ACRP

REPORT 39

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Recommended Guidelines for the Collection and Use of Geospatially Referenced Data for Airfield Pavement Management

TRANSPORTATION RESEARCH BOARD
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AIRPORT COOPERATIVE RESEARCH PROGRAM

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Recommended Guidelines for the Collection and Use of Geospatially Referenced Data for Airfield Pavement Management

Timothy Parsons
APPLIED RESEARCH ASSOCIATES, INC.
Vicksburg, MS

Clifton Ogden
CIVIC ENGINEERING AND INFORMATION TECHNOLOGIES, INC.
Nashville, TN

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AIRPORT COOPERATIVE RESEARCH PROGRAM

Airports are vital national resources. They serve a key role in transportation of people and goods and in regional, national, and international commerce. They are where the nation's aviation system connects with other modes of transportation and where federal responsibility for managing and regulating air traffic operations intersects with the role of state and local governments that own and operate most airports. Research is necessary to solve common operating problems, to adapt appropriate new technologies from other industries, and to introduce innovations into the airport industry. The Airport Cooperative Research Program (ACRP) serves as one of the principal means by which the airport industry can develop innovative near-term solutions to meet demands placed on it.

The need for ACRP was identified in *TRB Special Report 272: Airport Research Needs: Cooperative Solutions* in 2003, based on a study sponsored by the Federal Aviation Administration (FAA). The ACRP carries out applied research on problems that are shared by airport operating agencies and are not being adequately addressed by existing federal research programs. It is modeled after the successful National Cooperative Highway Research Program and Transit Cooperative Research Program. The ACRP undertakes research and other technical activities in a variety of airport subject areas, including design, construction, maintenance, operations, safety, security, policy, planning, human resources, and administration. The ACRP provides a forum where airport operators can cooperatively address common operational problems.

The ACRP was authorized in December 2003 as part of the Vision 100-Century of Aviation Reauthorization Act. The primary participants in the ACRP are (1) an independent governing board, the ACRP Oversight Committee (AOC), appointed by the Secretary of the U.S. Department of Transportation with representation from airport operating agencies, other stakeholders, and relevant industry organizations such as the Airports Council International-North America (ACI-NA), the American Association of Airport Executives (AAAE), the National Association of State Aviation Officials (NASAO), and the Air Transport Association (ATA) as vital links to the airport community; (2) the TRB as program manager and secretariat for the governing board; and (3) the FAA as program sponsor. In October 2005, the FAA executed a contract with the National Academies formally initiating the program.

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Research problem statements for the ACRP are solicited periodically but may be submitted to the TRB by anyone at any time. It is the responsibility of the AOC to formulate the research program by identifying the highest priority projects and defining funding levels and expected products.

Once selected, each ACRP project is assigned to an expert panel, appointed by the TRB. Panels include experienced practitioners and research specialists; heavy emphasis is placed on including airport professionals, the intended users of the research products. The panels prepare project statements (requests for proposals), select contractors, and provide technical guidance and counsel throughout the life of the project. The process for developing research problem statements and selecting research agencies has been used by TRB in managing cooperative research programs since 1962. As in other TRB activities, ACRP project panels serve voluntarily without compensation.

Primary emphasis is placed on disseminating ACRP results to the intended end-users of the research: airport operating agencies, service providers, and suppliers. The ACRP produces a series of research reports for use by airport operators, local agencies, the FAA, and other interested parties, and industry associations may arrange for workshops, training aids, field visits, and other activities to ensure that results are implemented by airport-industry practitioners.

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The members of the technical panel selected to monitor this project and to review this report were chosen for their special competencies and with regard for appropriate balance. The report was reviewed by the technical panel and accepted for publication according to procedures established and overseen by the Transportation Research Board and approved by the Governing Board of the National Research Council.

The opinions and conclusions expressed or implied in this report are those of the researchers who performed the research and are not necessarily those of the Transportation Research Board, the National Research Council, or the program sponsors.

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Eileen P. Delaney, *Director of Publications*

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FOREWORD

By Amir N. Hanna
Staff Officer
Transportation Research Board

This report presents recommended guidelines for the collection and use of geospatially referenced data for airfield pavement management. The guidelines provide a data schema, data collection methods, data quality requirements, and other relevant information required for developing specifications and standards for integrating geospatial data into pavement management systems. The material contained in the report should be of immediate interest to airport professionals, consultants, and others involved in the management of airfield pavements.

The collection of data on pavement structure, pavement condition, traffic, climate, maintenance actions, testing and evaluation, and other items is essential for effective management of airfield pavements; such data are regularly collected, as part of airfield pavement management systems, by many airports across the country. However, the data and information collected by various agencies have often differed in definition and format, making it difficult for others to interpret and use. Also, state-of-the-art technologies and processes applicable to data collection have not been effectively used for collecting airfield management systems data. The use of global positioning systems in developing geospatially referenced data is one of the technologies that will greatly enhance the effectiveness of airfield management systems. Therefore, research was needed to develop guidelines for the collection and use of geospatially referenced data for use in the management of airfield pavements.

Under ACRP Project 9-01, "Guidelines for the Collection and Use of Geospatially Referenced Data for Airfield Pavement Management," Applied Research Associates, Inc. worked with the objective of developing guidelines for the collection and use of geospatially referenced pavement-related data for the management of airfield pavements. To accomplish this objective, the research (a) reviewed available information and surveyed current practices relevant to the collection and use of geospatially referenced data for the management of airfield pavements, identified and categorized the items necessary for developing guidelines for the collection and use of such data, and developed preliminary guidelines, and (b) evaluated the guidelines, introduced the necessary changes, and developed the recommended guidelines. To evaluate the preliminary guidelines, the research created a typical pavement management data framework using the data schema presented in the guidelines, acquired pavement management data for different pavement types from airfields using different software packages, transferred the acquired data into the framework, exercised all feature class definitions in the guidelines, and identified issues of concern. These issues were then addressed in the recommended guidelines.

The guidelines recommended in this research will be particularly useful to airport professionals, consultants, and others involved in the management of airfield pavements because they promote compatibility of data collected at different facilities; improve integration, sharing, and analysis of data; provide an effective means for addressing issues of common concern; and help better manage investments in airfield pavements.

Appendixes A through C contained in the research agency's final report provide the findings of the survey and further elaboration on the research. These appendixes are not published herein but they are available on the *ACRP Report 39* summary webpage at http://www.trb.org/Main/Blurbs/164102.aspx.

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Note: Many of the photographs, figures, and tables in this report have been converted from color to grayscale for printing. The electronic version of the report (posted on the Web at www.trb.org) retains the color versions.

CHAPTER 1

Introduction

Project Objective

The objective of this research was to develop guidelines for the collection and use of geospatially referenced pavement-related data for the management of airfield pavements. Geospatially referenced data is also known as geodata, geo-referenced data, geospatial data, and geographic information. It identifies the locations of features on Earth. This data can be mapped, is usually stored as coordinates or in raster format, and can be accessed through Geographic Information Systems (GIS) and Computer Aided Drafting (CAD) systems.

The collection of data on pavement structure, pavement condition, traffic, climate, maintenance actions, testing and evaluation, and other items is essential for effective management of airfield pavement; such data are regularly collected as part of airfield pavement management systems (PMS) by many airports across the country. However, the data and information collected by various agencies have often differed in definition and format, making it difficult for others to interpret and use. Also, state-of-the-art technologies and processes applicable to data collection have not been effectively used for collecting airfield management systems data. The use of global positioning systems (GPS) in developing geospatially referenced data is one of the technologies that will greatly enhance the effectiveness of airfield management systems. Therefore, there was a need to develop guidelines for the collection and use of geospatially referenced data for use in the management of airfield pavements. Such guidelines will promote compatibility of data collected at different facilities; improve integration, sharing, and analysis of data; provide an effective means for economically addressing issues of common concern; and help better manage investments in airfield pavements.

Project Scope

The work performed to achieve the project objective was divided into several tasks. This work included developing preliminary guidelines, demonstrating their application using real-world data, documenting lessons learned during the process, and recommending improved guidelines, including step-by-step procedures for using the guidelines to transfer spatial and non-spatial data from a PMS into a GIS. This work included the following tasks:

- Collecting and reviewing information and current practices. This work consisted of a literature review, research into current and emerging PMS and GIS technologies, and an interview questionnaire that was sent to various airport operators throughout the country.
- Identifying and categorizing PMS elements that should be included in the guidelines. This work consisted of reviewing and analyzing the survey responses and analysis of the underlying database structure of the various PMS packages used by the respondents. Categories of users were developed based on how the various users interact with the PMS and GIS data.
- Preparing a plan for developing guidelines.
- Determining the technical requirements of the data elements and formats to be included in the guidelines, and developing preliminary guidelines.
- Creating a typical pavement management data framework using the data schema presented in the guidelines. The data framework consisted of an empty database (i.e., containing no data) that implements all data elements and relationships described in the guidelines. The database was implemented in a format in which it is easy to rapidly prototype databases, the Environmental Systems Research Institute (ESRI) Personal Geodatabase.
- Acquiring pavement management data to test the data framework. The data was acquired for flexible and rigid pavements from two airfields using two different PMS software packages. Spatial data was requested in Autodesk AutoCAD and ESRI GIS formats.

- Transferring the acquired PMS data into the data framework. The spatial data was modified as necessary to meet the spatial data criteria in the guidelines. The typical data framework was attached to the spatial data, and the attribute data was manually transferred from the PMS to the GIS and CAD systems.
- Exercising all feature class definitions in the guidelines. The GIS data set was exported into Geographic Markup Language (GML) and re-imported to verify lossless data transfer.
- Identifying issues and deficiencies in the guidelines, recommending changes to the data schema.
- Preparing revised guidelines to incorporate the recommended changes.
- Preparing a final report that documents the entire research effort.

Organization of the Report

Chapter 2 of this report presents the state of practice in geospatial data collection methods. Chapter 3 discusses data elements, and Chapter 4 describes the development of spatial data guidelines. Application and verification of the guidelines are presented in Chapter 5. Chapter 6 provides remarks on implementation of the guidelines. The guidelines are provided as an attachment to the report.

Appendix A is a survey instrument of airport operators regarding the practices used for collecting, storing, and analyzing spatial and non-spatial pavement data. Appendix B contains the information obtained from this survey. Appendix C describes relevant PMS software data elements. Appendixes A, B, and C are not published herein; they are available at www.trb.org by searching for “ACRP Report 39” or at http://www.trb.org/Main/Blurbs/164102.aspx.

CHAPTER 2

State-of-Practice

Literature Review

The objectives of the literature review were to (a) document the state-of-the-practice and the state-of-the-art in geospatial data collection methods and (b) survey the current standards for geospatial and PMS data collection methods. Current standards were summarized in the contexts of the seven areas the guidelines are envisioned to address. These areas are:

1. Applicability and use of standards
2. Data user categories
3. Data framework
4. Collection methodologies
5. Data storage methods
6. Data quality
7. Metadata

The review included Federal Aviation Administration (FAA) advisory circulars (AC); the Department of Defense (DoD) Spatial Data Standards for Facilities, Infrastructure, and Environment (SDSFIE); the Federal Geographic Data Committee (FGDC) Content Standard for Digital Geospatial Metadata (CSDGM); and international standards such as the Infrastructure for Spatial Information in Europe (INSPIRE) and the Aeronautical Information Exchange Model (AIXM). Most of these standards focus entirely on PMS and neglect spatial aspects of PMS data, or focus on non-PMS spatial data such as pavement data in general, aerial photography, or obstruction surveys.

The standards surveyed fell into two distinct categories: concept-level standards and implementation-level standards. The FAA document AC 150/5380-7a, "Airport Pavement Management Program," is a concept-level standard. It "discusses the Airport Pavement Management System (APMS) concept, its essential components, and how it can be used to make cost-effective decisions about pavement maintenance and rehabilitation," but does not provide specific information regarding data formats or specific data elements to collect (FAA, 2006a). INSPIRE (ASWG, 2002) is also a concept-level standard, defining a general method for data sharing among European governments at all levels. It recommends operating procedures and incorporates technical details by reference to existing standards. For example, the flow of information among data creators, users, and stakeholders is defined, but the details of the data format are based on the ISO 19100 series standards and OpenGIS Consortium standards.

Implementation-level standards included AC 150/5300-17, "General Guidance and Specifications for Aeronautical Survey Airport Imagery Acquisition and Submission to the National Geodetic Survey" (FAA, 2006b), which specifies in great detail the data that must be included in any submission of aerial photography. This AC is prescriptive (specifying practices), addressing both data products [tagged image file format (TIFF) images georeferenced using the 1983 North American Datum delivered on a digital versatile disc (DVD) or universal serial bus (USB) external hard drive] and acceptable methods to collect data (imaging system must have manufacturer's specifications equivalent to a "Single lens metric camera with quality equivalent to or better than a Wild RC 30 or Zeiss RMK-TOP, with forward motion compensation") (FAA, 2006b). AC 150/5300-18, "General Guidance and Specifications for Submission of Aeronautical Surveys to NGS: Field Data Collection and Geographic Information System (GIS) Standards" (FAA, 2006c), is similar, although it is a mix of a functional specification (specifying results) and a prescriptive specification. Certain practices are required, but the details of how those practices are carried out are left to the individual organizations, assuming the required data products are developed. AC 150/5370-10A (FAA, 1991) is an example of an implementation standard in a non–information technology topic, describing allowable materials, compositions, constituent properties, and pavement methods of materials used in airfield construction.

AIXM (Brunk and Prosnicu, 2004; FAA and EUROCONTROL, 2007) includes both concept-level and implementation-

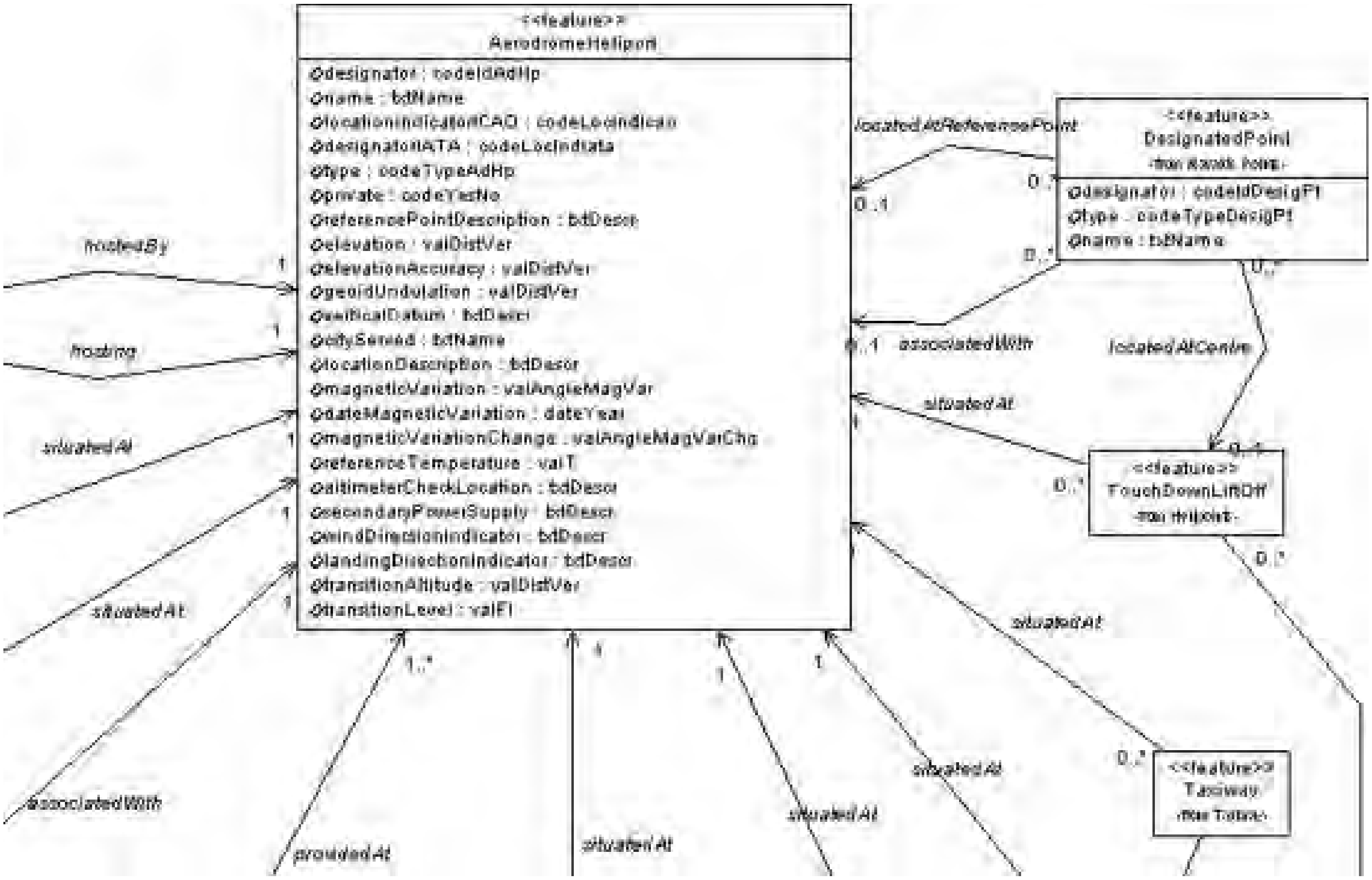

Figure 2.1. Partial UML class diagram of aerodrome/heliport associations (FAA and EUROCONTROL, 2007).

level elements. The conceptual model is presented in Universal Modeling Language (UML) (FAA and EUROCONTROL, 2007). It provides both business rules and feature data definitions that allow for data transfer among users. A portion of the UML model describing AIXM is shown in Figure 2.1. AIXM also includes an extensible markup language (XML) schema that precisely defines the data elements and data transfer mechanisms (FAA and EUROCONTROL, 2007).

Applicability and Use of Standards

The applicability and use of each standard is normally addressed in a general information section located at the beginning of the standard. FAA advisory circulars usually contain a statement of purpose describing why the standard was developed and a statement of applicability describing the appropriate use of the standard. This information is summarized on a cover sheet that also lists the issuing authority and point of contact for each standard (FAA, 1991; FAA, 2006a; FAA, 2006b; FAA, 2006c; FAA, 2007). Each standard spells out its intended audience and conditions for use, such as "The standards contained herein are recommended by the Federal Aviation Administration for use in the construction of airports. For federally funded projects, the standards are mandatory" (FAA, 1991). All INSPIRE documents convey that INSPIRE is a Pan-European standard recommendation to the legislative bodies of Europe (ASWG, 2002; DPLI, 2002; IETC, 2002; RDMWG, 2002). The applicability and use of the AIXM standard is not included as part of the standard itself. Instead, the FAA and EUROCONTROL maintain websites with an introduction to AIXM; its key concepts, including the impetus for the standard; and downloads of the universal UML and XML standards.

Data User Categories

Data user categories describe which organization or person is responsible for the various aspects of a data element, such as creation, storage, or use. Implementation-level standards typically do not explicitly distinguish among data user types, but implicitly recognize two categories of data user: developers and owners. These type of standards typically address highly technical work performed by a contractor or consultant (the developer) and delivered to the airport owner or a federal agency (the owner), and separate the responsibilities of each data user (FAA, 1991; FAA, 2006b; FAA, 2006c).

The INSPIRE explanatory memorandum and proposed directive (Proposal, 2004) identify four categories of data users "with an interest in the spatial data": user, producer, added value service provider, and coordinating bodies. These terms are not explicitly defined, but the text indicates that any given user could occupy any or all of the user categories at any given time. Each user category is further divided into three user types:

- Public authorities (i.e., governments)
- Public users (i.e., private citizens, academia, research institutes, and nongovernmental organizations)
- Commercial endeavors (i.e., those that make money using the data or derivatives)

The INSPIRE Data Policy and Legal Issues position paper (DWG, 2006) identifies one additional category of user: the data owner (i.e., a person or organization held responsible for a data set who has legal ownership rights to the data).

AIXM is specifically designed to facilitate data transfer among various categories of data users. The following types of data user are identified in a typical group of users that share a given set of data:

- Data source (data creation and origination)
- Data stewards
- Data analyzers (quality control, analysis, design, and other data preparation)
- Data publishers
- Commercial data providers (data integration and transmission)
- End users

The relationship among the various users is shown in Figure 2.2.

Data Framework

A data framework specifies how various data elements of a data set interact and is concerned with data organization at a higher level than data storage formats, which are discussed later. Data frameworks operate at both the conceptual level, providing categories and groupings of data elements, and the semantics level, providing data definitions for data elements to facilitate the seamless exchange of data.

AC 150/5380-7A (FAA, 2006a) does not recommend a data framework, but it lists the major categories of data that should be included in a PMS. Therefore, one can infer that any data framework should incorporate data elements from each of the following categories (FAA, 2006a):

- Pavement structure
- Maintenance history
- Traffic data
- Pavement condition data

AC 150/5300-18 (FAA, 2006c) explicitly addresses geospatial specifications and standards, describing both geospatial representations of entities and attributes. For example, it states that all spatial data elements "except the Airport Reference Point will be collected in 3D coordinates." Geospatial data definitions are intentionally limited to the relatively simple data types of points, lines, and polygons "to facilitate data exchange between software handling . . . complex data types differently" (FAA, 2006c).

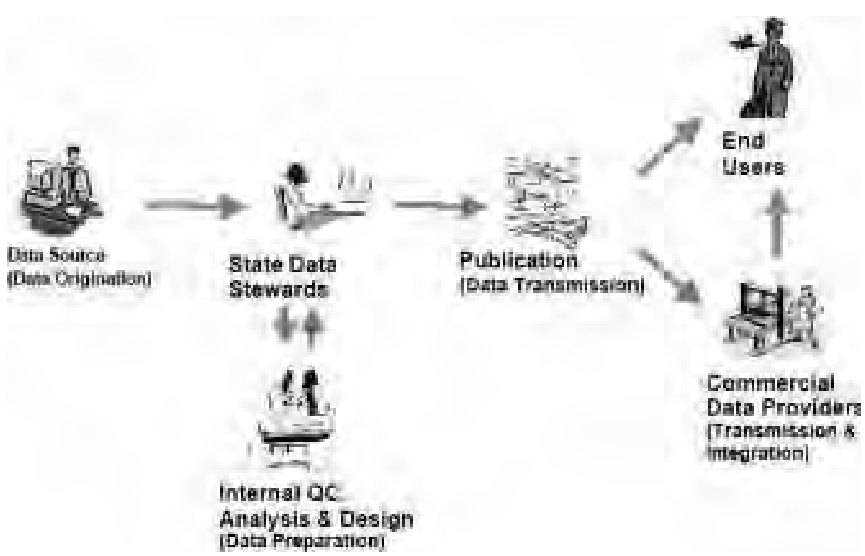

Figure 2.2. Typical aeronautical information data chain served by AIXM (Brunk and Prosnicu, 2004).

AC 150/5300-18 (FAA, 2006c), AIXM (FAA and EUROCONTROL, 2007), National System for Geospatial Intelligence Feature Information Catalog (NSGFC) (NGA, 2006), and SDSFIE (SDSFIE, 2007) each define data elements at the semantics level. The advisory circular defines each data element in 10 parts (FAA 2006c):

- Definition
- Geometry type
- Feature group
- Sensitivity
- Requirements
- Positional accuracy
- Data capture rule
- SDSFIE equivalent
- Required for
- Attributes

The definition usually includes a figure to clarify the spatial extent of each data element, as shown in Figure 2.3. Much of this information can be considered metadata, and is not included in the definition of SDSFIE (SDSFIE, 2007) and AIXM (FAA and EUROCONTROL, 2007), both of which are represented using UML models. Each data element is defined by a description, geometry type, and attributes.

SDSFIE (SDSFIE, 2007) and AIXM (FAA and EUROCONTROL, 2007) also include topology, or relationships among data elements. A common data relationship is for one data element to constitute a portion of another data element. These relationships often reflect real-world relationships of the entities that the data elements model. For example, an airport or

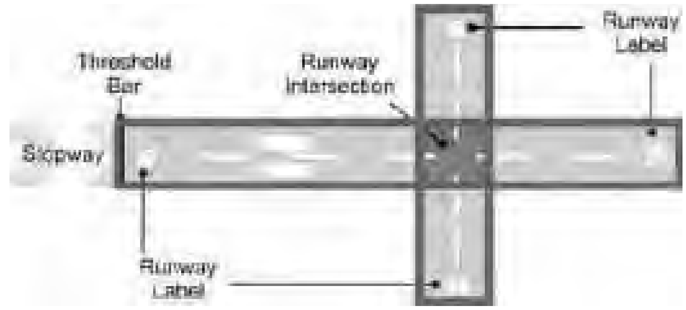

Figure 2.3. Definition of the spatial extent of a data element from AC 150/5300-18 (FAA, 2006c).

aerodrome, which has its own data elements, is composed of many smaller entities, each with its corresponding data elements, as shown in Figure 2.4.

Pavement management database topology typically follows a hierarchical model, with each data element being completely contained in the data element above it in the hierarchy. The typical PMS database hierarchy, from top to bottom, follows (Green and Eckrose, 1988; Shahin et al., 2004; Parsons, 2001):

- Network
- Branch
- Section
- Inspection
- Sample unit
- Distress

None of the existing data standards currently have data elements defined that adequately represent all PMS data. INSPIRE

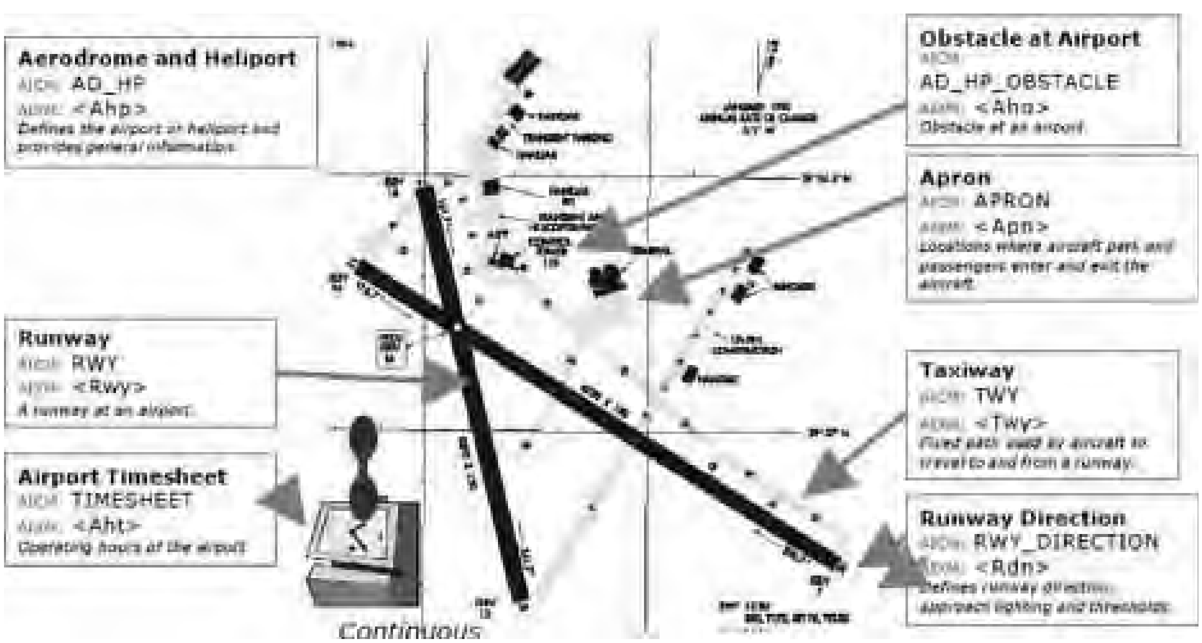

Figure 2.4. Topology is derived from real-world relationships (Brunk and Prosnicu, 2004).

is focused on environmental data, with plans to add transportation themes to the standard at a later date (IETC, 2006). AIXM is more oriented toward aviation processes and navigation than pavements (Brunk and Prosnicu, 2004). Pavements are addressed in the AerodromeHeliport package, where pavement entities are defined at a level comparable to the branch level in PMS software (runway, taxiway, apron). These areas can be subdivided, but attribute data are limited to size, surface type, operational code, structural capacity, and one surface condition code (FAA and EUROCONTROL, 2007). The NSGFC defines 10 attributes for airfield pavement condition, including surface type, a "good–fair–poor" surface condition field, and various aspects of structural capacity. The information appears to be oriented towards making a "go/no-go" decision concerning operations at a given airfield (NGA, 2006). The current version of the SDSFIE (2.600) includes dozens of attributes for airfield pavements. The attributes correlate to those at the section level in a PMS database, including structural and surface condition information. Several fields are provided to store "narrative information" summarizing PMS data, such as distresses present or maintenance required (SDSFIE, 2007). No data elements are provided to store detailed PMS data below the section level; however, materials returned by the United States Air Force (USAF) in response to a survey circulated for this research indicate that data elements for this information have been proposed. The proposed data elements appear to be modeled after the data stored in the MicroPAVER PMS used by the USAF.

Collection Methodologies

Collection methodologies are addressed only in implementation-level standards governing collection of specific data sets (FAA, 2006b; FAA, 2006c; FAA, 2006d). Collection methodology specifications range from functional specifications that are more concerned with data quality to those that specify all aspects of the data collection in exacting detail.

AC 150/5300-16 (FAA, 2006d), which concerns establishing geodetic control points for airfields, is very detailed in specifying what data must be collected and allowable methods to collect the data. A seven-step process to locate and set monuments at reference points is outlined, including:

- Coordinate with airport authorities
- Conduct a survey and reconnaissance
- Develop a project survey plan
- Select the sites of the Primary Airport Control Station (PACS) and two Secondary Airport Control Stations (SACS)
- Construct monuments for the PACS and SACS
- Confirm accuracy of PACS and SACS with survey ties
- Submit all data to National Geodetic Survey (NGS) and the airport authority

The circular explicitly states that GPS methods must be used to locate the reference stations. The specification goes beyond listing approved technologies and specifies operating procedures for each technology used in the process, such as "at least 4 hours of data are required in the final computer reductions" for GPS observations or providing acceptable methods for using an engineer's level, as shown in Figure 2.5. The specific contents of the data are also addressed, such as requiring three photographs showing a close-up, eye-level, and area overview of each survey mark recovered. Each photograph must have a watermark containing station name, station identifier, airport identifier, photograph number, photograph direction, station type, and date the photograph was taken (FAA, 2006d).

AC 150/5300-17 (FAA, 2006b), which concerns aerial photography of airports, is similar. The data collector has a choice of whether to use film or digital photography, and a choice of

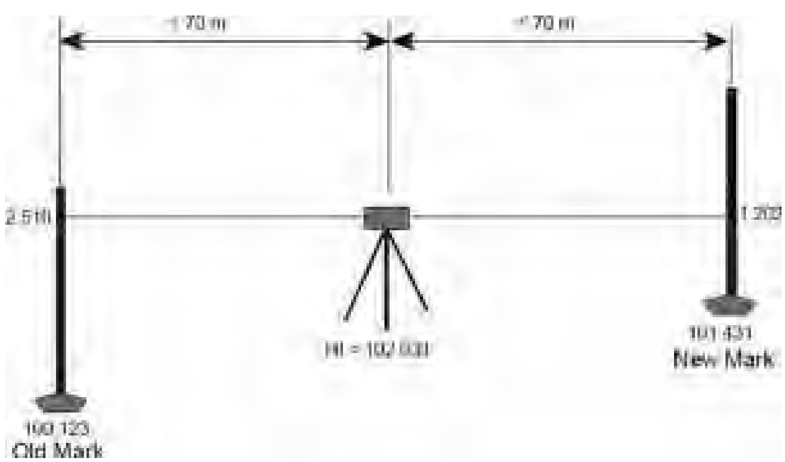

Figure 2.5. Conventional leveling observation sequence recommended in AC 150/5300-16 (FAA, 2006d).

methods to locate ground control points. Image quality and positional accuracy are specified using functional requirements. For example, pixel ground sample distance must be between 10 cm and 30 cm regardless of the method used to collect the imagery (e.g., film or digital photography). Other aspects of data collection are more rigidly defined, such as the altitude of the data collection aircraft, which must maintain an altitude between 11,760 ft above ground level (AGL) and 12,600 ft AGL with a target altitude of 12,000 ft AGL (FAA, 2006b).

AC 150/5300-18 (FAA, 2006c) "provides the specifications for the collection of airport survey data through field and office methodologies in support of aeronautical information and airport engineering surveys" and should be used when no other standards apply to the data being collected. It is a broad-ranging specification addressing many types of spatial and non-spatial data to be used in various activities including "other miscellaneous activities." Data collection methodologies generally are not specified; accuracies and data products are. New and nontraditional data collection methods are explicitly allowed, provided that the methodology is approved, thoroughly documented, and meets accuracy and other requirements. Some data collection methods are specified, such as the requirement that data collectors should "use the JPEG (Joint Photographic Experts Group) format for digital images taken with a hand-held digital camera. This includes the required images of photo points" (FAA, 2006c).

Data Storage Methods

"Data storage methods" refers to both the electronic format and the media for storage. The electronic format may be a standard, such as American National Standards Institute ASCII, or a proprietary format, such as Microsoft Word or Adobe PDF. The media are the physical device or material that contains the encoded data, such as a CD-ROM or hard disk drive.

Physical media are addressed prominently in the advisory circulars because these documents govern the submission of data to a federal agency (FAA, 2006b; FAA, 2006c; FAA, 2006d). It is impractical for a single agency to maintain devices to read every type of media available; therefore, a few commonly available media were selected as the standard "data containers" for submitting data to the FAA. Large quantities of data, primarily aerial photography, are to be submitted using a DVD or external USB hard drive. Most other data are to be submitted using CD-ROM. A notable exception is that status reports concerning data collection projects governed by AC 150/5300-16 are to be submitted via email (FAA, 2006d), which is a subset of a special type of media: the network.

In a network, data are stored remotely and delivered to the user's computer. The specific media types used to store the remote data are irrelevant, as long as the data are made available in a specific manner. INSPIRE explicitly states that much data will be stored and delivered via a network, with the realization that "large volumes of data, for instance satellite images, may be delivered on off-line media like tape and DVD" (ASWG, 2002).

Electronic formats incorporated by reference are typically generic formats, including JPEG, TIFF, Scalable Vector Graphics (SVG), GML, XML, and text. Proprietary formats incorporated by reference include Autodesk DWG and DXF, ESRI Shapefile, Adobe PDF, and Microstation DGN. AC 150/5300-16 mandates the use of specialized formats for reduction of GPS receiver data on government-provided software (ASWG, 2002; FAA, 2006b; FAA, 2006c; FAA, 2006d). The advisory circular standards mandate use of a particular file format more often than either INSPIRE or AIXM, again likely because advisory circulars govern the collection of data that will be submitted to a federal agency. INSPIRE recommends the use of technologies and formats included in ISO or Open GIS Consortium standards, for instance Standard Query Language (SQL), but does not forbid inclusion of other file formats in the INSPIRE infrastructure (ASWG, 2002). AIXM is an XML implementation of the Aeronautical Information Conceptual Model. As such, the AIXM standard is an XML schema that "define[s] how to exchange aeronautical information as XML documents" (Brunk and Prosnicu, 2004). It is a file format in its own right, as much as HTML or Adobe PDF. AIXM recommends using the GML format as a companion to AIXM to convey spatial aeronautical data (FAA and EUROCONTROL, 2007).

