

AS/NZS 4270.1:1995

Australian/New Zealand Standard

**Geographic information systems—
Spatial data transfer standard**

Part 1: Logical specifications

[Based on FIPS PUB 173-1992, Spatial Data Transfer Standard]

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 Australia New Zealand Land Information Council
 Australian Bureau of Statistics
 Australian Geological Survey Organization
 Australian Key Centre in Land Information Studies
 Australian Map Circle
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Geographic information systems— Spatial data transfer standard

Part 1: Logical specifications

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PREFACE

This Standard was prepared by the Joint Standards Australia/Standards New Zealand Committee IT/4 on Geographical Information Systems. It is based on and reproduced from FIPS PUB 173, *Spatial Data Transfer Standard*, Part 1: *Logical specifications*, a US Federal Information Processing Standard (FIPS) publication. The Standard varies from FIPS PUB 173-1992 as follows:

- (a) The Australia and New Zealand revisions to the FIPS PUB 173 text are contained in Appendix AA. The FIPS PUB 173 text has been left as published to simplify future revisions.
- (b) In the FIPS PUB 173 text, read ‘metres’ for ‘meters’.
- (c) References to specific American spatial reference systems have been retained in this Standard to ensure compatibility with the US Standard. Spatial reference systems common in Australia and New Zealand, such as the Australian Map Grid, are catered for as versions of the Universal Transverse Mercator grid system. Particular Australian State and Territory co-ordinate systems, such as the Lambert Conformal Conic and Integrated Survey Grid systems, are catered for specifically. Similarly, the New Zealand Map Grid, which is a minimum error conformal projection, is also catered for specifically.
- (d) Reference to Part 2 of the FIPS PUB 173 Standard is included for compatibility with the US Standard. Users may replace Part 2 by specific Australian and New Zealand spatial feature definition Standards.

The objective of this Standard is to provide users of geographical information systems with a uniform format for the transfer of information.

AS 2482, *Geographic information systems—Geographic data—Interchange of feature-coded digital mapping data*, has been used to specify a file structure and formats for the interchange of digital mapping data and associated information. The Committee is mindful that, while it is preferred that the AS/NZS 4270 series be used for data transfer, AS 2482 has been implemented in many systems. As such, it is intended that AS 2482 be withdrawn five years after publication of this Standard.

The Standard contains a specification of the Spatial Data Transfer Standard (SDTS), that will serve as a national spatial data transfer mechanism for Australia and New Zealand. As such, it is designed to transfer a wide variety of data structures that are used in the spatial sciences, such as cartography, geography, geology, and geographic information systems. Part 1 of this Standard contains the SDTS logical superstructure that presents the organization and structure of the SDTS transfer mechanism.

In this Standard, Australian and New Zealand variations have been listed in Appendix AA and, accordingly, the source text should be amended, supplemented or replaced as required. The changes to the source text are indicated with a marginal bar against each clause, table, figure or part thereof affected.

For the purpose of this Joint Standard, the references in the FIPS PUB 173 text to international or other Standards should be replaced by references to the following Australian/New Zealand Standards:

Reference to International Standard or Other Publication		Australian/New Zealand Standard	
ANSI		AS	
X3.4	Information systems—Coded character sets—7-bit American National Standard Code for information interchange	1776	Information processing—7-bit coded character set for information interchange

X3.173	Unrecorded Magnetic Tape and Cartridge for Information Interchange, 20-Track, Serial, 1/2 in (12.65 mm) 12000 ftpi (472 ftpmm)	—	
FIPS PUB		AS	
4-1	(ANSI X3.3) Representation for Calendar Date and Ordinal Date for Information Interchange	3802	Data elements and interchange formats—Information interchange—Representation of dates and times (ISO 8601). (See note)
5-2	Codes for Identification of the States, District of Columbia and Outlying Areas of the United States	—	
6-3	Counties and County Equivalents of the States of the United States and District of Columbia	—	
8-5	Metropolitan Statistical Areas	—	
9	Congressional Districts of the United States	—	
10-3	Counties, Dependencies, Areas of Special Sovereignty and their Principal Administrative Division	—	
19-1	Catalog of Widely Used Code Sets	—	
58-1	(ANSI X3.43) Representations of Local Time of the Day for Information Interchange	—	
59	(ANSI X3.51) Representations of Universal Time, Local Time Differentials, and United States Time Zone References for Information Interchange	—	
70-1	(ANSI X3.61) Representation of Geographic Point Locations for Information Interchange	—	
95	Codes for Identification of Federal and Federally Assisted Organizations	—	
103	Codes for the Identification of Hydrological Units in the United States and Caribbean Outlying Areas	—	
104-1	Guideline for Implementation of ANSI Codes for the Implementation of Names of Countries, Dependencies and Areas of Special Sovereignty	—	
FIPS PUBS		AS	
123	(ANSI/ISO 8211) Information processing—Specification for a data descriptive file for information interchange (DDF)	3654	Information processing—Specification for a data descriptive file for information interchange (ISO 8211)
128	(ANSI X3.122) Computer Graphics Metafile (CGM)	3603	(NZS/ISO 8632) Computer graphics—Metafiles for the storage and transfer of picture description information

153	(ANSI X3.144) Information Systems—Computer Graphics—Programmer’s Hierarchical Interactive Graphics Systems (PHIGS)	3732	(NZS/ISO-IEC 9592) Computer graphics-Programmer’s Hierarchical Interactive Graphics Systems (PHIGS)
IEEE			
803	Recommended Practice for Unique Identification in Power Plants and Related Facilities—Principles and Definitions	—	
803A	Recommended Practice for Unique Identification in Power Plants and Related Facilities—Component Function Identifiers	—	
ISO			
6093	Information processing—Representation of numerical values in character strings for information interchange	3767	Information processing—Representation of numerical values in character strings for information interchanges (ISO 6093)
TR 9973	Information processing—Procedures for registration of graphical items	—	

NOTE: AS 3802 is not technically equivalent to FIPS PUB 4-1.

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AUSTRALIAN/NEW ZEALAND STANDARD

Geographic information systems—Spatial data transfer standard**Part 1:****Logical specifications****1 Introduction**

This Spatial Data Transfer Standard (SDTS) provides a solution to the problem of spatial (i.e., geographic and cartographic) data transfer from the conceptual level to the details of physical file encoding. Transfer of spatial data involves modeling spatial data concepts, data structures, and logical and physical file structures. To be useful, the data to be transferred must also be meaningful in terms of data content and data quality. SDTS addresses all of these aspects for both vector and raster data structures.

The standard is in three parts. Part 1 addresses the logical specifications in terms of conformance requirements, a conceptual model, quality specifications, the data structure model, and the transfer format. Part 2 addresses data content by providing a standard list and definitions of spatial features and their attributes. Part 3 specifies the implementation of SDTS in terms of the International Organization for Standardization for a Data Descriptive File for Information Interchange.

Section 1 of part 1 includes a statement of scope and conformance requirements for SDTS. It also includes normative references to other standards and definitions of terms.

The conceptual model of spatial data is presented in section 2 to provide a framework for defining spatial features and a context for the definition of a set of spatial objects. This conceptual model supports the translation of user data models to and from the SDTS model. Within section 2 is a defined set of spatial objects, for zero, one, and two dimensions, used in spatial data systems to represent real-world spatial phenomena. Three-dimensional spatial objects have not been specified. The defined set of objects will support the three major types of spatial data operations: (1) geometry only, (2) geometry and topology, and (3) topology only. These objects have been specified in a modular fashion so that more elaborate composite objects can be constructed from them.

Section 3 includes specifications for a quality report concerning the objects in a transfer and their attributes. The purpose of the quality report is to provide detailed information for a user to evaluate the fitness for a particular use. This style of standard can be characterized as "truth in labeling," rather than fixing arbitrary numerical thresholds of quality. To implement this portion of the standard, a producer is urged to include the most rigorous and quantitative information available on the components of data quality described in this section.

Sections 4 and 5 present specifications for the transfer of spatial data. Section 4 contains general concepts and specifications, the underlying models that pertain to the transfer module specifications of section 5. Section 4 also specifies the general elements of an implementation, the relationships of the logical constructs of the data models to the

general elements of a detailed implementation, and general constraints on the implementation. Finally, section 4 presents the transfer module specification conventions used in section 5. Logical modules consisting of detailed record, field and subfield specifications are presented in section 5.

