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Standards for Transportation Related GIS Data

by

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Final Report

prepared by

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Introduction

The use of geographical information systems (GIS) has grown dramatically in the last five years. This is primarily due to the great capabilities GIS offers for the storage, display, and analysis of information, and the rapidly decreasing costs for the necessary computer hardware and software. Improvements in user friendly access systems to GIS information and the introduction of inexpensive desktop systems operating on personal computers, have extended the types of users from computer technology specialists to planners, administraters, researchers, and the general public. The growing number of GIS users and the demands for data have contributed to the availability of large amounts of digital information. In most States in the 1980's, there were only a few groups such as environmental and transportation agencies, or university departments managing GIS facilities. Now, as in Delaware, there are numerous groups and individuals using several types of GIS in a range of applications.

With so many people involved in GIS and generating data, there is increased concern with how members of the community can communicate with each other. In any one locale there is several millions of dollars being spent on GIS technology. GIS users in a community often have overlapping information needs, and governments realize a growing need for coordination and are looking for ways to protect and optimize the benefits of their investments in the technology. The major costs incurred by GIS projects are directly related to data acquisition or conversion. If information can be shared, and a high degree of quality can be maintained, everyone in the community could benefit.

The function of standards is primarily to support communication and coordination in a community. This report summarizes research sponsored by the Delaware Transportation Institute to address standards for geographical information systems (GIS). The research was focused on those areas of standards of most concern to transportation agencies, but the findings and recommendations are applicable to any agency using GIS technology. Substantial effort was made to research how groups at the national, state, and local level are addressing standards. Numerous reports and literature were collected, some of which are presented in the appendix. Recommendations are made at the end of several of the chapters in consideration of the many types of GIS used in Delaware, and of the efforts which are currently underway.

In addition to this main document, an executive summary, and a second appendix* were prepared and are available on request.

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* Appendix B, see Table of Contents for a listing.

1 Forms and Features of Standards

1.1 Standards as Modes of Communication and Operation

A standard in its most general meaning can be viewed as a common point of reference or specification which can be shared, accepted, and developed by groups to establish a mode of communication and/or operating convention. The strength and usefulness of a standard is judged as to the level of acceptance it receives by a community as a basis for communication. The need for addressing standards is always associated with the call for coordination between groups since the ability to communicate is a prerequisite to coordination. The goals of setting standards are focused on minimizing costs related to difficulties of communication. Costs could be in terms of loss of time and money in translation procedures, lost opportunities, isolation, duplicated efforts and expenditures, and misunderstandings.

Standards represent modes of operation. They are the ground rules for operation in a community, and for informed, responsible, and efficient action. They enable the most people in the community to interact with technology and resources in an efficient way. They promote quality and assist in addressing inevitable issues.

1.2 An Overview of Types of Standards for GIS

With so many forms of information being represented and communicated in GIS, there are several areas which can be addressed by standards. This section briefly describes major areas of GIS which can be addressed by standards. Each area is discussed in detail later in this report.

Coordinate Systems

Coordinate systems provide a framework for describing the location of data on the earth. They are based on a geodetic network established through a study and measurement of the Earth, and they scientifically address the problem of modeling a round Earth on a flat map surface. When spatial data layers are specified in the same coordinate system in a GIS, they can be overlaid and spatially related with each other. Most GIS can work with a variety of coordinate systems and have utilities to easily convert from one system to another. Coordinate system standards can assist users in defining a common system with which they may transfer information.

Accuracy

Accuracy in GIS usually refers to positional accuracy which is the precision to which spatial features are located with respect to their true ground positions. Positional accuracy standards are usually described in terms of the resolution and scale of spatial mapping. There are other types of accuracy that are referred to when addressing a spatial data set. The primary feature of GIS is the ability to tie attribute information to map features (points, lines, areas) which are representations or models of the physical world. The descriptive accuracy of attributes for spatial features of GIS data (i.e. a land area is in fact commercially zoned when the zoning attribute for that area says it is) is referred to as attribute accuracy. Accuracy has a much broader definition in that it describes the overall quality of spatial data. Such quality measurements are the completeness of data, the internal consistency and appropriateness of models of the real world, and the accuracy in which the relationships between spatial features are represented.

Standards for accuracy in GIS describe methods for measuring and describing the accuracy of spatial data. Accuracy standards are necessary for quality control and supporting valid analysis when multiple GIS layers are combined as in overlay analysis. They form the basis for knowledge of the limitations of the results and conclusions presented by analysis and products.

Documentation of Information (Metadata)

Metadata (data about data) describes the content, quality, condition, and other characteristics of information. For the transfer of information between groups, metadata is vital to ascertaining the fitness for a particular use, the availability, and the format of data. The major uses of metadata are to help organize and maintain an organization's spatial data, provide information about an organization's data holdings, and to provide information to process and interpret data received through a transfer from an external source. Metadata standards serve as guidelines to the types of descriptive information which will be compiled for data. Documentation or metadata standards are the primary focus of GIS standards by agencies across the country because they are vital for the informed, efficient sharing of information. Data cannot be shared, if it cannot be identified. Efficient distribution of information and realizing the full potential of computer networks depends on documentation and documentation standards.

Attributes and Coding

Physical features such as roads, properties, sewer lines, and water wells are represented as points, lines, and polygons in GIS, and these graphic entities can be identified and linked to attribute information in the form of data tables. A line could represent a segment of roadway which would have a common name or identifier to link information kept on traffic flows, road conditions, accidents, etc.. This identifier could be "Shipley Street" or "Maintenance Road 34" or in a more coded fashion "M34". If transportation agencies in a particular area used different identifiers for road segments, and hence different links to tabular data, there would obviously be difficulty (without some kind of cross reference) in using and relating each others information. Inconsistent coding of attribute information can cause similar problems where for instance, agencies use different land use coding or classification systems. Standards are therefore promoted for the identification, classification, and coding of information so that groups can more easily share and relate each others data.

Elements within a data table such as "land use" or "zoning" or "address" exist as fields (items) in the table and have a specific storage structure. The structure of a data element includes its name (i.e. ADDRESS1) and its data type with which it is represented in the computer system. Examples of data types include "Character field of length 20", and "Real Number of width 20 with 2 decimal points". Because the storage structure of the data element also effects the how the information can be used and referenced, there are standards which specify the structure of data elements within data sets. These standards are usually presented in the form of a standard data dictionary which includes a specific name, structure, definition, and description of each data element addressed.

Data Transfer

GIS deals with numerous representations and data types which include, data tables, linear, point, and polygon representations of the real world, digital images, text, elevation models, and a range of map types and graphics. The way a GIS stores data differs from one system to another. This is of great concern for organizations who desire compatibility between systems to the extent that information can be easily and reliably transferred. There are a number of ways that information can be transferred between different GIS depending on the source and target system, and the type of data. GIS vendors continue to develop utilities which can convert and transfer data, but frequently the process of data conversion is not straight forward and sometimes a great deal of time is spent and data is lost. For users who are not data conversion specialists, data transfer can be frustrating.

Coordination and avoiding duplication of effort depends on reliable methods of sharing information. The identification and use of standard methods and data types for transfer, help simplify the process of information sharing. When services are contracted for data products or when data products are a by product of projects, the identification of effective transfer methods and data formats simplifies distribution and insures that products are not lost or inaccessible, given different hardware or software configurations.

Geographic Framework and Model Standards

A main feature of GIS is that it uses coordinate objects such as points, lines, and polygons to represent real world features. The method in which information is represented forms a structure or framework for the organization of physical information. For example, a traffic zone delineated by physical boundaries such as rivers and roads, and represented in GIS by lines and polygons, can form a framework or standard for the reporting of population or employment data. If two groups addressing the same area defined sets of traffic zones independently using different methodology and boundaries, and different sets of lines and polygons to represent them, then the framework (units) of the traffic zone data they each manage would be in many cases incompatible for analysis. This happens frequently and can be difficult and time consuming to resolve. It is particularly a problem when examining historical data for trends where the units which the data were collected were different. An example of a linear geographic framework would be the Tiger Line Files for roadways. The lines in the TIGER Files form the framework for address range and other road attribute information.

A primary framework for transportation GIS is the road center line file. A road center line file enhanced with a linear referencing systems represents roads as a collection of line segments and measures with a identification for each segment which forms the link to attribute data. Route classifications, location of accidents, roads being paved, the width of a road, and location of access points are all types of information which can be spatially referenced using a center line file. Digital files for transportation facilities coupled with those for political boundaries, water bodies, and other physical features also form a framework on which data can be referenced.

The concept of a framework put forth by the Federal Geographic Data Committee is similar in that it represents a basic, consistent set of digital data and supporting services which will provide a geospatial foundation to which an organization may add detail and attach attributes and other themes of data. The primary feature of a framework in regards to standards is that it represents a common way of structuring information.

Locational Reference Systems

Related to frameworks are locational reference systems. A prime feature of GIS is their ability to locate information spatially. There are a few ways spatial objects can be located. One way is through the specifications of horizontal and vertical coordinates (i.e. X/Y or latitude/longitude). Another way of locating people or facilities is by address. In transportation systems the primary way of locating facilities or incidents is through a linear referencing system by specifying a road or route and a mile point on that route. Consistent methods of locating data foster communication and coordination in the GIS community.

Distribution

Data transfer as referred to above refers more to data formats and the transfer of data files, and is a vital technical component to distribution. Distribution in a general sense depends more on policies and modes of operation used to disseminate information. Issues in distribution include those involving security, contribution and access of data, and overall specifications for the delivery of data products. Standards in this area take the form of guidelines for agencies.

As there are some difficult issues involved, distribution policies are often lacking and become a major source of confusion and frustration for many users in the rapidly developing area of GIS.

Hardware and Software Platforms as Standards

Administrators and Purchasing Directors are particularly interested in the compatibility of information systems. The costs associated with the implementation and maintenance of GIS and the investments necessary in training of personnel, data collection, and setup and configuration of computer systems are related to the particular GIS platform employed. To avoid the percieved or real technical difficulties and financial repercussions resulting from the use of several GIS platforms within or between groups that work together, organizations such as state governments have adopted particular GIS platforms as official or approved systems. Selection of a particular platform can be a way of focusing investments. The GIS platform chosen becomes an "official" standard.

The selection of a particular GIS platform does not address all areas to which standards can apply. Quality, documentation, database format, coding standards, and other information and procedures which support the communication of data and coordination of efforts are not determined by the GIS platform chosen. The main advantage of selecting a GIS platform as a standard is to simplify the technicalities of data sharing, user support, and system maintenance and configuration. Overall costs may or may not be lower depending on the system chosen, and benefits may or may not be greater depending on the needs of the users and the capabilities of the system. In cases where one platform will not meet all needs of users, or in the case where a number of systems have evolved over time with previous investments (typically the case), the setting of a particular GIS platform as an operating standard may be impractical or impossible.

Even with standard software and hardware, there is no guarantee how that platform will change or be supported or effective in the future. Computer hardware platforms and features are changing at an exciting, but sometimes frightening pace. GIS is used in many diverse areas and users differ widely in regards to their technical experience and needs. Where some users require the high end features available in systems like InterGraph or ARC/INFO, others find their needs met very well by relatively inexpensive personal computer based GIS such as Map/Info and ATLAS GIS.

State transportation agencies generally use InterGraph or ARC/INFO, and Federal agencies predominantly use ARC/INFO. But there are a range of other very effective systems for transportation planning being used. Practically speaking, within a department and in a specific network environment using certain data resources, users must select a particular system. For the Delaware Department of Transportation (DELDOT) the primary platform for the development and maintenance of cartographic products, center line files, and linear referencing systems is INTERGRAPH. The DELDOT Planning Department has had success using MapInfo for their applications. Groups in Delaware and in other States also employ desktop GIS and a range of more specific systems designed for special applications in transportation such as travel demand forecasting, transit planning, and commuter services. Many GIS now have the ability to read a much broader range of data types which allows for more flexibility. In the area of GIS data access their are major developments. Products like InterGraph's VISTA MAP and ARC/INFO's ARC/VIEW are designed as inexpensive query and display systems which are user friendly.

GIS is very effective in bringing together data and organizations of all types. GIS hardware and software options are always changing, and the needs of users are very diverse. For these reasons, and as a long term view, this researcher believes that standards should focus on information and policies, rather than on a particular computer hardware or software configuration. When identifying standards for data file archive and transfer formats it is important to take into account the capabilities and features of GIS software currently available. Beyond this, the research conducted does not reference particular hardware and software.

1.3 Desired Features of Standards

1.31 Acceptance and Support

As a basis and facility for communication and operations, the primary feature of a successful standard is its acceptance and use by the community. Most standards are established not by proclamation or planning but through precedence, or a Darwinian emergence in the market place. In many cases the merit of a standard lies solely in its acceptance as a fixed reference point to focus efforts and support. With huge investments spent on particular computer hardware, software, and systems development, standards (official or unofficial) form the common basis for users, hardware manufacturers, and software and system developers to work together in a necessarily symbiotic relationship. As a standard is more universally accepted, it of course becomes more firmly rooted and is more successful as a tool to focus attention. The less "standards" used to address a particular issue, the less dispersed and more efficient will be the combined investments of the community.

1.32 Ease of Implementation

For a standard to be useful and realize broad support over other possible standards, there must be operating advantages to its use. The ease of which the community can adhere to a standard will effect its acceptance and therefore success. Official approval of a standard through a government dictate or standards organization can exert a strong influence, but if a standard is too difficult to implement it will not be supported and will not be as successful. There would be a problem for instance, if a transfer standard was established that was too complicated and costly for GIS vendors or small operations to support. Or if a positional accuracy standard was implemented which demanded a level of accuracy which users could not attain. Addressing the practical needs of users and providing the necessary tools for implementation of a standard is vital.

Crucial to the ease of implementation of a standard is that the community knows about it and understands it. Documentation of standards, and tools to implement them must be made available to the community. Important inititatives sited in this report describe efforts across the country to provide literature to communities to make them aware of guidelines and standards.

1.33 Functionality

Finally, a standard must be functional. A transfer standard must preserve the original integrity of the data transferred. A standard coding or classification system must provide an effective and consistent way for users to represent their data. A standard access system must serve the users needs and form an effective interface to information systems. The functionality of a standard forms the basis for its acceptance and implementation. Questions to consider are; Does it make sense? Does the standard match the scope for which it was intended? Does it effectively promote the particular communication it addresses?

2 Relevance of Standards to Transportation Agencies

Standards are concerned with the ability to effectively communicate information and coordinate efforts. State and national transportation agencies are providers and users of information. They are responsible for diverse activities conducted by a large array of agencies and individuals. To meet the needs of these organizations and individuals there are large investments in information systems and data acquisition. To invest efficiently, transportation agencies must be able to share resources where their information needs overlap. With the requirements of ISTEA, the Clean Air Act, and other initiatives at state levels which address transportation planning and issues more comprehensively, there is an even greater need for transportation departments to effectively communicate externally as well as internally. The following sections discuss the importance of transportation agencies addressing standards.

2.1 Transportation Agencies As Users of Information

Users of information wish to be able to determine as easily as possible what information resources are available to meet their particular needs. They want information of a quality which is usable for their needs. They wish to have a convenient distribution mechanism. They wish to have little or no data conversion needs, or difficulties working with data on their particular computer systems.

Standards can support users in addressing all of the areas mentioned above. Documentation standards which comprehensively describe aspects of available data can help the user determine the usability, structure, and origin of data. Standards for the development and accuracy of data help insure a specific quality. Standard methods of publishing or making data available assist the user in accessing and making use of the data.

2.11 Users Within Transportation Agencies

Transportation departments at the state and national level are made up of several different agencies each with their own responsibility, whether it is planning, highway maintenance, public transit, cartography, engineering, or some other function. The size of these agencies and the varied responsibilities of each group make coordination and communication a continuing challenge. In many cases, there are as many ways to deal with information as there are groups using it. The automated mapping, computer aided drafting, facilities management, video logging, accounting, and geographical information systems which are in use by each group cater to different work focuses but often have overlapping information needs. To standardize around particular hardware or software systems is not always possible or desirable. A range of software exists to handle specific applications. Standards within transportation agencies are crucial to efficient operation as they promote communication and cooperation and therefore avoid unnecessary costs associated with duplication of effort, and lack of consistent information frameworks. Sharing resources requires adherence to some common reference for the structure of information (such as a common identification system for roads) and accepted and understood procedures for the documentation and access of information.

2.12 Using Data From Outside Groups

At times the development of GIS technology seems slow, particularly when it involves addressing some of the harder issues such as the maintenance of data, privacy and ownership, distribution, and sale and financing of data products. The continuing technological advances in data storage, processing speed, inexpensive user friendly desktop GIS, and networks, however, are getting people involved rapidly. With the greater accessability to GIS technology there is an explosive increase in the demand and supply of digital data. Public and private groups of all types are building spatial information systems and producing data. Transportation agencies can realize great benefits in being able to use data from outside sources, especially to assist in planning activities.

Occurring at the same time more spatial information is being made available, is the shift of transportation agencies from a infrastructure building and maintenance function toward requirements to take a more comprehensive planning approach. The 1990 Amendments to the Clean Air Act, the 1991 Intermodal Surface Transportation Efficiency Act (ISTEA), and the National Environmental Policy Act (NEPA -since 1969), require broad based management systems and a more comprehensive look at transportation systems. This not only makes it more important than ever for agencies within transportation agencies to work together, but it also demands a greater communication with outside agencies.

2.13 Contracting for Data Products

Transportation agencies around the country are investing in the development of digital products. These investments are sometimes focused specifically on data products such as with the creation of digital orthophotography or digital road center line files. Digital products can also be created as a by product of a project, such as the development of a congestion management system or a corridor study. Specification of deliverables with reference to operational accuracy requirements or to standard formats for submission of digital products will help insure greater value and usability of the information.

2.2 Transportation Agencies as Providers of Information

Those who provide information are providing a service to users. This service involves informing the user as to the content and usability of the data, as well as providing the data itself. It often involves agreements or contractual arrangements specifying how the data may be used or obtained. Providers must prepare data on a particular transfer media (i.e.disk, tape, network) in a particular format. Providers of data seek to minimize the overhead costs associated with this service.

Standards help providers of data. Documentation standards and procedures can save countless hours on the phone answering questions like "What do you have?", "What is the format and accuracy?", and "When and how was it created?". Standard formats for data transfer allow the provider to focus services around certain accepted structures rather than trying to support a wide range of GIS file types. Standard modes of distribution assist with the administrative overhead involved. Standards allow providers of information to efficiently offer a better service.

2.21 Base Maps and Road Network Files

In several states, the department of transportation has made significant investment in the development and maintenance of digital map files representing road systems and facilities. For cartographic purposes base map features such as streams, railways, and public lands have been compiled as well. Cartographic products developed for road maps can represent a considerable contribution as base maps to serve the needs of several public and private groups. They are generally of a higher accuracy than commercially available products such as the TIGER Line Files. Users internal to DOT's, and external, benefit from the use of common base map since there is a consistent reference for the display and development of other data.

In some states, as in Delaware, transportation departments have refined their cartographic products into accurate road centerline files and into road network frameworks used to locate data. Much of the data important to transportation applications is located by using linear referencing systems (i.e. route and mile point) which are built on these road network frameworks. It is in the best interests of those who work with transportation data to develop standards for linear referencing, and the road network on which the locational scheme is based. Easy access to base map and road network representations encourage users to not redevelop this data and to conform to a representation of road features which is useful to a wider audience.

2.22 Federal Guidelines for the Distribution and Reporting of Information

State transportation agencies must adhere to standard specifications for the reporting of data to the Federal government. In particular, the Highway Performance Monitoring System (HPMS) is the major set of guidelines which States, MPO's and local governments must conform to when providing information to federal agencies. The HPMS Field Manual describes in detail the types and formats necessary for the submission of data. The HPMS guidelines for reporting represent a standard to which all states must adhere. By understanding standards promoted at a federal level and by making efforts to address these standards, State transportation agencies can ease the burden of reporting.

Federal agencies as part of the National Spatial Data Infrastructure must conform to various information standards. These include standards for the documentation and transfer of information, and standards for the representation of information such as is the Federal Information Processing Standards (FIPS) Codes. There will be a growing importance for state and local agencies to become familiar with and in some cases conform to these standards.

3 Federal Activities in Standards

3.1 Responsibilities of the Federal Geographic Data Committee

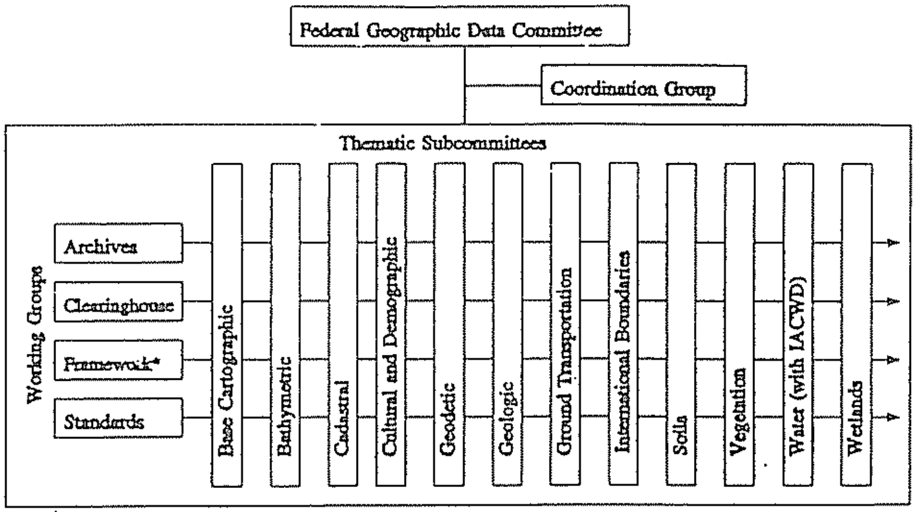
The Federal Geographic Data Committee (FGDC) is charged thru the Office of Management and Budget Circular A-16 "Coordination of Surveying, Mapping, and Related Spatial Data Activities," with the responsibility of "encouraging the development and implementation of standards, exchange formats, specifications, procedures, and guidelines" as applied to surveying, mapping, and related geospatial data. The FGDC is made up of representatives from several federal and State agencies (see figure 1). The FGDC oversees and provides policy guidance for agencies' efforts. The FGDC's primary mechanism is a series of subcommittees which work on issues related to categories coordinated under the circular. Working groups have been established for issues which include a clearinghouse for data, a framework of data, data archives and technologies (see figure 2).

Figure 1. Federal Agencies Comprising the Federal Geographic Data Committee (1994)

Chair - Bruce Babitt, Secretary of the Interior
Department of Agriculture
Department of Commerce
Department of Defense
Department of Energy
Department of Housing and Urban Development
Department of Labor
Department of the Interior
Department of State
Department of Transportation
Environmental Protection Agency
Federal Emergency Management Agency
Library of Congress
National Aeronautics and Space Administration
National Archives and Records Administration
Tennessee Valley Authority

In Section 2 of Executive Order 12906, "Coordinating Geographic Data Acquisition and Access: The National Spatial Data Infrastructure", signed on April 11, 1994 by President Clinton, the FGDC is assigned responsibility of coordinating the Federal Government's development of the NSDI. Order 12906 also charges the committee to seek to involve State, local and tribal governments in the development and implementation of the initiatives, and to use the expertise of academia, the private sector, and other organizations to aid in the development and implementation of objectives.

Figure 2. FGDC Subcommittees and Working Groups



* - Includes representatives of State and local government.

FGDC Subcommittees and Lead Departments

Base Cartographic - Interior
Bathymetric - Commerce
Cadastral - Interior
Cultural and Demographic - Commerce
Geodetic - Commerce
Geologic - Interior
Ground Transportation - Transportation
International Boundaries - State
Soils - Agriculture
Vegetation - Agriculture
Water - cosponsored with the Interagency Advisory Committee on Water Data
Wetlands - Interior

3.2 FGDC Activities Relevant to Standards

A broad range of activities are currently managed by the FGDC and the following sections discuss some of the highlights relevant to standards.

3.21 FGDC Content Standards for Digital Geospatial Metadata

The Documentation of data and data systems is referred to as metadata. Metadata (data about data) describes the content, quality, condition, and other characteristics of information. On June 8, 1994 the FGDC approved the "Content Standards for Digital Geospatial Metadata" (for convenience referred to here as the Content Standards) which is a documentation standard designed to help GIS users determine what data exist, the fitness of data for specific applications, and the conditions for access and transfer of GIS data. Executive Order 12906 (April 11,1994), "Coordinating Geographic Data Acquisition and Access: The National Spatial Data Infrastructure", instructs all Federal agencies to use the standard to document new geospatial data beginning in 1995, and to provide these metadata to the public through the National Geospatial Data Clearinghouse.

The standard defines data elements for the following areas for documentation:

- Identification Information
- Data Quality Information
- Spatial Data Organization Information
- Spatial Reference Information
- Entity and Attribute Information
- Distribution Information
- Metadata Reference Information
- Citation Information

The Content Standards, an example of its application in documenting a center line file, and other literature are provided in the appendix of this report, and are discussed in more detail in Section 4. The Content Standards are perhaps the greatest contribution to standards to date, and for the FGDC to promote them so strongly underscores the importance of documentation as the foundation of communication in GIS.

3.22 FGDC Ground Transportation Subcommittee Position and Recommendations on Linear Reference Systems

All States as part of the Highway Performance Monitoring System (HPMS) must submit a digital highway network database and/or set of maps showing the location of all HPMS inventory routes and their corresponding linear reference system attributes. These submittals will be used for updates to the FHWA NHPN. However, there currently is no standard method used by States for specification of highway facilities or linear referencing. Recognizing this, the FGDC Ground Transportation Subcommittee has prepared a position paper which outlines recommendations for structures of linear referencing systems. These recommendations include identification of key attribute fields for transportation network data, and recommended structures for linear referencing along roads, rail, and waterways. Linear referencing is discussed more fully in the chapter in this report dealing with locational reference systems. A copy of the FGDC position paper is included in Appendix A.

3.23 FGDC Framework Working Group

The FGDC has recognized that while applications of digital geospatial data vary greatly, there is often a need for a few common themes of data. Such common themes would include base maps showing roads, railroads, and water bodies, digital photography, demographic data and planning zone information, political boundaries and public lands, and primary environmental layers such as wetlands, flood plains, and lands restricted from development. Often this information is available in some States and localities, but not in others. As no system currently exists to maintain and manage the variety of common information being collected by the public and private sector, representatives from local, State, and Federal agencies are developing the concept of a "framework" of geospatial data to meet this need.

The framework is defined as a basic, consistent set of digital geospatial data and supporting services which include the following purpose and features.

- Provide a geospatial foundation to which an organization may add detail.
- Provide a base on which an organization can accurately register and compile data themes.
- Framework data should be certified as to complying with standards for quality.
- Framework data should be representative of the best data available
- The Framework should contain consistently generalized data to support regional and national applications.
- Framework data should be accessible at the cost of dissemination, free from use criteria or constraints, and available in non-proprietary forms.
- Rules for contributing to the framework, and the requirements placed on the contributions should be minimal and stable.
- The framework should evolve with users' and contributors' changing requirements and capabilities.

The framework will be operated and maintained by a group of participants that agree to provide data and meet content, quality, policy, and procedural criteria. Institutional roles identified for participants include, Data Producer, Area Integrator, Data Distributor, Theme Manager, Theme Expert, and Policy Coordinator. Work is currently underway by the FGDC Framework Working Group to develop an implementation strategy. The FGDC Bulletin describing the National Geospatial Data Framework, which the above description was summarized from, is included in Appendix A.

3.24 National Geospatial Data Clearinghouse

Executive Order 12906 "Coordinating Geographic Data Acquisition and Access: The National Spatial Data Infrastucture" requires that each agency use the FGDC metadata standards to document new data and make them electronically accessible through the National Geospatial

Data Clearinghouse (NGDC). "The Clearinghouse will allow its users to determine what geospatial data exist, find the data they need, evaluate the usefulness of the data for their applications, and obtain or order the data as economically as possible". Each agency will determine how its geospatial data will be managed and presented through the Clearinghouse. The NGDC is meant to be a distributed, electronically connected network of geospatial data producers, managers, and users. This broad definition is meant to allow for flexibility. A plan must be completed by April 1995 in consultation with FGDC to address the following questions:

- How will existing data be documented?
- How will data be made available to the public?
- How will the agency make use of the Clearinghouse prior to expending funds for collection of new data?

The Clearinghouse allows data providers to make known what geospatial data exist, and instructions for accessing the data. Each data provider describes and provides information over the network using a variety of software tools. The Clearinghouse uses the Internet which currently connects more than 2 million host computers and 15 to 20 million users in more than 100 countries. Data providers participate by providing a network node on the Internet or working with others to establish a site that provides the metadata and access to the geospatial data.

3.3 The Spatial Data Transfer Standard

The Spatial Data Transfer Standard was designed to address a range of issues involved in the transfer of spatial data. SDTS has been developed so that "Vector data and raster data of many different types, models, and structures, along with associated attribute data also of widely varying types, models, and structures, can be exchanged between dissimilar systems"[1]. SDTS is a product of an approximately 9 year effort by many individuals and groups, with the U.S. Geologic Survey (USGS) playing the primary leadership in its development and promotion. After review and testing by government agencies and private industry, SDTS was submitted to the National Institute of Standards (NIST) for approval as a Federal Information Processing Standard (FIPS). It was subsequently approved in July 29, 1992 as FIPS Publication 17. As of February 1994 all federal agencies are required to make available all new spatial data in this format.

SDTS facilitates the exchange of coordinate and attribute data. It is different from most spatial data exchange formats in that SDTS requires metadata, citation, and distribution information within exchange files. A large number of publications describing SDTS are made available by USGS and other organizations. As SDTS is composed of other official standards

[1] SDTS Fact Sheet, September 1994

for data transfer and metadata, there is also a large body of information on features within SDTS. An investment in time is necessary to understand the requirements of a comprehensive transfer of information as represented by SDTS, and the actual implementation of the standard. A chapter in this report focuses on identifying the key elements that make up the standard, the considerations involved in its implementation, and determining the value of the standard for GIS facilities as they currently exist.

3.4 FHWA National Highway Planning Network

Version 2.0 of the Federal Highway Administration National Highway Planning Network (FHWA NHPN) is a digital base currently available on compact disk, and used in the production of the Proposed National Highway System Maps. It is a collection of road and political boundary, representations accurate to about+/- 80m, taken from a variety of state and federal sources. Its data schema includes link and node table files which define a digital structure for roads and their length and classification. The FHWA NHPN forms the beginning of a national standard for specifying transportation facilities and linear referencing. A linear referencing system is system of identified road segments (or routes) which together with a mile point or kilometer point measuring system, allows for the description of features along the road to be located by curvilinear measure along the road. Address geocoding is considered another form of linear referencing based on address ranges on road sections rather than mile point. A long term effort of the FHWA's Office of Research is to develop a national standard of locating data either by linear reference, addressing, or coordinates which can be used for vehicle location in vehicle navigation, and routing under various IVHS projects.

3.5 FHWA Highway Performance Monitoring System

While seen more as a reporting form for information required by law, than a standard, the FHWA Highway Performance Monitoring System is produced because of the necessity for the collection of information from several groups. The guidelines for HPMS submittals form a standard method for the submittal of state transportation information. It provides a standard coding for data, defines standard categories of how information is collected, and presents guidelines for linear reference systems. Each State is required to submit to FHWA a digital network database and /or a set of maps showing the location of all HPMS inventory routes and their corresponding linear reference system attributes. These submissions will be used by FHWA to develop a linear network for the FHWA National Highway Planning Network. The HPMS is a major mechanism for the standardization of transportation data format.

4 State and Local Activities

4.1 Coordinating Bodies

Within State government there has always been a need for large amounts of information. GIS is very powerful in storing, displaying, and accessing information. Recognizing this, agencies within States have rapidly embraced GIS to meet their information management and analysis needs. Data acquisition and/or conversion is the largest cost for the establishment of GIS facilities.[2] Government agencies in particular have many common data requirements for GIS such as base maps, digital photography, demographics, land use, and environmental themes. Therefore, as the number of agencies who use GIS increases, States through a number of different organizational structures, begin to meet and investigate issues of communication and coordination, and begin to formulate multi-agency standards or ground rules.

Such coordinating agencies include groups like the Wisconsin Land Information Board (WLIB). The WLIB is a group that evolved from studies which showed the benefits of the modernization of land record information systems. Its primary duties are in the following areas;

County-Wide Plans for Land Records Modernization
State Agency Integration
State Clearinghouse for Land Information and Land Information Systems
Grant-In-Aid to Local Governments
Provision of Technical Assistance to State and Local Government.

This group, funded by filing fees collected by the county Register of Deeds office, provides a mechanism to induce local governments to meet information standards and sharing requirements. WLIB has produced guidelines for standard development (December 1992) which detail the official process for the creation, review, and adoption of standards.

There are several other examples of such groups. The Mississippi Automated Resource Information System facilitates information sharing and standards, and assists users in the state in obtaining, developing, and analyzing data. The North Carolina Geographic Information Coordinating Council, established in 1991 provides technical oversight and direction to the state's overall approach to information resource management. There is the Texas Department of Information Resources which was created to provide leadership and coordination of information resources in the State. The New Mexico Geographic Information Council includes private and public groups and by executive order works to encourage coordination and cooperation. Under a 1985 Growth Management Act, Florida formed a multi-agency coordinating council, the Growth Management Data Network Coordinating Council to facilitate

[2] Utah SGID Users Guide, pg.O2, 70% to 80% of total costs

the sharing of information. In several states the State Mapping Advisory Committee (SMAC's) originally created to focus on mapping issues have developed into addressing GIS coordination within States. Most of these groups have some official mandate for GIS coordination and they all represent several agencies within the State involved in the development of guidelines and standards. In other States, a university, or a particular government agency such as a department of transportation or department of natural resources assumes a leadership role because of experience, technical capability, or funding. DOT's due to their size and traditional mapping and facilities management responsibilities are usually very strong players.

Some coordinating bodies or lead agencies are developing specific standards or establishing GIS resources in the community. Others are in the process of self definition to lay a foundation for a multi-agency role in GIS. The following sections describe some specific achievements relevant to standards.

4.2 Resource Guides and Handbooks

Many agencies within a community or State have similar needs when they operate GIS systems or seek to develop them. They are looking for data sets which will meet their needs and want to know how they could obtain them. They wish to know about standards or policies for GIS. They want to know what others are doing. A major contribution to helping the community and to establishing standards is a State GIS resource guide or handbook. With such a document users can find in one place the answer to many of their questions. They can identify human and information resources in their area, and they can determine guidelines for data distribution and access. Such handbooks are very powerful in establishing standards and educating the community.

In most cases GIS users very much appreciate needs and benefits of standards and guidelines. While they wish the freedom to use their own individualized system for their specific needs, they do wish to conform their operations to guidelines and methods used in the community, particularly in areas of data transfer and sharing. Responsible and efficient investment in information systems depends on the community being informed. A GIS resource guide or handbook is a document that government agencies, consultants, universities, and other groups can reference as the standard for present and future activities. It can represent a multi agency consensus on technical and policy issues.

A few examples are referenced in the next sections.

4.21 The New Jersey GIS Resource Guide

Prepared and Published by the New Jersey State Mapping Advisory Committee (SMAC), the New Jersey GIS Resource Guide is a wealth of information on all aspects of GIS and is a great resource to the New Jersey GIS community. For the general user, it is packed with figures, references, standards, inventories, contacts, and numerous articles and other contributions of the community. For the beginner, it discusses background on GIS concepts and data types. For the administrator it addresses State activities and policies such as the distribution of information and guidelines for contracting the development of data products. Several types of reference materials are presented in the appendix of the New Jersey GIS Resource Guide. It is the collaborative effort of representatives of different levels of government, universities, private sector companies, and members of quasi-public utilities. The New Jersey GIS Resource Guide is envisioned as a dynamic reference which will go through continual update by the members of the New Jersey SMAC and the community.

4.22 The Vermont GIS Policies, Standards, Guidelines, and Procedures Handbook

Legislation in Vermont (Act 200 of 1988) provides funds for the creation of a Vermont Geographic Information System and an Office of Geographic Information Services (OGIS) has been established by Executive Order within the Agency of Administration. The State OGIS operates as a small office at the center of a network of many service centers and data sources. OGIS acts as a clearinghouse, review board, and desseminator of information. The Vermont Center for Geographic Information, originally a government agency established by legislation and now a non-profit agency, was contracted to create the Vermont GIS Policies, Standards, Guidelines, and Procedures Handbook (the Handbook). The Handbook addresses standards in documentation, accuracy, coordinate systems, cadastral mapping, attributes (e.g. land use/land cover codes), and distribution. It also presents formal policy statements on regional and local government roles, public access, pricing of data and services, and procurement. The tables of contents for this handbook is shown in figure 3.

4.23 The Utah State Geographic Information Database (SGID) Users Guide

The Automated Geographic Reference Center (AGRC), an office of the Division of Information Technology Services within the Department of Administrative Services in Utah, provides leadership in the state in the development and effective use of GIS. A primary function of AGRC is to make information about existing geographic data available to those who need it. As part of this mission they produce the State Geographic Information Database (SGID) which was designed to function as a inventory, repository, and set of standards for geographic data in Utah. The SGID Users Guide, describes in detail, metadata standards, attribute and database standards, data quality ratings, file organization, access methods, and agency participation guidelines. This guide also provides the format, content, and quality of over one hundred and twenty GIS layers which are available within the SGID, and which form a comprehensive GIS data framework for the State. A listing of these layers is provided in the appendix of this report as an example of a GIS data framework.

Figure 3. VGIS Handbook Table of Contents

Policies, Standards, Guidelines, and Procedures Handbook

GIS
VERMONT GEOGRAPHIC INFORMATION SYSTEM
HELPING VERMONTERS VISUALIZE CHOICE

Vermont Geographic Information System

4.3 Compilation and Distribution of Transportation Facility Data and Base Maps

In many States, departments of transportation have a history of working with automated mapping systems and GIS for use in cartography, planning, and design. Most States maintain digital cartographic base maps and center line files which comprise the layout of transportation facilities and include other features such as streams, railroads, and political boundaries. These data sets have taken years to develop. Often they are superior to data derived from Tiger Line Files or USGS DLG sources in that they more accurately represent features and include transportation network specifications. Some of the cartographic elements such as road names are more complete and up to date. These files developed by DOT's are often in demand by the local community. DOT's have in many cases contributed digital map data for projects to the community under informal arrangements.

The communities benefit greatly by having more accurate data products. Distribution of these files can also benefit the community by providing a standard, "official", accurate base map and center line file which agencies across the State can use for their individual needs. The base maps form a consistent framework to which data can be commonly referenced. The Pennsylvania DOT is an example of one DOT which has made a major effort to package and distribute their transportation facility base maps. Through an arrangement with the universities, PennDOT distributes this data to those who request it on compact disk (CD-ROM). Transportation facility attribute data such as traffic counts and road classifications are also included. Data is provided in InterGraph and ARC/INFO file formats. Data is compiled at the state, district, and county levels, and metadata is also included on the CD-ROM.

4.4 National Spatial Data Infrastructure Competitive Cooperative Agreements Program

The National Spatial Data Infrastructure (NSDI) Competitive Cooperative Agreements Program (CCAP) was established by the FGDC to help form partnerships with the non-Federal sector that will assist with the evolution of the NSDI. Goals are to encourage resource sharing projects through the use of technology, networking, and interagency coordination. As effective use of networks requires the use of standards for the identification and transfer of data, the CCAP projects are very focused on metadata standards and transfer standards. The Texas Natural Resources Information System, the State Library and DNR of Iowa, the State of Montana, the Wisconsin Land Information Board, Florida State University and Florida libraries and coordinating groups, the New Jersey DEP, and a coalition of North Carolina planning and GIS coordinating agencies, all had projects in 1994 which dealt with the preparation of data and network facilities to provide a network node on the Internet for access to GIS data. All of these projects reference the FGDC Content Standards for Geospatial Metadata as the tool used to post and describe GIS listings which will be made available. Alexandria Technical College and the Minnesota DNR developed training programs to address FGDC standards for producing geospatial data.

4.5 Locational Reference Systems

A locational reference system is a method of locating information in a GIS. One way to locate a spatial feature is by coordinates (e.g. longitude/latitude). Information about people or places can be located by address. Locational reference system standards for addressing are very important to public safety organizations. Another location method most useful for transportation facilities is by linear reference using route and milepoint. Many DOT's have focused on the development of linear reference systems to create a standard system for location. It is sometimes the case that one transportation agency will identify roads and routes one way and another will have a different method to meet a specific need. Lack of a consistent linear system can make data sharing very difficult. Changes in the way information is located over time can in some cases make data sets incompatible.

The Minnesota Department of Transportation' Council (MDTC) for Geographic Information is focused on developing an information infrastructure which allows data about transportation facilities, traffic, natural resources, and other spatial information to be fully integrated and shared. Standards for GIS applications are seen as a vital part of this infrastructure, and standards for locating data are a primary focus. To this end MDTC has prepared "Recommendations for Supporting and Developing Automated Translations among Location Reference Systems" which addresses methods of locating information and translation techniques between these systems.

The Delaware Department of Transportation (DELDOT) currently has projects underway to support and to establish locational reference standards. Digital cartographic products have been refined and built into center line files which support the linear reference system which has been in use for several years. DELDOT has taken the work a step further by working with the U.S. Census Bureau to conflate their 1:12,000 scale road/railroad centerline file with the TIGER/Line file. Conflation deals with the transfer of attribute data from one spatial feature to another. In this case DELDOT is working on a project to translate address ranges and census boundary information from the Tiger Line road and rail segments to those more accurate road segment representations of the DELDOT centerline file. The result will be a GIS road network file which can more accurately locate information by address as well as by route and mile point.

4.6 Cadastral Standards

A cadastral map or cadastre is a line drawn to scale depiction of property boundaries within a government jurisdiction. Many states are going from a manual drafting to an automated digital drafting of property maps. Digital property maps are very powerful for applications such as corridor analysis, land use surveys, and environmental protection. Specifications for standards for mapping, symbology, identification, and development of digital property layers can be very detailed and are considered at this time beyond the scope of this report. Cadastral standards are however of increasing importance to local governments and States who wish to foster uniformity and compatibility between different localities. Specifications and standards are available from governments who have automated their property management and mapping systems. One notable report has been produced by the North Carolina Land Records Management Program. The FGDC also has a subcommittee addressing cadastral standards.

5 Documentation Standards

5.1 Identifying Information

GIS is an information technology that brings together several types of information including maps, drawings, data tables, satellite imagery, graphics, digital photography, text, and programs. GIS data is available in numerous formats from a variety of sources and computing platforms. Every data set has its own unique history of how it was developed and generally every source agency uses, manages, and distributes their information differently. This complexity often makes the questions "What is the data?", "Is it useful and fit for a particular use?" and "Can I get and use the data?" very difficult and time consuming to answer. Easily available, comprehensive documentation is the only alternative to often painstaking research, and long hours on the telephone asking and answering the same types of questions again and again,

5.2 Establishing a Community of Information Users

Any effort to share information or coordinate efforts within a community of users must begin with documentation. Users must be aware that the information exists to use it. To use the information properly and to perform valid analysis, they must know how the information was developed and the restrictions for its use. Technical advances in the distribution of data over networks is making data transfer and communication easier, and the need for documentation greater.

5.3 Protecting Investments

A typical GIS facility will manage literally thousands of data files of various types, sizes, sources, and ages which are in various levels of completion. Often data must be archived to tape or other storage media because it outgrows the capacity of a system to hold it. At the same time, their is a great demand for personnel experienced with GIS and there is a corresponding turn over rate of GIS employees. Comprehensive documentation is necessary to facilitate change or addition of personnel. Knowledge of data systems must reside elsewhere besides the current employee's head. If no one knows what information is on a computer system, it is worthless.

One of the primary advantages of performing analysis and mapping with GIS is that while information may be time consuming to prepare at first, the digital representation provides a foundation which can be improved and built upon. Outside consultants serving government have the ability to work with GIS data and prefer it to the costly development of new data. A lack of documentation from the user community however can make the task of finding source data costly and time consuming. Such consultants, researchers, and members of the user community must often go through an awkward process of finding, assessing, and obtaining information for each new project. To make matters worse when the project is completed, resultant data products are often not documented, properly archived, or published and are left as practically inaccessible by-products of the project, which can only be taken advantage of for later work by a similar time consuming search. As this happens for many projects across the state, year after year, the result is a very inefficient use of resources.

5.4 Requirements and Tools Needed for Documentation

Documentation of data is an overhead associated with the use of data systems which is often not addressed. It can be very time consuming for system managers and users, it requires discipline to maintain, and is generally not required and budgeted as a deliverable in projects. Many GIS facilities are operated by a small staff of very dedicated individuals whose attention is stretched in many directions to create maps, perform analysis, and compile data. Overhead associated with the accumulation and maintenance of hardware and software systems is necessary for continued operation. Documentation is generally the last thing to do if time allows.

GIS users need procedures and software tools to make the job of documentation easier, more consistent, and less time consuming. Software vendors and users across the country are addressing this need. The method in all cases is to store information about GIS data in data tables, and then to employ user friendly menu systems integrated with GIS software to take the user step by step through the documentation process. Each record in these data tables contains the necessary items to describe the data set such as "Title", "Source", "Scale", and "Description". Software procedures are then created which can extract documentation data from these tables and format this information in reports. Having the documentation in data tables makes entry, update, and reporting much easier.

5.5 Importance in the Establishment of Standards

In areas which move as fast as GIS technology, standards are often set by simply documenting procedures and data formats. By making users aware of the existing forms of data through publication and communication, a standard can be born. The community must know about the standard. At one level, documentation procedures are important as standard methods for users to describe their data. At another level documentation is crucial for the establishment of all other standards.

5.6 Federal Geographic Data Committee (FGDC), "Content Standards for Digital Geospatial Metadata"

Documentation of data and data systems is referred to as metadata. Metadata (data about data) describes the content, quality, condition, and other characteristics of information. On June 8, 1994 the FGDC approved the "Content Standards for Digital Geospatial Metadata" (for convenience referred to here as the Content Standards) which is a documentation standard designed to help GIS users determine what data exist, the fitness of data for specific applications, and the conditions for access and transfer of GIS data. Executive Order 12906 (April 11,1994), "Coordinating Geographic Data Acquisition and Access: The National Spatial Data Infrastructure", instructs all Federal agencies to use the standard to document new geospatial data beginning in 1995, and to provide these metadata to the public through the National Geospatial Data Clearinghouse.

The standard defines data elements for the following areas:

- Identification Information
- Data Quality Information
- Spatial Data Organization Information
- Spatial Reference Information
- Entity and Attribute Information
- Distribution Information
- Metadata Reference Information
- Citation Information

The Content Standards define and specify data elements that will be included in documentation. The categorization and defined elements form the standard. It is left to the user to develop methods for producing or managing metadata. The Content Standards do not specify how information is organized in a computer system or in a data transfer, or the means by which this information is transmitted or communicated to the user.

The required metadata elements are best reviewed by using an example. An implementation of the Content Standards for the DELDOT Center Line File is in Appendix A. Also included in the appendix are the database formats used by ARC/INFO to store these items. These database formats were created as part of an ARC/INFO user interface for documentation (DOCUMENT.AML) originally authored by USGS and EPA and currently supported and distributed by Environmental Systems Research Institute (ESRI). The particular names or formats of the documentation elements listed need not be used. However, the transfer of documentation data tables between users is simplified when all users store metadata in the data tables specified in the same way.

5.7 Recommendations and Proposed Standards for Documentation of Spatial Data

- Adopt the FGDC Content Standards for Digital Geospatial Metadata as the official spatial data documentation standard in Delaware.

- Through a consensus process, define, adopt, and publish a specific data table format which can be used by all government agencies to store and submit metadata.

- Require that documentation tables in the adopted format be submitted for spatial data products created as part of government projects.

- Provide incentives for State and local agencies to provide descriptions of current data holdings in the standard documentation format to be stored at a clearing house site.

- Develop a GIS Resource Guide for Delaware, containing policies, standards, and guidelines modeled after the VGIS Handbook and the New Jersey GIS Resource Guide

6 Coordinate System Standards

6.1 Datums and Coordinate Systems

6.11 The Official Coordinate System and Survey Base for Delaware

The official coordinate system for Delaware as adopted in State Code, Volume 45, Chapter 266, is the "Delaware Coordinate System" whose full specification is as follows:

Delaware Coordinate System, Approved March 27, 1945
Type: State Plane Coordinate System of 1927, Zone 3551, FIPS Zone 700
Projection: transverse Mercator
Spheroid: Clark Ellipsoid of 1866
Units: feet, decimal feet
Datum: North American datum of 1927 (NAD27)
Coordinate Origin: defined as x = 500,000 y= 0 feet at longitude 75 25' and latitude 38 00'

This law has established the official surveying coordinate system to which public land records or deed records must conform. It also establishes feet as the official state unit of measurement for land surveying. The Delaware Coordinate System is based on the State Plane Coordinate System designed in 1930's by the U.S. Coast and Geodetic Survey (predecessor of the National Ocean Service) to enable surveyors, mappers, and engineers to connect their land or engineering surveys to a common reference system, the North American Datum of 1927. As of August 1988, 42 States had legislated a 1927 State Plane Coordinate System. Each State is encompassed by one or more zones in this system which used coordinate projection parameters selected to minimize the distortion inherent in representing a round earth on a flat map.

6.12 Datums and GRS80

A datum is a set of parameters defining a coordinate system and a set of known points which serve as a reference base. The definition of the coordinate system relies in part on the specifications of the spheroid used to approximate the curved surface of the earth or portions of the earth. The control points and approximation of the Earth's shape are used to define a geodetic framework to locate points on the Earth. The establishment of the North American Datum of 1927 (NAD27) consisted of about 25,000 stations (control points) across the country and an approximation of the earth as a spheroid known as the Clark spheroid of 1866. Calculations were done manually for the control network and there were varying degrees of error from station to station. Technological advances in surveying and geodesy, since NAD27 was established, helped determine a new spheroid identified as the Geodetic Reference System of 1980 (GRS80) which approximated the Earth's true shape and size better.

The North American Datum of 1983 (NAD83) was the result of a multi national effort to improve the quality of horizontal control required by surveyors and engineers. Based on GRS80, Earth and satellite observations, and precise measurements to improve the internal consistency of the geodetic network, NAD83 forms a superior coordinate reference system for North America. A comparison of datum elements for NAD27 and NAD83 is shown in the figure 4. A major change from NAD27 to NAD83 is that all points published on NAD83 by the National Geodetic Survey are in meters. The adjustment to NAD83 shifts the geodetic positions of every station in the geodetic framework and of course the positions of all points defined within the network. Figures from an article published in 1985 showing expected latitude and longitude changes from NAD27 to NAD83 are included on the following page in figures 5 and 6.

Figure 4. Comparison of Datum Elements, NAD27 and NAD83[3]

—Comparison of Datum Elements

Element (1)	NAD 27 (2)	NAD 83 (3)
Reference ellipsoid	Clarke Ellipsoid of 1866 a = 6,378,206.4 m b = 6,356,583.8 m	GRS 80 a = 6,378,137 $1/f$ = 1/298.2572221
Datum point	Triangulation station MEADES RANCH	None (mass center of Earth)
Longitude origin	Greenwich meridian (BIH zero meridian)	Greenwich meridian (BIH zero meridian)
Azimuth orientation	From south	From north
Adjustment	25,000 points Several hundred base lines Several hundred astro azimuths	250,000 points 30,000 EDMI base lines 5,000 astro-azimuths Doppler point positions VLBI vectors
Best fitting	North American	Worldwide

[3] Wade, E.B, Impact of North American Datum of 1983, pg.60

Figure 5. Expected Latitude Change from NAD27 to NAD83 (in meters)[4]

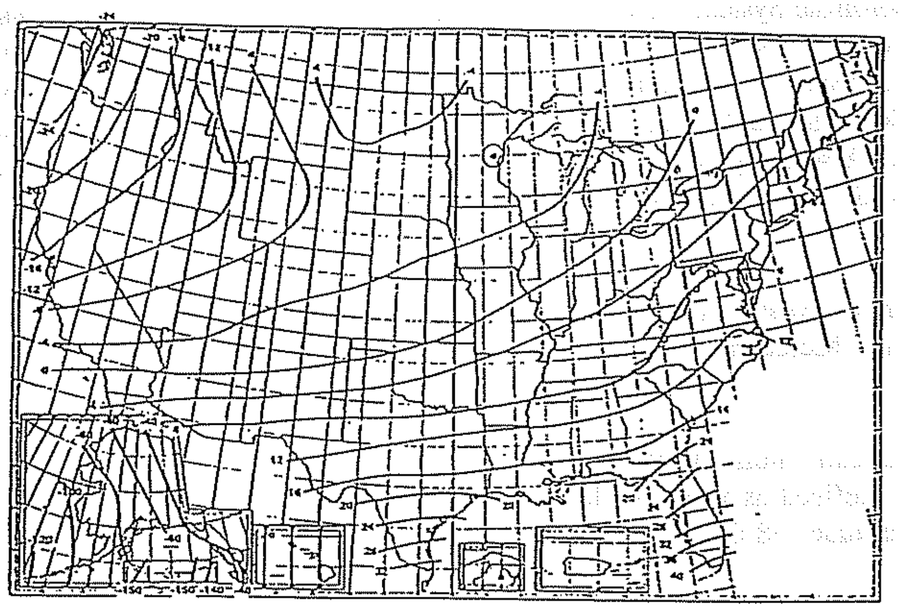
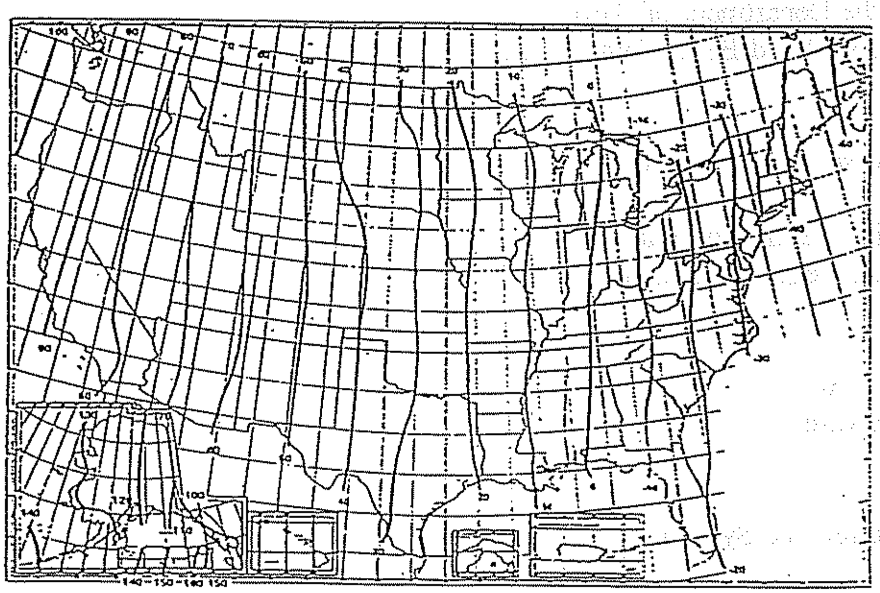


Figure 6. Expected Longitude Change form NAD27 to NAD83[5]



[4] Ibid, pg.59

[5] Ibid,pg.59

6.13 The State Plane Coordinate System of 1983

The State Plane Coordinate System (SPCS) was modified based on NAD83 adjustments by the National Geodetic Survey in 1986. The SPCS27 design was retained for SPCS83 primarily because SPCS had been accepted by legislative action in 37 States, and engineers and surveyors were familiar with the definition and procedures involved with SPCS and had been using them for more than 40 years. Also the philosophy of SPCS is sound, it is the datum on which it is based which has improved. . A definition of SPCS83 for Delaware is given below.