Data Quality

Data quality is the correctness and usefulness of a given set of data. It typically concerns accuracy and precision for spatial data. Accurate data are data with values close to the true value. Precision is the level of repeatability or exactness of the data, and is independent of accuracy (Benton and Taetz, 1991). Applying these definitions to spatial data, "accuracy" asks "is the entity represented in the correct location?" Precision of spatial data depends on whether the data is raster or vector. Precision in raster data is directly related to resolution, with high resolution correlating to high precision. The precision of vector data is the difference between where a typical entity is represented and where it is actually located, and can be thought of as a margin of error. Practically, this means that saying Honolulu, Hawaii is located in the Pacific Ocean is accurate, but not precise. Providing the latitude and longitude of the city would be accurate and precise. Providing the latitude and longitude of New York City as the location of Honolulu is precise, but not accurate. Saying Honolulu is located in the Atlantic Ocean is neither accurate nor precise.

The advisory circulars use a confidence-level model for accuracy and precision. They specify an "accuracy limit." These limits are the maximum number of feet between the actual position of an entity and its position in the data set. At least 95% of all data in a data set are expected to fall within the limit. The accuracy limit required by the advisory circulars varies with the data, ranging from PACS that must be located to within 1 cm horizontally and 0.2 cm vertically, to deicing areas that need only be precise to within 50 ft (FAA, 2006b; FAA, 2006c; FAA, 2006d). (Note that the units are not consistent among the various standards.) Precision of data representations is also addressed, such as the requirement that a series of segments representing an arc must have all points on a segment within a distance of one-half the required accuracy limit to the nearest point on the arc (FAA, 2006c).

Data quality parameters not related to precision and accuracy are provided for aerial photography. These parameters apply more to the photograph contents, such as maximum permissible cloud cover, sun angle, and foliage condition. While these factors do not affect the technical aspects of collecting an aerial photograph, they do affect the usefulness of the data contained in the photograph.

INSPIRE addresses data quality by recognizing that different data have different precision and accuracy needs and that "the settings of data quality parameter levels will require further study" (RDMWG, 2002). It identifies two additional quality elements to be evaluated to determine the quality of a data set: logical consistency and completeness. INSPIRE recommends determining data quality by conformance testing according to International Organization for Standardization (ISO) 19113. Quality measurements and the results of conformance testing should be documented in the metadata fields specified by ISO 19115.

Metadata

AIXM (FAA and EUROCONTROL, 2007), INSPIRE (RDMWG, 2002), and AC 150/5300-18 (FAA, 2006c) mandate the use of metadata elements defined in ISO 19115, "Geographic Information—Metadata." (ISO 19115, 2003). AC 150/5300-16 (FAA, 2006d) incorporates the use of ISO 19115 by reference to AC 150/5300-18. ISO 19115 lists five goals for the standard:

- Allow data producers to properly characterize data
- Facilitate organization of metadata for geographic data
- Facilitate the most efficient use of geographic data by describing its basic characteristics
- Allow users to efficiently locate, access, evaluate, purchase, use, and re-use geographic data
- Allow users to evaluate the usefulness of a data set for a particular use

The metadata elements defined in ISO 19115 are quite extensive, and range from the obvious (e.g., data set name) to metadata about metadata (e.g., metadata language, which is distinct from the data set language). The complete implementation of the standard contains 409 elements, which are grouped into the following 11 entities, or classes, of metadata:

- Identification—information that uniquely identifies the data set
- Constraints—legal or security restrictions on data use and distribution
- Data Quality—an assessment of the quality of the data, including accuracy, consistency, and completeness
- Maintenance Information—information regarding the updating of the data set
- Spatial Representation—the base mechanisms used to represent spatial data
- Reference System—the coordinate system used by the data
- Content Information—information to aid locating the data in a portrayal catalog
- Portrayal Catalog Reference—information identifying the portrayal catalog used by the data set
- Distribution—information concerning how to obtain a data set
- Extension Information—information documenting extended, nonstandard metadata provided by the user
- Application Schema Information—information about the application used to generate the data set

The FAA has identified 29 data elements considered useful to aeronautical geographic data sets. The remaining data elements are not included in AC 150/5300-18 because they are considered optional, conditional, or redundant and therefore not applicable (FAA, 2006c).

ISO 19115 also recognizes that not all the metadata defined in the standard is necessary to characterize every data set. It defines 22 "core metadata for geographic datasets" (ISO, 2003) designed to answer the following questions:

- What does the data set contain?
- For what area is the data set applicable?
- For what time is the data set applicable?
- Who should be contacted for more information?

Of the 22 core elements, only 7 are mandatory, 11 are optional, and 4 are conditional. Conditional metadata are metadata that document other metadata, or are a group of related metadata, at least one of which must be provided. The core metadata are definitely oriented toward internationalized data sets, with metadata elements including character sets and languages.

The FGDC CSDGM is solely about metadata. The collection of geospatial metadata was mandated for U.S. federal entities by Executive Order 12906, "Co-ordinating Geographic Data

Acquisition and Access: The National Spatial Data Infrastructure," in April 1994. The Content Standard for Digital Geospatial Metadata is the standard for transfer and storage of metadata developed to comply with the executive order. It was developed by the Federal Geospatial Data Committee, a working group of federal agencies that has developed several standards for data exchange. The CSDGM is an XML-based format and is compatible with GML.

The FGDC CSDGM consists of a data dictionary of metadata elements applicable to all types of geographic data. All of the metadata elements defined in AC 150/5300-18A can be represented using the CSDGM, but many of the metadata elements are named differently. The hundreds of metadata elements defined are divided into seven general categories:

- Identification information
- Data quality information
- Spatial data organization information
- Spatial reference information
- Entity and attribute information
- Distribution information
- Metadata reference information

The FGDC is currently working to implement a profile of ISO 19115 with the intention of replacing the CSDGM with this profile. This will improve compatibility of metadata collected in the United States with ISO-compliant organizations.

Available Technology

Any method used to determine position can be used to collect geospatially referenced data. The diversity of PMS data collected requires a wide range of techniques and technologies to collect spatial attributes of PMS data.

Pavement Management Systems

A PMS is simply an organized method of data management with predictive techniques to assist decisionmakers in finding optimum strategies for providing and maintaining pavements in a serviceable condition over a given period of time. The function of a PMS is to improve the efficiency of decisionmaking, expand its scope, provide feedback on the consequences of decisions, facilitate the coordination of activities, and ensure the consistency of decisions.

PMS is any management system for pavements that is capable of:

- Tracking pavement inventory and condition
- Considering multiple maintenance strategies
- Identifying the optimum strategy
- Basing decisions on a rational procedure with quantified attributes, criteria, and constraints
- Using feedback information regarding the consequences of decisions
- Being updated and/or modified as new information and better models become available

Not all pavement management systems are computer based; however, since the guidelines address exchange of electronic data, they focus on the computer-based PMS packages. Two basic types of PMS software are available: thick client and thin client. Thick-client applications are software packages in which the bulk of data processing takes place on the user's local computer (the machine a user physically uses). These applications require specialized software to be loaded on the user's local computer. PMS data may be stored locally or on a server. Most PMS packages, including MicroPAVER (Shahin, 2004; Shahin, 2007) and AirPAV (Aho, 2007; ARA, 2005), perform these functions by determining at what point in its life cycle a pavement is, and making decisions to optimize the remaining life of the pavement. Thick-client applications generally give the user more control over data and data processing, but users are limited to the processing power of the local machine. Thin-client applications perform the bulk of data processing on a remote server and use the user's local computer for display only. A web portal accessing PMS data and analyses is an example of a thin-client application. Thin-client applications require the use of centralized data storage and are generally easier to deploy, but normal (non-administrator) users may have less access to unprocessed data to perform nonroutine calculations.

Most PMS packages, including MicroPAVER and AirPAV, are designed to aid a pavement manager in optimizing the remaining life of the pavement. The packages assume a pavement life-cycle curve as shown in Figure 2.6. As the condition decreases, applicable maintenance and rehabilitation (M&R) treatments become more involved, and therefore more costly, as shown in Figure 2.7. This concept is important, because pavements often remain in serviceable condition for a long period of time, followed by a period of rapid deterioration. Waiting a small amount of time to perform M&R can result in a significant cost increase. Existing PMS packages attempt to minimize costs by tracking pavement condition and determining where in the pavement life cycle a particular pavement section is. The software then recommends M&R designed to minimize life-cycle costs. Generally, pavement in the early portion of the life cycle will be assigned routine maintenance, older pavement in good condition will be assigned comprehensive rehabilitation, and older pavement in poor condition will be assigned reconstruction (Green and Eckrose, 1988; Shahin, 2004). Exact practices and policies may differ for each organization.

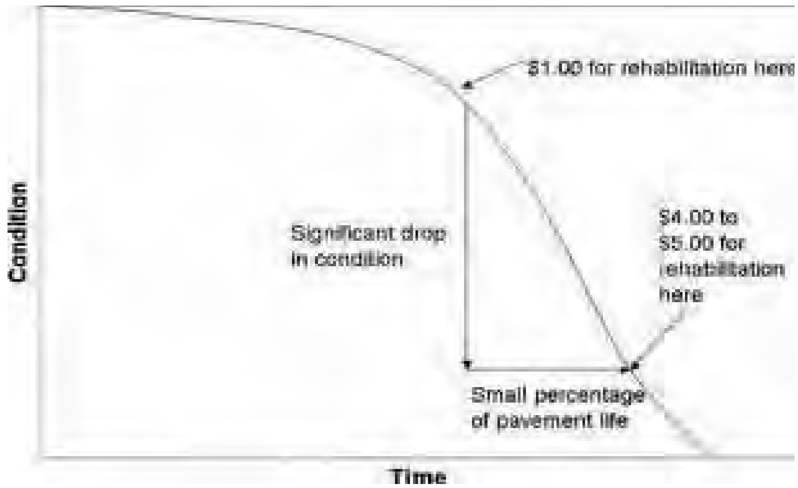

Figure 2.6. Pavement life cycle (Shahin, 2004).

Plane Surveying

Surveying, which "is defined as measurement of the surface of the earth" (PEPLS, 2006), is essentially the collection of geospatially referenced data. Plane surveying is the activity typically considered "surveying" by the non-engineer, involving engineer's levels, transits, theodolites, chains, and more recently, total stations and GPS equipment. Most of the data collected using plane surveying techniques are inherently spatial data, that is, data that have the primary purpose of conveying spatial information such as control points, runway corners, or airfield elevation.

Plane surveying is a common method of developing maps. These maps can provide the outline and layout of airfield pavements. These "base maps" provide a template to which PMS data can be added for analysis and display. Data may be added manually or by computer, and may take the form of color coding representing different properties of the pavement (e.g., condition) or text annotations (e.g., PMS section identification map). Additionally, spatial data such as pavement areas may be extracted from these maps for use in a PMS. Plane surveying may also be used to locate events and objects such as pavement distresses on an airfield, although the PMS user surveys (discussed later) did not indicate that it is a common practice.

Plane surveying is highly precise, and requires skilled and licensed personnel to perform. Plat survey tolerances required by the state of Mississippi are shown in Table 2.1 as an example of tolerances required by a state agency.

Plane surveying data may be available in many formats, including hard copy, CAD, and GIS. It was the only method available for collection of spatial data for many years. It is still the only acceptable method for collection of some data, such as establishing Image Control Points for Aeronautical Survey

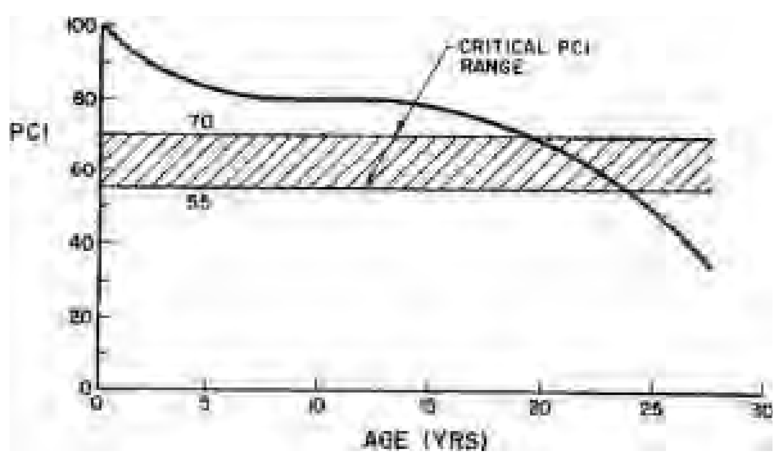

Figure 2.7. Significant drop in pavement condition near end of pavement life cycle (FAA, 2006a).

Table 2.1. Example of plane surveying allowable measurement tolerances (PEPLS, 2006).

Survey Type	Condition D Rural	Condition C Suburban	Condition B Urban	Condition A Urban Business District	Remarks and Formula
Unadjusted Closure (Minimum)	1:2000	1:5000	1:7500	1:10000	Loop or between Control Monuments
Angular Closure (Minimum)	60” SN	30” SN	25” SN	15” SN	N= Number of Angles in Traverse
Accuracy of Bearing	± 5 Min.	± 3 Min.	± 2 Min.	± 1 Min	Relative to Source
Accuracy of Distances	0.10 ft +200 ppm	0.07 ft +150 ppm	0.05 ft +100 ppm	0.03 ft +50 ppm	100 ppm= 1:10000
Elevations for Boundaries Controlled by Tides, Contours, Rivers, etc. Accurate to:	±0.30 ft	±0.20 ft	±0.10 ft	±0.05 ft	Based on NGVD
Location of Improvements Structures, Paving, etc. (Tie Measurement)	± 2.0 ft	±1.0 ft	±0.2 ft	±0.1 ft	
Positional Error in Map	25 ft	10 ft	5 ft	2 ft	Generally 1/40th of an inch at scale (National Map Accuracy calls for 1/50th inch)
Plotting not to Exceed: (Applies to original map only)	1”=1000’	1”=400’	1”=200’	1”=100’	

Airport Imagery submitted to the National Geodetic Survey (FAA, 2006b).

Photography

Photogrammetry, the use of aerial photography to map the Earth, is a method that allows the relatively quick development of a spatial data set for a specific purpose (Benton and Taetz, 1991). The aerial photograph is itself a spatial data set, but in raster (pixel-based) format. Most PMS software packages, such as MicroPAVER, conceptualize pavement in vector (shapes and lines) format. While they cannot use the photograph directly, the photograph can be imported into a CAD or GIS package and visible features extracted (by tracing, as shown in Figure 2.8) to develop a spatial data set that the PMS can use directly.

Feature extraction from aerial photography provides a base map for PMS data extraction, analysis, and display that is

Figure 2.8. PMS spatial data being developed from aerial photography in AutoCAD.

nearly identical to that produced by plane surveying. The chief difference is in the data precision, which differs based on both the plane surveying and aerial photography data extraction methods used. The primary advantage of aerial photography is the speed with which PMS features may be developed. This technique has been used to develop PMS geodata sets for many U.S. Air Force bases. A base map of a medium-large airfield (10 million ft^2 of pavement; 75 pavement features) showing pavement divisions at the branch, section, sample unit, and portland cement concrete (PCC) slab level requires a single skilled technician approximately a week to complete.

Features can also be extracted from photography from other sources, such as a camera van that collects detailed images of the pavement. For example, images can be processed manually or with a computer to extract the location of individual distresses on a pavement.

The accuracy and precision of data developed using aerial photography depends on the quality of the aerial photograph and the amount and type of post processing applied to the imagery. The two common post-processing operations are georeferencing and orthorectifying. Photography can be georeferenced through the use of control points on the ground or GPS equipment attached to the imaging system. Orthorectification is correction of an image so that it appears the camera was pointing straight down over every pixel in the image, increasing the horizontal accuracy of the image. Image quality for use in PMS applications depends mostly on resolution. Resolution is expressed in terms of how much area each pixel in the image represents, e.g., in 15-cm resolution photography, each pixel in the photograph correlates to a 15- × 15-cm square of the surface the Earth. Higher resolutions are expressed by smaller numbers, e.g., 15-cm photography has a higher resolution than 30-cm photography. Higher resolutions allow the generation of more precise data sets from the photography.

Global Positioning System

Global Positioning System (GPS) is a satellite-based navigation and geolocation system. GPS works from a geometric principle known as trilateration, which uses the distance from the subject point to three or more known points to calculate the location of the subject point. In practice, satellites with known position broadcast their position and a time code to a receiver. The receiver uses the time code to calculate the distance to each satellite, and then uses the distances and broadcast satellite positions to calculate the receiver position.

GPS equipment varies greatly in cost and precision, and has improved greatly since its inception. In the early 1990s, survey-grade GPS equipment "cost somewhat more than a good total-station instrument" and required "about an hour" to obtain satellite lock and calculate position (Benton and Taetz, 1991). Consumer-grade equipment did not exist. Modern GPS equipment prices start at approximately $50 for entry-level, consumer-grade receivers and increase with precision and accuracy.

The wide range of receiver prices and data quality means that GPS can be used for many different spatial data collection applications, with equipment and techniques tailored to specific needs. The simplest use of a GPS is to write down the coordinates where a photograph is taken or a distress is located. More advanced systems "tag" data by embedding the spatial data, determined by the GPS, in the photograph collected by digital camera. A sample GPS coordinate watermark from the system is shown in Figure 2.9. The GPS data are also stored in the Exchangeable Image File (EXIF) metadata in the JPEG header for easy extraction by computer. The process is nearly instant and automatic, reducing the level of operator effort required and eliminating several steps that could introduce a transcription error into the data.

The most advanced GPS systems are typically used by professional surveyors in combination with or in place of total

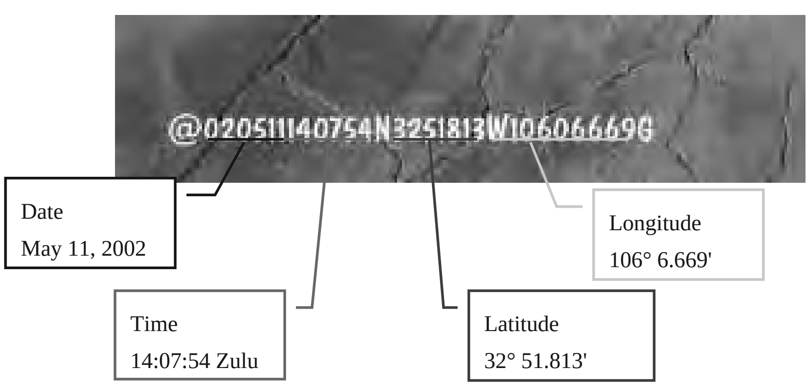

Figure 2.9. GPS coordinates on photos.

station equipment. These systems may also be used to develop a base map for PMS data. The relative simplicity of using these systems means they are also well suited to identifying the location of individual items on a pavement, such as a test location. They could also be used to locate and identify sample units during the condition evaluation process. Corners of sample units to survey can be difficult to find, especially sample units in the middle of a large asphalt apron. GPS equipment can be used to find a predetermined set of coordinates, in this case, the corners of the sample unit to be evaluated. It can also be used to collect the location of individual pavement distresses.

Survey-grade GPS equipment has been able to provide sub-centimeter precision since its inception (Benton and Taetz, 1991). Consumer-grade equipment precision started at about 100 m and has been steadily increasing as various uses for GPS have been discovered. Current consumer-grade equipment is precise to within a few meters. The single greatest improvement in precision came at midnight Greenwich Mean Time, May 1, 2000, when Selective Availability (SA) was discontinued. SA was the intentional degradation of the satellite signal to "protect the security interests of the U.S. and its allies by globally denying the full accuracy of the civil system to potential adversaries" (FGDC, 2007). When SA was discontinued, GPS accuracy was increased to the inherent precision of a given receiver. One manufacturer claims a precision of approximately 15 m for its consumer-grade equipment. A precision of 3 m is claimed for Wide Area Augmentation System (WAAS) enabled receivers. WAAS is an FAA enhancement of the DoD GPS service that uses ground-based reference stations to calculate an error-correction signal. This signal is broadcast from a geosynchronous earth orbit satellite on similar frequencies and encoding as the GPS signal (FAA, 2001). The claimed precision of differential GPS (DGPS) units, which require additional equipment, is approximately 5 m (Garmin, 2007). DGPS works on a similar principle to WAAS, but with the correction signal being broadcast terrestrially over a smaller area.

Dead Reckoning

Dead reckoning is the determination of position by estimating location with respect to a point of known position. It is easy to do and does not require any special equipment, but it lacks accuracy and requires that personnel be able to accurately estimate their location.

A common form of dead reckoning is marking events or items on a map, as shown in Figure 2.10. This allows personnel to record spatial data even when surveying or GPS equipment is not available. The map shown in Figure 2.10, generated from a georeferenced AutoCAD map, shows the locations of photographs taken during a pavement condition index (PCI) survey. The location of each photograph was determined in relationship to the branches, sections, samples, and slabs of pavement, and then marked in the appropriate spot on the map. Special marks are used to indicate the direction of the photograph, and the digital photograph number is recorded. The location of each photograph in georeferenced coordinates can then be determined by comparing the location marked on the map to known points on the map, such as corners of slabs or sample units. This method geolocates the photograph to within approximately 25 ft (the size of a slab) on PCC pavement or 100 ft (a typical sample unit size) on AC pavement.

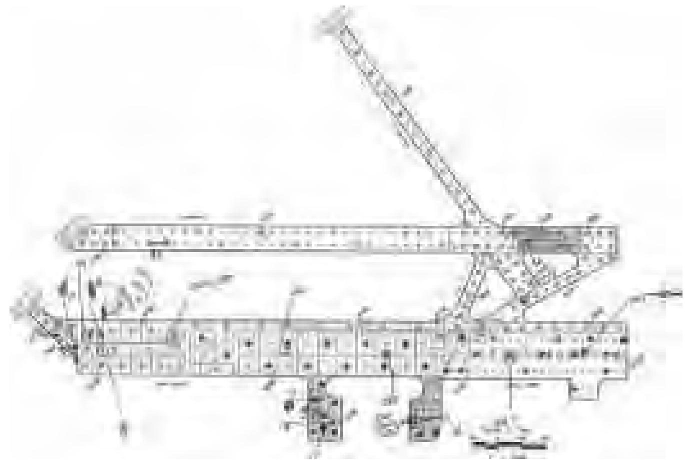

Figure 2.10. Example data recorded by dead reckoning.

Another form of dead reckoning is to pre-locate and number or otherwise identify discrete units of pavement, such as pavement slabs. Geolocating an item then consists of recording the unit number in which it is located (e.g., Photograph 2 was taken in slab 12A).

Dead reckoning is often used to "lay out" a pavement for surveys. Sections and sample units identified for the PMS are marked out on the ground using paint or chalk. This allows the pavement evaluators to focus more on the condition of the pavement, instead of keeping track of their location on the airfield and to which section or sample it corresponds. Laying out asphalt pavements is commonly performed with a measuring wheel, starting at a known location like a section break and measuring the distance to each sample within the section. Laying out PCC pavements often consists of counting slabs from a section break to determine the location of sample units.

Computer Aided Drafting

Computer Aided Drafting (CAD) is production and management of technical drawings using a computer. Among the primary users of CAD are civil engineers and cartographers (Giesecke et al., 1991). CAD has an advantage over manual drafting in that much less effort is required to revise and reproduce technical drawings that are stored electronically and printed or plotted as needed. For example, reproducing a drawing at a different scale requires only adjusting the plot settings and sending the drawing to a plotting device as opposed to reproducing the entire drawing by hand. PMS data can be reproduced at one scale for display as a wall map, another scale for printed reports, and yet another scale for producing maps for personnel to take to the field for pavement evaluation and maintenance.

Drawings are stored as digital data in CAD systems, i.e., they are represented by coordinates, points, and lines stored as numbers. Digital data are cheaply, easily, and flawlessly reproduced. This allows for easy backup and distribution of drawings. It also allows for re-use of drawing elements in multiple drawings, such as using the same edge-of-pavement data in both a PMS section location map and a color-coded condition map. The digital nature of the data also enables it to be transformed using software, for example, to be georeferenced. The base drawing can be produced, and then positioned in space once the georeferencing data become available.

CAD also allows for greater organization and integration in data. Each CAD object in a drawing may be assigned to a layer. A layer is a group of related objects. Attributes may be defined for entire layers, such as "all objects on this layer are displayed in blue." In practice, layers often have real-world meaning, such as all lines representing slab joints are on one layer, while lines representing the edge-of-pavement are on another layer, and drawing annotations are on yet another layer. The layers provide added flexibility in that the display of each layer can be independently controlled. Thus, a single drawing will contain all the information and the user may select specific information to display, as opposed to keeping an individual drawing for each type of information. In this manner, the drawing is updated only once in the main file, rather than applying the same change to each drawing in a group of related drawings.

The great strength of CAD is the development and display of new spatial data, which is often done by adding to or adapting from an existing data set, such as developing PMS section location data from aerial photography or existing drawings. Figure 2.11 shows CAD data representing PMS sections, sample units, and pavement slabs that have been traced from aerial photography. CAD does not require the user to assign meaning to an object; therefore, the drafter is free to manipulate objects independently. Objects can be extended, shortened, deleted, or added without affecting neighboring objects. For example, each line representing the side of a slab is treated as an independent object and thus may be deleted. While this approach may be convenient, the CAD operator must ensure that changes made to the drawing do not introduce errors into the drawing.

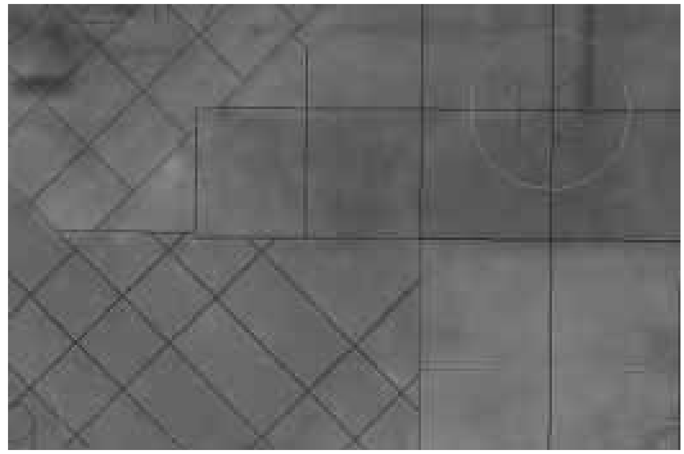

Figure 2.11. Close-up of CAD data developed from aerial photography.

While the bulk of CAD work still takes place in the office on a desktop computer, computing technology has improved such that mobile CAD stations can be taken to the field. This allows the CAD operator to verify the correctness of the drawing and make changes as necessary. This method of operation has proven successful at many Air Force bases. The CAD station is more convenient than bringing maps of various scales to the field. The measuring capabilities of a CAD station are also of use to workers in the field, for example, when determining section size to calculate the optimum size for sample units and the number of sample units that should be surveyed.

Geographic Information Systems

A Geographic Information System (GIS) is a system for managing collections of data that have spatial attributes. Historically, the spatial or location relevance of collected data could only be analyzed manually. In such cases, location data was often limited to CAD or hard-copy maps, and spatially referenced feature data was illustrated by annotations, labels, color-coding, and dimensions. GIS offers many of the same advantages to PMS operators as CAD. In addition, the data model used by GIS assumes that all spatial entities in the GIS will have attribute data. A GIS assumes that a map of pavements contains non-spatial information defined by the user, such as pavement type and condition; there is no such assumption in CAD.

Within a GIS, spatial elements have a "background" of associated attribute data. This data may consist of a simple, two-dimensional table, similar to a spreadsheet, or it could be a complex relationship among several tables. Regardless of the attributes or format, within a GIS, the data is natively linked to a geographic feature such as a point, line, polygon, or other geometry.

Because of the native spatial link that exists within a GIS, queries on the data can be made based on geography or by a tabular attribute. For instance, a traffic signal may have tens or hundreds of attributes that relate to the physical feature. A user could select by location and view the attributes, as shown in Figure 2.12, or query the attributes to automatically select the feature within the map view. The user can also perform a query that combines both spatial and feature attributes and return a list of relevant features for review. A GIS user can relate, analyze, report, and display data from a location perspective. Often, related data have, at minimum, a location in common. For instance, if a GIS user desires to know how many radio antennae are within 1 mile of an airport, the user can assemble maps and visually locate the antennae manually by simple measuring. Within GIS, given the proper data, one can perform a spatial query, in the same manner that a database or tabular data query could be run to obtain the information.

A GIS is also a very powerful tool for relating data from different sources. Within a GIS, one can relate or overlay CAD data, aerial photography, scanned maps, and several other formats from varying sources and visualize and relate this data simultaneously within the same context. In addition, queries can be run utilizing several data sources that have a spatial relationship. These powerful features allow visualization of trends and relationships that would otherwise be overlooked within tabular-only data.

Current Practice

The current practice determined from a survey of five airport operators representing large and small airports, civil and military use, and a variety of PMS software is described in this section. These organizations are:

- Denver International Airport (DIA)—a large airport system using custom software
- Houston Airport System (HAS)—a large airport system using AirPAV PMS software
- The North Dakota Aeronautics Commission (NDAC)—a state agency managing smaller airfields using AirPAV
- The Oklahoma Aeronautics Commission (OAC)—a state agency managing smaller airfields using custom software
- The United States Air Force (USAF)—a military organization managing various size airfields using MicroPAVER

The survey questionnaire is provided in Appendix A, and the responses to the survey are provided in Appendix B. (Appendixes A and B are not published herein; they are available at www.trb.org by searching for "ACRP Report 39.") The survey focused on four areas:

- GIS data
- PMS data

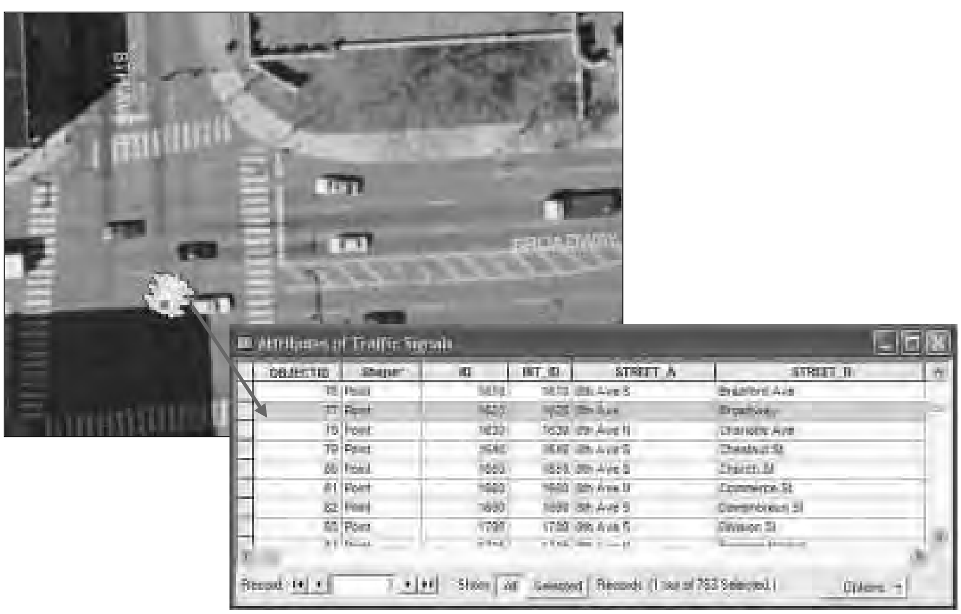

Figure 2.12. A GIS organizes spatial and non-spatial data.

- Integration of PMS and GIS data
- Identifying those responsible for various aspects of data

Also, standards or specifications concerning spatial data collection received from these organizations were reviewed. The findings of the survey are summarized.

Data Collection and Responsibility

DIA, HAS, NDAC, and the USAF use consultants or contractors to collect pavement management data. The OAC collects data entirely in-house, and the USAF collects data in-house between surveys by consultants. No organization reported a standard or regulation governing the collection of pavement data, and all indicated that data collection by consultants is handled on an individual contract basis. All respondents except the USAF indicated not having formal specifications for collecting spatial data that pertains to a PMS. The USAF indicated having no specific requirement for spatial PMS data other than it must meet the Base Design Standards, which essentially specify SDSFIE compliance and the appropriate projection.

The authority to collect data rested above the individual airfield level in all cases. The state aeronautics commissions for North Dakota and for Oklahoma program for data collection in their respective states; USAF Major Commands program data collection for the bases under their control; and data collection decisions at DIA and HAS are made by their personnel and at the city and county levels. No organization cited a standard requiring the collection of PMS data of a certain type or at particular intervals, although NDAC did cite the FAA Advisory Circular 150/5380-7a as the authority for collecting PMS data. The USAF, NDAC, and OAC inspect airfields on a cyclical basis, approximately every 3 years. HAS issues a multiyear contract, with a portion of the network inspected every year. DIA collects PMS data annually. In all cases, funds are provided by the office or organization authorizing the data collection, with the state aeronautics commissions receiving some funding from the FAA.

The method of collecting data varied among the respondents. The USAF and HAS reported collecting PMS data using paper forms, and OAC reported using a tablet PC to collect data. DIA reported the use of devices supporting ArcPad, which is integrated into the ArcGIS Server–based custom PMS software, and NDAC reported using automated/image-based methods.

Data collected are typically delivered to the organization that funded data collection (i.e., the aeronautics commission), except for the USAF, where data collection is funded by the major command but data are delivered to the installation. Once delivered, PMS data are maintained by engineers. OAC and NDAC engineers also maintain custody of the spatial data relating to a PMS. However, information technology departments at HAS and the USAF maintain custody of the spatial data.

PMS Software and Data

Four different PMS software packages were reported by the respondents, as indicated in Table 2.2, and each respondent indicated that its particular PMS package met the needs of the organization. A list of data elements used by each PMS package is presented in Appendix C (the data elements for GAPEMS were not available). (Appendix C is not published herein; it is available at www.trb.org by searching for "ACRP

Table 2.2. Overview of PMS packages reviewed.

PMS Software	AirPAV	AFID	GAPEMS	MicroPAVER
Custom/COTS*	COTS	Custom	Custom	COTS
Developer	Applied Research Associates	University of Oklahoma	DMJM Aviation	U.S. Army Corps of Engineers
Database	Flat file text	MySQL	Oracle	Microsoft Jet (MS Access)
GIS Integration	Static map display	Yes	Yes	Map display and feature selection
	Bitmap/GIF images	Custom	ArcInfo/ArcGIS w/Spatial Analyst	ArcObjects Lite

*COTS: commercial off-the-shelf

Report 39.") None of the organizations indicated intention to change PMS software in the next 2 years, but the USAF indicated an intent to upgrade to the latest version of their software when it becomes available.

Two of the reported packages, AirPAV (Aho, 2007; ARA, 2005) and MicroPAVER (Shahin, 2004; Shahin, 2007), are off-the-shelf software that are more oriented toward analysis of pavement condition, maintenance, and economics. They take the form of a stand-alone computer program in which the user enters data, performs an analysis, and uses the results to make a decision or develop a report. Airport Facility Infrastructure Database (AFID) is a custom web-based software created by the University of Oklahoma (OAC, 2007; Parsons, 2001). Although it has analysis routines, AFID is oriented more toward data dissemination via the Internet. Geospatial Airfield Pavement Evaluation and Pavement Management System (GAPEMS) was reported by DIA to be a custom ArcGIS Server–based software package developed by DMJM Aviation. Screenshots from MicroPAVER, AirPAV, and AFID are shown in Figures 2.13 through 2.15 (screenshots were unavailable for GAPEMS).