1.1 Scope

This standard specifies a structure and content for spatially referenced data in order to facilitate data transfer between dissimilar spatial data base systems.

1.2 Conformance

This standard anticipates products that do not contain instances of all the specified information and syntactic forms. This portion specifies the conditions of conformance and the requirements of a conformance statement. This standard does not specify requirements for processing data into and out of the standard, therefore such processing cannot itself conform to this standard.

1.2.1 General Conformance

Any product claiming conformance to this standard shall follow the applicable requirements and specifications of parts 1, 2, and 3 with respect to both the syntax and the semantics of all included data elements.

1.2.2 Data Quality

This standard requires that spatial data to be transferred shall include a report on data quality. This Data Quality Report shall always accompany the data in a standard transfer. It consists of five portions described in detail in section 3: lineage, positional accuracy, attribute accuracy, logical consistency, and completeness. Where a spatial variation in quality is known, the quality report shall record that variation.

1.2.2.1 Form of a Quality Report. The Data Quality Report shall always accompany the data in a standard transfer. Because the quality report will function in the assessment of fitness for use, it shall also be obtainable in its entirety and separately from the actual data. This separate quality report may be issued as a Spatial Data Transfer or as a paper document.

1.2.2.2 Tests for Data Quality. In 3.2, 3.3, and 3.4 below, options are described for different categories of testing. Informed assessment of fitness for use is best served by the most rigorous types of tests.

1.2.2.3 Quality Overlays. For those components of quality displaying spatial variation, a quality overlay system may be used. The producer of the quality report may choose to

produce a comprehensive quality overlay describing all components of quality or separate overlays portraying various components. When the quality report is issued on paper, the quality overlays appear as diagrams with text labels or thematic map depictions. In digital form, the overlays shall be encoded using the specifications of sections 4 and 5.

1.2.3 Conformance Statement

A statement claiming conformance to this standard shall specify the profile and level of conformance for each applicable component of the Transfer Specification as defined in 1.2.4.

1.2.4 Transfer Specification Conformance Field

The Identification module of the Transfer Specification (5.2.1) includes a Conformance field. This field contains subfields for a profile specification, external spatial reference conformance and a level of conformance to spatial feature definitions. Each subfield is required to contain one of the values enumerated in 5.2.1.2.

1.2.4.1 Profile Specification. The transfer shall include the profile specification described in 5.2.1.2.1. This specification defines the domain of object types included in the transfer. Object types other than those identified in the Profile Specification subfields shall not be included in the transfer.

1.2.4.2 External Spatial Reference Conformance. Whether or not one of the three recommended reference systems-- Geographics, UTM/UPS, or State Plane-- has been used, shall be specified in the External Spatial Reference subfield of the Conformance field of the Identification module, as described in 5.2.1.2.2, as well as in the Reference System Name subfield of the External Spatial Reference module (5.2.4.2).

1.2.4.3 Features Level. The level of conformance to the list of standard terms and definitions of spatial Entities and Attributes contained in part 2 of this standard shall be specified in the Features Level subfield of the Conformance field of the Identification module. Each level has the meaning specified in 5.2.1.2.3.

1.2.5 Private Agreements

Private agreements limit the scope of the transfer and are discouraged. Recurring needs for similar private agreements should be referred to the maintenance organization for this standard.

1.3 References

This standard shall be used in conjunction with the following normative references. When a publication is superseded by a revision approved by the authorizing organization,

the revision shall apply. (An informative list of references that includes the following in addition to other sources used in preparing this standard is contained in annex F.)

- 1.3.1 American National Standards Institute, Inc., 1986, American National Standards for Information Processing -- Coded Character Sets -- 7-Bit ASCII. 1.3.2 American National Standards Institute, Inc., 1430 Broadway, New York, New York 10018.
- 1.3.2 American National Standards Institute, Inc., 1986, American National Standard for Information Systems - Database Language - SQL (SQL). American National Standards Institute, Inc., 1430 Broadway, New York, New York 10018.
- 1.3.3 American Society for Photogrammetry and Remote Sensing, Committee for Specifications and Standards, 1990, "ASPRS Accuracy Standards for Large-Scale Maps," (approved by ASPRS Professional Practicing Division, March 1990), Photogrammetric Engineering and Remote Sensing, Volume LVI, No. 7, July 1990, pp. 1068-1070.
- 1.3.4 Calendar Date, 1968, FIPSPUB 4-1, 27 Jan 88; also ANSI/X3.30-1985.
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- 1.3.14 Guideline for Implementation of ANSI Codes for the Implementation of Names of Countries, Dependencies and Areas of Special Sovereignty, 1983, FIPSPUB 104-1, 12 May 86.
- 1.3.15 Guideline: Codes for Names of Populated Places, Primary County Divisions, Other Locational Entities in the United States, 1983, FIPSPUB 55-2, 3 Feb 87.
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- 1.3.18 National Zip Code and Post Office Directory, U.S. Postal Service Publication 65.
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- 1.3.22 Representations of Local Time of the Day for Information Interchange, 1979, FIPSPUB 58-1, 27 Jan 88; also ANSI/X3.43-1986.
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1.4 Definitions

The following terms are used in the definitions of concepts essential to this standard. The concepts for which this standard provides normative definitions appear in section 2, Spatial Data Concepts; section 3, Spatial Data Quality; and section 4, General Specification. An informative list of all defined terms is contained in annex E.

- 1.4.1 Accuracy - The closeness of results of observations, computations, or estimates to the true values or the values accepted as being true.
- 1.4.2 Altitude - Elevation above or below a reference datum, as defined in FIPSPUB 70-1; the z-value in a spatial address. See also elevation.
- 1.4.3 Control (mapping) - A system of points with established horizontal and vertical positions that are used as fixed references in positioning and relating map features.
- 1.4.4 Coordinates - Pairs of numbers expressing horizontal distances along orthogonal axes; alternatively, triplets of numbers measuring horizontal and vertical distances.
- 1.4.5 Data base - Related subject information stored as a volume set, volume, file set, or file.
- 1.4.6 Data element - A logically primitive item of data.
- 1.4.7 Digital encoding - To convert to a form that can be operated upon by electronic computer as binary digits.
- 1.4.8 Elevation - Conforming to FIPSPUB 70-1, the term "altitude" is used in this standard, rather than the common term elevation, for the z-value in a spatial address.
- 1.4.9 Field - Consists of one or more related subfields. It may contain part or all of a module field. It does not contain parts of two or more module fields.
- 1.4.10 Field name - A name associated with a field.

- 1.4.11 File** - An identifiable collection of zero or more related records. It may contain part of, or all of one or many modules.
- 1.4.12 File set** - An identifiable collection of zero or more related files.
- 1.4.13 Geocodes** - A system of encoding used to represent an exhaustive list of a class of spatial features (usually applied to political units).
- 1.4.14 Implementation method** - A method of encoding data content and data structure to accomplish a transfer between dissimilar computer systems without loss of content, meaning, or structure.
- 1.4.15 Map** - A spatial representation, usually graphic on a flat surface, of spatial phenomena.
- 1.4.16 Media** - The physical devices used to record, store, and (or) transmit data.
- 1.4.17 Media record** - A physical unit of data. The characteristics of a record and its means of delimitation are defined by standards specific to each given medium.
- 1.4.18 Misclassification Matrix** - Results of an attribute accuracy test given in the form of a row by column contingency table (crosstabulation) sometimes called a classification error matrix. The rows represent the interpretation tested and the columns represent the verification assumed to be correct. The diagonal elements represent the correct classifications when the matrix is square and the rows and columns are strictly comparable. The remaining elements can be treated row-wise as errors of commission, and column-wise as errors of omission.
- 1.4.19 Module** - A logical collection of module records.
- 1.4.20 Module field** - A defined set of one or more module subfields in a Spatial Data Transfer.
- 1.4.21 Module record** - A defined set of one or more module fields in a Spatial Data Transfer.
- 1.4.22 Module specification** - The meaning, identification, order requirements, and data structure requirements for data belonging to the module.
- 1.4.23 Module subfield** - A logical construct defining a single data element in a Spatial Data Transfer.
- 1.4.24 Primitive** - The quality of not being subdivided; atomic.

