Long-Term Pavement Performance Compliance with Department of Transportation Information Dissemination Quality Guidelines

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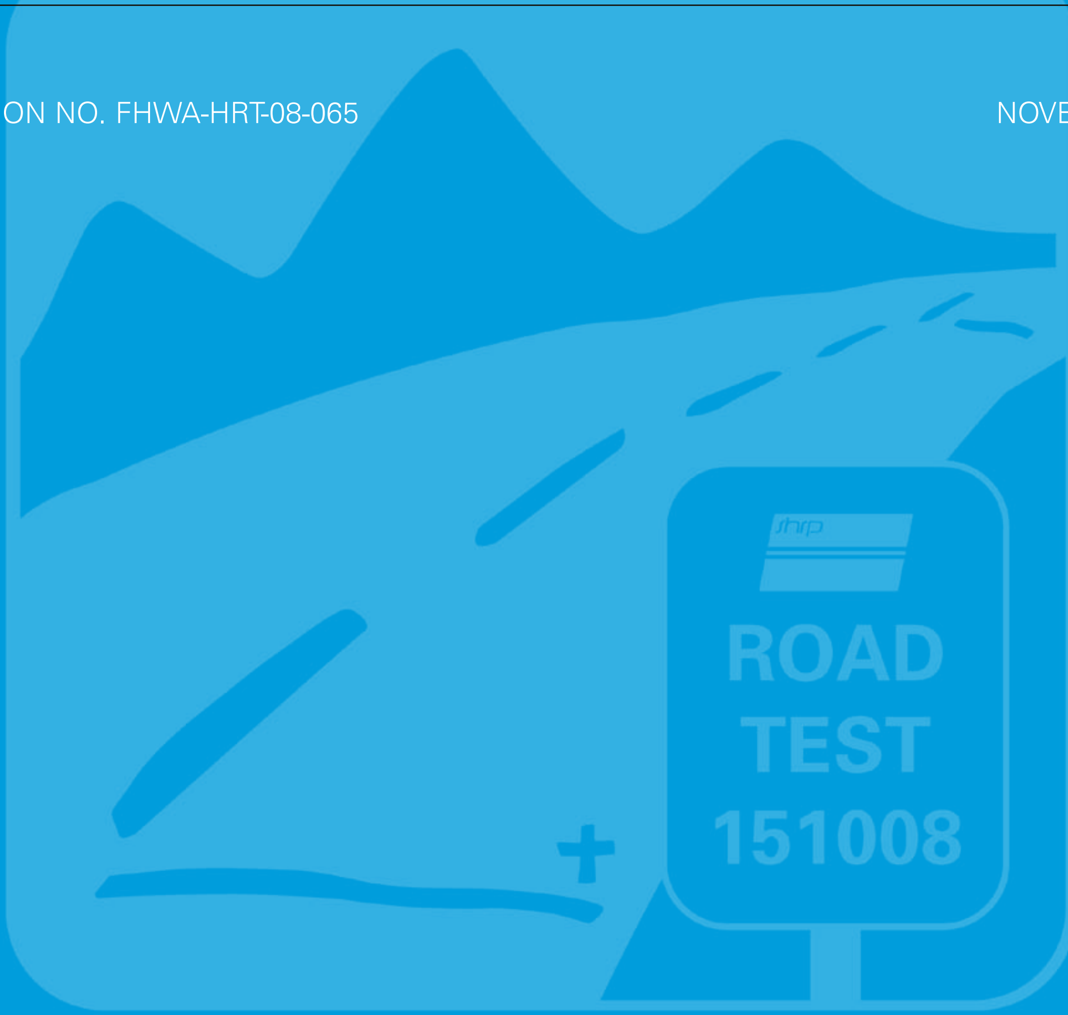

U.S. Department of Transportation
Federal Highway Administration

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LTPP

FOREWORD

This document provides information on the compliance of the Long-Term Pavement Performance (LTPP) program with the guidelines the Department of Transportation (DOT) issued Information Dissemination Quality Guidelines (IDQG). These guidelines were developed in response to requirements of Section 515 of the Treasury and General Government Appropriations Act for fiscal year (FY) 2001. The purpose of the guidelines is to ensure and maximize the quality, utility, objectivity, and integrity of information that is disseminated by the Federal government. This document discusses the activities performed under the LTPP program, and it also addresses the policies and procedures established by these guidelines.

The LTPP program is an ongoing and active program. To obtain current information and access to other technical references, LTPP data users should visit the LTPP Web site at http://www.fhwa.dot.gov/pavement/ltpp/index.cfm. LTPP data requests, technical questions, and data user feedback can be submitted to LTPP customer service via e-mail at ltppinfo@fhwa.dot.gov.

Gary L. Henderson
Director, Office of Infrastructure
Research and Development

Notice

Quality Assurance Statement

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16. Abstract
This document provides information on the compliance of the LTPP program with the guidelines the Department of Transportation (DOT) issued Information Dissemination Quality Guidelines (IDQG). These guidelines were developed in response to requirements of Section 515 of the Treasury and General Government Appropriations Act for fiscal year (FY) 2001. The purpose of the guidelines is to ensure and maximize the quality, utility, objectivity, and integrity of information that is disseminated by the Federal government. This document discusses the activities performed under the LTPP program, and it also addresses the policies and procedures established by these guidelines.

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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
		NOTE: volumes greater than 1000 L shall be shown in m^3		
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		TEMPERATURE (exact degrees)		
^oF	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	^oC
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
		TEMPERATURE (exact degrees)		
^oC	Celsius	1.8C+32	Fahrenheit	^oF
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

*SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380.
(Revised March 2003)

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LIST OF ACRONYMS AND ABBREVIATIONS

AADT	Annual average daily traffic
AASHO	American Association of State Highway Officials
AASHTO	American Association of State Highway and Transportation Officials
AC	Asphalt concrete
ASTM	American Society for Testing and Materials
AVC	Automated vehicle classification
AWS	Automated weather station
CCC	Canadian Climatic Center
DLR	Dynamic load response
DMI	Distance Measuring Instrument
DOT	Department of Transportation
ESAL	Equivalent single-axle load
ETG	Expert Task Groups
FAR	Federal Acquisition Regulation
FHWA	Federal Highway Administration
FIPS	Federal Information Processing Standards
FWD	Falling-weight deflectometer
FY	Fiscal year
GPS	General Pavement Studies
HPMS	Highway Performance Monitoring System
IDQG	Information Dissemination Quality Guidelines
IMS	Information Management System
ISO	International Organization for Standardization
LTPP	Long-Term Pavement Performance
MEPDG	Mechanistic-Empirical Pavement Design Guide
NCDC	National Climatic Data Center
NCHRP	National Cooperative Highway Research Program
NRC	National Research Council
PADIAS	Pavement Distress Analysis System
PCC	Portland cement concrete
QC	Quality control
RDBMS	Relational database management system
SHRP	Strategic Highway Research Program
SI	International System of Units
SMP	Seasonal Monitoring Program
SPR	Software Performance Report
SPS	Specific Pavement Studies
SQL	Standard Query Language
TFHRC	Turner-Fairbank Highway Research Center
WIM	Weigh-in-motion

INTRODUCTION

On October 1, 2002, the Department of Transportation (DOT) issued Information Dissemination Quality Guidelines (IDQG) to implement Section 515 of the Treasury and General Government Appropriations Act for fiscal year (FY) 2001. The purpose of the guidelines is to ensure and maximize the quality, utility, objectivity, and integrity of information that is disseminated. This document presents the policies and procedures established by the Long-Term Pavement Performance (LTPP) program related to compliance with the DOT IDQG.

In the interest of brevity, this document does not recite all of the DOT IDQG specifications. Instead, each chapter on a specific topic covered in the DOT IDQG provides a general summary of the intent of the guidelines. A copy of the DOT IDQG can be found at http://www.thecre.com/pdf/20021026_dot-final.pdf.

BACKGROUND

The LTPP program started as a States initiative in the early 1980s. Preimplementation research planning was conducted under a joint effort between the Federal Highway Administration (FHWA), Transportation Research Board (TRB), and the National Cooperative Highway Research Program (NCHRP). These plans were published by NCHRP in May 1986 in the report *Strategic Highway Research Program: Research Plans*. Implementation of the LTPP program was authorized under the Surface Transportation and Uniform Relocation Act of 1987. The 20-year LTPP program began operations under the 5-year Strategic Highway Research Program (SHRP) administered by the National Academy of Sciences. In 1992, the FHWA made a commitment to assume management and administrative responsibilities to continue LTPP and complete the baseline 20-year period of pavement performance monitoring. Continuation of LTPP under FHWA was formally authorized by Congress in the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA). In 1998, the Transportation Equity Act for the 21st Century (TEA-21) funded LTPP as a national program to 2003.

The LTPP Program received its foundational mission from a 1984 study entitled, *America's Highways: Accelerating the Search for Innovation* (Special Report 202), published by the TRB. The program's mission is to "increase pavement life by the investigation of the long-term performance of various designs of pavement structures and rehabilitated pavement structures, using different materials and under different loads, environments, subgrade soils, and maintenance practices." The strategic goals and objectives for LTPP were stated in the original LTPP work plan as follows:

- Evaluate existing design methods.
- Develop improved design methodologies and strategies for the rehabilitation of existing pavements.
- Develop improved design equations for new and reconstructed pavements.

- Determine the effects of loading, environment, material properties and variability, construction quality, and maintenance levels on pavement distress and performance.
- Determine the effects of specific design features on pavement performance.
- Establish a national long-term pavement database to support program objectives and future needs.

LTPP DATA QUALITY HIGHLIGHTS

Data quality has been a prime concern in the development and operation of the LTPP program. Although the LTPP program started more than 14 years prior to the issuance of the Federal data quality guidelines, it is remarkable how many of the concepts and procedures contained in the guidelines were followed by LTPP. Some of the highlights of the LTPP data quality process include the following:

- Extensive peer review by experts and highway agency practitioners. A TRB committee was created in 1986 to monitor the status and progress of the LTPP studies and provides technical assistance to FHWA concerning courses of action and the future direction of the studies. The TRB LTPP Committee is supplemented with smaller Expert Task Groups (ETGs) created on specific subjects. Over the years, ETGs have been created on Experiment Design, Materials Testing, Environmental Data Collection, Profile Measurement, Falling Weight Deflectometer (FWD) Measurements, Traffic Data Collection, Pavement Distress Measurement, Construction Specifications, Data Analysis, Metrication, and Database Operations.
- Statistically-based factorial experimental designs were used to plan the studies. The experimental designs were prepared by nationally and internationally recognized statisticians and research engineers. These designs were reviewed by an ETG.
- LTPP has documented all phases of its activities. More than 300 documents have been prepared describing the details of the planning process, experiment design, construction guidelines, agency participation requirements, data collection procedures, data processing procedures, data evaluation checks, data collection equipment calibration procedures and checks, data analysis results, standard data release format and data user aids, and details of construction and instrumentation installation on specific test sections.
- Inclusion of an indicator of “data quality” on each record in the database was developed in the early 1990s and has been refined over time. This data quality indicator encompasses measures of identifying missing data, out of range data, inconsistencies in relational data structures between tables, and illogical data. The data quality indicator is disseminated with the data.
- In the design of the data collection plan, LTPP had to develop new procedures, protocols, and test methods. Some of these methods have been adopted as

American Association of State Highway and Transportation Officials (AASHTO) standards.

- In 2000, LTPP implemented International Organization for Standardization (ISO) management quality standards in its data collection and processing activities. All data collection contractors developed management procedures for data quality control (QC). These procedures are audited by an independent source on a nominal 6-month cycle.
- Currently, LTPP data updates are released on a 1-year interval. Prior to data release, a central contractor, independent from data collection sources, performs a predistribution review of the data in order to identify, and if possible, corrects data problems not previously discovered.
- LTPP created a customer service and data problem feedback process in the early 1990s. A formal data problem and feedback mechanism was created in the late 1990s which allows data users, analysts, and others to submit problem reports. These reports and their resolution are now posted on the LTPP Web page http://www.fhwa.dot.gov/pavement/ltpp/index.cfm.