The AirPAV, MicroPAVER, and AFID software packages are designed around ASTM D 5340, "Standard Test Method for Airport Pavement Condition Index Surveys," and as a result have similar data hierarchies. All three software packages make use of the following concepts:

- Network—a group of pavements being managed
- Node, site, or airfield—pavements in the same aerodrome
- Branch—a readily identifiable part of a network, such as a taxiway or runway
- Section—a portion of a branch that is uniform in use, structure, traffic, and construction history
- Inspection—an event documenting the condition of a pavement section
- Sample unit—a portion of a section designated for the purpose of a pavement inspection (ASTM D 5340, 2004; Shahin, 1994)

Each software implements these concepts in different manners. For example, AirPAV and AFID use the concept of a site or node to organize data from multiple airfields within a network, but MicroPAVER allows the simultaneous analysis of multiple networks with each airfield being a separate network, eliminating the need for nodes.

The naming conventions for the data differ among software packages for branches and sections. AFID and MicroPAVER allow character-based names (e.g., Taxiway A), while AirPAV uses a numeric code to identify pavement. AirPAV designates Taxiway A as branch 100 and Taxiway B as branch 200. Section 301 is the first section in Taxiway C. Sample units are designated using the numbers right of the decimal, so that the number 502.14 is the 14th sample unit of the second section

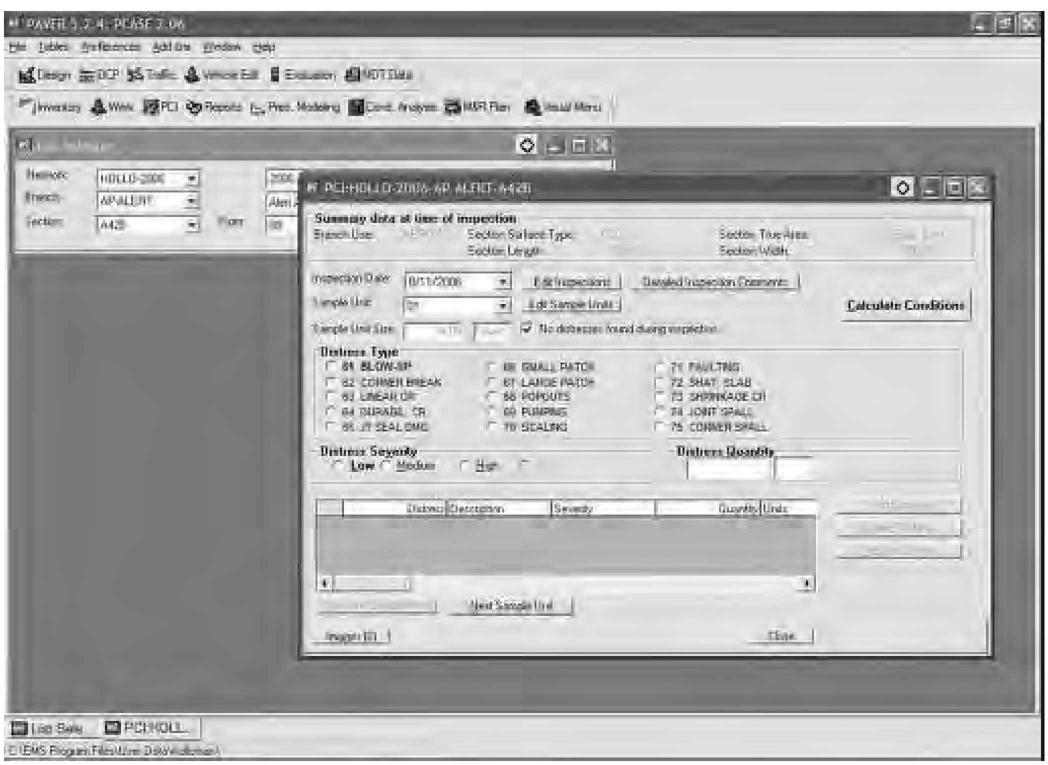

Figure 2.13. MicroPAVER distress entry screen.

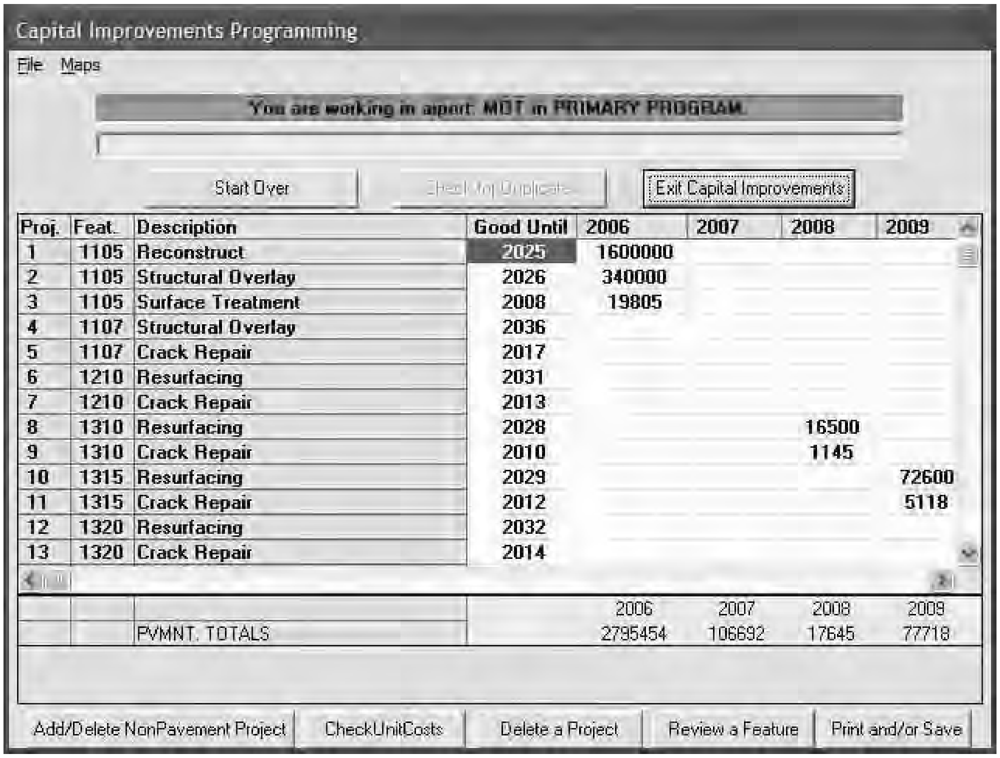

Figure 2.14. AirPAV screen shot showing a capital improvement plan.

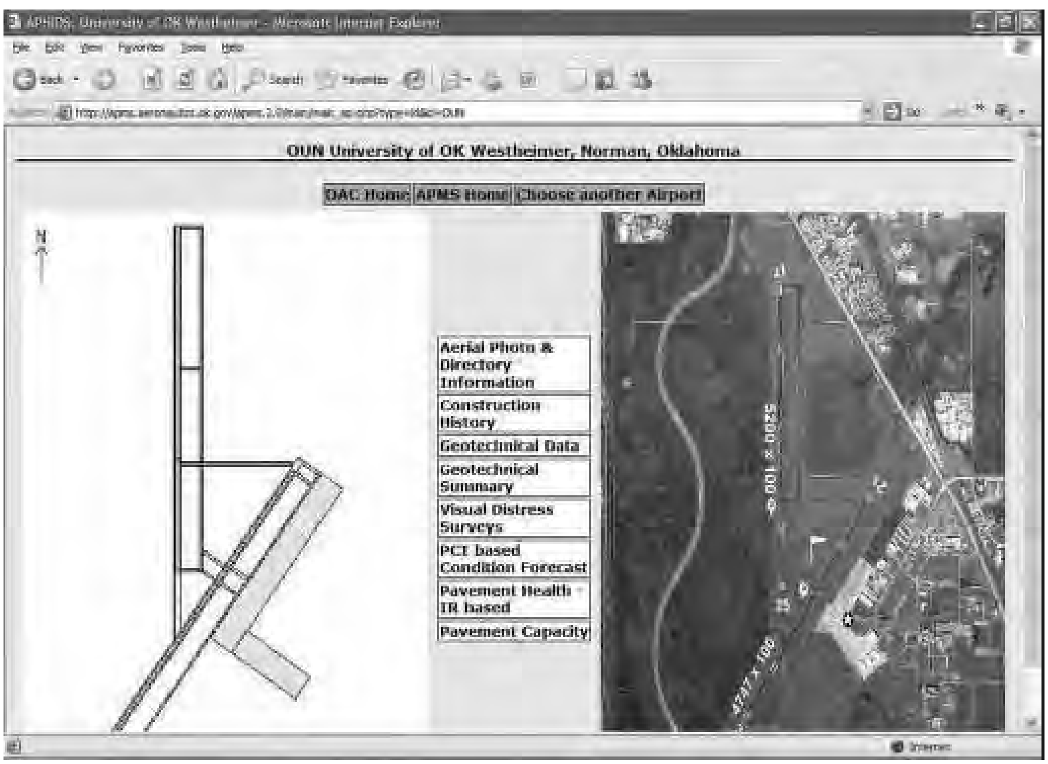

Figure 2.15. AFID airport information screen shot.

of Taxiway E. Numbers in the 4000 series are aprons, and numbers above 6000 are runways (Aho, 2007). AirPAV also only allows one inspection per section, whereas AFID and MicroPAVER allow multiple inspections.

Each software has provisions to store other pavement property or condition data. MicroPAVER allows the creation of additional condition measurements, including textual descriptions, numerical indices, and distress indices based on ASTM D5340 distresses (Shahin, 2007). The USAF reported storing digital photographs in MicroPAVER. They also include pavement thickness, friction data, Dynamic Cone Penetrometer (DCP) data, Heavy Weight Deflectometer (HWD) data, and other structural data in their PMS. These data are stored in PCASE, companion software to MicroPAVER. AFID is specifically designed to store geotechnical and nondestructive testing information. It is currently used to store pavement thickness data, Atterberg limits, moisture content, DCP data, grain size distribution, layer moduli, and mobility in addition to pavement condition data (OAC, 2007). HAS reported storing HWD and coring-boring results in AirPAV.

MicroPAVER and AirPAV have complex analysis capabilities. MicroPAVER contains a modeling tool, allowing the user to develop regression models that reflect pavement deterioration and performance, as shown in Figure 2.16. Both AirPAV and MicroPAVER allow the user to estimate future pavement condition given the current condition of the pavement, then estimate the amount and type of M&R required. AirPAV allows the user to estimate the effect of various M&R strategies on a pavement section, as shown in Figure 2.17. Both MicroPAVER and AirPAV allow the user to estimate M&R treatment quantities and costs from distress details. AFID has analysis capabilities, including condition prediction and M&R planning, but focuses on data distribution. AFID contains many different types of data, including condition data, structural data, geotechnical data, M&R estimates, and capital improvement projects, including non-pavement projects. An example of a geotechnical data plot is shown in Figure 2.18. The software is web based, and may be accessed by anyone.

Each of the three PMS software packages uses different data storage platforms for pavement data. AirPAV uses two data storage platforms: a set of flat-file database files that forms the core of the database, and a Microsoft Access file used for communicating with other software, including a GIS. MicroPAVER uses Microsoft Access exclusively for data storage, including the main data file, image libraries, work planning reports, and condition analysis reports. AFID uses MySQL [an open-source relational database management system (RDBMS)] to store pavement data.

GIS Systems

Except for OAS, respondents reported the use of ESRI GIS software. OAC reported the use of a custom GIS embedded in the PMS software. ESRI ArcView and ArcGIS software are

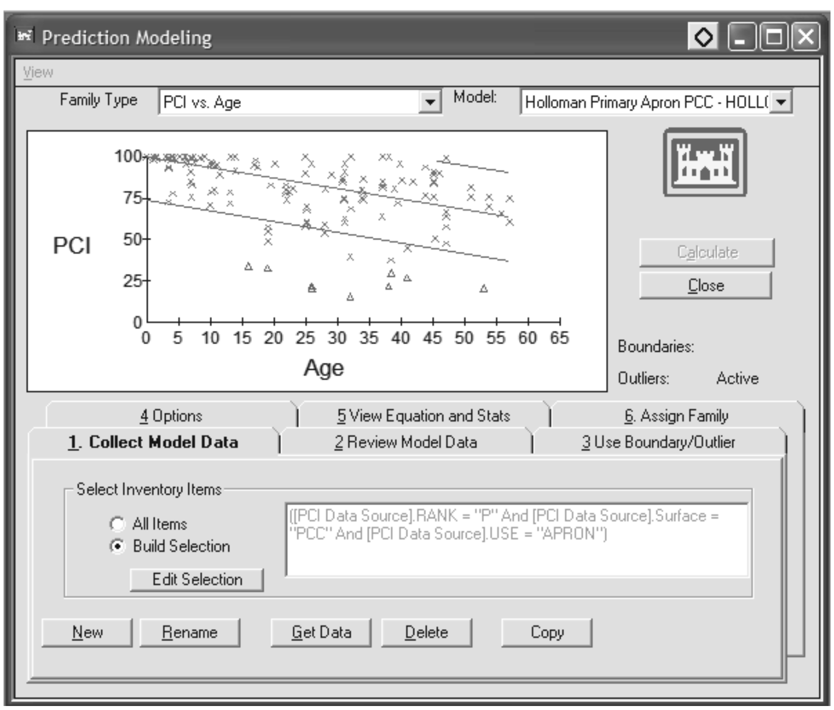

Figure 2.16. MicroPAVER modeling tool.

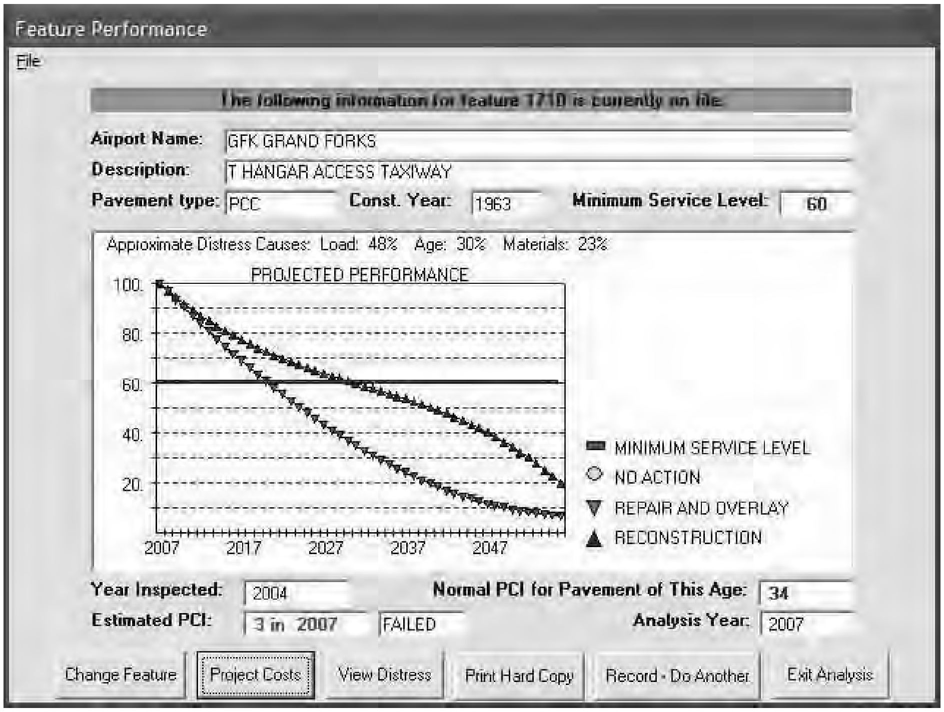

Figure 2.17. AirPAV M&R alternative analysis tool.

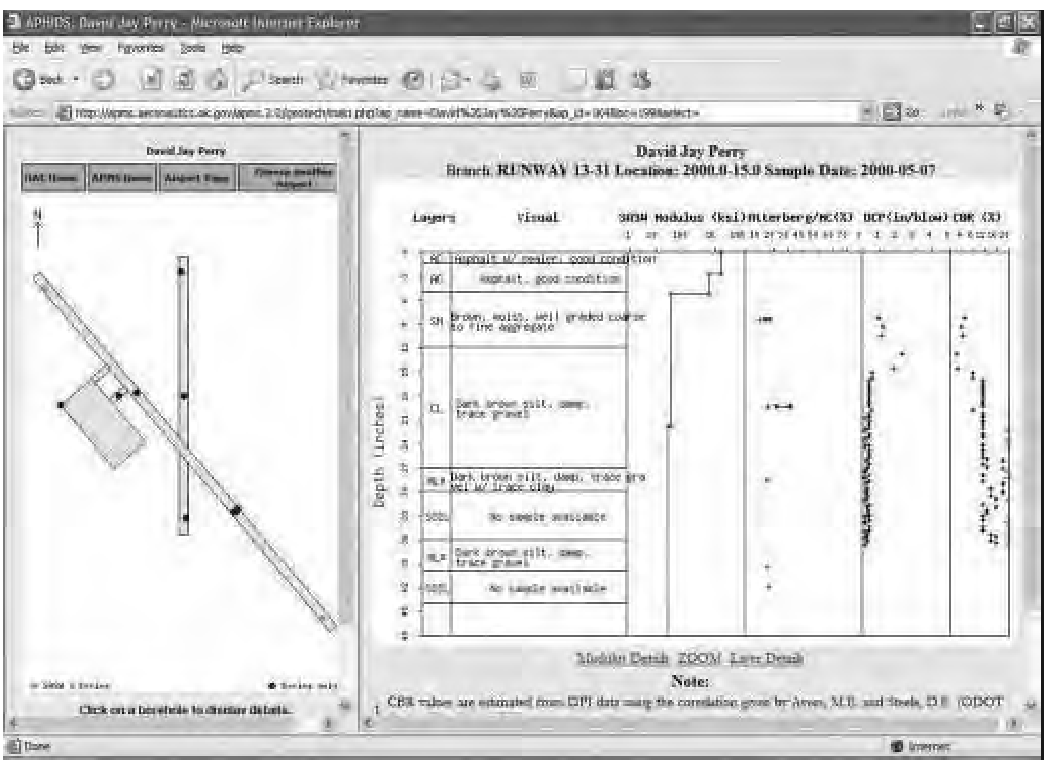

Figure 2.18. AFID geotechnical data distribution.

general purpose GIS software packages that can be used to display many different types of data from different sources. The functionality of the software can be extended using scripting or programming languages. The software allows users to create, edit, analyze, display, and transform data sets. A typical use of ArcGIS is shown in Figure 2.19, which depicts the locations of photographs taken during the survey. Clicking on a photograph retrieves and displays the image. The OAC GIS application was custom written in PHP and HTML by the University of Oklahoma. Data are posted by dynamically generating PNG images and a corresponding HTML USEMAP fragment. The USEMAP defines the interactive properties of the data, allowing the web page to act like a GIS (Parsons, 2001). Figures 2.20 and 2.21 show screenshots of the custom GIS. It is used for both data display and navigation within the PMS.

None of the organizations reported intentions to change GIS systems, except that NDAC intends to upgrade the current system. The USAF reported that pavement data are integrated into a base-wide GIS called GeoBase. There are no written standards for integrating the data into GeoBase, but data are generally developed to conform to the U.S. Army Corps of Engineers SDSFIE. AutoCAD and ArcGIS are used to develop spatial data sets relating to PMS for HAS and the USAF.

DIA, NDAC, and OAC reported the use of U.S. Customary units in their GIS and PMS systems. The USAF reported the use of both U.S. Customary and SI unit systems: GIS spatial data are SI, and attribute data may be SI or U.S. Customary. Spatial data are SI to conform to the UTM Zone 11N projected coordinate system (WGS84 datum). DIA and NDAC reported the use of state plane coordinates. OAC uses a local coordinate system for each airfield. The spatial data are by definition not georeferenced because they are not tied to a unique location on Earth.

PMS–GIS Connection

Three basic methods of using spatial data for PMS were reported:

- Exporting data from the PMS for use in the GIS
- Integrating GIS functionality into the PMS
- Integrating PMS functionality into the GIS

The USAF noted a desire for tighter integration between the PMS and the GIS systems. Integrated GIS capabilities provide the ability to view or analyze data in a spatial context from within the software. An integrated system provides relatively easy access to the spatial data, but it displays only predetermined data views, limiting the breadth or depth of analysis by the user. Data export capabilities provide a defined interface to make data available to third-party GIS software, such as ESRI ArcGIS, thus allowing the user more analysis and viewing possibilities if the third-party GIS software is available.

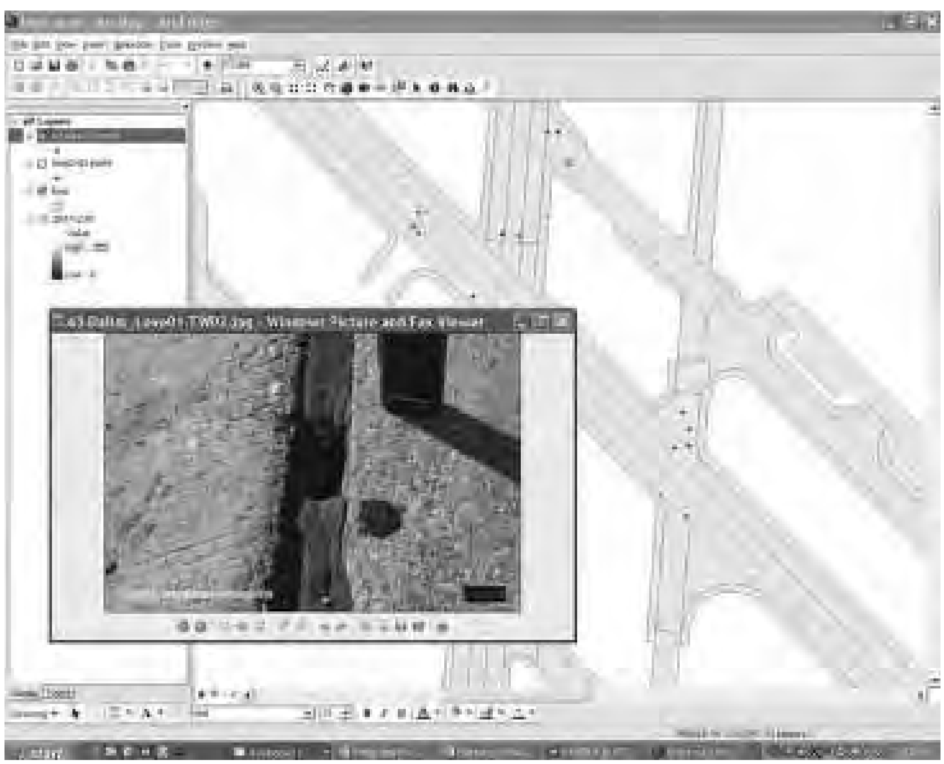

Figure 2.19. ESRI ArcGIS output.

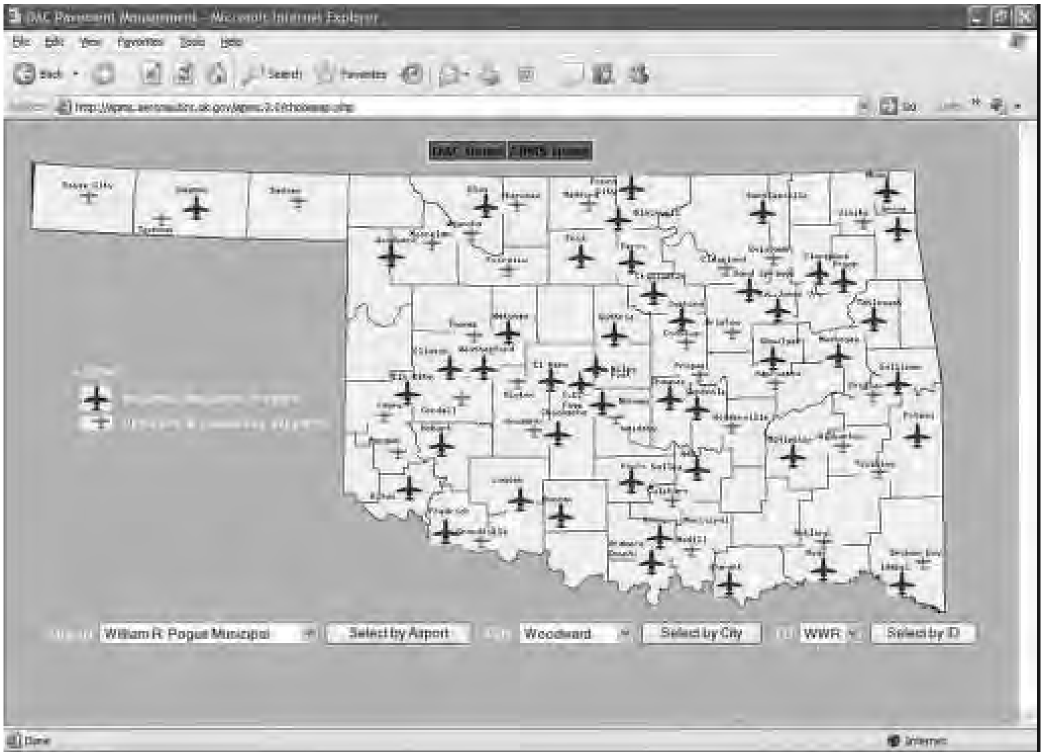

Figure 2.20. OAC custom GIS application to select an airport.

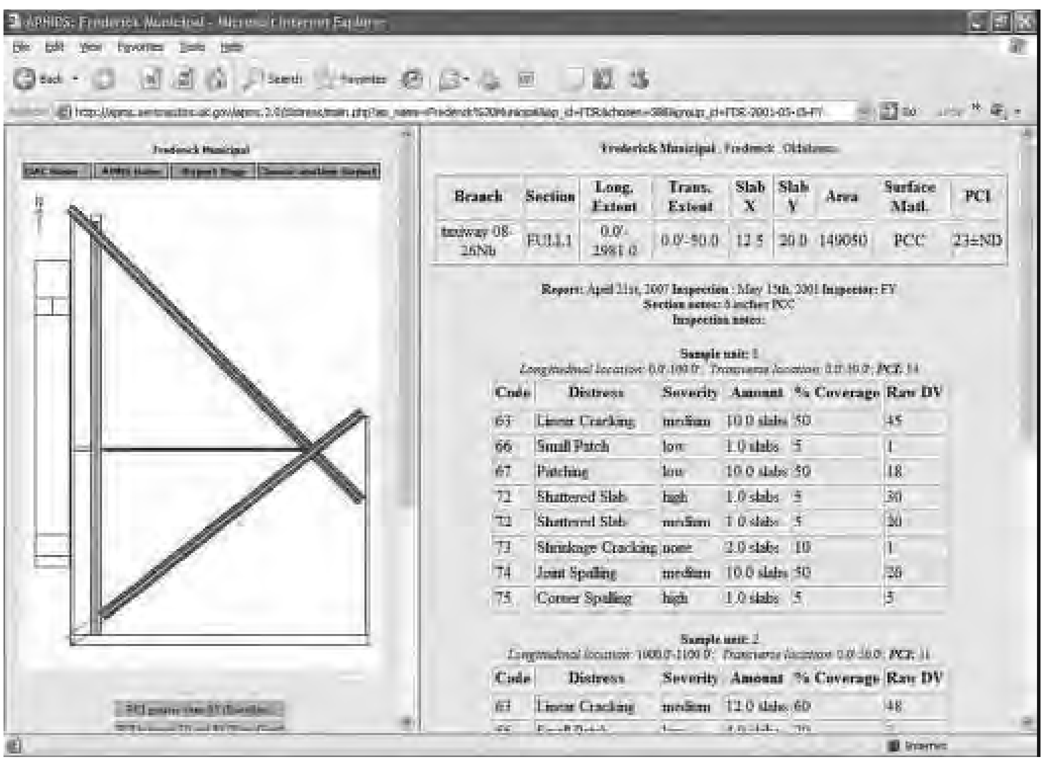

Figure 2.21. OAC custom GIS application to display current pavement condition.

The four noted software systems have integrated GIS capabilities. Each system provides different levels of integration. The GIS is the primary software in GAPEMS; the PMS functionality is an extension of the GIS analysis capabilities. The GIS in AFID is completely integrated into the PMS to the point that the PMS does not function properly without it. AFID provides a list-based navigation system only at the airport level, allowing the user to select an airfield by name, city, or FAA identifier. Data for pavement sections and test points must be retrieved via the GIS, as illustrated in Figures 2.18 and 2.21. Interactive maps are the primary navigation tool within both AFID and GAPEMS; that is, users click on an airfield section to retrieve data about that section. MicroPAVER provides a GIS module that allows the user to rapidly view preselected pavement data in a spatial context, but a lack of spatial data does not unduly affect the operation of the software. The use of the embedded GIS module in MicroPAVER was not reported, although it has been used when implementing PMS. Most data in the PMS may be viewed using the built-in GIS module, which does not provide analysis capabilities. Any GIS display may be used to change the currently selected pavement section. A display of pavement surface information from the MicroPAVER GIS module is shown in Figure 2.22. AirPAV does not provide a true GIS interface, in that the attributes displayed are static, not dynamic. ("Static" indicates that the data display is updated manually by a user; "dynamic" indicates that the software automatically updates the data display to reflect any changes in the database.) For AirPAV, color-coded attribute maps, like the one shown in Figure 2.23, are manually prepared and the software accesses these maps as requested by the user. The operation is not significantly different from that of other embedded GIS software from the user's point of view, as the user has access only to a limited set of data views, whether the data are dynamic or static.

Data export for viewing and analysis in GIS is not needed for GAPEMS; the PMS data are stored directly in the GIS database. Consequently, GAPEMS has the most information available for analysis using GIS methods and techniques. DIA reported that all levels of the PMS hierarchy, including distresses, were available for display and analysis in the GIS.

Data export is accomplished both by MicroPAVER and AirPAV by creating a file containing data that can be read by a GIS. No distinction is made between server-based and desktop-based GIS. In server-based GIS (thin-client), all the software and data reside on a server, and all the processing takes place on the server. In the case of PMS data from AirPAV and MicroPAVER, which are desktop-based PMS software packages, the server must be able to locate the PMS data. This requires either mapping the desktop computer as a network resource for the server, or directly uploading the data from the desktop to the server. Desktop-based (thick-client) GIS allows the user easy access to the PMS data because it is located on the same computer. In both cases an export file is created

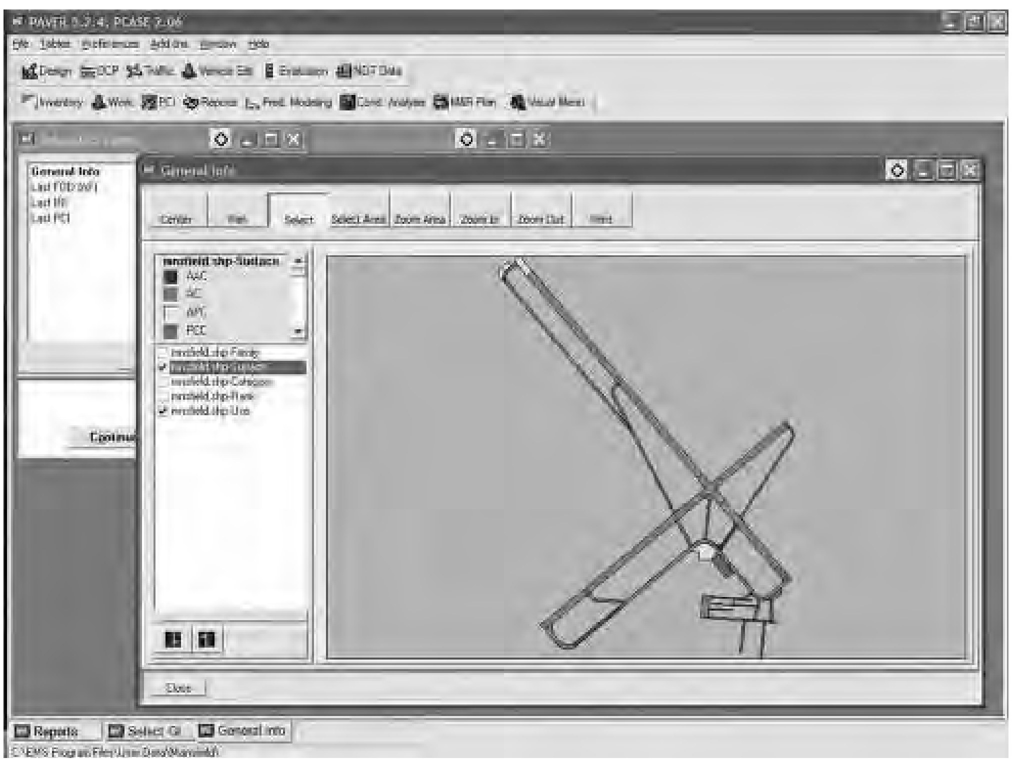

Figure 2.22. MicroPAVER GIS module.

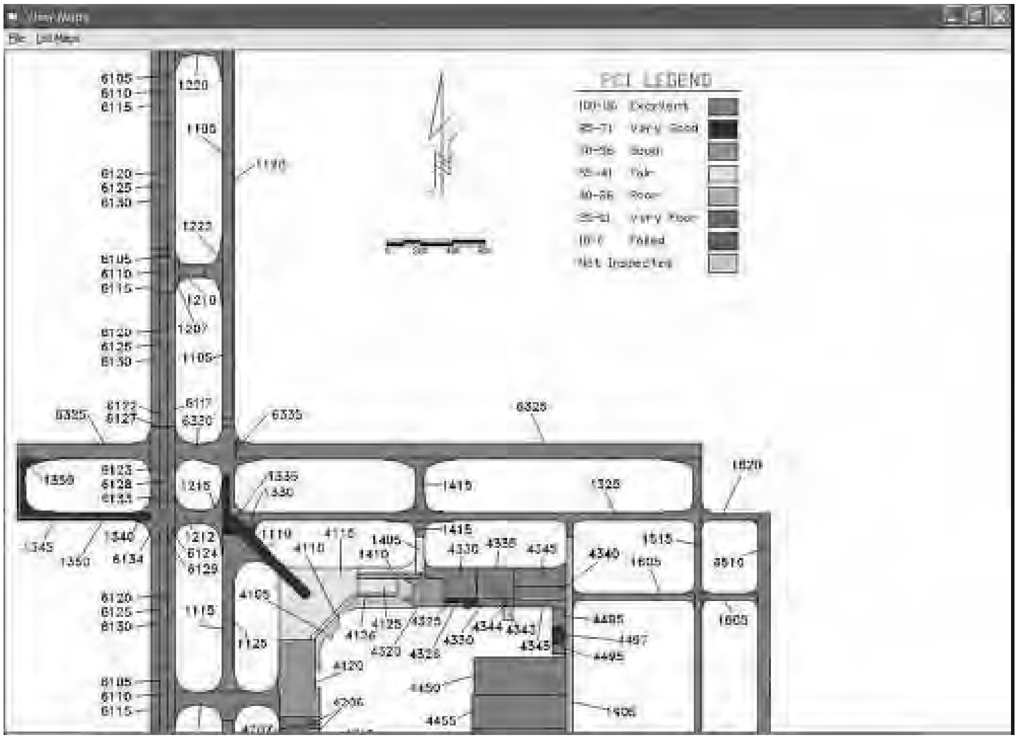

Figure 2.23. AirPAV "View Maps" module.

and added to the GIS data set. Attribute data are linked to spatial data by means of keys (i.e., unique identifiers). Both MicroPAVER and AirPAV perform the link at the section level, such that each entity in the spatial data has a corresponding section record in the PMS. Details below the section level in the PMS are not available to the GIS. The USAF reported that it has set up additional "joins" below the section level to link information at the slab level for at least one installation. (A "join" is a database technique of merging two related data sets.) The exact method of linking was not specified, as slabs are not assigned a unique identifier in the current version of MicroPAVER (5.x).