- 1.4.25 Quality** - An essential or distinguishing characteristic necessary for spatial data to be fit for use.
- 1.4.26 Quality overlay** - A collection of points, lines, and areas organized to represent quality information for another set of map information. An overlay describing lineage may be termed a source data index; a positional accuracy overlay may be termed a reliability diagram.
- 1.4.27 Record** - An implementation-dependent construct that consists of an identifiable collection of one or more related fields.
- 1.4.28 Representation** - Graphical symbolization of a spatial object.
- 1.4.29 Resolution** - The minimum difference between two independently measured or computed values that can be distinguished by the measurement or analytical method being considered or used.
- 1.4.30 Spatial data transfer** - A collection of related modules.
- 1.4.31 Subfield** - A physical area containing, or logical construct defining, a single data element.
- 1.4.32 Transfer construct** - A volume set, volume, file set, file, module, module record, module field, module subfield, field, subfield, record, or media record.
- 1.4.33 Transformation** - A computational process of converting a position from one coordinate system to another.
- 1.4.34 Volume** - A media-dependent construct consisting of an identifiable collection of part of or all of one or more files. A volume is a discrete interchange construct such as a unit of dismountable media or a single online session.
- 1.4.35 Volume set** - A media-dependent construct consisting of an identifiable collection of one or more volumes containing a single file set.

2 Spatial Data Concepts

The basis of SDTS is a model of spatial data sufficiently general so that any user data model can be accepted.

2.1 Conceptual Model

The SDTS conceptual model has three parts: a model of spatial phenomena, a model of the spatial objects used to represent phenomena, and a model of spatial features that explains how spatial objects and spatial phenomena are related (see also annex A).

The following terms define the parts of the model.

(a) *Phenomenon*. A fact, occurrence, or circumstance. Route 10, George Washington National Forest, and Chesterfield County are all phenomena.

(b) *Classification*. The assignment of similar phenomena to a common class. An individual phenomenon is an instance of its class. Route 10 is an instance of the class road.

(c) *Generalization*. A process in which classes are assigned to other classes. The general class includes all the instances of the constituent classes. Sewers are included in the more general class of utilities.

(d) *Aggregation*. The operation of constructing more complex phenomena out of component phenomena. A lock is an aggregation of walls, gates, and a reservoir.

(e) *Association*. The assignment of phenomena to sets, using criteria different from those used for classification. Concrete roads may be associated with concrete sewers, concrete locks, and other phenomena constructed of concrete.

2.1.1 Model of Spatial Phenomena

SDTS transfers information about phenomena that are defined in space and time and are described by using a fixed location-- spatial phenomena. All phenomena are defined as belonging to a class of phenomena. (Smith's Farm belongs to Farm.) A characteristic of such a class is called an attribute. (Area is an attribute for Farm.) An attribute value is a specific quantity or quality of the attribute assigned to a phenomenon in that class. (Smith's Farm has an Area of 160 acres.)

Whether a given phenomenon belongs to a class is determined by the definition of the class. The definition consists of a statement about characteristics that all members of the

class have in common. It also includes characteristics that distinguish the class from other classes. These definitional characteristics are necessary and sufficient conditions for classifying some phenomena into the class and excluding others. The data collector may define which classes of phenomena are of interest. Those classes of phenomena are called entity types, and the individual phenomena are called entity instances.

Certain attributes are identified with each class. The attributes of a class include key attributes. The combination of values of the key attributes forms a unique identifier for each entity instance.

Entity instances may be aggregated into instances of a different type of entity.

Entity types can be generalized into themes based on definitional characteristics shared by more than one class. A theme can also have its own attributes, including name.

Associations of entity instances are defined in terms of characteristics other than those used to define an entity type. A common association is the spatial domain, which groups all entity instances having coordinates within a specified range. Another useful association is temporal domain. SDTS represents entity instances as static, without temporal dimension. However, values of a temporal attribute such as Age may be assigned to entity instances and used to associate them into sets with a common extent in time.

A relationship is a special case of an association. A relationship exists between entity types. A relationship instance is an association between entity instances with a unique relationship value.

2.1.2 Model of Spatial Objects

Entity instances have a digital representation. That digital representation consists of one or more spatial objects. A spatial object may be an aggregation of other spatial objects, not all of which necessarily represent an entity instance. A spatial object that represents all of a single entity instance is an entity object. It may be classified into an entity object class. Entity objects have generalizations and associations as well: the representation of an entity theme is an object theme, and an entity spatial domain, an object spatial domain. In general, the correspondence between entity instance and entity object is paralleled by all characteristics of entities and objects.

Entity objects have locational attributes (spatial address), nonlocational attributes, and relationships (topology). The attributes and relationships of entity objects need not be as extensive as those of their corresponding entity instances. The key attributes used to distinguish a particular entity instance may not be present in the actual transfer; instead, the entity object record identifier may be the only way to distinguish between instances.

Spatial objects may have attributes independently of whether they are entity objects or not. All objects may be classified, aggregated, and associated in the same general manner that entity instances may be.

This standard defines a set of simple spatial objects. These simple spatial objects are either primitive objects (not aggregated from any other objects), or aggregated only from spatial objects belonging to different classes (polygons, for example, are not aggregated from polygons, only from rings, chains or strings). The only exception is the composite object. Composite spatial objects may be aggregated from simple objects or from other composites.

Spatial objects are classified into module types, one of the basic building blocks of the standard. Once defined, modules may be associated into sets by spatial domain, temporal domain, data quality, security requirements, topological relationships, or any other criteria.

2.1.3 Model of Spatial Features

The terminology in geographic data handling has traditionally not distinguished between the phenomenon and its representation, referring to both as features. For the sake of clarity, a feature is defined as the combination of the phenomenon and its representation. A feature instance consists of an entity instance and the entity object that represents it, and belongs to a feature type.

Table 1 Feature Instance

<u>An instance of a defined entity and its object representation</u>	
<u>Entity instance</u>	<u>Entity object</u>
A spatial phenomenon of a defined type.	A digital representation of an entity instance.

2.2 Classification and Intended Use of Objects

This standard defines three classes of spatial objects. Two classes are defined explicitly: geometry only and geometry and topology. The third class, topology only, can be defined implicitly by removing the coordinates from the geometry and topology class of objects. The intended use of these three classes of objects is as follows:

- (a) Geometry only - for drawing, display, and geometrically defined operations.
- (b) Geometry and topology - for vector data structures that use geometric drawing and topological operations.

(c) Topology only - for certain analytical operations.

The relationship between the explicitly defined classes of objects and their intended use is specified in table 2.

Table 2 Intended use of defined spatial objects

Number of dimensions	Intended use	
	Geometry only (G)	Geometry and topology (GT)
zero dimensions	point*	node
one dimension	line segment	link
	string	chain*
	arc	
	G-ring	GT-ring
two dimensions	G-polygon	GT-polygon*
	pixel	
	grid cell	

*There are additional special objects that are based on the point, the chain, and the polygon.

2.3 Definition of Spatial Objects

The spatial objects specified in 2.3.1 through 2.3.3 represent the simple objects required for digital spatial processing which can be used to construct composite objects that represent a more complex realization of the real world. The following definitions are valid in planar and non-planar, Euclidean geometry, as well as simple curved surfaces such as the sphere or ellipsoid. Each object type is associated with one or more two-character object representation codes. Use of the codes is explained in 5.6 and 5.7 (see also tables 31 and 37).

Composite objects (object representation code FF) shall be constructed from the simple objects by aggregation. Specifically, a composite object consists of one or more other objects, either simple or composite.

2.3.1 Definition of Zero-dimensional Spatial Objects

2.3.1.1 Point (NP). A zero-dimensional object that specifies geometric location. One coordinate pair or triplet specifies the location.



The three point definitions that follow are special implementations of the general case:

2.3.1.1.1 Entity point (NE). A point used for identifying the location of point features (or areal features collapsed to a point), such as towers, buoys, buildings, places, etc.

2.3.1.1.2 Label point (NL). A reference point used for displaying map and chart text (e.g., feature names) to assist in feature identification.

2.3.1.1.3 Area point (NA). A representative point within an area usually carrying attribute information about that area.

2.3.1.2 Node (NO, NN). 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.



2.3.2 Definition of One-dimensional Spatial Objects

A line is a generic term for a one-dimensional object.