As a unique national research program whose operations model consists of providing research quality data for analysis to those who did not participate in the data collection process, all of the issues in recent Federal guides on data quality had to be addressed by LTPP. Improvements are continuously occurring to enhance LTPP's conformance to the new IDQG. These improvements are resource constrained and are dependent on budget allocation from Congress.

CHAPTER 1. LTPP DATA SYSTEM PLANNING

The DOT IDQG indicates that the following factors should be considered for planning a data system:

- Data system should be linked to the organization's strategic plan.
- Objectives for the data system should be expressed in terms of goals.
- Data requirements should be based on achievement of goals.
- Data acquisition methods are based on data requirements and use.

DATA SYSTEM OBJECTIVES

In order to garner widespread support and keep relevancy over a long period of time, LTPP goals were purposely expressed in terms of general topical areas of pavement engineering needs. Although a formal assessment of the program has been performed, the objective statements still remain relevant.

The LTPP program was started as a States' initiative and implemented as part of the SHRP, operated under the auspices of the National Academy of Sciences, to meet a need for research quality data on long-term performance of pavements in North America. The strategic goals for the program were establish by a committee with representation from State and Provincial highway agencies, Federal agencies, and academia. These goals were endorsed by AASHTO.

Although the LTPP program did not start as a program managed by a Federal agency, its goals and objectives were congruent with those of FHWA in the early 1990s. This is why at the end of the 5-year SHRP effort in 1992, FHWA management agreed to provide management services for the remainder of this long-term effort. Although the LTPP program is not specifically addressed in the changing strategic objectives of FHWA, it has continued to be a line item in all of the highway bills passed by Congress to date. Due to the LTPP program's unique enabling role in the advancement of pavement technology, its data will be used as a tool far into the future to address future highway infrastructure engineering needs.

Highlights of LTPP's compliance with this portion of the guidelines include the following:

- Updates to the formal objective statements have not been necessary.
- Key questions to be answered by the data are expressed in the objective statements.
- Timeliness of data is not an important aspect to the accomplishment of the project's goal, as this is a long-term project, and therefore is not directly addressed in the objectives.

- The data system objectives are distributed with the data in the form of a database user's reference guide. This guide is also available from the LTPP Web site (http://www.fhwa.dot.gov/pavement/pub_details.cfm?id=96).
- Data user information and feedback is obtained through a variety of sources. Biannual meetings of the LTPP TRB Committee are held to provide input on programmatic issues. The LTPP ETGs provide input on specific data topics. A data user satisfaction survey is distributed with the data and is available on the LTPP Web site. LTPP holds two sessions at the annual TRB meeting allowing questions and comments from Federal, State, academia, and industry. These groups represent LTPP's stakeholders.

The objective of the LTPP data system is to provide data to engineering researchers that enable the evaluation of existing pavement design methods, the development of improved pavement design methods, and the study of the effect of relevant factors that influence pavement performance.

DATA REQUIREMENTS

The LTPP data requirements are based on the achievement of the program's goals and objectives. The data requirements were developed by experts in each associated engineering discipline with review and critique by other stakeholders through TRB- facilitated national meetings.

The development of measurement concepts for the LTPP program followed a scientific approach methodology. Data needs were based on existing models, theories of pavement performance, and anticipated needs of future models of pavement performance. The findings from previous studies of the performance of in-service pavements were also used.

The LTPP program relies on thousands of measurement concepts. Some of the more important measurement concepts used in the LTPP program include the following:

- Important characteristics in determining the cause and effect relationship on why pavements perform as they do include the following:
  - The strength of the pavement structure.
  - The thickness and types of materials in the pavement structure.
  - The strength, elastic, and plastic properties of the pavement materials.
  - The magnitude and volume of wheel loads applied to the pavement.
  - The response of the pavement structure to load.
  - The climate characteristics at the site.
  - The condition of a pavement as a function of its roughness and features related to fracture, distortion, and disintegration of the surface materials.

- In order to maintain coherence across other databases, many existing concepts used in other databases were adopted. Some of these include the following:
    - Federal Information Processing Standards (FIPS) for geographic codes.
    - Highway Performance Monitoring System (HPMS) test section identification.
    - National Transportation Thesaurus for keywords.
    - World Geodetic System 1984 for location coordinates.
    - AASHTO classification system for soils and unbound base material.
    - AASHTO material test standards.
    - American Society for Testing and Materials (ASTM) test standards.
- While desired data accuracy and repeatability targets were developed for a vast array of measurement concepts, formal targets were not set for all data elements. Where possible, LTPP has strived to provide data users with quantitative information that permits an assessment of actual measurement error, accuracy, and repeatability.
    - An accuracy of 90 percent the confidence level being within 10 percent of the mean was a goal for traffic monitoring measurements, stated in terms of annual loading of equivalent 18-kips single axle loads in the LTPP test lane. Because many factors enter into the accuracy of field axle weight measurements, some of which are difficult to control, information on sources of error introduced by sampling and equipment calibration are stored in the database.
    - Use of industry standardized material testing protocols permits use of accuracy and repeatability studies performed in development of the protocol.
    - In some cases, where equipment calibration standards did not exist, LTPP developed calibration protocols and test procedures to assess equipment accuracy and repeatability. For example, a reference calibration procedure was developed by LTPP for FWDs.

The LTPP data requirements are based on the concept of providing the user with baseline raw data that can be used to support a wide range of measurement concepts. This is a fundamental requirement of a research-based program. While the database contains traditional measurement concepts, data users are able to access the baseline measurement data in order to investigate their applicability for development of new measurement concepts.

METHODS TO ACQUIRE DATA

The methods to acquire LTPP data were developed by expert staff working in-concert with program stakeholders and other experts. The preliminary planning for the LTPP program was funded under an NCHRP-sponsored study conducted under the auspices of the LTPP TRB committee. A comprehensive process was used to examine and evaluate data acquisition methods that took into account budget, complexity, ease, and time considerations.

Due to the complexity of many LTPP data elements, an early decision in the program was to use qualified data collection contractors with experience in operation of technical data collection equipment and working with highway agencies on collection of other data. Greater resources were planned and used on the more complex data elements requiring specialty resources.

FHWA served as a cooperative partner in this work by funding an equipment evaluation project to evaluate the state of the practice and art in the critical data elements needed for the project during the preimplementation phase of the project.

SOURCES OF DATA

LTPP data sources were developed based on past experience in performing similar field studies. Findings from a research study sponsored by FHWA in the early 1980s called the Long-Term Pavement Monitoring Program[1] provided the basis for selection of data sources.

Since provision of data to the LTPP program was not a matter of public law, LTPP had to rely upon contractual data collection services, available data sources, and the good will of participating highway agencies.

The sources of data selected for the LTPP program included the following:

- Participating highway agencies were used for inventory and construction information that were contained only in their files.
- Pavement monitoring measurements were assigned to a team of expert contractors operating the same type of equipment in order to improve uniformity and reduce variability. Highly technical measurements which included specialized test section instrumentation were assigned to contractors.
- Climate data were obtained from the National Climate Data Center (NCDC) for test sections in the United States and the Canadian Climate Center (CCC) for test sections in Canada.
- The FHWA's advance material testing laboratory at Turner-Fairbank Highway Research Center (TFHRC) was used for measurement of the coefficient of thermal expansion on portland cement concrete (PCC) and for Superpave™ tests on asphalt cement.
- The National Aggregate Institute performed material tests on the angularity of fine aggregates in asphalt concrete (AC) mixtures.
- Mixed approaches for the collection of some data items were required due to budgetary limitations. Early in the program, all material tests were performed

under LTPP contract. Another set of material tests on newly constructed pavement test sections was assigned to participating highway agencies.

- Over time, shifts in data sources have been necessary due to data quality and availability concerns. Collection of traffic data on LTPP test sections has been a participating highway agency responsibility. In order to overcome the limitations of this data, the LTPP Specific Pavement Study Traffic Pooled Fund Study TRF-05 (004) was implemented to obtain needed data from high priority test sections (http://www.fhwa.dot.gov/pavement/ltpp/spstraffic/index.cfm).

DATA COLLECTION DESIGN

The LTPP data collection design was based on a wide variety of methods, as follows:

- Due to cost considerations, the population of test sections was not selected to represent a statistical sample of the pavement types used in North America but rather was restricted to a subset of pavement types thought by experts to represent "good" engineering practice.
- Factorial sampling designs were used in which test sections were categorized by significant design features relative to the pavement type and environmental factors to direct test section selection. A large majority of LTPP experiments can be most properly described as uncontrolled fractional factorials since test section selection and sample size depended upon voluntary agency participation and the "diagonal" effect of public roads. The diagonal effect of properly engineered roads means that some of the combinations of factors in an experimental design are not common. For example, thin pavement structures on high traffic volume routes on poor subgrade are difficult to find since they are contrary to engineering design practice. The "diagonal" is best described as typical engineering practice in which thicker pavements are built on roads with higher traffic loadings and volume.
- For the Specific Pavement Studies (SPS)-1 and -2 controlled experiments, which started with new construction, blocked fractional factorial experimental designs were used to reduce the number of test sections constructed at a site and still maintain desired statistical inferences. This permitted construction of some off "diagonal" pavement structures designed to have a "limited" life.
- All experiment designs were developed and reviewed by expert statisticians with pavement research experience. These designs also received peer review by an ETG consisting of both expert statisticians and pavement research engineers.
- Testing patterns were designed to capture known seasonal and location effects; in order to capture these effects, randomized testing patterns were not used.
- Repeat measurements were used when possible to provide an estimate of measurement variances. For example, measurements of pavement stiffness using a FWD used four drops from each drop height. Measurement of longitudinal pavement profile used a minimum of five and up to nine repeat measurement passes on a test section.

- When possible, the sampling theory used for the experiment and the data collection design are contained in the program documentation. Most of this information is included within the Reference Library disseminated with the data.
- The one critical data element which LTPP relies on for statistical sampling is the collection of traffic weight, classification, and volume data. Although the stated preferred sampling practice is continuous monitoring of traffic weight and classification by a calibrated weigh-in-motion (WIM) station, since this portion of LTPP data collection is primarily dependent upon voluntary highway agency participation, the program developed a hierarchical approach to different sampling scenarios. Due to the lack of other information, an analysis study of data from sites with full-time operating WIM scales was used to evaluate traffic data sampling errors and bias. The basis of these sampling scenarios is documented in a report whose findings are published in a LTPP TechBrief.[2]

CHAPTER 2. COLLECTION OF DATA

The DOT IDQG regarding the collection of data are generic to encompass a wide range of data collection methods. LTPP data collection methodology is best characterized as a mix of one-time surveys, periodic collection of condition data, continuous reporting of climate and traffic loading, and compilation of data collected by others.

The LTPP data collection operations comply and, in some cases, surpass the DOT's IDQG. The LTPP data collection operations include an array of techniques including data collection forms, electronic measurement systems, automated data acquisition, and use of data collected by third parties. The one data collection approach not used by LTPP is a statistical response survey. Some of the LTPP activities noted under data collection operations should be considered for addition to the DOT guidelines.

DATA COLLECTION OPERATIONS

With the vast array of data collection methods employed by the LTPP program, the following operational procedures had to be developed:

- All data recorded on paper forms included written instructions on all requested pieces of information.
- When possible, all pertinent information needed to complete a paper form were included on the form. For example, when codes were used to represent a response, the codes were printed on the form.
- All forms were numbered and dated for document control.
- Revisions to forms were issued in a formal directive documenting changes.
- A response was requested for all information items contained on the form. A "NA" was requested when a piece of information was not available or was not appropriate to confirm that the requested data item was considered or ignored.
- Data collected by instrumentation require a calibration process or a check on the state of calibration of the instrument used.
    - For the vast array of LTPP operated measurement instrumentation, requirements for instrument calibration or checks on the state of calibration were specified.
    - Where required, calibration procedures were developed by the program.
    - Where possible, calibration procedures were specified that could be traced back to the National Institute of Standards and Technology.
    - Adjustments to equipment calibration factors were documented and stored in the database.
    - When adjustments to measurement equipment calibration factors were not possible, guidelines were developed to check equipment calibration and to

return it to the manufacturer for recalibration or discard and purchase new equipment. The guidelines include rules on disposition of data collected using equipment found to be out of calibration after measurement.

