6.25800	8.22500
1	12	26000.0	29999.0	6.2890	5.53815	8.87700	11.83800
1	13	30000.0	999999.0	11.3950	8.68277	14.20700	19.27500
Single Axle - Dual Tire Factors							
2	1	0000.0	2999.0	0.0002	0.000182	0.000197	0.000212
2	2	3000.0	6999.0	0.0050	0.005010	0.00553	0.00593
2	3	7000.0	7999.0	0.0260	0.034300	0.03840	0.04130
2	4	8000.0	11999.0	0.0820	0.087700	0.09940	0.10700
2	5	12000.0	15999.0	0.3410	0.360200	0.39400	0.43100
2	6	16000.0	18000.0	0.7830	0.796000	0.87400	0.93900
2	7	18001.0	18500.0	1.0650	1.060000	1.16800	1.24100
2	8	18501.0	20000.0	1.3360	1.3070	1.44900	1.53000
2	9	20001.0	21999.0	1.9260	1.8260	2.04900	2.17300
2	10	22000.0	23999.0	2.8180	2.5630	2.92800	3.12200
2	11	24000.0	25999.0	3.9760	3.5330	4.04500	4.33500
2	12	26000.0	29999.0	6.2890	5.3890	6.26000	6.76200
2	13	30000.0	999999.0	11.3950	9.4320	11.16800	12.19676
Tandem Axle - Dual Tire Factors							
3	1	000.0	5999.0	0.0100	0.000105	0.000113	0.000122
3	2	6000.0	11999.0	0.0100	0.004550	0.00502	0.00535
3	3	12000.0	17999.0	0.0620	0.036000	0.04040	0.04350
3	4	18000.0	23999.0	0.2530	0.1480	0.16900	0.18300
3	5	24000.0	29999.0	0.7290	0.4260	0.48000	0.52500
3	6	30000.0	32000.0	1.3050	0.7530	0.83400	0.91700
3	7	32001.0	32500.0	1.5420	0.8440	0.97500	1.07400
3	8	32501.0	33999.0	1.7510	1.0010	1.09900	1.21300
3	9	34000.0	35999.0	2.1650	1.2300	1.35400	1.48500
3	10	36000.0	37999.0	2.7210	1.5330	1.69700	1.84500
3	11	38000.0	39999.0	3.3730	1.8860	2.09800	2.26300
3	12	40000.0	41999.0	4.1290	2.2900	2.56100	2.74100
3	13	42000.0	43999.0	4.9970	2.7500	3.09300	3.28600
3	14	44000.0	45999.0	5.9870	3.2700	3.69700	3.93700
3	15	46000.0	49999.0	7.7250	4.1700	4.75400	5.08300
3	16	50000.0	9999999.0	10.1600	5.8300	6.72400	7.23300

APPENDIX B

ARE INC MECHANISTIC LOAD EQUIVALENCE FACTORS
(As extracted from Volume 1, Appendix F)

CONTENTS OF FILE ARE.EQF   AXLE SET TYPE: Single axle, single tires
SURFACE THICKNESS: 0 inches

INDEX	ROADBED SOIL MODULUS (psi)	TIRE PRESS. (psi)	WEIGHT (1000s) (lbs)	----EQUIVALENCE FACTORS--- BS/SUB THICK. 8 in.	BS/SUB THICK. 14 in.	BS/SUB THICK. 20 in.
1	4000.	75.	4.	.0572	.0134	.0047
2	12000.	75.	4.	.0572	.0134	.0047
3	20000.	75.	4.	.0573	.0134	.0047
4	4000.	110.	4.	.0706	.0138	.0046
5	12000.	110.	4.	.0705	.0138	.0046
6	20000.	110.	4.	.0706	.0138	.0046
7	4000.	145.	4.	.0787	.0139	.0046
8	12000.	145.	4.	.0786	.0139	.0046
9	20000.	145.	4.	.0787	.0139	.0046
10	4000.	75.	10.	1.1998	.4940	.2180
11	12000.	75.	10.	1.1997	.4940	.2180
12	20000.	75.	10.	1.1999	.4940	.2180
13	4000.	110.	10.	1.8745	.5871	.2322
14	12000.	110.	10.	1.8742	.5872	.2322
15	20000.	110.	10.	1.8746	.5872	.2321
16	4000.	145.	10.	2.4018	.6396	.2359
17	12000.	145.	10.	2.4015	.6397	.2360
18	20000.	145.	10.	2.4021	.6397	.2359
19	4000.	75.	18.	5.6072	4.0385	2.1907
20	12000.	75.	18.	5.6065	4.0388	2.1910
21	20000.	75.	18.	5.6077	4.0389	2.1906
22	4000.	110.	18.	11.0434	5.4143	2.5499
23	12000.	110.	18.	11.0420	5.4146	2.5502
24	20000.	110.	18.	11.0444	5.4148	2.5498
25	4000.	145.	18.	16.3016	6.3461	2.7404
26	12000.	145.	18.	16.2996	6.3465	2.7408
27	20000.	145.	18.	16.3031	6.3468	2.7403