2.3.2.1 Line Segment. A direct line between two points.



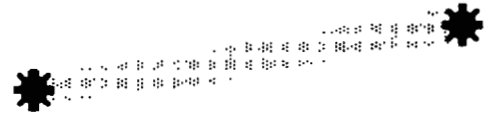
2.3.2.2 String (LS). A connected nonbranching sequence of line segments specified as the ordered sequence of points between those line segments.
Note: A string may intersect itself or other strings.



2.3.2.3 Arc (AC, AE, AU, AB). A locus of points that forms a curve that is defined by a mathematical expression.



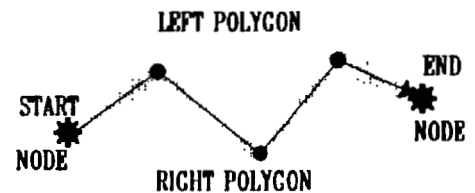
2.3.2.4 Link (LQ). A topological connection between two nodes. A link may be directed by ordering its nodes.



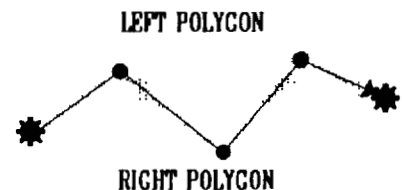
2.3.2.5 Chain. A directed nonbranching sequence of nonintersecting line segments and (or) arcs bounded by nodes, not necessarily distinct, at each end.

The following three objects are special cases of chain. They share all characteristics of the general case as defined above.

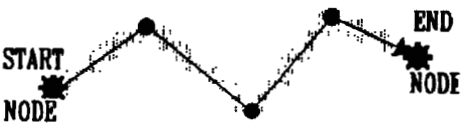
2.3.2.5.1 Complete chain (LE). A chain that explicitly references left and right polygons and start and end nodes. It is a component of a two-dimensional manifold (2.3.4.5.2).



2.3.2.5.2 Area chain (LL). A chain that explicitly references left and right polygons and not start and end nodes. It is a component of a two-dimensional manifold.

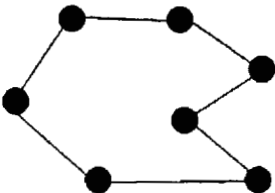


2.3.2.5.3 Network chain (LW, LY). A chain that explicitly references start and end nodes and not left and right polygons. It is a component of a network (2.3.4.5.3).

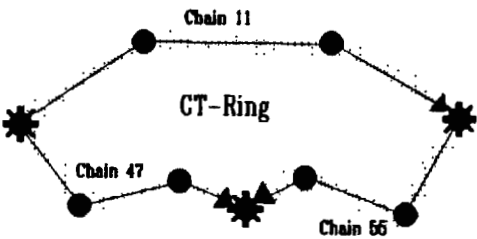


2.3.2.6 Ring. A sequence of nonintersecting chains or strings and (or) arcs, with closure. A ring represents a closed boundary, but not the interior area inside the closed boundary.

2.3.2.6.1 G-ring (RS, RA, RM). A ring created from strings and (or) arcs.



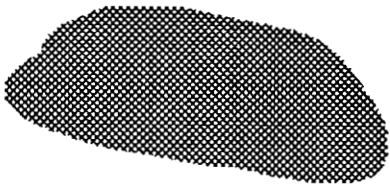
2.3.2.6.2 GT-ring (RU). A ring created from complete and (or) area chains.



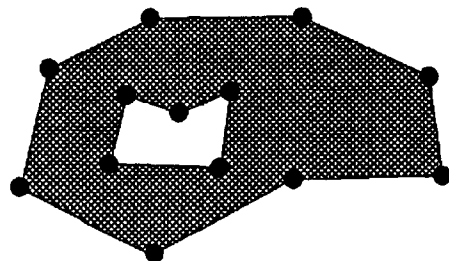
2.3.3 Definition of Two-dimensional Spatial Objects

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

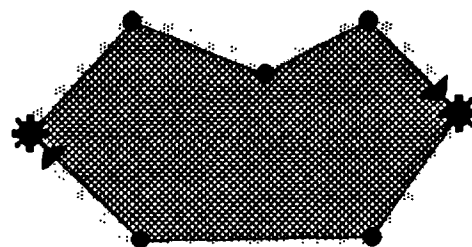
2.3.3.1 Interior Area. An area not including its boundary.



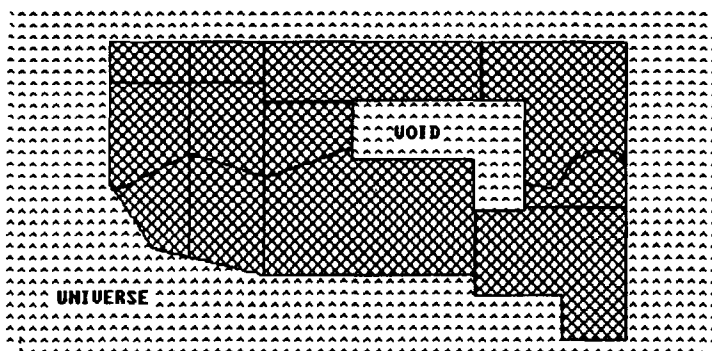
2.3.3.2 G-Polygon (PG). An area consisting of an interior area, one outer G-ring and zero or more nonintersecting, nonnested inner G-rings. No ring, inner or outer, shall be collinear with or intersect any other ring of the same G-polygon.



2.3.3.3 GT-Polygon (PR, PC). An area that is an atomic two-dimensional component of one and only one two-dimensional manifold. The boundary of a GT-polygon may be defined by GT-rings created from its bounding chains. A GT-polygon may also be associated with its chains (either the bounding set, or the complete set) by direct reference to these chains. The complete set of chains associated with a GT-polygon may also be found by examining the polygon references on the chains.



2.3.3.3.1 Universe polygon (PU, PW). Defines the part of the universe that is outside the perimeter of the area covered by other GT-polygons ("covered area") and completes the two-dimensional manifold. This polygon completes the adjacency relationships of the perimeter links. The boundary of the universe polygon is represented by one or more inner rings and no outer ring. Attribution of the universe



polygon may not exist, or may be substantially different from the attribution of the covered area.

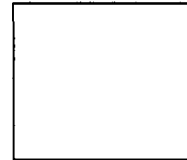
2.3.3.3.2 Void polygon (PV, PX). Defines a part of the two-dimensional manifold that is bounded by other GT-polygons, but otherwise has the same characteristics as the universe polygon. The geometry and topology of a void polygon are those of a GT-polygon. Attribution of a void polygon may not exist, or may be substantially different

from the attribution of the covered area.

2.3.3.4 Pixel. A two-dimensional picture element that is the smallest nondivisible element of a digital image (2.3.4.1).



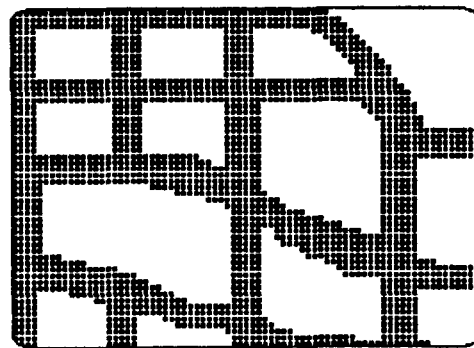
2.3.3.5 Grid Cell. A two-dimensional object that represents the smallest nondivisible element of a grid (2.3.4.2).



2.3.4 Definition of Aggregate Spatial Objects

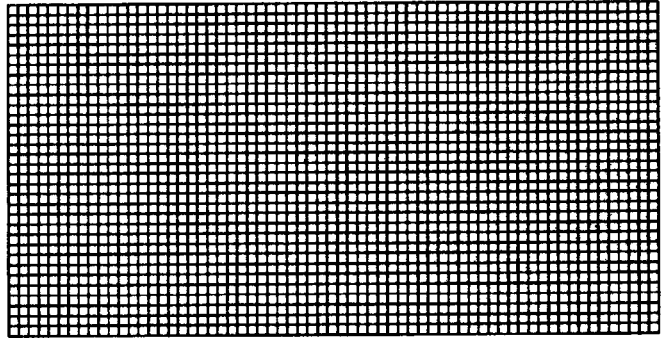
Certain aggregate spatial objects must be defined to provide context for many of the simple objects defined above. These aggregate objects are necessary for the definition of (a) raster objects (grid, image, layer, and raster) and (b) topology objects (three types of graphs, with or without geometry).