State Plane Coordinate System of 1983, Zone 3551, FIPS Zone 700
Projection: transverse Mercator
Spheroid: GRS80
Units: meters
Datum: North American datum of 1983
Coordinate Origin: defined as x = 200,000 y= 0 meters at longitude 75 25' and
latitude 38 00'

6.14 UTM Coordinates

Another coordinate system in wide use is the Universal Transverse Mercatur projection system. Originated by the Department of Army in 1958 it is used by several Federal and local agencies including the USGS and EPA. 1983 UTM specifications for the northern hemisphere follow.

Projection Transverse Mercatur in 6 degree width zones
Ellipsoid: GRS80
Longitude of origin: Central meridian of each zone
Latitude of origin: 0 degrees (equator)
Unit: Meter
False northing: 0
False easting: 500,000
Zone : 18 for Delaware

6.15 The Geographic Reference System

The Geographic Reference System (GRS), also known as the Global Reference System, Spherical Coordinate System or, Latitude/Longitude treats the globe as sphere divided up horizontally and vertically into 360 degrees, each degree divided into 60 minutes, each minute divided into 60 seconds. Lines of longitude run north and south and lines of latitude run east and west. As changes in longitude move horizontally, longitude can be thought of as the horizontal ("x") coordinate. Changes in latitude move vertically and are the vertical ("y") coordinate. The GRS being a spherical coordinate system is not a projection. The GRS is defined for points on the Earth relative to a datum but not a projection.

To be referenced as a base ten (decimal) number longitude and latitude values in degrees, minutes, seconds (DMS) can be transformed to decimal degrees (DD). Decimal degrees is a default method of specifying coordinate values by several GIS including Atlas GIS and MapInfo. All GIS have the ability to translate coordinate data in a number of projections and coordinate systems. As decimal degrees does not involve a projection some software stores data in decimal degrees as a starting point.

6.2 What This All Means to GIS

To most GIS facilities the choice of what coordinate system to use is based on what those around them are using or what has been in use in the past. Practically all GIS software has the ability to transform coordinate data from one projection to another using accepted conversion procedures. In some systems, data can be displayed in another coordinate system or in other units (feet, meters, miles) at the touch of a button.

The change or update of coordinate system is mostly driven by the availability and use of higher technologies in surveying, global positioning systems, and digital photography. GPS position calculations are based on NAD83 (or datums and ellipsoids which are for all practical purposes the same). Digital orthophotography as that which is being produced for Delaware uses NAD83. Higher accuracy data developed by higher technology means will naturally be based on datums more representative of the Earth's actual shape. The NAD83 represents a major correction to global mapping and is currently supported by GIS systems. As NAD83 is supported by GIS software vendors and in line with the use of GPS and digital photography a coordinate system based on NAD83 should be used as a standard at this time. As the State Plane Coordinate System serves as the framework for Delaware's current survey base, the coordinate system recommended as a standard would be SPCS83. Newly developed datums will improve the accuracy of positioning by millimeters rather than meters. While of great concern to high accuracy surveying and the development of geodetic networks accurate enough to serve as control for GPS observations, the bulk of the GIS community will be busy for quite a while coming to terms with affording, acquiring, and maintaining data in the +/- one meter range.

6.3 Units

The United States, Burma, and Liberia are the only nations in the world that still use the English foot/pound measuring system. The world's standard measurement is the International Units (SI), the metric system. It is a simpler system to learn as it is a decimal based system and there would be global advantages to conformance. However, the mile/foot/pound measurement system is ingrained in our culture, our industry, and our dashboard, and the conversion in the United States has proven very difficult.

From a transportation perspective the national standard unit is set through the adoption of Order 1020.1D, issued on March 23, 1992 which defined SI as the official metric system. For Delaware, the Department of Transportation has an approved Metric Conversion Plan. All plans and design work must use the metric system. Linear referencing along roads, and speed limit assignments however, will still use units of mile point and miles per hour.

Most GIS software allows users to easily change working units at any time regardless of whether coordinates are stored in longitude/latitude or in a projection.

Note:

.3048m = 1 International Foot   1200/3937 m = U.S. Survey foot (0.304800609....)

6.4 How States Are Addressing Coordinate Systems

As of 1988, 42 States had legislated a 1927 State Plane Coordinate System and 26 States had enacted 1983 State Plane Coordinate System legislation which permitted the use of SPCS83. In adopting SPCS83 half of those States required meters as the unit for SPCS83 while the others allowed for units of feet (either the International Foot, 0.3048 m exactly or U.S. Survey Foot - 1200/3937 m) and meters. Delaware has not adopted SPCS as an official survey base. Agencies in many States are using UTM.

The SPCS and UTM systems are what most States are using in their GIS. GIS facilities in Delaware are going toward the use of SPCS83 with units of meters, in particular DNREC, and DELDOT. Some groups in Delaware did lobby USGS to have State Plane Coordinates on new 7-1/2 Minute Topographic Quadrangle Maps (USGS Quads) to be expressed in feet.

6.5 How the Federal Government is Addressing Coordinate Systems

The federal government has actively promoted use of the metric system for many years starting with the Metric Conversion Act of 1975. UTM is used by most agencies at the national level. For many products, longitude and latitude values are referenced. USGS Quads have registration marks shown for longitude/latitude, UTM, and State Plane coordinates.

6.6 Geographic Coordinates

Geographic Coordinates (latitude/longitude) and units which include degrees, minutes, seconds and decimal degrees are used by many desktop GIS. As they are spherical coordinates, they do not employ a projection. For this reason, some GIS work better with coordinates specified in geographic coordinates. There is something to be gained by using a system which does not employ a projection and the corresponding distortions that result. As the underlying method used for how data is stored, it may have some performance advantages. It would not be recommended as a standard though, because first of all no one is accustomed to describing distances in decimal degrees or degrees,minutes.seconds (transversing a second is a different distance depending where on the globe you are) and in some cases in data transfer, if users are not careful precision is lost[6].

6.7 Recommendations and Proposed Standards for Coordinate Systems

- Adopt the North American Datum of 1983 as the official datum to be used with GIS. Adopt the Delaware State Plane Coordinate System NAD83, using units of meters, as the official coordinate system to be used for the distribution and development of GIS data.

- Retain mile point as the measure for linear referencing systems. For planning and design work use units of meters, and where possible convert specifications from feet to meters. In general, speak meters.

[6] The reason is, to locate within a foot requires six places past the decimal, i.e. 76.343625.

7 Accuracy Standards

7.1 Issues of Error and Accuracy in GIS

Standards for accuracy are set to assure consistent data quality, compatibility between data sets, and to support validity and quality of analysis. The determination of how accurate a data set is, depends on an assessment of the error in source materials, the error introduced in analysis and operations, and the error associated with modeling assumptions. While the literature on GIS accuracy raises many problems and issues, their are few solutions offered.

7.11 The Nature of GIS

In a preface to the proceedings of the National Center for Geographic Information and Analysis's meeting on the Accuracy of Spatial Data, Goodchild and Gopal (1989) outline several points on why digital spatial data handling, as opposed to conventional mapping, raises so many issues of error and accuracy. It is helpful to review some of these points (shown in quotes below) to address the particular problems associated with GIS systems.

"The precision of GIS processing is effectively infinite."[7] Coordinate data in most GIS carries 8 to 16 decimal digits of precision. This type of precision in most applications far exceeds the accuracy of available GIS data. On the globe 8 decimal digits of precision would resolve positions to the nearest 10 centimeters. As processing is usually performed with at least the precision of input coordinates, such unwarranted precision is carried into analysis products. Data is often reported with a precision which greatly exceeds the source data. The ability to display features on a monitor or hard copy map in great detail is often a representation that goes beyond the accuracy that source data would warrant.

"All spatial data are of limited accuracy." Many digital map layers are derived from idealized representations of the earth and from photography at different scales and accuracy. Most base map layers representing features such as roads and streams are derived from 24,000 scale USGS 7-1/2 Minute Quadrangle Maps or the 100,000 scale Tiger Line Files. The location of features from this map can be off by anywhere from 15 meters to 100 meters or more. Many other data layers have been digitized from such base maps and of course are limited at least to that accuracy. Some States have gone through the costly process of developing 12,000 scale corrected orthophotography, which are a great improvement in locating clearly distinguishable features such as roads, but digital files based on these maps are accurate to only a few meters. More significantly, many of the objects that are mapped in GIS are abstractions or generalities and are not as clearly defined as the center of a road. The delineation of a wetland or soil type,

[7] Goodchild and Gopal, pg.xii-xv. The other points presented in quotes in this subsection have this same reference.

or the location of an aquifer depend to a great deal on interpretation. Boundary lines by their interpretation are only representations of change which are in reality, gradual or vague. Generalities, such as population or employment density with respect to some geographic unit such as a census tract, when combined with other data at a different resolution can produce unexpected results.

"The ability to change scales and combine data from various sources and scales in a GIS means that precision is usually not adapted to accuracy." The principal advantages of GIS over traditional mapping is the ability to display data at any scale and combine and overlay maps. It is very easy for instance to overlay a digital map layer derived from 200,000 scale floodplain maps with 12,000 scale land use maps, and report the percentage of agricultural land which is in floodplain to a tenth of an acre. The effects on the accuracy of a product of overlay analysis are hard to judge for non uniform representations of the real world. Nothing in the technology prevents the user from performing invalid mapping or modeling through the combination of data with unknown or widely different accuracy. GIS technology in fact encourages it.

"We have no adequate means to describe the accuracy of complex spatial objects." While there is some things that can be said about the accuracy of points in space or the accuracy in reproduction of maps through a digitizing process, the accuracy of many spatial objects is difficult to describe because there are so many possible sources of error in representation and interpretation. GIS also deals with a very wide range of data types and operations. How do you describe the accuracy of a boundary line of a water resource area determined as the result of a geologist's interpretation of unevenly distributed, sparse data points? How do you describe the accuracy of a suitability analysis which combines several types of data and is a model or concept of suitability in the first place. In a single data set it can be difficult to obtain an accuracy statement. When data is combined from various scales, under different categorical schemes, with portions of the data missing or non uniform, which goes through numerous spatial operations with different spatial tolerances, there is little hope in getting any kind of firm quantitive measure of the accuracy. Rigorous statistical approaches to error assessment exist for well defined, very focused areas, but for most users there is no straightforward way of confronting error and the issues are mostly ignored.

7.12 Defending GIS in the Face of Inaccuracies, and Confronting Error

With traditional mapping, a land use map obviously created using pens and overlays suggested a certain degree of error and use, linked to a scale. The entire process of data collection, compilation, distribution and analysis was around a target scale. Map making was time consuming and various types of analysis were practically impossible. With GIS, mapping and analysis functions are almost too easy. The saying "Garbage in, garbage out" was popularized in the age of computers, and implies a blind procedure dissociated from the sense of the information.

Computerization, however, allows us to look at information and relate it in ways that we never could. GIS allows for the compilation and organization of a range of data types. GIS has a huge capacity to develop and evolve. Digital products are much easier to refine and use again. Being able to relate and overlay information has allowed us to take a more comprehensive, multi-agency view of the world. And while the overlay of the data can show major discrepancies and inaccuracies, and while assessing the specific accuracies of our data are very difficult, there is a strong sense that our information is more accurate than it was, and is improving. The conversion and mapping of older data generally identifies several errors.

The ability to map something to the millimeter has made us realize just how inaccurate we are. At some level there will always be error. It is necessary to know how these inaccuracies impact our conclusions and products. It is important to find methods of specifying our uncertainty in products to the community. Accuracy requirements and assessment must be considered in relation to the application. It is impractical to mandate the highest level of precision of precision and quality for data so that requirements of all users are met. A regional planner should not wait for data with a locational accuracy of plus or minus a meter before taking advantage of the capabilities of GIS. Across applications there is no one standard. Accuracy standards must form as sets of guidelines for the use, documentation, and development of data in reference to application needs and requirements.

7.13 The Responsibilities of Data Providers and Users

Many GIS data sets have their origin in government agencies or projects and were created as tools for administrative requirements or to fulfill mandates. The community sees the value of this data for their applications and their is a demand for it. The situation becomes complicated because even if the source agency is very aware of the limitations of the data as it is used in their own applications, they cannot control the misuse of this information or the level of quality control employed by others once it is distributed. Misrepresentation of source data by external users can sometimes reflect poorly on source agencies.

If data was not distributed between government agencies there would be duplication of effort and complete lack of coordination or synergy. Source agencies must accept the overhead of documenting the estimated accuracy and limitations of their data by addressing its estimated positional accuracy, lineage, completeness, scope, temporal limitations, and other measures of the data's accuracy. Disclaimers as to the reliability or validity for general uses, or specific restrictions for use are appropriate. Ideally, the data can be so described as to make clear the accuracy and limitations of its use. Accuracy assessment and documentation cannot be seen only as a sacrifice for the good of the community, but as a necessity for internal operations and quality control as well. If guidelines for accuracy documentation and distribution are prepared by consensus of the community, this will simplify the process and allow for a more straight forward flow of information.

Users have a responsibility to use information appropriately. This includes not drawing conclusions at a precision or extent not warranted by the source data. Data should not be reported in line with its precision. Users must accept dedicating time to qualifying analysis and mapping resulting from the use of data sources of variable accuracy. Sources should be referenced and some indications to the inaccuracies and limitations should accompany products. The depth of accuracy assessment undertaken by the user in products should be in line with the scope, scale, and complexity of the product or analysis. If an agency is preparing a reference map showing school locations for general reference at a small scale (1:24,000 for instance), accuracy statements can be simpler such as "Only public schools shown as of map date. Locations shown by a star at +/- 100 meters.". If a septic suitability analysis for specific areas in a region is portrayed by a product as a result of examining soil types, infiltration rates, elevations, and other data, a much more serious effort must be made to examine the validity of the portrayal and a much more detailed communication of the assessment must be provided, especially where GIS products will be used to determine policy.

7.14 The Costs of Accuracy

Overhead required for the assessment and reporting of accuracy of digital products was referenced in the previous section. Addressing accuracy issues indeed takes time. Most GIS facilities are very pressed for time and resources and are under pressure to produce products. The often drab and tedious tasks involved with quality control are not as appreciated as the production of brightly colored maps and comprehensive analysis. Quality control tasks and documentation in general are often not included in project budgets. Documenting and tracking processes and sources of error can easily take twice the time as performing GIS analysis. Guidelines and tools established in the community, and effort linked to the complexity of scale, can help minimize the costs of quality control. Quality control still requires discipline, commitment, and resources.

It is a worthwhile goal to develop GIS data that has better accuracy. As positional accuracy requirements approach meter and sub meter however, costs sky rocket. As requirements move toward these very large scale levels, operations become very labor and time intensive, and measurements require substantial replications. An effort to capture the work of surveyors developed for engineering and construction of new facilities is feasable, but mapping existing facilities at very large scales can be financially impossible. Differences in how actual construction differs from design plans complicates the matter. Once a very large scale target is set for a GIS there are major concerns in how the data can be maintained.

7.2 Sources of Error and Types of Accuracy

While the magnitude of error in GIS data sets can be difficult to judge, the sources of spatial data are fairly well known. Openshaw (1994) references Goodchild (1988) who lists the following: errors in the positioning of objects, errors in the attributes associated with objects, and errors in modeling spatial variation over or between objects for instance by assuming spatial homogeneity. Added to these are errors resulting from GIS operations on spatial data, the effects of generalization operations (such as aggregation), the effects of model error in predictions stored as spatial data, errors due to differences of a temporal nature, and representational errors (such as referencing area objects as point objects).

These sources of error speak to types of accuracy that can be associated with spatial data. In GIS, the focus on accuracy is mostly on the positional accuracy of digital map features. A map feature is a point, line, or region which represents a real world entity such as a bus stop, road, or property. The positional accuracy of a digital map feature is judged by either its positioning relative to an actual location on the earth as measured by a grid (coordinate system) which is based on precise measurements of the shape of the earth, or by its relative positioning to other map features. These two types of positional accuracy are termed "absolute" and "relative".

There are other types of accuracy in addition to positional. GIS products include attribute data linked to coordinate representations of real world entities. Therefore there are accuracy considerations related to the quality of attribute data. As GIS is composed of representations of the physical world, there is accuracy associated with the consistency and validity of models of real world entities. With both coordinate and attribute data there are issues as to whether information is complete or correct at any given time (e.g. "Are all the roads and relevant physical features shown on the map?" or "Is the land use in a particular area still Residential?"). These are accuracies related to the completeness or temporal nature of spatial data.

7.3 Addressing Accuracy in GIS

The following sections discuss current methods for addressing accuracy.

7.31 Current Mapping Standards

The National Map Accuracy Standards

The U.S. National Map Accuracy Standards form the current official policy on map accuracy. The U.S. Bureau of the Budget (now the Office of Management and Budget) introduced the first version in 1941 as an attempt to develop standards for all maps and all scales. For horizontal accuracy the standard says that "on publication scales larger than 1:20,000 not more than 10 percent of the points tested shall be in error more than 1/30 inch, measured on the publication scale: for maps on publication scales of 1:20,000 or smaller, 1/50 inch." The following figure summarizes the precision necessary for various scales using the 1/30 of an inch and 1/50 of an inch factors. For vertical accuracy, "not more than 10 percent of the elevations tested shall be in error more than one-half the contour interval."

NMAS goes on to say;

"These limits of accuracy shall apply in all cases to positions of well-defined points only. Well-defined points are those that are easily visible or recoverable on the ground, such as the following: monuments or markers, such as bench marks, property boundary monuments: intersections of roads, railroads, etc.....In general what is well defined will also be determined by what is plottable on the scale of the map within 1/100 inch."

Figure 7. National Map Accuracy Standards
Horizontal Accuracy Examples

SCALE	NMAS (plus or minus)
1:1,200	3.33 feet
1:2,400	6.67 feet
1:4,800	13.33 feet
1:9,600	26.67 feet
1:10,000	27.78 feet
1:12,000	33.33 feet
1:24,000	40.00 feet
1:63,360	105.60 feet
1:100,000	166.67 feet

The choice of what well defined points are chosen is flexible as stated by NMAS. With global positioning systems measuring the location of well defined points is now easier. In regards to testing, the NMAS goes on to say;

"The accuracy of any map may be tested by comparing the positions of points whose locations or elevations are shown upon it with corresponding positions as determined by surveys of a higher accuracy.."

But how are points to be used and how many? How is a test performed? What constitutes a survey of higher accuracy? These questions are not answered by NMAS and there is not much accuracy testing being done.

American Society for Photogrammetry and Remote Sensing Standards

The Specifications and Standards Committee of the American Society for Photogrammetry and Remote Sensing (ASPRS) have produced the "ASPRS Interim Accuracy Standards For Large Scale Maps" which provide a method to indicate accuracy at ground scale so that digital spatial data of known ground scale accuracy can be related to the appropriate map scale for graphic presentation at recognized standards. Horizontal map accuracy is defined as the RMS error in terms of the digital data set's planimetric survey coordinates for checked points as determined at full ground scale. RMS is the square root of the average of squared discrepancies, i.e.

$$RMS = \frac{(d1^2 + d2^2 + d3^2 \ldots)^{1/2}}{n^{1/2}}$$

where d1 = distance between point1 and ground ref for point1
and n = number of points tested

The RMS error is considered as the cumulative result of all errors including those introduced by the processes of ground control surveys, map compilation, and final extraction of ground dimensions from the map. A "Class 1" category of coordinate accuracy is specified by the standard and is shown in figure 8 below. The standard also allows for maps of lower accuracy to be classified. A Class 2 or Class 3 map would be one which is within twice or three times the RMS for Class 1, respectively.

Figure 8. Planimetric Coordinate Accuracy Requirements
Class 1 Maps, ASPRS Standard

Limiting RMS Error in Feet	Typical Map Scale
.05	1:60
.10	1:120
.20	1:240
.30	1:360
.40	1:480
.50	1:600
1.00	1:1,200
2.00	1:2,400
4.00	1:4,800
5.00	1:6,000
8.00	1:9,600
10.00	1:12,000
16.70	1:20,000

The ASPRS standards also present guidelines for the testing of digital maps. Testing for horizontal compliance involves using a minimum of 20 check points which are derived from a horizontal check survey of higher accuracy. The spatial distribution of the check points is not specified due to the various purposes for which a data set could be created or used, but a method is suggested. For a conventional rectangle map, 20% of the checkpoints should be located in each quadrant and these points should be spaced at intervals equal to at least 10% of the map sheet diagonal. Check surveys are to be designed based on the National standards of accuracy and field specifications for control surveys established by the Federal Geodetic Control Committee (FGCC).

The ASPRS standard is being considered as the basis for the revision of the U.S. National Map Accuracy Standards. It presents an accuracy rating scheme and a foundation for testing the accuracy of maps in a manner which can be understood by most users. Testing a map does require a series of check points. These check points could be derived from digital photography as discussed in the next section or by locating points with GPS.

7.32 Use of Base Maps and Digital Photography

Because overlay of data is a primary tool offered by all GIS systems, it is natural for users to address accuracy by attempting to register or conform all layers to a base map or other reference layer. If basemaps or photography exist of a known accuracy, a judgement of the accuracy of a particular data layer could be in terms a proximity of corresponding features. In the past and present for many facilities, the USGS 7-1/2 Minute Quadrangle Maps (USGS Quads) have served this function. The limits to accuracy then are those of the USGS Quads (+/- 40feet) and errors associated with the ability to register layers to this reference layer.

Digital orthophotography at the 12,000 scale is also very valuable for this purpose, as are files developed from these images. Clearly identifiable features such as roads can be located at an estimated accuracy of 3 to 5 meters which would be well within NMAS Standards for the 1:9600 scale. Contractors employed to delineate wetlands for the Delaware Department of Natural Resources have guaranteed a ASPRS Class 1 map accuracy for wetland maps derived from quarter quad orthophotography.

7.33 Scale Versus Use

Before digital mapping when all drawings and maps existed as hard copy products, the measure of accuracy or resolution was related to the scale of the map. The NMAS is based upon the concept of scale which in the digital world is becoming irrelevant. Scale for a hard copy map is fixed. Scale for a digital map layer is not. When someone is viewing an area of a digital map they can zoom in or out on the image and the focus area will automatically change scales to fit the screen. There is no limit to the degree of magnification attainable besides the number of decimal places used to represent a coordinate. Just because data can be mapped at a particular scale or magnification does not mean that the data is meaningful or accurate at that view.

Operationally, judging whether GIS data is accurate or has sufficient quality is a determination as to its adequacy to support a particular application. In this sense accuracy speaks to the use of the data, which is highly dependent on the scale and scope of the application. For this reason accuracy is often discussed in terms of a precision needed for a particular use. To locate a road feature to within plus or minus 500 feet of its true ground position may be adequate for a regional planning effort but will be inadequate for a corridor analysis for new road facilities.

Scale is a useful concept as an indication of a particular resolution or generality of mapping or analysis. The data resolution needed for a particular activities is often described in terms of scale (see the following figures). If some accuracy standard linked to the scale is assumed such as with data conforming to NMAS, then activities can be described as to recommended scales and related precisions. Along these lines, an approach to accuracy standards could then be to require users to employ data in analysis and mapping which is accurate to a particular scale/precision target.

7.34 Use of GPS

Global Positioning Systems (GPS) are very useful in identifying control and test points. The hand held versions can locate points within a few meters once readings are computer calibrated. Survey grade units can locate to the centimeter and below. Such accurate readings take a great deal of time, care, and replication, but the technology is improving rapidly.

7.35 Vehicle Video Logging

GIS for transportation has an advantage over other areas in that the spatial features are generally well defined. Also advances in video logging from high speed, high accuracy, data acquisition vehicles show great promise in placing transportation facilities at an accuracy which will meet most needs. Paired with GIS, video logging adds new dimensions in the ability to acquire information about transportation facilities. Vehicles can now video record and measure road texture, roughness, skid resistance, unevenness in surface, and reflectivity.

Figure 9.

MAP SCALE ISSUES FOR GIS

Which Scale is best for a GIS base map? 1:100,000
1:24,000 or, some other scale?

Common Scales Used at DelDOT

Verbal or Stated Scale	Representative Fraction (R.F.)	N.M.A.S. (USGS) for Scale Factor	Uses by DelDOT Section
1"=8,333' or "One inch equals 8,333 feet."	(1;100,000)	1/50" or +/-166.6'	IGC, MapInfo; Large area studies (county and statewide)
1"=5,280' or "One inch equals 1mile."	(1:63,360)	1/50" or +/-105.6'	Mapping (GIS), State Highway Maps
1"=2,000' or "One inch equals 2,000 feet."	(1:24,000)	1/30" or +/-66.6'	Mapping (GIS), Intergraph; USGS 7.5 Min. Topographic Maps, NWI Maps used by Location & Environ. Studies USDA Soils Maps - 1:15,840 to 1:20,000
1"=100' or "One inch equals 100 feet."	(1:1,200)	1/30" or +/3.33'	Design Review-Preliminary Plans; ROW - Tax Parcel Maps
1"=50' or "One inch equals 50 feet."	(1:600)	1/30" or +/-1.66'	Design Review - Conceptual Plans
1"=30' or "One inch equals 30 feet."	(1:360)	1/30" or +/-1'	Design/Review - ROW and Construction Plans; Subdivision Plans, Bridge Plans (Note: More detailed construction plans may be drawn at 1"=20' or 1"=10' scale; Bridge drawings also in architectural scales of 1/8 in.=1 ft., 3/4 in.=1 ft.)

Representative Fraction

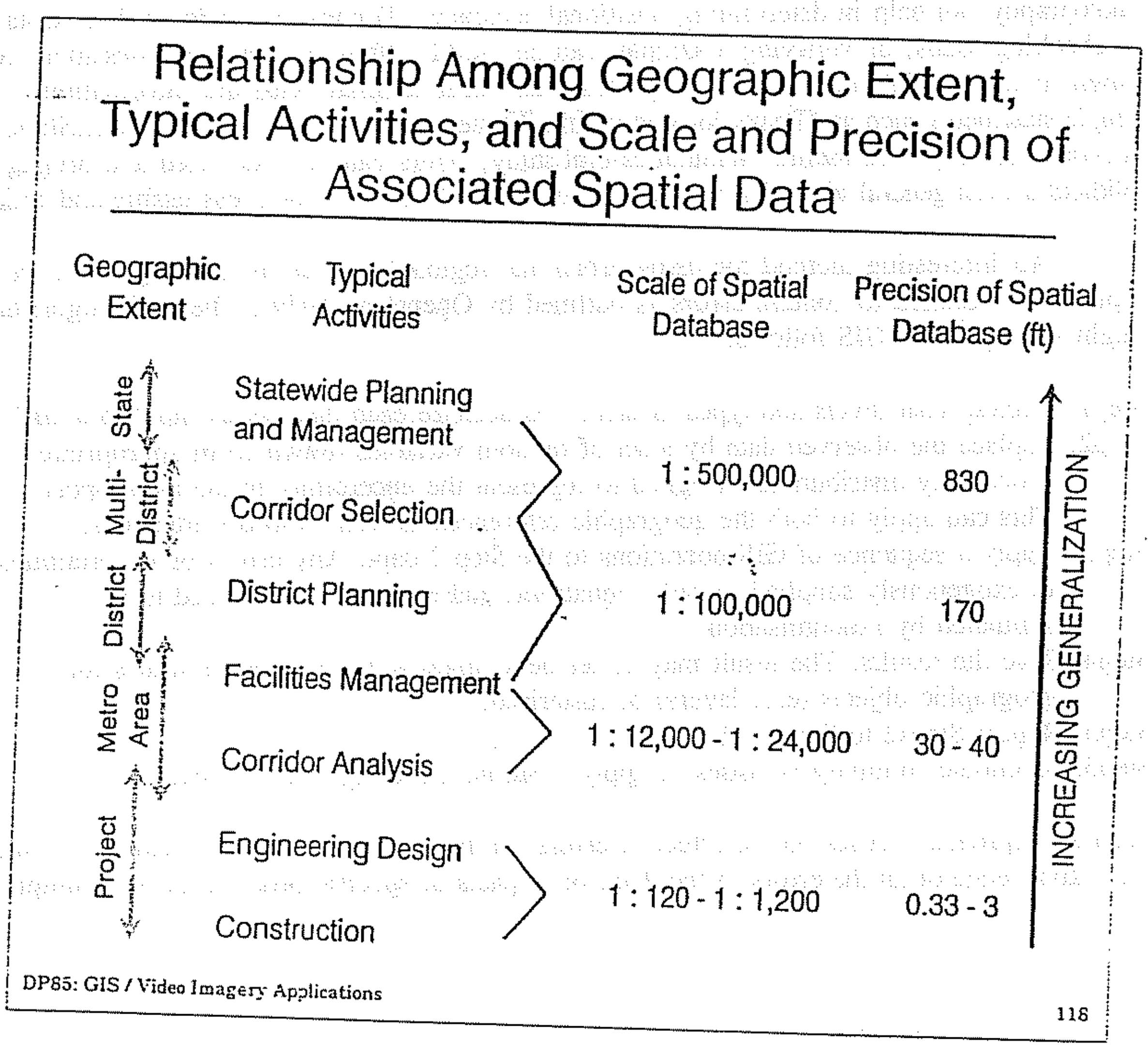
What is the difference in Representative Fraction (R.F.) for the various scales?

R.F. indicates 1 unit on the map : _____ units in the real world.

Example: 1:24,000 or 1/24,000 means one inch on the map is proportional to 24,000 inches in the real world. Translated to a verbal scale: 24,000 in./12 in. per ft. = 2,000 ft. or "One inch equals 2,000 feet."

Prepared by M. L Raley, 11/19/92

Figure 10.[8]



[8] USDOT/FHA GIS/Video Imagery Applications Demonstration

7.36 Error Assessments

The more scientific and quantitive an agency can be in determining the accuracy of spatial data, the better. Ideally a systematic method can be followed to statistically test the accuracy of the data. Comparisons with data of known accuracy, such as USGS Quads or digital photography can help in determining positional accuracy. For testing attribute data, tests such as checking totals, or verifying a sample, can be useful. Often an accuracy assessment comes down to the careful judgement of a professional most familiar with the information. Even simple statements such as "Points located within 20 meters", or "At least 95% of attribute data is coded correctly" are useful. Without careful study, errors can be undetected and propagated. Without a even general idea of accuracy and errors, GIS data is much less usable and reliable.

An interesting method for using urban and regional models in planning when the data inputs are assumed to contain errors is outlined by Openshaw(1979). The basic algorithm as might be applied to GIS follows:

Step1. Decide what levels and types of error characterize each data set as input to a GIS.
Step2. Replace the observed data by a set of random variables drawn from appropriate probability distributions designed to represent the uncertainty in the data inputs. This can apply to both the geographic references as well as to the attributes.
Step3. Apply a sequence of GIS operations to the Step 2 data. Any errors or uncertainties in exogenously supplied models, equations, and parameters also need to be simulated by randomisation.
Step4. Save the results. The result may either be a single value or a set of values for geographic objects (e.g. layers) or rasterised.
Step5. Repeat Steps2 to Step4, M times.
Step6. Compute summary statistics or apply a Monte Carlo significance test.

Such an approach focuses on the effect of errors on the model or products, without having an exact knowledge of all the errors in the data, or impacts of specific procedures or assumptions.

7.37 Accuracy Reporting

Documentation of data sets and data products is vital to sharing information and agencies functioning together in a professional manner. All data and data products (including maps) should reference sources, dates, and accuracy assessments. The lineage of the data sets as well as important procedures and assumptions which could effect the form or effect of the product or analysis should be referenced. For various types of models such as suitability analysis or where a data set is defined from a set of others such as "Developable Lands" or "Areas most suitable for transit service.", a detailed explanation of components, models, assumptions, and limitations of data used, should be referenced. Established guidelines and accuracy coding schemes can help users deal with this reporting. For example the statement "This map was compiled to meet the ASPRS Standards for Class 1 Map Accuracy" is a shorthand way of describing the positional accuracy of spatial features.

7.38 Digitizing Guidelines

Numerous agencies and consultants are in the process of creating GIS data through some type of digitizing process. In most cases the accuracy and how the data will be used is most effected by the methods chosen for digitizing and the information that is captured. If digitizing is done without careful thought and planning, the resultant products can not be as useful. Digitizing guidelines address the types of source materials to use, methods for registration, digital tolerances (snap, fuzzy, dangle,minimum size of line segments), documentation of procedures, proofing, and accuracy assessment. For different types of products there can be different types of specifications. An example of a digital data conversion guideline from the VGIS Handbook provided in the appendix.

7.4 Recommendations and Proposed Accuracy Standards

- Develop guidelines and tools which can be used by the community for accuracy assessment of GIS data.

- Perform accuracy assessment for GIS data layers which form a common framework.

- Require that all new data be provided with an accuracy assessment.

- Encourage the use of accuracy references on all mapping products.

- Do not report data at a precision that is beyond that of the data.

8 Locational Reference System Standards

8.1 Locating Data Referenced to a Coordinate System

The prime feature of geographical information systems is their ability to locate information spatially. A system to locate data is referred to as a locational reference system. The most basic way to view spatial data is to prepare a map of a particular area and display map layers, such as the location of schools or bus stops, referenced to a base map showing highways and other physical features. Map layers are referenced to a particular coordinate system so that not only can you define the location of a school, for instance, in relation to a major road, but you could also view the location referenced by a horizontal and vertical coordinate pair (i.e X,Y or Longitude Latitude) to specify its absolute position in space. Based on the spatial reference offered by the use of the coordinate system, questions could be asked such as "How many gas stations are within 100 meters of the water well, or "What is the position of the road relative to the wetlands". The definition of coordinate systems form the framework for spatial overlay and distance questions such as these. The location of data by coordinate representation is the locational reference system most basic to GIS. Standards for coordinate systems were discussed in a previous section.

8.2 Address Geocoding

Much of the information of interest to governments, particularly in the area of social services, is about people. People are most commonly located by an address of where they live or work. The source locational information for people or facilities most often takes the form of addresses in databases. Most GIS software has the ability to some extent to locate an address along a road or within an area to spatially reference the people or facilities in reference to other information. For instance if someone called 911 and said they were at a particular address, a dispatcher could determine what service district they were in. Being able to find an address on the map is an important capability and forms another major type of locational reference system. Address geocoding refers to the process of locating information by address. Because of the many ways people can specify an address or place, the process of geocoding is not always successful or straight forward.

8.21 Address Ranges

The natural method of address geocoding is to use address ranges defined on road segments. A road segment as discussed here refers to a digital spatial entity often termed a link or a network chain. A link is a straight line connection between two nodes. A node is an end point of a link or network chain which has an X-Y coordinate associated with it. A network chain is just a link with intermediate shape points each of which have coordinates associated with them. Address ranges are defined on the segments in terms of the end point nodes designated as "from" and "to" nodes. As roads have two sides to them, there is a right and left address range defined for each to or from node. Locating the address is then done by identifying the proper road segment and interpolating to a position on the road segment proportionally based on the address number and the "from" and "to" address number associated with the nodes.

8.22 Address Matching

The success of locating the address depends on the ability to interpret the format of the address from the source to recognize a road number and road segment, and the presence of an underlying digital structure for roads which has the same road name and appropriate address range. The source address (i.e. address entry from a customer data table) is matched with an address reference in the underlying digital road framework. This can be difficult or impossible in some cases. If the road is spelled differently or absent in the road framework their will be no match. If the digital road network is incomplete, and the road segment is not represented for a particular address there can be no match. If no road name is present in the source as with the designation of an address by rural route or on an address designated as a place such as "Fox Run Condominiums" there would be no match or interpolation possible. For addresses which reference a place or P.O Box such as the "University of Delaware" or "P.O. Box 235" address matching is impossible unless the place or post office box is somehow located in an auxiliary digital framework or look up table. The general problem of location that emergency management groups must face is much broader and thorny, where positioning may be by address, place ("the gas station near 7th street"), intersection, or telephone number record. The effectiveness of locational reference systems for these groups is often a matter of life and death, and is why they are, and must be, a part of all standards for addressing and road naming.

8.23 Address Formatting

Given an address, the ability to find the location depends on having the necessary components for the address. The components that form an address are listed below.

Component	Example
Number of Address	**23** W. Rodney Street
Street Name	23 W. **Rodney** Street
Street Type	23 W. Rodney **Street (also Ave,Lane,Court, Blvd etc)**
Direction	23 **W.** Rodney Street (West, North, South, East)
Unit Numbers	Apt. K-14
Zone	Wilmington, Delaware, 19806
Zone Zipcode	19806
Subzone or Alias Addresses	University of Delaware (A.K.A 1000 College Ave.) or P.O. Box 3441

If any components are missing, mis-spelled, or incorrect in some way, address matching will fail. If no look up table exists for alias addresses which can relate a place name or P.O. Box to a street segment within an address range, the address can not be located.
Rural route addressing is a problem because there is no particular road segment or address range which can be referenced. Some GIS software have utilities to clean up and parse addresses into the basic components before address matching is attempted. These utilities can also standardize abbreviations, for instance the street type "Boulevard" can be specified as "BD", "BL", "BV", "BLVD", or "BOULEVARD" and the utility will convert all types to "BLVD" which is the standard abbreviation used by the U.S. Census Bureau.

8.24 Addressing Standards

Standard data formats for addressing are published by the United States Postal Service. Figure 11 shows the ZIP +4 file layout from the U.S. Postal Service Address Management System Products Guide (AMS II). AMS II also defines all data fields, includes data samples, and discusses possible future enhancements.

Figure 11. ZIP+4 File Layout.

Detail

FIELD REF NUMBER	FIELD DESCRIPTION	LOGICAL LENGTH	RELATIVE POSITION FROM	RELATIVE POSITION THRU	CONTENT NOTES
1	COPYRIGHT DETAIL CODE	01	01	01	D=DETAIL
2	ZIP CODE	05	02	06	
3	UPDATE KEY NUMBER	10	07	16	
4	ACTION CODE	01	17	17	A=ADD, D=DELETE (ALWAYS "A" FOR BASE FILE)
5	RECORD TYPE CODE	01	18	18	F=FIRM G=GENERAL DELIVERY H=HIGHRISE P=PO BOX R=RURAL ROUTE/ HIGHWAY CONTRACT S=STREET
6	CARRIER ROUTE ID	04	19	22	
7	STREET PRE DRCTN ABBREV	02	23	24	
8	STREET NAME	28	25	52	
9	STREET SUFFIX ABBREV	04	53	56	
10	STREET POST DRCTN ABBREV	02	57	58	
11	ADDR PRIMARY LOW NO	10	59	68	
12	ADDR PRIMARY HIGH NO	10	69	78	
13	ADDR PRIMARY ODD EVEN CODE	01	79	79	
14	BUILDING OR FIRM NAME	40	80	119	

Detail (Continued)

FIELD REF NUMBER	FIELD DESCRIPTION	LOGICAL LENGTH	RELATIVE POSITION FROM	RELATIVE POSITION THRU	CONTENT NOTES
15	ADDR SECONDARY ABBREV	04	120	123	(ONLY FOR REC-TYPE F, H)
16	ADDR SECONDARY LOW NO	08	124	131	(ONLY FOR REC-TYPE F, H)
17	ADDR SECONDARY HIGH NO	08	132	139	(ONLY FOR REC-TYPE F, H)
18	ADDR SECONDARY ODD EVEN CODE	01	140	140	(ONLY FOR REC-TYPE F, H)
19	ZIP ADD ON LOW NO				
	ZIP SECTOR NO	02	141	142	
	ZIP SEGMENT NO	02	143	144	
20	ZIP ADD ON HIGH NO				
	ZIP SECTOR NO	02	145	146	
	ZIP SEGMENT NO	02	147	148	
21	BASE ALT CODE	01	149	149	B=BASE A=ALTERNATE
22	LACS STATUS NO	01	150	150	L=LACS CONVERTED BLANK=NOT APPLICABLE
23	GOVT BLDG NO	01	151	151	
24	FINANCE NO	06	152	157	
25	STATE ABBREV	02	158	159	
26	COUNTY NO	03	160	162	
27	CONGRESSIONAL DISTRICT NO	02	163	164	
28	MUNICIPALITY CITY STATE KEY	06	165	170	
29	URBANIZATION CITY STATE KEY	06	171	176	
30	PREFD LAST LINE CITY STATE KEY	06	177	182	

8.3 Linear Referencing Systems

Rather than locating facilities by address or coordinate, the most common way to reference the location of transportation facilities is by route and milepoint on a route. Points are located by using a route designator for all roads in a system and mile point measures for each route. In a digital representation of roads, routes are made up of one or more links or network chains. Distances are measured by the curvilinear distance measured along the route from point to point. The units of measure are most often milepoint but could be kilometers, meters, or feet. An accident site, or the position of a sign or bus stop are can all given in terms of a route and measure along the route. The framework of all routes and measures make up a linear referencing system. By this description an address geocoding system is a type of linear referencing system. The address ranges are substituted for beginning node milepoint and end node milepoint. Linear referencing systems are used for railways and rivers as well, because they too are best modeled as linear features and information about them is best referenced along their length.

8.31 Federal Guidelines for Linear Referencing Systems

There is currently no standard linear referencing system (LRS) used by States or localities. It is common for different agencies in the same area to have distinctly different methods of designating routes and measures. A bus company may define routes according to a system specific to their uses, and a sign maintenance organization will use another. This poses many difficult problems for information sharing.

As part of the development of the Highway Performance Monitoring System (HPMS) and the development of the National Highway Planning Network (NHPN), the Federal Highway Administration (FHWA) is addressing issues associated with the development of an LRS at the national level. The development of a national LRS is also being investigated by FHWA's Office of Research to be used for vehicle location, in vehicle navigation, and routing under various Intelligent Vehicle Highway System (IVHS) projects.

A standard linear referencing system (LRS) as proposed by the Federal Geographic Data Committee (FGDC) Transportation Subcommittee with would have the following features;

- A route identifier for all network segments
- A beginning reference distance with respect to the start of the route
- A ending reference distance with respect to the end of the route
- Road type identifiers and classifications
- Street name, beginning address, ending address, zip code, for a second level LRS.

Other recommendations offered by the FGDC Transportation Subcommittee towards a standardized LRS for the country include;

- Identify a single route number for each network segments
- All routes should be newly referenced after major alignment
- Change from a county-based to a State-based road inventory system. State sign routes which cross county lines would be sequentially referenced from beginning to end instead of being reset at county boundaries.
- Expand the address range coverage currently available in the Tiger files through such initiatives as 911 directories and cooperative agreements with the U.S. Postal service.

8.32 Segments and the Construction of a Transportation Network Framework

A segment is defined as a spatial object equivalent to a link or network chain as defined by the Spatial Data Transfer Standard. A link is a straight line connection between two nodes. A network chain is a link with shape points in between. A route is made up of a non-branching sequence of segments (links or network chains) sharing a common route identifier. Segments and routes always begin and end with nodes. A transportation network at the base level is made up of segments. These segments in many representations are those portions of road between intersections. Each segment exists as a coordinate feature within a GIS, and has at least one internal identifier. The segments are the building blocks of the modeled transportation network.

There are a number of ways roads can be segmented. Segments could be those road sections which are between intersections, places where the paving changes, portions which have shoulders, or portions segmented based on values of address ranges. InterGraph and ARC/INFO have advanced features including "dynamic segmentation" which enables portions of segments or routes to be addressed by route/mile point references and attributed without changing the underlying coordinate representations of the segments. That is, they can address a portion of a segment as a "virtual segment" without the need to split the segment, add end point nodes, and define a new coordinate feature. These GIS are less dependent on the form of the underlying segmentation scheme and work at the route level. Some GIS do not use dynamic segmentation.

While the linear reference system is primarily determined by unique routes and measures, a digital transportation network to be used as a stable resource and linear referencing system for the GIS community also depends on the method of segmentation used. Data transfer between GIS platforms depends on specifications for segments. If there is any portion of a segment which will hold attribute data, such as "the portion which holds address numbers 100 to 200", the segment must be split. If the model of the transportation network which serves as the common framework is constantly being changed by redefining segments, there can be great difficulty attaining coordination in the community. While advanced transportation analysis depends on dynamic segmentation, the base framework of segments must be stable.

One simple way of segmenting requires the definition of a new segment where ever two or more lines come together, or where road classification changes, or where there is a discontinuity in address ranges. This method of segmentation will generally lead to a network made up of segments formed from road portions between intersections. Changes in route designation or naming between intersections or at non road features or political boundaries would make for a more segmented network. If Tiger Line Files were fully conflated to road network files to include not only address ranges but also the demographic boundaries such as blocks and tracts, the segmenting would become much more fragmented.

8.33 Primary Structure for a Linear Reference System.

A way to specify and transfer a linear reference system can be done using two primary data structures linked to coordinate features. The two structures are a segment data table, and a node data table. These structures are demonstrated below.

Figure 12. Primary Segment Data Table

Field	Description
Segment_ID	Unique segment identifier, the reference to coordinate information
From_Node	From node of segment
To_Node	To node of segment
Midpoint_X	Horizontal coordinate locator and curvilinear shapepoint of segment
Midpoint_Y	Vertical coordinate locator and curvilinear shapepoint
Segment_Direction	Directional code for segment, direction of measurement
Segment_Length	Length of segment, could be feet, miles, meters
Begin_Milepoint	Beginning MilePoint in terms of route measure
End Milepoint	Beginning milepoint in terms of route measure
Route_ID	The unique route that this segment belongs to.
Name	Primary road name this segment is known by.
Name2	Secondary road name this segment is known by.
RoadClass	The road classification of this segment

The node data table consists of the following;

Figure 13. Primary Node Data Table

Field	Description
Node_ID	Unique node identifier, used in From_Node & To_Node above
Intersection_Class	Classification of intersection (if it represents an intersection)
Intersecton_ID	Unique identifier for interscctions
Segment_List	List of Segment_ID's meeting at this node
X-Coord	Horizontal coordinate of the node in adopted coordinate system
Y-Coord	Vertical coordinate of the node in adopted coordinate system

Both of these tables could be placed in any number of data tables formats such as DBASE and easily transferred to other platforms. With the coordinate data fields included (X-Coord and Y-Coord in Node Table, MidPoint X & Y in the Segment Table) a schematic version of the network could be generated without any other coordinate files. Some coordinate file format would be used to hold segment shape points in a given GIS or data transfer file. Refined shaping of segments could be easily incorporated if the same Segment ID was used in old and new versions.

8.34 Secondary Attribute Files

The previous Segment and Node data tables shown, represent the primary information framework for the transportation network. All other attribute data for a variety of applications could be kept in separate tables containing the primary relate fields Segment_ID or Node_ID. Some examples of secondary tables follow. Field names used are specified for readability.

Figure 14. Addressing Framework Table

Segment_ID
DirectionCode
LeftAddressFrom
RightAddressFrom
LeftAddressTo
RightAddressTo
Road_Name1
Road_Name2
StreetType
ZipCode
County

Figure 15. Facilities Table

Segment_ID
RouteID
Road_Name1
Road_Name2
RoadClass
NumberOfLanes
Capacity
Volume
SpeedLimit
Impedance

Figure 16. HPMS Subset Table

Segment_ID
Route_ID
CountyCode
Ownership
AADT
NumberOfLanes
Pavement_Condition
Median_Type
Shoulder_Type
Lane Width
Peak Capacity
Vol_Service_Ratio
SignalType

8.35 Effective Locational Reference Systems As A Basis For Interagency Coordination

Different applications and responsibilities in transportation associated with highway safety, inventory of facilities, long range planning, bridge maintenance, and transit planning, generate numerous types of attribute data and attribute tables. The ability to efficiently relate this information across departments and agencies depends on a standard framework for locational reference. The extent to which government agencies can take advantage of GIS depends very much on an effective locational system framework. Emergency management service agencies must quickly and reliably locate incidents. Agencies such as schools, health clinics, and libraries need to locate target populations. Development of effective locational systems depends on the contributions and cooperation of several groups which include local governments, the Post Office, emergency management groups, and transportation agencies.

In Delaware several initiatives are underway to develop locational capabilities. The Delaware Department of Transportation (DELDOT) is building a road centerline file which will conform to NMAS accuracy standards at the scale of 1:12,000. The linear reference system that has been in use for many years has all of the desirable features recommended by standards organizations and is currently being refined and extended to all road classifications. DELDOT is also conflating the new centerline files with the TIGER Line Files to allow for more accurate address geocoding. Kent and Sussex County Governments within the year will complete new road naming and addressing projects for all county roads. All three counties are in the process or investigating full automation of property mapping and land use records. 911 is working on projects to improve its locational capabilities.

To avoid duplication of effort and to combine resources, agencies must have open and frequent communication in regards to locational reference system development. One of the primary ways to coordinate and establish strong frameworks and standards is to document and make available (in easily read standard formats) products as they are completed.

8.4 Recommendations and Proposed Standards for Locational Reference Systems

- Support current efforts to complete and/or refine the DELDOT Centerline Network, the linear referencing system, and the centerline conflation with the Tiger Line Files.

- Develop effective mechanisms for the continual update, maintenance, and refinement of centerline, linear referencing system, and addressing systems.

- Adopt the DELDOT Linear Referencing System as the standard for the location of transportation facilities to be used by all transportation agencies and in all research

- Document and distribute, on an annual basis, current linear referencing systems in formats which can be read by most GIS. Further investigate methods used by PENNDOT to distribute base maps and locational reference systems data sets, to see the benefits and feasibility of a similar release in Delaware

- Investigate opportunities to develop a multi agency approach to the development and maintenance of locational reference systems.

- Support the completion, review, and adoption of new road naming and addressing for Kent and Sussex County, and incorporate new naming and addressing into current locating data sets.

9 Standards For Attributes Of Spatial Features

9.1 Spatial Objects and Attributes.

In spatial information systems, one or a collection of coordinate values are grouped together as points, lines, or polygons to represent real world features. There are a variety of terms used in the various GIS software for these coordinate 'objects' such as arcs, links, segments, regions, areas, features, points, chains, rings, pixels, and nodes. These collections of coordinate values are used to model the real world, and in the terminology of the Spatial Data Transfer Standard are referred to as "spatial objects".

Traditional computer aided drafting and design (CADD) and GIS both employ spatial objects such as lines, shaded areas, and points, and are able to use various colors and symbols to display the spatial objects in maps and drawings. The primary difference between traditional CADD and GIS, and a primary feature of GIS, is that information can be associated with the spatial object to extensively represent and model real world entities. "Entities" are the real world phenomena such as roads, streams, transit routes, and farms, which the spatial objects represent. Attribute data can be associated with each modeled entity to support spatial analysis. For instance, a series of lines in a digital map could represent road segments. In order to represent properties at different points of the road, attribute information can be linked to the digital line segments. The roadname, length, road surface condition, number of lanes, speed limit, and route name are examples of attribute information which could be associated with each line segment to produce a digital spatial model of the road. Another example would be a polygon object which represents a piece of real estate. Attributes associated with the polygon to model it as a property would include the acreage, zoning, owner, assessed value, and landuse. The attribute information is what breathes life into the data which is otherwise a collection of graphic objects.

All GIS have utilities for managing, analyzing, and displaying attribute information for spatial objects. Attribute data can be stored as data tables in a number of spreadsheet or relational database management system formats including, DBASE3, Oracle, Lotus123, INFO, and ADABASE. Most GIS can work with several file formats. Standard formats for the transfer of attribute data are available and discussed in another section of this report. This chapter deals with standards which can be applied to the content and structure of attribute information which can support better coordination and communication within a community of GIS users.