CONTENTS OF FILE ARE.EQF AXLE SET TYPE: Single axle, single tires
SURFACE THICKNESS: 3 inches

INDEX	ROADBED SOIL MODULUS (psi)	TIRE PRESS. (psi)	WEIGHT (1000s) (lbs)	----EQUIVALENCE FACTORS--- BS/SUB THICK. 8 in.	BS/SUB THICK. 14 in.	BS/SUB THICK. 20 in.
1	4000.	75.	4.	.0057	.0075	.0087
2	12000.	75.	4.	.0243	.0336	.0387
3	20000.	75.	4.	.0533	.0748	.0849
4	4000.	110.	4.	.0145	.0199	.0237
5	12000.	110.	4.	.0830	.1198	.1404
6	20000.	110.	4.	.2163	.3169	.3640
7	4000.	145.	4.	.0256	.0363	.0441
8	12000.	145.	4.	.1748	.2585	.3058
9	20000.	145.	4.	.5025	.7522	.8696
10	4000.	75.	10.	.3143	.3582	.3875
11	12000.	75.	10.	.5050	.5795	.6206
12	20000.	75.	10.	.6067	.6951	.7370
13	4000.	110.	10.	1.1503	1.4001	1.5687
14	12000.	110.	10.	2.9176	3.6845	4.1029
15	20000.	110.	10.	4.6694	5.9532	6.5540
16	4000.	145.	10.	2.6854	3.3955	3.8837
17	12000.	145.	10.	9.0513	12.0412	13.6810
18	20000.	145.	10.	17.2642	23.2856	26.1037
19	4000.	75.	18.	2.6410	2.6089	2.6115
20	12000.	75.	18.	1.8094	1.6702	1.6234
21	20000.	75.	18.	1.2639	1.1195	1.0729
22	4000.	110.	18.	12.1649	13.2739	14.0289
23	12000.	110.	18.	14.8410	15.9646	16.6286
24	20000.	110.	18.	14.9743	15.9235	16.4174
25	4000.	145.	18.	33.2393	38.4042	41.8467
26	12000.	145.	18.	58.4867	68.4934	73.9737
27	20000.	145.	18.	74.4180	87.2329	93.2695

CONTENTS OF FILE ARE.EQF

AXLE SET TYPE: Single axle, single tires
SURFACE THICKNESS: 6 inches

INDEX	ROADBED SOIL MODULUS (psi)	TIRE PRESS. (psi)	WEIGHT (1000s) (lbs)	----EQUIVALENCE FACTORS--- BS/SUB THICK. 8 in.	BS/SUB THICK. 14 in.	BS/SUB THICK. 20 in.
1	4000.	75.	4.	.0005	.0006	.0007
2	12000.	75.	4.	.0014	.0017	.0020
3	20000.	75.	4.	.0022	.0028	.0032
4	4000.	110.	4.	.0006	.0008	.0009
5	12000.	110.	4.	.0021	.0027	.0032
6	20000.	110.	4.	.0036	.0048	.0056
7	4000.	145.	4.	.0008	.0010	.0012
8	12000.	145.	4.	.0026	.0035	.0042
9	20000.	145.	4.	.0047	.0064	.0075
10	4000.	75.	10.	.1202	.1320	.1424
11	12000.	75.	10.	.2210	.2506	.2709
12	20000.	75.	10.	.2809	.3242	.3515
13	4000.	110.	10.	.2323	.2668	.2980
14	12000.	110.	10.	.5384	.6370	.7070
15	20000.	110.	10.	.7675	.9305	1.0347
16	4000.	145.	10.	.3346	.3986	.4564
17	12000.	145.	10.	.8971	1.0935	1.2359
18	20000.	145.	10.	1.3720	1.7120	1.9321
19	4000.	75.	18.	2.5279	2.6256	2.7030
20	12000.	75.	18.	3.0895	3.1944	3.2688
21	20000.	75.	18.	3.1103	3.1910	3.2524
22	4000.	110.	18.	6.4311	6.9233	7.3430
23	12000.	110.	18.	10.3380	11.4097	12.1346
24	20000.	110.	18.	12.2216	13.6371	14.5247
25	4000.	145.	18.	11.3235	12.5331	13.6050
26	12000.	145.	18.	21.7864	24.9098	27.0708
27	20000.	145.	18.	28.3352	33.0511	36.0227