  - Field checks for reasonableness of data from electronic measurement equipment were developed. Many of these checks involved computer programs that plotted a data time history that permitted an assessment of operational condition. Guidelines were published to aid technicians to recognize faulty equipment. This allowed trouble shooting and repair activities to be conducted in the field whenever possible.
  - Before using equipment for measurement of critical test section characteristics, side-by-side equipment measurement studies were conducted.
- Electronic data obtained from third parties were evaluated and subjected to automated QC checks before entry into the LTPP database.
  - Errors were found from checks of climate data obtained from the NCDC. The errors where the supplied data indicated that the average daily air temperature was not between the low and high temperature for the day was flagged and not used in calculations.
  - Traffic volume, classification, and weight data supplied by participating highway agencies were preprocessed through software developed by the LTPP program to detect a variety of known errors. Data error reports were then sent back to the agency for review and comment.
- In order to better interface with participating highway agencies, North America was divided up into four "data collection" regions based on the number of agencies in each region. Regional data collection support centers were established in each region to coordinate data collection activities with highway agencies. The regional centers are responsible for collection, review, and processing of critical data and review and processing of all data on test sections located in their region.

MISSING DATA AVOIDANCE

Missing data avoidance is a significant issue for a program like LTPP that relies on voluntary participation by highway agencies for supply of important data elements. The program also relies on notification from highway agencies prior to the application of maintenance and rehabilitation treatments so that pavement condition measurements can be made. Some of the steps employed by the LTPP program to reduce missing data include the following:

- The regional data collection contractors have established data tracking systems to track the status of data collection and processing functions for the test sections in their territory.
- The paper data collection forms sent to highway agencies used a positive feedback response methodology where data items not applicable were marked as

such. This method was used to avoid confusion over items on data forms left blank.

- Group meetings were held with participating highway agencies on a regional basis where data needs and requirements were discussed. Data packets and status reports on missing data were distributed to agency representatives at these meetings.
- Visits to each agency were performed to follow up on data needs and discuss the status of missing data.
- In some cases, it was necessary to send contractor staff to the highway agencies' offices in order to obtain the needed data directly from agencies' files.
- An internal assessment of the program was performed in 1996. One of the results of this assessment was the development of a formal program to identify missing critical data and formulate a plan to obtain the needed data. Visits with all participating highway agencies were held. A signed agreement was obtained from each agency to document what data would and would not be supplied by the agency.
- From this assessment, a pooled fund study was set up with participating highway agencies to obtain missing traffic monitoring data on high-priority test sections. The benefits of the pooled fund study approach to this highly technical area of data collection were the opportunity to provide centralized expert resources and to lessen the impact of manpower resources at the agency to provide this data.
- In another instance, program funds were reallocated to obtain missing materials data, which were the responsibility of participating highway agencies, on a subset of high-priority test sections. In this exercise, the new data collection effort was based on an assessment of both missing and questionable data.
- While some of these efforts have been documented in various methods, due to the engineering research nature of the LTPP program, it is LTPP management's position that a data user would not benefit from information on the procedures used to avoid missing data. Therefore, these procedures are not disseminated with the data.

CHAPTER 3. LTPP DATA PROCESSING

LTPP's data processing operations started in 1988 at a time when modern database software was evolving. In the development of the data quality approach to LTPP data, all of the features covered in the IDQG were addressed. The data QC process started with procedures to calibrate and check the functioning of field data collection equipment. Data forms and data collection procedures always received an independent review prior to use. Extensive data editing checks were developed to automate the process of identifying and correcting erroneous data. Methods were developed to identify and address missing data. A codified procedure was developed to address the issue of computed parameters containing estimates, projects, and imputations. The data analysis plan and analyses were subjected to scrutiny from an expert panel operating outside the program.

DATA EDITING AND CODING

Efforts are made to reduce errors at the source, i.e., during data collection. An extensive number of methods have been developed to identify, and where possible, correct erroneous data. Data checks are made before and after data are entered into the database. A primary objective of the data checks made prior to entry is to prevent "bad" data from being entered into the database. Some of the data editing and coding methods used by the LTPP program include the following:

- Predata entry processor programs developed by LTPP to prevent "bad" data from being entered into the database include:
    - AWSCHECK—This program is used for Automated Weather Stations (AWS) operated by the program at some test section sites. In addition to range and integrity checks, the program plots the climate data allowing for time-history consistency checks to be performed. This preprocessor program allows deletion of "bad" measurement data and adjustments to data fields such as time to correct for daylight savings time adjustments. The output of this program is an input file for loading data into the LTPP database.
    - SMPCHECK—The Seasonal Monitoring Program (SMP) includes instrumentation that measures air temperature, subsurface pavement gradient temperatures, subsurface electrical resistivity (frost indicator), and subsurface dielectric constant (moisture indicator) on a subset of test sections. In addition to automated range and integrity checks on the data, time-history plots of this temporal data are also used to identify data inconsistencies. This preprocessor program allows deletion of "bad" data and time-based adjustments. The output of this program is an input file for loading into the LTPP database.
    - FWDSCAN—This program scans electronic FWD data files to identify data collection rules violation issues, data file format integrity, and range values violations.

    - P46CHECK—This preprocessor program automates checks on the results of laboratory resilient modulus tests on unbound materials. In addition to all of the routine checks on data values, advanced statistical based checks are performed on details such as conformance of load-pulse shape and duration to protocols rules.
    - P07CHECK—While the primary function of this preprocessor program is a check on the integrity of the results of resilient modulus measurements in indirect tension on asphalt concrete cores, it also uses a documented algorithm to calculate the test results from the raw measurement data, which are stored in the database.
    - PROQUAL—Like P07CHECK, this program is both a preupload data check processor and a computed parameter generator. This program processes, evaluates, and generates computed parameters for both longitudinal and transverse profile measurements. In the LTPP series of preupload programs, this software is unique in that it is the primary data-entry point for manually collected profile data. It automates detection of spatial-based measurement anomalies as well as computers parameters, such as International Roughness Index. The output files from this program are used as input files to load data into the LTPP database.
    - Traffic database—Since traffic load data are an input to the pavement performance database, separate data storage and processing functions were developed for traffic load, classification, and volume data. Graphical, automated-range, and statistical-based checks are employed to identify suspect, invalid, duplicate, and erroneous data. Since the bulk of traffic data for the LTPP program are supplied by participating highway agencies in the United States, Canada, and Puerto Rico, data identified as suspect are returned to the agency for review and comment. "Bad" data are purged from the system prior to generation of annual estimates.
- While calculated measures have been used to reduce the reliance on subjectivity in detecting data anomalies, there are still many errors that can not be detected using automated methods. With the complex data structures collected by the LTPP program, some of the simple time-based, distance-based, or binned statistical distribution plots have proven to be more effective at detecting data problems.
- To make some of the automated data checks effective, LTPP had to develop a system of human review of records failing the checks to weed out false positives. In order to make many automated data checks effective, such as range checks, a percentage of valid results must be flagged for further investigation. Another example is the check that LTPP uses to see if the ratio of the standard deviation to the mean is less than 0.5. While valid data sets can exist that fail this check, its purpose is to flag suspect data for further review.
- The best way to avoid deletion of valid outliers that violate a range check is with subjective human review. It is LTPP's policy not to delete something just because it is an outlier.

- Entry of duplicate data into the database is primarily controlled by judicious use of key fields in the relational database software, which restricts entry of duplicate data sets. The key fields are specified such that only one logical record can exist for a given measurement or data set. To detect duplicate data sets in which one of the keys was changed, for example, the date of the measurement was changed; data studies are performed to detect this type of duplicates using Standard Query Language (SQL).
- The size of LTPP's database makes it impractical and cost prohibitive to both track and report all data edits. To track changes in the more than 7,000 data fields and more than 125 million records would be a worthless exercise to the data user. Some of the measures used by LTPP to address changes to measured data and data released to the public include:
    - If corrections are required to a raw electronic data file, when possible, the corrections are made in the file prior to upload into the database.
    - If corrections are required to data submitted on a paper data collection form, the corrected values are written onto the form with the previous values crossed out in a fashion that makes them still legible.
    - Data releases are numbered and dated.
    - To track important changes between data releases, a public data feedback report process was implemented. Problems identified in the data and their resolutions are posted on the LTPP Web page (http://www.fhwa.dot.gov/pavement/ltpp/index.cfm).
- The size of the LTPP database also makes it impractical to comment on every piece of missing information. The complication is related to tables containing multiple data attributes, some of which may not be applicable in a specific situation. On average, each table contains 17 fields, and some tables contain up to 256 data fields. The missing data approach taken by LTPP includes the following:
    - For data collected via paper form, nonapplicable data fields are identified on the form using a not applicable code. In many fields, a nonapplicable code is used in the database.
    - For electronically measured data, a rigid enforcement of the use of null values is used. The objective is to differentiate between a zero and null, where null represents value not present, not measured, or removed. Modern database tools no longer translate null values into zeros when performing mathematical functions on a data set.
    - For data types measured electronically, manually recorded on a data form, and manually input into the database, a variety of data checks are used to detect missing data.
        - The use of automated required data checks in the database to identify data that should be present but are not.

        - For groups of related data, both referential data integrity checks are directly coded into the database software, and external relational data checks are used.
        - Data transcription error checks are made to identify improper data entries.
        - Data checks are used to identify widows and orphans. A widow occurs when a parent table exists, but the related child table(s) containing some part of the data does not exist. An orphan is when a child table exists, but the parent table no longer contains a matching record. These types of checks are necessary when using relational databases to store a linked data set in multiple tables.
- There is an extensive set of comment fields included in the database where a controlled vocabulary is enforced using codes. A code table that describes all of the code fields is included in all data releases. Since some comment fields do not lend themselves to codes and a controlled vocabulary, these fields are regularly checked for spelling, grammar, and consistency prior to each data release.
- LTPP has produced extensive documentation on its data editing and processing procedures. Distributed with each standard data release is a Reference Library disk which contains copies of all important documents on LTPP data editing and processing procedures. Some of the measures used by LTPP to enhance the transparency and understanding of its data include the following:
    - Inclusion of a database user reference guide with each data release. The user reference guide contains a listing of all operational documents for experimental designs, data collection methods, data checks, QC, data editing procedures prior to upload into the database, and missing data identification.
    - A separate document is contained in the Reference Library that contains all of the data checks performed on the data after upload into the database. This document currently exceeds 700 pages.
    - A data quality flag indicator is included in every record in the database containing "data." At this time, a single flag field is used to indicate a relative level of data completeness, data range, and relational data integrity. A comment table explains the actions taken on records failing the automated checks. This explanatory table is no longer distributed with the data due to the passage of time and changes in the data checks; some of the comments are no longer applicable, and due to funding cuts, a review of these comments has not been possible.
    - A plan was devised to separate automated data quality flag fields into three distinct flags on the data quality attributes of completeness, logical range value, and data structure integrity. These flags would record each failure of a data check in a database table and indicate to a data user the action taken. Due to program budget cuts, this enhancement to the data quality system has not been implemented.

HANDLING MISSING DATA, ESTIMATES, AND PROJECTIONS

The approach to handling missing data, production of estimates, and projections for the LTPP program is similar enough to be classified under one topic.

- A truth in data concept was developed in the early days of LTPP since it was intended that users of the data would perform direct manipulations of the data. The truth in data concept requires that measured values be separated from imputed or estimated values. Information on the statistical nature and basis of values obtained from samples is stored in the database.
- Traffic volumes and loads over a test section are the only data that LTPP provides cumulative annual estimates for a data user from a monitoring data sample. While LTPP has developed various statistically-based traffic data sampling schemes, based on analysis of "real life" traffic monitoring data, in many cases, the best that participating highway agencies could do is provide LTPP with unstructured sample data. Thus, LTPP had to develop a wide range of estimation methods that included very basic time expansion algorithms that use days of the week, month of the year weighting factors to arrive at the best annual estimate from the data provided. The database contains information on the size of the sample used in the estimate which indirectly infers the amount of missing data.
- Although some attempts have been made to impute, estimate, forecast, backcast, or otherwise compute missing data through various data analysis studies, to date, none of these data have been added to the database. If these data are added, they will follow LTPP's policy on computed parameters that require algorithms and procedures used to be documented and available from the LTPP Web site (http://www.fhwa.dot.gov/pavement/ltpp/index.cfm).
- Since most of the applications of LTPP data involve development, evaluation, calibration, or validation of complex models, missing critical data generally result in exclusion of a test section from the analysis. Thus, missing data rates and weights are not used in the bulk of LTPP analysis projects.
- Due to the diversity of uses of LTPP data in engineering pavement performance research, as well as the dynamic changing nature of the database, data analysts and users are charged with responsibility for their use and interpretation of the database relative to the data study design, imputations, statistical methodology, etc.
- Analysis of LTPP data have been used by universities as part of their engineering curriculum. The motto for use of LTPP in the classroom is, "LTPP…an endless source of unique problems." In this context, problems are questions assigned to students to solve as part of the curriculum.