9.2 Identification of Spatial Objects and Entities

The most fundamental attribute of a spatial object is that which uniquely identifies it. The identifier constitutes the bridge between the spatial object and related attribute information. An identifier for a roadway might be a road name or road number. An identifier for a census tract is the FIPS Census Tract Number. A property identifier is typically the tax parcel identifier. Obviously if members of the community identify roads, census tracts, or properties differently, their ability to share information about these features is greatly impaired. This is why the Census Bureau publishes unique FIPS codes for identifying states, counties, municipalities, and other areas, and uses these same codes to reference all demographic data. Identifiers are the "names" of the spatial feature and without common names there must always be some kind of translation in order for communication in a community. There are several examples that can be found in any locale where agencies who manage different types of information, in line with there respective missions, about the same real world entity, cannot readily share or relate information because there information systems do not identify the entity (whether it is a road, intersection, water well, demographic area, client, etc) in the same way. Relationships between data sets can not occur because there is no common link unless cross reference tables are used.

The only solution for this is the establishment of standard identification schemes determined by consensus and supported by the user community. Generally speaking, an identification scheme should be flexible and robust over time, well documented, and use existing schemes where possible.

It is one problem as discussed previously to have several names or identifiers for the same entity. It is another to not agree on a common terminology or definition for the entity itself. What is a road to one agency, to another might be a ramp, alley, avenue, path, highway, track, cul de sac, trail, causeway or other such entity. The different terminology and the individual needs to model the real world using spatial information systems lead to a different information system view of the world. In order to share information it is not only necessary to physically transport and structure the data, but also to have a common terminology for, or understanding of the spatial features represented. An effort to provide standard definitions for spatial entities has been made by federal agencies over several years and is presented in Part 2 of the Spatial Data Transfer Standard. Approximately 2,600 definitions of geographic features were examined, compared, and distilled into 200 entity types. These entity types are defined and referenced to alternative terms. Definition of transportation terms is also included in the FHA Highway Performance Monitoring System Field Manual.

9.3 Coding and Classification Systems

Many data sets employ coding systems for attribute data. A USGS Land Use/Land Cover coding system is shown in figure 17. Coding and classification schemes assign numeric or alphanumeric codes to each particular value. The land use/land cover coding system shown is an example of a hierarchal classification system which has general categories which are broken down further in the second tier. Because different groups have different interests and responsibilities there can be many different views of the same attribute. Someone doing a land survey for natural habitat protection will have different information needs and focus than a company who is reviewing an area for where they might build a suburban housing development.

The differences in how the information is classified, what information is collected, the interpretation of the value of the attribute, and the way it is coded, all have an effect on how

Figure 17. USGS Land Use /Land Cover Classification System for Use with Remote Sensor Data

Level I	Level II
1 Urban or built-up land	11 Residential
	12 Commercial and service
	13 Industrial
	14 Transportation, communications, and utilities
	15 Industrial and commercial complexes
	16 Mixed urban or built-up land
	17 Other urban or built-up land
2 Agricultural land	21 Cropland and pasture
	22 Orchards, groves, vineyards, nurseries, and ornamental horticultural areas
	23 Confined feeding operations
	24 Other agricultural land
3 Rangeland	31 Herbaceous rangeland
	32 Shrub and brush rangeland
	33 Mixed rangeland
4 Forest land	41 Deciduous forest land
	42 Evergreen forest land
	43 Mixed forest land
5 Water	51 Streams and canals
	52 Lakes
	53 Reservoirs
	54 Bays and estruaries
6 Wetland	61 Forested wetland
	62 Nonforested wetland
7 Barren land	71 Dry salt flats
	72 Beaches
	73 Sandy areas other than beaches
	74 Bare exposed rock
	75 Strip mines, quarries, and gravel pits
	76 Transitional areas
	77 Mixed barren land
8 Tundra	81 Shrub and brush tundra
	82 Herbaceous tundra
	83 Bare ground tundra
	84 Wet tundra
	85 Mixed tundra
9 Perennial snow or ice	91 Perennial snowfields
	92 Glaciers

well data sets from different sources can be used together and how an information set will be applicable to a particular need. In some cases groups can never come to full agreement on a common coding or classification scheme because their needs differ. The type and detail of information collected is very related to the costs for data gathering and maintenance, and this can also determine the form of the data. When information from several groups is to be incorporated, the coding systems must be studied in relation to each other. This involves not just a cross reference between the codes but also desicions on how information of different scope and detail can be related.

In cases where effective coding and classification systems are available, the information community benefits by knowing about them and using them. Often, agencies will create a new coding system, simply because no other is readily available or known. Decisions on an initial structure of information can have long term implications and complications.

9.4 Database Formats and Structures

Attribute data for spatial features is stored as database tables. Each attribute in a table represents a field of information. All database management systems allow for the identification of the attribute through a field name, and through a specifications for the storage structure. Attribute data is of a certain type such as "Character", "Numeric", "Boolean", "Date", or "Integer". Each field also has a precision in terms of the number of bytes or digits used to store the data which in some systems is called the field or item width. How the data is displayed or formated is also specified. Each attribute is stored in the data table in a particular order. These parameters and others for each attribute item form the data table structure.

Standards for specific data tables structures can assist the automated relation and analysis of data tables, and the development of automated methods for data query and display, production of user interfaces, and data compilation. When data from various sources is defined, named, coded, ordered, and formated in the same way, then a total conformance with respect to data structure is achieved. From an information systems management standpoint, this situation allows for the most efficient and automated processing of the data.

The specification of the structure of data is found in data dictionaries. An example of a data dictionary and the documentation of attribute data is given in figure 18 which is the description of the Link Table File used in the Version 2.0 of the National Highway Planning Network (NHPN). The NHPN is a digital road network database developed in many phases with information taken from USGS DLG-3 road lines and the assimilation of data from each of the fifty States, District of Columbia, and Puerto Rico. Without documentation of the structure of information it can not be fully understood or shared.

Figure 18. NHPN File Structure for the Link Table File

The Link Table File

The Link table file contains single fixed length records for each Link in the NHPN. Each Link contains the following attributes.

Table Name:	sxxlink.tbl
Record Length:	120
Record Type:	Fixed Length

Reference Section		
RECTYPE	Character	Always 'L'
VERSION	Numeric	Version Code
RECID	Numeric	Unique Link ID.
Key Section		
STFIPS	Numeric	State Fips Code
CTFIPS	Numeric	County Fips Code
ORNL-ID	Numeric	Oak Ridge National Laboratory assigned link ID.
LGURB	Numeric	Adjusted Urbanized Area
SMURB	Numeric	Adjusted Small Urban Area
FNODE	Numeric	NHPN Node ID
TNODE	Numeric	NHPN Node ID
Description Section		
SIGN1	Composite Field	Primary Sign Route
SIGN2	Composite Field	Alternate Sign Route
SIGN3	Composite Field	Alternate Sign Route
LNAME	Character	Local Road Name
MILES	Numeric	Length of link (miles)
KM	Numeric	Length of link (kilometers)
FACTYPE	Numeric	Facility Type
TOLL	Numeric	Toll Flag
LANES	Numeric	Number of lanes
ACONTROL	Numeric	Access Control classification
MEDIAN	Numeric	Median classification
SURFACE	Numeric	Surface classification
FCLASS	Character	Functional Class
ACLASS	Character	Administrative Class
RUCODE	Numeric	Rural/Urban Code
STATUS	Numeric	Open status of road
NHS	Numeric	Subnetwork: Proposed National Highway System (NHS)
STRAHNET	Numeric	Subnetwork: STRAHNET
TRANSAM	Numeric	Subnetwork: Example Trans-America Corridor

9.5 Recommendations and Proposed Standards for Attributes of Spatial Features

- Where possible consistent identification of spatial features should be promoted. A standard code to identify road segments as can be derived from current models of the DELDOT centerline file should be used by transportation agencies.

- Coding and classification systems for attribute data should be made available as part of a Delaware GIS Resource Guide. Groups should be encouraged to use compatible coding and classification schemes where possible.

- Data structures and standard formats for transportation data should be promoted and popularized through documentation and distribution.

10 Framework Standards

10.1 A Standard View of the World

GIS equipment and software is becoming less expensive each year. Their are many effective systems which operate on personal computers and systems, and on all platforms, systems are more user friendly. More individuals and groups have access to GIS than ever before. With so many new, independent users, it is difficult to keep track of all of the players and their accomplishments. Users are constantly being surprised at the data that is being generated by the rapidly growing GIS community around them. The power offered by these systems, the many data products being made available commercially, and the increased use of computer networks, is promoting a trend toward decentralization of information. Within government their is increasing concern with the duplication of effort and investments. Their is also great concern with how GIS users can talk to each other.

GIS technology is a general tool which finds application in any area which is concerned with information of a spatial nature. Each group has their own needs and specialties. The information within the GIS community can never be fully tracked or controled. The best focus of efforts to coordinate a GIS community and of most concern is where information needs overlap. Information layers such as basemap layers showing transportation infrastructure and environmental features provide a geospatial framework for information and are needed by almost all GIS users. Demographic frameworks (i.e. census tracts, planning districts) are another example of GIS data which is needed by many users and can serve as a common information framework.

Federal Geographic Data Committee (FGDC) promotes the concept of a digital geospatial framework as a basic consistent set of digital data and supporting services which will provide a geospatial foundation for a community to view and analyze information, and to which an organization may add detail and attach attributes and other themes of data. Examples of types of data which could be included in a framework are listed in figure 19. This type of information is needed by most GIS users, particularly those working in government. By incorporating the highest quality into these information sets and by effectively maintaining and distributing them, GIS users are spared the development costs of this information, and users have the most accurate representations of the data available. If a consistent framework is not available to a community, users will endeavor to develop the base layers they need for their work, and the result is numerous variations on the same information with a great deal of duplicated effort and a wide range of quality. Their will also be duplication of effort in attempts to maintain and update the data. In contrast, the availability of such information has an immediate coordinating effect on the community. Information sets are more compatible and data is located in a more consistent manner.

Figure 19. Data Constituting a Framework.

Transportation: roads, rail, transit, bridges, airports, tunnels, center line files, etc.
Hydrography: streams, ponds, rivers, etc.
Land Use / Land Cover
Political Boundaries: municipal boundaries, representative districts, etc.
Demographic Frames: census tracts, planning districts, traffic zones, etc.
Demographic Data: population, housing, income, employment, etc.
Digital Imagery: orthophotography, satellite data, etc.
Cadastral: property boundaries, in particular public lands and large holdings
Geodetic Control: control stations
Addressing: addresses, official road names, zip codes, address ranges

10.2 Features of Effective Spatial Frameworks

In the publication entitled "National Digital Geospatial Data Framework: A Status Report", the FGDC discusses the importance and benefits of data frameworks, and their implementation. This paper is included in the appendices of this report. It deals mostly with the development of a national framework, but the concept applies as well to the State or county level. By focusing on the GIS data which is needed by most groups, frameworks provide a focus of coordinating efforts and information standards.

Some of the major features of the framework promoted by FDGC[9] are:

- The framework should contain the "best" data available.
- Users must be able to integrate framework data into their applications and still preserve an existing investment in attribute and other information.
- The framework should be a reliable and dependable supplier of data. The technical demands for using the data should be minimal and stable.
- Access to the framework should be available at the least possible cost.
- Framework data will be "data you can trust". Framework data will be certified as complying with standards for different characteristic. The framework should be reliable and dependable.
- The design of framework data sets must consider the needs of Federal, State, and local government users, and of the private sector.
- The framework should evolve with the contributors' changing requirements and capabilities.

[9] FGDC Framework Discussion Paper

- The framework should provide basic information. It should enhance, and not interfere With the contributors' plans to provide value-added information and services for their data.
- The framework will be operated and maintained by participants who agree to provide digital geospatial data that meet various content, quality, policy, and procedural criteria.

10.3 Recommendations and Proposed Standards for Frameworks

Recommendations with regards to framework standards include:

- Develop a comprehensive GIS framework for the community. Framework data will include GIS layers for transportation facilities, center line files, environmental features, census and planning zone geography and demographic information, land use, and political boundaries.
- Provide an efficient distribution mechanism which will offer inexpensive and easy access to the framework data. This could be through network file servers, or by publishing the data on compact disk in several GIS software formats.
- Develop effective means to update and add to the framework.
- Develop guidelines for the creation and development of new frameworks.

11 Transfer Standards

11.1 Types of GIS Information

In GIS, one or a collection of coordinate values are grouped together as points, lines, or polygons to represent real world features. There are a variety of terms used in the various GIS software for these coordinate 'objects' such as arcs, links, segments, regions, areas, features, points, chains, rings, pixels, and nodes. These collections of coordinate values are used to model the spatial dimensions of real world entities, such as a river, road, or census tract, and in the terminology of the Spatial Data Transfer Standard are referred to as "spatial objects". Identifiers and other attribute information are linked to the spatial objects to further model the entity. For instance a road name, the length, the number of lanes, the speed limit and other information is attached to a line segment to model it as a road. The capability to manipulate spatial objects and associate attribute information to the spatial objects is the most common feature between all GIS software.

The uses of GIS for spatial data analysis involve several other types of information. Many GIS can make use of image based data, such as scanned drawings, satellite data, and digital orthophotography. The creation of digital maps involves a range of computer graphics which can be displayed on printers and plotters. Video files stored on optical disk as used in the video loging of roadways can be incorporated into GIS. Menu systems can be created by the user to more easily perform mapping, data query, and analysis, and many GIS include a substantial programming language which can be used to customize systems. GIS is a multimedia technology with each software system using several data types and data formats.

11.2 The Importance and Focus of Transfer Standards

In most areas, as in Delaware, several types of GIS hardware and software are in use for a variety of applications. One thing all systems have in common is that they need data. All groups are busy generating or collecting data from a range of sources to meet their needs, and the investments in data development far outway other costs. Often users have overlapping data needs. If GIS users in the community cannot share information then the result is substantial duplication of effort, higher costs, and a lack of consistency between information bases. Being able to share information is the key focus of issues of compatibility of information systems.

The transfer of information between different types of GIS software can be time consuming and difficult for many users. The identification and use of standard methods for data transfer can help simplify the process. Transfer standards can be formed as a set of guidelines that users can follow to focus their data transfer efforts. Ideally for each data type there would be a particular data format which all users in the community could use for translation. GIS users though not familiar with all GIS software used in the community, can know that if data of a certain type is prepared in a certain way, then outside groups will be able to use it. For archiving or distribution users, can all focus on a particular data format and acquire the necessary tools and procedures to produce and accept it.

A major effort to develop one GIS data exchange format which can reliably transfer data is the Spatial Data Transfer Standard (SDTS) and is discussed in Section 12. SDTS is designed to handle a wide range of data types and to accomodate a number of ways of modeling spatial data. Spatial objects, images, attribute data, and metadata can all be transfered using SDTS. At this time however it is not fully supported by the GIS software vendor community. ARC/INFO includes an SDTS translator with its software, and InterGraph has produced a translator which is now in beta testing. SDTS could solve a lot of problems.

The focus of this research was to try to identify currently available standard file formats and/or transfer procedures which could be used as transfer standards. The value of a transfer format is in its ability to preserve the data model, accuracy, and completeness of the information through the data import and export process. The GIS data types addressed are as follows and form the primary types of information to be shared:

* Attribute information (data tables)
* Point layers
* Line layers
* Polygon layers
* Cell based data (raster)
* Images and graphics

Currently available tools for data transfer for GIS were considered. ARC/INFO, InterGraph, MapInfo, and Atlas GIS were specifically studied.

11.3 Current Information Transfer Capabilities

No GIS directly reads all data from any other GIS. Some type of data conversion is almost always necessary for data transfer. While data is successfully transfered between all GIS, the process can be sometimes complicated and unreliable. Even when a proven method of data transfer is known, results should always be carefully reviewed. There is no one method for transfering GIS data between different systems. Because each GIS manages several types of information in many different digital formats, data transfer must be approached with respect to the different data types. Some data types are not supported in all GIS software. As many GIS users are not computer science specialists or experienced with more than one type of GIS, data transfer is often a difficult trial and error process, and is very time consuming.

To perform a data transfer or conversion, users must rely on utilities built into their GIS software or available from third party vendors. Conversion programs often work on "exchange" or intermediate formats of the data which can be produced by each GIS (see figure 20). After running the conversion utility there is usually additional review and processing necessary. Based on user demand, GIS software vendors build different types of data translators into their products. The data translators produce (export) data exchange files and can accept (import) data exchange files. Each vendor programs their translators slightly differently depending on the particular features that work well for their particular GIS products, and for this reason one GIS software may export or import the exchange file slightly different from another. A knowledge of the content and structure of the data aids the data conversion process.

Figure 20. Common GIS Data Exchange Formats

Abreviation	Name
DXF	AutoCAD ASCII Drawing Interchange File
EOO	ARC/INFO Exchange File
DLG	Digital Line Graph Format
IGDS	Interactive Graphics Design Software File (InterGraph)
BNA	Atlas GIS ASCII File
TIGER	U.S. Census Bureau TIGER Line Format
MIF	MapInfo Data Interchange Format

11.4 Spatial Objects and Attributes

Spatial Objects are used to digitally represent real-world features. They are the graphic components of GIS layers, and are defined as sets of coordinates or referenced cells which can be linked to descriptive information. A collection of line segments can form the representation of a road network or river. A closed set of line segments can form a ring which represents the boundaries of a traffic zone or property. Designed to accomodate spatial systems in general, the Spatial Data Transfer Standard (SDTS) identifies simple spatial objects and a standard terminology as shown in figure 21. Spatial objects are the graphic and locational elements used to create GIS layers. Spatial objects form the spatial framework for information and the geographic unit of analysis.

Each spatial object or collection of objects is assigned alphanumeric identifiers in GIS and these alphanumeric identifiers are used to link all descriptive information which would identify the object as a real world entity. For instance, a line segment made by connecting several coordinate points is identified as one object, and a road name, length, speed limit, address range, surface condition, and other type of attribute is associated with the object to model it as a road. In this way real world entities are modeled by spatial objects and attribute information. The various GIS software use different objects, terminology, and data structures for their models but the information which makes up a GIS layer is generally of two types, spatial object and attribute information. To accurately translate information from one system to another is to preserve the model of the real world entity between systems which use different data formats and structures for spatial object and attribute information.

Some GIS data is primarily made up of spatial objects as with a cartographic products or a computer aided drafting drawing. Other information is primarily attributes as in the case of data tables and database systems. The transfer process can be broken into two processes.

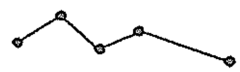
Figure 21. SDTS Spatial Objects

GEOMETRY-ONLY (G) SPATIAL OBJECTS

Point. A zero-dimensional object that specifies geometric location. One coordinate pair or triplet specifies the location.
Note: There are three sub-types of Point: Entity Point, Area Point, and Label Point.

Line Segment. A direct line between two points.
(A line is a generic term for a one-dimensional object.)

String. A connected nonbranching sequence of line segments specified as the ordered sequence of points between those line segments. Note: A string may intersect itself or other strings.



Arc. A locus of points that forms a curve that is defined by a mathematical expression.

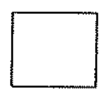
G-ring. A sequence of nonintersecting strings and (or) arcs, with closure. A ring represents a closed boundary, but not the interior area inside the closed boundary. (G-Ring is a sub-type of Ring.)

Interior Area. An area not including its boundary. (An area is a generic term for a bounded, continuous, two-dimensional object that may or may not include its boundary.)

G-Polygon. An area consisting of an interior area, one outer G-ring and zero or more nonintersecting, nonnested inner G-rings. No ring, inner or outer, shall be collinear with or intersect any other ring of the same G-polygon.

Pixel. A two-dimensional picture element that is the smallest nondivisible element of a digital image (a defined aggregate spatial object).

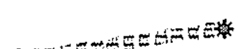
Grid Cell. A two-dimensional object that represents the smallest nondivisible element of a grid (a defined aggregate spatial object).



GEOMETRY AND TOPOLOGY (GT) SPATIAL OBJECTS

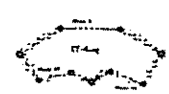
Node. A zero-dimensional object that is a topological junction of two or more links or chains, or an end point of a link or chain.

Link. A topological connection between two nodes. A link may be directed by ordering its nodes.



Chain. A directed nonbranching sequence of nonintersecting line segments and (or) arcs bounded by nodes, not necessarily distinct, at each end.
Note: there are three sub-types of Chain: Complete Chain, Area Chain, and Network Chain.

GT-ring. A sequence of nonintersecting chains, with closure. A ring represents a closed boundary, but not the interior area inside the closed boundary. (GT-Ring is a sub-type of Ring.)



GT-Polygon. An area that is an atomic two-dimensional component of one and only one two-dimensional manifold (a defined aggregate spatial object). The boundary of a GT-polygon may be defined by GT-rings created from its bounding chains. A GT-polygon may also be directly associated with its chains (either the bounding set, or the complete set).

One process for transfering spatial objects, and another to transfer attribute information. As long as the spatial object can maintain an identifier which can be used to reference related attribute information, then the model of the real world entity can be reconstructed.

11.5 The Transfer of Attribute Data

Data associated with spatial objects and descriptive data in general is managed in data tables using data base management systems (DBMS) which are encorporated into each GIS. Examples of DBMS used are ORACLE, INFO, ADABASE, DBASE-IV, and INFORMIX. Data tables are in file storage formats which can be read by the DBMS used. The following figures show an example of the data table structure and a sample row (record) from a data table which holds information about a road segment. The data table structure addresses the name,

Figure 22. A Sample Data Table Structure For Road Segments

COLUMN	ITEM NAME	WIDTH	OUTPUT	TYPE	Num Decimals
1	LINK_ID	6	6	I	
7	FROM-NODE	6	6	N	0
13	TO_NODE	6	6	N	0
19	DIRECTION	2	2	C	
21	LENGTH_MILE	8	8	N	2
29	LENGTH-KM	8	8	N	2
37	BEGIN_MILEPNT	8	8	N	2
45	END_MILEPNT	8	8	N	2
53	ROADNUM	6	6	C	-
59	NAME	20	20	C	-
79	ROADCLASS	2	2	C	-

Figure 23. Sample Record (row) from Road Segment Data Table

LINK_ID	= 2143
FROM-NODE	= 16
TO_NODE	= 18
LINK_DIRECTION	= 3
LINK-LENGTH_MILE	= 0.36
LINK-LENGTH-KM	= 0.58
BEGIN_MILEPNT	= 0.51
END_MILEPNT	= 0.87
ROADNUM	= 17
NAME	= NAAMANS ROAD
ROADCLASS	= 4

storage requirements, and data type (ie. Integer, Numeric, Character, Date). Each information entry is called a item, or field. The data structure and information for each record defines the table. In the example above LINK_ID is a data table item which can be used to relate this descriptive information to the spatial object for the road segment with the same identifier.

Some GIS software can directly read the structure and data of data tables stored in a number of DBMS formats. Where a particular data table format is supported, there is no need for conversion. A very common DBMS data table format is DBASE3 (DBF) format. MapInfo and Atlas GIS work directly with DBF files, and conversions are supported in ARC/INFO.

Some GIS will work directly with common spreadsheet file formats such as used in LOTUS123 or EXCEL software. More often there is a specific or optimal data table format that each GIS needs and a conversion is necessary.

Other standard methods for the transfer of attribute are based on placing the data in a text file, sometimes called ASCII files. The text formats most common are "fixed format" and "delimited". In a fixed format file each data item or field is placed in certain columns, and there is one line of text for each record. In delimited format each data item is separated by a comma. Examples of fixed format, and delimited (by comma) text data files are shown in figures 24 and 25. Notice that unless the user understands the data represented in each column or between each set of delimiters, the data file is meaningless. Text describing data structures, coding systems, and other metadata must also be provided with the text files for users to understand what the data file comprises. Users must redefine the data base structure for the text file being imported. Fixed format and delimited data files are used by several types of information system software, and provide a very reliable means of transfering attribute data. GIS facilities should acquire or develop methods to handle data stored in these formats if the software used does not handle them.

Figure 24. 8 records as fixed format text

```
2143   16   183   0.36   0.58   0.51   0.8717    NAAMANS ROAD          4
2142   19   163   0.51   0.82   0.00   0.5117    NAAMANS ROAD          4
   9   19   161   0.77   1.24   6.00   6.774     CONCORD PIKE          4
  10   14   183   0.32   0.51   4.63   4.95221   BEAVER VALLEY RD      2
   6   12   223   0.54   0.87   7.98   8.529     KENNETT PIKE          3
  16   24   141   0.59   0.95   4.64   5.23225   THOMPSON BRIDGE RD    2
  12   18   253   1.47   2.37   0.87   2.3417    NAAMANS ROAD          4
   7   14   283   3.51   5.65   1.12   4.63221   BEAVER VALLEY RD      2
```

Figure 25. 8 records as comma delimited text

```
2143,16,18,"3",0.36,0.58,0.51,0.87,"17","NAAMANS ROAD","4"
2142,19,16,"3",0.51,0.82,0.00,0.51,"17",NAAMANS ROAD,"4"
9,19,16,"1",0.77,1.24,6.00,6.77,"4","CONCORD PIKE","4"
10,14,18,"3",0.32,0.51,4.63,4.95,"221","BEAVER VALLEY RD","2"
6,12,22,"3",0.54,0.87,7.98,8.52,"9","KENNETT PIKE","3"
16,24,14,"1",0.59,0.95,4.64,5.23,"225","THOMPSON BRIDGE RD","2"
12,18,25,"3",1.47,2.37,0.87,2.34,"17","NAAMANS ROAD","4"
7,14,28,"3",3.51,5.65,1.12,4.63,"221","BEAVER VALLEY RD","2"
```

11.6 Point Layers

Sometimes data is referenced to points on a map in GIS. The location of an intersection, park and ride, center of a traffic zone, water discharge point into a stream, or accident location are all examples of real world entities that could be located and modeled as points in a GIS layer. A point is a very basic spatial object which can be defined by a horizontal and vertical coordinate pair. A reliable method of transfering the coordinates for the point and the associated descriptive data is by placing all attribute data and coordinates into a data table, and then use a method of transfer as discussed previously.

Figure 26 presents a data table for a GIS point layer which references the center of a traffic zone, and estimates of employment (for construction, manufacturing, and total) in Delaware in the year 1995. Such a table contains attribute information and the coordinates which constitute the spatial object (point). Once this data table is transfered, it is a very straightforward process to create a graphic layer showing the point and to query and analyze the attribute data. Transfer of point data and attributes in one data table or data base file is the easiest method.

Figure 26 Point Data Table for Traffic Zones with Associated Employment Data

TZONENAME	X-COORD	Y-COORD	Construction95	Manu95	Total_Employ95
117	187753.781	202690.359	0	8	1253
129	186007.219	201729.453	0	0	1052
126	191066.875	203414.766	730	29	1139
132	183218.750	203034.844	0	0	67
118	189365.297	202044.844	255	122	3269
119	190323.906	202026.031	22	6	190
125	193982.641	202794.516	133	17	211
120	191529.125	201891.688	33	11	469
131	181368.891	202163.953	389	0	503
124	193159.281	201971.922	0	15	783

Handling the transfer of this data through data table text files introduces the capability of GIS systems to import spatial objects from coordinate values listed in text files. The spatial object (in this case points) is transferred in one text file, and the attribute data is transferred in a data table. Figures 27 and 28 present examples of the two text files. GIS software will read the spatial object text file which contains a unique identifier for each point and the coordinates, and prepares the graphic layer. InterGraph software uses the ASCII Loader Module to import and export spatial objects using text files, ARC/INFO uses the Generate and Ungenerate commands, Atlas GIS works on a text format called "BNA", MapInfo uses a text format it calls Map Interchange Format (MIF). Most GIS software have some way of importing and exporting spatial objects from text files. The attribute table can be transfered as a data table. The points can be linked to the associated tabular data using the unique identifier which is in this case the Traffic Zone Name. Notice that both files contain the traffic zone identifier which is used to relate the two files. The ability to relate spatial objects to attribute tables using a relate field is basic to all GIS.

Figure 27, Example of a text file used to import points.

```
117     187753.781   202690.359
129     186007.219   201729.453
126     191066.875   203414.766
132     183218.750   203034.844
118     189365.297   202044.844
119     190323.906   202026.031
125     193982.641   202794.516
120     191529.125   201891.688
131     181368.891   202163.953
124     193159.281   201971.922
```

Figure 28, The attribute data to be associated with the above points

TZONENAME	Construction95	Manu95	Total_Employ95
117	0	8	1253
129	0	0	1052
126	730	29	1139
132	0	0	67
118	255	122	3269
119	22	6	190
125	133	17	211
120	33	11	469
131	389	0	503

11.7 Event Data

As discussed in Chapter 8 the most common way to reference information for transportation facilities is by a linear referencing system base on route and measure along the route. Event databases are tables containing attributes along linear objects using a route-measure system. A portion of the Delaware 1993 Traffic Summary is shown below and serves as an example of an event database.

Figure 29 , Traffic Counts in an Event Database

Route ID	Milepoint	Road Name	AADT	TRK_PCT_AADT
23	0.45	MARSH ROAD, DEL. 3	3121	05
24	2.85	PHILA. PK., U.S. 13B	13648	05
24	0.52	WALNUT & KING, WILM.	28430	05
24	3.64	PHILA. PK., U.S. 13B	8687	05
24	1.30	N. MARKET ST., WILM.	15494	05
24	8.06	PHILA. PK., U.S. 13B	11748	06
24	7.41	PHILA. PK.U. S. 13B	21497	06
24	3.25	PHILA.PK.U. S. 13B	14768	05
24	0.94	WALNUT & KING, WILM.	20306	05
24	8.48	PHILA. PK., U.S. 13B	4828	06
24	5.13	PHILA. PK., U. S.13B	12398	05
24	6.82	PHILA. PK., U.S. 13B	18005	05

This event table, much like an event table for an accident database, are data occuring at a point in the road, and each record (row) is a point event. There are also linear events. Linear events reference information along a portion of a road. An example is presented in the figure below which shows the road surface along routes. To specify the portion of the road addressed by each record a beginning measure point and ending measure point for the linear event must be referenced. Events are stored as tables and can be transfered by the methods outlined above for attribute tables. Of course, in order to use the data, a GIS must have the road network framework in which routes and measures are defined in the same way, and must have dynamic segmentation utilities.

Figure 30, Example of a Linear Event Table

Route ID	Begin_milepnt	End_ milepnt	Surface_condition	Fix Date
33A	0.0	.7	Poor	9/23/82
33A	0.7	1.3	Poor	11/06/82
33A	1.3	2.0	Fair	04/01/88
33A	2.0	3.1	Good	05/03/88

11.8 Line Layers

As illustrated in the subsection on transfer of point layers, the process of transferring GIS data can be approached in two processes, one to transfer the spatial object, and one to transfer the attribute data. Attribute data can always be linked to the spatial object if a unique object identifier is transferred with the coordinate data for the object. Line layers should specified in terms of line segments (portions between graphic intersections) and each line segment must have a unique identifier. In InterGraph systems this unique identifier is the "MS-Link" identifier. A route identifier as used in most transportation modeling systems cannot be used for general translation because it is not unique for all road segments. Attribute data which could include beginning and end nodes, length, measures, route, address ranges, name, etc., can be transferred in tables provided that one column (item,field) is included for the line segment identifier used for relation to the line segment objects. Once the relationship is established between line segment objects and attribute data and successfully imported into a GIS, roads are referenced by name, or route-measure, and the line segment id is generally not used by the operator. The attribute data transfer is accomplished as described previously. The trick ussually is to translate the spatial object and its unique identifier. An example of a line layer would be a GIS center line file used to specify a road network.

As mentioned earlier there is no one standard method to translate from one GIS software format to another, but most GIS software includes software to transfer spatial objects using text (ASCII) files. Examples of text files defining line segments are shown on the next page. The sketch shows the coordinates of vertices on a simplistic coordinate system and line segment identifiers for three line segments. Text files which can be used in the various GIS software are similar, and include identifiers, coordinates, and the number of coordinates for each segment or an end of segment marker. There are a number of ways using a text editor to change one text format to another. For InterGraph, MGE ASCII Loader (MGAL) provides several options and tools for interpreting and writing text files which can be used for the translation of spatial objects as well as attribute files.

Sample line segments described by text files below:

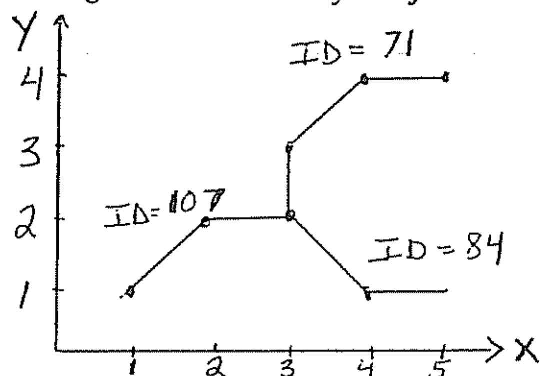


Figure 31. Atlas Text File Example For Line Segments

```
"71",4                    {segment ID, then number of coordinate pairs to follow}
5,4
4,4
3,3
3,2
"107",3
3,2
2,2
1,1
"84",3
3,2
4,1
5,1
```

Figure 32. ARC/INFO Text File Example for Line Segments

```
71
   5    4
   4    4
   3    3
   3    2
END
107
   3    2
   2    2
   1    1
END
84
   3    2
   4    1
   5    1
END
END
```

Figure 33. InterGraph Text File Example for Line Segments

```
 71                  {segment ID}
     5     4
     4     4
     3     3
     3     2
EOC                  {each segment ends with EOC, also possible to delineate
 107                   segment records by specifying number of coordinate pairs
     3     2           as with AtlasGIS}
     2     2
     2     1
EOC
 84
     3     2
     4     1
     5     1
EOC
```

11.9 Polygon Layers

Taking the same approach to determining a standard way of specifying and transfering spatial objects as for line layers, this section reviews the use of text files for transfer of polygon layers. A polygon is shown below with GIS text file expressions from four GIS systems. All GIS software have the ability to read as well as produce their own text format. All the files include the list of coordinates specifying the polygon. Of the four shown, ARC/INFO is the only one which uses the "END" statement between polygon records, the others include the number of coordinate pairs making up the polygon. Header lines are sometimes included as in the MapInfo MIF file. InterGraph MGE has extensive abilities to read and define how text files can be produced and read, the example shown is the most basic.

There are a number of ways that one text format could be read by another. In any case, it is conceivable that the text files from one GIS could be edited to conform to another. If there are not many object records the file could be edited line by line in a text processor. Using clever methods of text replacement the files could be changed more quickly. Also simple programs could be written to convert the text files. Attributes could all be transferred as data tables and associated to polygons through the polygon ID. If users in a community could focus on one text format to serve as a standard, and have procedures ready for conversion of that format to the GIS each use, then transfer of spatial data would be easier and less mysterious. Such standard transfer formats using text files are proposed in Appendix A.

The transfer of polygon data can be complicated in the case where more than one polygon describes the region to be represented. There are two major classes of this, termed here as "polygons with holes", and "islands". A polygon with holes is similar to describing a piece of swiss cheese. If you are describing only the areas of the slice which are cheese, you would have to represent the slice digitally by specifying the polygon representation of all the interior holes. A real life example is when modeling the above water area of a region which has lakes within it. To model the part of the region that was dry land, one would also need to know the dimensions of the lakes. Islands are the case where several seperated polygons are considered as one entity. For instance Hawaii can be described by State level statistics, but is made up of several islands. Polygons with holes and islands are also addressed in the standard transfer formats presented in the Appendix A.

11.10 AutoCAD DXF For Translation of Points, Lines, and Polygons

An exchange format supported by several GIS software is the AutoCAD ASCII Drawing Interchange File (DXF). As AutoCAD is computer aided drafting and design software the DXF exchange file format is based mostly on the exchange of graphics and not attribute data. Personal computer based GIS software such as MAP/INFO and Atlas GIS can transfer GIS data particularly well using DXF. As long as spatial objects can be identified and linked to attribute tables then using DXF files is a viable transfer approach. The DXF format was studied as a possible standard transfer format, but owing to difficulties transfering attributes and the fact that

Sample polygon described by text files below:

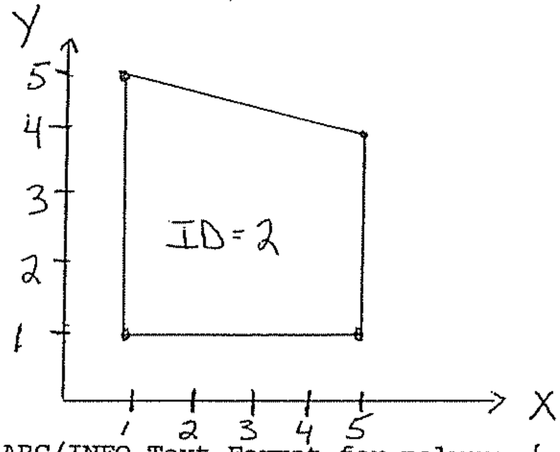


Figure 34. ARC/INFO Text Format for polygons{ comments, not part of the file }

```
      2              2.5  3.5         {polygon ID,  X & Y coordinates of Centroid}
       1.000000           1.000000    {beginning of X,Y coordinates}
       1.000000           5.000000
       5.000000           4.000000
       5.000000           1.000000
       1.000000           1.000000    {close of polygon}
END                                   {end of polygon record,another could follow}
END                                     {END,END signals end of file}
```

Figure 35. An AtlasGIS Text Format for polygons

```
"2",5        {one or more ID's then the number of X,Y coords. to follow}
1,1                {beginning of X,Y coordinates}
1,5                {coordinates could be shown with more precision if needed}
5,4
5,1
1,1                {close of polygon, no record end needed, another could
                    follow}
```

Figure 36. MapInfo Text Format (MIF) for polygons

```
Version 2                                                    {Header Lines}
Delimeter ","                                                {     ""     }
CoordSys NonEarth Units "ft" Bounds (43,43) (49,49)          {     ""     }
Columns 3                                  { three attribute definitions to follow}
   ID Char                                 { ID's and attribs kept in attached "MID"
   _NAME Smallint                            comma delimited file, in same order as
   _NAME2 Smallint                           listed in this file.}
Data

Region                     {object type and number of objects}
   5                       {number of coordinate pairs to specify folowing region}
1.000000 1.000000          {beginning of X,Y}
1.000000 5.000000
5.000000 4.000000
5.000000 1.000000
1.000000 1.000000          {close of polygon}
   Pen (1,2,16711680)
   Brush (1,117440512,201326591)
   Center 3 3
```

Figure 37. InterGraph MGE Text Format for polygons

```
   2        5           {polygon ID, then the number of X,Y pairs to follow}
1.000000 1.000000
1.000000 5.000000
5.000000 4.000000
5.000000 1.000000
1.000000 1.000000       {close of polygon}
```

GIS software reads and writes the DXF files differently, it is expected that users will have difficulty using it unless they are only concerned with graphics or strictly cartographic data.

11.11 Image Formats

An image or raster file contains a graphic by addressing every small dot on the page at a certain resolution (dots per inch). This is similar to the way a television screen displays a picture which is the result of a grid of colored dots. Since information for every dot is kept, these files can be large. In an image format, a letter of the alphabet is not a letter or code, but a collection of white and black dots which when taken together is the picture of a letter. In word processing software a letter is not stored as a series of dots but as a letter code along with some text attribute information. In most digital map formats a line is not stored as the collection of dots which give the picture of a line, but as a "vector" format consisting of a series of X,Y coordinates for the beginning and end of the line and for the bends or shape points in the middle. Simply stated an image format is a picture made up of many dots. Differences in image formats are in the method used to store the dot information. The dots are also referred to as pixels, or cells. Image files can be produced by scanning documents or maps. Images can be made up of black or white dots, or dots which have a range of greyscale or color values. Digital photography, satellite imagery, and graphics, are examples of GIS data which is stored as images. Some GIS software stores all data in image formats.

ARC/INFO, InterGraph MGE, and other high end GIS software can work with, and have utilities to convert between several different image formats. Scanning equipment ussually comes with software which can be used to prepare over a dozen different types of images. An image format designed to be a universal image format by Aldus Corporation and Microsoft Corporation is the Tagged Interchange File Format (TIFF or TIF). TIF is very popular with desktop publishing packages and is supported by several GIS. TIF can be used to store black and white (monochrome), greyscale, and color images. Another popular format for working with monochrome images is Run Length Compressed (RLC). A format which is used extensively on networks is the GIF format created by CompuServe as a machine independent image file format. The Postscript format (discussed in the next section) can also be used to store image data. While Postscript creates large files relative to other formats, it has an advantage in that there are commercially available software which can convert a Postscript file to numerous image or plotter/printer hardware formats. Not all GIS and CADD software have the ability to work with image data, but for those that do, TIF, RLC, GIF, and PostScript are image file formats which are most common.

11.12 A Text Format for Image or Cell Based Data

An image as discussed in the previous section can be thought of as so many rows and columns of dots, with so many dots per inch in the vertical and horizontal directions. Actually the entire space spanned by the image is described as a collection squares (cells) of a grid formed by horizontal and vertical lines at a certain spacing. Each grid cell is a dot. When associated with a real world coordinate system, a cell covers so much area on the earth and has a width and a height. The size of the cell is related to the resolution of the grid or image. For instance, the dot or cell size of the 12,000 scale digital orthophotography available for Delaware is 1 meter on a side.

Information described as grid cells or dots is called raster data. A grid cell (pixel, dot) is just another type of spatial object, and attribute information can be associated with grid cells just as it can with lines or polygons. A color value can be associated with each cell or dot to make a picture. Light reflectance values can be associated with each cell as with satellite imagery to support analysis of land cover. A land area could be described as a series of squares, and the presence of a certain type of soil in each square could be designated with some code associated with each square.

An image or grid can be specified with respect to a coordinate system if one knows the cell width and height, the row and column of the cell, and horizontal and vertical coordinate values that place the rows and columns in space. One text format which would describe such a grid is given in figure 38. Just as with other spatial objects, attribute

Figure 38. A Text Description of Cell Based Data (Grids, general raster)

```
Origin
Coordinate of some other point on vertical axis
CellWidth, CellHeight
NumRows,NumCols
row,col,cell id,attrib1,attrib2,....
row,col,cell id,attrib1,attrib2,....
Etc, continuing for number of cells
```

data associated with cells could be stored and transfered in attribute tables containing reference to the row and column, or a unique cell id.

11.13 The Need to Address Digital Graphics and Report Formats

One of the primary uses of GIS is to create maps, and the primary deliverables in most GIS projects are maps and reports. Traditional methods of producing maps, charts, posters, and other graphics by hand are used less and less these days. A problem exists, however, in that graphics files produced in many projects are created specifically for a particular GIS software or for particular printers or plotters. The platform specific nature of the products makes them less useful to the general community. Until recently the majority of people were not familiar with digital products and the size of graphic files made data transfer inconvenient. For such reasons and because there is often no guidelines, requirements, or facilities to archive digital graphics or reports, they are generally provided only in hard copy.

Hard copy maps and reports have several disadvantages, including the space it takes to store them, difficulty in using them with future projects, and difficulty copying or sharing them. In many cases maps and reports end up forgotten, gathering dust in a closet. Digital products can also be lost. They can be archived on computer tapes with no documentation till no one knows what they are, or what they were used for. Years of contributions can remain unknown and unavailable. This is an unnecessary waste. While there is of course an overhead in documentation, and storage and access facilities, current computer and data storage technologies have come a long way in offering cost effective alternatives. With a proper method of cataloging and archiving in place, digital formats for information products provide a superior mechanism for archiving, accessing, and distributing information.

With the use of computer networks things are changing rapidly. Agencies all over the country are providing reports, graphics, and other types of information as computer files residing on network servers. With access to the Internet, groups and individuals are able to review file catalogues and references of different types, find what they need, and conveniently obtain information. It is no longer necessary to depend on having a hard copy report or data file sent through the mail. Less time is needed from the source agency to meet information requests, and users everywhere are developing a deep appreciation of digital formats for accessing information. Documentation of all types are now being kept in digital format. Software and hardware manufacturers who produce manuals which can fill a bookshelf for a particular system are now putting them onto compact disk. Magazines, complete with text and graphics are being distributed over networks. Government budgets are provided on computer files on networks.

There are numerous digital formats for text, maps, and various types of graphics. Some are text and text format oriented such as a word processing format like WordPerfect. Many are of in a image (raster) format which array a page surface into so many dots per inch. From a standards point of view, which one should be used? While most users will use a particular graphics format which best suits their software and plotter or printer, the goal is to identify one or few formats which can be effectively and reliably used for the transfer of graphics (includes maps) and reports. These standard formats would be those which can be used directly or translated into formats supported by most GIS and can be plotted on a number of output devices (printers/plotters). The following sections discuss popular formats which could be used as standards.

11.14 Common Formats for Graphics and Documents

PostScript

The PostScript language is a file format which supports text and graphics and has become a standard among all major computer, printer, and imagesetter/typesetter vendors. Printers and software with PostScript interpreters allow users to print or view PostScript files independently of the application that generated them. Encapsulated PostScript (EPS) is a subset of PostScript which is the most common file format found for desktop output and high end publishing. The files can contain complex text and graphic specifications and they are in a ASCII text readable format that can be edited. Utility software is available from several vendors to convert a PostScript file to a range of image, plotter, and graphics formats. Because of its popularity and versatility, PostScript is recommended as a standard format to be used for graphics and documents.

WordPerfect and MS-WORD

WordPerfect and MicroSoft Word are perhaps the most popular brands of word processing software being used. Because of the their success, the file formats used are supported by several types of software, and it is not uncommon to see documents distributed as WordPerfect or MS Word documents. The format includes all of the text and font specifications that are used to create a professional report. Several other software packages can read this format.

American Standard Code for Information Interchange (ASCII) Text

The most basic way a text file can be stored or transmitted is by an ASCII text file which contains only the alphanumeric characters and white space characters (spaces, tabs, linefeeds) and no font or formatting instructions. While it isn't pretty, it is very simple, and therefore easy and reliable to share.

CGM

CGM is an American National Standard Institute (ANSI X3.122 1986) and International Standards Organization approved format for the storage and transfer of graphic information. It is supported by several GIS and by many personal computer based software systems including Harvard Graphics, Ventura, and Pagemaker. There are three CGM formats, CGM Character Encoding, CGM Clear Text, and CGM Binary. The first is a compressed ASCII format, the second is a readable uncompressed ASCII format, and the third is a binary format which optimizes compression and processing encoding.

Image Formats

Those image formats mentioned previously could also be used to distribute maps, graphics, and scanned documents.

11.15 Recommendations and proposed standards for GIS data transfer are:

- Promote the creation and use of guidelines for GIS data transfer which include specifications and procedures for the transfer of each data type. Support an effort to develop the utilities and instructions needed for each type of GIS software to address the standard transfer formats adopted by the community. Consider formats summarized in the appendix as a starting point for standard data transfer.

- Promote the use of the Spatial Data Transfer Standard (SDTS). Encourage vendors to develop SDTS software utilities.

- Require that all new data products be provided using standard transfer formats and be documented using metadata standards.

12 The Spatial Data Transfer Standard (SDTS)

12.1 What is a SDTS? (Brief Version)

The Spatial Data Transfer Standard was designed to address a range of issues involved in the transfer of spatial data. "Vector data and raster data of many different types, models, and structures, along with associated attribute data also of widely varying types, models, and structures, can be exchanged between dissimilar systems"[10]. SDTS is a product of an approximately 9 year effort by many individuals and groups, with the U.S. Geologic Survey (USGS) playing the primary leadership in its development and promotion. After review and testing by government agencies and private industry, SDTS was submitted to the National Institute of Standards (NIST) for approval as a Federal Information Processing Standard (FIPS). It was subsequently approved in July 29, 1992 as FIPS Publication 173.

A large number of publications describing SDTS are made available by USGS and other organizations. As SDTS is composed of other official standards for data transfer and metadata, there is also a large body of information on features within SDTS. An investment in time is necessary to understand the requirements of a comprehensive transfer of information as represented by SDTS, and the actual implementation of the standard. The review that follows was focused on identifying the key elements that make up the standard, the considerations involved in its implementation, and determining the value of the standard for GIS facilities as they currently exist.

But briefly, what is it? An SDTS data transfer in its most physical form is a collection of a dozen or more text files each composing what is known as a "Module". Each SDTS module contains information of a certain type about the data being transferred. The SDTS modules can be categorized into types which are; Global, Data Quality, Spatial Object, Attribute, and Graphic Representation. Each module addresses a specific area for the comprehensive transfer of information including metadata, coordinate data, attribute data, data quality, and symbology. The files are named in a specific way to allow users to determine which module is represented by which file. When viewed on a word processor a file comprising a particular module is one line of contiuous streaming code with no carriage returns. The format of this code follows an existing standard for data transmission referred to as ISO 8211. Programs are necessary to encode and decode data into and out of the ISO8211 format comprising the SDTS module file.

In the SDTS model, real world 'entities' such as a road, stream, or a farm, are represented in a computerized form as a defined set of standard 'spatial objects' . The "Object Types" include representations of spatial entities as points, labels, nodes, links, chains, rings, polygons, pixel, and others. SDTS is more demanding on users because it requires that the user

[10] SDTS Fact Sheet, September 1994

Figure 39. SDTS Spatial Objects

Zero-dimensional Spatial Objects

Point	An object that specifies a single geometric location.
Point Subtypes:	
Entity Point	A point used to identify the location of a feature such as a building, tower, buoy, etc.
Label Point	A point used to identify the location of text or symbology on a display.
Area Point	A point representing an area for purposes of storing attribute information about the area.
Node	An object that represents the junction of two or more links or chains, or the termination of a one-dimensional object.

One-dimensional Spatial Objects

Line Segment	An object representing a straight line connecting two points.
String	An ordered sequence of connected, nonbranching line segments (a string may intersect itself or other strings).
Arc	A curve that is defined by a mathematical function.
Link	A topological connection between two nodes.
Chain	A directed, nonbranching sequence of nonintersecting line segments and/or arcs bounded by nodes.
Chain Subtypes:	
Complete Chain	A chain that explicitly references left and right polygons and beginning and ending nodes.
Area Chain	A chain that references left and right polygons, but not beginning and ending nodes.
Network Chain	A chain that reference beginning and ending nodes, but not left and right polygons.
Ring	A sequence of nonintersecting chains, strings, and/or arcs that close to form the boundary of an area.
Ring Subtypes:	
G-Ring	A ring created from strings and/or arcs.
GT-Ring	A ring created from complete and/or area chains.

Two-dimensional Spatial Objects

Interior Area	An area not including its boundary.
G-Polygons	An area consisting of an interior area, one outer G-ring and zero or more nonintersecting, nonnested inner G-rings.
GT-Polygons	An area that is an atomic two-dimensional component of one and only one two-dimensional manifold. A GT-polygon can be asociated with its chains.
GT-Polygons Subtypes:	
Universe Polygon	The part of the universe outside the perimeter of the area covered by the other GT-polygons.
Void Polygon	Defines a part of the two-dimensional manifold that is bounded by other GT-polygons, but otherwise has the same characteristics as the universe polygon.
Pixel	A two-dimensional picture element that is the smallest nondivisible element of a digital image.
Grid Cell	A two-dimensional object that represents the smallest nondivisible element of a grid.

provide additional descriptive data and requires users to map their data into an SDTS model of standard spatial objects, standard real world entity types, and standard data labels and structures for attribute data.

A major difference between the use of SDTS and DXF, DLG, ASCII, or other commonly used transfer formats is that an SDTS transfer includes not only coordinate and attribute information, but also a range of metadata information such as data source, accuracy, and security references. In its current form SDTS has been built with a flexibility to accomodate a range of spatial data (vector or raster) models which could exist in present and future software systems. SDTS was designed so that it can be used on a variety of computer hardware and software platforms, and stored on a variety of media. It focuses on all of the components necessary for a comprehensive and complete transfer of data.

While at this time tools are not yet available to most users for an implementation and common use of SDTS as a practical transfer format, the study of the components of SDTS offers important insight into how information can be properly managed and communicated. Once SDTS is supported more fully by GIS software vendors, it will provide a superior transfer mechanism for spatial data. Many types of spatial data can then be transfered using the same format.

12.2 SDTS Conceptual Model of Spatial Data

By positioning points, lines, polygons and other spatial objects within a coordinate system framework, GIS models spatial relationships between representations of real world phenomena. Descriptive and attribute information associated with the digital spatial objects identify them as real world objects. For example, lines on a page can represent the layout of a road network. Attribute data such as a road name, route number, number of lanes, and surface type, can be associated with the lines on the page to build a representation or model of a real road network in a particular locale. As another example, a bus stop could be represented as a point in space, capturing its location with respect to a road or population. Information associated with the point such as the time a bus is scheduled to stop there, or condition of the facility, model it as a real bus stop. Analysis capabilities built into GIS can answer questions regarding spatial relationships such as how many people are within a mile of the bus stop. Other capabilities can analyse the attribute information, such as how many bus stops have shelters. The spatial data management systems of today, and the future, employ diverse data types and structures to build these models. A successful mechanism for the transfer of data between different systems requires that the concepts and model of the real world be preserved in the process.