2.3.4.1 Digital Image (GI, GJ, GK, GM). A two-dimensional array of regularly spaced picture elements (pixels) constituting a picture.

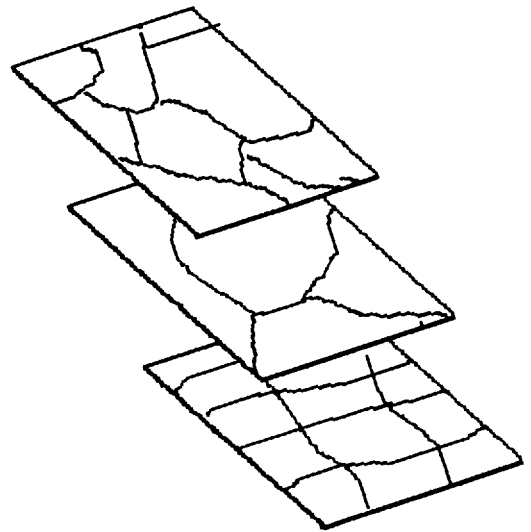


2.3.4.2 Grid (GI, GJ, GK, GM).

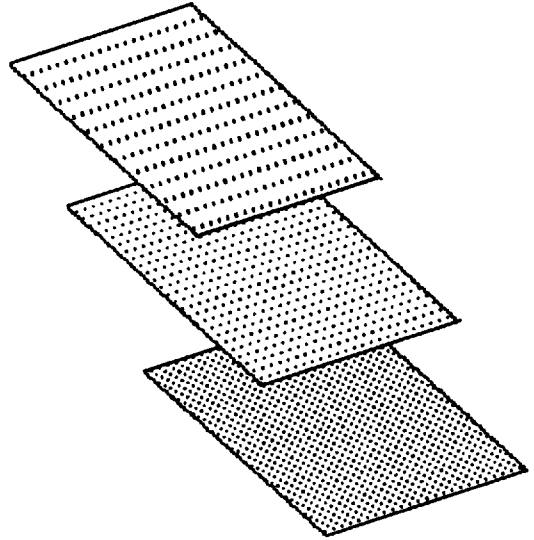
A set of grid cells forming a regular, or nearly regular, tessellation of a surface. The tessellation is regular if formed by repeating the pattern of a regular polygon, such as a square, equilateral triangle, or regular hexagon. The tessellation is nearly regular if formed by repeating the pattern of an "almost" regular polygon such as a rectangle, non-square parallelogram, or non-equilateral triangle.



2.3.4.3 Layer. An areally distributed set of spatial data representing entity instances within one theme, or having one common attribute or attribute value in an association of spatial objects. In the context of raster data, a layer is specifically a two-dimensional array of attribute values associated with all or part of a grid or image.



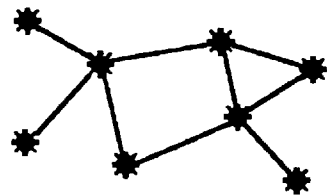
2.3.4.4 Raster. One or more overlapping layers for the same grid or digital image.



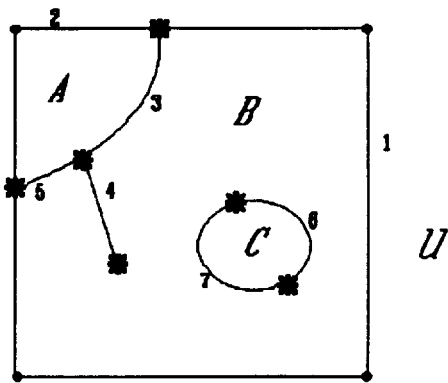
2.3.4.5 Graph. A set of topologically interrelated zero-dimensional (node), one-dimensional (link or chain), and sometimes two-dimensional (GT-polygon) objects that conform to a set of defined constraint rules. Numerous rule sets can be used to distinguish different types of graphs. Three such types, planar graph, network, and two-dimensional manifold, are used in this standard. All three share the following rules: each link or chain is bounded by an ordered pair of nodes, not necessarily distinct; a node may bound one or more links or chains; and links or chains may only intersect at nodes.

Planar graphs and networks are two specialized types of graphs, and a two-dimensional manifold is an even more specific type of planar graph.

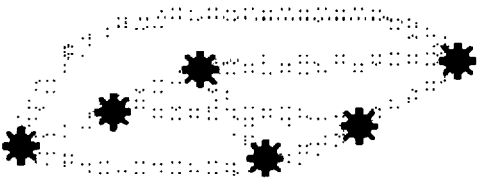
2.3.4.5.1 Planar graph. The node and link or chain objects of the graph occur or can be represented as though they occur upon a planar surface. Not more than one node may exist at any given point on the surface. Links or chains may only intersect at nodes.



2.3.4.5.2 Two-dimensional manifold. A planar graph and its associated two dimensional objects. Each chain bounds two and only two, not necessarily distinct, GT-polygons. The GT-polygons are mutually exclusive and completely exhaust the surface.



2.3.4.5.3 Network. A graph without two dimensional objects. If projected onto a two-dimensional surface, a network can have either more than one node at a point and (or) intersecting links or chains without corresponding nodes.



3 Spatial Data Quality

The Data Quality Report consists of five portions covering lineage, positional accuracy, attribute accuracy, logical consistency, and completeness. Each portion of the report shall contain reference to temporal information.

3.1 Lineage

The lineage portion of a quality report shall include a description of the source material from which the data were derived and the methods of derivation, including all transformations involved in producing the final digital files. The description shall include the dates of the source material and the dates of ancillary information used for update. The date assigned to a source shall reflect the date that the information corresponds to the ground; however, if this date is not known, then a date of publication may be used, if declared as such.

Any data base created by merging information obtained from distinct sources shall be described in sufficient detail to identify the actual source for each element in the file. In these cases, either a lineage code on each element or a quality overlay (source data index, etc.) shall be required.

The lineage portion shall also include reference to the specific control information used. Control from the National Geodetic Reference System shall be identified according to identifiers in that system, while other points used for control shall be described with sufficient detail to allow recovery.

The lineage portion shall describe the mathematical transformations of coordinates used in each step from the source material to the final product. The locations of any registration points for coordinate transformations shall be given. The methods used to make coordinate transformations shall be documented. To fulfill this standard, it is acceptable to make reference to separate documentation for the coordinate transformation algorithm used, but the specific parameters applied shall be described for the particular case. Documentation of a transformation algorithm shall include the nature of computational steps taken to avoid loss of digits through roundoff and shall include a set of sample computations including numerical values of coefficients to confirm equivalence of transformations. The documentation of a transformation algorithm shall be available on request by a user obtaining digital data even if that user is not licensed to use the particular software.

3.2 Positional Accuracy

The quality report portion on positional accuracy shall include the degree of compliance

to the spatial registration standard (see section 4.1.3.5). Quality of control surveys shall be reported by using the procedures established in the geodetic standard. If a separate control survey has been used, it shall be described in the standard form, even if results fall below the recognized classification thresholds.

Descriptions of positional accuracy shall consider the quality of the final product after all transformations. The information on transformations forms a part of the lineage portion of the quality report.

The report of any test of positional accuracy shall include the date of the test. Variations in positional accuracy shall be reported either as additional attributes of each spatial object or through a quality overlay (reliability diagram).

Measures of positional accuracy may be obtained by one of the following optional methods.

3.2.1 Deductive Estimate. Any deductive statement based on knowledge of errors in each production step shall include reference to complete calibration tests and shall also describe assumptions concerning error propagation. Results from deductive estimates shall be distinguished from results of other tests.

3.2.2 Internal Evidence. Federal Geodetic Control Committee procedures will be used for tests based on repeated measurement and redundancy such as closure of traverse or residuals from an adjustment.

3.2.3 Comparison to Source. When using graphic inspection of results ("check plots"), the geometric tolerances applied shall be reported and the method of registration shall also be described. Use of check plots shall be included in the lineage portion.

3.2.4 Independent Source of Higher Accuracy. The preferred test for positional accuracy is a comparison to an independent source of higher accuracy. The test shall be conducted using the rules prescribed in the "ASPRS Accuracy Standards for Large Scale Maps" (see 1.3.3). When the dates of testing and source material differ, the report shall describe the procedures used to ensure that the results relate to positional error and not to temporal effects. The numerical results in ground units, as well as the number and location of the test points, shall be reported. A statement of compliance to a particular threshold is not adequate in itself. This test may only be applicable to well-defined points.