CONTENTS OF FILE ARE.EQF

AXLE SET TYPE: Single axle, dual tires
SURFACE THICKNESS: 0 inches

INDEX	ROADBED SOIL MODULUS (psi)	TIRE PRESS. (psi)	WEIGHT (1000s) (lbs)	----EQUIVALENCE FACTORS--- BS/SUB THICK. 8 in.	BS/SUB THICK. 14 in.	BS/SUB THICK. 20 in.
1	4000.	75.	4.	.0044	.0018	.0018
2	12000.	75.	4.	.0044	.0018	.0018
3	20000.	75.	4.	.0044	.0018	.0018
4	4000.	110.	4.	.0048	.0019	.0018
5	12000.	110.	4.	.0048	.0019	.0018
6	20000.	110.	4.	.0048	.0019	.0018
7	4000.	145.	4.	.0050	.0019	.0018
8	12000.	145.	4.	.0050	.0019	.0018
9	20000.	145.	4.	.0050	.0019	.0018
10	4000.	75.	10.	.1403	.0876	.0867
11	12000.	75.	10.	.1403	.0876	.0867
12	20000.	75.	10.	.1403	.0876	.0867
13	4000.	110.	10.	.1789	.0904	.0891
14	12000.	110.	10.	.1789	.0904	.0891
15	20000.	110.	10.	.1789	.0904	.0891
16	4000.	145.	10.	.2039	.0918	.0904
17	12000.	145.	10.	.2038	.0918	.0904
18	20000.	145.	10.	.2039	.0918	.0904
19	4000.	75.	18.	1.0000	1.0000	.9999
20	12000.	75.	18.	.9999	1.0000	1.0000
21	20000.	75.	18.	1.0001	1.0001	.9999
22	4000.	110.	18.	1.4728	1.0600	1.0514
23	12000.	110.	18.	1.4726	1.0601	1.0515
24	20000.	110.	18.	1.4730	1.0601	1.0514
25	4000.	145.	18.	1.8281	1.0916	1.0791
26	12000.	145.	18.	1.8278	1.0917	1.0792
27	20000.	145.	18.	1.8282	1.0917	1.0790
28	4000.	75.	30.	4.3940	7.8361	8.0148
29	12000.	75.	30.	4.3935	7.8366	8.0158
30	20000.	75.	30.	4.3944	7.8370	8.0144
31	4000.	110.	30.	7.6224	8.6779	8.7125
32	12000.	110.	30.	7.6215	8.6784	8.7136
33	20000.	110.	30.	7.6231	8.6788	8.7121
34	4000.	145.	30.	10.4815	9.1322	9.0977
35	12000.	145.	30.	10.4802	9.1328	9.0988
36	20000.	145.	30.	10.4825	9.1332	9.0972
37	4000.	75.	50.	22.0705	55.6762	59.8567
38	12000.	75.	50.	22.0677	55.6797	59.8639
39	20000.	75.	50.	22.0725	55.6823	59.8538
40	4000.	110.	50.	31.5971	66.6981	68.8502
41	12000.	110.	50.	31.5931	66.7021	68.8585
42	20000.	110.	50.	31.6000	66.7053	68.8468
43	4000.	145.	50.	49.1950	72.9529	73.9789
44	12000.	145.	50.	49.1887	72.9574	73.9879
45	20000.	145.	50.	49.1995	72.9608	73.9753

CONTENTS OF FILE ARE.EQF

AXLE SET TYPE: Single axle, dual tires
SURFACE THICKNESS: 3 inches

INDEX	ROADBED SOIL MODULUS (psi)	TIRE PRESS. (psi)	WEIGHT (1000s) (lbs)	----EQUIVALENCE FACTORS--- BS/SUB THICK. 8 in.	BS/SUB THICK. 14 in.	BS/SUB THICK. 20 in.
1	4000.	75.	4.	.0004	.0005	.0006
2	12000.	75.	4.	.0017	.0023	.0026
3	20000.	75.	4.	.0042	.0057	.0064
4	4000.	110.	4.	.0007	.0009	.0011
5	12000.	110.	4.	.0037	.0052	.0060
6	20000.	110.	4.	.0102	.0144	.0163
7	4000.	145.	4.	.0009	.0013	.0015
8	12000.	145.	4.	.0058	.0083	.0096
9	20000.	145.	4.	.0169	.0244	.0278
10	4000.	75.	10.	.0582	.0644	.0683
11	12000.	75.	10.	.1157	.1352	.1446
12	20000.	75.	10.	.1794	.2145	.2290
13	4000.	110.	10.	.1407	.1647	.1801
14	12000.	110.	10.	.4033	.5050	.5555
15	20000.	110.	10.	.7805	1.0047	1.0990
16	4000.	145.	10.	.2454	.2988	.3338
17	12000.	145.	10.	.8799	1.1447	1.2790
18	20000.	145.	10.	1.9380	2.5921	2.8710
19	4000.	75.	18.	.9999	1.0000	1.0000
20	12000.	75.	18.	.9999	1.0001	1.0000
21	20000.	75.	18.	.9999	1.0001	.9998
22	4000.	110.	18.	2.8428	3.0490	3.1721
23	12000.	110.	18.	4.5276	5.0502	5.2950
24	20000.	110.	18.	6.1090	6.9337	7.2658
25	4000.	145.	18.	5.6841	6.3636	6.7844
26	12000.	145.	18.	12.1663	14.4268	15.5174
27	20000.	145.	18.	19.7405	23.9814	25.7315
28	4000.	75.	30.	19.0543	17.0015	15.9922
29	12000.	75.	30.	9.3619	7.6416	6.9729
30	20000.	75.	30.	5.9371	4.6355	4.1955
31	4000.	110.	30.	31.9022	31.0658	30.5956
32	12000.	110.	30.	26.9385	25.7982	25.2954
33	20000.	110.	30.	24.1128	22.8957	22.4261
34	4000.	145.	30.	69.8816	71.9363	73.1172
35	12000.	145.	30.	84.3226	88.2967	90.0965
36	20000.	145.	30.	95.2656	100.5637	102.6190
37	4000.	75.	50.	278.4919	229.8350	206.0408
38	12000.	75.	50.	97.0122	70.4466	60.4970
39	20000.	75.	50.	50.7524	34.4326	29.2275
40	4000.	110.	50.	703.4823	619.1404	577.4562
41	12000.	110.	50.	327.2975	262.1705	236.9475
42	20000.	110.	50.	202.3232	154.6423	138.6527
43	4000.	145.	50.	1089.8980	984.7924	933.6120
44	12000.	145.	50.	560.3387	464.8528	427.7284
45	20000.	145.	50.	361.6348	287.3463	262.1188