SDTS is designed to accomodate diverse digital models of the real world and to be independent of specific computer software and hardware platforms. The SDTS conceptual model provides a basis for a common understanding of spatial data and a means for representing spatial phenomena digitally. The SDTS model describes the world as consisting of "entities"

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[10] SDTS Fact Sheet, September 1994

Figure 41. Examples of SDTS Standard Attribute Definitions

Normative Annex

B: Attributes

ABANDONED	Deserted.
ACCESS	The type of connection available to a given transportation feature.
ACIDITY	The degree to which hydrogen ions are held by soil colloids or water.
ACTIVE/INACTIVE	Engaged in activity versus no longer in use.
ADMINISTRATION	The organization that has charge of or directs or manages the operation of the feature.
AERONAUTICAL_NAVIGATIONAL	Involving transmission of special radio signals intended to assist in the determination of aircraft position including that relative to collision hazards.
AGE	The first year in existence.
AIR/LAND/WATER	Existing in or part of the atmosphere, the Earth's dry surface, or a body of water.
AIRCRAFT_LANDING	Suitable for or designed for aircraft to descend toward and settle on.
ALTITUDE	The height of a thing above a reference level, especially above the Earth's surface. See also HEIGHT, ELEVATION.
ANNUAL_PRECIPITATION	The quantity of rain and snow falling within the period of a year.
ARCHITECTURAL_PROPERTIES	The style or method of design or construction.
AREA	The measure of a planar region of the Earth's surface.
AREA_DIVIDED	The part of the Earth's surface apportioned.

Figure 42. Examples of SDTS Included Terms For Standard Entities

Normative Annex

C: Included Terms

C.1 Entity Types

Accessway	ROAD
Administrative boundary	BOUNDARY
Aeration beds	FILTRATION BEDS
Aerial cableway	CABLEWAY
Aerial cableway lines	CABLEWAY
Aerial cableway pylon	TOWER
Aerodrome	AIRPORT
Aerodrome beacon	BEACON
Aerodrome control tower	TOWER
Aeronautical beacon	BEACON
Aeronautical light	BEACON
Aeronautical navigational radio station	BUILDING, BUILDING COMPLEX
Aeronautical radio beacon	BEACON
Air beacon	BEACON
Air route	LANE
Airdrome	AIRPORT
Airfield	RUNWAY
Airfield revetment	WALL
Airport beacon	BEACON
Airport traffic area	APPROACHWAY
Airport traffic control tower	TOWER
Airstrip	RUNWAY
Alley	ROAD
Alluvial fan	DELTA
Alternate aerodrome	AIRPORT
Alternating light	BEACON
Amphitheater	OUTDOOR THEATER
Amusement park	PARK
Anabranch	WATERCOURSE
Anchor buoy	BUOY
Anchor light	BEACON
Anchorage	HARBOR
Anchorage buoy	BUOY
Animal sanctuary	PARK
Animal sanctuary boundary	BOUNDARY
Anse	INLET

characterized by attributes that are assigned attribute values. An example of an entity could be a bridge, intersection, bus stop, or a road. The points, lines, and polygons are the spatial objects used to digitally represent the spatial characteristics of real-world entities. The term "feature" is defined as both the real world entity and its digital representation. SDTS defines several spatial objects as shown in Figure 39. The object representations are oriented toward two dimensional data but can be extended to include three dimensional data. A data transfer using SDTS involves correlating the geometric primitives and other digital representations of a particular GIS to the SDTS spatial objects.

In a SDTS transfer, one's own view of geographic and cartographic reality must also be described in terms of the SDTS model of entities and attributes. In addition to a set of defined spatial objects, SDTS also defines standard entity types and attributes. Figures 40, 41,and 42 show examples of the basic entity types, definitions of standard attributes, and cross referenced terms for entity types (included terms) , as taken from Part 2 of the SDTS specifications. These definitions respond to the need for common definitions of spatial features to support communication. The definitions and lists provided by SDTS are the product of several years of effort during which approximately 2,600 definitions fo geographic features were distilled into an initial list of 200 entity types and alternative terms.

12.3 SDTS Modules

SDTS organizes information to be transferred into modules. There is separate SDTS data file for each module. The SDTS modules can be grouped into five categories which are; Global, Data Quality, Spatial Object, Attribute, and Graphic Representation (see figure 43). Each module addresses a specific area for the comprehensive transfer of information including metadata, coordinate data, attribute data, data quality, and symbology.

The Global Modules together with the Data Quality Modules form the primary difference between SDTS and most transfer formats in that they provide and require metadata. Global modules provide metadata and information for interpreting the transfer. Global modules can be further categorized into five subtypes: identification, catalog, spatial reference, data dictionary, and other. The identification modules reference the version of SDTS used and other basic information about the data transfer. The catalog modules describe the organization and relationships of modules. Spatial reference modules define the reference systems and format of coordinate data. The data dictionary modules convey the meaning and structure of entity and attribute data. The statistics module deals with the number of records, data coordinates, and the security model deals with security issues. Modules included in the global category are shown in Figure 43. Global modules provide information as to the content and organization of the data transfer, the spatial extent, the data structure and definitions of attribute data, security restrictions, and other descriptive information. Metadata is provided in accordance with standards outlined by the Federal Content Standards for Metadata.

The Data Quality Modules characterize the fitness for use, and the quality of the data being tranfered. Five components of data quality are specified in SDTS: lineage, positional accuracy, attribute accuracy, logical consistency , and completeness. The lineage of the file is the sources, status, age, and processing history of the data. The positional accuracy is concerned with how closely the encoded coordinate values represent true locations. Positional

Figure 43. SDTS Modules

Global
- Identification
- Catalog
  - /Directory
  - /Cross-Reference
  - /Spatial Domain
- Spatial Reference
  - Internal Spatial Reference
  - External Spatial Reference
  - Registration
  - Spatial Domain
- Data Dictionary
  - /Definition
  - /Domain
  - /Schema
- Security
- Transfer Statistics

Spatial Object
- Composite
- Vector modules
  - Point-Node
  - Line
  - Arc
  - Ring
  - Polygon
- Raster modules
  - Raster Definition
  - Cell

Graphic Representation
- Text Representation
- Line Representation
- Symbol Representation
- Area Fill Representation
- Color Index
- Font Index

Data Quality
- Lineage
- Positional Accuracy
- Attribute Accuracy
- Logical Consistency
- Completeness

Attribute
- Attribute Primary
- Attribute Secondary

accuracy can be judged by, deductive estimate based on the errors in each production step, repeated measurement, comparison to source (check plots), or tests based on comparison of the data to a source of higer accuracy in conformance to methods prescribed in the ASPRS Accuracy Standards for Large Scale Maps. The attribute accuracy can be described as to its reliability, or estimate of the percentage of error in attribution of spatial features. Logical consistency deals with the fidelity of models and relationships encoded in the data structure of the digital data, and specifically addresses errors in the structure of the spatial objects (e.g. incorrect intersections, overshoots, duplications, malformed regions). Completeness describes the relationship between the objects represented and the abstract universe of all such objects or entities the data set is meant to address.

Attribute Modules transfer tabular information and database systems. While generally not containing coordinate data, attribute modules contain information to link attribute tables to spatial objects as well as descriptive information. Real world entities are modeled then by a coordinate representation as a spatial object and by ways in which attribute data is structured for further description.

Spatial Object Modules include the locational data encoded for each of the several spatial objects defined by SDTS (see figure 39). The relationships of the spatial objects to each other and to attribute data is also encoded with the coordinate data used to specify the object.

Six graphic representations are accomodated in the Graphic Modules and include; Text Representation, Line Representation, Symbol Representation, Area Fill Representation, Color Index, and Font Index. Though the focus of design was not on purely graphic picture data, SDTS allows for the transfer of cartographic information and this type of information through the Graphic Modules.

12.4 ISO 8211 Encoding Scheme for SDTS

The physical implementation of SDTS uses an existing data exchange standard, International Standards Organization (ISO) 8211. ISO 8211 is a general purpose data exchange format that can be used to transfer any type of data, not just spatial data, and it is designed to work for any media including communications lines. ISO 8211 provides an intermediate transfer file which must be converted before the data can be used. SDTS modules encoded in ISO 8211 are somewhat desiferable to someone familiar with the format. There are various delimiters within data files but there are no carriage returns, so that when viewed on a word processor the entire file can appear as a string of data on one line or wrapped onto several lines. An example formated with carriage returns for clarity is presented in figure 44. A detailed discussion of the ISO 8211 exchange format is beyond the scope of this report.

Figure 44. Example of an ISO 8211 File

```
003972L   0600106   2304
00001500000012801SLINE34043ATID36077PIDL38113PIDR39151SNID35190EN
ID33225SADR33258▲
0000;&WMHYLE01▲
0100;&DDF RECORD IDENTIFIER▲
1600;&LINE▼MODN!RCID!OBRP▼(A,I,A)▲
2600;&ATTRIBUTE ID▼*MODN!RCID▼(A,I)▲
1600;&POLYGON ID LEFT▼MODN!RCID▼(A,I)▲
1600;&POLYGON ID RIGHT▼MODN!RCID▼(A,I)▲
1600;&STARTNODE ID▼MODN!RCID▼(A,I)▲
1600;&ENDNODE ID▼MODN!RCID▼(A,I)▲
2600;&SPATIAL ADDRESS▼*X!Y▼(I,I)▲
00191 D     00089   2204
00010600
LINE1406
PIDL1120
PIDR1131
SNID1142
ENID1153
SADR1964
SADR1983▲
    1▲
LE01▼   15▼LE▲
PC01▼    6▲
PC01▼    1▲
NO01▼   20▲
NO01▼   19▲
-75532576▼39625001▲
-75531838▼39625001▲
00191 D     00089   2204
00010600
LINE1406
PIDL1120
PIDR1131
SNID1142
ENID1153
SADR1964
SADR1983▲
    2▲
LE01▼   16▼LE▲
PC01▼    7▲
PC01▼    1▲
NO01▼   21▲
NO01▼   20▲
-75533649▼39625001▲
-75532576▼39625001▲
                ---
```

12.5 Implementation of SDTS

A full implemenatation of SDTS for a data transfer requires that the user prepare the necessary documentation, metadata, and accuracy evaluation of the information to be transfered. The particular spatial framework and spatial objects used in the source data set must be translated into the spatial objects used by SDTS. All entities and attribute data must be described in detail and related to SDTS standard entities and attribute specifications. Finally, all of the information must be organized into the appropriate module and encoded into the ISO 8211 data exchange format. For someone receiving the SDTS transfer the process works in reverse. The data from each module must be decoded, and the data must be extracted into the spatial object, attribute, and entity models used in the destination system.

A number of tools and documentation are available for SDTS through FGDC. Public domain programs in the "C" programming language are available to decode and encode information into the ISO 8211 format. Because SDTS is so comprehensive and flexible, users must take more time in preparing a data transfer than they would using other methods, particularly in regards to handling metadata. Users who have a detailed knowledge of SDTS and their GIS software, and the resources and technical skills, could prepare SDTS transfers using programming tools. For the large majority of GIS users, SDTS will only be viable if SDTS translation utilities are built into GIS software by the GIS software manufacturers. Just as translators are available for AutoCAD DXF, Digital Line Graph, TIGER, and other exchange formats, translators must be available in GIS software for import and export of SDTS files.

ARC/INFO is the only major GIS software which currently includes SDTS translation utilities. As part of this research, SDTS data transfer files were produced using these utilities and an SDTS version of TIGER Line data was imported using them. The preparation of the metadata and quality estimates in the ARC/INFO translator involves the use of a script file which can be time consuming and awkward to deal with. Hopefully, advances in user friendly interfaces for documentation and metadata can be integrated with SDTS translators. As no other translator was available, SDTS's ability to transfer data between popular GIS software could not be tested. InterGraph will have a Beta version of SDTS translation utilities ready for field testing in July of 1995. As the establishment of schemas and data structures is so prominent in the operation of InterGraph's MGE products, these translators may work well with attribute and metadata. Software vendors provide conversion utilities based on the demand of their customers, and apparently the preparation of SDTS utilities are not a priority issue at this time for many vendors.

As a study of SDTS, a Road Center Line File, a Traffic Zone Demographic File, and the 1993 Traffic Summary were prepared in SDTS format. The Road Center Line File was derived from a preliminary version of the center line file being produced at the Delaware Department of Transportation (DELDOT) and serves as a 24,000 scale framework for the display and reference of road information. The Traffic Zone Demographic File comprises the framework to hold a variety of demographic information including population, employment, number of autos and other information related to the demand for transportation. The Accident Location Database is a portion of existing data at DELDOT which locates information about accidents through a mile point referencing system on routes defined by the Center. The translation utilities worked well for most of the SDTS modules. As expected the metadata and data quality modules were difficult to implement using the current features of the translator. Ideally, the user interfaces and databases for metadata included in the ARC/INFO program DOCUMENT.AML should be integrated with the SDTS translator.

12.6 Conclusions in Regard to the Study of SDTS

SDTS represents a multiyear effort by numerous federal and state agencies to solve in a comprehensive manner all issues associated with the transfer of spatial data. SDTS builds on several existing standards. Unlike currently available methods of GIS data transfer, SDTS addresses metadata and data quality. Several data types can be transferred and packaged using the same data exchange format. SDTS is recommended as a data transfer standard which should be supported by the community.

If SDTS utilities for the import and export of data were available in major GIS software systems, SDTS would solve many data transfer problems. However, until it is supported more by the vendor community, the majority of users will not be able to take advantage of its benefits.

User friendly menu systems which guide the user through documentation and the creation of metadata, and are intergrated with transfer mechanisms, are vital features of effective SDTS encoding utilities.

Where SDTS transfer utilities are included in GIS software, users should become familiar with the standard. Where it is not supported, users should contact their software vendors and request that it be supported.

13 Distribution Standards

13.1 Distribution Standards as Guidelines and Organizational Frameworks for Data Sharing

Transfer standards as discussed in previous chapters address the standard formats for information which insure that spatial data can be archived and distributed in a manner which makes the information usable by a range of computer software and hardware systems. Distribution standards designed to streamline the operations of distribution as a whole are needed by the community so that policies for distribution are clearly understood, and common distribution mechanisms are in place. These standards address the manner and efficiency in which users find and provide data.

Distribution standards can address the use of other standards. For example, distribution guidelines could require that data is provided in particular transfer formats, using a standard coordinate system, documented using FGDC Contents Standards for Digital Spatial Metadata, and with estimates of accuracy provided in conformance with methods outlined in the ASPRS Accuracy standards. The information could be required to be compatible with existing standard data frameworks in use by the community, in line with coding schemes and standards structures for attribute data, and referenced in state clearing houses for GIS data. States which had established clearinghouses or coordinating bodies proposed such guidelines and encouraged distribution in the resource guides and other literature they prepared. Specific methods and terms of distribution were left to the distributor, but information about standards, publishing, and data sharing agreements and policies were made known in the community.

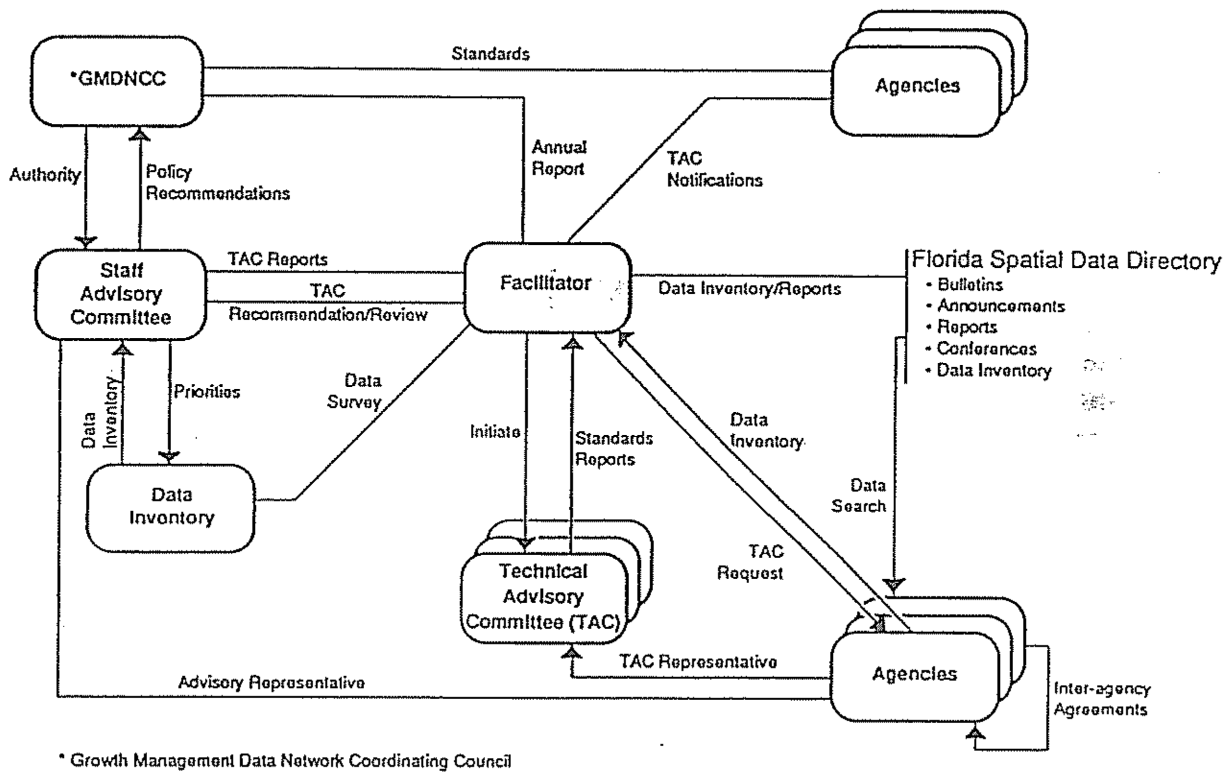
Beyond the technical considerations of data sharing, there are many other organizational impediments to communities fully working together. Several States across the country are wrestling with the issues.[12] Each area has its own particular circumstances and their are no standard policies apart from what is dictated by open records laws. Involvement of adminstrative groups is necessary for the approval and support of statewide policies, but as these groups are unfamiliar with many of the technical issues it is necessary to acquire the resources of several groups in the community to develop and present working frameworks for data sharing. Distribution policies determined by technical advisory committees with the support and/or direction of administrative bodies can be effective.

In Florida, the Florida Growth Management Data Network Coordinating Council (GMDNCC) was created by the Florida Legislature in 1985 to facilitate the sharing of information needed for growth management planning. A major objective of this group was to promote information sharing through the creation of a federation of independently held databases that are linked together by standards and a management structure. A facilitator for this program

[12] Several papers on how organizations across the country are dealing with data sharing issues are available in Sharing Geographic Information, Onsrud and Rushton

concluded after three years of operation that the primary impediments to information sharing are the difficulties of operating in a multi-agency environment without the appropriate support mechanism to facilitate cooperative activities.[11] A diagram of the State of Florida geographic information network is presented in figure 45 and demonstrates the major committments of several agencies and individuals necessary to effectively bring GIS resources together in a State.

Figure 45. State of Florida Geographic Information Network[12]



Stage, David, Sharing Geographic Data in Florida, 1995.This paper, presented in Sharing Geographic Information,[Onsrud and Rushton] discusses the development of management structures and standards in Florida for their information network, and is highly recommended for those interested in the issues involved in State GIS networks.

[12] IBID.

13.2 Use of the Internet

A method for efficient distribution is the establishment of information clearinghouses and information distribution centers which exist as nodes on computer networks accessible by the community. At the federal level, the establishment of an electronic National Geospatial Data Clearinghouse is mandated by Executive Order which "will allow its users to determine what data exist, find the data they need, evaluate the usefulness of the data for their applications, and obtain or order the data as economically as possible". Several Federal agencies already offer a wealth of information over the Internet. The National Spatial Data Infrastructure (NSDI) Competitive Cooperative Agreements Program (CCAP) was established by the FGDC to help form partnerships with the non-Federal sector that will assist with the evolution of NSDI. Several States have received funding through this program. As effective use of networks require the use of standards for the identification and transfer of data, the CCAP projects in addition to establishing nodes on networks, are very focused on metadata and data transfer standards.

While some initiatives address the creation of a centralized repository for data, the use of the Internet makes this less important and in fact promotes a situation where each agency maintains a node on the network for data for which they are the suppliers or custodians. As long as users know the available resources on the network, and the network addresses of the contributors, data can easily made available without an attempt to collect all the information available in the community in one spot. Having the data distributed across several custodian sites, distributes the responsibility and overhead of providing, maintaining, and updating the information. The information is closer to its source and this improves the reliability. Having a public area on a network file server is a standard method for distribution.

13.3 Use of Compact Disks

For large data sets and data which forms a standard GIS framework for the community as with base maps, transportation networks, demographics, land use, and other such information as discussed in a previous section, it can be very convenient to have the data prepared and packaged on compact disk (CD-ROM) for distribution. Most agencies in the community have computer hardware that can read CD-ROM and production costs for CD-ROM are rapidly decreasing. The Pennsylvania Department of Transportation distributes all of their official transportation systems maps, highway travel and performance statistics, transportation network models, and other data on CD-ROM. This is a great resource to any GIS user who wishes to work with Pennsylvania information and serves as one model of how a transportation agency can distribute data. The use of CD-ROM is suggested as a standard media for distribution of GIS data.

13.4 Data Sharing Agreements

Apart from the method or media used for the distribution of digital data there are other issues to be addressed. Many agencies require those requesting information to prepare formal written requests, and to comply with a data distribution agreements, for tracking and legal reasons. In some states standard agreements and procedures have been adopted, and where such forms are necessary, standard forms can help streamline the policy aspects of the transfer process. A standard set of guidelines and procedures for the publication and distribution should be promoted in the community.

13.5 Recommendations and proposed standards for distribution are:

- At the State level establish a location(s) on the network for access to inventories and descriptions of GIS data available in the community.

- Provide network servers and clear procedures for users in the community to document and make available GIS data.

- Encourage the publication of GIS data to be made available on the network.

- Publish standards for file transfer, documentation, and distribution policies in a GIS Resource Guide.

- Require that new data products resulting from government contracts be described and made available on community network servers.

- Follow closely FGDC activities in the establishment of the National Geospatial Data Clearinghouse to address responsibilities of users and providers of information, update and maintenance of the clearinghouse, inventories of information, and other technical, staffing, and logistical considerations.

- Prepare a DELDOT CD-ROM containing cartographic layers, center line files, traffic zone data, highway travel and performance statistics, and other transportation related data which can be distributed to the community.

- Data which forms a common GIS data framework for the community, such as land use data, base maps, property data, basic demographics, zoning, transportation systems, digital imagery, etc. should be published on CD-ROM and on network servers for distribution to the community.

- Efforts across the country to develop organizational structures to address data sharing should be reviewed to assist in determining appropriate policies in Delaware.

14 Conclusion

In addition to recommendations and proposed standards presented so far, and summarized in the appendix, the research suggests the following general conclusions.

The major role of GIS standards is to protect the primary investment which is data. GIS standards protect and fully realize data investments through identification, transferability, accuracy assessment, structural compatibility, and by minimizing access and distribution costs.

Research has revealed that agencies using GIS in Delaware, and across the country have a strong appreciation for the importance of standards to promote efficiency and information sharing in their community. There are many examples of efforts in GIS standards development by State, local, and Federal agencies.

There are a number of tools that are available or could be developed so that agencies could more easily adhere to standards adopted by the community. The implementation of standards will take an intitial investment, but the long term benefits in terms of better information management and the ability to more efficiently share information and coordinate are well worth it.

If users are unaware of standards and guidelines in the community, they can not adhere to them. Communities need published guidelines and tools for the implementation of standards. The creation of a GIS Resource Guide, modeled after guides available in Vermont and New Jersey, would substantially assist in the establishment of standards and promotion of coordination among GIS users in Delaware. The guide would include an inventory of GIS resources and distribution sites, transfer standards, documentation standards, accuracy standards, coding and classification systems, and policies. A GIS resource guide would be the one greatest contribution to the promotion of standards and coordination among GIS users in Delaware.

The implementation of standards in a community need not be restrictive or limit an agency in applying GIS technology as best suits their needs.

The establishment of network clearinghouses and distribution sites are focal points for coordination and standardization.

BIBLIOGRAPHY

DelDOT Metric Conversion Steering Committee, Metric Conversion Plan. DelDOT, February 1994.

Department of the Interior, U.S. Geological Survey, National Mapping Division, Office of Geographic and Cartographic Research. Proceedings of the workshop on Methods and Techniques for Digitizing Data, Department of the Interior, Reston, Virginia, 1985.

Edmisten, Rufus L. Technical Specifications for Base, Cadastral, and Digital Mapping, North Carolina Land Records Management Program, November 1987.

Federal Geographic Data Committee. Content Standards for Digital Geospatial Metadata, Federal Geographic Data Committee, June 1994, Washington, DC.

FGDC Secretariat c/o U.S. Geological Survey. The Value of Metadata, FGDC Secretariat c/o U.S. Geological Survey Reston, Virginia.

FGDC Ground Transportation Subcommittee. FGDC Ground Transportation Subcommittee Position and Recommendations on Linear Referencing Systems Draft, FGDC, 7/21/94.

FGDC Ground Transportation Subcommittee, Highway Performance Monitoring System (HPMS) Field Manual, FGDC Ground Transportation Subcommittee, April 22,1994.

FGDC Ground Transportation Subcommittee(version 2.0). Description, Schema, and File Structures, FGDC Ground Transportation Subcommittee June, 1994.

GIS/Trans, Ltd. Geographic Information System for Transportation Strategic Planning, GIS/Trans, Ltd, July 15, 1994.

Goodchild, Michael and Sucharita Gopal, The Accuracy of Spatial Databases, National Center for Geographic Information & Analysis, University of California, Santa Barbara, Ca 1989

Holland, William S., Wisconsin Land Information Program, Wisconsin Land Information Board, Madison Wisconsin.

Morrison, Joel l, Wortman, Kathryn. Cartography and Geographic Information Systems, Journal of American Congress on Surveying and Mapping, Bethesda, Maryland, Vol. 19, no 5, December 1992.

Minnesota Department of Transportation, Location Data Server Task Force, Recommendations for Supporting and Developing Automated Translations among Location Reference Systems, Minnesota Department of Transportation, January 10, 1994.

Moyer, D. David., Reis, Tom. Proceedings GIS - T '93 Geographic Information Systems for Transportation Symposium, AASHTO, Washington, DC. May 1993.
Environmental Systems Research Institute, inc, Map Projections and Coordinate Management, Environmental Systems Research Institute, March 1992.

New Jersey State Mapping Advisory Committee (SMAC). New Jersey GIS Resource Guide 1995, New Jersey State Mapping Advisory Committee, Trenton, NJ, 1995.

Openshaw, S.,1979, A methodology for using models for planning purposes. Environmental and Planning A, 11, 879-896

Raley, Moley I, DelDOT GIS Committee Survey of GIS Applications, DelDOT Office of Planning, July 1993.

Stitt, Susan. Graphical Representation of: The Federal Geographic Data Committee's Content Standards for Digital Geospatial Metadata, Technology Transfer Center, National Biological Survey, In conjunction with the FGDC Standards Working Group, June 1994.

Thompson, Morris M. Maps for America Third Edition, U.S. Department of The Interior, Geological Survey National Center, Raston, Virginia, 1987.

Thornton, Lawerence L., Appendix D.3, Data Standards for the New Jersey Dept. Of Environmental Protection, Geographic Information System, NJDEP, Trenton, NJ.

U.S. Geological Survey, Spacial Data Transfer Standard Technical Review Board (as of Oct. 1991), U.S. Geological Survey, Digital Cartographic Data Standards Task Force, Federal Interagency Coordinating Committee for Digital Cartography, Standards Working Group. Spacial Data Transfer Standard parts 1-4,

U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Ocean Service, Charting and Geodetic Services, State Plane Coordinate System of 1983, National Geodetic Information Center, Rockville, MD, April 1994.

U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National

Ocean Service, Coast and Geodetic Survey, National Geodetic Survey Division. Catalog of Products and services of the National Geodetic Survey, U.S. Department of Commerce, Silver Spring, MD, November 1994.

U.S. Department of Transportation, Federal Highway Administration. GIS / Video Imagery Applications Participants Workbook, U.S. Department of Transportation, October 1994.

Utah State Geographic Information Database (SGID) Users Guide, Seventh Edition, State of Utah Department of Administrative Services, Division of Administrative Services, August 1994.

Vermont Geographic Information System, Policies Standards Guidelines and Procedures Handbook, Vermont Center for Geographic Information, Burlington, VT, 1992.

Wade, Elizabeth B., Impact of North American Datum of 1993, Journal of Surveying Engineering, Vol. 112, No. 1, June 1986.

Wisconsin Land Information Association, WLIA Standard, Wisconsin Land Information Association, 1992.

APPENDIX A

Summary of Recommendations and Proposed Standards

Documentation Standards

- Adopt the FGDC Content Standards for Digital Geospatial Metadata as the official spatial data documentation standard in Delaware.

- Through a consensus process, define, adopt, and publish a specific data table format which can be used by all government agencies to store and submit metadata.

- Require that documentation tables in the adopted format be submitted for spatial data products created as part of government projects.

- Provide incentives for State and local agencies to provide descriptions of current data holdings in the standard documentation format to be stored at a clearing house site.

- Develop a GIS Resource, containing policies, standards, and guidelines modeled after the VGIS Handbook and the New Jersey GIS Resource Guide

Coordinate System Standards

- Adopt the North American Datum of 1983 as the official datum to be used with GIS. Adopt the Delaware State Plane Coordinate System NAD83, using units of meters, as the official coordinate system to be used for the distribution and development of GIS data.

- Retain mile point as the measure for linear referencing systems. For planning and design work use units of meters, and where possible convert specifications from feet to meters. In general, speak meters.

Accuracy Standards

- Develop guidelines and tools which can be used by the community for accuracy assessment of GIS data.

- Perform accuracy assessment for GIS data layers which form a common framework.

- Require that all new data be provided with an accuracy assessment.

- Encourage the use of accuracy references on all mapping products.

- Do not report data at a precision that is beyond that of the data.

Locational Reference Systems Standards

- Support current efforts to complete and/or refine the DELDOT Centerline Network, the linear referencing system, and the centerline conflation with the Tiger Line Files.

- Develop effective mechanisms for the continual update, maintenance, and refinement of centerline, linear referencing system, and addressing systems.

- Adopt the DELDOT Linear Referencing System as the standard for the location of transportation facilities to be used by all transportation agencies and in all research

- Document and distribute, on an annual basis, current linear referencing systems in formats which can be read by most GIS. Further investigate methods used by PENNDOT to distribute base maps and locational reference systems data sets, to see the benefits and feasibility of a similar release in Delaware

- Investigate opportunities to develop a multi agency approach to the development and maintenance of locational reference systems.

- Support the completion, review, and adoption of new road naming and addressing for Kent and Sussex County, and incorporate new naming and addressing into current locating data sets.

Framework Standards

- Develop a comprehensive GIS framework for the community. Framework data will include GIS layers for transportation facilities, center line files, environmental features, census and planning zone geography and demographic information, land use, and political boundaries.

- Provide an efficient distribution mechanism which will offer inexpensive and easy access to the framework data. This could be through network file servers, or by publishing the data on compact disk in several GIS software formats.

- Develop effective means to update and add to the framework.

- Develop guidelines for the creation and development of new frameworks.

Attribute Standards

- Where possible consistent identification of spatial features should be promoted. A standard code to identify road segments as can be derived from current models of the DELDOT centerline file should be used by transportation agencies.

- Coding and classification systems for attribute data should be made available as part of a GIS Resource Guide. Groups should be encouraged to use compatible coding and classification schemes where possible.

- Data structures and standard formats for transportation data should be promoted and popularized through documentation and distribution.

Transfer Standards

- Promote the creation and use of guidelines for GIS data transfer which include specifications and procedures for the transfer of each data type. Support an effort to develop the utilities and instructions needed for each type of GIS software to address the standard transfer formats adopted by the community. Consider formats summarized in Appendix A as a starting point for standard data transfer.

- Require that all new data products be provided using standard transfer formats and be documented using metadata standards.

- Promote the use of SDTS. Encourage vendors to develop SDTS software utilities.

Distribution Standards

- At the State level establish a location(s) on the network for access to inventories and descriptions of GIS data available in the community.

- Provide network servers and clear procedures for users in the community to document and make available GIS data.

- Encourage the publication of GIS data to be made available on the network.

- Publish standards for file transfer, documentation, and distribution policies in a GIS Resource Guide.

- Require that new data products resulting from government contracts be described and made available on community network servers.

- Follow closely FGDC activities in the establishment of the National Geospatial Data Clearinghouse to address responsibilities of users and providers of information, update and maintenance of the clearinghouse, inventories of information, and other technical, staffing, and logistical considerations.

- Prepare a DELDOT CD-ROM containing cartographic layers, center line files, traffic zone data, highway travel and performance statistics, and other transportation related data which can be distributed to the community.

- Data which forms a common GIS data framework for the community, such as land use data, base maps, property data, basic demographics, zoning, transportation systems, digital imagery, etc. should be published on CD-ROM and on network servers for distribution to the community.

- Efforts across the country to develop organizational structures to address data sharing should be reviewed to assist in determining appropriate policies in Delaware.

Proposed Transfer Formats

Points

Comma delimited text files with or without attributes

```
ID,X,Y          {Unique object identifier, horizontal and vertical coordinates
ID,X,Y          {Same as above, repeating for as many points}
```

Or fixed format or space delimited with or without attributes

```
ID    X     Y
ID    X     Y
```

Or DBASE type data table with ID, and X and Y coordinates as columns with or without attributes.

Lines

```
"ID", NumCoord        {Unique segment identifier and number of coordinates
x,y                    making up the segment. First and last coordinates will
 .                     will be segment nodes}
 .
x,y
"ID",NumCoord         {Repeat for as many segments}
x,y
 .
 .
x,y
```

Basic Polygons

```
ID,NumCoord          {Unique polygon ID and number of coordinates that follow}
X,Y
 .
 .
 .
X,Y                  {close with first x,y pair}
ID,NumCoord
X,Y
 .
 .
X,Y {close}
And continuing for each polygon
```

Polygons with Holes {format below can be imbedded in basic polygon format}

```
ID,NumCoord         {external polygon ID and total coordinates for external and
X,Y                  all holes}
 .
 .
X,Y                 {close external polygon}
HOLE                {A flag to signal start of interior hole}
x,y                 {coordinate of hole}
 .
 .
x,y                 {close. If more holes insert here after "HOLE" flag.
ID,Numcoord         {Holes are then addressed as separate polygons as usual}
x,y                 {Coordinate data for all holes should be included
 .                   whether or not there is attribute data.
 .
 .
x,y
```

Polygons with Islands

Islands should be seperated as polygons with unique idenitifiers and transferred as basic polygons. An attribute field can be transmitted which indicates grouped polygons.

Attributes and Data Tables

All data tables which serve as attribute data associated with spatial objects will have the unique object identifier in the first column (e.g.field,item). Transferred as

Fixed format text files

```
ID    Attrib1     Attrib2     Attrib3,....
ID    Attrib1     Attrib2     Attrib3,....
ID    Attrib1     Attrib2     Attrib3,....
Continue for number of records
```

or, comma delimited text files

```
ID,Attrib1,Attrib2,Attrib3,....
ID,Attrib1,Attrib2,Attrib3,....
ID,Attrib1,Attrib2,Attrib3,....
Continue for number of records
```

or, DBASE format files (DBF)

Event Tables

Transferred as data tables, with route and measure columns

Documents

Transferred as:

ASCII Text files
or
Postscript files
or
WordPerfect files

Graphics (ie mapping products)

Transferred as:

PostScript Files or Image Files

Images

Transferred as:

TIFF (uncompressed, Group3,Group4,or PackBits, single band, multiband)
or
RLC (run length compressed) for monochome images

Cell Based Data (Grids, general raster)

```
Origin
CellWidth, CellHeight
NumRows,NumCols
row,col,attrib1,attrib2,....
row,col,attrib1,attrib2,....
Etc, continuing for number of cells
```

The Federal Geographic Data Committee (FGDC)

Geographic Data: A Growing Investment, A Timely Opportunity
Government agencies and many private sector organizations are asked to respond quickly in addressing many issues. New and growing administrative and regulatory responsibilities place tremendous pressure on information delivery systems. Timely and accurate geographic information, such as environmental, natural resources, and socioeconomic data, is needed to understand national problems and find answers.

Government agencies and private industry increasingly depend on computerized technologies for analyzing geographic data, such as geographic information systems, as highly efficient and effective tools for solving these issues. These powerful technologies are acutely dependent on the availability, quality, and compatibility of computer-readable, or digital, geographic data. Development of the needed digital geographic data is invariably the largest cost factor in computer-assisted analyses.

The ways of creating and using these data are changing, and the process is interdependent and complex. With billions of dollars being invested annually in geographic data and related technology by Federal, State, and local governments and the private sector, interest has grown quickly in finding a means of reducing costs and duplication of efforts.

This investment and interest have created an opportunity to build a comprehensive geographic information resource, or National Spatial Data Infrastructure (NSDI), to meet the needs of the Nation. The NSDI would provide a pool of current and reliable data, partnerships among data producers and users, and standards for sharing data. Dependable supplies of reliable data will increase the Nation's commerce by giving rise to a new industry that integrates and adds value to geographic data for special markets.

The Federal Geographic Data Committee (FGDC)

Chair — Bruce Babbitt, Secretary of the Interior

Department of Agriculture — Tom Hebert, Deputy Assistant Secretary for Natural Resources and Environment

Department of Commerce — Diana H. Josephson, Deputy Under Secretary for the National Oceanic and Atmospheric Administration

Department of Defense — corepresentatives: Paul Barber, Chief, Engineering Division, Directorate of Civil Works, U.S. Army Corps of Engineers, and Kenneth Daugherty, Deputy Director, Defense Mapping Agency

Department of Energy — Jay Hakes, Administrator, Energy Information Administration

Department of Housing and Urban Development — John Cook, Community and Planning Development

Department of the Interior — Debra Knopman, Deputy Assistant Secretary for Water and Science

Department of State — William B. Wood, The Geographer

Department of Transportation — T. R. Lakshmanan, Director, Bureau of Transportation Statistics

Environmental Protection Agency — John Z. Cannon, Assistant Administrator for Administration and Resource Management

Federal Emergency Management Agency — John Matticks, Deputy Associate Director, Operations Support Directorate

Library of Congress — Ralph Ehrenberg, Chief, Geography and Map Division

National Aeronautics and Space Administration — Dixon Butler, Director, Operations, Data and Information Division

National Archives and Records Administration — Kenneth Thibodeau, Director, Center for Electronic Records

Tennessee Valley Authority — Robert Chappell, Manager, Maps and Surveys Department

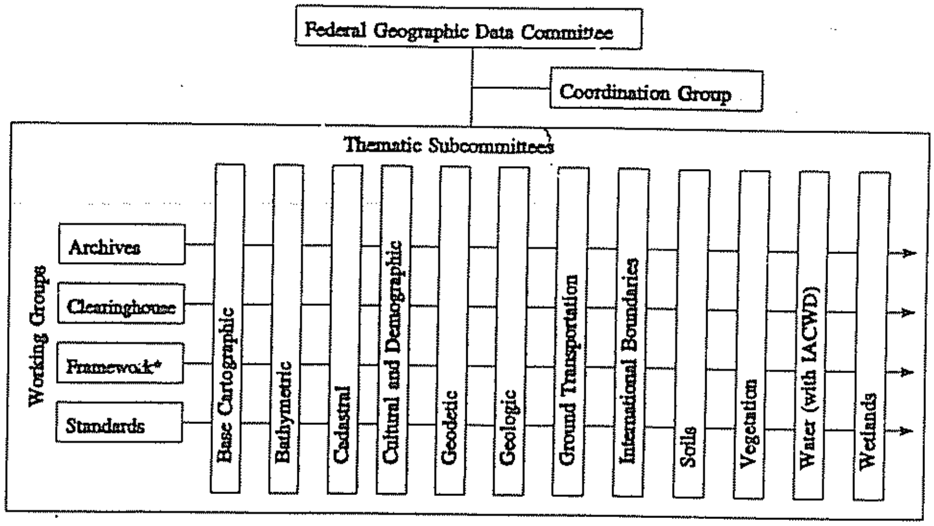
OMB Circular A-16 and the FGDC
The Federal Government has a critical role as a catalyst for developing this vital national information resource. It provides a forum for the geographic data community, including Federal agencies, State and local governments, private industry, and academia, to determine the direction in which the resource will develop, to plan the roles and responsibilities of the partners in this development, and to encourage opportunities for cooperation. It supports and provides a process for developing needed standards. The Federal Government also has an important stake in the development of

this resource because of its widespread need for and use of geographic data.

With these opportunities in mind, the Office of Management and Budget (OMB) issued a revised Circular A-16, "Coordination of Surveying, Mapping, and Related Spatial Data Activities," in 1990. The goals of the circular are to develop the NSDI, to reduce duplication, to reduce the expense of developing geographic data, and to increase the benefits of using available data by ensuring coordination of Federal geographic data activities.

The circular assigns to Federal agencies the responsibilities of leading coordination activities for categories of data (see table at right). These categories form the data foundation for many applications. Agency responsibilities include providing governmentwide leadership in developing data standards, assisting information and data exchange, and coordinating data collection.

The circular establishes the Federal Geographic Data Committee to promote the coordinated development, use, sharing, and dissemination of geographic data. The FGDC promotes the development, maintenance, and management of distributed data base systems that are national in scope for geographic data; encourages the development and implementation of standards, exchange formats, specifications, procedures, and guidelines; promotes technology development, transfer, and exchange; promotes interaction with other existing Federal coordinating mechanisms that have interest in the generation, collection, use, and transfer of spatial data; publishes periodic technical and management articles and reports; performs special studies and provides special reports and briefings to OMB on major initiatives to facilitate understanding of the relationship of spatial data technologies with agency programs; and ensures that activities related to Circular A-16 support national security, national defense, and emergency preparedness programs.



* - Includes representatives of State and local government.

FGDC Subcommittees and Lead Departments

Base Cartographic - Interior	Geologic - Interior	Water - cosponsored with the Interagency Advisory Committee on Water Data
Bathymetric - Commerce	Ground Transportation - Transportation	Wetlands - Interior
Cadastral - Interior	International Boundaries - State	
Cultural and Demographic - Commerce	Soils - Agriculture	
Geodetic - Commerce	Vegetation - Agriculture	

The committee oversees and provides policy guidance for agencies' efforts to coordinate data categories. One mechanism is a series of subcommittees which work on issues related to the data categories coordinated under the circular. Subcommittees establish and implement standards for data content, quality, and transfer; encourage the exchange of information and the transfer of data; and organize the collection of geographic data to reduce duplication of effort.

Working groups have been established for issues that span those of interest to the subcommittees. These issues include a clearinghouse for data, a framework of data, data archives, standards, and technology.

Executive Order 12906
On April 11, 1994, President Clinton issued Executive Order 12906, "Coordinating Geographic Data Acquisition and Access: The National Spatial Data Infrastructure." Section 2 of the order assigns to the FGDC the responsibility of coordinating the Federal Government's development of the NSDI. It also instructs the committee to seek to involve State, local, and tribal governments in the development and implementation of the initiatives contained in the order, and to use the expertise of academia, the private sector, professional societies, and others as necessary to aid in the development and implementation of the objectives of the order.

For More Information
For information about the NSDI or the FGDC's activities, or to receive the committee's newsletter, please contact:

FGDC Secretariat
c/o U.S. Geological Survey
590 National Center
Reston, Virginia 22092;
telephone: (703) 648-5514;
facsimile: (703) 648-5755;
or Internet gdc@usgs.gov.

The FGDC maintains an anonymous FTP site at

fgdc.er.usgs.gov

Users that have a WWW browser (such as Mosaic) can access the FGDC Web server at

http://fgdc.er.usgs.gov/fgdc.html

[Executive Order 12906, published in the April 13, 1994, edition of the Federal Register, Volume 59, Number 71, pp. 17671-17674.]

EXECUTIVE ORDER

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COORDINATING GEOGRAPHIC DATA ACQUISITION AND ACCESS: THE NATIONAL SPATIAL DATA INFRASTRUCTURE

Geographic information is critical to promote economic development, improve our stewardship of natural resources, and protect the environment. Modern technology now permits improved acquisition, distribution, and utilization of geographic (or geospatial) data and mapping. The National Performance Review has recommended that the executive branch develop, in cooperation with State, local, and tribal governments, and the private sector, a coordinated National Spatial Data Infrastructure to support public and private sector applications of geospatial data in such areas as transportation, community development, agriculture, emergency response, environmental management, and information technology.

NOW, THEREFORE, by the authority vested in me as President by the Constitution and the laws of the United States of America; and to implement the recommendations of the National Performance Review; to advance the goals of the National Information Infrastructure; and to avoid wasteful duplication of effort and promote effective and economical management of resources by Federal, State, local, and tribal governments, it is ordered as follows:

Section 1. Definitions. (a) "National Spatial Data Infrastructure" ("NSDI") means the technology, policies, standards, and human resources necessary to acquire, process, store, distribute, and improve utilization of geospatial data.

(b) "Geospatial data" means information that identifies the geographic location and characteristics of natural or constructed features and boundaries on the earth. This information may be derived from, among other things, remote sensing, mapping, and surveying technologies. Statistical data may be included in this definition at the discretion of the collecting agency.

(c) The "National Geospatial Data Clearinghouse" means a distributed network of geospatial data producers, managers, and users linked electronically.

Sec. 2. Executive Branch Leadership for Development of the Coordinated National Spatial Data Infrastructure. (a) The Federal Geographic Data Committee ("FGDC"), established by the Office of Management and Budget ("OMB") Circular No. A-16 ("Coordination of Surveying, Mapping, and Related Spatial Data Activities") and chaired by the Secretary of the Department of the Interior ("Secretary") or the Secretary's designee, shall coordinate the Federal Government's development of the NSDI.

(b) Each member agency shall ensure that its representative on the FGDC holds a policy-level position.

(c) Executive branch departments and agencies ("agencies") that have an interest in the development of the NSDI are encouraged to join the FGDC.

(d) This Executive order is intended to strengthen and enhance the general policies described in OMB Circular No. A-16. Each agency shall meet its respective responsibilities under OMB Circular No. A-16.

(e) The FGDC shall seek to involve State, local, and tribal governments in the development and implementation of the initiatives contained in this order. The FGDC shall utilize the expertise of academia, the private sector, professional societies, and others as necessary to aid in the development and implementation of the objectives of this order.

Sec. 3. Development of a National Geospatial Data Clearinghouse. (a) Establishing a National Geospatial Data Clearinghouse. The Secretary, through the FGDC, and in consultation with, as appropriate, State, local, and tribal governments and other affected parties, shall take steps within 6 months of the date of this order, to establish an electronic National Geospatial Data Clearinghouse ("Clearinghouse") for the NSDI. The Clearinghouse shall be compatible with the National Information Infrastructure to enable integration with that effort.

(b) Standardized Documentation of Data. Beginning 9 months from the date of this order, each agency shall document all new geospatial data it collects or produces, either directly or indirectly, using the standard under development by the FGDC, and make that standardized documentation electronically accessible to the Clearinghouse network. Within 1 year of the date of this order, agencies shall adopt a schedule, developed in consultation with the FGDC, for documenting, to the extent practicable, geospatial data previously collected or produced, either directly or indirectly, and making that data documentation electronically accessible to the Clearinghouse network.

(c) Public Access to Geospatial Data. Within 1 year of the date of this order, each agency shall adopt a plan, in consultation with the FGDC, establishing procedures to make geospatial data available to the public, to the extent permitted by law, current policies, and relevant OMB circulars, including OMB Circular No. A-130 ("Management of Federal Information Resources") and any implementing bulletins.

(d) Agency Utilization of the Clearinghouse. Within 1 year of the date of this order, each agency shall adopt internal procedures to ensure that the agency accesses the Clearinghouse before it expends Federal funds to collect or produce new geospatial data, to determine whether the information has already been collected by others, or whether cooperative efforts to obtain the data are possible.

(e) Funding. The Department of the Interior shall provide funding for the Clearinghouse to cover the initial prototype testing, standards development, and monitoring of the performance of the Clearinghouse. Agencies shall continue to fund their respective programs that collect and produce geospatial data; such data is then to be made part of the Clearinghouse for wider accessibility.

Sec. 4. Data Standards Activities. (a) General FGDC Responsibility. The FGDC shall develop standards for implementing the NSDI, in consultation and cooperation with State, local, and tribal governments, the private and academic sectors, and, to the extent feasible, the international community, consistent with OMB Circular No. A-119 ("Federal Participation in the Development and Use of Voluntary Standards"), and other applicable law and policies.

(b) Standards for Which Agencies Have Specific Responsibilities. Agencies assigned responsibilities for data categories by OMB Circular No. A-16 shall develop, through the FGDC, standards for those data categories, so as to ensure that the data produced by all agencies are compatible.

(c) Other Standards. The FGDC may from time to time identify and develop, through its member agencies, and to the extent permitted by law, other standards necessary to achieve the objectives of this order. The FGDC will promote the use of such standards and, as appropriate, such standards shall be submitted to the Department of Commerce for consideration as Federal Information Processing Standards. Those standards shall apply to geospatial data as defined in section 1 of this order.

(d) Agency Adherence to Standards. Federal agencies collecting or producing geospatial data, either directly or indirectly (e.g. through grants, partnerships, or contracts with other entities), shall ensure, prior to obligating funds for such activities, that data will be collected in a manner that meets all relevant standards adopted through the FGDC process.

Sec. 5. National Digital Geospatial Data Framework. In consultation with State, local, and tribal governments and within 9 months of the date of this order, the FGDC shall submit a plan and schedule to OMB for completing the initial implementation of a national digital geospatial data framework ("framework") by January 2000 and for establishing a process of ongoing data maintenance. The framework shall include geospatial data that are significant, in the determination of the FGDC, to a broad variety of users within any geographic area or nationwide. At a minimum, the plan shall address how the initial transportation, hydrology, and boundary elements of the framework might be completed by January 1998 in order to support the decennial census of 2000.

Sec. 6. Partnerships for Data Acquisition. The Secretary, under the auspices of the FGDC, and within 9 months of the date of this order, shall develop, to the extent permitted by law, strategies for maximizing cooperative participatory efforts with State, local, and tribal governments, the private sector, and other nonfederal organizations to share costs and improve efficiencies of acquiring geospatial data consistent with this order.

Sec. 7. Scope. (a) For the purposes of this order, the term "agency" shall have the same meaning as the term "Executive agency" in 5 U.S.C. 105, and shall include the military departments and components of the Department of Defense.

(b) The following activities are exempt from compliance w[illegible] this order:

(i) national security-related activities of the Department of Defense as determined by the Secretary of Defense;

(ii) national defense-related activities of the Department of Energy as determined by the Secretary of Energy; and

(iii) intelligence activities as determined by the Director of Central Intelligence.

(c) The NSDI may involve the mapping, charting, and geodesy activities of the Department of Defense relating to foreign areas, as determined by the Secretary of Defense.

(d) This order does not impose any requirements on tribal governments.

(e) Nothing in the order shall be construed to contravene the development of Federal Information Processing Standards and Guidelines adopted and promulgated under the provisions of section 111(d) of the Federal Property and Administrative Services Act of 1949, as amended by the Computer Security Act of 1987 (Public Law 100-235); or any other United States law, regulation, or international agreement.

Sec. 8. Judicial Review. This order is intended only to improve the internal management of the executive branch and is not intended to, and does not, create any right to administrative or judicial review, or any other right or benefit or trust responsibility, substantive or procedural, enforceable by a party against the United States, its agencies or instrumentalities, its officers or employees, or any other person.

WILLIAM J. CLINTON

THE WHITE HOUSE,
April 11, 1994.

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[Executive Order 12906, published in the April 13, 1994, edition of the Federal Register, Volume 59, Number 71, pp. 17671-17674.]

EXECUTIVE ORDER

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(e) The FGDC shall seek to involve State, local, and tribal governments in the development and implementation of the initiatives contained in this order. The FGDC shall utilize the expertise of academia, the private sector, professional societies, and others as necessary to aid in the development and implementation of the objectives of this order.

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(b) Standardized Documentation of Data. Beginning 9 months from the date of this order, each agency shall document all new geospatial data it collects or produces, either directly or indirectly, using the standard under development by the FGDC, and make that standardized documentation electronically accessible to the Clearinghouse network. Within 1 year of the date of this order, agencies shall adopt a schedule, developed in consultation with the FGDC, for documenting, to the extent practicable, geospatial data previously collected or produced, either directly or indirectly, and making that data documentation electronically accessible to the Clearinghouse network.

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(e) Funding. The Department of the Interior shall provide funding for the Clearinghouse to cover the initial prototype testing, standards development, and monitoring of the performance of the Clearinghouse. Agencies shall continue to fund their respective programs that collect and produce geospatial data; such data is then to be made part of the Clearinghouse for wider accessibility.

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(b) Standards for Which Agencies Have Specific Responsibilities. Agencies assigned responsibilities for data categories by OMB Circular No. A-16 shall develop, through the FGDC, standards for those data categories, so as to ensure that the data produced by all agencies are compatible.

(c) Other Standards. The FGDC may from time to time identify and develop, through its member agencies, and to the extent permitted by law, other standards necessary to achieve the objectives of this order. The FGDC will promote the use of such standards and, as appropriate, such standards shall be submitted to the Department of Commerce for consideration as Federal Information Processing Standards. Those standards shall apply to geospatial data as defined in section 1 of this order.

(d) Agency Adherence to Standards. Federal agencies collecting or producing geospatial data, either directly or indirectly (e.g. through grants, partnerships, or contracts with other entities), shall ensure, prior to obligating funds for such activities, that data will be collected in a manner that meets all relevant standards adopted through the FGDC process.