3.3 Attribute Accuracy

Accuracy assessment for measures on a continuous scale shall be performed using procedures similar to those used for positional accuracy (providing a numerical estimate of expected discrepancies). The report of a test of attribute accuracy shall include the

date of the test and the dates of the materials used. In the case of different dates, the report shall describe the rates of change in the phenomena classified. Spatial variations in attribute accuracy may be reported in a quality overlay.

Accuracy tests for categorical attributes may be performed by one of the following methods. All methods shall make reference to map scale in interpreting classifications.

3.3.1 Deductive Estimate. Any estimate, even a guess based on experience, is permitted. The basis for the deduction shall be explained. Statements such as "good" or "poor" should be explained in as quantitative a manner as possible.

3.3.2 Tests Based on Independent Samples. A misclassification matrix shall be reported as counts of sample units crosstabulated by the categories of the sample and of the tested material. The sampling procedure and the location of sample units shall be described.

3.3.3 Tests Based on Polygon Overlay. A misclassification matrix shall be reported as areas. The relationship between the two maps shall be explained; as far as possible, the two sources should be independent and one should have higher accuracy.

3.4 Logical Consistency

A report on logical consistency shall describe the fidelity of relationships encoded in the data structure of the digital spatial data. The report shall detail the tests performed and the results of the tests.

3.4.1 Tests of Valid Values. Tests for permissible values may be applied to any data structure. Such a test can detect gross blunders, but it does not ensure all aspects of logical consistency.

3.4.2 General Tests for Graphic Data. A data base containing lines may be subjected to the following general questions:

- Do lines intersect only where intended?
- Are any lines entered twice?
- Are all areas completely described?
- Are there any overshoots or undershoots?
- Are any polygons too small, or any lines too close?

Different tests may be applied to address these questions, but the quality report shall contain a description of the tests applied or a reference to documentation of the software used. The report shall state whether all inconsistencies were corrected or it shall detail the remaining errors by case.

3.4.3 Specific Topological Tests. For exhaustive areal coverage data transmitted as chains or derived from chains, it is permissible to report logical consistency as "Topologically Clean" under the condition that an automated procedure has verified the following conditions:

- (a) All chains intersect at nodes. Use of exact case or tolerance shall be reported.
- (b) Cycles of chains and nodes are consistent around polygons. Or, alternatively, cycles of chains and polygons are consistent around nodes.
- (c) Inner rings embed consistently in enclosing polygons.

The quality report shall identify the software (name and version) used to verify these conditions.

3.4.4 Date of Test. The report shall include the date on which the tests were applied. If corrections and modifications have occurred after the test for logical consistency, the quality report shall indicate how the new information was checked for logical consistency.

3.5 Completeness

The quality report shall include information about selection criteria, definitions used and other relevant mapping rules. For example, geometric thresholds such as minimum area or minimum width shall be reported.

In encoding spatial entities, standard geocodes (such as described in the FIPS codes for States, counties, municipalities, and places) shall be employed if possible. Deviations from standard definitions and interpretations shall be described.

The report on completeness shall describe the relationship between the objects represented and the abstract universe of all such objects. In particular, the report shall describe the exhaustiveness of a set of features. Exhaustiveness concerns spatial and taxonomic (attribute) properties, both of which can be tested. A test for spatial completeness can be obtained from topological tests for logical consistency described in 3.4.3. Tests for taxonomic completeness operate by comparison of a master list of geocodes to the codes actually appearing in the file. The procedures used for testing and the results shall be described in the quality report.

4 General Specification

This section contains general concepts and specifications that pertain to the transfer module specifications of section 5. It also specifies the general elements of an implementation and the relationships of the logical constructs of the data models to the general elements of a detailed implementation as well as general constraints on implementations. This section consists of two main parts: (1) the underlying models and (2) specific transfer module specification conventions used in section 5. This section also contains specifications for the relationships of the logical constructs of the model to the general constructs of an implementation.

4.1 Spatial Data Transfer Models

Three data models-- the conceptual model, the data structure model, and the transfer model-- form the basic foundation for the process of converting from a user representation of a spatial entity to a corresponding digital object representation in a spatial data transfer.

4.1.1 The Conceptual Model of Spatial Data. This model describes the spatial objects, as well as the logical and topological relationships between the spatial objects and the captured spatial entities. This general model is object oriented and is also based on existing topological and graph models for spatial data. The conceptual model is presented in section 2 and more fully described in annex A.

4.1.2 The Data Structure Model. This model is used to express the spatial objects of the conceptual model in terms of transfer data structures. The data structures used in this transfer standard are based on the traditional relational and network models. Data structures viewed as spatial data structures are both the traditional vector and raster models. One or more data structures used in the transfer are encoded in the Profile Specification subfields of the Conformance field in the Identification module.

4.1.3 The Transfer Model. This model is used to express the logical constructs of the transfer form in terms of implementation-media constructs. The implementation constructs are made operational by an implementation method. The implementation method selects one or more media and defines the constructs pertaining to those media.

The transfer model is defined in terms of its constructs and logical relationships. It deals with three types of transfer constructs: (1) logical constructs solely pertaining to this standard, (2) constructs relating to the implementation method, and (3) constructs solely pertaining to the transfer media. The three types are summarized in tables 3a and 3b. Logical characteristics of constructs are defined in 4.2 that have physical instances that are implementation and (or) medium dependent. Definitions for the corresponding

physical constructs may be found in the implementation requirements of part 3 where additional constraints exist.

Table 3a Transfer constructs of this standard

<u>Construct</u>	<u>Logical</u>	<u>Implementation</u>	<u>Media</u>
Spatial Data Transfer	X	X	X
Module	X		
Module record	X		
Module field	X		
Module subfield	X		
Subfield		X	
Field		X	
Record		X	
File		X	X
File set		X	
Volume			X
Volume set			X
Media record			X

Table 3b depicts the relationships of the logical constructs specified in part 1 of this standard to the implementation constructs of part 3 and to typical media constructs.

Table 3b Relationships between the transfer logical constructs, implementation constructs, and typical medium constructs

<u>Logical Constructs of this Standard</u>		<u>Implementation Constructs</u>		<u>Medium Constructs</u>
spatial data transfer	>	file set	>	volume set
^		^		^
^		^		volume
				^
				^
module	p > >	file	=	p file
^		^		^
^		^		^
module record	p > >	record	p > >	media record
^		^		
^		^		
module field	p > >	field		
^		^		
^		^		
module subfield	=	subfield		

Note: B = A implies functional equivalence of A and B
B > A implies A contains one of B
B > > A implies A contains one or more of B
B p > > A implies A contains part of, or one or more of B

The transfer model specifies relationships of the following basic types: (1) implicit relationships between constructs expressed through order and (2) explicit cross-references between constructs.

4.1.3.1 Ordering Concepts. An implementation of this standard shall preserve the meaning of the data including any logical associations required by this standard. The specifications require:

the preservation of or means for reconstruction of a logical order in which the recipient may retrieve data comprising module subfields, module fields, module records, and modules.

- the preservation of the identity of the interchange data elements.

The general principles behind these requirements are explained as follows.

Order is the sequential arrangement of elements in a construct. In a data transfer, the reason for a sequential arrangement is that each element has an implied sequence number that serves to identify its participation in the construct, so that its structure can be preserved.

This standard does not impose general ordering requirements for transfer constructs with specific identification. In particular, most modules, which are assigned unique module names, and fields and subfields that carry names assigned by the standard, need not occur in any specific order in the context in which they are used. However, the order of presentation in the standard is recommended as a default order.

The standard imposes ordering requirements on unnamed or nonuniquely named transfer constructs such as elements in repetitive lists resulting from repeated fields and subfields. This ordering can be imposed on repeated instances of fields or subfields to capture the structure of the data to be transferred in such a repetitive list. For example, repeated instances of the Spatial Address field containing point data for a line shall be encoded in a certain order and decoded in the same order to fully preserve the meaning of the line. Ordering can also be imposed on repetitive instances of two or more types of fields when elements of repetitive lists are correlated. Ordering requirements of this type are imposed on a field by field basis as set out in 4.1.3.3.3 and 4.2.3.3.