AirPAV uses the Microsoft Access file format and exports attribute data; the user sets up the appropriate join relationship to properly display the data. MicroPAVER uses the ESRI Shapefile format and exports both spatial and attribute data. The join is performed by the built-in GIS module and stored in a subdirectory of the MicroPAVER data structure, where it can be accessed by third-party GIS software. Data are exported by viewing the GIS report in the built-in GIS module. The contents of the resulting file depend on the data being viewed; it generally consists of section-level condition and attribute data for condition reports or attributes of each section and its parent branch for general information reports.

CHAPTER 3

Data Elements

Data elements selected for the guidelines were identified from the survey responses, existing data standards defining similar data sets, and data required to organize PMS data. These latter data elements are items such as database keys required to make the PMS–GIS linkage or pavement identifiers that allow a relational database to organize the data according to the hierarchical concepts used by the PMS software packages.

Due to the nature of GIS and database systems in general and the interrelation of PMS data with other data sets, there is no obvious or natural boundary to the scope of the data elements included in the guidelines. However, the scope of the guidelines was limited to data elements collected specifically for the purpose of pavement management. Data elements that are related to pavement management but collected by other agencies or for other purposes are not included. A foreign key is provided to link to detailed climate and traffic data, as these data were specifically identified as useful to PMS. The scope of the guidelines was defined to avoid duplication of effort and possible conflicts with existing data standards, yet still allow these data to be integrated with PMS data on an as-needed basis.

Most data elements were selected based on the spatial information collected by users of integrated or linked PMS–GIS systems, and on the data elements that the three identified PMS software packages are capable of storing and displaying as determined from PMS–GIS links. Data elements common to all three PMS data structures are included. Data elements not common to all three PMS systems, but that are logical extensions of the data hierarchy or particularly useful data elements unique to one or two of the identified PMS software packages, were also included.

In several cases, data table definitions in the guidelines overlapped significantly with existing data tables in the SDSFIE and FAA AC 150/5300-18A. In these cases, data elements from the SDSFIE and FAA AC 150/5300-18A were included in the guidelines to maintain compatibility or at minimum data exchange to the extent possible. Feature class names were not re-used, as these guidelines are envisioned as complementary to existing standards (e.g., advisory circulars, FGDC, or AIXM). Re-use of feature class names would result in confusion should both sets of standards be used at once.

Organizational and metadata elements were added as necessary to organize the data. The bulk of elements added for this reason are foreign keys or metadata elements specific to PMS data. Most foreign keys are internal, and serve the purpose of providing a hierarchical data structure within an RDBMS. These keys enforce real-world relationships, such as all pavement sections being a subdivision of a single pavement branch. Other foreign keys are provided to link to an external data set, such as data from various weather stations collected by National Oceanic and Atmospheric Administration. Included metadata elements are typically those providing information concerning a particular method or standard used to collect or calculate PMS-specific data.

Specific distress-condition data elements were selected to represent PCI (ASTM D5340) and PASER (AC 150/5320-17). These distress conditions were selected because they are the FAA-recommended PMS surface condition methodologies (FAA, 2006a). The distresses recorded for each index are generally the same; therefore, the data elements to display distresses from either index were placed into the same feature class.

The engineering assessment (EA) data elements were included in the standard, in spite of being military specific, to encourage use of the guidelines by the U.S. military, thereby increasing the amount of data available for integration and exchange.

CHAPTER 4

Development of Spatial Data Guidelines

Format of Guidelines

The guidelines were envisioned as a supplement to FAA advisory circulars. Therefore, the content and style of the guidelines were selected to be compatible with FAA advisory circulars. The format of the guidelines is also modeled after FAA advisory circulars, in particular, FAA ACs 150/5300-16, 150/5300-17, and 150/5300-18A. These three advisory circulars address the collection and storage of spatial data. The guidelines were envisioned as an extension to FAA AC 150/5300-18A.

Data Users

The types and organization of user categories is a general information technology topic. As such, it has applications beyond PMS–GIS systems; that is, the user categories could also be applied to a computerized work-order system or an accounting system. The categories and organization presented in the guidelines are based on basic IT principles, responses to the survey regarding division of responsibility, and the user categories defined by AIXM (as discussed in Chapter 2). The presented categories and organization are intended to provide users a "big picture" look at all the activities required to acquire and maintain PMS data, not to provide a "Staff Organization Chart" for any given airfield. The organizations that are envisioned using these guidelines are diverse, ranging from individual general aviation airports to statewide or multistate networks of airfields. Division of responsibility for organization and management of data is best determined by executives of individual organizations because of their understanding of the needs and resources of their particular organization. Available resources will range from a single person performing all executive, engineering, IT, and administrative functions to large organizations with well-defined roles and multiple personnel capable of performing each role.

Data Storage Methods

Data Format

The preferences for the data format were to use an existing standard and a nonproprietary standard. Because the guidelines define a data *exchange* format, not a data *storage* format, users may store data in whatever format they choose if the data can be converted to the format specified in the guidelines when sending to other organizations. The data exchange format was designed to require that all data be sent (i.e., both spatial and attribute) when exchanging data, to reduce the possibility of sending attribute data in one file and mismatched geospatial data in another file. However, sending complete data sets increases the likelihood of transmitting redundant geospatial data (i.e., two distinct attribute sets for the same spatial entities) and eliminates the possibility of sending just an attribute table to be joined to a geodata set. The value of sending a complete data package every time appears to outweigh the cost of sending redundant geospatial data. It also allows each set of entities to be completely independent of the other data sets if required. While attribute joins and links are common operations in the GIS realm, some airports with fewer resources may not have the capability to perform such operations. Requiring complete data packages for transfer also increases uniformity of the data and ease of data exchange. The data will always be received as a complete package and imported into the user's software in the same manner.

FAA AC 150/5300-18A allows use of DWG, DGN, and SHP files, all of which are proprietary formats, and only SHP files are specifically defined as a GIS file format. Although DWG and DGN are designed for use in CAD systems, they support GIS functions.

FAA AC 150/5300-18A also allows the use of the Level 0 Profile of GML (version 3), which was renamed the Simple Features profile of GML in 2005. While the SHP format is a published format, it is still controlled by ESRI. GML has several advantages, and was selected for use as the standard format in the guidelines.

GML is the XML grammar defined by the Open Geospatial Consortium (OGC) to express geographic features. The GML standard is a vendor-independent language that can store and transmit spatial data as well as describe spatial operations, attribute queries, and specify arguments. GML can be composed of a single XML file or an unlimited number of related files or data streams. GML is specifically suited to streaming data by allowing the user to receive and view data in the GML stream without receiving the entire data file.

In contrast to the Shapefile specification, GML is not a data format, but a language. Therefore, to specify a particular data format, one must specify the schema for the data elements within the specific GML data set or data stream. Often the GML schema specified is for a particular application, which is thus referred to as an application schema. Two examples of GML application schemas are the AIXM and the U.S. Census Topologically Integrated Geographic Encoding and Referencing Schema (TigerGML).

GML supports several features not present in the SHP format, including aggregate and dynamic features, circular and elliptical arcs, topology, time, and time-based information. It is designed such that newer versions of the specification are backwards compatible to previous versions to allow use of any defined application schema defined in future systems.

GML has been defined in accordance with applicable ISO specifications, including:

- ISO/TS 19103—Conceptual Schema Language (units of measure, basic types)
- ISO 19107—Spatial schema (geometry and topology objects)
- ISO 19108—Temporal schema (temporal geometry and topology objects, temporal reference systems)
- ISO 19109—Rules for application schemas (features)
- ISO 19111—Spatial referencing by coordinates (coordinate reference systems)
- ISO 19123—Schema for coverage geometry and functions

The guidelines require that the data be capable of being converted into a specific format, but not necessarily transmitted in that format. The guidelines are designed to allow two users using software that support the same format (e.g., Shapefile) to exchange data directly in their mutually selected format. This eliminates the need to convert the data to GML, transmitting it, and then converting back into the original format. However, if software packages with differing file formats are used, the data can be converted from the original format into GML, and then into the format required by the receiving party. GML is used as a clearinghouse, thus defining the minimum requirements for a data format to be compatible with the guidelines (i.e., the ability to represent spatial data and associate non-spatial data with the spatial entities).

Hardware Formats

A hardware format is not defined in guidelines because organizations have different needs and do not need the same technology, as evidenced by the multitude of hardware storage options available in the computing marketplace. Requiring an organization to use one format or another may result in a mismatch of capability and unwarranted expense to some organization's needs.

In addition, because of the rapid change in the computing industry, the support for a specific format may diminish in the future (e.g., ZIP drives or 3.5 in. floppy disks). In addition, the growth of the Internet now allows network delivery of much data by email, FTP, download, peer-to-peer file sharing, and other technologies, making the actual hardware storage format irrelevant. The sender and receiver can store data in completely different formats if a network transfer method (e.g., an email attachment) is used.

Entity Types and Attribute Field Types

Specific data types, both spatial and non-spatial, were identified in the guidelines to allow easy access to a variety of PMS and GIS software packages. Thus, the "lowest common denominator" approach was used to select data entities.

Instead of cross-referencing all the various types of entities supported in all the GIS and CAD packages to determine equivalence, the basic geometric entities of points, polylines, and polygons were selected. For example, ESRI Shapefiles support 14 different types of vector spatial data entities (ESRI, 1998); however, all data entity types can be categorized as some form of a point, polyline, or polygon. Most data in the PMS systems used by the survey respondents are associated with pavement areas, which are best represented by polygons in a GIS. Point-data entities were included to represent test locations. Polylines were included primarily to represent linear distresses and pavement tests (e.g., GPR), but can be used for any linear feature.

A similar process was used to select non-spatial data. Various types of data entities are defined in each database system, including various types of integers and floating-point numbers, text or string data types, Boolean data types, temporal (time/date), binary data, and links. After examination of the data schemas for the PMS software reported by the survey respondents, it was determined that all the data elements that would be integrated into a GIS could be represented as numbers, text, and time data. A text (or string) field is the most general data type, and can contain numbers, labels, dates, or any other type of data. Strings have the disadvantage of requiring the user to interpret the data, and are not always the most efficient method for storing some data, such as numbers. Data collected by different PMS systems and stored in different manners are stored as string data in the guidelines. The best example is pavement rank. Some PMS systems rank pavement using numeric codes (e.g., 1 for primary, 2 for secondary) while others use letter codes (e.g., P for primary, S for secondary). Numbers can be stored as strings, but letters cannot be stored as numbers, therefore, the guidelines require pavement rank to be stored as string data.

Primary and foreign keys are also stored as string data for the same reason. Some databases use numerical keys to improve indexing performance; however, MicroPAVER uses a text-based primary key for each record in the database. Keys are therefore defined as a string format field.

Some data are stored as numeric data in all PMS packages. These data are inherently numeric (i.e., they cannot be expressed as anything except a number), such as length or width. The guidelines require storage of these data elements as floating-point data; integer data types were not used to minimize the number of data types used. All integers can be stored as floating-point numbers. Floating-point data must be truncated to store as an integer.

Temporal data can be stored as time data, numeric data, or string data. For example, the SDSFIE stores time stamps in a string data type, with the format input by the user. This approach was not used because of the possibility of using the wrong format when entering data, and because of the capability many modern database management systems have to perform time-based calculations on temporal data types. Temporal data are stored as GML date/time data types.

Metadata Storage

The primary requirement of metadata storage was its compatibility with primary data storage format. Initial thinking was that the metadata could be embedded directly in the GML stream, but further research revealed that the Level 0 Profile of GML forbids embedding metadata in the GML stream. Therefore, developing an application schema (similar to AIXM) or using a completely different format for metadata was necessary.

Developing an application schema would result in a compact, all-in-one data format. While creating an application schema by adding metadata to the Level 0 Profile may not cause existing applications to malfunction, it is equally unlikely that existing applications would have the capability to process the metadata in a meaningful manner. Also, it would represent a minor departure from the formats specified in FAA AC 150/5300-18A.

Using a non-GML format for metadata results in a more complex specification by requiring at least two files for each data set that must be addressed by the guidelines. Regarding the format, two early candidates, DBF and Microsoft Jet (the proper name of the Microsoft Access format), were identified. Both candidates are proprietary and the DBF format is over 10 years old. The research did not reveal a widely accepted nonproprietary standard for general data storage.

A metadata structure was developed by the U.S. federal government specifically for storage and transfer of geospatial metadata known as the FGDC CSDGM. Federal entities are required to collect metadata according to this standard. For this reason, and the compatibility of XML with GML, the XML version of this standard was selected for the transport of metadata.

Three-Dimensional Data

Three-dimensional data provide compatibility with other airfield data sets that are required to be represented in three dimensions and allow the user to create complex visualizations of construction layers. However, three-dimensional data are not always available and PMS data are often represented in a two-dimensional plan view.

Collection Methods

When defining acceptable collection methods, it is necessary to ensure adequate data quality while allowing technical innovation. A prescriptive guideline that specifies exact equipment and methods that are acceptable will guarantee adequate data quality, but does not allow organizations to take advantage of new technology such as Light Detection and Ranging (LIDAR) or GPS. Further, a functional guideline that specifies end results is preferred. This prevents the guidelines from requiring data collection methods that become outdated or are rarely used; users are free to experiment and innovate with new technology. A functional guideline works on the premise that adequate data quality must be achieved regardless of the means necessary to achieve it. This approach is used in FAA AC 150/5300-18A, dividing data collection into basic types: remote sensing and field survey. The only two restrictions placed on data collection are that all data must meet accuracy requirements specified in the AC and that remote sensing must use stereo models.

The requirement of stereo models in remote sensing is a prescriptive requirement that appears to require all data to be collected in three dimensions. The same approach is used in the guidelines by specifying data quality requirements. The user will determine the best method to achieve the desired results.

The guidelines address collection for two distinct types of spatial data: entities representing pavements or divisions thereof, and spatial attributes of non-pavement data. Spatial data representing pavement are essentially map data and have the potential to be used for non-PMS purposes, such as an obstruction survey. In this case, having imprecise data is worse than having no data, as misrepresentation of the location of an airfield surface could result in danger to the flying public. Conversely, spatial attribute data are attributes of a data record that provide geospatial information for data that are primarily non-spatial, such as a photograph or borehole log. For these types of data, imprecise data create little or no hazard to the flying public, and thus having imprecise data is better than having no data. Collection methods for this type of spatial data are not restricted.

Simply referencing FAA AC 150/5300-17 and AC 150/5300-18 for data collection for entities representing pavement was considered. This approach would maintain compatibility between the guidelines and the AC and minimize risk to the public in the event that spatial PMS data are used in non-PMS applications. This approach was modified because the survey indicated that users did not necessarily use stereo models to develop spatial PMS data, and the users reported satisfaction with the current GIS system and data. The guidelines were adjusted to allow additional data collection methods that may be less precise or otherwise yield less data (e.g., 2-D instead of 3-D data), provided the resulting data are used only for pavement management purposes. Preference is given to data developed by field survey or remote sensing under the advisory circulars. Otherwise, an existing pavement data set developed according to the advisory circulars (such as planimetric data developed from a stereo model) should be edited, as the precision of the data set will not be affected by simply splitting existing entities of the data set so long as existing vertices are not altered. If this is not practical, feature extraction using georeferenced, orthorectified aerial photography should be used. This type of aerial photography will provide horizontal precision that meets the requirements of AC 150/5300-18A, but will not provide elevation data, which, while it may be desirable, is not necessarily essential for display of PMS data.

Precision and Accuracy

Precision and accuracy are two related concepts that are addressed independently.

Precision requirements were divided into measurement precision and representation precision. Measurement precision is defined by the resolution of the measuring device used to collect data about an object. Representation precision is defined by the resolution of the storage format—typically vertex spacing for a vector file format, pixel size for raster data, field length for text data, and the number of significant digits for numerical data. The precision requirement for spatial data was defined in terms of accuracy (i.e., all measuring devices, collection methods, and storage formats must have precision requirements in excess of the accuracy requirements of the data). Precision requirements for attribute data were determined by selecting the most precise data representation for each attribute from the database schemas of the different PMS packages. The purpose of this requirement is to ensure that any loss of accuracy or information is not caused by improper collection or storage of the data.

Accuracy requirements were divided into requirements for entities representing pavements, entities not representing pavements, and attribute data accuracy. Pavement and non-pavement entities were not combined to eliminate the possibility of pavement entities being used for purposes beyond those intended. Spatial and attribute data were separated because of the fundamental differences in what they represent and how they are stored.

Entities representing pavements could be used in a GIS for non-PMS applications. Therefore, the general accuracy requirements of AC 150/5300-18 were incorporated by reference into the guidelines, maintaining compatibility with the advisory circular, and ensuring data acceptability for general use as a data set governed by the advisory circular.

The accuracy requirements for non-pavement entities are not specified to allow the use of a broad range of collection methods, not restricting use of specific technology that best suits the needs of accuracy and budget. It also allows use of non-pavement data with different precision and accuracy requirements. Metadata elements inform the user of the accuracy and precision of a given data set of non-pavement entities.

Accuracy requirements for numerical attribute data were selected based on the source of the data. Data representing test results or condition indices is governed by the accuracy requirements of the test method condition index standard [e.g., a 95% confidence interval of 5 points for PCI (ASTM D 5340, 2004)]. Numerical data representing pavement dimensions or other measurements is based on the accuracy of spatial data, because a complete set of numerical data representing pavement dimensions is needed to create a spatial representation of the pavement.

Accuracy requirements for text data have not been defined because of the wide range of data that can be stored as text.

Accuracy requirements for temporal data were set at 1 day, but may be increased if required by a testing or evaluation method. For example, HWD tests record the time of test to the nearest minute for technical analysis. An accuracy of 1 day was the same accuracy required by the three PMS packages to record construction history, inspection dates, and most test data.

Data Framework

PMS data frameworks are moderately complex and based on a real-world hierarchy of pavement divisions and subdivisions. One of the goals of the guidelines is to facilitate data exchange by using a simpler data framework and structure. Data elements were grouped into nine different feature classes, with each feature class defined by a different level of the PMS pavement hierarchy, plus airfield construction, airfield events, and photographs. The framework outlined in the guidelines is based on the premise that users may not have the need to exchange all data elements defined by the guidelines and each feature class should be able to function independently of the other eight feature classes. Separating each level of the PMS hierarchy also has the advantage of allowing PMS systems that organize sample units as parents of inspections and those that organize inspections as parents of sample units to use the guidelines without reorganizing the data. Because sample units constitute their own feature class, the relationship between inspections and sample units is not explicitly defined in the guidelines. Each data set is considered a "snapshot" of PMS data (i.e., valid for the time limits indicated in the metadata).

The UML diagram for the data framework is quite large; it requires C-size drafting paper to print. To reduce the footprint of the model, a skeletonized version defining primary and foreign keys and illustrating the relationships among the various feature classes is provided in the guidelines. Details of the attribute definitions are provided in tabular format.

Two feature classes (Section Location and Section Distresses) use the same spatial entities but have different attributes. The Section Location feature class is for general data (surface condition, thicknesses, widths, last construction date, etc.). The Section Distresses feature class is for detailed distress data. These classes were separated to minimize the number of attribute fields attached to each feature class (commonly referred to as "the attribute table being too wide"). The Section Distresses has over 100 fields in the feature class to allow for the accurate storage of the various severities of defined PCI and PASER distresses. Separating the PCI and PASER distresses would not result in a significantly narrower table, because PCI alone requires only three fewer fields than the combined feature class.

Although the feature classes are designed to be independent of one another, the relationship between the various divisions of pavement was considered. Because it may sometimes be necessary to perform an analysis based on some property of the parent section (branch, network, etc.), foreign keys identifying the parent pavement entities have been included in each feature class to link feature classes defined by the guidelines, or to the original PMS database.

Each entity name contains the keyword PMS to identify the data set as being specific to PMS. Entity names use underscores ("_") to mark internal word boundaries. Camel case (e.g., internalWordBoundary) was considered, but it was not used because of the tendency of some software to display attribute names or column headings in all uppercase. Spaces were not used, to eliminate a known problem in the MicroPAVER-integrated GIS. (Spaces in field names " " are changed to dashes "–" when merging spatial and attribute data. This allows duplicate field names in the GIS data to be created, causing the display to malfunction.)

Feature classes defined in FAA AC 150/5300-18A were not directly re-used. The ARP is defined in the advisory circular, but no PMS-related attribute data was defined. The advisory circular places branches in different feature classes depending on use, but the PMS software packages and the SDSFIE do not. The definition for PMS pavement sections has minimal attribute data and the name does not specifically refer to pavement management data. Pavement divisions below the section level (sample units and slabs) are represented by one feature class in the advisory circular (OtherPolygon, the general purpose polygon). Also, the nomenclature selected is based more on the PMS data hierarchy because of familiarity by the engineers and technicians with those terms. The approach assumes that the engineer might have difficulty following a database schema using unfamiliar terms, but an IT specialist could implement the schema without understanding the technical significance of the data elements it contains. A PMS-specific photograph feature class was created because existing definitions did not allow for explicitly associating a photograph with a particular piece of pavement as defined in a PMS.

The naming convention and data set identification scheme for data sets were selected to be intuitively obvious. Because the user could have multiple sets of the same data classes from multiple airfields, the data sets need to be easily distinguishable, whether browsing through a file system or geodata catalog or being displayed in a GIS. The metadata elements allow identification of the airfield to which the data set pertains. Because not all users and PMS software packages have metadata browsers, identifying the pertinent airfield in the file name is both the simplest and most reliable method of airfield identification. It will also be displayed in the same manner whether the data are viewed within a GIS, data catalog, or file system. Including "PMS" in the feature class name clearly identifies the data as being PMS-related; the airfield could have multiple pavement data sets (e.g., PMS, aircraft parking schemes, tenant areas, fire/crash/rescue zones, and allowable gross load maps).

CHAPTER 5

Application and Verification of Guidelines

Data Sets

Sample data sets were obtained from Dallas Love Field and Fort Wayne International Airport. The City of Dallas owns and operates Dallas Love Field. The airfield is located 7 miles northwest of the downtown central business district and is managed by the city's Department of Aviation. Love Field is serviced commercially by Southwest Airlines, Continental Express, and American Airlines, with seven fixed base operators servicing general aviation needs. Approximately seven million passengers per year utilize Love Field (Dallas, 2009). Fort Wayne International Airport started as a World War II military base and is now operated by the Fort Wayne-Allen County Airport Authority. It is located near Fort Wayne, Indiana and is served by five airlines (FWA, 2009).

The Fort Wayne data were provided in ESRI Shapefile file format using the AirPAV GIS export data schema. A database duplicating the attribute information in the Shapefile was also provided. There were 216 features in the Shapefile. The Dallas Love Field data were provided as a MicroPAVER database and associated Shapefile. It contained 345 features. Both data sets were provided with granularity equivalent to AIRFIELD_PMS_SECTION (i.e., at the section level). Manipulation of the PMS database, not just the GIS output from the PMS software, was required to access other information.

A tool to convert between the AirPAV and MicroPAVER database formats is available to AirPAV licensees from the AirPAV vendor. The difficulties of parsing a text-based, flat-file database to extract data from AirPAV could be avoided by converting AirPAV into a MicroPAVER format and performing the conversion to the guidelines schema on the converted database.

The PMS databases were concerned only with PMS data (i.e., photographs and event data were provided separately). The data were not provided in a database format, but in an organized manner using the file system (e.g., photographs are in a directory named "Photos" and use branch and section numbers for file names).

Data Transfer Process

Fort Wayne International Airport

The Fort Wayne data set provided consisted of a single ESRI Shapefile containing 145 attributes. The GIS file is the method used by AirPAV to make data available to the GIS. The GIS file is much easier to use in the extraction and transformation than the flat-file database underpinning the software. The Shapefile contains all the pavement attributes; construction history; selected capital improvements; last inspected PCI; current-year PCI; 5-, 10-, and 20-year projected PCI (without improvements); as well as pavement design/capacity and current functional use.

AIRFIELD_PMS_ARP. Some data for Airfield_PMS_ARP was entered manually. The FAA Airport ID was used as the network_short_name. The network_name would have to be supplied by the user, in this case "Fort Wayne International Airport." The data structure of AirPAV does not appear to support the concept of a network_pms_key. If needed, the airport ID fulfills this role by making the tacit assumption that one airfield correlates to one network. Network_area was calculated as the sum of Features.Area. The condition indices (network_pci, network_paser, network_fod, network_friction_index, and network_pcn) were calculated as area-weighted averages using Features.Area and the appropriate index. Condition index data were available only for PCI in AirPAV. The "rating fields" associated with each index were determined by applying the rules in each standard (e.g., ASTM D5340 states that a PCI of 86 has a PCR of "Very Good"). No data was supplied for the climate foreign key; however, the AWOS identifier KFWA or the URL to access the AWOS data http://weather.noaa.gov/weather/current/KFWA.html could be used to populate network_climate. If the URL is used, the 20-character field size is insufficient.

AIRFIELD_PMS_BRANCH. AirPAV uses a numerical naming scheme to denote branches and does not provide

Features.AC_Polished_M	Features.AC_Polished_L	Features.AC_Weather_H	Features.AC_Weather_M	Features.AC_Weather_L	Features.AC_Rutting_H
<Null>	<Null>	<Null>	<Null>	<Null>	<Null>
<Null>	<Null>	<Null>	300	7100	<Null>
<Null>	<Null>	<Null>	1475	11250	<Null>

Figure 5.1. Distress data in Fort Wayne data set.

explicit branch identifiers. Taxiways have feature IDs of 100 through 2600, with 100 being Taxiway A and 2600 being Taxiway Z. Runways appear to start at 6000, with aprons having feature IDs between 2700 and 6000. These numbers can be used for branch_pms_key, although the user would have to have a strong understanding of the database to know that it would be possible to have both a branch 100, representing all of Taxiway A, and a section 100, representing only a single section in Taxiway A. The FAA_key was not provided and had to be calculated. In addition to the naming convention, branch_use was determined from Feature.Cl, where 1=Taxiway, 2=Apron, and 3=Runway. Foreign keys such as network_short_name were determined in the same manner as for AIRFIELD_PMS_ARP, as were the condition indices and ratings.

AIRFIELD_PMS_SECTION. Section information is the native detail level of the records in the AirPAV data set. The feature_id corresponded to the section_id, and was also used as the section_pms_key. The FAA_key was not supplied, but calculated. Other foreign keys (branch and network names and IDs) were also determined. Several fields had a one-to-one correspondence between the data set and guidelines, including area, construction year, and PCI. The section_pms_surface was determined from PaveType, where the surface type was coded as 1=AC, 2=PCC, 3=AC over AC, and 4=AC over PCC. Structural data were available, but not in index form. Structural adequacy is expressed in terms of overlay deficiency, e.g., a pavement that requires a 2-inch overlay, to be structurally adequate, has a structural rating of −2. Design traffic is provided in terms of aircraft type (e.g., F-16, Boeing 727), instead of gear configuration and maximum take-off weight. Structural data on pavement layers is not provided, only the modulus of subgrade reaction (k-value) or the California bearing ratio (CBR) of the subgrade.

AIRFIELD_PMS_SECTION_DIST. Identification fields in AIRFIELD_PMS_SECTION_DIST (all fields but the distresses) are identical to the corresponding fields in AIRFIELD_PMS_SECTION. Distress fields in AirPAV have a one-to-one correlation with the PCI distress fields defined in the guidelines, although they have different field names. PCI distress components were stored in the Fort Wayne data as attributes that contain quantities of each distress for each section as shown in Figure 5.1. The quantities had to be divided by the area attribute to determine density as specified in the guidelines.

AIRFIELD_PMS_SAMPLE. Sample data was not present in the GIS data set provided as part of AirPAV. Investigation of the flat-file text database indicated that AirPAV stores sample data in summarized form. It appears data concerning sample units are summarized as they are input and the summary data stored. Data elements related to individual sample units could not be identified in the AirPAV database.

AIRFIELD_PMS_CONSTRUCTION. Construction history in AirPAV data consists of 10 free-form text attributes. History1 is most current and History2, History3, etc. are progressively older, as shown in Figure 5.2. The year of construction is shown first in the free-form field, so it was parsed out and translated into the construction date field. The activity is set based on the keywords (such as “OVERLAY” in the description). The oldest history in the data is considered the initial construction of the section. Thicknesses were parsed out as the first thickness shown. AC or PCC was parsed to determine the construction_material. The construction_pms_key was determined by concatenating the feature_id with history1, history2, and history3. Foreign keys were determined as described above. The remaining fields were left null, as they did not seem to correspond to anything in the source data.

Photograph, Event, Slab, and Distress Data Elements. Photograph, event, slab, and distress data were not provided as part of the AirPAV Fort Wayne data set.

Dallas Love Field

Pavement data for Dallas Love Field was provided in MicroPAVER format with spatial data in both AutoCAD and ESRI Shapefile formats. Most data elements in the guidelines corresponded well with the data elements in the MicroPAVER database.

Features.Feature_ID	Features.History1	Features.History2	Features.History3
6215	1997 - 4 1/2" P401 AC OVERLAY ON 0-1 1/2" LEVELING	1942 6" PCC OVERLAY	1941 6" PCC PAVEMENT ON 4" GRANULAR SUBBA
2563	1997 - 4 1/2" P401 AC OVERLAY W/0-1 1/2" AC LEVELING	1942 - 6" PCC OVERLAY	1941 - 6" PCC PAVEMENT ON 4" AGG SUBBASE
712	1997 - 6"+OR- P401 TRANSITION PAVEMENT	1941 - 6-8" PCC PAVEMENT	*
6216	1997 - 4 1/2" P401 AC OVERLAY ON 0-1 1/2" LEVELING	1942 - 7" PCC PAVEMENT ON 17" GRANULAR SUBBASE	*

Figure 5.2. AirPAV history data.

AIRFIELD_PMS_ARP. Network identifying information (network_short_name, network_name, network_pms_key) could each be determined directly from the MicroPAVER database table Network. The network_area was calculated using a query from the MicroPAVER database. The area in MicroPAVER was stored in SI units; it was converted from square meters to square feet (this applies to all measurements in the MicroPAVER database.) As with AirPAV, condition indices were manually calculated as area-weighted averages using the MicroPAVER database; ratings (text descriptions of the condition index) were determined using the appropriate standard. The averaging calculation used the relationship between the tables Network, Branch, Section, and Condition to determine appropriate areas and conditions for the calculation. The climate data foreign key was manually entered as the AWOS station identifier, KDAL.

AIRFIELD_PMS_BRANCH. All of the non-condition data could be copied directly from the MicroPAVER database table Branch. The FAA_key had to be manually calculated and entered. Condition indices were manually calculated as area-weighted averages using the MicroPAVER database, and ratings (text descriptions of the condition index) were determined using the appropriate standard. The averaging calculation used the relationship between the tables Network, Branch, Section, and Condition to determine appropriate areas and conditions for the calculation.

AIRFIELD_PMS_SECTION. Many data elements in AIRFIELD_PMS_SECTION corresponded well to similarly named data elements in the MicroPAVER database table Section, but the area, the structural and construction data, and the condition data did not. The area was calculated from the length, width, and [_Area Adjustment] fields in the MicroPAVER Section table. Section conditions were stored in the Conditions table, which is related to the Section table in MicroPAVER using [_SUniqueID] as a foreign key. The section_constructed could be determined directly from the MicroPAVER Section table, but other information, such as section_maint and section_surface_thick was located in the MicroPAVER Work Tracking table. Manual parsing was required to interpret the construction history and assign appropriate values for pavement layer types and thickness, although a small routine to programmatically parse the data with a relatively high degree of accuracy could be written. This routine would be unique to each database and depend primarily on how construction data were entered. A table for recording pavement layer properties (LayerAndMaterials) contained no data, and would also require parsing in a manner similar to the Work Tracking table to determine layer properties. The database contained no design data (MTOW, gear, and pass level).

AIRFIELD_PMS_SECTION_DIST. AIRFIELD_PMS_SECTION_DIST relies on three tables in the MicroPAVER database: Section, Inspections, and Extrapolated Distresses. Inventory data is determined in the same manner as for AIRFIELD_PMS_SECTION. Distresses are determined by relating the three MicroPAVER tables and filtering the inspections to view only the most recent data for each section. The Extrapolated Distresses table provides a list of distresses in each section and the distress density (AuxReal1). These data were manually transformed from a one-to-many relationship in the database into the defined-list–based format in the guidelines.

AIRFIELD_PMS_SAMPLE. To populate AIRFIELD_PMS_SAMPLE the MicroPAVER database table Samples was joined to Inspections using _INSPUniqueID. This provided the sample ID; PMS key; date; foreign keys for the network, branch, and section; area; surface type; and sample type. Distress data were accessed from the MicroPAVER database table Distresses using _SMPUniqueID as a foreign key. The distresses were transformed in the same manner as for AIRFIELD_PMS_SECTION_DIST. The individual condition indices for sample units were not accessible. The MicroPAVER database contained a table called SampleConditions, but it was empty and appears unused.

AIRFIELD_PMS_SLABS. The MicroPAVER database holds no data on slabs. Attribute data concerning parent entities was calculated using spatial queries (e.g., all slabs located within a section are assigned that section ID and PMS key). Distress data were not detailed enough to assign to individual slabs.

AIRFIELD_PMS_PHOTO. MicroPAVER has the capability to store photographs in a database separate from the pavement data. Data are stored in the same directory as the pavement data in a Microsoft Access-format database named image.iml. The file stores a path to the image location in the local file structure and a section unique ID that can be used to link the images to the pavement database (_ImUniqueID in image.iml, SUniqueID in MicroPAVER). There is also a unique ID for the image that is not compatible with an FAA globally unique ID. The path corresponds to filenpath, and the name or description field appears to correspond to img_narrative. The difference between name and description is not obvious, because of the presence of a path data element.

Photograph data not included in the MicroPAVER database were also provided with the Dallas Love Field data set, and were manually entered to test the data set. The photographs included time and location information as a watermark in the JPG EXIF header. These data were extracted and the location information were used to determine corresponding sample, section, branch, and network. The appropriate identifying information (names and *_pms_keys) were then entered as foreign keys for each photograph.

AIRFIELD_PMS_EVENT. Event data were provided outside of the MicroPAVER PMS database for Dallas Love Field. These data were manually converted into the guidelines format. Three types of events were converted: Coreholes, DCP tests, and HWD tests. These data were respectively stored in the following:

- AIRFIELD_PMS_EVENT_CORES_DAL
- AIRFIELD_PMS_EVENT_DCP_DAL
- AIRFIELD_PMS_EVENT_HWD_DAL

Core results were stored in Microsoft Excel format, with all results on a single worksheet. The worksheet name was used as event_table and the line number was used as the event_foreign_key. The data were unsorted, however, and AIRFIELD_PMS_EVENT did not provide a data element to store the test identifier. The guidelines assumed that the event_foreign_key would be the test identifier, but it was not. For example, the data for corehole 29 was stored on line 2 of the spreadsheet. The data element event_number was changed to capture this data, and event_num_result was added to store simple numeric results of the event. The name of event_text was changed to event_text_result for consistency. The DCP tests were stored in Microsoft Excel format, with each test recorded on a separate worksheet within the workbook. The worksheet name was stored in event_table and event_foreign_key was left null. The HWD tests were stored in both unprocessed text files and semi-processed Excel files. Referencing the Excel file data was straightforward, similar to referencing the corehole data. When referencing the text file, event_table was left null and the line number of the first line of the record was used for event_foreign_key.