Sec. 5. National Digital Geospatial Data Framework. In consultation with State, local, and tribal governments and within 9 months of the date of this order, the FGDC shall submit a plan and schedule to OMB for completing the initial implementation of a national digital geospatial data framework ("framework") by January 2000 and for establishing a process of ongoing data maintenance. The framework shall include geospatial data that are significant, in the determination of the FGDC, to a broad variety of users within any geographic area or nationwide. At a minimum, the plan shall address how the initial transportation, hydrology, and boundary elements of the framework might be completed by January 1998 in order to support the decennial census of 2000.

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Sec. 7. Scope. (a) For the purposes of this order, the term "agency" shall have the same meaning as the term "Executive agency" in 5 U.S.C. 105, and shall include the military departments and components of the Department of Defense.

(b) The following activities are exempt from compliance with this order:

(i) national security-related activities of the Department of Defense as determined by the Secretary of Defense;

(ii) national defense-related activities of the Department of Energy as determined by the Secretary of Energy; and

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(d) This order does not impose any requirements on tribal governments.

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Sec. 8. Judicial Review. This order is intended only to improve the internal management of the executive branch and is not intended to, and does not, create any right to administrative or judicial review, or any other right or benefit or trust responsibility, substantive or procedural, enforceable by a party against the United States, its agencies or instrumentalities, its officers or employees, or any other person.

WILLIAM J. CLINTON

THE WHITE HOUSE,
April 11, 1994.

# # #

October 11, 1994

Federal Geographic Data Committee
Standards Development Schedule

The Federal Geographic Data Committee (FGDC) has been charged through Office of Management and Budget Circular A-16 with the responsibility of "encouraging the development and implementation of standards, exchange formats, specifications, procedures, and guidelines" as applied to surveying, mapping, and related geospatial data. This responsibility was reinforced by Executive Order 12906, "Coordinating Geographic Data Acquisition and Access: The National Spatial Data Infrastructure [NSDI]," which was issued by President Clinton on April 11, 1994. The executive order included the following section:

> Sec. 4. Data Standards Activities. (a) General FGDC Responsibility. The FGDC shall develop standards for implementing the NSDI, in consultation and cooperation with State, local, and tribal governments, the private and academic sectors, and, to the extent feasible, the international community, consistent with OMB Circular No. A-119 ("Federal Participation in the Development and Use of Voluntary Standards"), and other applicable law and policies.
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> (b) Standards for Which Agencies Have Specific Responsibilities. Agencies assigned responsibilities for data categories by OMB Circular No. A-16 shall develop, through the FGDC, standards for those data categories, so as to ensure that the data produced by all agencies are compatible.
>
> (c) Other Standards. The FGDC may from time to time identify and develop, through its member agencies, and to the extent permitted by law, other standards necessary to achieve the objectives of this order. The FGDC will promote the use of such standards and, as appropriate, such standards shall be submitted to the Department of Commerce for consideration as Federal Information Processing Standards. Those standards shall apply to geospatial data as defined in section 1 of this order.
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> (d) Agency Adherence to Standards. Federal agencies collecting or producing geospatial data, either directly or indirectly (e.g. through grants, partnerships, or contracts with other entities), shall ensure, prior to obligating funds for such activities, that data will be collected in a manner that meets all relevant standards adopted through the FGDC process.

Standards promote consistency and quality, improve communication and exchange, and enable networking and integration of activities. Because data needed by the Federal Government often may be produced by State, local, and tribal governments, the private sector, non-profit organizations, or others, and because data produced by the Federal Government may be useful to these entities, the process for developing these standards must allow all parties to participate.

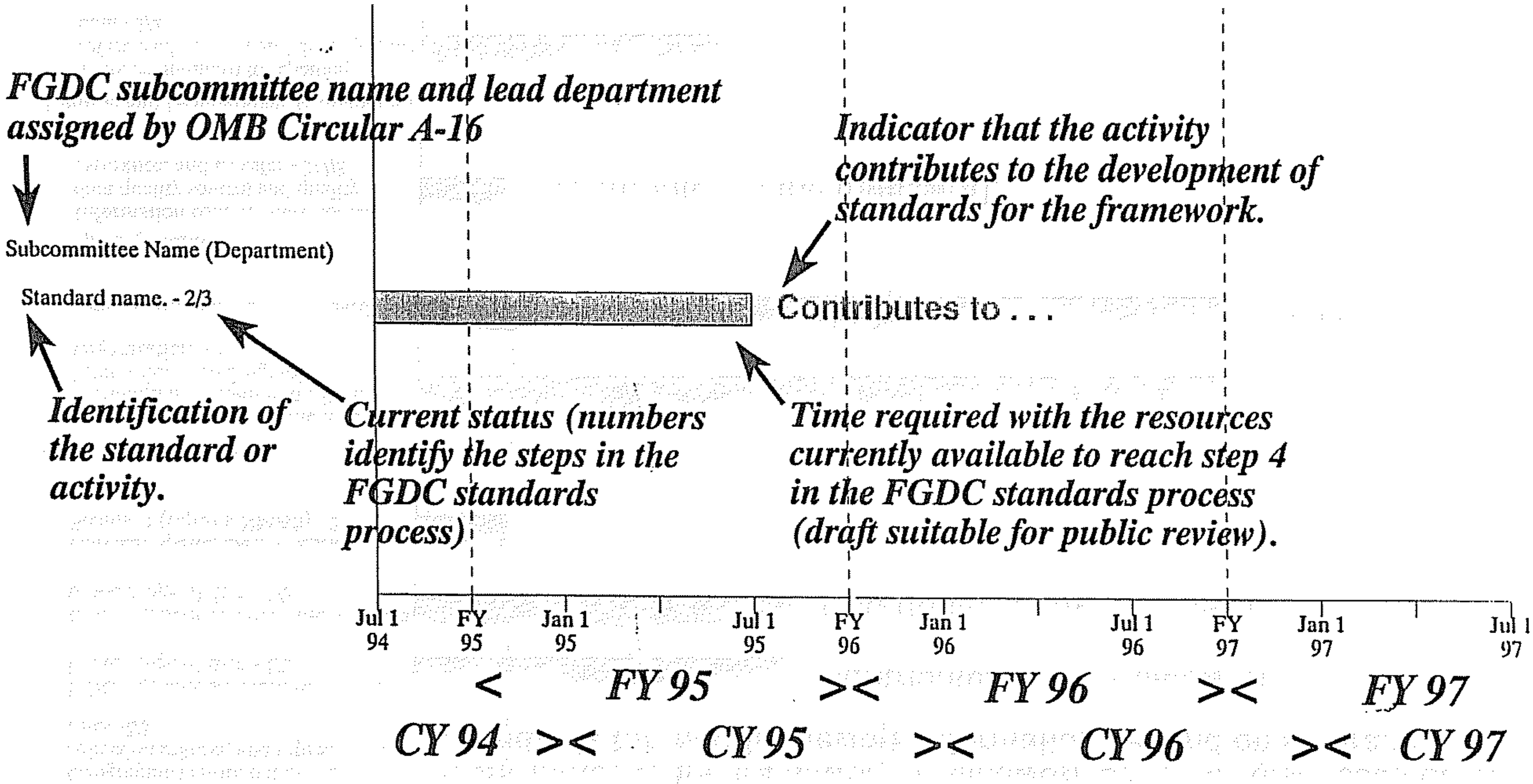
The major standards now being developed by the FGDC are related to themes of data. In some cases, these standards respond to a unique aspect of the theme. In other cases, the effort is to implement a general standard for use within a theme. The FGDC's subcommittees, which are organized by theme of data and lead by a Federal Department with expertise in the theme, lead the development of these standards.

In addition to these theme-based efforts, the FGDC is developing the concept of a framework of data for the NSDI. The schedule includes an overview of the types of standards needed and the approach to developing standards to support the framework data. Subcommittee efforts which aid the development of standards for the framework also are noted in the schedule.

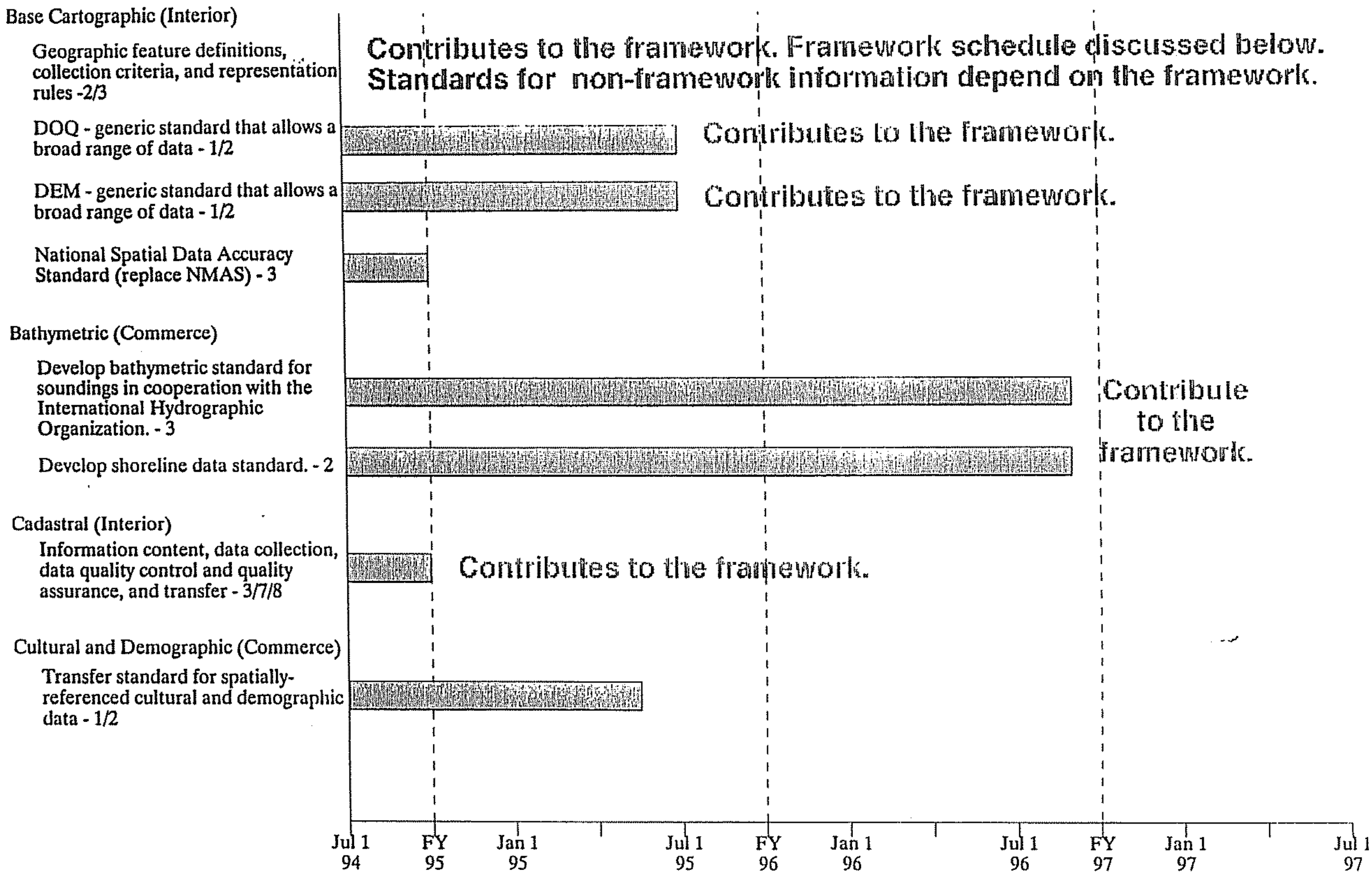
In developing the schedule, the subcommittees assumed that no additional resources would be available to aid their efforts. This assumption resulted in subcommittees identifying fewer standards on which to work in some cases, and lengthing their estimates of development time in other cases. The availability of additional resources often would speed development or allow a larger number of issues to be addressed.

The schedule describes the time needed to develop a draft that is sufficiently robust for public review and comment. Additional time will be needed to respond to comments and to issue the standard. The length of this period will vary depending on the issues encountered and the complexity of the standard.

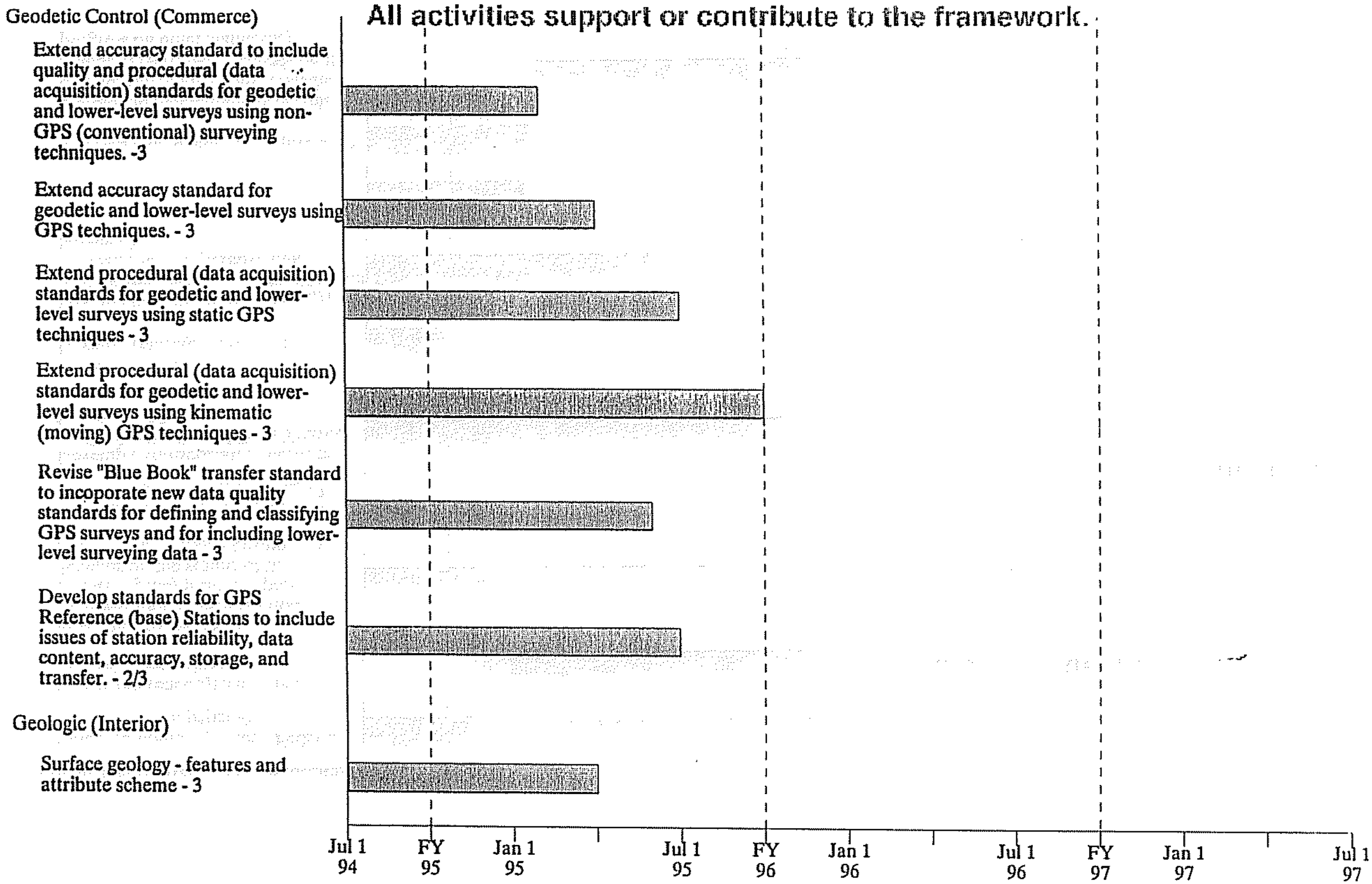
Reading the FGDC Standards Development Schedule

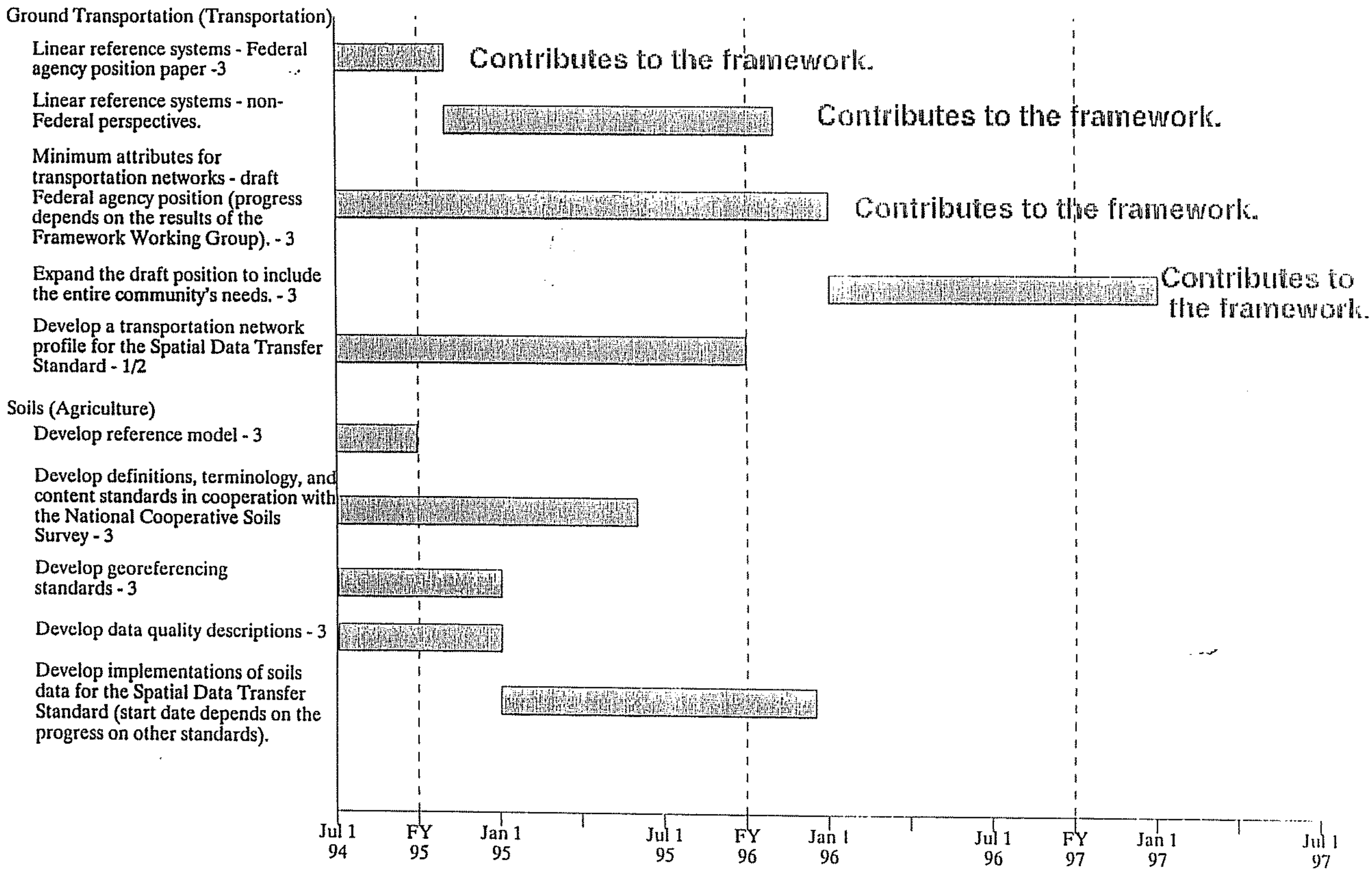


Acronyms Used in the Schedule:
- *DEM - digital elevation model*
- *DOQ - digital orthophoto quadrangle*
- *GPS - Global Positioning System*
- *NMAS - National Map Accuracy Standard*



Base Cartographic (Interior)
Geographic feature definitions, collection criteria, and representation rules -2/3
Contributes to the framework. Framework schedule discussed below.
Standards for non-framework information depend on the framework.
DOQ - generic standard that allows a broad range of data - 1/2
Contributes to the framework.
DEM - generic standard that allows a broad range of data - 1/2
Contributes to the framework.
National Spatial Data Accuracy Standard (replace NMAS) - 3
Bathymetric (Commerce)
Develop bathymetric standard for soundings in cooperation with the International Hydrographic Organization. - 3
Develop shoreline data standard. - 2
Contribute to the framework.
Cadastral (Interior)
Information content, data collection, data quality control and quality assurance, and transfer - 3/7/8
Contributes to the framework.
Cultural and Demographic (Commerce)
Transfer standard for spatially-referenced cultural and demographic data - 1/2
Jul 1 94
FY 95
Jan 1 95
Jul 1 95
FY 96
Jan 1 96
Jul 1 96
FY 97
Jan 1 97
Jul 1 97


All activities support or contribute to the framework.
Geodetic Control (Commerce)
Extend accuracy standard to include quality and procedural (data acquisition) standards for geodetic and lower-level surveys using non-GPS (conventional) surveying techniques. -3
Extend accuracy standard for geodetic and lower-level surveys using GPS techniques. - 3
Extend procedural (data acquisition) standards for geodetic and lower-level surveys using static GPS techniques - 3
Extend procedural (data acquisition) standards for geodetic and lower-level surveys using kinematic (moving) GPS techniques - 3
Revise "Blue Book" transfer standard to incoporate new data quality standards for defining and classifying GPS surveys and for including lower-level surveying data - 3
Develop standards for GPS Reference (base) Stations to include issues of station reliability, data content, accuracy, storage, and transfer. - 2/3
Geologic (Interior)
Surface geology - features and attribute scheme - 3
Jul 1 94
FY 95
Jan 1 95
Jul 1 95
FY 96
Jan 1 96
Jul 1 96
FY 97
Jan 1 97
Jul 1 97



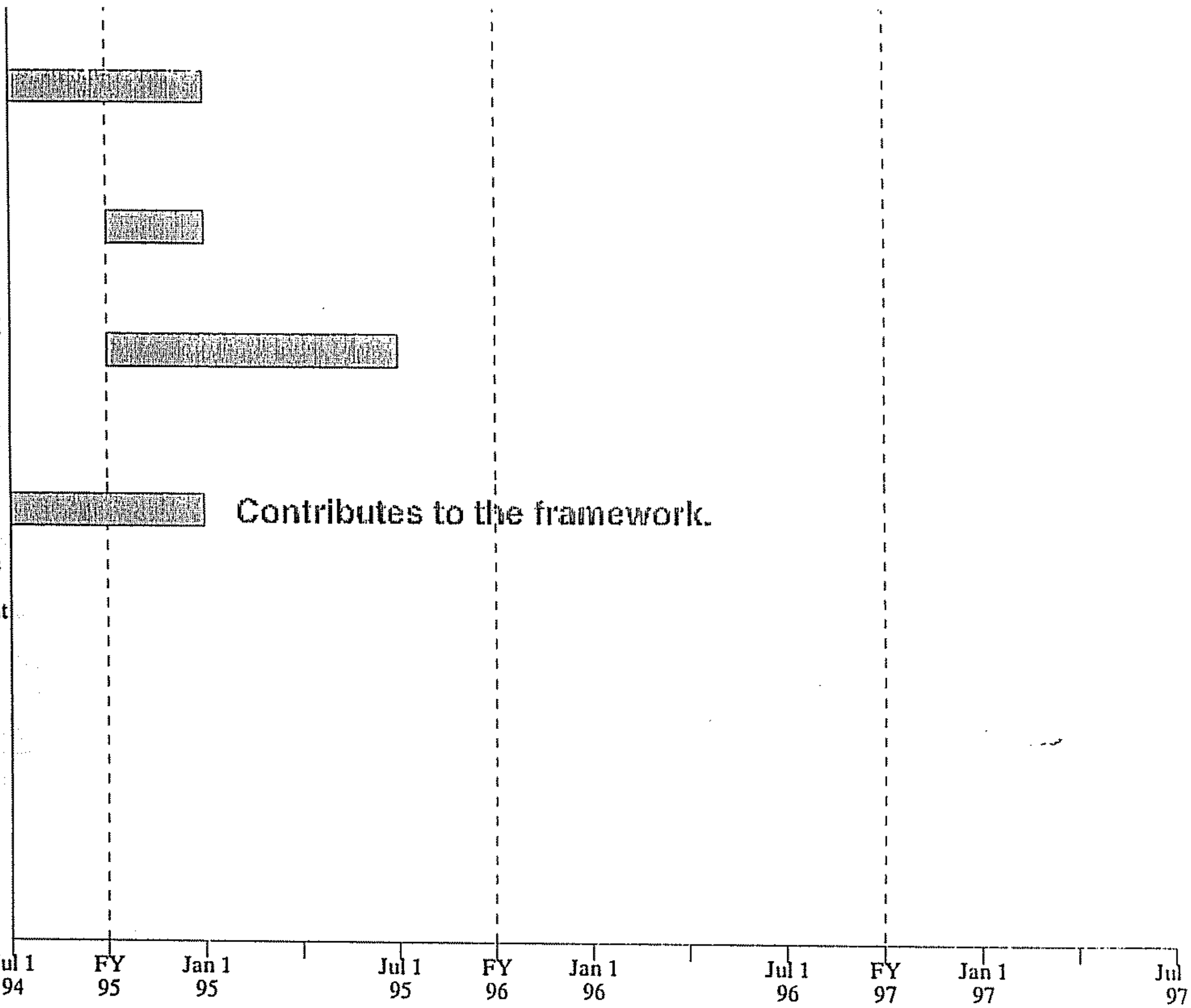
Ground Transportation (Transportation)
Linear reference systems - Federal agency position paper -3
Contributes to the framework.
Linear reference systems - non-Federal perspectives.
Contributes to the framework.
Minimum attributes for transportation networks - draft Federal agency position (progress depends on the results of the Framework Working Group). - 3
Contributes to the framework.
Expand the draft position to include the entire community's needs. - 3
Contributes to the framework.
Develop a transportation network profile for the Spatial Data Transfer Standard - 1/2
Soils (Agriculture)
Develop reference model - 3
Develop definitions, terminology, and content standards in cooperation with the National Cooperative Soils Survey - 3
Develop georeferencing standards - 3
Develop data quality descriptions - 3
Develop implementations of soils data for the Spatial Data Transfer Standard (start date depends on the progress on other standards).
Jul 1 94
FY 95
Jan 1 95
Jul 1 95
FY 96
Jan 1 96
Jul 1 96
FY 97
Jan 1 97
Jul 1 97

Vegetation (Agriculture)

- Draft standard for high-level vegetation classification system, including terms, definitions, and methodology (under review by subcommittee). - 3
- Plan and conduct public forum with the vegetation classification community to frame the next steps in developing a working standard. - 2
- Identify existing vegetation classification standards for finer-level detail, such as those under development by the Ecological Society of America, and combine them with the higher-level system. - 2

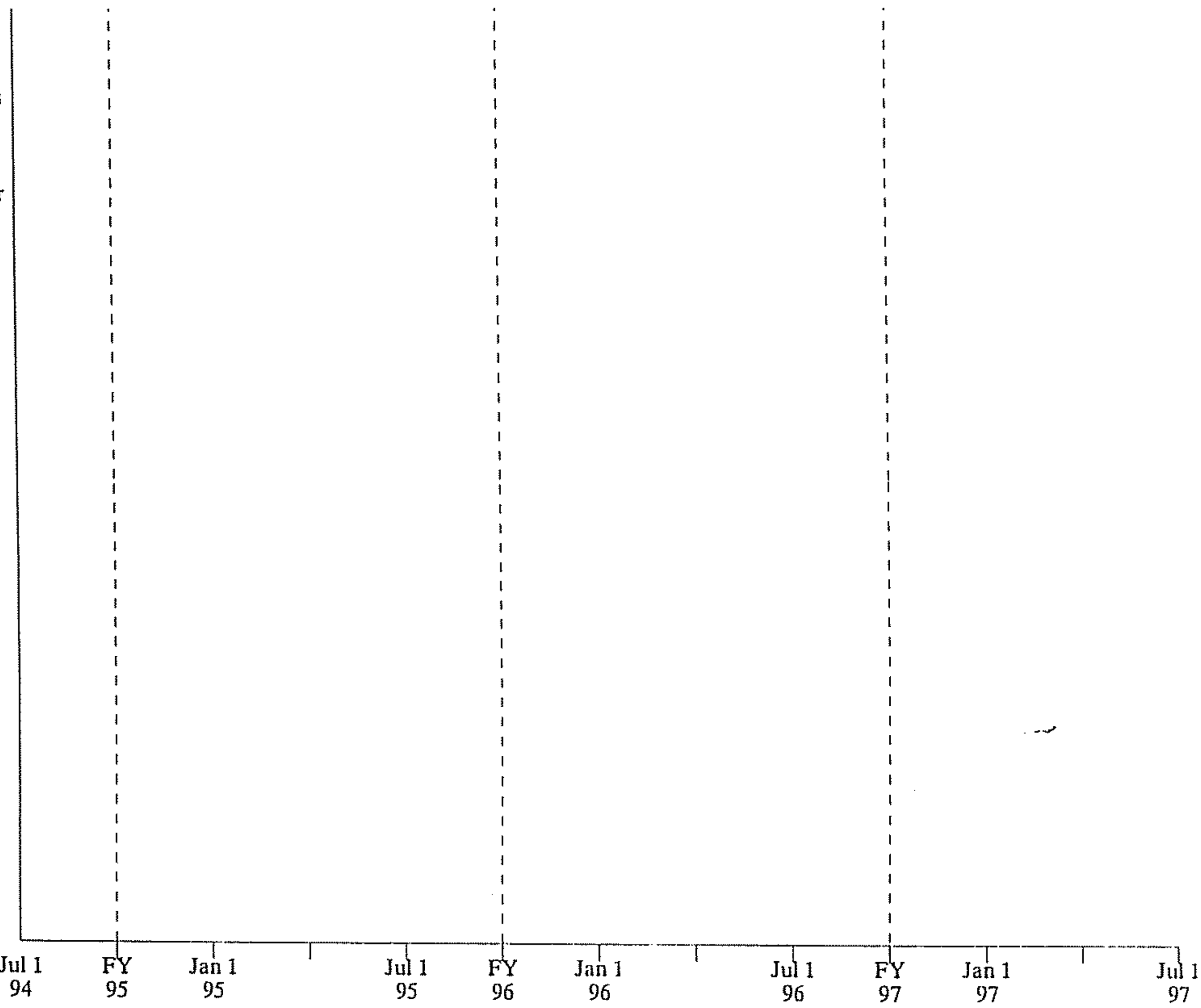
Water (Interior)

- Complete standard for River Reach code. - 3
- Consider extension of the hydrologic unit codes to watershed and subwatershed units, and development of a related set of boundaries. - 1



Wetlands (Interior)

Commonly used conventions in the Federal community include wetlands classification scheme (Cowardin and others); photointerpretation, cartographic, and digitizing conventions; lists of plants that occur in wetlands; and list of hydric soils. The subcommittee has reviewed and endorsed these items. The subcommittee will offer these documents for formal public review and adoption.



Framework Standards

The framework approach is based on integrating the contributions of many participants, and providing useful information to many consumers. Several factors are important to the success of the framework, including the willingness of contributors to provide data in a common way so that these contributions can be processed efficiently and effectively; a common means for customers to access and use the data; and a clear understanding of the information contained by the framework. Standards provide a tool for ensuring that these factors are in place.

Poorly developed, poorly understood, or overly complicated standards also can help to discourage the develop and use of the framework. In addition, it is likely that the framework will be developed in phases, and different standards will be needed as the different phases are designed and implemented. For these reasons, standards for the framework will be developed as part of the pilot projects for the framework. The schedule for the development of these standards will vary with the schedule for these projects, and so a detailed schedule for standards related to the framework is not provided.

The technical characteristics of the framework for which standards may be needed have been identified. These are listed below in two categories: general, technical standards for the overall operation of the framework, and information content standards for framework data.

Technical Characteristics of the Framework

Standards are needed to support the technical characteristics of the framework. The framework:

- is composed of geographically distributed data holdings that are connected through information networks and digital media and are accessible using a common query mechanism.
- supports transactional updates that minimize impacts on producers and users.
- employs feature-based encoding of geographic phenomena and the use of attributes for non-locational information. Locational (coordinate) information is encoded in associated spatial objects. Vector-based spatial objects will conform to topological rules.
- may provide multiple resolutions of data for any given location.
- uses permanent feature identifiers that serve to associate framework and users' attribute data, to identify data involved in transactions, and to link multiple representations of features.
- uses common means of referencing coordinate positions, based on nationally-recognized horizontal and vertical datums.
- retains past versions so that data are available for historical or process studies.

• preserves positions of contributed data. Edges of adjoining contributions will not be adjusted, although the disjoint lines will be associated through a common feature. Alignments in generalized data may be joined if the alignment errors can be resolved within the error tolerances.

• integrates data across themes where possible.

Forms of instructions for accomplishing these goals may include standards, guidelines, and procedures.

Information Content

Information content standards are needed for the components of the framework. The Federal contribution to the development of these standards will most often be provided by FGDC subcommittees. The activities that will most likely contribute these standards are highlighted in the detailed schedule.

Information content standards are needed for:

• *Geodetic Control* — geodetic control stations, and their names, unique identifiers, and locations and orthometric and ellipsoid heights with accuracy information.

• *Digital Orthoimagery* — georeferenced image prepared from a perspective photograph or other remotely-sensed data in which displacements of images due to sensor orientation and terrain relief have been removed. Framework data may range in resolution from sub-meter to tens of meters.

• *Elevation Data* — for land surfaces, an elevation matrix; for depths, soundings and gridded bottom models. Shorelines will have the attribute of shoreline type (or tidal reference).

• *Transportation* — roads, trails, railroads, waterways, airports, ports, bridges, and tunnels. Attributes include a permanent feature identifier and name. Where available, linear referencing systems will be used as the identifier. In addition, roads will have the attributes of functional class and street address range. Trails and railroads will have the attribute of type.

• *Hydrography* — reaches, based on the approach of the U.S. Environmental Protection Agency's Reach File Version 3.0 (RF3). Reaches will have the attributes of reach code, name, reach type (eg. stream or lake), and spatial representation.

• *Governmental Units* — Nation, States, counties, incorporated places and consolidated cities, functioning and legal minor civil divisions, American Indian Reservations and Trustlands, and Alaska Native Regional Corporations, each with the attribute of name and applicable Federal Information Processing Standard (FIPS) code. Boundaries will include information about associated features and the type of association.

• *Cadastral* — cadastral reference systems (such as the Public Land Survey System), large publicly-administered parcels (e.g. military reservations or state parks), and survey corners and boundaries. Each will have a name or other common identifier and quality information.

Content Standards for Digital Geospatial Metadata

Overview

At its June 8, 1994, meeting, the Federal Geographic Data Committee (FGDC) approved the "Content Standards for Digital Geospatial Metadata." Metadata, or "data about data," describe the content, quality, condition, and other characteristics of data. The standard specifies the information content of metadata for a set of digital geospatial data. The purpose of the standard is to provide a common set of terminology and definitions for documentation related to these metadata.

The FGDC invites and encourages organizations to use the standard to document their geospatial data. The main reason to document data is to maintain an organization's investment in its geospatial data. Organizations that do not document their data often find that, over time or because of personnel changes, they no longer know the content or quality of their data. Organizations then cannot trust the results generated from the data in which they have invested their time and resources. In addition, the lack of information about other organizations' data often leads to a needless duplicating of effort.

The standard specifies information that helps prospective users to determine what data exist, the fitness of these data for their applications, and the conditions for accessing these data. Metadata also aid the transfer of data to other users' systems.

On April 11, 1994, President Clinton signed Executive Order 12906, *Coordinating Geographic Data Acquisition and Access: The National Spatial Data Infrastructure.* This executive order instructs Federal agencies to use the standard to document new geospatial data beginning in 1995, and to provide these metadata to the public through the National Geospatial Data Clearinghouse.

The Standard

The standard provides a common set of terminology and definitions for the documentation of geospatial data. The standard establishes the names of data elements and groups of data elements to be used for these purposes, the definitions of these data elements and groups, and information about the values that are to be provided for the data elements. Information about terms that are mandatory, mandatory under certain conditions, and optional (provided at the discretion of the data producer) also is provided by the standard.

The major uses of metadata are:

- to help organize and maintain an organization's internal investment in spatial data,
- to provide information about an organization's data holdings to data catalogues, clearinghouses, and brokerages, and
- to provide information to process and interpret data received through a transfer from an external source.

The information included in the standard was selected on the basis of four characteristics that define the role of metadata:

- availability — data needed to determine the sets of data that exist for a geographic location.
- fitness for use — data needed to determine if a set of data meets a specified need.
- access — data needed to acquire an identified set of data.
- transfer — data needed to process and use a set of data.

These characteristics form a continuum in which a user moves through a number of choices to determine what data are available, to evaluate the fitness of data, to acquire the data, and to transfer and process the data. The order in which data elements are evaluated, and the relative importance of the data elements, will not be the same for all users or for all tasks that use metadata. In addition, users with different tasks or at different stages of evaluation may require (or prefer) that a set of information be available at different levels of abstraction or in different forms.

The standard defines data elements for the following topics:

Identification Information — basic information about the data set. Examples include the title, the geographic area covered, currentness, and rules for acquiring or using the data.

Data Quality Information — an assessment of the quality of the data set. Examples include the positional and attribute accuracy, completeness, consistency, the sources of information, and methods used to produce the data. Recommendations on information to be reported and tasks to be performed are in the Spatial Data Transfer Standard (Federal Information Processing Standard 173) (1992).

Spatial Data Organization Information — the mechanism used to represent spatial information in the data set. Examples include the method used to represent spatial positions directly (such as raster or vector) and indirectly (such as street addresses or county codes) and the number of spatial objects in the data set.

Spatial Reference Information — description of the reference frame for, and means of encoding, coordinates in the data set. Examples include the name of and parameters for map projections or grid coordinate systems, horizontal and vertical datums, and the coordinate system resolution.

Entity and Attribute Information — information about the content of the data set, including the entities types and their attributes and the domains from which attribute values may be assigned. Examples include the names and definitions of features, attributes, and attribute values.

Distribution Information — information about obtaining the data set. Examples include a contact for the distributor, available formats, information about how to obtain data sets online or on physical media (such as cartridge tape or CD-ROM), and fees for the data.

Metadata Reference Information — information on the currentness of the metadata information and the responsible party. Examples include currentness and information about the organization that provided the metadata.

The standard has sections that specify contact information for organizations or individuals that developed or distribute the data set, temporal information for time periods covered by the data set, and citation information for the data set and information sources from which the data set was derived.

The standard does not specify how this information is organized in a computer system or in a data transfer, nor the means by which this information is transmitted or communicated to the user. The variety of means of organizing data in a computer or in a transfer, the differences between data providers to describe their data holdings because of varying institutional and technical capabilities, and the rapid evolution of means to provide information through the Internet for different purposes determined this decision.

Development of the Standard

The FGDC initiated work on the standard in June, 1992, with a forum on spatial metadata. At the forum, the participants agreed on the need for a standard on information content for metadata about spatial data. A committee of volunteers developed an initial draft content standard. This draft was slightly revised and offered for public review from October 1992 to April 1993. Extensive comments were received from the public. The FGDC's Standards Working Group revised the draft, which was provided for further review and testing in July 1993. Revised drafts were reviewed and tested again in January, March, and May 1994. The standard was approved by the FGDC on June 8, 1994.

Obtaining Copies of the Standard

The standard is available from:

FGDC Secretariat
c/o U.S. Geological Survey
590 National Center
Reston, Virginia 22092;
telephone: (703) 648-5514;
facsimile: (703) 648-5755;
or Internet gdc@usgs.gov.

The standard is available via anonymous FTP from:

fgdc.er.usgs.gov under /pub/metadata

The files are also avaliable in WordPerfect5.1 or PostScript format with '.wp5', or'.ps' extensions. Remember to transfer in binary/image format.

The WordPerfect file is set up for 10-point, Times Roman font on an HP LaserJet 4 printer. It can be printed using other fonts or printers, but the sections that refer to page numbers (i.e. the table of contents and list of data elements with page numbers) may have to be regenerated. The file contains codes that aid efforts to regenerate the page numbers.

Users that have a browser (such as Mosaic) can access the FGDC Web server at

http://fgdc.er.usgs.gov/fgdc.html

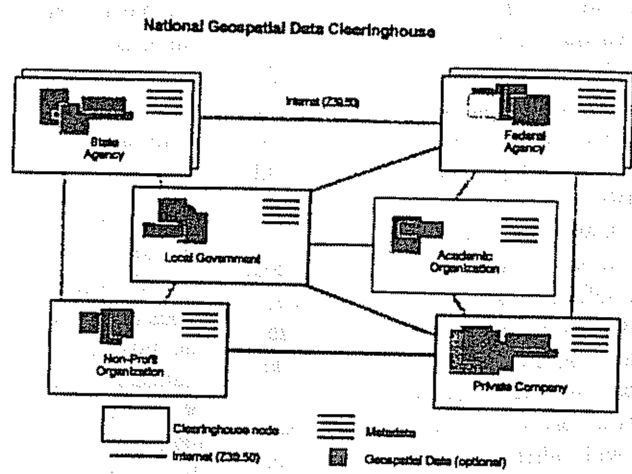
The FGDC also is developing implementation guidelines for the clearinghouse. The guidelines are in the directory:

http://fgdc.er.usgs.gov/clearinghouse/chguide.6894.txt

Federal Geographic Data Committee

National Geospatial Data Clearinghouse

The National Geospatial Data Clearinghouse is a distributed, electronically connected network of geospatial data producers, managers, and users. The clearinghouse will allow its users to determine what geospatial data exist, find the data they need, evaluate the usefulness of the data for their applications, and obtain or order the data as economically as possible.



The clearinghouse is an electronically connected network that has information about geospatial data.

Why is it needed?
Like the information-based economy of which it is a part, the geospatial data community is in the midst of change. Decreasing costs and the increasing capabilities of hardware and software are lowering the initial investment needed for technology and are increasing demands for geospatial data. But even with billions of dollars going into geospatial data production, few users can answer the basic question, "Where are the data?" The result is that agencies and the public spend money collecting data that may already exist.

Electronic networking capabilities increasingly assist communication within the geospatial data community. There is still much work to be done to move from traditional means of communicating about geospatial data to using the emerging information infrastructure. The clearinghouse provides a means to inventory, document, and share geospatial data. For data users, the clearinghouse makes data easier to find and access.

As part of their participation in the National Spatial Data Infrastructure (NSDI), Federal agencies are beginning to provide data and use the clearinghouse. On April 11, 1994, President Clinton signed Executive Order 12906, "Coordinating Geographic Data Acquisition and Access: The National Spatial Data Infrastructure." The order instructs Federal agencies to use the Content Standards for Digital Geospatial Metadata to document new geospatialdata beginning in 1995 and to provide these metadata to other agencies and to the public through the clearinghouse.

How does it work?
As part of the NSDI, which is building on initiatives such as the National Information Infrastructure, the clearinghouse allows data providers to make known what geospatial data exist, the condition of these data, and instructions for accessing these data. Each data provider describes available data in an electronic form and provides these descriptions (or "metadata") to the network using a variety of software tools. In addition to these metadata, the provider also may provide access to the geospatial data. The data described in the clearinghouse may be located at the sites of data producers or, where appropriate, at sites of designated data disseminators throughout the country.

The clearinghouse uses the Internet to link computer nodes that contain information about geospatial data. The Internet is a global "network of networks" that enables computers of all kinds to communicate and share services throughout much of the world. The Internet currently connects more than 2 million host computers and 15 to 20 million users in more than 100 countries.

Using the Internet, data users can search the descriptions provided by producers to locate data that are suitable for their applications. A public-domain software tool known as WAIS (Wide Area Information Servers) enables users to perform queries for data over the network. A recent enhancement to WAISallows users to search on the basis of geographic coordinates. WAIS uses a communications protocol known asZ9.50, which is emerging as an international standard. In addition, the rapidly expanding World Wide Web (WWW) technologies, including browse software such as Mosaic, provide gateways to WAIS servers, and allow graphic or forms-based queries for data.

What if the desired data don't exist?
As the clearinghouse evolves additional functions will be supported, such as thecapability for producers to publicize datathat are being prepared or are planned and for users to advertise their data needs.

These capabilities will foster communication between the users and producers, which will encourage dialogue on new product needs and developments, will help to form partnerships for data production, and will minimize duplication in data collection. This communication is vital to ensuring that the NSDI continues to be responsive to the needs of the community.

What will it cost?
The clearinghouse will be distributed across thousands of data producers and users, and so the total cost is not known and is difficult to estimate. Costs will be distributed among organizations and will primarily be borne by data producers. Costs include those for the hardware needed to store and provide the metadata, for the software to access the metadata, for activities to collect and maintain the metadata that are provided to users, and for telecommunications charges. The benefits of many of these items will be shared with other applications within an organization. Data users will incur some costs in software to search for data and fees for network usage.

What are the benefits?
The ability to search for and make sense of data in an increasingly information driven world will be one of the most critical required skills in the future. The use of GIS technologies is spreading and the clearinghouse is responding to the demands of this community of users for ways to manage and share geospatial data. There will be increasing demands for clearinghouse activities to sift through the billions of bytes of data on electronic networks to find useful information. The clearinghouse effort will provide the foundation for finding, sharing, and using geospatial data.

Who is developing it?
People like you. Many contributors from the geospatial data community are collaborating on this project, including Federal, State, and local governments, academia, and the commercial sector. The Federal Geographic Data Committee (FGDC) is serving as the contact for prospective participants.

How can I participate?
Data Providers
- Learn and use the metadata standard. Much of the information requested by the standard is available during data production. Begin to record this information and provide it to others.
- Investigate means to provide metadata to the clearinghouse. Set up a clearinghouse node and provide metadata on the Internet. Or work with others to establish a site that provides the metadata on behalf of the group.
- Encourage vendors to provide the tools needed to participate in the clearinghouse. Vendors need to hear from you about what's important.

Data Users
- Learn about the metadata standard and provide feedback to producers on the types of information that would help you the most. Encourage producers to provide metadata through the clearinghouse.
- Investigate means to access to the Internet. Learn and use software such as WAIS and WWW, and use the clearinghouse. Provide feedback on improvements needed to make your use more efficient.
- Encourage vendors to provide the tools needed to use the clearinghouse as part of their products.

Additional Information
For more information contact:

FGDC Secretariat
c/o U.S. Geological Survey
590 National Center
Reston, Virginia 22092;
telephone: (703) 648-5514;
facsimile: (703) 648-5755;
or Internet gdc@usgs.gov

Implementation guidelines about the clearinghouse for Federal agencies are available by anonymous FTP from:
fgdc.er.usgs.gov under
/pub/clearinghouse/chguide.txt

The metadata standard is under:
/pub/metadata/meta523.txt

The files are also available in WordPerfect5.1 or PostScript format with '.wp5', or '.ps' extensions. Remember to transfer in binary/image format.

Users that have a WWW browser (such Mosaic) can access the FGDC server at
http://fgdc.er.usgs.gov/fgdc.html

The WAIS server and client software is available through Mosaic via:
ftp://waisqvarsa.er.usgs.gov/wais

or anonymous FTP at:
waisqvarsa.er.usgs.gov/wais

WWW server and client software is available at many locations via anonymous FTP including The National Center for Supercomputing Activities:
ftp.ncsa.uiuc.edu

Two Internet discussion groups contain items related to the NSDI, metadata, clearinghouse, and other subjects:

NSDI-L - Issues, policies, and technical questions about the NSDI. Unmoderated.

To subscribe: send email to
majordomo@fgdc.er.usgs.gov
with no subject. In the message body include
subscribe NSDI-L (your email address)
to submit: send email to
NSDI-L@fgdc.er.usgs.gov

Geoweb - Archiving, cataloging, and retrieving geospatial information on the Internet and the WWW. Unmoderated.

To subscribe: send email to
majordomo@census.gov,
with the following body:
subscribe geoweb <your Internet address> (e.g., jsmith@org.gov)
To submit: send email to
geoweb@census.gov

The following is an example of an FGDC Compliant Metadata Report for the DELDOT Center Line File. The primary purpose of the example is to exhibit the categorization and elements of the documentation standard. An effort was made to correctly list all information but actual details about the DELDOT Center Line File must be reviewed, corrected, and approved by DELDOT.

Example: FGDC-Compliant Metadata for CENTERLN

I) Identification_Information:

Citation:
Originator: Delaware Department of Transportation
Publication_Date: 010195
Publication_Time: 1200
Title: DELDOT Center LIne FIle
Edition: spring95
Geospatial_Data_Presentation_Form: map
Series_Information:
Series_Name: 1.00
Issue_Identification: 1.00
Publication_Information:
Publication_Place: Dover, Delaware
Publisher: DELDOT
Other_Citation_Details:
Online_Linkage: DELDOT Server, ** not available at this time **
Larger_Work_Citation:

Description: Delaware Department of Transportation Center Line File,
Abstract:

The DELDOT Center Line File forms the official digital representation of all roads in Delaware. A route system is defined which forms the framework for linear referencing of spatial features and events on the road network by specifying road identifier and mile point. Road inventory data, address ranges, road conditions, and a wide range of data related to roads can be referenced using this file.

Descriptors:
Center Line, Road System, Linear Referencing, Routes, Mile Point

Purpose:

Useful for linear referencing of data for roads, road network modeling and forcasting,

Intended use of data

Serves as a framework for referencing transportation facility data.

Supplemental_Information:

Originally derived from DELDOT cartographic products, all files were corrected to overlay 1992 digital orthophotography at the 12,000 scale.

This is the first version of the center line files. Data will be continuously updated. Reviews applied to data (review type, date, person, description)

Related spatial and tabular data sets and programs

Numerous data sets are located using these files as the standards linear referencing system for Delaware roads

References cited

Notes

Time_Period_of_content:
  Time_Period_Information:
    Range_of_Dates/Times:
      Beginning_Date: 01/01/95
      Beginning_Time: 1200
      Ending_Date: 01/01/95
      Ending_Time: 1200
  Currentness_Reference: Publication date of sources

Status:
  Progress: Draft, Awaiting correction using orthophotography in Summer 1995
  Maintenance_and_Update_Frequency: Unknown

Spatial_Domain:
  Bounding_Coordinates:
    West_Bounding_Coordinate: -79.3390
    East_Bounding_Coordinate: -71.7303
    North_Bounding_Coordinate: 43.1086
    South_Bounding_Coordinate: 35.2336
  Data_Set_G-Polygon:
    Data_Set_G-Polygon_Outer G-Ring:

Keywords:
  Theme:
    Theme_Keyword_Thesaurus: none
    Theme_Keyword: DELDOT CENTER LINE FILE
  Place:
    Place_Keyword_Thesaurus: none
    Place_Keyword: New Castle County
  Stratum:
    Stratum_Keyword_Thesaurus: none

Stratum_Keyword:
Temporal:
Temporal_Keyword_Thesaurus: none
Temporal_Keyword:

Access_Constraints: none

Use_Restrictions:
(for use at certain scales, date ranges, for use with other data)

Point_of_Contact:
Contact_Information:
Contact_Person_Primary:
Contact Person: I. Kenneth Richter
Contact_Organization: DELDOT IRM
Contact_Position: IRM Manager
Contact_Address:
Address_Type: mailing address
Address: DELDOT, P.O. Box 778
City: Dover
State_or_Province: Delaware
Postal_Code: 19903
Country: USA
Contact_Voice_Telephone: 344-3434
Contact_TDD/TTY_Telephone: unknown
Contact_Facsimile_Telephone: 302-739-6119
Contact_Electronic_Mail_Address: unknown
Hours_of_Service: 9-5
Contact_Instructions: Please submit all requests in writing to the above address.

Security Information:
Security_Classification_System:
Security_Classification: UNCLASSIFIED
Security_Handling_Description:

Native_Data_Set_Environment: UNIX

Cross_Reference:
Originator: DELDOT
Publication_Date: 01/01/1995
Publication_Time: 1200
Title: DELDOT Center Line File
Edition: 1.00
Geospatial_Data_Presentation_Form: map
Series_Information:
Series_Name: 1.00
Issue_Identification: 1.00
Publication_Information:
Publication_Place:
Publisher: DELDOT

Other_Citation_Details:
Online_Linkage: DELDOT SERVER, ** not available at this time **
Larger_Work_Citation:

II) Data_Quality_Information:

Attribute_Accuracy:
Attribute_Accuracy_Report: See Entity_Attribute_Information
Quantitative_Attribute_Accuracy_Assessment:
Attribute_Accuracy_Value: See Explanation
Attribute_Accuracy_Explanation:
Attribute accuracy is described, where present, with each attribute defined in the Entity and Attribute Section.

Logical_Consistency_Report: Chain-node topology present.