CONTENTS OF FILE ARE.EQF

AXLE SET TYPE: Single axle, dual tires
SURFACE THICKNESS: 6 inches

INDEX	ROADBED SOIL MODULUS (psi)	TIRE PRESS. (psi)	WEIGHT (1000s) (lbs)	----EQUIVALENCE FACTORS--- BS/SUB THICK. 8 in.	BS/SUB THICK. 14 in.	BS/SUB THICK. 20 in.
1	4000.	75.	4.	.0000	.0000	.0000
2	12000.	75.	4.	.0001	.0001	.0001
3	20000.	75.	4.	.0001	.0001	.0001
4	4000.	110.	4.	.0000	.0001	.0001
5	12000.	110.	4.	.0001	.0001	.0001
6	20000.	110.	4.	.0001	.0001	.0002
7	4000.	145.	4.	.0001	.0001	.0001
8	12000.	145.	4.	.0001	.0001	.0001
9	20000.	145.	4.	.0001	.0002	.0002
10	4000.	75.	10.	.0203	.0218	.0232
11	12000.	75.	10.	.0312	.0333	.0348
12	20000.	75.	10.	.0366	.0394	.0411
13	4000.	110.	10.	.0269	.0301	.0327
14	12000.	110.	10.	.0475	.0530	.0567
15	20000.	110.	10.	.0604	.0680	.0723
16	4000.	145.	10.	.0317	.0361	.0395
17	12000.	145.	10.	.0593	.0683	.0742
18	20000.	145.	10.	.0791	.0917	.0989
19	4000.	75.	18.	1.0000	1.0000	1.0000
20	12000.	75.	18.	1.0001	.9999	.9999
21	20000.	75.	18.	.9997	1.0001	.9999
22	4000.	110.	18.	1.3749	1.4482	1.5146
23	12000.	110.	18.	1.9255	2.0105	2.0672
24	20000.	110.	18.	2.1456	2.2596	2.3236
25	4000.	145.	18.	1.7666	1.9181	2.0476
26	12000.	145.	18.	2.8026	3.0182	3.1623
27	20000.	145.	18.	3.3399	3.6300	3.7964
28	4000.	75.	30.	29.8532	29.2611	28.8179
29	12000.	75.	30.	25.8550	24.2780	23.3992
30	20000.	75.	30.	21.5430	19.6593	18.7574
31	4000.	110.	30.	42.2364	42.0698	41.9422
32	12000.	110.	30.	40.0801	38.6256	37.8447
33	20000.	110.	30.	35.1200	33.6902	33.3052
34	4000.	145.	30.	50.3630	50.5607	51.4764
35	12000.	145.	30.	60.5648	61.6068	62.3000
36	20000.	145.	30.	63.2897	64.6849	65.4380
37	4000.	75.	50.	656.7026	624.7160	600.9060
38	12000.	75.	50.	464.4071	410.7268	381.1671
39	20000.	75.	50.	343.5912	290.5050	265.1522
40	4000.	110.	50.	1184.9360	1153.1240	1129.4750
41	12000.	110.	50.	984.6438	913.7089	874.0429
42	20000.	110.	50.	801.5163	720.8344	682.0047
43	4000.	145.	50.	1601.4830	1580.8940	1565.3830
44	12000.	145.	50.	1444.4520	1372.1200	1332.1810
45	20000.	145.	50.	1231.0350	1139.4150	1096.0340