PRODUCTION OF ESTIMATES AND PROJECTIONS

Due to the research nature of the LTPP program, there is a division between the LTPP database and the LTPP data analysis results. The responses to LTPP's actions relative to this part of the IDQG will focus on database contents. Discussion of production of estimates and projections from LTPP-sponsored analysis of the data are presented in the next portion of this document.

The LTPP database contains a vast array of derived data to enhance the data set and reduce user and data supplier burden. Since a primary purpose of the database is to provide raw data to researchers and analysts, only a limited number of estimates are contained in the database. Virtually no projections are contained in the database. These quantities are contained in published analysis reports distributed independently of the database.

Examples of derived data contained in the database include the following:

- The derived climate data are provided as virtual weather stations using weighting factors based on the distance from the test section site to each weather station. A gravity model is used in which the weighting factors are based on the square of the distance.
- Derived data are computed from climate data obtained from NCDC and the CCC after passing LTPP data quality checks. Derived climate data in the LTPP database include the following:
    - Monthly and annual mean maximum, minimum, and standard deviation of air temperature. The number of days of data included in the time period is also reported.
    - Monthly and annual freeze index, freeze-thaw index, days above 32 °C, and days below 0 °C.
- Derived data similar to that computed from climate data obtained from other sources is also computed for weather stations operated by LTPP.
- The LTPP database contains estimates of annual traffic loading statistics from traffic monitoring data supplied by participating highway agencies. A separate traffic database was established that contains the raw and processed data used to supply the annual estimates from monitored traffic data from highway agencies. The objective of this separation was to provide derived traffic estimates most commonly used by pavement researchers but to still maintain a comprehensive traffic data resource that can be used by other researchers. Examples of derived estimates of traffic data contained the LTPP database include the following:
    - Axle weight distributions by vehicle class and axle configuration.
    - Annual volume estimates by axle class.
    - Weighting factors used to expand volume and weight measurements to annual estimates.

- LTPP measures the longitudinal profile of its test sections. Along with the raw profile measurements, ride statistics such as the international roughness index are computed from the profile measurements and stored in the database.
- LTPP measures test section transverse profiles at varying distance intervals. Information such as rut depth, rut location, rut width, and other transverse profile distortion indices are computed from the raw profile measurements.
- The most important part of the measured material properties database module is derived data from laboratory measurements. Basic engineering properties computed from measurements of load, displacement, weight, volume, and time are provided in terms such as stress, strain, elastic modulus, resilient modulus, creep compliance, thermal coefficient of expansion, specific gravity, air voids, density, moisture content, etc.
- Most of the estimates of standard error contained in the database are based on simple descriptive statistics of standard deviation derived from repeat measurements. While research studies have been performed to investigate higher order levels of error and uncertainty, these data have not been included in the database.

DATA ANALYSIS AND INTERPRETATION

A multiproject approach by topic area is used for analysis of LTPP data. To date, there have been approximately 55 analysis projects performed under LTPP management and 21 LTPP analysis projects performed under the auspices and funding of the NCHRP. There have been more NCHRP- and State-sponsored research projects that have used LTPP data. With this volume of research, it is easy to understand that no single approach is used for LTPP data analysis, and different approaches have been used for analysis of the same set of data.

The bulk of LTPP sponsored analyses are performed under contracts with consultants, experts, academicians, and university researchers. Thus, a formal contractual approach to analysis is used. Topics are selected from the LTPP analysis plan; formal statements of work are developed; request for proposals are issued; proposals are evaluated; a contactor is selected; on some projects a project panel is used to review work in progress; and all results are reviewed prior to publication.

Highlights of LTPP conformance to the IDQG relative to data analysis and interpretation are as follows:

- The LTPP program was designed to serve a broad range of pavement management needs that dissect traditional engineering disciplines. Because the objectives contained in the initial project plans were written on a topical basis, LTPP was required to develop detailed plans for specific analysis topics covering a variety of inter-related topics. The LTPP data analysis plan was developed from input from program staff, highway agency personnel, industrial stakeholders, and academicians using an outreach process. The process was based upon solicitation of candidate research needs statements, combination of statements into projects, review and assessment of projects relative to data availability, and classification of projects into a unified plan. The unified plan was developed in concert with the LTPP ETG on Data Analysis. The analysis plan is periodically updated using the ETG peer review process. In addition to deriving new knowledge from higher order analytical investigations, the plan includes exploratory analyses, data studies, and development of derived data for input into the database. The analysis plan is publicly available on the LTPP Web site (http://www.fhwa.dot.gov/pavement/ltpp/index.cfm).

- A variety of statistical approaches have been used in the various LTPP-sponsored data analysis. All of the details contained in the IDQG guidelines have been addressed in one or more of the analyses. The degree to which statistical assumptions are tested, deviations are examined, and statistical sensitivities are evaluated depends on the nature of the analysis efforts. LTPP relies on a formal peer review process consisting of a panel of statistical experts.
- The issue of replication in a field study of pavement test sections is an ongoing source of debate within the LTPP program. It is the nature of field pavement performance studies that variance and errors from uncontrolled and, in some instances, unmeasured co-variates can overshadow the significance of main effects of experimental design constructs and make significant higher order interactions difficult to detect. In some cases, Bayesian modeling approaches have been used to deal with these issues.
- In many of the LTPP data analysis projects, modeling approaches are used to include related variables when the relationship between two or more primary variables are being assessed.
- The wording of results contained in LTPP-sponsored data analysis documents is peer reviewed by an expert panel before dissemination. One of the concepts used in the LTPP program concerning evaluation of statistical significance tests is the engineering or physical significance of a difference or similarity. For example, an analysis of variance may result in a highly significant effect due to a very low error term when the physical reality of the difference has no impact in engineering terms. The opposite is also true due to a very large variance in a data set—items with significant physical or engineering difference can be found to have no statistical significance. This is why LTPP has adopted the use of both statistical and physical tests of inference as indicators of the possible significance of an effect.
- LTPP does not always handle the results of 100 percent sample data. However, there are instances when external data sources on commonly expected variability inputs are needed to assess confidence intervals. One example is the assessment of variability in material test results from SPS projects where multiple test sections are located on the same site. Variance estimates from external industrial sources were used to assess the robustness of the variability in the material test results at these sites.

- Since the basic nature of higher order analysis of LTPP data is a time series problem, stability of interim findings is addressed by requirements that the time stamp of the data set used for the analysis be documented, new analysis projects document findings from previous efforts, and recommendations are included regarding changes to improve the analysis topic within data collection operations.

CHAPTER 4. DISSEMINATION OF INFORMATION

Dissemination of information is one of the stated objectives of the LTPP program. The primary focus of the program is to provide a macro release of raw data for use by scientists, engineers, and researchers for engineering based analysis. While published summaries and microdata releases are not the primary dissemination mechanism, a limited amount of data have been distributed in this fashion. The macrodata release includes documentation of data sources and, where possible, accuracy indicators. In accordance with the IDQG, all disseminated data are required to receive some type of review prior to release.

PUBLICATIONS AND DISSEMINATED SUMMARIES OF DATA

Since a primary objective of the LTPP program is to provide raw data for analysis and interpretation by researchers, dissemination of information in printed publications containing statistical summaries is not the primary dissemination mechanism.

- The published results of FHWA-sponsored data analysis of LTPP data contain statistical summaries and data interpretation relevant to the subject.
- All published reports are subjected to the FHWA publication process which includes editorial review for conformance with FHWA publication standards, inclusion of a report documentation page, which lists all pertinent meta information about the authors, contact information for the authors, contract reference, time period the work was performed, abstract, key words, and other metadata.
- Many of the LTPP publications predate the introduction of Section 508 of the Americans with Disabilities Act by more than 10 years; documents published after the act's implementation date have been formatted in conformance and are reviewed by individuals trained in DOT Section 508 compliance standards.
- References in publications are documented following FHWA publication guidelines. All documents are dated.
- Data analysis documents, which contain estimates and projections, are required to contain a description of the analysis methodology. These documents receive both an internal and independent external review by knowledgeable experts on the subject prior to publication.
- All publications contain contact information for the report author, FHWA Contract Officer's Technical Representative, and other citations as required on the FHWA's Technical Report Documentation Page (Form DOT F 1700).
- Due to the breadth of the LTPP program, a number of unpublished documents on specialty topics have been made available to the public. Due to practical budget constraints, these documents do not receive the same level of scrutiny or review as published documents. Although many of these documents do not receive a formal peer review, they are reviewed internally prior to release.

MICRODATA RELEASES

Although the primary thrust of the LTPP program are macrodata releases, the following microdata releases are used to encourage participation in the program and serve targeted sectors of the transportation research community:

- A microrelease of data is used for preparation of information packages intended to encourage continued highway agency voluntary participation in the program. These packages present data extracted from the database which show time history and pavement performance trends on the agency's test sections. The extracted data used in these releases have been subjected to all data QC and assurance checks.
- In order to better serve users of analysis software that require a specific data format, LTPP has provided microdata releases in standardized formats. These data have undergone data quality checks prior to release. Examples include the following:
  - FWD time history data that are not included in the database, in the native format produced by the device.
  - Profile data in an industry developed data interchange format.
  - Raw traffic data measurements are provided in the FHWA standard "card" formats.
- LTPP offers a custom data extraction service. This service is designed to provide data to those interested in pursuit of analysis of a specific topic.

SOURCE AND ACCURACY STATEMENTS

While LTPP does not have formal publication-named Source and Accuracy Statements (S&As), it has developed a vast array of documents which contain the content covered in this part of the guidelines.

- In many cases, data sources are contained in code fields in each record in the database. For example, materials testing laboratories are assigned an identifying code that is contained in each database record containing data from that laboratory.
- Where possible, descriptive statistical information is contained in the database to permit data users to quantify variability and uncertainty in key measured data elements.
- A data user reference guide, distributed with data releases, contains documentation on data sources on a module and table basis. This document is updated with each data release to reflect changes in data sources and collection methods.

- Topical data collection and data processing guides have been prepared by LTPP. Appendix A contains a list of this documentation. Updated data collection and data processing guides are documented by issuance of formal program directives.

LTPP has collected data that could be used to better evaluate data accuracy. Due to funding constraints, these data and reports have not been distributed on a published basis. Some of the information collected by LTPP that could potentially aid a user in assessing the accuracy of the reported measurements are as follows:

- Reference and relative calibration results on FWD geophones are not contained in the database. The electronic files created as a part of this function are considered part of the Ancillary Information Management System (AIMS). Efforts are currently underway to store these data in a central location and populate a metadata database on the contents of these files.
- The reports documenting the side-by-side comparison of FWD and profile equipment operated by LTPP have not been formally published. Through the TRB peer review process, data users have indicated that although these detailed measurement information could theoretically be valuable, the limited amount of research funding in the United States would create too many expenditures for the limited use of the data.

PREDISSEMINATION REVIEWS

All formal data disseminated by the LTPP program undergo some type of review prior to release. The type and extent of the review depends on the subject matter being released. LTPP is developing an information category for dissemination that does not receive a "formal" review prior to dissemination.

The following types of formal predissemination reviews have been conducted by LTPP:

- The contents of the database are reviewed by experts and specialists on the central Technical Support Services Contractor (TSSC) staff prior to release. These review staff members are not directly involved with data collection or analysis. Data collection is the responsibility of four regional data collection contractors who collect data, process data, and review data prior to each upload to the national database. At the national level, data from the four regions are combined into a single database. Prior to each release of the database, the TSSC staff members perform a predissemination review of the database contents, notify the regional data collection contractors on needed corrections, and review corrections received prior to the release. Known data problems not corrected prior to release are documented using the Data Analysis Operation Feedback Report process.
- Paper publications are subjected to a variety of predissemination reviews depending on subject content.
    - All published paper documents are reviewed by editors employed or contracted by the FHWA TFHRC publication staff. These editors are

specialists trained in style and visual information content of FHWA publication standards.