Completeness_Report: See Data Set Description Section

Positional_Accuracy:
Horizontal_Positional_Accuracy:
Horizontal_Positional_Accuracy_Report:
Quantitative_Horizontal_Positional_Accuracy_Assessment:
Horizontal_Positional_Accuracy_Value: +/- 40 feet
Horizontal_Positional_Accuracy_Explanation: Resolution as reported

Lineage: See Supplemental information.
Source_Scale_Denominator:
Type_of_Source_Media:
Source_Time_Period_of_Content:
Source_Currentness_Reference:
Source_Citation_Abbreviation:
Source_Contribution:
Process_Step:
Process_Description: DR RENAME NCNET CENTERLN
Process_Date: 19950308
Process_Time: 1149
Cloud_Cover: Unknown

III) Spatial_Data_Organization_Information:

Direct_Spatial_Reference_Method: Vector

Point_and_Vector_Object_Information:
SDTS_Terms_Description:
SDTS_Point_and_Vector_Object_Type: Point
Point_and_Vector_Object_Count: 0
SDTS_Point_and_Vector_Object_Type: String
Point_and_Vector_Object_Count: 1676
SDTS_Point_and_Vector_Object_Type: GT-polygon composed of chains
Point_and_Vector_Object_Count: 0

IV) Spatial_Reference_Information:

Horizontal_Coordinate_System_Definition:
Horizontal_Coordinate_System: geographic
Geographic_Coordinate_Units: Decimal Degrees
Horizontal_Datum_Name: NAD83
Ellipsoid_Name: GRS1980
X-Shift: 0.0000000000
Y-Shift: 0.0000000000

V) Entity_Attribute_Information:

Detailed_Description:
Number_of_Attributes_in_Entity: 21
Entity_Type:
Entity_Type_label: CENTERLN.AAT
Entity_Type_Definition: Tables containing all primary identifiers for the DELDOT Centerline Framework
Entity_Type_Definition_Source: DELDOT IRM and other DELDOT agencies
Attribute:
Attribute_Label: -
Attribute_Definition: Tables containing all primary identifiers for the DELDOT Centerline Framework
Attribute_Definition_Source: DELDOT IRM and other DELDOT agencies
Attribute:
Attribute_Label: LINK_ID
Attribute_Definition: Unique network link identifier (linear segment) on which all routes are built.
Attribute_Definition_Source: DELDOT IRM
Attribute_Domain_Values:
Enumerated_Domain:
Enumerated_Domain_Value: 1 to 999,999
Attribute_Value_Accuracy_Information:
Attribute_Measurement_Frequency: Unknown
Attribute:
Attribute_Label: FROM_NODE
Attribute_Definition: Official From Node ID for network links for routes in the center line file.
Attribute_Definition_Source: DELDOT IRM and other DELDOT agencies
Attribute_Domain_Values:
Enumerated_Domain:
Enumerated_Domain_Value: 0 to 999,999
Attribute_Value_Accuracy_Information:
Attribute_Measurement_Frequency: Unknown
Attribute:
Attribute_Label: TO_NODE
Attribute_Definition: Official/unique To Node Identifier for network links for the center line file.
Attribute_Definition_Source: DELDOT IRM and other DELDOT agencies
Attribute_Domain_Values:
Enumerated_Domain:
Enumerated_Domain_Value: 0 to 999,999
Attribute_Value_Accuracy_Information:
Attribute_Measurement_Frequency: Unknown
Attribute:
Attribute_Label: LINK_DIRECTION
Attribute_Definition: Network Link Direction
Attribute_Definition_Source: DELDOT
Attribute_Domain_Values:

Enumerated_Domain:
Enumerated_Domain_Value: 1 through 4, could be refined at a later date
Attribute_Value_Accuracy_Information:
Attribute_Measurement_Frequency: Unknown
Attribute:
Attribute_Label: LINK_LENGTH_MILE
Attribute_Definition: Network link length in miles
Attribute_Definition_Source: Calculated from measurement studies by DELDOT.
Attribute_Domain_Values:
Enumerated_Domain:
Enumerated_Domain_Value: 00000.00 to 99999.99
Attribute_Value_Accuracy_Information:
Attribute_Measurement_Frequency: Unknown
Attribute:
Attribute_Label: LINK_LENGTH_KM
Attribute_Definition: Network link length in kilometers
Attribute_Definition_Source: DELDOT measurement studies
Attribute_Domain_Values:
Enumerated_Domain:
Enumerated_Domain_Value: 00000.00 to 99999.99
Attribute_Value_Accuracy_Information:
Attribute_Measurement_Frequency: Unknown
Attribute:
Attribute_Label: BEGIN_MILEPNT
Attribute_Definition: Beginning route mile point of a network link. Refers to route sytem on roadnum
Attribute_Definition_Source: DELDOT
Attribute_Domain_Values:
Enumerated_Domain:
Enumerated_Domain_Value: 0 to 100
Attribute_Value_Accuracy_Information:
Attribute_Measurement_Frequency: Unknown
Attribute:
Attribute_Label: END_MILEPNT
Attribute_Definition: End route mile for a network link. Refers to route system on roadnum.
Attribute_Definition_Source: DELDOT
Attribute_Domain_Values:
Enumerated_Domain:
Enumerated_Domain_Value: 0 to 100
Attribute_Value_Accuracy_Information:
Attribute_Measurement_Frequency: Unknown
Attribute:
Attribute_Label: ROADNUM
Attribute_Definition: Primary, unique, official route identifier for all roads in Delaware.
Attribute_Definition_Source: DELDOT
Attribute_Domain_Values:
Enumerated_Domain:
Enumerated_Domain_Value: alph representation of a number (1 to ?) sometimes followed by a letter.
Attribute_Value_Accuracy_Information:
Attribute_Measurement_Frequency: Unknown
Attribute:
Attribute_Label: NAME
Attribute_Definition: Local name for a road segment represented by a network link.
Attribute_Definition_Source: DELDOT
Attribute_Domain_Values:

Enumerated_Domain:
Enumerated_Domain_Value: Valid names (upper case alpha) for roads in Delaware, (eg NAAMANS ROAD).
Attribute_Value_Accuracy_Information:
Attribute_Measurement_Frequency: Unknown
Attribute:
Attribute_Label: ROUTENAME
Attribute_Definition: Common state or national route name used to reference road.
Attribute_Definition_Source: DELDOT
Attribute_Domain_Values:
Enumerated_Domain:
Enumerated_Domain_Value: alphanumeric names e.g. DEL. 92, I-95
Attribute_Value_Accuracy_Information:
Attribute_Measurement_Frequency: Unknown
Attribute:
Attribute_Label: COUNTY
Attribute_Definition: FIPS code for counties
Attribute_Definition_Source: Bureau of Census, and political boundaries of Delaware
Attribute_Domain_Values:
Enumerated_Domain:
Enumerated_Domain_Value: 01 (Kent County), 03 (New Castle), 05 (Sussex County)
Attribute_Value_Accuracy_Information:
Attribute_Measurement_Frequency: Unknown
Attribute:
Attribute_Label: ROADCLASS
Attribute_Definition: Road Classification
Attribute_Definition_Source: DELDOT
Attribute_Domain_Values:
Enumerated_Domain:
Enumerated_Domain_Value: maintenance, municipal streets. suburban roads, ramps, other
Attribute_Value_Accuracy_Information:
Attribute_Measurement_Frequency: Unknown

Overview_Description:
Entity_and_Attribute_Overview:

Primary attributes fields are LINK_ID AND ROADNUM. LINK_ID is the identifyer for network links which are the building blocks of the DELDOT route system. ROADNUM holds the route identifier used for all linear referencing. Beginning and ending mile point measures are all in terms of this identifier.

Entity_and_Attribute_Detail_Citation: Not Available

VI) Distribution_Information:

Distributor: Delaware Department of Transportation
Contact_Information:
Contact_Person_Primary:
Contact Person: I. Kenneth Richter
Contact_Organization: DELDOT IRM
Contact_Position: IRM Manager
Contact_Address:

Address_Type: mailing address
Address: DELDOT, P.O. Box 778
City: Dover
State_or_Province: Delaware
Postal_Code: 19903
Country: USA
Contact_Voice_Telephone: 344-3434
Contact_TDD/TTY_Telephone: unknown
Contact_Facsimile_Telephone: 302-739-6119
Contact_Electronic_Mail_Address: unknown
Hours_of_Service: 9-5
Contact_Instructions: Please submit all requests in writing to the above address.
Resource_Description: DELDOT Center Line File, Version Spring 1995
Distribution_Liability: None
Standard_Ordering_Process:
Digital_Form:
Digital_Transfer_Information:
Format_Name: DXF
Format_Version_Number: 345. 2
Format_Version_Date: 6/94
Format_Information_Content: Centerline File Network Chain and Identifiers
File_Decompression_Technique: Self Extracting EXE, Type Center

Format_Name: SPATIAL DATA TRANSFER STANDARD
Format_Version_Number: FIPS 173
Format_Version_Date: 06/10/1994
Format_Specification: TOPO VECTOR PROFILE
Format_Information_Content: All vector and tabular data for DELDOT Center Line File
File_Decompression_Technique: Self extracting EXE, for MS DOS platforms
Digital_Transfer_Option:
Online_Option:
Computer_Contact_Information:
Network_Address:
Network_Resource_Name: dotinfo@deldot.state (177.662.??.??) not established at this time
Computer_Contact_Information:
Dialup_Instructions:
Lowest_BPS: 9600
Highest_BPS: 9600
Number_DataBits: 7
Number_StopBits: 1
Parity: NONE
Compression_Support: none
Dialup_Telephone: 302-739-????
Dialup_File_Name: unknown
Access_Instructions: ftp to site listed, extract files from /pub/centerlin
Online_Computer_and_Operating_System: UNIX Server
Offline_Option:
Offline_Media: UNIX 8mm Tape, CDROM
Recording_Capacity:
Recording_Density: 0.0
Recording_Density_Units:
Recording_Format: UNIX Tape uses "TAR", CD in text or binary formats
Compatibility_Information: DXF, SDTS, DBASE, SEQUAL
Fees: $100.00

Ordering_Instructions: Send written request to designated contact.
Turnaround: 2 weeks

Custom_Order_Process: Send written requests to contact address for review
Technical_Prerequistes: Capability to read DXF or SDTS spatial data export files and DBASE/ Sequal DBMS
Available_Time_Period:
Beginning_Date/Time: AVAILABLE 05/01/1995
Ending_Date/Time: Ongoing

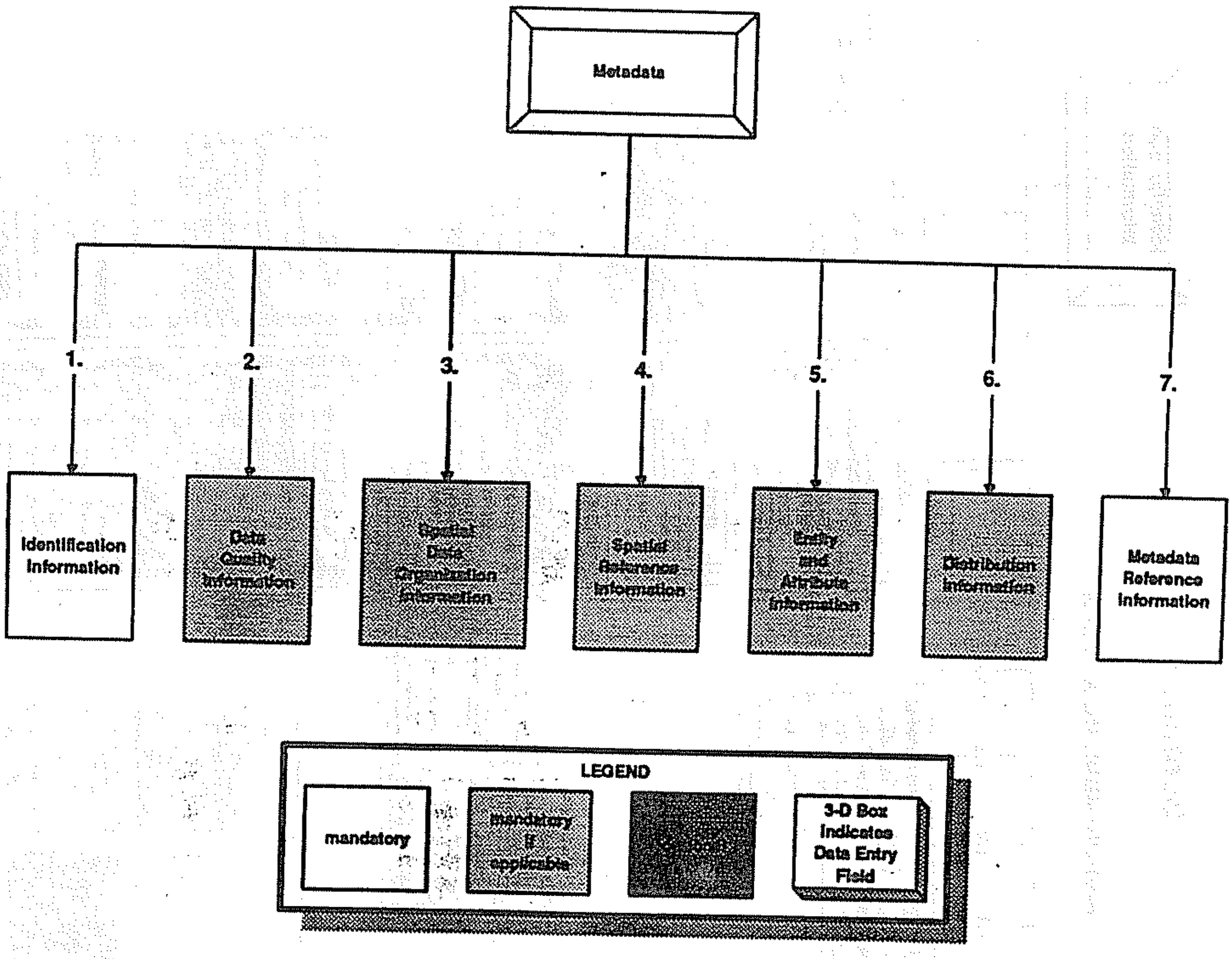
Metadata_Reference_Section:

Metadata_Date: 19950308
Metadata_Contact: dr
Metadata_Standard_Name: FGDC Content Standards for Digital Geospatial Metadata
Metadata_Standard_Version: 19940608
Metadata_Time_Convention: Local Time
Metadata_Security_Information:
Metadata_Security_Classification_System: None
Metadata_Security_Classification: UNCLASSIFIED
Metadata_Security_Handling_Description: None

Graphical Representation of:
The Federal Geographic Data Committee's
Content Standards for Digital Geospatial Metadata

June 8, 1994 version

Prepared by Susan Stitt, Technology Transfer Center, National Biological Survey
in conjunction with the FGDC Standards Working Group



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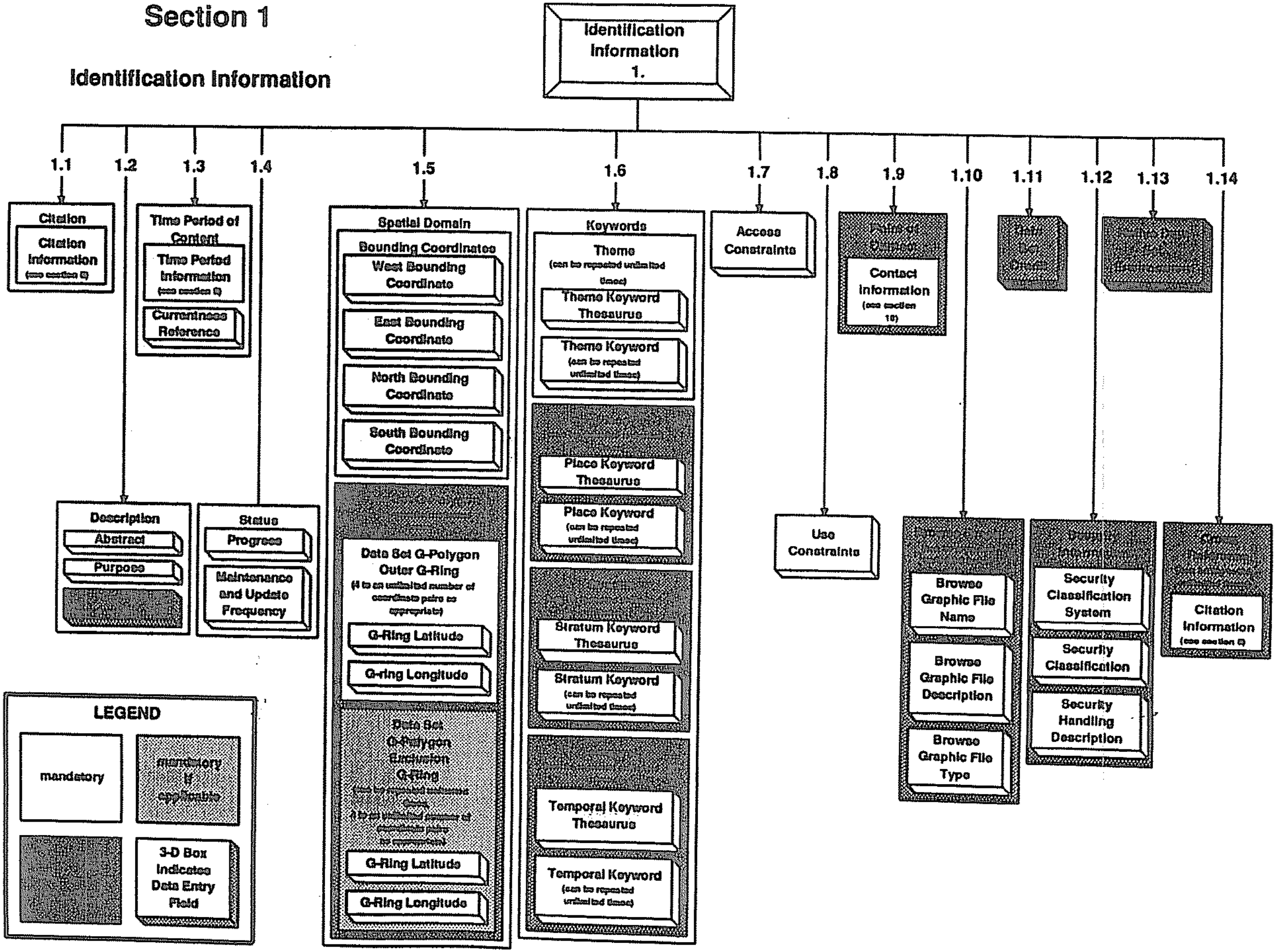

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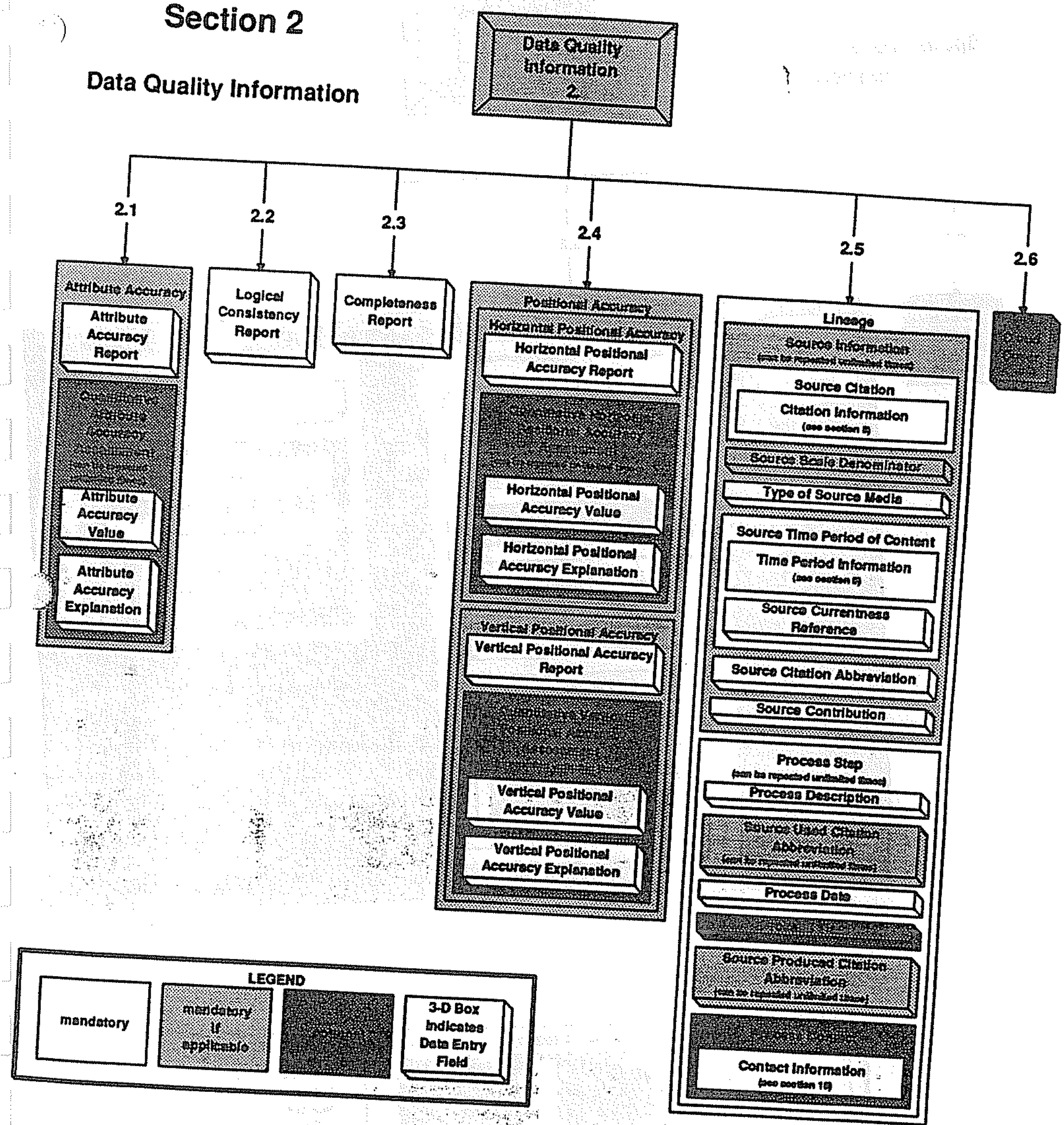

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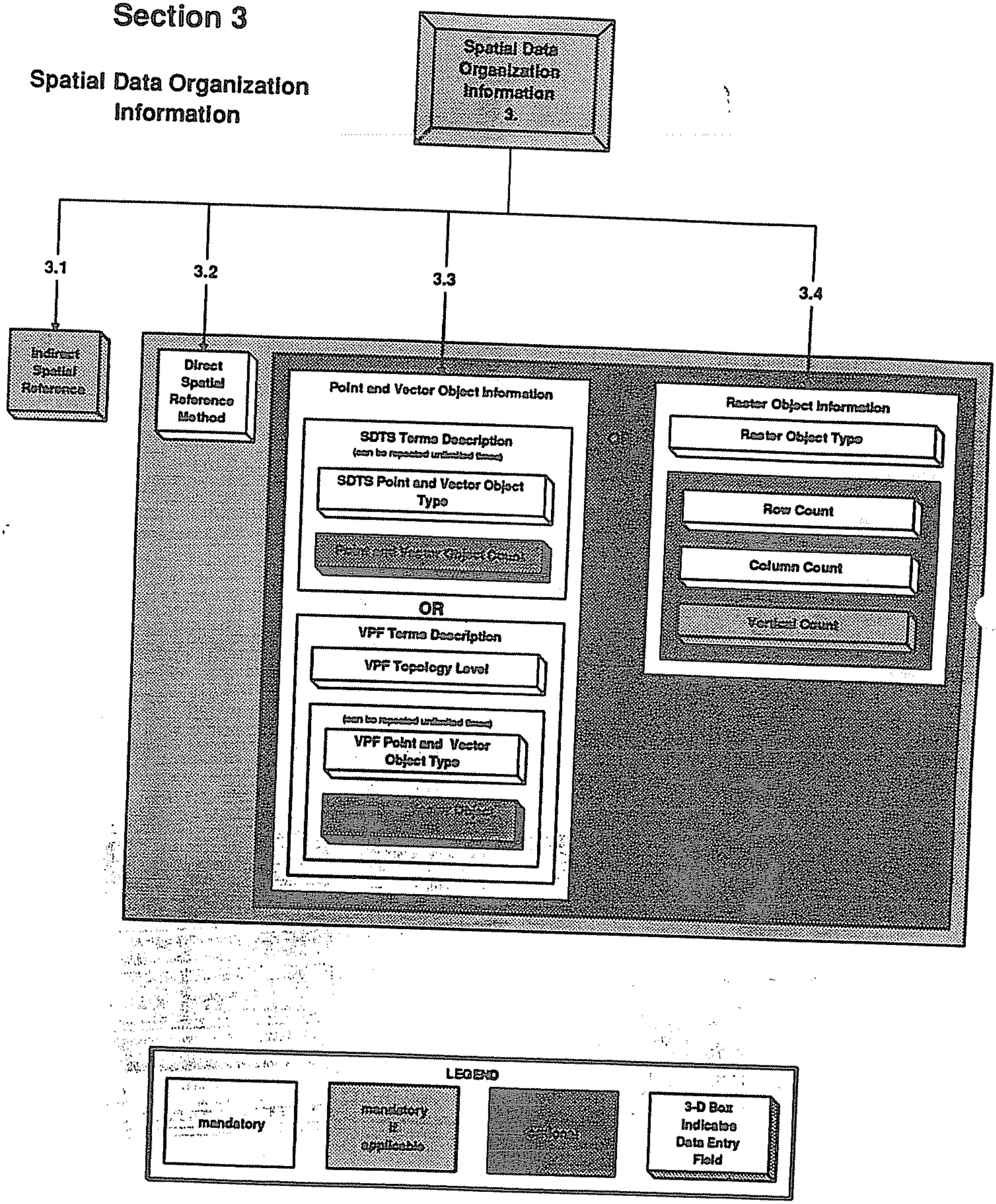

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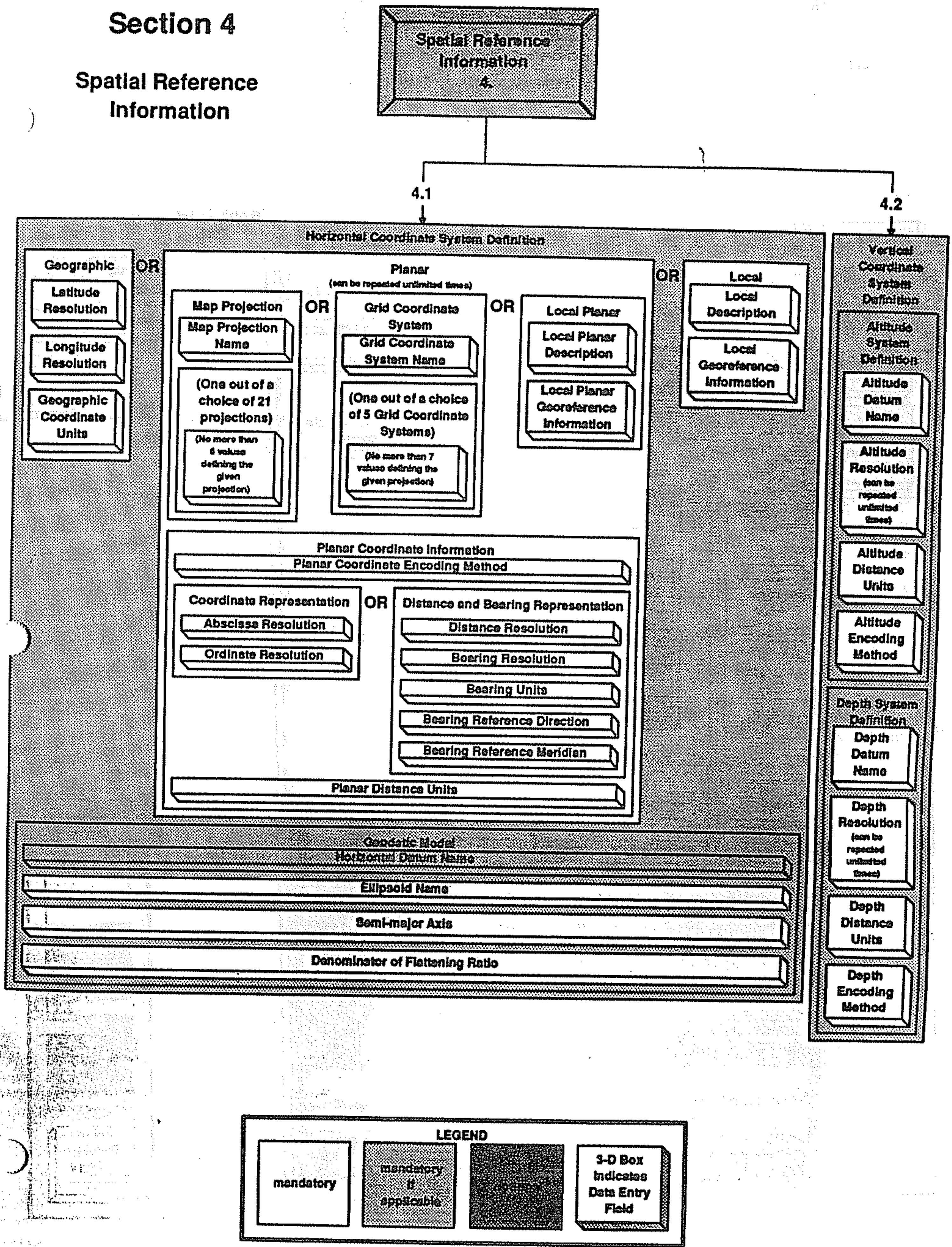

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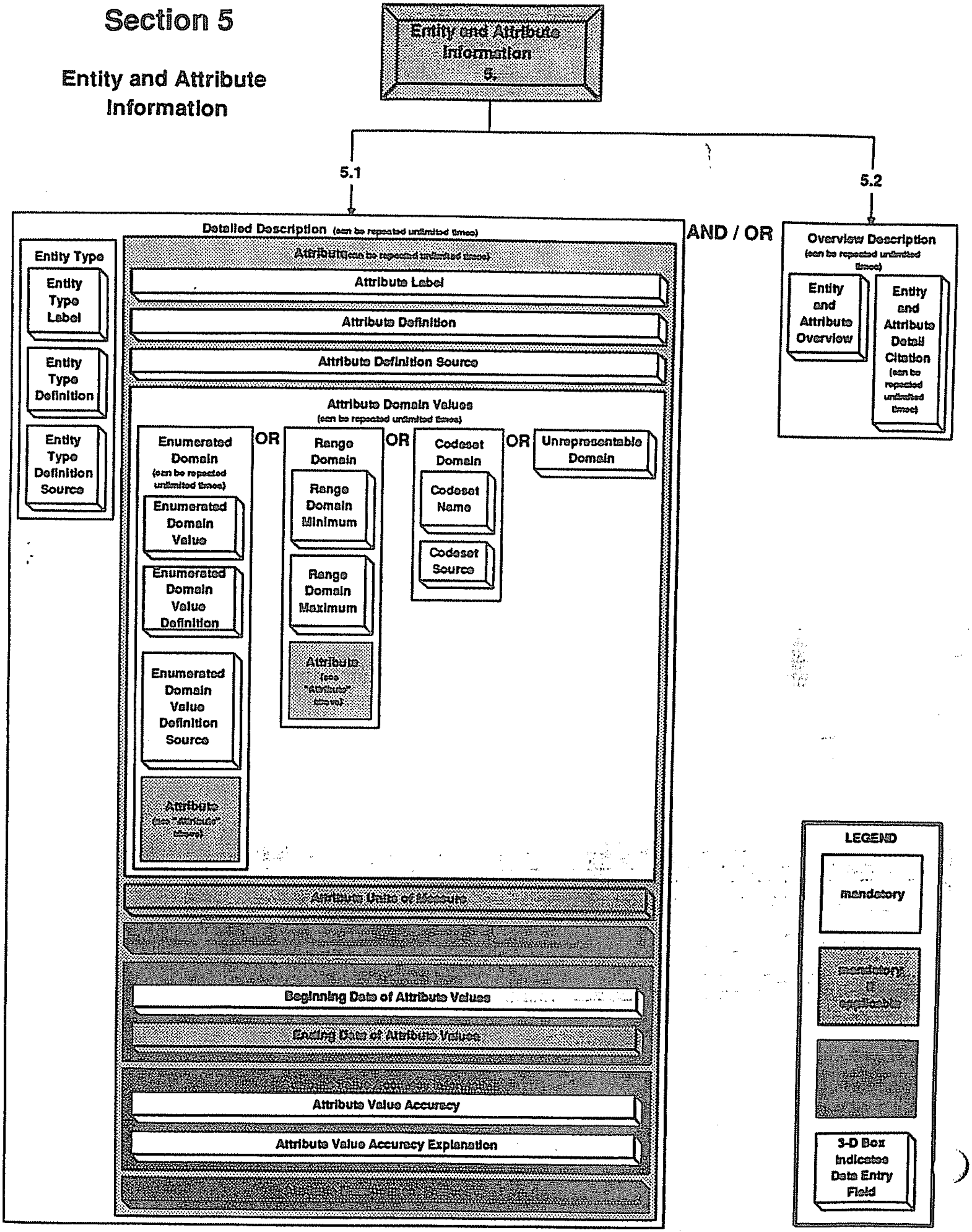

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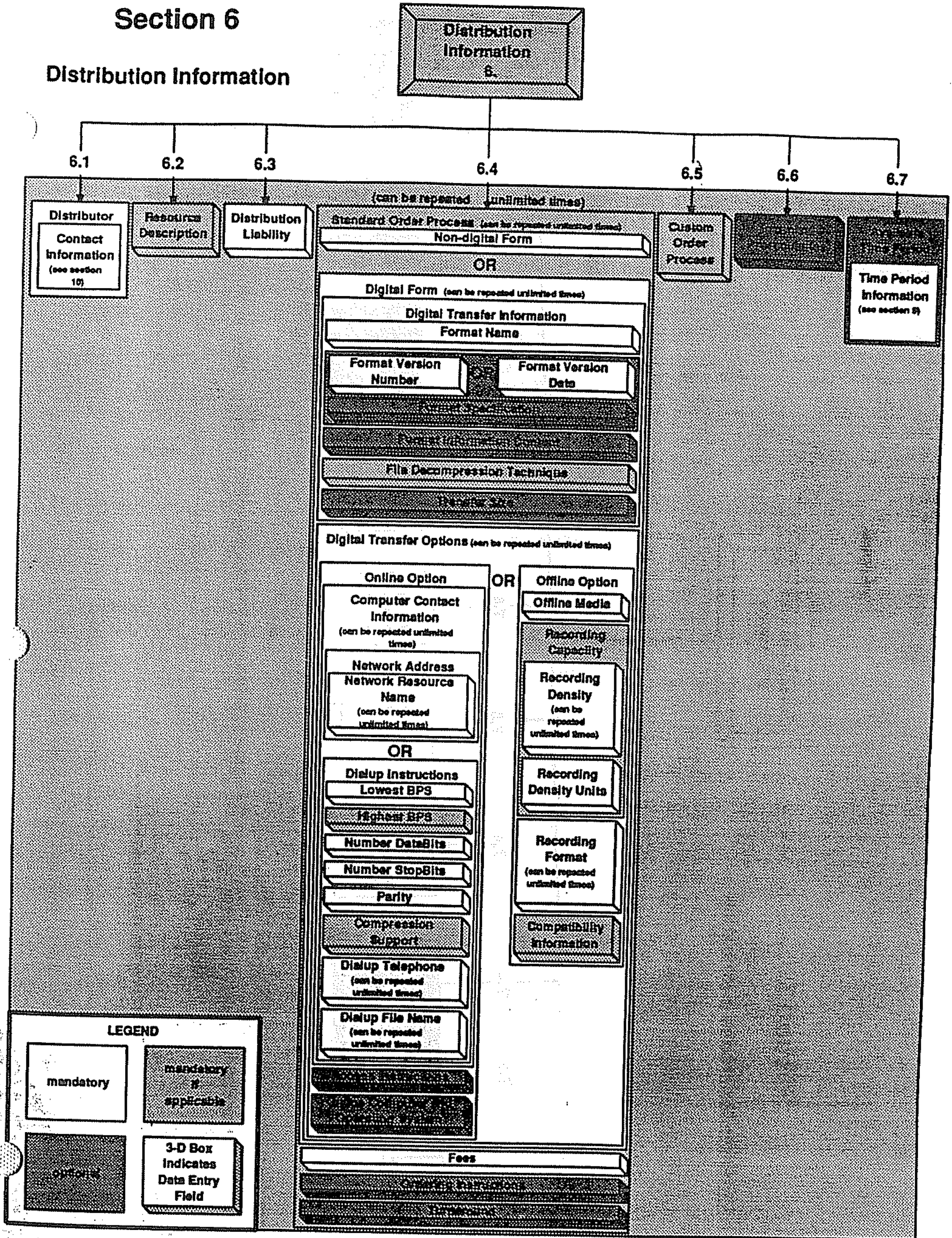

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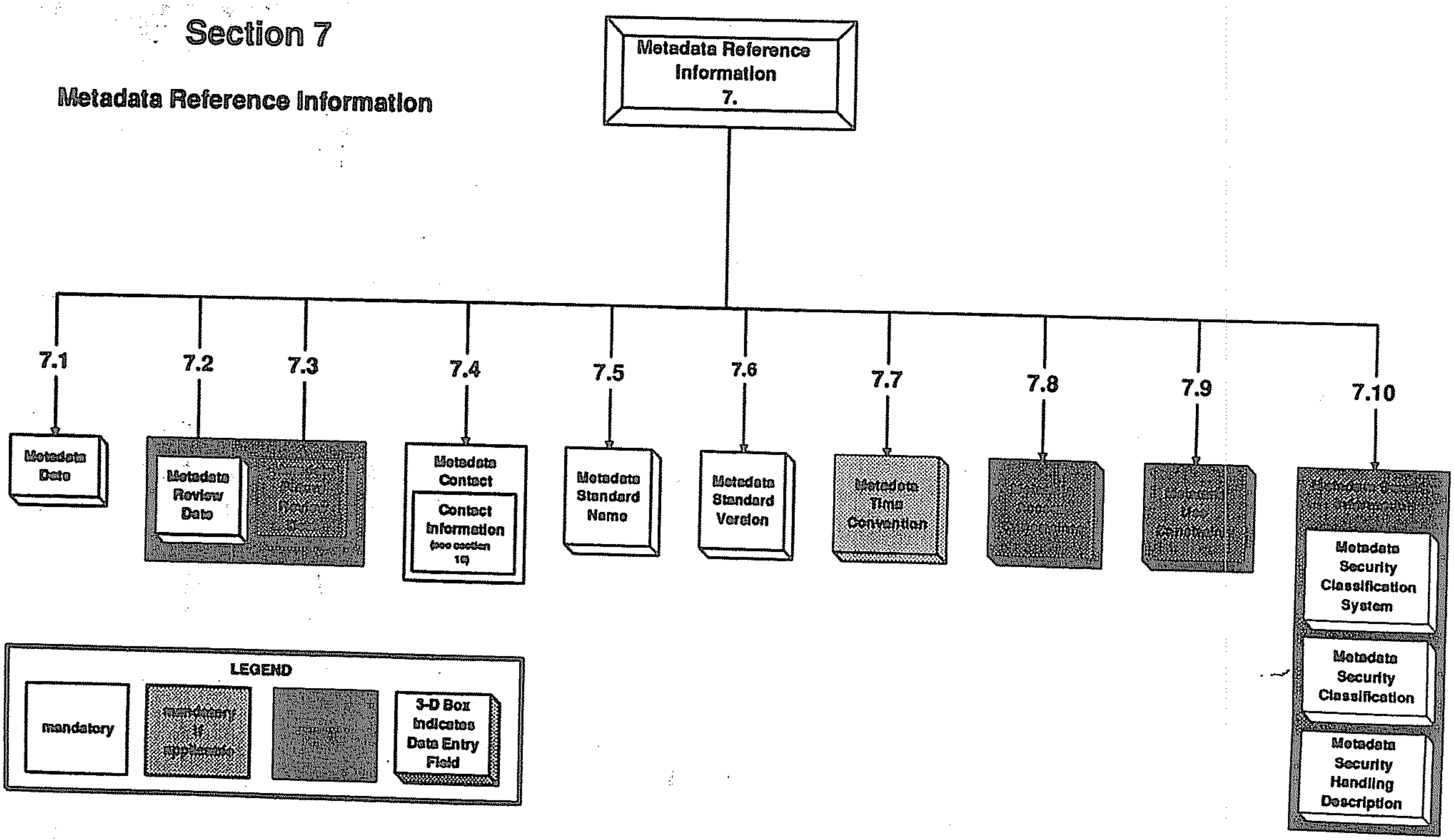
Metadata Reference Information



Section 8

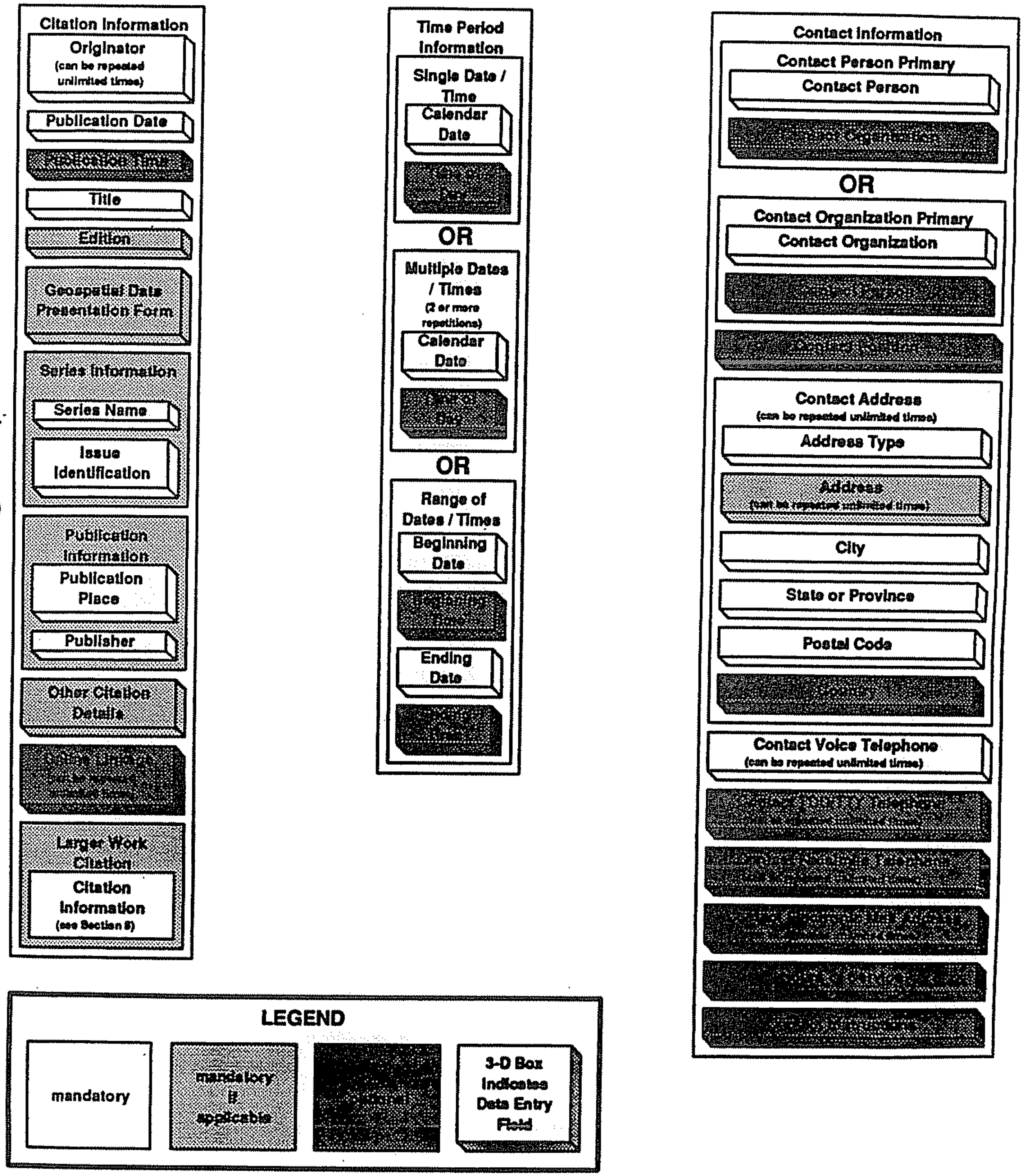
Citation Information

Section 9

Time Period Information

Section 10

Contact Information



GUIDELINES FOR IMPLEMENTING THE NATIONAL GEOSPATIAL DATA CLEARINGHOUSE

(Guidelines for Federal Agencies)
Version 1.0

Federal Geographic Data Committee

June 3, 1994

This document was distributed to the Federal Geographic Data Committee (FGDC) on June 8, 1994. It will be maintained and updated by the FGDC Secretariat and made available electronically on the FGDC server.

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Federal Geographic Data Committee

Established by Office of Management and Budget Circular A-16, the Federal Geographic Data Committee (FGDC) promotes the coordinated development, use, sharing, and dissemination of geographic data. The FGDC is composed of representatives from the Departments of Agriculture, Commerce, Defense, Energy, Housing and Urban Development, the Interior, State, and Transportation; the Environmental Protection Agency; the Federal Emergency Management Agency; the Library of Congress; the National Aeronautics and Space Administration; the National Archives and Records Administration; and the Tennessee Valley Authority. Additional Federal agencies participate on FGDC subcommittees and working groups. The Department of the Interior chairs the committee.

FGDC subcommittees work on issues related to data categories coordinated under the circular. Subcommittees establish and implement standards for data content, quality, and transfer; encourage the exchange of information and the transfer of data; and organize the collection of geographic data to reduce duplication of effort. Working groups are established for issues that transcend data categories.

For more information about the committee, or to be added to the committee's newsletter mailing list, please contact:

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1. OVERVIEW

The National Geospatial Data Clearinghouse is intended to be a distributed, electronically connected network of geospatial data producers, managers, and users. The Clearinghouse will allow its users to determine what geospatial data exist, find the data they need, evaluate the usefulness of the data for their applications, and obtain or order the data as economically as possible.

Executive Order 12906 specifies that each agency use the Federal Geographic Data Committee (FGDC) metadata standard to document new data and make them electronically accessible through the Clearinghouse. Additionally, each agency is responsible for developing a plan or procedures addressing the following questions: How will existing geospatial data be documented? How will geospatial data be made available to the public? And finally, how will the agency make use of the Clearinghouse prior to expending funds for collection of new data. Each agency will determine, according to its unique operating and management conditions, how its geospatial data will be managed and presented through the Clearinghouse. This flexibility is fundamental to keeping the Clearinghouse operational for the long term. Each agency is expected to have completed, in consultation with the FGDC, a plan for Clearinghouse implementation by April 1995.

Responsibilities and resources will need to be defined for the following activities:

Using the Content Standard for Digital Geospatial Metadata to create standardized documentation for newly collected or produced geospatial data.

Determining what is practicable for documenting previously collected or produced geospatial data.

Making the documentation electronically accessible to the Clearinghouse network.

Making geospatial data available to the public.

Adopting procedures to further cooperative efforts in collecting or producing new geospatial data.

Implicit in these activities are others such as completing an inventory of previously collected or produced geospatial data, assuring the quality of the metadata, maintaining the currentness of the metadata, and responding to queries about agency geospatial data.

The FGDC Clearinghouse Working Group developed the following guidelines to assist agencies in meeting the mandate of the Executive Order and in the development of Clearinghouse implementation plans. General policies and principles are set forth that should be used as guidance within agencies. Issues relating to implementing the Clearinghouse and options for resolving them are also described.

Experience will define operational procedures that work best for an agency to achieve the objectives of the Clearinghouse. Changes in Clearinghouse technology will likely require continual affirmation or modification of these procedures. The FGDC Clearinghouse Working Group will continue to evaluate different technologies and report on their suitability for meeting the Clearinghouse objectives. The working group will continue to make available examples of how individual agencies have accomplished their implementation of the Clearinghouse. Agencies can benefit from these experiences by participating in the working group. The FGDC server will provide current information and pointers to software and guidelines.

2. BACKGROUND

Executive Order

On April 11, 1994, the President signed Executive Order 12906, *Coordinating Geographic Data Acquisition and Access: The National Spatial Data Infrastructure*. The Order calls for the establishment and use of a National Geospatial Data Clearinghouse as described in the following excerpts:

Section 1. Definitions.

(a) "National Spatial Data Infrastructure" ("NSDI") means the technology, policies, standards, and human resources necessary to acquire, process, store, distribute, and improve utilization of geospatial data.

(b) "Geospatial data" means information that identifies the geographic location and characteristics of natural or constructed features and boundaries on the earth. This information may be derived from, among other things, remote sensing, mapping, and surveying technologies. Statistical data may be included in this definition at the discretion of the collecting agency.

(c) The "National Geospatial Data Clearinghouse" means a distributed network of geospatial data producers, managers, and users linked electronically.

Sec. 3. Development of a National Geospatial Data Clearinghouse.

(a) Establishing a National Geospatial Data Clearinghouse. The Secretary, through the FGDC, and in consultation with, as appropriate, State, local, and tribal governments and other affected parties, shall take steps within 6 months of the date of this order, to establish an electronic National Geospatial Data Clearinghouse ("Clearinghouse") for the NSDI. The Clearinghouse shall be compatible with the National Information Infrastructure to enable integration with that effort.

(b) Standardized Documentation of Data. Beginning 9 months from the date of this order, each agency shall document all new geospatial data it collects or produces, either directly or indirectly, using the standard under development by the FGDC, and make that standardized documentation electronically accessible to the Clearinghouse network. Within 1 year of the date of this order, agencies shall adopt a schedule, developed in consultation with the FGDC, for documenting, to the extent practicable, geospatial data previously collected or produced, either directly or indirectly, and making that data documentation electronically accessible to the Clearinghouse network.

(c) Public Access to Geospatial Data. Within 1 year of the date of this order, each agency shall adopt a plan, in consultation with the FGDC, establishing procedures to make geospatial data available to the public, to the extent permitted by law, current policies, and relevant OMB circulars, including OMB Circular No. A-130 ("Management of Federal Information Resources") and any implementing bulletins.

(d) Agency Utilization of the Clearinghouse. Within 1 year of the date of this order, each agency shall adopt internal procedures to ensure that the agency accesses the Clearinghouse before it expends Federal funds to collect or produce new geospatial data, to determine whether the information has already been collected by others, or whether cooperative efforts to obtain the data are possible.

Policy Statements for Federal Geospatial Data Sharing

In 1992-93, the FGDC adopted the following policy statements to express the position of the Committee on issues of geospatial data access. These are provided as general guidance to agencies in establishing a Clearinghouse activity.

The overall purpose of these policy statements is to facilitate full and open access to Federal geospatial data by Federal users and the general public. They were prepared in consonance with the goals of the Federal Geographic Data Committee, Office of Management and Budget Circular A-16 and Circular A-130, and the Data Management for Global Change Research Policy Statements. As such, they represent the U.S. Government's position on access to Federal geospatial data.

Geospatial data that are created, collected, processed, disseminated, and stored by the Federal Government are a valuable national resource. The Federal Government serves as a steward of this resource, shall exercise information resource management with special emphasis on the information life cycle, and shall ensure the effective and economical development of the Nation's spatial data infrastructure.

Agencies shall commit to the maintenance, validation, description, accessibility, and distribution of geospatial data.

Agencies shall manage geospatial data in a way that facilitates data sharing and use by other agencies and the general public. Geospatial data shall be maintained consistently among agencies. Data sharing maximizes the net return on the investment of public resources.

Federal program managers are data managers and have a responsibility to plan for information resource management as an integral part of overall mission planning. Agencies need to plan from the outset for the steps in the information life cycle.

Federal, national, and international standards shall be used to the greatest extent possible for data content, processing, and dissemination of geospatial data sets.

Agencies shall disseminate geospatial data in a manner that achieves the best balance among the goals of maximizing the usefulness of the data and minimizing the cost to the government and the public. Geospatial data products should be disseminated equitably and on timely and equal terms. Agencies should take advantage of all dissemination channels, Federal and non-Federal, including State and local governments and private sector entities, in discharging agency geospatial data dissemination responsibilities.

Agencies should set use charges for geospatial data products at a level sufficient to recover the cost of dissemination but no higher. They also should exclude from the calculation of the charges costs associated with the original collection and processing of the data. Exceptions to this policy are described in section 8a(7)(c) of the OMB Circular A-130--Revised, "Management of Federal Information Resources."

Federal agencies shall maintain an information dissemination management system for geospatial data that shall include easily accessible information about the data holdings, including quality assessments, supporting information, and guidance and aids for locating and obtaining the data.

For those programs in which selected principal investigators have initial periods of exclusive data use, the data shall be made openly available as soon as the exclusive use period has expired. In each case, the funding agency shall explicitly define the duration of any exclusive use period.

Geospatial Data Clearinghouse Operating Principles

During 1993 the FGDC Clearinghouse Working Group developed the following set of operating principles.

Metadata used in the Clearinghouse will be electronic.

"New" geospatial data will be documented with the FGDC Content Standards for Digital Geospatial Metadata. To the extent practicable previously collected or produced geospatial data will be documented using the metadata standard.

A phased approach to geospatial data inclusion will be followed. Initially, bureaus or agencies -- though encouraged to include as much geospatial data as possible -- will have discretion on inclusion, based on ability to disseminate geospatial data and other constraints. "Eventually," all geospatial data will be included in the Clearinghouse as defined in bureau or agency policies.

Geospatial data producers are responsible for creating metadata. Geospatial data "custodians" are responsible for maintaining metadata. Producers and custodians may be one and the same in some agencies.

Geospatial data dissemination mechanisms are at the discretion of bureaus or agencies.

The Clearinghouse will make use of, to the maximum extent possible, Federal Information Processing Standards, and support the development of new data standards that enhance geospatial data sharing and the ability to form geospatial data partnerships.

The Clearinghouse will ensure access to metadata through electronic means, including the use of the Internet, and dial-up access via modem over telephone lines.