Distress. Distress attribute data were provided in the MicroPAVER database, but spatial data were unavailable. To exercise the data set, the attribute data were attached to arbitrary spatial data within the appropriate sample units. Both linear and areal distresses were included. An issue with the conversion was that the primary key for each distress in the MicroPAVER database is not compatible with the FAA Globally Unique ID. Distress names were correct, but importing severity required converting data from H, M, and L into HIGH, MEDIUM, and LOW, respectively. Distress quantities are stored in slabs for PCC and SI units for AC, requiring a conversion to U.S. Customary units. The date on which the distress was recorded was not provided in the distress table; it required joining to the tables SAMPLES and INSPECTIONS to determine the inspection date. MicroPAVER does provide for recording an X-Y coordinate for the distress location, but the database schema calls for UTM coordinates, not latitude/longitude. Elevation data were not present. Distress data are explicitly linked sample units in the MicroPAVER database, making it simple to determine the appropriate identification data for parent features (section, branch, and network). Distresses could not be linked to individual slabs.

AIRFIELD_PMS_CONSTRUCTION. Data for AIRFIELD_PMS_CONSTRUCTION were extracted from the MicroPAVER Work Tracking table as shown in Figure 5.3. Inventory parent section, branch, and network information was available by joining on the appropriate table using the _SUNIQUEID. The thickness appeared to be in millimeters, even though data element to specify material thickness units was set to inches. No place was provided in the MicroPAVER database to store material strength. The MicroPAVER database has a data element for project cost, which is not included in the guidelines.

Metadata. Metadata for the dataset was developed using the ESRI ArcGIS suite of tools, including the ArcCatalog editor. The ESRI tool has a built-in FGDC metadata module, and the appropriate metadata fields were simply accessed and the data entered. To validate the compliance with FGDC-STD-001-1998 standard, *mp-A compiler for formal metadata* (USGS, 2009) was utilized. The *mp* compiler is maintained by the U.S. Geological Survey and is used by many agencies and software vendors to validate the syntax of FGDC metadata. No significant issues were encountered in the entry of metadata. One potential issue that did not occur in the sample data sets was the application of metadata to only specific features within a feature class. The guidelines do not address how to provide a list of features to which the metadata applies (i.e., which data element should be used to uniquely identify a feature). The primary key of each feature class was used to uniquely identify features in a feature class.

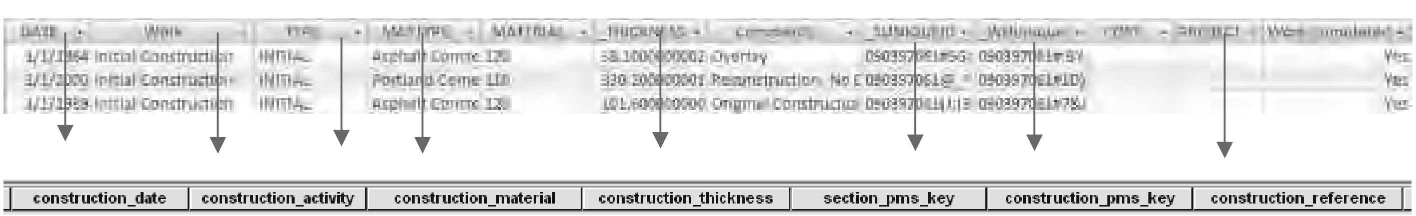

Figure 5.3. MicroPAVER Work Tracking data elements.

Issues with Guidelines and Conversion Process

Several issues were noted during the conversion process from both MicroPAVER and AirPAV database formats.

One issue pertains to the large amount of manual parsing and input required to convert data from a PMS format into the guidelines schema or to import the data from an external source, because of the different structures of each database. The greatest difficulty was encountered with the ancillary data (i.e., data not directly related to pavement size, use, or condition) such as event and photograph data. They add significant value to the data set, but basic PMS functions can be performed without them. These data were not provided as part of the data set, thus making the "conversion" process a data entry process.

While exercising feature classes that involve file paths, it was noted that 100 characters may not be long enough, especially where data may be stored several directories deep. Also, some files, especially photographs, tend to have long filenames as well.

Dallas Love Field presented an unexpected issue because the airfield is divided into three networks. By using the ARP as the spatial representation, this situation results in three networks that have the exact same spatial location, but have different attributes such as area and area-weighted average condition. This creates problems for AIRFIELD_PMS_ARP, which was designed with the assumption of one-to-one correspondence between airfields and networks. The schema cannot attach multiple networks to a single AIRFIELD_PMS_ARP feature. The option of changing the representation from a point to polygons does not allow representation of each airfield at a very large scale (state- or nationwide). Another option is to have co-located geospatial representations of the data (Dallas Love will have three entities in the AIRFIELD_PMS_ARP all at the same location.) The latter option was selected because having multiple networks at a single airfield seems to be a rare occurrence.

When calculating FAA Globally Unique IDs, FAA AC150/5300-18A indicates that the ID is supposed to be a 25-digit number and that numeric equivalents for faaRegion_d, faaLocID_d, featType_d are provided in an appendix. However, the text versions were used.

The AIRFIELD_PMS_PHOTO feature set presented two issues. First, one photograph was located in a sample unit that was not surveyed. This situation led to data in one feature class being tied to non-existent data in another feature class. The known sample ID of the location was entered with the sample_pms_key left null because it does not exist in the database. In addition, when importing photograph data from the image.iml MicroPAVER file, the image unique IDs are not compatible with FAA Globally Unique IDs.

AIRFIELD_PMS_EVENT was designed assuming that the event_foreign_key would also be the "short" name used to reference the event (e.g., corehole 29 would have a primary key value of 29), but this was not always the case. There was no data element to store the short name.

Primary keys that are to be referenced by metadata are not identified in the guidelines.

Recommended Changes to Guidelines

Based on verification, the following changes were made to the guidelines:

- Lengthen all path data elements to a minimum of 255 characters; this should be explicitly recognized as a minimum.
- Add FAA_key to events, distresses, and photographs to allow for PMS-assigned unique IDs.
- Identify the primary key of each feature class in the guidelines.
- Change AIRFIELD_PMS_DISTRESS.distress_date and AIRFIELD_PMS_EVENT.event_date to Text(8).
- Change the data element AIRFIELD_PMS_EVENT.event_number to the format Text(30). This allows the greatest flexibility to retain information concerning named events (corehole B-1, DCP test 37). Add the data element event_num_result to store simple numeric results for events. Change event_text to event_text result for consistency.

CHAPTER 6

Remarks on Implementation

The objective of the research was to develop guidelines that promote the compatibility of PMS and GIS data collected at various organizations. The primary audience of these guidelines consists of engineering and information technology professionals responsible for the preparation of geospatially referenced data related to pavement management. The secondary audience of these guidelines consists of executives and technical managers tasked with ensuring the integration of geospatially referenced pavement management data with other data sets, both from other (non-pavement) disciplines and other organizations. The intended ultimate users of these guidelines are (a) airport owners, who can implement the guidelines; (b) software developers, who can develop tools to manipulate data that adhere to the guidelines; and (c) spatial data vendors, who can follow the guidelines when providing data to airport owners.

These users are familiar with the systems they currently have in place. To aid implementation, the guidelines re-use aspects of the various systems and standards surveyed in order to bring familiarity—for example, keeping data field names similar to those used by existing software packages. Also, the guidelines follow the general contents and format of FAA AC 150/5300-18A to capitalize on audience familiarity with the FAA advisory circulars. This approach will facilitate individual organizations learning the new system, while lowering the cost of implementing the guidelines.

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APPENDIXES A, B, AND C

Unpublished Material

Appendixes A through C are available on the TRB website. To find Appendixes A through C for this report, go to www.trb.org and search for "ACRP Report 39" or see http://www.trb.org/Main/Blurbs/164102.aspx. The titles are as follows:

Appendix A: Survey Questionnaire

Appendix B: Questionnaire Responses

Appendix C: PMS Software Data Elements

ATTACHMENT

Recommended Guidelines for the Collection and Use of Geospatially Referenced Data for Airfield Pavement Management

The proposed guidelines are the recommendations of ACRP Project 9-01 staff at Applied Research Associates, Inc. and CIVIC Engineering, Inc. The guidelines have not been approved or otherwise formally accepted as a standard by ACRP or any other agency.

TABLE OF CONTENTS

SUMMARY: RECOMMENDED GUIDELINES FOR THE COLLECTION AND USE OF GEOSPATIALLY REFERENCED DATA FOR AIRFIELD PAVEMENT MANAGEMENT

RESEARCH SIGNIFICANCE

The collection of data on pavement structure, pavement condition, traffic, climate, maintenance actions, testing and evaluation, and other items is essential for effective management of airfield pavement; such data are regularly collected as part of airfield pavement management systems by many airports across the country. However, the data and information collected by various agencies have often differed in definition and format, making it difficult for others to interpret and use. Also, state-of-the-art technologies and processes applicable to data collection have not been effectively used for collecting airfield management systems data. The use of global positioning systems in developing geospatially referenced data is one of the technologies that will greatly enhance the effectiveness of airfield management systems. Therefore, there was a need to develop guidelines for the collection and use of geospatially referenced data for use in the management of airfield pavements.

These guidelines will promote compatibility of data collected at different facilities; improve integration, interagency sharing, and analysis of data; provide an effective means for economically addressing issues of common concern; and help better manage investments in airfield pavements. The guidelines will also aid organizations in providing a standard schema for display and exchange of spatial Pavement Management System (PMS) data by providing methods and standards for:

- Organizing user interaction with the data.
- Defining data precision and accuracy requirements for data collection and storage.
- Collecting geospatially referenced data.
- Storing geospatially referenced data and linking it to non-geospatially referenced data.
- A data dictionary and framework for geospatially referenced airfield pavement management data and associated metadata.

PROJECT OBJECTIVE AND SCOPE

The objective of this research was to develop guidelines for the collection and use of geospatially referenced pavement-related data for the management of airfield pavements. To accomplish this objective, the research included the following six tasks:

1. Collection and review of relevant information and current practices. The literature review verified that there were no existing standards addressing geospatial PMS data and documented the content and structure of related standards from the aviation, Geographic Information System (GIS), and pavements fields. Research into current and emerging PMS and GIS technologies identified Computer Aided Drafting (CAD), GIS, and Global Positioning System (GPS) as the technologies most likely to be used to develop geospatial PMS data now and in the near future. An interview questionnaire that was sent to various airport operators throughout the country was used to identify the geospatial PMS data that are currently being collected and used. The responses indicated that MicroPAVER is the predominant PMS software in use.

2. Identification and categorization of pavement management system elements that should be included in the guidelines. Based on the results of the airport operators' survey and analysis of the underlying database structure of the various PMS packages used by airport operators, approximately 300 data elements were identified for inclusion in the guidelines. Also, users were divided into categories based on the means for interacting with the PMS and GIS data.
3. Preparation of a plan for developing the guidelines based on the findings of the work performed in previous research activities.
4. Organizing the data elements into feature classes and assigning data definitions that will provide the most portability across PMS software packages.
5. Providing a formal data dictionary and recommending data collection methods in the form of these guidelines.
6. Preparation of the guidelines.
7. Preparation of a project report that documents all research and development performed to support the development of the guidelines. This report is provided as Attachment 1 to guidelines.

SUMMARY OF GUIDELINES

The guidelines are organized into 7 chapters. Chapter 1 is an introduction and provides information concerning purpose, scope, and appropriate use of the guidelines as well as term definitions and references.

Chapter 2 presents the recommended five data user categories: owners, developers, maintainers, administrators, and users. It also identifies the various modes of interaction that different users can have with the data, and provides an overview of the various activities that must be performed to maintain geospatial data.

Chapter 3 specifies data storage methods, focusing primarily on software storage methods. To ensure maximum portability, only six data types are defined as acceptable in these guidelines: three spatial types (points, lines, polygons) and three attribute types (text, numbers, dates). This chapter also defines the Simple Features profile of Geographic Markup Language (GML) as the preferred format for data transfer, and includes provisions for the use of other GIS and CAD formats.

Chapters 4 and 5 specify acceptable precision, accuracy, and collection methods for data elements, which are closely related. Data elements representing pavement entities should be collected using methods defined in Federal Aviation Administration Advisory Circular 150/5300-18 (current version) and meet the precision and accuracy requirements in that standard. Specific collection methods and precision requirements are not defined for non-pavement data elements (e.g., test points and photographs).

Chapter 6 categorizes the approximately 300 data elements included in the guidelines into 10 feature classes and provides data definitions for each. Chapter 7 provides the data definitions for the metadata that should accompany the data elements.

APPLICATION

The guidelines describe methods of collecting spatial data in support of an airfield Pavement Management System (PMS) and organizing the data for integration into a Geographic Information System (GIS) system such that the data may easily shared with other departments and organizations. As such, the guidelines may be used for any airport pavement management project involving spatial data.

The data schema defined in the guidelines is intended for data export to and display in a GIS, and for transfer of PMS data with a spatial aspect among differing organizations. The data elements defined in this report include only the most common PMS data elements that can be displayed in a GIS. Use of the guidelines will help ensure that data elements from any PMS software at any organization will be provided in a consistent manner for transfer or display in a GIS.

ANTICIPATED BENEFITS

The primary anticipated benefit of implementing these guidelines is improved capability to analyze and display pavement management data using GIS. The guidelines provide a standardized means for transferring the spatial aspects of PMS data for both business (financial planning) and technical (engineering analysis) purposes. Practically, these guidelines provide a means to transmit not only tables and reports representing pavement conditions and maintenance needs, but also maps representing PMS data and analyses. It is anticipated that these guidelines will lead to increased data sharing among organizations, resulting in the use of larger data sets for analyzing issues of common concern among the various organizations in the airfield pavement community. In this manner, these concerns can be adequately addressed and resolved.

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1 GENERAL INFORMATION

1.1 INTRODUCTION

The information collected, organized, and stored according to these guidelines can be used in part to complete the following tasks:

- Provide base map data for pavement management systems (PMS) with mapping capabilities.
- Geospatially reference inventory, condition, and other pavement data stored in PMS software systems.
- Record the location of PMS related events such as test points, distresses, or maintenance activities.
- Organize PMS-related geospatial data for efficient analysis.
- Allow efficient exchange of PMS-related geospatial data among organizations.

These guidelines were developed to support surveys and pavement evaluations at airfields.

1.2 SCOPE

The guidelines are intended to provide a data schema and other relevant information required to develop specifications and standards for integrating geospatial data into a PMS. They are compatible with Federal Aviation Administration Advisory Circular 150/5300-18A, but are not promulgated by the FAA. The guidelines are also compatible with the Federal Geographic Data Committee Framework Data Content Model Air Part, which are technically equivalent to the guidelines provided in the advisory circular. These guidelines are also compatible with the Aeronautical Information Exchange Model (AIXM) in the sense that the subject data are not specifically addressed by AIXM and do not violate general AIXM concepts, although metadata requirements for AIXM and these guidelines are slightly different, with AIXM generally more focused on internationalization of data. The guidelines were developed for capturing and organizing spatial data for PMS and integrating it into GIS and Computer Aided Drafting (CAD) systems. Specific topics included in these guidelines are:

- Data user roles and responsibilities.
- Precision and accuracy requirements of spatial data elements.
- PMS-related data elements and definitions.
- PMS-related metadata elements and definitions.
- Methods for associating PMS attribute data with spatial data.
- A schema for organizing, storing, and transporting spatial and attribute data.
- File formats for storing and transporting spatial and attribute data.

The guidelines constitute a complete specification for integrating spatial data into a PMS such that the data can be readily accessed by GIS and CAD programs.

The guidelines address only PMS-specific spatial data elements. Data elements that are related to PMS but typically not collected as part of a pavement management program (e.g., climate or traffic data) are not included in the guidelines. These data elements that are useful in a PMS but not collected for the primary purpose of including in a PMS, and may have a standard schema defined by another organization such as NOAA or the FAA. Integration of these data elements into the PMS data set is accomplished by means of a foreign key. Addition of user-defined data elements to the data schema in these guidelines by an organization is acceptable.

The guidelines are intended for use with airside PMS and GIS systems. Landside pavement management systems and GIS are not addressed; however, many of the principles, schemas, data elements, and recommendations contained in these guidelines may be readily adapted for use in landside applications.

1.3 ANTICIPATED BENEFITS

Use of these guidelines will facilitate more streamlined exchange of geospatial PMS data both within and between organizations and thus enhance the quality and types of analyses available for PMS operators. It should also allow investigating issues of common interest to the airfield pavements community using data from a broad cross section of airfields.

1.4 CONVENTIONS

1.4.1 Compliance Conventions

"Shall" indicates that conformance is mandatory for compliance with these guidelines. "Should" indicates the preferred option.

1.4.2 Terms and Definitions

The following terms and definitions apply:

AC: Advisory Circular.

ACRP: Airport Cooperative Research Program

AIXM: Aeronautical Information Exchange Model

Attribute Data: Information concerning the properties of an object or event other than location or extent.

CAD: Computer Aided Drafting, a computer system used for production of maps, blueprints, and other technical drawings.

CSDGM: Content Standard for Digital Geospatial Metadata, a standard method of transmitting geospatial metadata developed by the FGDC.

Data Element: A piece of information about an object or event, usually corresponding to a database field.

Data Set: A group of related data elements.

Database: A computer system used to store and retrieve information.

DGN: The computer filename extension used to identify MicroStation files; it can also be used to signify any file of that format.

DWG: The computer filename extension used to identify Autodesk AutoCAD files; it can also be used to signify any file of that format.

Event: An entity, procedure, or data for which temporal (time) data are significant.

FAA: Federal Aviation Administration.

FGDC: Federal Geographic Data Committee, an U.S. Federal Government interagency committee that promotes the coordinated development, use, sharing, and dissemination of geospatial data on a national basis.

Field: The named portion of a record in which a particular data element is recorded.

Geodatabase: A database that has the capability to store spatial data.

Georeferenced: An object or event having spatial data that uniquely identify its location or extent on the Earth.

Geospatially Referenced: See "Georeferenced."

GIS: Geographic Information System, a computer system used for producing, organizing, and analyzing spatial and attribute data.

GML: Geographic Markup Language, a subset of XML for storing and transmitting spatial data.

Inherently Spatial Data: Data collected for the primary purpose of storing/analyzing/displaying location information.

Metadata: Data concerning the origin, quality, or use of a dataset, or other information related to a dataset but not part of that dataset.

NOAA: National Oceanic and Atmospheric Administration

Object: An entity or data for which temporal (time) data are not significant.

Record: A complete set of data elements for a single object or event.

ShapeFile: A file format defined by the company ESRI for use in its GIS products.

Spatial Attribute Data: Location data for a data element or record for which location information is not the primary purpose of collecting/storing/analyzing/displaying the data.

Spatial Data: Information that identifies the location or extent of an object or event.

SQL: Structured Query Language, a computer language used to interact with database systems.

UML: Universal Modeling Language, a computer language for representing computer systems, databases, programs, and other software items and processes.

XML: Extensible Markup Language, a computer language for storing and transmitting diverse types of data.

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2 DATA USERS

2.1 PURPOSE OF DEFINING USER CATEGORIES

User categories are defined to allow an organization to more effectively control and use its PMS data. Each user category relates to the data in a different manner, with a unique set of recommended responsibility and authority with respect to the data. These user categories serve the purpose of identifying the tasks required to effectively manage PMS data and to providing a starting point for assigning data access rights (permissions) to the various staff that use PMS data. The user categories defined in these guidelines may also be applied to non-PMS data sets.

2.2 USER DATA CATEGORIES DEFINITIONS

2.2.1 Owners

Owners are responsible for the data, but may not use it in day-to-day operations. The Owner sets data policy (e.g., what types of data should be collected and how often), and then uses the data to make decisions concerning the activities of the organization. Owners typically hold an executive position in an organization. An Owner may be a group, such as a board of aviation, city council, or state aeronautics commission. Owners in this context should not be confused with "owners" in the context of IT administration, in which an owner refers to a person with complete control over a database or file system.

Owners should have read access permission to data sets, but, due to the technical difficulty of manipulating data, should rarely have write access to data sets. Due to the executive nature of the position, Owners typically request complex data analyses and reports from Administrators or other technical staff rather than directly manipulating data. Data are then provided to the Owners in an appropriately summarized format for their review and analysis.

Implementation of the guidelines will make more data available to Owners for pavement management system analysis. Requiring data providers, both in-house and consultant, to follow the guidelines will improve the consistency of data products.

2.2.2 Developers

Developers are responsible for the initial production of a data set, which typically involves collecting field data. Developers are typically called on when a new type of data is required, or a dataset for which an incremental update is inappropriate becomes out of date. Developers typically possess specialized skills and/or equipment for technically sophisticated tasks, such as surveying or production of orthorectified aerial photography. Developers typically hold a technical position (surveyor, engineer, technician, or similar) in an organization or are contractors. Developers should be trained appropriately and/or hold an appropriate certification for the data collection method being used to ensure adequate data quality (e.g., registered land surveyor). Developers should consider the requirements of these guidelines when collecting data in order to provide a complete, accurate data set and to prevent excess post-processing to make the data conform to the guidelines.

Developers should have read and write access rights to a data set, and rarely, to an entire database. The recommended practice is to have the developer create a working data set independent of the actual in-use production database and then merge the new data from the working data set into the production database once it has been verified and checked for quality.

Implementation of the guidelines will reduce the amount of effort required to provide data to Owners because data will be developed to the same standard for different users. Developers will also be able to more easily re-use older data developed by other organizations because data will be provided in a consistent manner regardless of origin.

2.2.3 Administrators

Administrators are responsible for the day-to-day use of the data, including keeping the data secure and up to date. The primary responsibilities of a data Administrator are to maintain data integrity, to control access to the data, and to implement the policies set by the owner. Administrators also oversee and review data provided by developers and maintainers. While Administrators have some responsibility for maintaining the data, these responsibilities are primarily in the information technology and administrative realms. For example, maintenance might include keeping track of the most recent aerial photography and arranging for updates of this particular data according the policies set forth by the Owners or ensuring that the entire database is properly backed up. Administrator duties may be divided between an information technology professional and an engineering professional.

Administrators should have complete read and write access to the entire database, including administrative functions such as setting access permissions for other users. They are responsible for seeing that all users can access the data they require, but still minimize the possibility for corruption of the database. They would be responsible for merging data delivered by a developer into the production database as well as for acquiring data, directly or through developers or maintainers, to provide analyses or reports to Owners.

Implementation of the guidelines will provide uniformity in data presentation and exchange of spatial PMS both within the organization and outside the organization. GIS analysis packages will only need to recognize a single format to use the spatial data; thus eliminating the need to tune the data for display. Data exchanged between the engineering and IT departments or provided by an outside consultant will be treated the same in software, thus reducing the amount of effort required to integrate a dataset into an organizations over GIS.

2.2.4 Maintainers

Maintainers are responsible for performing the database updates. Data maintainers are typically responsible maintaining the detailed technical contents of the database, (e.g., entering the data related to completion of a repair project or work order into the database). This activity differs from the maintenance responsibilities of an Administrator, who is more concerned with the quality of entire data sets and the information technology principles of database and computer maintenance. Maintainers typically hold a technical, clerical, or production position in the maintenance, information technology, or engineering departments of an organization.

Maintainers should have read and write access to limited portions of the database that are required to perform their job functions. Implementation of the guidelines should have very little impact on maintainers.

2.2.5 Users

Users are allowed to view and analyze but not to manipulate data. Users are generally responsible for performing technical analyses and producing charts, tables, and maps for presentation to beneficiaries. Users typically hold technical or maintenance positions within an organization.

Users should have read access to all data sets to allow them to perform complex analysis and reporting functions. Some users will require write access to portions of the database to perform specific analyses, such as performing a time intensive computation and saving the results. It is recommended that users not be given write access to primary data (to prevent accidental corruption of difficult-to-replace primary data) provided by developers or maintainers; however, users may be given write access to secondary data that can be re-computed if corrupted. User access to secondary data is less dangerous, as it may always. Users in a maintenance position use the data to plan specific tasks such as crack sealing or patching.

Implementation of the guidelines will provide uniformity of the data available for analysis. Users will be able to use compliant data from any source without the need to re-map data fields or study the data set dictionary to understand what each data field represents.

2.3 SUGGESTED USER DATA CATEGORY ORGANIZATIONAL CHART

Figure 2.1 shows the suggested organization chart and relationships between the various data user categories. The user categories will not necessarily have a one-to-one correspondence with personnel or departments. In smaller agencies, a single person may fit into multiple categories. For example, the duties of Administrator, maintainer, and user all require similar data manipulation skill sets. However, a large agency may divide responsibilities, (e.g., having multiple data Administrators). For example, Administrator duties may be divided among an IT professional who manages the technical aspects of the database and an engineering professional who manages the data quality aspects of the database and oversees acquisition of new data.

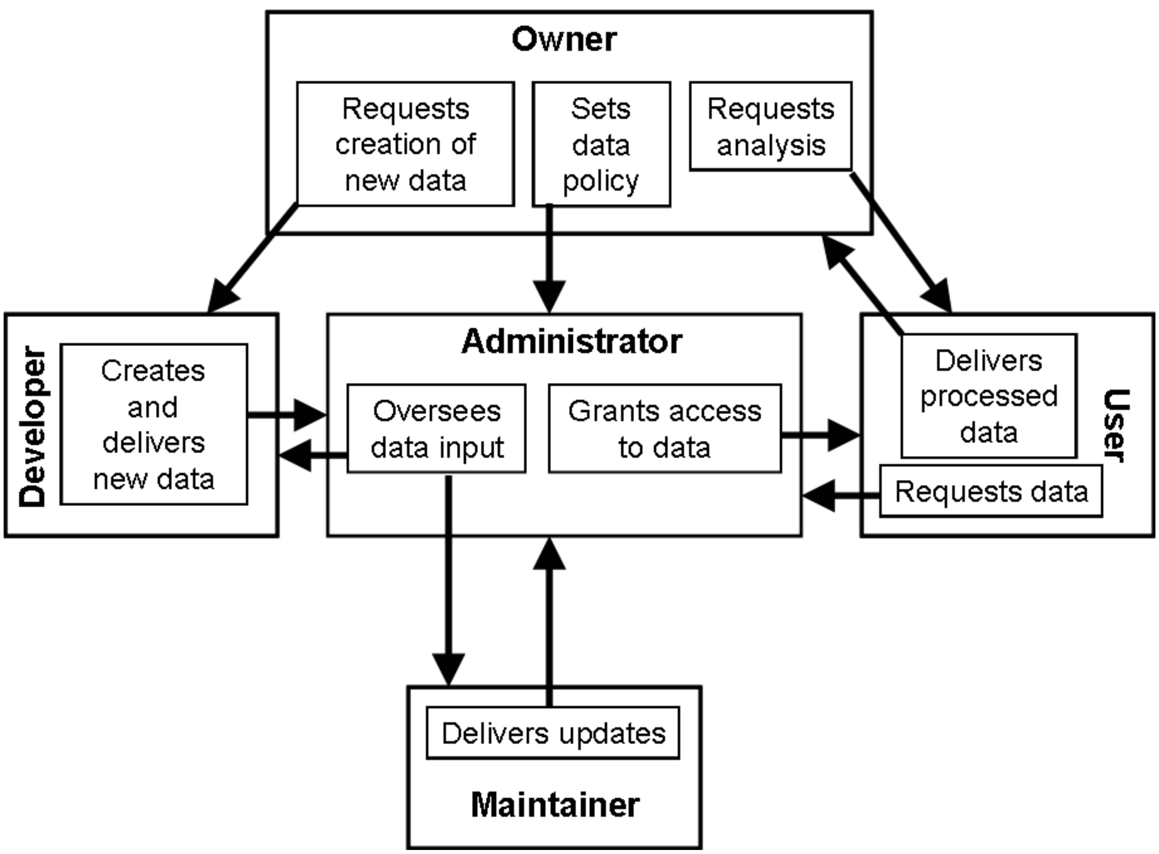

Figure 2.1. Suggested organization chart for the recommended user data categories.

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3 STORAGE METHODS

3.1 DATA REPRESENTATIONS

The number of data representations used in the guidelines has been minimized to increase inter-agency compatibility. Spatial data are represented by points and polygons, and attribute data are represented by numerical data, text data, and temporal (time) data.

3.1.1 Point Data

Point data shall be used to represent objects or events for which extent is not important; that is, a location. A photograph location is a good example of point data. Most test data may be represented by points.

3.1.2 Polyline Data

Polyline data shall be used to represent objects or events which are linear in nature; (i.e., data with a defined starting and stopping point with a path between the two for which the width of the path is not important). Crack location or pavement roughness trace data are examples of polyline data.

3.1.3 Polygon Data

Polygon data shall be used to represent objects with location and extent; (i.e., an area). All pavement and divisions of pavement shall be polygon data.

3.1.4 Numerical Data

Numerical data shall be used to represent only inherently numeric data. These data cannot be represented as anything except a number, such as a length or width. Data that are arbitrarily numeric, such as a pavement rank or sample number, shall be stored as text. In addition to physical properties, some condition data may be represented numerically. All numerical data shall be stored as floating point data. Boolean data shall also be stored as numerical data with 0 being false and non-zero numbers being true.

3.1.5 Text Data

Text data shall be used to represent all descriptive data that is neither inherently numeric nor temporal. This data includes all pavement identification codes for all levels of inventory.

3.1.6 Temporal Data

Temporal data shall be used to represent times. All temporal data shall be capable of storing a 4-digit year (Y2K compliant). Time intervals should be represented by two temporal data elements clearly marked “start” and “end” or similar, as appropriate.

3.2 FILE FORMAT

Data shall be transmitted in a vector representation using Simple Features Profile (formerly Level 0 Profile) of Geographic Markup Language (version 3) (GML) or an equivalent. Equivalent formats must be convertible to GML and back using the import/export tools of commercial off-the-shelf software with no other data manipulation, no loss of spatial data, and no loss of attribute data, including the properties of individual data fields. Raster data (aerial photography) standards are defined in FAA AC 150/5300-17 if required.

The guidelines require the use of GML. However, other data formats, (e.g., personal Geodatabase), are acceptable if both the originating organization and the receiving organization agree on the transmission format and that the data can be provided in GML if requested. In addition, the following formats can be used when submitting data to the FAA in accordance with AC 150/5300-18 if they contain both spatial and attribute data:

- DWG/DXF (Autodesk AutoCAD version 2002 or later)
- SHP (ESRI Shapefile)
- DGN (MicroStation Design File version 8 or later)

The guidelines do not address the format that an organization selects for in-house data storage and manipulation.

3.3 COORDINATE SYSTEMS AND SPATIAL DATUM

Spatial data shall be provided in conformance with FAA AC 150/5300-18 paragraph 9-5.

3.4 USE OF THREE DIMENSIONAL DATA

PMS data representing pavement shall be provided in three dimensions when possible, especially if other datasets collected by an organization are three-dimensional. Derived PMS datasets shall match underlying three-dimensional spatial data. If underlying spatial data are two-dimensional, data may be represented in two dimensions. PMS data representing non-pavement entities (events, distresses, photographs, and construction) shall be three-dimensional when pavement data are three-dimensional. Three dimensional spatial data representing construction data shall represent the top surface of the material layer indicated.

Three dimensional data are desired to provide compatibility with other airfield data sets that are required to be represented in three dimensions by FAA AC 150/5300-18 (current version). Three dimensional data also allows the user to create complex visualizations of construction layers. Three-dimensional data are generally desired; but it is not always available and PMS data currently are often represented in a two-dimensional plan view.

4 PRECISION AND ACCURACY

4.1 ACCURACY REQUIREMENTS

Accuracy is the difference between the location or attribute value of an object and its representation in a dataset. Unless otherwise stated, the minimum accuracy requirements are a 95% confidence level of five (5) feet horizontally and ten (10) feet vertically for airfield pavement elements and other inherently spatial data. Spatial data elements representing pavements or portions thereof shall meet or exceed the accuracy requirements defined in AC 150/5300-18 (current version) Part 1 Chapter 4 and Part 2 Chapter 10. Spatial data that are derived (calculated) from another spatial data set shall meet the accuracy requirements of field-collected data. Spatial data for non-pavement entities collected in the field have no accuracy requirements, but the accuracy of each data set shall be documented in the associated metadata. However, it is expected that non-pavement entity accuracy generally will not exceed the minimum precision of readily available commercial-off-the-shelf consumer GPS receivers. Numerical attribute data representing condition data or test results shall meet the accuracy requirements of the standard defining the test method or condition index. Numerical attribute data representing pavement dimensions derived from inherently spatial data shall meet the same accuracy requirements as the primary data. Temporal data shall have a minimum accuracy of one day unless more precision is required by a test method or other standard defining the data element of which the temporal data is an attribute. Textual attributes shall have accuracy requirements defined by the data set owner, and shall be expressed in terms of percent of records containing an error in any textual data element.

4.2 PRECISION REQUIREMENTS

Precision is the level of repeatability or exactness of the data. Precision has two components: measurement precision and representation precision.

4.2.1 Measurement Precision

Measurement precision is defined as the resolution of the measuring device used to collect data about an object. The precision of all measurements of a data object shall meet or exceed the accuracy requirements for that object. Derived (calculated) data shall not have more precision than the primary (measured) data from which it is developed. Temporal data shall be precise to the nearest day unless more precision is required by a test method or other standard defining the data element of which the temporal data is an attribute.

4.2.2 Representation Precision

Representation precision is defined as the resolution of the storage format, typically vertex spacing for a vector file format, pixel size for raster data, field length for text data, and the number of significant digits for numerical data. Representations of an object shall be capable of storing and displaying the full precision of all measurements of the object.

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5 COLLECTION METHODOLOGIES

5.1 SPATIAL DATA REPRESENTING PAVEMENT

The acceptable methods of data collection for spatial data entities listed, in order of preference are as follows.

1. Collection according to the methods described in FAA AC 150/5300-17 and FAA AC 150/5300-18 (current version) 7-1 and 7-2. These methods are field surveying and feature extraction from a stereo model.
2. Editing a data set collected according to the methods described in FAA AC 150/5300-17 and FAA AC 150/5300-18 (current version). This can include subdividing existing features or adding new features. If new features are added, the data set may only be used for PMS applications.
3. Feature extraction from georeferenced orthorectified aerial photography.
4. Editing existing data sets, such as Architectural/Engineering drawings.

Methods 3 and 4 may only be used for data sets used exclusively in PMS.

5.2 SPATIAL DATA REPRESENTING NON-PAVEMENT ENTITIES

There are no restrictions placed on the collection and development of spatial data representing events, except that the method used to collect the data and a determination or estimation of precision shall be provided in the metadata for the data set. If the data are derived data, the precision of the primary data set also shall be provided. For example, if photograph locations are recorded using dead reckoning methods and marked on a map, the metadata should state in the Data_Quality_Information Positional_Accuracy fields the accuracy of the spatial data, and then note in the Data_Quality_Information Lineage field that the data were collected using dead reckoning and also list the base map used in the dead reckoning process.