Wherever repetitive lists occur on which the standard does not impose any ordering requirements, a user of the standard may still encode the field instances in a significant order, and decode these instances in the same order, because any implementation shall preserve the order for a repetitive list. This is explicitly stated in 4.1.3.3.8, Preservation of Order.

4.1.3.2 Backus-Naur Form. For clarification, the Backus-Naur Form (BNF) is used to concisely express structure, relationships, and layout of the transfer constructs in this specification.

Each production rule has a left side (identifier) and a right side (expression) connected by the symbol "::<=", meaning that the left side is replaced by or produces the right side. Terms in the right side either match other identifiers or are terminal symbols. Making substitutions using matching symbols in the production rules therefore leads to explaining the highest level identifier in terms of the lowest level terminal symbols. Other identifiers are intermediate, explaining the organization of the lower level symbols, and it is this expressive power of BNF that is used to define the organization of the transfer constructs in this standard. Most often the terminal symbols will actually be absent, but the production rules are presented in an indented form which indicates the levels of

organization. The BNF used here is an extension from normal usage, where the order of the terms in the right hand side of the production rule implies a physical ordering of these terms (as characters in a sentence, for example). However, for data transfer, order may not be important at times, and the terms may be considered a set. When order is not important, the convention of separating the terms with a "," will be used.

The symbols used in the production rules have the following meaning:

<u>Symbol</u>	<u>Meaning</u>
::=	is replaced by, produces, consists of
	exclusive or
[]	term enclosed is optional (not used or used once)
{ }	term enclosed is used any number of times (not used, used once, or used several times)
< >	term enclosed is nonterminal
,	exists together with (no order implied)
...	indicates a repetitive list of similar items

4.1.3.3 Implicit Relationships between Constructs. The ordering relationships between the logical constructs of this standard in the transfer are designated in table 3b. This table also designates the relationships between the logical constructs and the implementation and media constructs.

4.1.3.3.1 Modules within a Spatial Data Transfer. Spatial data transfers may occur on sequential media where order is significant, or on random access media where, depending on the level of detail, order might not be significant. On a medium where order is significant, the Identification Module and the Catalog modules shall be the first modules in the sequence. Unless otherwise specified by the Catalog/Directory module, the remaining modules shall be organized in the order that they appear in section 5. When the Catalog/Directory module implies a different ordering, this default ordering for the remaining modules is not required. For random access media the Identification modules and Catalog modules shall be easily identifiable, preferably through file names that reflect the module type. Regardless of the type of media used, each global information module (see table 8 for a list of global module types) shall be contained in one or more separate files that contain only that module.

Modules may be included or omitted, with the following exceptions:

- (a) Modules referred to by foreign identifiers in other modules in the transfer shall also be present in the transfer.
- (b) The global modules stated as required in 5.2 shall always be present.

- (c) The inclusion of the Identification module is mandatory.
- (d) When the Attribute Authority or Entity Authority subfield of any Data Dictionary/Schema module is null, or when the authority referred to is an authority other than this standard, appropriate Data Dictionary modules to define the entity or attributes and (or) the entity or attribute authority shall be used. Detailed conventions for the use of the authority subfields are found in 5.2.6.

Data Dictionary/Definition and Data Dictionary/Domain modules may be separate and external to a transfer, but if separate, they must be uniquely referenced (by module name and version) and labeled as "external" in Catalog/Directory records. The separate Data Dictionary modules shall easily merge with SDTS transfer data which reference them (e.g. no module name conflicts, no file name conflicts, and only editing of the Volume and External subfields of the Catalog/Directory module records for the Data Dictionary/Definition and Data Dictionary/Domain modules).

- (e) The five quality modules described in 5.3 shall always be included.

Data Quality modules may be separate and external to a transfer, but if separate, they must be uniquely referenced (by module name and version) and labeled as "external" in Catalog/Directory records. In addition, external Data Quality modules shall have no records with foreign identifier fields. The separate Data Quality modules shall easily merge with SDTS transfer data sets which reference them (e.g. no module name conflicts, no file name conflicts, and only editing of the Volume and External subfields of the Catalog/Directory module records for the Data Quality modules).

- (f) For each Attribute Primary or Secondary module there shall be a related Schema module.
- (g) For each Raster Cell module there shall be a related Raster Definition module. For each Raster Definition module there can be more than one related Raster Cell module.
- (h) For the Line Representation, Symbol Representation, and Area Fill Representation modules, a standard field can take on specified values that are defined in the domain description column, or additional values defined in a Data Dictionary module. If additional values are used, the values and the authority for the values shall be defined in an associated Data Dictionary module, and the Data Dictionary module shall always be present.

4.1.3.3.2 Module Records within Modules. Module records should preferably occur in ascending sorted order, according to the module record identifier field. Module records representing spatial objects or relationships between components of spatial objects shall occur in the order dictated by the spatial data model (2.1.2).

4.1.3.3.3 Module Fields within Module Records. It is recommended that module fields within module records occur according to the sequence specified in section 5. Module fields may occur in a different order on a module by module basis, provided that each field is identified through the selected implementation method and that significant relationships between fields are preserved. Within a module, the ordering, type and number of types of fields shall be identical for each module record. Multiple Object Representation codes are allowed within the same module (see 5.6 and 5.7).

Module fields within each module description are arranged so that within a given module record the primary module field will not repeat, whereas the instances of the secondary module field may repeat a fixed or variable number of times.

The structure of a module with a primary field "Primfield" and secondary fields "Secfield1, Secfield2,...,Secfieldn" is expressed as:

$\langle \text{module record} \rangle ::= \langle \text{Primfield} \rangle, \{ \langle \text{Secfield1} \rangle \}, \{ \langle \text{Secfield2} \rangle \},$
 $\dots, \{ \langle \text{Secfieldn} \rangle \}$

The rules for the case where a field is absent are given in 4.1.3.3.5.

The order of repetition of a module field can be significant. Moreover, the order of repetition can be correlated with the order of repetition of another field. The following three classes are therefore recognized:

- (a) The order of repetition is not significant.
- (b) The order of repetition is significant.
- (c) The order of repetition is significant and is correlated with the repetition of another field.

This standard dictates for each field which of the above conditions apply through an appropriate code in the field description for each field (see 4.2.3). This indicates whether ordered information shall be supplied for that field.

A number of modules in this specification have a simple relational structure in which all subfields may be represented as an n-tuple within a single implementation field. A module is said to have a relational structure when either one of the following conditions

exists:

- (a) there is only a single primary field per module record and no variably repeating subfields. The relational structure of a module record is:

$$\begin{aligned} \langle \text{module record} \rangle &::= \langle \text{Primfield} \rangle \\ \langle \text{Primfield} \rangle &::= \langle \text{Subfield1} \rangle, \\ &\quad [\langle \text{Subfield2} \rangle], \\ &\quad \vdots \\ &\quad [\langle \text{Subfieldn} \rangle] \end{aligned}$$

where the subfields are optional according to the rules of 4.1.3.3.6.

- (b) the module record is composed of one primary field and one or more nonrepeating secondary fields. This alternate form is sometimes present to take advantage of predefined shared fields. This structure is expressed as:

$$\begin{aligned} \langle \text{module record} \rangle &::= \langle \text{Primfield} \rangle, \langle \text{Secfield1} \rangle, [\langle \text{Secfield2} \rangle], \\ &\quad \dots, [\langle \text{Secfieldn} \rangle] \end{aligned}$$

where the optionality of the fields is according to the specifications of 4.1.3.3.5.

4.1.3.3.4 Subfields within Fields. A module subfield with a given name may be repeated a variable number of times within a given spatial data transfer if this is so specified within this standard (see 4.2.3.5).

4.1.3.3.5 Optionality of Module Fields. Module fields may be included or excluded. Both inclusion and exclusion may be either mandatory or optional, depending on the context for the use of the fields. When included, field contents may be null or may not be null. The following rules apply. Unless stated otherwise in a particular field description in the module specification table, module fields may be omitted provided that fields can be properly identified in the decoding process without additional external information not contained in the transfer. This can be satisfied with the current implementation method that uses tagged fields. The meaning of missing module fields is specified in 4.1.3.3.9. Mandatory fields shall not be null. The mandatory absence of fields shall have the meaning of "undefined, not relevant," as specified in 4.1.3.3.9. Mandatory fields in mandatory modules shall never be absent or null.