3. ESTABLISH OVERALL ROLES AND RESPONSIBILITIES

The Clearinghouse may not fit discretely into existing roles and responsibilities within the Agency, and procedures for documenting and sharing geospatial data may not have been tested in many situations. Each bureau will determine individually how geospatial data producers, data managers, librarians, information resource management specialists, public affairs personnel, and others will ensure that Clearinghouse objectives are met.

One way an agency might establish responsibilities for its FGDC Clearinghouse implementation is outlined here.

Within an agency:

Determine the appropriate institutional unit(s) for development of plans and implementation of procedures. Most agencies may do this at the bureau or office level. For example, the plan for the Department of the Interior (DOI), will be the combination of the individual plans of its constituent bureaus (the U.S. Geological Survey, the Bureau of Land Management, the Fish and Wildlife Service, and other DOI bureaus).

Consider formation of a departmental or agency coordinating group (such as the Interior Geographic Data Committee (IGDC) or the Agriculture Geographic Data Committee (AGDC)) for management oversight of geospatial data activities within the organization.The coordinating group can:

Facilitate the communication among agency bureaus so "lessons learned" and technical expertise (including identification of potential contractors) are shared.

Work to ensure that each bureau head is aware of the responsibilities for and priority placed on the Clearinghouse, including allocation of resources to meet the schedule in the Executive Order.

Review plans developed by each bureau for implementing the Clearinghouse, to ensure the appropriate level of implementation occurs throughout the department or agency.

Establish accountability for organizations participating in the Clearinghouse. Responsibilities include:

meeting the deadlines for using the FGDC metadata standard.

making the metadata accessible to the Clearinghouse.

planning for documenting the bureau's previously collected or produced geospatial data.

making the bureaujs geospatial data available to the public.

Within an organization:

Staff and resources should be identified to accomplish the following:

establish policy guidance on geospatial data access and dissemination, and ensure that Clearinghouse operations are consistent with such guidance.

allocate sufficient staff and funds to meet the deadlines in Executive Order 12906.

determine what geospatial data, beyond metadata, will be made available to the public.

create the metadata for new geospatial data.

ensure the metadata comply with the FGDC standard, to the extent possible for that organization.

provide training and technical assistance to metadata producers, quality assurance personnel, and end users.

update and maintain metadata as necessary.

develop a plan for documenting previously collected or produced geospatial data, including defining what geospatial data are appropriate to add to the Clearinghouse.

specify, acquire, and manage the hardware, software, and telecommunications services so the metadata is electronically accessible through the Clearinghouse.

determine how to set up directories; organize, label, or standardize filenames; and link or crossreference geospatial data and metadata to ensure consistency, maintainability, easy query or search, and easy access.

respond to questions about or orders for geospatial data sets.

ensure consistency between Clearinghouse procedures and those required to meet the National Archives and Records Administration guidance for records inventories and preservation schedules.

4. DEVELOP AN INVENTORY OF GEOSPATIAL DATA

Agencies will have different ways of deciding what previously collected or produced geospatial data to add to the Clearinghouse. Maintaining a data inventory is an important part of good data stewardship and applied records management. The purpose of a data inventory at this stage in the Clearinghouse plan is to:

determine which programs or individuals produce, manage, or disseminate data that are to be included in the Clearinghouse.

identify what geospatial data an agency holds, where the data are located, and their condition.

identify priorities for documenting previously collected or produced data based on demand, geographic extent, uniqueness, or other criteria to be determined by the agency.

The inventories developed for geospatial data will contribute to developing the records schedules needed to comply with National Archive and Records Administration requirements as defined in 44 U.S.C. 3301.

5. ESTABLISH CRITERIA AND STRATEGIES FOR METADATA DOCUMENTATION

In planning to document previously collected or produced geospatial data, priority should be given to those data sets of the greatest potential value to other users. This will require evaluating who might be interested in the geospatial data, the unique nature or value of the data, the age of data, size of the data set, and cost to document the data. A summary of cost and a schedule overview for all geospatial data sets to be documented could also be developed to provide managers with necessary planning information.

The Executive Order does not require that the FGDC Content Standard for Digital Geospatial Metadata be used to document previously collected or produced geospatial data. Agencies are, however, required to document such geospatial data and make that documentation electronically available through the Clearinghouse. Since geospatial data collected or produced after January, 1995, will have to use the metadata standard, the practicability of continuing support for older documentation standards within the agency will need to be evaluated.

One of the requirements for the agency is to begin using the FGDC Content Standard for Digital Geospatial Metadata to document all new geospatial data collected or produced, either directly or indirectly. This will likely involve some modification to current practices to ensure that the required documentation is efficiently collected or produced during the production process. The FGDC Secretariat has initiated discussions with commercial GIS software vendors to provide integrated tools to populate the metadata directly from different systems.

The plan should also identify the techniques to be used in making the metadata electronically accessible to the Clearinghouse. These could include options ranging from hosting the information on agency servers, bureau servers, or commercial servers. The bureau should choose the best and most cost effective technique for the data item that is consistent with law, regulation, organizational structure and data management policies.

Once the plan has been developed, it should be submitted to the bureau's management for review, and where appropriate, for review by other bureaus, the agency coordinating committee, or other organizations. The approved plan should be issued by the bureau head to ensure the widest possible implementation.

6. ESTABLISH PROCESSES FOR SERVING METADATA AND GEOSPATIAL DATA

Organizational Considerations

In some organizations, individual geospatial data producers with small holdings may choose to provide access to metadata and geospatial data. For larger holdings, or within organizations with different data management approaches, aggregation at a regional or higher organizational level may be more practical. The roles of geospatial data producer, data custodian, and data distributor will vary among agencies. A single individual at a single site may perform all three roles, or the responsibilities for each role may be at widely distributed locations and organizations.

In the Department of the Interior, for example, each bureau probably will individually manage the process of identifying and adding data to the Clearinghouse. Within some bureaus, the Clearinghouse process may be managed by a single office to ensure quality control and timely metadata updates. In other bureaus, individual programs or geographically dispersed offices may manage their metadata and Clearinghouse systems separately. In some cases, one bureau may serve or distribute the data of another.

Normally, responsibility for initial metadata creation will rest with the producer of the geospatial data. Most of the required metadata is known to the producer during the generation of the data. When this producer is a contractor, the agency still has the responsibility to ensure metadata are generated and made available. Improvements in GIS and other software will make compliance with the FGDC metadata standard more feasible, though substantial training and technical assistance will be required. The responsibility for reviewing the initial metadata for completeness and reliability, and for actually managing the computers on which the metadata reside, could be combined, assigned to separate units within an agency, or managed through outside organizations, including contractors.

Hardware and software technologies compliant with the Government Information Locator Service (GILS) Profile will meet the objectives of the Clearinghouse. The technology used in the prototype Clearinghouse, Wide Area Information Servers (WAIS), meets this requirement. Agency bureaus will not be required to implement all variations of data sharing technology, but each bureau must make its metadata accessible electronically by at least one approach compliant with GILS and recognized by the FGDC.

Current technologies for serving geospatial data range from establishing an anonymous file transfer (FTP) site to the use of WAIS, Gopher, World-Wide Web, or other commercial or public domain data serving software. Type of data, agency preferences, and evolution of new tools and groups of users will affect which of these options an agency chooses to select. Agencies that have extensive holdings and can support the necessary infrastructure are encouraged to deploy improved technologies as they become available.

An agency may provide access to their metadata and geospatial data either using its own information resources, through service arrangements with another agency, or through a contractor.

Those agencies that distribute metadata or geospatial data on fixed media, such as CD-ROM, also need to provide a way for their metadata to be searched electronically via the Clearinghouse. Providing access to metadata and geospatial data through the Clearinghouse meets the requirement of the executive order; additional modes of data distribution are at the discretion of the individual agency.

Technical Considerations

The level of Internet services needed will vary depending on the volume of metadata and geospatial data that will be served. For those agencies that do not have Internet services, the Government-Wide Internet Access initiative is expected to provide some capabilities. In addition, the InterNIC InfoGuide (at http://www.internic.net/ or contact the InterNIC staff at 800 444 4345) has information about the Internet, including a listing of service providers.

In connecting an agency to the Internet, security considerations must be addressed. Protection of internal systems and networks, along with data and information that is sensitive or has release restrictions, will need to be assured. Managers will need to protect these organizational assets. Security policy must, of course, conform to existing policies, regulations, and laws. Data of significant value included in the Clearinghouse, will likely fall under the auspices of the Computer Security Act of 1987, Public Law 100-235, and require an appropriate level of protection. The Internet Engineering Task Force's Site Security Handbook (RFC 1244) is a place to start in determining levels and types of computer security policies and procedures needed. The National Institute of Standards and Technology has information on computer security at ftp://csrc.ncsl.nist.gov/.

Staffing Considerations

Technical knowledge and experience requirements will vary within and among agencies. A minimum level of competence in computer system operation, electronic networking, the UNIX operating system, Internet protocols, and system security will be needed at some place within the agency or must be easily accessible under contract. The abilities to set up and maintain the server software systems will be needed by those involved in geospatial data dissemination.

Knowledge and understanding of the content of the geospatial metadata and data holdings, and geospatial data applications experience, will also be needed for development of the metadata documentation and procedures and for assistance to users of the metadata and geospatial data. Training guides in the use of the metadata standard are under development by the FGDC. Additionally, the FGDC Secretariat will continue to sponsor training courses in metadata and the Clearinghouse (for information about this training, telephone 703 648 5514, or send a message to gdc@usgs.gov).

Logistical Considerations

Existing review and approval processes should be examined for their applicability to electronic dissemination. Existing policies should be extended, where possible, to avoid inventing new ones.

In making metadata and geospatial data electronically accessible, an agency should consider whether there is a single official version and a means to verify the approved status, or whether researchers, analysts, and data managers may serve whatever data they have available. Maintenance of current information is a responsibility and will cost money. A common look and feel to graphical and textual materials within an agency or bureaus can make information easier to find. A wide range of user access methods and modes, which are likely to continue to change, exist, and systems should be designed for maximum accessibility.

Other operations and information sources will need to be coordinated with electronic dissemination. If not already in existence, a distribution process will need to be established for organizations who cannot, or choose not to, provide the geospatial data electronically. Policies regarding charging for special services will need to established or extended.

7. USE THE CLEARINGHOUSE

Inform the Users

Some users likely will consistently use the Clearinghouse as part of their normal duties. Others will use it only intermittently. Making agency holdings electronically accessible will also create new users and constituencies. Outreach activities that address the needs of both types of users will need to be conducted. Brochures or other means advertising data availability within an agency may be useful. When an agency establishes a site for serving metadata or data, the FGDC Secretariat should be notified (telephone 703 648 4543, or send a message to tmccullo@usgs.gov). The FGDC will maintain an information server of servers (initially at ftp://fgdc.er.usgs.gov/) to help in the navigation of the network to find geospatial data. This FGDC server will provide one location to point users to geospatial data sets.

Train the Users

Internal users will need training that may include how to use computers, how to use computer- based tools, how to use the Internet, and how to use the appropriate software for querying, and obtaining metadata or geospatial data. Training in how to use the information obtained through the Clearinghouse may also be needed. As noted above, classes are being offered and training materials are under development for this last task.

Use the Clearinghouse During Planning

The Executive Order requires that agencies adopt procedures to ensure that the Clearinghouse is checked before expending Federal funds for new geospatial data collection or production. Organizations might consider tracking of planned geospatial data collection activities. Additionally, the FGDC intends to support a Clearinghouse data base that will allow users to register interest in data in specific geographic areas. The Clearinghouse may also be used to document planned geospatial data collection. This allows for maximum efforts with State, local, tribal, and other non-federal agencies to share costs and improve efficiency in acquiring geospatial data. Agencies must document these procedures and approaches in their plans.

8. MEASURE PROGRESS

Over the next several months, the Clearinghouse Working Group, the Coordination Group, and the FGDC will discuss means of measuring progress in development of the Clearinghouse. Measurements may include: number of programs serving geospatial data, number of servers connected to the Internet, number of data sets documented with the metadata standard, number of data sets served to the network, percentage of data sets documented or served, number of accesses to a server, number of organizations using a server, or specific problems that have been solved based on data access through the Clearinghouse. Agencies should begin to consider measures that would indicate progress.

National Digital Geospatial Data Framework: A Status Report

While applications of digital geospatial data vary greatly, users have a recurring need for a few common themes of data. Because of a lack of coordination, common approaches, and investment, these needs are not being met. This situation results in important information not being available for many areas, and many organizations supporting data that are basically the same for other areas. A system does not exist to maintain and manage the variety of common information being collected by the public and private sector.

Representatives from local, State, and Federal agencies are developing the concept of a framework of geospatial data to meet this need. This Framework Working Group, organized by the Federal Geographic Data Committee (FGDC), is identifying the purpose, goals, and content of the framework, how it would work, and reasons why organizations should participate. This fact sheet describes the status of the working group's discussions.

Purpose and Goals

The framework is a basic, consistent set of digital geospatial data and supporting services that will:

- provide a geospatial foundation to which an organization may add detail and attach attribute information.
- provide a base on which an organization can accurately register and compile other themes of data.
- orient and link the results of an application to the landscape.

The framework should be widely used and widely useful:

- Framework data should be "data you can trust," and should be certified as complying with standards.
- Framework data should be the "best" data available. These data often are collected by local governments, utilities, regional and field offices of State and Federal agencies, and others.
- Along with these high-resolution data, the framework should contain consistently generalized, lower-resolution data to support regional and national applications. These data should be created from higher-resolution framework data where available.
- Users must be able to integrate framework data into their applications while preserving their existing investment in attribute and other information.
- Framework data should be accessible at the cost of dissemination, free from use criteria or constraints, and available in non-proprietary forms.

The framework will depend on many organizations contributing to its construction and maintenance:

- Rules for contributing to the framework, and the requirements placed on contributions, should be minimal and stable.
- Contributions will be from a large number of geographically distributed organizations, which have different missions and goals.

The framework should evolve with users' and contributors' changing requirements and capabilities.

Benefits

The success of the framework depends on both contributors and users recognizing its benefits. The framework will help a participant:

- gain customers for other data products and services by making data easier to use and by increasing the number of organizations that use geospatial data.
- reduce expenditures for data collection and integration by avoiding the costs of redundant activities.
- focus on its primary business by ensuring the availability of reliable information.
- simplify and speed the development of applications.
- benefit more quickly and easily from data gathered by others.
- gain recognition of its programs.

Technical Characteristics

The framework:

- is composed of geographically distributed data holdings that are connected through information networks and digital media and are accessible using a common query mechanism.
- supports transactional updates that minimize impacts on producers and users.
- employs feature-based encoding of geographic phenomena and the use of attributes for non-locational information. Locational (coordinate) information is encoded in associated spatial objects. Vector-based spatial objects will conform to topological rules.
- may provide multiple resolutions of data for any given location.
- uses permanent feature identifiers that serve to associate framework and users' attribute data, to identify data involved in transactions, and to link multiple representations of features.
- uses common means of referencing coordinate positions, based on nationally-recognized horizontal and vertical datums.

• retains past versions so that data are available for historical or process studies.

• preserves positions of contributed data. Edges of adjoining contributions will not be adjusted, although the disjoint lines will be associated through a common feature. Alignments in generalized data may be joined if the alignment errors can be resolved within the error tolerances.

• integrates data across themes where possible.

Information Content
Framework data include:

• *Geodetic Control* — geodetic control stations, and their names, unique identifiers, and locations and orthometric and ellipsoid heights with accuracy information.

• *Digital Orthoimagery* — georeferenced image prepared from a perspective photograph or other remotely-sensed data in which displacements of images due to sensor orientation and terrain relief have been removed. Framework data may range in resolution from sub-meter to tens of meters.

• *Elevation Data* — for land surfaces, an elevation matrix; for depths, soundings and gridded bottom models. Shorelines will have the attribute of shoreline type (or tidal reference).

• *Transportation* — roads, trails, railroads, waterways, airports, ports, bridges, and tunnels. Attributes include a permanent feature identifier and name. Where available, linear referencing systems will be used as the identifier. In addition, roads will have the attributes of functional class and street address range. Trails and railroads will have the attribute of type.

• *Hydrography* — reaches, based on the approach of the U.S. Environmental Protection Agency's Reach File Version 3.0 (RF3). Reaches will have the attributes of reach code, name, reach type (eg. stream or lake), and spatial representation.

• *Governmental Units* — Nation, States, counties, incorporated places and consolidated cities, functioning and legal minor civil divisions, American Indian Reservations and Trustlands, and Alaska Native Regional Corporations, each with the attribute of name and applicable Federal Information Processing Standard (FIPS) code. Boundaries will include information about associated features and the type of association.

• *Cadastral* — cadastral reference systems (such as the Public Land Survey System), large publicly-administered parcels (e.g. military reservations or state parks), and survey corners and boundaries. Each will have a name or other common identifier and quality information.

Institutional Roles
The framework will be operated and maintained by a group of participants that agree to provide digital geospatial data that meet content, quality, policy, and procedural criteria. Roles include:

• *Data Producer* — provides the contributions on which the framework is developed. Produces or maintains framework data to standards (including attributes, metadata, and quality testing). Some producers may provide framework data under contract.

• *Area Integrator* — ensures that framework data for a geographic area are coordinated. Implements standards and certification policies and procedures, coordinates maintenance activities within the theme or among themes, and processes updates. Areas of responsibility could cover a State, a group of States, or part of a State.

• *Data Distributor* — provides data to users. Designated distributors will be charged with holding the official distribution copy.

• *Theme Manager* — provides continuing operational support nationwide. Delegates production responsibilities, coordinates integrators, serves as a producer and integrator "of last resort," generates lower-resolution data, develops certification policies and procedures, develops and recommends standards, and ensures a safe archive.

• *Theme Expert* — provides the technical perspective of the community knowledgeable about a theme of data. It is likely that this community will generate the bulk of the data for a theme.

• *Policy Coordinator* — provides overall guidance to the otherwise distributed roles for the framework. This role includes approving standards; identifying resource needs and working with others to obtain resources; designating theme managers; resolving issues that develop among themes; initiating pilot studies, concepts, and implementation strategies; and encouraging partnerships.

Next Steps
Work is underway to develop an implementation strategy. The implementation will be phased, with the goal to have an initial implementation of a national geospatial data framework by the year 2000.

Public comment is sought to help refine the concept. Framework sessions are planned for the URISA and other conferences.

To obtain additional details about the framework or to provide comments, please contact the FGDC Secretariat by mail at the U.S. Geological Survey, 590 National Center, Reston, Virginia 22092; by telephone at (703) 648-5514; by facsimile at (703) 648-5755; or by Internet at gdc@usgs.gov. Additional information about the framework also is available by anonymous FTP from fgdc.er.usgs.gov

Development of a National Digital Geospatial Data Framework

A Status Report from the Framework Working Group

Contents

Abstract

While applications of digital geospatial data vary greatly, users have a recurring need for a few common themes of data. Because of a lack of investment, coordination, and common approaches, these needs are not being met. This situation results in important information not being available for many areas, and many organizations supporting data that are basically the same for other areas. A system does not exist to maintain and manage the variety of common information being collected by the public and private sector.

The concept of a framework to organize and enhance the activities of the geospatial data community to meet these needs is being developed by representatives of local, State, and Federal agencies under the auspices of the Federal Geographic Data Committee (FGDC). This Framework Working Group identified the purpose and goals for the framework; identified incentives for participating in the framework; developed preliminary technical, operational, and business contexts for the framework; and specified the institutional roles needed for the framework. The Federal Government expects that the results of this effort may help to organize data collection efforts[1]. Aspects of the framework are underway in many parts of the community, and the working group hopes that these efforts will use these ideas to plan more effectively for the future.

Where Are We?

The use of digital geospatial data and geographic information systems continues to expand into many activities in the public and private sectors. While the needed geospatial data can vary greatly in geographic area, purpose, and content, these needs almost always include a few, basic themes of data. This information — geographic features such as roads, railroads, streams, lakes, governmental units, cadastral information, and elevation — provide a framework for data collection and analysis activities. They may merely orient an audience and link the results of an application to the landscape. They provide the geospatial foundation on which an organization may perform analyses and to which it may attach attribute information. Or they provide a base on which an organization can accurately register and compile other themes of data.

Because of an insufficient investment of resources, the lack of innovative institutional arrangements, and the lack of common technical approaches, the Nation has not organized its resources to develop and maintain these important data. The relative importance of these factors varies geographically and by theme of information. The results of the situation include:

- In many parts of the country, there are no data, or the data are incomplete and not maintained. Investment is needed to collect and maintain even low resolution framework data.
- In other parts of the country, high resolution data that could contribute to a framework are being collected[2] but are not widely available. Reasons for this situation include:

- a lack of arrangements by which these data routinely can be located and made available to others.

- a lack of institutions to coordinate data collection and maintenance; accept, certify, and incorporate data contributions; and receive and act on reports of errors.

- a lack of standards that would simplify the integration of data across local boundaries or for a large area.

- a lack of standards that enable data to be integrated into other organizations' data holdings without endangering their existing investments in spatial and attribute data.

- a lack of a certification process for data, which hinders data sharing efforts, especially in cases where a number of organizations are involved.

- a lack of plans, or knowledge of plans, to maintain data.

• Many organizations are collecting data, but a relative few are at the point where they routinely maintain data. In the long term the issue of duplicated maintenance efforts is by far the largest cost issue.

These factors cause great uncertainty and confusion. An organization faces several options to meets its needs for data. It may collect (and then try to maintain) the data — often a time consuming and expensive task that is outside the primary business of the enterprise, and that may duplicate the work of other organizations. It may try to obtain the data from other organizations — a time consuming task of locating sources of data, negotiating different arrangements and licenses for data, integrating a multitude of data collected to different standards and specifications, and trying to make arrangements to receive updates. A lack of framework data may cause organizations that collect other thematic data to locate and register observations inaccurately, and thus face the inability to analyze its data properly or integrate them with data from others.

Purpose and Goals

The framework is a basic, consistent set of digital geospatial data and supporting services that will:

• provide a geospatial foundation to which an organization may add detail and attach attribute information.

• provide a base on which an organization can accurately register and compile other themes of data, such as soils, vegetation, or geology.

• orient and link the results of an application to the landscape.

The framework will help data producers to locate their information in its correct position and provide a means of integrating this information with other geospatial data.

The framework should be widely used and widely useful. Inherent in this goal are the following:

• The framework will be "data you can trust." The framework will provide a nationally accepted and used referencing capability that will reduce the recollection, duplicate collection, or incompatible collection of data. Framework data will be certified as complying with standards for different characteristics.[3]

• The framework data will be a robust set of information:

  - The framework should contain the "best"[4] data available. It should incorporate the high resolution data collected by local governments, utilities, regional and field offices of State and Federal agencies, and others.

  - The framework also should include consistently generalized, lower resolution data needed for regional or national studies. These data should be produced from higher-resolution framework data. Links or references among different representations of features should exist.

• The framework data should represent real world features (and not cartographic symbols).

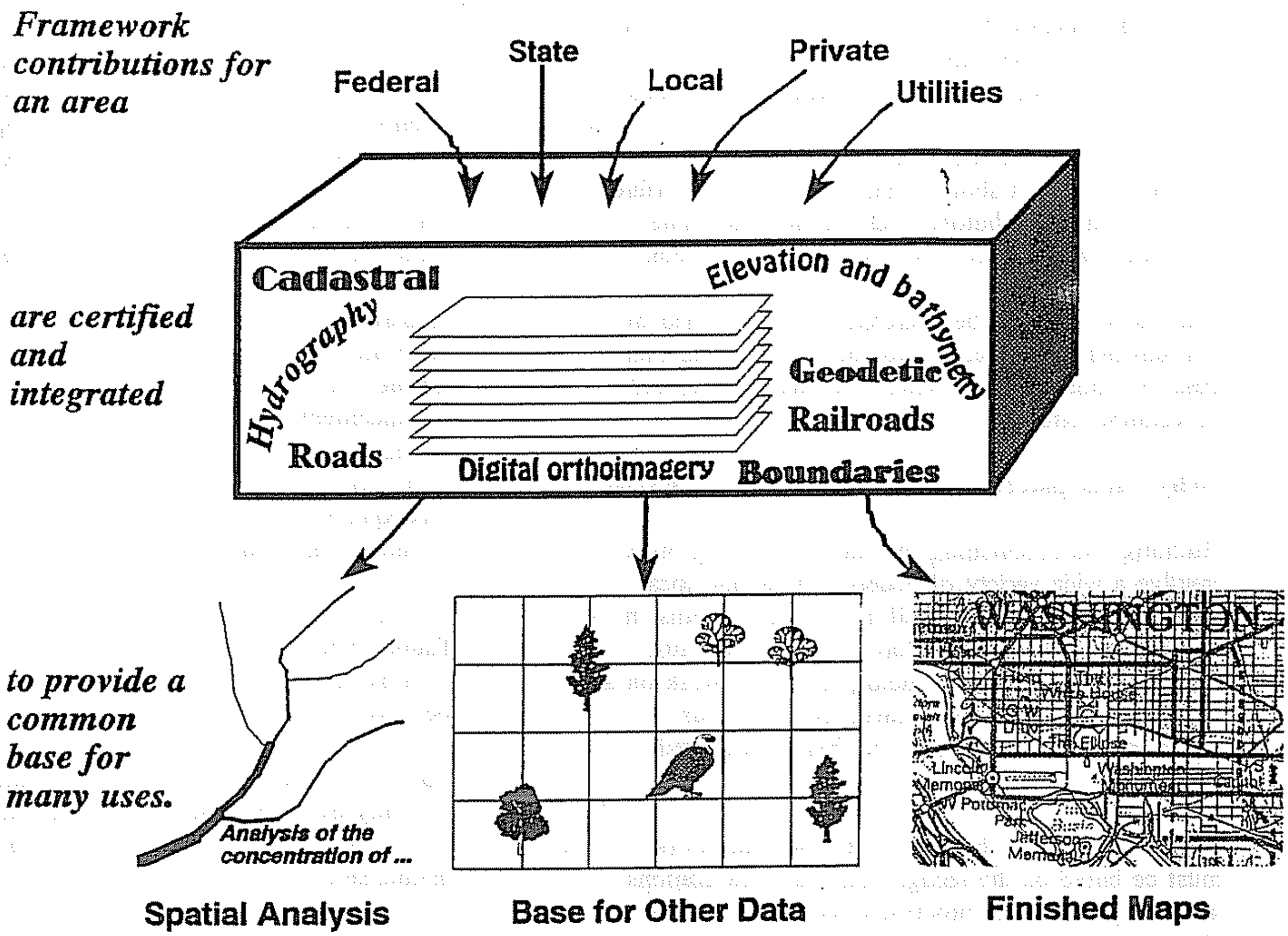

Figure 1. Framework data would provide a geospatial foundation for many activities.

- Users must be able to integrate framework data into their applications and still preserve an existing investment in attribute and other information.
- The framework should be a reliable and dependable supplier of data. The technical demands for using the data should be minimal and stable. The framework should be implemented quickly and evolve with users' changing needs and capabilities.
- Access to the framework should be available at the least possible cost. The goal should be to provide data at no more than the cost of dissemination. There should be no restrictions on the use of data obtained from the framework, but value-added products may be generated based on framework data.
- The design of framework data sets must consider the needs of Federal, State, and local government users, and of the private sector.

The approach to building the framework should encourage many organizations to contribute to its construction and maintenance. Inherent in this goal are the following:

- The framework should be reliable and dependable. The technical and other demands placed on contributors should be minimal and stable. The framework should be able to incorporate as wide a range of data as is possible.
- The framework should evolve with contributors' changing requirements and capabilities.

- The framework should be able to accommodate the contributions of a large number of geographically distributed organizations, and be sensitive to the different missions, goals, resources, and schedules of these organizations.

- The framework should provide basic information. It should enhance, and not interfere with, the contributors' plans to provide value-added information and services for their data.

The framework will be operated and maintained by participants who agree to provide digital geospatial data that meet various content, quality, policy, and procedural criteria.

Why Participate?: Benefits from the Framework

Building and maintaining the framework data must involve a wide variety of Federal, State, and local government agencies as well as private concerns in an ongoing, cooperative effort. Contributors must see clearly the benefits of doing any more work on a data set than is required to meet its own needs. Users must understand how the framework would aid them.

Careful analysis of the benefits of the framework must be based on the recognition that organizations increasingly are both producers and users of data. Contributing data to the framework may require a little more effort than an organization requires for its immediate needs, but the organization recoups this investment when it uses data from the framework, or thematic and attribute data registered or linked to the framework, that are provided by others.

The framework would help an organization:

- reduce expenditures for data collection and integration. Reducing redundant data collection and integration will offer cost avoidance and improved capabilities for the same level of investment.

- focus on its primary business ("back to basics"). As an organization sees that reliable information is or will be available, one can make more rational, less risky decisions to focus effort on what that organization does best and needs most. This argument becomes more telling as one considers the effort required to maintain data sets once they are acquired.

- simplify and speed the development of applications:

  - Critical applications needed for emergency response, natural resource management, and economic development can be developed more quickly and operated more effectively as errors and uncertainty are reduced, and one does not have sole responsibility for the entire data set the applications require.

  - Expert staff, whose skills often cannot be replicated at any price, can spend their time on the system development and data enhancements needed for an application instead of on the basic geospatial data. Users will spend less time struggling with inadequate information, and in correcting or updating basic information.

  - Permanent feature identifiers and standard feature categories will mean software, as well as the information it manipulates, can be reused much more broadly and easily.

  - Having standardized information available will improve the quality and reduce the cost of systems development, training, and data maintenance.

- gain customers for other data products and services. The framework is designed to be a basic geospatial reference set to which other information can be linked. Participants that also provide spatially-referenced attribute data that can be linked to the framework can increase their customer base.

- benefit more quickly and easily from data collected by others. Other organizations will use framework data as a base on which to register other themes of data, or attach attribute information. Organizations whose data form the framework will find it easier to incorporate and take advantage of these other data.

- gain recognition of program. Framework participation may offer increased funding or avoidance of funding cuts. Being recognized as a contributor to the framework effort will give participants higher visibility and credibility in the competition for scarce funding or for market share, and offers a public relations bonus for good citizenship.

In addition, the framework offers benefits to the entire community. Through improved utility of geospatial data, the framework will make efforts of organizations broadly useful beyond any one community or set of customers.

Proposed Framework Design

Data Context

Technical Characteristics

Evaluation of the goals resulted in a multi-resolution, feature-based framework design. This approach incorporated the following decisions:

- To meet the different needs of users, the framework will support geospatial data at varying resolutions. Multiple resolutions of data (for example, data at different levels of generalization and having nominal positional accuracies of 50, 10, and 1 meter) may exist at any given location. Where suitable higher resolution data exist, the lower resolution data will be generalized from the higher resolution data.[5] The data will be generalized according to a set of predefined rules for each theme. Alternate rule sets may be needed for a broad range of generalization.

- To allow maintenance of users' existing investments, to minimize the effort required to integrate data from the framework, and to link representations at different resolutions, a consistent method of identifying units of framework data is needed.

To provide for these capabilities, the framework is based upon a philosophy that considers a spatial data base to be, in itself, a multifaceted model of geographic reality. The most fundamental aspect of the framework model, and the greatest distinguishing characteristic from earlier geographic data models, is the existence of features. A feature is a description of geographic phenomenon (for example, a road) at or near the Earth's surface. Locational (coordinate) information is encoded by linking the feature object to spatial objects (such as points, nodes, lines, and areas).

Each occurrence of a feature, or "feature instance," is assigned a unique permanent feature identification code. This identifier provides users a "key" through which they can associate framework data to their attribute data, serves as a tracking mechanism for performing transactional updates, and provides a link among representations of a feature at different resolutions and across different areal extents. Once assigned, the identifier should not change.

When a feature is defined, it may be further described by a set of attributes and relationships. Attributes define the feature's characteristics; examples include name and function. Relationships may be defined to express interactions that occur between features, such as flow in a river system or connectivity in a transportation network.

Use of a common means of referencing coordinate positions on the Earth is essential to allow contributions to the framework to be joined and integrated. In addition, to be used as the locational framework for other thematic data, the coordinate system used for framework data must be well established, clearly specified, and consistent with national and world use. Coordinate information for framework data would be referenced to the North American Datum of 1983 and the North American Vertical Datum of 1988.

As appropriate to theme and feature content, vector-based spatial objects will conform to topological rules.

The framework will retain past versions of data so that information is available for historical or process studies. Thematic data requiring the framework for registration go back many years, and time-based studies are essential in many applications. A "movie" roll-forward/roll-back capability often is sought in base geographic data for research and policy studies.

As a general principle, the positions of contributed data will not be modified. For example, if a road crosses the boundary of two (otherwise equivalent) contributions, the positions of the road at the common edge will not be geometrically joined. This decision is based on the assumption that organizations that integrate data would not have information better than those that contributed the data. The disjoint lines that represent the location of the road will be associated through a common road feature, resulting in "logical seamlessness." Lower resolution data generalized from these data will be "geometrically seamless" (joined) if the alignment ambiguities present in higher resolution data sets can be resolved within the error tolerances of the lower resolution data sets.

Framework data sets should be integrated across themes where possible.

Information Content

Geodetic Control

Geodetic control provides the means for determining locations of features referenced to common, nationally-used horizontal and vertical coordinate systems. It is the essential ingredient in developing a common coordinate reference for all other geographic features. Control stations are monumented points (or in some cases active Global Positioning System (GPS) control stations) whose horizontal or vertical location is used as a basis for obtaining locations of other points. The framework will include geodetic control stations, and the name, unique identifier (permanent feature identifier), latitude and longitude (with accuracy code), orthometric height (with accuracy code), and ellipsoid height (with accuracy code) for each station.

Digital Orthoimagery

An orthoimage is a georeferenced image prepared from a perspective photograph or other remotely-sensed data in which displacements of images due to sensor orientation and terrain relief have been removed. Orthoimages have the same metric properties as a map and a uniform scale. Digital orthoimages are orthoimages composed of an array of georeferenced pixels, or picture elements, that encode ground reflectance as a discrete digital value. Many geographic features, including those that are part of the framework, can be interpreted and compiled from an orthoimage. Orthoimages also can serve as a backdrop and link the results of an application to the landscape.

The framework may include imagery that varies in resolution from sub-meter to tens of meters. Accurately positioned, high-resolution (one meter or smaller pixels) are thought to be the most useful to support the compilation of framework features, especially those that support local data needs. In some areas lower resolution imagery may be sufficient to support framework needs.

Elevation Data

Elevation refers to a spatially referenced vertical position above or below a datum surface. The framework includes elevations of land surfaces and the depths below water surfaces (bathymetry).

For land surfaces, an elevation matrix, or a regularly spaced grid of locations with elevation values, will comprise the framework. Elevation values will be collected at post spacings of not greater than 2 arc-seconds. In areas of low relief, a spacing of 1/2 arc-second or less is desired.

For depths, the framework will consist of soundings and a gridded bottom model. Depth of water is determined relative to a specific vertical reference surface, usually derived from tidal observations. In the future this vertical reference may be based on a global model of the geoid or the ellipsoid, which is the reference for expressing Global Positioning System height measurements.

Shorelines are included as an aspect of elevation data. A shoreline is the intersection of the water's surface with land, and is usually referenced to some analytically determined stage of the tide or water level (as in lakes and rivers). Multiple shorelines are included in the framework due to the wide variety of uses and the complex nonlinear relationships between various shorelines. Attributes will include shoreline type (or tidal reference).

Transportation

The framework transportation data includes roads, trails, railroads, waterways, airports, and ports, and two types of supporting structures: bridges and tunnels. Roads will have the attributes of permanent identifier (using linear referencing system(s) where available), functional class, name (including route numbers), and street addresses to the street address range level. Trails will have the attributes of permanent identifier (using linear referencing system(s) where available), name, and type. Railroads will have the attributes of permanent identifier (using linear referencing system(s) where available) and type. Waterways will have the attributes of permanent identifier (using linear referencing system(s) where available) and name. Airports and ports will have the attributes of permanent identifier and name. Bridges and tunnels will have the attributes of permanent identifier and name.

Hydrography

The framework hydrography data will be based on the approach used for the U.S. Environmental Protection Agency's Reach File Version 3.0 (RF3). A reach defines a surface-water feature that may or may not be connected to other surface-water features. Reaches that are connected to one another hydrologically form a skeletal structure representing the branching patterns of surface-water drainage systems. Connectivity and direction of flow are desired, but are not needed for the framework.

The permanent feature identifier for each reach will be the Reach Code. The design of this code allows reaches to be subdivided in a way that links the parts to the original reach. In addition to the identifier, the reach will have the attributes of name, reach type (identifying the geographic features, such as stream/river, lake/pond, wash, or shoreline represented by the reach), and spatial representation (identifying the spatial elements used to delineate the reach, such as single line, open water area, open water shoreline, transport path, junction, or "super node").

Governmental Units

The geographic features for governmental units included in the framework are Nation, States and statistically equivalent areas (of which there were 57 in 1990), counties and statistically equivalent areas (3,248 in 1990), incorporated places and consolidated cities (19,371 in 1990), functioning and legal minor civil divisions (which exist in 28 states and the District of Columbia) (17,021 in 1990), Federal- or State-recognized American Indian Reservations and Trustlands (362 in 1990), and Alaska Native Regional Corporations (12 in 1990). Each will have the attribute of name and the applicable Federal Information Processing Standard (FIPS) code. In addition, the boundaries of the features will include information about other features (such as roads, railroads, or streams) with which the boundaries are associated, and the description of the association (such as coincidence, offset, or corridor).

Cadastral

Two aspects of cadastral information are included in the framework: cadastral reference systems (such as the Public Land Survey System) and large, publicly-administered parcels (such as military reservations, national forests, and state parks). Features include the survey corner, survey boundary, and parcel. Each instance will have the attribute of name or other common identifier, and information on quality. It is desirable that each instance have a permanent identifier. Cadastral reference system information will be provided to the section level or equivalent.

Operational Context

In addition to the characteristics of data, the framework should provide the following operational characteristics:

- the framework must support transactional updating so that producers need only provide change files and users only need to process changes. This approach reduced the impacts of change on existing investments.
- access to an official version of framework data (current and past versions) by information networks and digital media must be ensured.
- updates to framework data should preserve investments in existing data to the maximum extent possible. Permanent identifiers should be changed only when necessary.
- users should be able to find any part of the data through the National Geospatial Data Clearinghouse.

In addition, the contributions will cover a minimum areal extent that is economical to process. There is some minimal areal extent for which the resources required to manage the data holding will exceed the value of the data contributed. This extent will vary by theme.

An important companion to the framework data are Global Positioning System technology and related services provided by GPS base stations and differential GPS techniques that are tied to the national coordinate reference systems. These technologies can significantly lower the costs of acquiring accurately-positioned data. They also provide a means for users to locate themselves in reference to framework data during field operations.

To exploit the capabilities of the GPS, the following items are needed: (1) a network of a few, very accurately positioned and easily accessed monumented points, (2) a set of continuously operating reference stations, (3) a high resolution geoid (needed to relate heights determined by conventional surveying to those determined by GPS techniques), and (4) precise post-fit GPS satellite orbits. The Federal Government has proposed enhancing the National Spatial Reference System (NSRS) to provide this capability. Included in the upgraded NSRS will be 25 to 50 continuously operating reference stations at the most accurately determined geodetic control stations in the Federal Base Network. Observables from GPS satellites will be recorded and made available through electronic networks. Differential GPS base stations operated by the public and private sectors can be positioned relative to the reference stations and provide information that are tied to a single, consistent, and very accurate coordinate reference system.

Business Context

A goal of the framework is that it be widely used and useful. To attain this goal, framework data should:

- be free from use criteria or constraints. Licenses, copyrights, or other restraints will not allow the wide use needed for framework data to be effective, and will lead to duplication of effort as those who cannot use the restricted data create their own. However, limitation parameters and suggested or optimal use of data need to be provided and a disclaimer and liability structure should be firmly in place.

- be available at the lowest cost possible, and no higher than the cost of dissemination. The calculation of the cost to obtain framework data shall not include costs associated with the original collection and processing of the information.

- be available in public, non-proprietary formats.

- conform to approved standards. This allows users to know the characteristics of the data. At a minimum, conformance to relevant FGDC standards should be required and subject to verification.

- be created and updated by organizations or partnerships that are knowledgeable about the data.

- be certified to ensure that they meet the minimal standard for all framework criteria. A certification process of some form is essential: an independent assessment is needed to establish and maintain trust.

Institutional Roles

The framework will take advantage of geospatial data that are being created locally and regionally by many entities: local and regional governments, utilities, private companies, and local and regional offices of State and Federal agencies. Much of this data is created for an area in response to an issue or need of local importance. Creating, maintaining, and distributing framework data will involve many organizations.

Work will be needed to gather, integrate, and certify the locally-produced data to meet the goal of consistent, integrated framework data. Six institutional responsibilities have been identified to attain this goal: policy establishment, theme expertise, framework management, area integration, data producer, and data distributor.

These roles may be assigned to many different organizations. Organizations that have policies, missions, and mandates needed to undertake these roles will be the most successful participants in the framework.

Policy Establishment

The role of establishing policy provides overall guidance for the development and operation of the framework. Policies are of key importance because of the distributed nature of the responsibilities for the framework, and the requirement that framework data be able to support applications of varying natures and geographic areas. These responsibilities include approving standards; identifying resources needed for the framework; designating and working with framework managers and others to obtain funding; initiating pilot studies, concepts, and implementation strategies; encouraging partnerships; resolving issues caused by different views among the themes; and coordinating and resolving competing ideas about the operation and advancement of the framework. The FGDC, with participation from the non-Federal community, could fill this role.

Theme Expertise

The changing needs of the public and private sectors must be considered if the framework is to be a robust and viable effort. These needs include accommodating new standards and techniques. Many of these requirements will be developed within the organizations and disciplines that generate or use the bulk of themes of framework data, and contribution of this thematic expertise to identify needs and trends is required. Appropriate thematic subcommittees of the FGDC, with participation from thematic expertise from the non-Federal community, could fill this role.

Framework Management

Beyond the role of determining needs and trends is that of providing nationwide continuing, operational support to the framework. The responsibilities include:

- managing the production of a theme of data (or "theme management") that meets the user requirements by:
  - creating and maintaining framework data for those areas not covered by certified data producers.
  - certifying and coordinating the activities of the area integrators and serving as an area integrator on a national scale.
  - generating and maintaining lower resolution data, including positional adjustments based on higher-resolution data.
  - determining the needs for maintenance within the theme.
- managing the integration of the themes of data (or "integration management") to ensure that a "whole" framework can be assembled from its thematic parts. The scope of duties is similar to those listed above for "theme management."
- recommending and maintaining technical standards that describe the essential characteristics of the theme data, and the rules and processes for generalization (simplification, selection, aggregation, and dimensionality parameters).
- developing certification policies and procedures to ensure that data conform to framework standards.
- ensuring the maintenance of a record of the location of official data and a safe archive.

Because of the size of the task and the variations among the themes of data, a consortium of organizations knowledgeable about the themes and having national responsibilities is needed. This role could be filled by Federal agencies that have been assigned to lead efforts for data by Office of Management and Budget Circular A-16.

Area Integrator

A certified area integrator incorporates the contributions of data producers into the framework. An integrator:

- implements the technical standards that describe the essential characteristics of the theme data.
- implements certification policies and procedures to ensure that a particular data set conforms to the framework standards. This activity could include both guidance documents and verification software. Certification authority could be delegated to data producers.
- coordinates data creation and maintenance activities for an area. The integrator is the focal point for users to report problems with data or to request enhancements or modifications.
- updates the framework based on new contributions.
- provides guidance to ensure that data producers integrate their data among themes.

Two aspects of integration are needed for a robust framework: integration within a theme (providing coverage for an area by knitting together contributions that cover smaller areas), and integration among themes (bringing different themes for the same area into accord). An organization may not be willing or able to provide both services for a geographic area.

Areas of responsibility could cover different units of geography (for example, a State, a group of states, or part of a State). The units of geography may vary regionally (for example, in some parts of the country, integration might be done on the basis of political units such as counties or states, but in other parts by ecosystems). In addition, the units of geography may vary by theme within a region (for example, cadastral data might be done on the basis of political units, and hydrography on the basis of a watersheds). The framework managers will be the default integrators for those areas not having an integrator.

Data Producer

This function would involve producing or maintaining framework data to standards. Some producers may provide framework data under contract. Others may propose including their existing data as part of the framework.

The data producers must:

- provide data and updates to data using the framework standards. This activity includes:
  - encoding required metadata.
  - performing and reporting the results of required data quality tests.
  - encoding data, including permanent feature identifiers, to framework standards.
- provide the data and metadata without restriction to the area integrators.

Data Distributor

The data distributor is the primary source for users wanting copies of the data. The distributor may or may not be the same agency that produces the data. There may be many data distributors, but only one will be responsible for holding the official distribution copy.

Framework Implementation

The framework will take a number of years to be realized. Near term requirements, such as those stated in Executive Order 12906[1], make it apparent that a phased implementation is needed. The approach requires that ongoing national-scale activities be effectively combined with those at the State, regional, and local levels. In particular, the 1998 deadline set out in the executive order will present organizational and technical challenges in the data integration and certification activities and coordination challenges to establish the necessary partnerships.

Actions Needed

Implementation actions are divided into three phases: from now until June 1995, July 1995 to December 1997, and 1998 and beyond. The goals for each phase are described below, as are the details of institutional and operational actions[6].

Phase 1: Now Until June 1995 — begin to establish institutional arrangements and conduct "proof of concept" projects.

Institutional — begin to establish the necessary organizational relationships and agreements for framework operations; to prototype arrangements needed for framework operations, especially those of area integrators; and to raise the awareness of the framework by organizations whose participation is needed.

- clarify and synchronize the authorities and responsibilities of Federal agencies. The Secretary of the Interior, in his role of chairman of the FGDC, should meet with the Secretaries of Agriculture, Commerce, and Transportation to determine theme management responsibilities for the framework. The decisions from these meetings should be documented as FGDC Decision Memoranda and forwarded to the Office of Management and Budget.
- each State shall identify and empower an organization for framework activities that can (1) participate in theme expert groups, (2) initiate partnerships to build the framework, and (3) serve a functional role as an area integrator. Such organizations should include the interests and capabilities of county, regional, and local jurisdictions, and the private sector. The National States Geographic Information Council will recommend the process to determine the organization in each State.
- within the limits of the Federal Advisory Committee Act and economic constraints, the FGDC will involve State, local, and tribal governments, the private, academic, and non-profit sectors, and others in subcommittee and working group activities.
- the Federal Government will commit to the use of the "best" data, if provided in the appropriate form(s) and timeframe(s), in the geographic base for the 2000 decennial census.

- the FGDC will develop a nationwide inventory of data producers and integrators.

Technical — encourage the production of framework data that do not require further prototyping or technological development: conduct studies and technical prototypes to remove impediments for the remaining framework data, especially those needed to meet the 1998 deadline: raise the technical expertise of the community so that a larger number of organizations can participate; and develop recommendations for framework standards.

- theme management agencies begin to develop certification policies and data archive procedures.

- conduct framework "proof of concept" projects. The projects would evaluate, exchange, integrate, and update Federal, State, local, and privately-held data sets, investigate cross-theme integration, and would test framework management, theme expert, and area integrator responsibilities. Examples of projects might include:

  - investigate the integration of Topologically Integrated Geographic Encoding and Referencing (TIGER), digital line graph (DLG), and local data sets in a major metropolitan area (lead - Census Bureau and U.S. Geological Survey)

  - investigate the use of State, local, and Federal data to develop, update, and maintain framework data over a geographic area at a minimum scale of 1:24,000, with a natural resource or rural emphasis (lead - U.S. Geological Survey and selected State agency (or agencies))

  - investigate the use of survey or parcel level information as a framework component, and the use of cadastral data as the basis for building partnerships. Identify roles, assess organizations' capabilities, investigate the ability to integrate cadastral with other themes of data, and evaluate the applicability of the FGDC's developing cadastral data standards. (lead - FGDC cadastral subcommittee and American Congress on Surveying and Mapping (ACSM)).

  - investigate the development of educational curricula that focus on geospatial data collection to construct framework data sets at the high school level using GIS and telecommunications technologies (lead - the U.S. Department of the Interior and others, possibly including the National Geographic Society).

- using partnerships to leverage resources, expedite the collection of geodetic control, elevation, and digital orthoimage data as quickly as resources allow.

- build public outreach, education, and technology transfer programs (forms for the programs may include workshops for partners, manuals of instruction, and the identification of organizations' full time contacts for framework data).

- develop "proof of concept" framework data sets for evaluation by the user community.

Phase 2: July 1995 to December 1997 — continue the data collection activities started in Phase 1, and begin operational data collection activities tested in Phase 1 to the extent allowed by available resources.

Institutional — begin the establishment of an institutional consortium for the framework, especially the institutional links required to meet the 1998 deadline.

- with the participation of Federal, State, local, and tribal governments agencies, the private sectors, and others, begin to identify the long term organizational structures, arrangements, and partnerships needed to sustain the framework, and explore the alternatives.

- establish a "Framework '98" Program Office, staffed by key Federal agencies and (possibly) persons from State and local government agencies, to focus on the 1998 deadline.

- establish a means of continuing communication and information exchange among framework participants, especially those participating in "Framework '98."

Operational — based on the evaluation of the "proof of concept" projects, establish framework operations; data collection and exchange activities; initial framework standards.

- evaluate the results of the "proof of concept" projects and data sets.

- through the "Framework '98" Program Office, collect and update transportation, boundary, and hydrography data to support the Census 2000 activities.

- target the production of digital orthoimage data to support the geographic areas addressed by the "Framework '98" program.

- through the use of pilot and other projects, continue the cooperative production, enhancement, and update of other themes of framework data.

Phase 3: 1998 and beyond — continue the maintenance and update of framework data and evolve routine operations for the framework.

- build on the results of the "Framework '98" program to extend the responsibilities for framework operations, especially the roles of area integrator, data contributor, and data distributor.

- seek additional contributors for framework data to increase coverage, currentness, and responsiveness of framework data.

- implement, evaluate, and tune the long term arrangements needed for sustain the framework.

- collect and maintain framework data.

Next Steps

The goal is to develop a plan and schedule by January 1995 for completing an initial implementation of the framework by the year 2000. To meet this goal:

- Work is underway to complete recommendations on institutional roles, an implementation strategy, and information content for the framework. The working group continues to develop these recommendations, and invites ideas and comments.

- Federal agencies have begun reviewing their data collection programs to decide how they might contribute to the framework. These efforts will continue into the fall.

- The FGDC is sponsoring discussions of ways to maximize data sharing among public and private sector organizations. These discussion will be used to refine the implementation strategy for the framework.

For Information or to Provide Comments

To obtain additional details about the framework or to provide comments, please contact the FGDC Secretariat by mail at the U.S. Geological Survey, 590 National Center, Reston, Virginia 22092; by telephone at (703) 648-5514; by facsimile at (703) 648-5755; or by Internet at gdc@usgs.gov. Additional information about the framework also will be available by anonymous FTP from ftp://fgdc.er.usgs.gov/gdc/framework

Endnotes:

1. On April 11, 1994, President Clinton issued Executive Order 12906, *Coordinating Geographic Data Acquisition and Access: The National Spatial Data Infrastructure*. Section 5 of the order states "National Digital Geospatial Data Framework. In consultation with State, local, and tribal governments and within 9 months of the date of this order, the FGDC shall submit a plan and schedule to OMB for completing the initial implementation of a national digital geospatial data framework ("framework") by January 2000 and for establishing a process of ongoing data maintenance. The framework shall include geospatial data that are significant, in the determination of the FGDC, to a broad variety of users within any geographic area or nationwide. At a minimum, the plan shall address how the initial transportation, hydrology, and boundary elements of the framework might be completed by January 1998 in order to support the decennial census of 2000."

2. The working group discussed the subjects of the amount of data suitable for the framework that is being collected by the public sector, the areas for which data are available, and the plans to maintain these data. The working group agreed that better information is needed. The FGDC is working with the National Association of Counties and the National League of Cities to begin collecting this information.

3. The existence of the framework will not preclude the development and use of other data in the National Spatial Data Infrastructure (NSDI). The NSDI clearinghouse allows data producers to describe whatever holdings they wish to offer to the community, and to report the characteristics of these data.

4. The idea of "best" data, however, is a complicated one. Different applications require, or at least tolerate, different mixes of the qualities normally associated with the idea of "best" data: currentness, positional and attribute accuracy, consistency, and completeness.

5. Decisions to store lower resolution data sets for later use, or to regenerate them "on demand," are considered to be a business decision (based on costs, legal requirements, and other factors).

6. The framework is a different way of doing business for all the parties concerned. During this time, organizations must continue to support their existing operations to meet their mandates and missions. Because of this need, resources must be available during the transition period to both maintain existing operations and participate in the framework. In the short term, additional resources will be needed. Once operational, the framework should result in net savings over the aggregate costs of existing operations and more than recover the additional initial expenditures needed for its establishment.