    - Program promotional material and status reports are reviewed by FHWA LTPP staff and contractors who did not actively participate in preparation of the draft document.
    - Research reports containing engineering and statistical analyses receive an external and internal peer review in addition to the other predissemination reviews previously mentioned. The peer reviews are conducted by a diverse group including voluntary experts from the TRB ETG on data analysis, paid experts from the LTPP TSSC, and, most importantly, engineering staff from the regional data collection contractors. This rigorous peer review process includes knowledgeable individuals from outside the program who represent program stakeholders and academia; a paid staff of researchers not involved with the performance of the data analysis work, but who have unique knowledge of the LTPP program and have resources available to independently check reported results; and, most importantly, reviewers who collected the data and possess knowledge on its proper analytical interpretation.
    - Report reviewers on the TRB ETGs are required to report prior DOT technical/policy positions on issues related to LTPP as part of their conflict-of-interest disclosures required by the National Academy of Sciences before being appointed.
    - LTPP contractors are required by the Federal Acquisition Regulation (FAR) guidelines to report conflict-of-interest concerns in their proposals.
    - The peer review process has resulted in nonpublication of program-funded analysis reports.

- After the passage of Section 508 of the Americans with Disabilities Act, all disseminations of information via electronic media have been reviewed by specialists who have received training on this legislation. All LTPP contractors responsible for managing Web pages containing LTPP program information have Section 508 compliance clauses included in their contracts. All LTPP-sponsored Web pages have been reviewed by LTPP staff for compliance conformance. As a long-term program, LTPP has been hampered by the lack of effective FHWA guidelines on implementation of this policy. To date, LTPP electronic documents have not been challenged by persons with disabilities for nonconformance with the Section 508 requirements.
- Data products were disseminated by LTPP prior to enactment of Section 508 of the Americans with Disabilities Act. Since these data products can no longer be controlled by the program, documentation has been published that these data products are no longer supported by the program, and concerned data users should use current data products or contact LTPP concerning accessibility accommodation for the disabled. To date, LTPP has not received such a request.

LTPP had developed plans for a system that allows dissemination of raw data that has not undergone a formal predissemination review. While the bulk of these data are contained in the database, the data included in this category are classified as objects in database terminology. Most of these electronic objects consist of electronic picture formats, but, on the advice of the external peer reviewers, many are the unedited electronic files from data collection devices. This allows a data user the opportunity to evaluate LTPP data processing and quality systems. At the heart of the process was the creation of a metadata database. The concept that was previously developed is that the metadata about an object contain adequate information to describe the format, content, quality review level, and nature of the data included in this module. The LTPP metadata database was planned as an electronic library based on the Dublin Core Standard and in concert with electronic library standards currently under development by the U.S. National Archives, Library of Congress, and internal FHWA publications staff. Due to budget cuts, development of the formal metadata database has been curtailed to documents indexed by the FHWA library staff.

CHAPTER 5. EVALUATING INFORMATION QUALITY

The methods used by LTPP to evaluate and improve its data are the development of QC systems during data collection and processing, regular assessments of data quality, special studies of key aspects of the data, and data collection processes.

DATA QUALITY ASSESSMENTS

LTPP has developed two approaches to quality assessments. The first approach was a major program assessment conducted in 1996–1998. The second approach was the development of a quality control/quality assurance system based on the ISO 9001 quality management principles.

The objective of the 1996 assessment was to evaluate the program goals, objectives, and future direction. This was completed by evaluation of the impacts on deviations from the program's plans, number of test sections, data collection deficiencies, and resources. The ultimate objective of the assessment was to develop a revised strategic plan that focused on high-payoff product objectives that met States' needs, improved program efficiency, and provided better quality data for product development. Some of the aspects of this assessment related to the Federal data quality guidelines, including the following:

- The assessment was conducted by a team composed of expert contractor staff and FHWA staff, in concert with a special peer review subcommittee made up of State DOT, TRB, and AASHTO representatives.
- Through the TRB advisory mechanism, stakeholders in State agencies were contacted to obtain input on agency needs as related to the goals and objectives of the program goal established 10 years earlier.
- One member of the assessment team was a FHWA loan staff member from Canada who was knowledgeable of data quality but did not participate in preparing data system information or public dissemination.
- The findings from this assessment resulted in a highly publicized "Campaign for Program Improvement," which involved meetings with each participating State and Canadian provincial highway agencies to resolve missing data issues and obtain a written agreement on their intended level of support for the program on a test section basis. Program priorities were changed to focus on high-payoff areas of research in the program, and resource allocation reductions were made in areas judged to provide limited impacts. In addition to numerous presentations at national, regional and local meetings, a report was prepared on the results of the assessment.

With the letting of the four regional LTPP data collection contracts in 2001, FHWA required documentation for the preparation of formal data collection and a processing QC system. After central review by a contractor with ISO 9001 certification, these QC documents were transformed into quality management documents based on ISO 9001 principles. Some of the relevant features of this management process, as related to this portion of the Federal data quality guidelines, include the following:

- Designation of a regional data QC manager on each regional contractor staff. The regional data QC manager is responsible for the following:
  - Conducting regularly scheduled and impromptu internal audits of compliance with quality control and data collection guidelines and procedures.
  - Documenting internal audits conducted and their results.
  - Documenting corrective actions resulting from both internal and external audit findings.
  - Conducting annual or more frequent reviews and updates of the QC and management procedures.
- The central TSSC established a quality assurance audit team and process to assess compliance by the data collection contractors with their data quality control and management guidelines and compliance with LTPP program requirements. The quality assurance audits include the following:
  - Announced office visits to review designated sections of the quality control and management plans. The different parts of the plans are rotated so that each part is reviewed on a 2-year cycle, if budget permits. Prior to an audit, a data review is conducted to identify data issues of concern to be investigated during the audit.
  - Unannounced audits of primarily field data collection personnel. Each regional data collection contractor is required to maintain a data collection schedule posted on the Internet. Auditors arrive unannounced at data collection sites to observe activities and compliance with both the contractor's internal requirements and the program requirements. Negative findings from these inspections are discussed with field personnel and then reported to management.
  - An example of an unanticipated and unannounced field audit was conducted in Hawaii. This audit was conducted since data collection efforts on sites not located on the mainland require an alternate set of procedures and tools not common to other test sections.
  - All audit results are documented in an audit report that includes a description of audit activities, items reviewed, positive findings, correction action requests, and improvement recommendations. All corrective action requests and improvement recommendations are discussed with the data collection management contractor in order to reach an agreement on corrective actions to be taken. On each audit visit, all previously agreed to corrective action findings and improvement requests are reviewed.

Quality assurance audits are performed on highway agency operated FWD reference calibration facilities used by LTPP. These facilities were developed under cooperative agreements with select highway agencies. The facilities use LTPP-provided equipment and follow LTPP test protocols. Annual audits are performed on conformance to test protocols on the operators of these facilities. Audit results are documented and certificates of compliance are issued.

EVALUATION STUDIES

LTPP has used evaluation studies to analyze data quality issues that can not be identified by mere inspection of the data. Evaluation studies have also been performed in the development, refinement, or implementation of new or advanced data collection systems. The following are some of the evaluation studies conducted by the LTPP program:

- Since the methods used to rate pavement distresses rely on a subjective interpretation by trained personnel, an evaluation study was conducted to examine the between rater variability and variability between rating methods. The study was conducted by engineering and statistical consultant experts and peer reviewed by a TRB ETG on pavement distress monitoring. The study was based on a statistical sample of data obtained from distress rater accreditation workshops. In addition to documenting probable ranges of uncertainty in these measurements, recommendations on improvements to the rating methods resulted from this work. The results of this work were published in the report, *Study of LTPP Distress Data Variability,* FHWA-RD-99-075.
- An evaluation study was performed on the resilient modulus test on AC in indirect tension developed by the LTPP program when it was managed by the National Academy of Sciences as part of the SHRP. Due to the severity of the problems found with the data from these tests and the uncertainty associated with test results which appear reasonable, the data were archived and removed from the database distributed to the public.
- As a part of the QC system, evaluation studies are routinely performed on advanced field data collection equipment which includes FWDs and pavement profilers. These evaluation studies typically consist of a statistically designed experiment that allows an analysis of variance approach to be used to evaluate the results of side-by-side equipment comparisons. These evaluation procedures have also been used to evaluate equipment during the procurement process.
- The State-sponsored pooled fund study, TPF-5(039), managed by LTPP FHWA staff was established in 2004 to investigate improvements to the LTPP-developed FWD calibration protocols. The contractor is charged with evaluating current methods, procedures, and instrumentation to develop an improved system compatible with current computer technology.

LTPP has established the basis for future evaluation studies that may not be able to be conducted with current funds. For important data elements based on measurements from instrumentation, when possible, equipment calibration factors are stored in the database. This permits evaluations of the effect of changes in the calibration factors over time.

QUALITY CONTROL SYSTEMS

LTPP has invested significant resources in developing data QC systems to address the variety of data sources and measurement technologies employed in the program. The goal of these QC systems is to provide a preventive system of error identification to avoid data errors before entry of data into the database. Within the LTPP program, data quality control is defined as the processes and procedures used to inspect data and data collection equipment prior to entry of data into the database.

The major categories of QC systems developed by LTPP include equipment calibration procedures, equipment calibration checks, operator training and certification, post data collection reviews, data screening from external program sources, and formal quality control management procedures.

Equipment Calibration

In the development of the data collection plan, it was determined that the LTPP program needed to own and operate specialized data collection equipment judged by panels of experts to be critical to its success. While the LTPP program tried to rely on existing technology, in some cases, it had to develop its own measurement technology. In some cases, LTPP had to develop calibration procedures for its specialized equipment and, in other cases, used exiting procedures. Some highlights of LTPP equipment calibration procedures include the following:

- LTPP developed the first reference calibration procedure for FWD in the United States. This procedure provides a calibration procedure independent from the equipment supply contractor. Federal, State, and international highway agencies have adopted the LTPP FWD reference calibration procedure. Changes to sensor calibration factors are stored in the database to permit analytical evaluation of potential impact of these changes by data users.
- LTPP developed cutting-edge equipment calibration procedures for the very sensitive tests on the elastic response of pavement materials in the laboratory. These tests, informally called start-up procedures, involve expert instrumentation engineers who check the internal functions of advanced laboratory electronic measurement equipment to identify sources of bias and error that can not be reliably detected by inspection of the output data. The nature of these checks is to measure the output from a controlled electrical input into the system. The objective is to discern if the instrumentation is correctly calibrated to the manufacturer's specifications.   .
- Calibrations of distance measurement instruments critical to vehicle mounted pavement related measurements are codified in LTPP directives.

- It is LTPP policy to use equipment whose calibration can be traced back to the National Institute of Standards and Technology, when possible.

In those cases where it is not possible to directly calibrate a device, equipment calibration checks are used to ensure proper function. For example, measurements by temperature sensors are conducted on items of known temperature such as ice and boiling water, and if found to be outside an established range, are either returned to the manufacturer for adjustment or replacement.

It is LTPP policy to identify data collection equipment operators or data collectors in the database to allow evaluation of operator biases and errors.

Data Collection Operator Training and Certification

Due to the complexity and subjectivity of many of the LTPP data collection functions, LTPP has established formal data collection training classes and certification evaluations.

LTPP requires that collection and interpretation of pavement distress data be performed by someone who has an active certification from a LTPP distress rater accreditation workshop. Raters must meet minimum experience and time-based recertification requirements in order to maintain their certification.

The LTPP regional data collection contractors are required to train and certify operators of equipment used to collect LTPP data as a part of their formal data QC management plan. Regional equipment operator training is documented, as required. Evaluation of the performance of new personnel by the regional data collection management staff is also documented, as required.

To promote consistency among regional data collection contractors, national meetings of regional data collection operators have been conducted on each major data collection topic. When the program began, annual meetings of data collectors were held. Due to program budget cuts, national meetings were scheduled on a priority basis, and the use of teleconferences was increased.