CONTENTS OF FILE ARE.EQF

AXLE SET TYPE: Tandem axle
SURFACE THICKNESS: 0 inches

INDEX	ROADBED SOIL MODULUS (psi)	TIRE PRESS. (psi)	WEIGHT (1000s) (lbs)	----EQUIVALENCE FACTORS--- BS/SUB THICK. 8 in.	BS/SUB THICK. 14 in.	BS/SUB THICK. 20 in.
1	4000.	75.	4.	.0008	.0006	.0008
2	12000.	75.	4.	.0019	.0015	.0022
3	20000.	75.	4.	.0030	.0023	.0034
4	4000.	110.	4.	.0008	.0006	.0009
5	12000.	110.	4.	.0019	.0015	.0022
6	20000.	110.	4.	.0030	.0023	.0034
7	4000.	145.	4.	.0007	.0006	.0009
8	12000.	145.	4.	.0019	.0015	.0022
9	20000.	145.	4.	.0030	.0023	.0034
10	4000.	75.	10.	.0146	.0130	.0190
11	12000.	75.	10.	.0377	.0335	.0490
12	20000.	75.	10.	.0585	.0519	.0759
13	4000.	110.	10.	.0162	.0132	.0192
14	12000.	110.	10.	.0416	.0339	.0495
15	20000.	110.	10.	.0645	.0526	.0768
16	4000.	145.	10.	.0169	.0133	.0194
17	12000.	145.	10.	.0434	.0341	.0498
18	20000.	145.	10.	.0674	.0529	.0773
19	4000.	75.	18.	.0851	.0942	.1381
20	12000.	75.	18.	.2188	.2422	.3552
21	20000.	75.	18.	.3396	.3758	.5511
22	4000.	110.	18.	.1017	.0963	.1409
23	12000.	110.	18.	.2616	.2477	.3625
24	20000.	110.	18.	.4059	.3844	.5624
25	4000.	145.	18.	.1118	.0974	.1424
26	12000.	145.	18.	.2875	.2506	.3663
27	20000.	145.	18.	.4462	.3888	.5683
28	4000.	75.	30.	.3459	.5145	.7593
29	12000.	75.	30.	.8897	1.3236	1.9535
30	20000.	75.	30.	1.3808	2.0539	3.0306
31	4000.	110.	30.	.4535	.5349	.7854
32	12000.	110.	30.	1.1665	1.3761	2.0205
33	20000.	110.	30.	1.8104	2.1353	3.1346
34	4000.	145.	30.	.5268	.5455	.7992
35	12000.	145.	30.	1.3550	1.4034	2.0561
36	20000.	145.	30.	2.1029	2.1776	3.1898
37	4000.	75.	50.	1.2002	2.7121	4.0596
38	12000.	75.	50.	3.0869	6.9769	10.4438
39	20000.	75.	50.	4.7908	10.8261	16.2022
40	4000.	110.	50.	1.7789	2.9024	4.2941
41	12000.	110.	50.	4.5752	7.4663	11.0472
42	20000.	110.	50.	7.1007	11.5856	17.1383
43	4000.	145.	50.	2.2258	3.0028	4.4208
44	12000.	145.	50.	5.7247	7.7245	11.3732
45	20000.	145.	50.	8.8845	11.9862	17.6441

CONTENTS OF FILE ARE.EQF

AXLE SET TYPE: Tandem axle
SURFACE THICKNESS: 3 inches

INDEX	ROADBED SOIL MODULUS (psi)	TIRE PRESS. (psi)	WEIGHT (1000s) (lbs)	----EQUIVALENCE FACTORS--- BS/SUB THICK. 8 in.	BS/SUB THICK. 14 in.	BS/SUB THICK. 20 in.
1	4000.	75.	4.	.0001	.0002	.0002
2	12000.	75.	4.	.0015	.0023	.0027
3	20000.	75.	4.	.0061	.0093	.0109
4	4000.	110.	4.	.0002	.0003	.0003
5	12000.	110.	4.	.0022	.0034	.0041
6	20000.	110.	4.	.0094	.0148	.0174
7	4000.	145.	4.	.0002	.0003	.0004
8	12000.	145.	4.	.0027	.0042	.0051
9	20000.	145.	4.	.0120	.0189	.0224
10	4000.	75.	10.	.0131	.0177	.0209
11	12000.	75.	10.	.0961	.1364	.1579
12	20000.	75.	10.	.3129	.4522	.5143
13	4000.	110.	10.	.0222	.0313	.0378
14	12000.	110.	10.	.2014	.2953	.3468
15	20000.	110.	10.	.7334	1.0910	1.2536
16	4000.	145.	10.	.0305	.0443	.0541
17	12000.	145.	10.	.3100	.4646	.5506
18	20000.	145.	10.	1.2023	1.8183	2.1031
19	4000.	75.	18.	.1733	.2189	.2499
20	12000.	75.	18.	.8470	1.1193	1.2593
21	20000.	75.	18.	2.1596	2.9045	3.2250
22	4000.	110.	18.	.3539	.4667	.5452
23	12000.	110.	18.	2.2837	3.1711	3.6406
24	20000.	110.	18.	6.9019	9.7723	11.0393
25	4000.	145.	18.	.5517	.7507	.8911
26	12000.	145.	18.	4.2266	6.0347	7.0084
27	20000.	145.	18.	14.0828	20.4771	23.3390
28	4000.	75.	30.	1.3437	1.5916	1.7535
29	12000.	75.	30.	4.1707	5.0110	5.4172
30	20000.	75.	30.	8.0000	9.6843	10.3523
31	4000.	110.	30.	3.1351	3.9028	4.4183
32	12000.	110.	30.	13.8033	17.8749	19.9447
33	20000.	110.	30.	33.0919	43.5497	47.9951
34	4000.	145.	30.	5.4387	6.9871	8.0480
35	12000.	145.	30.	29.7472	40.1431	45.5532
36	20000.	145.	30.	81.4321	111.9795	125.2762
37	4000.	75.	50.	11.9589	12.7398	13.2949
38	12000.	75.	50.	18.2244	18.1163	18.0205
39	20000.	75.	50.	22.0562	22.7259	22.7699
40	4000.	110.	50.	23.4746	27.2934	29.7677
41	12000.	110.	50.	63.9394	74.5521	79.5477
42	20000.	110.	50.	112.9138	132.0625	139.3171
43	4000.	145.	50.	44.2626	53.5052	59.6059
44	12000.	145.	50.	158.6049	196.7098	215.5634
45	20000.	145.	50.	331.9489	416.3932	451.0707