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6 DATA FRAMEWORK

Spatial PMS data are divided into nine record sets. Record set names are to be appended with the FAA airport identifier code. For example, the Airport Reference Point dataset for John F. Kennedy International Airport in New York City, New York would be named AIRFIELD_PMS_ARP_JFK. The primary key of each feature class is indicated in **boldface** type.

Foreign keys may be added to any feature class to incorporate data that are related to PMS but not primarily PMS data (e.g., climate and traffic). Climate data is a good example of this type of data. Climate data are important to pavement management, but not collected primarily for the purpose of pavement management. As such, standards and systems for storage of climate data already exist. A foreign key for climate data has been included in the AIRFIELD_PMS_ARP feature class to access this data. For example, the AWOS station identification of an AWOS station near an airfield could be stored as the climate data foreign key. Database links or joins then use the foreign key to access the AWOS system and retrieve climate and weather information about the airport.

6.1 UML REPRESENTATION

Figures 6.1 and 6.2 present the data framework, illustrating data types and entity relationships in UML format. The nomenclature “1…*” in a relational UML chart indicates a “one-to-many” relationship between feature classes, meaning that a single feature in one feature class may be related to multiple features in another feature class (a single branch can contain multiple sections). The symbol  in a feature definition UML chart indicates inheritance, or that properties of the parent feature class are transferred to the child feature class unless explicitly changed.

Figure 6.1 defines which data types that each feature class may consist of. In UML, this is done by defining top-level feature classes for each geometry type, and then specifying from which domains a feature class is allowed to inherit. General users will rarely if ever encounter or use these top-level features. In general, entities representing pavement defined using polygons or surfaces, photos and the airport reference point are defined using a point, and distresses and events may use points, polygons/surfaces, or lines.

Figure 6.2 defines the relationship of each feature class to the other feature classes. While each feature class is designed to be complete and independent data set, there are real world relationships between the entities each feature class represents, such as airports are divided into branches, which are in turn divided into sections, which are further divided into samples. The data schema is designed to organize data using these relationships. Each feature class contains at least one foreign key to define the parent feature of a particular entity, as shown in Figure 6.2.

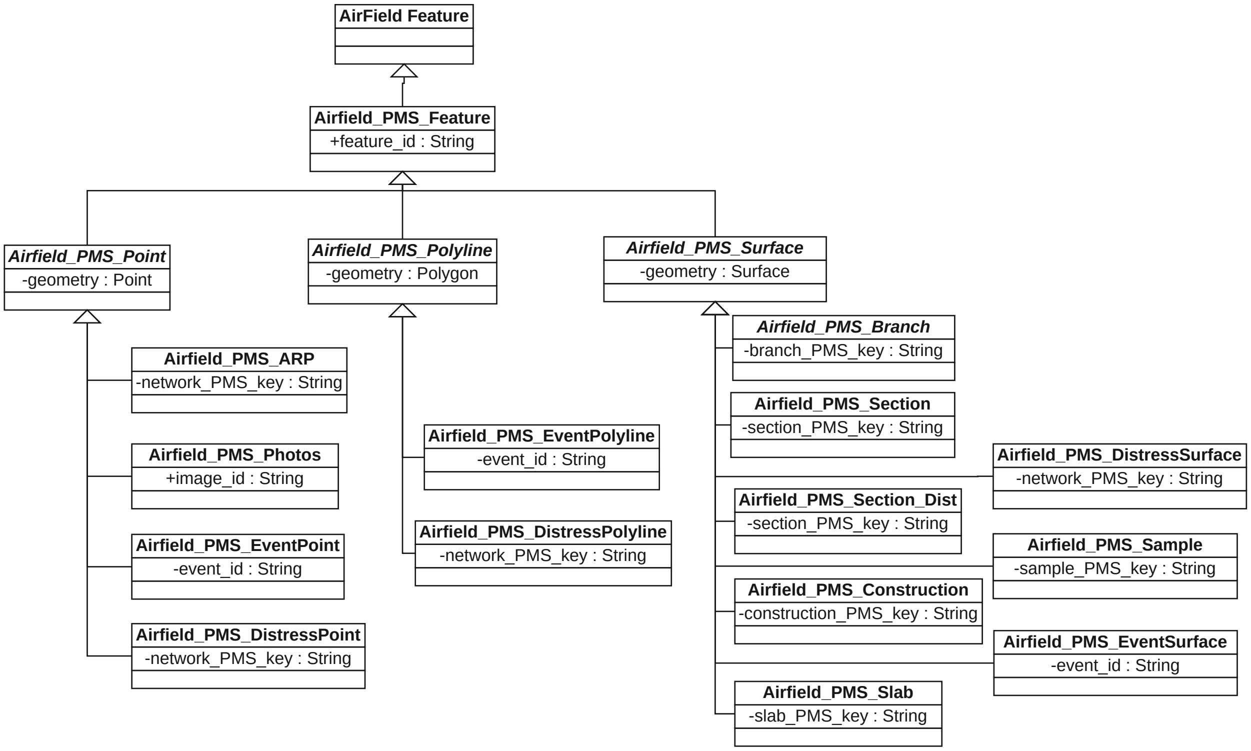


Figure 6.1. Data framework features in UML format.

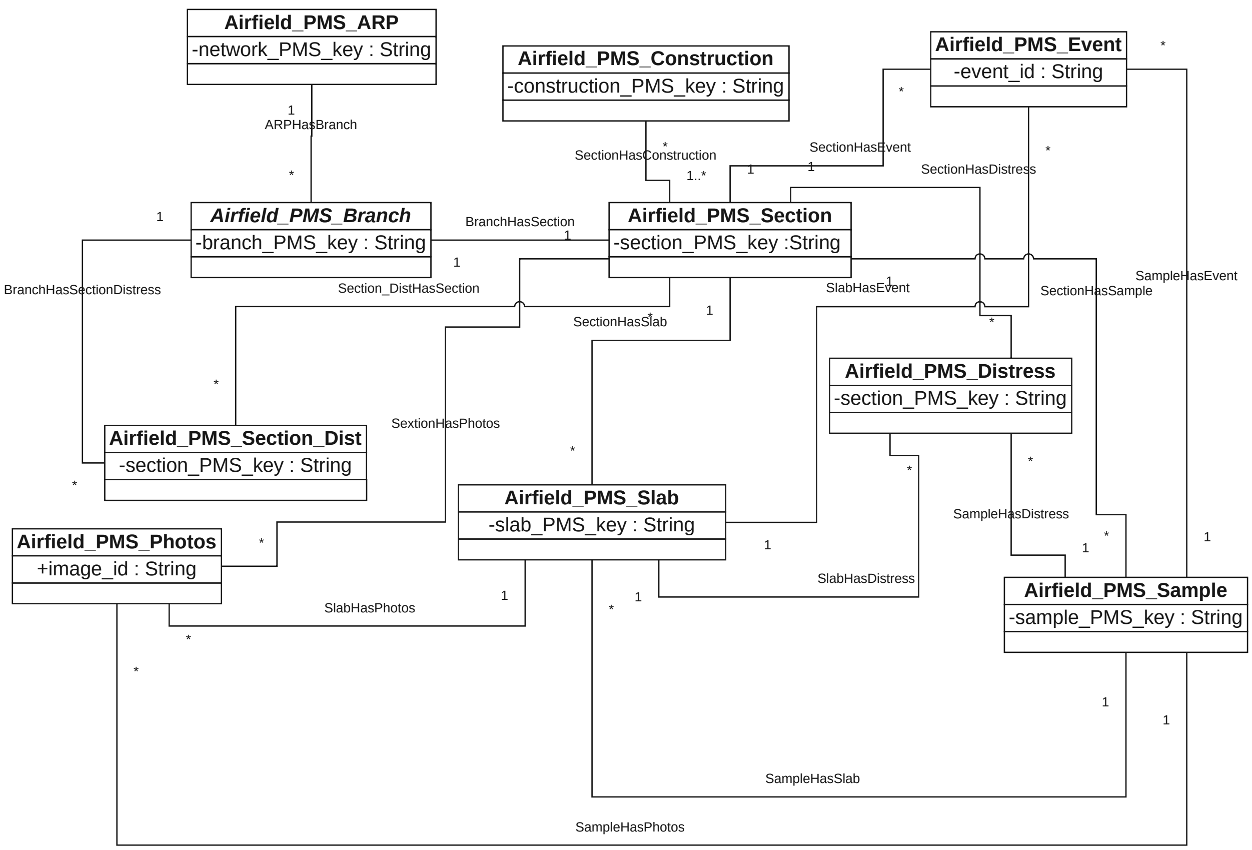


Figure 6.2. Data framework feature relationships in UML format.

6.2 AIRPORT REFERENCE POINT

Name: AIRFIELD_PMS_ARP

Definition: A point representing the location of the airfield, intended for large-scale analysis, such as viewing all the airfields in a state at once.

Sensitivity: Unclassified.

FAA AC 150/5300-18A Equivalent: Airport Reference Point.

SDS Entity Equivalent: airfield_surface_site

Geometry: Point

Requirements: Each airfield shall have one point representing the airfield location.

Data Capture Rule: The airport reference point shall be determined according to FAA AC 150/5300-18 (CURRENT VERSION) Appendix 2 Section 2-1. Attribute data shall be averages or other aggregated attribute data of pavement divisions in the airport.

Attributes:

Attribute	Data Type	Minimum Length	Definition
network_short_name	Text	10	Network ID or short name
network_name	Text	60	Network name
network_pms_key	Text	20	Primary key from PMS database network table
network_area	Number	Float	Total area in the network in square feet.
network_pci	Number	Float	Area-weighted average PCI from ASTM D5340
network_pcr7	Text	10	Seven-category PCR from ASTM D5340
network_pcr3	Text	4	Three-category PCR from ASTM D5340
network_paser	Number	Float	Area-weighted average PASER rating from FAA AC 150/5320-17
network_fod	Number	Float	Area-weighted average FOD index. Specify calculation method in metadata
network_friction_index	Number	Float	Friction index, from mu-meter or similar. Specify collection method in metadata.
network_friction_rating	Text	4	Friction rating, from USAF ETL 04-09
network_pcn_value	Number	Float	PCN from AC 150/5335-5 (civil) or PCASE (military). Specify roll-up method in metadata.
network_pcn_descriptor	Text	4	Letters after the PCN numerical value from AC 150/5335-5 (civil) or PCASE (military), e.g., R/A/W/T for rigid pavement on subgrade strength A with unlimited tire pressure determined by technical evaluation
network_ea	Text	14	Engineering assessment from ETL 04-09
network_climate	Text	20	Climate data foreign key. Specify source in metadata.

6.3 BRANCH LOCATION

Name: AIRFIELD_PMS_BRANCH

Definition: The location of each portion of pavement with a specific use, as shown in Figure 6.3. Branches are generally named portions of pavement, e.g., Runway 09/27, Taxiway A, or Air Cargo Apron.

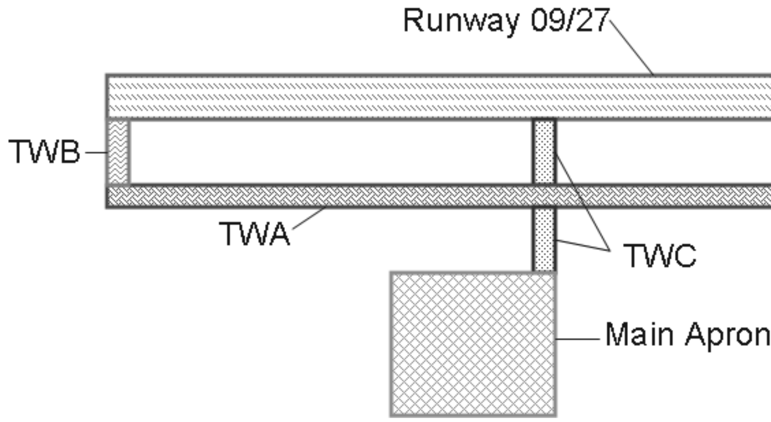


Figure 6.3. Branch Location definition.

Sensitivity: Restricted.

FAA AC 150/5300-18A Equivalents: Runway, Stopway, Helipad TLOF, Taxiway Segment, Taxiway Intersection, Apron, Runway Blastpad, Shoulder.

SDS Entity Equivalent: airfield_surface_site.

Geometry: Polygon.

Requirements: Each pavement branch shall be collected as a polygon or group of polygons. Branches shall correspond with branches defined in the PMS.

Data Capture Rule: Adjoining polygons shall be collected with collocated or shared vertices and edges. Branch location data should be collected by field surveying or remote sensing methods. Branch location data may consist of derived data developed by combining polygons from the section location data set. Attribute data shall be averages or other aggregated attribute data of pavement divisions in the branch. Aggregation method shall be specified in associated metadata.

Attributes:

Attribute	Data Type	Minimum Length	Definition
branch_short_name	Text	10	Branch ID or short name
branch_name	Text	50	Branch name
branch_pms_key	Text	20	Primary key from PMS database branch table
FAA_key	Text	25	Globally unique FAA primary key defined in AC 150/5300-18A 9-3-2
branch_area	Number	Float	Total area in the branch in square feet.
branch_use	Text	8	Branch use: APRON, HELIPAD, OVERRUN, RUNWAY, TAXIWAY.
network_short_name	Text	10	Short name of parent network.
network_pms_key	Text	20	Primary key of parent network from PMS database.
branch_area	Number	Float	Total area in the branch in square feet.
branch_pci	Number	Float	Area-weighted average PCI from ASTM D5340.
branch_pcr7	Text	10	Seven-category PCR from ASTM D5340.
branch_pcr3	Text	4	Three-category PCR from ASTM D5340.
branch_paser	Number	Float	Area-weighted average PASER rating from FAA AC 150/5320-17

Attribute (continued)	Data Type	Minimum Length	Definition
branch_fod	Number	Float	Area-weighted average FOD index. Specify calculation method in metadata.
branch_friction_index	Number	Float	Friction index, from mu-meter or similar. Specify collection method in metadata.
branch_friction_rating	Text	4	Friction rating, from USAF ETL 04-09.
branch_pcn_value	Number	Float	PCN from AC 150/5335-5 (civil) or PCASE (military)
branch_pcn_descriptor	Text	4	Letters after the PCN numerical value from AC 150/5335-5 (civil) or PCASE (military), e.g., R/A/W/T for rigid pavement on subgrade strength A with unlimited tire pressure determined by technical evaluation
branch_ea	Text	14	Engineering assessment from ETL 04-09

6.4 SECTION LOCATION

Name: AIRFIELD_PMS_SECTION

Definition: The location of each portion of pavement that is unique with respect to construction history and use, shown in Figure 6.4. Attribute data describes pavement structure, condition, and use.

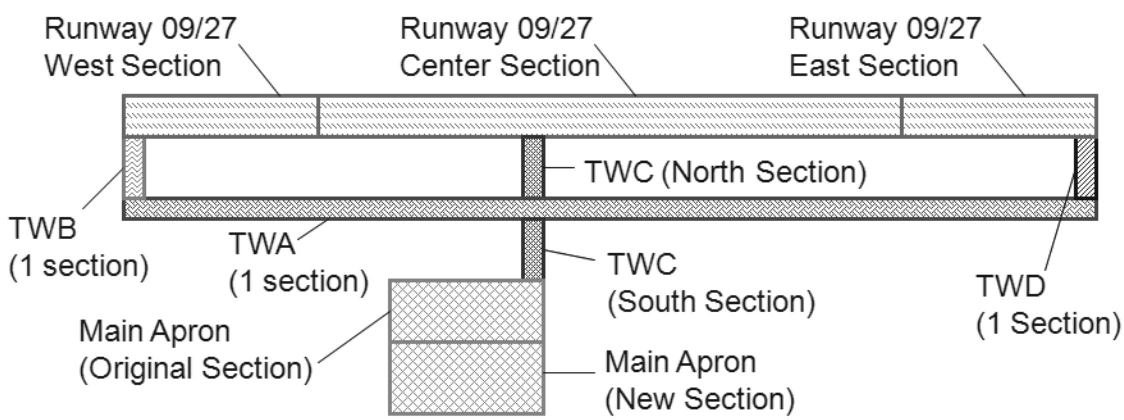


Figure 6.4. Section Location definition.

Sensitivity: Restricted.

FAA AC 150/5300-18A Equivalent: PavementSection.

SDS Entity Equivalent: airfield_surface_site

Geometry: Polygon.

Requirements: Each pavement section shall be collected as a polygon or group of polygons. Sections shall correspond with sections defined in the PMS. Groups of polygons (multipart polygons) shall be used when a pavement section is non-contiguous (e.g., a group of parking pads or hard stands that make up a single section).

Data Capture Rule: Adjoining polygons shall be collected with collocated or shared vertices and edges. Section location data should be collected by field surveying or remote sensing methods. Data collection shall be as specified for the parent branch in FAA 150/5300-18A, except that accuracy requirements are relaxed to 5 feet horizontally and 10 feet vertically unless the data will be used for applications other than PMS. Section data may consist of derived data developed from a branch location data set by dividing polygons appropriately. Attribute data should be developed from existing record sets such as as-built drawings and from field investigations such as bore holes and pavement evaluation surveys.

Attributes:

Attribute	Data Type	Minimum Length	Definition
section_id	Text	10	Section ID or short name
section_pms_key	Text	20	Primary key from PMS database section table
FAA_key	Text	25	Globally unique FAA primary key defined in AC 150/5300-18A 9-3-2
branch_short_name	Text	10	Branch ID of pavement branch
branch_pms_key	Text	20	Primary key of parent branch from PMS database
network_short_name	Text	10	Short name of parent network
network_pms_key	Text	20	Primary key of parent network from PMS database
section_area	Number	Float	Area in the section in square feet.
section_use	Text	8	Branch use: APRON, HELIPAD, OVERRUN, RUNWAY, TAXILANE, TAXIWAY
section_rank	Text	1	Pavement PMS priority (Primary, Secondary, Tertiary)
section_pms_surface	Text	3	Surface type for purposes of condition survey.
section_constructed	Date		Date section was constructed
section_maint	Date		Date section was last maintained
section_insp_date	Date		Date section was last inspected
section_ol	Text	5	Overlay type: AC, PCC, or item identifier from AC 5300-10A.
section_ol_thick	Number	Float	Overlay thickness in inches
section_surface	Text	5	Original surface type: AC, PCC, or item identifier from AC 5300-10A.
section_surface_thick	Number	Float	Original surface thickness in inches
section_base	Text	5	Base material: GRAN for unspecified granular base or item identifier from AC 5300-10A
section_base_thick	Number	Float	Base thickness in inches
section_subbase	Text	5	Subbase material: GRAN for unspecified granular subbase or item identifier from AC 5300-10A
section_subbase_thick	Number	Float	Subbase thickness in inches
section_subgrade	Text	5	USCS soil classification of subgrade
section_subgrade_strength	Number	Float	Subgrade strength CBR or k-value
section_subgrade_unit	Text	3	“CBR” for strengths expressed as CBR or “PCI” for strengths expressed as k-values or PSI for moduli
section_design_gear	Text	5	Gear designation from FAA Order 5300.7 of design aircraft landing gear.
section_design_mtow	Number	Float	Maximum take-off weight of design aircraft
Section_design_passes	Number	Float	Design passes for design aircraft
section_pci	Number	Float	Area-weighted average PCI from ASTM D5340
section_pcr7	Text	10	Seven-category PCR from ASTM D5340
section_pcr3	Text	4	Three-category PCR from ASTM D5340
section_paser	Number	Float	Area-weighted average PASER rating from FAA AC 150/5320-17
section_fod	Number	Float	Area-weighted average FOD index. Specify calculation method in metadata

Attribute (continued)	Data Type	Minimum Length	Definition
section_friction_index	Number	Float	Friction index, from mu-meter or similar. Specify collection method in metadata.
section_friction_rating	Text	4	Friction rating, from USAF ETL 04-09
section_pcn_value	Number	Float	Numerical PCN value from AC 150/5335-5 (civil) or PCASE (military)
section_pcn_descriptor	Text	4	Letters after the PCN numerical value from AC 150/5335-5 (civil) or PCASE (military), e.g., R/A/W/T for rigid pavement on subgrade strength A with unlimited tire pressure determined by technical evaluation
section_ea	Text	14	Engineering assessment from ETL 04-09
section_traffic	Text	20	Foreign key referencing traffic records.

6.5 SECTION DISTRESSES

Name: AIRFIELD_PMS_SECTION_DIST

Definition: The location of each portion of pavement that is unique with respect to construction history and use. The geospatial aspect of the data is identical to Section Location, shown in Figure 6.4. Attribute data describes distresses present on the pavement surface collected using the PCI (ASTM D5340) or PASER (AC 150/5320-17) methods.

Sensitivity: Restricted.

FAA AC 150/5300-18A Equivalent: None.

SDS Entity Equivalent: airfield_surface_site

Geometry: Polygon.

Requirements: Each pavement section shall be collected as a polygon or group of polygons. Sections shall correspond with sections defined in the PMS

Data Capture Rule: Adjoining polygons shall be collected with collocated or shared vertices and edges. Data collected in the field shall be collected as specified for the parent branch in FAA 150/5300-18A, except that accuracy requirements are relaxed to 5 feet horizontally and 10 feet vertically unless the data will be used for applications other than PMS. Section data may consist of derived data developed from a branch location data set by dividing polygons appropriately. Attribute data should be developed from field investigations such as pavement evaluation surveys. Distress density (distress quantity divided by section area) provides an estimate of each type of distress in a pavement section, and may be directly measured or can be calculated as the area-weighted average of the distress density of sample units in a pavement section.

Attributes: Distress attribute fields are the distress density for the entire section.

Attribute	Data Type	Minimum Length	Definition
section_id	Text	10	Section ID or short name
section_pms_key	Text	20	Primary key from PMS database section table
FAA_key	Text	25	Globally unique FAA primary key defined in AC 150/5300-18A 9-3-2
branch_short_name	Text	10	Branch ID of pavement branch
pms_key	Text	20	Primary key of parent branch from PMS database
network_short_name	Text	10	Short name of parent network
network_pms_key	Text	20	Primary key of parent network from PMS database
section_area	Number	Float	Area in the section in square feet.
section_use	Text	8	Branch use: APRON, HELIPAD, OVERRUN, RUNWAY, TAXILANE, TAXIWAY
section_rank	Text	10	Pavement PMS priority (Primary, Secondary, Tertiary)
section_insp_date	Date		Date the section was inspected.
DISTRESS ATTRIBUTE FIELDS IN PARAGRAPH 6.12 INCORPORATED BY REFERENCE			

6.6 SAMPLE UNIT LOCATION

Name: AIRFIELD_PMS_SAMPLE

Definition: The location of pavement section subdivisions used to reduce the effort required to perform a condition survey, shown in Figure 6.5. Sample units are smallest discrete unit of AC pavement in a PMS.

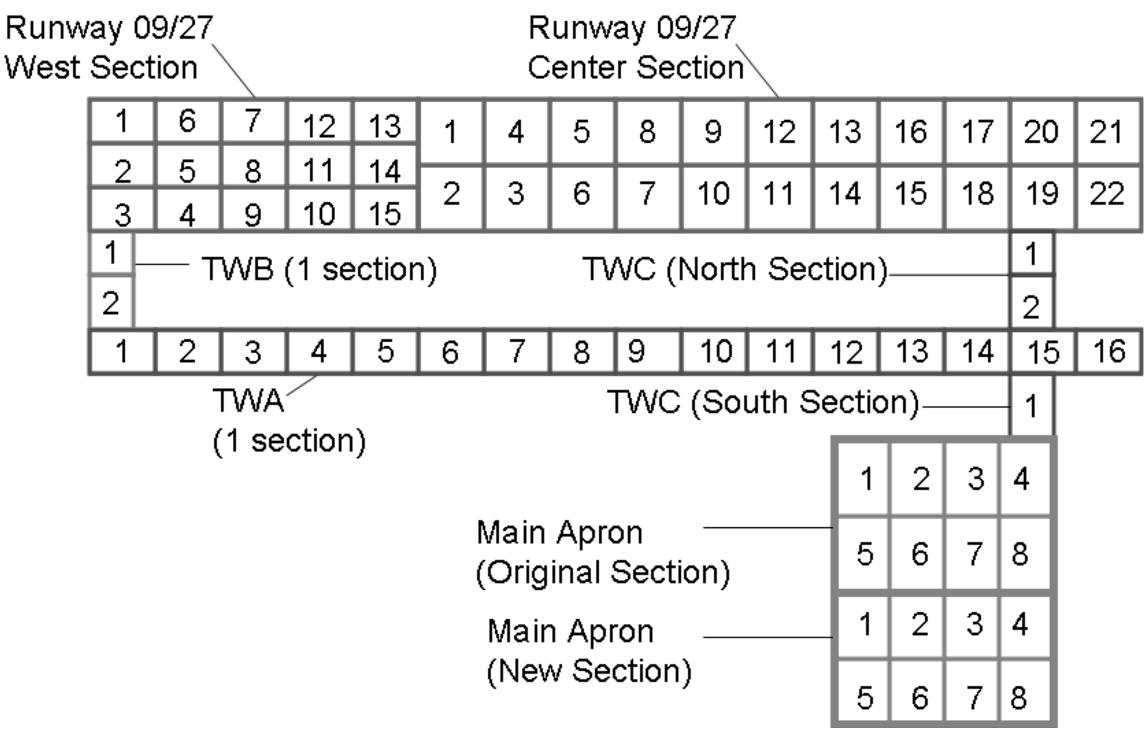


Figure 6.5. Sample Unit Location definition.

Sensitivity: Restricted.

FAA AC 150/5300-18A Equivalent: None.

SDS Entity Equivalent: airfield_surface_site

Geometry: Polygon.

Requirements: Each sample unit should be collected as a polygon or group of polygons.

Data Capture Rule: Adjoining polygons shall be collected with collocated or shared vertices and edges. Data collected in the field shall be collected as specified for the parent branch in FAA 150/5300-18A, except that accuracy requirements are relaxed to 5 feet horizontally and 10 feet vertically unless the data will be used for applications other than PMS. Dead reckoning methods are acceptable when locating sample units. Sample unit data may consist of derived data developed from a section location data set by dividing polygons appropriately.

Attributes:

Attribute	Data Type	Minimum Length	Definition
sample_id	Text	10	Sample ID
sample_pms_key	Text	20	Primary key (from PMS database sample table if available)
sample_date	Date		Date sample was inspected
section_id	Text	10	Section ID of parent section
section_pms_key	Text	20	Primary key of parent section from PMS database
branch_short_name	Text	10	Branch ID of parent branch
branch_pms_key	Text	20	Primary key of parent branch from PMS database
network_short_name	Text	10	Short name of parent network
network_pms_key	Text	20	Primary key of parent network from PMS database
sample_area	Number	Float	Area in the section in square feet for AC surfaced and slabs for PCC surfaces.
Sample_pms_surface	Text	8	Sample surface at time of inspection
sample_type	Text	10	Sample is a RANDOM or ADDITIONAL sample
sample_pci	Number	Float	Sample PCI from ASTM D5340
sample_pcr7	Text	10	Seven-category PCR from ASTM D5340
sample_pcr3	Text	4	Three-category PCR from ASTM D5340
section_fod	Number	Float	Sample FOD index. Specify calculation method in metadata
DISTRESS ATTRIBUTE FIELDS IN PARAGRAPH 6.12 INCORPORATED BY REFERENCE			

6.7 SLAB LOCATION

Name: AIRFIELD_PMS_SLAB

Definition: The location of each PCC pavement slab on the airfield. Slabs are the smallest discrete unit of PCC pavement in a PMS, as shown in Figure 6.6.

Sensitivity: Restricted.

FAA AC 150/5300-18A Equivalent: None.

SDS Entity Equivalent: airfield_surface_site

Geometry: Polygon.

Requirements: Each slab should be collected as a polygon.

Data Capture Rule: Adjoining polygons shall be collected with collocated or shared vertices and edges. Data collected in the field shall be collected as specified for the parent branch in FAA 150/5300-18A, except that accuracy requirements are relaxed to 5 feet horizontally and 10 feet vertically unless the data will be used for applications other than PMS. Slab data may consist of derived data developed from a section location data set by dividing polygons appropriately.

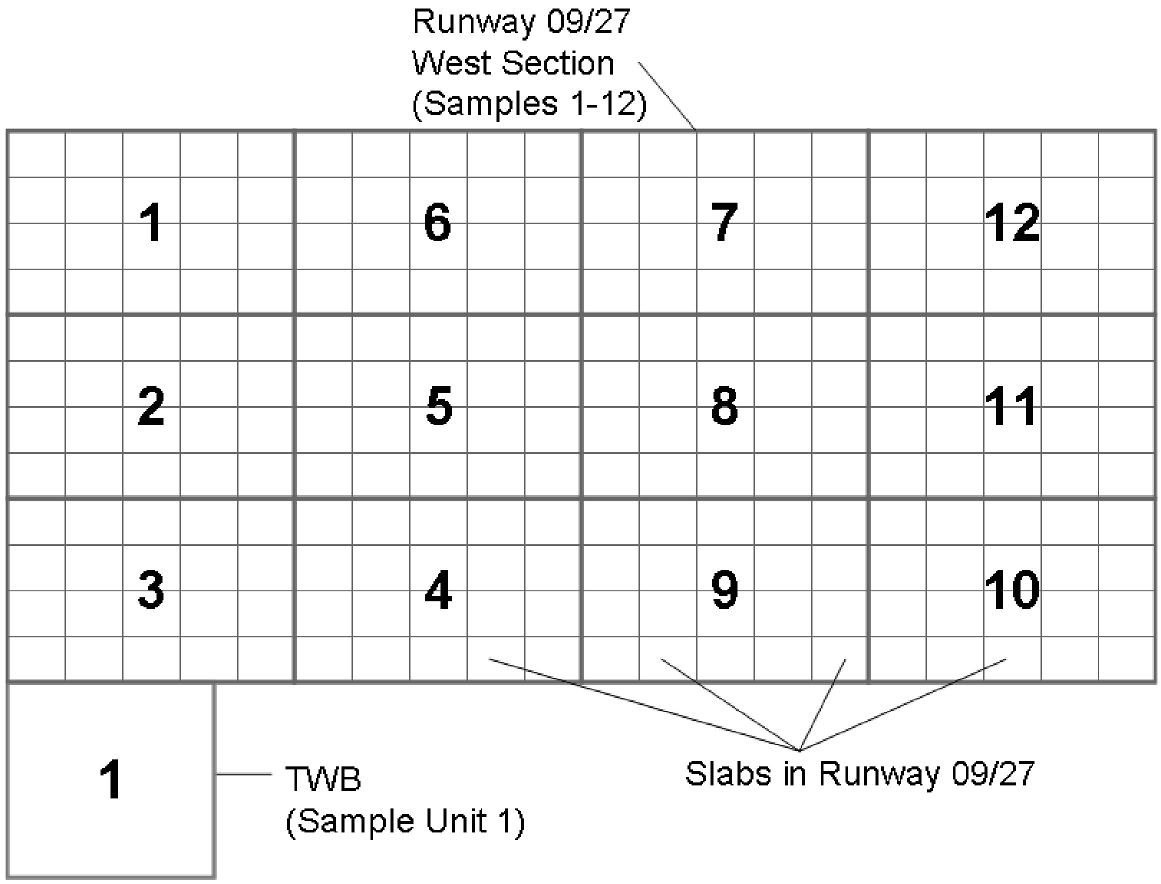


Figure 6.6. Slab Location definition.

Attributes:

Attribute	Data Type	Minimum Length	Definition
slab_id	Text	10	Slab ID
slab_pms_key	Text	20	Primary key (from PMS database slab table if available)
sample_date	Date		Date sample was inspected
sample_id	Text	10	Sample ID of parent sample
sample_pms_key	Text	20	Primary key of parent sample from PMS database
section_id	Text	10	Section ID of parent section
section_pms_key	Text	20	Primary key of parent section from PMS database
branch_short_name	Text	10	Branch ID of pavement branch
branch_pms_key	Text	20	Primary key of parent branch from PMS database
network_short_name	Text	10	Short name of parent network
network_pms_key	Text	20	Primary key of parent network from PMS database

Attribute (continued)	Data Type	Minimum Length	Definition
blowup_low	Number	Float	Low-severity blowups present on slab.
Blowup_medium	Number	Float	Medium-severity blowups present on slab.
Blowup_high	Number	Float	High-severity blowups present on slab.
Corner_break_low	Number	Float	Low-severity corner breaks present on slab.
Corner_break_medium	Number	Float	Medium-severity corner breaks present on slab.
Corner_break_high	Number	Float	High-severity corner breaks present on slab.
Ltd_crack_low	Number	Float	Low-severity LTD cracking present on slab.
Ltd_crack_medium	Number	Float	Medium-severity LTD cracking present on slab.
Ltd_crack_high	Number	Float	High-severity LTD cracking present on slab.
D_crack_low	Number	Float	Low-severity durability cracking present on slab.
D_crack_medium	Number	Float	Medium-severity durability cracking present on slab.
D_crack_high	Number	Float	High-severity durability cracking present on slab.
Jsd_low	Number	Float	Low-severity joint seal damage present on slab.
Jsd_medium	Number	Float	Medium-severity joint seal damage present on slab.
Jsd_high	Number	Float	High-severity joint seal damage present on slab.
Mi_cracking	Number	Float	Manhole and inlet cracking present on slab.
Patch_small_low	Number	Float	Low-severity small patching present on slab.
Patch_small_medium	Number	Float	Medium-severity small patching present on slab.
Patch_small_high	Number	Float	High-severity small patching present on slab.
Patch_large_low	Number	Float	Low-severity large patching present on slab.
Patch_large_medium	Number	Float	Medium-severity large patching present on slab.
Patch_large_high	Number	Float	High-severity large patching present on slab.
Popouts	Number	Float	Popouts present on slab.
Potholes	Number	Float	Polishing present on slab.
Polishing	Number	Float	Potholes present on slab.
Pumping	Number	Float	Pumping present on slab.
Scaling_low	Number	Float	Low-severity scaling present on slab.
Scaling_medium	Number	Float	Medium-severity scaling present on slab.
Scaling_high	Number	Float	High-severity scaling present on slab.
Faulting_low	Number	Float	Low-severity faulting present on slab.
Faulting_medium	Number	Float	Medium-severity faulting present on slab.
Faulting_high	Number	Float	High-severity faulting present on slab.
Shattered_slab_low	Number	Float	Low-severity shattered slab.
Shattered_slab_medium	Number	Float	Medium-severity shattered slab.
Shattered_slab_high	Number	Float	High-severity shattered slab.
Shrinkage_crack	Number	Float	Shrinkage cracks present on slab.
Spall_joint_low	Number	Float	Low-severity joint spalling present on slab.
Spall_joint_medium	Number	Float	Medium-severity joint spalling present on slab.
Spall_joint_high	Number	Float	High-severity joint spalling present on slab.
Spall_corner_low	Number	Float	Low-severity corner spalling present on slab.
Spall_corner_medium	Number	Float	Medium-severity corner spalling present on slab.
Spall_corner_high	Number	Float	High-severity corner spalling present on slab.

6.8 PHOTOGRAPH LOCATION

Name: AIRFIELD_PMS_PHOTO

Definition: The location where a photograph was taken.

Sensitivity: Restricted.

FAA AC 150/5300-18A Equivalent: None.

SDS Entity Equivalent: photograph_location_point

Geometry: Point.