4.1.3.3.6 Optionality of Module Subfields. Module subfields may be included or excluded. Both inclusion and exclusion may be either mandatory or optional, depending on the context for the use of the subfields. When included, subfield contents may be null or may not be null. The following rules apply. Unless stated otherwise in a particular

subfield description in the module specification table, module subfields may be omitted provided that subfields can be properly identified in the decoding process without additional external information not contained in the transfer. This can be satisfied with the current implementation method that uses labeled subfields. The meaning of missing module subfields is specified in 4.1.3.3.9. Mandatory subfields shall not be null. The mandatory absence of subfields shall have the meaning of "undefined, not relevant," as specified in 4.1.3.3.9. Mandatory subfields in mandatory modules shall never be absent or null.

4.1.3.3.7 Extra module fields and subfields shall not be added, except under private agreement. The names and mnemonics used for any additional fields and subfields, under such an agreement, shall not duplicate any of those specified in the standard.

4.1.3.3.8 Preservation of Order. For a repetitive list, the implementation shall preserve the order as received from the sender, and on output, preserve order as found on the media.

4.1.3.3.9 Nulls and Defaults. The definition and the method for implementing null values is implementation dependent, and for the user-defined fields and subfields will be application specific. Null values in fields and subfields may be indicated in two ways: (1) through the structure imposed on a transfer's contents by the implementation, and (2) by setting aside certain values in the domain of the specified field or subfields contents as null values. Structure indicated null values may be manifest in two ways: (1) through the absence of fields or subfields, and (2) through empty fields or subfields.

For the purposes of this standard, the default method for indicating null values shall be through the structure imposed by the implementation. Empty fields and subfields shall have the meaning of "missing, relevant but not known," while missing fields and subfields shall have the meaning of "undefined, not relevant." If this default option for implementing null values is not feasible, the user may define alternative meanings to missing and empty fields or subfields, or may opt to implement a different null scheme by designating domain values as null values. In this case, the user shall fully describe the selected method in the data quality Logical Consistency module, and if applicable, shall specify the designated null domain values in a Data Dictionary/Domain module.

The fields and subfields that may be omitted, and when omitted have the meaning of "undefined, not relevant," are specified in 4.1.3.3.5 and 4.1.3.3.6.

A subfield may have an associated default value that must be assumed in effect when the subfield is omitted from the transfer. In this specification, subfields with default values are flagged appropriately and the default values are indicated. Values of omitted subfields without a preassigned default value are assumed to be of the null type "undefined, not relevant," unless otherwise specified in the Logical Consistency module.

4.1.3.4 Explicit Relationships between Constructs. The following relationships between constructs are explicitly encoded in the spatial data transfer. The relationships described are not only restricted to relationships between transfer constructs, but also include other elements of the transfer such as spatial addresses and attributes.

4.1.3.4.1 Modules, Records, Files, and Volumes. As indicated in table 3b, a module record may occur in a part of, in all of, or in more than one media record, file, or volume. Global modules may occur in all of or in more than one media file, but shall not share the same media file with other modules. The Catalog/Directory module may be used to specify which records, files, and volumes are associated with a particular module. Each Catalog/Directory module record shall have a single field with subfields containing identifiers for module, record, file, and volume. More than one catalog module record may be used to express the relationships between a specific module and its associated media records, files, and volumes.

4.1.3.4.2 Module Cross-References. Certain modules can reference, have bearing on, or relate to other modules. These relationships are specifically expressed in the Catalog/Cross-Reference module. Each module record in this module shall have one field consisting of four subfields, containing module names and types for two modules.

4.1.3.4.3 Modules and Spatial Domain. Relationships between modules and spatial domain, map, theme and aggregate object (e.g., graph) are expressed through the Catalog/Spatial Domain module.

4.1.3.4.4 Module Record Cross-References. Explicit relationships between module records are established through module record identifiers and foreign identifiers.

Module Record Identifiers

A module record identifier shall provide a unique identification for the record in the entire transfer. The identifier has two subfields: (1) Module Name and (2) Record ID. The module record identifier exists as the first two subfields of the primary module field associated with the module record. The record number shall be unique within the module.

Foreign Identifiers

References to other records from a given record shall be made through foreign identifiers. Foreign identifiers consist of three subfields: (1) Module Name, (2) Record ID, and (3) Usage Modifier (see 5.1.2). Module Name and Record ID are mandatory subfields corresponding to the mandatory module record identifier fields with matching names. The Usage Modifier subfield is optional and has no equivalent module record identifier subfield.

4.1.3.4.5 Wildcard Characters in References. For the purpose of eliminating

multiple module reference records and multiple foreign identifiers for those cases where the reference model is one-to-many, the use of wildcard characters is allowed where indicated in a module domain description table in section 5. Wildcard characters are also used in attribute definition relationships. Except for the Record Identifier subfield, the subfield containing wildcard characters must be alphanumeric. When so indicated, the following rules apply:

- (a) An entire data element may be replaced with a "*", meaning "all."
- (b) If the data element refers to the Record ID subfield, it may be replaced by a negative integer corresponding to the maximum value in the subfield referenced, e.g., "-9328", meaning "all 9,328 records in the module referenced," or "the maximum number of records referenced in any of the referenced modules is 9,328."
- (c) Non-contiguous substrings of a data element may be replaced with a "*", meaning that the data element refers to those other data elements where the explicitly specified substrings are matched in their relative order.
- (d) Single characters of a data element may be replaced with a "?" meaning that the data element refers to those other data elements where the explicitly specified characters match in their relative order.

Whenever wildcard characters are used in data items that are part of a nested index, such as the foreign identifier, the scope of the elements referenced shall be restricted by the scope of the previous level of reference. For example, if wildcard characters are used in the same foreign identifier to refer to modules and also to refer to records, then the scope of the records is restricted to the set of modules referenced. For any transfer, the scope of a set of modules referenced shall be restricted to the modules in the Catalog/Directory module in which the referring module is cataloged.

The use of wildcard characters in the Module Name subfield of a foreign identifier field is not permitted except in global modules.

4.1.3.5 Spatial Registration. The standard includes a number of mechanisms by which spatial data contained in the transfer can be related to locations on the Earth's surface. The primary goal of this standard is to promote the transfer of data for which all spatial addresses have a known (and expressed) relationship to latitude and longitude. However, for certain types of applications this might not always be possible or meaningful. The standard therefore recognizes three spatial registration conformance levels. A transfer with conformance levels 1 or 2 shall contain data that have a specified relationship to latitude and longitude, while this relationship shall remain unspecified for a level 3 transfer.

The known relationship to latitude and longitude is expressed through the use of an external coordinate reference system, of which the three most widely used in the United States are (listed in order of preference): Latitude and Longitude (also termed Geographic), Universal Transverse Mercator/Universal Polar Stereographic (UTM/UPS) Grid Systems, and State Plane Coordinate Systems (metric). These systems are mathematically interconvertible, on a point by point basis, and are also officially recognized by many mapping and surveying agencies of the Federal and State governments. This standard allows the use of any of these preferred systems as the external coordinate reference system for spatial registration conformance level 1, and no other system shall be used for this conformance level.

Any other external reference system may be used for registration conformance level 2, in which case the standard requires a full disclosure of the reference system, its projection and parameters. The spatial registration conformance levels are summarized as:

- | | |
|---------|--|
| Level 1 | Relationship with latitude and longitude known through the use of one of the preferred external reference systems |
| Level 2 | Relationship with latitude and longitude known through the specification of an external reference system and its projection and parameters |
| Level 3 | Unspecified relationship with latitude and longitude |

In addition to the latitude-longitude system and the specified external reference system, the standard includes two additional reference systems: the internal reference system and the scan reference system. The four types of spatial referencing systems are defined as follows:

- (a) The scan reference system is a row-column reference system for use with raster data, further described in 5.7.1.2.
- (b) The internal reference system is a Cartesian coordinate system, one that does not assume any particular orientation. For raster data, the system shall be right-handed. The internal reference system is used to store the spatial addresses for the vector spatial objects of a transfer, while the scan reference system is used to store spatial addresses for raster data.
- (c) The external reference system is also a Cartesian coordinate system, without an assumed orientation, but the orientation of the internal and external reference systems shall be identical. The external reference system shall be either the Latitude-Longitude system, the UTM/UPS System, one of the State Plane Coordinate Systems (metric), or a system for which a transformation to latitude and longitude can be described through a