When new data collection technologies are being implemented, the LTPP program has used the following process:

- Development of draft guidelines.
- Review and comment on draft guidelines.
- National meeting to develop final guidelines.
- Field pilot activities to test and refine the guidelines.
- Issuances of final guidelines.
- Use of problem reports to document and request guideline changes.
- Update guidelines as appropriate.

Screening of Data from External Program Sources

The data collection plan relies upon multiple data sources. These data are screened prior to entry into the database. For data submitted on paper forms, the first level of screening is for completeness and logic checks on the provided information. Like all other data, these data are also screened after entry into the database using automated methods.
A large amount of data is received in electronic format. Two of the largest modules of data from other agencies are traffic monitoring data and climate data. The following screen method demonstrates the steps used by LTPP on these data:

- Traffic monitoring data are supplied by participating highway agencies in the standard FHWA card formats used for HPMS. The first step in the screening process is to determine if the data are in the correct format and will load into traffic quality control software. After the data are loaded, diagnostic checks are performed on the data. Many of these are graphs of the data used to determine common errors. A data review package containing graphs, a summary of data problems, and proposed actions to deal with problem data is prepared and submitted to the highway agency for review and comment. After agency comments are received, the data are processed, as appropriate.
- Climate data are obtained from the NCDC and CCC. Due to the large amount of data, these data are loaded into database tables. Automated checks on completeness, range, and logical statistics are performed on these data, and flags are set in these records to store the results. Records not passing the checks are excluded from use in the analysis process that creates temporal summary climate statistics for each test site.

DATA ERROR CORRECTION

The LTPP program has established standard and formal methods for data error correction. It has been LTPP's policy to not load known "bad" data into the database. Although steps are taken to prevent entry of erroneous data, there have been numerous instances when data in the database were found to contain errors, or, in some cases, unknown facts have caused previously entered data to be invalid.

When data errors are found, the standard mechanism is to correct the error if possible or remove the data from the database if the error cannot be corrected.

Error correction procedures are contained in formal documents issued by directive by data type. An example of an error correction policy is contained in the following excerpts from LTPP Directive I-85 on Manual Upgrades to QC Checks. This discussion describes the steps to be taken when data fail an automated check.

When a record does not pass a QC check, the first action that should be taken is to determine the cause, examine the data in the record or other related records, and try to rectify the situation if possible. Some types of possible errors that can be corrected include the following:

- ***Transcription errors.*** Transcription errors are an inherent problem with any manual data entry system. All data entry should be double checked for this type of error prior to saving a record to the database. When a record fails a QC check, this should be one of the first errors investigated.
- ***Improper referential data entry in another record.*** Because LTPP data are obtained from multiple sources, it is possible that a field used for referential links between tables will not have been properly recorded. LAYER_NO is a prime example of this type of correctable problem. There are times when a material testing laboratory may be assigned a LAYER_NO that is later changed in the database due to factors unknown to the laboratory contractor. This can cause a mismatch of material types in the layer tables. This type of error can be easily corrected by assigning the correct LAYER_NO in the mismatched record.
- ***Improper data acquisition or interpretation.*** In some cases, the supplier of the data may not have understood the intent or basis for the needed data element. These types of errors are usually associated with level-D range check errors. In these cases, the only recourse is to contact the data source and search for the correct value. For example, the percentage of longitudinal reinforcement steel in PCC pavements should never exceed 1 percent. When an agency has reported numbers in excess of this value, Regional Support Contract staff members should discuss the issue with agency contacts to decide if the correct value can be determined from the available records. In some cases, it may also be possible to resolve issues with photographs or direct field measurements.
- ***Errors, oversights, and blunders with interpreted data.*** There are instances where it is possible to reinterpret data from the raw measurements. Distress data from photographic based measurements is an example of a potentially correctable error in interpretation, since the photographs can be reinterpreted. When errors or problems are discovered in transverse profile measurements or distress measurements, the apparent errors should be referred to the data collector for possible correction.
- ***Potentially rectifiable data.*** The longitudinal and transverse profile data provide opportunities where erroneous data in the Information Management System (IMS) might be rectified. For longitudinal profile data, other measurement runs on a section may be available to replace runs, which contain spikes or other apparent data collection equipment errors, with other runs performed on the same day that do not contain such errors. Alternatively, on SPS projects, subsectioning of the raw data files can be corrected for apparent Distance Measuring Instrument (DMI) drift. Manually collected transverse profile data, in which the measurement width was varied along a section, may be salvaged with reinterpretation of the raw data.

- ***Two directly linked fields in a record are in conflict.*** For example, if a value is provided for the amount of admixture then the corresponding code indicating the type of admixture should not be null or no admixture.

During the QC error resolution process, it is also important to identify errors that are not possible to rectify. Some examples include the following:

- ***Equipment measurement errors.*** When a record failing a QC check can be traced to an identifiable equipment measurement error, manual upgrades should not be employed to elevate an erroneous data element to a higher status. When equipment malfunction can be determined, the errant data element should be deleted from the IMS. In records with multiple measurement fields, the "bad" data element should be set to null. In cases where all of the measurement data elements in a record are linked to the same measurement equipment malfunction, then complete removal of the record is the most appropriate action. In situations where a record contains multiple measurements from different sensors and the erroneous data removed from the record causes it to fail a QC check, manual upgrade may be appropriate.
- ***Required data not available.*** Circumstances can develop where critically required data are no longer available. There are instances when a required data element was not collected, was collected improperly, or is no longer possible to obtain or measure. These types of circumstance can potentially lead to a test section being removed from the LTPP study, taken out of study, or being recognized as not able to obtain the required data element.
- ***Indeterminable problem that requires investigation.*** When new tables are added to the IMS or new QC programs are issued, some records failing a QC check require further investigation to determine the cause. There are instances when it cannot be immediately determined if the error is a result of equipment malfunction, abnormal phenomena, or program error. In these instances, manual upgrades should not be performed until the exact cause for the problem can be determined. Some of these problems are resolved through the Software Performance Report (SPR) process. In general, SPRs should only be issued after it has been determined that the problem is not related to other issues.

The above policy and guidelines apply to data after entry into the LTPP database. Error correction guidelines are also contained in the data collection and processing documents for FWD measurements, profile measurements, seasonal monitoring measurements, AWS measurements, and traffic data.

CHAPTER 6. IMPROVEMENT OPPORTUNITIES

This document demonstrates the LTPP program's focus on data quality in relationship to the DOT IDQG issued more than 10 years after the start of the LTPP program. While the LTPP program is proud of its record on data quality issues, this quality focus also results in identification of improvement opportunities. Implementation of these improvements is highly dependent upon program funding.

The improvement opportunities are organized and presented using the main topic areas contained in the DOT IDQG.

PLANNING DATA SYSTEMS

The current date for the end of the LTPP program is 2009. No changes to this portion of the program are anticipated.

COLLECTION OF DATA

Although LTPP data collection operations have reached a mature stage, improvement opportunities currently identified by the program for possible implementation include the following:

- Introduction of new technology to collect previously collected data in a more efficient manner. An example is using instrumentation to automatically measure and record pavement gradient temperatures previously measured and recorded using a manual method. Another example is the use of LiDAR (Light Detection and Ranging) based profile technology, which provides an integrated measurement of both the transverse and longitudinal profile of a pavement.
- Issuance of a new contract for the collection of pavement surface distress permanent image records and interpreted distresses. The contract for this data collection operation expired in 2003 and has not been renewed due to a lack of funds. This data collection effort was rated a top priority from a peer review by the TRB LTPP Committee.
- Increased coverage of nondestructive measurements of within-section pavement thickness using ground penetrating radar. A limited number of measurements were previously performed on high priority sites due to budget considerations.
- Better characterization of the drainage related features at test sites which encompass geomorphologic, topographic, and engineered characteristics.
- Use of more advanced material characterization methods. The LTPP program is collaborating with other FHWA teams to develop a test protocol for using indirect tensile test methods to measure the dynamic modulus of AC from core samples obtained from in-service pavement test sections. The Mechanistic-Empirical Pavement Design Guide (http://www.trb.org/mepdg/guide.htm) developed by NCHRP uses this material property for characterization of the elastic modulus of

AC mixtures. Measurement of this property from field samples did not exist when LTPP began, and no formal measurement protocol has yet to be developed and accepted by the industry.

- Use of LTPP-managed funds to collect missing data previously assigned as the responsibility of participating highway agencies. As a result from a previous assessment of the LTPP program, the lack of traffic data and materials data from SPS project sites was identified as a critical area for improvement. These efforts are contingent on funding.
    - A pooled fund study was established to address missing traffic data issues.
    - LTPP program funds were reappropriated to obtain and test material samples from priority SPS project sites to fill in the gaps of missing data, add measurements from new tests, and provide more time sequence material properties.

PROCESSING DATA

This is an area where LTPP has internally documented improvement opportunities that have not been implemented due to dwindling budget resources. They include the following:

- Addition of computed parameters to the database to fill missing data gaps or add new parameters that is potentially useful to data users.
    - Estimation of pavement temperature profile during FWD testing when measured data are not available.
    - Estimation of load transfer efficiency from FWD tests.
    - Estimation of faulting in PCC pavements from longitudinal profile measurements.
    - Imputation of time based PCC material properties, such as the 28 day compressive strength.
    - Estimation of the dynamic modulus of AC mixes using empirical models and agency supplied data.
    - Estimation of joint opening from transverse joint gauge length measurements.
    - Interpretations of instrumentation measurements to provide estimates of frost depth locations and moisture contents in subsurface layers.
- Improved automation to data error detection and editing software. Many of the legacy data edit programs need to be upgraded to current software platforms.
- Increased use of codes and controlled vocabulary for comment fields. While some comment fields will always need to be retained as free form entries, work is needed to clean up those fields which can be codified and subjected to vocabulary control.

- Application and adaptation of changes to standardized coding schemes.
- Requirements that analysis contractors include in their proposals a detailed discussion of their analytical approach, statistical assumption tests proposed for use, statistical deviations to be examined, and statistical sensitivities to be evaluated in their approach. It is noted that this requirement can increase the cost of proposal preparation. It also requires that proposal review panels contain expertise, experience, and training to adequately evaluate proposed statistical approaches.
- Develop data analysis contractor guidelines in conformance with DOT guidelines on statistical approaches and wording of the interpretation of statistical test outcomes.
- Develop data analysis peer review guidelines in conformance with DOT guidelines on statistical approaches and wording of the interpretation of statistical test outcomes.

DISSEMINATION OF INFORMATION

In the last years of the LTPP program, improvements to information dissemination have been planned as a priority focus area. Some opportunities for improvements include the following:

- Improvements to uncertainty statements in measurements and statistical interpretations for traffic monitoring data.
- Improved access to updated planning documentation, collection, processing, and analysis methodology.
- Improvements in source and accuracy statements that accompany the data.
- Improved data user aids that simplify access to data stored in the LTPP relational database structure, including development of views and data user training aids.
- Development of a training course for data users.
- Use of technology advancements to improve data delivery, such as Web-based database servers optimized for delivery of large data sets.

EVALUATING INFORMATION QUALITY

The LTPP program intends to continue its established practices relative to evaluation and improvement of data quality. At this time, the only recognized opportunity for improvement is the enhancement of documentation for user notification of data errors.

APPENDIX A. LTPP OPERATIONS REFERENCE DOCUMENTS

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Revised Materials Sampling and Testing Plans, SPS-2, US 52 SB, Lexington, By-Pass, North Carolina, FHWA, Pavement Performance Division, February 1995.

SPS-5 Materials Sampling and Testing Plans, Project 230500, I-95 NB, Argyle, Maine, FHWA, Pavement Performance Division, July 1994.

SPS-5 Materials Sampling and Testing Plans, Project 240500, US-15 NB, Frederick, Maryland, FHWA, Pavement Performance Division, January 1992.

SPS-5 Materials Sampling and Testing Plans, Project 340500, I-195 WB, Imlaystown, New Jersey, FHWA, Pavement Performance Division, September 1994.

SPS-6 Materials Sampling and Testing Plans, Project 420600, I-80 WB, Centre County, Pennsylvania, FHWA, Pavement Performance Division, July 1994.

SPS-8 Materials Sampling and Testing Plans, Project 340800, Port Authority of NY/NJ, JFK Airport, FHWA, Pavement Performance Division, September 1994.