Requirements: Collect the location of each photograph taken.

Data Capture Rule: Point location and photograph direction the camera is facing shall be collected for each photograph. Dead reckoning is an acceptable method of obtaining the photograph location.

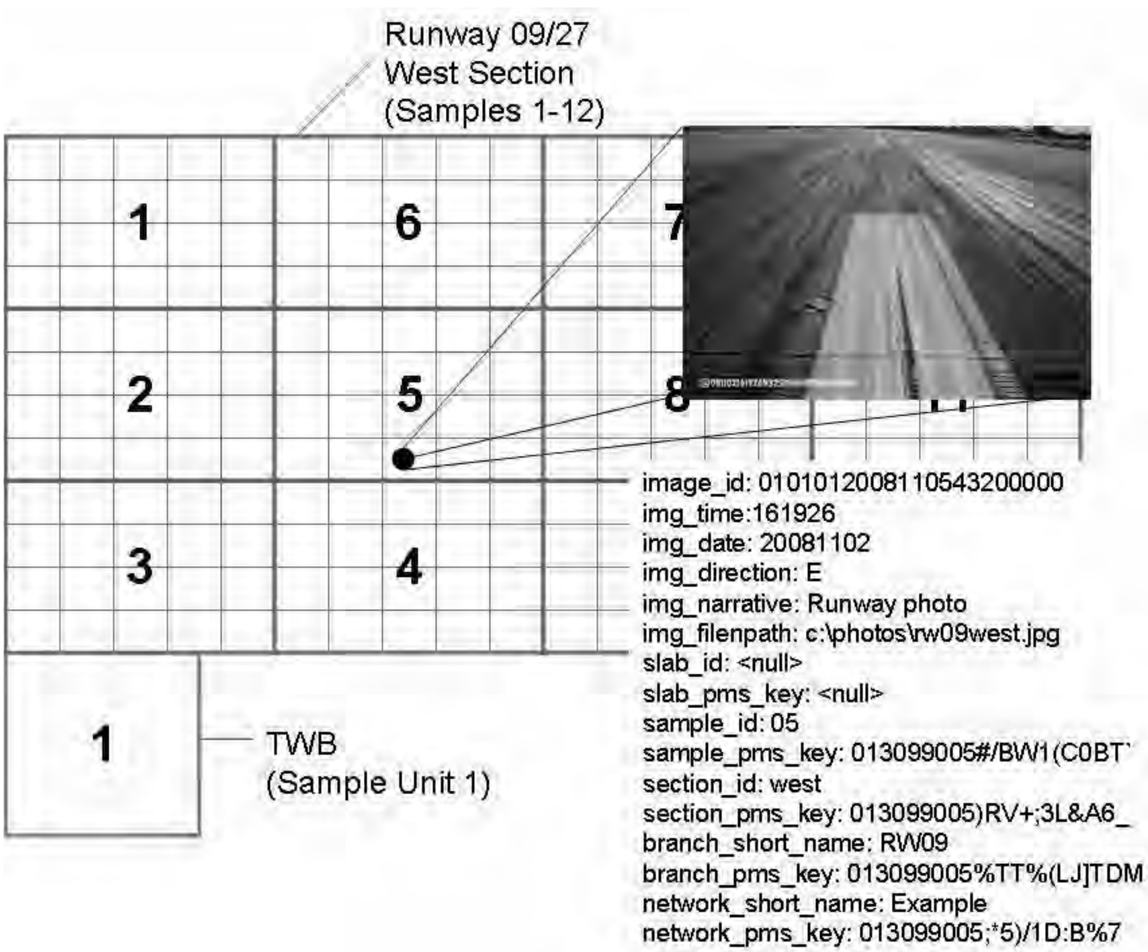


Figure 6.7. Photograph Location definition.

Attributes:

Attribute	Data Type	Minimum Length	Definition
image_id	Text	100	Primary key (from PMS database if available)
FAA_key	Text	25	Globally unique FAA primary key defined in AC 150/5300-18A 9-3-2
img_time	Text	6	Time of day the image was taken in 24-hour clock units Format for time of day is HHMMSS. Use the standard 24 hour clock.
Img_date	Text	8	The date the photo was taken. Format for date is YYYYMMDD (i.e., September 15, 1994 = 19940915).
Img_direction	Text	3	Direction the camera was facing when the photograph was collected. Use compass heading (045) or compass points (NE).
img_narrative	Text	240	A description or other unique information concerning the subject item.
img_filenpath	Text	255	The file name of the digital file of the image including the path indicating the location on the particular operating system of the digital file for this image.
Slab_id	Text	20	Slab ID of associated slab
slab_pms_key	Text	20	Primary key of associated slab from PMS database
sample_id	Text	10	Sample ID of associated sample
sample_pms_key	Text	20	Primary key of associated sample from PMS database
section_id	Text	10	Section ID of associated section
section_pms_key	Text	20	Primary key of associated section from PMS database
branch_short_name	Text	10	Branch ID of pavement branch
branch_pms_key	Text	20	Primary key of associated branch from PMS database
network_short_name	Text	10	Short name of associated network
network_pms_key	Text	20	Primary key of associated network from PMS database

6.9 AIRFIELD EVENT

Name: AIRFIELD_PMS_EVENT

Definition: An activity, condition, or item not part of the airfield pavements or appurtenances that occurs at a specific place and time on an airfield. Examples of events include: geotechnical boreholes, non-destructive testing, acceptance cores, and friction testing. Photographs are technically events, but should be placed in AIRFIELD_PMS_PHOTO. All test results related to PMS should be stored as events. All distresses should be stored as events. It is permissible to provide more than one AIRFIELD_PMS_EVENT provided the contents of each file are clearly described in the metadata. The GML file name may also be extended to identify the contents of multiple instances of AIRFIELD_PMS_EVENT. For example, boreholes and HWD testing can both be stored in the same instance of AIRFIELD_PMS_EVENT, but they may also be placed into the separate instances of AIRFIELD_PMS_EVENT_HWD and AIRFIELD_PMS_EVENT_BOREHOLE with appropriate documentation in the metadata. The intent of AIRFIELD_PMS_EVENT is to provide a general feature class to store a wide variety of data related to pavement management.

Sensitivity: Unclassified.

FAA AC 150/5300-18A Equivalent: None.

SDS Entity Equivalent: None.

Geometry: Point, Polyline, or Polygon.

Requirements: Collect the location of each event that is directly related to pavement management, typically a test that determines some property of the pavement.

Data Capture Rule: Collect data with a test point grid spacing of less than the typical slab size of an airfield, or 25-ft by 25-ft for airfields with no PCC surfaces, as a polygon. Collect all other data as point data. Dead reckoning is an acceptable method for determining location. Event records shall have either a simple result or a link to the complete event dataset.

Attributes:

Attribute	Data Type	Minimum Length	Definition
event_id	Text	30	Primary key (from PMS if available)
FAA_key	Text	25	Globally unique FAA primary key defined in AC 150/5300-18A 9-3-2
event_type	Text	30	Description of event
event_time	Text	6	Time of day the event occurred in 24-hour clock units Format for time of day is HHMMSS. Use the standard 24 hour clock.
event_date	Text	8	The date the event occurred.
event_longitude	Number	Float	Longitude of event, west negative.
event_latitude	Number	Float	Latitude of even, south negative.
event_elevation	Number	Float	Elevation of event in feet
event_depth	Number	Float	Depth below existing surface of event at time of event in inches
narrative	Text	240	A description or other unique information concerning the subject event.
filenpath	Text	255	The file name of the digital file containing data from the event (e.g., PDF or DWG file) including the path indicating the location on the particular operating system of the digital file for this image.
event_table	Text	50	Record set identifier for event data stored in database format
event_foreign_key	Text	25	Record set identifier for event data stored in database format
event_number	Text	30	Common identifier of event (e.g., borehole B-1)
event_num_result	Number	Float	Simple numerical result generated by event
event_text_result	Text	30	Simple textual result generated by event.
slab_id	Text	20	Slab ID of associated slab
slab_pms_key	Text	20	Primary key of associated slab from PMS database
sample_id	Text	10	Sample ID of associated sample
sample_pms_key	Text	20	Primary key of associated sample from PMS database
section_id	Text	10	Section ID of associated section
section_pms_key	Text	20	Primary key of associated section from PMS database
branch_short_name	Text	10	Branch ID of pavement branch
branch_pms_key	Text	20	Primary key of associated branch from PMS database
network_short_name	Text	10	Short name of associated network
network_pms_key	Text	20	Primary key of associated network from PMS database

6.10 AIRFIELD DISTRESS

Name: AIRFIELD_PMS_DISTRESS

Definition: A distress on a pavement.

Sensitivity: Unclassified.

FAA AC 150/5300-18A Equivalent: None.

SDS Entity Equivalent: None.

Geometry: Point, Polyline, or Polygon.

Requirements: Collect the location of each distress.

Data Capture Rule: Collect area distresses in AC and PCC distresses using polygons. Collect linear distresses using polylines. Corner breaks and joint seal damage may be considered linear or area distresses. Spalling is considered an area distress. Distresses less than two feet in any dimension may be collected as points. Dead reckoning is an acceptable method for determining location.

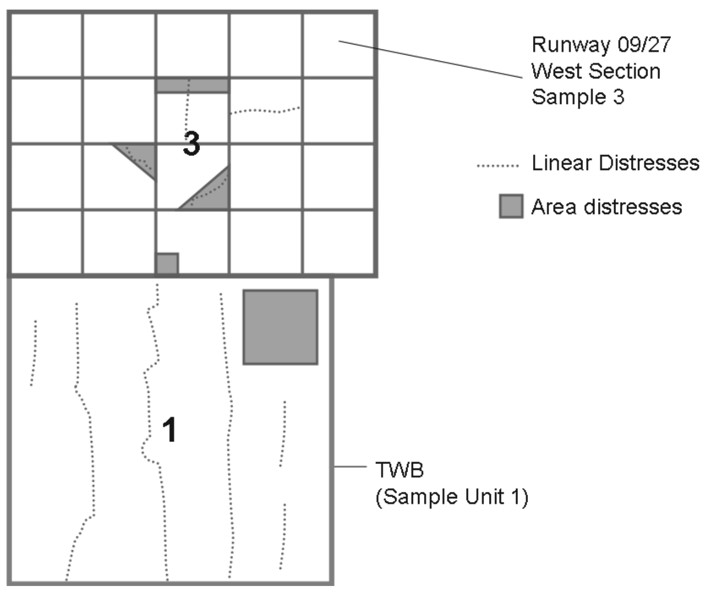


Figure 6.8. Representation of pavement distress (note linear and area distresses would be stored in different data sets).

Attributes:

Attribute	Data Type	Minimum Length	Definition
distress_id	Text	30	Primary key (from PMS database if available)
FAA_key	Text	25	Globally unique FAA primary key defined in AC 150/5300-18A 9-3-2
distress_type	Text	30	Description of distress (full name from ASTM D5340 or AC 150/5320-17)
distress_severity	Text	6	Distress severity (high, medium, or low)
distress_quantity	Number	Float	Quantity of distress
distress_units	Text	10	Units of distress_quantity
distress_date	Text	8	The date the distress was recorded.
distress_longitude	Number	Float	Longitude of distress, west negative.
distress_latitude	Number	Float	Latitude of distress, south negative.
distress_elevation	Number	Float	Elevation of distress in feet
slab_id	Text	20	Slab ID of associated slab
slab_pms_key	Text	20	Primary key of associated slab from PMS database
sample_id	Text	10	Sample ID of associated sample
sample_pms_key	Text	20	Primary key of associated sample from PMS database
section_id	Text	10	Section ID of associated section
section_pms_key	Text	20	Primary key of associated section from PMS database
branch_short_name	Text	10	Branch ID of pavement branch
branch_pms_key	Text	20	Primary key of associated branch from PMS database
network_short_name	Text	10	Short name of associated network
network_pms_key	Text	20	Primary key of associated network from PMS database

6.11 AIRFIELD CONSTRUCTION

Name: AIRFIELD_PMS_CONST

Definition: A pavement construction or project area on an airfield, including soil and other subsurface layers.

Sensitivity: Restricted.

FAA AC 150/5300-18A Equivalent: Construction Area.

SDS Entity Equivalent: construction_site.

Geometry: Polygon.

Requirements: Collect the location of each pavement construction event at an airfield.

Data Capture Rule: The outer edges of each constitutive layer of construction and maintenance project limits must be captured. If data are three-dimensional, capture the top surface of the layer. Due to the complexity of representing multiple construction projects through time, a sample record set is provided in Appendix B.

Attributes:

Attribute	Data Type	Minimum Length	Definition
construction_pms_key	Text	20	Primary key from PMS database work/construction history table
construction_date	Date		Date of construction/maintenance
section_id	Text	10	Section ID of parent section
section_pms_key	Text	20	Primary key of parent section from PMS database
branch_short_name	Text	10	Branch ID of pavement branch
branch_pms_key	Text	20	Primary key of parent branch from PMS database
network_short_name	Text	10	Short name of parent network
network_pms_key	Text	20	Primary key of parent network from PMS database
construction_activity	Text	60	Description of construction activity
construction_reference	Text	30	Project, Task Order, Delivery Order, or other project reference.
construction_material	Text	10	AC, PCC, granular, or material code from AC 5300-10A
construction_thickness	Number	Float	Thickness of construction material
construction_thick_unit	Text	10	Units of construction material thickness
construction_strength	Number	Float	Strength of construction material
construction_str_unit	Text	10	Units of construction material strength
construction_str_def	Text	20	Name of test method used to determine construction strength

6.12 DISTRESS ATTRIBUTE FIELDS

The following attributes are included in feature classes AIRFIELD_PMS_SAMPLE and AIRFIELD_PMS_SECTION_DIST.

Attribute	Data Type	Minimum Length	Definition
alligator_low	Number	Float	Distress density in percent of low-severity alligator cracking.
alligator_medium	Number	Float	Distress density in percent of medium-severity alligator cracking.
alligator_high	Number	Float	Distress density in percent of high-severity alligator cracking.
bleeding	Number	Float	Distress density in percent of bleeding.
block_low	Number	Float	Distress density in percent of low-severity block cracking.
block_medium	Number	Float	Distress density in percent of medium-severity block cracking.
block_high	Number	Float	Distress density in percent of high-severity block cracking.
corrugation_low	Number	Float	Distress density in percent of low-severity corrugation.
corrugation_medium	Number	Float	Distress density in percent of medium-severity corrugation.
corrugation_high	Number	Float	Distress density in percent of high-severity corrugation.
depression_low	Number	Float	Distress density in percent of low-severity depression.
depression_medium	Number	Float	Distress density in percent of medium-severity depression.
depression_high	Number	Float	Distress density in percent of high-severity depression.
jet_blast	Number	Float	Distress density in percent of jet blas.
joint_reflect_low	Number	Float	Distress density in percent of low-severity joint reflection cracking.
joint_reflect_medium	Number	Float	Distress density in percent of medium-severity joint reflection cracking.
joint_reflect_high	Number	Float	Distress density in percent of high-severity joint reflection cracking.
long_trans_low	Number	Float	Distress density in percent of low-severity longitudinal and transverse cracking.
long_trans_medium	Number	Float	Distress density in percent of medium-severity longitudinal and transverse cracking.
long_trans_high	Number	Float	Distress density in percent of high-severity longitudinal and transverse cracking.

Attribute (continued)	Data Type	Minimum Length	Definition
oil_spillage	Number	Float	Distress density in percent of oil spillage.
patch_low	Number	Float	Distress density in percent of low-severity patching.
patch_medium	Number	Float	Distress density in percent of medium-severity patching.
patch_high	Number	Float	Distress density in percent of high-severity patching.
polished_aggregate	Number	Float	Distress density in percent of polished aggregate.
raveling_low	Number	Float	Distress density in percent of low-severity raveling.
raveling_medium	Number	Float	Distress density in percent of medium-severity raveling.
raveling_high	Number	Float	Distress density in percent of high-severity raveling.
rutting_low	Number	Float	Distress density in percent of low-severity rutting.
rutting_medium	Number	Float	Distress density in percent of medium-severity rutting.
rutting_high	Number	Float	Distress density in percent of high-severity rutting.
shoving_low	Number	Float	Distress density in percent of low-severity shoving.
shoving_medium	Number	Float	Distress density in percent of medium-severity shoving.
shoving_high	Number	Float	Distress density in percent of high-severity shoving.
slippage	Number	Float	Distress density in percent of slippage.
swell_low	Number	Float	Distress density in percent of low-severity swelling.
swell_medium	Number	Float	Distress density in percent of medium-severity swelling.
swell_high	Number	Float	Distress density in percent of high-severity swelling.
blowup_low	Number	Float	Distress density in percent of low-severity blowups.
blowup_medium	Number	Float	Distress density in percent of medium-severity blowups.
blowup_high	Number	Float	Distress density in percent of high-severity blowups.
corner_break_low	Number	Float	Distress density in percent of low-severity corner breaks.
corner_break_medium	Number	Float	Distress density in percent of medium-severity corner breaks.
corner_break_high	Number	Float	Distress density in percent of high-severity corner breaks.
ltd_crack_low	Number	Float	Distress density in percent of low-severity LTD cracking.
ltd_crack_medium	Number	Float	Distress density in percent of medium-severity LTD cracking.
ltd_crack_high	Number	Float	Distress density in percent of high-severity LTD cracking.
d_crack_low	Number	Float	Distress density in percent of low-severity durability cracking.
d_crack_medium	Number	Float	Distress density in percent of medium-severity durability cracking.
d_crack_high	Number	Float	Distress density in percent of high-severity durability cracking.
jsd_low	Number	Float	Distress density in percent of low-severity joint seal damage.
jsd_medium	Number	Float	Distress density in percent of medium-severity joint seal damage.
jsd_high	Number	Float	Distress density in percent of high-severity joint seal damage.
meander_cracking	Number	Float	Distress density in percent of meander cracking.
mi_cracking	Number	Float	Distress density in percent of manhole and inlet cracking.
patch_small_low	Number	Float	Distress density in percent of low-severity small patching.
patch_small_medium	Number	Float	Distress density in percent of medium-severity small patching.
patch_small_high	Number	Float	Distress density in percent of high-severity small patching.
patch_large_low	Number	Float	Distress density in percent of low-severity large patching.
patch_large_medium	Number	Float	Distress density in percent of medium-severity large patching.
patch_large_high	Number	Float	Distress density in percent of high-severity large patching.
popouts	Number	Float	Distress density in percent of popouts.
potholes	Number	Float	Distress density in percent of potholes.
pumping	Number	Float	Distress density in percent of pumping.
scaling_low	Number	Float	Distress density in percent of low-severity scaling.
scaling_medium	Number	Float	Distress density in percent of medium-severity scaling.
scaling_high	Number	Float	Distress density in percent of high-severity scaling.
faulting_low	Number	Float	Distress density in percent of low-severity faulting.
faulting_medium	Number	Float	Distress density in percent of medium-severity faulting.
faulting_high	Number	Float	Distress density in percent of high-severity faulting.
shattered_slab_low	Number	Float	Distress density in percent of low-severity shattered slabs.
shattered_slab_high	Number	Float	Distress density in percent of high-severity shattered slabs.

Attribute (continued)	Data Type	Minimum Length	Definition
shrinkage_crack	Number	Float	Distress density in percent of shrinkage cracks.
spall_joint_low	Number	Float	Distress density in percent of low-severity joint spalling.
spall_joint_medium	Number	Float	Distress density in percent of medium-severity joint spalling.
spall_joint_high	Number	Float	Distress density in percent of high-severity joint spalling.
spall_corner_low	Number	Float	Distress density in percent of low-severity corner spalling.
spall_corner_medium	Number	Float	Distress density in percent of medium-severity corner spalling.
spall_corner_high	Number	Float	Distress density in percent of high-severity corner spalling.

6.13 DOMAIN VALUES

All material specifications are from Advisory Circular 150/5370-10 (current version) unless otherwise noted.

6.13.1 network_pcr7

Value	Remarks
excellent	PCI value 86-100
very_good	PCI value 71-85
good	PCI value 56-70
fair	PCI value 41-55
poor	PCI value 26-40
very_poor	PCI value 11-25
failed	PCI value 0-10

6.13.2 network_pcr3

Value	Remarks
good	PCI value 71-100
fair	PCI value 56-70
poor	PCI value 0-55

6.13.3 network_friction_rating

Value	Remarks
good	Mu-meter* value >0.50
fair	Mu-meter *value 0.35 to 0.50
poor	Mu-meter *value 0.00 to 0.34

* see USAF ETL 04-9 table 2 for determining friction ratings using other equipment

6.13.4 network_ea

Value	Remarks
adequate	pavement rates as “adequate” by USAF ETL 04-9
degraded	pavement rates as “degraded” by USAF ETL 04-9
unsatisfactory	pavement rates as “unsatisfactory” by USAF ETL 04-9

6.13.5 branch_use

Value	Remarks
APRON	aircraft parking, loading, and maintenance areas
HELIPAD	helicopter landing area
OVERRUN	paved safety area beyond runway ends
RUNWAY	pavement for aircraft landing and take off
TAXIWAY	pavement for aircraft to move from place to place on the ground
SHOULDER	non-aircraft pavement at edges of aircraft operation areas

6.13.6 branch_pcr7

Value	Remarks
excellent	PCI value 86-100
very_good	PCI value 71-85
good	PCI value 56-70
fair	PCI value 41-55
poor	PCI value 26-40
very_poor	PCI value 11-25
failed	PCI value 0-10

6.13.7 branch_pcr3

Value	Remarks
good	PCI value 71-100
fair	PCI value 56-70
poor	PCI value 0-55

6.13.8 branch_friction_rating

Value	Remarks
good	Mu-meter* value >0.50
fair	Mu-meter *value 0.35 to 0.50
poor	Mu-meter *value 0.00 to 0.34

* see USAF ETL 04-9 table 2 for determining friction ratings using other equipment

6.13.9 branch_ea

Value	Remarks
adequate	pavement rates as “adequate” by USAF ETL 04-9
degraded	pavement rates as “degraded” by USAF ETL 04-9
unsatisfactory	pavement rates as “unsatisfactory” by USAF ETL 04-9

6.13.10 section_use

Value	Remarks
APRON	aircraft parking, loading, and maintenance areas
HELIPAD	helicopter landing area
OVERRUN	paved safety area beyond runway ends
RUNWAY	pavement for aircraft landing and take off
TAXIWAY	pavement for aircraft to move from place to place on the ground
SHOULDER	non-aircraft pavement at edges of aircraft operation areas

6.13.11 section_rank

Value	Remarks
P	Primary pavement (critical to operations)
S	Secondary pavement (non-critical for operations)
T	Tertiary pavement (tow-only and non-structural pavement)

6.13.12 section_pms_surface

Value	Remarks
AAC	asphalt overlay of asphalt pavement
AC	asphalt pavement
ACT	asphalt over cement treated base
APC	asphalt overlay of PCC pavement
PCC	Portland cement concrete pavement
RMP	resin modified pavement
ST	surface treatment
X	other

6.13.13 section_ol

Value	Remarks
AC	asphalt overlay
PCC	pcc overlay
P401	asphalt meeting AC 5370-10 specification P-401
P402	porous friction course meeting AC 5370-10 specification P-402
P501	PCC meeting AC 5370-10 specification P-501

6.13.14 section_surface

Value	Remarks
AC	asphalt surface
PCC	pcc surface
P401	asphalt meeting P-401 specification
P402	porous friction course meeting P-402 specification
P501	PCC meeting P-501 specification

6.13.15 section_base

Value	Remarks
GR	granular base (unspecified)
P208	aggregate base
P209	crushed aggregate base course
P210	Caliche base course
P211	lime rock base course
P212	shell base course
P213	sand-clay base course
P301	soil cement base course
P304	cement treated base course
P306	econocrete base course
P401	asphalt stabilized base course meeting P-401 specifications

6.13.16 section_subbase

Value	Remarks
GR	granular subbase (unspecified)
P154	subbase meeting P-154 specification
P155	lime treated subgrade
P208	aggregate subbase
P209	crushed aggregate subbase course
P210	Caliche subbase course
P211	lime rock subbase course
P212	shell subbase course
P213	sand-clay subbase course
P301	soil cement subbase course
P304	cement treated subbase course
P306	econocrete subbase course
P401	asphalt stabilized subbase course meeting P-401 specifications

6.13.17 section_subgrade_unit

Value	Remarks
CBR	strength is expressed as a CBR for flexible pavement
PCI	inch-pounds per square inch; strength is a modulus of subgrade reaction (k-value) for rigid pavement
psi	strength is expressed as a modulus in pounds per square inch

6.13.18 section_pcr7

Value	Remarks
excellent	PCI value 86-100
very_good	PCI value 71-85
good	PCI value 56-70
fair	PCI value 41-55
poor	PCI value 26-40
very_poor	PCI value 11-25
failed	PCI value 0-10

6.13.19 section_pcr3

Value	Remarks
good	PCI value 71-100
fair	PCI value 56-70
poor	PCI value 0-55

6.13.20 section_friction_rating

Value	Remarks
good	Mu-meter* value >0.50
fair	Mu-meter *value 0.35 to 0.50
poor	Mu-meter *value 0.00 to 0.34

* See USAF ETL 04-9 table 2 for determining friction ratings using other equipment

6.13.21 section_ea

Value	Remarks
adequate	pavement rates as “adequate” by USAF ETL 04-9
degraded	pavement rates as “degraded” by USAF ETL 04-9
unsatisfactory	pavement rates as “unsatisfactory” by USAF ETL 04-9

6.13.22 construction_material

Value	Remarks
GR	granular subbase (unspecified)
AC	asphalt (unspecified)
PCC	Portland cement concrete (unspecified)
P154	subbase meeting P-154 specification
P155	lime treated subgrade
P208	aggregate subbase
P209	crushed aggregate subbase course
P210	Caliche subbase course
P211	lime rock subbase course
P212	shell subbase course
P213	sand-clay subbase course
P301	soil cement subbase course
P304	cement treated subbase course
P306	econocrete subbase course
P401	asphalt stabilized subbase course meeting P-401 specifications
P402	porous friction course meeting AC 5370-10 specification P-402
P501	PCC meeting AC 5370-10 specification P-501

7 METADATA

7.1 METADATA FORMAT

Metadata shall be provided compliant with Federal Geospatial Data Committee Content Standard for Digital Geospatial Metadata (FGDC CSDGM) FGDC-STD-001-1998. The North American Profile of ISO 19115 is expect in the near future; upon implementation, metadata shall be provided compliant with it.

7.2 METADATA CONTENTS

Metadata elements shall meet the content requirements for metadata of FAA AC 150/5300-18A 9-4. The minimum metadata elements are listed below. The equivalent metadata elements from FAA AC 150/5300-18A and the CSDGM are also listed. Metadata elements not part of the general FAA metadata element set but used in PMS data sets are identified with the phrase “PMS Specific Element”.

Metadata for a record set shall be transmitted in a file of the same name as the record set, except that the file name extension shall be “xml”. For example, if a record set is transmitted as GML in the file *AIRFIELD_PMS_ARP_JFK. GML*, the metadata would be transmitted as *AIRFIELD_PMS_ARP_JFK.XML*.

Metadata shall generally be collected and provided at the feature level, however, metadata may be provided at the feature class level if all features in an instance of a feature class have identical metadata. Identification of metadata granularity is provided by the *Identification_Information*, *Citation*, and *Other Citation Details* metadata fields, which are used to identify to which specific features the metadata pertain. If all features in a feature set have the same metadata, the *Other Citation Details* field may be omitted.

FGDC CSDGM Element	FAA Metadata Element	Definition
Identification_Information Description	Abstract	Description of the contents of the data.
	SpecificUsage	Description of how the data should be used
Identification_Information Point_of_Contact	IndividualName	Name of person that developed data
	OrganizationName	Organization that developed the data
	PositionName	Title of person that developed the data
	DeliveryPoint	Street address of the person that developed the data
	City	City
	AdministrativeArea	State
	PostalCode	ZIP Code
	ElectronicMailAddress	email address
	VoicePhoneLine	Phone number
Identification_Information Status	Status	Status of the data being submitted.
Identification_Information Citation	Dataset	List of feature classes to which the metadata pertains
Identification_Information Citation Other Citation Details	Features	List of features to which the metadata pertains

FGDC CSDGM Element (continued)	FAA Metadata Element	Definition
Identification_Information Time_Period_of_Content	BegUsageDateTime	The first date/time for which the data are valid
	EndUsageDateTime	The last date/time for which the data are valid
Data_Quality_Information Positional_Accuracy	HorizontalAccuracy	
	EvaluationMethodName	Name of data quality evaluation method
	EvaluationMethodDescription	Description of data quality evaluation method
	VerticalAccuracy	
	EvaluationMethodName	Name of data quality evaluation method
	EvaluationMethodDescription	Description of data quality evaluation method
	Pass	Indication of whether data set passed or failed quality evaluation
Data_Quality_Information Lineage	Statement	Description of the source of the data
Spatial_Data_Organization_Information Point_and_Vector_Object_Information Point and Vector Object Count	GeometricObjectCount	Number of feature instances in data set.
Spatial_Reference_Information Horizontal_Coordinate_System_Definition	HorizontalDatum	Horizontal datum of data set
	Code	Four digit code for the state plane coordinate system
Spatial_Reference_Information Vertical_Coordinate_System_Definition	VerticalDatum	Vertical datum of data set
Entity_and_Attribute_Information Detailed_Description	Attributes	List of attributes to which the metadata pertains
	PMS Specific Element: rollUpMethod	Description of averaging or other method used to develop condition values for higher order pavement entities.
	PMS Specific Element: ConditionMethod	Name of condition index method
	PMS Specific Element: ConditionStandard	Standard governing condition index method
	PMS Specific Element: FODMethod	Name of FOD index method
	PMS Specific Element: FODStandard	Standard governing FOD index method
	PMS Specific Element: FrictionMethod	Device/method used to collect friction data

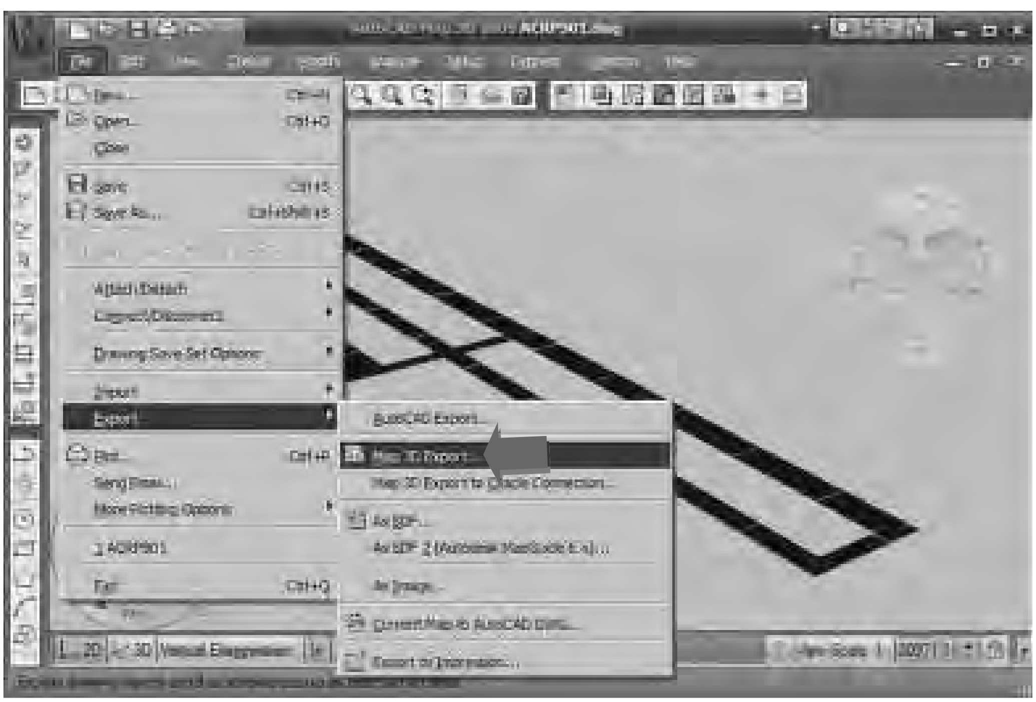
APPENDIX A CREATING GML FILES

A.1 AUTOCAD TO GML

Exporting Data from an *AutoCAD* data file that contains feature attributes to GML requires the use of AutoCAD Map:

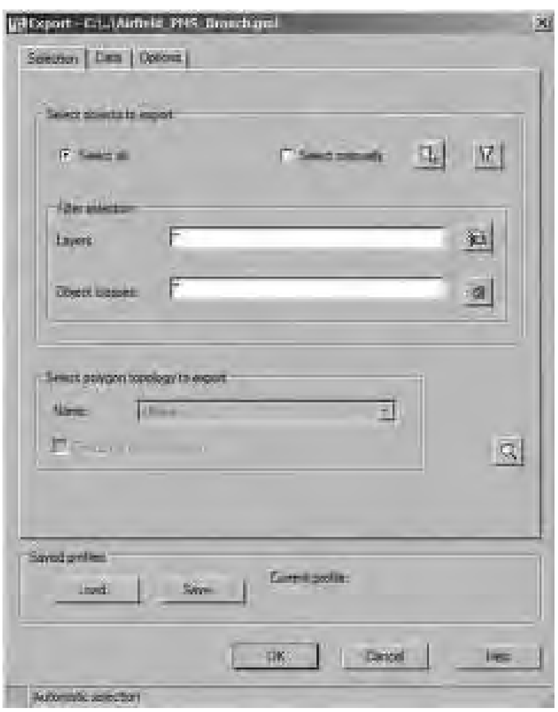
1. Launch AutoCAD Map and open the desired data to be exported to GML. The example below is a simple branch data set.

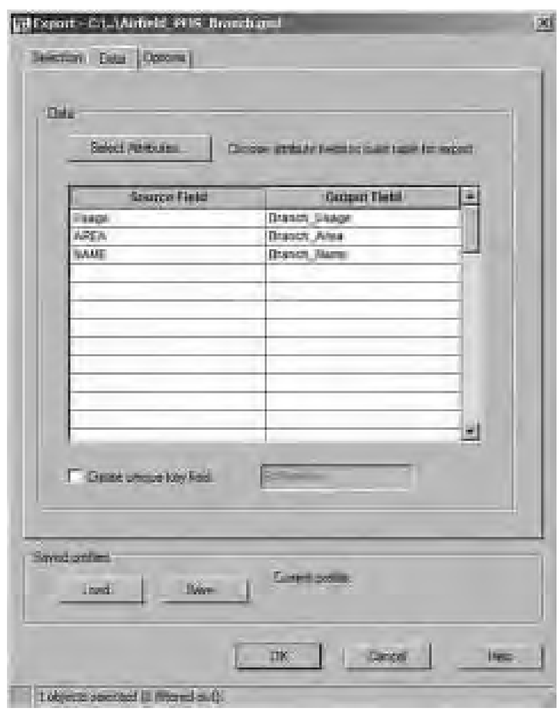
2. Once the *AutoCAD* data is loaded, navigate to File>Export> Map 3D Export.