CONTENTS OF FILE ARE.EQF

AXLE SET TYPE: Tandem axle
SURFACE THICKNESS: 6 inches

INDEX	ROADBED SOIL MODULUS (psi)	TIRE PRESS. (psi)	WEIGHT (1000s) (lbs)	----EQUIVALENCE FACTORS--- BS/SUB THICK. 8 in.	BS/SUB THICK. 14 in.	BS/SUB THICK. 20 in.
1	4000.	75.	4.	.0000	.0000	.0000
2	12000.	75.	4.	.0001	.0001	.0001
3	20000.	75.	4.	.0002	.0002	.0002
4	4000.	110.	4.	.0000	.0000	.0000
5	12000.	110.	4.	.0001	.0001	.0001
6	20000.	110.	4.	.0002	.0002	.0003
7	4000.	145.	4.	.0000	.0000	.0000
8	12000.	145.	4.	.0001	.0001	.0001
9	20000.	145.	4.	.0002	.0002	.0003
10	4000.	75.	10.	.0037	.0048	.0056
11	12000.	75.	10.	.0145	.0192	.0225
12	20000.	75.	10.	.0290	.0383	.0442
13	4000.	110.	10.	.0045	.0057	.0067
14	12000.	110.	10.	.0174	.0235	.0278
15	20000.	110.	10.	.0362	.0493	.0575
16	4000.	145.	10.	.0052	.0066	.0076
17	12000.	145.	10.	.0195	.0264	.0312
18	20000.	145.	10.	.0405	.0559	.0654
19	4000.	75.	18.	.0989	.1229	.1439
20	12000.	75.	18.	.3453	.4320	.4937
21	20000.	75.	18.	.6327	.7954	.8975
22	4000.	110.	18.	.1246	.1594	.1898
23	12000.	110.	18.	.4810	.6234	.7258
24	20000.	110.	18.	.9350	1.2151	1.3925
25	4000.	145.	18.	.1442	.1865	.2216
26	12000.	145.	18.	.5704	.7577	.8913
27	20000.	145.	18.	1.1496	1.5289	1.7695
28	4000.	75.	30.	1.4801	1.7586	1.9963
29	12000.	75.	30.	4.2644	5.1100	5.6913
30	20000.	75.	30.	7.0715	8.4986	9.3659
31	4000.	110.	30.	2.1139	2.5958	3.0177
32	12000.	110.	30.	7.0676	8.7425	9.9278
33	20000.	110.	30.	12.6537	15.7392	17.6627
34	4000.	145.	30.	2.5611	3.2236	3.8005
35	12000.	145.	30.	9.3549	11.8611	13.6565
36	20000.	145.	30.	17.5745	22.3721	25.3998
37	4000.	75.	50.	24.2185	28.0133	30.9883
38	12000.	75.	50.	54.3905	61.9884	67.0768
39	20000.	75.	50.	76.3698	85.1160	90.4116
40	4000.	110.	50.	31.4373	36.7135	40.8886
41	12000.	110.	50.	82.0802	97.3111	107.6587
42	20000.	110.	50.	132.1818	156.7759	171.5635
43	4000.	145.	50.	40.4505	48.6728	55.7744
44	12000.	145.	50.	123.9050	150.3218	168.6958
45	20000.	145.	50.	211.9985	258.3732	286.8695