SPS-8 Materials Sampling and Testing Plans, Project 360800, Lake Ontario State Parkway, Brockport, New York, FHWA, Pavement Performance Division, February 1994.

SPS-8 Materials Sampling and Testing Plans, Project 370800, SR 1245, Jacksonville, North Carolina, FHWA, Pavement Performance Division, revised August and October 1997.

SPS-9 Pilot, Materials Sampling and Testing Plans, Project 240900, I-70 WB, Frederick, Maryland, Memo, July and September 1992.

SPS-9 A Materials Sampling and Testing Plan Revisions, Connecticut, FHWA, Pavement Performance Division, December 1997.

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SPS-9 A Materials Sampling and Testing Plans, Project 370900, NB/SB, Sanford, North Carolina, FHWA, Pavement Performance Division, revised February and June 1997.

SPS-9 A Materials Sampling and Testing Plans, Project 870900, Hwy. 17 WB, Petawawa, Ontario, FHWA, Pavement Performance Division, revised May 1997.

SPS-9 A Materials Sampling and Testing Plans, Projects 890900, NR 170 WB, and 89A900, NR 170 EB, Jonquiere, Quebec, FHWA, Pavement Performance Division, revised February 1997.

A.10.1.2. North Central Region

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As-Sampled Sampling and Testing Plan, SPS-2 Experimental Project, US-23 Northbound, Monroe County, Michigan, FHWA, Pavement Performance Division, March 1995.

Sampling and Testing Plan, SPS-2 Experimental Project, Westbound and Eastbound, Marathon County, Wisconsin, FHWA, Pavement Performance Division, updated July 1997.

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As-Sampled Sampling and Testing Plan, SPS-8 Experimental Project, Ramp A, Delaware County, Ohio, FHWA, Pavement Performance Division, May 1995.

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Sampling and Testing Plan, SPS-9A, Experimental Project, US-23 Southbound, Delaware County, Ohio, FHWA, Pavement Performance Division, September 1995.

Materials Sampling and Testing Plan, SPS-9A, Highway 16 (Yellowhead Highway), Saskatoon, Saskatchewan, FHWA, Pavement Performance Division, May 1996.

A.10.1.3. Southern Region

Sampling and Testing Plan for SPS-1 Test Site in Alabama, FHWA, Pavement Performance Division, April 1992.

Materials Sampling and Testing Plan, Arkansas SPS-1 Project 050100, US-63 NBL, Craighead County, Arkansas, FHWA, Pavement Performance Division, January 1993.

Materials Sampling and Testing Plan, Florida SPS-1 Project 120100, US-27 SBL, Palm Beach County, Florida, FHWA, Pavement Performance Division, August 1996.

Laboratory Materials Testing for LTPP SPS-1 Project 2201, US-171, Calcasiu Parish, Louisiana, FHWA, Pavement Performance Division, July 1995.

Louisiana SPS-1 (220100), Revised Materials Sampling and Testing Plan, FHWA, Pavement Performance Division, January 1993, revised December 1993.

Materials Sampling and Testing Plan, New Mexico SPS-1 Project 350100, IH-25 NBL, Dona Ana County, New Mexico, FHWA, Pavement Performance Division, June 1994.

Materials Sampling and Testing Plan, Oklahoma SPS-1 Project 400100, US-62 EBL, Comanche County, Oklahoma, FHWA, Pavement Performance Division, July 1996.

Materials Sampling and Testing Plan, Texas SPS-1 Project 480100, US-281 SBL, Hidalgo County, Texas, FHWA, Pavement Performance Division, December 1996.

Arkansas SPS-2 (050200), Materials Sampling and Testing Plan, FHWA, Pavement Performance Division, February 1994.

Materials Sampling and Testing Plan, Arkansas SPS-2 Project 050200, IH-30 WBL, Hot Spring County, Arkansas, FHWA, Pavement Performance Division, January 1997.

Materials Sampling and Testing Plan, Alabama SPS-5 Project 010500, US-84 EBL, Houston County, Alabama, FHWA, Pavement Performance Division, March 1996.

Materials Sampling and Testing Plan, Florida SPS-5 Project 120500, US-1 SBL, Martin County, Florida, FHWA, Pavement Performance Division, November 1994.

Materials Sampling and Testing Plan, Georgia SPS-5 Project 130500, IH-75 SBL, Bartow County, Georgia, FHWA, Pavement Performance Division, April 1993.

Materials Sampling and Testing Plan, New Mexico SPS-5 Project 350500, IH-10 EBL, Grant County, New Mexico, FHWA, Pavement Performance Division, September 1995.

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Materials Sampling and Field Testing Plan, Arkansas SPS-6 Project 05A6, US-65 Southbound, Jefferson County, Arkansas, FHWA, Pavement Performance Division, June 1997.

Materials Sampling and Field Testing Plan, Oklahoma SPS-6 Project 4006, IH-35 Southbound, Kay County, Oklahoma, FHWA, Pavement Performance Division, March 1992.

Materials Sampling and Field Testing Plan, Tennessee SPS-6 Project 4706, IH-40 Westbound, Madison County, Tennessee, FHWA, Pavement Performance Division, June 1995.

Materials Sampling and Field Testing Plan, Louisiana SPS-7 Project 2207, IH-10 Eastbound, Ascension Parish, Louisiana, FHWA, Pavement Performance Division, May 1991.

Materials Sampling and Testing Plan, Arkansas SPS-8 Project 050800, US-65 East Terminal Interchange, Right Frontage Road, Jefferson County, Arkansas, FHWA, Pavement Performance Division, October 1996.

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Materials Sampling and Testing Plan, Arkansas SPS-9A Project 050900, US-65 Southbound, Jefferson County, Arkansas, FHWA, Pavement Performance Division, June 1997.

Materials Sampling and Testing Plan, Florida SPS-9A Project 120900, Columbia County, Florida, IH-10 Eastbound, FHWA, Pavement Performance Division, March 1996.

Materials Sampling and Testing Plan, Mississippi SPS-9A Project 280900, Panola County, Mississippi, IH-55 Southbound, FHWA, Pavement Performance Division, June 1995.

Materials Sampling and Testing Plan, New Mexico SPS-9A Project 350900, Grant County, New Mexico, IH-10 Eastbound, FHWA, Pavement Performance Division, August 1995.

Materials Sampling and Testing Plan, Texas SPS-9A Project 480900, Bexar County, Texas, Loop 1604 Southbound, FHWA, Pavement Performance Division, August 1995.

A.10.1.4. Western Region

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Materials Sampling, Field Testing, and Laboratory Testing Plan, Strategic Highway Research Program, SPS-1 and SPS-2 Experimental Projects, Interstate Highway No. I-80, Humboldt and Lander Counties, Nevada, FHWA, Pavement Performance Division, September 1994.

Addendum to Materials Sampling, Field Testing, and Laboratory Testing Plan, Strategic Highway Research Program, SPS-1 and SPS-2 Experimental Projects, Interstate

Highway No. I-80, Humboldt and Lander Counties, Nevada, FHWA, Pavement Performance Division, April 1995.

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Materials Sampling, Field Testing, and Laboratory Testing Plan, Strategic Highway Research Program, SPS-2 Experimental Project, Federal Aid Project No. IR-10-2(146), Ehrenberg-Phoenix State Highway, Maricopa County, Arizona, FHWA, Pavement Performance Division, January 1993.

Materials Sampling, Field Testing, and Laboratory Testing Plan, Strategic Highway Research Program, SPS-2 Experiment Project, Federal Aid Project No. ACNH-P099(370)Y, SR 99 at and Near Delhi and Various Locations, Merced County, California, FHWA, Pavement Performance Division, February 1999.

Materials Sampling, Field Testing, and Laboratory Testing Plan, Strategic Highway Research Program, SPS-2 Experimental Project, Federal Aid Project No. ACDPS-0027(001), 395–Lind to Ritzvile, Washington, FHWA, Pavement Performance Division, March 1993.

Materials Sampling, Field Testing, and Laboratory Testing Plan, Strategic Highway Research Program, SPS-2 and SPS-8 Experimental Projects, Federal Aid Project No. I 076-1(138), State Highway No. I-76, Adams County, Colorado, FHWA, Pavement Performance Division, May 1992.

Materials Sampling, Field Testing, and Laboratory Testing Plan, Strategic Highway Research Program, SPS-8 Experimental Project (Flexible and Rigid), Federal Aid Project No. ACNH-P099(370)Y, Sycamore Street, Delhi, Merced County, California, FHWA, Pavement Performance Division, February 1999.

Materials Sampling, Field Testing, and Laboratory Testing Plan, Strategic Highway Research Program, SPS-8 Experimental Project, Federal Aid Project No. RS 273-1(2)0, State Highway No. RS 273, Deerlodge County, Montana, FHWA, Pavement Performance Division, April 1994.

Materials Sampling, Field Testing, and Laboratory Testing Plan, Strategic Highway Research Program, SPS-8 Experimental Project, Utah Forest Highway and Federal Lands Highway Project 5-2(3), State Highway 35 (Wolf Creek Road), Wasatch County, Utah, FHWA, Pavement Performance Division, April 1996.

Materials Sampling, Field Testing, and Laboratory Testing Plan, Strategic Highway Research Program, SPS-8 Experimental Project, Project Nos. PFH 176-1(1) and RS-A070(002), North Touchet Road, Columbia County, Washington, FHWA, Pavement Performance Division, June 1994.

Materials Sampling, Field Testing, and Laboratory Testing Plan, Strategic Highway Research Program, SPS-8 Experimental Project (Rigid), Project No. CRP 93-13, Smith Springs Road, Walla Walla County, Washington, FHWA, Pavement Performance Division, September 1999.

A.10.2. SPS Construction Reports

The SPS construction reports provide data users with site-specific information and notes on the general layout of the site, site features, construction problems, nonstandard construction features, and other information not easily captured on the data sheets.

A.10.2.1. North Atlantic Region

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Construction Report on LTPP 510100, SPS-1 Project, Danville, Virginia, FHWA, Pavement Performance Division, June 1996.

Construction Report on LTPP 100200, SPS-2 Project, Ellendale, Delaware, Publication No. FHWA-TS-96-10-04, FHWA, Pavement Performance Division, October 1996.

Report of Site Investigation on Delaware SPS-2 Problem Test Sections, FHWA, Pavement Performance Division, July 1999

Construction Report on LTPP 370200, SPS-2 Project, Lexington, North Carolina, FHWA, Pavement Performance Division, August 1994.

Construction Report on LTPP 24A300, SPS-3 Project, Ocean City, Maryland, FHWA, Pavement Performance Division, October 1990.

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Construction Report on LTPP 42A300 and 42B300, SPS-3 Projects, Lewisburg and Knoxville, Pennsylvania, FHWA, Pavement Performance Division, October 1990.

Construction Report on LTPP 51A300, SPS-3 Project, Petersburg, Virginia, FHWA, Pavement Performance Division, 1990.

Construction Report on LTPP 87A300 and 87B300, SPS-3 Projects, Moonstone and Bracebridge, Ontario, FHWA, Pavement Performance Division, October 1990.

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Construction Report on LTPP 240500, SPS-5 Project, Frederick, Maryland, FHWA, Pavement Performance Division, March 1993.

Construction Report on LTPP 340500, SPS-5 Project, Imlaystown, New Jersey, FHWA, Pavement Performance Division, December 1994.

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Construction Report on LTPP 370800, SPS-8 Project, Jacksonville, North Carolina, Publication No. FHWA-TS-98-37-02, FHWA, Pavement Performance Division, December 1998.

Construction Report on LTPP 240900, SPS-9 Project, Frederick, Maryland, FHWA, Pavement Performance Division, December 1992.

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Construction Report on LTPP 340900, SPS-9A Project, Allentown, New Jersey, Publication No. FHWA-TS-00-34-01, FHWA, Pavement Performance Division, December 2000.

Construction Report on LTPP 370900, SPS-9A Project, NB and SB, Sanford, North Carolina, Publication No. FHWA-TS-00-37-02, FHWA, Pavement Performance Division, June 2000.

Construction Report on LTPP 870900, SPS-9A Project, Petawawa, Ontario, Publication No. FHWA-TS-98-87-02, FHWA, Pavement Performance Division, March 1998.