Membership of the Framework Working Group

Name	Affiliation	Nominated by
Martha McCart Lombard (Chair)	Gwinnett County, Georgia	Urban and Regional Information Systems Association
Bill Belton	U.S. Forest Service	U.S. Forest Service
Penny Capps	U.S. Army Corps of Engineers	U.S. Army Corps of Engineers
Charles Dingman	Bureau of the Census	FGDC* Cultural and Demographic Subcommittee
Michael Domaratz	FGDC Secretariat	FGDC Secretariat
Christopher Friel	Florida Marine Research Institute	Coastal States Organization
Dennis Goreham	Utah Automated Geographic Reference Center	National States Geographic Information Council
CAPT Melvyn Grunthal	National Oceanic and Atmospheric Administration	FGDC Federal Geodetic Control Subcommittee
Steve Guptill	U.S. Geological Survey	FGDC Standards Working Group
Susan Carson Lambert	U.S. Geological Survey	FGDC/IACWD** Water Subcommittee
Kenneth Lanfear	U.S. Geological Survey	FGDC/IACWD Water Subcommittee
Jerry Mills	National Oceanic and Atmospheric Administration	FGDC Bathymetric Subcommittee
John Moeller	Bureau of Land Management	FGDC Cadastral Subcommittee
Sheryl Oliver	Illinois Department of Energy and Natural Resources	National States Geographic Information Council
Bob Parrott	San Diego Association of Governments	National Association of Regional Councils
Roger Petzold	Federal Highway Administration	FGDC Ground Transportation Subcommittee
James Plasker	U.S. Geological Survey	FGDC Base Cartographic Subcommittee
Charles Roswell	Defense Mapping Agency	Defense Mapping Agency
Cyril Smith	Kansas Water Office	Urban and Regional Information Systems Association
Todd Smith	Minnesota Department of Transportation	American Association of State Highway and Transportation Officials
Gary Speight	Bureau of Land Management	FGDC Cadastral Subcommittee
Gary William Thompson	North Carolina Geodetic Survey	American Congress on Surveying and Mapping
Gene Thorley	U.S. Geological Survey	FGDC Base Cartographic Subcommittee
Nancy Tosta	FGDC Secretariat	FGDC Secretariat

* FGDC — Federal Geographic Data Committee
** IACWD — Interagency Advisory Committee on Water Data

United States National Map Accuracy Standards

With a view to the utmost economy and expedition in producing maps which fulfill not only the broad needs for standard or principal maps, but also the reasonable particular needs of individual agencies, standards of accuracy for published maps are defined as follows:

1. **Horizontal Accuracy:** For maps on publication scales larger than 1:20,000, not more than 10 percent of the points tested shall be in error by more than 1/30 inch, measured on the publication scale; for maps on publication scales of 1:20,000 or smaller, 1/50 inch. These limits of accuracy shall apply in all cases to positions of well- defined points only. Well-defined points are those that are easily visible or recoverable on the ground, such as the following: monuments or markers, such as bench marks, property boundary monuments; intersections of roads, railroads, etc.; corners of large buildings or structures (or center points of small buildings); etc. In general what is well defined will also be determined by what is plottable on the scale of the map within 1/100 inch. Thus while the intersection of two road or property lines meeting at right angles would come within a sensible interpretation, identification of the intersection of such lines meeting at an acute angle would obviously not be practicable within 1/100 inch. Similarly, features not identifiable upon the ground within close limits are not be considered as test points within the limits quoted, even though their positions may be scaled closely upon the map. In this class would come timber lines, soil boundaries, etc.

2. **Vertical Accuracy:** as applied to contour maps on all publication scales, shall be such that not more than 10 percent of the elevations tested shall be in error more than one-half the contour interval. In checking elevations taken from the map, the apparent vertical error may be decreased by assuming a horizontal displacement within the permissible horizontal error for a map of that scale.

3. The accuracy of any map may be tested by comparing the positions of points whose locations or elevations are shown upon it with corresponding positions as determined by surveys of a higher accuracy. Tests shall be made by the producing agency, which shall also determine which of its maps are to be tested, and the extent of such testing.

4. Published maps meeting these accuracy requirements shall note this fact on their legends, as follows: "This map complies with National Map Accuracy Standards."

5. Published maps whose errors exceed those aforestated shall omit from their legends all mention of standard accuracy.

ASPRS Interim Accuracy Standards For Large Scale Maps

These standards have been developed by the Specifications and Standards Committee of the American SocieMw for Photogrammetry and Remote Sensing (ASPRS). It is anticipated that these ASPRS standards may form the basis for revision of the U.S. National Map Accuracy Standards for both small-scale and large-scale maps. A major feature of these ASPRS standards is that they indicate accuracy at ground scale. Thus, digital spatial data of known ground-scale accuracy can be related to the appropriate map scale for graphic presentation at recognized standards.

These standards concern the definitions of spatial accuracy as they pertain to large-scale topographic maps prepared for special purposes or engineering applications. Emphasis is on the final spatial accuracies that can be derived from the map in terms most generally understood by the users.

1. **Horizontal Accuracy:** map accuracy is defined as the rms error in terms of the project's planimetric survey coordinates (X, Y) for checked points as determined at full (ground) scale of the map. The rms error is the cumulative result of all errors including those introduced by the processes of ground control surveys, map compilation, and final extraction of ground dimensions from the map. The limiting rms errors are the maximum permissible rms errors established by this standard. The limiting rms errors for Class 1 maps are listed below. These limits of accuracy apply to tests made on well-defined points only.

Planimetric Coordinate Accuracy Requirements
Class 1 Maps

LIMITING RMS, ERROR, IN FEET	TYPICAL MAP SCALE
0.05	1: 60
0.10	1: 120
0.20	1: 240
0.30	1: 360
0.40	1: 480
0.50	1: 600
1.00	1: 1,200
2.00	1: 2,400

3. Lower Accuracy Maps: Map accuracies can also be defined at lower spatial accuracy standards. Maps compiled with limiting rms errors of twice or three times those allowed for a Class 1 map shall be designated Class 2 or Class 3 maps respectively. A map may be compiled that complies with one class of accuracy in elevation and another in planimetry.

4. Map Accuracy Test: Tests for compliance of a maps sheet are optional. Testing for horizontal accuracy compliance is done by comparing the planimetric (X and Y) coordinates of the same points as determined by a horizontal check survey of higher accuracy. The check survey shall be designed according to the Federal Geodetic Control Committee (FGCC, 1984) standards and specifications to achieve standard deviations equal to or less than one-third of the "limiting rms error" selected for the map. The distance between control points (d) used in the FGCC standard for the design of the survey shall be the horizontal ground distance across the diagonal dimension of the map sheet.

Testing for vertical accuracy compliance shall be accomplished by comparing the elevations of well-defined points as determined from the map to corresponding elevations determined by a survey of higher accuracy. For purposes of checking elevations, the map position of the ground point may be shifted in any direction by an amount equal to twice the limiting rms error in position. The vertical check survey should be designed to produce rms errors in elevation differences at check point locations no larger than 1/20th of the contour interval. The distance (d) between bench marks used in the FGCC standard for the design of the survey vertical check survey shall be the horizontal ground distance across the diagonal of the map sheet. Generally, vertical control networks based on surveys conducted according to the FGCC standards for third order provide adequate accuracy for conducting the vertical check survey.

Discrepancies between the X, Y or Z coordinates of the ground point, as determined from the map and by the check survey, that exceed three times the limiting rms error shall be interpreted as blunders and will be corrected before the map is considered to meet this standard.

The same survey datums, both horizontal and vertical, must be used for both the project and the check control surveys. Although a national survey datum is preferred, a local datum is acceptable.

A minimum of 20 check points shall be established throughout the area covered by the map and shall be distributed in a manner agreed upon by the contracting parties. Maps produced according to this spatial accuracy standard shall include the following statement in the title block:

"THIS MAP WAS COMPILED TO MEET THE ASPRS STANDARDS FOR CLASS 1 MAP ACCURACY"

* the discrepancies are normally distributed about a zero mean;

* the standard deviations in the X and Y coordinate directions are equal;

* sufficient check points are used to accurately estimate the variances.

To compute the "circular map accuracy standard" [CMAS which corresponds to the 90% circular map error defined in the NMAS [ACIC, 1962, p.26, p.41]:

$$CMAS = 2.146$$

Given these relationships and assumptions, the limiting rms errors correspond approximately to the CMAS of 1/47th of an inch for all errors and related scales indicated in Table 1E. For the metric case indicated in Table 1M, the CMAS is 0.54 mm for all rms errors and corresponding scales. It is emphasized that for the ASPRS Standard, spatial accuracies are stated and evaluated at full or ground scale. The measures in terms of equivalent CMAS are only approximate and are offered only to provide a comparison to the National Map Accuracy Standard of CMAS of 1/30th inch at map scale.

Check Survey

Both the vertical and horizontal (planimetric) check surveys are designed based on the National standards of accuracy and field specifications for control surveys established by the Federal Geodetic Control Committee (FGCC). These standards and specifications [FGCC, 1984] are intended to establish procedures which produce accuracies in terms of relative errors. For horizontal surveys, the positional accuracies for the various orders and classes of survey are stated in Table 2.1 of the FGCC document and for elevation accuracy in Table 2.2. These tables along with their explanations are reproduced here. From FGCC [1984]:

Horizontal Control Network Standards

When horizontal control is classified with a particular order and class, NGS certifies that the geodetic latitude and longitude of that control point bear a relation of specific accuracy to the coordinates of all other points in the horizontal control network. This relationship is expressed as a distance accuracy, 1:1. A distance accuracy is the ratio of relative positional error of a pair of control points to the horizontal separation of those points.

Elevation Accuracy Standards

CLASSIFICATION	MAXIMUM ELEVATION DIFFERENCE ACCURACY
First-order, class I	0.5
First-order, class II	0.7
Second-order, class I	1.0
Second-order, class II	1.3
Third-order	2.0

"An elevation difference accuracy, b, is computed from a minimally constrained, correctly weighted, least squares adjustment by:

$$b = S/d$$

where:

d = approximate horizontal distance in kilometers between control point positions traced along existing level routes.

S = proposed standard deviation of elevation difference in millimeters between survey control points obtained from a least squares adjustment. Note that the units of b are (mm)/(km).

For an example of designing a check survey (selecting an order and class), assume that a survey is to be designed to check a map which is intended to possess a planimetric (horizontal) "limiting rms error" (see Table 1E. of the map standard) of one foot and a contour interval of two feet. In contrast to survey accuracies, which are stated in terms of relative horizontal distances to adjacent points, map features are intended to possess accuracies relative to all other points appearing on the map. Therefore, for purposes of the check survey, the distance between survey points (d) is taken as the diagonal distance on the ground across the area covered by the map. According to the FGCC survey standards this is the distance across which the "minimum distance accuracy" and "maximum elevation difference accuracy" is required (see Table 2.1 and 2.2 of the [FGCC, 1984] document).

For the planimetric check survey, assume that the diagonal distance on the ground covered by the map is 6000 feet. The propagated standard deviation(s) required for the check survey is one-third of the limiting rms error of one foot or 0.33 foot in this example. Returning to the equation from the FGCC [1984] document relating distance between survey points (d), standard deviation(s) and distance accuracy denominator (a):

$$a = d/s = (6000 \text{ feet})/(0.33 \text{ feet}) = 18{,}182$$

FGDC Ground Transportation Subcommittee Position and Recommendations on

LINEAR REFERENCING SYSTEMS

Summary and Overall Recommendation

While spatial features are typically located using planar (2-dimensional) referencing systems, many transportation features are located using a linear (1-dimensional) referencing system (LRS). These features include bridges and other structures, changes in pavement condition, or accident sites. Often, spatial and linear-referenced features must be combined for specific transportation applications. Examples include: (1) finding the minimum clearance height on a section of highway by locating all bridges that cross over the highway; or (2) using dynamic segmentation to highlight sections of a highway with poor pavement conditions to prioritize rehabilitation activities.

Although a LRS cannot entirely replace a planar referencing system for geographic display, it does represent the format in which most transportation infrastructure and incident data are currently reported. In the absence of extremely high accuracy base maps and locational measurements, using planar coordinates alone to match point data to the transportation network will yield anomalous cases where the resulting spatial object does not lie on the network. This cannot happen using a LRS.

It is the position of the FGDC Ground Transportation Subcommittee that a LRS is an essential component of transportation network spatial databases. The FGDC Ground Transportation Subcommittee therefore recommends that:

1. **A standard LRS data structure, together with the key attribute fields required to support such a data structure, be included as part of any Transportation Network Profile established under the Spatial Data Transfer Standard (SDTS).**

2. **Any transportation network databases developed as part of the National Spatial Data Infrastructure (NSDI) framework include and populate, as part of their core data, all key LRS attribute fields.**

The remainder of this paper provides more specific recommendations for LRS requirements on network data structures and for the three major transportation networks -- roads, railroads, and navigable waterways.

Network Data Structure

For the purposes of this paper, the following definitions are used:

1. A **Segment** is a simple spatial object, equivalent to either a **link** or **network chain**, as defined in the Spatial Data Transfer Standard (SDTS) - Part 1. A **link** is a topological, straight-line connection between two nodes. A **network chain** is simply a link with intermediate shape points.

2. A **Route** is a composite spatial object, as defined in SDTS - Part 1, consisting of a directed, non-branching sequence of **links** or **network chains**, sharing a common route identifier (e.g., Route 60).

In a LRS, features are, by definition, restricted to lie on or along the segments that make up the base network. Their locations are described by a distance along a specified route from a known reference point. If the reference point and the route are explicitly identified in the base network, then the linear-referenced feature can be located by calculating the distance along the segments comprising the specified route. In order to carry out these calculations, each segment in the base network must include the following attributes:

a. A **route identifier** that is consistent with the route naming convention used for the linear-referenced feature.

b. **Beginning and ending reference points** (e.g., mileposts or kilometerposts) that bound the distance calculations within each segment.

Several popular Geographic Information System (GIS) software packages have implemented procedures for linking linear-referenced data to a spatially referenced transportation network. However, each vendor's software procedure operates somewhat differently, and each requires that key LRS attributes be in specific formats to facilitate the linking. For example, several of the leading transportation GIS software packages explicitly require that a route must begin and end at a node. Consequently, the network database must include nodes at every location where a new route begins and ends.

Recommendations

In order to provide a consistent framework for incorporating LRS within a network data structure, the FGDC Ground Transportation Subcommittee recommends that a standard LRS data structure be included as part of any approved SDTS Transportation Network Profile. Establishment of this standard LRS data structure will require consideration of the specific software requirements of key GIS software and development of a software-neutral data format. However, an initial set of key attributes and rules is proposed below:

Any network segment that is used in a LRS must include the following attribute fields:

1. **A route identifier;**[1]

2. **A beginning reference distance (mile or kilometer) with respect to the start of the route;**

3. **An ending reference distance (mile or kilometer) with respect to the start of the route;**

Roads LRS

There is currently no single national LRS for roads and highways. Any organization responsible for collecting data about a particular road network creates its own unique LRS. It is not unusual for a local transit agency to maintain a LRS for its bus routes, while the municipal government uses a different LRS for local streets, and the State DOT uses yet another LRS for state roads. Thus, a single road segment could be represented by three or more different LRS, and may require all of these to link attributes from each agency's databases. Standardization of agency-specific LRS occurs only if linear-referenced data must be shared across agencies and if the costs associated with converting to a common LRS are less than the costs associated with collecting and maintaining redundant data linked to each agency's own LRS.

The issues associated with coordinating diverse agency-specific LRS at the national level are currently being addressed by the Federal Highway Administration (FHWA) as part of its Highway Performance Monitoring System (HPMS).[2] All rural arterial, urban principal arterial and National Highway System (NHS) segments included in the HPMS database must be referenced using each State's own LRS. Furthermore, each State is required to submit to FHWA a digital highway network database and/or a set of maps showing the location of all HPMS inventory routes and their corresponding LRS attributes. FHWA will use the information from these submissions to develop a LRS for the FHWA National Highway Planning Network (NHPN) Version 2.0 database. The NHPN and its LRS attributes will be updated annually.

The HPMS submissions will establish a common LRS for each rural arterial, urban principal arterial and NHS segment in each State. The FHWA will accept different systems from different

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1 It may be necessary to provide more than one attribute field in order to unambiguously identify a route. Typically, a second attribute field is used to differentiate among two or more subroutes which share the same primary route number, but do not satisfy the topological requirements of a **route** spatial object. For example, a divided highway may be represented by two parallel lines in a map database, and for inventory purposes, both lines would have the same route number. Alternatively, a State sign route may reset its reference points at county boundaries and would require a subroute field to avoid ambiguities caused by having the same route milepost value (e.g., milepost 2.5) in two different counties.

2 **Federal Highway Administration,** ***Highway Performance Monitoring System Field Manual,*** **August 1993, Chapter 5.**

States. For example, some States use a county-based system, where milepost values are reset to zero each time a route crosses into a new county. This system requires a county identifier in addition to the route identifier to uniquely locate a point on the network. Other States use a statewide control section atlas where every inventory route has its own unique identifier, regardless of what county it is located in. Still other States may uniquely identify each segment in their network, creating what amounts to a unique route for each segment. FHWA requires that each road segment be associated with one and only one inventory route, and that each road segment be uniquely identified by the combination of State/county code, inventory route, inventory subroute, and beginning and ending mileposts (or kilometerposts).

The FHWA requires that States submit a LRS for those roads and streets functionally classified as Interstate (rural and urban), other Freeways and Expressways (urban), other Principal Arterials (rural and urban), and Minor Arterials (rural), plus any remaining roads designated as part of the NHS. FHWA does not require States to submit a LRS for other roads, such as collectors and local streets. Indeed, depending on the municipality, milepost-based LRS may not even exist for many of these roads. On the other hand, most local roads do have address ranges.

Address ranges are, in fact, simply another type of LRS. With address ranges, the route number is replaced by a road name, and the beginning and ending distance measurements are replaced by beginning and ending addresses on each road segment. An initial set of address ranges were included in the TIGER/Line databases, but these were limited to urban areas as defined in the 1980 GBF/DIME files. The address range coverage was expanded in TIGER/Line 1992 from 50 million to 80 million potential addresses, based on input from Census takers during the 1990 decennial Census.

The existence of duplicate street names within a county can cause locational ambiguities using address ranges. These ambiguities can be reduced significantly by including Zip Codes as a further qualifier to the State/county FIPS Codes. However, neither address ranges nor Zip Codes were designed specifically as map-based locational referencing systems. Consequently, even with Zip Codes, certain address locations, such as vanity addresses, centralized mail boxes, or rural postal routes still cannot be matched to a position on the road network.

The combination of a milepost-based LRS for higher level roads, and address ranges for lower level roads functionally classified as urban minor arterials, rural/urban collectors, and local streets should provide reasonably complete LRS coverage for a national road network. It may therefore be necessary to include attributes for both address ranges and the HPMS milepost based LRS on any national road network database.

A related long-term effort by FHWA's Office of Research is investigating the development of a national (if not universal) Locational Referencing System, to be used for vehicle location, in vehicle navigation, and routing under various Intelligent Vehicle Highway System (IVHS) projects. A national Locational Referencing System is necessary to unambiguously and efficiently communicate the locations of places and moving vehicles across different spatial network databases, using different display software and different communications media

A preliminary assessment of the existing mix of address ranges and LRS[3] suggests that they will not be adequate for IVHS applications. One proposed solution calls for the development of a comprehensive system of national route identification numbers for principal roads and highways and a master street name list for local non-route numbered roads. Each route or named street would be uniquely and unambiguously identified according to some established hierarchical naming convention (e.g., roads that have both an Interstate and a State or county route number would be identified by their Interstate route number). Every route would have well defined start and end points, including geographic coordinates to some standard level of accuracy and unambiguous descriptions of intersections with other spatial features (e.g., a State boundary, another route, etc.). A national register of route numbers and street names will be much easier to maintain if States and localities adopted consistent route naming conventions for use in their own LRS.

Another long-term effort of the FHWA Office of Environment and Planning, USGS, and Bureau of the Census is to explore the feasibility of a methodology for the development of a unique identifier for each roadway section. The objective would be to create an identification system that is uniform across the country, will require minimum maintenance, and can track changes (e.g, new roads, realignments, or abandonments) over time.

Recommendations

The FGDC Ground Transportation Subcommittee recommends the establishment of a standardized, national LRS for U.S. roads, and supports the development of a unique road identification system that can be used for both current inventory applications and future vehicle location and navigation systems emerging from IVHS.

At this time, it is too early to recommend a specific development approach, but the FGDC and FHWA should closely monitor the various locational referencing initiatives that are now in progress, and should endeavor to coordinate these initiatives into a single, consensus strategy.

The Subcommittee recognizes that the development of a unique identification system for all U.S. roads is a long-term goal. In the interim, additional steps can, and should be taken to address current LRS requirements associated with road inventory data and to facilitate the transition to a national LRS. These steps are presented below.

1. **Utilize current State-based LRS to match key transportation performance data to the FHWA NHPN 2.0. This is consistent with FHWA's current HPMS guidelines.**

2. **Include State/county FIPS codes as additional key attribute fields in NSDI framework road network databases to uniquely identify State sign routes which are currently reset at county lines.**

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[3] Viggen Corp., "Location Referencing Systems: Analysis of Current Methods Applied to IVHS User Services", Report E2 (draft), March 8, 1994.

3. **Include the following additional key attribute fields in NSDI framework road network databases to support address ranges as a second-level LRS:**

    a. **Street Name**

    b. **Beginning address**

    c. **Ending address**

    d. **Zip Code**

4. **Expand the address range coverage currently available in the Census TIGER files through such initiatives as 911 directories and cooperative agreements with the U.S. Postal Service.**

5. **Encourage States to adopt a more standardized LRS that will satisfy FHWA's HPMS requirements while reducing the disparity that currently exists among State inventory systems. At a minimum, a standardized LRS would:**

    a. **Establish a well-defined hierarchy of route numbers (e.g., Interstate, U.S. Primary, State Route, County Route, etc.) such that a single route number can be associated with each network segment.**

    b. **Eliminate the practice of using equations to tie reconstructed routes back historically to original reference points. All routes would be newly referenced after major realignment.**

    c. **Change from a county-based to a State-based road inventory system. More specifically, State sign routes which cross county lines would be sequentially referenced from their beginning to end instead of being reset at county boundaries.**

NOTE: **Items 5.b and 5.c can be accomplished by electronically transforming existing State LRSs to statewide referencing systems without equations.**

<u>Railroad LRS</u>

Unlike the road network, there is a single industry-wide approach for linear referencing of railroads. The approach is based on track ownership, and a particular line is uniquely identified by a combination of owner railroad and its internal operating designations. Although the definitions of operating segments (regions, divisions, subdivisions, districts, or other operating entity) may differ from railroad to railroad, in general each operating segment is delineated by a system of mileposts which orient the operating personnel as to the beginning and end of that geographical subsection -- starting at a specific base point and proceeding linearly along the rail line to the end of that segment. Virtually all main line and branch line tracks are mileposted in this manner; track segments within rail yards, sidings, or private spurs are not typically mileposted.

Most railroads were originally mileposted based on the actual distance along the track. However, over time, mergers, line abandonments, new construction or other factors such as changes in ownership and track configuration have altered the uniformity of the milepost numbering system. Mileposts are published in engineering department track charts and in employee timetables issued by each railroad, which contain detailed operating rules and instructions as well as other information such as signals, speeds, etc. relating to specific mileposts or sections.

Milepost markers are usually placed along the line every mile at the whole mile points. While intermediate points such as stations, turnouts, and other operating features are not usually marked in the field, they generally are referenced in the track charts and timetables in tenths (or even hundredths) of a mile between the markers. Junction points are often repeated for each connecting line and may be assigned different milepost numbers for each segment for which they are a part.

The major problem associated with appending this LRS to a national railroad network database is that most of the data will have to be input manually, using time tables obtained from individual railroads. This will be a time consuming and costly effort, and will require the cooperation of the railroads themselves.

Recommendations

The FGDC Ground Transportation Subcommittee recommends the following approach to developing a national LRS for U.S. railroads.

1. **Include additional key attribute fields in NSDI framework rail network databases to identify track owner, internal division, and subdivision designations as a means of uniquely identifying rail "routes" for LRS purposes.**

2. **Encourage and support efforts by the Federal Railroad Administration (FRA) to obtain complete milepost data from each operating railroad, and include this data as part of the National Railroad Network.**

<u>Waterway LRS</u>

A national standard LRS has been established for navigable inland and intracoastal waterways by the Corps of Engineers. The standard is based on the waterway name and a milepost measured from a known reference point (e.g., a confluence, the mouth, or the termination of a navigable channel). The LRS is maintained by the Corps of Engineers and is being incorporated into the National Waterway Network.

Recommendations

The FGDC Ground Transportation Subcommittee recommends that current efforts by the Corps of Engineers to establish river mile referencing of all commercially navigable rivers and the Intracoastal waterway system be completed, and adopted as the national LRS for inland and intracoastal waterways.

Federal Geographic Data Committee (FGDC)

Public Review of Position Paper and Recommendations on Linear Referencing Systems

SUMMARY: The FGDC is sponsoring a public review of a draft position paper and set of recommendations on linear referencing systems for roads, railroads, and navigable waterways. A linear referencing system is a mechanism to identify locations on a transportation system, such as a road network, using defined reference points and distances from the reference points measured along routes in the network. Linear referencing systems are employed to locate features such as bridges and other structures, events such as accidents, and attributes such as pavement condition. The development of a standard system would aid the exchange of data, which in turn would increase the utility of information and decrease duplication of efforts.

The draft recommendations will be used to guide the activities of the FGDC, especially in the implementation of the concept of framework data for the National Spatial Data Infrastructure. The success of these actions depends on the inclusion of views of State and local governments, industry, and the public. The purpose of this notice is to solicit such views. The FGDC invites the community to evaluate the draft position paper and recommendations.

DATES: Comments must be received on or before March 10, 1995.

ADDRESSES: Written comments concerning the draft should be sent by mail to LRS Review, FGDC Secretariat, U.S. Geological Survey, 590 National Center, 12201 Sunrise Valley Drive, Reston, Virginia 22092. The draft may be requested from the same mailing address, or from Internet address gdc@usgs.gov or facsimile number (703) 648-5755. Internet users should identify their name, affiliation, and postal and Internet addresses at the bottom of their message.

SUPPLEMENTARY INFORMATION: The draft was prepared by the FGDC's ground transportation subcommittee under responsibilities assigned by Office of Management and Budget Circular A-16. The subcommittee, chaired by the Federal Highway Administration, includes representives of other modal agencies of the Department of Transportation, as well as other Federal agencies. The subcommittee plans to sponsor additional discussions about linear referencing systems at the Geographic Information Systems for Transportation (GIS-T) Symposium, which is scheduled to be held April 2-5, 1995, in Sparks, Nevada.

If you are interested in subscribing to the newsletter or receiving other FGDC publications, please check the boxes of interest, and mail it to Publications, U.S. Geological Survey, 590 National Center, Reston, Virginia 22092 USA or send it by facsimile to (703) 648-5755.

Name/Position ______________________

Organization ______________________

Street Address ______________________

City/State/Zip (Postal Code)/Country ______________________

Telephone/FAX ______________________

E-mail ______________________

General Information

- ☐ FGDC Newsletter.
- ☐ First Annual Report to the Director, OMB, by the Federal Geographic Data Committee, December 1991 (contains Circular No. A-16).
- ☐ Executive Order 12906, "Coordinating Geographic Data Acquisition and Access: National Spatial Data Infrastructure, April 1994.
- ☐ The 1994 Plan for the National Spatial Data Infrastructure, March 1994.
- ☐ Factsheet on the National Spatial Data Infrastructure.
- ☐ "Continuing Evolution of the NSDI", paper by N. Tosta from the '94 GIS/LIS Proceedings.
- ☐ Application of Satellite Data for Mapping and Monitoring Wetlands, September 1992.
- ☐ Technical Meeting on the National Spatial Data Infrastructure, February 1993.
- ☐ NSGIC Report "Survey of State GIS Coordination Activities, May 1994.
- ☐ 1993 National GeoData Policy Forum Summary Report, May 10-12.
- ☐ 1995 National GeoData Forum Summary Report, May 7-10 (in press).
- ☐ Ordering information for the Manual of Federal Geographic Data Products, January 1993.

Standards

- ☐ Federal Geographic Data Committee Standards Development Schedule.
- ☐ Final "Content Standards for Digital Geospatial Metadata", June 1994.
- ☐ Content Standards for Digital Geospatial Metadata Workbook, March 1995.
- ☐ Factsheet on the Content Standards for Digital Geospatial Metadata.
- ☐ The Value of Metadata, Manager's Brochure.
- ☐ Information about the Spatial Data Transfer Standard, FIPS 173.
- ☐ Cadastral Standards for the National Spatial Data Infrastructure, FGDC Cadastral Subcommittee, September 1994
- ☐ Factsheet on the Cadastral Data Standards: A Status Report.
- ☐ Technical Forum of Spatial Features, Summary Report, March 1993 (in press).
- ☐ Strategic Interagency Approach to Developing a National Digital Wetlands Data Base, July 1994.

Clearinghouse

- ☐ The National Geospatial Data Clearinghouse Guidelines (v. 1.0), June 1994.
- ☐ Factsheet on the National Geospatial Data Clearinghouse.
- ☐ The National Geospatial Data Clearinghouse, The First Six Months Report, December 1994.

Framework

- ☐ Development of a National Digital Geospatial Data Framework, April 1995.
- ☐ Factsheet on the National Digital Geospatial Data Framework

Partnerships

- ☐ Guidelines to Encourage Cooperative Participation in Support of the National Spatial Data Infrastructure.
- ☐ Factsheet of the 1994 Awards for the NSDI Competitive Cooperative Agreements Program.
- ☐ Factsheet of the 1995 Awards for the NSDI Competitive Cooperative Agreements Program.

U.S. Department of the Interior
U.S. Geological Survey

Request for Spatial Data Transfer Standard (SDTS) Information

Order Form

1. Use this form to request the SDTS information listed below. If you request data on cartridge or cassette tape, please provide a blank tape.

2. To obtain SDTS FIPS 173-1, contact:

National Technical Information Service
Computer Products Office
5285 Port Royal Rd.
Springfield, VA 22161
703-487-4600

3. Return this form to:

U.S. Geological Survey
SDTS Request
526 National Center
Reston, VA 22092
FAX 703-648-4270

Name (first, middle initial, last)	Date	Phone (day)
Company or Agency ☐ Federal ☐ State/local ☐ Private ☐ Academic		FAX number
Address		
City, State, and ZIP Code		

☐ General SDTS information

☐ Topological Vector Profile

☐ Topological Vector Profile sample data sets and SDTS support software and documentation

☐ Draft Raster Profile

☐ Draft Raster Profile test data sets and SDTS support software and documentation

Specify medium for raster and vector profile data sets:

☐ 3.5" DOS diskette

☐ 3.5" Unix tar diskette

☐ 5.25" DOS diskette

☐ 1/4" Unix tar tape cartridge (please provide blank tape)

☐ 8mm Unix tar tape cassette (please provide blank tape)

Please send me information on participating in the following SDTS development activities:

☐ Part 2—feature and attribute dictionary

☐ Attending workshops

☐ Additional vector profiles

☐ Additional SDTS software

SDTS FIPS 173-1 and other information are available in electronic form through Anonymous FTP on Internet:

Internet address: sdts.er.usgs.gov
User name: anonymous
After connecting: cd pub/sdts

October 1994

Spatial Data Transfer Standard (SDTS)

Background

The Spatial Data Transfer Standard (SDTS) is a mechanism for the transfer of spatial data between dissimilar computer systems. The SDTS specifies exchange constructs, addressing formats, structure, and content for spatially referenced vector and raster (including gridded) data.

Advantages

Advantages of the SDTS include data and cost sharing, flexibility, and improved quality, all with no loss of information.

Components

SDTS components are a conceptual model, specifications for a quality report, transfer module specifications, and definitions of spatial features and attributes.

Status

The SDTS was approved as Federal Information Processing Standard (FIPS) in July 1992. Implementation was effective in February 1993, and use of the SDTS became mandatory for Federal agencies in February 1994. In June 1994, FIPS-173 was amended as FIPS 173-1. The SDTS serves as the spatial data transfer mechanism for all Federal agencies and is available for use by State and local governments, the private sector, and research and academic organizations.

Implementation Support

The U.S. Geological Survey's (USGS) commitment, as the designated maintenance authority, is to increase access to and use of SDTS. This commitment includes the following activities:

- Profile development-A profile is a clearly defined and limited subset of SDTS, designed for use with a specific type of data. The most effective way to use the SDTS is first to define a profile; encoding and decoding software can then be designed to handle only the options in that profile. Part 4 of the SDTS consists of the topological vector profile (TVP), which was adopted in June 1994 and is the revised component of FIPS 173-1. A raster profile is being developed and will be finalized in early 1995.

- Software development-The USGS is coordinating the development of public-domain software tools. One tool is a software function library designed to support the encoding and decoding of logically compliant SDTS data into and out of the ISO 8211-FIPS 123 general information interchange standard used by the SDTS. Translators specific to USGS data structures are also being developed.

- User guides-To address the complexity of the SDTS and to promote education, the USGS will coordinate the development of a series of user guides for the SDTS, for profiles and the profile development process, and for software support tools.

- Workshops and training-The USGS will continue to conduct SDTS workshops and other presentations to educate the spatial data community and to promote the use of the SDTS.

- Spatial features register-Part 2 of the SDTS contains a preliminary list of standard hydrographic and topographic features. The USGS SDTS Task Force is accepting submissions to the spatial features register, which will serve to update the current features in part 2.

- Conformance testing-The USGS is developing conformance tests that will validate commercial implementations of SDTS translators. They will test data sets, encoders, and decoders. Vendors are encouraged to participate in the development of these tests.

Information

For additional information about the SDTS or how to participate in related development activities, contact:

U.S. Geological Survey
SDTS Task Force
526 National Center
Reston, VA 22092
FAX 703-648-4270
E-mail: sdts@usgs.gov

Paper copies of TVP (FIPS 173-1, part 4) are available from the SDTS Task Force at the above address.

Paper copies of the SDTS base standard (FIPS 173-1, parts 1,2, and 3) are available from:

National Technical Information Service (NTIS)
Computer Products Office
5285 Port Royal Road
Springfield, VA 22161
703-487-4600

The SDTS (FIPS 173-1, all parts) and related documentation are available in electronic form via anonymous FTP on the Internet:

Internet address: sdts.er.usgs.gov (130.11.52.170)
User name: anonymous
After connecting: cd pub/sdts

File README contains information.

September 1994

FS-94-043

Metadata Table Specifications Used in DOCUMENT.AML

COLUMN	ITEM NAME	WIDTH	OUTPUT	TYPE	N.DEC	ALTERNATE NAME	INDEXED?
1	DOC-REV	8	8	C	-		-
9	CREATE-DATE	13	13	C	-		-
22	UPDATE-PERSON	30	30	C	-		-
52	UPDATE-DATE	13	13	C	-		-
65	COVER	16	16	C	-		-
81	WORKSPACE	128	128	C	-		-
209	EXTENT	80	80	C	-		-
289	PRECISION	6	6	C	-		-
295	TOLERANCES	40	40	C	-		-
335	NUM-ARCS	6	6	C	-		-
341	NUM-SEGS	7	7	C	-		-
348	NUM-POLYS	6	6	C	-		-
354	NUM-POINTS	6	6	C	-		-
360	NUM-TICS	5	5	C	-		-
365	NUM-ANNOS	5	5	C	-		-
370	THEME	30	30	C	-		-
400	DESCRIPTION	80	80	C	-		-
480	CONTACT-PERSON	30	30	C	-		-
510	CONTACT-INSTRUC	80	80	C	-		-
590	ORGANIZATION	30	30	C	-		-
620	COVER-REV	8	8	C	-		-
628	LOCATION	80	80	C	-		-
708	RESOLUTION	30	30	C	-		-
738	SCALE	30	30	C	-		-
768	ARCHIVE	80	80	C	-		-
848	PUB-STATUS	80	80	C	-		-
928	CITATION-1	80	80	C	-		-
1008	CITATION-2	80	80	C	-		-
1088	CITATION-3	80	80	C	-		-
1168	CITATION-4	80	80	C	-		-
1248	CITATION-5	80	80	C	-		-
1328	BEGDATE	8	8	C	-		-
1336	BEGTIME	4	4	C	-		-
1340	ENDDATE	8	8	C	-		-
1348	ENDTIME	4	4	C	-		-
928	THETITLE	80	80	C	-		-
1008	ORIGINATOR	80	80	C	-		-
1088	PUBLCNDATE	20	20	C	-		-
1108	PUBLCNTIME	10	10	C	-		-
1128	TYPEOFMAP	20	20	C	-		-
1148	SERIESNAME	20	20	C	-		-
1168	ISSUEIDENT	5	5	C	-		-
1173	ONLINELINK	60	60	C	-		-
1233	LGRWRKCTN	15	15	C	-		-
1248	PUBLPLACE	20	20	C	-		-
1268	PUBLISHER	30	30	C	-		-
1298	OTHCITINFO	30	30	C	-		-
1118	EDITION	10	10	C	-		-
510	DISTRIB1	20	20	C	-		-
530	DISTRIB2	20	20	C	-		-
550	DISTRIB3	20	20	C	-		-
570	DISTRIB4	20	20	C	-		-

*.ref

COLUMN	ITEM NAME	WIDTH	OUTPUT	TYPE	N.DEC	ALTERNATE NAME

INDEXED?

1	CITATION-1	80	80	C	-		-
81	CITATION-2	80	80	C	-		-
161	CITATION-3	80	80	C	-		-
241	CITATION-4	80	80	C	-		-
321	CITATION-5	80	80	C	-		-
	** REDEFINED ITEMS **						
1	THETITLE	80	80	C	-		-
81	ORIGINATOR	80	80	C	-		-
161	PUBLCNDATE	20	20	C	-		-
181	PUBLCNTIME	10	10	C	-		-
191	EDITION	10	10	C	-		-
201	TYPEOFMAP	20	20	C	-		-
221	SERIESNAME	20	20	C	-		-
241	ISSUEIDENT	5	5	C	-		-
246	ONLINELINK	60	60	C	-		-
306	LGRWRKCTN	15	15	C	-		-
321	PUBLPLACE	20	20	C	-		-
341	PUBLISHER	30	30	C	-		-
371	OTHCITINFO	30	30	C	-		-

*.att

COLUMN	ITEM NAME	WIDTH	OUTPUT	TYPE	N.DEC	ALTERNATE NAME	INDEXED?
1	PATHNAME	128	128	C	-		-
129	TYPE	6	6	C	-		-
135	FILENAME	32	32	C	-		-
167	ITEMNAME	16	16	C	-		-
183	ITEMWIDTH	4	4	I	-		-
187	OUTPUTWIDTH	4	4	I	-		-
191	ITEMTYPE	1	1	C	-		-
192	NUMDECIMAL	2	2	I	-		-
194	USERNAME	8	8	C	-		-
202	SHORTDEF	80	80	C	-		-
282	DATADOMAIN	80	80	C	-		-
362	DATASOURCE	80	80	C	-		-
442	ATTACCURACY	80	80	C	-		-

*.NAR

COLUMN	ITEM NAME	WIDTH	OUTPUT	TYPE	N.DEC	ALTERNATE NAME	INDEXED?
1	TXT-NARR	80	80	C	-		-

contactsdb

COLUMN	ITEM NAME	WIDTH	OUTPUT	TYPE	N.DEC	ALTERNATE NAME	INDEXED?
1	CONTACT_ID	20	20	C	-		-
21	CON_PERSON	80	80	C	-		-
101	CON_ORG	80	80	C	-		-
181	CON_TITLE	80	80	C	-		-
261	ADD_TYPE	4	4	C	-		-
265	ADD_STR	80	80	C	-		-
345	ADD_CTY	35	35	C	-		-
380	ADD_ST	35	35	C	-		-
415	ADD_PC	10	10	C	-		-
425	ADD_CTRY	35	35	C	-		-
460	TEL_VOICE	80	80	C	-		-
540	TEL_TDD_TTY	80	80	C	-		-
620	TEL_FAX	80	80	C	-		-
700	EMAIL	80	80	C	-		-

780	SVC_HOURS	80	80	C	-		-
860	SUPP_INSTR	80	80	C	-		-

distribdb

COLUMN INDEXED?	ITEM NAME	WIDTH	OUTPUT	TYPE	N.DEC	ALTERNATE NAME	
1	DIS_ID	20	20	C	-		-
21	DIS_RES	80	80	C	-		-
101	DIS_NAME	80	80	C	-		-
181	DIS_LIAB	80	80	C	-		-
261	DIS_CORD	80	80	C	-		-
341	DIS_TECHPR	80	80	C	-		-
421	DIS_TMAVLB	80	80	C	-		-
501	DIS_TMAVLE	80	80	C	-		-
581	DIS_NUMSOP	3	3	I	-		-

distsopdb

COLUMN INDEXED?	ITEM NAME	WIDTH	OUTPUT	TYPE	N.DEC	ALTERNATE NAME	
1	DIS_ID	20	20	C	-		-
21	DIS_SOPID	3	3	I	-		-
24	FORMAT	80	80	C	-		-
104	DIS_NODIG	14	14	C	-		-
118	DIS_DIG	14	14	C	-		-
132	DIS_FEES	80	80	C	-		-
212	DIS_ORD	80	80	C	-		-
292	DIS_TURN	80	80	C	-		-
372	DIS_NUMDIGF	3	3	I	-		-
375	DIS_NUMDIGOLT	3	3	I	-		-
378	DIS_NUMDIGDUT	3	3	I	-		-
381	DIS_NUMDIGGTI	3	3	I	-		-
384	DIS_NUMDIGOFT	3	3	I	-		-

digformdb

COLUMN INDEXED?	ITEM NAME	WIDTH	OUTPUT	TYPE	N.DEC	ALTERNATE NAME	
1	DIS_ID	20	20	C	-		-
21	DIS_SOPID	3	3	I	-		-
24	NAME	80	80	C	-		-
104	VERNUM	10	10	C	-		-
114	VERDATE	10	10	C	-		-
124	SPEC	80	80	C	-		-
204	INFO	80	80	C	-		-
284	COMPYN	7	7	C	-		-
291	COMPTECH	80	80	C	-		-

digoltdb

TYPE	NAME	INTERNAL NAME	NO. RECS	LENGTH	EXTERNL
DF	CONTACTSDB	ARC0000DAT	0	940	
DF	DISTRIBDB	ARC0001DAT	0	584	
DF	DISTSOPDB	ARC0002DAT	0	386	
DF	DIGFORMDB	ARC0003DAT	0	370	
DF	DIGOLTDB	ARC0004DAT	0	104	
DF	DIGDUTDB	ARC0005DAT	0	226	
DF	DIGGTIDB	ARC0006DAT	0	184	
DF	DIGOFTDB	ARC0007DAT	0	344	

digdutdb

COLUMN INDEXED?	ITEM NAME	WIDTH	OUTPUT	TYPE	N.DEC	ALTERNATE NAME	
1	DIS_ID	20	20	C	-		-
21	DIS_SOPID	3	3	I	-		-
24	LOWBPS	8	8	I	-		-
32	HIBPS	8	8	I	-		-
40	DATABITS	1	1	I	-		-
41	STOPBITS	1	1	I	-		-
42	PARITY	5	5	C	-		-
47	COMPMETH	20	20	C	-		-
67	PHONENUM	80	80	C	-		-
147	FILENAME	80	80	C	-		-

diggtidb

COLUMN INDEXED?	ITEM NAME	WIDTH	OUTPUT	TYPE	N.DEC	ALTERNATE NAME	
1	DIS_ID	20	20	C	-		-
21	DIS_SOPID	3	3	I	-		-
24	ACCESSINSTR	80	80	C	-		-
104	OS_AND_COMP	80	80	C	-		-

COLUMN INDEXED?	ITEM NAME	WIDTH	OUTPUT	TYPE	N.DEC	ALTERNATE NAME	
1	DIS_ID	20	20	C	-		-
21	DIS_SOPID	3	3	I	-		-
24	MEDIA	50	50	C	-		-
74	DENSITY	80	80	C	-		-
154	DENS_UNITS	30	30	C	-		-
184	REC_FORMAT	80	80	C	-		-
264	COMPAT	80	80	C	-		-

Descriptions of metadata fields

Description (1.2): A short description of the geo_dataset. The abstract (1.2.1), intended use and purpose (1.2.2), and Supplemental information (1.2.3) are included in the narrative file in order to include a more detailed discussion.

Contact Person (1.9): the owner or person in charge of distributing the geo_dataset. The value of this field must exist in the contact file. Enter a "?" to specify where the contact information is stored and to display the current contact records. You will be first prompted to enter the pathname to the distribution and contact files.
Distribution Profiles: enter the identifier of a distribution record, or enter "?" to open the database storing distribution information. The value is a relate link to the distribution records and is not an element in the FGDC standards.

Organization: name of the organization of the contact.

Geo_Dataset Revision: if applicable, the revision number.

Description of location or extent (1.6.2): the geographic location of the geo_dataset in descriptive terms such as "The state of Iowa" or as bounding coordinates.

Resolution: input the horizontal and/or vertical accuracy of the data including the unit of measure (i.e. .0001 lat/long).

Scale: if applicable, the scale at which the data was collected. Enter only the denominator of the scale: 100000, 100K, or 100,000.

Storage location, if archived: applicable platform directory pathname, computer name, Internet address, etc. For example, on a UNIX platform you may use /gis/cusa/tile/virginia on dis2qvarsa (130.11.51.171).

Progress or status (1.4.1): the status of the dataset. Enter Complete, In-work or Planned.

Dates and Times of Data Coverage (1.3): the time period for which the dataset corresponds to the ground. Currentness Reference (1.3.1) is not collected by DOCUMENT, but appears in the output files with a default of "ground condition".

Citation information (1.1.4): citation for this dataset as it would appear in text publication.

Author(s)(8.1): the name of the person or organization for the data.

Title (8.4): the name of the dataset as it is known.

Pub.Date (8.2): the date this data was published. Enter Unknown, Unpublished, or the date.

Pub Time (8.3): the time of day when the dataset was published, or Unknown.
Edition/Version (8.5): the version of this title.

Map Type (8.6): the mode in which the dataset is represented. Domain values include atlas, diagram, map, image and globe.

Series Name (8.7.1): the name of the publication series.

Issue/Number (8.7.2): information identifying the issue of the series publication.
Publisher (8.8.2): the name of the person or organization that published the dataset.

Pub. Place (8.8.1): the name of the city, state, country, etc. where the dataset was published.

Other Information (8.9): other information required to complete the citation.

Larger Work Citation Key (8.11): the information identifying a larger work in which the dataset is included.

On-line Line (URL) (8.10): the name of an online computer resource that contains the dataset.

Short description of this attribute table (5.1.1.2): a description of the contents of the table. For example, a coverage with line topology could be described as "Arc attribute table", and a grid.VAT as "Value attribute table".

Data source for the items in this table (5.1.1.3): the source of the attribute items stored in the table. For example, if the data was created by converting a TIGER/Line file, the source of the items in the attribute table is the U.S. Census TIGER/Line file.

Short description of this item (5.1.2.2): a definition or description of the item.

Domain (valid codes) for this item (5.1.2.4): values that are valid for this item. The domain may be enumerated values, a range including minimum and maximum values, or a list or codeset (such as the U.S. FIP codes). The domain may also be "unrepresentable" as a preset list, such as names.

Data Source of this item (5.1.2.3): the authority or source for the attribute values.

Accuracy of this item (5.1.2.9, 5.1.2.10): an estimate of the accuracy of the assignment of attribute values and a defintion of the accuracy measure and units.

Contact ID: a unique identifier, either text or numeric. To see existing records, press the right mouse button. You will be first prompted to enter the pathname to where the contact files are stored.

Contact Person (10.1.1 or 10.2): the name of the contact person or organization.

Contact Organization (10.1.2): the name of the organization of the contact person or organization.

Contact Position/Title (10.3): the position title of the contact person or organization.

Contact Address (10.4): The address where the contact person or organization can be reached. Pick the type of address the information refers to.

Contact Telephone Number(s) & Electronic Mail Addresses(es): enter all numbers that can be used to reach the contact person or organization.

Hours of Service (10.9): The time period during which the contact can be reached.

Contact Instructions (10.10): supplemental instructions on how or when to contact the indivdual or organization.

Distributor (6.1): this must be the value of an existing Contacts ID.

To see a list of contacts, enter a "?". If the distributor does not exist, return to the contact menu to add a new record.

Resource Description (6.2):an identifier by which the distributor knows the dataset.This may be a label or catalog number to identify the dataset.

Distribution Liability (6.3): a statement of liability assumed by the distributor.

Standard Ordering Process (6.4): press [BROWSE/UPDATE] to go to the Standard ordering process menu.

Custom Order Process (6.5): description of available custom distribution services, and any conditions for obtaining these services.

Technical Prerequisites (6.6): description of any technical capabilities a consumer must have in order to use the dataset in the form provided by the distributor.

Available Time Period (6.7): the time period when the dataset will be available.

Beginning Date/Time (9.3.1 and 9.3.2): the first year (and optionally month and day)/the first hour.

Ending Date/Time (9.3.3 and 9.3.4): the last year/ the last hour.

Non-Digital Form (6.4.1): describe options to obtain dataset on non-computer media. This option will be checked if you fill in this field, and Digital form will not be allowed.

Digital Form (6.4.2): press [BROWSE/UPDATE] to open the Digital data format menu and other menus to enter required elements for distribution of datasets in digital format. This option will be checked once you fill in further information.

Fees (6.4.3): Fees and terms for obtaining the dataset.

General Ordering Instructions (6.4.4): general instructions and advice about any terms or services for obtaining the dataset.

Turnaround Time (6.4.5): typical turnaround time for filling an order.

Format Name (6.4.2.1.1) the name of the tranfer format. Press the right mouse button to popup a scrolling list of formats.

Format Version Number (6.4.2.1.2): the version number of the format.

Format Version Date (6.4.2.1.3): the date of the version of the format.

Format Specification (6.4.2.1.4): The name of a subset, profile or product specification of the format.

Format Information Content (6.4.2.1.5) : description of the content of the data encoded in the format. This field may be needed if data are distributed in more than one file, and the files have different formats and content.

File Decompression Technique (6.4.2.1.6): processes or algorithms that can be used to read datasets which have been compressed.

Network Resource Name and address (6.4.2.2.1.1): enter the electronic address and the name of file. This could be an URL, Uniform Resource Locator

Lowest BPS (Bits per Second) Transfer Speed (6.4.2.2.1.1.2.1): the lowest or only speed for the connection's communication. This must be an integer greater than or equal to 110.

Highest BPS (Bits per Second) Transfer Speed (6.4.2.2.1.1.2.2): the highest speed for the connection's communication.

Number of Databits (6.4.2.2.1.1.2.3): the number of data bits in each character exchanged in the communication. Pick 7 or 8.

Number of Stopbits (6.4.2.2.1.1.2.4): the number of stop bits in each character exchanged in the communication. Pick 1 or 2.

Parity (6.4.2.2.1.1.2.5): the parity error checking used in each character exchanged in the communication. Pick one of the choices.

Compression Support (6.4.2.2.1.1.2.6): the data compression available through the modem service to speed data transfer. Press the right mouse button to pop up a list.

Dial-up Telephone Number(s) (6.4.2.2.1.1.2.7): the telephone number of the distribution computer.

Dial-up File Name(s) (6.4.2.2.1.1.2.8): the name of a file containing the data set on the distribution computer.

Access Instructions (6.4.2.2.1.2): the steps necessary to obtain the data set.

Online Computer and Operating system (6.4.2.2.1.3): the brand of the computer and its operating system.

Offline Media (6.4.2.2.2): the name of the media on which the dataset may be obtained. Press the right mouse button to pop up a list of media options.

Recording Capacity (6.4.2.2.2.2)

Recording Density: the density in which the dataset can be recorded.

Recording Density Units: the units of measure for the recording density.

Recording Format (6.4.2.2.2.3): the options or method used to write the dataset to the medium. Press the right mouse button to pop up a list of formats.

Compatibility Information (6.4.2.2.2.4): a description of other limitations or requirements for using the medium.

NARRATIVE

1. Abstract

(a concise abstract of the data as presented in the same format as a USGS publication)

Descriptors:
(keywords or reference words as used in the Publications Guide for searching on)

2. Applications that use this data
(types of projects that do or might use the data, models, general use, illustrations, specific type of analysis, etc.

Be specific if the data are really geared towards a narrow set of applications!)

2.1 Intended use of data
(application types it was designed for, if appropriate)

2.2 Limitations of data
(for use at certain scales, date ranges, for use with other data)

3. Attribute discussion
(Describe each table that has meaningful attributes in it. Use the contents of the ATT table for reference. For each column or item give a brief description and a list of valid attribute values that are associated with it.)

4. Procedures used to create or automate data
(Describe from beginning to end all procedures used to process the data from raw/received format into what is being documented here. Include source organization and tape type and format, tape to disk conversion -- tapewrite or dd or cpio -- reblocking, if performed. List each step performed and the commands and arguments used. Include any processing tolerances and whether the data were in single or double precision. If other on-line data sets were used, name and reference them in the text but also use the CITE option of DOCUMENT afterwards to formalize it. This section should stand alone as a narrative that anyone could take and apply to raw data and end up with the same results you did!)

5. Revisions made to data (revision number, date, description)
(Number each revision starting with 1. and describing the changes associated with that revision. Different versions of spatial data may have different results in analysis. Need to pass this information along to the user.)

6. Reviews applied to data (review type, date, person, description)
(Spatial data ready to be documented and placed in a library must go through some in-house review. Review should include inspection of the LOG file for completeness and conformance to the steps described in this narrative, verification of table and column/item identities and definitions, validity of the reference data sets and citations, and review of any additional quality assurance measures performed on the data that may be required in standard Spatial Data Automation Guidelines.)

7. Related spatial and tabular data sets and programs
(The identity and location of data sets or tables that may be related to the basic feature attribute tables. These include symbol lookup tables, additional tables that might contain extended definitions, like county names to match county numbers. Be sure to identify what items or columns one can use to relate on.)

8. References cited
(In bibliographic reference form)

9. Notes
(Any additional comments, caveats, etc.)

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