CONTENTS OF FILE ARE.EQF

AXLE SET TYPE: Triple axle
SURFACE THICKNESS: 0 inches

INDEX	ROADBED SOIL MODULUS (psi)	TIRE PRESS. (psi)	WEIGHT (1000s) (lbs)	----EQUIVALENCE FACTORS--- BS/SUB THICK. 8 in.	BS/SUB THICK. 14 in.	BS/SUB THICK. 20 in.
1	4000.	75.	4.	.0001	.0002	.0004
2	12000.	75.	4.	.0008	.0013	.0027
3	20000.	75.	4.	.0020	.0029	.0064
4	4000.	110.	4.	.0001	.0002	.0005
5	12000.	110.	4.	.0008	.0012	.0027
6	20000.	110.	4.	.0019	.0028	.0064
7	4000.	145.	4.	.0001	.0002	.0005
8	12000.	145.	4.	.0007	.0012	.0027
9	20000.	145.	4.	.0018	.0028	.0064
10	4000.	75.	10.	.0028	.0037	.0079
11	12000.	75.	10.	.0186	.0245	.0530
12	20000.	75.	10.	.0449	.0589	.1271
13	4000.	110.	10.	.0027	.0037	.0080
14	12000.	110.	10.	.0180	.0243	.0527
15	20000.	110.	10.	.0434	.0584	.1269
16	4000.	145.	10.	.0026	.0037	.0080
17	12000.	145.	10.	.0174	.0242	.0527
18	20000.	145.	10.	.0419	.0583	.1268
19	4000.	75.	18.	.0140	.0231	.0501
20	12000.	75.	18.	.0924	.1529	.3317
21	20000.	75.	18.	.2227	.3678	.7978
22	4000.	110.	18.	.0148	.0233	.0504
23	12000.	110.	18.	.0976	.1538	.3338
24	20000.	110.	18.	.2350	.3704	.8035
25	4000.	145.	18.	.0151	.0234	.0507
26	12000.	145.	18.	.0997	.1544	.3349
27	20000.	145.	18.	.2401	.3717	.8063
28	4000.	75.	30.	.0515	.1113	.2409
29	12000.	75.	30.	.3409	.7360	1.5941
30	20000.	75.	30.	.8210	1.7720	3.8371
31	4000.	110.	30.	.0606	.1123	.2432
32	12000.	110.	30.	.4012	.7434	1.6093
33	20000.	110.	30.	.9660	1.7900	3.8735
34	4000.	145.	30.	.0654	.1128	.2442
35	12000.	145.	30.	.4325	.7467	1.6164
36	20000.	145.	30.	1.0414	1.7976	3.8911
37	4000.	75.	50.	.1584	.3876	.8492
38	12000.	75.	50.	1.0482	2.5652	5.6201
39	20000.	75.	50.	2.5241	6.1761	13.5280
40	4000.	110.	50.	.1874	.3996	.8716
41	12000.	110.	50.	1.2401	2.6443	5.7680
42	20000.	110.	50.	2.9863	6.3666	13.8844
43	4000.	145.	50.	.2082	.4059	.8835
44	12000.	145.	50.	1.3772	2.6860	5.8467
45	20000.	145.	50.	3.3164	6.4670	14.0742