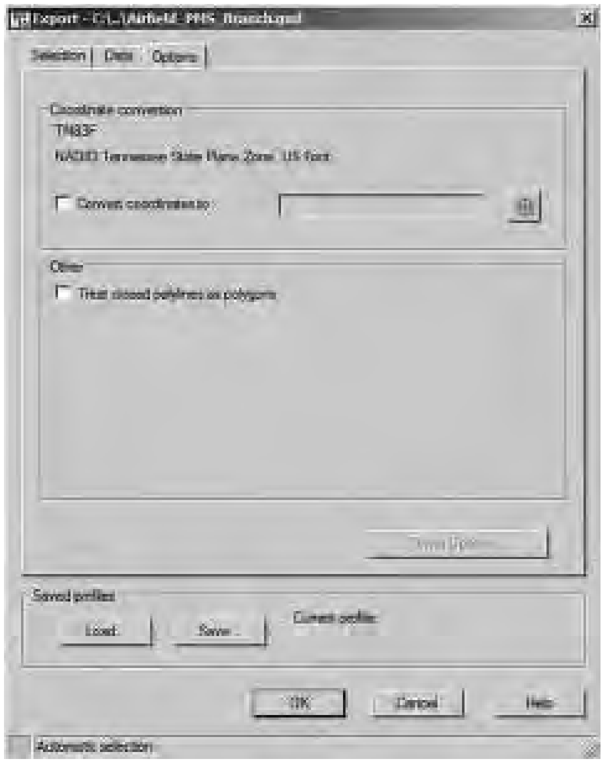


3. Next, *change* the export *File of Type* to *GML – Geography Markup Language* and provide a Path and File name for the export GML and click *OK.*

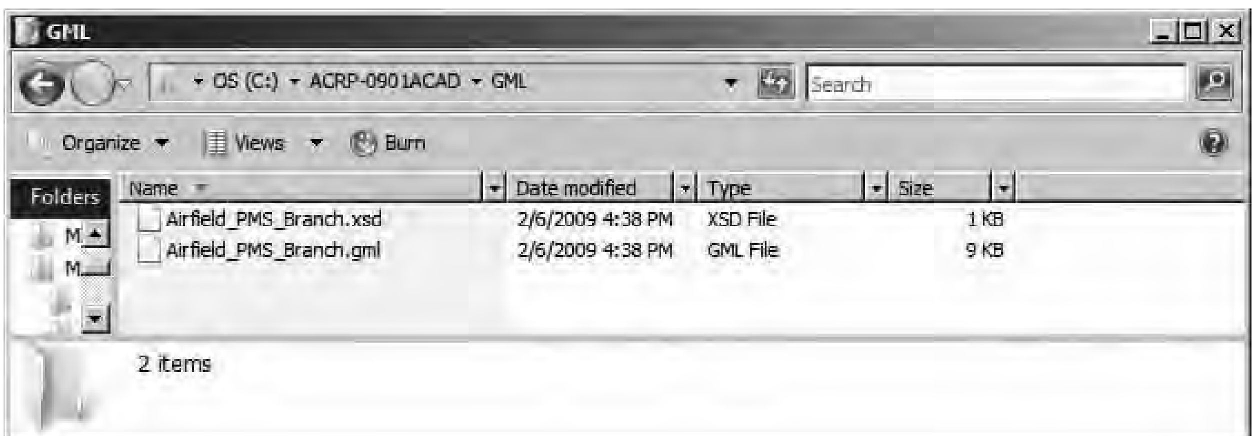
4. The GML export options dialog will appear. The Dialog contains three tabs: *Selection, Data* and *Options*. *Selection* allows for specific features to be selectively exported, or you can choose to export all features. *Data* provides for the ability to map AutoCAD feature attributes to the corresponding ACRP standard field names, if the source data is not name congruent, but does contain compatible data and data types. The *Options* tab allows for modification of the resulting output coordinate system.







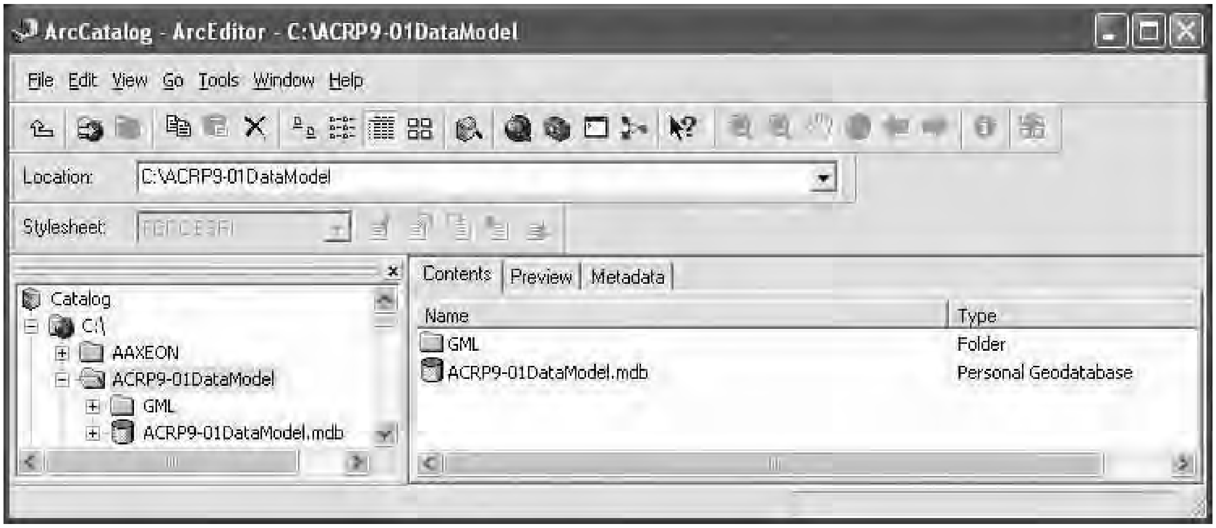
5. Once these setting are set, clicking *OK*, initiated the file output process. The resulting output files will be found in the location that was specified in the earlier step. The output location should contain a *GML Data File* and the accompanying *XML Schema File*.



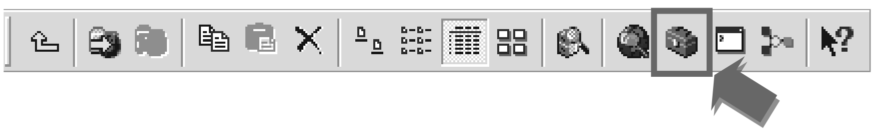
A.2 ARCGIS TO GML

Exporting Data from *ArcGIS* to GML using the Simple Features Profile requires the use of the ArcGIS Data Interoperability extension. However, to use the GML export tools does not require activation or a license the Interoperability extension; however the extension must be installed. To export data sources to GML:

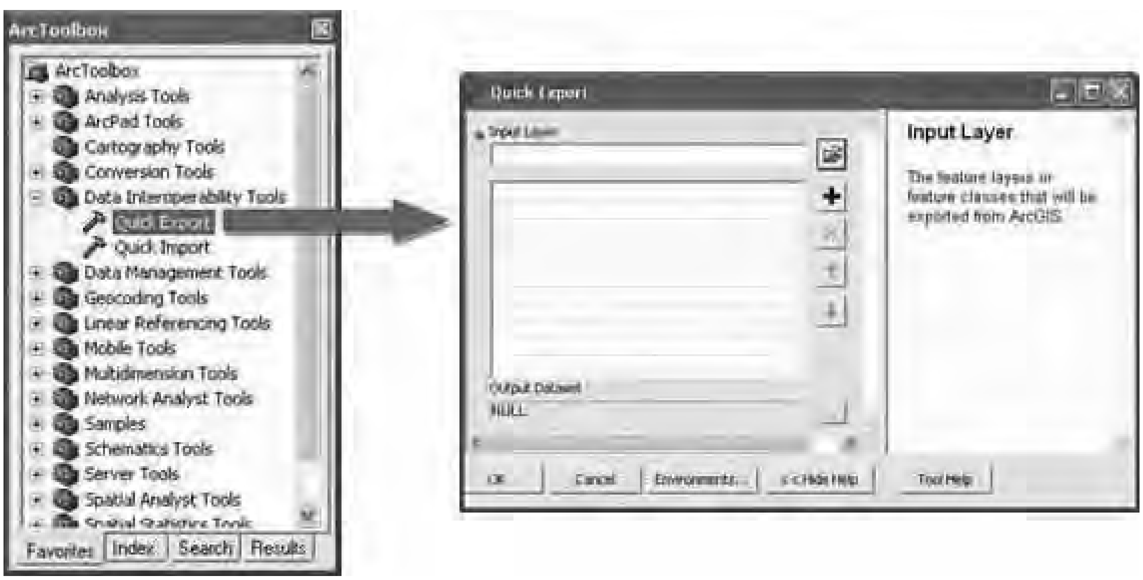
1. Launch *ArcCatalog* or *ArcMap 9.2* or higher (GML support begin with v9.2), for this example, *ArcCatalog* is used.



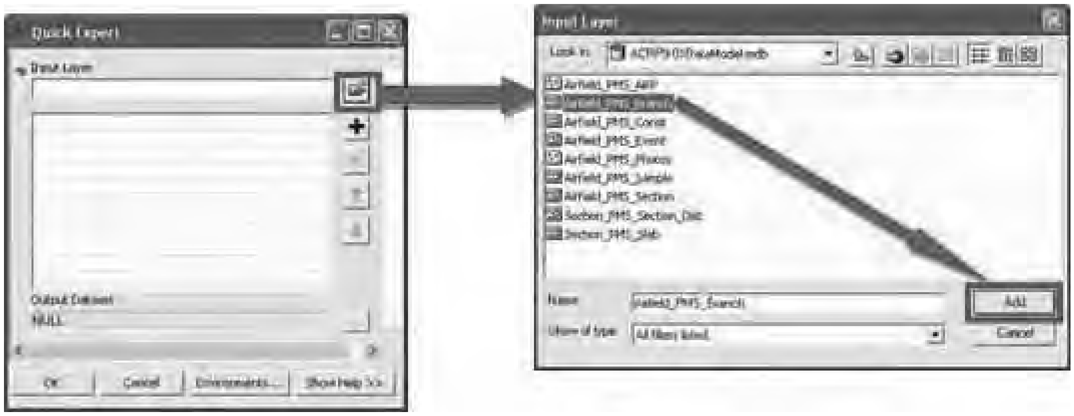
2. Locate and click the *ArcToolbox* icon on the Standard Menu button toolbar:



3. Once the ArcToolbox menu of tools appears, expand the *Data Interoperability Tools* Group and double-click *Quick Export* and the *Quick Export* dialog should appear.

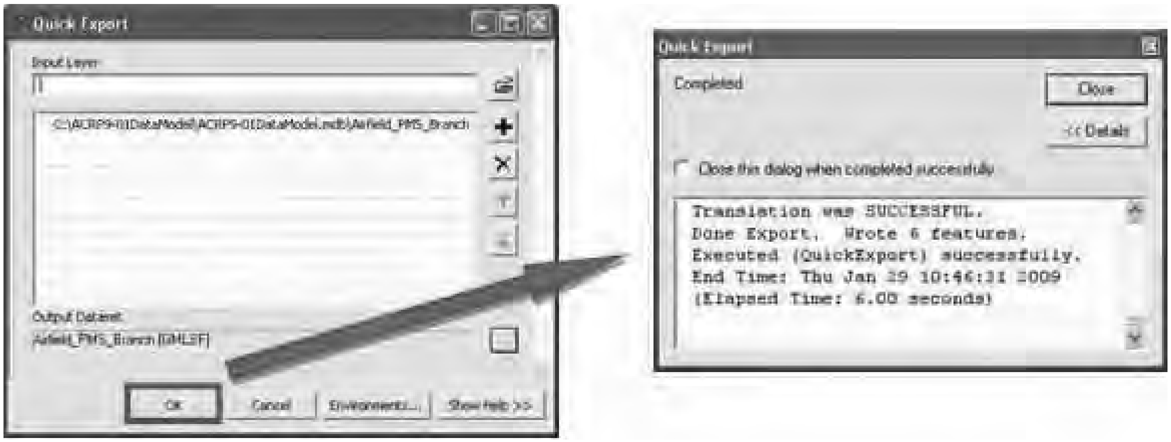


4. In the *Quick Export* dialog for the *Input Layer* navigate to an ArcGIS data source (Personal Geodatabase, File Geodatabase or SDE database) and select the feature class that you wish to export as GML Simple Features. For this example, a Personal Geodatabase is used.



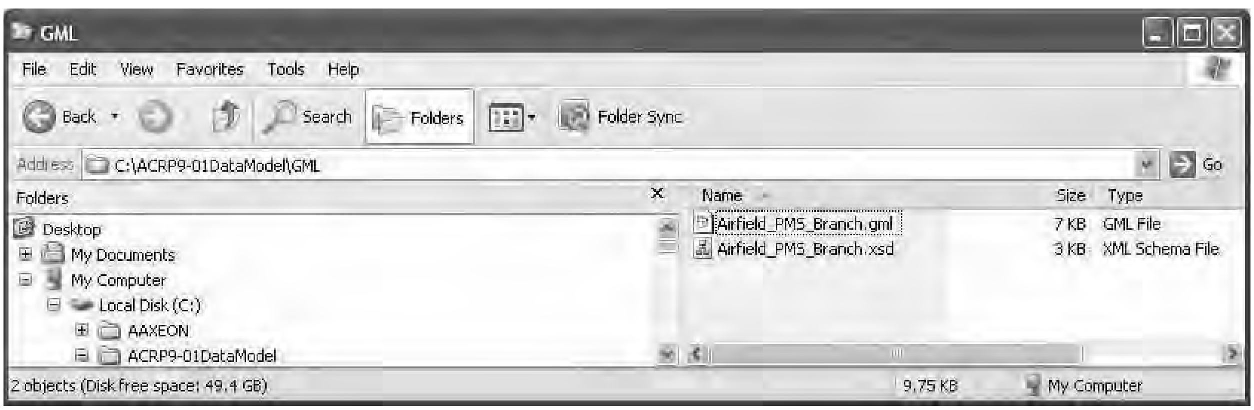
5. Once the feature class has been added, you will be returned to the *Quick Export* Dialog. Verify the *Input Layer* is correct and click the ... button in the bottom left of the dialog under the *Output Dataset* section. Next, select *GML SF-0 (Geography Markup Language Simple Features Level SF-0 Profile)* as the *Format* and for *Dataset* select the path where you wish for the GML data files to be saved. If you wish to re-project the data (change coordinate systems or units) in the Output GML Data, you can select the new Coordinate system in this step as well. In this example, the output GML will be in the same coordinate system as the source feature class.

6. After setting the options in the *Specify Output Data Destination* dialog, click *OK* to return to the Quick *Export* Dialog. The *Quick Export* Dialog should reflect the settings by showing the name of the output GML data file as well as the output format (GMLSF). Once the settings are confirmed, click *OK.*



7. After Clicking OK, the export process should begin running. Depending on the size of the data set this process can take a few seconds to several minutes to complete. At the end of the process the dialog should report the number of features exported successfully. If there is an error, this dialog will provide details of the errors encountered.

8. As a final step, verify the datafiles have been written to to speficifed folder in the file system. The output location should contain an *GML Data File* and the accompanying *XML Schema File*.



APPENDIX B DATA TRANSLATION GUIDE FOR MICROPAVER AND AIRPAV

AirPAV uses a numerical naming scheme to denote branches and does not provide explicit branch identifiers. Taxiways have feature ID's of 100 through 2600 with 100 being Taxiway A and 2600 being Taxiway Z. Runways appear to start at 6000, with aprons having feature ID's between 2700 and 6000. These numbers can be used for branch_pms_key, although the user would have to have a strong understanding of the database to know that it would be possible to have both a branch 100, representing all of Taxiway A, and a section 100, representing only a single section in Taxiway A.

NA=data not natively available in source data set

B.1 AIRPORT REFERENCE POINT

Attribute	MicroPAVER	AirPAV
network_short_name	network.networkid	features.aptid
network_name	network.name	NA
network_pms_key	network._nuniqueid	features.aptid
network_area	sum(branch._area)	sum(features.area)
network_pci	calculate from conditions.condition where conditions._latest=yes	calculate from features.insppci
network_pcr7	from airfield_pms_arp.network_pci	from airfield_pms_arp.network_pci
network_pcr3	from airfield_pms_arp.network_pci	from airfield_pms_arp.network_pci
network_paser	NA	NA
network_fod	calculate from conditions.condition where conditions._latest=yes	NA
network_friction_index	NA	NA
network_friction_rating	NA	NA
network_pcn_value	NA	NA
network_pcn_descriptor	NA	NA
network_ea	NA	NA
network_climate	NA	NA

B.2 BRANCH LOCATION

Attribute	MicroPAVER	AirPAV
branch_short_name	branch.branchid	determine from features.feature_id
branch_name	branch.name	NA
branch_pms_key	branch._buniqueid	determine from features.feature_id
FAA_key	NA	NA
branch_area	branch._area	sum(features.area)
branch_use	branch.use	feature_cl (Shapefile only)
network_short_name	parent in network.networkid	APTID
network_pms_key	branch._nuniqueid	APTID
branch_pci	calculate from conditions.condition where conditions._latest=yes	calculate from features.insppci
branch_pcr7	from airfield_pms_branch.branch_pci	from airfield_pms_branch.branch_pci
branch_pcr3	from airfield_pms_branch.branch_pci	from airfield_pms_branch.branch_pci
branch_paser	NA	NA

Attribute (continued)	MicroPAVER	AirPAV
branch_fod	calculate from conditions.condition where conditions._latest=yes	NA
branch_friction_index	NA	NA
branch_friction_rating	NA	NA
branch_pcn_value	NA	NA
branch_pcn_descriptor		NA
branch_ea	NA	NA

B.3 SECTION LOCATION

Attribute	MicroPAVER	AirPAV
section_id	section.sectionid	features.desc
section_pms_key	section._suniqueid	features.feature_id
FAA_key	NA	NA
branch_short_name	from parent in branch.branchid	NA
branch_pms_key	section._buniqueid	determine from featrures.feature_id
network_short_name	from parent in network.networkid	features.aptid
network_pms_key	from parent in branch._nuniqueid	features.aptid
section_area	section._length*section._width +section.[_area adjustment]	features.area
section_use	from parent in branch.use	determine from features.feature_id
section_rank	section.rank	NA
section_pms_surface	section.surface	features.pavetype
section_constructed	section.const_date	features.conyear
section_maint	determine from table [work tracking]	NA
section_insp_date	determine from table inspections	features.inspdate
section_ol	NA	NA
section_ol_thick	NA	NA
section_surface	NA	NA
section_surface_thick	NA	NA
section_base	NA	NA
section_base_thick	NA	NA
section_subbase	NA	NA
section_subbase_thick	NA	NA
section_subgrade	NA	NA
section_subgrade_strength	NA	features.cbr or features.kvalue
section_subgrade_unit	NA	NA
section_design_gear	NA	from features.desacft
section_design_mtow	NA	from features.desacft
section_design_passes	NA	features.desops
section_pci	determine from conditions.condition	features.insppci
section_pcr7	from airfield_pms_section.section_PCI	from airfield_pms_section.section_PCI
section_pcr3	from airfield_pms_section.section_PCI	from airfield_pms_section.section_PCI
section_paser	NA	NA
section_fod	determine from conditions.condition	NA
section_friction_index	NA	NA
section_friction_rating	NA	NA
section_pcn_value	NA	NA
section_pcn_descriptor	NA	NA

Attribute (continued)	MicroPAVER	AirPAV
section_ea	NA	NA
section_traffic	NA	NA

B.4 SECTION DISTRESSES

Attribute	MicroPAVER	AirPAV
section_id	section.sectionid	features.desc
section_pms_key	section._suniqueid	features.feature_id
FAA_key	NA	NA
branch_short_name	from parent in branch.branchid	NA
branch_pms_key	section._buniqueid	from features.feature_id
network_short_name	from parent in network.networkid	features.aptid
network_pms_key	from parent in branch._nuniqueid	features.aptid
section_area	section._length*section._width +section.[_area adjustment]	features.area
section_use	from parent in branch.use	determine from features.feature_id
section_rank	section.sectionid	NA
section_insp_date	determine from table inspections	features.inspdate

Distress data elements in Paragraph 6.12, Distress Attribute Fields, have a one-to-one correspondence with the fields features.ac_allig_h through features.pcc_cornerspall_l. To determine the density, perform the calculation [features].[ac_allig_h]÷[features].[area]. Distress density data in MicroPAVER must be extracted from [extrapolated distress].[auxreal1], which has a many-to-one relationship with sections.

B.5 SAMPLE UNIT LOCATION

Attribute	MicroPAVER	AirPAV
sample_id	samples.samplenr	NA
sample_pms_key	samples._smpuniqueid	NA
sample_date	from parent in inspections.date	NA
section_id	from parent in section.sectionid	NA
section_pms_key	from parent in inspections._suniqueid	NA
branch_short_name	from parent in branch.branchid	NA
branch_pms_key	from parent in section._buniqueid	NA
network_short_name	from parent in network.networkid	NA
network_pms_key	from parent in branch._nuniqueid	NA
sample_area	sample._samplesize	NA
sample_pms_surface	from parent in inspections.inspected_surface	NA
sample_type	sample.sampletype	NA
sample_pci	NA	NA
sample_pcr7	NA	NA
sample_pcr3	NA	NA
sample_fod	NA	NA

B.6 SLAB LOCATION

Attribute	MicroPAVER	AirPAV
slab_id	NA	NA
slab_pms_key	NA	NA
sample_date	NA	NA
sample_id	samples.samplenr	NA
sample_pms_key	samples._smpuniqueid	NA
section_id	from parent in section.sectionid	NA
section_pms_key	from parent in inspections._suniqueid	NA
branch_short_name	from parent in branch.branchid	NA
branch_pms_key	from parent in section._buniqueid	NA
network_short_name	from parent in network.networkid	NA
network_pms_key	from parent in section.sectionid	NA
blowup_low	from child data in distresses._quantity	NA
blowup_medium	from child data in distresses._quantity	NA
blowup_high	from child data in distresses._quantity	NA
corner_break_low	from child data in distresses._quantity	NA
corner_break_medium	from child data in distresses._quantity	NA
corner_break_high	from child data in distresses._quantity	NA
ltd_crack_low	from child data in distresses._quantity	NA
ltd_crack_medium	from child data in distresses._quantity	NA
ltd_crack_high	from child data in distresses._quantity	NA
d_crack_low	from child data in distresses._quantity	NA
d_crack_medium	from child data in distresses._quantity	NA
d_crack_high	from child data in distresses._quantity	NA
jsd_low	from child data in distresses._quantity	NA
jsd_medium	from child data in distresses._quantity	NA
jsd_high	from child data in distresses._quantity	NA
mi_cracking	from child data in distresses._quantity	NA
patch_small_low	from child data in distresses._quantity	NA
patch_small_medium	from child data in distresses._quantity	NA
patch_small_high	from child data in distresses._quantity	NA
patch_large_low	from child data in distresses._quantity	NA
patch_large_medium	from child data in distresses._quantity	NA
patch_large_high	from child data in distresses._quantity	NA
popouts	from child data in distresses._quantity	NA
potholes	from child data in distresses._quantity	NA
polishing	from child data in distresses._quantity	NA
pumping	from child data in distresses._quantity	NA
scaling_low	from child data in distresses._quantity	NA
scaling_medium	from child data in distresses._quantity	NA
scaling_high	from child data in distresses._quantity	NA
faulting_low	from child data in distresses._quantity	NA
faulting_medium	from child data in distresses._quantity	NA
faulting_high	from child data in distresses._quantity	NA
shattered_slab_low	from child data in distresses._quantity	NA
shattered_slab_medium	from child data in distresses._quantity	NA
shattered_slab_high	from child data in distresses._quantity	NA
shrinkage_crack	from child data in distresses._quantity	NA
spall_joint_low	from child data in distresses._quantity	NA
spall_joint_medium	from child data in distresses._quantity	NA
spall_joint_high	from child data in distresses._quantity	NA
spall_corner_low	from child data in distresses._quantity	NA

Attribute (continued)	MicroPAVER	AirPAV
spall_corner_medium	from child data in distresses._quantity	NA
spall_corner_high	from child data in distresses._quantity	NA

B.7 PHOTOGRAPH LOCATION

Attribute	MicroPAVER	AirPAV
image_id	file image.iml images._imguniqueid	NA
FAA_key	NA	NA
img_time	NA	NA
img_date	NA	NA
img_direction	NA	NA
img_narrative	file image.iml images.name	NA
img_filenpath	file image.iml images._fullpath	NA
slab_id	NA	NA
slab_pms_key	NA	NA
sample_id	NA	NA
sample_pms_key	NA	NA
section_id	from parent in section.sectionid	NA
section_pms_key	file image.iml images._imuniqueid	NA
branch_short_name	from parent in branch.branchid	NA
branch_pms_key	from parent in section._buniqueid	NA
network_short_name	from parent in network.networkid	NA
network_pms_key	from parent in branch._nunuiqueid	NA

B.8 AIRFIELD EVENT

Attribute	MicroPAVER	AirPAV
event_id	NA	NA
FAA_key	NA	NA
event_type	NA	NA
event_time	NA	NA
event_date	NA	NA
event_longitude	NA	NA
event_latitude	NA	NA
event_elevation	NA	NA
event_depth	NA	NA
narrative	NA	NA
filenpath	NA	NA
event_table	NA	NA
event_foreign_key	NA	NA
event_number	NA	NA
event_num_result	NA	NA
event_text_result	NA	NA
slab_id	NA	NA
slab_pms_key	NA	NA
sample_id	NA	NA
sample_pms_key	NA	NA
section_id	NA	NA
section_pms_key	NA	NA
branch_short_name	NA	NA
branch_pms_key	NA	NA
network_short_name	NA	NA
network_pms_key	NA	NA

B.9 AIRFIELD DISTRESS

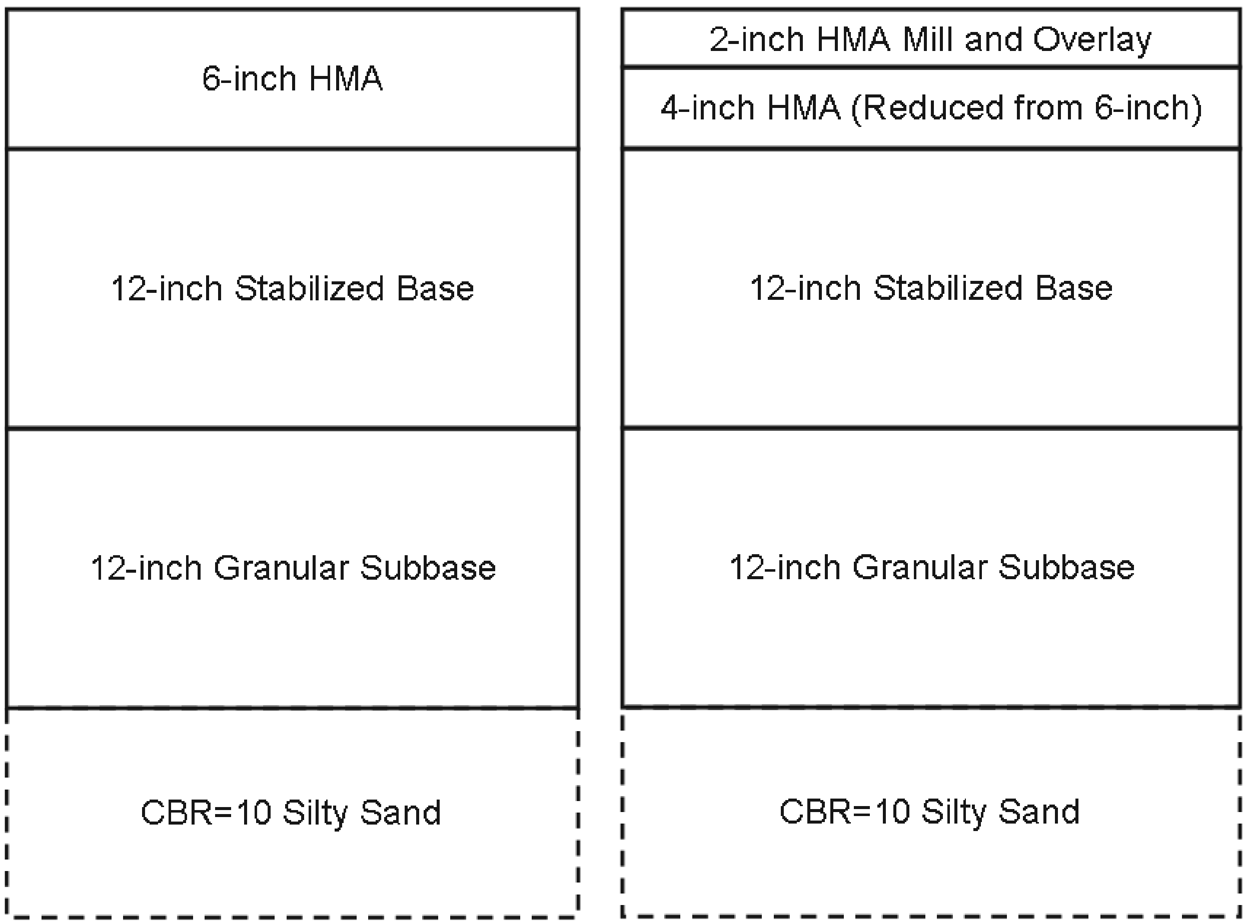
Attribute	MicroPAVER	AirPAV
distress_id	distresses._duniqueid (MicroPAVER 6.x only)	NA
FAA_key	NA	NA
distress_type	distresses.description	NA
distress_severity	distresses.severity	NA
distress_quantity	distresses._quantity (metric)	NA
distress_units	distresses._quantityunits	NA
distress_date	from parent in inspections.date	NA
distress_longitude	from distresses.utm_x	NA
distress_latitude	from distresses.utm_y	NA
distress_elevation	NA	NA
slab_id	NA	NA
slab_pms_key	NA	NA
sample_id	from parent in samples.samplenr	NA
sample_pms_key	distresses._smpuniqueid	NA
section_id	from parent in section.sectionid	NA
section_pms_key	from parent in inspections._suniqueid	NA
branch_short_name	from parent in branch.branchid	NA
branch_pms_key	from parent in section._buniqueid	NA
network_short_name	from parent in network.networkid	NA
network_pms_key	from parent in branch._nuniqueid	NA

B.10 AIRFIELD CONSTRUCTION

Attribute	MicroPAVER	AirPAV
construction_pms_key	[work tracking]._whuniqueid	concat(features.feature_id,"HistoryX") where 1<X<10
construction_date	[work tracking].date	parse from features.historyX
section_id	from parent in section.sectionid	features.desc
section_pms_key	[work tracking]._suniqueid	features.feature_id
branch_short_name	from parent in branch.branchid	NA
branch_pms_key	from parent in section._buniqueid	from features.feature_id
network_short_name	from parent in network.networkid	features.aptid
network_pms_key	from parent in branch.branchid	features.aptid
construction_activity	[work tracking].work	parse from features.historyX
construction_reference	[work tracking].project	parse from features.historyX
construction_material	[work tracking].mattype	parse from features.historyX
construction_thickness	[work tracking]._thickness	parse from features.historyX
construction_thick_unit	[work tracking]._thickness_units	parse from features.historyX
construction_strength	NA	NA
construction_str_unit	NA	NA
construction_str_def	NA	NA

APPENDIX C CONSTRUCTION LAYER RECORD SET EXAMPLE

Consider the following hypothetical pavement section originally constructed in 1990 and rehabilitated in 2005:



1990 2005

The attributes for this hypothetical section are shown in the following table.

Table C.1.

PMS-assigned primary key for construction records. (→ construction_pms_key)

Date of construction. If date of completion of individual layers is known it can be used, otherwise the date of project completion should be used. (→ construction_date)

Pavement network, branch, and section identifiers. These are all the same because this project occurs entirely within one section of one branch of one network. (→ section_id, section_pms_key, branch_short_name, branch_pms_key, network_short_name, network_pms_key)

construction_pms_key	construction_date	section_id	section_pms_key	branch_short_name	branch_pms_key	network_short_name	network_pms_key	construction_activity	construction_reference	construction_material	construction_thickness	construction_thick_unit	construction_strength	construction_str_unit	construction_str_def
0001	3/1/1990	A01B	0001	Apron 1	0006	JFK	0001	Construct Apron 1	JFK-1990-01	SM			10	%	CBR
0002	4/1/1990	A01B	0001	Apron 1	0006	JFK	0001	Construct Apron 1	JFK-1990-01	P-154	12	inch	30000	psi	HWD
0003	5/1/1990	A01B	0001	Apron 1	0006	JFK	0001	Construct Apron 1	JFK-1990-01	P-304	12	inch	450,000	psi	HWD
0004	6/1/1990	A01B	0001	Apron 1	0006	JFK	0001	Construct Apron 1	JFK-1990-01	P-401	6	inch	250,000	psi	HWD
0005	6/1/2005	A01B	0001	Apron 1	0006	JFK	0001	Rehab Apron 1	JFK-2005-36A	Mill	-2	inch			
0006	6/15/2005	A01B	0001	Apron 1	0006	JFK	0001	Rehab Apron 1	JFK-2005-36A	P-401	2	inch	200,000	psi	Design

Description of each project. Note projects may require multiple lines if they involve multiple layers. (→ construction_activity)

User assigned project number. (→ construction_reference)

Description of layer material and thickness. Note that removing material is considered a layer with negative thickness. Milling is shown, but this is applicable to all demolition activities. (→ construction_material, construction_thickness, construction_thick_unit)

Material strength descriptor. Note that multiple strength methods can be used. This example shows a CBR for subgrade and moduli for constructed layers. Note that moduli based on HWD testing are shown for 1990 construction layers, but a design modulus is shown for the 2005 overlay. (→ construction_strength, construction_str_unit, construction_str_def)

Abbreviations and acronyms used without definitions in TRB publications:

AAAE	American Association of Airport Executives
AASHO	American Association of State Highway Officials
AASHTO	American Association of State Highway and Transportation Officials
ACI–NA	Airports Council International–North America
ACRP	Airport Cooperative Research Program
ADA	Americans with Disabilities Act
APTA	American Public Transportation Association
ASCE	American Society of Civil Engineers
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
ATA	Air Transport Association
ATA	American Trucking Associations
CTAA	Community Transportation Association of America
CTBSSP	Commercial Truck and Bus Safety Synthesis Program
DHS	Department of Homeland Security
DOE	Department of Energy
EPA	Environmental Protection Agency
FAA	Federal Aviation Administration
FHWA	Federal Highway Administration
FMCSA	Federal Motor Carrier Safety Administration
FRA	Federal Railroad Administration
FTA	Federal Transit Administration
HMCRP	Hazardous Materials Cooperative Research Program
IEEE	Institute of Electrical and Electronics Engineers
ISTEA	Intermodal Surface Transportation Efficiency Act of 1991
ITE	Institute of Transportation Engineers
NASA	National Aeronautics and Space Administration
NASAO	National Association of State Aviation Officials
NCFRP	National Cooperative Freight Research Program
NCHRP	National Cooperative Highway Research Program
NHTSA	National Highway Traffic Safety Administration
NTSB	National Transportation Safety Board
PHMSA	Pipeline and Hazardous Materials Safety Administration
RITA	Research and Innovative Technology Administration
SAE	Society of Automotive Engineers
SAFETEA-LU	Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (2005)
TCRP	Transit Cooperative Research Program
TEA-21	Transportation Equity Act for the 21st Century (1998)
TRB	Transportation Research Board
TSA	Transportation Security Administration
U.S.DOT	United States Department of Transportation