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A.10.2.2. North Central Region

SPS-1 Construction Report, US-54 Near Fort Madison, Iowa, Sections 190101 to 190112, FHWA, Pavement Performance Division, April 1994.

SPS-1 Construction Report, US-54 Near Greensburg, Kansas, Sections 200101 to 200164, FHWA, Pavement Performance Division, April 1994.

SPS-1 Construction Report, U.S. Highway 81 Southbound, 80 Miles Southwest of Lincoln, Nebraska, (4 Miles) North of the Kansas Border, Sections 310113 to 310124, FHWA, Pavement Performance Division, June 1996.

SPS-1 Construction Report, U.S. Highway 23 Southbound, Delaware County, Ohio, Sections 390101 to 390112, 390159, and 390160, FHWA, Pavement Performance Division, September 1998.

SPS-1 Construction Report, STH 29 Westbound, Marathon County, Wisconsin, Sections 550113 to 550124, FHWA, Pavement Performance Division, March 2000.

SPS-2 Construction Report, US-65 Northbound, Polk County, Iowa, Sections 190213 to 190224, FHWA, Pavement Performance Division, June 1996.

SPS-2 Construction Report, I-70 Near Abilene, Kansas, Sections 200201 to 200212, FHWA, Pavement Performance Division, March 1993.

SPS-2 Construction Report, US 23 Northbound, Monroe County, Michigan, FHWA, Pavement Performance Division, December 1995.

SPS-2 Construction Report, I-94 Eastbound, West of Fargo, North Dakota, Sections 380213 to 380224, FHWA, Pavement Performance Division, June 1996.

SPS-2 Construction Report, U.S. Highway 23 Northbound, Delaware County, Ohio, Sections 390201 to 390212 and 390259 to 390265, FHWA, Pavement Performance Division, September 1998.

SPS-2 Construction Report, STH 29 Westbound, Marathon County, Wisconsin, Sections 550213 to 550224 and 550259 to 550266, FHWA, Pavement Performance Division, December 1999.

SPS-5 Construction Report, Trunk Highway 2 Westbound, 14 Miles West of Bemidji, Minnesota, Core Sections 270501 to 270509 and Supplemental Sections 270559 to 270561, FHWA, Pavement Performance Division, June 1996.

SPS-5 Construction Report, PTH No. 1 Westbound, 35 Miles East of Winnipeg, Manitoba, Sections 830501 to 830509, FHWA, Pavement Performance Division, June 1996.

SPS-6 Construction Report, I-35 Southbound, Between Ames and Des Moines, Iowa, Test Sections 190601 to 190608, FHWA, Pavement Performance Division, June 1996.

SPS-6 Construction Report, US-10 Eastbound, Bay County, Michigan, FHWA, Pavement Performance Division, December 1995.

SPS-6 Construction Report, US Highway 12 Westbound, Approximately 15 Miles East of Aberdeen, South Dakota, Test Sections 460601 to 460608, FHWA, Pavement Performance Division, June 1996.

SPS-7 Construction Report, I-35 Near Ames, Iowa, Sections 190701 to 190710, FHWA, Pavement Performance Division, April 1994.

SPS-7 Construction Report, Interstate 94 Eastbound, Between Moorhead and Barnesville, Minnesota, Sections 270701 to 270709, FHWA, Pavement Performance Division, June 1996.

Construction Report for SPS-7, *Route 67 Northbound, Jefferson County, Missouri*, FHWA, Pavement Performance Division, December 1995.

Construction Report for SPS-8, Ramp A, Delaware County, Ohio, FHWA, Pavement Performance Division, December 1995.

SPS-8 South Dakota, Construction Report, State Highway 1804, Pollock, South Dakota, Sections 460803 and 460804, Supplemental Section 460859, FHWA, Pavement Performance Division, June 1996.

SPS-9 Construction Report, US-54 Near Greensburg, Kansas, Sections 200901 to 200903, FHWA, Pavement Performance Division, December 1993.

SPS-9 Construction Report, US-169, Near Belle Plaine, Minnesota, Sections 270901 to 270903, FHWA, Pavement Performance Division, April 1995.

SPS-9 Construction Report, I-94 Near Tomah, Wisconsin, Sections 550901 to 550909, FHWA, Pavement Performance Division, June 1994.

SPS-9 Construction Report, I-43 Near Milwaukee, Wisconsin, Sections 55A901 to 55A909 and Sections 55B901 to 55B909, FHWA, Pavement Performance Division, June 1994.

SPS-9A Construction Report, U.S. 65 Southbound, Sedalia, Missouri, Sections 290901 to 290903 and 290959 to 290964, FHWA, Pavement Performance Division, September 1998.

SPS-9A Construction Report, U.S. Highway 81 Southbound, 80 Miles Southwest of Lincoln, Nebraska, (4 Miles) North of the Kansas Border, Sections 310901 to 310903, FHWA, Pavement Performance Division, June 1996.

SPS-9A Construction Report, Yellow Head Highway Westbound, Radisson, Saskatchewan, Sections 900901 to 900903 and 900959 to 900962, FHWA, Pavement Performance Division, September 1998.

A.10.2.3. Southern Region

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SPS-1 Project 0101, Strategic Study of Structural Factors for Flexible Pavements, US-280 Westbound, Lee County, Alabama, Final Report, FHWA, Pavement Performance Division, February 1996.

SPS-1 Project 0501, Strategic Study of Structural Factors for Flexible Pavements, US-63 Northbound, Craighead County, Arkansas, Final Report, FHWA, Pavement Performance Division, October 1996.

SPS-1 Project 1201, Strategic Study of Structural Factors for Flexible Pavements, US-27 Southbound, Palm Beach County, Florida, Final Report, FHWA, Pavement Performance Division, December 1996.

SPS-1 Project 2201, Strategic Study of Structural Factors for Flexible Pavements, US-171 Northbound, Calcasieu Parish, Louisiana, Final Report, FHWA, Pavement Performance Division, May 1998.

SPS-1 Project 3501, Strategic Study of Structural Factors for Flexible Pavements, IH-25 Northbound, Dona Ana County, New Mexico, Final Report, FHWA, Pavement Performance Division, April 1996.

SPS-1 Project 4001, Strategic Study of Structural Factors for Flexible Pavements, US-62 Eastbound, Comanche County, Oklahoma, Final Report, FHWA, Pavement Performance Division, August 1998.

SPS-1 Project 4801, Strategic Study of Structural Factors for Flexible Pavements, US-281 Southbound, Hidalgo County, Texas, Final Report, FHWA, Pavement Performance Division, December 1997.

SPS-2 Project 0502, Strategic Study of Structural Factors for Rigid Pavements, I-30 Westbound, Hot Springs County, Arkansas, Final Report, FHWA, Pavement Performance Division, November 1997.

Report on the SPS-3 Experiment of the Long-Term Pavement Performance Project in the Southern Region, Publication No. FHWA-IF-00-026, FHWA, Pavement Performance Division, August 2000.

SPS-3 Construction Report, SHRP Southern Region Coordination Office, FHWA, Pavement Performance Division, January 1991.

SPS-4 Construction Report, SHRP Southern Region Coordination Office, FHWA, Pavement Performance Division, February 1991.

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SPS-5 Project 1205, Asphalt Rehabilitation Study, US-1 Southbound, Martin County, Florida, Final Report, FHWA, Pavement Performance Division, April 1996.

SPS-5 Project 1305, Asphalt Rehabilitation Study, IH-75 Southbound, Bartow County, Georgia, Final Report, FHWA, Pavement Performance Division, January 1996.

SPS-5 Project 2805, Asphalt Rehabilitation Study, IH-55 Northbound, Yazoo County, Mississippi, Final Report, FHWA, Pavement Performance Division, April 1993.

SPS-5 Project 3505, Asphalt Rehabilitation Study, IH-10 Eastbound, Grant County, New Mexico, Final Report, FHWA, Pavement Performance Division, May 1997.

SPS-5 Project 4005, Asphalt Rehabilitation Study, US-62 Westbound, Comanche County, Oklahoma, Final Report, FHWA, Pavement Performance Division, October 1998.

SPS-5 Project 4805, Asphalt Rehabilitation Study on US-175 in Kaufman County, Texas, Final Report, FHWA, Pavement Performance Division, July 1992.

SPS-6 Project 0106, Rehabilitation of Jointed Portland Cement Concrete Pavements, I-59 Southbound, Etowah County, Alabama, Final Report, FHWA, Pavement Performance Division, May 1999.

SPS-6 Project 05A6, Rehabilitation of Jointed Portland Cement Concrete Pavements, US-65 Southbound, Jefferson County, Arkansas, Final Report, FHWA, Pavement Performance Division, October 1997.

SPS-6 Project 4006, Rehabilitation of Jointed Portland Cement Concrete Pavements, IH-35 Southbound, Kay County, Oklahoma, Final Report, FHWA, Pavement Performance Division, June 1993.

SPS-6Project 4706, Rehabilitation of Jointed Portland Cement Concrete Pavements, IH-40 Westbound, Madison County, Tennessee, Final Report, FHWA, Pavement Performance Division, March 1997.

SPS-7 Project 2207, Bonded Concrete Overlay of a Concrete Pavement, IH-10 Eastbound, Ascension Parish, Louisiana, Final Report, FHWA, Pavement Performance Division, April 1993.

SPS-8Project 0508, Environmental Effects in the Absence of Heavy Loads, US-65 East Terminal Interchange, Right Frontage Road, Jefferson County, Arkansas, Final Report, FHWA, Pavement Performance Division, December 1998.

SPS-8 Project 2808, Environmental Effects in the Absence of Heavy Loads, SR-315 Westbound, Panola County, Mississippi, Final Report, FHWA, Pavement Performance Division, February 1998.

SPS-8 Project 3508, Environmental Effects in the Absence of Heavy Loads, IH-10 Frontage Road, Grant County, New Mexico, Final Report, FHWA, Pavement Performance Division, May 1997.

SPS-8 Project 4808, Environmental Effects in the Absence of Heavy Loads, FM-2223 Eastbound, Brazos County, Texas, Final Report, FHWA, Pavement Performance Division, October 1996.

SPS-8 Project 48A8, Environmental Effects in the Absence of Heavy Loads, FM-2670 Eastbound, Bell County, Texas, Final Report, FHWA, Pavement Performance Division, July 2000.

SPS-9A Project 0509, Superpave Asphalt Binder Study, US-65 Southbound, Pulaski County, Arkansas, Final Report, FHWA, Pavement Performance Division, September 1997.

SPS-9A Project 1209, Superpave Asphalt Binder Study, IH-10 Eastbound, Columbia County, Florida, Final Report, FHWA, Pavement Performance Division, March 1997.

SPS-9A Project 2809, Superpave Asphalt Binder Study, IH-55 Southbound, Panola County, Mississippi, Final Report, FHWA, Pavement Performance Division, November 1996.

SPS-9A Project 3509, Superpave Asphalt Binder Study, IH-10 Eastbound, Grant County, New Mexico, Final Report, FHWA, Pavement Performance Division, May 1997.

SPS-9A Project 4809, Superpave Asphalt Binder Study, FM-1604 Southbound, Bexar County, Texas, Final Report, FHWA, Pavement Performance Division, January 1996.

A.10.2.4. Western Region

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Construction Report on Site 060600, Interstate Highway No. I-5, Mt. Shasta City, California, Final Report, FHWA, Pavement Performance Division, April 1996.

Construction Report on Site 060800, Sycamore Street, Delhi, California, Final Report, FHWA, Pavement Performance Division, August 2002.

Construction Report on Site 06A800, Sycamore Street, Delhi, California, Final Report, FHWA, Pavement Performance Division, August 2002.

Construction Report on Site 080500, Interstate 70, Colorado Department of Transportation, Lincoln County, Colorado, Final Report, FHWA, Pavement Performance Division, October 1994.

Construction Report on Site 080800, Chestnut Street, Colorado Department of Transportation, Adams County, Colorado, Draft Report, FHWA, Pavement Performance Division, June 1998.

Construction Report on Site 300100, Interstate Highway 15, Cascade County, Montana, Final Report, FHWA, Pavement Performance Division, November 2002.

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Construction Report on Site 300800, SR 273, Adams County, Washington, Final Report, FHWA, Pavement Performance Division, August 1996.

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