CONTENTS OF FILE ARE.EQF

AXLE SET TYPE: Triple axle
SURFACE THICKNESS: 3 inches

INDEX	ROADBED SOIL MODULUS (psi)	TIRE PRESS. (psi)	WEIGHT (1000s) (lbs)	----EQUIVALENCE FACTORS--- BS/SUB THICK. 8 in.	BS/SUB THICK. 14 in.	BS/SUB THICK. 20 in.
1	4000.	75.	4.	.0000	.0001	.0001
2	12000.	75.	4.	.0013	.0023	.0028
3	20000.	75.	4.	.0089	.0152	.0186
4	4000.	110.	4.	.0001	.0001	.0001
5	12000.	110.	4.	.0013	.0022	.0028
6	20000.	110.	4.	.0087	.0152	.0186
7	4000.	145.	4.	.0000	.0001	.0001
8	12000.	145.	4.	.0013	.0021	.0027
9	20000.	145.	4.	.0085	.0146	.0180
10	4000.	75.	10.	.0058	.0095	.0124
11	12000.	75.	10.	.1516	.2590	.3232
12	20000.	75.	10.	1.0009	1.7263	2.0805
13	4000.	110.	10.	.0069	.0117	.0155
14	12000.	110.	10.	.1950	.3332	.4169
15	20000.	110.	10.	1.3145	2.2485	2.7086
16	4000.	145.	10.	.0075	.0130	.0173
17	12000.	145.	10.	.2138	.3681	.4622
18	20000.	145.	10.	1.4473	2.4680	2.9780
19	4000.	75.	18.	.0898	.1313	.1634
20	12000.	75.	18.	1.3296	2.0893	2.5251
21	20000.	75.	18.	6.6329	10.6098	12.4818
22	4000.	110.	18.	.1172	.1821	.2328
23	12000.	110.	18.	2.2560	3.6435	4.4514
24	20000.	110.	18.	12.5495	20.4177	24.1657
25	4000.	145.	18.	.1464	.2330	.3005
26	12000.	145.	18.	3.0375	4.9640	6.0986
27	20000.	145.	18.	17.7404	29.1066	34.5775
28	4000.	75.	30.	.6557	.9860	1.2395
29	12000.	75.	30.	7.5510	11.0701	13.0238
30	20000.	75.	30.	29.6766	44.2578	50.9161
31	4000.	110.	30.	.6750	1.0899	1.4154
32	12000.	110.	30.	13.1666	20.8978	25.2829
33	20000.	110.	30.	64.3776	101.7747	119.2124
34	4000.	145.	30.	1.2388	2.0289	2.6431
35	12000.	145.	30.	24.8183	38.9352	46.8968
36	20000.	145.	30.	121.1161	189.8578	221.8589
37	4000.	75.	50.	2.8043	3.7149	4.3829
38	12000.	75.	50.	19.0622	25.3689	28.6240
39	20000.	75.	50.	56.4509	80.3763	90.6557
40	4000.	110.	50.	8.4041	11.3306	13.5255
41	12000.	110.	50.	72.5919	103.4700	120.4135
42	20000.	110.	50.	267.2357	388.6187	442.8723
43	4000.	145.	50.	10.9190	15.2729	18.5683
44	12000.	145.	50.	119.3716	177.9727	210.8484
45	20000.	145.	50.	500.7688	762.0837	882.4536

CONTENTS OF FILE ARE.EQF

AXLE SET TYPE: Triple axle
SURFACE THICKNESS: 6 inches

INDEX	ROADBED SOIL MODULUS (psi)	TIRE PRESS. (psi)	WEIGHT (1000s) (lbs)	----EQUIVALENCE FACTORS--- BS/SUB THICK. 8 in.	BS/SUB THICK. 14 in.	BS/SUB THICK. 20 in.
1	4000.	75.	4.	.0000	.0000	.0000
2	12000.	75.	4.	.0001	.0001	.0001
3	20000.	75.	4.	.0004	.0004	.0004
4	4000.	110.	4.	.0000	.0000	.0000
5	12000.	110.	4.	.0001	.0001	.0001
6	20000.	110.	4.	.0004	.0004	.0005
7	4000.	145.	4.	.0000	.0000	.0000
8	12000.	145.	4.	.0001	.0001	.0001
9	20000.	145.	4.	.0004	.0002	.0005
10	4000.	75.	10.	.0013	.0021	.0027
11	12000.	75.	10.	.0134	.0220	.0288
12	20000.	75.	10.	.0457	.0740	.0945
13	4000.	110.	10.	.0015	.0021	.0027
14	12000.	110.	10.	.0127	.0208	.0271
15	20000.	110.	10.	.0433	.0713	.0908
16	4000.	145.	10.	.0017	.0024	.0029
17	12000.	145.	10.	.0128	.0204	.0262
18	20000.	145.	10.	.0415	.0677	.0861
19	4000.	75.	18.	.0903	.1272	.1592
20	12000.	75.	18.	.5516	.7926	.9816
21	20000.	75.	18.	1.4172	2.0268	2.4565
22	4000.	110.	18.	.0829	.1116	.1348
23	12000.	110.	18.	.4657	.6980	.8779
24	20000.	110.	18.	1.2945	1.9505	2.4070
25	4000.	145.	18.	.1049	.1408	.1698
26	12000.	145.	18.	.6073	.8908	1.1005
27	20000.	145.	18.	1.6282	2.4300	2.9723
28	4000.	75.	30.	.2574	.4020	.5598
29	12000.	75.	30.	3.8640	6.3134	8.4338
30	20000.	75.	30.	13.2972	21.2525	27.1490
31	4000.	110.	30.	.2318	.3679	.5118
32	12000.	110.	30.	2.9576	4.7780	6.3283
33	20000.	110.	30.	10.2451	16.7087	21.6989
34	4000.	145.	30.	.2120	.3406	.4785
35	12000.	145.	30.	3.3240	5.7155	7.7995
36	20000.	145.	30.	13.9434	24.1978	31.9326
37	4000.	75.	50.	6.1938	8.4012	10.4338
38	12000.	75.	50.	37.3319	51.6079	62.6559
39	20000.	75.	50.	92.6352	128.0472	152.3259
40	4000.	110.	50.	10.1434	13.8962	17.3704
41	12000.	110.	50.	71.8230	103.2867	128.0332
42	20000.	110.	50.	207.9424	296.8741	353.9282
43	4000.	145.	50.	15.9908	22.8506	28.5917
44	12000.	145.	50.	96.0793	134.7679	165.2304
45	20000.	145.	50.	244.7442	345.0066	415.2554